Biocultural diversity of herpetofauna in South Africa: State and relevance as a science-based policy tool for conservation and social inclusion

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Thesis accepted in fulfilment of the requirements for the degree *Doctor of Philosophy in Science with Environmental Sciences* at the North-West University

and

Doctor of Sciences: Biology degree at Hasselt University

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Graduation July 2022
25985469

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Acknowledgements

The traditional cultures that inspired this research believe “it takes a community to raise a child”. Like a child to herpetology, this ethnoherpetological research is a novel approach to studying frogs and reptiles which would not have come of age without a community of people and organisations supporting it. My late grandfather discussed African cultures with me from an early age and that fascination allowed me to see new perspectives of wildlife besides modern science. My late uncle’s last words before his untimely passing were “finish school” and that stayed with me in the journey to become the first person in my clan to finish graduate school. This final leg of graduate school was financially supported by North-West University, Flemish Interuniversity Council, National Research Foundation, South Africa Institute of Aquatic Biodiversity, South African National Biodiversity Institute, and Youth 4 African Wildlife NPC. Research permits were provided by South Africa’s Department of Environment, Forestry and Fisheries along with its provincial departments in Gauteng and KwaZulu-Natal. Other research permits were obtained from the North-West University Animal Care, Health and Safety Research Ethics Committee and Hasselt University Social-Societal Ethics Committee. Without the support of friends and family there would not have been time to pursue this degree. They allowed me to be absent from important days, filled in for me in my absence, and their unwavering faith in me kept me motivated. Research mentors provided an enabling environment to develop into an independent researcher. Custodians of traditional culture enthusiastically shared their knowledge, which combined with scientific mentorship and culminated in what is my proudest work yet; a fascination of the overlaps between modern science and traditional culture. I am eternally grateful to the community of people and organisations that made this work possible, my clan’s ancestors and the almighty. As another cultural saying goes; “I am, because you helped me to be.”

Preface

This thesis is compiled according to an article-based format and written in UK English using NWU Harvard referencing style. This format presents a unified thesis comprising of published articles and manuscripts intended for publication in Chapters 1 to 7 which are complemented with a general introduction in Chapter 1 and a summative discussion at the end of the thesis. The publishing agreements of the published articles permit them to be included in a thesis for examination purposes. Contributors to each manuscript/article consented to their inclusion in this thesis (Table A).

Articles and manuscripts included in thesis are as follows:

Chapter 1.1 (published commentary): Environmental science investigations of folk taxonomy and other forms of indigenous knowledge. 2020. *South African Journal of Science*.

Chapter 2 (unpublished manuscript): Trends and biases in peer-reviewed literature based on the relationship between South African traditional cultures and biodiversity.

Chapter 3 (published article): Reviewing taxonomic bias in a megadiverse country: primary biodiversity data, cultural salience, and scientific interest of South African animals. 2022. *Environmental Reviews.*

Chapter 4 (unpublished manuscript): Conservation prospects and challenges of South Africa's cultural traditions about herpetofauna.

Chapter 5 (unpublished manuscript): Folk taxonomy of South African frogs and reptiles.

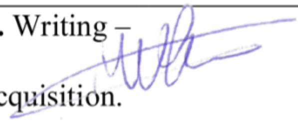
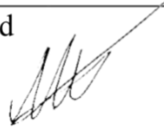
Chapter 6 (unpublished manuscript): Identifying herptiles in South Africa's urban traditional medicine markets: DNA barcoding and cultural perspectives inform monitoring and conservation.

Chapter 7 (unpublished manuscript): Books as environmental management capacity building opportunities exclude most South African languages.

Chapter 7.1 (published article): Life sciences reading material in vernacular: lessons from developing a bilingual (IsiZulu and English) book on South African frogs. 2021. *Current Issues in Language Planning*.

Chapter 7.2 (published article): Idwi, *Xenopus laevis*, and African Clawed Frog: teaching counternarratives of invasive species in postcolonial ecology. 2022. *The Journal of Environmental Education.*

Table A: Individual co-author contributions and consent for inclusion in this thesis.

Chapter/Article	CRediT (Contributor Roles Taxonomy)	Consent
Chapter 2 - 7	**Louis H. du Preez**: Conceptualisation**.** Writing – Review and Editing. Supervision. Funding Acquisition.	
	Jean Hugé: Conceptualisation**.** Writing – Review and Editing. Supervision. Funding Acquisition.	
	Maarten P. M. Vanhove: Conceptualisation**.** Writing – Review and Editing. Supervision. Funding Acquisition.	
Chapter 6	**Edward Netherlands:** Methodology. Review and Editing.	
	Gontran Sonet: Methodology. Review and Editing.	Gontran Sonet (Authentication) Digitally signed by Gontran Sonet (Authentication) Date: 2022.05.24 11:16:52 +02'00'
	Maarten Van Steenberge: Methodology. Review and Editing.	
	Erik Verheyen: Methodology. Review and Editing.	
Chapter 7.1 - 7.2	**Dax Ovid:** Conceptualisation. Methodology. Investigation. Writing - Original draft preparation. Writing – Review and Editing.	

Abbreviations

BBDuk: Decontamination Using Kmers

BLAST: Basic Local Alignment Search Tool

BOLD: Barcode of Life Data Systems

COI: Cytochrome *c* oxidase subunit I

DNA: Deoxyribonucleic acid

GLM: Generalized linear model

GISD: Global Invasive Species Database

GRIIS: Global Register of Introduced and Invasive Species

IDS: BOLD Identification System

IK: Indigenous knowledge

IKS: Indigenous knowledge systems

IPBES: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IUCN: International Union for Conservation of Nature

LoLT: Languages of learning and teaching

NCBI: National Center for Biotechnology Information

NEMA: National Environmental Management Act 107 of 1998

NGO: Non-Profit Organisation

PCR: Polymerase chain reaction

UNESCO: United Nations Educational, Scientific and Cultural Organisation

Summary

The world's regions of high biodiversity in general also have high cultural or linguistic diversity. Researchers noticed this coincidence and started to question whether the connection between the two diversities extended beyond their geographical co-occurrence. This concept of an inextricable connection between biological and cultural diversity became known as biocultural diversity and started being a research topic in the 1990s. Answering research questions about the interlinking of social and biological components of the world requires knowledge from different scientific fields. Ethnobiology which combines social and biological science methodology to investigate past and present relationships between biodiversity and people's cultures, provided an ideal hybrid approach to investigate biocultural diversity. Through this approach that transcends scientific disciplines, the current research provides the first comprehensive analysis of the relationship between South African cultures and the country's diversity of herptiles (frogs and reptiles). South Africa as a country rich in both biological and cultural diversity has a low number of biocultural diversity research in comparison to other research topics. Frogs and reptiles feature in many South African cultural practices and the interaction of South Africa's cultures with the country's herptile species is generally believed to be based on negative perceptions which pose a conservation threat for those species. This comprehensive analysis confirms conservation threats arising from traditional cultural practices in addition to highlighting prospects for social inclusion and just conservation planning that can be derived from the interactions of cultural diversity with biodiversity (specifically herptile diversity). Furthermore, the cultural importance of biodiversity can influence accumulation of primary biodiversity data that is used in biodiversity research and conservation. The study shows herptiles are important to various elements of people's traditional cultures including language, entertainment, spirituality, traditional medicine and gastronomy. Within each element of culture there is either consumptive use of herptiles, or cultural practices are non-detrimental towards herptiles species. By increasing the understanding of the relationship between the two diversities, previously neglected perceptions of the natural environment are revealed along with cultural practices that promote or compel protection of nature. Increased understanding also makes it possible to extend the generic species names used by different cultures into individual names for all described species to enable better communication between specialists and society at large. Compiling comprehensive lists of species names in indigenous languages advances development of African languages and fosters learning about wildlife in vernacular. Cultural norms and practices relating to herptiles can provide opportunities to enhance teaching about herptiles by incorporating practical components of their importance to people. The conservation prospects and marginalised wildlife perspectives highlighted here can be incorporated into South African conservation planning to make conservation initiatives more just and inclusive towards South Africa's diverse people and their contexts. From a policy perspective, this socially inclusive and just approach to conservation is attainable since South Africa's environmental management principles provide for consideration of all perspectives and knowledge (including indigenous knowledge) in environmental management and decision-making. Ensuring that this and other biocultural diversity studies realise the ambitions of becoming science-based policy tools for conservation and social inclusion will require collaboration between various parties that are interested in and/or affected by the management of South Africa's natural environment.

Keywords: Biodiversity hotspot, ethnoherpetology, Indigenous knowledge systems, multimethodology research, postcolonial conservation

Chapter 1

General Introduction

Researchers are at odds about whether conservation efforts should be eco-centric or anthropocentric (Adams & Hutton, 2007; Dowie, 2009). While there are academic disagreements about whether conservation should give preference to humans or biodiversity (Washington *et al.,* 2017, Mikkelson *et al.*, 2007), some researchers found synergy in these two approaches (Elands & van Koppen, 2012). Conservation focus in the last few decades has also changed from a predominant focus on biodiversity to being interdisciplinary and integrating social sciences (Mace, 2014). This is telling, since the majority of the world's biologically megadiverse countries are also among the world's most linguistically or culturally diverse countries (Harmon, 1996a). South Africa is among the countries that are high in both biodiversity (Mittermeier *et al.*, 1997) and cultural diversity (Department of Environment, Forestry and Fisheries, 2015). Along with the co-occurrence of biological and cultural diversity, comes the possibility of shared threat of extinction. Biodiversity extinction risk is a well-documented phenomenon (Chapin *et al.*, 2000; Wake & Vredenburg, 2008). Less well-documented, but of equal importance, is the threat of cultural and linguistic extinctions (Sutherland, 2003). Linguistic diversity is under threat and some languages are reported to have gone extinct (Krause, 1992; Crystal 2000). When Sutherland (2003) assessed the extinction risk of languages using criteria similar to those used for assessing species' extinction risk they found languages to have a greater extinction risk than birds and suggested the possibility of parallel extinction risk between languages and species. Gorenflo *et al.*, (2012) later suggested that as global biodiversity decreases so does linguistic and cultural diversity. Given the possibility of linkages between biological and cultural diversity, it is perhaps necessary to have approaches that jointly focus on these two diversities. This thesis seeks to explore some approaches that jointly focus on biological and cultural diversity, and the conservation and social inclusion benefits that can be derived from this joint focus. The focus is specifically on herpetofauna as they are salient to South African cultures (Phaka *et al.*, 2022) and tend to be neglected in conservation matters (Christoffel & Lepczyk, 2012). With 418 reptile species (Uetz *et al.*, 2022) and 131 anuran species (Frost, 2021), herptiles are an important contributor to the biodiversity of South Africa. Biodiversity conservation efforts are generally biased in their taxonomic focus (Di Marco *et al.*, 2017). Further justification for focusing on herpetofauna is that their populations are experiencing global declines (McCallum, 2007) with the extinction risk of reptile species possibly being underestimated (de Oliveira Caetano *et al.*, 2022). These animals are also negatively perceived by the public (Reimer *et al.*, 2013; Tarrant *et al.*, 2016), and negative perceptions about herpetofauna can threaten their populations (Ceriaco, 2012). The current chapter provides an overview of biocultural approaches and their potential benefits for both people and wildlife.

Introduction to the concept of biocultural diversity

Humans, as part of the biosphere, have an intimate relationship with the natural environment. Part of this relationship is that high biodiversity tends to co-occur with high diversity of people's languages as was shown in studies by Harmon (1996a), Gorenflo *et al.*, (2012), and Loh & Harmon (2005) among others. A majority of the world's biologically megadiverse countries are also among the world's most linguistically diverse (Harmon, 1996a). Decreases in biological diversity are associated with decreased diversity of languages and cultures (Gorenflo *et al.*, 2012). It is worth noting that these inferences on similarities in the occurrence of biodiversity with linguistic or cultural diversity are based on global studies and thus it is possible that on a higher resolution there exists places with an indirect correlation between the phenomenon. Languages are considered an indicator of cultural diversity (Posey, 1999), and generally they are a good proxy or representative for culture that allow for delineation of people into respective cultural groups (Harmon, 1996b). The interaction between biological and cultural/linguistic diversity, beyond their mere co-occurrence, is of interest to researchers (Maffi, 1999). As early as the 1980s, there were suggestions that the interaction between biological and cultural diversity was a complex one (Maffi, 2007). Researchers started to investigate this interaction between the two forms of diversity in the 1990s (Maffi, 2005), and among those researchers were Dearden (1995), Harmon (1996a; 1996b), Gray (1999), and Posey (1999).

The term ‘biocultural diversity’ was coined to highlight the complex relationship between biological and cultural diversity (Harmon, 2002). Usage of the term has increased but there has been little critical reflection on the precise definition of biocultural diversity (Cocks, 2006). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) referred to biocultural diversity as a dynamic aspect of nature resulting from links and feedback between biological and cultural diversity (IPBES 2017). A joint programme of the Convention on Biological Diversity and The United Nations Educational, Scientific and Cultural Organisation refers to biocultural diversity as links between biological and cultural diversity (UNESCO, 2018). According to Cocks and Wiersum (2014), biocultural diversity embraces the intricate interaction between biodiversity and complex value-practice systems relating to how people live with and give meaning to biodiversity. Biocultural diversity comprises all manifestations of the diversity of life (biological and cultural) which are interrelated and possibly coevolved within a complex socio-ecological adaptive system (Maffi, 2007). Elands and van Koppen (2012) refer to biocultural diversity as biodiversity that is understood to be interacting with human culture, moulded and influenced by culture and appraised through culture. Gray (1999) posits that for indigenous people in particular, biodiversity (or the environment) provides a spiritual inspiration for life within their complex value-practice systems. Following a study of biocultural diversity manifestations among South Africa’s AmaXhosa (i.e., people of Xhosa culture), Cocks and Wiersum (2014) provided a more rigorous definition for this difficult-to-define concept when they concluded that the concept of biocultural diversity involves human interactions with biodiversity, rather than the sum of all forms of biological and cultural diversity.

In recognition of the definitional problems of biocultural diversity, Bridgewater and Rotherham (2019) proposed a definition for use in research and policy. This definition frames biocultural diversity as "a dynamic, place-based aspect of nature arising from links and feedbacks between human and cultural diversity and biological diversity" (Bridgewater & Rotherham, 2019). A universal definition for biocultural diversity is yet to be agreed upon. There are however key elements emerging from existing definitions of this concept which are that (1) diversity of life also includes people's cultural/linguistic diversity, (2) biological and cultural diversity do not exist in parallel as they interact with and affect each other in complex ways, and (3) these diversities of life have developed their linkages over time through social-ecological adaptation at the local level (Maffi, 2007). The abovementioned definitions frame the cultural aspect of biocultural diversity as a broad concept. Within this broad notion, culture is recognised as a phenomena that is not limited to indigenous, rural or tribal societies (Philander *et al.,* 2011; Cocks & Wiersum, 2014).

A keyword in the different definitions of biocultural diversity is "interaction(s)". Other authors use "links" instead of "interaction(s)" (see Maffi, 1999; Posey, 1999; Cocks, 2006) in recognition of a connection between phenomenon which are seemingly separate. Without interactions, biocultural diversity would merely refer to the coincidental occurrence of two diversities. If interactions are not a prerequisite for grouping two phenomenon as a single concept, then biocultural diversity may be viewed as a superficial notion that does not warrant any scientific attention. Biocultural diversity manifestations can be verified through evidence that people's cultures are interacting with biodiversity beyond the two phenomenon occurring in the same area; e.g. culturally-motivated consumption of wildlife, animals in folk (or traditional cultural) lore, or wildlife assigned names based on how different cultures perceive and utilise them.

Verification of the interactions between biological and cultural diversity can also involve analytical methods from different scientific fields. For example, molecular analysis was used to show that linguistic boundaries and traditional seed systems have an impact on genetic diversity of crop plants in Southern Mexico (Orozco-Ramírez *et al.*, 2016) and various African countries (Westengen *et al.*, 2014). The definition of biocultural diversity used by Cocks and Wiersum (2014) denotes instances where wildlife is of value to traditional cultural practices. Within these cultural practices organisms either have practical usage value, or they gain value when people show interest in them and they end up being included in those people's lore. Cocks and Wiersum (2014) gave examples of the various ways that AmaXhosa place utilitarian and non-utilitarian value on wildlife through their traditional cultural practices. The current study's approach relies on the definition of biocultural diversity by Cocks and Wiersum (2014), which refers to an overarching concept that deals with complex interactions between biodiversity and people's value-practice systems (i.e., culture or cultural diversity). Coining a new definition of biocultural diversity is avoided as this study only investigates how traditional cultures interact with herpetofauna and does not question the concept of biocultural diversity itself. Furthermore, biodiversity in the context of this study refers to the variability of all living organisms both within species and between species as defined by the Convention of Biological Diversity (United Nations, 1992).

The current study focuses on a comprehensive analysis of the relationship between culture and biodiversity, rather than dwelling on how the concept of this complex relationship should be defined. Working with an existing definition avoids adding to the myriad of definitions currently available (Maffi, 1999; Posey, 1999; Cocks, 2006; etc.) and promotes a move towards a standard or widely accepted definition of biocultural diversity. Studying cultural and biological diversity in their entirety is not feasible and thus it is necessary to use proxies or representatives of the two diversities in biocultural diversity studies. Proxies for biodiversity include ecosystems and taxa, while cultural diversity proxies include languages, cultural groups, and religions. The current research opted to use the term 'cultural groups' rather than 'ethnic groups' as the latter requires prior knowledge people's ancestry (which is not the case here), and the former categorisation can be based on a common language (which was known in this study). It is possible to have a single culture/language being used as a cultural diversity proxy in instances like South Africa where the name of a language can be the same as the name of the cultural group and each culture/language has dialects. Frogs and reptiles are chosen as the biological diversity proxy in this study as they are underrepresented in studies that focus on the relationship between biological and cultural diversity in addition to being part of South Africa's nature-based cultural traditions. Research from other biologically and culturally diverse places such as Amazonian countries shows that frogs and reptiles have potential to feature prominently in biocultural research (Alves *et al.,* 2012; Serrano-Martínez *et al.,* 2017; Ríos-Orjuela *et al.,* 2020)

Interactions between biological and cultural diversity develop at local levels (Maffi, 2007), yet the conservation decisions that may affect this relationship can be either regional, national or local. Furthermore, the biocultural diversity research that can inform these conservation decisions is mostly conducted at a global scale. Significant differences in biocultural diversity are revealed when we consider regional or national contexts (Collard & Foley, 2002). The African continent is generally considered to have high biocultural diversity (Loh & Harmon, 2005), but the distribution of biological and cultural diversity is not homogenous throughout the continent. Research with a regional or national focus, rather than global or continental focus, may find parts of the continent where biocultural diversity is low.

Upon consideration, it becomes clear that there is a mismatch between globally focused research and local or national practice that is based on that research's recommendations. For conservation decision-makers to reach conclusions that embrace the coupling of cultural and natural systems at a local (or national) level, they have to base their inferences on evidence from globally-focused research due to a lack of higher resolution investigations. Conservation that is focused on people and nature requires development of relevant science to ensure its effectiveness (Mace, 2014). Decisions made on generalized inferences may therefore lack relevance and could have limited effectiveness as they do not fully embrace local contexts. The African continent in comparison to the rest of the world has a high concentration of biocultural diversity and South Africa is in the mid-to-high categories of countries harbouring this diversity (Loh & Harmon, 2005). This ranking of biocultural diversity provides a generalised view at continental and national scales with limited indication of nuances at each of those scales. Studies with a specific focus on biocultural diversity at a national or local scale are lax. These knowledge gaps provide motivation for this study focused on the relationship between South African biological and cultural diversity at a national and local level. Further motivation comes from South Africa being a multicultural, multilingual country whose environmental policy considers biodiversity to be a contributor to its heritage of nature-based cultural traditions (Department of Environment, Forestry and Fisheries, 2015). In addition to being multicultural, South Africa is among the world's most biodiverse countries (Mittermeier *et al.*, 1997). South Africa's overarching environmental policy, which forms the basis for the country's biodiversity conservation policy, makes provision for acknowledging traditional cultural practices and consideration of traditional cultures in environmental management processes and planning (Republic of South Africa, 1998). Given that South Africa's history of oppression directed towards the majority of the population also resulted in exclusionary conservation practices which included forced removals and suppression of traditional wildlife perspectives (Leonard, 2013), the social inclusion and integrative conservation benefits stemming from increased understanding of culture's interactions with biodiversity makes biocultural diversity research are important for the country's ambition of socially just conservation.

As this study focuses on the convergence of social and natural components, the methodology used for analysis is required to take this duality into consideration while still remaining grounded in the natural science field from which this study departs. Ethnozoology has emerged as a discipline that caters to this convergence of different components by using a hybrid of social and biological science methodology in its analysis (Alves, 2017). A mixed methods approach is ideal for the purpose of this study, which combines qualitative analysis based on questionnaires, culturomics (computational lexicology), statistical methods, and DNA barcoding, among others. While the hybrid approach is intended to introduce novel ways of solving persisting problems in natural science, the approach can never fully belong to either natural or social science. The mixed methods of this hybrid approach also deviate from their natural and social science origin when they are modified according to the problem they are intended to solve. Besides the dual focus on biological and cultural diversity, the current study's methodologies were also influenced by movement and personal contact restrictions that were put in place to curb the spread of the Coronavirus disease 2019 global outbreak. To keep in line with these restrictions, data collection relied on online sources with the only exception being surveying traditional medicine markets to investigate how DNA barcoding could help increase understanding of traditional medicine practices that rely on frogs and reptiles. The benefit of internet-based data collection was that the online questionnaire received responses from representatives of all the official indigenous languages of South Africa. Achieving this balanced representation of indigenous languages would not have been financially feasible if data were collected through in-person interviews. Relying on the internet for data collection has inherent problems as many South Africans cannot get access to the internet and thus their perspectives will not be represented online. Internet search engines are useful for research but they do have biases (Ćurković & Košec, 2018). Among search engine drawbacks are their search results being biased towards certain countries (Vaughan & Thelwall, 2004), and search algorithms that inherently have some bias (Haim *et al.,* 2017) Even with the inherent drawbacks of internet-based data collection, the study succeeds in giving consideration to South African indigenous cultures that are marginalised from matters relating to the natural environment. The DNA barcoding investigation could not be carried out without interacting with traditional medicine practitioners to obtain tissue samples for analysis and was thus delayed until movement restrictions were eased. The outcomes of this mixed methods research also transcend disciplines, as the different chapters of this thesis are relevant to anthropology, herpetology, ecology, conservation policy, linguistics, language development, equity studies, and post-colonial pedagogy. The subsequent sections of this introduction explain the purpose of this study, provide an outline of how the thesis is presented, and frames the transdisciplinary research conducted here as a contributor to environmental science and socially inclusive conservation planning in South Africa.

Alignment with national and international policy

International and intergovernmental organisations alike are recognising the importance of biocultural diversity. The Convention on Biological Diversity and The United Nations Educational, Scientific and Cultural Organisation launched the Joint Programme on the Links between Biological and Cultural Diversity as a means of strengthening linkages between biological and cultural diversity initiatives (UNESCO, 2018). The International Union for Conservation of Nature, which South Africa's Ministry of Forestry, Fisheries and The

Environment is a member of, actively works with the Convention on Biological Diversity and World Intellectual Property Organisation in increasing recognition of the importance of biocultural diversity and as an effort to support cultural diversity and traditional ecological knowledge (IUCN, 2018). Article 8j of the Convention on Biological Diversity further endorses biocultural approaches through an encouragement to work within national legislation to promote and preserve traditional cultural practices that are relevant to biodiversity conservation (United Nations, 1992). The Convention on Biological Diversity's Local Biodiversity Outlooks 2, a report representing the perspectives of local communities and indigenous communities, recommends mainstreaming of bicultural approaches and provides updates of the success of biocultural approaches (Convention on Biological Diversity, 2020).

The United Nations Environment Program, Society for Conservation Biology, UNESCO, and IUCN have contributed to getting biocultural diversity into policy by commissioning and/or publishing biocultural diversity related studies (see Borrini-Feyerabend *et al.,* 2004, Maffi *et al.,* 1999, Skutnabb-Kangas *et al.,* 2003). The IUCN's Commission on Environmental, Economic and Social Policy seeks to provide advice on the promotion of biocultural diversity and to increase understanding of the relationships between culture, and biocultural heritage (IUCN, 2016). United Nations' Draft Declaration on the Rights of Indigenous Peoples seeks to protect indigenous people's cultures and encourage inclusion of indigenous people in solving global issues (United Nations General Assembly, 2007). South African strategies are affected by the abovementioned international strategies as the country is party to The Convention on Biological Diversity, and a United Nations and World Intellectual Property Organisation member state.

The transdisciplinary nature of biocultural diversity should make for research that is more sensitised to real world needs and research findings that are more applicable to policy

(Maffi, 2005). Biocultural diversity research is better positioned to inform conservation policy as it focuses on both beneficiaries (humans and wildlife) of such policy. In recent years, there has been an increase in calls for the development of South Africa's indigenous languages and their possible inclusion as a medium of instruction in schools. There has also been a push to include more South Africans in conservation to afford them a chance to participate in the bioeconomy. One of the major components of increased inclusion is increasing the understanding of biodiversity and its importance. The objectives of this research align themselves to the development of indigenous languages and the promotion of biodiversity as a relatable concept to a larger audience.

Some of this research's outcomes are intended for non-scientists as a response to South Africa's 2015 National Biodiversity Strategy and Action Plan's acknowledgement that biodiversity is not as broadly understood as it should be (Department of Environment, Forestry and Fisheries, 2015). The current study also contributes to improving public knowledge of an endangered frog species, as provided for by the Biodiversity Management Plan for *Hyperolius pickergilli* (Department of Environment, Forestry and Fisheries, 2017). In line with the Protection, Promotion, Development and Management of Indigenous Knowledge Systems Bill (B6-2016), this research encourages the use of indigenous knowledge and also documents and preserves this knowledge (Republic of South Africa, 2016). The inclusion of traditional cultural perspectives into environmental management is encouraged by National Environmental Management Act 107 of 1998 (NEMA) which is South Africa's overarching environmental legislation (Republic of South Africa, 1998). This overreaching legislation gives power to the National Environmental Management: Biodiversity Act 10 of 2004 which informs protection of endangered species (Republic of South Africa, 2004).

Problem statement

Biocultural diversity, or the interaction between biological and cultural diversity, is often discussed at a global scale with a focus on high taxonomic ranks (i.e., class or family) and rural societies (Harmon, 1996a; Stepp *et al.*, 2004), thus providing a generalised picture of the state of biocultural diversity. Consideration of the relationship between biological and cultural diversity at a higher resolution reveals nuances of biocultural diversity that are not apparent at the global level (Collard & Folley 2002; Manne, 2003). Thus, research that builds on the global view of biocultural diversity by providing an understanding of biocultural diversity within local and national contexts is required. Furthermore, within biocultural diversity research, it is necessary to have a broad notion of culture, where culture is recognised as a phenomenon that occurs beyond rural areas, to provide an understanding of biocultural diversity in other contexts besides those of rural societies. These investigations of the relationship between biological and cultural diversity largely focus on plants, while animals are ignored (Phaka, 2020). This is because plants feature more prominently in traditional cultural practices (Mathibela *et al.*, 2015). However, amphibians and reptiles are a culturally relevant group of animals in South Africa (Simelane & Kerley, 1997; Whiting *et al.*, 2013) and would be an ideal focus in biocultural analysis.

Aims and objectives

The study aims to provide the first comprehensive analysis of how South African cultures that were previously marginalised from wildlife matters interact with the country's herptile diversity. Understanding the nature of the interactions between the two diversities will help gain insights into the interaction's potential value for conservation and social inclusion policy through consideration of previously marginalised perspectives, languages, and knowledge systems. The study's aim will be realised through achievement of the following objectives which individually have varying degrees of relevance to both conservation and social inclusion policy:

Objective 1. Assess the state of research that focuses on the relationship between biodiversity and cultural diversity in South Africa.

Objective 2: Investigate how a culture's interaction with biodiversity can influence the accumulation of the primary biodiversity data required for zoological research.

Objective 3: Investigate the past and present relationship between South African traditional cultures and herptiles, organise these relationships according to elements of culture and analyse their conservation implications.

Objective 4: Conduct an analysis of how traditional cultures interact with herptiles through their naming practices.

Objective 5: Investigate manifestations of biocultural diversity outside rural areas by focusing on use of herpetofauna in urban traditional medicine markets.

Objective 6: Assess social inclusion prospects arising from research focused on the relationship between biological and cultural diversity.

Thesis outline

The introduction to this thesis broadly frames the research conducted here within a niche focused on how biological and cultural diversity are interlinked. The subsequent text focuses on specific aspects of this relationship through a series of articles and unpublished manuscripts that, when combined, provide an understanding of the state of the relationship between South Africa's cultural and herpetofaunal diversity and how this relationship can be a tool for social inclusion and conservation. Following from this brief overview, **Chapter 1.1** moves from the broad introduction of research focused on the relationship between biological and cultural diversity and introduces the South African context in this research niche.

Chapter 2 provides a detailed analysis of past research focused on the interaction between South Africa's biological and cultural diversity. This analysis shows how biocultural research tends to focus on plants used in traditional medicine, which in turn creates bias towards pharmacological interests. The ethical consideration required to protect people's traditional cultural knowledge and prevent undue harm of animal subjects in this research niche exists but is unsatisfactory. The analysis in this chapter highlighted the need for research into the relationship between South Africa's biological and cultural diversity to focus on other fields besides health sciences, increase investigations of animals' cultural relevance, and have equitable focus on all South African cultures.

Chapter 3 explores the influence of cultural salience on accumulation of primary biodiversity data for South African animal species and compares it with the influence of scientific interest. Cultural salience was found to potentially play a greater role than scientific interest in influencing which animal taxa become the focus of primary biodiversity data collection efforts. This taxonomic bias can be lessened by introducing species occurrence record collection targets to existing conservation, and biodiversity monitoring initiatives.

Chapter 4 groups past and present relationships between South African cultural and herptile diversity into different elements of culture and analyses the conservation implications of these relationships. The outcomes confirm that there are conservation threats arising from cultures' interactions with biodiversity, but they also highlight that this relationship provides prospects for enhancing existing conservation measures. These conservation prospects can potentially be incorporated into existing conservation policy and South Africa's legislation for management of the natural environment makes provision for this consideration of traditional perspectives of wildlife.

The focus of **Chapter 5** is on the indigenous names that South African cultures use for frogs and reptiles and an understanding of the principles underlying the assignment of these names to herptile species. These underlying principles have similarities with other folk taxonomies across the world and with scientific taxonomy. South African folk taxonomies lack specific names for all described South African herptile species. The similarities between folk and scientific taxonomy present a chance to extend indigenous names so they are specific to all described species thus simplifying communication when multiple stakeholders collaborate on conservation initiatives.

In **Chapter 6**, the analysis shows that the concept of biocultural diversity is also applicable to urbanised societies and not just rural communities. The focus is specifically on traditional medicine as one of the most noticeable interactions between biological and cultural diversity in urban settings. Traditional medicine markets sell more reptile than frog species and the use of herptiles in urban traditional medicine markets is likely increasing, thus increasing the conservation pressure of this traditional cultural practice. It is possible to ease this pressure on herptiles through collaboration with traditional health practitioners on conservation initiatives aimed at the species they use.

In **Chapter 7**, the analysis focuses on whether South African traditional communities are sufficiently included in opportunities to learn about the natural environment to enable their participation in the management of this environment and have their perspectives considered. The results show that environmental management capacity building opportunities are mostly available to a small percentage of the population, which is at odds with South Africa’s environmental legislation which promotes social inclusion in those opportunities. **Chapter 7.1** discusses how concerted efforts for social inclusion in environmental capacity building do more than just increase inclusivity. They can also contribute to African language development and reveal previously marginalised cultural perspectives of wildlife. **Chapter 7.2** demonstrates the potentially far-reaching implications of considering social inclusion with a case study that theorises how the consideration of culture’s interaction with one frog species (*Xenopus laevis*) could inspire life sciences lessons to encompass species' relevance to previously overlooked communities while highlighting the social injustices that are sometimes associated with sampling species for scientific purposes. Unlike the preceding work, this sub-chapter is a theoretical text discussing social inclusion implications within frameworks of postcolonialism, indigenous studies, and race.

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Chapter 1.1

Environmental science investigations of folk taxonomy and other forms of indigenous knowledge.

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Adapted from: *South African Journal of Science.* 2020.

https://doi.org/10.17159/sajs.2020/6538

Following the discussion of biocultural approaches in the preceding section, this text provides a brief commentary on what is possible in the South African context and the chapters that follow analyse what is briefly highlighted here. This commentary is foregrounded with a summary of what Phaka *et al.,* (2019) achieved in their assessment of the relationship between Zululand frog diversity and culture as that local scale pilot study served as a predecessor to the current nationwide study.

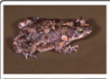
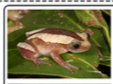
The strides made in standardising English and Afrikaans frog names created a gap to achieve the same for the other South African languages spoken by most of the country's population. This gap hints at an exclusion of indigenous languages and associated cultures from wildlife-related matters. Frog names in indigenous languages are part of mostly undocumented cultural/indigenous knowledge systems and are subject to indigenous naming and classification guidelines. Indigenous names often have localised use due to cultural specificity. Indigenous taxonomy is part of a pre-scientific knowledge system which is often considered a pseudoscience. However, a recent study was able to show that indigenous amphibian taxonomy from the Zululand region of South Africa's KwaZulu-Natal Province has scientific merit (Phaka *et al.,* 2019). Scientific merit means it has applicability in scientific contexts beyond its use in pre-scientific traditional cultural contexts. This scientific merit is deduced from the analysed indigenous naming and classification guidelines having similarities to those used when formulating scientific names as well as Afrikaans and English names. A comparison with other indigenous taxonomy research shows that similarities also exist between Zululand's taxonomy and indigenous taxonomies of other parts of the world. Researchers also found indigenous names to be condensed forms of knowledge rather than abstract words (Hidayati *et al.,* 2018) Information about species' behaviour and ecology is often contained within indigenous names (Mourão *et al.,* 2006). Linnaean taxonomy's basic structure is inspired by indigenous taxonomy's fundamental organising principles (Ross, 2014).

Other investigations have shown that some traditional medicinal and gastronomic uses of wildlife purported in South African indigenous knowledge systems have scientific validity (Abdillahi *et al.*, 2011; Harvey *et al.*, 2011). Conversely, overexploitation of natural resources under the guise of indigenous knowledge systems has also been reported (Hunter *et al.*, 2013; Dickman *et al.*, 2015). Cross-disciplinary research that investigates the scientific merit of indigenous knowledge systems is not meant to justify culturally motivated overexploitation. This research seeks to explore an under-investigated knowledge base while also increasing social inclusion in environmental matters. Studies of this nature are spurred on by the recent research focus on the interactions between biological and cultural biodiversity (Maffi, 2005), and the environmental science sector's acknowledgement of the coupling of ecological and social systems (Kareiva & Marvier, 2014). Zululand's rural setting is steeped in culture and high in amphibian diversity, and thus presented the region as an ideal area to pilot a study investigating interactions between South Africa's herpetofaunal and cultural diversity.

This pilot was completed with two major outcomes. Firstly, there is merit in researching how South African cultures interact with local biodiversity (in this case herpetofauna). Secondly, it is possible to standardise the indigenous names of South Africa's amphibians and bridge the gap left by the standardisation of names in only two of the country's 11 official languages. The outcomes fulfil scientific curiosity (as this is a relatively novel research field) and also contribute to social inclusion. The social inclusion begins before the actual research takes place as one has to sufficiently integrate into the community whose culture they are researching in order to understand their ways and also introduce them to the type of wildlife research being undertaken. This integration helps with being welcomed into the community and enables discussions about potential benefits to be obtained in return for allowing the survey of elements of their culture that interact with biodiversity. Social inclusion is a clear benefit from the researcher's point of view, but for the community it may be perceived as being intangible. More tangible benefits are likely to appeal to research participants. For the Zululand community, a tangible benefit was an educational publication (a handbook) based on their knowledge of amphibians in their area. The publication was translated to their own language (IsiZulu) and thus contributed to efforts of developing IsiZulu into a language of learning and teaching. Indigenous knowledge relating to amphibians has also been preserved in the process.

Employing purposive sampling to collect cultural data has a greater chance of yielding results when there is minimal negativity towards the research project. The purposive sampling of 13 Zululand community members using a semi-structured questionnaire technique allowed documentation of naming and classification guidelines used for amphibians in the area. The study's sample consisted of 3 female and 10 male native IsiZulu speakers whose socio-economic status varied from unemployed to full-time students and the permanently employed. The participants were from five different parts of Zululand with similar environmental conditions. Analysis of the documented guidelines revealed that Zululand's indigenous taxonomy groups amphibian species according to their habits, habitats or appearance. Scientific taxonomy conventions also group species according to morphology, while commonly used English and Afrikaans names sometimes refer to habits and habitats of species. Species with similar traits are placed under uninomial IsiZulu names. These single word IsiZulu names correspond to either scientific genera or families (Figure 1) that are also represented by uninomial names. Zululand taxonomy's use of single word names to group some species based on morphological similarities (e.g., *Hyperolius* spp. are called umgqagqa) is in line with the International Code of Zoological Nomenclature (International Commission on Zoological Nomenclature, 1999).

The similarities between indigenous and scientific taxonomy guidelines have enabled supplementation of indigenous taxonomy guidelines with their modern knowledge counterparts. These supplemented guidelines were then used to assign individual IsiZulu names to Zululand's amphibian species (Table 1). The newly formulated IsiZulu species names have a meaning that is similar to English and/or scientific names and they also retain their relevance to IsiZulu speakers as they are modified from existing indigenous names.

	Genus	Family	Indigenous name
	*Arthroleptis* Smith, 1849	Arthroleptidae Mivart, 1869	Umanswininiza[a]
	*Leptopelis* Günther, 1859	Arthroleptidae Mivart, 1869	Isele
	*Breviceps* Merrem, 1820	Brevicipitidae Bonaparte, 1850	Isinana
	*Poyntonophrynus* Frost et al., 2006	Bufonidae Gray, 1825	Ixoxo
	*Schismaderma* Smith, 1849	Bufonidae Gray, 1825	Ixoxo
	*Sclerophrys* Tschudi, 1838	Bufonidae Gray, 1825	Ixoxo
	*Hadromophryne* Van Dijk, 2008	Heleophrynidae Noble, 1931	Isele
	*Hemisus* Günther, 1859	Hemisotidae Cope, 1867	Isinana
	*Afrixalus* Laurent, 1944	Hyperoliidae Laurent, 1943	Umgqagqa
	*Hyperolius* Rapp, 1842	Hyperoliidae Laurent, 1943	Umgqagqa
	*Phlyctimantis* Laurent and Combaz, 1950	Hyperoliidae Laurent, 1943	Ukassina[b]
	*Kassina* Girard, 1853	Hyperoliidae Laurent, 1943	Ukassina[b]
	*Phrynomantis* Peters, 1867	Microhylidae Günther, 1858 (1843)	Isele
	*Phrynobatrachus* Günther, 1862	Phrynobatrachidae Laurent, 1941	Isele
	*Hildebrandtia* Nieden, 1907	Ptychadenidae Dubois, 1987	Ixoxo
	*Ptychadena* Boulenger, 1917	Ptychadenidae Dubois, 1987	Uvete

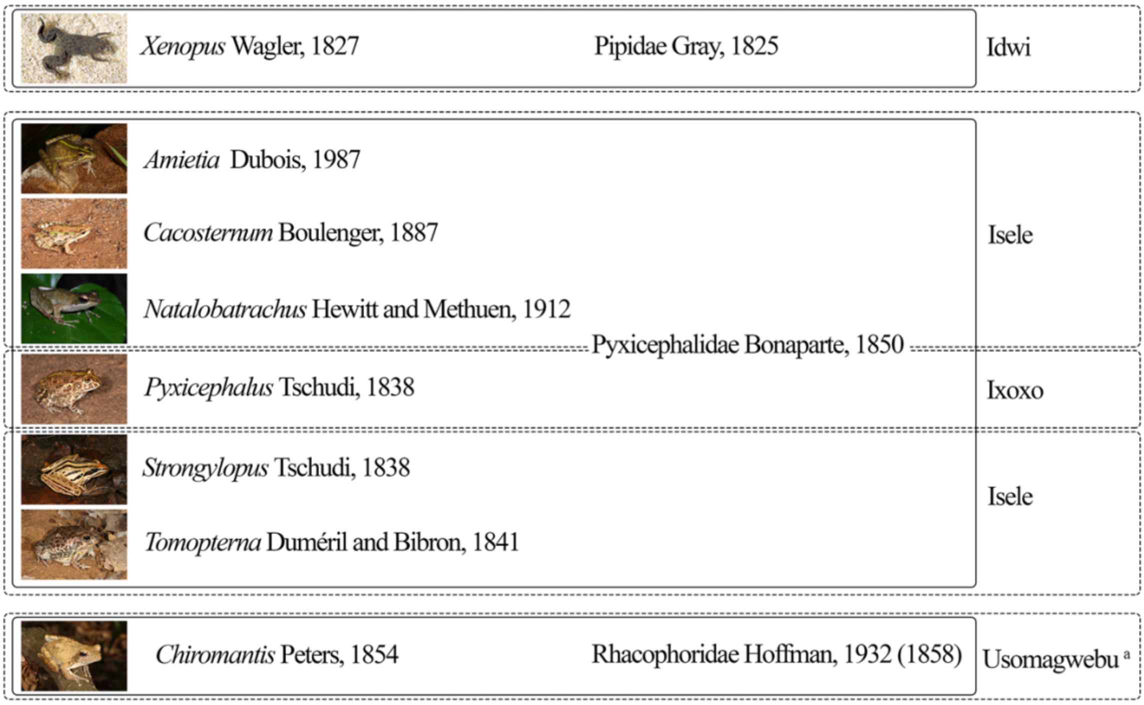


Figure 1: Zululand's indigenous amphibian taxa and their corresponding scientific taxonomy equivalents (Phaka *et al.,* 2019).

[a] IsiZulu names modified from Tarrant (2015) with the assistance of Mr Bongani Mkhize.

[b] Name borrowed from existing English generic and common name.

When the newly formulated names are checked against conventions of the International Code of Zoological Nomenclature (1999), 55% conform to the principles of binomial nomenclature as each name is composed of two words with the first word being a name that group's multiple species together. Due to the IsiZulu language's descriptive nature, the remaining 45% of names could not conform to the principles of binomial nomenclature without their meaning being altered.

The semi-structured interview technique fostered discussions among participants of the pilot study. Those discussions presented an opportunity to document folkloric elements of the cultural knowledge system in addition to indigenous taxonomy. There is an indication that some folklore is more than mere mythical beliefs and may constitute observations of amphibian behaviour coupled with attempts to explain the observed behaviour using available knowledge. For instance, members of the Zululand community believe that grass frogs (Ptychadenidae) bring rain as they are often seen moments before a rain event. Without knowledge of amphibian biology, the repeated observation of rainfall being preceded by the presence of grass frogs may reinforce this idea of them bringing rain. With an understanding of amphibian biology, increased activity of the frogs would be attributed to the humid and moderate conditions associated with rain. These favourable conditions precede rainfall and thus prompt frog activity to also precede rainfall. The indigenous taxonomy and folklore investigated in the pilot study represent a few of the many elements in the relationship between biological and cultural diversity.

Other aspects of this relationship include medicinal usage, gastronomy, and traditional ecological knowledge. This thesis presents research conducted as continuation of the pilot study summarised above, and investigations of the relationship between cultural and herpetofaunal diversity have been broadened to cover the entire country and also include reptiles. Upon conclusion of this research project, it will be possible to make inferences about the state of the relationship between South African cultures and herpetofaunal diversity, and how this relationship can inform environmental policy that embraces the coupling of social and environmental systems.

Table 1: IsiZulu names assigned to 58 Zululand frog species, published in Phaka *et al.,* (2017).

IsiZulu name (Scientific name)
1. Umanswininiza Onyawo Zingamafosholo (*Arthroleptis stenodactylus* Pfeffer, 1893)
2. Umanswininiza Wasehlathini[a] (*Arthroleptis wahlbergii* Smith, 1849)
3. Isele Lasezihlahleni Elinsundu[a] (*Leptopelis mossambicus* Poynton, 1985)
4. Isele Lasezihlahleni LaseNatali (*Leptopelis natalensis* (Smith, 1849))
5. Isinana Sasehlathini[a] (*Breviceps adspersus* Peters, 1882)
6. Isinana SikaBilbo[a] (*Breviceps bagginsi* Minter, 2003)
7. Isinana SakwaPhinda (*Breviceps carruthersi* Du Preez, Netherlands, and Minter, 2017)
8. Isinana SaseMozambique (*Breviceps mossambicus* Peters, 1854)
9. Isinana SakwaNdumo (*Breviceps passmorei* Minter, Netherlands, and Du Preez, 2017*)*
10. Isinana Sekhwela/Somtshingo (*Breviceps sopranus* Minter, 2003)
11. Ixoxo Elifishane (*Poyntonophrynus fenoulheti* (Hewitt and Methuen, 1912))
12. Ixoxo Elibomvu[a] (*Schismaderma carens* (Smith, 1848))
13. Ixoxo Eliklabalasayo[a] (*Sclerophrys capensis* Tschudi, 1838)
14. Ixoxo Eliluhlaza Okotshani (*Sclerophrys garmani* (Meek, 1897))
15. Ixoxo Lembodlomane[a] (*Sclerophrys gutturalis* (*Power, 1927)*)
16. Ixoxo Lomhlane Oyisicaba (*Sclerophrys pusilla* (Mertens, 1937))
17. Isele Lasempophomeni (*Hadromophryne natalensis* (Hewitt, 1913))
18. Isinana Esimabhadubhadu[a] (*Hemisus guttatus* (Rapp, 1842))
19. Isinana Esipendiwe (*Hemisus marmoratus* (Peters, 1854))
20. Umgqagqa Oyigolide (*Afrixalus aureus* Pickersgill, 1984)
21. Umgqagqa Othambile (*Afrixalus delicatus* Pickersgill, 1984)
22. Umgqagqa Omkhulu[a] (*Afrixalus fornasini* (Bianconi, 1849))

23. Umgqagqa i-Argus[a] (*Hyperolius argus* Peters, 1854)

24. Umgqagqa Opendiwe[a] (*Hyperolius marmoratus* Rapp, 1842)

25. Umgqagqa Ka-Pickersgill (*Hyperolius pickersgilli* Raw, 1982)

26. Umgqagqa Omude (*Hyperolius poweri* Loveridge, 1938)

27. Umgqagqa Weminduze[a] (*Hyperolius pusillus* (Cope, 1862))

28. Umgqagqa Wemigqa Ephuzi (*Hyperolius semidiscus Hewitt, 1927*)

29. Umgqagqa Oluhlaza Okotshani[a] (*Hyperolius tuberilinguis* Smith, 1849)

30. UKassina Wemilenze Ebomvu (*Phlyctimantis maculatus* (Duméril, 1853))

31. UKassina Obhadlayo[a] (*Kassina senegalensis* (Duméril and Bibron, 1841))

32. Isele Elisanjoloba Elinemigqa[a] (*Phrynomantis bifasciatus* (Smith, 1847))

33. Isele Lechibi Lasempumalanga Afrika (*Phrynobatrachus acridoides* (Cope, 1867))

34. Isele Lechibi Elifishane[a] (*Phrynobatrachus mababiensis* FitzSimons, 1932)

35. Isele Lechibi Elihonayo[a] (*Phrynobatrachus natalensis* (Smith, 1849))

36. Ixoxo Elihlotshisiwe[a] (*Hildebrandtia ornata* (Peters, 1878))

37. Uvete Olujwayelekile (*Ptychadena anchietae* (Bocage, 1868))

38. Uvete Olunomugqa Obanzi (*Ptychadena mossambica* (Peters, 1854))

39. Uvete LwaseNile[c] (*Ptychadena nilotica* (Seetzen, 1855))

40. Uvete Olunempumulo Ecijile[a] (*Ptychadena oxyrhynchus* (Smith, 1849))

41. Uvete Olunemigqa[a] (*Ptychadena porosissima* (Steindachner, 1867))

42. Uvete Olufishane (*Ptychadena taenioscelis* Laurent, 1954)

43. Idwi Elijwayelekile[a] (*Xenopus laevis* (Daudin, 1802))

44. Idwi Lika-Müller (*Xenopus muelleri* (Peters, 1844))

45. Isele Elithambile Elijwayelekile (*Cacosternum boettgeri* (Boulenger, 1882))

46. Isele Elithambile LaKwaZulu (*Cacosternum nanogularum* Channing et al., 2013

47. Isele Elithambile Elisathusi[a] (*Cacosternum nanum* Boulenger, 1887)

48. Isele Elithambile Elinemigqa (*Cacosternum striatum* FitzSimons, 1947)

49. Isele Lase-Kloof (*Natalobatrachus bonebergi* Hewitt and Methuen, 1912)

50. Isele Lasemfuleni Elijwayelekile[a] (*Amietia delalandii (Duméril and Bibron, 1841)*)

51. Inkunzi Yexoxo (*Pyxicephalus edulis* Peters, 1854)

52. Isele Lasemfuleni Elinemidwa[a] (*Strongylopus fasciatus* (Smith, 1849))

53. Isele Lasemfuleni Eligqafazayo[a] (*Strongylopus grayii* (Smith, 1849))

54. Isele Lasesihlabathini Elinemigqa (*Tomopterna cryptotis* (Boulenger, 1907))

55. Isele Lasesihlabathini Elingqongqozayo[a] (*Tomopterna krugerensis* Passmore and Carruthers, 1975)

56. Isele Lasesihlabathini LaseNatali[a] (*Tomopterna natalensis* (Smith, 1849))

57. Isele Lasesihlabathini LikaTandy (*Tomopterna tandyi* Channing and Bogart, 1996)

58. Usomagwebu Waseningizimu[a] (*Chiromantis xerampelina* Peters, 1854)

A total of 30 new IsiZulu species names were formulated, 28 were modified from published names, and six folk generic names were obtained through interviewing 13 Zululand community members.

[a] Name modified from Tarrant (2015) with the assistance of Mr. Bongani Mkhize.

[c] This species appears as *uvete LwaseMaskarina* in Phaka *et al.*, (2017). In this study it was changed to *uvete LwaseNile* to correspond with the scientific name change of this species in South Africa (Zimkus *et al.,* 2017).

Indigenous knowledge's place in science

The interaction of traditional knowledge with nature has generally been viewed to have negative environmental consequences. This view is justified by reports of environmental abuses informed by traditional knowledge (Hunter *et al.,* 2013; Dickman *et al.,* 2015). Furthermore, the view was pervasive in environmental science as evidence of less destructive interactions was limited, but it started changing when research into the relationship between biological and cultural diversity started generating evidence to the contrary. Research solely focused on understanding the relationship between the two diversities started gaining prominence in the 1990s within the framework of biocultural diversity (Maffi, 2005). A systematic review of scientific literature on South Africa's biocultural diversity research shows that focus over a period of 28 years has collectively transcended more than 10 disciplines or fields of study. Some of this literature presents evidence of indigenous knowledge's applicability in human health science (Abdillahi *et al.,* 2011), veterinary science (Moyo *et al.,* 2009) and ecology (Brook & McLachlan, 2008). The research presented is transdisciplinary as questions stemming from one discipline are answered using methods from another field of study. Transdisciplinarity is a critical, self-reflexive research approach relating societal with scientific problems and producing new knowledge through integration of different scientific and extra-scientific insights with the aim of contributing to both societal and scientific progress (Jahn *et al.,* 2012). The consideration of extra-scientific insights translates to inclusion of indigenous knowledge practitioners as well as their perspectives. This inclusion is especially vital for conservation planning which often focuses on intrinsic value of wildlife protection while disregarding people who should ultimately be beneficiaries of conservation initiatives. People's perspectives have become integral to conservation planning, and failing to integrate people lessens the effectiveness of this planning (Bennett *et al.,* 2017). In a culturally rich country such as South Africa, people's perspectives are often linked to their culture. Biodiversity is especially important to the culture of many South Africans as it features in their names, praises, folklore, art and traditional medicine. The country has a rich heritage of nature-based cultural traditions and this reiterates the importance of wildlife to the country's cultures (Department of Environment, Forestry and Fisheries, 2015). Conservation planning that embraces the complex interaction between biological and cultural diversity is more likely to succeed in reducing biological and cultural diversity loss, and could potentially provide effective and just conservation outcomes across different socio-ecological contexts (Gavin *et al.,* 2015). Socio-ecologically just conservation planning requires the knowledge pool from which it draws evidence to also embrace the interaction between biological and cultural diversity. The pilot study and its follow-up project as mentioned above aim to contribute to this knowledge pool through focusing on languages/cultures and taxa that are often marginalised from environmental science research.

Studying the relationship between South African biological and cultural diversity

The research required to inform appropriate environmental planning for the unique South African biological and cultural landscape should adequately embrace local contexts. A systematic review of 263 peer-reviewed articles shows this required research is succeeding in providing a greater understanding of the South African culture and biodiversity relationship, but the local context is not fully embraced due to knowledge gaps that still exist. Research focus is biased towards four of the country's nine provinces. Within provinces, research tends to concentrate on certain localities (Figure 2).

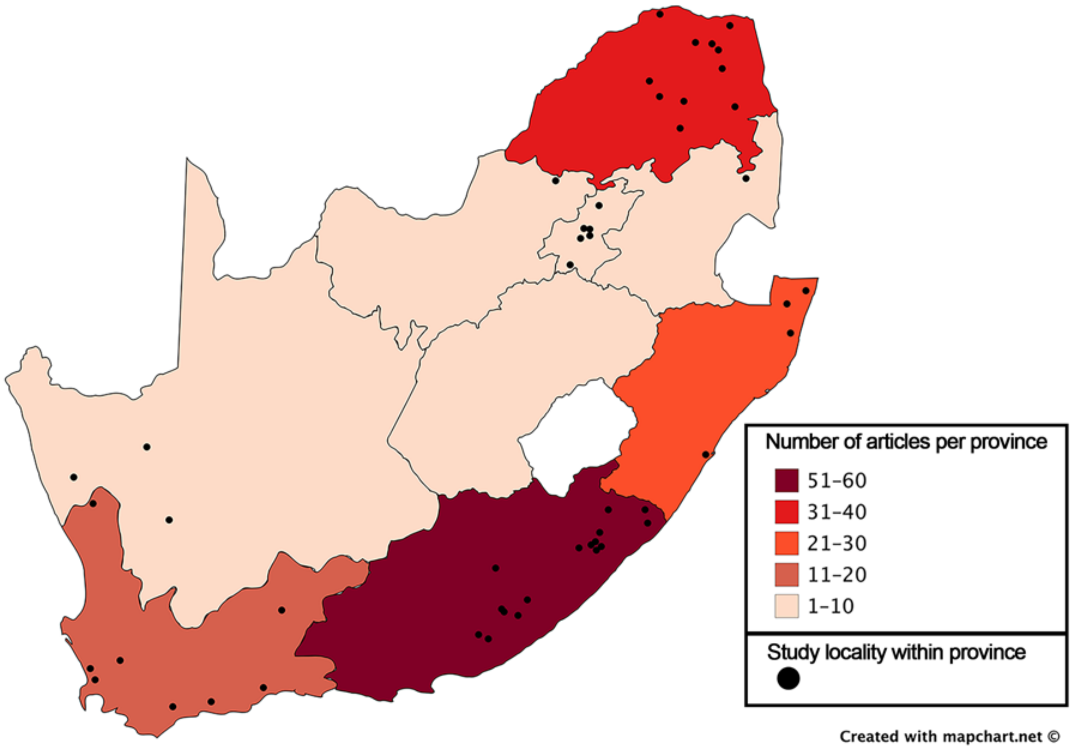


Figure 2: Distribution of biocultural diversity research within South Africa. The map plots spatial research focus (grouped by province) of 142 of 263 peer-reviewed articles published between 1990 and 2018. The remaining 121 articles have a national research focus.

Investigations of South African biocultural diversity have steadily increased from 1990, when the biocultural diversity concept gained prominence, to 2018, when the follow-up project commenced (Figure 3). Ethical consideration or the reporting thereof was only present in 74 of the 263 articles in the review sample. Without this ethical consideration there is no assurance that researchers did not exploit participants or subject non-human organisms to undue stress.

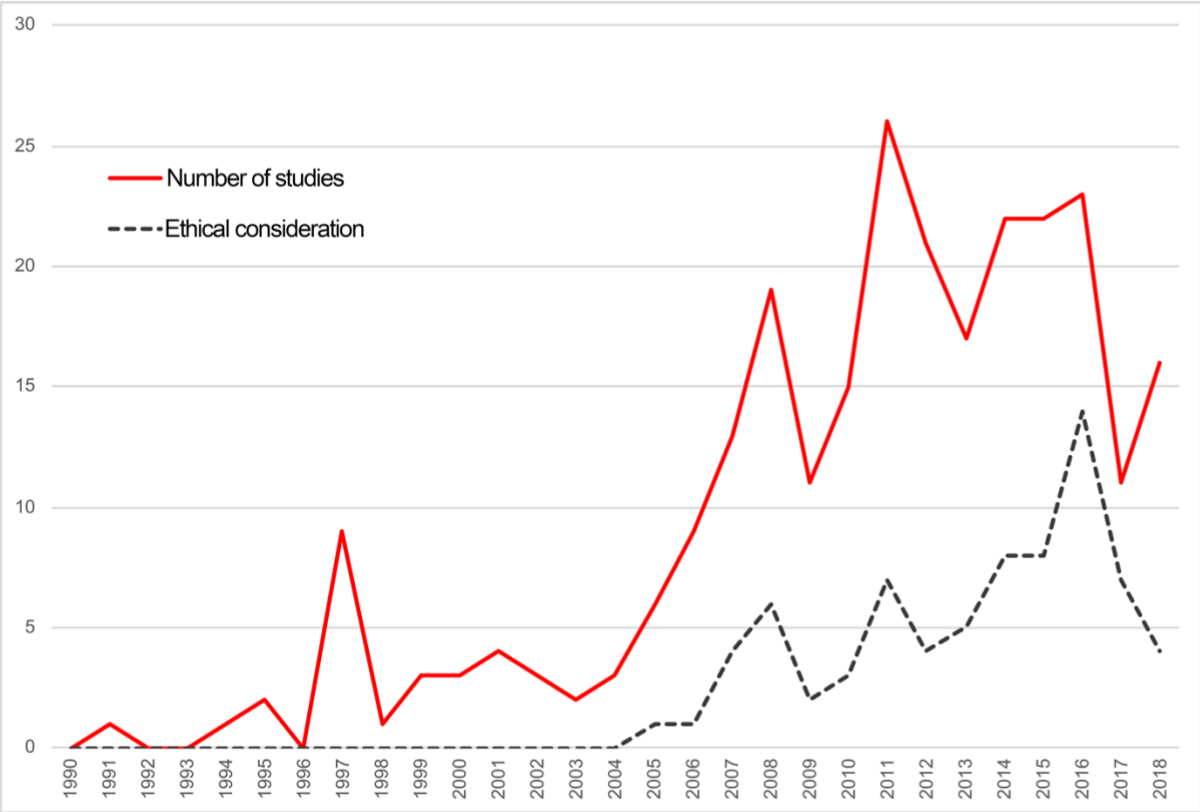


Figure 3: South African biocultural diversity literature published in 1990–2018 and the ethical considerations of these studies. The studies were searched on the Scopus database and the ethical consideration data were extracted using a pre-determined review protocol.

The consideration of ethics began in 2005, the year before adoption of the International Society of Ethnobiology's code of ethics following deliberations that began in 1996 (International Society of Ethnobiology, 2006). Ethical consideration is not extended to plants which feature prominently in this research niche as they have a weaker moral standing than humans and non-human animal research subjects. Plants dominate the focus of South African biocultural diversity investigations (Figure 4). This taxonomic bias misrepresents the proportion of taxa which interact with culture. The dominance of plants is due to their importance in traditional medicine, and this results in a bias in the field of study within which investigations are carried out. Of the 14 fields of study explored in the review sample, human health science was explored in 84% of the articles. The taxonomic bias provides motivation to increase representation of herpetofauna (along with other non-plant taxa) in research to make the South African biocultural diversity knowledge pool more contextually appropriate and suited to informing socio-ecologically just environmental policy.

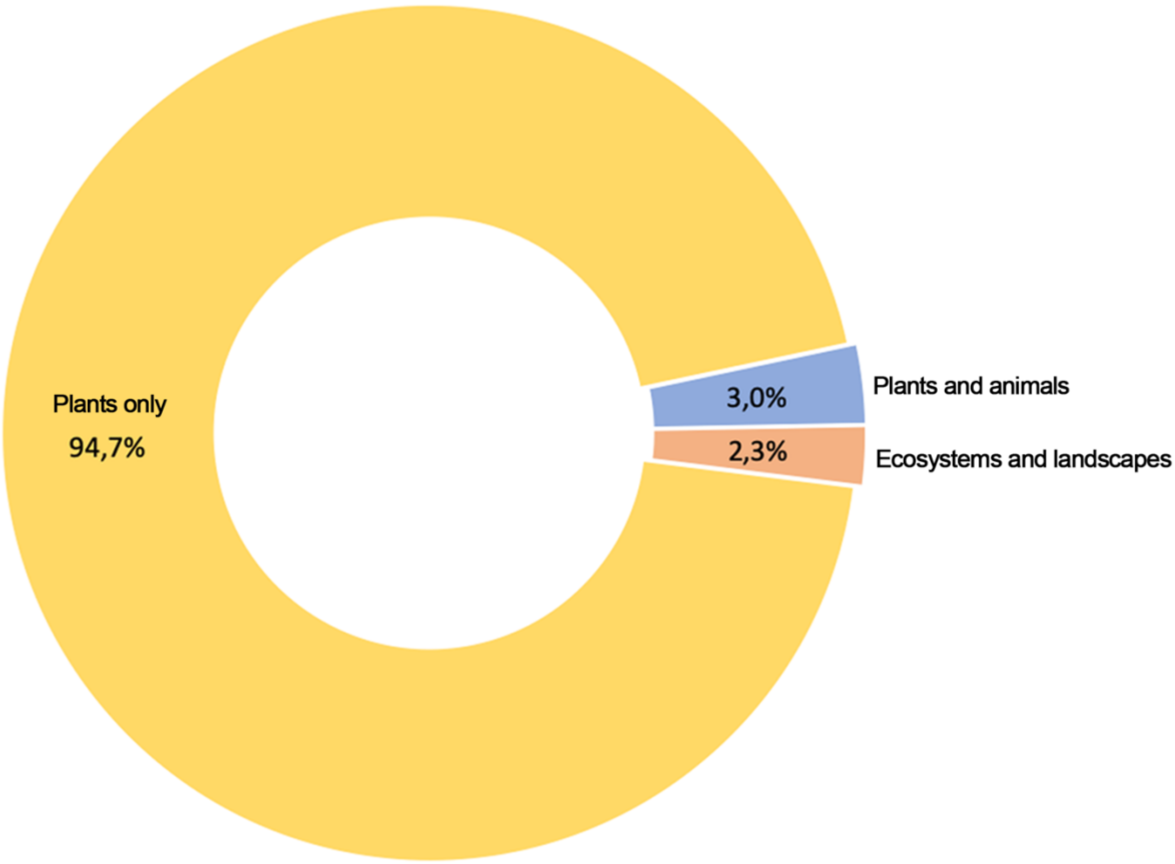


Figure 4: Taxonomic focus of South African biocultural diversity research from 1990 to 2018.

