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A Roadmap to Advance Marine and Coastal Monitoring, Biodiversity Assessment, and International Reporting: A Developing Nation Perspective

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Despite the increasing number of tools and indicators to measure biodiversity status and trends, many developing countries struggle to initiate and advance coastal and marine assessments needed to monitor and track national and international progress in biodiversity targets. We identified five key challenges that hinder progress in this context, based on a national marine assessment workshop held in South Africa, and developed recommendations and tangible actions to address these challenges drawing from multiple national assessments, regional initiatives, and global collaborations over the last 15 years. Challenges include a poor understanding of methods, limited capacity and funding for assessments, a lack of systematic approaches to biodiversity assessment and indicator development, and scattered efforts that often fail to link science to policy. Key actions could enable the development of a coordinated framework to feed into policy and decision-making at multiple scales. We provide South African examples to highlight a developing country's progress toward marine biodiversity assessment and provide a roadmap to integrated monitoring, assessment, and reporting based on positive outcomes. Recommendations to address challenges include building collective understanding of assessment tools and methods, prioritizing pressures urgently needing mitigation measures, using relevant indicators to support reporting at multiple scales, applying coordinated approaches to identify gaps and opportunities, codeveloping coordinated approaches with direct policy links, and leveraging resources and technical capacity for iterative improvement. This roadmap can guide developing and developed countries and support global best practices to collaboratively advance marine and coastal ecosystem monitoring and assessment at multiple scales for meeting many objectives.

Keywords: indicators, marine and coastal biodiversity, global reporting, ecological condition, tangible actions

INTRODUCTION

Increased human pressures in the oceans are linked to unprecedented losses in marine biodiversity and ecosystem services that are essential for human wellbeing (Hooper et al., 2005; Crain et al., 2008; Halpern and Floeter, 2008; Micheli et al., 2014). To mitigate these impacts and maintain healthy oceans, we need sustained measurements of the status and trends of marine biodiversity and ecosystem condition to better assess the effects of human pressures and to apply this information to inform management actions and policy development. Global policies, research initiatives, and biodiversity frameworks have resulted in the development of numerous tools to track progress in meeting biodiversity targets; this has led to the identification of a wide range of methods and indicators for biodiversity monitoring and assessment, particularly in developed countries (Teixeira et al., 2016; Smit et al., 2021). However, this has resulted in confusion and a lack of standardization. Moreover, top-down indicators developed for global synthesis and reporting are often not useful at a national scale, unless validated with country-level data and accurate interpretation of available indicators. Thus, there is a need to identify flexible global indicators that can be tailored to regional- to local-scale requirements, with appropriate institutional support structures, including cross-cutting national indicators that can support meaningful reporting in a global context.

South Africa has made substantial progress in assessing the marine and coastal environment at a national scale and could be regarded as a leader among developing nations [considered here as countries receiving Official Development Assistance (ODA) aid (oecd.org/dac)] in this context. The South African National Biodiversity Institute (SANBI) is mandated to conduct a National Biodiversity Assessment (NBA) every 5–7 years, reporting on two headline indicators; ecosystem threat status and protection level to track the state of biodiversity over time (Skowno et al., 2019). In the most recent NBA, the IUCN Red List of Ecosystems (RLE) criteria (Rodríguez et al., 2015; Bland et al., 2018; Bland et al., 2019) were applied to determine ecosystem threat status at a national scale (Sink et al., 2019a). At a regional level, in the Western Indian Ocean (WIO) a state of the coast report has been developed every few years (UNEP-Nairobi Convention and WIOMSA, 2015), and a recent assessment following the IUCN RLE approach was used to determine the threat status of marine ecoregions in the WIO region (Obura et al., 2021a). In this paper, we refer to biodiversity assessments in a broad sense that encompasses species and ecosystem assessments in the marine environment.

