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EDITED BY
Quentin Groom,
Botanic Garden Meise,
Belgium

REVIEWED BY
Richelle Li Tanner,
Chapman University,
United States

*CORRESPONDENCE
Carol Jean Poole
✉ c.poole@sanbi.org.za

†These authors have contributed equally to this work and share first authorship

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Taking state of biodiversity reporting into the information age – A South African perspective

Carol Jean Poole[1*†], Andrew Luke Skowno[1,2†], Jock C. Currie[1], Kerry Jennifer Sink[1,3], Brenda Daly[1] and Lize von Staden[1,4]

[1]Kirstenbosch Research Centre, South African National Biodiversity Institute, Cape Town, South Africa, [2]Plant Conservation Unit, Department of Biological Science, University of Cape Town, Cape Town, South Africa, [3]Institute for Coastal and Marine Research, Nelson Mandela University, Gqeberha, South Africa, [4]Department of Botany, Nelson Mandela University, Gqeberha, South Africa

South Africa's National Biodiversity Assessment (NBA) is the primary tool for monitoring and reporting on the state of biodiversity, with a focus on spatial information and key indicators. The NBA distills information that informs policies and strategies, meets national and international reporting requirements, and helps prioritize limited resources for managing and conserving biodiversity. The three previous versions of the NBA (2004, 2011 and 2018) are in the form of detailed thematic technical reports and a synthesis report, served on a simple, static web page. Selected spatial products from the report are available *via* a dedicated web platform (http://nba.sanbi.org.za/). While all methods and data are clearly described in the technical reports, most of the underlying analyses are inaccessible, lacking reproducibility and transparency. This makes iterative updates to indicators or metrics challenging and inefficient, complicates version control, and exacerbates the risk of capacity, knowledge and data loss during staff turnover. To move the assessment process into the information age we aim to develop well documented and reproducible workflows, and to serve the indicators and their accompanying synthesis on an interactive web platform that facilitates uptake. Achieving these aims will deliver efficiency, greater transparency and trust in future NBA products and will strengthen communication and engagement with the content by the many different users of those products. While these visions will not be realized overnight, the skills and systems required to achieve them can be adaptively built towards an improved NBA that better serves the needs of our society.

KEYWORDS

national biodiversity assessment, South Africa, data science, state of biodiversity, convention on biological diversity

1. Introduction

Biodiversity monitoring and reporting at national and global scales plays an important role in meeting the goals of the Rio conventions (Convention on Biological Diversity, United Nations Convention to Combat Desertification, United Nations Framework Convention on Climate Change) and other multilateral environmental agreements (e.g., Sustainable Development Goals, the Ramsar Convention on Wetlands, Convention on the Conservation of Migratory Species of Wild Animals). As signatories to these agreements, parties need to report regularly against a series of indicators that draw on a wide range of biodiversity and environmental observations

(including pressures and drivers). This data-to-knowledge pipeline is undergoing rapid change in the information age, with an explosion of available data and the evolution of new tools for analysis and information delivery (Wilkinson et al., 2016; MacFadyen et al., 2022). Policy, planning and decision-making bodies with a mandate over biodiversity conservation and sustainable use are set to benefit from these changes; if the supporting agencies can adapt their processes and avoid "drowning in data." This is particularly important–and challenging–in the parts of the world where high biodiversity coincides with pressing social and employment imperatives that require economic development.

The National Biodiversity Assessment (NBA) of South Africa is an iterative body of work that collates and summarizes biodiversity information for both national and global reporting requirements, and informs local to national policies that influence, or are influenced by, biodiversity considerations (Reyers and McGeoch, 2007; Skowno et al., 2019). Many of the components of the NBA are used in systematic conservation planning, which has a clear statutory influence on land and sea use decision making and strategic planning in South Africa (Reyers et al., 2007; Botts et al., 2020; Skowno and Monyeki, 2021).

The NBA is led by the South African National Biodiversity Institute (SANBI) as a core part of their mandate [in terms of the National Environmental Management: Biodiversity Act (Act 10 of 2004)], to monitor and report on the status of the Republic's biodiversity. SANBI does not work alone; the NBA 2018 was a collaborative effort from more than 470 individuals from approximately 90 institutions. This co-production of knowledge both improves the credibility of the science and promotes the collective ownership and application of the products by the biodiversity science and management communities.

