



Frogs of the greater Nature's Valley Area: Biodiversity and conservation

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PREFACE

Nature's Valley is a true paradise on earth. Dalene Matthee illustrated the beauty of the Tsitsikamma forests and fynbos in her acclaimed Forest novels and she described it as a place that swallows you whole in awe and serenity; quick to make you feel isolated from the outside world and welcomed into theirs. You find yourself staring – frequently – at the white-beige beaches, emerald canopies and hanging, misty cliffs of “the Otter-trail”. Somewhere above, the knysna turaco dances among the figs, its red wings flashing intermittently, alerting all to your presence. In the distance you hear a Trogon's monologue, subtly breaking the monotony of the wind and waves. In these verdant, primeval woodlands, you are never alone. A palpable sense of being observed envelops you, as if the very forest itself is alive and aware of your steps. And you are aware that somewhere deep within this lush world, the spectral form of the last remaining Knysna elephant cries for the forest and haunts those that dare to come and destroy and exploit this timeless place. Dalene Matthee chronicled the threats facing this delicate ecosystem; man coming to destroy and exploit. But what about the frogs whose croaking chorus remains as a constant, defiant soundtrack in this irreplaceable habitat?

Let this be a testimony for the plight for frogs. Their hope for a better future dwindling by the day, and their plea for help in their battle against extinction noticed by only a few. Forty-one percent of all amphibian species are threatened with extinction, one of which hides within the trees and shrubs of Nature's Valley. Being in the Western Cape, this area holds immense conservation potential across various taxonomical boundaries – yet frogs remain left out. Classified as a Marine Protected Area, efforts are on the rise and has already yielded good results. Amphibian diversity of the area remains disproportionately unknown for the last 4 decades leaving the fundamental cornerstone for effective amphibian conservation missing.

This one endangered species – conveniently called the Knysna leaf-folding frog – remains largely understudied in its reproductive, behavioural and ecological niche. With just a few known sites in its range of occurrence, this special frog utilises ingenious reproductive methods to ensure maximum survivability of their offspring. Software improvement further allows for accurate call description and allocation of call-associated behaviours, never witnessed in this species before. Human intervention is paramount for this species' long-term viability and surrounding human community's views on them and kin will determine their conservation success. Science, nature and society are all intertwined in a complex matrix of co-existence. How do we choose to play the game?

Dalene Matthee wrote about it too – Man versus man, and man versus nature. Saul Barnard realised the intricate consequence of our presence in the natural world. Our obligation to our world

is mutualistic in nature, but why do we bleed Mother Earth dry? In this forest, I find myself listening to the Turaco, the Trogon, and faintly noticing the last forest phantom. I hear her cry for the forest and dread the day her haunt might fall on me. The forest's symphony continues to play. Oh, how dull it would be without the frogs.

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I owe this manuscript to God, from whom are all things and to whom all things flow. He gave me this passion and talents needed for this dissertation. I thank Him for His love and grace.

Summary

The Nature's Valley area in the Western Cape of South Africa is a topographically unique region with immense conservation potential. Amphibians are classified as the most threatened group of vertebrates globally, yet they remain largely neglected, underfunded and overlooked in terms of conservation and research, especially in this area.

CHAPTER ONE discusses the extent of threats facing amphibian and conservation trends globally, then narrows down to the need for biodiversity studies, threatened species conservation and human-frog interaction interventions that could support viable frog populations in the Nature's Valley area.

CHAPTER TWO aims to contribute to the need for updated amphibian distribution maps by conducting the first thorough amphibian biodiversity assessment in this area since 1987, with the use of modern passive acoustic monitoring technology. This chapter expands on the species list for the area by sharing insight in habitat selection, circadian vocal patterns, seasonal change in chorus composition, and associated weather affinity of each species.

CHAPTER THREE utilises modern statistical software to add to the description and analysis of the calls of the Knysna leaf-folding frog (*Afrixalus knysnae*). R coding language is frequently used in various fields for statistical analysis but was only recently made suitable for acoustic analysis. This chapter expands on the use of this coding language in the description and analysis of the two-part call of this endangered frog, contributing to future taxonomic studies. Behavioural observations made *in situ* forms an important part of this chapter – building on what was thought to be known of this species.

CHAPTER FOUR solely reports on the effect that various environment factors have on tadpole development of *A. knysnae*. Knowledge obtained from this could contribute to future *ex situ* conservation – probable and possibly effective conservation action according to the second Global Amphibian Assessment.

CHAPTER FIVE explores a potential threat to effective amphibian conservation in South Africa, namely human behaviours, attitudes and actions towards the environment. In this chapter, various factors that influence human behaviours and attitudes towards frogs are explored, discussed and applied in the Nature's Valley context. Important future conservation interventions – taking local communities (and their views and beliefs) into consideration – are discussed.

CHAPTER SIX contextualises all that is discussed above and attempts to discuss this in a practical sense to contribute to effective frog conservation approaches in the Nature's Valley area. Aims and objectives, conclusions and recommendations are revisited and expanded upon.

Key Words: Frogs, Biodiversity, Endangered species, Human-wildlife conflict, Conservation.

OPSOMMING

Die Nature's Valley-gebied is 'n topografies unieke streek met enorme bewaringspotensiaal. Amfibieë word geklassifiseer as die mees bedreigde gewerweld dieregroep op aarde, tog word hulle grotendeels geïgnoreer, selfs in Nature's Valley, Suid-Afrika, veral in hierdie spesifieke area.

HOOFTUK EEN bespreek die omvang van amfibiebedreigings en bewaringsneigings wêreldwyd, en fokus daarna op die behoefte aan biodiversiteitsnavorsing, die bewaring van bedreigde spesies en mens-padda-interaksies en -intervensies vir die welvaart van volhoubaarheid van paddabevolking in hierdie pragtige gebied.

HOOFTUK TWEE poog om by te dra tot die groot behoefte aan opgedateerde verspreidingskaarte van amfibieë deur die eerste deeglike biodiversiteitsassessering van amfibieë in hierdie gebied sedert 1987 met behulp van moderne passiewe akoestiese moniteringstechnologie uit te voer. Hierdie hoofstuk brei die spesieslys van die gebied uit deur insig oor habitatkeuse, sirkadiese vokale patrone, seisoenale veranderinge in gemeenskapskoorkomposisie, en die gepaardgaande weersaffiniteit van elke spesie te gee.

HOOFTUK DRIE gebruik moderne statistiese sagteware om tot die beskrywing en analise van die oproepe van *Arixalus knysnae* – die Knysna-blarevou-padda – by te dra. R koderingstaal word gereeld in verskeie velde vir statistiese ontleding gebruik, maar is eers onlangs vir akoestiese analise geskik gemaak. Hierdie hoofstuk brei uit oor die gebruik van hierdie koderingsplatform in die beskrywing en ontleding van die tweedelige roep van hierdie bedreigde padda, en dra by tot toekomstige taksonomiese studies. Gedragswaarnemings wat *in situ* gemaak word, vorm 'n belangrike deel van hierdie hoofstuk en bou op wat voorheen oor hierdie spesie bekend was.

HOOFTUK VIER rapporteer uitsluitlik oor die invloed wat verskillende ontwikkelingsomgewings het op die uitkoms van paddavis-metamorfilie van *A. knysnae*. Kennis wat hieruit verkry word, kan tot toekomstige *ex situ* bewaring bydra soos aangedui deur die tweede Globale Amfibie-Assessering (waarskynlike en moontlik effektiewe bewaringsaksies)

HOOFTUK VYF ondersoek 'n nuwe bedreiging vir effektiewe amfibiebewaring in RSA – menslike denke, gedrag, houdings en optrede teenoor die omgewing. In hierdie hoofstuk word verskeie faktore wat menslike gedrag en houdings teenoor paddas beïnvloed, ondersoek, bespreek en toegepas binne die Nature's Valley-konteks. Belangrike toekomstige bewaringsintervensies – wat plaaslike gemeenskappe (en hul sienings en oortuigings) in ag neem – word bespreek.