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Chapter 2

Trends and biases in peer-reviewed literature based on the relationship between South African traditional cultures and biodiversity.

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(Manuscript submitted to journal)

Abstract: There is a growing research focus on the interactions between biological and cultural diversity, and South Africa as a biologically and culturally diverse country is ideal for this type of research. Through this research we can understand a country's past and present traditional cultural relationships with biodiversity and how they are of value to modern conservation. We reviewed scientific articles for a snapshot of the state of research based on the interactions between South Africa's biological and cultural diversity. Peer-reviewed literature based on interactions between biodiversity and culture in South Africa is increasing but this knowledge pool has several biases limiting its usefulness to conservation planning. A strong bias towards plants resulting from ethnopharmacological research is among the shortfalls, and it cascades into several other biases in this research niche. Remedying these biases requires researchers to increase focus on animal species, overlooked cultures and understudied localities. Investigations should go beyond human health contexts, and also consider other cultural diversity proxies besides languages. Furthermore, urban areas should be embraced as study areas due to them containing subsets of various traditional cultures. This current synthesis provides a template for reviewing trends and biases of research based on the interactions between a country's biological and cultural diversity.

Keywords: Biodiversity, Biocultural diversity, Ethnobiology, Indigenous Knowledge Systems, Sustainability.

Introduction

The co-occurrence of biological and cultural diversity is a global phenomenon (Moore *et al.*, 2002). Correlations between the two diversities becomes more apparent when looking at the global distribution of Indigenous Communities (Gray, 1999). As many as 83% of countries considered to be megadiverse are also among the 25 countries with the highest linguistic diversity (Harmon, 1996). This linguistic diversity is considered an indicator of cultural diversity (Manne, 2003). More than 4800 of the over 6900 languages spoken globally occur in regions containing high biodiversity without any obvious reason why high biodiversity areas host high linguistic diversity (Gorenflo *et al.*, 2012). This biodiversity's future is inextricably linked to the future of Indigenous Communities (FPP, 2016). Around the 1990s it became apparent from international conservation discourse that a complex interaction exists between biological and cultural diversity (Maffi, 1999). It was in the same decade that ideas emerged to empirically investigate the interaction between biological and cultural diversity, or biocultural diversity (Maffi, 2005). With time, biocultural diversity became considered part of the biocultural paradigm; biocultural approaches that recognize the complex interactions between biological and cultural diversity, but they differ in the amount of emphasis placed on ecological or anthropological contexts (Merçon *et al.*, 2019). Of interest to this study is the focus of peer-reviewed literature within this biocultural paradigm.

Researching biological and cultural diversity in their entirety is not feasible and thus it is necessary to use proxies of the two diversities in biocultural diversity studies. Proxies for biodiversity in literature include ecosystems and biological taxa, while cultural diversity proxies include languages, cultural groups, and religions. In the South African context, a single culture/language can be used as a cultural diversity proxy since many of the cultural groups and languages are referred to using a single name, and within a certain culture/language grouping there are several subsets of cultural groups and language dialects.

A practical example: SePedi is a South African language, and the term also refers to a culture. This SePedi language/culture includes, inter alia, Batlokwa, Matebele, Balobedu and Mapulana groupings who have their own language dialects and value-practice systems which overlap in varying degrees. Researching how these cultures are linked to biodiversity contributes to environmental sustainability by providing a clear understanding of the connection between biological and cultural diversity and the related feedback mechanisms (Bridgewater & Rotherham, 2019). An enhanced understanding of people's values and world views is likely to improve natural resource management (Cocks *et al.*, 2012).

An explicit focus on providing an enhanced understanding of biocultural diversity in academic research is relatively new, and to understand the extent of this research requires a systematic review of relevant literature (Phaka, 2020). The current review of peer-reviewed literature with a focus on the interaction between biological and cultural diversity aims to inform future research in order to improve the understanding of this relationship at a national level and in turn have a more contextually appropriate knowledge pool on which to base socio-ecologically just environmental policy. South Africa is an ideal case study for investigating the relationship between culture and biodiversity as it is one of the most biodiverse countries in the world (Mittermeier *et al.*, 1997) and there are multiple cultures interacting with this biodiversity. We use a literature review to assess the state of peer-reviewed research that is based on interactions between South Africa's biological and cultural diversity. This literature review has the potential to be a template for quantifying research that is based on interactions between biological and cultural diversity at a national scale while also enhancing understanding of the heterogeneity of those interactions.

Materials and Methods

Reviews provide platforms for new ideas, expose inconsistencies in existing research and synthesize diverse results (Bem, 1995). It is essential for systematic reviews to include a study protocol with descriptions of research questions, a hypothesis, and criteria for article evaluation and inclusion/exclusion (Ressing *et al.*, 2009). Systematic reviews aim to find and synthesize research on a particular topic using structured, replicable procedures (Littell *et al.*, 2008). This current review focuses on literature published between 1990, when investigations of the interaction between biological and cultural diversity started gaining prominence (see Maffi, 2005), and the commencement of this review on 26 May 2020, the century in which scientists gave recognition to the coupling of social and ecological systems (see Kareiva & Marvier, 2014). Articles investigating the various aspects of the relationship between people and the environment without factoring in people's cultures are excluded from analysis. We first outline biocultural research's trends and investigate the methodology it employs. Then, we discuss its shortfalls and possible ways of overcoming them. The review methodology used here are adapted from guidelines provided by Collaboration for Environmental Evidence (CEE, 2013) and have been similarly applied by various authors in recent review articles (see Mukherjee *et al.*, 2018; Ochieng *et al.*, 2018; Young *et al.*, 2018).

We conducted a literature search on the Scopus database (https://www.scopus.com) using the following terms:

TITLE-ABS-KEY (South AND Africa) AND TITLE-ABS-KEY ("Biocultural diversity") OR TITLE-ABS-KEY ("Biocultural diversity") OR TITLE-ABS-KEY (ethno*) OR TITLE-ABS-KEY ("Biocultural conservation") OR TITLE-ABS-KEY ("Biocultural conservation") OR TITLE-ABS-KEY ("Traditional conservation") OR TITLE-ABS-KEY ("Indigenous conservation") OR TITLE-ABS-KEY ("Traditional ecological knowledge")

OR TITLE-ABS-KEY ("Traditional environmental knowledge") OR TITLE-ABS-KEY ("aboriginal conservation") OR TITLE-ABS-KEY ("indigenous knowledge")

The terms used in the search query are likely to have various synonyms overlooked by this study. To maximize the number of results obtained from the search query we included “TITLE-ABS-KEY” which means that the search looks for term matches in the titles (TITLE), abstracts (ABS) and keywords (KEY) of articles indexed on the Scopus database. The inclusion criteria for this search was that only peer-reviewed original research articles (not review articles) in the following study fields or disciplines would be considered: pharmacology, toxicology and pharmaceutics, health professions, social science, agricultural and biological science, biochemistry, genetics and molecular biology, environmental science, and medicine. Reviews synthesizing original research are secondary sources, hence the exclusion of previous reviews from this current review. Articles that match inclusion criteria but are published in journals that are not indexed on the Scopus database will not appear in the search results. The search query returned 3,657 results. Initial screening based on abstract and title narrowed the results to 334 articles (Supplementary Material 1; http://dx.doi.org/10.17632/b6fhzcvzmp.1) that fit the inclusion criteria. These 334 articles were subjected to full text screening using a pre-determined review protocol (Supplementary Material 2).

Results

The sample of 334 reviewed articles are diverse in their research focus, but taxonomic, spatial, disciplinary and cultural biases, among others, are still apparent. Some languages/cultures and taxonomic groups do not receive research attention and research efforts are not homogenous within South Africa’s nine provinces (Figure 1).

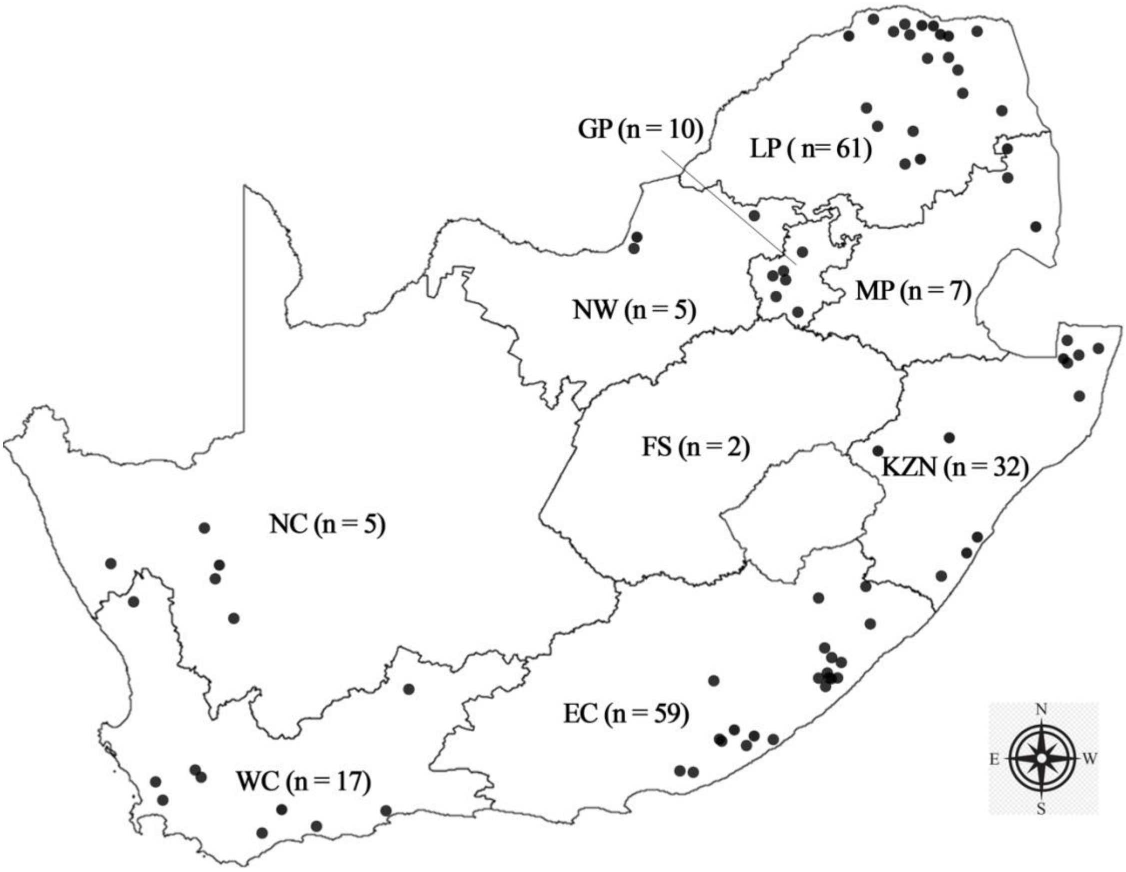

Figure 1: Provincial focus of peer-reviewed literature based on the interaction between South African biological and cultural diversity. Map plots spatial research focus (lumped by province) of 198 of 334 peer-reviewed articles published between 1990 and 2020 (modified from Phaka, 2020). Dots represent specific research locations in provinces. The remaining 136 articles have a national research focus. Province names: EC = Eastern Cape, FS = Free State, GP = Gauteng, KZN = KwaZulu-Natal, LP = Limpopo, MP = Mpumalanga, NC = Northern Cape, and NW = North West, WC = Western Cape.

Within the sample, 198 articles have their research focus at the provincial level or on specific localities within provinces, while the remaining 136 articles focus on South Africa as a whole in their analysis. Limpopo and Eastern Cape Province received the highest research focus (61 and 59 articles respectively) while Free State received the lowest (two articles). This review reveals that most research based on the interactions between South African biological and cultural diversity is transdisciplinary; extra-scientific phenomena are investigated using descriptive and analytical methods.

Evolution of a novel research niche in South Africa

This study's sample shows that research based on the interaction between South Africa's biological and cultural diversity has increased steadily since 1990 (Figure 2). Statements about ethical considerations and/or formal acknowledgement of ethical consideration started being a feature of this research in 2005 and their occurrence has followed a trend similar to published article numbers (Figure 2). South Africa's ratification of the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits arising from their utilization to the Convention on Biological Diversity (UNEP, 2011) in 2013 does not show any obvious or immediate effect on the number of published articles and their related ethical considerations.

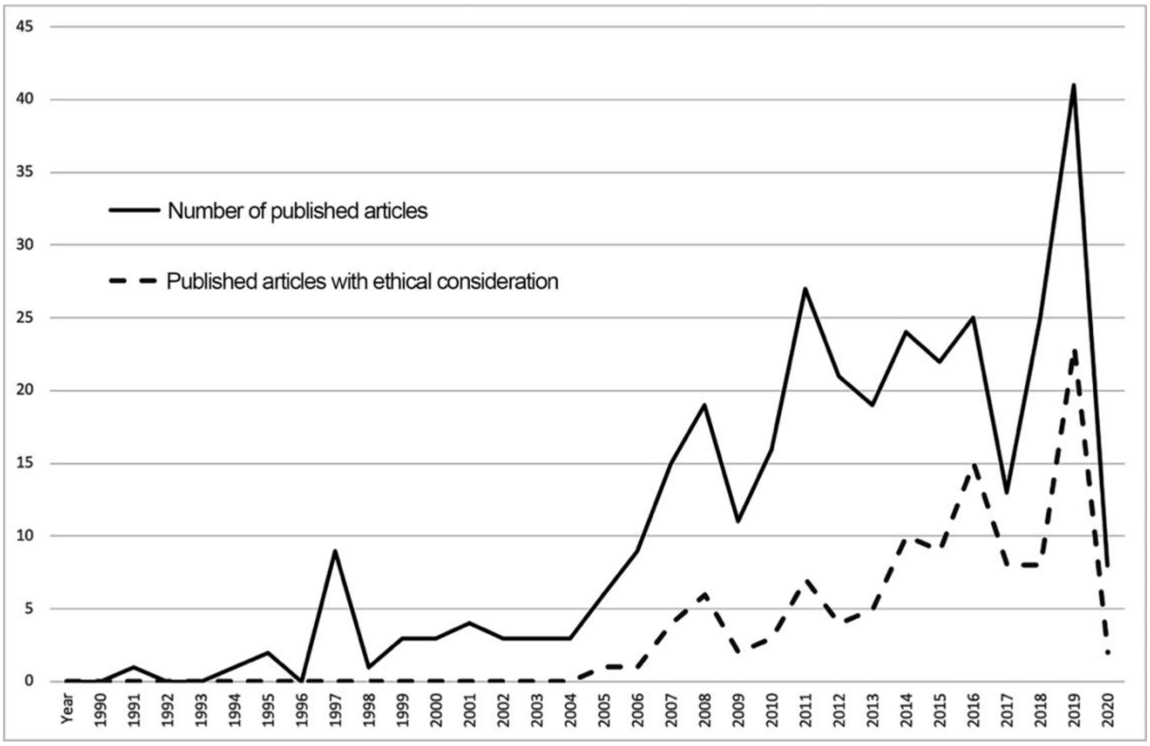

Figure 2: Peer-reviewed literature based on the interaction between South African biological and cultural diversity research published 1990–2020 and the ethical considerations of these studies (modified from Phaka, 2020). The studies were searched on the Scopus database and the ethical consideration data was extracted using a pre-determined review protocol (S2).

Ethics statements were made in 108 of the 334 reviewed articles (32.3%). In 37 of the 108 ethics statements there is no specification whether ethical consideration is for the human or non-human subjects of the research, 26 specify consideration for non-human animals, 38 specify consideration for people who were participants, five specify their consideration for people and plants, and the remaining two of 108 ethics statements extend consideration to plants only.

Methodology used in a growing research niche

The reviewed articles often used biological analysis to answer research questions that stem from a different field of study and/or have extra-scientific origin. The articles collectively span 10 disciplines (Figure 3a) and the scope of investigation in some studies encompasses multiple disciplines. Human health science is the most represented discipline in literature based on the relationship between South Africa’s biological and cultural diversity. It is the sole focus of 74,3% of the reviewed literature and in an additional 3,9% of the sample human health science received joint focus alongside at least one other discipline (e.g., veterinary health science, or gastronomy). The remaining 21.8% of articles cover a diversity of disciplines from construction to archaeology and agronomy (Figure 3a).

To establish the existence of an interaction between biodiversity and culture, researchers relied on participatory techniques (e.g., interviews of Indigenous Knowledge custodians) and/or published literature (e.g., articles about traditional medicine). Subsequently, descriptive techniques or a combination of descriptive and analytical techniques were employed to investigate research questions relating to the interaction between biodiversity and culture. For instance, in some of the reviewed articles plant usage for traditional medicinal purposes was recorded using interviews, the results were quantified using descriptive statistics, and the efficacy of the recorded traditional plant remedies was tested by analysing their antimicrobial activity.

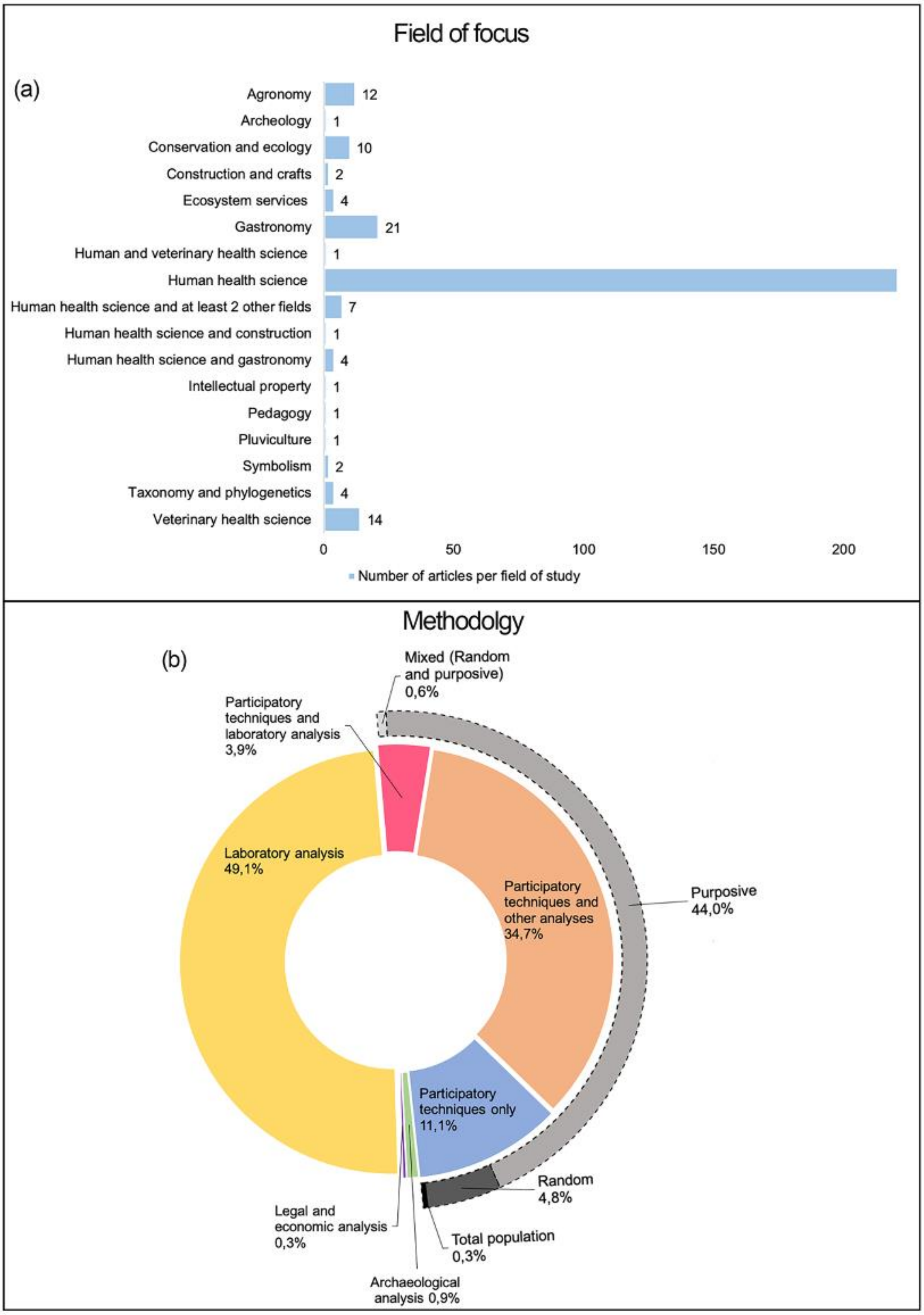

Figure 3: (a) Research disciplines explored, and (b) modes of investigation employed to establish the presence of an interaction between biodiversity and culture by articles in this study's sample.

The 166 studies (49,7% of the review sample) that used participatory techniques to gather data employed three sampling strategies: total population sampling, purposive sampling to seek out the most knowledgeable participants on a particular subject, and random sampling that interviewed anyone who consented to participation regardless of their knowledge of the research topic (Figure 3b). Only two studies mention conducting a pre-test to evaluate their participatory techniques. The 49,1% of studies that did not use participatory techniques opted instead for deducing the presence of a connection between biodiversity and culture by reviewing existing literature.

Biological and cultural diversity proxies

The review sample shows languages or cultural groups to be the preferred cultural diversity proxy in research based on the relationship between biological and cultural diversity. It is worth reiterating that in South Africa one name is often used in reference to both language and culture which in themselves contain subsets of languages and value-practice systems. Multiple languages or cultures in general serve as a cultural proxy in 54,5% of the reviewed articles (Figure 4a). In studies using a single language or cultural group as a proxy, IsiXhosa (received the most research attention (12,6%) while SeSotho received the least (0,3%). IsiNdebele and SiSwati are the only two of South Africa's nine official Indigenous languages that do not receive research attention. Rare among cultural diversity proxy choices in this sample are studies that opted for religion as they account for 0,6% of the reviewed articles (Figure 4a). Localities of cultural diversity proxies (Figure 4b) were either urban (5%), rural (42%), or studies opted for both rural and urban areas (53%). Plants were found to be the preferred biological diversity proxy as they are the sole proxy choice of 302 of the 334 reviewed articles. The remaining 32 articles have a diverse mix of proxies including ecosystems and invertebrates (Figure 4c).

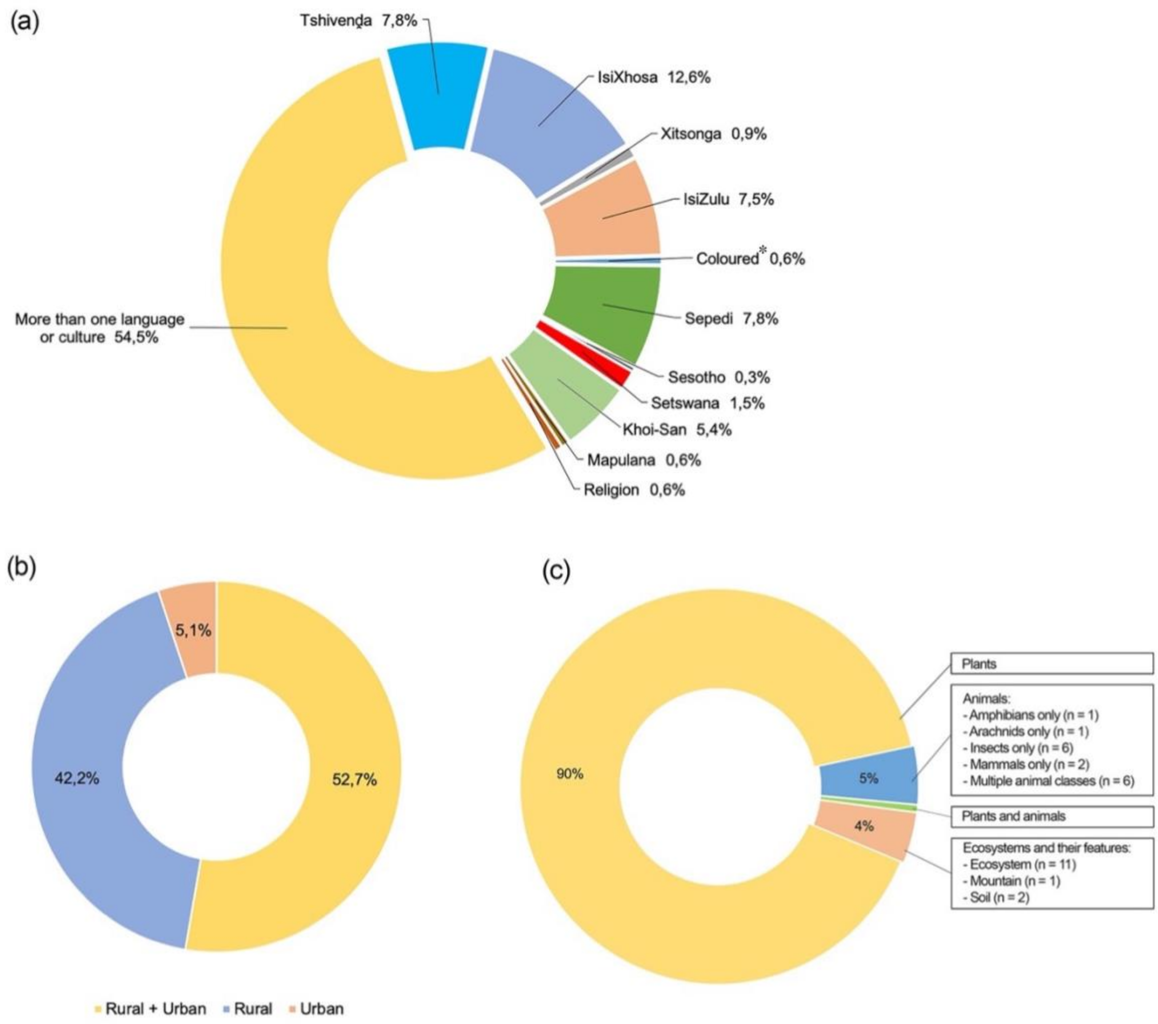

Figure 4: Biological and cultural diversity proxies used in peer-reviewed literature based on the interaction between South African biological and cultural diversity. Graph (a) shows proxies used for cultural diversity, graph (b) shows research localities, and graph (c) modified from Phaka (2020) shows proxies used for biological diversity.

* Coloured refers to one of South Africa's population groupings (Statistics South Africa, 2018), and a community that people self-identify with.

Recommendations made

Recommendations are made in 69,2% of the sample, and they either relate to research methodology, human benefit, or conservation. Methodology recommendations are aimed at advancing research through suggestions of improved analyses and ways to bridge knowledge shortfalls (e.g., suggesting topics that are a continuation of current research or making recommendations on how to succeed where current research failed). Human benefit recommendations focus on how research findings can benefit the public. Conservation recommendations suggest ways of protecting biological and/or cultural diversity. The combinations of recommendations made in respective studies can be grouped into eight categories as illustrated in Figure 5.

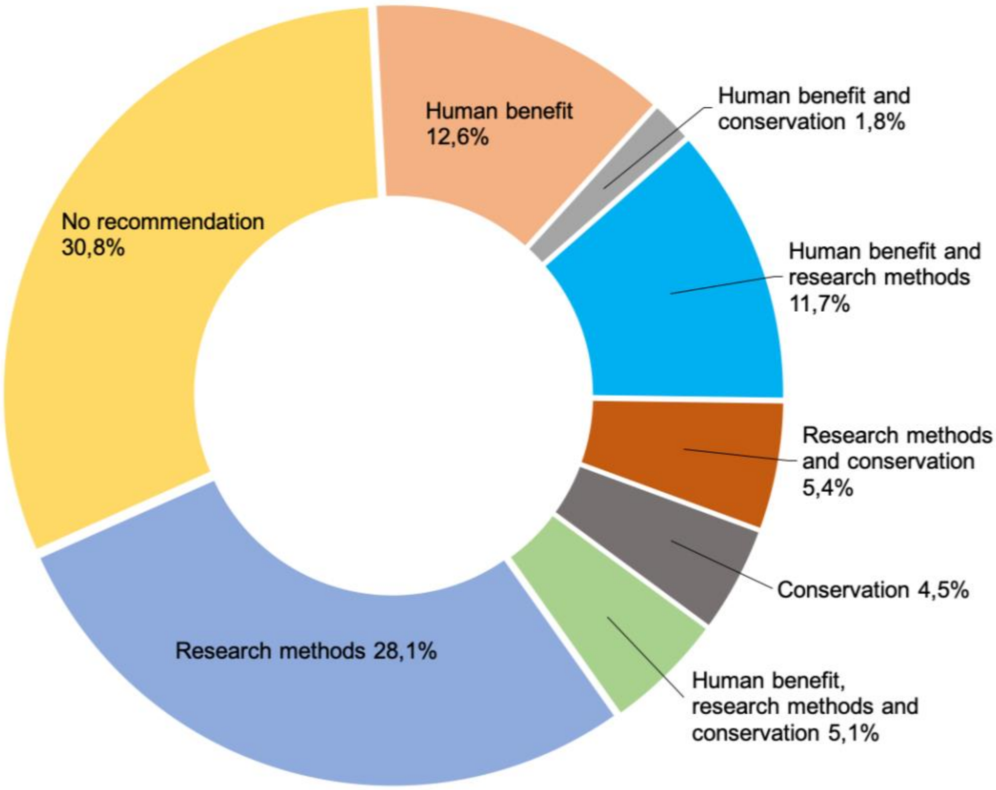

Figure 5: Recommendations made in 231 of the 334 peer-reviewed articles based on the interaction between South African biological and cultural diversity research. The remaining articles do not make recommendations.

Discussion

Research based on the relationship between South Africa's biological and cultural diversity is integrated and mostly transdisciplinary. A definition synthesized from a literature analysis by Jahn *et al.,* (2012) describes transdisciplinarity as a critical, self-reflexive research approach relating societal with scientific problems and producing new knowledge through integration of different scientific and extra-scientific insights with the aim of contributing to both societal and scientific progress. While there is potential to produce new knowledge for science, transdisciplinarity can also verify societal benefits and highlight risks associated with extra-scientific insights. This review's sample shows that research based on the interactions between South Africa's biological and cultural diversity is growing and the multiple biases and knowledge gaps that exist necessitate further studies specifically geared towards addressing the shortfalls. The systematic approach for obtaining this sample of scientific articles was aimed at making this study replicable, but this unwittingly limited sample size as literature that is not indexed on the Scopus database and grey literature are omitted.

Multiple biases of a novel research niche

There is generally a positive coincidence between focus of the reviewed literature and biodiversity as the most of this literature is focused on high biodiversity areas (Figure 1) within South Africa (BirdLife International, 2022). This could be a result of biodiversity's co-occurrence with cultural diversity and researchers opting to focus their biocultural studies where both diversities are high. Provincial research focus is higher than national research focus (59,3% vs 40,7%), and this provincial level research is biased towards three of the country's nine provinces (Eastern Cape, Limpopo and KwaZulu-Natal). Rural areas are preferred over urban areas as sources of cultural diversity (Figure 4b). The reviewed articles are biased towards using multiple languages as cultural proxies in one study while IsiXhosa is the preferred choice for studies that use single languages/cultures as a proxy (Figure 4a). IsiNdebele and SiSwati do not feature as sole culture proxies in any of the reviewed studies. This may have been caused by lack of accessibility to these two languages as they occur in Mpumalanga; a province which historically did not have a university. Mpumalanga's first university was formally promulgated in 2013 (South African Department of Higher Education and Training, 2013). Accessibility is however unlikely to be the sole reason as SeTswana, SeSotho and XiTsonga are languages that are underrepresented yet they occur in provinces with well-established universities. Researchers' personal preferences may also contribute to focal language choice as XiTsonga is spoken in one of the most researched provinces but it is still not well-represented. People may also be reluctant to share details of their culture with outsiders (i.e., researchers) thus leading to underrepresentation of their language/culture. Other possible contributing factors to this underrepresentation include language barriers between researchers and potential participants, remoteness of rural research areas, cultural tensions between researchers and potential participants. The focus and expertise of higher education institutions is another potential contributor as certain research niches research may be outside their scope.

A strong taxonomic bias exists in biodiversity proxy choice as plants are the preferred focal taxa (used as sole biodiversity proxy in 90,4% of reviewed articles). Human health science is the most popular discipline (explored in 78,1% of reviewed articles) in peer-reviewed literature based on the interaction between South African biological and cultural diversity (Figure 3a). A bias towards plants in ethnomedical research is also evident on a global scale (Solovan *et al.*, 2004), and even in places with well-recorded traditional medicine usage such as India (Betlu, 2013). This strong bias towards medicinal plants and human health science may be motivated by potential commercialization of such studies and their contribution to human well-being. Ethnoveterinary medicine in African countries remains largely unrecorded and livestock health is an important issue in rural areas (Beinart & Brown, 2013), thus bias towards plants is likely to increase when there is more focus on ethnoveterinary in the future. The bias may also be an indication of plants having greater utility than other taxa, and possible evidence that subjectification of biota by value-practice systems is primarily motivated by practical usage value. Kepe (2008) attributes the narrow focus in studies of plant usage to the lack of contextual analysis of plants' social and ecological value. A broader focus on other values that cultures place on plants would lessen the bias towards human health science studies. Animals generally do not seem to feature significantly in traditional medicine as Williams and Whiting (2016) noted that plants form a larger component of products available at some traditional medicine markets in South Africa. Plants are also easier to collect, store and trade (Alves *et al.*, 2011). This relative ease of access to plants with traditional medicine salience may also be contributing to greater research focus on them.

Gaps in ethical consideration

Ethics in peer-reviewed literature based on the interaction between South African biological and cultural diversity started being considered 15 years after the research niche gained prominence and this inclusion of ethical consideration began a year before the International Society of Ethnobiology's code of ethics was adopted. Prior to adoption of this code, the Declaration of Belém provided guidelines for the protection of both biological and cultural diversity, and the rights of traditional communities (International Society of Ethnobiology, 1988). The effects of ratifying the Nagoya Protocol on biocultural research outputs and ethics are not immediately obvious, and this may be due to a lag between the time of its ratification and its implementation. In 2014 when the protocol came into effect, the numbers of articles and ethical considerations show no immediate impact. In subsequent years, ethical consideration experienced its steepest increase and decrease while the number of published articles shows its steepest decrease (Figure 2). These fluctuations could have occurred by chance or a myriad of factors besides the Nagoya Protocol.

Ethical consideration in ethnobiological research provides assurance that participants' intellectual property rights are upheld and the relationship between biological and cultural diversity is protected (International Society of Ethnobiology, 2006). Furthermore, ethics safeguard against the abuse of human rights and ensure that non-human organisms do not experience undue stress. For researchers, the guidelines and code of ethics seek to ensure integrity and promote equitable sharing of benefits with research participants. The natural resources and traditional knowledge of Indigenous Communities have often been exploited (Longacre, 2002). Only 108 of the reviewed articles had an ethics statement, while 166 articles employed a participatory research methodology (Figure 3b). Thus, there is no assurance that at least 58 studies employing participatory techniques respected participants' human rights and protected their intellectual property. Furthermore, only 38 of the 108 studies with ethics statements specify that their consideration is for participants thus increasing the number of studies without assurance of human rights protection from 58 to 128.

Ethical consideration is low for plants in the reviewed articles, yet plants feature extensively in this review sample. Plants have a weaker ethical/moral standing than humans and non-human animal research subjects (Kallhoff, 2014; Pouteau, 2014). The lack of ethical consideration for plants helps explain why some literature did not include ethics statements even after a code of ethics for the research niche was adopted in 2006 (Figure 2). Furthermore, ethical clearance may not be required for studies that investigate details of the relationship between biological and cultural diversity which are already published in existing literature.

Participatory techniques, participants, and selective preservation of indigenous knowledge

Pre-testing of participatory techniques is either not reported or it is unpopular among researchers. Only two of the 166 studies that employ participatory techniques report pre-testing in their articles. Pre-testing is vital to the development and refinement of interview methods (Beatty & Willis, 2007, Young *et al.,* 2018). It also helps ascertain that interviews will achieve their intended goal and verify whether participants understand interview questions (Perneger *et al.,* 2015). The use of participatory techniques for data collection translates into increased documentation and preservation of Indigenous knowledge systems (IKS), which is beneficial as Indigenous knowledge (IK) practitioners are declining (DeJong, 1991). However, preservation may be biased towards IK that is of interest to researchers while the rest remains neglected thus providing an incomplete view of IKS.

Ecological knowledge contained in IKS is being increasingly recognized as having scientific merit (Wilson, 1992; Paneque-Gálvez *et al.,* 2018). The current review shows that consideration of traditional ecological knowledge in South Africa is low as only 10 of the 334 reviewed articles focus on conservation or ecology (Figure 3a). This is in line with Brook and McLachlan's (2008) study showing that Africa in comparison to the rest of the world has fewer studies incorporating traditional ecological knowledge. However, recent literature is reporting an increase in studies of African traditional ecological knowledge (see Aswani *et al.,* 2019). Studies that employ analytical techniques provide scientific context to IK, help assess its scientific merit and verify potential benefits or risks. In the case of traditional medicinal use, biological activity analysis helps test the efficacy of traditional remedies and their suitability for human consumption. While the use of analytical techniques is beneficial, they don't feature in some of the reviewed literature as other researchers are only focused on recording undocumented interactions between culture and biodiversity.

Within the review sample, there are participants in 49,7% of the research, 32,3% of the studies have ethics statements, and ethical consideration for the people participating in a study is specified in only 12,9% of the articles. Lack of ethical consideration is worrisome since no assurance against exploitation of participants and their IKS is provided. Furthermore, it goes against guidelines provided by South Africa's Bioprospecting, Access and Benefit Sharing Regulations (Department of Environment, Forestry and Fisheries, 2012) which mention that research involving IKS should at the very least obtain traditional knowledge custodian's permission and prior informed consent, and also notify the environmental affairs ministry about the research. These regulations give national level effect to the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits arising from their Utilization which the country adopted. The Nagoya Protocol provides countries with a means of protecting IKS and there is an example of this from Burundi where a Nagoya Protocol framework was setup to protect and valorise IKS to prevent exploitation of its custodians (Janssens de Bisthoven *et al.*, 2017). Exploitation of IKS is a problem occurring in many countries including India (Udgaonkar, 2002), Perú (Landon, 2007), and Canada (Oguamanam & Koziol, 2018)

Cultural focus in researching biodiversity and cultures' relationships

Cultural diversity proxy choice is biased towards using multiple languages/cultures. While this is ideal for revealing multi-cultural importance of taxa, it masks the local nuances of different cultures and misses instances of undocumented cultural significance in certain cultures. For example, Zulu medicinal plant usage is believed to be adequately documented yet a recent high resolution study in the Amandawe locality (KwaZulu-Natal province) reported 110 new medicinal species records, 60 newly recorded IsiZulu names, and 1106 new usage records (Mhlongo & Van Wyk, 2019). Another study in the KwaNibela Peninsula (KwaZulu-Natal province) discovered previously unrecorded medicinal plants, and 61 novel uses along with 15 additional variations to recorded usage of known medicinal plants (Corrigan *et al.,* 2011). These nuances will be important for biodiversity management planning at provincial or local level.

Rural areas are rich in cultural knowledge but lack the diverse mix of cultures which exists in urban areas as each cultural group tends to settle in its own homeland or village whereas South African urban areas are not subject to this settlement pattern. Urban areas may not seem like viable sources for collecting data relating to cultural significance of biota, but South African cities tend to be multicultural. Research has shown that urban dwellers in some countries of sub-Saharan Africa, attach cultural significance to biota by maintaining their rural cultural practices (DeJong, 1991; Wiersum & Shackleton, 2005; Marsland, 2007). Gurney *et al.,* (2017) suggest this continuation of traditional cultural practices in urban areas in Australia may contribute to creating a sense of community among urban dwellers, while Elands and van Koppen (2012) show that the biocultural diversity concept is also applicable in a highly modernized society in the Netherlands. Commercialization is also increasing the flow of traditional culture to urban areas (Wiersum & Shackleton, 2005). Culturally-motivated consumption of wildlife in urban areas is increasing in frequency (Marsland, 2007). Further increases could be fuelled by consumption that serves as a coping mechanism for the stresses of urban life (Hardon *et al.,* 2008).

Biodiversity focus in researching biodiversity and cultures' relationships

Traditional medicinal use is a common form of cultural significance attached to biota as reflected here by an 82.3% cumulative focus on human and veterinary health related research

(Figure 3a). Plants are commonly used in traditional medicine and this has resulted in 302 studies out of 334 of the review sample solely focusing on plants. A 17,4% focus on non-medicinal significance may not adequately represent the relationships South African cultures have with biodiversity, but from a socio-economic perspective it may be justifiable and thus more worthwhile for researchers to focus on medicinal plants. The World Health Organization reports that 88% of their member states have acknowledged use of traditional medicine by their citizens (World Health Organization, 2019). For a fuller representation of the relationship between biodiversity and culture, taxa that have non-medicinal cultural significance and have been neglected from analyses in the reviewed articles can also serve as biodiversity proxies. The other forms of cultural significance that are underrepresented in the literature reviewed here include: folk taxonomy or traditional naming practices (Phaka *et al.,* 2019), folklore (Osemeobo, 1994), and totems (Clemence & Chimininge, 2015). These cultural significances may not be important for human health, but they are part of cultural diversity and its relationship with biodiversity. Exclusion of some aspects of the culture's relationship with biodiversity leads to exclusion of taxa to which they are linked and provides limited representation in research. Thus, the focus on traditional medicinal usage is leading to taxonomic bias in research that is based on the relationship between biological and cultural diversity. A focus biased towards research on practical usage value in some Africa countries was suggested to result in overemphasis of the utilitarian value of biodiversity in environmental policy (see Hugé *et al.,* 2017 for an example from environmental impact assessments in West Africa). There is also the case of researchers having their preferred focal taxa and research funding being made available for predetermined taxa. Both these factors could lead to underrepresentation of taxa that are not used in traditional medicine or are not preferred by researchers and funders.

Recommendations resulting from researching biodiversity and cultures' relationships

It may not be compulsory or necessary for every study to make recommendations, but recommendations help clarify the role of research in real-world contexts, and they steer future research towards bridging knowledge gaps. Recommendations can help guide the translation of research findings into tangible benefits for people, outline research priorities noted during a study and also suggest improvements to research methodology. Brown *et al.*, (2006) noted that most articles contain general recommendations that are not helpful, and recommendations thus lose their potential value. To this effect, 30,8% of the articles in this review have made no recommendations and thus potential value of those suggestions for future research has been lost. The recommendations made in 69.2% of the reviewed articles are of value to human health, protection of the biological and cultural diversity being studied, and enhancement of future research methodology.

Conclusion

This study provides a template for assessing the extent of research based on the relationship between biodiversity and people's cultures. The uneven spatial, cultural, and taxonomic focus of these biocultural studies provide hints of heterogeneity of biocultural diversity at this high resolution of research, as was mentioned by Manne (2003) and Collard and Foley (2002) that research at high resolution will likely reveal differences in biocultural diversity distribution which would be overlooked when extrapolating from a global scale study. Articles reviewed in this study increase understanding of the relationship between biodiversity and culture, and this synthesis of literature highlights biases in a growing knowledge base. This knowledge base reveals some previously marginalized wildlife perspectives that can be incorporated into conservation planning, thus understanding its related biases can help lessen and thus increase the social inclusion value of biocultural approaches.

To avoid perpetuating the bias towards plants and human health sciences that was highlighted in this synthesis, it is recommended that future research based on biocultural approaches should aim for their focus to be representative of a country's biological and cultural diversity. A focus on lessening the noted biases would work best if the commitment comes from both researchers and funders of research. This is however not to say that the well-represented elements should be neglected all together as there are numerous interactions between biological and cultural diversity that could still be investigated. Specific recommendations for future studies to decrease biases noted in the current study include focusing on traditional ecological knowledge, South Africa's minority languages, religion as a culture proxy, biocultural diversity manifestations in urban areas, and animals as a biodiversity proxy.

Acknowledgements

North-West University and Hasselt University are thanked for approving the bilateral scientific cooperation that enabled this research. FMP is supported by the National Research Foundation (UID: 114663; 130501), South African Institute of Aquatic Biodiversity, Youth 4 African Wildlife NPC and the Flemish Interuniversity Council (VLIR-UOS) Global Minds program (contract number: R-9363); MPMV by the Special Research Fund of Hasselt University (BOF20TT06). Gratitude is extended to the reviewers of this manuscript. No conflict of interest to be declared.

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Chapter 3

Reviewing taxonomic bias in a megadiverse country: primary biodiversity data, cultural salience, and scientific interest of South African animals.

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Adapted from: *Environmental Reviews.* 2022.

https://doi.org/10.1139/er-2020-0092

Abstract: Taxonomic bias, resulting in some taxa receiving more attention than others, has been shown to persist throughout history. Such bias in biodiversity distribution data needs to be addressed because the data are vital to environmental management. This study reviews taxonomic bias in South African biodiversity distribution data obtained from the Global Biodiversity Information Facility (GBIF). The focus was specifically on animal classes, and regression analysis was used to assess the influence of scientific interest and cultural salience or importance on taxonomic bias. A higher resolution analysis of the 2 explanatory variables' influence on taxonomic bias is conducted using a generalised linear model on a subset of herpetofaunal families from the focal classes. Furthermore, the potential effects of cultural salience and scientific interest on a taxon's extinction risk are investigated. The findings show that taxonomic bias in South Africa's biodiversity distribution data has similarities with global scale taxonomic bias. Among animal classes, there is strong bias towards birds while classes such as Polychaeta and Maxillopoda are under-represented. Cultural salience has a stronger influence on taxonomic bias than scientific interest. It is, however, unclear how these explanatory variables may influence the extinction risk of taxa. We recommend that taxonomic bias can be reduced if biodiversity distribution data collection has a range of targets that guide (but do not limit) accumulation of species occurrence records per habitat. Within this range, a lower target of species occurrence records accommodates species that are difficult to detect. The upper target means occurrence records for any species are less urgent but nonetheless useful and thus data collection efforts can focus on species with fewer occurrence records.

Keywords: Biodiversity hotspot, Biomonitoring, Conservation, Surrogate species, Taxonomic chauvinism.

Résumé : Il a été démontré que le biais taxonomique, qui fait que certains taxons reçoivent plus d'attention que d'autres, persiste à travers l'histoire. Ce type de biais dans les données primaires de biodiversité doit être abordé, car ces données sont vitales pour la gestion de l'environnement. Cette étude examine le biais taxonomique dans les données primaires de biodiversité d'Afrique du Sud obtenues auprès du Global Biodiversity Information Facility (GBIF). L'accent est mis sur les classes d'animaux, et une analyse de régression est utilisée pour évaluer l'influence de l'intérêt scientifique et de la prégnance culturelle sur le biais taxonomique. Une analyse à plus haute résolution de l'influence des deux variables explicatives sur le biais taxonomique estmenée à l'aide d'un modèle linéaire généralisé sur un sous-ensemble de familles herpétofauniques de classes focales. En outre, les effets potentiels de la prégnance culturelle et de l'intérêt scientifique sur le risque d'extinction d'un taxon sont étudiés. Les résultats montrent que le biais taxonomique des données primaires sur la biodiversité en Afrique du Sud présente des similarités avec le biais taxonomique à l'échelle mondiale. Parmi les classes d'animaux, il existe un fort biais en faveur des oiseaux, tandis que des classes telles que les Polychaeta et les Maxillopoda sont sousreprésentées. La prégnance culturelle a une plus grande influence sur le biais taxonomique que l'intérêt scientifique. Cependant, la manière dont ces variables explicatives peuvent influencer le risque d'extinction des taxons n'est pas claire. Les auteurs recommandent que le biais taxonomique puisse être réduit si la collecte de données primaires sur la biodiversité est assortie d'une série de cibles qui guident (sans la limiter) l'accumulation d'enregistrements d'occurrence d'espèces par habitat. À l'intérieur de cette fourchette, une cible inférieure de relevés d'occurrence d'espèces permet de prendre en compte les espèces difficiles à détecter. La cible supérieure signifie que les relevés d'occurrence d'une espèce sont moins urgents, mais néanmoins utiles et que les efforts de collecte de données peuvent donc se concentrer sur les espèces ayant moins de relevés d'occurrence.

Mots-clés: point névralgique de la biodiversité, conservation, collecte de données, espèces substitutives, chauvinisme taxonomique.

Background

Primary biodiversity data reflects the knowledge and practices in the study of biodiversity (Troudet *et al.*, 2017) and consists of, among others, species occurrence records (Soberón & Peterson, 2004). This study focuses on these occurrence records (hereafter referred to biodiversity distribution data), which include details about taxonomic information, collection/observation date, and location (Ball-Damerow *et al.*, 2019). Accumulating biodiversity distribution data is an important step towards biodiversity conservation policy (Flemons *et al.*, 2007) and it is also vital to biodiversity research (Lira-Noriega *et al.*, 2007). Making biodiversity distribution data publicly available is an important requirement for biodiversity research and planning (Huang *et al.*, 2013). An organisation called Global Biodiversity Information Facility (GBIF) facilitates the sharing of, and access to, accumulated biodiversity distribution data (Edwards, 2004), and in 2012 GBIF was said to host the largest open access biodiversity database in the world (Boyd & Crawford, 2012). GBIF is rapidly growing, and at the time of writing this article, the GBIF network consisted of 101 countries and international organisations dedicated to advancing open access biodiversity distribution data (GBIF, 2020b).

The biodiversity data making up the GBIF (2020a) dataset consists of contributions from data publishers which include academic institutions, museums, herbaria, nongovernmental organisations, and citizen science projects such as iNaturalist (www.inaturalist.org) and AntWeb (www.antweb.org). Georeferenced data from these data publishers is collected by individuals with varying levels of biodiversity knowledge, including scientists and amateur biodiversity enthusiasts (GBIF, 2020a). The GBIF dataset is highly cited in scientific articles (Ball-Damerow *et al.*, 2019). There are also many other biodiversity databases through which biodiversity distribution data are published and accessed: these include Integrated Digitized Biocollections and The Barcode of Life Data

System (Ball-Damerow *et al.,* 2019). Biodiversity databases are not exempt from bias and they have a myriad of errors. Large disparities in the number of occurrence records of different taxa highlights a taxonomic bias. This taxonomic bias is a global phenomenon that has persisted for many years (Russell, 1984; Ponder, 1992; Troudet *et al.,* 2017; Gordon *et al.,* 2020). Understanding taxonomic bias in biodiversity distribution data assists with addressing knowledge gaps and informing policy (Donaldson *et al.,* 2016) because these data are important for biodiversity research and management (Flemons *et al.,* 2007; Lira-Noriega *et al.,* 2007; Huang *et al.,* 2013). Taxonomic bias can cause underestimation of the extinction risk for taxa that receive less attention (McKinney, 1999); might limit understanding of anthropogenic impacts on nature (Feeley *et al.,* 2017); and could deprive threatened species of the conservation resources they urgently require (Seddon *et al.,* 2005).

Biased representation of taxa in biodiversity distribution data may result from intrinsic features, such as abundance, remoteness, and behaviour, which can make it difficult to obtain the occurrence records of some species. The more extinction resistant species (common species) tend to be recorded first (McKinney, 1999). Biodiversity distribution data are generally biased towards species that are easy to identify (Boakes *et al.,* 2016) or locally abundant (Royle & Nichols, 2003). Intrinsic features are, however, not solely responsible for taxonomic bias, and the cause of this bias is not fully understood (Troudet *et al.,* 2017). It has been hypothesized that taxonomic bias in biodiversity distribution data is influenced by either scientific interest (Pawar, 2003) or societal interest (Wilson *et al.,* 2007). Studies, such as this current one, aim to understand which of the biases, in the interests of science and society, lead to taxonomic bias in biodiversity distribution data accumulation. Scientific interest can be deduced from scientific articles (Troudet *et al.,* 2017) because these articles provide an idea of which taxa the scientific community is dedicating its resources to. Societal interest can be quantified from frequency of words in web pages (Wilson *et al.,* 2007). The frequency, or number of times, that words (e.g., taxon names) occur in a large body of text such as web pages indexed by search engines can be used as a measure for cultural salience (Correia *et al.,* 2016; Davies *et al.,* 2019). This cultural salience denotes the cultural visibility (or importance) and profile of species (Correia *et al.,* 2016; Davies *et al.,* 2019), or the popularity of a species, which reflects the interactions of cultural value-practice systems with that species' traits (Ducarme *et al.,* 2013). According to Correia *et al.,* (2017), inferring cultural salience from web pages as large bodies of text relies on the assumption that content on the World Wide Web is a reflection of the interests of the citizenry generating it. There is evidence supporting this assumption that internet activity reflects societal interests (Funk & Rusowsky, 2014; Kim *et al.*, 2014; Schuetz *et al.*, 2015; Troumbis, 2017). Interests of society members that do not use the internet either out of choice or lack of access to the internet would not be reflected in this cultural salience inferred from web pages as large bodies of text. When conducting web-page searches, the scientific and vernacular names of taxa can be used interchangeably as keywords (Jaric *et al.,* 2016). There are high correlations between scientific and vernacular species name search results at both the global and country level (e.g., in Australia, Brazil, Indonesia, Spain, Tanzania, and USA), regardless of lingual and cultural differences (Correia *et al.,* 2017). High correlations are also found between the Google search engine results for the scientific and English names of diurnal birds of prey, carnivores, and primates (Jaric *et al.,* 2016).

Investigations of taxonomic bias generally focus on its causes and seldom discuss what would be considered an ideal representation of a taxon. This ideal representation of a taxon would provide guiding and non-limiting targets for biodiversity distribution data collection. Proposing target species occurrence records to guide biodiversity distribution data collection would also be cognizant of the sample size requirements of multiple biodiversity data applications. When using biodiversity data for regression analysis, at least 10 subjects per variable are required for accurate models (Harrell, 2001). High accuracy species distribution models can be created using samples of 5, 10, or 25 (Hernandez *et al.,* 2006). For African taxa in particular, accurate species distribution models can be developed with at least 14 occurrence records for species with a limited distribution range, and 25 records for widely distributed species (van Proosdij *et al.,* 2016). In biostatistics, a minimum sample size of 30 is considered sufficient for the design of field studies (Cohen & Cohen, 1995). To accommodate these varied sample size requirements for biodiversity data applications would require the target occurrence records per species to be made up of a range of numbers. A range of target sample sizes that would be considered an ideal representation of a taxon in biodiversity distribution data are also better suited to the varying levels of difficulty in collecting species occurrence records. The ease with which species occurrence records can be collected is often affected by species' abundance, habits, habitat type and accessibility of habitats.

Biodiversity research focus is misaligned with global biodiversity distribution (Griffiths & Dos Santos, 2012; Di Marco *et al.,* 2017). Considering that South Africa is a megadiverse country (Mittermeier, 1988; Mittermeier *et al.,* 1997), it is important to understand the extent of biodiversity knowledge and also to investigate the factors influencing biodiversity distribution data accumulation to inform research and planning. This current study seeks (i) to quantify taxonomic bias in the biodiversity distribution data of South African animal taxa and make suggestions of the ideal representation of a taxon required to lessen bias; (ii) based on hypotheses put forward in previous research (Pawar, 2003; Wilson *et al.,* 2007), to test the likely influence of cultural salience and scientific interest on taxonomic bias in biodiversity distribution data; and (iii) assess how cultural salience and scientific interest compare with the extinction risk for a given taxon.

Review approach

The current study assess taxonomic bias in biodiversity distribution data of South African animal species by checking the number of these records per animal taxon and investigating whether the cultural salience and scientific interest of a taxon influences accumulation of biodiversity distribution data. This assessment of taxonomic bias in South Africa focuses on the timespan from 1998, when the country's National Environmental Management Act (Republic of South Africa, 1998) was promulgated, and the commencement of this study in 2020. The act sought to increase biodiversity monitoring and access. The highest yearly species occurrence records for South African species (ranging between 20 271 and 1.6 million) started being submitted to GBIF in the third year of this act being in effect. The dataset containing species occurrence records of South African animals was downloaded from the GBIF database on 21 February 2020, and the search parameters along with the dataset are viewable at https://doi.org/10.15468/dl.5upuwl and in the Supplementary data (supplementary material 11). Not all taxon names used in GBIF datasets represent natural groupings, but those names are used here verbatim for the sake of consistency and comparability. Occurrence statistics are computed based on species occurrence records from the GBIF dataset and the number of known animal species distributed within South Africa. The numbers of known animal species are obtained from the South African Animal Checklist maintained by the South African GBIF node (SANBI Biodiversity Advisor, 2020). A ratio of GBIF occurrence records (or species occurrence records submitted to GBIF) to number of known species is used to determine the average number of times each species had their occurrence records submitted to GBIF. Medians of GBIF occurrence records are used for their robustness to outliers. Absolute deviation around the median (i.e., median absolute deviation) gives a measure of variability (Troudet *et al.*, 2017). Because no guidelines exist for the ideal number of species occurrence records required for taxa to be considered sufficiently represented, we deem it necessary to suggest a range of guiding targets. Lower and upper targets of 10 and 30 occurrence records per species per habitat, respectively, can serve to guide biodiversity data collection. This range of targets is based on sample sizes that are suitable for various biodiversity data applications. The targets also consider the intrinsic traits of the various species, with the lower target being suitable for collecting data about species that are difficult to detect, and the upper target being more suitable for abundant species that are easier to detect. Should the upper target be reached for any species, then researchers can consider re-directing data collection resources to species with occurrence records that are lower than the suggested targets in a habitat. With such guiding targets, biodiversity data collection can be orientated towards lessening persisting taxonomic bias while ensuring there is sufficient biodiversity distribution data for research and management.

Cultural salience and scientific interest are investigated as explanatory variables for taxonomic bias in biodiversity distribution data. Regression analysis is used to understand the relative influence of the 2 explanatory variables and their interactions on GBIF occurrence records. We use scatterplots and Pearson's correlation to investigate correlations between the dependent variable (GBIF occurrence records) and the 2 explanatory variables. Cultural salience, in the South African context, is determined by the frequency of focal taxa names in the South African web corpus (or body of text contained in web pages). The advanced search option on the Google search engine (https://www.google.com/advanced_ search?), was used to search for the exact scientific names of each class (e.g., "Amphibia") and the search was narrowed by region to South Africa (Supplementary data, supplementary material 11).

Google search results include a numeric value that represents cultural salience or the approximate number of times a search term appears in the South African web corpus. Based on previous studies (Funk & Rusowsky, 2014; Kim *et al.*, 2014; Schuetz *et al.*, 2015; Troumbis, 2017) we assume that the South African web corpus is a general reflection of the interests of South Africans that are generating it. We say “general reflection” as acknowledgement that South Africa is a diverse country with varied access to the internet. Thus, the interests of people that voluntarily avoid using the internet and those in remote areas without internet access, will not be reflected in the South African web corpus. A more representative measure of South African public interest would require an extensive survey of the country’s citizenry. Scientific interest is quantified by the number of scientific articles published within this study’s focal timeframe, with their topic being South African animal taxa. This scientific interest data was obtained from Web of Science (WoS; http://apps.webofknowledge.com/). The WoS search query (Supplementary data, supplementary material 11) was as follows “Class” OR “Family” AND “South Africa*”; e.g., TS = (“Amphibia” OR “Arthroleptidae” OR “Brevicipitidae” OR “Bufonidae” OR “Heleophrynidae” OR “Hemisotidae” OR “Hyperoliidae” OR “Microhylidae” OR “Phrynobatrachidae” OR “Pipidae” OR “Ptychadenidae” OR “Pyxicephalidae” OR “Rhacophoridae”) AND TS = (“South Africa*”). The result of this search includes a numeric value which represents scientific interest or the number of scientific articles with a South African animal taxon as their topic (specifically from journals indexed by WoS).

For a higher resolution investigation into the effects of explanatory variables on taxonomic bias, we additionally analysed a subsample consisting of herpetofauna (amphibians and reptiles). We chose herpetofauna for the subsample because they are generally under-represented in wildlife research and management literature (Christoffel & Lepczyk, 2012); are negatively perceived by the general public (Reimer *et al.,* 2014; Tarrant *et al.,* 2016); and their populations are experiencing global declines (McCallum, 2007). The relatively lower cultural salience and scientific interest of herpetofauna is not without efforts like the Southern African atlases for frogs and reptiles (Minter *et al.,* 2004; Bates *et al.,* 2014) that should ideally have contributed to lifting the taxa’s profiles. A generalized linear model

(GLM) fitted using a negative binomial distribution was used to analyse the influence of the 2 explanatory variables on the number of GBIF occurrence records for each family within the subsample. The validity of the models was checked by testing homogeneity of residuals when plotting the values of residuals against predicted values. Outliers were excluded because they negatively impacted the model's resolution. Identification of outliers was achieved using the interquartile rule; Q1 – 1.5   interquartile range, or above Q3 + 1.5   interquartile range. Similar to the methods for the main sample mentioned above, cultural salience for the subsample was obtained through a search of exact family names (e.g., "Arthroleptidae") on Google's advanced search page, with results narrowed by region to South Africa only (Supplementary data, supplementary material 11). The subsample's scientific interest was retrieved from WoS using the following query (Supplementary data, supplementary material 11) "Family" OR "Genus" AND "South Africa*": e.g., TS = ("Arthroleptidae" OR "Leptopelis" OR "Arthroleptis") AND TS = ("South Africa*"). For increased accuracy of the subsample's regression analysis, families with fewer than 10 GBIF occurrence records were excluded from the analysis because a minimum of 10 subjects per variable is necessary for greater accuracy of regression modelling (Harrell, 2001). This study's analysis was extended to the likely influence of the 2 explanatory variables on conservation status by comparing cultural salience and scientific interest with the threat status of South African animals that are on the IUCN Red List of threatened species (IUCN, 2020). This IUCN (2020) Red List has the total number species in all threatened categories per country organized by taxonomic groupings (i.e., birds, mammals, molluscs, fishes, reptiles, amphibians). The seventh IUCN (2020) grouping of animal taxa, labelled "other invertebrates", was excluded from analysis because of uncertainty about which taxa are included in the grouping.

Twelve classes, from 8 phyla, with occurrence records submitted to GBIF during this study's timeframe were not listed on the South African Animal Checklist (SANBI

Biodiversity Advisor, 2020), making it impossible to compute their ratios for occurrence records to known species (Table 1). Six classes, from 5 phyla, listed on the South African Animal Checklist (SANBI Biodiversity Advisor, 2020) did not have occurrence records in GBIF during the focal timeframe (Table 1), thus it was not possible to compute any statistics for them either. All of the statistical analyses were performed using R statistical software (R Core Team, 2019) with the following packages: base (Becker *et al.*, 1988); MASS (Venables & Ripley, 2002); stats (R Core Team, 2019); regclass (Petrie, 2020); and ggplot2 (Wickham, 2016).