The NBA presents findings on the state of biodiversity (i.e., reports on metrics and indicators), but also includes messaging that aims to explain the implications of the findings and what can be done in response. The goals of the NBA are to (i) inform policy and decision making without being prescriptive, (ii) support planning and prioritization for conservation action, (iii) present indicators for national and international reporting, (iv) report on key issues for educational and fund-raising purposes, and (v) provide a platform for collaboration and capacity building across the biodiversity sector.

At the heart of the most recent NBA lies a series of documents (a Synthesis Report and eight technical reports) with associated appendices and spatial datasets. The Synthesis Report is available as a hardcopy book (Skowno et al., 2019), but all other outputs are digital products served on the NBA website.[1] None of the web content is dynamic or interactive; it is purely a repository of reports and files that can be downloaded for offline use.

In this perspective, we consider the current structure and workflows of the NBA and its delivery, and how they can be improved for greater efficiency, transparency and impact in a world of escalating data availability. By highlighting systems that succeed in effectively delivering robust data to decision makers, and considering NBA user needs, we describe a vision, of improved workflows and an effective, interactive web delivery.

2. Current context

The NBA has been undertaken three times in the last two decades (Driver et al., 2005, 2012; Skowno et al., 2019). Each iteration has seen an increase and broadening in the scope, content and contributor base. All three iterations essentially followed the same approach of collating the best available information on biodiversity, undertaking analyzes, and writing up a series of reports, with key datasets posted to an online spatial data repository on SANBI's Biodiversity Advisor web platform.[2] All reports and layers are static, so information and messages contained in them age between version releases, regardless of whether updated information becomes available for certain components. The majority of analyzes that constitute the NBA (e.g., threat status and protection level assessments of taxonomic groups and ecosystem types) were conducted manually using spreadsheets and GIS platforms, generally without prescribed or explicitly documented data and analytical workflows or version control. Staff turnover and methodological advances between releases mean most analyzes have to be conducted from scratch, making the process inefficient and difficult to reproduce (Figure 1).

Global efforts to operationalize the collection of Essential Biodiversity Variables and establish global biodiversity observation networks (Pereira et al., 2013; Han et al., 2017; Turak et al., 2017), combined with parallel initiatives to promote improved data management, stewardship and uptake (Wilkinson et al., 2016; MacFadyen et al., 2022), make it clear that the past NBA workflows are inadequate and will greatly benefit from the incorporation of tools and platforms of the information age.

3. Future plans

The vision for moving the NBA into the information age is of a 'living', interactive, online platform, with clear supporting workflows that can:

- Deliver suitable content for the full range of outputs of the NBA (data, indicators and messages).
- Efficiently accommodate updates to metrics and indicators as new data or methods become available.
- Facilitate easy access to programming scripts and source data, enhancing the reproducibility and transparency of the NBA.

Moving from flat data file-based approaches to relational databases is an important step in making consistent datasets available across a broader user base and to ensure that web-based systems such as SANBI's Biodiversity Advisor can access information. Using centralized databases containing expert validated data also improves preservation and simplifies version control and integration of other products and services. Data providers often lack the capacity or resources to develop Application Programming Interfaces (APIs) and indexing directly from an institutional database is not typically supported. Building capacity for database design and maintenance is critical, when members of the team have been accustomed to working

1 http://nba.sanbi.org.za/

2 http://biodiversityadvisor.sanbi.org

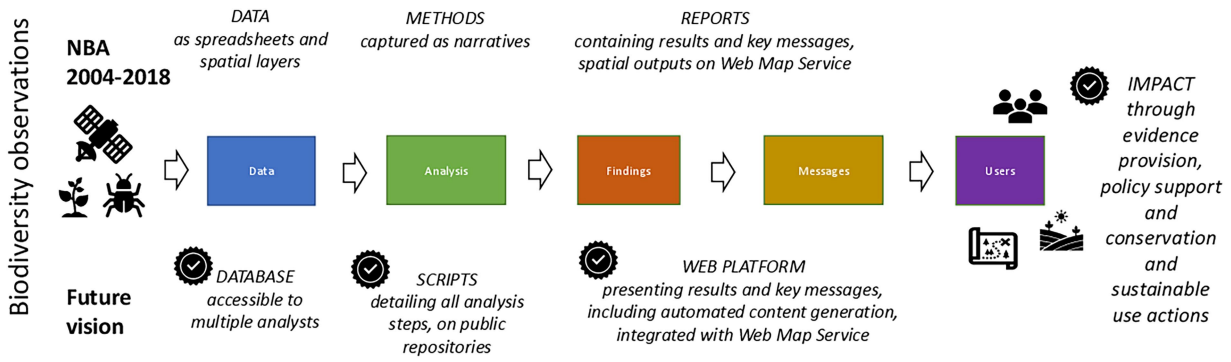

FIGURE 1
Schematic diagram showing the simplified workflow for the National Biodiversity Assessment of South Africa, contrasting between the 2004 to 2018 approach and the vision for the future onwards.