HOOFTUK SES plaas alles wat hierbo bespreek is in konteks en poog om dit te praktieseer vir doeltreffende paddabewaring in die pragtige Nature's Valley-gebied. Studie-doelwitte en mylpale, gevolgtrekkings en aanbevelings word bespreek en op uitgebrei.

Sleutelwoorde: Paddas, Biodiversiteit, Bedreigde spesie, Mens-wildlewe konflik, Bewaring.

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LIST OF ABBREVIATIONS

Abbreviation	Definition
<i>Bd</i>	<i>Batrachochytrium dendrobatidis</i>
<i>Bs</i>	<i>Batrachochytrium salamandrivorans</i>
CR	Critically Endangered
DD	Data Deficient
DMR	Directional microphone recordings
EA	Environmental Attitudes
EN	Endangered
EW	Extinct in the Wild
EX	Extinct
FFT	Fast Fourier Transform
GAA1	First Global Amphibian Assessment
GAA2	Second Global Amphibian Assessment
IUCN	International Union for Conservation of Nature
LC	Least Concern
NT	Near Threatened
NVT	NVT Tsitsikamma NPC
PA	Protected Area
PAM	Passive acoustic monitoring
QDGC	Quarter-degree grid cells
RR	Repetition Rate
SA-FRoG	South African Frog Re-Assessment Group
SANPARKS	South African National Parks
SM	Song Meter®
TCFNP	Tsitsikamma Coastal & Forest National Parks
VU	Vulnerable

Symbols and Measurements

Abbreviation	Definition
AM	Ante meridiem
cm	Centimetres
DF	Dominant frequency
df	Degrees of freedom
FF	Fundamental frequency
Hz	Hertz
kHz	Kilohertz
km	Kilometres
km ²	Squared kilometres
m	Metres
m ²	Squared metres
mm	Millimetres
ovl	Window overlap
P	Significance level
PM	Post meridiem
s	Seconds
sd	Standard deviation
wl	Window length
ρ	Correlation coefficient
ϕ	Phi value
χ^2	Chi-squared

Chapter 1: General introduction

1.1 The Plight of Amphibians in the Anthropocene.

1.1.1 Amphibians today

Global amphibian diversity is made up of three orders, namely the Caudata (salamanders, n = 758 described species), Gymnophiona (worm amphibians, n = 206 described species) and Anura (frogs and toads, n = 7 047 described species) (Re:wild, 2023). Distribution of these three orders shows global localisation, where Southern Africa only hosts Anurans and a few Caecilians; Caudata occur in Europe, Asia, North Africa and North and Central Americas; and Gymnophiona inhabit tropical Asia, Africa and South America only (Stuart et al., 2004; Stuart et al., 2008;). Approximately 8 600 species of amphibians are disproportionately distributed across the globe with the exception of Antarctica.

Modern amphibians show clear morphological specialisation (Feller & Hedges, 1998), yet monophyletic ancestry of the three orders made the biggest step forward in evolutionary history for modern vertebrates (Szarski, 1962; Mohun & Davies, 2019). It was traditionally thought that frogs and salamanders shared a common ancestor since the Paleozoic era (more than 250 million years ago). This conventional hypothesis is challenged when considering geographical isolation since the initial breakup of the supercontinent, Pangaea, - to which the origin for salamanders and caecilians is directly linked (Feller & Hedges, 1998). Other studies suggest the possible consideration of polyphyletic ancestry among amphibians (Anderson, 2008). Irrespective of the relationship between modern amphibian orders, the emergence of finned animals onto land is mainly associated with the morphological adaptations that facilitate locomotion and sensory awareness on land – five-digit appendages and increased brain- and eye- sizes (Nilsson, 2017). It is accepted that the first tetrapod emerged some 385 million years ago (Nilsson, 2017) and lead directly to the evolution of the amphibians we see today. Though amphibians have diverse, but specific habitat requirements (Villiger, 2022), since 1980 they have been globally identified as environmentally important and crucial for ecological stability (Alford & Richards, 1999; Stuart et al., 2004; Stuart et al., 2008; Haliday, 2008; Re:wild, 2023; Leudtke et al., 2023). Amphibians are distinguished from reptiles and birds by their nutritious, unshelled, jelly-like eggs and cartilaginous skeletoned larvae. The eggs are laid and hatched in their millions each year and they serve as important food sources for many orders in the animal kingdom. Animals that show biphasic lifestyles are crucially important for nutrient fluxes across the aquatic-terrestrial boundary, as nutrient fluxes are largely influenced by abiotic, physical forces (Fritz & Whiles, 2018). Studies

have provided probable cause for adult frogs keeping invertebrates at manageable levels for humans and economically worthwhile (Shuman-Goodier et al., 2019; Ceron & Pires, 2024), with frogs being used as sustenance for third-world populations (Patocka et al., 1999; du Preez et al., 2024) and delicacies elsewhere.

Because amphibians generally exhibit biphasic lifestyles (Fritz & Whiles, 2018), they are exposed to greater environmental factors than animals that are monophasic – hence their environmental significance. Most frog eggs are encapsulated by a jelly-like, protective layer, and adults exhibit very permeable skin properties, resulting in higher sensitivities to immediate chemical and physical environmental changes (Kruger, 2014).

1.1.2 Declining amphibians

In 2004, the first comprehensive amphibian assessment was conducted on a global scale using the IUCN Red-list categories. This was known as the first Global Amphibian Assessment (GAA1) and changed amphibian conservation for good, yet it only measured the, then current, projected extinction risk of amphibians, but cannot be used as an indicator for how this risk changes over time. In 2023, the second GAA (GAA2) was completed and brought good evidence for what the future of global amphibian populations will look like, and the impact that effective conservation interventions are capable of achieving in the face of extinction. The second GAA concluded that:

- Forty-one percent (41%) of global amphibians are threatened with extinction – a 2% increase from 2004. It is estimated that 222 species are already extinct.
- Habitat loss remains the highest cause for global amphibian decline with disease and climate change being dangerous emergent threats. Ninety-three percent (93%) of all threatened species are affected by habitat loss.
- Threatened global amphibians are unevenly and disproportionately distributed across the globe with biogeographic realms hosting more species threatened with extinction than some countries have in total.
- Conservation intervention needs to be scaled up drastically. Sixty-three species have had their extinction threats down graded due to intervention since 2004. Key fields to focus on for the near future of amphibian conservation include taxonomic research (species description and species complex clarification), population monitoring, species

recovery and conservation impact, and maintaining IUCN Red List Assessments (every 5 years).

South African amphibian research also contributed towards the GAA2. In 2004 the Atlas and Red Data Book for frogs of South Africa, Lesotho and Swaziland (the Frog Atlas) (Minter *et al.*, 2004) was released and in 2010 Red List assessments were updated by the South African Frog Re-Assessment Group (SA-FRoG) (Measey *et al.*, 2011). The outcomes of this were published in a strategy document titled “Ensuring a future for South Africa’s frogs: a strategy for conservation research” (Measey *et al.*, 2011). The most recent (2018) published Red List assessments for South Africa, Lesotho and Eswatini included 137 species, of which 73 (59%) are endemic. Sixteen (13%) are in a threatened category (Critically Endangered, Endangered or Vulnerable), twelve (10%) were assessed as Near Threatened (NT), ninety-two (74%) are considered to be Least Concern (LC) and four (3%) are Data Deficient (DD) (Table 1-1). The updated Red List assessments are due to be published in 2025, with significant category changes expected.

Table 1-1: Total endemic frog species in South Africa categorised according to a Red List Category since the most recent assessment.

Red List Category 2018	Endemic in South Africa	%
Critically Endangered	6	4.8
Endangered	9	7.3
Vulnerable	1	0.8
Near Threatened	12	9.7
Least Concern	92	74.2
Data Deficient	4	3.2
Grand Total	124	

1.1.3 Threats facing amphibians

Threats to global amphibian populations cover a wide range of categories (Table 1-2). Between 2004 and 2023, amphibians considered threatened, have doubled in certain categories. Since 2004 habitat loss [timber and plant harvesting (53%), infrastructure development (47%), pollution (29%), mining and energy production (16%) and water management (11%)] is threatening 30% more species globally. Climate change concerns [drought (67%), habitat shifting and alteration (49%), storms and flooding (18%) and temperature extremes (16%)] are considered as “emerging threats,” yet are the second highest threat concern in the GAA2. Other threats, such as fire, disease and invasive species, to name a few, all displayed an increased number of species affected. The global amphibian status shows promise in conservation initiatives, but the number of amphibian species threatened with extinction rose, and is still rising, as a myriad of enigmatic

declines become evident (Campbell-Grant *et al.*, 2023; Luedtke *et al.*, 2023). These threats are due to human expansion, consumption and growth.