Findings

Taxonomic bias in the biodiversity distribution data of South African animal taxa

More than 15million occurrence records encompassing 49 South African animal classes were submitted to the GBIF database from 1998 to 21 February 2020 (Table 1). These occurrence records are from 88 datasets, which are viewable at https://doi.org/10.15468/dl.5upuwl. Among these datasets, the largest (with over 13 million occurrence records) was from a volunteer/citizen science project called Southern African Bird Atlas Project 2, which is published on GBIF by the Animal Demography Unit of the University of Cape Town. The second largest dataset (with more than 1 million occurrence records) is from historical bird ringing records (2005–2009) published by the South African National Biodiversity Institute.

Table 1: Occurrence data statistics for South African animal taxa arranged alphabetically by class name.

Class*	GBIF occurrence records	Total known species	Median: GBIF occurrence records	Median absolute deviation	Occurrence records to known species ratio

Actinopterygii	14,240	2,200	3	2	6.47
Adenophorea[a]	5		2	2	
Amphibia	1,148	123	4	2	9.33
Anthozoa	534	174	4	3	3.07
Aplacophora[b]		2			
Appendicularia[b]		80			
Arachnida	2,925	6,630	2	1	0.44
Ascidiacea	559	176	17	13	3.18
Asteroidea	54	91	1	0	0.59
Aves	15,870,476	854	419	418	18,584
Bivalvia	127	650	1	0	0.20
Branchiopoda	9	120	1	0	0.08
Cephalochordata[b]		1			
Cephalopoda	18	195	2	0	0.09
Cestoda	32	83	1	0	0.39
Chilopoda	147	141	2	1	1.04
Chondrichthyes[c]	549	188	2	1	2.92
Clitellata	78	102	2	1	0.76
Crinoidea	30	19	11	6	1.58
Cubozoa	1	2	1	0	0.50
Demospongiae[a]	409		10	6	
Diplopoda	209	462	8	6	0.45
Echinoidea	18	59	2	0	0.31
Entognatha	10	195	2	2	0.05
Eoacanthocephala[a]	1		1	0	

Eurotatoria[a]	1		1	0	
Gastropoda	553	2,262	1	0	0.24
Gordioida[a]	2		2	0	
Gymnolaemata[a]	440		4	4	
Hexanauplia[a]	3		1	0	
Holothuroidea	30	122	1	0	0.25
Hydrozoa	203	457	4	3	0.44
Insecta	54,681	43,893	3	2	1.25
Malacostraca	202	1,763	2	2	0.11
Mammalia	617	307	2	1	2.01
Maxillopoda	12	511	1	0	0.02
Monogenea	9	49	2	0	0.18
Myxini	7	4	2	1	1.75
Ophiuroidea	128	119	2	1	1.08
Ostracoda	18	165	1	0	0.11
Pauropoda[b]		2			
Phylactolaemata[a]	17		2	1	
Polychaeta	9	760	1	0	0.01
Polyplacophora	7	29	1	0	0.24
Pycnogonida	5	101	5	0	0.05
Reptilia	3,181	381	4	3	8.35
Rhynchonellata[a]	30		15	14	
Sarcopterygii	17	3	17	0	5.67
Scaphopoda	2	16	1	0	0.13
Scyphozoa[b]		10			

Secernentea[a]	166		1	0	
Stenolaemata[a]	55		1	0	
Symphyla[a]	1		1	0	
Trematoda	58	72	2	1	0.81
Turbellaria[b]		42			
Unassigned[d]	770	-	-	-	-
Total	15,952,803	63,615	578	497	18,638.15

Note: The occurrence records obtained from GBIF (2020) are for the period from 1998 to 21 February 2020 and exclude fossil records and occurrences designated as unknown. Total number of known species is obtained from the South African Animal Checklist (SANBI Biodiversity Advisor, 2020).

[*] Taxon names copied verbatim from GBIF (2020) and South African Animal Checklist (SANBI Biodiversity Advisor, 2020), some classes on this list are paraphyletic.

[a] Taxa not listed on South African Animal Checklist (SANBI Biodiversity Advisor, 2020)

[b] No records submitted to GBIF during this study's period of interest.

[c] Listed as two separate classes on GBIF, namely Elasmobranchii and Holocephali.

[d] Animal occurrence records that were not assigned to any class or lower taxonomic level

The number of GBIF occurrence records per class show strong bias towards Aves, while some classes (e.g., Polychaeta and Branchiopoda) have comparatively fewer records (Table 1). A graphic representation of the ratio of GBIF occurrence records to the number of known species per South African animal class (Figure 1) illustrates the differences between most and least represented classes, along with all other classes in between the 2 extremes. The ratio of GBIF occurrence records to number of known species of birds is 18 584, whereas there are an average 0.01 occurrences submitted for each species of Polychaeta (i.e., ratio of GBIF occurrence records to number of known species = 0.01). The study sample has 23 under-represented classes (with ratios < 1) and Polychaeta is the least represented among those classes. Only 14 of the 49 classes submitted to GBIF have their ratio of occurrence records to number of known species greater than 1. The dashed section on Figure 1 represents the suggested lower target of 10 and upper target of 30 occurrence records per species, which would be ideal for various applications in biodiversity planning and research, bearing in mind the difficulty of collecting occurrence data differs according to species.

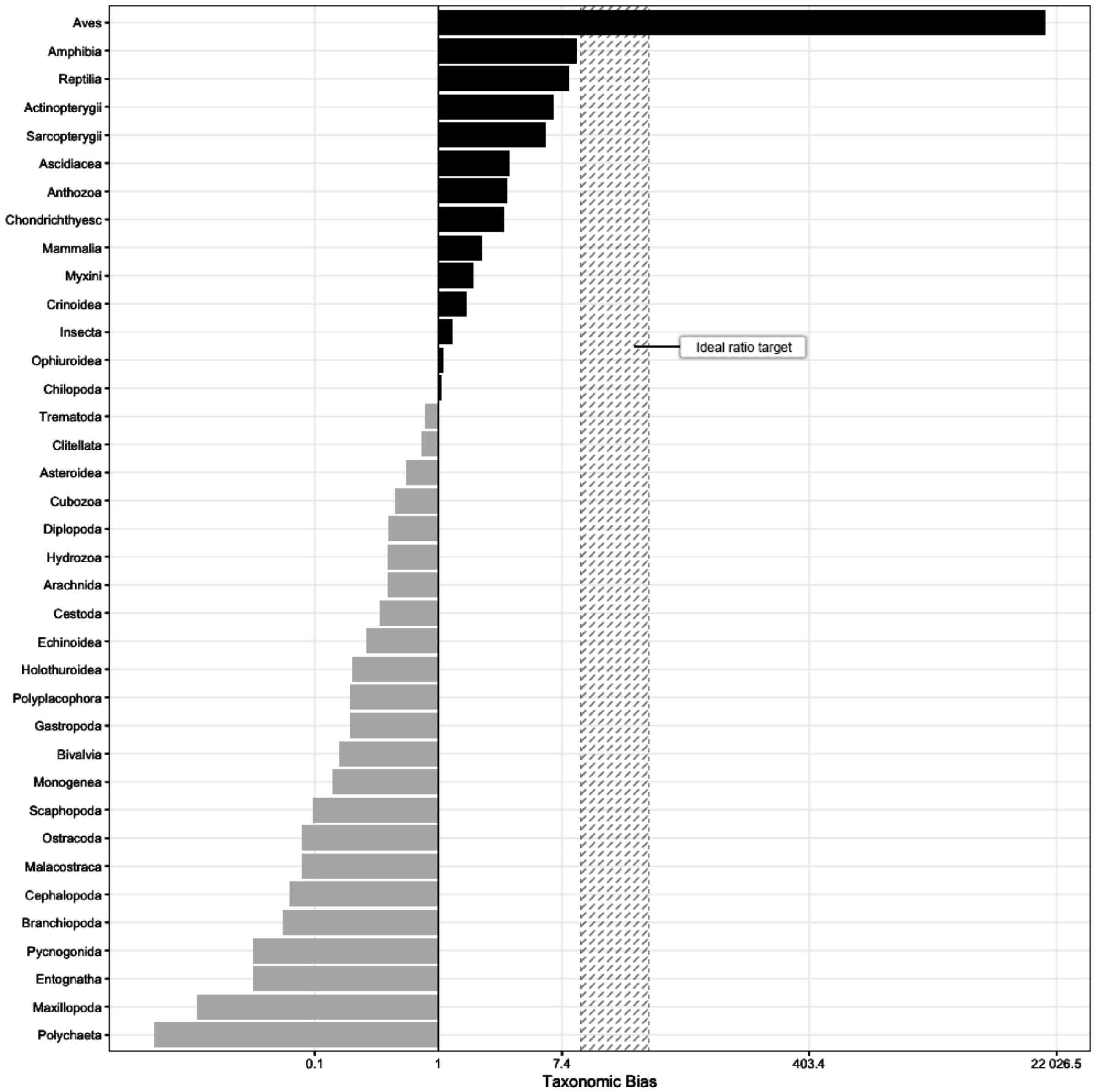

Figure 1: Taxonomic bias in South African animal classes. The number “1” on the X-axis

represents the point where occurrence records are equal to the total number of species per class. Ordering is by decreasing ratio of representation where, values > 1 denote over-representation, and values < 1 denotes under-representation of a class in Global Biodiversity Information Facility (GBIF) occurrence records. Log-transformation is used on the horizontal axis due to disparities between the least- and most-represented species. The dashed section suggests a 10–30 occurrence per species threshold that would be ideal for various biodiversity data uses. Taxa with no records submitted to GBIF (2020b) for this study's timespan or not listed on the South African Animal Checklist (SANBI Biodiversity Advisor, 2020) are omitted from this graph because it was not possible to calculate their occurrence records to known species ratio.

Insecta, the most species-rich South African animal class (SANBI Biodiversity Advisor, 2020) in the sample, accounts for 0.34% of the GBIF occurrence records under review here. The second most species-rich class, Arachnida, accounts for 0.02% of the occurrence records in the review sample. Aves accounts for 99.49% of occurrence records in the study sample, yet it is >51 times and 6 times less speciose than South African Insect and arachnid species, respectively (SANBI Biodiversity Advisor, 2020). The remaining 46 South African animal classes jointly accounted for 0.15% of the total occurrence records submitted to GBIF between 1998 and 21 February 2020. The highest median number of occurrences per species (419) was for Aves, whereas the rest of the classes in this sample had a median of 17 occurrence records per species or less (Table 1).

Cultural salience and scientific interest as explanatory variables of taxonomic bias

The class with highest ratio of GBIF occurrence records to number of known species, Aves, also has the highest cultural salience (Supplementary data, supplementary material 21).

Scientific interest was highest for Insecta, which had a lower ratio of occurrence records to known species by comparison with Aves (1.25 vs. 18 584). The least represented class in this study sample, Polychaeta, had cultural salience and scientific interest in the mid–low ranges. Scaphopoda and Entognatha had the least scientific interest and cultural salience, respectively. Both classes are under-represented in the GBIF occurrence records. The correlation coefficient for GBIF occurrence records and cultural salience ($r = 0.799$) indicates a strong positive linear relationship; the number of species occurrence records for South African animals tend to increase with their cultural salience (Figure 2) and this relationship is statistically significant ($p < 0.05$). Scientific interest and GBIF occurrence records show a weak linear relationship ($r = 0.011$) that is statistically nonsignificant ($p = 0.95$). Six outliers on each of the 2 plots were identified using the interquartile rule (Figure 2). When these outliers were removed to achieve more evenly distributed data points, cultural salience and GBIF occurrence records showed a moderate positive relationship that is statistically significant ($r = 0.599$, $p < 0.05$), whereas GBIF occurrence records and scientific interest showed a weak positive correlation that is also statistically significant ($r = 0.396$, $p < 0.05$).

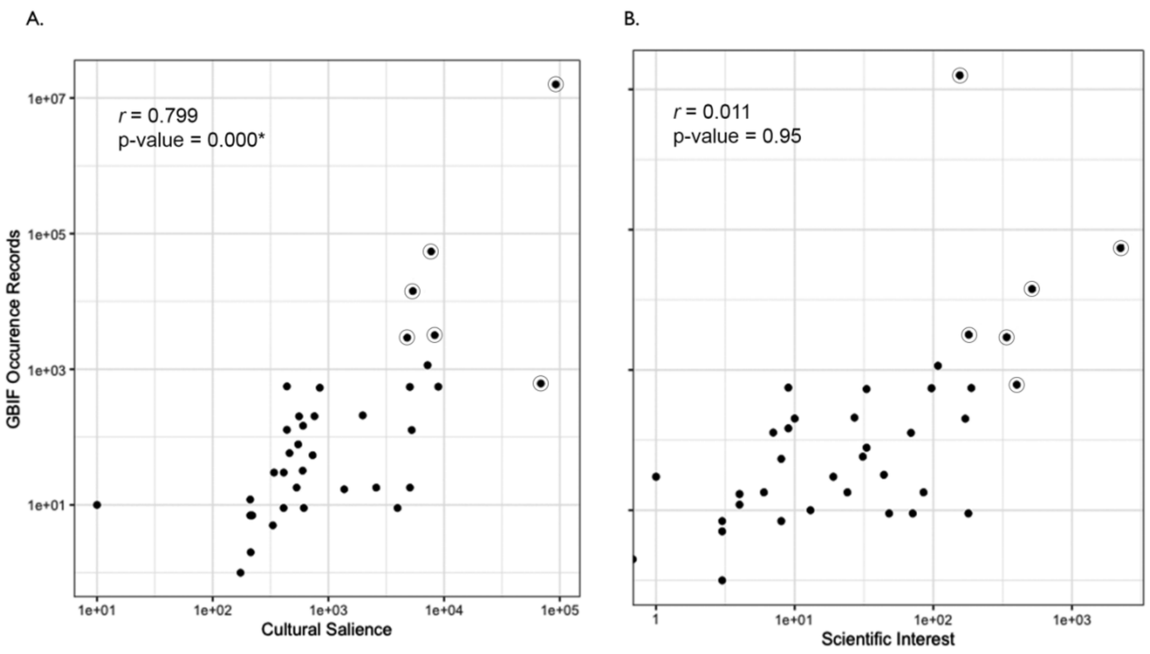

Figure 2: Correlations of Global Biodiversity Information Facility (GBIF) occurrence records with cultural salience and scientific interest of South African animal taxa. The occurrence records of South African taxa obtained from GBIF (2020b) are plotted on the vertical axis. Cultural salience is represented by frequency of taxon names in web pages, and scientific interest is represented by number of scientific articles focused on a taxon and these explanatory variables are plotted on the horizontal axis. Axes are log-transformed due to disparities among the plotted variables. Circled points represent outliers.

Higher resolution investigation of taxonomic bias using a subsample

The subsample used for higher resolution analysis of taxonomic bias consisted of 4329 occurrence records of South African herpetofauna submitted to GBIF between 1998 and 21 February 2020 (Table 2). The amphibian occurrence records were from 9 datasets (viewable on https://doi.org/10.15468/dl.vletu9) and the largest of these datasets (with 660 occurrence records) is published by the South African Institute for Aquatic Biodiversity. Occurrence records of reptile species are from 9 datasets (viewable on https://doi.org/10.15468/dl.insbbc) and the largest among these had 946 occurrence records and is published by the South African National Biodiversity Institute. The GBIF occurrence records of South African herpetofauna spanned 31 families, with Pipidae, Agamidae, and Lamprophiidae being the most represented.

Table 2. Occurrence data statistics for South Africa's herpetofaunal taxa.

Family[a]	GBIF occurrence records	Total known species	Median: GBIF occurrence records	Median absolute deviation	Occurrence records to known species ratio

Amphibians					
Arthroleptidae	7	5	3	0	1.40
Brevicipitidae	62	15	2	1	4.13
Bufonidae	168	17	5	3	9.88
Heleophrynidae	13	7	2	1	1.86
Hemisotidae	3	3	2	0	1.00
Hyperoliidae	63	18	4	1	3.50
Microhylidae	15	2	8	2	7.50
Phrynobatrachidae	15	3	6	4	3.00
Pipidae	221	3	11	9	73.67
Ptychadenidae	15	10	2	2	1.50
Pyxicephalidae	559	39	4	3	14.33
Rhacophoridae	7	1	7	0	7.00
Total	**1,148**	**123**	**56**	**26**	**128.16**
Reptiles					
Agamidae	182	7	7	2	26.00
Amphisbaenidae	9	10	2	1	0.90
Chamaeleonidae	103	21	8	7	4.90
Cheloniidae[b]	0	4	0		
Colubridae	179	68	2	2	2.63
Cordylidae	184	44	2	2	4.18
Crocodylidae	1	1	1	0	1.00
Dermochelyidae[b]	0	1			
Elapidae	70	15	2	2	4.67
Gekkonidae	856	71	5	4	12.06

Gerrhosauridae	80	13	3	2	6.15
Hydrophiidae[b]	0	1			
Lacertidae	157	25	5	3	6.28
Lamprophiidae	407	12	5	3	33.92
Leptotyphlopidae	46	8	10	8	5.75
Pelomedusidae	18	5	9	2	3.60
Pythonidae	11	1	11	0	11.00
Scincidae	556	65	5	4	8.55
Testudinidae	159	15	2	1	10.60
Typhlopidae	45	9	1	0	5.00
Varanidae	24	2	10	3	12.00
Viperidae	94	13	8	6	7.23
Total	**3,181**	**411**	**98**	**52**	**166.42**

Note: The table is arranged alphabetically by class, then family. These occurrence records are obtained from the Global Biodiversity Information Facility (GBIF, 2020b) for the period from 1998 to 21 February 2020, and exclude fossil records and occurrences designated as unknown. The total number of known species is obtained from the South African Animal Checklist (SANBI Biodiversity Advisor, 2020).

[a] Family names copied verbatim from GBIF (2020) and South African Animal Checklist (SANBI Biodiversity Advisor, 2020).

[b] No records submitted to GBIF for this study's focal timespan.

The ratio of GBIF occurrence records to number of known species was > 1 for 30 of the 31 reviewed families, with Amphisbaenidae being the least represented. Three families listed on the South African Animal Checklist (SANBI Biodiversity Advisor, 2020) did not have occurrence records submitted to GBIF during this study's timeframe (Table 2), and are thus excluded from analysis. The most species-rich families (Pyxicephalidae, Colubridae, Cordylidae, Gekkonidae, Scincidae) have median occurrence records per species of 5 or fewer. Pipidae and Pythonidae, which are among the least speciose of South Africa's herpetofaunal families, had the highest median occurrence records per species (Table 2). The GLM results (Table 3) show a positive and significant correlation between GBIF occurrence records and cultural salience of the subsample. Correlations between the subsample's GBIF occurrence records and scientific interest are nonsignificant (Table 3). The GLM further shows that the interactions between cultural salience and scientific interest have statistically significant and mostly negative influence on GBIF occurrence records, thus the interactions of the two explanatory variables could be influencing the accumulation of biodiversity distribution data.

Table 3: Results for the generalised linear model for assessing correlations between the dependent variable (GBIF occurrence records of herpetofaunal families) and 2 explanatory variables (cultural salience and scientific interest) and their combined influence.

Herpetofaunal family[a]	**Cultural salience influence p-value**	**Scientific interest influence p-value**	**Interaction influence p-value**
Brevicipitidae	(+) 0.002[b]	(+) 1.356	(-) 0.004[b]
Bufonidae	(+) 0.003[b]	(+) 0.093	(-) 0.000[b]
Colubridae	(+) 0.002[b]	(-) 0.549	(-) 0.000[b]
Cordylidae	(+) 0.004[b]	(+) 0.298	(-) 0.000[b]

Elapidae	(+) 0.001 [b]	(+) 0.245	(-) 0.000 [b]
Gekkonidae	(+) 0.001 [b]	(+) 0.463	(+) 0.000 [b]
Lacertidae	(+) 0.003 [b]	(+) 0.537	(-) 0.001 [b]
Lamprophiidae	(+) 0.001 [b]	(+) 1.122	(-) 0.001 [b]
Pyxicephalidae	(+) 0.002 [b]	(+) 0.834	(-) 0.001 [b]
Scincidae	(+) 0.001 [b]	(-) 0.165	(-) 0.001 [b]
Testudinidae	(+) 0.002 [b]	(+) 0.079	(-) 0.000 [b]

Note: (+) and (–) respectively indicate positive and negative correlation of explanatory variable with number of Global Biodiversity Information Facility (GBIF) occurrence records.

[a] Family names copied verbatim from GBIF (2020b) and South African Animal Checklist (SANBI Biodiversity Advisor, 2020).

[b] Indicates a significant p-value (5% threshold).

Conservation status, cultural salience, and scientific interest

No clear patterns emerged for the relationship between extinction risk of taxa, their cultural salience, and scientific interest (Table 4). Of the 6 IUCN taxonomic groupings of threatened animals, the second highest cultural salience and scientific interest was for mammals, which also represented the second-highest number of threatened species relative to the total number of known species. The lowest cultural salience and scientific interest was for amphibians, which also showed the highest number of threatened species relative to the number of known species. The third highest cultural salience and scientific interest was for molluscs (including Gastropoda, Bivalvia, and Cephalopoda, as per the IUCN taxonomic grouping), which were the least-threatened species relative to the total number of known species in South Africa.

Table 4: Comparison of extinction risk with cultural salience and scientific interest of South African animal taxa.

Cultural salience ranking*	IUCN Taxonomic grouping	Threatened Species	Known species[+]
1	Birds	54	854
2	Mammals	30	307
3	Molluscs[a]	22	3107
4	Fishes[b,c]	128	2395
6	Reptiles[b]	19	381
8	Amphibians	16	132
Scientific interest ranking*	**IUCN Taxonomic grouping**	**Threatened Species**	**Known species[+]**
2	Fishes[b,c]	128	2395
4	Mammals	30	307
5	Molluscs[a]	22	3107
8	Reptiles[b]	19	381
11	Birds	54	854
12	Amphibians	16	132

Note: Columns arranged by ascending order of the magnitude of cultural salience and scientific interest out of the 49 classes under review herein.

[*] Ranking out of the 49 classes in this study's sample.

[+] Number of known species obtained from the South African Animal Checklist (SANBI Biodiversity Advisor 2020).

[a] Molluscs collectively refers to Gastropoda, Bivalvia, Cephalopoda.

[b] The conservation status of these taxonomic groupings has not been fully assessed. Numbers of threatened species should be interpreted as the number of species known to be threatened within those species that have been assessed, and not as the overall number of threatened species within a grouping (IUCN 2020).

[c] Fishes collectively refers to Actinopterygii, Chondrichthyes, Myxini, and Sarcopterygii.

Interpretation and policy implications of findings

Taxonomic bias in the biodiversity distribution data of South African animal taxa

This current study found biases in the biodiversity distribution data of South African animal taxa. There is a strong bias towards Aves in the South African context, and also at a global scale (Troudet *et al.,* 2017). Classes such as Polychaeta, Bivalvia, and Arachnida are under-represented in both global (Troudet *et al.,* 2017) and South African biodiversity distribution data (Figure 1). Intrinsic factors may be contributing to the bias towards taxa such as Aves and Mammalia, since some are large (Zapponi *et al.,* 2017), abundant (Royle & Nichols, 2003), and easily recognizable (Boakes *et al.*, 2016). Arachnida and Insecta are both abundant, and yet these 2 taxa are not as well-represented as Aves and Mammalia. Arachnid and insect species are, however, smaller in size and thus more difficult to identify in comparison to Aves and Mammalia. Herpetofauna are generally secretive, with some cryptic species, which makes them difficult to identify, yet they are among the over-represented taxa within this study sample (Figure 1). This reiterates an assertion made by Troudet *et al.,* (2017), that intrinsic features cannot solely account for the existing taxonomic bias.

Approaches to lessening taxonomic bias should take into consideration that extrinsic features also contribute to underrepresentation of taxa in biodiversity distribution data.

In addition to taxonomic bias, this review noted differences in class names and records among the biodiversity data sources consulted (Table 1). These discrepancies necessitate standardisation across sources of biodiversity data (in this case GBIF and the South African Animal Checklist) to maximise their value for biodiversity data applications. Assessment of the taxonomic bias of 18 classes could not be completed because some of the data required to compute the ratio of GBIF occurrence records to number of known species was not available; 12 classes from the GBIF dataset did not have corresponding records on the South African Animal Checklist (SANBI Biodiversity Advisor, 2020), thus pointing out a need for improved synchronisation as the institution producing this checklist also hosts the South African node of GBIF. The remaining 6 of the unanalysed 18 classes do not have records submitted to GBIF during the 22-year timeframe of this study. The lack of biodiversity distribution data records of 6 classes for this duration suggests lax monitoring of species within those classes, or that the custodians of these data are not publishing them to GBIF.

The suggested lower and upper targets of species occurrence records do not seek to introduce limits for what should constitute taxonomic bias. Hard limits are impractical because species differ in population dynamics, and biodiversity distribution data requirements vary according to application. Suggesting targets introduces a dimension that is often missing from taxonomic bias research; the steps that follow confirmation of disparities in attention received by taxa. If the disproportionate representation of taxa in biodiversity databases is to be lessened, then guidelines for the target number of occurrence records per species should be available. These guidelines should be cognisant of the multiple uses of biodiversity distribution data and intrinsic features that determine the ease with which species' occurrences can be recorded. This lower target of 10 occurrence records per species accommodates the secretive and less abundant taxa, and would serve to decrease under-representation of species. The upper target of 30 occurrence records per species would guide data collection for all species and also serve to avoid perpetuating existing biases. If the upper target per species per habitat or niche was reached, then data collection resources could be used for other species with fewer occurrence records. Collecting biodiversity data beyond the upper target would then be less urgent but still necessary because larger data sets are beneficial for the accuracy of statistical models. The cumulative impacts of a minimum 10 occurrence records per species per habitat is that average species occurrence records for each South African animal class would end up being at least 10. In such a scenario, species that are easy to detect would still have higher representation, but even the least represented species would still have enough occurrence records to sufficiently inform research and planning.

Cultural salience and scientific interest as explanatory variables for taxonomic bias

Globally, there is a mostly positive influence from public interest on the representation of taxonomic classes in biodiversity distribution data and a few instances of positive correlation between scientific interests and taxon representation (Troudet *et al.*, 2017). A possible contributor to the positive correlation between biodiversity distribution data and societal interest is the ease with which societal interest can be translated into biodiversity distribution data through citizen science platforms such as iNaturalist. The spread of mobile technology is increasingly making it easier to collect citizen science observations and could further increase the influence of societal interest on biodiversity distribution data or even increase observations of underrepresented species. This study found a statistically significant and positive correlation between cultural salience and biodiversity distribution data for South African animal classes, whereas the correlation between scientific interest and South African animal taxa representation is not statistically significant. The regression results after removal of outliers with either high GBIF occurrence records, cultural salience, or scientific interest (Figure 2), suggest increased influence of scientific interest on species occurrence records when the focus on taxa is less biased. The study considered cultural salience and scientific interest in the general sense and it is thus possible that the likely influence of the two phenomenon differs at the different levels at which they exist.

Higher resolution investigation of taxonomic bias using a subsample

A higher resolution analysis of taxonomic bias found positive and statistically significant correlation between cultural salience and GBIF occurrence records of a subsample of herpetofaunal families. No statistically significant correlation was found between GBIF occurrence records and scientific interest in this subsample. Scientific interest's effect on biodiversity distribution data accumulation appears negligible, but should not be overlooked because the interaction between scientific interest and cultural salience has a statistically significant influence on GBIF occurrence records (Table 3). Statistically significant interaction effects indicate that there is possibly an interaction between cultural salience and scientific interest that is affecting the number of GBIF occurrence records per South African animal taxon. Thus, the influence of cultural salience on GBIF occurrence per species may depend on the scientific interest a species has (and vice versa). Consequently, it may not be possible to solely attribute taxonomic bias in GBIF occurrence records to cultural salience because these biodiversity distribution data are collected by both scientists and nonscientists, and scientists' internet activities likely influence web-based measures of cultural salience. There is also evidence that societal and scientific interests in biodiversity matters are not mutually exclusive (Eisner *et al.,* 1995; Wilson *et al.,* 2007; Martín-López *et al.,* 2009). Herpetofauna being generally well represented in GBIF occurrence records at both national and international scales is good for herpetofaunal research and conservation because it means there are generally sufficient amounts of biodiversity distribution data to work with. Furthermore, increased representation of herpetofauna in biodiversity distribution data is an encouraging result considering that they are generally understudied (Christoffel & Lepczyk, 2012); the public mostly has negative perceptions about them (Reimer *et al.,* 2014; Tarrant *et al.,* 2016); and their global populations are declining (McCallum, 2007).

Conservation status, cultural salience, and scientific interest

This study's inferences about the relationship between extinction risk, cultural salience, and scientific interest are based on data with a small scale of focus and further investigation at a higher resolution (i.e., species level) is required to better understand the relationship. The published literature shows mixed results with regard to the correlation of extinction risk with cultural salience and scientific interest. Higher-resolution investigations from previous research found that some taxa with high societal preference also have a high extinction risk (Courchamp *et al.,* 2018). Society's taxonomic preferences can be affected by factors such as species abundance and charisma, and are not necessarily motivated by concern for a taxon's welfare (Davies *et al.,* 2019). For endangered taxa that receive increased attention, the focus is biased towards taxa that fit certain criteria, e.g., threatened vertebrates receive greater scientific interest than threatened invertebrates (Donaldson *et al.,* 2016). Furthermore, the number of IUCN threat status assessments for invertebrates is much lower than vertebrate assessments (Eisenhauer *et al.,* 2019). Threatened vertebrates have higher cultural salience if they are birds or mammals (Davies *et al.,* 2019). Species that are threatened generally obtain higher scientific interest than nonthreatened species, and this is due to conservation efforts being based on IUCN's threatened species categories (Martín-López *et al.,* 2011). Previous research has shown that high cultural salience alone does not correlate with increased species protection (Courchamp *et al.,* 2018); however, higher cultural salience alone can drive funds towards species protection (Simberloff, 1998). These funds can in turn be used to increase scientific focus on the underfunded biodiversity research necessary to inform conservation policy. Cultural salience influences scientific interest (Wilson *et al.*, 2007) and society plays a role in biodiversity research and planning (Martín-López *et al.*, 2009). There are suggestions that biodiversity protection is most effective when based on scientific knowledge and has societal approval (Eisner *et al.*, 1995). Biodiversity researchers and managers often direct scientific interest and cultural salience towards certain species for the benefit of many other species. This surrogate species concept chooses species to be proxies for ecosystems (Favreau *et al.*, 2006) or conservation problems (Dietz *et al.*, 1994). By updating the surrogate species framework to incorporate the suggested targets of 10–30 occurrence records per species, its scope of benefits can be broadened to include lessening of persisting taxonomic bias. In this way the outcomes of dedicating resources towards surrogates would include 10–30 occurrence records per surrogate species and the species meant to benefit from protection of the surrogate.

Concluding remarks and recommendations

This study quantifies taxonomic bias in the biodiversity distribution data of animal taxa in a megadiverse country and shows there is a severe bias towards birds while some classes are underrepresented. Statistical analyses have suggested that cultural salience has greater influence on the noted taxonomic bias than scientific interest. A high-resolution analysis of taxonomic bias with a subsample, also shows cultural salience to have stronger influence and additionally suggests there is statistical interaction between the 2 explanatory variables. No clear correlation was found in the relationship between a taxon's extinction risk, cultural salience, and scientific interest. The intrinsic traits of species, together with the limitations of ecological research, make it difficult to completely avoid taxonomic bias. It is more feasible to investigate extrinsic factors (such as cultural salience and scientific interest) and use the findings to avoid the current situation where taxonomic bias in biodiversity distribution data has prevailed for decades and the majority of animal taxa of a megadiverse country are under-represented. Approaches that will, at the least, increase representation of severely under-represented taxa to lessen persistent taxonomic bias are required. Once taxonomic bias has been quantified, additional research time should be dedicated to finding ways to address persisting biases. The recommendation to introduce soft targets of between 10 and 30 species occurrence records per habitat seeks to increase representation of under-represented taxa in biodiversity distribution data. The species occurrence targets can also be incorporated into surrogate species frameworks for their benefits to be extended to include the lessening of persisting taxonomic bias. Given that cultural salience seems to have greater influence on accumulation of primary biodiversity, it is possible that stimulating cultural salience of underrepresented taxa could contribute to decreasing the bias against them. Understanding how to increase the importance of species in people's cultures will require collaboration with social scientists. Furthermore, it will be worth assessing which taxa are ecologically more important to prioritise increasing their cultural importance for the sake of increasing accumulation of their primary data. Investigations of extrinsic factors should also consider how scientific interest's influence on cultural salience and vice versa could in turn influence taxonomic bias. Given the possibility of interaction effects between societal and scientific preferences, it will be worth researching the extent of this interaction between explanatory variables and how it can be used to lessen taxonomic bias.

Acknowledgements

This research is made possible by a bilateral scientific cooperation between North-West University and Hasselt University. Financial support for F.M.P. was provided by the National

Research Foundation (UID: 114663), North-West University, and the Flemish Interuniversity Council (VLIR-UOS) Global Minds program (Contract Number: R-9363); M.P.M.V. was supported by the Special Research Fund of Hasselt University (BOF20TT06). The authors declare that there is no conflict of interest associated with this work.

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Chapter 4

Conservation prospects and challenges of South Africa's cultural traditions about herpetofauna.

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(Manuscript submitted to journal)

Abstract: Human cultures have developed complex interactions with biodiversity over time, and researching these interactions involves natural and social sciences. Understanding those interactions helps inform biodiversity conservation, and this can be beneficial for organisms experiencing global declines like frogs and reptiles. Ethnoherpetology specifically investigates the interactions between herpetofauna and traditional cultures. This current ethnoherpetological case study of the culturally and biologically diverse country of South Africa provides an understanding of the conservation implications of cultural traditions. Some cultural norms and practices compel and inspire protection of herptiles and have the potential to benefit their conservation. Conversely, other cultural interactions threaten herptiles through consumptive use and negative perceptions. Leveraging protective cultural norms and practices as a conservation tool and mitigating culture-motivated threats will require collaboration between conservation practitioners and indigenous knowledge custodians for an integrative conservation approach. South African conservation policy already has provisions for this type of integration and realising this integration would also contribute towards achieving Sustainable Development Goals and targets of the Global Biodiversity Framework through biodiversity conservation measures that consider the cultural norms and practices of communities who continue to be unjustly excluded from conservation planning. Consideration of cultural norms and practices thus contributes to preserving the cultural heritage of such communities.

Keywords: Biocultural conservation, Herpetology, Indigenous knowledge systems, Socio-ecological systems, Sustainability, Traditional ecological knowledge

Background

Human cultures develop ways of interacting with local biodiversity over time (Alves, 2012) and understanding the complexity of such interactions involves multiple disciplines bridged by ethnozoology (Alves & Albuquerque, 2017). This ethnozoology is a hybrid of social and natural sciences, that focuses on past and present relationships between animals and people's cultures (Alves & Souto, 2015; Alves, 2017). Ethnozoological investigations have potential to inform conservation planning (Alves & Albuquerque, 2017). Ethnoherpetology, a subfield of ethnozoology that investigates the interactions between cultures and herpetofauna (Linares-Rosas *et al.*, 2021), is essential to establishing conservation strategies as it increases understanding of human factors that negatively and positively impact herpetofaunal populations (Alves *et al.*, 2013). Understanding the conservation implications of cultural traditions is especially important for animal groups that are experiencing population declines due to human-related impacts, such as herpetofauna (Collins & Storfer, 2003; Hof *et al.*, 2011). As at March 2021, the Red List of threatened species showed at least 34% of amphibian and 17% of reptile species whose conservation status had been evaluated to be under threat, in comparison to 23% of mammals, 13% of birds and 16% of fishes that are threatened globally (IUCN, 2021). While there are studies that suggest that the categorisation of extinction risk used here is flawed (de Oliveira Caetano *et al.*, 2022), the current study's motivation for using it is that South African conservation policy (to which this study's recommendations are relevant) relies on that categorisation. Consideration of cultural traditions in herptile conservation would contribute to progress towards Sustainable Development Goals (SDG 11, 15 and 16) by promoting biodiversity conservation action that is inclusive of previously excluded members of society and also protecting cultural norms that are relevant to conservation (United Nations, 2015). Such culturally inclusive conservation would also be in line with the encouragement from the Global Biodiversity

Framework (Target 17) to consider cultural norms in decision-making (Convention on Biological Diversity, 2021). Consideration of cultural norms and practices in biodiversity conservation planning should be promoted as the United Nations Declaration on the Rights of Indigenous Peoples Protection acknowledges indigenous people's cultural heritage and the right for people to maintain their traditional cultural norms and practices (United Nations, 2007).

This current ethnoherpetological assessment focuses on South Africa and highlights the conservation implications of cultural traditions as these traditions are part of the human-related impacts contributing to herptile population declines. South Africa has diverse nature-based cultural traditions (Department of Environment, Forestry and Fisheries, 2015), and conservation in any cultural landscape requires an understanding of cultures (Archer *et al.*, 2018). South African conservation policy makes provisions for the lessons learned from interactions between biological and cultural diversity. Consideration of the interactions between biological and cultural diversity can increase effectiveness of conservation planning and contribute to a balance between social and conservation objectives (Gavin *et al.*, 2015). The National Environmental Management Act 107 of 1998 (NEMA) which establishes an overarching conservation framework (Republic of South Africa, 1998) and the 2015 National Biodiversity Strategy and Action Plan which aims to fulfil the objectives of the Convention on Biological Diversity in South Africa (Department of Environment, Forestry and Fisheries, 2015) specifically make provisions for all forms of knowledge (including indigenous knowledge) to be acknowledged and incorporated into conservation processes. Here we present an assessment of herptile conservation challenges and opportunities arising from South African cultural norms and discuss prospects of incorporating them into conservation processes.

Methods

We reviewed published literature for details of interactions between South Africa's indigenous cultures (cultures of African origin) and herptiles. Other instances of this relationship were recorded using a multilingual online questionnaire between 09 May 2020 and 22 March 2021. Literature was obtained using snowball sampling that started with the following search query on Google Scholar (www.scholar.google.com); "herpetology" AND "South Africa". This snowball sampling served to find relevant literature that did not contain the keywords used in the search (Lecy & Beatty, 2012). From the Google Scholar search results, we selected publications with details of interactions between indigenous cultures and herpetofauna in their abstracts for inclusion in this study's sample. The reference lists of suitable publications were used to identify other publications whose abstracts were also pre-screened and included in this study's sample if they had details of interactions between indigenous cultures and herpetofauna.

The online questionnaire was in nine of South Africa's official indigenous languages and had an option to provide responses for either frogs or reptiles (Supplementary Material 1). This questionnaire was advertised to South African indigenous language speaking internet users through multiple paid posts (i.e., paid advertisements) that targeted those with an interest in wildlife on Twitter (www.twitter.com/wild_vernac), Facebook (www.facebook.com/wildvernac/), and Instagram (www.instagram.com/wild_vernac/). This questionnaire is semi-structured with a combination of targeted questions and open-ended questions about different herptile species that are displayed alongside photographs embedded in the questionnaire. Semi-structured interview style enables discussion and sharing of additional information that could not be gained through structured questions (Galletta, 2012). Targeted questions seek responses about name, use and cultural importance of each pictured species. Open-ended questions ask respondents to provide additional information about how their culture relates to the pictured species that was not covered by the questions which they answered previously.

A total of 67 publications were reviewed (cited in-text and listed in Supplementary Material 2). The online questionnaire had 259 respondents (Figure 1) belonging to ten indigenous cultural groups (AmaNdebele, AmaXhosa, AmaZulu, BaLobedu, BaPedi, BaSotho, BaTswana, MaSwati, VaTsonga and VhaVenḓa). The respondents were composed of 187 males and 72 females aged between 25 and 57 years.

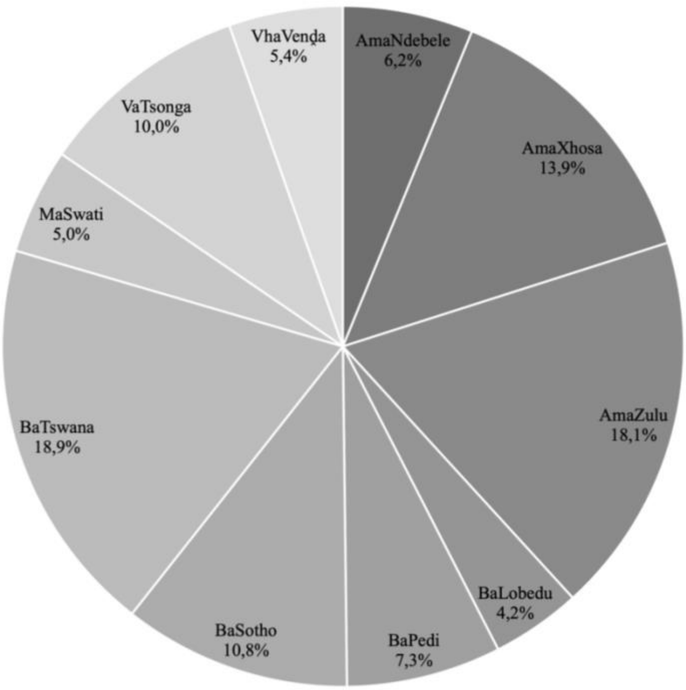

Figure 1: Respondents to a questionnaire about South Africa's cultural traditions about herpetofauna grouped according to their culture.

Interactions of cultural practices and norms with herptiles from the reviewed literature and questionnaire responses were coded and organised into elements of culture (emerging from the data) or a society's shared beliefs and practices that can be grouped together based on similarities. These interactions are assessed to understand their conservation implications and their relevance to the conservation guidelines in NEMA and South Africa's 2015 National Biodiversity Strategy and Action Plan.

Results

The questionnaire responses and reviewed literature reveal various interactions between people's cultural traditions and herptiles. Ten elements of culture emerged from this study's data and the findings are thus grouped according to those elements as shown in Table 1.

Table 1: South Africa's cultural traditions about herpetofauna categorised into different elements of culture. The inclusion criteria for each element of culture are shown in brackets. Within each element of culture, herpetofauna are organised according to taxonomic order.

1. Gastronomy (Ingestion of herptiles for protein)

<u>Anura:</u> Bullfrogs (*Pyxicephalus* spp.) are opportunistically hunted and eaten in Zulu, Pedi and Tsonga cultures (Du Preez & Cook, 2004; Phaka *et al.,* 2017; Questionnaire*).

<u>Crocodylia:</u> Nile Crocodile (*Crocodylus niloticus*) is opportunistically hunted and eaten in Ndebele, Pedi, and Zulu cultures (Questionnaire*).

<u>Squamata:</u> Southern African Python (*Python natalensis*) is opportunistically hunted and eaten in Pedi culture (Questionnaire*).

<u>Testudines:</u> Leopard Tortoise (*Stigmochelys pardalis*) is opportunistically hunted and eaten in Pedi and Tsonga cultures (Anthony & Bellinger, 2007; Questionnaire*). Unspecified tortoises are opportunistically hunted and eaten in Eastern Cape province (Van Zyl, 2020).

2. Traditional medicine (Use of herptiles to remedy illness)

<u>Anura:</u> Giant Bullfrog (*Pyxicephalus adspersus*) is used as medicine in Sotho culture (Du Preez, 1996). *Schismaderma carens* is used in traditional medicine (Whiting *et al.*, 2011).

<u>Crocodylia:</u> Nile Crocodile is used in traditional medicine (Whiting *et al.*, 2011).

Squamata: Aurora House Snake (*Lamprophis aurora*), Black Mamba (*Dendroaspis polylepis*), Boomslang (*Dispholidus typus*), Central African Forest Cobra (*Naja melanoleuca*), Flap-necked Chameleon (*Chamaeleo dilepis*), Giant Legless Skink (*Acontias plumbeus*), Green Mamba (*Dendroaspis angusticeps*), Mozambique Spitting Cobra (*Naja mossambica*), Mole Snake (*Pseudaspis cana*), Nile Monitor (*Varanus niloticus*), Olive Grass Snake (*Psammophis phillipsii*), Puff Adder (*Bitis arietans*), Rinkhals (*Hemachatus haemachatus*), Rock Monitor (*Varanus albigularis*), Rough-scaled Plated Lizard (*Broadleysaurus major),* Southern African Python, Southern Tree Agama (*Acanthocercus atricollis*), Snouted Cobra (*Naja annulifera*), Spotted Skaapsketer (*Psammophylax rhombeatus),* Striped Skaapsketer *(Psammophylax tritaeniatus*), Sungazer (*Smaug giganteus*), Transvaal Girdled Lizard (*Cordylus vittifer*), Tropical Girdled Lizard (*Cordylus tropidosternum*), Warren's Girdled Lizard (*Smaug warreni*), Vine Snake (*Thelotornis capensis*), and Yellow-throated Plated Lizard (*Gerrhosaurus flavigularis*) are used in traditional medicine (Cunningham & Zondi, 1991; Cunningham, 1993; Simelane, 1996; Simelane & Kerley, 1997; Simelane & Kerley, 1998; Ngwenya, 2001; Whiting *et al.*, 2011; Nieman *et al.*, 2019). Night Adders (*Causus* spp.), Water Snakes (*Lycodonomorphus* spp.) are used as medicine specifically in Zulu culture (Donda, 1997).

Testudines: Angulate Tortoise (*Chersina angulata*), Bell's Hingeback Tortoise (*Kinixys belliana*), Hawksbill Turtle (*Eretmochelys imbricata*), Leopard Tortoise, Natal Hingeback Tortoise (*Kinixys natalensis*), and Speke's Hingeback Tortoise (*Kinixys spekii)* are used in traditional medicine (Whiting *et al.*, 2011).

3. Rituals and Symbolism (Herptiles symbolising desirable traits or phenomena)

Anura: Rain Frogs (*Breviceps* spp.) symbolise rain in Venḓa culture and harming them is forbidden (Mutshinyalo & Siebert, 2010). Clawed Frogs (*Xenopus* spp.) symbolise fertility in KhoiSan cultures (Thorp, 2013, 2015). Unspecified frogs were sacrificed for rain control rituals of Sotho cultures and unnamed Hunter-gatherer communities (Riep, 2011; Brunton *et al.,* 2013). Unspecified frogs symbolise rain in KhoiSan cultures and harming them is forbidden (Potgieter, 1955; Bleek, 1933a, 1933b; Lewis-Williams & Pearce, 2004).

Crocodylia: Nile Crocodiles are rain symbols in Pedi culture and harming them is forbidden (Lekgothoane & van Warmelo, 1938).

Squamata: Nile Monitor carcasses are used for rain control rituals in Tswana culture, but it is forbidden to harm living animals (Lye *et al.,* 1975). Southern African Pythons are generally considered a symbol of wealth and power (Questionnaire*), while in Tswana culture they symbolise sexuality, knowledge and transition and harming them is forbidden (Kenalemang & Kaya, 2012; Mandillah & Ekosse, 2018). Southern African Python and Nile Monitor are sacrificed for rain control rituals in Zulu culture (Krige, 1950). Unspecified lizards, snakes, and turtles are sacrificed for rain control rituals in Hunter-gatherer and Sotho cultures (Riep, 2011; Brunton *et al.*, 2013). Unspecified snakes and tortoises symbolise rain in KhoiSan cultures and harming them is forbidden (Potgieter, 1955; Bleek, 1933a, 1933b; Lewis-Williams & Pearce, 2004).

Testudines: Unspecified tortoises symbolise rain in KhoiSan cultures and harming them is forbidden (Lewis-Williams & Pearce, 2004).

Herptiles in general: Aquatic herptiles symbolise the sanctity of waterbodies in Venḓa culture (Questionnaire*).

4. Religion (Worship or divinisation of herptiles)

Anura: Unspecified frogs are messengers from ancestors or deities and harming them is forbidden in Cape Nguni culture (Hirst, 1991).

Squamata: Southern African Python, Nile Monitor, Brown House Snake (*Boaedon capensis*), and unspecified chameleons are regarded as messengers from ancestors or deities and harming them is forbidden (Hirst, 1991; Donda, 1997; Simelane & Kerley, 1997; Bernard, 2003, Letsoalo, 2009; Mutshinyalo & Siebert, 2010). Unspecified snakes are believed to be river-dwelling deities by various South African cultures (Hirst, 1991; Hoff, 1997; Bernard, 2003; Riep, 2011; Kenalemang & Kaya, 2012).

5. Totemism (Attaching kinship to herptiles)

Crocodylia: Nile Crocodiles are totem animals for many South African clans including Bakwena, Bakoena, and Ngwenya (Malungana, 1994; Bongela, 2001; Tšiu, 2006; Riep, 2011; Koma, 2012; Graham, 2016; Thwala, 2018).

Squamata: Mole Snakes are totem animals for the IsiXhosa speaking Majola clan (Bongela, 2001).

Testudines: Unspecified tortoises are the totem animals for some Pedi clans (Van Zyl, 1941; Maahlamela, 2017).

6. Languages (Use of herptiles in figures of speech)

Herptiles in general: Frogs and reptiles are generally used in riddles, expressions, euphemisms, and similes of various languages (Blacking, 1961; Mathumba, 1988; Kgoroeadira, 1993; Donda, 1997; Thwala, 2017; Thwala, 2019).

7. Entertainment (Herptiles in traditional forms of entertainment)

Anura: Unspecified frogs feature in folk songs (Johnston, 1973; Nemukovhani, 1977).

Crocodylia: Nile Crocodile represents human qualities in the poetry of various cultures (Kgoroeadira, 1993).

Squamata: Unspecified skinks, and snakes, represent human qualities in the poetry of various cultures (Lekgothoane & van Warmelo, 1938; Van Zyl, 1941; Kgoroeadira, 1993; Malungana, 1994; Mamabolo, 1995; Groenewald, 1998).

8. Folk tales (Myths, superstitions, and stories in a culture's oral traditions)

Anura: Toads (*Sclerophrys* spp.) are said to attract lightning in Zulu culture (Questionnaire*).

Unspecified frogs portray shape-shifting characters (Callaway, 1868).

Squamata: Black Mamba and Southern African Python portray powerful traditional healers in Tsonga and Zulu cultures (Mavikane, 1990; Koopman, 2015). Tropical House Geckoes (*Hemidactylus mabouia*) are said to be purveyors of evil spirits and have an incurable bite wound in Pedi and Tswana cultures (Questionnaire*). Unspecified chameleons and skinks portray messengers, or contrasts between punctuality (skink) and tardiness (chameleon) (Canonici, 1990; Mogapi, 1990). Unspecified snakes are said to kill people that disregard taboos and this tale is used to reinforce cultural taboos (Ngubane, 1977; Sinthumule & Mashau, 2020). Unspecified snakes portray deceptive characters in Tsonga culture (Mavikane, 1990).

9. Taxonomy (Naming and classification relating to herptiles)

Anura: South Africa's traditional cultures have their own taxonomic systems for frogs that have similarities to scientific taxonomy (Phaka *et al.*, 2019).

Crocodylia: The indigenous language words for Nile Crocodile are used as a surname (e.g., Mokwena, Mokoena, and Ngwenya) by various cultures (Kgoroeadira, 1993; Ndimande, 1998; Futhwa, 2011; Koma, 2012; Thwala, 2018). Koena (Nile Crocodile) is a given name in Pedi culture (Questionnaire*). Crocodiles are used in the names of places: Mokgalakwena – fierce crocodile (originates from SePedi).

Squamata: Puff Adder is used as a placename for Keiskamma River which means Puff Adder River in this word (Keiskamma) originating from Khoekhoen languages (Raper, 2018). Nsuze, a word meaning snake in IsiZulu, is used as a name for a place (Questionnaire*). Snake as a generic term (nyoka) is a given name in Ndebele and Zulu culture (Ngubane, 2000; Skhosana, 2005).

Testudines: Unspecified tortoises are as a placename for Nakop which means tortoise place River in this word originating from Khoekhoen languages (Raper, 2018).

10. Observations (Animal observations interpreted using indigenous knowledge)

Anura: Bullfrogs are said to fall from the sky during heavy rain according to Tsonga culture (Questionnaire*). Clawed frogs are said to fall from the sky during heavy rain according to Zulu culture (Phaka *et al.*, 2019). Grass Frogs (*Ptychadena* spp.) and other unspecified frogs are said to bring rain when they start being active according to Zulu culture (Basdew *et al.*, 2017; Phaka *et al.*, 2019; Vilakazi *et al.*, 2019).

Squamata: Unspecified snakes signal onset of spring when they start being active (Zuma-Netshiukhwi *et al.*, 2013).

Testudines: Unspecified tortoises signal onset of spring when they start being active (Zuma-Netshiukhwi *et al.*, 2013).

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*Data obtained from this study's online questionnaire.

Some cultural norms and practices listed in Table 1 have negative conservation implications as they use animals consumptively or perpetuate negative perceptions (for example through their association of some herptiles with deception in folk tales). Ritualistic sacrifice and consumption of herptiles for protein or traditional medicine results in animals being killed (Table 1, categories 1-3). Among those herptiles being killed there are four species of high conservation priority; critically endangered Hawksbill Turtle, vulnerable Natal Hingeback Tortoise, vulnerable Sungazer (IUCN, 2021), and the Giant Bullfrog which is included in the list of protected species issued in terms of South Africa's National Environmental Management: Biodiversity Act (Republic of South Africa, 2004).

There are also cultural traditions which are protective of herptiles and thus have potential for incorporation into conservation policy. Table 2 demonstrates how cultural norms and practices that compel or inspire protection of herptiles correspond with conservation principles that are outlined in South African conservation policy. Among the examples of cultural norms and practices that protect wildlife is the belief of a river-dwelling deity in serpent form, which affords protection to riverine ecosystems as people avoid disturbing the deity and this has similarities to NEMA's precautionary approach (Table 2).

Table 2: Matching protective cultural norms and practices to South African conservation principles

Cultural norms and practices	Potential conservation benefit	Relevant conservation principles
Snake-like deity inhabiting sacred riverine ecosystems. People avoid such ecosystems out of respect of this deity.	Water pollution prevention, and minimal disturbance of sensitive riverine ecosystems.	1. NEMA Principle 4ai (Disturbance of ecosystems must be minimised if it cannot be avoided).
People consider themselves to have kinship with various herptiles which are their totem animals. Cultures compel protection of totem animals.	Instilling a culture of care for the totem animal and the habitat it requires for survival.	1. NEMA Principle 4ai (Disturbance of ecosystems must be minimised if it cannot be avoided). 2. NEMA Principle 4g (Decisions must recognise all forms of knowledge).
Herptiles that symbolise rain should not be killed (especially during mating season).	Protects herptile populations by preventing interruption of mating.	1. NEMA Principle 4g (Decisions must recognise all forms of knowledge). 2. NBSAP Strategic Objective 6 (Effective knowledge foundation, including indigenous knowledge, to support conservation).
Some herpetofauna symbolise various desirable traits such as heroism, wisdom, and traditional healing ability.	Creates awareness of herpetofauna and attaches positive perceptions to them.	1. NEMA Principle 4f and 4h (Raising environmental awareness empowers community and promotes meaningful participation in conservation).
Farmers use the activity patterns of herptiles as rainfall indicators, so they know when to start sowing.	Using natural cues to reduce dependence on municipal water infrastructure and maximise crop yield by sowing when climatic conditions afford the best chance of a successful harvest.	1. NEMA Principle 4g (Decisions must recognise all forms of knowledge). 2. NBSAP Strategic Objective 6 (Effective knowledge foundation, including indigenous knowledge, to support conservation).

The killing of herpetofauna that are considered rain symbols or totems is tabooed and Table 2 shows that this corresponds with NEMA’s conservation decision-making principles. Having herpetofauna as symbols of heroism in poems and portraying other desirable traits or phenomena in folk tales reduces negative perceptions and is in line with NEMA’s principles of raising awareness (Table 2).

Discussion

This study explores ethnoherpetology in South Africa to understand conservation prospects and challenges arising from the interaction of cultural traditions with herptiles. Although these interactions can be organised into elements of culture based on similarities in shared beliefs and practices, there are overlaps in the shared norms used to organise them and in their conservation implications (Figure 2). The most prominent overlap between the elements of culture emerging from this study are shown in Figure 2. An example of a less prominent overlap omitted from Figure 2 is between gastronomy and taxonomy; herpetofauna that people eat are likely to have distinct indigenous names but some herpetofauna will still have distinct indigenous names regardless of their gastronomic value. For reporting purposes, these overlaps would mean that some shared beliefs and practices may be categorised differently within the elements of culture depending on an author’s interpretation of the shared beliefs and practices. In conservation contexts the overlaps would result in those beliefs and practices being uniformly categorised according to their usage (consumptive or non-consumptive), regardless of which elements of culture they are placed in.

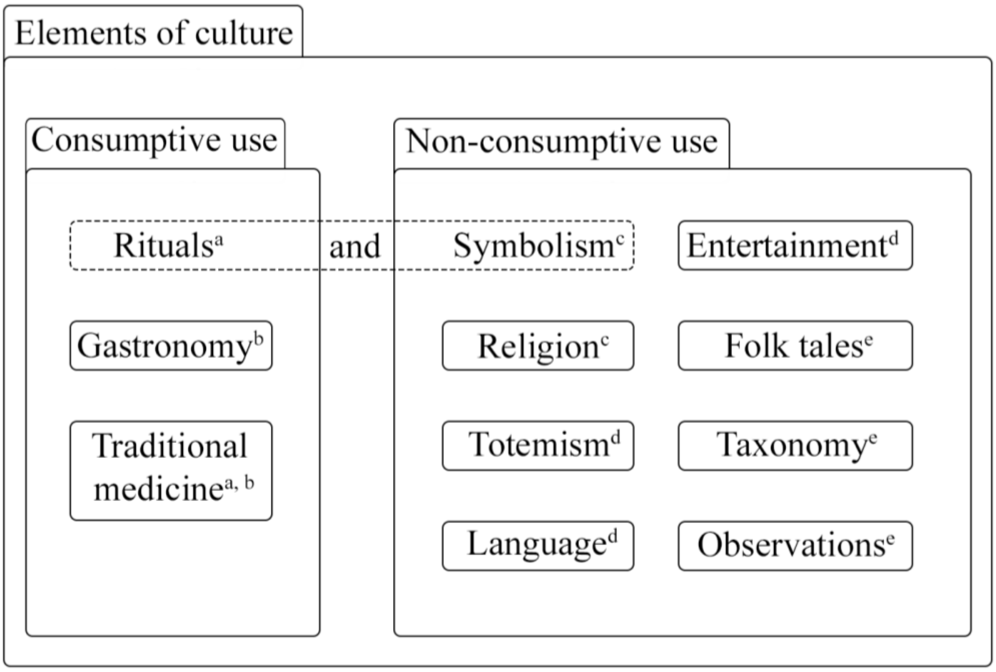

Figure 2: Overlaps between elements of culture emerging from an ethnoherpetological assessment of South Africa. There are overlaps in the shared beliefs and practices that are used to organise cultures' interactions with herpetofauna into elements of culture: [a] magico-medicinal value, [b] ingestion, [c] magico-religious value, [d] symbolic value, [e] interpretation of observed traits.

This assessment of how cultural norms and practices interact with herptiles culminates in understanding which interactions pose conservation challenges and which provide conservation prospects. Framing these interactions within the context of conservation helps realise the potential of ethnozoological investigations to inform conservation as discussed by Gavin *et al.*, (2015) and Alves and Albuquerque (2017) among others.

Herptile conservation prospects of cultural traditions

Cultural traditions are acknowledged as having potential to serve as conservation tools (Simelane & Kerley, 1997; Chibememe *et al.*, 2014). It is possible to draw parallels between these cultural traditions and conservation policy and these parallels serve to highlight where traditions can potentially be incorporated into policy (Table 2). African communities historically learned nature’s instrumental and spiritual value from a young age, while rules and taboos were used to govern their relationship with nature (Mashige, 2011). Some taboos are accompanied by myths that are meant to prevent people from disregarding those taboos. For example, Venḓa culture taboos firewood collection from their sacred forests and there is a myth of a snake that kills people that collect firewood from sacred forests (Sinthumule & Mashau, 2020). Other boundaries are established through totemism (Mashige, 2011), which compels members of a clan to protect their totem animal. The notion of a clan for South Africans is based on being united by common ancestry or kinship. Incidentally, protecting an animal requires preservation of their habitat and this extends totemism’s protection to animals’ habitats. Most totems are however specific to a clan, and this makes totemism a conservation tool mostly suited for the local ordinances of areas that are dominated by relevant clans. At a national level, totemism could be integrated into the national conservation planning for animals such as Nile Crocodile that are totems for multiple clans across South Africa. Furthermore, positive perceptions of Nile Crocodile through their symbolism of rain and heroism demonstrates that one animal can be linked to multiple protective cultural norms and practices.

The deification of herpetofauna is common across South African cultures and it reduces disturbance of riverine ecosystems believed to be inhabited by a snake-like deity that people avoid encountering (Table 2). It is not possible to identify this snake-like deity based on available descriptions, but Southern African Pythons and Nile Monitors are associated with this deity and ancestors in most South African cultures thus providing the possibility for these two species to be flagship species or species chosen as representatives for conservation issues due to the desirable traits people associate with them (Veríssimo *et al.*, 2011). Revered species have potential to be flagships (Simelane & Kerley, 1997), to stimulate conservation action to benefit their ecosystems (Meffe & Carroll, 1997). Besides using reverence as a reason to protect animals, their value to traditional health practitioners could serve as motivation to conserve them (Simelane, 1998), and the habitats they require to thrive when those practitioners are made to understand the conservation issues of their valued animals, so they understand that supply of those animals is finite. The benefits that people derive from biodiversity serve as justification for biodiversity conservation (Millennium Ecosystem Assessment, 2005). Through collaboration with traditional health practitioners, conservation measures can be developed to introduce alternatives to the threatened species used in traditional medicine. This introduction of alternatives can also be a first step in jointly developing sustainable use practices with traditional health practitioners. Such collaborations are possible as shown by the collaborative efforts between Burundese researchers and traditional health practitioners to promote fair and equal benefit sharing of genetic resources (Janssens de Bisthoven *et al.*, 2017). An additional measure to reduce use of herptiles in traditional medicine could be to collaborate in testing the efficacy of animal-based remedies and enable traditional health practitioners to make scientific evidence-based choices about those remedies. Besides their value as collaborators, traditional health practitioners also have potential to be sustainable utilisation ambassadors among indigenous communities that hold them in high regard (Simelane, 1998). The value of herpetofauna to traditional health practices provides motivation to conserve them so they continue being available to use and thus traditional health practitioners would be mostly relied upon to carry the message of needing ensure the animals are used sustainably. Collaborating with practitioners to promote sustainable use would also demonstrate that positive conservation prospects can also be derived from consumptive use.

Interactions with herptiles through cultural traditions generally lead to awareness of local biodiversity and its value for people. South African environmental management principles encourage raising awareness of biodiversity to enable participation in initiatives to conserve this biodiversity (Republic of South Africa, 1998). Conservation of herptiles can be motivated by positive perceptions towards herptiles that are expressed through religion, totemism, poetry, and other non-consumptive elements of culture. In addition to the awareness raised and positive perceptions, cultural norms and practices that specifically forbid harming herptiles can be integrated into conservation processes as provided by South Africa's conservation policy (Table 2). South Africa's overarching conservation framework, NEMA, provides for consideration of all forms of knowledge and governance that is inclusive of all interested and affected parties (Republic of South Africa, 1998). Additionally, the 2015 National Biodiversity Strategy and Action Plan's strategic objectives encourage adoption of practices that sustain biodiversity benefits (Department of Environment, Forestry and Fisheries, 2015). Traditional cultural norms and practices have demonstrated potential to conserve natural ecosystems in another biologically and culturally diverse country (Brazil) through collaboration with custodians of traditional culture (Nimmo *et al.*, 2020).