with their own, diverse file-based systems. Examples of effective data science solutions applied in environmental or ecological monitoring and assessments, such the United States Long Term Ecological Research (LTER) Program (Michener et al., 2011; Kaplan et al., 2021) and Ocean Health Index project (Lowndes et al., 2017), speak to the importance of data organization and wrangling, versioning, and the documentation (metadata) aspects of data management. An additional consideration in the context of the NBA is that data are often spatial in nature and comprise raster (grid-based data and imagery) and complex vector data, which require appropriate database types and structures. Bastin et al. (2017) explain some lessons learned from the Digital Observatory for Protected Areas, which include: tracking 'change-only' updates of key spatial datasets, recognizing the value of using different software tools suited to different steps in the workflow, and tips on how to overcome challenges such as legal restrictions of sharing certain datasets.

The challenge in maintaining and updating a centralized database is the interoperability of various data types and formats (e.g., Csv, MS Access, and shape files) from many and varied source datasets. For such integration to be successful, data partners need to agree on a fixed file schema and data standards that enable interoperability [e.g., Atlas of Living Australia and Global Biodiversity Information Facility use the Darwin Core schema for species-related data; the Spatial Data Infrastructure Act (Act 54 of 2003) outlines standards for spatial data infrastructure implementation in South Africa]. Migration tools, such as FME Workbench or Node-Red, can be used to facilitate data integration from disparate flat data files and existing databases. In this way, source data are maintained, and project leads can continue using their preferred systems. Centralizing all NBA datasets will ensure the integration of the necessary data to monitor biodiversity change, increasing accessibility and improving the quality and efficiency of workflows.

Once the data have been queried from the database(s), the next steps in research computing tend to be data preparation, analyzes and presentation. To promote transparency and reproducibility, these should be implemented *via* clearly documented programming scripts, preferably with widely used and open-source data science languages, such as Python and R. Besides their strength of enabling replication of results, such scripted workflows greatly enhance efficiency when iterative adjustments or updates are needed over time–i.e., 'better science in less time' (Lowndes et al., 2017). They also lend themselves to effective version control and collaboration, as the scripted 'recipe' and input files can be organized within a project structure that is easily shared, within a collaborative team and online once it is finalized (Wilkinson et al., 2016). Developing these data science skills within the NBA team is critical to making inroads to the 'smarter' and more transparent NBA vision. Lowndes et al. (2017) illustrate how the application of data science tools improved the quality, efficiency, reproducibility and accessibility of iterative research outputs from the Ocean Health Index project. In line with this reasoning, many scientific journals are increasingly emphasizing open science standards, with a requirement for authors to have reproducible workflows and their data in accessible online repositories.

The use of databases combined with scripts that largely automate the analyzes, lays the foundation for building 'live' web platforms that deliver information to users interactively and can be updated as new results, methods or data become available. Bastille et al. (2020) gives a technical overview of their workflows for integrated ecosystem assessments, including ideas for creating reproducible data visualizations for various programming languages so that time spent customizing visualizations is reduced. Also noted is how the custom web coding (e.g., in JavaScript, CSS, and HTML) is no longer a barrier, because entire websites can be generated in the scientific programming languages such as R and Python.

Delivering a complete data pipeline for the NBA, from databases through to web platform, will require substantial development of staff capacity, supporting infrastructure, and shifts in thinking and practice, all of which should not be underestimated. Fortunately, these aspirations can be developed and implemented in steps that improve the workflows over time, as demonstrated by Lowndes et al. (2017).

A key feature of the envisaged new NBA format is that the work is broken down into smaller 'modules', each with leads and contributing authors assigned. Each module would typically aim to be published as a peer-reviewed journal article, a GitHub repository containing the code required to replicate the analyzes, and a link to an online data repository with the input data. From these, summary text and figures optimized for delivery to a web platform will be created. The efforts of all NBA authors and contributors, many of whom are not SANBI employees, should be acknowledged and the ability to cite each module will re-enforce trust between stakeholders. It is also crucial that the NBA still meets the needs of its numerous and diverse users, including those that have become accustomed to the current report format. The option to download and print certain summary text and figures must therefore be explored.