Table 1-2: Number and percentage of amphibians or Anurans threatened by the top 5 threat categories provided by the GAA1, GAA2 and SA-FRoG. The GAA1 and GAA2 indicates threats for global populations and the biogeographical region that is most affected by these threats, and how this changed from 2004 to 2023. SA-FRoG shows reassessed affects from 2004 to 2010 in South Africa.

→ Top 5 threats per assessment →					
GAA1	All habitat loss	Pollution	Fire	Disease	Invasive species
Number of Anura	3700	1122	615	451	452
% of Anura	63%	19%	10%	8%	8%
Biogeographical region most affected	Afrotropical	Australasian	Australasian	Australasian	Australasian
GAA2	All habitat loss	Climate change	Disease	Fire	Invasive species
Number of amphibians	2686	846	600	572	415
% of amphibians	93%	29%	22%	21%	14%
Region most affected	Indomalaya	Australasia	Australasia	Australasia	Australasia
SA-FRoG	Agriculture and aquaculture	Invasive species	Residential and commercial development	Natural systems modifications	Biological resource use
Number of Anura	58	43	38	30	6
% of Anura	50%	37.1%	32.8%	25.9%	5.2%

1.1.4 Amphibians of the Tsitsikamma Core Conservation area

South Africa is home to 137 species of frogs (Frost, 2025), with the most recently described species occurring in the Western Cape Province (*Cacosternum cederbegense*) (Angus *et al.*, 2024). Species distribution throughout the country is understandably concentrated in the more temperate and tropical coastal regions, where higher endemism and lower diversity can be found in the Western Cape Province, lower endemism and higher diversity in the KwaZulu-Natal province in the eastern high rainfall area, and lower endemism and lower diversity in the drier Northern Cape Province (Minter *et al.*, 2004; Du Preez & Carruthers, 2009; Du Preez & Carruthers, 2017). Of the 137 species found in South Africa, 68% are endemic (Frost, 2025), and approximately 60 species occur in the Western Cape Province (Turner & Baard, 2017). According to Minter *et al.* (2004) and Du Preez and Carruthers (2017), distribution data suggests that approximately 19 species occur in the greater area around the study area – the Tsitsikamma Core Conservation area (Branch & Hannekom, 1987). Thirty-seven species are regarded endemic to the Western Cape Province, one of which is the Knysna leaf-folding frog (*Afrixalus knysnae*)

(Loverage, 1954) (Pickersgill, 1996; Channing *et al.*, 2012). This species is Red Listed as Endangered and is also the only threatened amphibian species in the Tsitsikamma area.

To date, amphibian diversity indices are relatively lacking for this region, where the last comprehensive survey was done in 1987 (Branch & Hanekom, 1987). Ecotonal properties of this region makes amphibian diversity particularly unique here, with only ‘so-called’ tree dwelling species lacking (De Lange, 2019).

1.2 *Afrixalus knysnae* (Anura: Hyperoliidae)

1.2.1 Description of *A. knysnae*

Afrixalus knysnae is a small anuran member of the *Afrixalus* genus. This genus is commonly referred to as the “leaf-folding frogs” – since oviposition occurs through deposition of eggs in folded leaves – of which there are 33 taxa found throughout sub-Saharan Africa (Frost, 2018; De Lange, 2019). *Afrixalus knysnae* is grouped with the *A. spinifrons* complex (Figure 1-1) of which *A. spinifrons spinifrons* and *A. spinifrons intermedius* are its closest, non-sympatric family members.

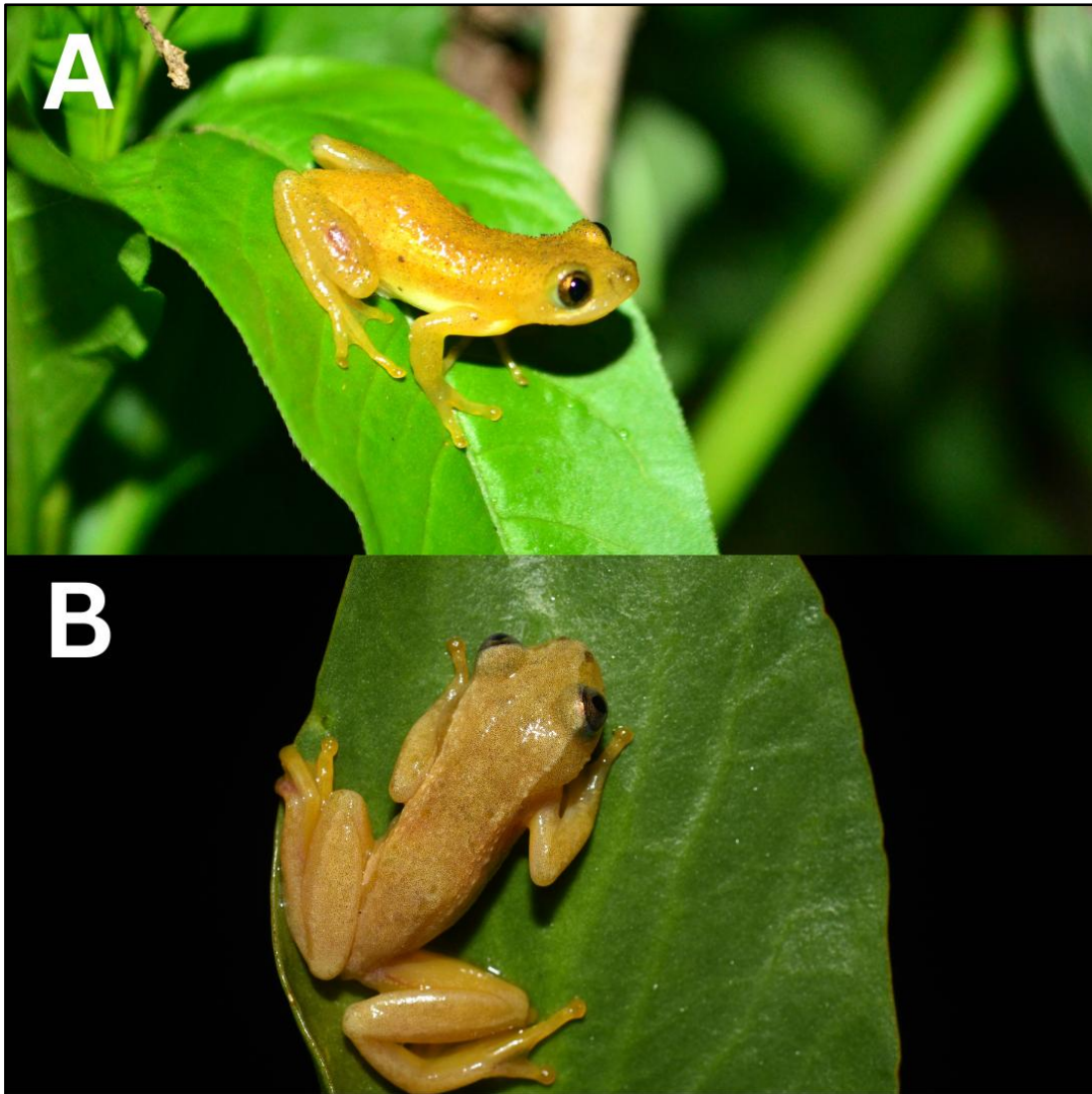


Figure 1-1: Side-by-side comparison of the two non-sympatric, but cryptic species of (A) *Afrixalus spinifrons* (Baynesfield, KwaZulu-Natal) and (B) *A. knysnae* (Nature's Valley, Western Cape). Pictures are not to scale. (Photos: Tiaan Botha).