Herptile conservation challenges of cultural traditions

Integrating protective cultural traditions into conservation could unwittingly create the impression that all cultural traditions are allowable in modern legal contexts and possibly increase the popularity and thus the frequency of cultural norms and practices that negatively impact herptile populations. Use of vertebrate animals in traditional medicine is already a conservation concern (Still, 2003), and integrative conservation could unwittingly be seen as unconditional approval of traditional medicine thus exacerbating related conservation concerns. Quantities of animals in general being used in traditional medicine are likely to increase in many African countries with acceptance of traditional medicine (Soewu & Adekanola, 2011).

From this study we found the number of reptile (Crocodylia, Squamata, and Testudines) species used in traditional medicine in South Africa to be used more than anurans (Table 1), and this is also the case globally (Alves *et al.*, 2013). This pressure on reptiles may increase, given that quantities of animals required for traditional medicine might increase as the human population grows (Soewu & Adekanola, 2011), and there is no indication that traditional medicine use will decrease (Soewu, 2013). Reliance on traditional medicine in Sub-Saharan Africa is not diminishing (Wiersum & Shackleton, 2005). Of the countries that are member states of the World Health Organization, 88% of them acknowledged usage of traditional medicine in their respective countries (World Health Organization, 2019).

The seasonal and specific focus of some cultural norms and practices can result in conservation challenges. Giant Bull Frog whose populations were reported to be declining (Du Preez & Cook, 2004) seasonally emerge from their subterranean aestivation chambers and that is when they are hunted. High harvest rates during seasonal hunting can cause local extinctions of the hunted species (Brook *et al.*, 2019). Totems are specific to clans and the protection afforded to totem animals by totemism is restricted to each clan's region. Totemism does not prevent animals from being harmed by members of different clans. Non-totemic taboos that afford animals protection also tend to be specific to clans thus limiting their potential effectiveness in conservation. The lack of specific indigenous names creates problems when people persecute all snakes out of fear (Simelane & Kerley, 1997), since there is minimal linguistic distinction between dangerous and harmless snakes. There are also negative perceptions about herpetofauna which can threaten their populations (Ceriaco, 2012). Association of undesirable traits with herptiles in a culture's lore lessens the chance of people empathising with those animals' conservation issues.

Conclusion and recommendations

The lack of consultation among conservation practitioners and interested parties leads to reliance on *a priori* conservation as the threats from interactions between cultural traditions and herptiles are understudied thus leading to measures that do not consider local community contexts of wildlife. Without consultation the decision-making influence lies with a powerful few individuals while local communities continue without a sense ownership in conservation planning processes (Janssens de Bisthoven *et al.,* 2022). The study provides an overview of conservation prospects and challenges that emerge from an ethnoherpetological case study, and provides a first step in moving away from *a priori* herptile conservation. This work contributes to herpetofaunal conservation by bridging herpetology (natural sciences) with cultural anthropology (social sciences) and increasing understanding of human cultural factors that influence herptile populations. Some cultural traditions are protective of herpetofauna and have potential for use as tools in conservation planning that considers the diverse contexts within which people experience wildlife, while other traditions have potentially adverse conservation implications related to consumptive use and negative perceptions. Consumptive use can also provide motivation for conservation of species for people to have continued access to those species with utility value. The variation of cultural traditions across clans could limit their application as conservation tools and it requires detailed surveys to determine where specific cultural traditions would be useful in local ordinances. Such a survey of cultural tradition distribution can be combined with the currently lax consultations between conservationists and custodians of traditional culture.

Acknowledgements

This research is made possible by a bilateral scientific cooperation between North-West University and Hasselt University. Financial support for FMP was provided by the National

Research Foundation (UID: 114663), North-West University, Youth 4 African Wildlife NPC and the Flemish Interuniversity Council (VLIR) Global Minds program (Contract Number: R-9363). MPMV is supported by the Special Research Fund of Hasselt University (BOF20TT06).

Ethical consideration

The first page of the questionnaire explains the purpose and potential benefits of this study to prospective respondents in their preferred South African language and states that they are under no obligation to participate and they may withdraw their participation at any time they choose. Before proceeding to provide responses, respondents give consent for participation and acknowledge that they have read and understood the explanation of the study provided to them. Ethics approval for this study was obtained from the North-West University Animal Care, Health and Safety Research Ethics Committee (Ethics number: NWU-00185-18-S5) and Hasselt University Social-Societal Ethics Committee (Reference: REC/SMEC/VRAI/189/127). The research conducted complies with the Nagoya Protocol on Access and Benefit-sharing (UID: ABSCH-IRCC-ZA-257320-1).

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Chapter 5

Folk Taxonomy of South African frogs and reptiles.

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(Unpublished Manuscript)

Abstract: Scientific names provide a standardised means to communicate about species, but these names likely have limited use in the conversational languages of non-scientists. Folk taxonomy or local, prescientific naming and classification of species can be used to facilitate communication in collaborative conservation initiatives with non-scientists who primarily use previously marginalised languages. Folk taxonomies are mostly undocumented and thus inaccessible for further development and use in conservation contexts. This study presents the first comprehensive analysis of the folk taxonomy of herptiles in South Africa. The names of frogs and reptiles in South Africa's previously marginalised official languages, which are also indigenous languages, were documented and analysed to understand principles underlying the assigning of names. These folk names were found to lack individual names for most species and they grouped species together based on similarities in their traits. Although mostly generalised, folk taxonomy is nonetheless systematic and shares some similarities with scientific taxonomy. Documenting folk names makes them available for use in conservation contexts and contributes to inclusion of indigenous languages and their cultures in wildlife matters. Understanding the principles underlying folk taxonomy will later enable the compilation of a comprehensive list of South African indigenous names for the country's known herptile species based on the analysed folk-generic names.

Keywords: Biodiversity hotspot, Ethno-herpetology, Indigenous knowledge systems, Postcolonial conservation

Introduction

Scientific taxonomy or the biological classification of species has provided a standardised means to communicate about biodiversity and organise it into groups. The International Code for Zoological Nomenclature (ICZN) outlines guidelines and recommendations for assigning specific scientific names to animal taxa thus promoting standardised names with universal applicability (International Commission on Zoological Nomenclature, 1999). These specific names can enable people from different linguistic and educational backgrounds to communicate about a species with certainty that they are referring to the same species. The specific names also avoid conservation efforts being unwittingly directed at non-threatened species that share a name with threatened species (Phaka *et al.*, 2019). Conservation action relies on delineation of species through scientific names and changes in this scientific taxonomy can lead to changes in conservation action to ensure that efforts are directed at the species they were originally meant for (Garnett & Christidis, 2017). Further complexity is added when such conservation action is involves people that do not know scientific names or other names besides those in their home language.

Although intended to be universal, scientific names of animals may have minimal use in the conversational language of societies without formal science education or people with and interest in wildlife. Thus, folk taxonomy, or the local ways of naming and grouping (i.e., classifying) wildlife, is important for communicating to local communities about species of interest (Raven *et al.*, 1971; Mkize *et al.*, 2003; Loko *et al.*, 2018) when community members only know/use local names of species. Folk or indigenous taxonomy is mostly undocumented (Loko *et al.*, 2018, Phaka *et al.*, 2019). Documenting and analysing this undocumented indigenous taxonomy can serve to facilitate communication about species when collaborating with indigenous communities, and to ensure that conservation efforts are directed at the correct species in such collaborations. The nomenclature and classification in folk taxonomy is based on traditional cultural perspectives (Atran, 1998), and this indigenous taxonomy exists without a formalised set of guidelines. A study of how AmaZulu assign indigenous names (or folk names) to frog species and group them according to similarities in their traits in South Africa's Zululand region demonstrated that folk taxonomy has underlying guidelines that can be deduced through ethnographic analysis of local names for animals (Phaka *et al.,* 2019). Folk taxonomies are systematic, relatively well developed and names are generally based on species' morphological similarities (Berlin, 1973). These indigenous taxonomies are limited to naming and classification, and do not include delineation of species. The principles underlying folk nomenclature tend to be similar across all languages (Berlin, 1973), but the folk names themselves are localised to a certain culture/language (Phaka *et al.,* 2019).

Multiple studies have provided details on South African folk taxonomies including, but not limited to, IsiXhosa taxonomy for insects (Mkize *et al.,* 2003), IsiZulu taxonomy for birds (Koopman, 2009), SePedi taxonomy for birds (Louwrens, 2004), SeSotho taxonomy for animals (Moffet, 2010), and SeSotho taxonomy for plants (Moteetee & van Wyk, 2006). The commonality in these and other examples of South African folk taxonomies is that some folk names are used in reference to several species and sometimes used for species from different genera (or high taxonomic ranks). The use of one folk name for multiple species is also apparent in folk taxonomies across the world including Tzeltal Maya folk taxonomy of mushrooms in Mexico (Lampman, 2007), folk taxonomy of Moroccan medicinal plants (de Boer *et al.,* 2014), arthropod folk taxonomy of five indigenous communities from Papua New Guinea and Central Australia (Meyer-Rochow, 1975), and invertebrate folk taxonomy of Hungarian speakers from three central European countries (Ulicsni *et al.,* 2016).

The lack of specific indigenous names in conservation contexts is a problem as there is no certainty about the identity of the focal species when conservation initiatives are a collaboration between specialists and non-specialists. For herptiles, specifically snakes, the lack of specific indigenous names leads to persecution of all snakes as non-specific names do not enable distinction between venomous and non-venomous snakes (Simelane & Kerley, 1997), and such persecution presents a conservation threat. Frogs and reptiles are among South African taxa that received minimal attentions in studies of the country's folk taxonomies. Documenting and analysing existing indigenous names to understand their underlying principles is the first step towards solving the problem of insufficient indigenous names for species. Understanding the principles underlying the mostly non-specific animal names enables their subsequent extension into a comprehensive list of indigenous names for known species (Phaka *et al.,* 2019). Such a comprehensive list of species names in local languages would contribute to social inclusion and African language development (Mkize *et al.,* 2003), in addition to providing individual species names to use for conservation planning. Further conservation value of folk taxonomy investigations is that they provide an understanding of previously undocumented local perceptions of species diversity (Phaka & Ovid, 2021). These indigenous taxonomies contain information on the biology and ecology of wildlife as observed by traditional communities (Mourão *et al.,* 2006) without formal natural science training. In some instances, scientific names originated from widely used folk names of species (Ulicsni *et al.,* 2016). Through folk taxonomies we can obtain an understanding of how people observe discontinuities or different components of nature (Atran, 1998), and this can help inform conservation of those species through consideration of previously ignored local perspectives (Beaudreau *et al.,* 2011). A further benefit of increased understanding of folk taxonomies is that it could reveal cryptic traits of species that are only known to indigenous communities that have been interacting with species longer than scientists.

On the backdrop of the conservation, linguistic and social importance of documenting and analysing folk taxonomies, this investigation seeks to provide the first comprehensive analysis of South African folk taxonomy of herptiles. Names for frogs and reptiles in South

Africa’s indigenous languages were documented and analysed to understand principles underlying the naming. Such understanding of underlying principles will later on enable the compilation of a comprehensive list of South African indigenous language names for the country’s known herptile species.

Methods

The names of frog and reptile species in South Africa’s indigenous languages (languages of African origin) were documented through reviewing existing literature and an online questionnaire.

Literature review

Snowball sampling, starting with 2 search queries on the Google Scholar web search engine (https://scholar.google.com/); ‘Frog indigenous names South Africa’ and ‘Reptile indigenous names South Africa’, was used to obtain species names for frogs and reptiles in South African indigenous languages. Results from the search queries, which consisted of postgraduate dissertations, books, and scientific articles, were checked for indigenous names of herpetofauna. The reference lists of suitable sources were screened for other publications which mention indigenous names of herptiles to include in this study’s sample. The snowball sampling of published sources yielded 13 suitable results and these are cited in the results section.

Online Questionnaire

The names of frog and reptile species in South Africa’s indigenous languages were documented using an online questionnaire (available here: https://www.wildvernac.org/contributions) between 09 May 2020 and 22 March 2021, The questionnaire solicited responses through a combination of questions that required set answers about the names of species shown in embedded photographs and discussion-type answers about the etymology of those provided names (Figure 1).

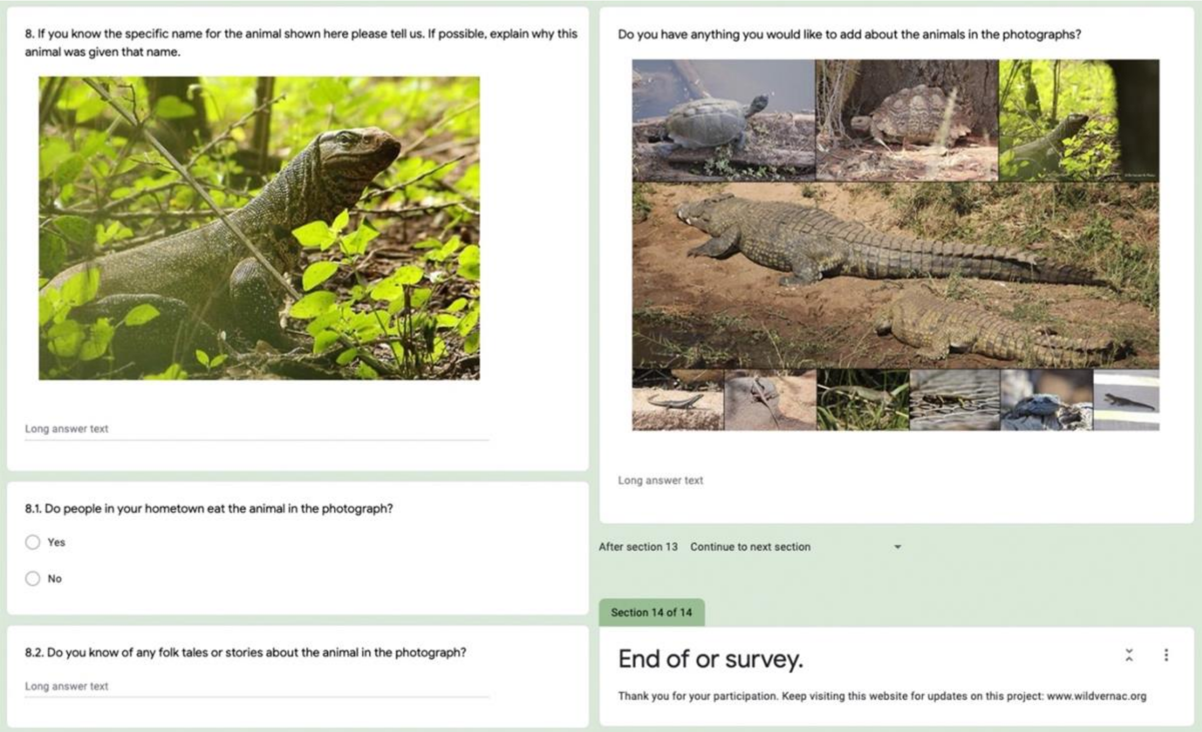

Figure 1: Screenshot of multilingual questionnaire survey used by this study to document folk taxonomies of South Africa's frog and reptile species. English version of questionnaire provided for ease of reference.

This questionnaire, which was also used to collect data for an ethnoherpetological overview of South Africa, was promoted using paid advertisements to indigenous language speaking South Africans who have shown an interest in wildlife on Facebook (advertised from www.facebook.com/wildvernac/), Instagram (advertised from www.instagram.com/wild_vernac/), Twitter (advertised from www.twitter.com/wild_vernac). Social media platforms collect interests and language preferences of their users, and this data is used target adverts to users according to the advertiser's requirements.

Respondent profile

The questionnaire had 72 female and 187 male respondents between the ages of 25 and 57. These 259 respondents indicated their home languages as follows; IsiNdebele (n = 16), IsiXhosa (n = 36), IsiZulu (n = 47), KheLobedu, currently classified as a SePedi dialect (n = 11), SePedi (n = 19), SeSotho (n = 28), SeTswana (n = 49), SiSwati (n = 13), XiTsonga (n = 26) and TshiVenḓa (n = 14).

Data analysis

The recorded indigenous names of South Africa's herptile species were captured alongside their Afrikaans, English, and scientific equivalents. These indigenous names were analysed under the emic/etic research strategies used for studying cultural phenomena where emic research focuses on one culture and the etic strategy studies cross-cultural differences (Van de Vijver, 2010). Using the emic research strategy for indigenous names of a certain culture as cultural phenomena allows those names to be assessed as suitable local equivalents (but not replacements) to scientific names, thus enabling understanding of the correspondence between folk and scientific taxonomy. Etic research strategies on the other hand allow for assessment of cross-cultural differences in indigenous names and enable understanding of the commonalities inherent/underlying naming guidelines across the different South African indigenous cultures and their languages.

Results

Folk taxonomies of nine indigenous South African languages were found to have similarities in their underlying principles for assigning of names to frogs and reptiles. The principles found to be inherent to the folk taxonomy of South African herptiles are that; (1) names are generally based on or describe species' habits, habitats or morphology, and (2) species with similar attributes are grouped together using the same name. This folk taxonomy of South

Africa's indigenous languages is not comprehensive to all species herptile species occurring in the country (Figure 1; 2).

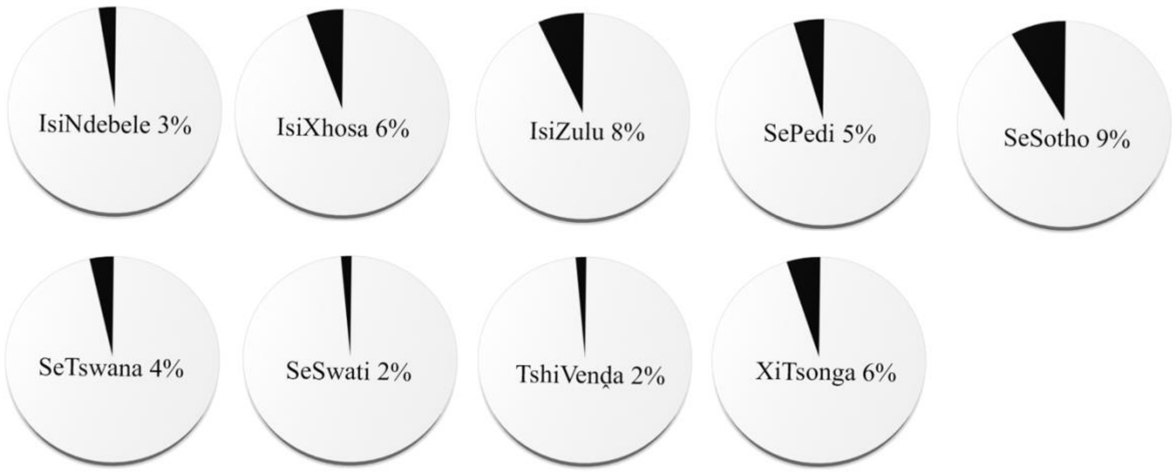

Figure 1: Percentage of frog scientific names with equivalents in South African indigenous languages

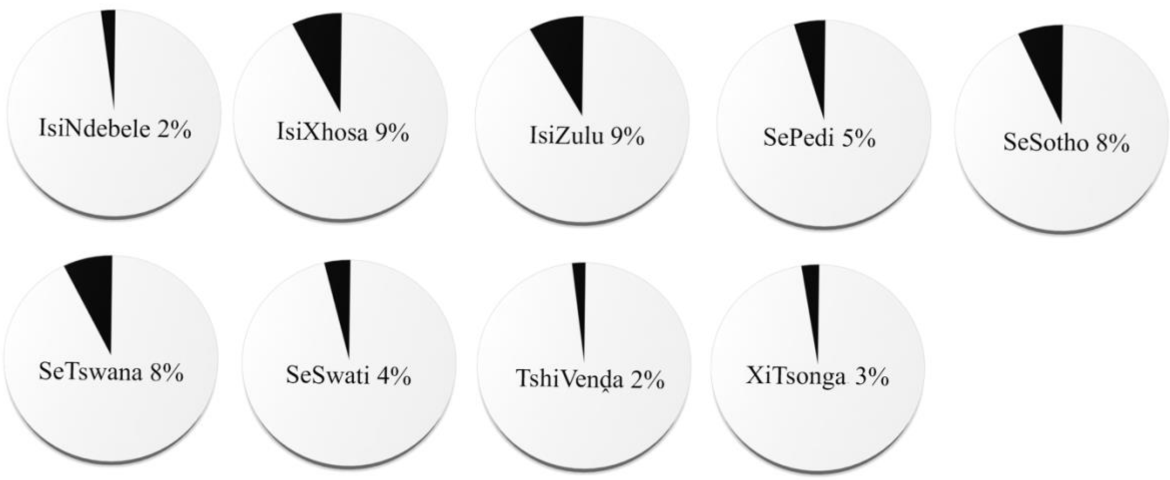

Figure 2: Percentage of reptile scientific names with equivalents in South African indigenous languages.

General names (for different species) are mostly uninomial (one word or term), for example all snakes (Serpentes spp.) are called noga in SePedi or inyoka in IsiZulu (Table 2). Only a few species have individual indigenous names for species, for example *Python natalensis* (Southern African Python) is uniquely called nhlarhu in XiTsonga and inhlatfu in SiSwati.

The etymology of some indigenous names was provided by questionnaire respondents and deduced from analysis of the collected names. The name mabhruku (a word meaning trousers and borrowed from the Afrikaans word for pants, broek) is specifically assigned to *Ptychadena anchietae* (Plain Grass Frog) for their long hindlegs and jumping ability that is perceived to be superior to other frog species. The indigenous names for Anura in IsiNdebele, SePedi, and SeTswana are onomatopoeic words based on the 'gwa-gwa' sound that frogs are believed to make (Table 1). The SePedi name for Brevicipitidae (Rain Frogs), senanatswidi, is another onomatopoeic word based on the whistling sound that is characteristic of the calls made by frogs of this family. Brevicipitidae and another fossorial family, Hemisotidae (Shovel-nosed Frogs), are grouped together under one general name in each of the respective languages under consideration here (Table 1), and the name used for this grouping has the 'nana' sound in all these languages. Each respective language also has an indigenous name for the reptile class which translates to animals that crawl, creep or drag their abdomen along the ground as they walk (Table 2). IsiZulu and IsiXhosa uses the names 'ixoxo' and 'isele' for warty and smooth skinned frog species respectively. In IsiZulu, aquatic frog species (*Xenopus* spp.) are collectively called 'Idwi'. *Ptychadena* (Grass Frog) species are collectively called 'ntlampya' in Xitsonga based on their ability to jump further in comparison to other ground-dwelling frog genera. IsiXhosa, IsiZulu and SePedi each a have name they use to group together reptiles with typical lizard traits (i.e., Scincidae and Lacertidae spp.). Snakes that hood are grouped under specific names in most of the South African indigenous languages (Table 2).

Some of the folk-generic uninomial names collected in this study are cognates or have the same meaning and sound across different languages. One example of cognates among animal names in South African indigenous languages is the name for Hemisotidae, Brevicipitidae which a has “nana” sound with prefixes that vary according to each language (Table 1). Other examples of animal names that sound similar across several South African languages include *Crocodylus niloticus* (Nile Crocodile), and *P. natalensis* (Table 1; 2). Other cognates include the names for anurans (frogs in general) and *Pyxicephalus* (Bull frogs) in IsiNdebele, SePedi and SeTswana, and *Bitis arietans* (Puff Adder) in IsiNdebele, IsiXhosa, IsiZulu, SePedi, SeTswana, SiSwati, and TshiVenḓa. A comparison between indigenous names and their scientific counterparts shows that most of the existing folk-generic uninomial names for herptiles correspond with taxonomic ranks that are higher than species in scientific taxonomy (Table 1; 2). Indigenous names for individual South African herptile species are uncommon (Figure 1; 2) and there have been efforts to extend these general names into a comprehensive list of indigenous names for those herptile species (Phaka *et al.*, 2019, Tarrant, 2021).

Table 1: Existing indigenous names for frogs in South African languages and their scientific equivalents.

Scientific names	Isindebele	IsiXhosa	IsiZulu	Sepedi	Sesotho	Setswana	SiSwati	Tshivenda	Xitsonga
Anura	Iirhwerhwe (1)/ Isirhwarhwa	Isele (sobukwe)/ Ixoxo	Ixoxo/Isele	Segwagwa	Senqanqana/Seqoqwana (5)	Segwagwa	Selele/Sicoco	Tshidula	Chela
Arthroleptis stenodactylus Pfeffer, 1893			Umanswininiza onyawo zingamafosholo (3)						
Arthroleptis wahlbergii Smith, 1849		Isele eletswinayo lasethafeni (2)	Umanswininiza wasehlathini (3)						
Leptopelis mossambicus Poynton, 1985		Uvethe olunomqolo omdaka gebala (2)	Isele lasezihlahleni elinsundu (3)						
Leptopelis natalensis (Smith, 1849)		Uvethe lwaseNatal (2)	Isele lasezihlahleni laseNatali (3)						
Leptopelis xenodactylus Poynton, 1963		Uvethe oluneminwe emide (2)							
Brevicipitidae Bonaparte, 1850	Sinana	Isinana	Isinana	Senanatswidi		Senanatswii (6)	Sinana	Tshinana	Xinana
Breviceps Merrem, 1820			Isinana						
Breviceps acutirostris Poynton, 1963		Unomaqube wemvula (2)							
Breviceps adspersus Peters, 1882		Isele lemvula lasethafeni (2)	Isinana sasehlathini (3)						
Breviceps bagginsi Minter, 2003		Isele lemvula eleyiBilbo (2)	Isinana sikaBilbo (3)						
Breviceps carruthersi Du Preez, Netherlands, and Minter, 2017			Isinana sakwaPhinda						
Breviceps gibbosus (Linnaeus, 1758)		Isele lemvula laseKapa (2)							
Breviceps macrops Boulenger, 1907		Isele lemvula lasengtlango (2)							
Breviceps mossambicus Peters, 1854			Isinana saseMozambique (3)						
Breviceps passmorei Minter, Netherlands, and Du Preez, 2017			Isinana sakwaNdumo (3)						
Breviceps sopranus Minter, 2003			Isinana sekhwela/somtshingo (3)						
Bufonidae Gray, 1825					Sehoho (5)				
Capensibufo rosei (Hewitt, 1926)		Ixoxo lentaba iRose elincinane (2)							
Poyntonophrynus fenoulheti (Hewitt and Methuen, 1912)		Ixoxo elibhoveleyo laseMantla (2)	Ixoxo elifishane (3)						
Poyntonophrynus vertebralis (Smith, 1848)					Sehohwana (5)				
Schismaderma carens (Smith, 1848)		Ixoxo elibomvu (2)	Ixoxo elibomvu (3)						
Sclerophrys capensis Tschudi, 1838		Ixoxo elingqolayo (2)	Ixoxo eliklabalasayo (3)		Seqaqamarokolo (5) / Marokolo				
Sclerophrys garmani (Meek, 1897)		Isele lomnquma laseMpuma (2)	Ixoxo eliluhlaza okotshani (3)			Rantsape			
Sclerophrys gutturalis (Power, 1927)		Ixoxo elingqokolayo (2)	Ixoxo lembodlomane (3)		Lenga/Senqanqana,Seqaqa (5)				
Sclerophrys pantherina (Smith, 1828)		Unomahlosana waseNtshona (2)							
Sclerophrys pusilla (Mertens, 1937)			Ixoxo lomhlane oyisicaba (3)	Letlametlo					
Vandijkophrynus amatolicus (Hewitt, 1925)		Ixoxo lakwaMathole (2)							
Vandijkophrynus gariepensis (Smith, 1848)					Serarana (5)				
Hadromophryne natalensis (Hewitt, 1913)		Isele lengxangxasi laseNatal (2)	Isele lasempophomeni (3)						
Heleophryne rosei Hewitt, 1925		Unomsholongwana weNtab' eTafile (2)							
Hemisotidae Cope, 1867	Sinana	Isinana	Isinana	Senanatswidi				Tshinana	Xinana
Hemisus Günther, 1859	Sinana	Isinana		Senanatswidi					
Hemisus guttatus (Rapp, 1842)		Unomhlakulwana onamachokoza (2)	Isinana esimabhadubhadu (3)						
Hemisus marmoratus (Peters, 1854)			Isinana esipendiwe (3)						
Hyperoliidae Laurent, 1943			Umgqagqa						Xikwarikwari
Afrixalus Laurent, 1944			Umgqagqa						
Afrixalus aureus Pickersgill, 1984		Usongamagqabi obugolide (2)	Umgqagqa oyigolide (3)						
Afrixalus delicatus Pickersgill, 1984			Umgqagqa othambile (3)						
Afrixalus fornasini (Bianconi, 1849)		Usongamagqabi omkhulu (2)	Umgqagqa omkhulu (3)						
Hyperolius Rapp, 1842			Umgqagqa						
Hyperolius argus Peters, 1854		Isele leengcongolo i-Argus (2)	Umgqagqa i-Argusa (3)						
Hyperolius horstockii (Schlegel, 1837)		Isele lenyibiba (2)							
Hyperolius marmoratus Rapp, 1842		Isele leengcongolo elimabalabala (2)	Isinana esipendiwe (3)						
Hyperolius pickersgilli Raw, 1982		Isele leengcongolo lasePickersgill (2)	Umgqagqa ka-Pickersgill (3)						
Hyperolius poweri Loveridge, 1938			Umgqagqa omude (3)						
Hyperolius pusillus (Cope, 1862)		uNgomncama (2)	Umgqagqa weminduze (3)						
Hyperolius semidiscus Hewitt, 1927			Umgqagqa wemigqa ephuzi (3)						
Hyperolius tuberilinguis Smith, 1849		Isele lasezingcongolweni eliluhlaza (2)	Umgqagqa oluhlaza okotshani (3)						
Hylambates maculatus Duméril, 1853 (7)			Ukassina wemilenze ebomvu (3)						
Kassina senegalensis (Duméril and Bibron, 1841)		iKassina engqokolayo/elidumzelayo (2)	Ukassina obhadlayo (3)		Senqanqanasekopitsane (5)				
Semnodactylus wealii (Boulenger, 1882)		Isele elikhencezayo (2)							
Phrynomantis annectens Werner, 1910		Unomabhastile (2)							
Phrynomantis bifasciatus (Smith, 1847)		Isele elinomgca oburabharha (2)	Isele elisanjoloba elinemigqa (3)						
Phrynobatrachus acridoides (Cope, 1867)			Isele lechibi lasempumalanga Afrika (3)						
Phrynobatrachus mababiensis FitzSimons, 1932			Isele lechibi elifishane (3)						
Phrynobatrachus natalensis (Smith, 1849)		Igogode/Isele elirhonayo (2)	Isele lechibi elihonayo (3)						
Pipidae Gray, 1825			Idwi						
Xenopus Wagler, 1827			Idwi						
Xenopus gilli Rose and Hewitt, 1927		Unoplatana waseKapa (2)							
Xenopus laevis (Daudin, 1802)		Unoplatana oqhelekileyo (2)	Idwi elijwayelekile (3)		Lentsweta (5)/Lentsoeta				
Xenopus muelleri (Peters, 1844)			Idwi lika-Müller (3)						
Ptychadenidae Dubois, 1987									Ntlampya
Hildebrandtia ornata (Peters, 1878)		Isele elingunobuhle (2)	Ixoxo elihlotshisiwe (3)						
Ptychadena Boulenger, 1917			Uvete (3) / Umjamu (4)						
Ptychadena anchietae (Bocage, 1868)			Uvete olujwayelekile (3)						Mabhruku / Ntlampya
Ptychadena mossambica (Peters, 1854)			Uvete olunomugqa obanzi (3)						
Ptychadena nilotica (Seetzen, 1855)			Uvete lwaseNile (3)						
Ptychadena oxyrhynchus (Smith, 1849)		Unongungulwane / Isele elingutsolwana (2)	Uvete olunempumulo ecijile (3)						
Ptychadena porosissima (Steindachner, 1867)		Unomgcana wasengceni (2)	Uvete olunemigqa (3)						
Ptychadena taenioscelis Laurent, 1954			Uvete olufishane (3)						
Amietia delalandii (Duméril and Bibron, 1841)		Unomasele oqhelekileyo (2)	Isele lasemfuleni elijwayelekile (3)		Letlametlu (5)				
Amietia fuscigula (Duméril and Bibron, 1841)		Isele lomlambo laseKapa (2)			Letlametlu (5)				
Amietia hymenopus (Boulenger, 1920)					Serarana-sa-linoka				
Amietia vertebralis (Hewitt, 1927)		Isele lomlambo laseMaluti (2)			Letlametlulaloti (5)				

Table 1 continued …

Anhydrophryne rattrayi Hewitt, 1919		Isele elinkconkcozayo laseHogsback (2)							
Arthroleptella rugosa Turner and Channing, 2008		Isele lobulembu elirhabaxa (2)							
Arthroleptella subvoce Turner et al., 2004		Isele lobulembu lasemaNtla (2)							
Cacosternum boettgeri (Boulenger, 1882)		I-caco eqhelekileyo (2)	Isele elithambile elijwayelekile (3)		Lenkolane (5)				
Cacosternum nanogularum Channing et al., 2013			Isele elithambile laKwaZulu (3)						
Cacosternum nanum Boulenger, 1887		I-caco embala wobhedu (2)	Isele elithambile elisathusi (3)						
Cacosternum striatum FitzSimons, 1947			Isele elithambile elinemigqa (3)						
Microbatrachella capensis (Boulenger, 1910)		Unomaselana (2)							
Natalobatrachus bonebergi Hewitt and Methuen, 1912		Isele lomwonyo (2)	Isele lase-Kloof (3)						
Pyxicephalus Tschudi, 1838	Idlhamedlhu (1)/ Idlamedlu		Ingxangxa (2)/Inxanxa	Letlametlo		Letlametlo (7)			Khutla
Pyxicephalus adspersus Tschudi, 1838		Indubule (2)	Ingxangxa (2)/Inxanxa	Letlametlo	Sehohomarokolo/Marokolo (5)	Letlametlo (7)			Khutla
Pyxicephalus edulis Peters, 1854			Inkunzi yexoxo (3)						
Strongylopus bonaespei (Dubois, 1981)		Isele lomfula elinomgca emqolo (2)							
Strongylopus fasciatus (Smith, 1849)		Unomgcana wasemfuleni (2)	Isele lasemfuleni elinemidwa (3)						
Strongylopus grayii (Smith, 1849)		Isele lomfula elixokozela iziqhakancu (2)	Isele lasemfuleni eligqafazayo (3)		Letlametlu (5)				
Tomopterna krugerensis Passmore and Carruthers, 1975		Isele lentlabathi elinkqonkqozayo (2)		Isele lasesihlabathini elingqongqozayo (3)					
Tomopterna natalensis (Smith, 1849)		Isele lentlabathi laseNatal (2)	Isele lasesihlabathini laseNatali (3)						
Tomopterna tandyi Channing and Bogart, 1996			Isele lasesihlabathini likaTandy (3)						
Chiromantis xerampelina Peters, 1854		Isele elakha indlwane yogwebu lasemazantsi (2)		Usomagwebu waseningizimu (3)					

1 = (Skhosana, 2009). 2 = (Tarrant, 2021). 3. (Phaka e*t al.*, 2019). 4 = (Cowles, 1936). 5 = (Moffet, 2010). 6 = (Auerbach, 1986). 7 = (Brown, 1895).

Table 2: Existing indigenous names for reptiles in South African languages and their scientific equivalents.

Scientific Name	Isindebele	IsiXhosa	IsiZulu	Sepedi	Sesotho	Setswana	SiSwati	TshiVenḓa	Xitsonga
Reptilia	isirhurhubi	isirhubuluzi	izilwane ezihuquzelayo	Digagabi	Dihahabi	Digagabi	Imihumane	Zwikokovhi	Swikokozi
Crocodylia	Ngwenya	Ngwenya	Ngwenya	Koena	Kwena (5)	Kwena	Ngwenya	Ngweṇa	Ngwenya
Crocodylidae	Ngwenya	Ngwenya	Ngwenya	Koena	Kwena (5)	Kwena	Ngwenya	Ngweṇa	Ngwenya
Crocodylus	Ngwenya	Ngwenya	Ngwenya	Koena	Kwena (5)	Kwena	Ngwenya	Ngweṇa	Ngwenya
Crocodylus niloticus Laurenti, 1768	Ngwenya	Ngwenya	Ngwenya	Koena	Kwena (5)	Kwena	Ngwenya	Ngweṇa	Ngwenya
Agamidae			Intulo	Mankgwagwarape (4)	Kgantlape (5)	Kgatlampe	Intfulo		
Agama			Intulo	Mankgwagwarape (4)	Kgantlape (5)	Kgatlampe			
Agama aculeata Merrem, 1820			Intulo	Mankgwagwarape (4)	Kgantlape (5)	Kgatlampe	Intfulo		
Agama atra Daudin, 1802			iQhimlili		Pharwe (5)				pululu
Amphisbaenidae									Nyoka-hasi
Aparallactus capensis Smith, 1849						Magalane (6)			
Macrelaps microlepidotus (Günther, 1860)					Letsatsi				
Chamaeleonidae		ulovane	Unwabu	Lehobu	Lempetje	Lobodu (6)	Lunwabu	Hovhu	Rimpfani
Bradypodion dracomontanum Raw, 1976					Lempetje / Leobu (5)				
Crotaphopeltis hotamboeia (Laurenti, 1768)		Nomaqhetyana	Magalane / Makgaolane		Tlhako (5) / Phofu				
Dasypeltis scabra (Linnaeus, 1758)						Lesolamae (7)			
Dispholidus typus (Smith, 1828)		Inyushu	Ifulwa (1) / Idlondlo	Motlakgomo		Logwere	Umhlwazi	Khangala	
Philothamnus						Kgogedi			
Philothamnus semivariegatus (Smith, 1840)		lnambezulu	Ifula / ifulwa				Lidloti		
Thelotornis capensis Smith, 1849			Ukhokhothi			Legonyana	Linunkhu		Lukuri
Cordylus cordylus (Linnaeus, 1758)		imbedle	iMbhedle						
Pseudocordylus spinosus Fitzsimons, 1947					Sefelekoane-sa-loti				
Smaug giganteus (Smith, 1844)					Phatakalle				
Aspidelaps lubricus (Laurenti, 1768)		Inkamela (1)							
Aspidelaps scutatus Smith, 1849						Shaoshawane			
Dendroaspis			Imbamba / indlondlo	Mokopa		Mokwepa	imamba		
Dendroaspis angusticeps (Smith, 1849)		Imamba	imamba eluhlaza						
Dendroaspis polylepis Günther, 1864		Imamba	imamba emnyama		Lehwereleletsho (5)	Phika		Khangala	Mamba ya ntima
Hemachatus haemachatus Bonnaterre, 1790		Iphimpi	uPhempethwane		Mafole / Masumo (5)		Phemphetfwane		
Naja		Iphimpi		Petla		Kake			
Naja annulifera Peters, 1854	iLoyi	isiKhotsholo	uPhempethwane		Masumo	Kake	Imfeti		
Naja mossambica Peters, 1854	iPhimpi	iPhimpi	iMfezi			Kake	Phemphetfwane	Phakhuphakhu	
Naja nigricincta Bogert, 1940	iqhamule		iqhamule						
Naja nivea (Linnaeus, 1758)		Iphimpi	Imfezi (1)	moswa	Masumo	Kake (7)			
Naja subfulva Laurent, 1955									
Gekkonidae			iqhimilili			Bomampharing			
Afroedura hawequensis Mouton & Mostet, 1985				Checheiki					
Hemidactylus								Tshikwavhavha	Xipululu
Hemidactylus mabouia (Moreau De Jonnès, 1818)				Tšhitadingaka		Mmapharing			hokokwana
Lygodactylus capensis (Smith, 1849			Isibankwa (15)						
Pachydactylus capensis (Smith, 1846)					Ngwane / Tjheiki (5)				
Gerrhosauridae						Mogatsanoga (7)			
Gerrhosaurus flavigularis Wiegmann, 1828					Leupa (5)				

Table 2 continued …

Lacertidae		Icikilishi	Isibankwa	Mokgaditswane		Mansteane (6)			
Heliobolus				Kgetwane		Kgatwane			
Meroles				Kgetwane		Kgatwane			
Nucras				Kgetwane		Kgatwane			
Pedioplanis				Kgetwane		Lekgaolatshega (7)			
Pedioplanis burchelli (Duméril & Bibron, 1839)					Tjhallatjhalla (5)				
Boaedon capensis Duméril, Bibron & Duméril, 1854		Inkwakhwa	Umzingandlu		Mosoa / Tlatlametsi (5)				Nyoka ya Xikwembu
Boaedon fuliginosus (Boie, 1827)			UZwambuzwambu						
Gracililima							Lukhonkhotse		
Lamprophis aurora (Linnaeus, 1758)					Mosoa / Tlatlametsi (5)				
Limaformosa							Lukhonkhotse		
Limaformosa capensis (Smith, 1847		Intlangu (1)	Inhlangwana						
Lycodonomorphus inornatus (Duméril, Bibron & Duméril, 1854)			Umsenene	Moswinini					
Lycodonomorphus laevissimus *(Günther, 1862)*		Ezilenzi	Ivusamanzi limnyama						
Lycodonomorphus rufulus *(Lichtenstein, 1823)*		Izilenzi (2)	evimanzi / ivuzamanzi		Tlatlametsi		Livuvumanti		
*Lycophidion capense (*Smith, *1831)*						Phika			
Leptotyphlopidae		Umsundu	Umsundu			Seleka (7)			
Leptotyphlops conjunctus (Jan, 1861)					Lemao (5)				
Leptotyphlops scutifrons (Peters, 1854)					Kgutsanayanaha (5)				
Psammophis		idlezinye (2)				Mosenene (7)			
Psammophis crucifer (Daudin, 1803)					Mosenene (5)				
Psammophis mossambicus Peters, *1882*		Umhlwazi							
Psammophis subtaeniatus Peters, 1882		Umhlwazi							
Psammophis trinasalis Werner, 1902	Umhlwazi								
Psammophylax						Mosenene (7)			
Psammophylax rhombeatus (Linnaeus, 1758)		Unomathambezantsi (1)			Mosenene				
Pseudaspis cana (Linnaeus, 1758)		Inkwakhwa / Majola (2)	uBulube (1)	Noga ya Dipeba		Tshosabosigo (7)			
Duberria lutrix (Linnaeus, 1758)					Tlaku (5)				
Pythonidae	inHlathu	intlwathi (1)	intlwathi/inhlwathi	hlware / thlware	Hlware	Hlware	inhlatfu	Tharu	Nhlarhu
Python	inHlathu	intlwathi (1)	intlwathi/inhlwathi	hlware / thlware	Hlware	Hlware	inhlatfu	Tharu	Nhlarhu
Python natalensis Smith, 1840	inHlathu	intlwathi (1)	intlwathi/inhlwathi	hlware / thlware	Hlware	Hlware	inhlatfu	Tharu	Nhlarhu
Scincidae	Isibhadwa	Icilikishi	isibankwa	Mokgaditswane	Tjhelletjhelle (5)	Mogaditswane	sibankhwa	Tswiṋa	nkolombyana
Trachylepis	Isibhadwa	Icilikishi	isibankwa	Mokgaditswane	Mokgudutswane	Mansteane (6)			
Trachylepis capensis (Gray, 1831)					Sefelekwane (5)				
Trachylepis punctatissima (SMITH, 1849)							Umgololo		
Trachylepis striata (Pethersethers ETERS, 1844)					Mokholutsoaneoa				
Typhlosaurus caecus (Cuvier, 1816)		inyoka yomhlaba (1)	inyoka yaphansi (1)						
Typhlopidae			iNkambaphantsi			Modudu (7)			
Afrotyphlops	Usungulo		Usungulo						
Afrotyphlops bibronii (Smith, 1846)					Kgutsanayanaha (5)				
Afrotyphlops schlegelii (Bianconi, 1849)		inyoka yomhlaba	Inyoka yaphansi						
Rhinotyphlops lalandei (Schlegel, 1839)					Khutsanayanaha				

Table 2 continued …

Varanidae					Polo (5)	Gopane	Ncamu		
Varanus				hopane			Ncamu		
Varanus albigularis Daudin, 1802		uxam	Imbulu	hopane	Polomakgwashe (5)		Ncamu		
Varanus niloticus (Linnaeus, 1766)		uxam	uxamu	Polometsi (4)	Qamo / Polometsi	Polometsi (7)	Ncamu		nkwahle
Bitis		Irhamba	ibululu		Lehwere / Leqobete (5)				
Bitis arietans Merrem, 1820	iBululu	iBululu / iRhamba	iBululu / Ihobosha	Lebolobolo/Letšolobolo	Marabe (5) /Thamae	Lebolobolo	Libululu	Vuluvulu	Mhiri / Mbuyuya
Bitis atropos (Linnaeus, 1758)		Irhamba lamatye (1)	uMantshingeyana		Qwane (5)				
Bitis caudalis (Smith, 1839)						Sheusheuane (6)			
Bitis cornuta (Daudin, 1803)		Unompondwana (1)							
Causus			Inhlangwane (1)						
Causus rhombeatus (Lichtenstein, 1823)		Unomfuthwana	nyoka yasebusuku (1)				umhlwazi		
Testudines		ufudo	ufudu	Khudu		Khudu		Tshebhode	Xibozi
Cheloniidae						Khudu tsa lewatleng			
Dermochelyidae		ufudo lelwandle (1)	ufudulolwandle (1)			Khudu tsa lewatleng			
Emydidae		ufudo Iwamanzi (2)	ufudu Iwamanzi			Khudu tsa metsi			
Pelomedusidae		ufudo (2)	ufudu Iwamanzi			Dikhudubane (7)			
Pelomedusa subrufa (Bonnaterre, 1789)					phinyaleraga (5)				
Testudinidae		ufudo	ufudu Iwasendle			Khudu tsa lefatshe			
Homopus		Inqulo (2)		Khudu (4)					
Homopus femoralis Boulenger, 1888					Sekolopata / Kgudu (5)				
Kinixys zombensis Hewitt, 1931						Kgakgana (7)			
Stigmochelys pardalis (Bell, 1828)		Ufudo (2)		Khudi-kgomo (4)	Kgudu / Kokote (5)	Khudutlou (6)			

1 = (Simelane, 1997). 2 = (Hirst, 1990). 3. (Donda, 1997). 4 = (Quin, 1959). 5 = (Moffet, 2010). 6 = (Brown, 1925). 7 = (Auerbach, 1986).

Discussion

This folk taxonomy analysis has shown similarities in how South African indigenous languages assign names to frogs and reptiles. All the folk taxonomies of South Africa's nine indigenous languages analysed here do not have comprehensive lists of names for the country's described herptiles species and they mostly use uninomial names to group species according to observed similarities in their traits. Furthermore, some of these generalised uninomial names are cognate between multiple languages.

Folk taxonomies are known to have some similarities among themselves (Berlin, 1973). The folk taxonomies of South Africa's indigenous languages have the same underlying principles as folk taxonomies from other countries including Tanzania (Tibuhwa, 2012), Pakistan (Altaf *et al.*, 2017) and Hungary (Ulicsni *et al.*, 2016), as they group species based on similarities. The commonalities among folk taxonomies also extend to their shortfall of lacking individual names for most species known to science, and it is unclear from the current research why a few species have specific names while most are grouped together under one name. It has however been hypothesized that indigenous names for wildlife are either assigned to species with utilitarian value for people or species that most people are curious about (Berlin, 1990). Other possibilities could be that species which are most visible/encountered by members of a community tend to be assigned unique names, or that related species that co-occur tend to be grouped together under one name whereas a certain species that is not in sympatry with similar looking species is likely to be assigned a unique indigenous name. A similarity of folk taxonomies which was not sufficiently reported in previous research are cognate indigenous names or instances where indigenous names for certain taxa are similar across different languages. Examples of cognates include the indigenous names for Hemisotidae and Brevicipitidae (Table 1) in all the South African indigenous languages considered in this study having the same sound and linguistic derivation. This similarity of names across different languages opens areas of research into similarities of how cultures in different geographical settings experience wildlife and subsequently name wildlife based on that experience. In addition to names that are cognates, some species (e.g., *Bitis arietans*) have additional indigenous names assigned to them which are used as synonyms.

Existing indigenous names are excluded from most South African wildlife literature, and thus remain inaccessible to those seeking to learn about wildlife. This lack of indigenous names for species in books meant for South African nature enthusiasts resulted from lack of concerted efforts to document folk taxonomies. Those undocumented names were unknown to authors at the time of developing wildlife guides (books). Scientific, English and/or Afrikaans names with a few indigenous language variants are listed on the species' description pages of some popular wildlife guides for the country's frog and reptile diversity (see Minter *et al.,* 2004, Marais, 2011; Bates *et al.,* 2014. Du Preez *et al.,* 2017). Of South Africa's 11 official languages, most wildlife guides are available in English, while comparatively fewer of these have been published in Afrikaans, and the remaining nine indigenous languages are either excluded or have even fewer wildlife guides than Afrikaans. Investigation of folk taxonomy results in its preservation (Freely, 2009), and such research makes indigenous names easily accessible for future wildlife books and other publications used by people seeking to learn about the country's wildlife. This preservation and increased accessibility is in addition to the research's value for African language development, inclusion of previously marginalised languages (with their related cultures), and conservation value through enabling accurate communication about species of interest. Forwarding African language development through investigations of folk taxonomy will in turn be useful for conservation planning, as the increased presentation of wildlife in indigenous languages enables effective communication between conservation practitioners and non-specialist stakeholders. A practical example of the conservation value of indigenous names for species was demonstrated through a compilation of insect names in English and IsiXhosa to be used by scientists, farmers and other stakeholders whenever they needed to communicate and to also serve as the basis of an English-IsiXhosa bilingual dictionary (Mkize *et al.,* 2003). The use of folk names to contribute to an African language development effort such as a bilingual dictionary by Mkize *et al.,* (2003), highlights social inclusion value of folk taxonomy investigations in addition to their conservation value. This language development, forwarded through this study and others like it, is necessary promoting African languages to a point where wildlife reading materials can be solely presented in African languages (Phaka & Ovid, 2021). Such reading materials would make it possible for indigenous language speakers to learn about wildlife in their preferred language, thus highlighting the education benefits that can be derived from increased understanding of folk taxonomy.

The folk biological classification of species formed the basis for early scientific taxonomies (Raven *et al.,* 1971). Folk taxonomies share similarities with scientific taxonomy as they are systematic (Ross, 2014), and organize species according to similarities in their observed traits (Phaka *et al.,* 2019). But unlike scientific taxonomy, most of the generic names in folk taxonomy do not extend beyond higher taxonomic rankings to provide individual names for each known species. It is possible to remedy this lack of specific names through extension of existing indigenous names into a comprehensive list of indigenous names for herptile species. Such extension would leverage the similarities between the standardized scientific taxonomy guidelines and those principles underlying folk taxonomy to compile hybrid guidelines that can be used to extended generic folk names into specific indigenous names that conform to scientific standards yet remain relevant to indigenous language speakers (Phaka *et al.,* 2019).

Conclusion

This research contributes to the growing field of ethnoherpetology while promoting African languages by documenting and studying terms/words thus contributing to developing languages so they can be used as languages of teaching and learning in formal contexts. Future research is required to understand why the folk taxonomies analysed here have specific names for some species, while others are grouped using a single name. Further research is required to extend the limited folk taxonomies into comprehensive lists of species names in South Africa's indigenous languages. Such extension would make available specific indigenous names for use in herptile conservation while simultaneously contributing to inclusion of previously marginalized languages (and their cultures) in wildlife matters, thus promoting development of African languages. Once a comprehensive list of indigenous names for herptile species has been compiled, public outreach will be required to promote usage of these names in life sciences education, conservation and tourism, among other sectors.

Acknowledgements

This research is made possible by a bilateral scientific cooperation between North-West University and Hasselt University. Financial support for FMP was provided by the National Research Foundation (UID: 114663), North-West University, Youth 4 African Wildlife NPC, and the Flemish Interuniversity Council (VLIR) Global Minds program (Contract Number: R-9363). MPMV is supported by the Special Research Fund of Hasselt University (BOF20TT06).

Ethical considerations

The first page of this study's questionnaire explains the purpose and potential benefits of this research to prospective respondents in their preferred South African language and states that they are under no obligation to participate and may withdraw their participation at any time they choose. Before proceeding to provide responses, respondents give consent for participation and acknowledge that they have read and understood the explanation of the study provided to them. Ethics approval for this study was obtained from the North-West University Animal Care, Health and Safety Research Ethics Committee (Ethics number: NWU-00185-18-S5) and Hasselt University Social-Societal Ethics Committee (Reference: REC/SMEC/VRAI/189/127). The research conducted complies with the Nagoya Protocol on Access and Benefit-sharing (UID: ABSCH-IRCC-ZA-257320-1)

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Chapter 6

Identifying herptiles in South Africa's urban traditional medicine markets: DNA barcoding and cultural perspectives inform monitoring and conservation.

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(Unpublished manuscript)

Abstract: Urban areas are often overlooked when investigating the interactions between indigenous cultures and biodiversity as these indigenous traditions/practices are generally considered to be associated with rural societies. Research has however shown increased prevalence of indigenous cultural norms and practices in urban areas. We focus specifically on tradition medicine markets and their use of frogs and reptiles in urban South Africa. Some herptile populations are experiencing declines due to human activities which include consumption for traditional medicine purposes. Indigenous medicine practices are increasing throughout the African continent, thus leading to greater pressure on herptile populations. With a combination of DNA barcoding, visual confirmation, and review of existing literature we identify herptile species that are used for indigenous medicine in urban South Africa. Interviews with traditional health practitioners were used to document traditional medicine practices relating to collection and preservation of target animals, and their indigenous names. Indigenous tissue preservation methods are not focused on preserving specimens' morphological features, but they can preserve DNA well enough to enable DNA barcoding. Sequences of DNA were obtained from 73% of herptile tissue samples collected from traditional medicine markets, and 49,5% of the sampled tissue could be identified using DNA barcoding. Traditional medicine practices rely more on reptile than frog species thus placing greater conservation pressure on reptile diversity. Accurate identification of species through this current study's mixed methodology approach can increase effectiveness of conservation through ensuring conservation measures are directed at the correct species. Conservation measures will require collaboration between traditional health practitioners, researchers and those tasked with implementing conservation policy as previous measures failed without collaboration.

Keywords: Bio-cultural diversity, Ethno-herpetology, Indigenous knowledge systems, Mixed-method analyses, Zootherapy

Introduction

Traditional medicine, or the indigenous knowledge and practices that people of different cultures use for maintenance of physical and mental health, is prevalent across the world (World Health Organization, 2000; 2019). An estimated 80% of people in developing countries use traditional medicine (Maroyi, 2013). South Africa is among the developing countries where use of traditional medicine is prevalent, and this practice also occurs in the country's most urbanised areas such as Johannesburg and Durban (Longmore, 1958; Du Toit, 1980; Ngwenya, 2001; Williams & Whiting, 2016). Traditional medicine practices involve both consumptive and non-consumptive use of plants and animals. Non-consumptive traditional medicinal use is non-lethal and for example only the leaves of some plants are used. Consumptive use on the other hand would involve killing some plants to get their roots, or animals would be killed to use their tissue in traditional remedies. Traditional medicine practices use more plants than animals and this reliance on plants is common across the world (Betlu, 2013). This trend was shown to be also true for a South African urban traditional medicine market which generally trades in illegally acquired specimens a majority of which are plant species (Williams & Whiting, 2016).

Traditional medicine research is also mostly focused on plants (Solovan *et al.*, 2004), but animal use in traditional medicine nonetheless remains an important part of society as the demand for traditional medicine practices leads to overexploitation of animal species (Still, 2003; Alves *et al.*, 2015). Investigating this use of animals in traditional medicine is important for documenting this traditional practice, collaborative planning for the conservation of animals with traditional medicine value, and exploration of the economic value of animal trade for medicinal purposes (Alves *et al.*, 2015). Among animals that are used in traditional medicine across the world, there are at least 331 herptile species (47 amphibians and 284 reptiles) and this diversity could end up being higher when comprehensive studies of herptiles in traditional medicine are conducted (Alves *et al.*, 2013).

Research focused on traditional medicine markets generally has a problem with identification of specimens available at those markets (Veldman *et al.,* 2020). Traditional health practitioners generally identify their specimens using folk names which are specific to their home languages. Those folk names tend to group multiple species together using as single name (Phaka *et al.,* 2019). Morphology based identifications of animal specimens from an urban traditional medicine market in South Africa showed that some specimens could only be identified to genus or higher taxonomic ranks depending on how well the morphological traits are preserved (Simelane & Kerley, 1998; Ngwenya, 2001; Whiting *et al.,* 2011). Species level identifications of traditional medicine market specimens that are difficult to identify can be obtained with DNA barcoding (Whiting *et al.,* 2011), and folk names used by traditional health practitioners can also be confirmed with DNA barcoding (Veldman *et al.*, 2020). Using DNA barcoding to confirm the identity of species in a traditional medicine market helps increase understanding of the market and conservation issues relating to it (Veldman *et al.,* 2020) and to also detect substitution of species in traditional remedies (Newmaster *et al.,* 2013; Veldman *et al.,* 2020). Substitution of plant species in traditional remedies poses a risk to human health if non-toxic plants are substituted with toxic species (Ouarghidi *et al.*, 2012). DNA barcoding of traditional medicine specimens in this instance is vital to identifying human health risks in addition to confirming species' identification. Use of DNA barcoding to confirm the identity of traditional medicine specimens hence has promising prospects but its use remains low (Mishra *et al.,* 2016). Barcoding is an effective tool for identifying both known and unknown species by comparing fragments of an individual's DNA with DNA sequences of individuals from different species (Hebert *et al.,* 2003b). For barcoding animals, the mitochondrial 5’ end of the cytochrome *c* oxidase marker 1 (CO1) is often considered a universal barcode marker (Hebert *et al.,* 2003b).

Given that herptile diversity in traditional medicine is generally understudied and that previous research into animal species richness in South Africa’s urban traditional medicine markets found morphologically unidentifiable animal tissue, it is worth introducing DNA barcoding to solve the identification problems highlighted by previous research on animals in those markets and increase research interest and capacity on herptiles in traditional medicine. A research focus on traditional medicine markets further presents the opportunity to increase the understanding of the conservation issues related to these markets. There is general lack of research focused on urban areas in developing countries, and when this research relates to sustainability it provides opportunity for innovative research approaches that can benefit urban sustainability (Nagendra *et al.,* 2018). As growth of urban areas on the African continent continues to place pressure on the surrounding environment to meet the needs of the urban population (Grant, 2015), studies that investigate urban consumption of wildlife contribute to context-specific interventions to mitigate conservation threats posed by urban areas.

The current study focused on herptiles as an understudied group of animals in South African urban traditional medicine research. From this group of animals, 5% of reptile species and 12% of frog species known from the country are listed on the IUCN Red List of threatened species (IUCN, 2021). Threatened species as determined by the IUCN Red List are protected by South African law. This study aimed to combine identification of traditional medicine market specimens through visual surveys and reviewing published literature, with DNA barcoding. Furthermore, the study aimed to use DNA barcoding to confirm the indigenous names that traditional health practitioners assign to herptile specimens in their possession. Achieving these aims required tackling the following questions about herptile specimens sold in traditional medicine markets: 1) Do indigenous tissue preservation methods preserve DNA well enough for that tissue to be used in DNA barcoding? 2) Can DNA barcoding be used to obtain species level identification of unrecognisable animal parts from traditional medicine markets? 3) How do DNA barcoding, morphology-based identification, and indigenous nomenclature correspond with each other?

Materials and Methods

Frog and reptile species sold in South African urban areas for indigenous medicine purposes were identified by reviewing published literature, through visual confirmation from visits to traditional medicine vendors, and through DNA barcoding of specimens those vendors made available for research purposes.

Literature review

A search of the keywords: animal + traditional medicine + South Africa on Google Scholar (https://scholar.google.com/) returned results of literature whose titles and abstracts were pre-screened for mentions of animal use in South African traditional medicine. Following this initial screening, the suitable articles were studied to find records of herptiles sold in South Africa's urban traditional medicine markets or shops.

Fieldwork: interviews, tissue sampling and visual observation

Visual confirmation of herptile specimens available for sale at indigenous medicine markets by the first author involved visiting six traditional medicine markets or shops in five cities from three of South Africa's provinces (one shop from Polokwane in Limpopo province, one shop from Pretoria and two open markets from Johannesburg in Gauteng province, and one shop from Pietermaritzburg and one open market from Durban in KwaZulu-Natal province).

Identification of species using visual confirmation was based on wildlife guides for reptiles (Alexander & Marais, 2007; Marais, 2008). In accordance with North-West University Health Research Ethics Committee's guidelines, the participation of traditional health practitioners at the markets was sought after the first author explained the purpose of this study in SePedi to practitioners from Limpopo and IsiZulu for Gauteng and KwaZulu-Natal practitioners. SePedi was the preferred language for the Limpopo participants, IsiZulu was the most spoken language at the markets in Gauteng and KwaZulu-Natal. Following explanation of the study, 11 traditional health practitioners consented to participation in this study (two in Limpopo, two in Gauteng and seven in KwaZulu-Natal). An informal conversational interview approach was used to collect data about herptiles of traditional medicine value; their indigenous names, methods used to obtain herptiles sold at traditional medicine markets, and techniques for preservation of those specimens. This interview approach relies on continuous participant observation without predetermined questions (Gall *et al.*, 2003). The approach was chosen due to traditional health practitioners expressing apprehension towards researchers based on what they explained as past unpleasant experiences with researchers and conservation practitioners. This interview was guided by the first author's conversation with participants and questions were introduced to the conversation when participants were forthcoming with information about their practices. Answers to these questions were written in a field book once the practitioners gave permission for their answers to be recorded in that manner. The reasons for the practitioner's apprehension towards researchers were also noted.

From the 11 interviewed participants, nine IsiZulu speaking participants, two in Gauteng and seven in KwaZulu-Natal (Figure 1), agreed to the collection of tissue samples from the herptile specimens they had on sale, and 111 samples were collectively obtained from them. Practitioners were asked the IsiZulu names for each sampled specimen and notes were made of any morphological features that were still visible on the specimens from which tissue samples were obtained.