Despite progress made in South Africa and in Africa, developing countries (particularly those in the Global South) face a unique set of challenges in biodiversity monitoring and national assessment, resulting in clear disparities in progress compared with developed countries (OECD, 2020; Obura et al., 2021b). Some of these limitations include data availability, lack of funding, and poor infrastructure that inhibit data collection and assessment at relevant temporal and spatial scales. In addition, there is generally poor harmonization and coordination among relevant research agencies and reporting channels, and this is often underpinned by a lack of responsibility and ownership for assessment at the ecosystem level. A list of data gaps and research needs were identified in the South African NBA that included the need for "measuring and mapping ecological condition, which is crucial for biodiversity assessments, where biological and ecological data and indices of condition need to be explored across a range of ecosystem types to compare such assessments of condition with assessments made through cumulative pressure mapping" (Sink et al., 2019a). A first step toward addressing these needs included a national marine condition workshop that was hosted by SANBI and the University of Cape Town in October 2021, which provided the basis for this paper. The workshop was attended by participants spanning 11 institutions including representatives from national government, research agencies, and non-governmental organizations (NGOs) (a workshop summary is provided in the **Supplementary Material**). Discussions from the workshop led to the identification of key challenges for advancing marine biodiversity assessments in developing countries and provided the basis for a set of recommendations and priority actions that reflected our unified thoughts on how to consolidate fragmented efforts and facilitate a way to move biodiversity assessment in the marine realm through to management and policy level.

This paper aims to address the broad challenges identified in the workshop, by providing a roadmap of recommendations and priority actions to facilitate and support national biodiversity assessments. We use South Africa as an example because regular, home-grown national biodiversity assessments (NBAs) have been undertaken since 2004 (Driver et al., 2005; Driver et al., 2012; Skowno et al., 2019), which increasingly draw on and use international approaches in alignment with global best practice, but subject to local constraints (e.g., data or resource requirements). Further, regional and global initiatives are increasingly reaching out to South Africa (among other developing countries) for participation in a variety of new approaches to assessing coastal and marine ecosystems in the Indian, Atlantic, and Southern Oceans. Finally, like many African coastal nations, South Africa is expanding its ocean-based economy (WWF-SA, 2016; Findlay, 2018; AU-IBAR, 2019; Harris et al., 2022b) and must identify, assess, and employ appropriate indicators to monitor the effects of expanding, intensifying, and diversifying activities in support of sustainable development and environmental stewardship.

CHALLENGES AND OPPORTUNITIES FOR MARINE BIODIVERSITY ASSESSMENTS

Measurement of ecological condition is required to inform ecosystem threat status and other national indicators and project objectives (Sink et al., 2019b; Orejas et al., 2020; Harvey et al., 2021; Monaco et al., 2021). However, some of the biggest challenges that hinder the effective use of capacity and resources for marine assessment include uncoordinated reporting on multiple commitments and objectives and an often extensive but scattered marine policy and legislative landscape (Taljaard et al., 2019). For example, a concise list of

common reporting needs, including international strategies and frameworks, systemic assessments, networks, or research platforms and projects, that require indicators from the marine realm are outlined from a South African perspective (**Table 1**). Well-established international assessment frameworks, such as the European Marine Strategy Framework Directive, the Ocean Health Index (OHI), and the IUCN Red List of Ecosystems, have standardized fit-for-purpose indicators, especially suited to high-level national reporting (Borja et al., 2011; Halpern et al., 2012; Andersen et al., 2014; Rodríguez et al., 2015; Rowland et al., 2019; Nicholson et al., 2021). However, there are many limitations and challenges that hinder progress in implementing these frameworks, particularly in developing countries in a local context.

Outputs from the South African workshop (see Introduction) resulted in the identification of five key challenges that need to be addressed at the country level to advance marine biodiversity assessments (**Figure 1A**). These include (1) poor understanding of methods and tools for marine biodiversity assessment; (2) lack of systematic approaches to prioritize pressures and select pressure and state indicators; (3) limited data (and capacity) at a national scale, or at the scale of management objectives; (4) scattered initiatives and poor alignment among scientists, managers, and policymakers; and (5) a lack of funding and resources. It is beyond the scope of this paper to discuss in detail the underlying factors linked to these challenges. However, some common issues, particularly relevant to developing countries, include a history of scattered uncoordinated efforts to monitor and assess marine ecosystems, poor links to management and policy, and a lack of co-development and limited resources (including equipment, human capacity, and funding).