Afrixalus knysnae are a “dwarf species” and generally do not exceed 25 mm in length. The body is robust and small, with a broad head. Eyes present a metallic copper colour and pupils are vertically slitted. Base colours of body are yellow to brown with a dorsal vertebral band that is usually darker in colour. A plain dark stripe runs through the eye to the groin. Tiny, but prominent, spines uniformly scattered over the head and back can be observed. The underside is granular, creamy-white in colour and the gular disc is smooth. Fingers are slightly webbed and subarticular tubercles of the outer two fingers are conspicuous and fused. Moderate webbing is found between toes and no transverse band is observed on the tibia. Males have a yellow gular disc on throat (Du Preez, 2017) but look similar to females with reference to colour, morphology and dorsal patterns (Figure 1–2) (Figure 1–2).



Figure 1-2: Sexual dimorphism between male (A) and female (B) *A. knysnae* individuals. Male clearly presenting vocal sac and gular disc, and female with unfertilised ovum visible through abdomen. (Photos: Tiaan Botha).

Previously (2010), *A. knysnae* was assessed as Endangered on the IUCN Red List according to criteria B1ab (ii,iii,iv,v). These criteria stipulate that a species is (1a) limited to a geographical range of less than 100 km², the total population found in (b) fragmented locations displaying a continuing decline (ii) extent of occurrence, (iii) area of occupancy, (iv) area, extent and/or quality of habitat, and (v) number of mature individuals (IUCN, 2024). However, since then the assessment criteria have been updated and, in so doing, the assessment for *A. knysnae*. Currently, the species is still classified as Endangered, but under criteria B1ab (i,ii,iii,v)+2ab (i,ii,iii,v) which area of occupancy is estimated to be (2a) less than 500 km² where known populations are (b) severely fragmented and where declining (i) extent of occurrence, (ii) area of occupancy, (iii) area, extent and/or quality of habitat, and (v) number of mature individuals observed, inferred or projected (IUCN, 2024).

1.2.2 Distribution and habitat selection

Historical accounts of the distribution of *A. knysnae* are limited to a small number of sites (seven locations) (Figure 1.3 - Ak1–Ak7) between Covie (eastern limit) and Goukamma Nature Reserve, Groenvlei, Sedgefield (western limit) which has slightly more than 70 km between each limit (Pickersgill 1996, 2000; IUCN, 2010) (Figure 1-3). Habitat preferences recorded at the time were not clearly defined, and included microhabitats such as “marshy bogs, roadside pools, glades and reed-lined lakes” (Minter *et al.*, 2004; De Lange, 2019). In recent years, *A. knysnae* have been observed in and around the city of George, where they are found in ecotones between indigenous

forests and fynbos habitat (De Lange, 2018, 2019). Ponds utilised by livestock and marshes have been previously observed to host no *A. knysnae* populations (De Lange, 2019).



Figure 1-3: Locations previously observed to have *A. knysnae* populations (IUCN, 2016; De Lange, 2019).

Updates to the distribution map for *A. knysnae* suggest a range-shift in historical occurrence from Sedgefield to locations beyond George (or maybe these new subpopulations were not detected until now), but this wasn't conclusive as the number of localities before 2010 was not established. To improve the understanding of the species' distribution, Ecological Niche Modelling performed by De Lange (2019) was able to guide surveys for *A. knysnae* and confirmed previously unknown localities in the Nature's Valley area and in so doing, added one additional known location (Ak9) where this species occurs (Figure 1-3). Since 2019 at least four populations in and around George have been added, however, current investigations of the sites recorded in 2010 have found them to be severely transformed and degraded through anthropogenic activities (Ak1, Ak2 and *A. knysnae*6), rendering these locations severely transformed, destroyed or non-existent. Nevertheless, habitat utilisation of *A. knysnae* reported by De Lange (2019) had positive association with fynbos habitat.

1.2.3 Reproductive biology

As the name suggests, the Knysna leaf-folding frog employs a unique style of multiplicative behaviour (to the genus). Oviposition and external fertilisation generally occur on the surfaces of

leaves or in suitable vegetation. After deposition, the breeding couple stays in amplexus over the egg clump, and males use their hind legs to fold and “glue” leaves over the newly laid eggs, ensuring that the eggs aren’t completely encapsulated (Pickersgill, 1996) (Figure 1-4). Eggs take approximately 12 to 15 days to hatch, and even then, tadpoles stay within the folded leaves for up to two to three days before emerging (De Lange, 2019).



Figure 1-4: Folded leaf sheath of the Knysna leaf-folding frog with just hatched tadpoles inside.

Despite requiring specific habitat conditions, *A. knysnae* expresses reproductive versatility by utilising various available vegetation types (De Lange, 2019). Regardless, vegetation must have certain characteristics to be suitable for oviposition, such as adequate leaf pliability, size, and strength which requires an intuitive approach for this reproductive strategy.

1.3 Frogs and people: Why apathy threatens amphibian conservation efforts

1.3.1 Humans’ view toward the environment

Human presence and processes are intricately woven into the environment where we have a long lasting influence on our surroundings, and *vice versa* (Gifford, 2014). Our effect on planet Earth continues to reduce environmental stability. We have the responsibility to prevent and counter unsustainable and near-sighted exploitation of naturally occurring resources, however this goes against capitalist and consumerist extractive systems that dominate world economies and politics (Spash, 2006). To address the biodiversity crisis, humans should rather view themselves as part of nature and, consequently, part of the problem that needs to be solved (Evert *et al.*, 2022).

Society should insist upon, or be, more accountable for environmental protection and not rely on the perception that conservation organisations and government are mainly responsible for pro-environmental change (Evert *et al.*, 2022). Koruoglu *et al.* (2015) states that environmental behaviours are affected by attitude, and irresponsible behaviour accounts for the main cause of environmental problems. Though harsh and bold, many studies support this (Williams & Cary, 2002; Liu *et al.*, 2020; Evert *et al.*, 2022). Environmental Attitudes (EA) of the public provide a good understanding of the beliefs and values influencing environmental-friendly behaviours. These attitudes are shaped by peoples' beliefs, impressions and behavioural intentions relating to environmental activities or problems which are believed to be influenced by many direct and indirect personal (emotional and cognition), social (self-construal), cultural (possibly language, religion, race, traditions, etc.), economic (income, political orientation, urban-rural gradients) and environmental factors (proximity to environment and environmental harm or disasters) (Hurst *et al.*, 2013; Evert *et al.*, 2022; Colombelli-Négrel & Costello, 2024).

Environmental attitudes differ between individuals (Brick & Lewis, 2016) and identification of these variables can help reveal possible origins of pro-environmental behaviours. Pro-environmental behaviours (which are influenced by a person's EA's) have been recognised as a heterogeneous, multi-dimensional construct (Ertz *et al.*, 2016) that isn't necessarily the same between different groups of people, locations or persons. Individuals form part of society where societal norms, morals or cultures, as well as reliance on their immediate environment for survivability (utilisation) (Jiménez, 2014; Brom *et al.*, 2020) influence their view toward environmental stewardship and/or conservation (or the opposite) (Tarrant *et al.*, 2016).

Liberal and conservative philosophies, along with viewing environmental issues in moral terms, are considered robust predictors of the course of EA's (Feinberg & Willer, 2013). Associations between what people value, and concern for the environment, seem to be globally consistent (Gifford, 2014), where environmental psychology determines a person's response to climate and environmental values. Environmental psychology includes the behaviours that inhibit or foster sustainable, climate-conscious (healthy), and environmentally friendly (enhancing) choices, the precursors and associations of those behaviours, and interventions to increase pro-environmental attitudes and behaviours. As such, an understanding of a person's view of themselves towards their social environment (personal norms and beliefs) can help adequately predict behaviour from values. Political, economic and technological, as well as materialist/postmaterialist values also influence a person's relationship to environmentally healthy solutions, utilisation thereof or perceived consequence-less self-improvement. However, understanding pro-environmental concern and behaviour is complex, and behaviours which are influenced by attitudes isn't easily

encompassed in environmental concerns (Gifford & Nilsson 2014). People have multiple behaviours (and therefore attitudes) determining values (Gifford, 2014), both emotional and cognitive (Gangaas *et al.*, 2015) that could conflict with each other. This is important to consider in pro-environmental related investigations. Interventions to increase pro-environmental attitudes and behaviours tend to oppose financial and economical (even selfish/egoistic) interests (Gifford, 2014) - for example such as time saving and cost saving in managerial and consumer sectors (Ertz *et al.*, 2016).