Defining a clear plan, managing expectations and communicating clearly about the changes will be essential for updating the format and delivery of the NBA. Since the release of the last NBA in October 2019, SANBI has held several discussions with key users and authors through internal SANBI workshops, presentations at various fora regarding the proposed change in form, and a survey on the discovery and use of NBA 2018. The survey was distributed *via* mailing lists and was completed between August and November 2022. It received 153 responses from a cross-section of the biodiversity sector in South Africa. See Supplementary Information and Box 2.

Box 2 NBA use survey

Key findings of the NBA 2018 use/uptake survey (see Supplementary material) indicate that users need both web-based content and access to detailed digital reports, while hard copy books are not widely sought. Users discovered the NBA products primarily through internet searches, or used a known SANBI information portal such as Biodiversity Advisor (http://biodiversityadvisor.sanbi.org) or the NBA's short URL (http://nba.sanbi.org.za/), though email distribution lists were noted as important by some respondents. A substantial portion of users still rely on the PDF reports to access NBA information.

Most users wanted access to the maps and spatial data that accompany the NBA reports. Key messages (narratives) and high-level statistics were also sought-after items (Figure 2). The detailed technical reports were used by the specialist audiences–over 50% of respondents stated they use the terrestrial technical report 'frequently' or 'sometimes', while more specialized reports (e.g., those for the sub-Antarctic or genetic diversity) were used 'rarely' or 'never' by over 70% of respondents. Terrestrial and species datasets are in high demand, followed by freshwater, estuarine, marine and coastal datasets.

4. Promoting understanding and action through clear messaging

Effective state of biodiversity reporting hinges on efforts to distill and communicate a wide array of findings, spanning multiple levels of biodiversity, realms, pressures, states and responses. The NBA process in South Africa has demonstrated a process of iteratively improving messaging strategies and practice, to promote understanding across the user base (Maze et al., 2016). For example, the NBA summarizes benefits of biodiversity, with vignettes covering subjects such as pollination services, the traditional medicine economy, biodiversity-related jobs, food security, and spiritual and cultural uses of biodiversity (SANBI, 2019). The latest NBA includes 19 key messages each comprising a summary of findings, what they mean (the benefit) and what action can be taken. All three elements of the key message (i.e., the 'finding', the 'so what' and the 'call to action') are vital, as they promote understanding and inspire action (UNEP-WCMC and SANBI, 2022). For example, the finding that 30% of estuaries are impacted by freshwater flow reduction should explain the multiple benefits and requirements of sediment and freshwater flow reaching the coast (i.e., a complex interaction of fish nursery function, beach and dune stability, coastal water quality and