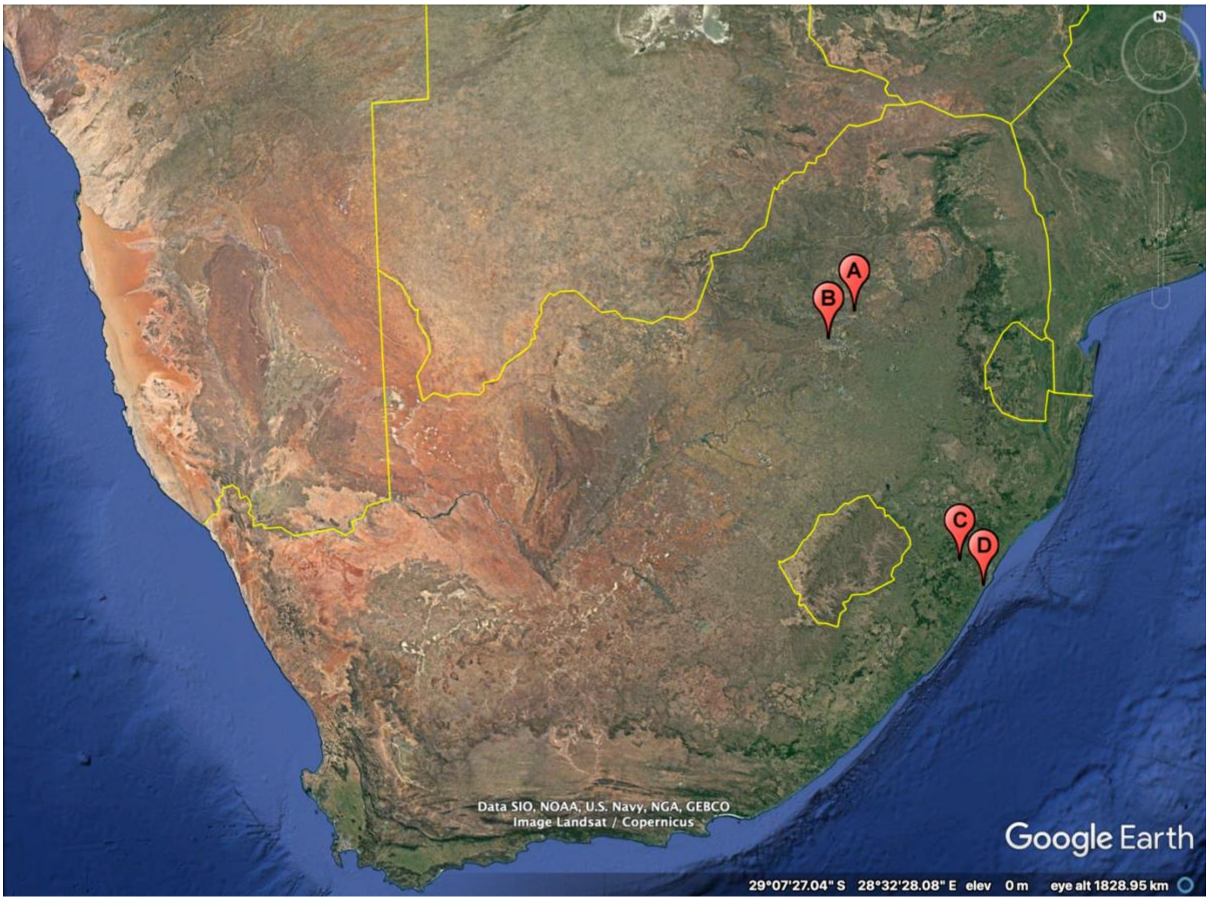

Figure 1: Locations of traditional medicine markets where tissue samples were collected displayed using Google Earth (https://earth.google.com). A = Pretoria Muthi Shop (Gauteng Province), B = Faraday Muthi Market (Gauteng Province), C = Pietermaritzburg Muthi Shop (KwaZulu-Natal), D = Warwick Muthi Market (KwaZulu-Natal).

Distinctive morphological traits were not visible on all sampled specimens as sometimes all that remained were ventral scutum, or bones with flesh but no skin. Opting for collection of tissue samples instead of taking entire specimens minimises this study's environmental impact as removal of entire specimens may prompt traditional health practitioners to acquire replacement specimens to satisfy demand from customers or patients.

DNA extraction and quantification

From the acquired samples, outside layers of tissue that were most likely exposed to contamination were shaven/scraped off and discarded before taking ~25mg of tissue for DNA extraction. This tissue's genomic DNA was extracted using the standard extraction protocols for animal tissue provided by the manufacturer in the NucleoSpin®Tissue Genomic DNA Tissue Kit (Macherey-Nagel, Duren, Germany).

To investigate how well DNA is preserved in herptile specimens obtained from traditional medicine markets, the purity of the extracted DNA was determined through measures of absorbance using photometry (ultraviolet-visible spectroscopy) measures of the DNA's absorbance (with peak absorbance of 260 nm for pure nucleic acid). Sample purity measurements were carried out on the NanoDrop One Spectrophotometer (Thermo Scientific) according to manufacturer's instructions. Blank measurements were first performed with 2 µl of the reference solution (elution buffer used during DNA extractions) to minimise this solution's contribution to the absorbance of the extracted DNA. Following blanking, 2 µl of each of the extracted DNA samples was loaded on the spectrophotometer's pedestal to carry out measurements, and the pedestal was cleaned before measurement of respective samples. To be able to make inferences about purity of the extracted DNA, spectrophotometry results from this study's sample are compared to typical absorbance of pure nucleic acid for DNA; a 260/280 nm (A260/280) absorbance ratio of ~1.8 (1.85 – 1.88) and a 260/230 nm (A260/230) absorbance ratio in the range of 1.8 – 2.3 (Desjardins and Conklin 2010; Koetsier and Cantor 2019). Samples with absorbance greater than 1.8 are generally considered suitable for downstream applications (Koetsier and Cantor 2019), but there are likely to be exceptions to this general rule. If the absorbance ratio is extremely lower than the value expected from pure nucleic acid, then it could be an indication that DNA extraction procedures need to be improved, while an extremely higher ratio could indicate impurities in the sample (Desjardins and Conklin 2010).

Following purity measurements, all the extracted DNA was amplified with a polymerase chain reaction (PCR) regardless of its purity ratio measurements to better understand whether the salt and or ash used by traditional health practitioners preserves DNA. This amplification of extracted DNA targeted a region of a length of maximum 664 bp of the CO1 gene with a primer set from a previous study by Nagy *et al.,* (2012). The RepCO1-F (5'-TNT TMT CAA CNA ACC ACA AAG A-3') and RepCO1-R (5'-ACT TCT GGR TGK CCA AAR AAT CA-3') primer combination was used (Nagy *et al.,* 2012). These PCR reactions were performed in total volumes of 25 µl: 12.5 µl Thermo Scientific DreamTaq Green PCR Master Mix (X2) (with DreamTaq DNA Polymerase, 2X DreamTaq Green buffer, dNTPs, at 0.4 mM each and 4 mM $MgCl_2$), 1.25 µl (10 µM) of each of the two RepCO1 primers mentioned above, 3 µl of the template DNA elution and 7 µl Thermo Scientific Nuclease-free water (PCR-grade). The reactions were carried out in the Applied Biosystems SimpliAmp Thermal Cycler (Thermo Fisher Scientific Inc) using the following PCR protocol: initial denaturation at 95°C for 3 minutes, 40 cycles of denaturation at 95°C for 30s, annealing at 48.5°C for 30s for 40 cycles, and extension at 72°C for 1 minute, followed by a final extension at 72°C for 10 minutes, and subsequent storage of PCR products at 4°C. These PCR products were visualised on 1% agarose gel under ultraviolet light on the E-BOX CX5 stand-alone gel imaging system (Vilber Lourmat Deutschland GmbH).

The PCR products were sequenced and purified by a commercial sequencing company (Inqaba Biotechnical Industries (Pty) Ltd, Pretoria, South Africa) using the same RepCO1 primers. The sequencing protocol as provided by the sequencing company was as follows: PCR conditions: 10 µl NEB OneTaq 2X MasterMix with standard buffer, 1 µl genomic DNA

(10-30ng/µl), 1 µl forward primer (10µM), 1 µl reverse primer (10µM), and 7 µl Nuclease free water. The sequencing PCR protocol was 94°C for 5 min, 35 cycles of 94°C for 30 seconds, 50°C for 30 seconds, and 68°C for 60 seconds, followed by one cycle of 68°C for 10 minutes and held at 4°C. PCR amplicon integrity was visualised on a 1% agarose gel (CSL-AG500, Cleaver Scientific Ltd) stained with EZ-vision® Bluelight DNA Dye. The PCR products were cleaned using the ExoSap Protocol: 10 µl amplified PCR product and 2.5 µl ExoSAP master mix (Exonuclease I 20 U/ul and Shrimp Alkaline Phosphatase 1 U/ul) mixed well and incubated 37°C for 15 minutes then held at 80°C for 15 minutes. The Nimagen, BrilliantDye™ Terminator Cycle Sequencing Kit V3.1, BRD3-100/1000 was used to sequence fragments according to manufacturer's instructions. Subsequently, products were cleaned with the ZR-96 DNA Sequencing Clean-up Kit and the cleaned products were injected on a Applied Biosystems ABI with a 50cm array (using POP7). Sequence chromatograms were analysed using the FinchTV analysis software.

Sequences obtained from the commercial sequencing company were trimmed with the Decontamination Using Kmers (BBDuk) trimmer, paired, then assembled using De Novo assembly on the Geneious Prime® 2022.0.2 (https://www.geneious.com/prime/) sequence analysis software (Biomatters New Zealand Ltd). The Barcode of Life Data Systems (BOLD) Identification System (IDS) was used to compare this study's sequences to reference samples on the BOLD database (https://v3.boldsystems.org/index.php/IDS_IdentificationRequest) to verify the sequence and species identity using neighbour-joining placement (Ratnasingham & Hebert, 2007). Furthermore, The Basic Local Alignment Search Tool or BLAST (Altschul *et al.*, 1997) was used to compare this study's sequences with published sequences on the National Center for Biotechnology Information NCBI Nucleotide collection (nr/nt) database (http://blast.ncbi.nlm.nih.gov/Blast.cgi) to determine species and sequence identity using the MegaBlast (Zhang *et al.*, 2000) algorithm for identifying highly similar sequences.

The sequences obtained from this study will be submitted to NCBI GenBank when this chapter is modified and submitted for consideration at a scientific journal.

Results

Literature review

From three published sources reviewed during this study there were records of herptiles in the urban traditional medicine markets/shops of Eastern Cape (Simelane & Kerley, 1998), Gauteng (Whiting *et al.*, 2001) and KwaZulu-Natal (Ngwenya, 2001). A total of 34 herptile species were identified in this literature (Table 1) and among these there were more reptile species sold for traditional medicine purposes in comparison to frog species in South Africa's urban traditional medicine markets (one frog species vs 33 reptile species).

Table 1: Herptile species identified from South Africa's urban indigenous medicine by existing literature.

Classification	**COI Reference Samples**
Frogs	
Schismaderma carens (Bufonidae) [1]	Available on BOLD and NCBI GenBank
Reptiles	
Acanthocercus atricollis (Agamidae) [1, 2]	Not available
Acontias plumbeus (Scincidae) [1]	Available on BOLD and NCBI GenBank

Bitis arietans (Viperidae) [1, 2, 3]	Available on BOLD and NCBI GenBank
Chamaeleo dilepis (Chamaeleonidae) [1]	Available on BOLD and NCBI GenBank
Chersina angulata (Testudinidae) [1]	Available on BOLD and NCBI GenBank
*Cordylus tropidosternum** (Cordylidae) [1]	Not available
Cordylus vittifer (Cordylidae) [1]	Available on BOLD only
Crocodylus niloticus (Cordylidae) [1, 2, 3]	Available on BOLD and NCBI GenBank
Dendroaspis angusticeps (Elapidae) [1]	Available on BOLD and NCBI GenBank
Dendroaspis polylepis (Elapidae) [1]	Available on BOLD and NCBI GenBank
Dispholidus typus (Colubridae) [1]	Not available
Eretmochelys imbricata (Cheloniidae) – CR [1]	Available on BOLD and NCBI GenBank
Gerrhosaurus flavigularis (Gerrhosauridae) [1]	Available on BOLD only
Gerrhosaurus major (Gerrhosauridae) [1]	Not available
Hemachatus haemachatus (Elapidae) [1, 2]	Available on BOLD and NCBI GenBank
*Kinixys belliana** (Testudinidae) [1]	Available on BOLD and NCBI GenBank
Kinixys natalensis (Testudinidae) – VU [2]	Available on BOLD and NCBI GenBank

Kinixys speckii (Testudinidae) [1]	Available on BOLD only
Lamprophis aurora (Lamprophiidae) [1]	Not available
*Naja melanoleuca** (Elapidae) [2]	Available on BOLD and NCBI GenBank
Naja annulifera (Elapidae) [2]	Available on BOLD and NCBI GenBank
Naja mossambica (Elapidae) [1, 2]	Available on BOLD and NCBI GenBank
*Psammophis phillipsii** (Psammophiidae) [1]	Available on BOLD and NCBI GenBank
Psammophylax rhombeatus (Psammophiidae) [1]	Available on BOLD only
Psammophylax tritaeniatus (Psammophiidae) [1]	Not available
Pseudaspis cana (Pseudaspididae) [1]	Available on BOLD and NCBI GenBank
Python natalensis (Pythonidae) [2, 3]	Available on BOLD and NCBI GenBank
Smaug giganteus (Cordylidae) – VU [1]	Available on BOLD and NCBI GenBank
Smaug warreni (Cordylidae) [1]	Available on BOLD and NCBI GenBank
Stigmochelys pardalis (Testudinidae) [1, 2]	Available on BOLD only
Thelotornis capensis (Colubridae) [2]	Not available
Varanus albigularis (Varanidae) [1, 2, 3]	Not available

Varanus niloticus (Varanidae) [1, 2, 3]	Available on BOLD and NCBI GenBank

CR – Assessed to be critically endangered (IUCN, 2022).

VU – Assessed to be vulnerable (IUCN, 2022).

*Species not native to South Africa.

[1] Records from Gauteng (Whiting *et al.*, 2001).

[2] Records from KwaZulu-Natal (Ngwenya, 2001).

[3] Records from Eastern Cape (Simelane & Kerley, 1998).

Fieldwork: interviews, tissue sampling and visual observation

Through visual surveys, 9 of the 34 species identified in published literature were confirmed to be on sale among plants and other animal specimens at traditional medicine shops and open markets (Table 2) in the urban areas of three South African provinces (Gauteng, KwaZulu-Natal, and Limpopo). The traditional health practitioners who provided access to these tissue samples explained their apprehension towards conservation practitioners resulted from conservation law enforcement officers confiscating specimens in their possession instead of seeking to collaborate with them to introduce measures that both adhered to environmental laws and respected traditional cultural practices. This collaboration is something they were willing to consider.

Traditional health practitioners from the surveyed traditional medicine markets obtain the herptile specimens they use or sell by either hunting the animals themselves, buying from hunters that regularly go on hunts to supply multiple traditional health practitioners, or taking roadkill and animals that died of natural causes. Practitioners specifically target species that they require at the time of their hunts, while the hunters take orders for specific animals from traditional medicine practitioners and will also opportunistically hunt other species they encounter when hunting to fulfil their list of orders. Traditional health practitioners and the hunters that supply them with herptile species employ the same tissue preservation methods and the specimens are either preserved at home or at the open market. They remove visible body fat, which has traditional medicine value, and place in it bottles according to species. The remaining muscle, bones and scales are then smothered with ash and/or salt and placed in the sun to dehydrate them.

Dried specimens of herptiles and other animals are placed together on display for customers. People usually buy pieces or body parts of the animals on display, rather than paying for the entire carcass. Due to how they are sold, herptile specimens were sometimes found missing parts of the body. In case of open traditional medicine markets, specimens may be removed at the end of each business day and stored together overnight in plastic containers. All storage of specimens is at ambient temperature, there is no refrigeration.

DNA barcoding of herptile tissue preserved using indigenous methods

The purity measurements of the extracted DNA suggest that indigenous tissue preservation methods used by traditional health practitioners can successfully preserve DNA to enable barcoding of herptile specimens from traditional medicine markets (Figure 2). Of the 111 extracted DNA samples, the A260/280 ratio was negative (suggesting extraction protocol adjustments were necessary) for 9%, below 1.8 (mostly usable for downstream analysis) for 44%, and 1.8 or above (suitable for downstream analysis but samples with extreme values suggest contamination) for 47% of the samples. The A260/230 ratio was negative for 28%, below 1.8 for 46%, 1.8 or above for 26% of the samples (Figure 2).

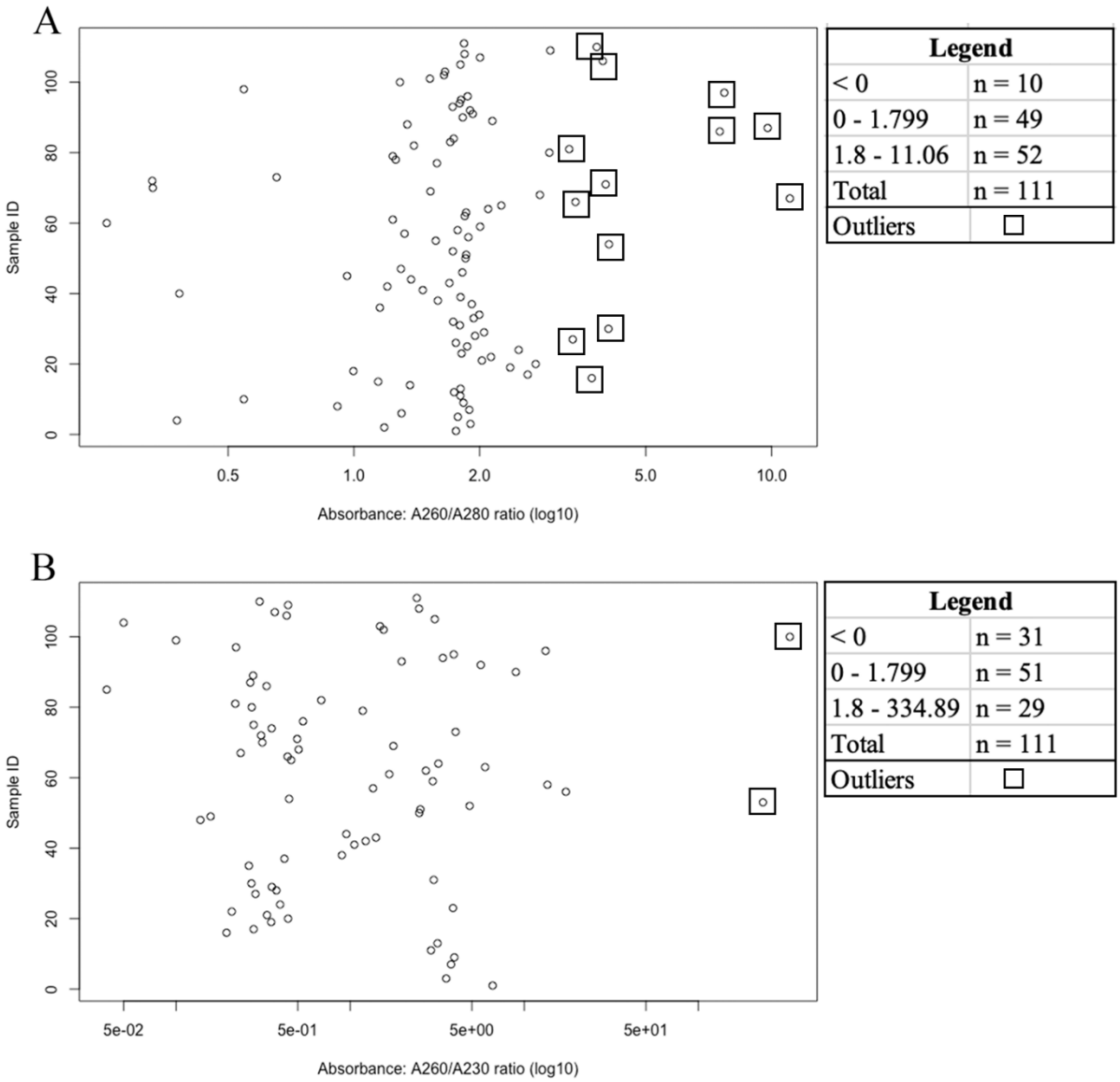

Figure 2: Scatterplots of A260/280 and A260/230 absorbance ratios of DNA extracted from herptile specimens sold at traditional medicine markets. The log transformed (log10) x axes do not plot negative absorbance ratios, 10 and 31 points were not plotted on plots A and B respectively. Samples with negative absorbance ratios suggest the DNA extraction protocols require improvements, while extreme values (with square outlines) on the plots suggest the samples could have contaminants. Extreme values are ratios that are higher than the sum of the upper quartile (Q3) of the absorbance ratios added to the product of the interquartile range (IQR) multiplied by 1.5 (Outliers > Q3 + IQR X 1.5).

Of the 111 extracted DNA samples, 90 were successfully amplified (based on the band structure of visualised PCR products) and subsequently sequenced. Sequences were successfully obtained from 81 samples and 38 of these had exact species matches (99.13 - 100% similarity) on the BOLD database while only three sequences had species level matches (99.0% pairwise identity) on the NCBI nucleotide database (Ng & Tay, 2004), with e-value of zero suggesting that there is no better match than the current result (Metzler, 2006). Other search results returned lists of species that are nearest matches, rather than exact species matches for 12 of this study's sequences on the BOLD database (98.12% - 99.05% similarity) and one more sequence (with 98.9% similarity) on the NCBI database. The identity of these 13 sequences with lists of nearest species matches were confirmed using morphology as the specimens from which the tissue was obtained had not yet been cut to a point of being unrecognisable. One of the matches (with 93.8% similarity) on the NCBI database was to a species that is not native to South Africa (*Psammophis phillipsii*) and this sequence was likely from members of the same genus that are native to the country as morphological traits observed during visual observation provide confirmation of genus (*Psammophis* sp.) level identification (Table 2).

Table 2: Herptile species from South Africa's urban traditional medicine markets identified in this study through visual confirmation and DNA Barcoding.

Classification	**Identification method**
Reptiles	
Acanthocercus atricollis (Agamidae) [1]	Visual [GP, KZN]
Bitis arietans (Viperidae) [1]	Visual [GP, KZN] + DNA [GP, KZN]
Chamaeleo dilepis (Chamaeleonidae) [1]	DNA [KZN]
Crocodylus niloticus (Cordylidae) [1]	Visual [GP, KZN, LP] + DNA [GP]

Dendroaspis angusticeps (Elapidae) [1]	DNA[GP, KZN]
Hemachatus haemachatus (Elapidae) [1]	Visual [GP, KZN] + DNA[GP]
Naja melanoleuca (Elapidae) [1]	DNA[KZN]
Naja annulifera (Elapidae) [1]	DNA[GP]
Naja mossambica (Elapidae) [1]	DNA[GP, KZN]
Philothamnus semivariegatus	DNA[GP]
Psammophis sp. (Psammophiidae)	Visual [KZN] + DNA[GP]
Pseudaspis cana (Pseudaspididae) [1]	Visual [KZN] + DNA[GP]
Python natalensis (Pythonidae) [1]	Visual [GP, KZN, LP] + DNA[GP]
Stigmochelys pardalis (Testudinidae) [1]	Visual [GP, KZN]
Varanus albigularis (Varanidae) [1]	Visual [GP, KZN] + DNA[GP, KZN]
Varanus niloticus (Varanidae) [1]	Visual [GP, KZN] + DNA[GP,KZN]

Visual = Identified during visual confirmation during surveys of traditional medicine markets/shops (identification based on morphology).

DNA = Identified using DNA barcoding.

[1] Also identified in previous literature.

[GP] Visually confirmed and/or sampled from Gauteng traditional medicine markets.

[KZN] Visually confirmed and/or sampled from KwaZulu-Natal traditional medicine markets.

[LP] Visually confirmed from Limpopo traditional medicine market.

The exact species matches and nearest species matches (supplemented with morphological observations) obtained from 55 of this study's sequences accounted for a total of 12 species and one genus level identifications of reptiles (Table 2) from the 34 species identified from previous literature (Table 1). One additional species identified by DNA barcoding in the current study was not previously identified in the reviewed literature (Table 2). The remaining 24 sequences had no matches on the BOLD database, but it could be ascertained that they were DNA fragments of reptiles by comparing them to their NCBI reference sequence matches of reptiles with a similarity of 81.2 – 86.9%, using 70% similarity to reference sequences as the similarity below which the results would not be meaningful (Baxevanis *et al.*, 2020). Two of this study's sequences matched with reference sequences from mammal species, *Ictonyx striatus* (99.2% similarity on the NCBI database) and *Procavia capensis* (with 98.14% similarity on the BOLD database). This mammalian tissue was obtained from bone and muscle tissue that a traditional health practitioner mislabelled in IsiZulu as uxam or imbulu (*Varanus* spp.) when asked to name the species from which the tissue was obtained (Table 3).

The species identification based on DNA barcoding alongside morphology-based identification from literature reviews and visual surveys of traditional medicine markets jointly accounted for one frog species and 34 reptile species sold in urban traditional medicine markets/shops in four South African provinces (Table 1; 2). From these identified species, one species (*Smaug giganteus)* has its conservation status as vulnerable, another (*Eretmochelys imbricata*) is critically endangered (IUCN, 2022). There are also four species are that are not native to South Africa: *Cordylus tropidosternum* is endemic to Eastern African countries (Broadley & Branch, 2002), *Kinixys belliana* occurs in the north of the Southern African region and beyond (Turtle Taxonomy Working Group, 2021), *Naja melanoleuca* is from Central and West African countries (Wüster *et al.,* 2018) and *Psammophis phillipsii* occurs in West African countries (Leaché *et al.,* 2006).

The DNA barcoding results verified some of the IsiZulu names used by traditional health practitioners to identify the herptile specimens sampled in this study and also revealed mislabelling of animal tissue that no longer had distinguishing features (Table 3). Some IsiZulu names for the specimens were accurate up to species level (e.g., *Dendroaspis* *angusticeps*, imamba eluhlaza in IsiZulu) while other indigenous names were only accurate to higher taxonomic ranks, for example specimens named as unwabu (IsiZulu word for members of Chamaeleonidae) were confirmed to be *Chamaeleo dilepis* with DNA barcoding. Further examples of DNA barcoding as a tool for verification folk taxonomy include specimens broadly labelled as snakes and monitor lizards in IsiZulu (inyoka and uxam/imbulu respectively) being confirmed up to species level by DNA barcoding as *Pseudaspis cana* and *Varanus niloticus* respectively (Table 3). Mislabelling of tissue meant for traditional medicine use involved herptile tissue (e.g. *Naja melanoleuca* mislabelled as *Naja mossambica* or imfezi in IsiZulu), and mammalian bone and muscle which was mislabelled as *Varanus* sp. (uxam/imbulu in IsiZulu) (Table 3).

Table 3: Herptile species identified using DNA barcoding and their IsiZulu names provided by respondents. Table arranged alphabetically according to IsiZulu species names.

Specimen ID by study respondents (in IsiZulu)	DNA barcoding result	Sample #
Ibululu (*Bitis arietans*)	*Bitis arietans*	D20
Ibululu (*Bitis arietans*)	*Bitis arietans*	D33
Ibululu (*Bitis arietans*)	*Bitis arietans*	J23
Imamba (*Dendroaspis* sp.)	*Hemachatus haemachatus*	J03
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Dendroaspis angusticeps*	D01
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Dendroaspis angusticeps*	D02
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Dendroaspis angusticeps*	D03
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Dendroaspis angusticeps*	D04
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Dendroaspis angusticeps*	D24
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Dendroaspis angusticeps*	D25
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Dendroaspis angusticeps*	D44

Imamba eluhlaza (*Dendroaspis angusticeps*)	*Dendroaspis angusticeps*	D55
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Dendroaspis angusticeps*	D56
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Dendroaspis angusticeps*	D57
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Dendroaspis angusticeps*	D58
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Philothamnus semivariegatus*	J07
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Psammophis* sp.	J15*
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Dendroaspis angusticeps*	J20
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Dendroaspis angusticeps*	J29
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Dendroaspis angusticeps*	J30
Imamba eluhlaza (*Dendroaspis angusticeps*)	*Dendroaspis angusticeps*	P06
Imfezi (*Naja mossambica*)	*Naja melanoleuca*	D13
Imfezi (*Naja mossambica*)	*Naja mossambica*	D42
Imfezi (*Naja mossambica*)	*Naja mossambica*	J01
Imfezi (*Naja mossambica*)	*Naja annulifera*	J21
Imfezi (*Naja mossambica*)	*Naja annulifera*	J31
Imfezi (*Naja mossambica*)	*Naja annulifera*	J32
Inyoka (Serpentes sp.)	*Pseudaspis cana*	J04
Inyoka (Serpentes sp.)	*Python natalensis*	J05*
Inyoka (Serpentes sp.)	*Python natalensis*	J24*
Isibankwa (Scincidae sp.)	*Varanus albigularis*	J18
Naja mossambica (Imfezi)	*Naja melanoleuca*	D26
Unwabu (Chamaeleonidae sp.)	*Chamaeleo dilepis*	D22
Unwabu (Chamaeleonidae sp.)	*Chamaeleo dilepis*	D23
Unwabu (Chamaeleonidae sp.)	*Chamaeleo dilepis*	D39

Uxam/Imbulu (*Varanus* sp.)	*Varanus niloticus*	D16
Uxam/Imbulu (*Varanus* sp.)	*Varanus niloticus*	D41
Uxam/Imbulu (*Varanus* sp.)	*Varanus niloticus*	D46
Uxam/Imbulu (*Varanus* sp.)	*Varanus niloticus*	D47
Uxam/Imbulu (*Varanus* sp.)	*Varanus niloticus*	D48
Uxam/Imbulu (*Varanus* sp.)	*Varanus niloticus*	D49
Uxam/Imbulu (*Varanus* sp.)	*Varanus niloticus*	D50
Uxam/Imbulu (*Varanus* sp.)	*Varanus niloticus*	D51
Uxam/Imbulu (*Varanus* sp.)	*Varanus albigularis*	D52
Uxam/Imbulu (*Varanus* sp.)	*Varanus albigularis*	D53
Uxam/Imbulu (*Varanus* sp.)	*Varanus albigularis*	D54
Uxam/Imbulu (*Varanus* sp.)	*Procavia capensis*[a]	J06*
Uxam/Imbulu (*Varanus* sp.)	*Varanus niloticus*	J09
Uxam/Imbulu (*Varanus* sp.)	*Varanus niloticus*	J10
Uxam/Imbulu (*Varanus* sp.)	*Ictonyx striatus*[a]	J17*
Uxam/Imbulu (*Varanus* sp.)	*Varanus albigularis*	J25
Uxam/Imbulu (*Varanus* sp.)	*Varanus albigularis*	J26
Uxam/Imbulu (*Varanus* sp.)	*Varanus niloticus*	P01*
Uxam/Imbulu (*Varanus* sp.)	*Varanus niloticus*	P02*
Uxam/Imbulu (*Varanus* sp.)	*Crocodylus niloticus*	T01*
Uxam/Imbulu (*Varanus* sp.)	*Crocodylus niloticus*	T02*

Note: Tissue mislabelled by traditional health practitioners is highlighted grey.

[a] Not a herptile species.*

Indistinguishable piece of bone and muscle tissue.

Discussion

The study aimed to combine visual surveys, literature reviews and DNA barcoding to identify herptile species in traditional medicine markets, and further use DNA barcoding to confirm folk taxonomy of the herptiles used by traditional health practitioners. This study further provided insights into indigenous tissue preservation methods and their ability to preserve DNA and the willingness of some traditional health practitioners to collaborate in conservation planning for traditional medicine markets.

DNA barcoding traditional medicine specimens

Although indigenous tissue preservation methods are capable of sufficiently preserving DNA to obtain species level identification through barcoding, storage of those specimens increases risk of DNA contamination as they are openly displayed, and multiple species are stored together in one container at ambient temperatures. Furthermore, there is a risk of DNA degradation from daily temperature and humidity fluctuations (Asari *et al.*, 2018), as a result of those storage methods. Spectrophotometry used to measure the absorbance of DNA samples extracted from herptile specimens gave indications of the purity of the extracted DNA.

Assessments of the purity of extracted DNA by analysing the 260/280 nm and A260/230 nm absorbance ratios suggested that some samples could be unsuitable for downstream analysis as their absorbance ratios were either negative or plotted as extreme values (Figure 2). Sample purity of 1.8 or above is generally considered suitable for using samples in downstream applications (Koetsier & Cantor, 2019) and if this purity ratio is lower (minor outlier) than 1.8 it could indicate that adjustments to improve DNA extraction procedures are required, whereas values that are higher (major outlier) than 1.8 could indicate impurities in the sample (Desjardins & Conklin, 2010). Based on these guidelines of sample purity, it may be considered that positive absorbance values that are lower than 1.8 can be usable in downstream analysis. It could thus be expected that at least 9 – 26% of this study's DNA extractions would not be suitable for downstream analysis due to the results showing negative A260/280 ratios in 9% and negative A260/230 in 26% of the sample. This estimation of extracted DNA that might be unsuitable for downstream analysis increases when positive extreme values are also considered. Regardless of these measures of purity amplification was attempted for all 111 samples of DNA extractions to gain further understanding on analysing DNA preserved using these non-standardised methods. From the 111 samples, 90 were sequenced and 81 sequences were successfully obtained. Based on the final number of sequences, 27.1% of the collected DNA was unsuitable for downstream analysis, while DNA purity measurements suggested that at least 9 – 26% of the samples would be unsuitable.

Spectrophotometry and subsequent sequencing have shown that DNA can be extracted from herptile specimens preserved using indigenous methods (i.e., smothering in salt and ash) but it might be necessary to refine extraction methods and be cognisant of contaminants due to the 27.1% of the extracted DNA not yielding DNA sequences and extreme values in the absorbance ratios of the DNA extractions (Figure 2). These absorbance measurements are encouraging as they suggest it could be possible to efficiently scale-up efforts to barcode herptiles that have traditional medicine value and thus increase the understanding of how indigenous cultural practices factor into herpetology. From the 81 sequences, 24 could only be confirmed to be reptile DNA, 55 sequences were identified to species level and one sequence was identified to genus rank through matches to reference sequences complemented with morphology. Since this chapter's research is still ongoing, one option for ascertaining the identity of the 24 unidentified fragments of the CO1 gene would be to target sequencing using a different gene such as 12S, 16S or cytochrome *b* (Vences *et al.*, 2012) and search for matches to reference sequences that could enable exact species identification.

DNA barcoding compared to morphology-based identification

This study's DNA barcoding confirmed 12 species and one genus from the 34 species identified based on morphology by previous traditional medicine market research. Furthermore, one species that is not mentioned in previous literature was identified in this study (Table 2). The current study also showed there is mislabelling of animal parts that are difficult to identify by the traditional health practitioners. Inconsistency between identifications from DNA barcoding and those based on morphology shows a need for additional barcoding studies of traditional medicine specimens (Veldman *et al.*, 2020). The current species richness of traditional markets is likely underestimated due to specimens that cannot be identified based on their morphology (Whiting *et al.*, 2011). Underestimation of species richness could lead to underestimation of conservation impacts of traditional medicine markets. The selling/buying of pieces of animal tissue, rather than the entire animal, may decrease conservation pressure by having an individual specimen being used by multiple people, but it increases the difficulty of morphology-based identification when the parts of a carcass with distinctive traits are removed.

Animal parts that are difficult to identify can be mislabelled by practitioners which could allow substitution of some species with protected species as was shown in this study with tissue from *Crocodylus niloticus* and *Python natalensis* being wrongfully labelled as bone and muscle tissue from either uxam or imbulu which are *Varanus* spp. (Table 3). Substitution of tissue in traditional medicine is said to pose human health risks when toxic plants are the substitute (Ouarghidi *et al.*, 2012). Substituting animal tissue (specifically reptiles) has been shown to occur in the current study and it has previously been reported that South African reptile species are ingested for medicinal purposes (Ngwenya, 2001), but analysis of that tissue's toxicity is yet to be carried out and thus the human health risks posed by substitution of reptiles in South African traditional medicine are still unknown. Besides the use of herptile tissue in traditional remedies, there is also consumption of herptiles such as *Stigmochelys pardalis* (Anthony & Bellinger, 2007) and *Pyxicephalus* spp. (Du Preez & Cook, 2004) for meat without any reports of adverse effects.

Conservation issues

From a conservation perspective, substitution can have positive consequences if used as basis for discussions with traditional health practitioners about substituting endangered species with abundant species of lower conservation priority. The practitioners would make suitable conservation ambassadors due to the respect they have from people that follow traditional cultural practices (Simelane & Kerley, 1998), and these practitioner's choices influence which species are collected for traditional medicine markets through their hunts or outsourcing to dedicated hunters. Another prospect for lessening conservation pressure of traditional medicine markets, but not necessarily their accumulation of endangered species, is that traditional health practitioners are willing to take animals that died due to accidental or natural causes (Whiting *et al.,* 2001). There is perhaps opportunity for collaboration between traditional health practitioners with initiatives that monitor and collect roadkill on busy roads to lessen hunting pressure on species used in traditional medicine. The conservation pressure of South Africa's urban traditional medicine markets is mostly placed on reptiles as they rely more on reptile species than frog species (34 reptile species vs 1 frog species were recorded in these markets). This trend of greater dependence on reptiles than amphibians in traditional medicine is global (Alves *et al.,* 2013).

Monitoring of species richness at traditional medicine markets would be vital to avoiding over-exploitation of threatened species but it has previously been difficult to estimate the number of individuals per species harvested for traditional medicine markets and their impact on wildlife populations as traditional health practitioners are reluctant to talk about their practices (Whiting *et al.,* 2011). Practitioners that participated in this study did express willingness to collaborate with conservation practitioners. The process of interacting with traditional health practitioners and explaining possible synergies between traditional and modern practices does however increase the amount of time required for field surveys. South Africa's overarching environmental management legislation is supportive of collaborative conservation planning as it states that decisions relating to the natural environment must account for the interest, needs, and values of interested parties and recognise all of forms of knowledge including traditional knowledge (Republic of South Africa, 1998). Within the context of South African environmental legislation, traditional medicinal uses of wildlife (as a form of traditional knowledge) should not be dismissed by conservation practitioners. This environmental legislation further states that management of the environment (natural or otherwise) should equitably provide for people's needs and their cultural interests (Republic of South Africa, 1998). Functional collaborations with traditional health practitioners have in the past been demonstrated by modern health professionals both in South Africa (Nkhwashu *et al.,* 2021) and other parts of the continent (Kayombo *et al.,* 2007) despite disagreement between the two parties, thus providing hope that collaborations with conservation practitioners are achievable. A collaborative approach to managing conservation issues arising from traditional medicine markets would not only be just, but it is also what is legally required. Studies of this nature that focus on the urban areas of developing countries can contribute to increased understanding of urban sustainability in such countries and can also contribute to policymaking when such research is published in high visibility journals (Nagendra *et al.,* 2018).

Conclusion

This study showed that indigenous tissue preservation methods can preserve DNA, species level identifications of unrecognisable animal parts sold in urban traditional medicine markets can be achieved through DNA barcoding, and DNA barcoding can complement other medicinal herptile identifications methods including folk taxonomy. This study transcends disciplines by combining indigenous knowledge with DNA barcoding and social science methodology for outcomes that can be used for socially inclusive conservation planning. The study's methodology has applicability to other countries seeking to enhance their understanding of the interactions between culture and biodiversity, and this wide applicability was demonstrated by Gombeer *et al.,* (2021) when they used DNA barcoding to identify bushmeat that was smuggled to Belgium from West African countries. Using DNA barcoding to complement existing identification methods will ensure that conservation measures are directed at the correct species. Further DNA barcoding and continuous monitoring of traditional medicine markets will be required to improve understanding of their species richness and prevent over-exploitation of herptile species. Efforts to better understand the conservation pressure of traditional medicine markets, prior to implementing any law enforcement action, should include collaboration with traditional medicine practitioners for conservation planning to be inclusive and just as stipulated in South Africa's law for the management of the natural environment. This collaboration is also necessary because in its absence traditional medicine use of herptiles has continued unmonitored and traditional health practitioners have developed resentment towards conservation enforcement. Collaboration would pave the way for investigations of the economic value, ecological impact, and social importance of urban traditional medicine markets.

Acknowledgements

This research is made possible by a bilateral scientific cooperation between North-West University and Hasselt University. Financial support for FMP was provided by the National Research Foundation (UID: 114663; 130501), South African Institute of Aquatic Biodiversity, Youth 4 African Wildlife NPC, and the Flemish Interuniversity Council (VLIR) Global Minds program (Contract Number: R-9363). MPMV is supported by the Special Research Fund of Hasselt University (BOF20TT06) and by Research Foundation–Flanders (FWO-Vlaanderen) research grant 1513419N.

Ethical considerations

The Traditional Healers Organisation in South Africa agreed to its members being approached for participation in a research project. Informed consent was obtained from the participants of this study after the first author explained the purpose of this research and that they could revoke their consent to participate at any point. This explanation was in either SePedi or IsiZulu which were languages preferred by the participants. Ethics approval for this study was obtained from the North-West University Animal Care, Health and Safety Research Ethics Committee (Ethics number: NWU-00185-18-S5) and Hasselt University Social-Societal Ethics Committee (Reference: REC/SMEC/VRAI/189/127). The research conducted complies with the Nagoya Protocol on Access and Benefit-sharing (UID: ABSCH-IRCC-ZA-257320-1)

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Chapter 7

Books as environmental management capacity building opportunities exclude most South African languages.

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(Manuscript submitted to journal)

Abstract: Social inclusion in South African environmental management remains a concern regardless of equality being enshrined in the country's environmental management policy. This policy makes provisions for citizens to be afforded equal opportunities to learn about the environment and develop capacity to participate in environmental management. As South Africa is a multilingual country where most of the population does not use English as their primary language, environmental capacity development opportunities should ideally be linguistically accessible to the country's citizens to avoid perpetuating the pre-democratic exclusion of a majority of the citizen's languages. Given that public libraries play a role in promoting democracy, the books they catalogue are assumed to provide environmental management capacity development opportunities and their language of publication thus provides a snapshot of the inclusion of South African languages in those opportunities. These books representing environmental management capacity development opportunities are mostly published in English. Dominance of English in capacity development contributes to exclusion of most citizens from learning about the environment when a majority of the population does not use English as their primary language. Such exclusion is at odds with South Africa's inclusive environmental management policy and decreasing it will require development of relevant books to make the linguistic accessibility more equitable.

Keywords: Environmental justice, Post-apartheid environmental management, Public participation, Social exclusion, Sustainability.

Introduction

Social exclusion which broadly refers to the withholding of resources and services (Levitas *et al.,* 2007), is a source of inequality that deprives people of involvement in society at large (Giddens *et al.,* 2006). According to a discussion of the conceptualisation of social inclusion in the United Nations' Sustainable Development Goals, interpretations of social inclusion depend on national contexts where the importance of various concepts of social inclusion differ according to each country's socio-economic, cultural and historical contexts (Silver, 2015). Research into people's wellbeing in European countries interprets social exclusion as the inability of individuals to participate in society's political and development activities (Bellani & D'Ambrosio, 2011). Studies of social exclusion in the context of African countries are generally low in comparison to those of European countries (Lupala, 2014). This social inclusion as discussed in the African report is considered a process of improvements meant to enable individuals to participate in society at large (Das & Espinoza, 2020). A South African development study frames social inclusion as having individuals be part of decision making and their rights not being limited, and that study also continues to say the concept of social exclusion highlights the importance of social relationships in the allocation and usage of resources (Adato *et al.,* 2006). The current study seeks to understand social inclusion (from the perspective of primary languages or the language spoken at home) in opportunities to learn and build an understanding that would enable equitable participation in planning for the use and allocation of natural resources (generally referred to as environmental management) in South Africa. The text to follow explains how social inclusion is interpreted from South Africa's National Environmental Management Act 107 of 1998 (NEMA), frames primary languages as an area of social inclusion and provides reasoning for assuming library books about the environment to be opportunities to develop capacity for participation in environmental management.

Environmental management contributes to the broad concept of sustainable development (Marchese *et al.*, 2018). This sustainable development, specifically in the context of social sustainability, has three pillars; social equity, participatory planning and integrative decision-making (Lupala, 2014). These three pillars of social sustainability are apparent in NEMA which stipulates South Africa's National Environmental Management Principles (Republic of South Africa, 1998). Principle 1e among those principles states their purpose is to guide the interpretation, administration and implementation of environmental protection or management laws (Republic of South Africa, 1998). Social equity, participatory planning, and integrative decision-making (as pillars of social sustainability) are addressed in the following National Environmental Management Principles from NEMA (Republic of South Africa, 1998);

- Principle 2 provides for environmental management to serve the needs of people equitably.
- Principle 3 provides for development that is socially and environmentally sustainable.
- Principle 4c provides for environmental justice to be pursued so that negative environmental impacts are not unfairly distributed towards certain people.
- Principle 4d provides for environmental benefits and services to be equitably accessible so people are able to meet basic needs and maintain their wellbeing.
- Principle 4f promotes participation of all interested and affected parties in environmental governance and provision of opportunities for them to develop understanding, skills and capacity required for this participation to be equitable and effective.
- Principle 4g provides for decision-making to consider the interests of all affected parties and recognise both modern and traditional forms of knowledge.

These guiding principles from NEMA promote socially inclusive environmental management through provisions for participation of all interested parties, equitable access to the environment and co-operative governance. This study is based on National Environmental Management Principle 4f which seeks to promote inclusive environmental management through provisions to develop the capacity of interested parties for equitable participation in environmental management. The interpretation of social inclusion in NEMA is broad as social inclusion is a broad concept and this ambiguity makes it possible to focus on different interpretations when assessing social inclusion. A review of Australian social inclusion literature argues that social inclusion interpretations include, inter alia, gender, culture, socio-economic status, and language (Gidley *et al.*, 2010). Given South Africa's history of suppressing indigenous languages (languages of African origin), multilingualism is an important area of social inclusion in the country as its constitution states that all 11 official languages must be treated equal and also be promoted alongside other non-official languages spoken in the country (Republic of South Africa, 1996). This history of language exclusion and the current policy of multilingualism provided the study with motivation to focus on primary languages as an interpretation of social inclusion.

On the backdrop of the multilingualism provisions of South Africa's constitution, a language policy was formulated to promote equitable use of the country's 11 official languages and facilitate inclusion of previously marginalised languages (Department of Arts and Culture, 2003). An analysis of language policy inconsistencies in South Africa however highlighted disparities between policy intentions and practices (Beukes, 2009). Another study focused on language planning in South Africa suggests that the country's language policy encourages multilingualism, but language practices in the country promote dominance of English (Kamwangamalu, 2001). The number of South Africans that can comprehensively speak and understand English is generally low (Sebolai, 2016), thus promoting dominance of the English language does not benefit all South Africans. English and to a lesser extent Afrikaans are the main languages of teaching in South African universities, but many prospective university students will generally struggle to effectively study in these languages as they are not fluent in them (Foley, 2004). University attendance in South Africa, which is generally measured according to racial groups, shows that only 12% of the black population (who tend have primary languages that are neither English nor Afrikaans) attend university (Scott *et al.*, 2007). English is the primary language, for only 8.1% of the country's population (Statistics South Africa, 2018). Considering the low proficiency and low primary use of English in South Africa, having English as the dominant language of learning is restrictive to the acquisition of knowledge (Prinsloo *et al.*, 2018). The language used for learning is important for acquisition of knowledge (Webb, 2004), as people generally learn better in their primary languages (Prinsloo *et al.*, 2018). Additional value of using primary languages was demonstrated by an assessment of a South African wildlife book published in an indigenous language which was found to reveal wildlife perspectives of a community that was previously marginalised from environmental matters (Phaka & Ovid, 2021).

The country's post-apartheid political transformation affords opportunities to study contrasts between democratic policies and reality (Lemon, 2005). South Africa's process of post-apartheid political transformation is believed to bring opportunities for promoting justice, especially in environmental management (Scott & Oelofse, 2005). Despite equality being enshrined in South Africa's post-apartheid policies, there are still concerns about social and racial equity in the environmental sector (Leonard, 2013), among other sectors. The Republic of South Africa's current political ideologies have contributed to persistence of the country's historical racial and social inequalities thus restricting progress towards inclusive environmental management (Musavengane & Leonard, 2019). Racial inequalities inevitability lead to inequalities against languages spoken by the discriminated races and if languages are considered an area of social exclusion then underrepresentation of languages would be part of social inequalities. A case study on racial exclusion in secondary school education shows that bridging this policy-practice divide requires presence of enabling factors which include the easing of macroeconomic constraints that preserve apartheid's racial exclusion (Lemon, 2005). A study specifically focused on disparities between language policy and practice also contends that for language practice to achieve the social inclusion envisaged by policy will require enabling factors such as changing perceptions that social progress cannot be achieved using multiple languages and that indigenous African languages cannot be developed into intellectual languages (Mutasa, 1999).

Research on social inclusion in the environmental sector has made similar conclusions to broader scale studies mentioned above. Published research on social inclusion in South Africa's conservation sector and the environmental sector is generally limited (Musavengane & Leonard, 2019). Among this small pool of social inclusion literature in South Africa's environmental sector is marine management research by Sowman and Sunde (2018) which shows that despite policy and legal commitments to inclusive environmental management, the pre-democratic top-down management style persists without appropriate structures to facilitate inclusion of local communities. According to Kothari (2006), discussions relating to social equality in environmental matters tend to be avoided by those in positions of authority. A study of racial discrimination in biodiversity matters by Kepe (2009) concluded that reluctance to deal with racial equality issues could prevent reconciliation of biodiversity conservation with social progress and acknowledgement of the discriminatory history of conservation on the African continent could promote socially just conservation by way of considering conservation perspectives of previously marginalised people. The current study adds to the limited literature on social inclusion in South African environmental matters with a focus on inclusion of South Africa's 11 official languages in opportunities to develop an understanding of environmental matters. These languages and their usage as primary languages among South Africans were as follows according to the country's last census in 2011 (Statistics South Africa, 2011); Afrikaans (13.5%), English (9.6%), IsiNdebele (2.1%), IsiXhosa (16%), IsiZulu (22.7%), SePedi (9.1%), SeSotho (7.6%), SeTswana (8%), SiSwati (2.6%), TshiVenḓa (2.4%), and XiTsonga (4.5%). The official languages have dialects and the languages of the South African KhoiSan communities are not officialised.

The books in public libraries, specifically their language of publication, provide a proxy of social inclusion in opportunities to learn about the environment and build capacity for its management. Other opportunities to learn exist in media such as television and the internet but those are avoided as their main reason for existence is not to provide learning or capacity development opportunities. Libraries enable individuals to fulfil their roles and obligations in society by empowering them with knowledge for self-reliance and continuous learning (Ocholla, 2009). In an assessment of civil society and good governance Arko-cobbah (2006) asserted that public library usage generally cuts across social classes, South African public libraries play a vital role in promoting good governance by providing unrestricted access to information, and these libraries are expected to fight against discrimination by having collections that reflect the interests of all citizens. Given the prospect of libraries in decreasing discrimination and promoting good governance, books can be considered as opportunities for decreasing this discrimination and promoting good governance which in the case of National Environmental Management Principle number 4f would mean books are opportunities to develop capacity for equitable participation in environmental management. It is against this background of disparities between policy and actions that the current research is interested in contrasting the ideal of social inclusion in NEMA (National Environmental Management Principle 4.f in particular) with whether South Africans have linguistically accessible opportunities to develop capacity for equitable participation in environmental management. Library books are assumed to provide opportunities for capacity development.

Methods

We surveyed non-fiction books available in the environment section (indexed under the subjects Biological Sciences, and Geography and Earth Sciences) of South African public libraries to understand representation of the country's official languages and how the publication languages of these books can have social inclusion implications if they are taken to represent opportunities to gain an understanding of the environment. The sample consisted of books about the South African environment which were published between 1996, when South Africa's Constitution introduced socially inclusive environmental policy, and 03 September 2021 at the commencement of this study.

A book search was conducted on the National Library of South Africa's (https://nlsa.on.worldcat.org/discovery/) catalogue of books held at South African public libraries. Obtained results were pre-screened to verify that they focus on South Africa's environment. Following pre-screening, the results were coded and categorised according to each book's language or languages of publication (i.e., unilingual, bilingual, or multilingual). The social inclusion potential of these language categories is then discussed within the context of NEMA's National Environmental Management Principles 4f, to gain an understanding of whether South Africans have equal opportunity to learn about the environment and gain sufficient capacity to participate in its management using a language of their choice from these books that can provide such an opportunity.

Results

The National Library of South Africa's catalogue shows 770 non-fiction print book titles published between 1996 and 03 September 2021 that are placed in the environment section of

South African public libraries (Supplementary Material 1). From this sample of books considered to be opportunities for environmental capacity building, 722 (94%) books are published only in English and 33 (4.1%) are published only in Afrikaans (Figure 1), thus 98.1% of the books in the sample are unilingual. The remainder of the books are either bilingual (0.6%) or multilingual (1.3%). South Africa's indigenous languages are the publication language in 11 of the 770 books in this study's sample of books (Figure 1).

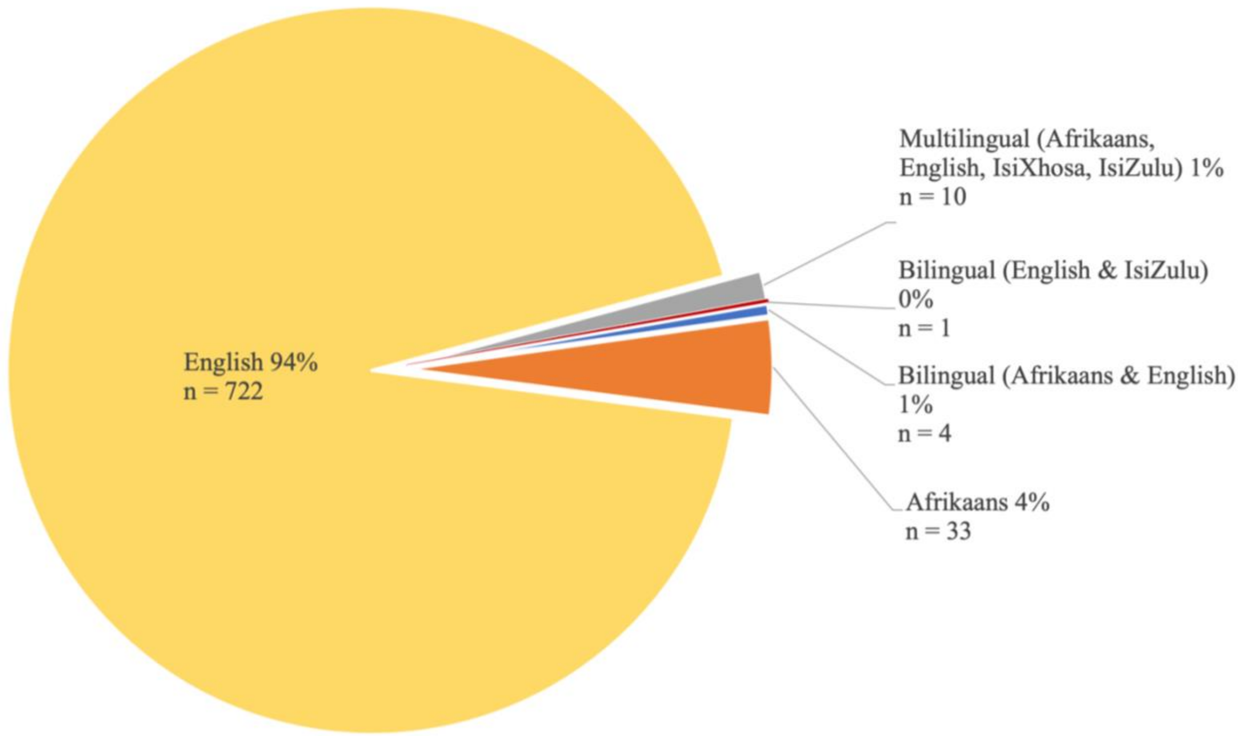

Figure 1: Primary language inclusion in books considered to be opportunities to learn and build capacity for environmental management in South Africa. These books are published between 1996 and 03 September 2021.

Seven of the country's 11 official languages (IsiNdebele, SePedi, SeSotho, SiSwati, SeTswana, TshiVenḓa, and XiTsonga) are not represented and there are no unilingual books published in indigenous language within this study's sample. The sample has 15 bilingual or multilingual books (Figure 1) which are most inclusive of South Africa's multilingual society in comparison to the 755 unilingual books. Fourteen of these bilingual or multilingual books are guides for identifying or learning the basic biology of South African wildlife (Table 1).

Table 1: Bilingual and Multilingual books about South Africa's environment published between 1996 and 03 September 2021.

Book title	**Publication language**	**Book's focus**
A bilingual field guide to the Frogs of Zululand = Isiqondiso sasefilidini sezilimi ezimbili ngamaxoxo AwelaKwaZulu (Phaka *et al.*, 2019).	English and IsiZulu.	Wildlife identification and basic biology.
Acacia : a field guide, Southern Africa : acacia interactive = Acacia : Suider-Afrika, 'n veldgids : acacia interaktief (Steyn, 2007).	Afrikaans and English.	Wildlife identification and basic biology.
Commiphora : a field guide Southern Africa = Suider-Afrika, 'n veldgids (Steyn, 2003).	Afrikaans and English.	Wildlife identification and basic biology.
My first book of Southern African animal tracks (Stuart and Stuart, 2014).	Afrikaans, English IsiXhosa and IsiZulu.	Wildlife identification and basic biology.
My first book of Southern African birds (Cuthbert, 2006).	Afrikaans, English IsiXhosa and IsiZulu.	Wildlife identification and basic biology.
My first book of Southern African birds volume 2 (Cuthbert ,2009a).	Afrikaans, English IsiXhosa and IsiZulu.	Wildlife identification and basic biology.

My first book of Southern African creepy-crawlies (Uys, 2010).	Afrikaans, English IsiXhosa and IsiZulu.	Wildlife identification and basic biology.
My first book of southern African frogs (Tarrant, 2015).	Afrikaans, English IsiXhosa and IsiZulu.	Wildlife identification and basic biology.
My first book of Southern African insects (Uys, 2009).	Afrikaans, English IsiXhosa and IsiZulu.	Wildlife identification and basic biology.
My first book of Southern African mammals (Apps, 2012).	Afrikaans, English IsiXhosa and IsiZulu.	Wildlife identification and basic biology.
My first book of Southern African ocean life (Griffiths, 2011).	Afrikaans, English IsiXhosa and IsiZulu.	Wildlife identification and basic biology.
My first book of Southern African seashore life (Griffiths, 2010).	Afrikaans, English IsiXhosa and IsiZulu.	Wildlife identification and basic biology.
My first book of Southern African wildlife (Cuthbert, 2009b).	Afrikaans, English IsiXhosa and IsiZulu.	Wildlife identification and basic biology.
SA ficus : identification guide for wild figs in S.A. = SA ficus : identifikasie gids vir wildevye in S.A (Steyn, 1996).	Afrikaans and English.	Wildlife identification and basic biology.
The role of soil conservation in the RDP = Or Die rol van grondbewaring in die HOP (Association of Soil Conservation Engineering Technology, 1996).	Afrikaans and English.	Conservation of abiotic environment.

Discussion

Library books taken as opportunities for social inclusion in capacity building for equitable participation in environmental management exclude some official South African languages thus suggesting those capacity building opportunities are not inclusive of all interested and effected parties as encouraged by NEMA's National Environmental Management Principle 4f. This study is based on books indexed in the environment section of public libraries thus limiting the study's sample by excluding books indexed under a different subject, and books from any public libraries that do not share their list of books with the National Library of South Africa for indexing purposes. Most of those books considered to be capacity building opportunities in this study's sample are published in English and other South African languages are underrepresented. If South African public libraries house materials in only a few languages, then they may be considered an inaccurate representation of the country's diverse cultural reality (Raju & Raju, 2010). The underrepresentation of some of South Africa's indigenous languages from published environmental books can contribute to the underrepresentation of wildlife perspectives as a study by Phaka and Ovid (2021) showed that wildlife books published in indigenous languages can reveal new or unpublished perspectives of wildlife from speakers of that indigenous language. These previously unknown wildlife perspectives are important for inclusive environmental management as NEMA National Environmental Management Principle 4g provides for consideration off all perspectives and forms of knowledge. The lack of indigenous knowledge in the collections of public libraries (Mhlongo & Ngulube, 2020) generally leads to less chances for perspectives of indigenous languages being learned. The speakers of the languages shown to be excluded from capacity building opportunities in this study are mostly indigenous communities that have always been marginalised from environmental management. People that experience the most environmental risk often do not have the means for effective participation in environmental management, and this leads to their exclusion from those processes (Weiler, 2009). This current study suggests that books which can provide a means for environmental management participation offer limited inclusion of previously marginalised people who speak the majority of the official languages that are underrepresented in those books. Meaningful inclusion of interested and affected parties in environmental management is generally lax (Clark e*t al.*, 2016), despite this inclusion being outlined in the environmental management principles of legislation like NEMA.

The books considered to provide opportunities to develop people's capacity for participation in environmental management in this study show those learning opportunities to be mostly suited for people with a good understanding of English (Figure 1). Seven of South Africa's 11 official languages (namely IsiNdebele, SePedi, SeSotho, SiSwati, SeTswana, TshiVenḓa, and XiTsonga) did not feature as languages of publication in this study's sample of books. This finding of English's dominance is contrary to South Africa's officialization of 11 languages which gives the impression that linguistic accessibility is equitable. If capacity development opportunities are accessible in all official languages, then progress can be made towards the inclusive environmental management envisaged by NEMA. Besides English, Afrikaans is the only other sole language of publication in the sample of books under discussion here, other books are either bilingual or multilingual. Afrikaans is nonetheless underrepresented in comparison to the capacity building opportunities available in English. Bilingual and multilingual books increase accessibility of learning opportunities (Kamwendo *et al.*, 2014). The social inclusion promoted by books published in other South African languages besides English reaches beyond inclusive environmental management. A language planning study found that a bilingual (English and IsiZulu) book about South African frog species has contributed to the development an African language into a language of teaching and learning which is a priority for language planning in many African countries, in addition to highlighting previously neglected indigenous perspectives of frogs and increasing linguistic accessibility of herpetology (Phaka & Ovid, 2021). It is possible that publication of bilingual or multilingual books is not profitable for publishers, and in which case it would be up to the South African National Biodiversity Institute to ensure linguistic accessibility of environmental books as they are legally mandated to disseminate biodiversity information to South Africans. This study's sample of library-indexed books assumed to be opportunities to increase knowledge about the environment found those books to be linguistically inaccessible to South Africans who are not proficient in English. The accessibility of libraries where these books are housed is unknown and thus the current study cannot speculate on how geographical location might affect access to books that are freely available to use. A study on South African public libraries' resource provision and access by Mhlongo and Ngulube (2020) recommended that beyond providing access to books, internet access, information and communication technology should be used to facilitate access and dissemination of knowledge (specifically indigenous knowledge). This recommendation to take advantage of information and communication technology provides inspiration for studies that are similar to the current one to compare the social inclusivity of learning opportunities between library books and the various information and communication technologies.

Conclusions and perspectives

If publicly accessible books assumed to be opportunities to develop capacity for participation in environmental management are not inclusive of all official South African languages, then they do not contribute towards inclusive environmental management capacity development. Beyond diversifying the publication language for environmental management capacity development opportunities, co-production of such learning opportunities with indigenous communities can facilitate the unveiling of a greater diversity of environmental perspectives. Entities that are legally mandated to make knowledge of the environment more accessible, like the South African National Biodiversity Institute, are encouraged to follow these recommendations for diversifying their publications to increase social inclusion. The current study discusses only one of a myriad of social inclusion interpretations. Other areas of social inclusion that can be assessed, to increase the pool of literature on disparities between policy and actions in the environmental sector, include socio-economic status, race, gender and formal education.