There is an urgent need to develop tangible actions to overcome these challenges to advance marine biodiversity assessment at scales relevant to a range of management and sustainable development objectives. The approach used in the South African National Biodiversity Assessment is effective for estimating ecological condition and threats to marine ecosystems at broad spatial scales covering a large (national) area. However, this approach relies on pressures, as a proxy of ecological condition rather than ecological data and *in situ* ocean observations. Thus, there is a need to groundtruth the country-level assessment, advance the IUCN Red List of Ecosystems assessment methods, and develop national condition assessments using observed (and modeled) data. Harmonization is required among current approaches and methods by identifying synergies, commonalities, and a common set of metrics and indicators that can inform

TABLE 1 | A concise list of marine-related frameworks and policies, integrated systemic assessments, networks, online data sharing platforms, and projects, relevant to marine biodiversity assessment in South Africa and that are commonly referred to in the text.

Category	Reporting channels	Scale	References
Strategy/framework/ policy	National Biodiversity Strategy and Action Plan (NBSAP)	National	Government of South Africa, 2015
	Benguela Current Commission[a]	Regional	https://www.benguelacc.org/
	Marine Strategy Framework Directive	Regional	European Commission, 2010
	CBD Global Biodiversity Monitoring Framework	Global	CBD, 2021
	UN Sustainable Development Goals (SDGs)	Global	https://www.undp.org/sustainable-development-goals
Systematic assessment	South African (SA) State of coast reports	National	e.g., Kirkman et al., 2018
	SA National Biodiversity Assessment (NBA)	National	Sink et al., 2019b
	Critical Biodiversity Areas, Key Biodiversity Areas, Ecologically and Biologically Significant Areas	National	Harris et al. 2022a; Harris et al. 2022b
	Marine Spatial Planning	National	The Department of Environmental Affairs., 2016
	Western Indian Ocean state of the coast report	Regional	UNEP-Nairobi Convention and WIOMSA, 2015
Network/research platform	Global Ocean Observing System (GOOS)	Global	https://www.goosocean.org/
	Marine Biodiversity Observation Network (MBON)	Global	https://marinebon.org/
	Scientific Committee on Oceanic Research (SCOR)	Global	https://scor-int.org/
	the Biodiversity Indicators Partnership (BIP)	Global	https://www.bipindicators.net/
	Integrated Marine Biosphere Research (IMBeR)	Global	https://imber.info/
	Future Earth Project bioDISCOVERY program	Global	https://biodiscovery.earth/
	MarineLife2030	Global	https://marinelife2030.org
Data sharing platform	Biodiversity Global Information System (BGIS)	National	https://www.sanbi.org/link/bgis-biodiversity-gis/
	South African Environmental Observation Network (SAEON) portal	National	http://www.saeon.ac.za/data-portal-access
	Marine Information Management System (MIMS)	National	https://data.ocean.gov.za/about/
	Global Biodiversity Information System (GBIF)	Global	https://www.gbif.org/
	Ocean Biodiversity Information System (OBIS)	Global	https://obis.org/
Project	Mission Atlantic	Regional	https://missionatlantic.eu/
	iAtlantic	Regional	https://www.iatlantic.eu/
	WioSymphony (Symphony Tool)	Regional	https://github.com/WIOSymphony
	One Ocean Hub	Global	https://oneoceanhub.org/
	IndiSeas	Global	http://indiseas.org

[a]*The Benguela Current Commission is one example of numerous conventions and policies that South Africa is signatory to (see Taljaard et al., 2019).*