Culture, as a construct of society, is notoriously difficult to quantify and qualify in terms of human-nature conflicts (Chwialkowska *et al.*, 2020) and there are widely differing views as to what defines it. Yet, literature proves that cultural dimensions of persons, villages, regions and countries have a definite direct effect on EA's with individualistic variations on such views (Gangaas *et al.*, 2015; Brom *et al.*, 2016; Tarrant *et al.*, 2016; Evert *et al.*, 2022). Some studies propose the thought that a person or group's view and orientation, as well as utilisation of nature and its natural resources, fundamentally and intricately forms part of their culture (Schultz, 2002). Others show how cultural values influence the environmental concern and pro-environmental behaviour relationship (Chwialkowska *et al.*, 2020) and therefore become an external determinant. When reporting on effects of culture on related environmental attitude investigations, it is important to define variables that are believed to be the most relevant components of the societal construct of the specific regions/persons in question. Common variables include language, ethnicity and religion, and this is what is to be considered when culture is mentioned in this dissertation (but it is still important to understand that culture is dynamic, lively and cannot necessarily be boxed in). Cultures have stories, and these stories (commonly referred to folklore, cultural superstitions, misconceptions and beliefs) strongly affect human-environmental interaction.

Various socio-demographic variables have been identified to have significant influences on EA's, although some still seem to be context, or location, specific. Socio-demographic variables tend to include age, gender, ethnicity, religion and religiosity, income, political orientation, and education. Literature concludes the following of each variable:

- *Age*: One study showed that age and gender in America show no significant relation to environmental concerns, but in the greater world context, follows a "concave" trend with relation to age and environmental concern; increasing first and decreasing later at more advanced ages (Franzen & Vogl, 2013). Other studies conclude no influence of age to environmental attitudes (Rutheford *et al.*, 2024) whilst,

still others, concluded inverse findings to what is found in literature (Colombelli-Négrei *et al.*, 2024).

- *Gender*: Gender does not necessarily significantly influence EA's. However, one study found that women show more concern towards the environment because of different social roles (Franzen & Vogl, 2013), and this is largely supported in many EA-related studies. However, in South Africa, a less obvious trend is followed.
- Global concern for the environment and its concerns, relates to religion and religiosity showing that religious persons/communities, especially Christian and Jewish believers (Feinberg & Willer, 2013; Evert *et al.*, 2022), tend to show higher environmental concern, therefore affecting EA's. For example, the Bible (specifically in the Old Testament – Genesis) states that one of man's purposes is to "subdue" and "have dominion" or "rule" over every creature, plant, or "thing that has life in it" (Genesis 1:28-31, The Bible). However, the influence of religion, or religiosity, on EA's is not well researched in South Africa (Evert *et al.*, 2022).
- *Political orientation*: Various studies have shown that political orientation (and the effect of political involvement in environmental concerns), is also linked to attitudes toward the environment (Franzen & Vogl, 2013; van Valkengoed *et al.*, 2022). Feinberg & Willer (2013) found that polarisation of environmental concerns occurs in different political orientations and levels, where in South Africa this shows no significant effect (Tarrant *et al.*, 2016; Brom *et al.*, 2020; Evert *et al.*, 2022).
- *Income*: Income level is a strong determinant of materialism (Hurst *et al.*, 2013) which is believed to have a strong influence on environmental attitudes. Literature suggests that in consumer and managerial sectors, individuals with higher incomes tend to show pro-environmental attitudes and participate in environmental-friendly acts – such as recycling, purchasing "green" products (which are generally more expensive), and installation of personal renewable energy sources (Ertz *et al.*, 2016). What is the converse for low-income individuals?
- *Education*: The case for education level and its effect on EA's is somewhat ambiguous (Evert *et al.*, 2022). Studies have found that educators need to become more aware of EA's because the environmental education level can affect their participation in pro-environmental activities (Sánchez *et al.*, 2016; Karpudewan, 2021). Likewise, education initiatives with experiential learning among scholars, leave them with tendencies to preserve the environment better (Braun *et al.*, 2018), however, as beliefs, attitudes (and therefore behaviours) become consolidated during late high school stage, attitudes and beliefs become more entrenched as people age (Koruoglu

et al., 2015). Education level influences knowledge, but the knowledge-attitude gap is considered weak (Heberlein, 2012). Attitudes are not behaviours, but a strong component thereof. It is difficult to change attitudes and a “cognitive fix”, through educating people, usually fails because of this.

1.3.2 Human-frog conflict

Chapter 5 of this thesis investigates determinants of human-environment dynamics that lean strongly towards human-wildlife conflict – specifically focused on human-frog interactions and persecution versus preservation. Global human-herpetofaunal conflict follows recognisable trends similar like those found towards the environment in general, though some variation occurs. Deutsch *et al.* (2021) found that education level and gender were strong socio-demographic influencers of the deadly persecution of the Ornate horned frog (*Ceratophrys ornata*) in some South American countries. Positive views towards herpetofauna in zoos in USA were also strongly dependent on education level and gender (Ogle & Devlin, 2022) and gender-related bias was found to be significant between men and women in the Brazilian Atlantic Forest (Seeger *et al.*, 2019). Income (or income bracket) also shows some influence towards human-frog interactions, where individuals with limited land holdings were more inclined to kill “trespassing” amphibians (Rabbe *et al.*, 2021). In the Philippines, pro-frog behaviours were strongly associated with farmers recognising utilitarian value (food, ecosystem services and weather predictors) (Propper *et al.*, 2020). In third world countries where technology, food and modern commodities aren’t readily available, such reliance of populations on their surrounding environment is crucial to understanding how they exploit or manage available natural resources. Strong divergence to what is found in literature regarding human-environmental interaction (frog focused), however, does occur. In Portugal, the presence of cultural stories (more accurately, folklore) (culturally significant) and negative values (such as fearing, or disliking certain animals due to looks, sounds or perceived attacks) affected people’s views towards herpetofaunal diversity in the area, but socio-demographic variables had no significant effect on the results (Ceríaco, 2012). Tarrant *et al.* (2016) and Evert *et al.* (2022) found no influence of political orientation and income on frog interactions and EA’s of study participants in South Africa, and cultural and cultural beliefs is one of the most influential determinants of behaviour (Mokuku & Mokuku , 2004; Prokop *et al.*, 2016; Tarrant *et al.*, 2016; Brom *et al.*, 2020; Deutsch *et al.*, 2021; Rabbe *et al.*, 2021; Vergara-Ríos *et al.*, 2021). Inconsistencies regarding influential variables on how people view, handle and think about frogs emphasise location specificity, fluidity of people’s emotions and cognition, as well as cultural needs, beliefs and utilisation of, and benefits from, the environment - or in this case, frogs. Human views towards frogs are especially important in a country such as South Africa. Human-

frog interactions increase in countries where species richness strongly correlates with population density (Botts *et al.*, 2011), and where groups of people or communities tend to associate herptiles with significant cultural utilitarian value (medicinal, economic, food, religious) (Phaka *et al.*, 2023). This, therefore, poses a threat to long-term survivability of wild herptile populations if left unmonitored.

1.4 Project aims and objectives

The overall aim of this project is to contribute to amphibian conservation in the Nature's Valley area of South Africa. Given that the area has high tourist volumes and remains a relatively pristine patch of coastal Afro-temperate Forest habitat within an otherwise highly fragmented area, calls for the need to contribute to global amphibian conservation. In this study various approaches concerned with amphibian conservation are explored. These include novel areas of concern such as human behaviours, intentions and attitudes towards frogs, and what this could mean for frog conservation in the area. Habitat preference studies are fundamental for informing frog conservation, as part of a broader holistic approach.