Acknowledgements

North-West University and Hasselt University are thanked for approving the bilateral scientific cooperation that enabled this research. FMP is supported by the National Research Foundation (UID: 114663; 130501), South African National Biodiversity Institute, South African Institute of Aquatic Biodiversity, Youth 4 African Wildlife NPC and the Flemish Interuniversity Council (VLIR-UOS) Global Minds program (contract number: R-9363); MPMV by the Special Research Fund of Hasselt University (BOF20TT06).

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Chapter 7.1

Life sciences reading material in vernacular: lessons from developing a bilingual (IsiZulu and English) book on South African frogs.

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Adapted from: *Current Issues in Language Planning* (2021).

https://doi.org/10.1080/14664208.2021.1936397

Abstract: The discussion of African languages as languages of learning and teaching can be traced back to the 1980s. To date, this discussion still continues and efforts to develop African languages for teaching and learning purposes have been lax. Here, we present practical South African examples of higher education achievements in African languages that demonstrate the challenges and opportunities of African language planning and corpus development. We particularly focus on the development of a peer-reviewed bilingual (IsiZulu and English) book on the frogs of Zululand, South Africa. The publication under consideration falls within the life sciences, and it is the first comprehensive book on South African frogs to be written in an African language. Developing life sciences reading material in vernacular is a time-consuming process that requires a multidisciplinary team which understands both life and social sciences. Furthermore, when vocabulary relating to a focal species is undocumented, field research is necessary to identify the nuances of a specific language or culture. This language planning effort under discussion demonstrates the IsiZulu language's ability to communicate life sciences and how language planning efforts can be made integrative and inclusive of previously marginalised languages.

Keywords: Community outreach research, Decolonizing curriculum, Ethnoherpetology, Life sciences education, Medium of instruction, Postcolonial science

Introduction

Language planning on the African continent, specifically corpus development (accumulation or development large bodies of text) and developing African languages into languages of learning and teaching (LoLT), is a long-standing challenge. In 1982, ministers of education from various African states convened for a conference in which having African languages as languages of education was discussed as a priority (UNESCO, 1982). According to the document for this meeting, having African languages as LoLT was a matter that required urgent attention. For African languages to be effective LoLT they must be developed into standard languages (Webb, 2004). The urgency of the development of African languages as discussed by the African minsters of education was, however, not translated into action, and the communities speaking these languages remain largely side-lined from language planning. Brock-Utne (2007) reported that little progress had been made towards the seemingly important goal of using African languages as LoLT. Resources are often focused on promoting African culture rather than on the language planning and development required for African languages to be viable alternatives to colonial languages for learning and teaching (Banda, 2009). It is widely agreed that African languages are important for the socio-economic development of the continent, but there is little clarity on how to achieve the desired development of these languages to bring them up to par with modern contexts (Prah, 2017). Achieving development of African languages, as the African minsters of education envisaged in their 1982 meeting, requires language planning.

Here, we discuss a South African example of socially-integrative African language corpus development using life sciences reading material developed for IsiZulu speakers as a case study. Traditional language planning places emphasis on corpus development to build a discrete linguistic system of specialised terminology and phrases that enable communication about abstract concepts (Newman, 2021). Banda (2009) contends that the drawback of language planning and policy in Africa is that they are based on Western and colonial notions of multilingualism, which simultaneously promote several monolingual streams of distinctive languages in their homogenous communities. In effect, bilingualism is said to arise through single language education (Banda, 2009). South Africa's move towards a multilingual language policy with African languages as LoLT began when the country came under democratic rule in 1994, thus enabling language policy and planning to start working towards language democratization (Kamwangamalu, 2001). In the country's language planning history, this goes down as an attempt to deconstruct monolingual ideology (Baldauf, 2012). However, minimal progress has been made in implementing this policy (Kamwangamalu, 2001; Webb, 2004).

Regardless of the little progress made in South Africa's democratic language policy, the LoLT issue continues to be an active discussion. South African language planning has mostly been preoccupied with the mother language debate (Banda, 2009). African languages as LoLT are a regular point of academic, political and conversational discussions in South Africa (Department of Basic Education, 2013; Mkhize & Balfour, 2017; Hadebe, 2020). Some of the ongoing discussions mention numerous advantages and disadvantages of teaching and learning in African languages. There are also discussions that focus on the logistics of corpus development required for African languages to be LoLT. Development of reading materials is a complex issue involving multiple stakeholders (Edwards & Ngwaru, 2012), and the complexity varies according to each subject area and the technical language it uses. Negative attitudes towards African Languages impede efforts to promote them (Kamwangamalu, 2001). The lack of modern terminology in African languages is also a hindrance to their use as LoLT (Madiba, 2001).

South Africa's past of oppression meant that the country was only officially recognised as multilingual, from previously bilingual (Afrikaans and English), when it came under democratic rule in 1994 (Kamwangamalu, 2001). Amidst the backdrop of the historic suppression of indigenous languages, along with oppression of their speakers, there is also negativity towards African languages. Despite the general lack of modernisation of African languages and the long-standing LoLT discussion, there are multiple achievements in indigenous languages emerging from South Africa's academic sector. These achievements, among others, include scientific articles written in SeTswana (Baitshenyetsi *et al.*, 2011) and IsiZulu (Gumbi, 2014; Nkosi, 2014), along with Doctoral dissertations written in IsiXhosa (Kunju, 2017), SePedi (Thokoane, 2008) and SeTswana (Pooe, 2019).

The abovementioned academic works bring practical examples to the LoLT discourse, and they can be regarded as successful manifestations of ongoing language planning efforts. A practical example that is of interest here is a bilingual book (written in English and IsiZulu) titled A Bilingual Field Guide to the Frogs of Zululand (Phaka *et al.*, 2017), with the IsiZulu title 'Isiqondiso Sasefilidini Esindimimbili Ngamaxoxo AkwelaKwaZulu' (hereafter Zululand Frog Guide). The book is the third in a zoological series of peer-reviewed publications called Suricata which is published by the South African National Biodiversity Institute (SANBI, 2020). As the first comprehensive guide for South African frogs written in an indigenous language, the Zululand Frog Guide is an ideal case study for the process of developing taxon-specific life sciences material in an African language, and gauging how far along the development of IsiZulu has come. A developed language is capable of discussing any subject regardless of its complexity (Khumalo, 2020). The lessons learned in developing the Zululand Frog Guide are applicable to other African countries with reasonable consideration of each country's unique culture/language contexts. An understanding of the various processes of corpus planning (i.e., codification and elaboration) forms the basis for development of reading materials (Liddicoat, 2005). In the text to follow, we discuss the issues pertaining to the authors and translators who developed life sciences reading material in IsiZulu.

Language as culture and scientific literacy

How can the life sciences, with a dominant historical narrative entrenched in European colonialism, be translated to advance language planning, scientific research, and education in South Africa? Ngũgĩ wa Thiong'o, who has broadly studied the politics of language in African literature, describes the debates over education and languages, focusing on Kenya but with the rest of the African continent in mind. Decolonizing the Mind (wa Thiong'o, 1992) describes the process and challenges of developing language for African creative literature and theatre. There are also opportunities to develop African languages beyond literary disciplines in the service of supporting science learning and engagement, which we detail in this article.

Because English proficiency is perceived as a necessary prerequisite for engagement with the global scientific community, science in South African schools is taught primarily in English. Historically, language policy maintained English dominance in South African educational institutions. In general, students are still expected to learn English to learn science. Consequently, students trying to learn the English language, as well as new scientific concepts presented in English, may struggle to learn both simultaneously (Webb, 2010). Ideally, the language that students use to learn science should be a language with which they are already familiar. If the language spoken at home is equivalent to the instructional language, a learner is more likely to demonstrate achievement in science and mathematics; however, students with non-equivalence of home and instructional languages are at a disadvantage when learning science (Rollnick, 2000; Prinsloo *et al.,* 2018; Prinsloo & Harvey, 2020). Further, it is argued that the technical vocabulary, status, acquisition, usage, and prestige of African languages should be developed to advance equitable science learning and national integration (Dlodlo, 1999; Webb *et al.*, 2010). The University of KwaZulu-Natal have been exemplary in their successful development and implementation of policy for IsiZulu to be one of its LoLT alongside English, thus making it possible to learn and teach in either IsiZulu or English (Kamwendo *et al.*, 2014). The corpus development resulting from the University of KwaZulu-Natal's promotion of IsiZulu plays a major role in overall development of this African language (Khumalo, 2020).

The process of developing the Zululand Frog Guide promotes community engagement in language development while also including cultures/languages/communities that are generally excluded from wildlife-related matters. Furthermore, publishing material in more than one language allows for freedom of choice to opt for a language that one is most comfortable with while also promoting bilingualism. Having lessons available in English and an African language makes lessons accessible regardless of the learner's home language (Kamwendo *et al.*, 2014). This article showcases an integrative approach of material development in language planning by engaging with life sciences as an alternative to learning English to learn science. In this case study, life sciences teaching is grounded in the intricate relationship between South African wildlife and indigenous cultures/languages. South Africa's biodiversity provides its citizens with nature-based cultural traditions (Department of Environment, Forestry and Fisheries, 2015). These nature-based traditions are evident in many aspects of culture including lore, spirituality, idioms, praise poetry, and totemism. The Zululand Frog Guide in particular focuses on cultural knowledge alongside the taxonomy of frogs. In turn, the reading material not only presents amphibians in a language with which the Zululand community is most familiar but also frames amphibians according to how the community experiences and relates to them. Focusing on animals from the everyday contexts of the community interacting with them helps with the sampling of animal-related vocabulary and dialects, which contributes to determining a local language's orthography and standardisation principles. The sampling described here is shown to be an important step in language planning by Keränen (2018) in the case study of Kven language maintenance through corpus planning.

Time and a multidisciplinary team are essential

The Zululand Frog Guide was developed as a pilot study in South Africa's KwaZulu-Natal province. If successful, the pilot would be expanded to include the rest of South Africa and its other indigenous languages (Phaka *et al.*, 2019). The process of developing the book started with field research to record local knowledge about frogs along with frog species names, the spelling of these names, and their pronunciation. Within language planning, this field research was vital to determining IsiZulu orthography and standardisation principles relating to the life sciences domain. The recording of the mostly undocumented species names contributed to understanding standardisation principles that specifically relate to taxonomy. Later in the article, the principles of standardisation are shown to be important in both linguistic and scientific contexts. In a multicultural country such as South Africa, another consideration for developing this type of vernacular reading materials is that the wildlife being discussed is likely to have regional and culturally-specific names and associations.

To make such reading materials engaging and relatable, it is important to include vernacular names instead of solely using scientific names, popular English names, or direct translations of English names. In many instances, these indigenous names are not documented and are passed down by word of mouth over the generations. If there are multiple names or dialect variations in the spelling of indigenous names for one species, then standardisation will be required. Dialects of the various languages are unlikely to be published, so they must be recorded through field research in different areas within a region where habitants speak the same language. The indigenous knowledge recorded through field research requires reframing for life sciences contexts, and this field research may also record life sciences terminology. We later find out that further field research was required in order to explicitly document the technical language necessary for explanations in the life sciences domain. The IsiZulu lexicon proved mostly adequate for writing a comprehensive guide for wildlife (particularly frogs), and only a few terms were borrowed. This process of recording terminology is expensive and generally overlooked thus resulting in the stereotype that African languages are incapable of coining terminology for abstract concepts (Alberts, 2010). Recording terminology through field research might reveal IsiZulu words for the borrowed terms shown in Table 1. For example, the Zululand community consists of cattle farmers that are likely to have indigenous names for livestock sicknesses. Nagana, originally modified from IsiZulu word 'nakane' (Williams & Williams, 1992), is one of the borrowed terms in the Zululand Frog Guide (see Table 1).

Developing life sciences reading materials in an African language requires contributors from various disciplines to ensure that the materials are scientifically and orthographically sound. Initial work on the Zululand Frog Guide began in 2015, and the book was published in 2017. From the start of field research to the book going to print, there was a process of continuous consultation between the various stakeholders involved in this language planning effort. The field research, data analysis, content development, and species descriptions were carried out by authors with qualifications in the life sciences and experience in the social sciences. The existing IsiZulu taxonomy of frogs did not include all frog species from the focus area. To extend the taxonomy to be inclusive of all Zululand frog species first required expertise in life sciences to interpret the recorded taxonomy. Following interpretation, the development from local taxonomy to a comprehensive list of locally relevant and scientifically appropriate names required joint expertise from life sciences, IsiZulu language studies, and wildlife tourism for communicating wildlife concepts to non-specialist audiences. Additionally, the IsiZulu language expert was required to have experience with technical vocabulary for the life sciences. This development of the local taxonomy was based on principles of standardisation and is fully explained in the sections to follow.

Dialects and technical language

Before recording dialects through field research, the multidisciplinary team first needed to identify where different dialects of the focal language occurred. Within the area covered by the Zululand Frog Guide, there are variations in the way IsiZulu is spoken and subtle differences in the way animal names are pronounced and spelled. In recognition of these dialects, local frog names from five different areas of the Zululand region were recorded (Phaka *et al.*, 2019). The dialects had three major differences in frog names. Some Zululand locals referred to frogs in general as 'amaselesele' while others used the shortened 'amasele'. Most of the Reed Frog species (i.e., frogs from the Hyperoliidae family) are called 'umgqagqo' in some parts of Zululand while in other areas they are called 'umgqagqa'. Burrowing frogs (of the families Brevicipitidae and Hemisotidae) were either called 'isnana' or 'isinana'. The Zululand Frog Guide opted to use 'amasele', 'umgqagqa', and 'isinana' as the standard names because they were more widely used among the IsiZulu dialects. Choosing the most widely used alternative applies the majority principle in the corpus planning principles about the relationship between people and their language, as outlined by Vikør (1993).

Conversational proficiency in indigenous languages is insufficient for their adaptation as LoLT because the ability to use a language in social settings does not equate to an ability to use that language for academic purposes (Webb, 2004). Proficiency in academic languages requires knowledge of academic and technical vocabulary (Cummins, 2001). What languages are considered to be technical and academic results from an imperial imposition of Eurocentrism, what Ngũgĩ wa Thiong'o calls colonial alienation (1992). Since the prevalent academic languages are colonial in origin, the development of indigenous languages into academic languages has been ignored, thus extending the colonialist ways for disregarding local communities and their languages. To temporarily solve the problem of insufficient IsiZulu technical terms, the Zululand Frog Guide borrowed some technical vocabulary from English and science to advance understanding of frog biology (Table 1).

Table 1. A list of technical terms that Phaka *et al.*, (2017) borrowed for use in IsiZulu life sciences text.

	Borrowed technical term	**IsiZulu form of technical term**
1	Amphibians	Imfibiya
2	Diameter	I-diameter
3	Diaphragm	I-diaphragm
4	Dinosaur	I-dinosaur
5	Genus	I-genus
6	Nagana	I-nagana
7	Pathogen	I-pathogen
8	Taxon	I-taxon
9	Toxin	I-toxin
10	Tympanum	I-tympanum
11	Virus	Ivirusi

Borrowing was limited to terminology which the book’s writing and translations team did not know the IsiZulu equivalents, and explanations for these borrowed terms are included in the book's glossary. Besides the 11 borrowed terms shown in Table 1, the IsiZulu lexicon was capable of providing the detailed and descriptive language required for scientific descriptions of wildlife.

Caution is necessary when defining and borrowing English or scientific terms for use in IsiZulu or other African languages. For example, the term 'tympanum' refers to a structure used for hearing in frogs and might be translated to an 'ear' in IsiZulu which would, in the academic sense, be inaccurate as a tympanum and an ear are not the same structure even though they are similar in their function. Due to the absence of an IsiZulu equivalent for tympanum, the Zululand Frog Guide borrowed the term (Table 1) and provided an IsiZulu definition that differentiates it from an ear. As IsiZulu language development advances, borrowed words such as those in Table 1 will be seen less frequently and eventually replaced. If South Africa's language policy ambitions of additive multilingualism (Kamwangamalu, 2001) are realised, then development of IsiZulu will progress until there is no need for borrowing technical terms. Since African languages are developing languages, they are likely to experience more problems with terminology than developed languages (Van Huyssteen, 1999). The policy required to enable development of IsiZulu and other indigenous South African languages is already in place, but the establishment of a systematic procedure for developing these languages has been slow (Madiba, 2001). It is also possible some technical terms exist but are unrecorded, or the authors missed already recorded terminology. Various terminology already exists in different domains of African languages, and it is likely undocumented and unstandardised (Alberts, 2010).

It is worth noting that there are words used interchangeably in conversational language, but the same words should not be interchanged in life sciences writing as they differentiate between species. Safeguarding against the potential problems that can result from interchanging words is possible when there is a multidisciplinary team working on language development. They can consult each other on the suitability of words as technical terms in various disciplines. ‘Stripes’ and ‘bands’ are words that are sometimes used interchangeably in conversational IsiZulu, but they should not be interchanged in life sciences contexts, for they form part of the unique names of different species. If ‘stripe’ is interchanged with ‘band’ in the species name Striped Grass Frog (IsiZulu name: ‘Uvete olunemigqa’), then this name might be confused with that of a different species known as the Broad-banded Grass Frog (IsiZulu name: ‘Uvete olunomugqa obanzi’). Interchanging IsiZulu words for ‘dots’ and ‘blotches’ in life sciences text would result in confusion, due to these words being key to accurate descriptions of various species. Dots on the underside of the body are a defining characteristic of the Northern Pygmy Toad while blotches on the underside are a defining characteristic of the Southern Pygmy Toad, and interchanging between dots and blotches would create confusion about the species of Pygmy Toad under discussion. The potential confusion in the field of animal studies that could result from interchanging terms which are part of conversational language only highlights the technicality of life sciences. The fact that such terms can be used in technical contexts for a previously marginalised language is a testament to IsiZulu’s ability to communicate concepts in different contexts—a vital requirement for language development.

A basic understanding of taxonomy is necessary

Numerous research articles show that cultures across the world have their own taxonomies for wildlife (Berlin, 1973; Ulicsni *et al.*, 2016; da Silva & Barbosa Filho, 2018). South African cultures also have their own taxonomies with wildlife names that are unique to each culture. Using indigenous wildlife names enables indigenous language speakers to more easily recognize different species. Indigenous taxonomies are established; however, they are not comprehensive for all groups of wildlife. Plants generally have more specific indigenous names for individual species in comparison to animal species, which tend to be grouped together under one indigenous name based on their similarities (Phaka *et al.,* 2019). An understanding of taxonomy and its related orthography and standardisation principles is necessary in order to interpret indigenous naming and classification rules. These indigenous naming and classification rules can be applied to extend taxonomies that may not be comprehensive. A particular nuance of recorded IsiZulu frog names that may have been missed by someone without an understanding of taxonomy are the two names used as generic terms for frogs; 'amasele' versus 'amaxoxo'. In Zululand, the word 'ixoxo' or 'amaxoxo' is used for frogs with warty skin (which are mostly toads), while 'isele' or 'amasele' is used for smooth-skinned frogs. This differentiation of frog species is one of the IsiZulu standardisation principles relating to taxonomy; this principle makes provision for the differentiation and grouping of frog species based on their similarities. Scientific taxonomy guidelines also make provision for classification of species based on similarities. Therefore, the standardisation principles for IsiZulu species names have scientific merit.

The case study published IsiZulu names of 58 frog species occurring in Zululand and a subsequent publication by Phaka *et al.,* (2019) details the corpus development process of creating this comprehensive list of IsiZulu species names from the non-comprehensive folk taxonomy recorded during field research for the Zululand Frog Guide. Guidelines of folk taxonomy in Zululand were found to have similarities to scientific taxonomy as both taxonomies group frogs according to observed traits (e.g., the aquatic frogs collectively called *Xenopus* in scientific taxonomy are grouped under the name 'idwi' in folk taxonomy), IsiZulu uninomial frog names are folk taxonomy's equivalents of scientific genera or families (e.g. the frog genus *Breviceps* has an equivalent folk-generic grouping called 'isinana' and the family Ptychadenidae's folk-generic equivalent is 'uvete'). Zululand folk taxonomy mostly conforms of the International Code of Zoological Nomenclature as species are grouped together using a uninomial name, and the groupings are based on similarities on the defining traits of various species (Phaka *et al.*, 2019). The organising principles of folk taxonomy are said to be a predecessor of the hierarchical structure used in scientific taxonomy (Ross, 2014). Since there are overlaps between folk and modern taxonomy, the principles of modern taxonomy were used by Phaka *et al.*, (2019) as a supplement to refining IsiZulu taxonomic principles into principles for the standardisation of IsiZulu frog names. This was necessary for the compilation a comprehensive list of Zululand frog species. The taxonomic principles in discussion here are mainly the domain of life sciences, but they do overlap into grammatication; they involve extraction and formulation of rules for structuring language (Baldauf, 1989). These principles of taxonomic standardisation used by Phaka *et al.*, (2019) are as follows: "(1) [A]void coining completely new names and give priority to existing appropriate names. (2) Formulating individual species names should rather involve modification or extension of existing indigenous names to improve their meaning. (3) Habit, habitat, or appearance should preferably be used whenever there is a need to coin a new name. (4) Use of call descriptions in names should be limited to frogs that are commonly observed calling. (5) Wherever possible, the coined indigenous names should bear a similar meaning to scientific names or other vernacular names published in a different language. (6) Dialects of the language in use should be considered and species' names made understandable across different dialects of the same language."

The uninomial IsiZulu nomenclature used for groups of frog species with similar traits is extended by additional words, which serve as epithets to differentiate among the various species that belong to a folk-generic grouping (Table 2). The folk-generic uninomial names are indicated by underlining in the example of extended IsiZulu species names provided in Table 2.

Table 2: Text from Phaka *et al.*, (2017) showing IsiZulu frog species names extended from folk-generic names (alongside scientific names). The underlined part of the IsiZulu species name is the uninomial folk-generic name recorded during field research.

Habitat	**Scientific name – IsiZulu name**
Amaxhaphozi	*Afrixalus aureus* – Umgqagqa Oyigolide
	Hemisus marmoratus – Isinana Esipendiwe
Avukuzayo	*Breviceps adspersus* – Isinana Sehlathi
	Breviceps bagginsi – Isinana SikaBilbo
	Breviceps carruthersi – Isinana SakwaPhinda
	Breviceps pasmorei – Isinana SakwaNdumo
	Breviceps mossambicus – Isinana SaseMozambique
	Breviceps sopranus – Isinana Sekhwela/Isinana Somtshingo
	Leptopelis mossambicus – Isele Lasezihlahleni Elinsundu
Ichibi	*Amietia delalandii* – Isele Lasemfuleni Elijwayelekile
	Hyperolius marmoratus – Umgqagqa Opendiwe
	Hyperolius pusillus – Umgqagqa Weminduze
	Hyperolius semidiscus – Umgqagqa Wemigqa Ephuzi
	Schismaderma carens – Ixoxo Elibomvu

For the sake of continuity and standardisation, these extended names are descriptive of their respective species. Furthermore, the extended names have a meaning similar to scientific names or already published names in other languages. The specific names constructed by extension of existing folk-generic names are new to both life sciences and IsiZulu, and they constitute what Baldauf (1989) calls terminological modernisation; regular development of new terminology in order for a language to be capable of being expressive in every domain. Developing terminology that is specific to a discipline contributes to the development a language into one that can be used for teaching and learning. The lack of such specific terminology is often cited as the reason African languages cannot be used as LoLT (Prah, 2017). The uninomial IsiZulu name remains part of the extended name to ensure that this new name is recognisable to IsiZulu speakers and also maintains its original function of grouping similar species together (Table 2). The IsiZulu language expert on the materials development team ensured that the extended names conform to IsiZulu language rules. The publication of these comprehensive frog species names initiates a process to put IsiZulu names on par with the developed Afrikaans and English names, which are published alongside scientific names in many South African wildlife books. Efforts to develop and standardise Afrikaans and English names of South African frog species were already underway in the 1970s (Jacobsen, 1978; Passmore & Carruthers, 1978; Van Dijk, 1978a, 1978b). Working towards standardised and comprehensive species names can help make communities aware of the biodiversity that exists in their immediate environment, especially for species that may not be fully expressed in the local language. The standardisation of IsiZulu names can also contribute to citizen science projects to ensure that non-scientists' conservation efforts are targeting the correct species because scientific names or popular English names may not be familiar to all non-scientists.

Setting guidelines for the extension of indigenous taxonomy, within the boundaries of both science and an African language, contributes to a systematic approach to language modernisation that Madiba (2001) highlighted. Furthermore, it moves closer to the realisation of the multilingual ambitions of South Africa's post-apartheid language policy with indigenous taxonomy guidelines that are applicable to other African languages in South Africa. By documenting frog names that are familiar to the speakers of the language and then developing the indigenous names to conform to scientific naming guidelines, the book extends the indigenous taxonomy with specific names for each of the 58 species. Without an understanding of taxonomy, this vernacular reading material would be less robust, for it would be overlooking the familiarity offered by indigenous names and specificity gained by extending the indigenous names.

Enthusiasm about the finished product leads to greater willingness to learn

One of the advantages of community-based and collaborative documentation of indigenous languages is multigenerational involvement, such as including both students and parents (Webb, 2004). Zululand locals showed eagerness to be involved in the development of the Zululand Frog Guide as early as the field research stage, despite their inhibitions towards frogs. This enthusiasm fostered learning about amphibian biology and presented the chance to dispel the misconceptions that affect the conservation of amphibians. In addition to having a book in their home language, the Zululand locals who were involved in the field research phase were appreciative that they were consulted about their knowledge of frogs prior to writing about frogs in the Zululand context. Once the book was published, it was delivered to schools in Zululand, and some of these schools sent letters of thanks to the authors to acknowledge receipt of the books. Even though the Zululand Frog Guide is specifically developed for one province, the book has also been bought by people from eight of South Africa's nine provinces. At the time of writing this article, the book had been read 2,712 times from the authors' ResearchGate (https://www.researchgate.net/) profile. The book was subsequently awarded and featured in news reports (Saayman, 2017; BizCommunity, 2019; Beautiful News SA, 2021). The evidence above mostly illustrates the enthusiasm about the book. To determine if the language accessibility of the book increased students' willingness to learn from it would require follow-up surveys to be carried out at the schools where the book was delivered. Here, we speculate that the communities' sentiments increased the likelihood of the book being embraced and thus a greater chance of engaging with the reading material. Based on previous findings, we might expect that use of African languages enables better engagement and increased participation in learning (Webb, 2004).

The process of developing the Zululand Frog Guide can be situated in a national agenda to support "identity reconstruction and innovation, human rights, sustainable development and democratization in South Africa and throughout the African continent" (Odora Hoppers, 2011, p. 388). Civic science, or public engagement in scientific knowledge production, not only bolsters trust in science but also supports efforts in sustainability when integrated with indigenous knowledges (Bäckstrand, 2011). The Zululand Frog Guide practices aspects of civic science and engages the local community in matters of ecological conservation. Furthermore, this approach responds to the challenges previously described by Prinsloo *et al.,* (2018). Instead of compromising scientific literacy by simultaneously learning English, communities use home languages and local ecology to develop languages for the life sciences. This case study demonstrates value in documenting Zululand fauna in the local language. Community members are engaged in the co-development of corpus about local wildlife. The product of these efforts, the Zululand Frog Guide, aims to serve as an impetus for the community to protect the species that were named and described as co-habitants of the immediate environment and instil pride in an African language. The next section addresses the value of community engaged documentation of indigenous knowledge systems, and how these efforts can advance the global scientific enterprise.

Global perspectives on postcolonial science and indigenous ecological knowledges

Language planning research and implementation, with corpus planning as a subset therein, share a history of international planning efforts and compromises based on ever-changing, socio-political power structures (Fishman, 2004). As postcolonial power structures continue to promote decolonised ideologies, there is also an increase of indigenous methodologies in various disciplines. In relation to language planning efforts, indigenous methodologies tend to be concentrated on social science research. There is a gap for how such methodologies could be extended to contexts of life, physical, and technical sciences (Smith, 2012) The Zululand Frog Guide is among examples of how to extend decolonized methodologies into both language planning and life sciences. We can find comparable examples in other parts of the world. For example, in Polynesia, Māori research their own value-practice systems using indigenous methodology and are executing indigenous language planning through revitalization projects (Smith, 2012).

Beyond shaping language planning research, Indigenous knowledge systems can shape how we understand science, the scientific process, and disciplinary boundaries (Nader, 1996). It is important that indigenous knowledge is extended into the classroom. Semali (1999) argues that "the curriculum [be] flexible enough to include space for indigenous literacy as part of local history, indigenous languages, metaphors, and folklore to nurture and support African identity" (pp. 316) without succumbing to rote memorization of facts. The challenges and opportunities of science learning in South African schools are two-fold—developing scientific literacy for local scientific advancement and English proficiency for global participation (Prinsloo *et al.*, 2018; Prinsloo & Harvey, 2020). A comparison can be made with the dualisms between uniqueness and internationalization, as described by Fishman (2004). The language of scientific discourse can benefit from projects like the Zululand Frog Guide by acknowledging the uniqueness of local language planning in concert with the inevitable internationalization of the binomial nomenclature of the life sciences. For example, local indigenous names can serve as alternatives to counter the global invasive labels applied to frogs sourced from South Africa and distributed around the world. An exemplar for this is using the IsiZulu name ‘idwi’ alongside references to the African Clawed Frog, *Xenopus laevis,* when teaching and learning about this globally-distributed species that is also a model organism in scientific research (Ovid & Phaka, 2022).

Concluding remarks

The Zululand Frog Guide as a case study demonstrates that it is possible, albeit time-consuming, to develop life sciences materials in an African language. A multidisciplinary team is required for the materials to be orthographically accurate, scientifically sound and also widely embraced by local language users. Life sciences experts, language practitioners with experience in life sciences terminology, and community members that use life sciences subjects in conversational contexts can collaboratively develop materials by bringing together their collective experiences of language use in different domains.

The book also demonstrates that IsiZulu has the technical capabilities for developing content in a comprehensive wildlife guide. Future research is required to understand the uptake of the Zululand Frog Guide and other academic IsiZulu publications. With continued corpus development, currently lead by the University of KwaZulu-Natal, IsiZulu may soon be developed enough to not require use of borrowed technical terms from other lexica. It is hoped that the corpus planning lessons learned through the development of this book can support the future development of IsiZulu life sciences materials in particular and other African languages in general. The integrative approach in the development of this material helped instil a sense of pride in the Zululand community. The lack of pride in African languages is often cited as a hindrance to their development. The general interest shown in scientific material that presents life sciences in an African language suggests that there may be increasing interest in learning in African languages. A positive perception coupled with interest and continued corpus development are positive results in language planning efforts. They contribute to the promotion of IsiZulu as a language of learning and teaching.

African languages theoretically have the capacity to function as media of instruction in education, but in practice, they have not been adequately adapted and standardised to function effectively in formal educational contexts (Webb, 2004). Efforts like the Zululand Frog Guide can contribute to adapting and standardising African languages for life sciences education. Given the minimal use of borrowed words for this technical life sciences material, IsiZulu has proven to be capable of functioning effectively in formal education. Significant progress has been made in adapting and standardising IsiZulu to a point where it can be used for teaching and learning in an institution of higher education (i.e., University of KwaZulu-Natal). The Zululand Frog Guide contributes to IsiZulu corpus development, specifically with guidelines for compiling a comprehensive list of IsiZulu names for South Africa's herptile species (Phaka *et al.*, 2019). The lessons learned about language planning processes for developing this technical material are applicable across different languages.

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Funding details

Financial support for Fortunate Mafeta Phaka was provided the National Research Foundation (UID: 114663), North-West University, and the Flemish Interuniversity Council (VLIR-UOS) Global Minds program (Contract Number: R-9363) and Youth 4 African Wildlife NPC.

Disclosure statement

No financial interest or benefit will arise from application of this work.

Biographical note

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Dax Ovid is currently a biology education postdoctoral researcher in the Department of Biology at San Francisco State University. Current research includes integrating postcolonial frameworks in science education, identifying challenges impeding systemic pedagogical innovation in the sciences, and investigating inclusive practices in higher education that foster belonging. Ovid's research aims to expand the defining features of 'being a scientist' in the 21st century to be more inclusive for current and future scientists.

Ovid received a Ph.D. from the Department of Integrative Biology at the University of California, Berkeley.

Chapter 7.2

Idwi, *Xenopus laevis*, and African Clawed Frog: teaching Counternarratives of Invasive Species in Postcolonial Ecology.

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Adapted from: *The Journal of Environmental Education* (2022)

https://doi.org/10.1080/00958964.2022.2032564

Abstract: This article presents a Pedagogical Framework for Invasive Species to shift how we understand, teach, and study invasive species, especially when people are responsible for their expansion into new ecosystems. The focus is on a species originating from countries in Sub-Saharan Africa that humans extracted and introduced in certain regions of the Americas, Europe, and Asia: *Xenopus laevis*, African Clawed Frog, or Idwi in the Zulu language. This article re-introduces the frog Idwi through lenses of de/post-colonial theory, Indigenous studies, and Critical Race Theory to create counternarratives. Through a popular press analysis, the article uncovers how humans in colonial contexts extracted species from de/colonizing spaces to export to other regions of the world. When the frogs were profitable, the entrepreneurs who exported them were valorised. However, once seen as invasive, the frogs were targeted with xenophobic projections. This article foregrounds counternarratives that challenge and critique the universal application of the "invasive species" label.

Keywords: Postcolonial theory, Decolonial studies, Indigenous studies, Ecology, Invasive species

Introduction

Consider how environmental science educators and researchers might approach the topic of invasive species differently when the relationship between culture and a species are taken into account along with social inclusion and justice. Instead of focusing on the ecological harm that "invasive" species cause to "native" ones, this article centres the story of a species that has been labelled as universally invasive. To tell this story and to model possible counternarratives, this article explores a series of questions. Firstly, what was the geographical site of origin for this species? How is this species named, described, researched, and recognized at the site of origin? How might we, as proponents of environmental education, consider the cultural value and scientific utility of certain "invasive" species? Further, how might we consider the intrinsic value of non-human species, especially those that are labelled as "invasive"? Over the course of history, who has benefitted from the introduction of this species? What social structures enabled this biological extraction? Lastly, how might we conceptualize counternarratives for invasive species more broadly?

Using these guiding questions to study one invasive species, we propose a Pedagogical Framework for Invasive Species Counternarratives (see Table 1). The focal species for this article is a frog that was extracted from multiple countries in Africa and imported into the United States (U.S.), where it is now labelled as invasive. Importation into the U.S. is an invasion pathway of this frog species hence this study's choice to use the particular country as case study. This study aims at "internationalising, indigenising, decolonising, and Africanising" the curriculum – educational concepts that are explored in the South African context (Le Grange, 2018), which is one of the frog's sites of origin. From the voyages of 19th Century European frigates to those of 20th Century U.S. entrepreneurs, this article explores the patterns of imperialism, de/colonization, and corresponding political upheavals that neglected to regulate the extraction and trade of this species. We consider how the history of one frog species can be understood as a microcosm of colonization and exploitation, and we propose how we might start to acknowledge issues like this in environmental education.

Table 1. Pedagogical Framework for Invasive Species Counternarratives

Identify a focal species
What are the geopolitical boundaries of the school site throughout history?
What are the different regions/countries/cultures of origin for students and their ancestors?
What anthropogenic invasions with nonhuman organisms have taken place in your site of geographical relevance? Which organisms are obvious in your surroundings? Not so obvious?
Foreground counternarratives of the focal species
Focusing on one organism, what is the history behind its given names?
What is the site of origin of the nonhuman organism of focus? What is the ecosystem like of the site of origin (e.g. predators, climate, food web)? What writings are there from the community of the site of origin about this species?
How might folk taxonomy, Indigenous Knowledge Systems, and local research/perceived value serve as a counternarrative for this organism? What are alternative views of this species to counter the invasive tag?
What is the species' value to medical and/or biological science (at a global level) as a study organism? What is the scientific value in addition to the social/cultural significance? What about the intrinsic value of the species, in and of itself?
Critique the "master narrative" of the focal species
How do people from these sites describe the nonhuman organisms and their site of origin? How are the humans responsible for the introduction of this organism described (or not)? Is the focus on environmental and/or economic impacts? How might we consider socio-historical forces (e.g. colonialism and orientalism)?
What is the distribution of the nonhuman organism following anthropogenic invasion, extraction, and dissemination?
Is there a predicted expansion/migration of the introduced organism with a changing climate? If so, how might the presence of the introduced organism affect other organisms in these sites?
Shift the language and focus of the focal species
What are our pre-existing experiences and assumptions with the terminology of "invasive" species?

What are the ethical implications of preventing, monitoring, or controlling anthropogenic invasions with non-human organisms?

How might Indigenous Knowledge Systems and community partnerships inform how we talk about and respond to "invasive" species?

With the frog as an example, this article explores how one might address the topic of invasive species in a decolonizing curriculum – decolonis-ing because the process is on-going and iterative. To dismantle the frog's "invasive" label and apply our proposed framework (Table 1), we weave together multiple counternarratives. In curriculum studies, the "master narrative" implies that white academics are the foundation of the field itself (Au *et al.,* 2016). One could even trace the genesis of scientific education as we know it to Immanuel Kant and the European Enlightenment (Nejadmehr, 2020). However, one might challenge this "master narrative" in two ways: (1) by foregrounding contributions made by scholars and communities of colour and (2) by critiquing the "master narrative" from within.

To foreground contributions made by scholars and communities of colour, we challenge the "master narrative" of Idwi, *Xenopus laevis*, and African Clawed Frog (three names for the same animal) by first exploring the history and process of naming the focal species. Next, we describe the species' site of origin along with their innumerable applications in global research. We ground ourselves in the socio-cultural context of the frog's site of origin by highlighting scholarship in folk taxonomy, Indigenous Knowledge Systems, and what intrinsic value could be associated with Idwi.

After describing these counternarratives, we further critique the "master narrative" from within by investigating the anthropogenic invasions that displaced tens of thousands of frogs from their site of origin. To do so, we conduct a popular press analysis of newspaper articles over the past century. We identify instances that document the people responsible for the extraction and introduction of the frog. Further, we analyse the language ascribed to the frog – which is ethnicised and xenophobic –once it becomes unprofitable to export them and research reveals them to be an ecological threat.

To foster responsible and responsive changes in environmental education, the present article offers counternarratives of an “invasive” species, Idwi, that can shape how we think, study, and teach about such species. We propose a curricular shift for invasive species which aims to selectively foreground counternarratives and challenge the “master narrative.” Each species has a site of origin and its own socio-cultural relationship with the community there. Each species may have value in medical and scientific research at a global level and may also have regional ethnobiological significance. Further, one must consider the intrinsic value of organisms, beyond their anthropocentric utility. Lastly, humans are often responsible for dispersal of species beyond their native distribution. Collectively, these counternarratives serve to challenge the universal label of invasive. To inform these counternarratives, this article draws from three theoretical and phenomenological frameworks: de/post-colonial theory, Indigenous studies, and Critical Race Theory.

Theoretical frameworks

A pedagogical comparative framework developed by Vanessa Andreotti (2011) informs the analysis of our case study in invasive species. Andreotti’s (2011) education science expertise provide and ideal lens through which to discuss shortfalls and speculate on improvements teachings about invasive species. Although Andreotti’s (2011) framework was found to be most suitable for the current study’s purpose, other literature is also relevant to this study and these are the works of Quijano (2007) and Mignolo (2009) which question whether modernity can exist without considering coloniality. In a thorough review of actionable postcolonial theory in education, Andreotti offers a synthesis for the lenses of Postcolonial theory, Decolonial studies, Indigenous studies, and Critical Race Theory. Importantly, Andreotti reminds us of the complexities, nuances, and heterogeneity of scholars in these fields while modelling possible applications of these theories in education. Below, we summarize the comparative pedagogical framework offered by Andreotti and describe how each lens is applied in the present study.

The first theoretical framework that drives this study is de/post-colonial theory. Postcolonialism acknowledges the impacts of colonialism as more than just geo-political dominance but also as an imposition of certain ways of thinking, ranging from the language of instruction in schools to the epistemic superiority of the Western Enlightenment. Imperialism has been described as, "a knowledge project as a way to domesticate a people, control their history and distort their representation through canons of knowledge" (Leonardo, 2018, p. 7). In general terms, Andreotti (2011, p. 59) describes the problem addressed through a Postcolonial lens to be, "European colonialism based on Enlightenment humanism and its legacies." The problem as seen through a Decolonial studies lens is premised on, "[the] Darker side of Eurocentered modernity: violent appropriation and exploitation of capitalism." The agents of change for Postcolonial theory are "scholars tackling colonialism within academia and society and reaching out to the Other" and for Decolonial studies are "scholars from the global periphery opening spaces for uncontested peripheral knowledges" (Andreotti, 2011, p. 59). The authors of this article are positioned accordingly. Even with these important distinctions between the lens of Postcolonial theory and Decolonial studies, there are shared values of anti-colonial and anti-imperial objectives within the scholarship for both 'post-' and 'de-' colonialism (Leonardo, 2018, p. 15). Given the positionality of the authors of this article and the shared values for each theory, we opt for a de/post-colonial theory here. The species of our present case study were extracted from various decolonizing African countries, going through a period of transition from colonial rule. They were a part of a series of large-scale biological extractions that occurred during the early stages of decolonization, as several African countries transitioned through civil conflict and liberation. It is well-documented that "many Europeans set off for the colonies because they [could] get rich over there in a very short time…" (Fanon, 2008, p. 88). However, an investigation of how the popular press depicted people who imported species and profited from this biological extraction *during decolonization* is yet to be considered through a de/post-colonial lens in environmental education.

The second framework informing the present study is Indigenous studies. Andreotti (2011, p. 59) lists problems explored through this lens, including but not limited to, "[t]erritorial occupation; genocide; continuous epistemic, geographical, and economic subjugation; [and] pathologizing practices." Alongside Indigenous teachers and academics are, "critics decolonizing their contexts and seeking to mainstream indigenous knowledges without domesticating them." (Andreotti, 2011, p. 59). Education scholars in the United States are providing materials to teach U.S. history that centres the place, presence, and perspectives of Indigenous Peoples (e.g. Schmitke *et al.,* 2020). In environmental education, there are possibilities emerging from international Indigenous perspectives as well (e.g. Carvalho *et al.,* 2020). Of relevance for the present study, Ngũgĩ wa Thiong'o described not only the struggle of preserving Kenyan and East African languages, but he also went on to advocate for a loyalty to Indigenous values at the centre of the syllabus (Thiong'o, 1981, p. 94). However, examples are still needed of how Indigenous languages and values could be centred in environmental education topics related to introduced species. Using the lens of Indigenous studies, this article acknowledges the epistemic subjugation through naming a species taken from its site of origin and also highlights scholarship in folk taxonomy, offering a mechanism of centring Indigenous values at the centre of the syllabus.

Lastly, the framework of Critical Race Theory suggests that storytelling and counter stories can serve to challenge racism and colourblindness (Andreotti, 2011). Emerging from legal scholarship (Bell, 1995; Crenshaw, 2010), then explored in the field of education (Ladson Billings and Tate, 1995), and recently subjected to a litany of social criticisms and policy regulations in the context of U.S. education (Copland, 2021), Critical Race Theory invites us to consider what systems reinforce observable social inequities that persist – and can be predicted by – the social construction of race. Here, we investigate how whiteness and objectivity are emphasized in historical popular media to valorise white entrepreneurs and sterilize the same species that, when found outside the laboratory, becomes the object of ethnicised and xenophobic projections. One may wonder how counternarratives in environmental education might disrupt these socially-constructed projections on invasive species.

These three frameworks aim to foreground subaltern and decolonizing methodologies originating from the communities of interest and to challenge the assumed values of the dominant narrative of Western discourse. These theories in action may be useful for, "those [translators and catalysts] in-between political communities who both benefit from and are critical of ethnocentric global hegemonies and who aspire to use their privilege/lines of social mobility in the work against the grain of ethnocentrism and hegemony" (Andreotti, 2011, p. 8). For educators and researchers in environmental education, we can begin to acknowledge the historical harms of biological extraction that we continue to benefit and profit from today, from museum displays to research specimens. Further, we can foreground the local, community-based methods used to engage people in environmental education around the world, especially in areas subject to the impacts of imperialism.

Before delving into the historical analyses informed by these theoretical and phenomenological frameworks, the next section offers definitions and a critical examination of the term ascribed to the species of our study and to many other translocated species in the world.

Defining invasive

In·va·sive /inˈvāsiv/ *adjective* (especially of plants or a disease) tending to spread prolifically and undesirably or harmfully. late Middle English: from obsolete French invasif, -ive or medieval Latin invasivus, from Latin invadere (see *invade*).

In·vade /inˈvād/ *verb* (of an armed force or its commander) enter (a country or region) so as to subjugate or occupy it. late Middle English (in the sense 'attack or assault (a person')): from Latin invadere, from in- 'into' + vadere 'go'.

The Global Invasive Species Database (GISD, 2020) lists "some of the **worst invasive species** as determined by international experts and analysis of datasets to identify species with serious impacts on biological diversity and/or human activities" [bold added for emphasis]. GISD, funded by a limited number of countries (United States, United Arab Emirates, New Zealand, Taiwan, United Kingdom, France, and Italy), gives a description of the "worst invasive species" that applies a universal label to a species as such, disregarding the potential value of species in their sites of origin. The criteria emphasize negative impacts on biodiversity and human activities, so they may exclude cases where people benefit from introduced species. Importantly, previous work demonstrates there is a geographical bias in invasive species research, with less research on the impact of introduced species in the continents of Africa and Asia (Pyšek *et al.*, 2008). Future plans of GISD are to create a Global Register of Introduced and Invasive Species (GRIIS), offering "country-wise validated, verified and annotated inventories of introduced and invasive species," which may help to keep track of these geographical discrepancies (GISD, 2020).

There are "widely divergent perceptions of the criteria for 'invasive' species" among invasive species researchers (Colautti & MacIsaac, 2004). This observation led to the development of descriptive stages to be applied biogeographically instead of taxonomically;

however, the focus for each stage is based on how successfully a species is establishing itself in a certain context. In this proposed research protocol, twelve terms with nuances of how the species arrived (Adventive, Alien, Exotic, Foreign, Immigrant, Imported, Introduced, Nonindigenous, Transferred, Translocated, Transplanted, and Transported) are collapsed into a single term – "Stage I-V" (Colautti & MacIsaac, 2004). Further, descriptive terms that offer insights into public perceptions of the organism (e.g. Noxious, Nuisance, Pest) are not defined by the model (Colautti & MacIsaac, 2004). While this is useful for creating a common discourse for the study of the *propagation* of invasive species, it does little to advance our understanding of the circumstances around the extraction of those species in the first place. Regardless, inconsistent terminology persists in invasive species research, likely due to the lack of agreement amongst scientists, older publications, and the creeping emergence of new definitions for the same terms over time (Colautti & Richardson, 2009). The inevitability of terminological pluralism leads some scientists to argue that we should embrace the variety of terms as a reminder for the contextualism of invasive species research (Heger *et al.*, 2013).

Among scholars in Indigenous Knowledge Systems, there are various perspectives on invasive species as well. For example, one perspective is that, "[t]o most people, an invasive species represents losses in a landscape, the empty spaces to be filled by something else. To those who carry the responsibility of an ancient relationship, the empty niche means empty hands and a hole in the collective heart" (Kimmerer, 2013, p. 150). The responses of Indigenous nations in North America to invasive species, "include all the generalized steps taken by settler governments and NGOs plus some unique, culturally informed strategies" (Reo *et al.*, 2017). As another example, fieldwork with Sault Ste Marie and Bay Mills tribes revealed that some tribal members saw invasive plant species as something to be eradicated in partnership with Western scientists, while other tribal members saw the arrival of these species as an opportunity to explore new uses (e.g. culinary) for the species (Reo & Ogden, 2018). There is a recent scholarship advocating for invasive species management to consider Indigenous Knowledge Systems, emphasizing the importance of consulting with tribal communities in environmental policy and ecological management more broadly (Mattes & Kitson, 2021; Newman, 2021). The diverse, context-specific perspectives of Indigenous Knowledge Systems can offer insights for responding to invasive species.

Even with divergent perceptions of what counts as an invasive species or how humans might to respond to their propagation, researchers have used the ability to identify invasive species as an objective measure of one's knowledge of nature across ages and contexts (Boshoff *et al.,* 2008; Byrne *et al.,* 2020; Cordeiro *et al.,* 2020; Crall *et al.,* 2013; Preston & Fuggle, 1987; Schreck Reis *et al.,* 2013; Skukan *et al.,* 2020; Zeng *et al.,* 2021). The prevalence of invasive species identification scholarship, as it relates to the public understanding of science and citizen science research, warrants attention. If the focus is on identifying an invasive species and its ecological impact, we miss the opportunity to learn the instrumental and intrinsic value of the species in different contexts or how humans played a role in their introduction. To follow this critique of what is "invasive," the next section explores the name(s) of the focal species.

Naming the frog

The process of naming a species offers an example of how imperialism and colonialism impacts our perceptions of species to date. The "master narrative" in scientific nomenclature is that European naturalists in the Age of "Discovery" were the first to name and categorize each organism they collected. However, recent investigations highlight the value of understanding Indigenous taxonomy. We propose learning and teaching the Indigenous names of "invasive" species from their site of origin to challenge this "master narrative."

To begin, what is the “master narrative” of the naming of the frog? The French naturalist Daudin (1802, p. 82) is often cited as naming the frog *Xenopus laevis*; however, a review of the original text reveals that Daudin labelled the frog as *Bufo laevis*. According to Frost (2020), the earliest recorded use of *Xenopus laevis* was an Austrian zoologist, Franz Steindachner (1867). *Xenopus laevis* is one of thousands of species collected in global voyages of the sailing vessel *Österreichischen Fregatte Novara*, which was made possible by the Imperial Academy of Sciences in Vienna (Novara Expedition *et al.,* 1867). The Novara voyage was organized less than a decade after Darwin’s publication On the Origin of the Species (1859) and less than a decade before the reorganization of Vienna’s Imperial Royal Natural History Court Museum, by Emperor Franz Joseph I (Beck & Joger, 2018, p. 515). The natural history museum is one example of many national museums established throughout Europe in the 19th century (Simmons, 2016). However, this practice of collecting organisms for research, private collections, and museums was unregulated biological extraction – a form of epistemic violence and injustice enacted by and for museums of colonizing nations (Vawda, 2019). Not only were specimens collected, but they were also named.

Binomial names derived through Linnaean taxonomy have a notable history. They are valorised as an international system that fosters communication among scientists (Notton *et al.,* 2011) yet also inextricably linked to racist hierarchies and ethnic racism (Kendi, 2017, p. 153; Roberts, 2011, p. 252; Washington, 2006, p. 83). While it is important to not project anthropocentric social issues such as racism on biological methods at-large such as classification, the emergence of the method must not be unilaterally accepted as objective and void of social implications. The myopic emphasis of scientific communities on Linnaean taxonomy also deprioritizes Indigenous names, even though Indigenous names have almost ubiquitous chronological precedence and can convey in-depth knowledge relating to form, uses, distribution, and ecology of species (Gillman & Wright, 2020).

Given this "master narrative" in naming the frog, how might one challenge it? One of the names for our focal species, used locally in the site of origin in Southern Africa, was only recently documented in a globally accessible format. Phaka *et al.*, (2019) published the folk taxonomy, including Indigenous names of some South African frogs. From semi-structured interviews of habitants of KwaZulu-Natal's Zululand region, Phaka *et al.,* (2019) reported that, "the local name Idwi corresponds perfectly with *Xenopus*."

In addition to Idwi, *X. laevis* in the site of origin is also known as Common Platanna, African Clawed Frog (English), or Gewone Platanna (Afrikaans). "*Xenopus*", a word of Greek origin, means strange foot in reference to the odd appearance of their clawed feet. The Latin word "*laevis*" means smooth in reference to the frog's slimy skin (Du Preez & Carruthers, 2017). Platanna, an Afrikaans name of Dutch origin, refers to this genus' flattened hands and feet (Du Preez & Carruthers, 2017). "Idwi" is an IsiZulu (or Zulu language) word whose etymology is still undetermined (Phaka *et al.,* 2019). Investigations of Indigenous taxonomy in South Africa are lax, thus the etymology of many Indigenous species names is unknown, and other Indigenous names remain unrecorded.

Knowledge of Indigenous taxonomy has been enabled by local community engagement with university partnerships. These partnerships must be built on trust to support the co-creation of local knowledge bases (Mbah, 2019). Community-based efforts to document local frog species in Zululand in IsiZulu has culminated in a bilingual guide on local frogs (Phaka *et al.*, 2017). This initiative required field work, community partnerships, and a multi-disciplinary team to produce South Africa's first comprehensive life sciences reading material about frogs in one of the country's Indigenous languages (Phaka & Ovid, 2021). Citizen science approaches to environmental education can reveal the challenge(s) of language(s) (Rodrigues *et al.,* 2020). Such local initiatives can be included in environmental education curriculum to deconstruct the global "invasive species" label. The documentation of the frog's name, Idwi, in the language of its local context highlights the importance of community-based research and citizen science. It is worth noting for how many species we may never get to know their names in the Indigenous languages of their local context.

Take a moment to reflect on the history of naming this frog; *Xenopus laevis,* African Clawed Frog, Gewone Platanna, and Idwi. Next, we consider the frog's site of origin.

Idwi's site of origin

The distribution of the *Xenopus* genus is often framed as "throughout Sub-Saharan Africa" (Blackburn *et al.,* 2019). Various African Clawed Frog species occur in most, if not all, of the countries south of the Sahara Desert (Channing & Rödel, 2019). *Xenopus laevis* is among the most widespread species of the *Xenopus* frogs with a wide distribution within South Africa along with occurrences in other Southern African states including Botswana, Lesotho, Malawi, Mozambique, Namibia, Swaziland and Zimbabwe (Channing & Rödel, 2019; Du Preez & Carruthers, 2017; Minter, 2004). Southern Africa has a rich amphibian diversity due to its diverse topography, habitats, and climatic conditions where rainfall increases from west to east (Du Preez & Carruthers, 2017). Within this Southern African distribution, Idwi is reported to have wide habitat tolerance (Du Preez & Carruthers, 2017) including disturbed habitats (Measey *et al.,* 2012), human-made waterbodies, and eutrophic waters (Minter *et al.,* 2004). *Xenopus laevis* is an ecologically important species for South African wetlands due to its abundance and voracious predation. It also gets preyed upon by larger vertebrate species including mammals and birds (Minter *et al.,* 2004). The species scavenges (Minter *et al.,* 2004) and preys on terrestrial organisms (Measey, 1998). Idwi's wide habitat tolerance poses a threat to native restricted species. In South Africa, the endemic *X. gilli* is being displaced from its range by Idwi (G. Measey & Davies, 2011; Picker, 1985).

Exports of *X. laevis* from South Africa, prompted by its usage in laboratories, first went to the United Kingdom and then to the rest of the world (Measey *et al.,* 2012). Laboratories across the world keep living populations of *X. laevis* to such extents that it is the most widely distributed amphibian (Measey *et al.,* 2012). This frog's history as a laboratory subject is linked to its usage as a human pregnancy test around the 1930s (Gurdon & Hopwood, 2000) and as a model research animal (Van Sittert & Measey, 2016). The global pet trade is also a contributor to Idwi's dispersal out of Africa (Weldon *et al.,* 2007). Colonization of other continents by *X. laevis* is human-assisted, but at the site of origin, this species is expanding its native distribution through local invasions resulting from a combination of natural dispersal and human-assisted translocation for research and training purposes (G. Measey *et al.,* 2012; G. Measey & Davies, 2011; Van Sittert & Measey, 2016). Later in this article, we investigate the people responsible for dispersing Idwi beyond its native distribution range. In the subsequent section, we consider the frog's global scientific significance.

The value of Idwi to scientific research at a global level

One of the earliest research articles into global invasions of Idwi was published in 1996 (Tinsley & McCoid, 1996). *Xenopus laevis* research in its native country of South Africa encompasses various subject areas in addition to invasion biology. A search on the Scopus database for *X. laevis'* original research articles focused on South Africa returns results spanning at least 15 subject areas including Engineering, Planetary sciences, Neuroscience and Pharmacology. Globally, Idwi is considered a model amphibian and one of the most studied organisms alongside fruit flies, mice, nematodes, and zebrafish (Measey *et al.,* 2012).

Idwi is a preferred model for research in developmental, molecular, and cellular biology (J. B. Gurdon, 1996; Lee-Liu *et al.*, 2017; Tseng & Levin, 2008). For developmental biology in particular, research on *X. laevis* has received high honours from the scientific community. John B. Gurdon and Shinya Yamanaka shared the 2012 Nobel Prize in Physiology or Medicine for their cell development research on this frog, showing that mature cells can become stem cells (Johnson & Cohen, 2012). Idwi's importance in developmental biology extends to it being a model for studying disorders such as Wolf–Hirschhorn syndrome (Lasser *et al.*, 2019) and retinal degenerative diseases (Vergara & Del Rio-Tsonis, 2009). This frog has also served as a model for research into genome editing (Park *et al.*, 2017) and ethology (Karplus *et al.*, 1981; Rothman *et al.*, 2016). *X. laevis* has been a subject of parasitology since the 1900s and at least 25 genera of parasites have been associated with this frog (Tinsley & Kobel, 1996). More recently, *X. laevis* has been dubbed "The UberXL of nematodes" in reference to seven previously unrecorded nematode species for which the frog acts as a reservoir within its native range (Schoeman *et al.*, 2020). Additionally, findings from studies of *X. laevis* have been used to explore possible treatments in humans, such as electrical stimulation of the immune system to manage COVID-19 (Allawadhi *et al.*, 2020).

Other scientific counternarratives exist for *X. laevis*, but there are too many to outline in one article. What is notable is that a species universally labelled as "invasive" in certain contexts of environmental education, yet it has broad scientific applications, beyond its ability to survive in a wide range of habitats that it has been introduced to. The frog also has ecological relevance in its site of origin, South Africa, contributes to our understanding of Indigenous Knowledge Systems, and has an intrinsic value outside of anthropocentric utility, as described in the next section.

Folk Taxonomy and Indigenous Knowledge Systems as Counternarratives

Beyond the modern sciences, there are several counternarratives that may serve to dismantle the universal "invasive" label of the frog. Here, we consider counternarratives that centre the significance of the frog in ethnobiology, folk taxonomy, culture more broadly, and intrinsically – in and of itself.

For scholarship in ethnobiology and folk taxonomy, *X. laevis* is proving to be a valuable species. Ethnobiology focuses on the environmental and cultural relationships of humans and non-humans. Idwi has been used to increase understanding of behavioural observations, rooted in Indigenous Knowledge Systems (Phaka *et al.,* 2019). For examples, some "cultural misconceptions" may be attempts to explain observed animal behaviour without knowledge of the organism's biology. A common myth about Idwi was that the frog would, "fall from the sky during torrential rain" (Phaka *et al.,* 2019). This observation that Idwi are found outside their usual aquatic boundaries during heavy rainfall corresponds to their behavioural response to venture overland to other ponds as a part of seasonal dispersal (Measey, 2016; Villiers & Measey, 2017). Ethnobiological investigations of Idwi also provide evidence that the more visible a species is to a cultural group the more likely it is to have a species level indigenous name – when indigenous names are usually generic. Studies in folk taxonomy explore how organisms are named and classified across cultures. For the most part, folk taxonomy is not documented or recognized outside the culture in which it is understood (Phaka *et al.,* 2019). In this case, Idwi is the Indigenous uninomial equivalent to the scientific taxonomy of the genus *Xenopus* and the family Pipidae (Phaka *et al.,* 2019). Additional studies in folk taxonomy can challenge the universal label of "invasive" by selectively foregrounding the name of the species in the vernacular of the species' geographical site of origin. This serves as a reminder that there is a place where this species is not "invasive." Further, in this place, Idwi and other frogs were the subject of a partnership between scientists and Indigenous communities to develop a bilingual field guide, resulting in a book in IsiZulu and English on South African frogs (Phaka *et al.*, 2017; Phaka & Ovid, 2021). Such partnerships in ethnobiological investigations increase understanding of cultural perspectives of South African amphibians and add to the country's small knowledge pool of ethnoherpetology. Further, this community-based collaboration could serve as a model for future studies in ethnobiology and folk taxonomy.

Counternarratives might also include how Idwi's cultural significance extends to one of South Africa's earliest inhabitants, the Khoi and San communities. KhioSan drawings resembling *Xenopus* have been found among the rock art in the Drakensberg, South Africa (Thorp, 2013). The interpretation of these *Xenopus* drawings is that they are linked to human reproduction (Thorp, 2013, 2015). It is, however, not possible to determine the precise *Xenopus* species depicted in the art as the various Clawed Frog species have similar morphology. This interpretation of a traditional culture is interesting, for a *Xenopus* species (*X. laevis*) also has significance to human reproductive health in modern culture (J. Gurdon & Hopwood, 2000).

Beyond the ethnobiological and cultural utility of the frog, counternarratives might also consider the intrinsic value of this non-human species. To explore this concept, one may consider previous studies on how humans have engaged with the perspectives of non-human species. For example, emerging scholarship in animal cultures may offer a more animal-centred perspective (Montford & Taylor, 2020). Performative acts of "minor players," such as young people pretending to be an animal labelled as invasive, are yet another approach to exploring human-animal relationality (Taylor, 2020). Even African literature – written as a first-person narrative with animals as the protagonists – may offer creative insights into the lived experiences of non-human species (Mwangi, 2019). Although this might be perceived as anthropomorphism, Mwangi's interpretation reframes narrative agency as setting the conditions of possibility for recognizing the intrinsic value of animals, beyond their instrumental value for humans. In the context of Indigenous studies, the tension of maintaining a "bi-epistemic negotiation within settler societies is often marked by the paradox of the need to resist the dominant epistemology while fighting to revive and protect indigenous epistemologies *through the dominant epistemology itself*" (Andreotti, 2011, p. 68). One might imagine a parallel with the tension between seeking to understand and communicate the intrinsic value of non-human animals and yet being confined to an anthropocentric discourse in environmental education. This tension highlights a need for Indigenous epistemologies to inform such counternarratives.

So far, this article has aimed to challenge the "master narrative" (Au *et al.*, 2016) of invasive species by introducing counternarratives stemming from the species' site of origin. After foregrounding Indigenous Knowledge Systems, the remainder of this article aims to dis-orient the western knowledge regime with a self-critical approach (Nejadmehr, 2020). In the context of invasive species, we describe the narrative of biological extraction to divulge the underlying cause of the frog's global dispersion. By using historical evidence in mainstream U.S. media as a symptom of western ideology, we critique western thought in efforts to decolonize the curriculum on this and other invasive species.

Analysing press coverage of *Xenopus laevis*

Newspapers have been described as a continuous reflection of public attitudes and concerns with content shaped by consumers (Montford & Taylor, 2020). In previous studies, the popular press has been a resource for studying human-animal relationships (Lloro & Hunold, 2020; Lloro-Bidart, 2017). From advice columns to op-eds, popular media analysis can offer insights into how a given species is represented in public discourse over time. Additionally, one might infer what socio-political structures enabled (or even encouraged) the extraction and redistribution of species that become invasive.