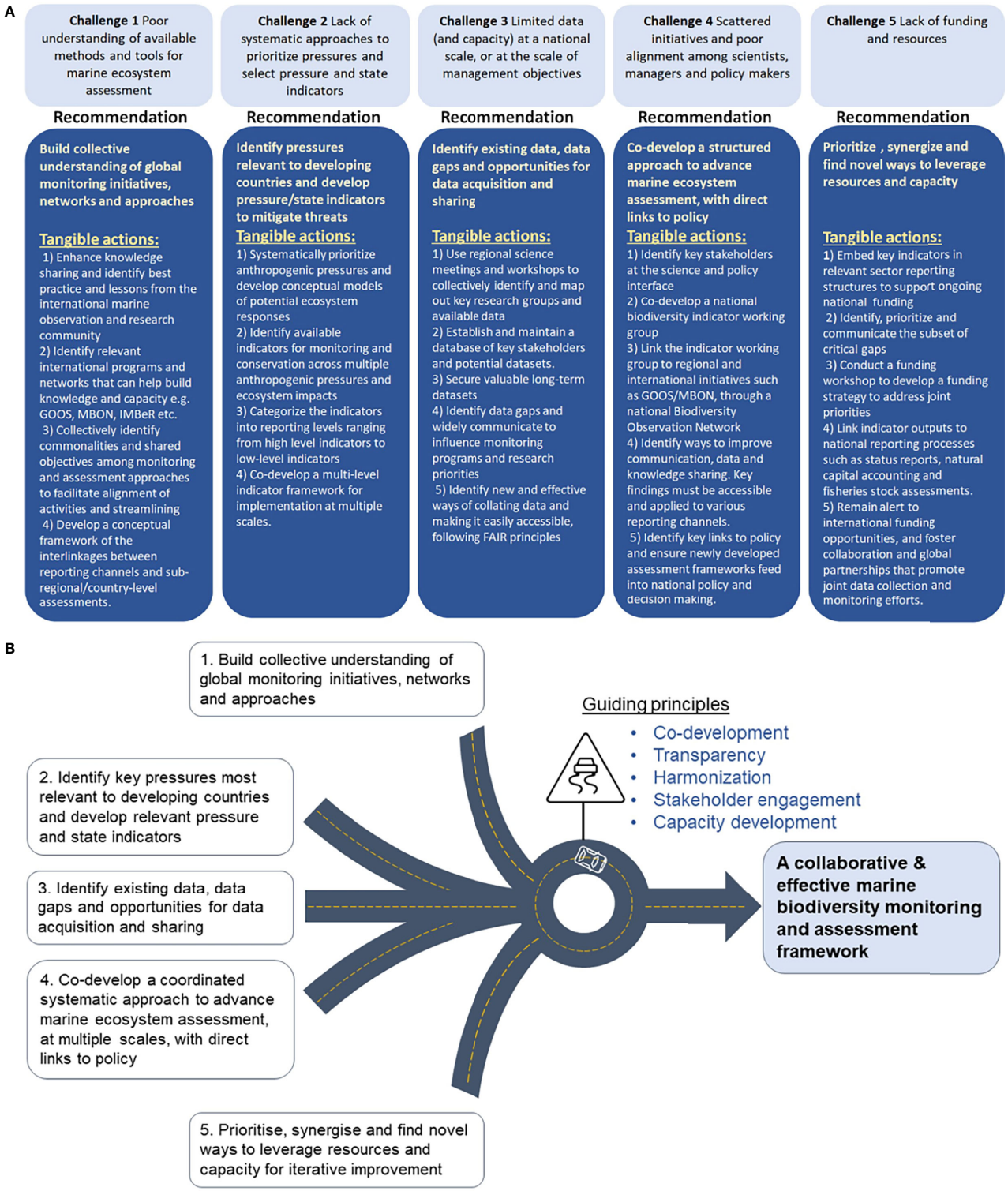

FIGURE 1 | **(A)** Schematic showing the five identified challenges that hinder progress for national marine biodiversity assessment in developing countries, recommendations (in bold text at top of each pillar), and tangible actions to overcome these challenges. **(B)** A roadmap illustrating how the five recommendations, linked to each identified challenge, should be collectively applied to advance marine biodiversity monitoring and the co-development of an assessment framework. These steps need to be guided by a set of key principles that will enable a harmonized, coordinated, equitable, and sustainable iterative process.

assessments at multiple scales and for multiple reporting objectives (**Table 1**) (Borja et al., 2019; Evans et al., 2019; McQuatters-Gollop et al., 2019; Pavlidou et al., 2019). Key to this will be to find ways to harness available data, resources, and technical capacity to codesign an indicator and assessment framework for national marine monitoring and assessment. The question is, how do countries go about doing this practically?