For this study, a complete species list was updated with seasonal, circadian and weather-associated call patterns of each monitored species illustrating how these patterns vary across different habitat types. This investigation will contribute to literature and knowledge pertaining to the habitat preference and range of the only threatened species of the area, *A. knysnae*. Call classification of *A. knysnae*'s advertisement call, with the use of statistically dedicated software (R and R-studios), was conducted. Tadpole development trends and breeding behaviours will also be reported to contribute to filling knowledge gaps of this species. The objectives to achieve these aims include:

1.4.1 Design and implementation of a Passive Acoustic Monitoring (PAM) plan enhances seasonal ecological investigations

Ecological acoustic monitoring has made impressive progress in the last few decades. Where whole vehicles were needed to conduct field tape recordings in the early years of this type of research, to pocket devices that can be strapped to a tree and left in the field for months on end, bioacoustics monitoring has become significantly more efficient. In this study, a bio-acoustic monitoring schedule was designed and implemented to gather call-recordings of various frog species at several sites across different habitats within the Nature's Valley area, at different times of the day and with weather conditions over all four seasons of the year.

1.4.2 Improved understanding of the advertisement call of *A. knysnae* through statistical analysis.

Modern bio-acoustic analysis is aided and streamlined through specialised and specific analysis software. R coding language, like Python, is predominantly used in mathematical calculations and statistics, however recent advancements in acoustic research have enabled acoustic scientists to analyse sound at very fine scales with this coding language. The objective for this study is to use this software to analyse and describe the advertisement call of *A. knysnae* and any other vocalisations recorded in field, by hand-held directional microphones.

1.4.3 The breeding behaviour and tadpole development of *A. knysnae* is better understood.

Frog advertisement calls are strongly associated with male-female, as well as male-male interactions, resource availability and fecundity. Advertisement calls are fundamentally used for mate attraction, as well as territory acquisition. Other calls may be vocalised for various behavioural purposes in reproduction, intra- and inter-specific interactions.

Ex-situ amphibian conservation is part of the solution toward securing population sustainability for species most at risk of extinction in the wild (Re:wild, 2023; Luedtke *et al.*, 2023). Understanding reproductive biology, as well as tadpole developmental trends, are cornerstones for the success of such initiatives. Though *A. knysnae* is not currently being bred for ex-situ conservation, this information, and what factors may impact larval development, is beneficial to informing conservation action for this Endangered species.

This objective, therefore, aims to study ex-situ *A. knysnae* tadpole development under two different condition scenarios. Inter- and intra-specific interactions of this species were also investigated and observed.

1.4.4 Investigating human-frog interactions and human attitudes to frogs of Nature's Valley communities contributes to conservation in the area

Nature's Valley experiences high volumes of tourists each year looking to enjoy the soothing properties that nature provides. The village of Nature's Valley resides within the local conservancy, and two other communities, namely Kurland and Covie are outside the conservancy. Both Kurland and Covie communities use the abundant shoreline where they carry out subsistence fishing. The three communities are, to differing degrees, dependent on this area for their specific needs and desires. Due to varying community characteristics, this area is suitable, possibly ideal, for human-frog conflict studies. As discussed above, local community

perspectives towards certain aspects of nature are critically important for sustainable conservation of the environment. This objective will attempt to investigate human-frog interactions, through mixed-method research, to improve the understanding of the dynamic factors driving how people in these communities' view and react towards frogs.

1.4.5 Information on the status of frog populations and conservation potential in the Nature's Valley area is provided to guide local conservation custodians

At the completion of this study, information and guidance will be provided to local and active environmental custodians. NVT Tsitsikamma NPC (hereafter NVT), is a registered conservation non-profit company (NPC) that has conducted conservation action and research for the past 20 years in and around Nature's Valley's natural ecosystems. Predominantly focusing on marine, estuary and forest ecosystems, NVT has the potential, and capability, to include frog conservation and research in their scope. NVT also serves as a partner to SANPARKS – who have a noticeable presence in and outside, the Valley. Both parties serve their own goals and strategies with the goal of protecting the areas where they are based. Research produced from this manuscript will provide information regarding frogs in all relevant areas where these parties operate. Forest and estuary ecosystems in Nature's Valley make up a considerable part of the landscape of the area. Both systems are intricately woven together with adjacent Fynbos systems and dependent human communities – all being elements discussed in this manuscript in the frog diversity, conservation and co-existence context. Information regarding biodiversity and distribution, threatened species, human-frog conflicts and solutions, will be available for these relevant parties.

Chapter 2: Circadian and seasonal vocalisation periodicity and calling responses to weather phenomena by Anuran diversity in the Nature's Valley area, South Africa

2.1 Introduction

South Africa has approximately 137 described amphibian species, 63% of these of which are endemic to the country and 29 are considered to be classified as threatened according to IUCN Red-list categories (that is, IUCN Red List categories Critically Endangered, Endangered and Vulnerable) (IUCN, 2024; du Preez & Carruthers, 2017). No species has been declared Extinct in the wild (EW) or Extinct (EX) in the country as of yet. Most threatened species in South Africa are concentrated in endemism centres in the Western Cape, Eastern Cape and Kwazulu-Natal. The topographic complexity of these areas of interest has provided opportunities for the allopatric speciation by geographic separation, with the result of a number of restricted species within the range (Minter, 2011). The Western Cape hosts 60 species, 14 of which are considered threatened (Measey, 2011; du Preez & Carruthers, 2017). Twenty-nine frog species are endemic to the Western Cape province and there undoubtedly remain more to be discovered.

The Garden Route National Park stretches approximately 225km from the coastal plateau to the foothills of the Outeniqua and Tsitsikamma mountain of southern South Africa. This area is predominantly occupied by large stretches of indigenous forests, agricultural land, plantations, towns and indigenous Fynbos biomes. It is considered one of the country's richest biodiversity regions (Tchoumi *et al.*, 2020). Within its designated boundary lies a small conservancy, rich with indigenous forests, coastal biomes and pristine Fynbos – the Nature's Valley area. Despite its reputation as a nature hotspot, negligible amphibian diversity studies have been conducted in this region. No up-to-date knowledge exists on the extent of amphibian diversity in the Nature's Valley area, especially within the Sout River and Groot River catchment areas. The most recent work available on amphibian diversity in the study area can be found in the Atlas and Red Data Book the of frogs of South Africa, Lesotho, and Swaziland (Minter *et al.*, 2004). Distribution maps of all frogs in the Atlas were predominantly based on a combination of data collected by field rangers, citizens, herpetologists and existing data from various museum databases and is displayed as quarter-degree grid cells (QDGC) across the country, limited to one species per distribution map.

QDGSs are effective for representing regional distribution of amphibians but do not give an indication of species richness (number of different species) in a specific area, but rather an estimation of species abundance (number of individuals of a given species) (Botts *et al.*, 2011). The other, more specified study of amphibians in the Tsitsikamma area was done by Branch & Hanekom (1987) and is based on work done by Carruthers & Robinson (1977). The study by Branch & Hanekom (1987) was exclusively limited to the Storms River area in the Tsitsikamma Coastal & Forest National Parks (TCFNP) and a general herpetofaunal survey and amphibian cataloguing was exclusively based on catch or see basis by mostly park personnel (Branch & Hanekom, 1987).

The recent Global Amphibian Assessment (GAA2, 2023) reassessed the status of the First Global Amphibia Assessment (GAA1, 2004) and reports that approximately 40.7% (2,873) amphibian species are globally threatened. This is an increase of 192 species (2,681) from 1980 (37.9%) and 85 (2,788) from 2004 (39.4%) and therefore concludes that the status of amphibians worldwide continues to deteriorate. Sub-Saharan Africa has been placed within a category of “Data scarcity” in terms of species richness by the GAA2. Nevertheless, species new to science are continually being described south of the Sahara since the last global assessment (Roedel *et al.*, 2009; Ofori-Boateng *et al.*, 2018; Liedtke *et al.*, 2024), but description, or redescription of species in regions in Sub-Saharan Africa varies substantially. Species richness and diversity indices are believed to drastically underestimate what is truly present in these regions. Recent novel species descriptions and re-discoveries in and around South Africa include *Breviceps ombelanonga* (Nielsen *et al.*, 2020), *Breviceps carruthersi* and *Breviceps passmorei* (Minter *et al.*, 2017) and *Cacosternum cederbergense* (Angus *et al.*, 2023). Conservation potential and prospective diversity assessments present good promise due to Nature’s Valley’s global positioning, understudied nature and potential endemism.