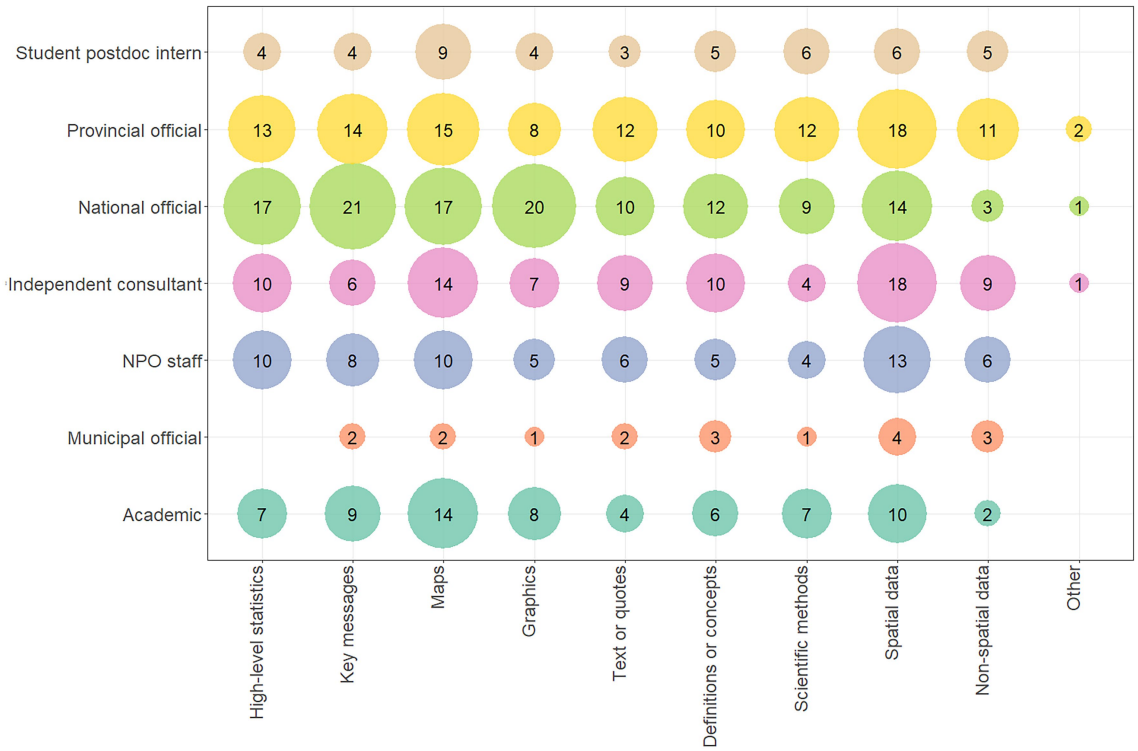

FIGURE 2
Results of the questions 'What type of information did you use from the NBA 2018?' and 'What is your role?'. Respondents could choose multiple responses for the first question. Academics, consultants, non-profit organizations (NPO) and provincial officials used mostly the spatial data and maps, while national officials were the main users of key messages. The high-level statistics were used broadly across all user groups.

other issues), and be followed by recommended actions for freshwater flow strategies and management.

Key messages are often the first thing presented to users, while the underlying detail of indicators and trends are provided as supporting material. NBA 2018's 'Facts, Findings and Key Messages' booklet was a vital product to ensure that the findings were succinctly articulated and acted as a 'summary for policy makers'–a recognized method of ensuring policy makers engage with the scientific findings (IPBES, 2018). This aspect of the NBA needs to be retained and its delivery enhanced. A web platform offers many advantages over the static documents of previous assessments. Through clever design, the most important 'headline' information or succinct messages can be summarized on header pages, with links to the explanations and technical details. In this way, users can access the relevant level of detail they require, from highly summarized messages to fully referenced scientific findings for those wanting to access technical and scientific details.

5. Four key requirements for biodiversity reporting in the information age

5.1. Data science capacity development

Achieving the vision of reproducible NBA workflows requires the development of institutional data science skills. As such skills have not been a priority at SANBI in the past, they need to be built through structured training programs, ongoing mentorship arrangements with key partner institutions and an emphasis of data science skills in the selection of new staff. Traditionally, SANBI staff working on the NBA analyzes have been ecologists or GIS specialists, so it is important to promote the vision that the 'modern analyst' requires some data science skills.

5.2. Enhanced information architecture

SANBI is in the process of redeveloping its Biodiversity Advisor platform, an upgrade that will integrate geospatial, species and ecosystem data, literature and other data made available by SANBI projects such as the NBA and many data partners (Daly and Ranwashe, n.d.). Funding and governance constraints, and the complex nature of the information SANBI serves, necessitate a phased approach to this redevelopment. A modern, web-based NBA requires that these efforts are fast tracked and remains an institutional priority.

5.3. Promoting biodiversity monitoring

A key message in NBA 2018 spoke to South Africa's need for investment in existing and future biodiversity monitoring programs. Without the continuation of monitoring programs and flow of fresh biodiversity observations, the NBA's trend analyzes and iterative computation of key indices would not be possible. Platforms to promote and support focused biodiversity monitoring are essential, requiring dedicated resources and sustainable funding models within and among relevant institutions.

5.4. Partnerships

SANBI operates within a network of partnerships, acknowledging that it is impossible to achieve its mandate or fulfill its vision and mission without the support of those partnerships. A policy and clear mechanisms are in place to operate in this 'network of partners' model. There is an ongoing need to maintain, strengthen and widen this network and SANBI welcomes discussions with parties who could assist with implementation of the NBA vision outlined here.

6. Conclusion

The NBA is a valuable instrument for communicating the state of South Africa's biodiversity, but there are opportunities to leverage tools of the information age for improved science and more effective product and message delivery. Key improvements include better managed and more accessible data, transparent and reproducible, scripted workflows, effective version control and a user-friendly delivery of findings and messages on a regularly updated 'living' platform. Such changes are going to be necessary to ease and strengthen the uptake of key biodiversity messages and priority actions in a society that lives among an increasingly crowded information flow, supporting improved decision making on the ground and in the water. SANBI welcomes offers of support or partnerships to achieve this vision of taking the NBA into the information age.

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 author.

Author contributions

CP conceptualized and wrote initial drafts. AS conceptualized, revised and edited, developed figures and analyzes. JC restructured manuscript and revised sections. KS, BD, and LS revised and edited manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fevo.2023.1107956/full#supplementary-material

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