A ROADMAP: RECOMMENDATIONS AND PRIORITY ACTIONS TO ADDRESS KEY CHALLENGES IN COASTAL AND MARINE BIODIVERSITY ASSESSMENT

The challenges presented here (**Figure 1A**) are not unique to developing countries but are often harder to overcome where limited technical capacity and resources hinder achieving goals and targets. A set of recommendations and priority actions was identified from discussions and key outputs from the national workshop held in South Africa to address each challenge (**Figure 1A**). This roadmap can guide developing and developed countries and support global best practices and networks to advance ecosystem monitoring and assessment at multiple scales for multiple sustainability objectives. This roadmap is targeted at researchers, managers, and decision-makers, to guide the efforts of those who are directly or indirectly involved with conducting marine biodiversity assessments. However, we note here that this roadmap will be most useful for national governments and research agencies who are responsible for national reporting and whose mandate is to monitor the status and trends of marine biodiversity and measure the condition of ecosystems.

The actions for implementing the proposed recommendations should be guided by a set of underlying guiding principles that will enable collaborative support for the co-development of an indicator and assessment framework for national marine biodiversity assessment (**Figure 1B**). Guiding principles were identified by participants during the workshop and drew from international literature (Ojaveer and Eero, 2011; Goldsmith et al., 2015; Haase et al., 2018; Muller-Karger et al., 2018; Skern-Mauritzen et al., 2018; McQuatters-Gollop et al., 2019) to identify enabling conditions to advance marine assessment. These principles include co-development with key links to policy, transparency, harmonization of assessment methods to include global best practices, stakeholder engagement, transparency, and capacity building to ensure iterative improvement of assessments (**Figure 1B**). The roadmap (**Figure 1B**) demonstrates how achievement of recommendations (and associated tangible actions) could lead to a collaborative and effective marine monitoring program and assessment framework. We propose that a successful implementation of priority actions (**Figure 1A**) could help to facilitate improved alignment of marine biodiversity assessment in developing countries, supported by international and regional efforts, and increase standardization of methods, indicators, and outputs to advance assessments in the developing world.

DISCUSSION

The proposed roadmap addresses the five key challenges that developing countries face in undertaking marine biodiversity assessments and presents a key recommendation and tangible actions for each challenge. If implemented, these actions could help to advance and synergize biodiversity monitoring and assessment for sustainable development. The roadmap illustrates the progress that can be made by developing countries to reduce the disparities with biodiversity assessment and monitoring in developed countries. The underlying challenges and proposed actions, with examples from South Africa's progress in overcoming some of these challenges, are discussed with lessons for other African and developing nations.

To address the first challenge, which centers on a poor understanding of methods and assessment approaches, an online national workshop was held in South Africa with the purpose of harmonizing marine biodiversity assessments at multiple scales, upon which the basis of this paper was developed. The workshop brought together relevant stakeholders, to provide a joint understanding of different methods and tools, and to investigate application in a local context. The intended outcome was to align global approaches (like those used in the EU Mission Atlantic project, the Ocean Health Index, and the Marine Strategy Framework Directive) (**Table 1**), with South Africa's upcoming fourth iteration of the NBA. Stakeholders improved their understanding of the different assessment approaches and indicators, culminating in a conceptual framework of how the different approaches can fit together in South Africa and potential ways to overcome some of the challenges that hinder progress in this context.