This study is predominantly focused on updating current knowledge and distribution databases on the current state of amphibians in the Nature’s Valley Conservancy and exploring habitat preference and selection of the current amphibian diversity found in this area. Correlations of amphibian call and breeding activity with weather phenomena will also be provided over a seasonal (June 2023 – April 2024) and circadian schedule. In doing so, synergistic goals will be reached by providing accurate data that could be used in conservation initiatives as set out in Campbell-Grant *et al.*, (2023) based on the latest GAA2. The understudied nature on amphibians of this area, as well as the topographic speciality and extreme endemism of Western Cape frog species offers copious motive and need for updated amphibian diversity studies. Through this,

SANPARKS and NVT Tsitsikamma NPC is provided with updated knowledge regarding frogs in this conservation area – information largely absent for approximately three decades.

2.2 Methods and materials

2.2.1 Study area

The study area falls within the boundaries of the Sout (East) River catchment near Nature's Valley, South Africa. Three acoustically monitored sites were selected as they are representative of different habitat types found in the area.

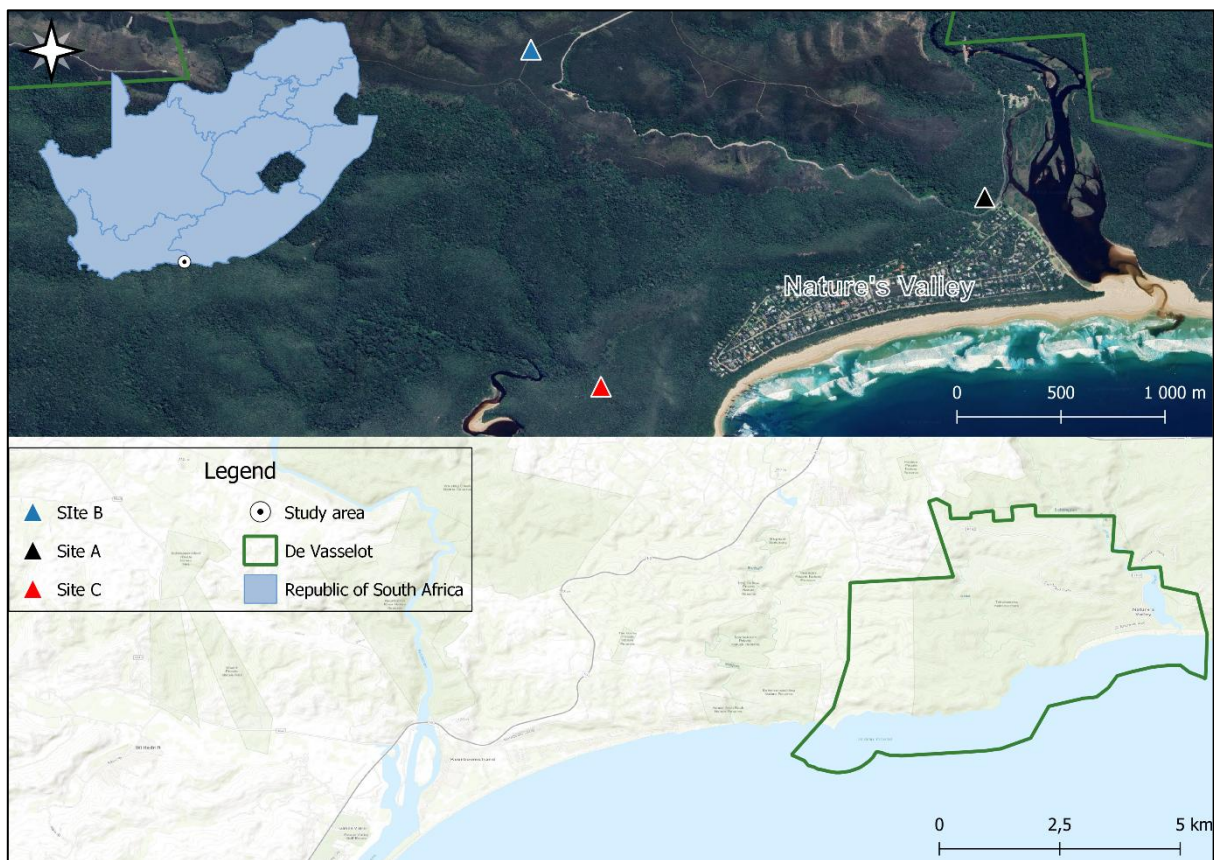


Figure 2-1: Study area and site allocation of conducted research. Site A (Black – Kalander Site), Site B (Blue – Sout Site), and Site C (Red – Forest Site) all fall within the De Vasselot Nature Reserve.

Site A (Coordinates: -33.9762, 23.5608 and 5 meters above sea level) is symptomatic of a Coastal Afro-temperate Forest. It is a small but established meander at the foot of the Kalander gorge system across from the Nature's Valley village entrance. Covering an approximate surface area of 1295.95 m² in size it has an approximate depth of 40 cm.

Site B (Coordinates: -33.9683, 23.5371 at 200 meters above sea level.) is a small, surface-runoff sustained water body symptomatic of Mesic Proteoid Montane Fynbos. It has a surface area of 8.67 m² in size and an average depth of 50 cm.

Site C (Coordinates: -33.9847, 23.5416 at 100 meters above sea level) is a rounded waterbody with an approximate surface area of 35 m² and a maximum depth of 30 cm. It is found near Afromontane Fynbos- and Coastal Afromontane Forest ecotones.

2.2.2 Passive acoustic monitoring (PAM)

Fixed point, passive acoustic monitoring (PAM) was conducted at each of the identified study sites (Figure 2-1) within the Sout River catchment near Nature's Valley. PAM is a non-intrusive method for monitoring various terrestrial (Sugai *et al.*, 2019) and aquatic (Desjonquères *et al.*, 2019) ecosystems and their associated species. PAM was conducted using Song Meter[®] SM 2+, SM 3 and SM4 Wildlife Acoustic recorders. SMs were positioned strategically to detect high quality acoustic readings at elevated positions (head height) that would avoid being submerged during abnormal water-level rises but still be easily accessible for data collection but out of direct sight to avoid theft or vandalism. Recording duration was set to record for 15 minutes, every hour from 18:00 (6 pm) to 06:00 (6 am) from June 2023 to January 2024. Five minutes of every other hour (7 am – 5 pm) was recorded to capture the full circadian amphibian soundscape. Recording configuration was set to digitise calls at a sampling rate of 48kHz (taking Nyquist frequency into account) with a sample size of 16 bits. From January 2024 to July 2024 the recorders were configured identically, except only 5 minutes of every half-hour was recorded from 18:00 (6 pm) to 06:00 (6 am) and no recordings were made during the day (06:00 – 18:00). File corruption occurred for all recordings between the middle of April 2024 to the end of July 2024 and subsequently could not be analysed.

Weather data was collected via an iWeather Twister[®] compact weather station (iWeather SA[™]), gathering readings on humidity, temperature, rain, clouds above ground level and air pressure. The weather station was positioned in the Nature's Valley village (Coordinates: -33.9768, 23.5625).

2.2.3 Data analysis

2.2.3.1 Passive acoustic monitoring (PAM)

Recordings from the Kalandar site were used to examine circadian call patterns every day from July 2023 to December 2023, utilising full 24-hour recordings to capture daily vocalisation cycles. Weather correlations are analysed across both years (2023–2024) using data exclusively from

Kalander to understand environmental influences on calling activity. Every 10th day of each month from January to April 2024 were assessed for seasonal call patterns using nighttime recordings (6 PM–6 AM) across 12 half-day intervals along with nighttime recordings from June 2023 – December 2023. Biodiversity and habitat selection are evaluated across all sites during September 2023 —Kalander, Sout, and Forest—to provide some understanding of species richness, habitat preferences, and ecological patterns within the study area. The first spring rains, fell during September and was therefore chosen for biodiversity analysis.