To investigate how public perceptions of *X. laevis* were shaped over the course of the century, we examined newspapers in one of the largest online repositories, archiving over 21,600 historical newspapers based mostly in the United States (newspapers.com). Using the search term "Xenopus" yielded 799 results, with the year of publication ranging from 1890 to 2021. If a search result met the inclusion criteria, it was archived through an extension for open-source citation management, Zotero. Excluded search results were reprints of the same article in different newspapers (*n* = 292); duplicate scans of the same newspaper (*n* = 230); ads/announcements for job postings, research talks, and grants or degrees awarded (*n* = 154); search results about a different *Xenopus* species (*n* = 18); or articles that only mentioned *Xenopus* once on a list of other animals and/or research topics for featured scientists (*n* = 27). The remaining 78 articles described *X. laevis* in greater detail for thematic analysis. The next section summarizes major themes emerging from this qualitative approach, based on the press coverage descriptions of *X. laevis*. Major themes included: (1) biological extraction of the frog from decolonizing African countries, (2) scientific and educational utility of the frog, and (3) problematization of the frog as an invasive species.

Biological extraction of Idwi by entrepreneurs in decolonizing African countries

Critiquing the "master narrative" (Au *et al.*, 2016) in a site of the frog's introduction (in this case, the U.S.) could inform societal counternarratives by describing the human activities resulting in Idwi's worldwide dispersal. Idwi has been used for pregnancy tests in hospitals, pets in aquaria, and tools for dissection and experimentation in classrooms. It eventually became labelled as an invasive species. Public perceptions of *X. laevis* and their site of origin can be deduced from the language choice in U.S. newspapers.

During times of biological extraction for their instrumental value, the frog was described with anthropomorphic and positive language. For example, reporting on the

London Zoo describes the frog as an “African ally” to other frogs at the zoo, and as an "expert swimmer” with “an excessive fondness of water” (Beddard, 1895). As they were extracted and imported, the frogs are said to be “an exotic variety, rare even in their native Africa” as one article describes how “2000 very lively frogs” arrived by ship and were “greeted” by the “dapper” entrepreneur Jay E. Cook (Banner, 1947). Another reporter writes, “Nine big and very important frogs are getting the best of care at McKennan Hospital. They have their own special multiple compartment tanks…and are given specially prepared raw meat twice a week–all this because they are to help to answer some mighty important questions. They are to be used in tests for pregnancy…” (Bechtold, 1948). Several articles directly associate the usefulness of the frog to anthropomorphic language, such as naming the frog Gertrude and referring to her as “a martyr for science” (Bothwell, 1949), reassuring readers that the pregnancy tests “do not harm them in any way” (Browne, 1947), calling the frog “a very, very smart little feller” (Comfort, 1945), and even using first-person language in photo captions, such as “I’m *Xenopus laevis*…and I’m the best thing going for pregnancy tests” (R. Clark, 1961).

In addition to the anthropomorphic language ascribed to the frog, several newspapers feature white U.S. entrepreneurs extracting frogs from decolonizing African countries and shipping them around the globe. One article titled “Clawed-Toad Capital of America” (Walker, 1952) begins, “It’s a long haul from the upper reaches of the Limpopo, the Congo, and the Zambesi rivers in Africa to Baltimore county, yet in a specially designed cellar...10,000 female clawed toads from the Dark Continent are quite at home.” The article claims that just “[b]y communicating with the Government of the Union of South Africa,” the entrepreneur Jay E. Cook was able to import 3,000 frogs. Cook, featured again in an article at 92 years old, reported selling frogs to “8,000 customers from Alaska to Argentina, and as far west as Guam” (Kobren, 1978), without mention of its subsequent ecological impacts.

Xenopus laevis could be used as a pregnancy test by injecting urine into the frogs (Associated Press, 1946; Bechtold, 1948; Golden, 1949; Wolfe, 1955), thus driving demand from research labs and hospital. Imports came from multiple de/colonized countries in Africa such as “Abyssinia” (No author, 1948), an exonym for Ethiopia. Eventually, the demand for frogs declined with the development of chemical pregnancy tests. At this point, John B. Aderhold was praised for offering “free frogs for science” (No author, 1972). However, the decline in demand did not stop persistent U.S. entrepreneurs from taking advantage of political upheaval in recently decolonized African states. Entrepreneur Roger Ruvell, “a handsome, curly haired six-footer” from Chicago, is reported to catch animals with “a Dahomeyan assistant” (Zeitlin, 1967). Dahomey was the name of the West African French colony, which became the decolonizing country of Benin. His original plan was to catch frogs, “but Dahomeyans are reluctant to catch them.” The assistants were paid 25 cents to $1 depending on the species. “Local python priests” were described as presenting pythons to Ruvell as “gifts, the idea being they could not sell the sacred critters.” An unnamed villager is quoted at the end of the article: “I know that you take the frogs and send them to France to put them in tins...then you will sell them to us to eat. Well, we don’t eat frogs.” France began the process of decolonization from Dahomey in the late 1950s, and political strife followed from the subsequent decade. Roger Ruvell and others like him took advantage of this political strife to extract biological resources, shipping reptiles and amphibia from their site of origin to other countries by the thousands. Ruvell is described in the headline: “Rhodesia man exporting frogs” (Canadian Press, 1975) in the middle of the Zimbabwe War of Liberation—a civil conflict from 1964 to 1979. Another white U.S. scientist and entrepreneur, Louis C. Herring was described as being one of the first to test the use of *Xenopus* for pregnancy tests. Herring “led an expedition to South Africa and collected 5,000 of the frogs and returned them to Orlando” (Martin, 1973). The celebratory depiction of white entrepreneurs may have reinforced a practice that culminated in the excess of *X. laevis* found in U.S. waterbodies today.

As we acknowledge the harm and socio-historical context of biological extraction when talking about any invasive species in environmental education, we learn from it. This historical analysis of U.S. press coverage reveals changing attitudes towards Idwi that correlate with their profitability. When entrepreneurs were profiting from the frogs, popular press used positive language to describe Idwi. The possible implications of introducing Idwi to novel environments were ignored. Furthermore, entrepreneurs who continually introduced a non-native species were valorised in the U.S. newspapers featuring them, and the decolonizing contexts in which these men conducted their business were ignored in the reporting. When money could no longer be made from Idwi, negative and xenophobic language started to be used to describe this frog. The harmful implications of its introduction to novel ecosystems started gaining attention. Even with the change of sentiment towards Idwi, the human element is still ignored. The rapid redistribution of Idwi could have been avoided. The success of this frog in new ecosystems was predicated on continual import of the non-native species. Neither the biosafety measures nor the potential impacts of this imported species to establish itself in new ecosystems and outcompete native species for resources were addressed. Next, we will consider other applications for the frog that drove marketable demand and provided chances for it to establish itself in even more ecosystems, thus further exacerbating their ecological impacts in the U.S.

Historical Use of the Frog for Pets and Education

The demand for frogs that drove their biological extraction led to new markets and applications in the U.S. For example, the continued decline of frog usage in pregnancy tests coincided with journalistic promotions of their use as pets and as educational tools. On the sociozoologic scale, pets and tools are considered to be "good animals" (Arluke & Sanders, 1996, p. 171), and *X. laevis* for these purposes were described accordingly. Chace (1974) writes that the frog was replaced by chemical pregnancy tests "and would normally now be left in its African environment… [however] importation was revived to supply the pet shops." *X. laevis* is described as an easy pet to feed that can live for 15 years, or more. An advice column circulated widely, urging readers to breed and sell *X. laevis* as a profitable hobby (Heartline, 1979).

In in the context of education, U.S. newspapers feature several educators talking about the frog. For example, *Xenopus* is one of few animals called upon to represent the letter X when teaching the English alphabet (Hinds, 2001; Knapp, 2014). One teacher describes students' interest in animals as an opportunity to teach other skills like reading (Ross, 2000). An alphabet book written by a schoolteacher highlighted "uncommon" and "exotic" animals, with *Xenopus* among them (Greene, 2014; Knapp, 2014). Along with this use of the frog's name was the use of the frog itself. Perhaps one of the earliest interactions with *X. laevis* in educational contexts is through classrooms introducing science students to dissections. One newspaper articles begins, "Frogs, long-time candidates for high school lab dissections, don't get much respect" (Stanley, 1997). Additionally, several newspapers showcase student finalists of local science fairs who conducted studies on *X. laevis* (Dukes, 1990; No author, 1977, 1989a, 1989b, 1993, 1998, 2011).

However, some teachers were criticizing the frog. Science teachers like Clinton Owen bred mice and frogs for high school classes. He reportedly said, "the African clawed frog...[is] competing unfairly with the existing frogs," specifically naming bullfrogs as threatened by *X. laevis* (Golum, 1978). American Bullfrogs, while endemic to the eastern U.S., are regarded as invasive in the western U.S. (Snow & Witmer, 2010), illustrating just how contextual the "invasive" tag is. Regardless, Owen states in his interview:

> "I'm systematically wiping out the population...I'm never gonna get them all. It's too late...The African frog has killed everything. But if you knock down the African, the balance will come back. They're just vicious little beasts, ugly compared to our native frogs." (Golum, 1978)

While this science teacher was acknowledged for doing a self-asserted public service, one may wonder how he talked about the frogs in the science classroom. Did he refer to the frogs as "African," as quoted in the article? Did Owen justify his commitment of "systematically wiping out the population" based on anecdotal observations of a single pond? Was he modelling an individual-level approach to environmental rehabilitation based on assumptions about how the environment ought to be? In this science teacher's interview, the role of U.S. entrepreneurs in the redistribution of the frog was not acknowledged. One may wonder if the sentiment expressed by this science teacher is an exception or an exemplar. It seems to be the latter, based on the ethnicised projections on the frog once it became labelled as invasive. We discuss this further in the next section.

Over time, the frog goes from being valued for its medical applications to being marketed for its potential as a pet and educational tool. Eventually, people who purchased the frogs began to find ways to dispose of the frogs, leading to the subsequent ecological impacts that rendered the frog a globally invasive species.

Becoming known as an invasive species

When Idwi were no longer used as pets or educational tools, they became labelled with language associated with pests on the sociozoologic scale, or "bad animals" (Arluke & Sanders, 1996, p. 175). Metaphorical language may be ascribed to animals, such as the rhetoric of immigration debates (in sparrows, Fine & Christoforides, 1991) and other social problems (Best, 2018; Kim, 2015). One example of this language applied to Idwi is observable in a fable by columnist Doug Clark (1987), who anthropomorphizes a character called, “Billy Bob the Frog,” who, “takes the fall for fugitive frogs,” according to the title. Clark writes, “while friends and loved ones looked on, the [armed game officers] got the jump on Billy Bob and nailed him with a 232-12-017. Suspicion of being an illegal amphibian, that is…He didn’t have a green card.” The mention of a green card, an identity document that allows people from other countries to legally reside and work in the U.S., directly ties the frog with xenophobic rhetoric. Comparable to African-American image making in the U.S. curriculum, historians described how images of African-Americans were created to “support the thesis that they were inherently incapable of being full-fledged citizens in the United States” (Au *et al.,* 2016, p. 120). The fable of Clark (1987) invisibilises the origins of frogs (white U.S. entrepreneurs’ biological extraction) and the historical context of their site of origin (decolonizing African countries). Instead, Clark writes, “he is a yucky xenopus laevis. (That’s African clawed frog, to the rest of us.)” From the title to the fable therein, Clark depicts the frog as an illegal criminal with stereotypical archetypes analogous to racist literature (Au *et al.,* 2016, p. 122). A comparable observation was made in Mel Chen’s analysis of an ethnicised yet non-living chemical, the lead found in U.S. children’s toys sourced from China referred to as “Chinese lead” in the media (2012, p. 160). The fable of Clark (1987), along with other news stories that warn of the “African clawed frog” (Jefferson City, 2005), ethnicises a non-human animal found in U.S. aquaria by using “African” in every mention of the name. The ethnicised name is juxtaposed with xenophobic rhetoric, going so far as to challenge the immigration status of frogs that did not enter the country on their own volition. Many species have the country-of-origin in their common English name; however, this critical assessment of the use of xenophobic rhetoric in media and educational materials warrants increased attention, even reconsideration, to how ethnicised names are used with non-human species labelled as invasive.

Public consideration for how to dispose of an increasingly less desirable pet turned pest became mainstream. *Xenopus laevis* were found in California riverbeds (Applegate, 1974). Local fishermen reported sighting the frogs in Tia Juana River, and the head of California Department of Fish and Game warned, “They can live anywhere, eat anything” (Sahagun, 1977). The headline “Voracious African frog turned into state agents: The illegal amphibian was left in a jar on the steps of Kaiser High” further depicts the frog with xenophobic terminology (Bernardo, 2002). They are described as “a threat” to local ecology (Org, 2004), an “enemy” to the endangered Three-spined Stickleback (Campuzano, 2004), and “one of many destructive exotic plants and animals” (Jefferson City, 2005). The empathy afforded to “good animals” like pets was publicly discouraged for the “bad animal” with which *Xenopus* was now associated.

Despite increased awareness of environmental impacts, U.S. entrepreneurs continued to conduct business as usual. In 2008, the press sympathized with Paul Rudnick for encountering “not so friendly” western states who banned his product. *Xenopus* was described as the “frog from hell” that could “wreak havoc in a native ecosystem,” yet Rudnick still applied for a waiver to ship frogs to states that banned them (Anderson, 2008).

Eventually, *X. laevis* was not only labelled as invasive but also linked to a deadly fungal disease called chytrid. The media compared chytrid to the Ebola virus and AIDS, and yet chytrid is described as a “fungus, which probably originated from Africa, [that] kills by thickening the frogs’ skin...suffocating the animal” (Rust, 2006). The spread of chytrid was tied to individual actions of pet owners, releasing their frogs or dumping water from aquaria, again not mentioning the U.S. entrepreneurs. Another headline, “Invasive frog linked to disease,” contradicts the main text claiming, “which species affected the others remains unresolved” (Mohan, 2013). The science teacher suggesting bullfrogs were threatened by *X. laevis* (Golum, 1978) could not have predicted that the spread of American Bullfrogs from the eastern U.S. to western states facilitated the spread of chytrid (Yap *et al.*, 2018). The tag of "invasive" may mislead media consumers, teachers, and learners that *X. laevis* is at fault for the spread of chytrid. A species endemic to the continental U.S., American Bullfrog, has been associated with the spread of this fungal disease that is lethal to countless other amphibia. As a species endemic to the U.S. is found to be the carrier of chytrid, we learn yet another lesson in how environmental history and new scientific discoveries call into question our assumptions around invasive species. If the frog had not been the target of xenophobic projections, would the media and scientific community have blamed *X. laevis* for chytrid so readily? Counternarratives in environmental education can reshape potential biases like these.

Discussion

From these examples, environmental educators could consider how to use language to describe invasive species with care. Instead of anthropomorphizing the species with ethnicised and xenophobic rhetoric, educators might focus on counternarratives that challenge and critique the "master narrative" throughout this article. Teaching about invasive species without their origin story invisibilises the root causes of their global distribution. In the case of *X. laevis*, the root causes are humans. Idwi were collected by European naturalists and displayed as a museum oddity then harnessed as reusable pregnancy tests. The biological extraction of Idwi from decolonizing African countries by U.S. entrepreneurs contributed to exacerbating the socio-economic inequity of the Global South. From ethnicised names used in the fables of U.S. popular press, *X. laevis* becomes a figurehead of xenophobia. These anthropomorphic associations arguably underlie the subsequent speculation of the frog as implicated in the spread of disease. In response to these attitudes towards *X. laevis* as conveyed in popular press, stakeholders in environmental education must be proactive in countering false stereotypes perpetuated by this "master narrative."

Previous investigations in invasive species offer models for responsible and responsive interventions. For example, one study models how “scaling down” and studying “minor players” can offer key insights into how we might study and educate ourselves about invasive species in the Anthropocene. By focusing on the embodied and performative connections of young people with rabbits in Australia, Taylor noted how during informal outdoor learning opportunities, such as recess, young people looked for, observed, and even pretended to be rabbits (Taylor, 2020), leaving us to wonder – what lessons might adults learn from minor players?

In the realm of policy, regulation, and even morality, Claire Jen Kim provides a case study on the regulation of animals, such as turtles and frogs, in the live markets of Chinatown in San Francisco, California, U.S. Kim (2015) reveals how self-proclaimed environmentalists and animal rights activists are caught up in xenophobic rhetoric when making arguments in public forums. The subsequent pattern that follows from people and cultures getting blamed for the importation of species – especially species perceived as causing ecological harm – is that the cultural communities regard such accusations as racist. Kim explores how both arguments are zero-sum games and that, “[i]n the meantime, the forces of neoliberal capitalism face few obstacles as they transform racialized others, nonhuman animals, and the earth into ‘resources’ in the game of perpetual capital accumulation.” (p. 287). Biological extraction, as previously described with Idwi, is just one part of ongoing patterns of resource exploitation that perpetuates ecological and societal harm, disproportionately benefiting the U.S. and Europe and harming the Global South (Funk, 2015; Klein, 2007, 2015). From the investigation of popular press provided this article, we urge environmental education scholars, practitioners, and activists to consider how we might hold businesses accountable for on-going biological extraction, as well as how we use language to describe species extracted and transported across geo-political borders.

Limitations and future directions

The way we teach about invasive species in environmental education can be enriched by the frameworks offered by de/postcolonial theory, Indigenous studies, and Critical Race Theory without detracting from lessons about the ecological impacts of species expanding into novel habitats. However, we note there are limitations to the present study that offer fruitful areas for future research. First, we acknowledge that there is scepticism about the value of Indigenous languages research in conservation contexts. Some may argue that such research does not contribute to advancing "real" scientific research or conservation efforts. Using the language of people who are native to a particular region to describe endemic species can support conservation efforts by engaging the local community in monitoring species of relevance while also incorporating diverse worldviews and including people that were previously marginalized from conservation. Biomonitoring is a prerequisite to conservation because it detects subtle shifts in population numbers or even just the presence/absence of an organism. Future research might compare regions with Indigenous language research to regions that have not engaged in such research to determine the extent to which biomonitoring occurs. Second, sceptics might misinterpret this work as an effort to undermine scientific taxonomy and then argue that Indigenous languages are not "robust" enough to replace the existing nomenclature. We are not attempting to replace scientific nomenclature but rather acknowledging that the binomial names used to describe species of the world (e.g. *Xenopus laevis*) are essential for communication among specialists. These scientific names are likely unrecognizable in the Indigenous communities where specialists carry out their conservation initiatives, and in such cases, local species names would help ensure conservation action in collaboration with communities is directed at the correct species. In future studies, one might consider the language of instruction and scientific content of environmental education curriculum and then assess the extent to which community members perceive value in documenting and using Indigenous languages in these contexts. Lastly, in the present study, there were several newspaper articles that addressed larger topic areas and merit a deeper dive. Frogs, as amphibians with aquatic and terrestrial life stages, offer unique insights into water quality, environmental impacts of pollutants, and climate change. Future work could explore the implications of scientific research on *X. laevis* in areas such as sex differentiation and morphological mutants that are impacted by environmental pollutants. Popular press coverage of such phenomena could be analysed through theoretical frameworks of gender and sexuality studies and disability studies. Further, one might consider how the xenophobic rhetoric expressed by popular press towards the frog – particularly in the U.S. – connects to how people consider the impacts of climate change on the frog's habitat and life cycles.

Conclusion

By focusing on one species through a wide range of fields and perspectives, we aim to recontextualize previously extracted organisms in their socio-cultural, linguistic, and ecological contexts – locally – and recognize historical harms that have exacerbated conservations problems – globally. From an investigation into the language surrounding this one species, we uncover ties of Idwi to its colonial past and present. This narrative is inextricably connected to a colonial matrix of power, and it is the ethical imperative of environmental educators to disentangle these power relations when discussing global issues in the classroom (Sund & Pashby, 2020). We believe this includes curriculum reform on the global issues of invasive species, for the "radical cut within the denominator of the human made by colonialism within an imperialist ontology makes curriculum reform a matter of life and death as colonial subjects fight off forms of social death in everyday life." (Leonardo, 2018, p. 13). Species like Idwi also connect to broader issues of climate justice: "The way that they zone us, where they locate their coal factories, where they plunder lands in Africa—that's how slavery started, stealing resources from black and brown communities," said Jazzlyn Lindsey (Lim, 2017). To teach about "invasive species," we must also teach about the role and responsibility of humans – both in biological extraction and in community-based education, advocacy, and reform.

It is imperative that environmental educators consider the counternarratives of so-called "invasive" species to include an understanding of the many names given to each species, the cultural and scientific value of each species, the socio-cultural value of each species to the communities of their endemic geographies, the intrinsic value, and the narrative of biological extractions responsible for their global dispersions.

Acknowledgements

We thank Tyrone B. Hayes and Michelle Wooten for feedback on earlier versions of the manuscript. We sincerely appreciate the thoughtful suggestions and perspectives from the Executive Editor and anonymous Consulting Editors.

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In Closing

Conclusions, recommendations, and practical value of biocultural approaches.

The current study is the most comprehensive analysis of South African biocultural diversity of animals (specifically frogs and reptiles) and the individual chapters add to the growing literature that illuminates the intricacies of the relationship between biodiversity and culture in South Africa and beyond. This study has succeeded in achieving its main aim of providing a snapshot of the state of the complex relationship between South Africa’s herpetofaunal biodiversity and the country’s traditional cultures. Achieving the aims of this study has provided insights into the potential conservation and social inclusion value to be derived from understanding biocultural diversity by way of considering the traditional cultural perspectives, languages, and knowledge systems that were previously marginalised from wildlife matters.

The study’s aim was achieved through attainment of six objectives. The first objective was to assess the state of research into the relationship between South Africa’s biological and cultural diversity, and Chapter 1.1 along with Chapter 2 used a sample of scientific articles to show this type of research to be increasing and biased towards plants and human health science research. Animal focused research accounted for 6% of the reviewed articles and herpetological research was less 1% in this sample of studies using biocultural approaches. A lack herpetology focus in a review of literature that takes interest in culture’s interaction with herpetofauna thus provided motivation that the current study would be contributing to a limited field of knowledge. The review sample also showed a lack of ethical consideration was not affording protection to the knowledge of communities previously marginalised from wildlife issues, and this research also had lax focus on traditional ecological knowledge which could serve to increase inclusion of the previously marginalised communities and their traditional knowledge in conservation planning. Chapter 2’s results made it apparent that further social inclusion can be achieved by diversifying research focus on provinces and languages as the review sample was biased towards a few South African languages and provinces. Increased focus on currently overlooked provinces and languages could reveal local communities' perspectives and knowledge of wildlife to be considered in conservation planning. The research towards Objective 1 was based on a systematic review of literature to ensure replicability, but this limited the scope of the study as it excluded grey literature and articles that were not indexed on the search engine used to obtain the reviewed articles. South Africa as a biologically and culturally diverse country provided an ideal candidate for a synthesis of biocultural research and this synthesis has potential to serve as a template for carrying out similar studies aimed at providing an understanding of past and present relationship between biological and cultural diversity in other countries.

Objective 2 was achieved through the research conducted in Chapter 3 which shows that culture's interaction with biodiversity, particularly the cultural salience of biodiversity, might be influencing the accumulation of biodiversity distribution data for South African animal species in general and the country's herptile species in particular. Furthermore, statistical analysis using a generalised linear model suggested that scientific interest might also have an influence on biodiversity distribution data accumulation, albeit weaker than cultural salience, and further suggested that is it possible for interactions between scientific interest and cultural salience to influence the accumulation of biodiversity distribution data. This biodiversity distribution data of South African animal species has a strong bias towards birds and underrepresents some species of high conservation priority. Based on the increased understanding of the roles played by culture and science in primary biodiversity data accumulation, it is possible to modify current biodiversity data collection frameworks so they contribute to increasing the biodiversity distribution data of underrepresented species to meet both conservation objectives and scientific interests. While Chapter 3 outlined the importance of biodiversity distribution data for conservation planning and provided insights into the possible role played by cultural salience and scientific interest in accumulation of this data, the chapter was not able to provide a clear indication of how cultural salience or even scientific interest might have affected the conservation priorities of frogs and reptiles. To arrive at robust conclusions about culture's influence on conservation priorities for herptiles will require additional analysis on how cultural salience and scientific interest of species translates to setting their conservation priorities.

Following on from the broad taxonomic focus of the two preceding objectives, Objective 3 specifically focused on South African cultures' past and present relationship with frogs and reptiles, and investigated the conservation implications of this relationship. The enthnoherpetological assessment conducted in Chapter 4 showed that traditional society's shared beliefs and practices relating to frogs and reptiles can be grouped into different elements of culture based on their similarity. These elements either pose a conservation threat through their negative perceptions and consumptive use of herptiles, or provide conservation prospects through norms and practices that foster protection of herptiles. Some herptile related cultural norms and practices were recorded and published for the first time in Chapter 4, thus making them available for future consideration in conservation planning as encouraged by South Africa's conservation policy (Republic of South Africa, 1998). Social inclusion is increased by this study's consideration of the wildlife perspectives of South African cultures that were previously marginalised from wildlife matters. There is further scope for social inclusion if these perspectives are considered in future conservation planning. These perspectives do however vary according to culture and it may be necessary to conduct further surveys in order to better understand these perspectives before incorporating them in conservation. Beyond this documentation and preservation of aspects of traditional culture relating to herptiles it will also be necessary to consult with custodians of this traditional culture for conservation governance that is integrative.

The successful attainment of Objective 3 and the resultant categorising of the elements of culture in Chapter 4 laid the foundation for a higher resolution focus on one of those elements, namely folk taxonomy, in the proceeding research objective. Chapter 5 achieved this study's fourth objective of analysing how traditional cultures interact with herptiles through their naming practices. The chapter reveals that South Africa's traditional cultures have established ways for assigning indigenous names to frogs and reptiles. This folk taxonomy, also known as indigenous taxonomy, is systematic, well-developed, and similar across different cultures (Berlin, 1973). These indigenous naming practices also have similarities with scientific taxonomy as names are assigned according to observed traits of species, and species are grouped together based on similarities in traits. Indigenous taxonomy however does not assign individual names to all known species like scientific taxonomy aims to do. The research could not provide clarity on why some indigenous names are specific to individual species while in some cases a single indigenous name is used for multiple species. Chapter 5 concluded that it is possible to extend existing, generalised indigenous names into a comprehensive list of species names that are specific to each known herptile species in South Africa and for these newly formulated individual names to have a similar meaning to scientific names wherever possible. These individual names for South African herptile species would ease communication between conservation practitioners and indigenous communities on collaborative conservation projects with communities that solely use or know indigenous names for wildlife thus ensuring that conservation is directed at the correct species, rather than a group of species with the same indigenous name. Further social inclusion value of such a comprehensive list of indigenous names for species is that it would make them available for inclusion in new wildlife books which mostly use species names from two of South Africa's eleven official languages.

Chapter 6 also focused on an element of culture that was categorised in Chapter 4, namely traditional medicine. This sixth chapter's research attained Objective 5 which was to investigate manifestations of biocultural diversity outside rural areas by focusing on use of herpetofauna in urban traditional medicine markets. The presence of traditional medicine markets in South African cities shows that traditional cultural practices persist in urban areas. Previous studies have also found that traditional norms and practices, specifically traditional medicine usage, to be prevalent in urban areas (Cocks & Møller, 2002). Traditional medicinal practices pose a conservation threat to herpetofauna as animals are used consumptively. Mitigation of this conservation threat will require collaboration with traditional health practitioners, which is currently lax. While conducting research for Chapter 6, the traditional health practitioners showed a willingness to collaborate which allowed for the collection of tissue samples for DNA barcoding of the herptile specimens they had in their possession and responded to questions about the current lack of collaborations between them and conservation practitioners. The DNA barcoding was used to identify the herptile species of traditional medicine relevance and confirmed the indigenous names traditional health practitioners used for the specimens in their possession. Their willingness to participate in this research project creates prospects of collaborating with traditional health practitioners and use DNA barcoding to identify any unrecognisable animal parts sold in urban traditional medicine markets while also confirming the folk taxonomy used by traditional health practitioners. Through such a collaboration, species of high conservation priority can be identified and measures to decrease the conservation pressure placed by traditional health practices on herptile species can be jointly decided upon. The social inclusion value from this study is derived from collaborating with traditional health practitioners and that in turn would translate into integrative conservation planning for traditional medicine usage.

Research conducted up to Chapter 6 has investigated the state of the relationship between traditional cultures and wildlife, provided an in-depth discussion of conservation prospects that arise from understanding this relationship, but only included brief discussions about social inclusion. Chapter 7 delves into social inclusion prospects arising from biocultural approaches to attain Objective 6. This chapter's focus on social inclusion is divided into three parts which show that (1) some opportunities to learn about the South African environment are linguistically/culturally inaccessible (thus socially exclusive) to many South Africans, (2) increased understanding of traditional culture's interactions with wildlife can lead to increased inclusion of indigenous perspectives and languages in wildlife books, and (3) how the consideration of indigenous names and perspectives of wildlife can inspire postcolonial teaching about wildlife and start discussions about the misrepresentation of traditional cultures in wildlife lessons. Chapter 7 analysed a sample of environmental books that are accessible through libraries and considered to be opportunities for people to learn about the environment and found those opportunities to be biased towards people who are literate in English. The assumption of books being opportunities to learn is based on the assertion by Ocholla (2009) that libraries facilitate the fulfilment people's obligations in society through empowerment with knowledge for self-reliance and continuous learning. The approach does however limit the scope of the study by excluding other forms publicly accessible opportunities for empowerment including the internet, television, newspapers and even scientific articles. Thus, the conclusions from this analysis are only limited to books archived in libraries and not necessarily all opportunities available to South African citizens to learn about the environment.

Considering that most South Africans do not use English as their primary language (Statistics South Africa, 2008), and that their English literacy is low (Sebolai, 2016), having these books considered as opportunities to learn about the environment published mostly in

English, excludes them from learning about the environment to build capacity for participation in its management. For environmental management to be integrative, there should firstly be equitable opportunities to learn about the environment so that all interested parties can meaningfully participate. Chapter 7.1 focuses on a bilingual (English and IsiZulu) book about frogs which relied on investigations of the relationship between Zulu culture and frogs for some of its content. This book considered to be an inclusive learning opportunity due to being bilingual and also bringing forth some of the Zululand community's previously undocumented perspectives about frogs. Developing more indigenous languages books about the environment would make opportunities to develop an understanding for participation in environmental management more socially inclusive than Chapter 7.1's review sample suggested them to be. South African environmental policy encourages this inclusion in learning about the environment. Chapter 7.2 expands on how prospects for social inclusion arise from research focused on the relationship between biological and cultural diversity and uses *Xenopus laevis* as a practical example of how increased understanding of the culture/biodiversity relationship could lead to culturally just narratives about species. The traditional knowledge and folk taxonomy of *X. laevis* revealed by previous studies was used as motivation for postcolonial lessons about *X. laevis* instead of narratives that merely present it as a globally invasive species. These counternarratives would teach about *X. laevis*' relevance to traditional cultures and how the frog species can be used as a model for understanding pre-scientific observations of animals in addition to being a model animal for multiple scientific fields. Unlike previous chapters, Chapter 7.2 deviates from the approach of analysing data and presenting results as it theorises how inclusion of traditional societies' perspectives in wildlife lessons could present counternarratives that in the case of *X. laevis* would result in lessons about the species' global invasion highlighting people's role in this invasion, and the racial connotations of the language used in reference to this invasive species. Chapter 7.2 theorises that in environmental education contexts, a greater understanding traditional culture's interaction with biodiversity can lead to socially inclusive lessons that incorporate traditional society's views in addition to that of modern knowledge, while also acknowledging the social injustices sometimes associated with gaining the modern knowledge used in environmental education. While the chapter seems too far out of scope with the rest of the current work that presents results instead theorising how widely social inclusion can reach, it demonstrates how transdisciplinary research can work to reconcile the complex elements of the interactions between biological and cultural diversity. Such transdisciplinary research provides a holistic approach that would contribute to biodiversity conservation being socially inclusive, just, and also aware of the social problems previously created when conservation planning did not consider biodiversity's complex connection with cultural diversity.

The various chapters and their-sub chapters were written to be standalone scientific articles exploring different topics that focus on biocultural approaches and when combined they collectively provide understanding of complex interactions between South Africa's biological and cultural diversity along with policy relevant implications for social inclusion and conservation. Following Chapter 1's general introduction, each chapter illuminates different aspects of culture's interactions with herptile diversity with Chapters 2 and 4 providing of snapshot of how this relationship reaches into a myriad disciplines and elements of culture respectively. Policy-relevant implications of social inclusion and conservation are also discussed throughout the chapters in varying degrees with chapters 7 and 4 providing detailed expositions about social inclusion and conservation respectively. The various chapters demonstrate the type of research conducted here can stay within its roots of hybridising social science and zoological methodology. Chapter 7.1 demonstrates that biocultural approaches can transcend into education science and linguistics, and Chapter 7.2

theorises the importance of such approaches to education science and decolonial studies while still being relevant to the main aim of increasing understanding of the interaction between culture and biodiversity.

With achieving this study's aims and objectives there also came a realisation of knowledge gaps and future research opportunities. This study shows that the positive outcomes of interactions between biological and cultural biodiversity are either understudied or underreported, in addition to confirming that culture's interaction with herptile diversity can have both positive and negative impacts on herptiles. In addition to being underreported, the protective elements of traditional culture are not being incorporated into conservation planning as provided for in South Africa's environmental management legislation. The next section speculates on and makes recommendations for future research that could bridge some of the knowledge gaps realised through the current research.

Future biocultural approaches in South Africa and beyond

South Africa in general needs more biocultural research focus on animals as most research in this niche is dominated by plant-related studies. Such studies should also strive for balanced focus on languages/cultures, provinces, and animal taxa to avoid exacerbating existing bias in the research foci of biocultural research. There is further need to ensure that findings or outputs of biocultural approaches by researches reach the specialists that use them practically and non-specialists that could derive educational benefits from them. Ensuring research outputs reach intended participants could require inclusion of communication scientists for better efficacy in delivering the message. It is also worth investigating whether ethical compliance is advancing sufficiently to keep up with the growing niche of biocultural research which often includes people and their intellectual property in the form of indigenous knowledge.

Despite biocultural diversity's definitional problems, the intricacies of the relationship between biological and cultural diversity continue to be investigated. Some of these investigations are reported without reference to the concept of biocultural diversity or classification of such research into this niche of mixed methodology research that transcends disciplines. Regardless of whether researchers refer to the relationship between biological and cultural diversity as biocultural diversity in their work, the outcomes of this dual focus continually highlight the social and conservation policy benefits of considering biological and cultural diversity as inseparable phenomena or at the very least acknowledging interactions between the two diversities. These benefits include intergovernmental organisations adopting biocultural approaches.

Based on current trends, it seems likely that biocultural approaches will continue to receive interest from science and society. Public interest in the idea of a link between biological and cultural phenomena has been steady over the years (Figure 1). This public interest is based on the number of global internet searches (Correia *et al.*, 2016), for the term 'biocultural' from 2004 when Google (Google LLC) started analysing trends in the popularity of search terms (https://trends.google.com/trends/) until 13 March 2022 at the drafting of this text.

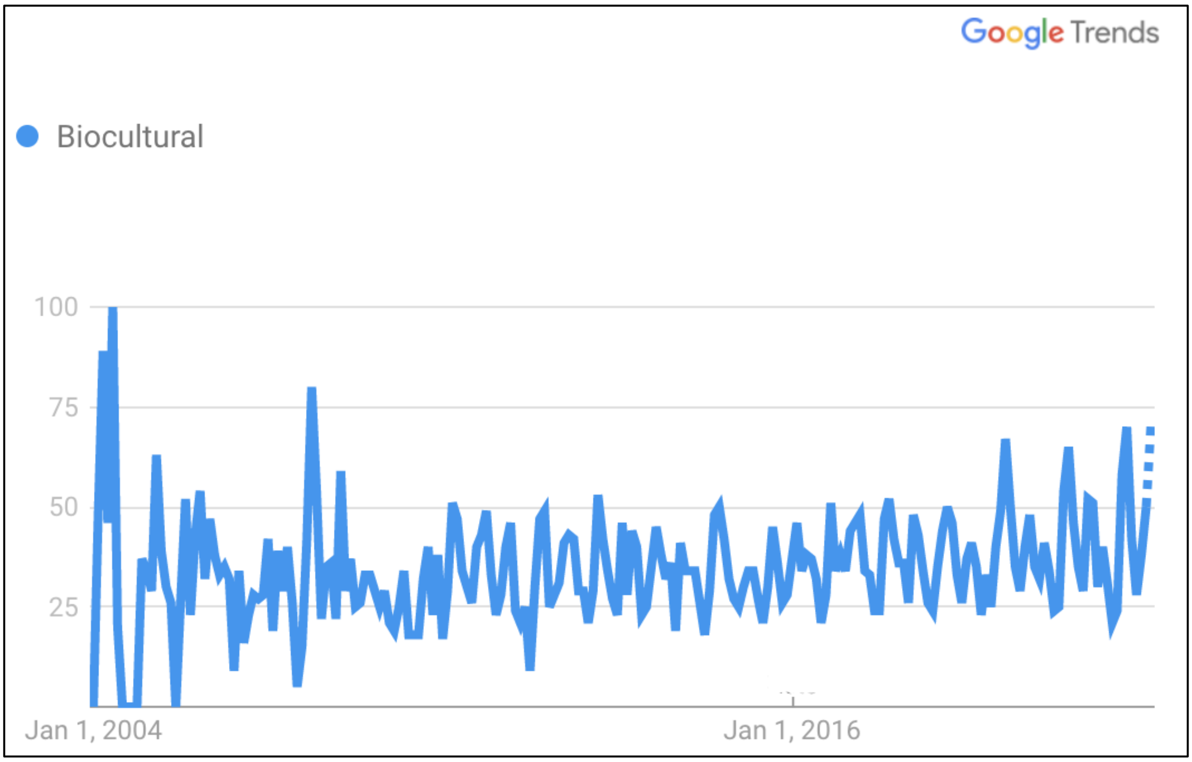

Figure 1: Trends in internet search queries for the term ‘biocultural’ between 1 January 2004 and 13 March 2022 as analysed by Google Trends (Google LLC).

Scientific interest in the concept has progressed to a point where any approaches or methodologies based on the idea of an intricate connection between nature and culture have been collectively grouped as the biocultural paradigm in discussion of their potential contribution to local and global sustainability (Merçon *et al.*, 2019). The recent recognition that the survival of people and their ways of life is inseparable from the survival of ecosystems reiterates the existence of an intricate connection between biological and cultural diversity and their co-evolution which has been overlooked by researchers for many years (Fischer-Kowalski & Weisz, 2016). A recent study highlighted this when it suggested that the Amazon rainforest’s composition is shaped by ancient tribes’ practices (Levis *et al.*, 2017). There is further acknowledgement that the futures of the two diversities are co-evolving (Folke *et al.*, 2016), thus making studies based on biocultural approaches important in planning the conservation of both biological and cultural diversity. Further impetus to the biocultural paradigm is added by its adoption by intergovernmental organisations such as Convention for Biological Diversity and the Intergovernmental Platform on Biodiversity and Ecosystem Services (Merçon *et al.,* 2019). This adoption of the biocultural paradigm by intergovernmental organisations stimulates curiosity about whether the biocultural paradigm will one day be explicitly made part of national legislation. Environmental management legislation steeped in the biocultural approaches might prove effective in securing the futures of both people and nature instead of treating them as discrete phenomena. For countries such as South Africa, integrating biocultural approaches into conservation policy could require minimal changes as some of the country's policies already recognise a connection between nature and people's cultures. For instance, South African cultures are referred to as nature-based cultures (Department of Environment, Forestry and Fisheries, 2015) and environmental management legislation makes specific provision for consideration of cultural practices when making decisions (Republic of South Africa, 1998).

Beyond the biocultural paradigm, there is an even broader field of interest based on the idea of a complex connection between biological and cultural diversity. The furthest this current study has perhaps strayed away from its field of natural sciences was when exploring language planning in Chapter 7 and decolonial pedagogy in Chapter 7.2 to show the possibilities of this approach. The social-ecological approach presents more research opportunities than the biocultural approach but the conceptualisation of the two concepts has similarities. In the social-ecological systems approach there is broad focus on a co-evolving social-ecological system and discussions of cultures' influence on this system when seeking to understand the relationship and intertwined futures of ecology and social systems (Hirons *et al.,* 2018). The research possibilities of the biocultural approach and broadly the social-ecological systems approach are demonstrated in studies of the climate change resilience of communities and the ecological landscapes they depend on (Hirons *et al.,* 2018), and there is further scope to apply these approaches in other field including linguistics, environmental law and anthropology (Pretty *et al.,* 2009). Despite the possibilities of applying the biocultural approach or solving problems though the social-ecological approach, these approaches are still mostly discussed in sustainability studies.

Biocultural approaches specifically focused on the South African context in published research were shown to mostly focus on plants through the review in Chapter 2, and the research focusing on animals generally excludes frogs and reptiles. Chapters 4 to 7 demonstrate the myriad of research opportunities, lessons to be learned, and practical applications of biocultural approaches that focus on frogs and reptiles. There is scope to apply the lessons learned in this study and practically apply biocultural approaches to other South African wildlife groups but what is perhaps missing is an effective way for the policy-relevant outcomes from this type of research to reach conservation policymakers and practitioners for consideration. One way of solving this could be consultation with policymakers during the development phase of policy relevant research projects to either co-design that research or gain an understanding of what is needed for policymakers to consider the results that will be presented by the research. The current study failed at co-designing the research with policymakers, but it did succeed in studying relevant policy beforehand and identifying contrasts between this policy and action so they could be addressed.

Research and documentation of previously marginalised wildlife perspectives contributes to increasing social inclusion in conservation planning. Social inclusion and conservation planning opportunities highlighted in this study require cooperation with other fields for them to be realised. For example, concerted effort from conservation practitioners is required to ensure that traditional perspectives are included in conservation planning as envisaged by South Africa’s environmental law (Republic of South Africa, 1998). Another example is that for folk taxonomy's potential benefits of linguistically inclusive wildlife reading materials to be realised, authors of popular wildlife books will have to start using indigenous names and publishers will also have to encourage multilingual writing. Such a commitment to multilingual publishing would facilitate greater learning about the environment as people generally learn better in their home language (Prinsloo *et al.*, 2018). The conservation and social inclusion benefits from approaches based on the intricate relationship between biodiversity and culture require collaboration from different stakeholders and interested parties. The values of such collaborations recently resulted in the compilation of insect names in English and IsiXhosa for the purpose of facilitating communication between scientists and non-specialists, and to contribute to a new English-IsiXhosa bilingual dictionary (Mkize *et al.*, 2003).

Conclusion

This study succeeded in its intention to assess the state of the biocultural diversity of herpetofauna in South Africa and in demonstrating relevance of understanding this relationship between biological and cultural diversity as a science-based policy tool for conservation and social inclusion. The current study provides a template of decolonised research in herpetology (and natural sciences in general), and further demonstrates what is possible when transdisciplinary, mixed-method research is embraced. From a conservation perspective, the study demonstrated that South Africa's inclusive conservation policy cannot be realised while the wildlife perspectives of some South Africa's are still excluded.

This research's public outreach

To stay true to the objective of being socially inclusive, the current study had public outreach outputs in addition to scientific articles. The website (www.wildvernac.org) was used to host this study's questionnaire and will continue to be active beyond the current study as an initiative called 'Wildlife in Vernacular' which is meant to share wildlife knowledge in the South African indigenous languages that are underrepresented in wildlife reading materials (Figure 2).

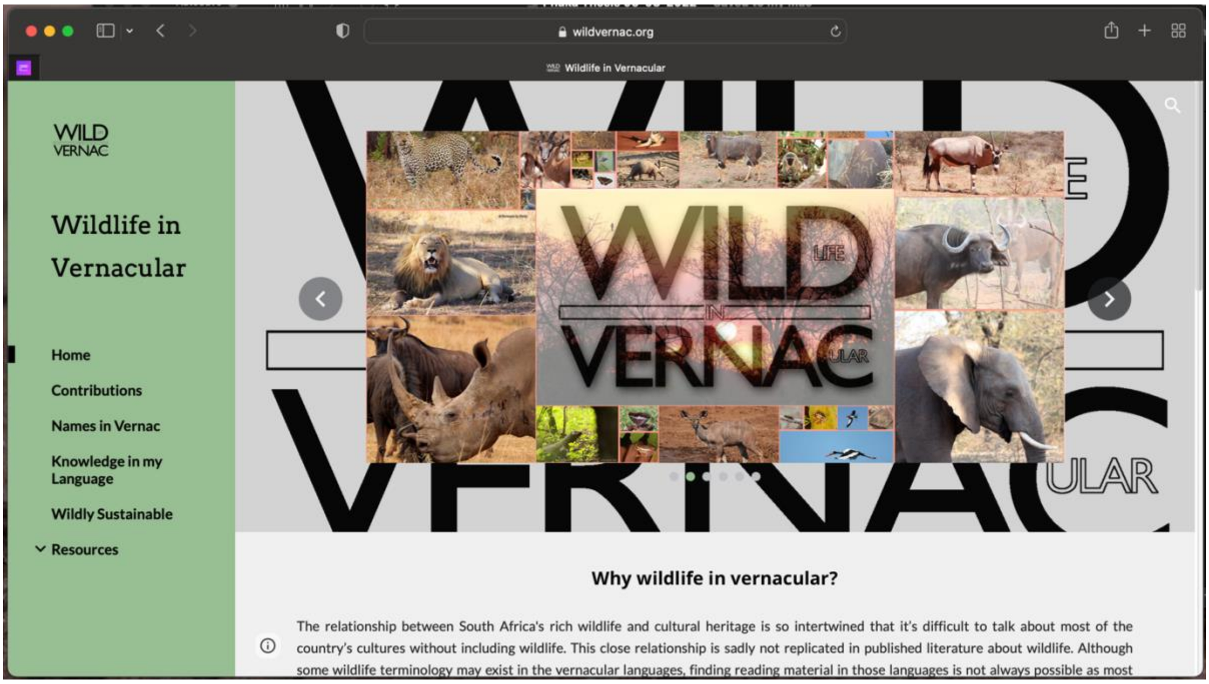

Figure 2: Screenshot of the homepage for the 'Wildlife in Vernacular' initiative's website (www.wildvernac.org).

The understanding of the relationship between culture and biodiversity gained through the research conducted here had further practical use in the position of content producer/supervisor for a South African television show called 'Imvelogy' which aims to educate viewers about how the country's indigenous cultures have practices that protect nature. The first season of Imvelogy, which is a property of the South African Broadcasting Corporation jointly produced by Sugar Bean Pictures (PTY) LTD and Akhani Productions, had 13 episodes (highlights viewable here: d/165FVGCLeaEFjXhNe6p0s4ToGxOZpiUng). This study's outputs meant for non-scientists have received commendation or praise through an award and creation of a comic character. In 2022 there was an award from South Africa's National Heritage Councils' Golden Shield Heritage Awards for these outputs (Supplement 1). This study's documentation of indigenous knowledge was the motivation for creating a comic character called The Scribe: a superhero whose speciality is preservation of knowledge among a league of fictional heroes used as a tool to communicate science to the youth by the SuperScientists (https://www.superscientists.org/) initiative (Figure 3).

Figure 3: A fictional character called the "The Scribe" created in recognition of this current research's documentation of indigenous.

Supplement 1: Award certificate for South Africa's National Heritage Councils' Golden Shield Heritage Awards in the 'Voice of Heritage' category.

Future public outreach benefits to be derived from this current work will include comprehensive lists of indigenous names for herptiles and other South African wildlife being readily available from the Wildlife in Vernacular website for use in new wildlife books and recommendations for incorporation of indigenous perspectives into herptile conservation.

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Appendix

Appendix Chapter 2

Supplementary Material 1: Literature reviewed for this study (Accessible through Mendeley Data: http://dx.doi.org/10.17632/b6fhzcvzmp.1).

Supplementary Material 2: Protocol used to review articles in this sample.

1) What is the spatial focus of the study? (study area may be local, provincial or national)

2) Did the study have a rural or urban focus? Or was the focus on both, or was this not specified?

3) Which taxa does the study focus on?

4) Which study field or discipline does the study fall into? (e.g. Health science).

5) What methods of investigation were employed? (social science and/or biological analysis)

6) What was used as a proxy for cultural diversity in the study? (e.g. culture, religion, ethnicity)

7) Is there ethical consideration for the study? Does it specify whether the consideration is for the human participants or biota?

8) Where the employed interview techniques purposive or random?

9) What type of recommendations and does the study make?

- Are they methodology related?
- Are they related to biological or cultural diversity conservation?
- Are they related to potential human benefits to be derived from the study?

Appendix Chapter 3

Supplementary Material 1: Search parameters for South African animal species occurrence records on GBIF.

Results are viewable on this link below: doi.org/10.15468/dl.5upuwl

Citation: GBIF.org (21 February 2020) GBIF Occurrence Download https://doi.org/10.15468/dl.5upuwl
License: CC BY-NC 4.0
File: 771 KB Species list
Involved datasets: 88
Make sure to read the data user agreement and citation guidelines.

API

And

Basis of record	Observation • Machine observation • Human observation • Material sample • Preserved specimen
Continent	AFRICA
Country or area	South Africa
Year	Between start of 1998 and end of 2020
Scientific name	Animalia

Search parameters for South African amphibian occurrence records on GBIF.

Results are viewable on this link below: doi.org/10.15468/dl.vletu9

Citation: GBIF.org (21 February 2020) GBIF Occurrence Download https://doi.org/10.15468/dl.vletu9
License: CC BY-NC 4.0
File: 4 KB Species list
Involved datasets: 9
Make sure to read the data user agreement and citation guidelines.

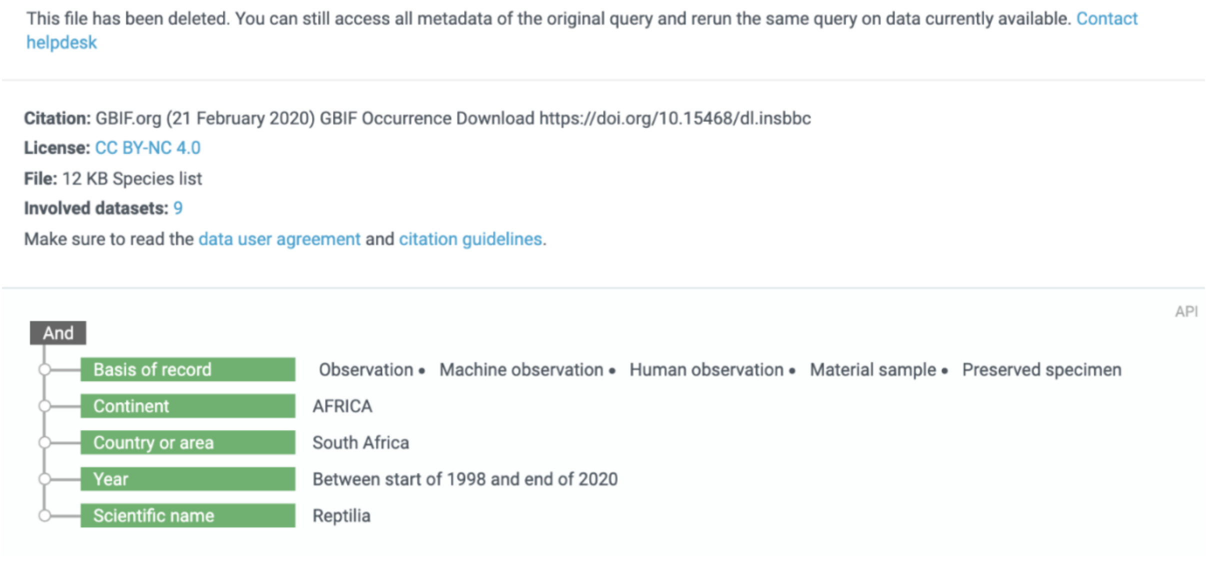
API

And

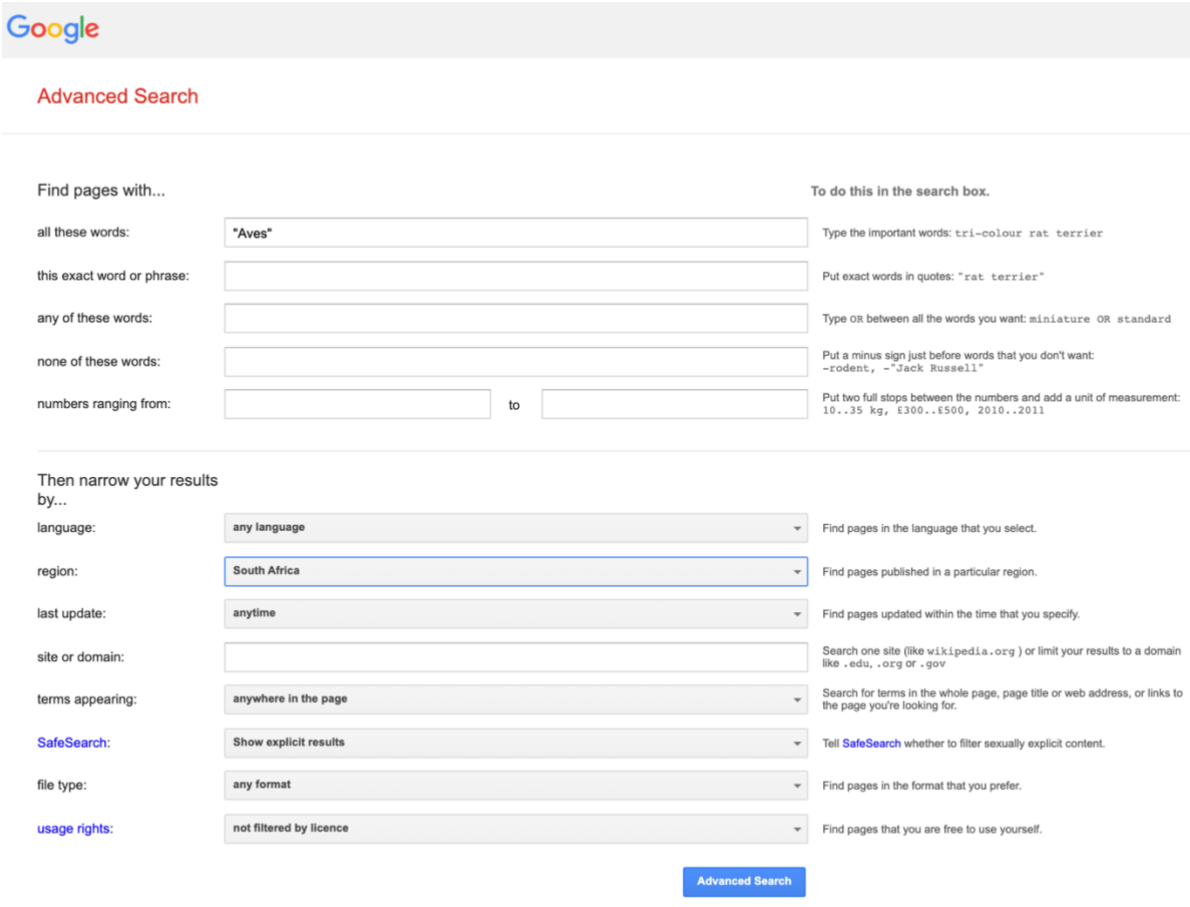
Basis of record	Observation • Machine observation • Human observation • Material sample • Preserved specimen
Continent	AFRICA
Country or area	South Africa
Year	Between start of 1998 and end of 2020
Scientific name	Amphibia

Search parameters for South African reptile occurrence records on GBIF.

Results are viewable on this link: doi.org/10.15468/dl.insbbc



Example of search parameters used on Google search engine's advanced search option.



Keywords used on Web of Science (WoS) for the sample of 49 South African animal classes.

Note: Scientific names are copied verbatim from GBIF (2020).

1.

TS=("Arachnida" OR “Salticidae” OR “Thomisidae” OR “Gnaphosidae” OR “Araneidae” OR "Lycosidae" OR "Theridiidae" OR "Buthidae" OR "Oxyopidae" OR "Zodariidae" OR "Linyphiidae" OR "Philodromidae" OR "Tetragnathidae" OR “Sparassidae" OR "Cheiracanthiidae" OR "Clubionidae" OR "Scorpionidae" OR "Corinnidae" OR "Theraphosidae" OR "Hormuridae" OR "Palpimanidae" OR "Pisauridae" OR "Trachelidae" OR "Scytodidae" OR "Triaenonychidae" OR "Pholcidae" OR "Cyrtaucheniidae" OR "Uloboridae" OR "Ammoxenidae" OR "Solpugidae" OR "Caponiidae" OR "Dictynidae" OR "Sicariidae" OR "Selenopidae" OR "Idiopidae" OR "Oonopidae" OR "Eresidae" OR "Phyxelididae" OR "Mimetidae" OR "Ctenidae" OR “Amaurobiidae” OR "Deinopidae" OR "Hersiliidae" OR "Agelenidae" OR "Segestriidae" OR "Zoropsidae" OR "Nemesiidae" OR "Hahniidae" OR "Anapidae" OR "Cyatholipidae" OR "Daesiidae" OR "Trochanteriidae" OR "Liocranidae" OR "Gallieniellidae" OR "Miturgidae" OR "Pettalidae" OR "Oecobiidae" OR "Phrynichidae" OR "Ctenizidae" OR "Geogarypidae" OR "Atemnidae" OR "Ixodidae" OR "Penestomidae" OR "Cheliferidae" OR "Torrenticolidae" OR "Tenuipalpidae" OR "Biantidae" OR "Phalangiidae" OR "Orsolobidae" OR “Barychelidae” OR “Withiidae” OR “Arrenuridae” OR "Microstigmatidae" OR "Tetranychidae" OR "Olpiidae" OR "Tridenchthoniidae" OR "Theridiosomatidae" OR "Prodidomidae" OR "Desidae" OR "Eriophyidae" OR "Dipluridae" OR "Mysmenidae" OR "Dysderidae" OR "Aturidae" OR "Hygrobatidae" OR "Caddidae" OR “Drymusidae” OR “Trombiculidae” OR “Migidae” OR “Toxopidae” OR “Anyphaenidae” OR "Chthoniidae" OR "Nesticidae" OR "Chernetidae" OR "Feaellidae" OR "Tuckerellidae" OR "Ceromidae" OR "Tydeidae" OR "Cheiridiidae" OR "Gymnobisiidae" OR "Iolinidae" OR "Eupalopsellidae" OR "Atypidae" OR "Phytoseiidae" OR "Phthiracaridae" OR "Hydrachnidae" OR "Stigmaeidae" OR "Symphytognathidae" OR "Polyaspididae" OR "Microdispidae" OR "Oribatidae" OR "Neopilionidae" OR "Podocinidae" OR "Erythraeidae" OR "Anystidae" OR "Trechaleidae" OR "Archaeidae" OR "Filistatidae" OR "Pseudochiridiidae" OR "Garypinidae" OR "Nephilidae" OR "Ammotrechidae" OR "Melanoblossiidae" OR "Siteroptidae" OR "Zorocratidae" OR "Paramegistidae" OR "Udubidae") AND TS=(“South Africa*”)

2.

TS=(“Branchiopoda” OR “Chrysomelidae" OR "Triopsidae" OR "Chydoridae" OR "Streptocephalidae" OR "Daphniidae" OR "Cyzicidae" OR "Ilyocryptidae") AND TS=(“South Africa*”)

3.

TS=(“Sarcopterygii” OR “Latimeriidae") AND TS=(“South Africa*”)

4.

TS=(“Eoacanthocephala” OR “Neoechinorhynchidae") AND TS=(“South Africa*”)

5.