For other developing countries, we recommend actions like this collaborative workshop to build collective understanding of approaches, networks, and potential interlinkages and to identify commonalities and shared objectives among monitoring and assessment approaches for key reporting channels (**Figure 1A**). In doing so, research and management agencies can facilitate the alignment of activities and streamline assessment efforts and reporting to increase harmonization and reduce duplication of effort without reinventing the wheel. For example, monitoring and assessment should also learn from, and align with, relevant networks and research platforms (**Table 1**). International networks often offer opportunities for collaboration with current research programs that can provide additional resources and technical capacity (i.e., funding, equipment, or data). We recommend that countries establish their own national working group or an official Biodiversity Observation Network (BON) that can facilitate these steps locally and provide support for collaboration, harmonization, and knowledge generation.

South Africa is making progress toward addressing the second challenge, the lack of a systematic (holistic,

methodological, and repeatable) approach for identifying key pressure and state indicators to facilitate biodiversity actions. A total of 31 human pressures are measured and mapped at a national scale for the NBA (Majiedt et al., 2019), with expert-driven scoring to quantify ecosystem impacts. Although the assessment provides a comprehensive overview of pressures in the EEZ, some sectors are poorly quantified. Further, there is a need for uncertainty to be accommodated, especially in the case of risks imposed on biodiversity by synergistic pressures. Recently, South Africa applied the Options for Delivering Ecosystem-Based Marine Management (ODEMM) approach to prioritize key sectors, pressures, and affected ecosystem components. Further, a literature review of indicator types and assessment approaches was conducted for country-level application (Smit et al., 2021). Key marine indicators are now being categorized for inclusion in a revised National Biodiversity Framework. However, there is still a need to codevelop a multilevel/hierarchical indicator framework of indicators that can be implemented at multiple scales, using global best practices as a departure point.

To address the second challenge, we recommend that a set of smaller projects be conducted that can test selected global indicators with available measured data for sensitivity/viability, and the hosting of a suite of focus workshops with managers and researchers to discuss and distill findings. From this, a hierarchical indicator framework can be built, with time frames (and possible funding streams) to facilitate this. Toward this, other countries could also investigate the use of the ODEMM approach, which is useful for identifying management objectives and guiding indicator selection for biodiversity assessment (Knights et al., 2011; Pedreschi et al., 2019). Further, a DPSIR (Driver Pressure State Impact Response) approach can help better quantify the links between drivers, pressures, and ecosystem state and inform management responses (Piet et al., 2015; Oesterwind et al., 2016; Patrício et al., 2016). Management agencies in developing countries should identify available indicators for marine assessment and categorize them according to reporting levels and relevant scale, like ecosystem threat status which is applied at a national scale, or Essential Ocean Variables (EOVs), which are applied at a more local scale (e.g., phytoplankton biomass) (Edgar et al., 2016; Miloslavich et al., 2018; Bax et al., 2019; Obura et al., 2019). These processes can help to identify existing gaps to monitoring ecosystem change under current and future pressures, with a view to informing appropriate management actions. Development of an indicator and assessment framework should be an objective, transparent, and inclusive process, which generates support for co-development (scientists, managers, and policymakers) and obtains consensus among stakeholders (McQuatters-Gollop et al., 2019; Stephenson et al., 2019; Lear et al., 2020; Karcher et al., 2022). Key to this is sector buy-in from government departments tasked with data collection, biodiversity assessment, and reporting.

For the third challenge of limited data, there are often more marine and coastal data available than are realized, and the challenge (and opportunity) is to increase collaboration to harness existing data and resources for biodiversity assessment. Using regular science gatherings, such as the Southern African Marine Science Symposium (SAMSS), can provide a platform to identify key stakeholders in the marine community and available datasets. In 2015, a national marine monitoring workshop was conducted to identify key marine datasets and identify monitoring needs for South Africa (Atkinson et al., 2016). South Africa also uses various national data platforms to make a range of datasets freely available for use and easily accessible (see examples in **Table 1**). The challenge here is to identify novel and innovative tools to increase collaboration and to develop a national database of key stakeholders and datasets, following FAIR (Findable, Accessible, Interoperable, and Reusable) principles. A potential way to do this is through the development of a mobile phone app or website to monitor students, researchers, and projects, including an incentivized program to implement this. Alternatively, a new database could be supported by existing data platforms, as seen in **Table 1**, which is already well supported in South Africa.

So far, positive outcomes from South Africa have provided examples of how to address the first three challenges; however, there are still many gaps that need to be filled, particularly related to the fourth and fifth challenges (**Figure 1A**). The recommendations and tangible actions outlined for these challenges require large effort with a few champions to drive these processes, yet to be achieved in South Africa. To address the fourth challenge of scattered initiatives and poor alignment, there is a need to develop an effective coordinated structure and framework of policymakers, practitioners, and scientists to enable co-development of assessment frameworks that are nested across multiple scales, linking to common objectives. The high number of sector role players tasked with managing activities and/or resources in the coastal and marine environment (e.g., fishing, water, biodiversity management, mining) (Taljaard et al., 2019) underpins the issue of scattered initiatives. A single management or research agency (e.g., SANBI in South Africa) needs to take ownership or responsibility of conducting biodiversity assessments at a national level, through collaborated efforts across sectors and stakeholder groups (Sink et al., 2019b). It is recommended that spatially explicit assessments at a national scale will be more effective for communicating results to policy and decision-makers than piecemeal assessments of individual ecosystem types (Botts et al., 2020). Through workshops and other training initiatives, improved knowledge generation and capacity building should be conducted with key actors in the policy and science realms, which will also enable the codesign of monitoring and assessment methods (McQuatters-Gollop et al., 2019; Rochette et al., 2019). Communicating results in an effective way for a specific target audience and being ready for new legislative developments are also key enabling conditions to improve co-development and collaboration between scientists and policymakers (Evans et al., 2019; Botts et al., 2020; Hetherington and Phillips, 2020). There is a need to develop a formal science-to-policy framework to improve communication and collaboration along these channels.

Tangible actions identified for the fifth challenge, relating to a lack of funding and resources, include the inclusion of indicators and biodiversity assessments into existing funded processes, as is done in the case of the National Biodiversity Assessment (Sink et al., 2019b). Ecosystem-level indicators are still missing from existing, regular national environmental and fisheries status reports. However, efforts are currently underway to develop ecosystem status reports that can be added to reports such as the annual "Status of the South African Marine Fisheries Resources" (DEFF, 2020). Government and management agencies should identify novel ways to leverage funding opportunities and sustainable financing solutions to minimize reliance on (not exclude) international donor funding (see other tangible actions in **Figure 1A**). Possible examples are provided by Emerton et al. (2006); Binet et al. (2015), and Riddell et al. (2020), including, but not limited to, payment for ecosystem services, environmental taxes, debt (i.e., blue bonds and debt-for-nature), and microfinance. In South Africa, progress has also been made in including natural capital accounting (including ocean accounts) into formal national budgets and economic reporting, which is supposed to help streamline funding channels for environmental activities and sustainable development (Potgieter, 2018; Findlay et al., 2020; Van Niekerk et al., 2020; Statistics South Africa, 2021). South Africa has also drafted a "Green Finance Taxonomy," which was published for consultation in June 2021, as a regulatory framework for sustainable finance including key objectives linked to marine resources (Government of South Africa, 2022).

Successful implementation of the proposed recommendations and tangible actions could lead to a more inclusive, coordinated, and holistic approach to managing marine and coastal resources, centered on environmental stewardship and effective use of available resources and capacity. Steps achieved in South Africa provided positive examples of how to overcome some of the challenges identified. The solution is to not reinvent the wheel but to apply international best practices in a local context to harness available data and capacity in a joint approach toward identifying key indicators that can be used for multiple sustainability objectives. The roadmap is presented to help guide an enabling environment with tangible actions to support the development of a codesigned indicator and assessment framework that can be taken up into policy. This framework would also guide biodiversity monitoring programs and research priorities, while achieving multiple reporting obligations.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**. Further inquiries can be directed to the corresponding authors.

AUTHOR CONTRIBUTIONS

All authors participated in the workshop from which this paper was developed. KPS drafted the manuscript and substantial input and revision was provided by LVN, LRH, LJS, KJS and AM-G. All authors contributed to the approved submitted version.

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SUPPLEMENTARY MATERIAL

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