TS=(“Insecta” OR “Scelionidae” OR “Formicidae” OR “Apidae” OR “Nymphalidae” OR “Lycaenidae” OR “Syrphidae” OR “Halictidae” OR “Bombyliidae” OR “Masaridae” OR “Asilidae” OR “Dryinidae” OR “Hydraenidae” OR “Pieridae” OR “Braconidae” OR “Megachilidae” OR “Leptoceridae” OR “Ichneumonidae” OR “Chironomidae” OR “Baetidae” OR “Simuliidae” OR “Pompilidae” OR “Melolonthidae” OR “Hesperiidae” OR “Acrididae” OR “Elmidae” OR “Ceraphronidae” OR “Hydropsychidae” OR “Colletidae” OR “Bethylidae” OR “Nemestrinidae” OR “Notonemouridae” OR “Leptophlebiidae” OR

“Diapriidae” OR “Crabronidae” OR “Platygastridae” OR “Scarabaeidae” OR “Cetoniidae” OR “Evaniidae” OR “Melittidae” OR “Papilionidae” OR “Rhiniidae” OR “Chalcididae” OR “Carabidae” OR “Coenagrionidae” OR “Sphecidae” OR “Barbarochthonidae” OR “Corydalidae” OR “Teloganodidae” OR “Calliphoridae” OR “Philopotamidae” OR “Chrysididae” OR “Proctotrupidae” OR “Figitidae” OR “Scirtidae” OR “Tenebrionidae” OR “Curculionidae” OR “Libellulidae” OR “Caenidae” OR “Ecnomidae” OR “Athericidae” OR “Gyrinidae” OR “Chrysomelidae” OR “Tiphiidae” OR “Naucoridae” OR “Hydroptilidae” OR “Pisuliidae” OR “Glossosomatidae” OR “Dryopidae” OR “Platypezidae” OR “Synlestidae” OR “Heptageniidae” OR “Histeridae” OR “Pteromalidae” OR “Tabanidae” OR “Dytiscidae” OR “Eumenidae” OR “Bittacidae” OR “Staphylinidae” OR “Gasteruptiidae” OR “Tipulidae” OR “Megaspilidae” OR “Myrmeleontidae” OR “Noctuidae” OR “Cynipidae” OR “Cerambycidae” OR “Pipunculidae” OR “Cicadidae” OR “Aeshnidae” OR “Sericostomatidae” OR “Silphidae” OR “Eulophidae” OR “Ceratopogonidae” OR “Ptilodactylidae” OR “Geometridae” OR “Petrothrincidae” OR “Platycnemididae” OR “Lentulidae” OR “Tephritidae” OR “Eucoilidae” OR “Andrenidae” OR “Empididae” OR “Perlidae” OR “Scoliidae” OR “Coccinellidae” OR “Veliidae” OR “Gomphidae” OR “Saturniidae” OR “Encyrtidae” OR “Agaonidae” OR “Hydrophilidae” OR “Mutillidae” OR “Phoridae” OR “Notonectidae” OR “Torymidae” OR “Cleridae” OR “Corixidae” OR “Sphingidae” OR “Limoniidae” OR “Aphidiidae” OR “Tettigoniidae” OR “Rutelidae” OR “Ampulicidae” OR “Sarcophagidae” OR “Sapygidae” OR “Crambidae” OR “Acroceridae” OR “Vespidae” OR “Blaberidae” OR “Elateridae” OR “Reduviidae” OR “Polycentropodidae” OR “Anthophoridae” OR “Arctiidae” OR “Muscidae” OR “Eupelmidae” OR “Pentatomidae” OR “Tricorythidae” OR “Mycetophilidae” OR “Pyrgomorphidae” OR “Meloidae” OR “Eurytomidae” OR “Chrysopidae” OR “Erebidae” OR “Gerridae” OR “Psychodidae” OR “Mydidae” OR “Buprestidae” OR “Dolichopodidae” OR “Nitidulidae” OR “Lycidae” OR “Psephenidae” OR “Bradynobaenidae” OR “Conopidae” OR “Melyridae” OR “Eucharitidae” OR “Cicadellidae” OR “Dynastidae” OR “Belostomatidae” OR “Stephanidae” OR “Tetrigidae” OR “Cercopidae” OR “Anostostomatidae” OR “Lygaeidae” OR “Dipseudopsidae” OR “Culicidae” OR “Chlorocyphidae” OR “Satyridae” OR “Pyralidae” OR “Plumariidae” OR “Elasmidae” OR “Stratiomyidae” OR “Corduliidae” OR “Bostrichidae” OR “Protoneuridae” OR “Coreidae” OR “Prosopistomatidae” OR “Aphodiidae” OR “Lampyridae” OR “Rhopalosomatidae” OR “Aphrophoridae” OR “Pamphagidae” OR “Nemopteridae” OR “Tachinidae” OR “Eupterotidae” OR “Nepidae” OR “Bacillidae” OR “Lasiocampidae” OR “Scutelleridae” OR “Signiphoridae” OR “Pyrrhocoridae” OR “Pleidae” OR “Megalyridae” OR “Xylocopidae” OR “Calopterygidae” OR “Derbidae” OR “Polymitarcyidae” OR “Oligoneuriidae” OR “Lestidae” OR “Hydrometridae” OR “Tenthredinidae” OR “Psychidae” OR “Ascalaphidae” OR “Mantidae” OR “Chaoboridae” OR “Himantopteridae” OR “Phasmatidae” OR “Limacodidae” OR “Thericleidae” OR “Discolomatidae” OR “Alydidae” OR “Tineidae” OR “Leucospidae” OR “Mymaridae” OR “Dermestidae” OR “Lucanidae” OR “Miridae” OR “Termitidae” OR “Leiodidae” OR “Mordellidae” OR “Ephydridae” OR “Trogidae” OR “Anthicidae” OR “Brachyceridae” OR “Fulgoridae” OR “Pterophoridae” OR “Ormyridae” OR “Scolytidae” OR “Machadorythidae” OR “Aphididae” OR “Ulidiidae” OR “Anthribidae
” OR “Mesoveliidae” OR “Sclerogibbidae” OR “Blattidae” OR “Sesiidae” OR “Lymantriidae” OR “Pneumoridae” OR “Embolemidae” OR “Haliplidae” OR “Notodontidae” OR “Psyllidae” OR “Anobiidae” OR “Salpingidae” OR “Dictyopharidae” OR “Gryllotalpidae” OR “Cossidae” OR “Scathophagidae” OR “Sepsidae” OR “Hepialidae” OR “Apionidae” OR “Rhyparochromidae” OR “Noteridae” OR “Scydmaenidae” OR “Mantispidae” OR “Aphelinidae” OR “Heteronemiidae” OR “Gryllidae” OR “Sisyridae” OR

“Ptinidae” OR “Cydnidae” OR “Blephariceridae” OR “Dixidae” OR “Cantharidae” OR “Cryptophagidae” OR “Cucujidae” OR “Rhipiceridae” OR “Tingidae” OR “Mantophasmatidae” OR “Stenopelmatidae” OR “Dryophthoridae” OR “Flatidae” OR “Chrysopolomidae” OR “Diapheromeridae” OR “Plataspidae” OR “Aphelocheiridae” OR “Corydiidae” OR “Tropiduchidae” OR “Philopteridae” OR “Therevidae” OR “Sciomyzidae” OR “Sciaridae” OR “Hemerobiidae” OR “Gelechiidae” OR “Tetracampidae” OR “Ciidae” OR “Corylophidae” OR “Schizodactylidae” OR “Brentidae” OR “Gelastocoridae” OR “Rhopalidae” OR “Tessaratomidae” OR “Aulacidae” OR “Phlaeothripidae” OR “Stenopsychidae” OR “Diaspididae” OR “Hydroscaphidae” OR “Limnichidae” OR “Monotomidae” OR “Oedemeridae” OR “Ptiliidae” OR “Scraptiidae” OR “Trogossitidae” OR “Tortricidae” OR “Blattellidae” OR “Keroplatidae” OR “Psychopsidae” OR “Ricaniidae” OR “Tanyderidae” OR “Coccidae” OR “Erotylidae” OR “Tridactylidae” OR “Diopsidae” OR “Trichogrammatidae” OR “Byrrhidae” OR “Cerylonidae” OR “Clambidae” OR “Latridiidae” OR “Lymexylidae” OR “Phalacridae” OR “Forficulidae” OR “Labiduridae” OR “Blissidae” OR “Siricidae” OR “Delphacidae” OR “Pulicidae” OR “Scythrididae” OR “Empusidae” OR “Tarachodidae” OR “Toxoderidae” OR “Perilampidae” OR “Lauxaniidae” OR “Milichiidae” OR “Oestridae” OR “Cimicidae” OR “Hybotidae” OR “Nolidae” OR “Liposcelidae” OR “Trigonidiidae” OR “Platypodidae” OR “Colydiidae” OR “Scolebythidae” OR “Trigonalyidae” OR “Lagriidae” OR “Ectobiidae” OR “Georissidae” OR “Galinthiadidae” OR “Protelmidae”) AND TS=(“South Africa*”)

6.

TS=(“Entognatha” OR “Isotomidae" OR "Entomobryidae" OR "Hypogastruridae" OR "Neelidae" OR "Neanuridae" OR "Onychiuridae" OR "Katiannidae" OR "Tomoceridae" OR "Poduridae" OR "Sminthurididae" OR "Bourletiellidae" OR "Sminthuridae" OR "Tullbergiidae") AND TS=(“South Africa*”)

7.

TS=(“Diplopoda” OR “Spirostreptidae” OR "Pachybolidae" OR "Julidae" OR "Sphaerotheriidae" OR "Dalodesmidae" OR "Harpagophoridae" OR "Siphonotidae" OR "Paradoxosomatidae" OR "Odontopygidae" OR "Polyxenidae") AND TS=(“South Africa*”)

8.

TS=(“Chilopoda” OR "Scolopendridae" OR "Henicopidae" OR "Scutigeridae" OR "Scutigerinidae" OR "Cryptopidae" OR "Lithobiidae" OR "Aphilodontidae") AND TS=(“South Africa*”)

9.

TS=(“Malacostraca” OR "Potamonautidae" OR "Ocypodidae" OR "Atyidae" OR "Talitridae" OR "Diogenidae" OR "Palinuridae" OR "Plagusiidae" OR "Sphaeromatidae" OR "Sesarmidae" OR "Paguridae" OR "Grapsidae" OR "Varunidae" OR "Palaemonidae" OR "Mysidae" OR "Inachidae" OR "Dromiidae" OR "Portunidae" OR "Armadillidiidae" OR "Amphisopidae" OR "Parapaguridae" OR "Cirolanidae" OR "Pontogeneiidae" OR "Stenopodidae" OR "Lysianassidae" OR "Porcellionidae" OR "Tylidae" OR "Epialtidae" OR "Carcinidae" OR "Detonidae" OR "Ligiidae" OR "Ovalipidae" OR "Gecarcinidae" OR "Eriphiidae" OR "Hippolytidae" OR "Odontodactylidae" OR "Cymothoidae" OR "Idoteidae" OR "Pilumnoididae" OR "Paguridea" OR "Callianassidae" OR "Hymenosomatidae" OR "Iphimediidae" OR "Stenothoidae" OR "Hippidae" OR "Alloniscidae" OR "Dotillidae" OR "Hymenoceridae" OR "Hyalidae" OR "Rhynchocinetidae" OR "Trapeziidae" OR "Xanthidae" OR "Parastacidae" OR "Pinnotheridae" OR "Scyllaridae" OR "Oziidae" OR "Matutidae" OR "Leucosiidae" OR "Alpheidae" OR "Penaeidae" OR "Janiridae" OR "Ochlesidae" OR "Coenobitidae" OR "Gnathophyllidae" OR "Thalassinidae" OR "Arcturidae" OR "Camptandriidae" OR "Paramelitidae" OR "Cyproideidae" OR "Pilumnidae" OR "Upogebiidae" OR "Paranthuridae" OR "Stenetriidae" OR "Sergestidae"

OR "Melitidae" OR "Goneplacidae" OR "Porcellanidae" OR "Potamidae" OR "Raninidae" OR "Armadillidae" OR "Corallanidae" OR "Philosciidae" OR "Galatheidae" OR "Chasmocarcinidae" OR "Spelaeogriphidae" OR "Percnidae") AND TS=("South Africa*")
10.
TS=("Maxillopoda" OR "Chthamalidae" OR "Tetraclitidae" OR "Balanidae" OR "Lepadidae" OR "Anelasmatidae" OR "Archaeobalanidae" OR "Platylepadidae" OR "Scalpellidae" OR "Chelonibiidae" OR "Coronulidae") AND TS=("South Africa*")
11.
TS=("Ostracoda" OR "Cyprididae" OR "Cytherideidae" OR "Trachyleberididae" OR "Cytherellidae" OR "Cytheruridae" OR "Bairdiidae" OR "Candonidae" OR "Limnocytheridae" OR "Macrocyprididae" OR "Pontocyprididae" OR "Xestoleberididae" OR "Progonocytheridae") AND TS=("South Africa*")
12.
TS=("Pycnogonida" OR "Callipallenidae" OR "Ammotheidae" OR "Nymphonidae" OR "Colossendeidae") AND TS=("South Africa*")
13.
TS=("Actinopterygii" OR "Cyprinidae" OR "Sparidae" OR "Cichlidae" OR "Gobiidae" OR "Labridae" OR "Serranidae" OR "Galaxiidae" OR "Anabantidae" OR "Anguillidae" OR "Chaetodontidae" OR "Scorpaenidae" OR "Clinidae" OR "Mochokidae" OR "Apogonidae" OR "Mugilidae" OR "Pomacentridae" OR "Blenniidae" OR "Acanthuridae" OR "Acanthuridae" OR "Tetraodontidae" OR "Muraenidae" OR "Cheilodactylidae" OR "Amphiliidae" OR "Austroglanididae" OR "Clariidae" OR "Centrarchidae" OR "Poeciliidae" OR "Balistidae" OR "Holocentridae" OR "Pomacanthidae" OR "Lutjanidae" OR "Haemulidae" OR "Pseudochromidae" OR "Myctophidae" OR "Mormyridae" OR "Mullidae" OR "Sciaenidae" OR "Syngnathidae" OR "Synodontidae" OR "Stomiidae" OR "Ariidae" OR "Monacanthidae" OR "Tripterygiidae" OR "Alestidae" OR "Clupeidae" OR "Macrouridae" OR "Kyphosidae" OR "Lethrinidae" OR "Soleidae" OR "Eleotridae" OR "Cirrhitidae" OR "Monodactylidae" OR "Triglidae" OR "Antennariidae" OR "Ophidiidae" OR "Gobiesocidae" OR "Sternoptychidae" OR "Pinguipedidae" OR "Salmonidae" OR "Scaridae" OR "Pempheridae" OR "Bothidae" OR "Callionymidae" OR "Scombridae" OR "Nototheniidae" OR "Caesionidae" OR "Ambassidae" OR "Congridae" OR "Oplegnathidae" OR "Diodontidae" OR "Ostraciidae" OR "Platycephalidae" OR "Engraulidae" OR "Paralepididae" OR "Paralichthyidae" OR "Atherinidae" OR "Ogcocephalidae" OR "Notosudidae" OR "Melamphaidae" OR "Microdesmidae" OR "Leiognathidae" OR "Terapontidae" OR "Kuhliidae" OR "Cynoglossidae" OR "Priacanthidae" OR "Bathylagidae" OR "Sillaginidae" OR "Sphyraenidae" OR "Gonostomatidae" OR "Gerreidae" OR "Loricariidae" OR "Batrachoididae" OR "Platytroctidae" OR "Lampridae" OR "Nomeidae" OR "Melanonidae" OR "Moridae" OR "Oneirodidae" OR "Zanclidae" OR "Samaridae" OR "Malacanthidae" OR "Trichiuridae" OR "Pleuronectidae" OR "Bythitidae" OR "Nemichthyidae" OR "Centriscidae" OR "Serrivomeridae" OR "Siganidae" OR "Schilbeidae" OR "Pomatomidae" OR "Derichthyidae" OR "Characidae" OR "Dichistiidae" OR "Sebastidae" OR "Dussumieriidae" OR "Phosichthyidae" OR "Ophichthidae" OR "Trachichthyidae" OR "Synaphobranchidae" OR "Belonidae" OR "Polynemidae" OR "Oreosomatidae" OR "Scopelarchidae" OR "Exocoetidae" OR "Berycidae" OR "Chiasmodontidae" OR "Parascorpididae" OR "Kneriidae" OR "Neoscopelidae" OR "Opisthoproctidae" OR "Creediidae" OR "Ephippidae" OR "Gempylidae" OR "Fistulariidae" OR "Champsodontidae" OR "Opistognathidae" OR "Apistidae" OR "Monocentridae" OR "Melanocetidae" OR "Dinopercidae" OR "Zoarcidae" OR "Plotosidae" OR "Aulostomidae" OR "Chlorophthalmidae" OR "Alepocephalidae" OR "Liparidae" OR "Peristediidae" OR "Tetrarogidae" OR "Bregmacerotidae" OR "Caristiidae" OR "Congiopodidae" OR

“Diretmidae" OR “Acropomatidae" OR “Ariommatidae" OR “Bramidae" OR “Epigonidae" OR “Zeidae" OR “Anoplogastridae" OR “Pentacerotidae" OR “Scombropidae" OR “Polymixiidae" OR “Aploactinidae" OR “Molidae" OR “Ateleopodidae" OR “Moringuidae" OR “Hemiramphidae" OR “Himantolophidae" OR “Caproidae" OR “Emmelichthyidae" OR “Citharidae" OR “Lotidae" OR “Solenostomidae" OR “Rondeletiidae" OR “Merlucciidae" OR “Lophotidae" OR “Setarchidae" OR “Microstomatidae" OR “Centrolophidae" OR “Drepaneidae" OR “Osphronemidae" OR “Psychrolutidae" OR “Callichthyidae" OR “Howellidae" OR “Isonidae" OR “Pristigasteridae" OR “Chanidae" OR “Regalecidae" OR “Chaunacidae" OR “Lophiidae" OR “Coryphaenidae" OR “Synanceiidae" OR “Cyttidae" OR “Aracanidae" OR “Albulidae" OR “Alepisauridae" OR “Trachipteridae" OR “Ceratiidae" OR “Notacanthidae" OR “Callanthiidae" OR “Echeneidae” OR “Percophidae” OR “Dactylopteridae” OR “Zenarchopteridae” OR “Grammicolepididae” OR “Muraenesocidae” OR “Nettastomatidae” OR “Chirocentridae” OR “Cobitidae” OR “Gonorynchidae” OR “Notopteridae” OR “Harpagiferidae” OR “Menidae” OR “Siluridae” OR “Triodontidae” OR “Melanotaeniidae” OR “Scomberesocidae” OR “Megalopidae” OR “Muraenolepididae” OR “Linophrynidae” OR “Pangasiidae” OR “Halosauridae” OR “Parazenidae” OR “Triacanthodidae” OR “Mastacembelidae” OR “Chlopsidae” OR “Bathysauridae” OR “Barbourisiidae” OR “Gyrinocheilidae” OR “Elopidae” OR “Radiicephalidae” OR “Argentinidae” OR “Pantodontidae” OR “Nemipteridae” OR “Hoplichthyidae” OR “Parabembridae” OR “Doradidae” OR “Pimelodidae” OR “Colocongridae” OR “Evermannellidae” OR “Giganturidae” OR “Carapidae” OR “Osteoglossidae” OR “Lobotidae” OR “Ostracoberycidae” OR “Uranoscopidae” OR “Saccopharyngidae” OR “Bagridae”) AND TS=(“South Africa*”)

14.

TS=(“Amphibia” OR “Arthroleptidae” OR “Brevicipitidae” OR “Bufonidae” OR “Heleophrynidae” OR “Hemisotidae” OR “Hyperoliidae” OR “Microhylidae” OR “Phrynobatrachidae” OR “Pipidae” OR “Ptychadenidae” OR “Pyxicephalidae” OR “Rhacophoridae”) AND TS=(“South Africa*”)

15.

TS=("Ascidiacea" OR "Polyclinidae" OR "Styelidae" OR "Didemnidae" OR "Pseudodistomidae" OR "Holozoidae" OR "Polycitoridae" OR "Euherdmaniidae" OR "Clavelinidae" OR "Pyuridae" OR "Ascidiidae" OR "Cionidae" OR "Molgulidae") AND TS=(“South Africa*”)

16.

TS=(“Aves” OR “Ploceidae” OR “Columbidae” OR “Hirundinidae” OR “Cisticolidae” OR “Muscicapidae” OR “Anatidae” OR “Accipitridae” OR “Sturnidae” OR “Ardeidae” OR “Passeridae” OR “Charadriidae” OR “Estrildidae” OR “Malaconotidae” OR “Threskiornithidae” OR “Motacillidae” OR “Pycnonotidae” OR “Nectariniidae” OR “Ramphastidae” OR “Apodidae” OR “Fringillidae” OR “Laniidae” OR “Coliidae” OR “Rallidae” OR “Zosteropidae” OR “Alcedinidae” OR “Phalacrocoracidae” OR “Phasianidae” OR “Laridae” OR “Cuculidae” OR “Alaudidae” OR “Corvidae” OR “Scolopacidae” OR “Turdidae” OR “Numididae” OR “Dicruridae” OR “Bucerotidae” OR “Picidae” OR “Musophagidae” OR “Acrocephalidae” OR “Meropidae” OR “Emberizidae” OR “Viduidae” OR “Sulidae” OR “Podicipedidae” OR “Falconidae” OR “Platysteiridae” OR “Sylviidae” OR “Macrosphenidae” OR “Otididae” OR “Upupidae” OR “Phoeniculidae” OR “Burhinidae” OR “Oriolidae” OR “Strigidae” OR “Recurvirostridae” OR “Anhingidae” OR “Coraciidae” OR “Monarchidae” OR “Ciconiidae” OR “Leiothrichidae” OR “Paridae” OR “Locustellidae” OR “Indicatoridae” OR “Scopidae” OR “Buphagidae” OR “Gruidae” OR “Struthionidae” OR “Phylloscopidae” OR “Phoenicopteridae” OR “Caprimulgidae” OR “Parulidae” OR “Psittacidae” OR “Jacanidae” OR “Haematopodidae” OR “Promeropidae” OR

“Campephagidae” OR “Pteroclididae” OR “Prionopidae” OR “Tytonidae” OR “Pelecanidae” OR “Glareolidae” OR “Sagittariidae” OR “Stenostiridae” OR “Remizidae” OR “Bucorvidae” OR “Trogonidae” OR “Pandionidae” OR “Nicatoridae” OR “Turnicidae” OR “Rostratulidae” OR “Spheniscidae” OR “Heliornithidae” OR “Chaetopidae” OR “Procellariidae” OR “Stercorariidae” OR “Eurylaimidae” OR “Diomedeidae” OR “Hydrobatidae” OR “Fregatidae” OR “Dromadidae” OR “Thraupidae" OR "Chionidae" OR "Hyliotidae" OR "Phaethontidae" OR "Certhiidae" OR "Prunellidae") AND TS=(“South Africa*”)
17.
TS=(“Chondrichthyes” OR “Scyliorhinidae" OR "Triakidae" OR "Carcharhinidae" OR "Myliobatidae" OR "Rajidae" OR "Hexanchidae" OR "Lamnidae" OR "Rhinobatidae" OR "Dasyatidae" OR "Sphyrnidae" OR "Etmopteridae" OR "Squalidae" OR "Gymnuridae" OR "Narkidae" OR "Odontaspididae" OR "Torpedinidae" OR "Pristiophoridae" OR "Squatinidae" OR "Alopiidae" OR "Arhynchobatidae" OR "Rhincodontidae" OR "Dalatiidae" OR "Cetorhinidae" OR "Rhinidae” OR “Chimaeridae” OR “Callorhinchidae”) AND TS=(“South Africa*”)
18.
TS=(“Mammalia” OR “Muridae” OR “Vespertilionidae” OR “Bovidae” OR “Molossidae” OR “Canidae” OR “Soricidae” OR “Felidae” OR “Suidae” OR “Miniopteridae” OR “Herpestidae” OR “Rhinolophidae” OR “Cercopithecidae” OR “Macroscelididae” OR “Procaviidae” OR “Chrysochloridae” OR “Mustelidae” OR “Viverridae” OR “Pteropodidae” OR “Nesomyidae” OR “Nycteridae” OR “Leporidae” OR “Hyperoodontidae” OR “Equidae” OR “Emballonuridae” OR “Hyaenidae” OR “Sciuridae” OR “Hystricidae” OR “Giraffidae” OR “Hominidae” OR “Pedetidae” OR “Rhinocerotidae” OR “Elephantidae” OR “Hipposideridae” OR “Hippopotamidae” OR “Otariidae” OR “Delphinidae” OR “Kogiidae” OR “Bathyergidae” OR “Orycteropodidae” OR “Galagidae”) AND TS=(“South Africa*”)
19.
TS=(“Myxini” OR “Myxinidae”) AND TS=(“South Africa*”)
20.
TS=(“Clitellata” OR “Naididae” OR “Tubificidae” OR “Glossiphoniidae” OR “Lumbriculidae” OR “Microchaetidae” OR “Acanthodrilidae” OR “Salifidae” OR “Glossoscolecidae”) AND TS=(“South Africa*”)
21.
TS=(“Polychaeta” OR “Eunicidae” OR “Aphroditidae” OR “Polynoidae” OR “Sabellidae” OR “Flabelligeridae”) AND TS=(“South Africa*”)
22.
TS=(“Hexanauplia” OR “Cyclopidae" OR "Caligidae”) AND TS=(“South Africa*”)
23.
TS=(“Symphyla” OR “Scutigerellidae”) AND TS=(“South Africa*”)
24.
TS=(“Rhynchonellata” OR “Kraussinidae”) AND TS=(“South Africa*”)
25.
TS=(“Gymnolaemata” OR “Adeonidae” OR “Phidoloporidae” OR “Candidae” OR “Lepraliellidae” OR “Buskiidae” OR “Gigantoporidae” OR “Cribrilinidae” OR “Calwelliidae” OR “Thalamoporellidae” OR “Celleporidae” OR “Chaperiidae” OR “Alcyonidiidae” OR “Victorellidae” OR “Lanceoporidae” OR “Bugulidae” OR “Flustridae” OR “Membraniporidae”) AND TS=(“South Africa*”)
26.
TS=(“Phylactolaemata” OR "Plumatellidae" OR "Fredericellidae") AND TS=(“South Africa*”)
27.

TS=(“Stenolaemata” OR "Tubuliporidae" OR "Leiosoeciidae”) AND TS=(“South Africa*”)
28.
TS=(“Bivalvia” OR “Veneridae” OR “Mytilidae” OR “Donacidae” OR “Pectinidae” OR “Tellinidae” OR “Cyrenidae” OR “Limidae” OR “Pteriidae” OR “Sphaeriidae” OR “Arcidae” OR “Psammobiidae” OR “Lucinidae” OR “Galeommatidae” OR “Cardiidae” OR “Glycymerididae” OR “Mactridae” OR “Carditidae” OR “Crassatellidae” OR “Ungulinidae” OR “Solenidae” OR “Semelidae” OR “Pharidae” OR “Ostreidae” OR “Anomiidae” OR “Nuculidae” OR “Hiatellidae”) AND TS=(“South Africa*”)
29.
TS=(“Ophiuroidea” OR “Ophiotrichidae” OR “Ophionereididae” OR “Gorgonocephalidae” OR “Ophiactidae” OR “Ophiocomidae” OR “Amphiuridae” OR “Ophiopezidae” OR “Ophiodermatidae” OR “Ophiolepididae” OR “Euryalidae” OR “Ophiacanthidae” OR “Ophiuridae” OR “Ophiomyxidae” OR “Ophiopsilidae”) AND TS=(“South Africa*”)
30.
TS=(“Holothuroidea” OR "Holothuriidae" OR "Cucumariidae" OR "Stichopodidae" OR "Phyllophoridae" OR "Sclerodactylidae") AND TS=(“South Africa*”)
31.
TS=(“Echinoidea” OR “Echinometridae” OR “Diadematidae” OR “Cidaridae” OR “Toxopneustidae” OR “Parechinidae” OR “Temnopleuridae” OR “Echinoneidae” OR “Stomopneustidae” OR “Eurypatagidae”) AND TS=(“South Africa*”)
32.
TS=(“Crinoidea” OR “Comasteridae”) AND TS=(“South Africa*”)
33.
TS=(“Asteroidea” OR “Goniasteridae” OR “Echinasteridae” OR “Asterinidae” OR “Ophidiasteridae” OR “Asteriidae” OR “Astropectinidae” OR “Mithrodiidae” OR “Oreasteridae” OR “Pterasteridae”) AND TS=(“South Africa*”)
34.
TS=(“Hydrozoa” OR “Aglaopheniidae” OR “Stylasteridae” OR “Sertularellidae” OR “Tubulariidae” OR “Sertulariidae” OR “Halopterididae” OR “Solanderiidae” OR “Hydridae” OR “Porpitidae”) AND TS=(“South Africa*”)
35.
TS=(“Cubozoa” OR “Carybdeidae”) AND TS=(“South Africa*”)
36.
TS=(“Anthozoa” OR “Gorgoniidae” OR “Alcyoniidae” OR “Dendrophylliidae” OR “Melithaeidae” OR “Spongiodermidae” OR “Sagartiidae” OR “Parazoanthidae” OR “Nephtheidae” OR “Actiniidae” OR “Acrophytidae” OR “Clavulariidae” OR “Echinoptilidae” OR “Parasphaerascleridae” OR “Keroeididae” OR “Chrysogorgiidae” OR “Leptophytidae”) AND TS=(“South Africa*”)
37.
TS=(“Reptilia” OR “Agamidae” OR “Amphisbaenidae” OR “Chamaeleonidae” OR “Colubridae” OR “Cordylidae” OR “Crocodylidae” OR “Elapidae” OR “Gekkonidae” OR “Gerrhosauridae” OR “Lacertidae” OR “Lamprophiidae” OR “Leptotyphlopidae” OR “Pelomedusidae” OR “Pythonidae” OR “Scincidae” OR “Testudinidae” OR “Typhlopidae” OR “Varanidae” OR “Viperidae”) AND TS=(“South Africa*”)
38.
TS=(“Cephalopoda” OR "Octopodidae" OR "Sepiidae" OR "Spirulidae") AND TS=(“South Africa*”)
39.
TS=(“Gastropoda” OR “Muricidae” OR “Cypraeidae” OR “Patellidae” OR “Planorbidae” OR “Calyptraeidae” OR “Burnupiidae” OR “Marginellidae” OR “Megalomastomatidae” OR

“Trochidae” OR “Cymatiidae” OR “Nassariidae” OR “Buccinidae” OR “Fasciolariidae” OR “Clavatulidae” OR “Ancillariidae” OR “Conidae” OR “Turbinidae” OR “Fissurellidae” OR “Haliotidae” OR “Columbellidae” OR “Triviidae” OR “Siphonariidae” OR “Lymnaeidae” OR “Triphoridae” OR “Epitoniidae” OR “Urocyclidae” OR “Cyclophoridae” OR “Littorinidae” OR “Naticidae” OR “Bulinidae” OR “Phasianellidae” OR “Mitridae” OR “Physidae” OR “Calliostomatidae” OR “Vermetidae” OR “Achatinidae” OR “Neritidae” OR “Nacellidae” OR “Streptaxidae” OR “Helicidae” OR “Volutidae” OR “Turritellidae” OR “Rhytididae” OR “Cepolidae” OR “Eulimidae” OR “Cancellariidae” OR “Pisaniidae” OR “Tonnidae” OR “Siliquariidae” OR “Cassidae” OR “Turridae” OR “Turbinellidae” OR “Harpidae” OR “Pyramidellidae” OR “Chromodorididae” OR “Proctonotidae” OR “Cadlinidae” OR “Pomatiidae” OR “Charitodoronidae” OR “Aeolidiidae” OR “Ovulidae” OR “Cystiscidae” OR “Acteonidae” OR “Cerithiidae” OR “Pseudolividae” OR “Trimusculidae” OR “Aplysiidae” OR “Glaucidae” OR “Facelinidae” OR “Strombidae” OR “Hipponicidae” OR “Cerastidae” OR “Dorcasiidae” OR “Strepsiduridae” OR “Mangeliidae” OR “Conorbidae” OR “Areneidae” OR “Eoacmaeidae” OR “Charoniidae” OR “Tomichiidae”) AND TS=(“South Africa*”)

40.

TS=(“Polyplacophora” OR “Ischnochitonidae” OR “Acanthochitonidae” OR “Chaetopleuridae” OR “Chitonidae”) AND TS=(“South Africa*”)

41.

TS=(“Scaphopoda” OR “Dentaliidae”) AND TS=(“South Africa*”)

42.

TS=(“Adenophorea” OR “Mermithidae” OR “Trichinellidae”) AND TS=(“South Africa*”)

43.

TS=(“Secernentea” OR “Trichostrongylidae” OR “Strongylidae” OR “Habronematidae” OR “Cosmocercidae” OR “Rhabdiasidae” OR “Haemonchidae” OR “Ancylostomatidae” OR “Ascarididae” OR “Spirocercidae” OR “Onchocercidae” OR “Oxyuridae”) AND TS=(“South Africa*”)

44.

TS=(“Gordioida” OR “Chordodidae”) AND TS=(“South Africa*”)

45.

TS=(“Cestoda” OR “Echinobothriidae” OR "Nematotaeniidae” OR "Bothriocephalidae” OR "Taeniidae” OR "Dipylidiidae”) AND TS=(“South Africa*”)

46.

TS=(“Monogenea” OR "Diplozoidae" OR "Gyrodactylidae" OR "Monocotylidae”) AND TS=(“South Africa*”)

47.

TS=(“ Trematoda” OR “Schistosomatidae” OR “Strigeidae” OR “Echinostomatidae” OR “Diplostomidae” OR “Brachylaimidae” OR “Notocotylidae” OR “Eucotylidae” OR “Gastrodiscidae”) AND TS=(“South Africa*”)

48.

TS=(“Demospongiae” OR “Microcionidae” OR “Chondropsidae” OR “Isodictyidae” OR “Chalinidae” OR “Irciniidae” OR “Polymastiidae” OR “Halichondriidae” OR “Latrunculiidae” OR “Tethyidae” OR “Acarnidae” OR “Hamacanthidae” OR “Spongillidae” OR “Aplysinellidae”) AND TS=(“South Africa*”)

49.

TS=(“Eurotatoria” OR “Brachionidae”) AND TS=(“South Africa*”)

Keywords used on Web of Science (WoS) for the sub-sample of 31 South African herpetofaunal families.

Note: Scientific names are copied verbatim from GBIF (2020).

1.
TS=(“Arthroleptidae” OR “Leptopelis” OR “Arthroleptis”) AND TS=(“South Africa*”)
2.
TS=(“Brevicipitidae” OR “Breviceps”) AND TS=(“South Africa*”)
3.
TS=(“Bufonidae” OR “Vandijkophrynus” OR “Sclerophrys” OR “Amietophrynus” OR “Schismaderma” OR “Poyntonophrynus” OR “Capensibufo” OR “Bufo”) AND TS=(“South Africa*”)
4.
TS=(“Heleophrynidae” OR “Heleophryne” OR “Hadromophryne”) AND TS=(“South Africa*”)
5.
TS=(“Hemisotidae” OR “Hemisus”) AND TS=(“South Africa*”)
6.
TS=(“Hyperoliidae” OR “Hyperolius” OR “Semnodactylus" OR "Kassina" OR "Afrixalus") AND TS=(“South Africa*”)
7.
TS=(“Microhylidae” OR “Phrynomantis”) AND TS=(“South Africa*”)
8.
TS=(“Phrynobatrachidae” OR “Phrynobatrachus”) AND TS=(“South Africa*”)
9.
TS=(“Pipidae” OR “Xenopus”) AND TS=(“South Africa*”)
10.
TS=(“Ptychadenidae” OR “Ptychadena”) AND TS=(“South Africa*”)
11.
TS=(“Pyxicephalidae” OR “Species” OR “Amietia” OR “Arthroleptella” OR “Cacosternum” OR “Strongylopus” OR “Tomopterna” OR “Anhydrophryne” OR “Pyxicephalus” OR “Poyntonia”) AND TS=(“South Africa*”)
12.
TS=(“Rhacophoridae” OR “Chiromantis”) AND TS=(“South Africa*”)
13.
TS=(“Agamidae” OR “Acanthocercus” OR “Agama”) AND TS=(“South Africa*”)
14.
TS=(“Amphisbaenidae” OR “Zygaspis” OR “Monopeltis”) AND TS=(“South Africa*”)
15.
TS=(“Chamaeleonidae” OR “Bradypodion” OR “Chamaeleo”) AND TS=(“South Africa*”)
16.
TS=(“Colubridae” OR “Dasypeltis” OR “Crotaphopeltis” OR “Philothamnus” OR “Dispholidus” OR “Thelotornis” OR “Telescopus” OR “Rhamnophis” OR “Dipsadoboa”) AND TS=(“South Africa*”)
17.
TS=(“Cordylidae” OR “Cordylus” OR “Platysaurus” OR “Karusasaurus” OR “Pseudocordylus” OR “Ouroborus” OR “Chamaesaura” OR “Hemicordylus” OR “Ninurta”) AND TS=(“South Africa*”)
18.

TS=("Crocodylidae" OR "Crocodylus") AND TS=("South Africa*")
19.
TS=("Elapidae" OR "Naja" OR "Aspidelaps" OR "Hemachatus" OR "Elapsoidea" OR "Dendroaspis") AND TS=("South Africa*")
20.
TS=("Gekkonidae" OR "Pachydactylus" OR "Chondrodactylus" OR "Lygodactylus" OR "Goggia" OR "Hemidactylus" OR "Afrogecko" OR "Afroedura" OR "Homopholis" OR "Ptenopus" OR "Rhoptropella" OR "Colopus") AND TS=("South Africa*")
21.
TS=("Gerrhosauridae" OR "Gerrhosaurus" OR "Tetradactylus" OR "Matobosaurus" OR "Cordylosaurus" OR "Broadleysaurus") AND TS=("South Africa*")
22.
TS=("Lacertidae" OR "Pedioplanis" OR "Meroles" OR "Nucras" OR "Heliobolus" OR "Ichnotropis" OR "Tropidosaura" OR "Lacerta" OR "Australolacerta") AND TS=("South Africa*")
23.
TS=("Lamprophiidae" OR "Psammophis" OR "Boaedon" OR "Psammophylax" OR "Pseudaspis" OR "Aparallactus" OR "Lycodonomorphus" OR "Lamprophis" OR "Lycophidion" OR "Atractaspis" OR "Duberria" OR "Prosymna" OR "Gonionotophis" OR "Homoroselaps" OR "Xenocalamus" OR "Dipsina" OR "Amblyodipsas" OR "Rhamphiophis" OR "Amplorhinus" OR "Hemirhagerrhis") AND TS=("South Africa*")
24.
TS=("Leptotyphlopidae" OR "Leptotyphlops" OR "Myriopholis") AND TS=("South Africa*")
25.
TS=("Pelomedusidae" OR "Pelusios" OR "Pelomedusa") AND TS=("South Africa*")
26.
TS=("Pythonidae" OR "Python") AND TS=("South Africa*")
27.
TS=("Scincidae" OR "Trachylepis" OR "Acontias" OR "Scelotes" OR "Panaspis" OR "Typhlosaurus" OR "Mabuya" OR "Lygosoma" OR "Mochlus" OR "Afroablepharus") AND TS=("South Africa*")
28.
TS=("Testudinidae" OR "Chersina" OR "Stigmochelys" OR "Homopus" OR "Kinixys" OR "Psammobates") AND TS=("South Africa*")
29.
TS=("Typhlopidae" OR "Afrotyphlops" OR "Rhinotyphlops" OR "Typhlops") AND TS=("South Africa*")
30.
TS=("Varanidae" OR "Varanus") AND TS=("South Africa*")
31.
TS=("Viperidae" OR "Causus" OR "Bitis") AND TS=("South Africa*")

Supplementary Material 2: Biases in the primary biodiversity data, cultural salience, and scientific interest of South African animal classes. Taxa are arranged alphabetically by class name.

Class*	Ratio	Science	Culture	Class*	Ratio	Science	Culture
Actinopterygii	6.47	515	5370	Holothuroidea	0.25	19	339
Amphibia	9.33	108	7200	Hydrozoa	0.44	10	758
Anthozoa	3.07	33	843	Insecta	1.25	2240	7740
Arachnida	0.44	338	4800	Malacostraca	0.11	170	558
Ascidiacea	3.18	9	438	Mammalia	2.01	400	68600
Asteroidea	0.59	8	731	Maxillopoda	0.02	4	211
Aves	18,584	155	94800	Monogenea	0.18	71	613
Bivalvia	0.2	69	5250	Myxini	1.75	3	211
Branchiopoda	0.08	179	410	Ophiuroidea	1.08	7	438
Cephalopoda	0.09	85	5070	Ostracoda	0.11	24	2590
Cestoda	0.39	44	599	Polychaeta	0.01	48	3960
Chilopoda	1.04	9	604	Polyplacophora	0.24	8	220
Chondrichthyes	2.92	97	5060	Pycnogonida	0.05	3	331
Clitellata	0.76	33	548	Reptilia	8.35	180	8300
Crinoidea	1.58	1	411	Sarcopterygii	5.67	4	1370
Cubozoa	0.5	3	174	Scaphopoda	0.13	0	213
Diplopoda	0.45	27	1980	Trematoda	0.81	31	461
Echinoidea	0.31	6	531	Holothuroidea	0.25	19	339
Entognatha	0.05	13	10				

* Taxon names copied verbatim from GBIF (2020) and South African Checklist (SANBI Biodiversity Advisor 2020), some classes on this list are paraphyletic.

Ratio = Ratio of GBIF occurrence records to known species

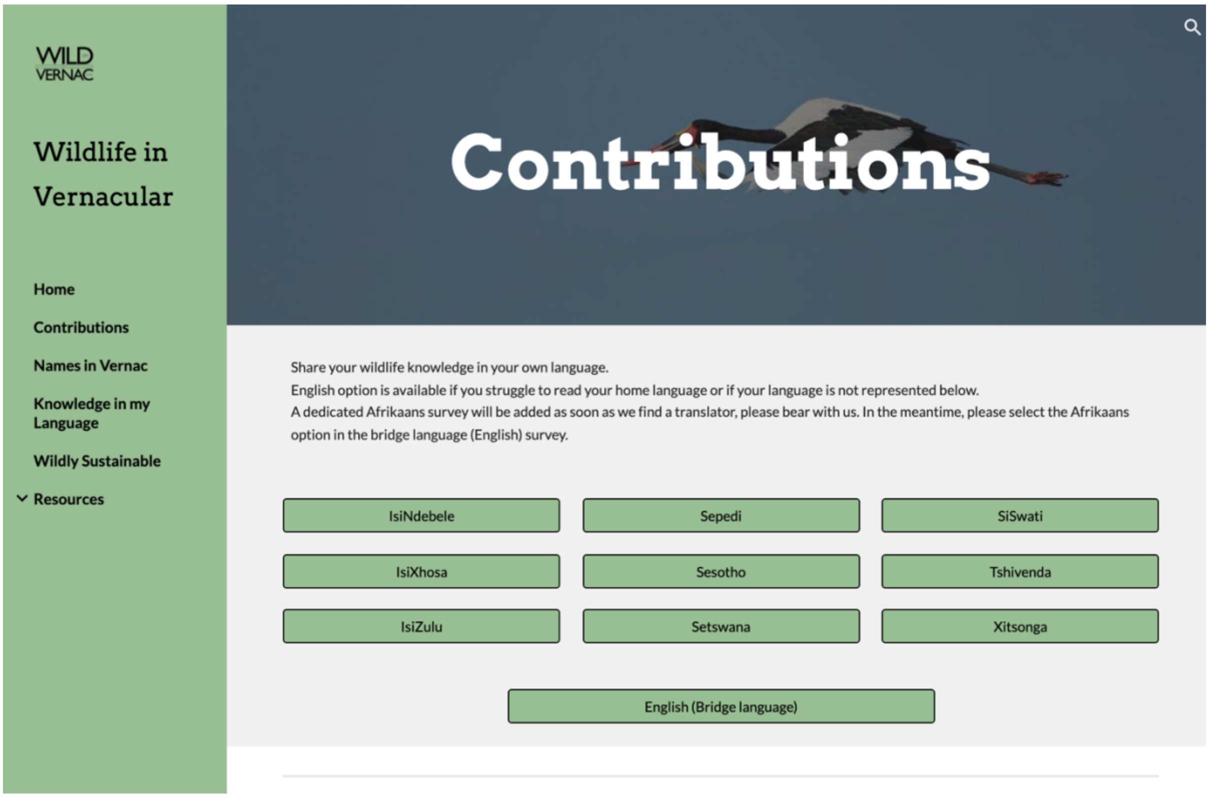
Science = Scientific Interest

Culture = Cultural Salience

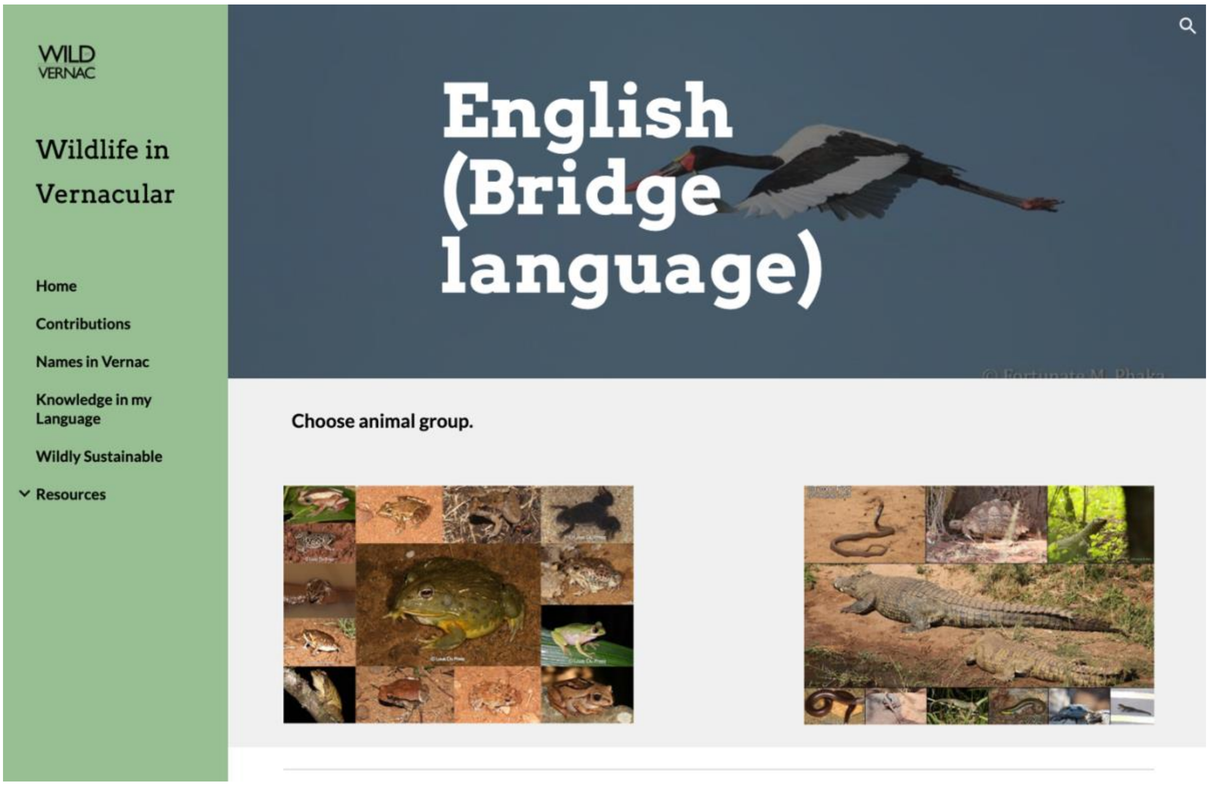
Appendix Chapter 4

Supplementary material: Multilingual online questionnaire used for this study (accessible on https://www.wildvernac.org/contributions)

Language selection page:



Taxon selection page:



Questionnaire informed consent page:

Wildlife in vernacular

Informed Consent

You are invited to take part in an online survey for a research project that investigates the relationship between South African cultures and wildlife. This research is for a Doctoral degree for Fortunate Phaka from North-West University and Hasselt University. Your participation will take approximately 15 minutes. Please take some time to read the information presented here, which will explain the details of this study. Please ask the researcher any questions about any part of this study that you do not fully understand using the contact details written below. It is very important that you are fully satisfied, that you clearly understand what this research is about and how you might be involved. Your participation in this survey is voluntary. You may refuse to take part in the research or exit the survey at any time without penalty. You cannot participate if you are under the age of 18.

If you agree to participate you will be expected to answer questions and how your culture relates to wildlife. The results will be published in scientific articles, a thesis and a book. The research contributes to the preservation of traditional knowledge and participant responses will be compiled into to a book about South African cultures and wildlife. The book will be written in South African indigenous languages. For confidentiality purposes, you will not be asked your name. To ensure that there is no duplication of participation, you will be requested to enter a phone number or email address, and these will not be used to contact you. No one will be able to identify you or your answers, and no one will know whether or not you participated in the study.

Researcher Name: Fortunate Mafeta Phaka
Phone number: 0658563696 (WhatsApp)
Email: wild@wildvernac.org

mafetap@gmail.com (not shared) Switch account

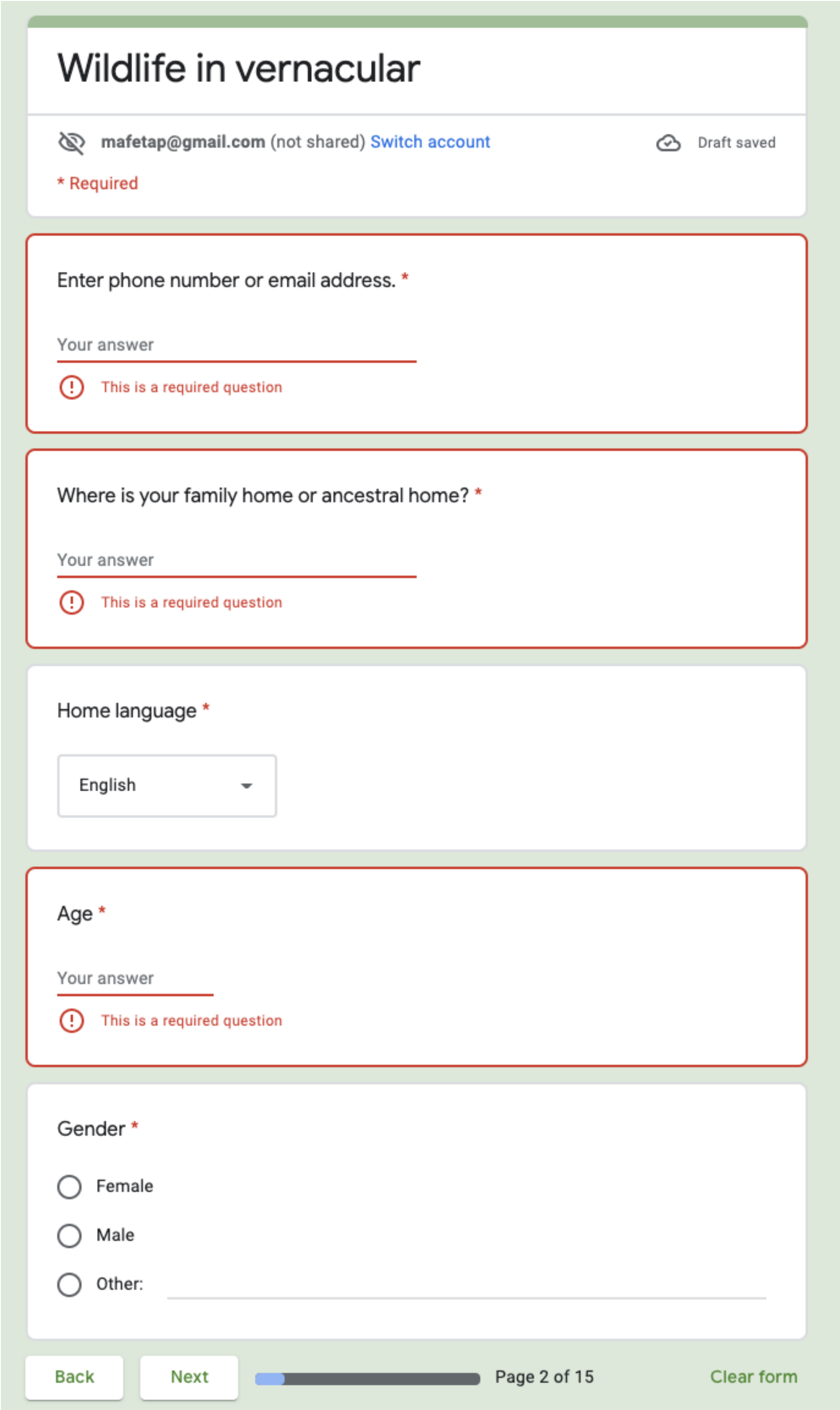
* Required

ELECTRONIC CONSENT: Please select your choice below to proceed with survey. You may print a copy of this consent form for your records. *

	I agree.
You are 18 years of age or older	☐
You have read the above information	☐
You voluntarily agree to participate	☐

Next — Page 1 of 15 — Clear form

Questionnaire demographic data page:



Wildlife in vernacular

mafetap@gmail.com (not shared) Switch account

Draft saved

* Required

Enter phone number or email address. *

Your answer

This is a required question

Where is your family home or ancestral home? *

Your answer

This is a required question

Home language *

English

Age *

Your answer

This is a required question

Gender *

- Female
- Male
- Other:

Back

Next

Page 2 of 15

Clear form

Questionnaire first page:

1. What are the animals shown in the photographs called in your home language?

Your answer

2. If you know the specific name for the animal shown here please tell us. If possible, explain why this animal was given that name.

Your answer

2.1. Do people in your hometown eat the animal in the photograph?

- ○ Yes
- ○ No

2.2. Do you know of any folk tales or stories about the animal in the photograph?

Your answer

2.3. Is the animal in the photograph used for healing or medicinal purposes in your culture?

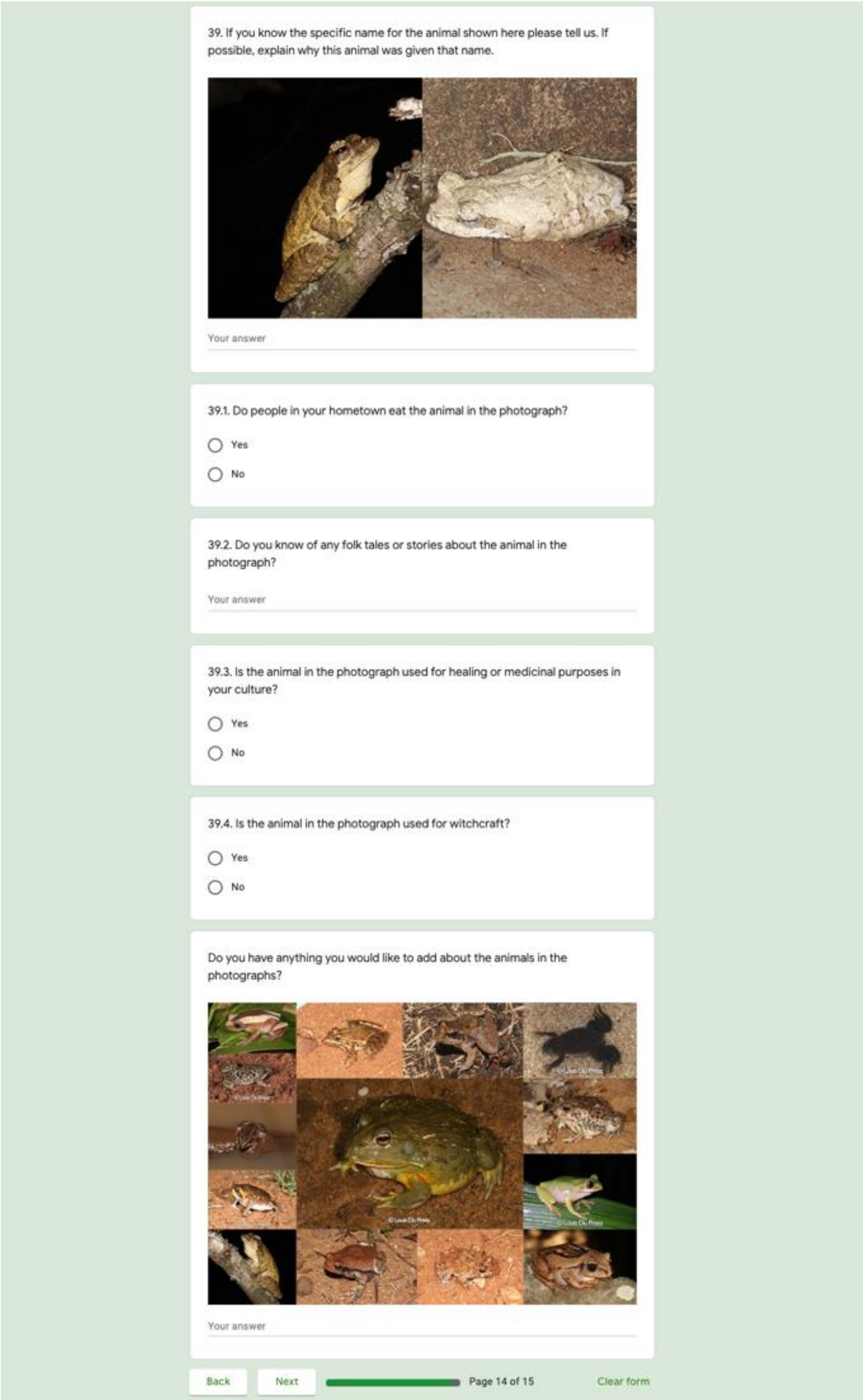
- ○ Yes
- ○ No

2.4. Is the animal in the photograph used for witchcraft?

- ○ Yes
- ○ No

Back   Next   Page 3 of 15   Clear form

Questionnaire last page encouraging respondents to provide additional information:



39. If you know the specific name for the animal shown here please tell us. If possible, explain why this animal was given that name.

Your answer

39.1. Do people in your hometown eat the animal in the photograph?

- Yes
- No

39.2. Do you know of any folk tales or stories about the animal in the photograph?

Your answer

39.3. Is the animal in the photograph used for healing or medicinal purposes in your culture?

- Yes
- No

39.4. Is the animal in the photograph used for witchcraft?

- Yes
- No

Do you have anything you would like to add about the animals in the photographs?

Your answer

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Supplementary Material 2: Supplementary Material 2: A list of literature reviewed to assess the conservation prospects and challenges of South Africa's cultural traditions about herpetofauna for this study.

Author(s)	**Year**	**Title**	**Journal/Book/Publisher**
Callaway, C.	1868	*Nursery Tales, Traditions, and Histories of the Zulus, in their own words, with a Translation into English, and Notes: I.*	John A. Blair, Trübner.
Bleek, D.	1933	Beliefs and customs of the /Xam Bushmen. Part V: The rain, Part VI: Rain-making.	*Bantu Studies*, 7:297-312; 375-392.
Lekgothoane, S.K.	1938	Praises of animals in Northern Sotho	*Bantu Studies*, 12(1):189-213.
Van Zyl, H.J.	1941	Praises in Northern Sotho.	*Bantu Studies*, 15(1):119-156.
Krige, E.J.	1950	*The Social System of the Zulus.*	Pietermaritzburg: Shuter and Shooter.
Potgieter, E.F.	1955	*The Disappearing Bushmen of Lake Chrissie.*	Pretoria: Van Schaik.
Ritter, E.R.	1955	*Shaka Zulu.*	London: Penguin Publishers.
Blacking, J.	1961	The social value of Venda riddles.	*African Studies*, 20(1):1-32.
Johnston, T.F.	1973	Tsonga Children's Folksongs.	*The Journal of American Folklore*, 86(341):225-240.
Lye, W.F., (ed).	1975	*Andrew Smith's journal of his expedition into the interior of South Africa, 1834–1836.*	Cape Town: Balkema.
Ngubane, H.	1977	Body and Mind in Zulu medicine: An Ethnology of Health and Diseases in Nyuswa-Zulu Thought and Practice.	London: Academic Press.

Nemukovhani, M.N.	1977	Tsingandedede.	Sibasa: Mbeu Mission Bookshop.
Raper, P.E., Moller, L.A. & du Plessis, T.L.	1987	*Dictionary of Southern African place names.*	Johannesburg: Lowry Publishers.
Mathumba, I.	1988	*Some aspects of the Tsonga proverb.*	Pretoria: University of South Africa (Thesis – MA).
Mavikane, D.J.	1990	*Mintsheketo.*	Pretoria: De Jagerhaum publishers.
Canonici, N.N.	1990	Trickery as the hallmark of comedy in Zulu folk-tales.	*South African Journal of African Languages*, 10(4):314-318.
Mogapi, M.P.	1990	*Praise poetry of the Bakwena ba Mogopa of Jericho.*	PhD dissertation: Rand Afrikaans University.
Hirst, M.M.	1991	*The healer's art: Cape Nguni diviners in the townships of Grahamstown.*	Makhanda: Rhodes University (Thesis – PhD).
Cunningham, A.B. & Zondi, A.S.	1991	*Use of Animal Parts for the Commercial Trade in Traditional Medicines.*	Pietermaritzburg: Institute of Natural Resources.
Cunningham, A.B.	1993	*Imithi IsiZulu: the Traditional Medicines Trade in Natal/KwaZulu.*	Durban: University of Natal (Thesis – MSc).
Kgoroeadira, K.O.	1993	*The Praise Poetry of Bafokeng of Phokeng*.	Johannesburg: Rand Afrikaans University (Thesis – MA).

Malungana, S.J.	1994	*Vuphato: Praise Poetry in Xitsonga.*	Johannesburg: Rand Afrikaans University (Thesis – PhD).
Mamabolo, M.R.	1995	*The Development of Northern Sotho Poetry.*	Johannesburg: University of Johannesburg (Thesis – MA).
Simelane, T.S.	1996	*The Traditional Use of Indigenous Vertebrates.*	Port Elizabeth: University of Port Elizabeth (Thesis – MA).
Hoff, A.	1997	The water snake of the Khoekhoen and /Xam.	*South African Archaeological Bulletin*, 52:21–37.
Simelane, T.S. and Kerley, G.I.H.	1997	Recognition of reptiles by Xhosa and Zulu communities in South Africa, with notes on traditional beliefs and uses.	*African Journal of Herpetology,* 46(1):49-53.
Simelane, T.S. & Kerley, G.I.H.	1998	Conservation implications of the use of vertebrates by Xhosa traditional healers in South Africa.	*South African Journal of Wildlife Research*, 28(4):121-126.
Ndimande, N.	1998	A Semantic analysis of Zulu surnames.	*Nomina Africana*, 12(2):88-98.
Groenewald, H.C.	1998	*Ndebele verbal art with special reference to praise poetry.*	Johannesburg: Rand Afrikaans University (Thesis – PhD).
Viljoen, R.	1999	Medicine, health and medical practice in precolonial Khoikhoi society: An anthropological-historical perspective.	*History and Anthropology*, 11(4):515-536.
Ngubane, S.	2000	*Reclaiming our names: Shifts post-1994 in Zulu personal naming practices.*	Durban: University of Natal (Thesis – PhD).
Ngwenya, M.P.	2001	*Implications for the medicinal animal trade for nature conservation in Kwazulu–Natal.* Ezemvelo KZN wildlife report No. NA/124/04	Cascades:. Ezemvelo KZN Wildlife.

Bongela, K.S.	2001	*Isihlonipho among amaXhosa.*	Pretoria: University of South Africa (Thesis – PhD).
Lewis-Williams, J.D. & Pearce, G.P.	2004	Southern African San Rock Painting as Social Intervention: A Study of Rain-Control Images.	*African Archaeological Review,* 21(4):199-228.
Minter, L.R., Burger, M., Harrison, J.A., Braack, H.H., Bishop, P.J. & Kloepfer, D., (eds).	2004	*Atlas and red data book of the frogs of South Africa, Lesotho and Swaziland. SI/MAB series #9.*	Washington: Smithsonian Institution.
Skhosana, P.B.	2005	Names and Naming Stages in Southern Ndebele Society with Special Reference to Females.	*Nomina Africana* 19(1):89-120.
Tšiu, W.M.	2006	Basotho clan praises (diboko) and oral tradition.	*South African Journal of African Languages*, 2:77-89.
Anthony, B.P. & Bellinger, E.G	2007	Importance value of landscapes, flora and fauna to Tsonga communities in the rural areas of Limpopo province, South Africa.	*South African Journal of Science,* 103(3-4):148-154.
Tšiu, W.M.	2008	*Basotho oral poetry at the beginning of the 21st century.*	Pretoria: University of South Africa (Thesis – PhD).
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Appendix Chapter 7

Supplementary Material 1: National Library of South Africa's catalogue of 770 non-fiction print book titles (1996 - 03 September 2021) indexed in the environment section of South African public libraries (Accessible through Mendeley Data: http://dx.doi.org/10.17632/5gpd85hdjd.1).

List of Publications

Peer-reviewed literature

1. Ovid, D. & **Phaka F.M.** 2022. Idwi, *Xenopus laevis*, and African clawed frog: teaching counternarratives of invasive species in postcolonial ecology. *The Journal of Environmental Education,* DOI: 10.1080/00958964.2022.2032564
2. **Phaka F.M.**, Vanhove, M.P.M., Du Preez, L.H. & Hugé J. 2022. Reviewing taxonomic bias in a megadiverse country: primary biodiversity data, cultural salience, and scientific interest of South African animals. *Environmental Reviews*, 30(1):39-49. https://doi.org/10.1139/er-2020-0092
3. **Phaka, F.M.** & Ovid, D. 2021. Life sciences reading material in vernacular: Lessons from developing a bilingual (IsiZulu and English) book on South African frogs. *Current Issues in Language Planning*, DOI: 10.1080/14664208.2021.1936397
4. **Phaka, F.M.**, Netherlands, E.C., Kruger, D.J.D. & Du Preez, L.H. 2019. Folk taxonomy and indigenous names for frogs in Zululand, South Africa. *Journal of Ethnobiology and Ethnomedicine*, 15:17. https://doi.org/10.1186/s13002-019-0294-3

Books

1. **Phaka, F.M.**, Netherlands, E.C., Kruger, D.J.D. & Du Preez, L.H. 2017. *A Bilingual Field Guide to the Frogs of Zululand. Suricata 3.* Pretoria: South African National Biodiversity Institute.

Commentaries and correspondences (non-peer reviewed)

1. **Phaka, F.M.** 2017. *Frogs of Zululand*. In: Richards, L., ed. Thola. Durban: The Durban Natural Science Museum. pp. 10-13.
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