2.2.3.2 Statistical analysis

Data from analysed recordings were captured on excel spreadsheets for each respective site and research outcome (Ex. Kalander – Circadian). Basic descriptive statistics and frequency indices were calculated for each species at each site. Respective graphs were drawn for each species' circadian activity, seasonal activity and call time at the different locations.

Further statistical analysis includes two types of tests – Chi square tests and symmetric measurements (Phi and Cramer V) – that assess the relationship between species diversity (Species) and habitat type (Location – research sites). The aim of the Chi-square test is to determine whether there is a significant correlation or relationship between these two categorical variables. It tests the null hypothesis that variables are independent, which means that there is no relationship between them. If the test statistics are significant, they suggest that variables are not independent and are in some way related. The purpose of symmetrical measurements (Phi and Cramer V) is to quantify the strength of the association between species and location. The Chi-square test gives an indication whether a relationship exists, but symmetrical measures such as Phi and Cramer's V measures the strength of that relationship. These measurements provide an overview of the magnitude of the relationship and higher values indicate stronger relationships.

2.3 Results

An approximate total of 50 400 minutes of recording time per SM-recorder was gathered during the first phase of the study and 12 600 minutes of recording time per song meter during the second phase of the study. This totalled to 189 000 minutes of overall recording time that required analysis and therefore needed to be compartmentalised. Selection tables were drawn over vocalisations of each species on spectrograms of recordings using Raven Pro[®] (v1.6).

PAM surveys confirmed eight vocally active amphibian species across the three investigated sites, one of which is the threatened Knysna leaf-folding frog (*Afrixalus knysnae*) (Table 2-1). Table 2-1 indicates crosstabulation between the number of detected calls of each species and

the location where it was detected. These call counts include any duration of call or calling bouts which could be any duration of time in the recording [a few seconds, or the whole 15-minute recording (900 seconds)].

Table 2-1: Univariate crosstabulation between species call count across the three research sites [Kalander (Site A), Sout (Site B), and Forest (Site C)]. Species include *Amietia fuscigula* (*A. fuscigula*), *Africalus knysnae* (*A. knysnae*), *Breviceps fuscus* (*B. fuscus*), *Cacosternum boetgerii* (*C. boetgerii*), *Cacosternum nanum* (*C. nanum*), *Hyperolius marmoratus* (*H. marmoratus*), Night Jars (Night Jar), *Strongylopus fasciatus* (*S. fasciatus*), and *Strongylopus grayii* (*S. grayii*).

Species	Location			Total (%)
	Forest	Kalander	Sout	
A. fuscigula	0	103	0	103 (2.6)
A. knysnae	3	81	795	879 (22.5)
B. fuscus	174	7	179	360 (9.2)
C. boetgerii	0	0	44	44 (1.1)
C. nanum	531	64	380	975 (24.9)
H. marmoratus	0	0	25	25 (0.6)
Night Jar	0	0	66	66 (1.7)
S. fasciatus	928	55	4	987 (25.2)
S. grayii	378	49	5	432 (11)

2.3.1 Species per location

Calling activity of each species at the three different locations showed some variation (Table 2-1). Site A (Kalander) showed high calling activity of species *Cacosternum nanum* (*C. nanum*), *Strongylopus fasciatus* (*S. fasciatus*) and *Strongylopus grayii* (*S. grayii*). At Site B (Sout) *S. grayii* were so active that most of the recordings detected full recording activity (900s), but *S. fasciatus* and *C. nanum* weren't detected to be as active. Similarly, *S. grayii* showed high calling activity at Site C (Forest). Sout site shows activity of *Hyperolius marmoratus* (*H. marmoratus*), *Cacosternum boetgerii* (*C. boetgerii*), and songs of Night Jars (nocturnal birds) (Night Jar), where the Forest and Kalander site shows no activity of *H. marmoratus*, *C. boetgerii* or Night jars. However, Kalander site shows to be the only site with presence of *Amietia fuscigula* (Figure 2-2). This is, however, unexpected and provides false information in terms of species occurrence and habitat selection. The importance of field visits is discussed later and contributes to the findings of this paper. It is important to remember that recordings from only September 2023 were used to construct these graphs.

The Chi-square test evaluated the significance of the relationship between variables “Species” and “Location”, and the Pearson Chi-square value was $\chi^2 = 3642.179$ and the likelihood ratio $p = 3722.557$, with $df = 20$ degrees of freedom and a p value of $p > 0.000$. These results show a significant correlation. In contrast, the symmetric measurement, Phi and Cramer's V, assess the strength of the association. The Phi coefficient with a value of $\phi = 0.965$ indicates a very strong positive relationship between variables, while the Cramer's V coefficient with a value of $V = 0.682$ indicates a strong general association. Phi and Cramer's V also have a p value of $p > 0.000$, indicating that the association's strength is statistically significant. Thus, while the Chi-square test confirms the existence of an important association, symmetrical measurements provide a deeper understanding of the strength of this relationship. In short, a statistically significant correlation occurs between location and species list with a strong positive differing relationship.

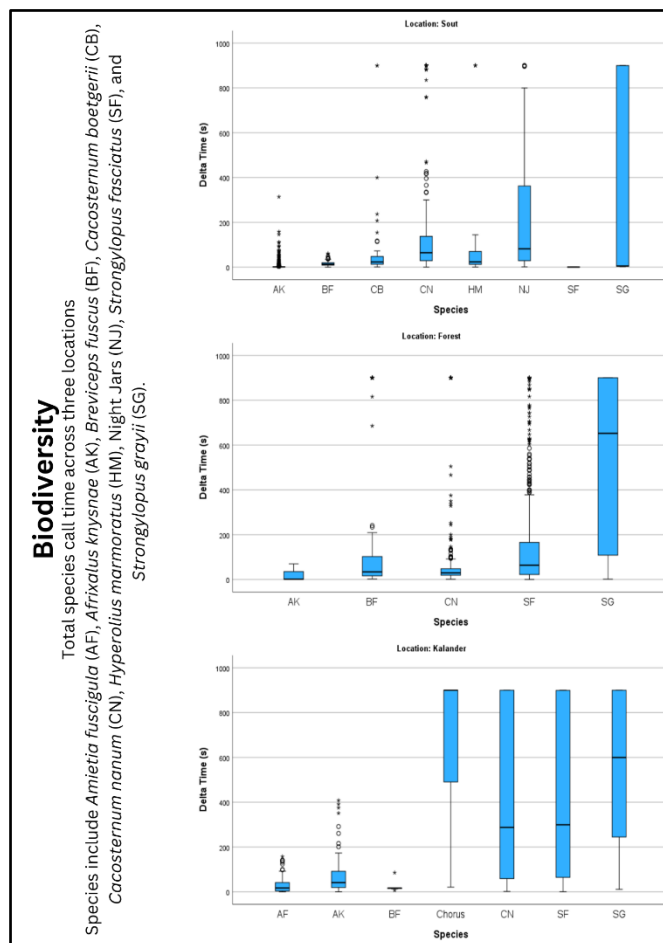


Figure 2-2: Detected vocally active species at the three different sites during the months of September 2023.

2.3.2 Circadian, Seasonal & weather associated calling activity

Measured weather variables are displayed in Figure 2-3. These variables all include the monthly means of clouds above ground level (m), ambient humidity (%), air pressure (hPa), temperature

(°C) and the daily sum per month of precipitation (mm). Humidity measures the wetness of the ambient atmosphere and is likened to the percentage (%) of water vapor in the air. Air pressure, or barometric pressure, is the atmospheric pressure in hectopascal (hPa). Temperature is the warmth or chill measured in degrees Celsius. Precipitation measures the average amount of rain that falls in one square meter (m²) in the overall area (measured in mm). Clouds above ground level measures the distance of clouds above the ground level of the weather station in meters (m). This was included as other rain associated variables (humidity, air pressure and precipitation) were also included in the dataset and was used to see if cloudsAGL could be used as a calling behaviour determinant (instead of precipitation, humidity or airpressure). Table 2-2 cross-tabulates species with possible positive, negative or no clear influence (NCI) correspondence with measured weather variables presented in Figure 2-3.

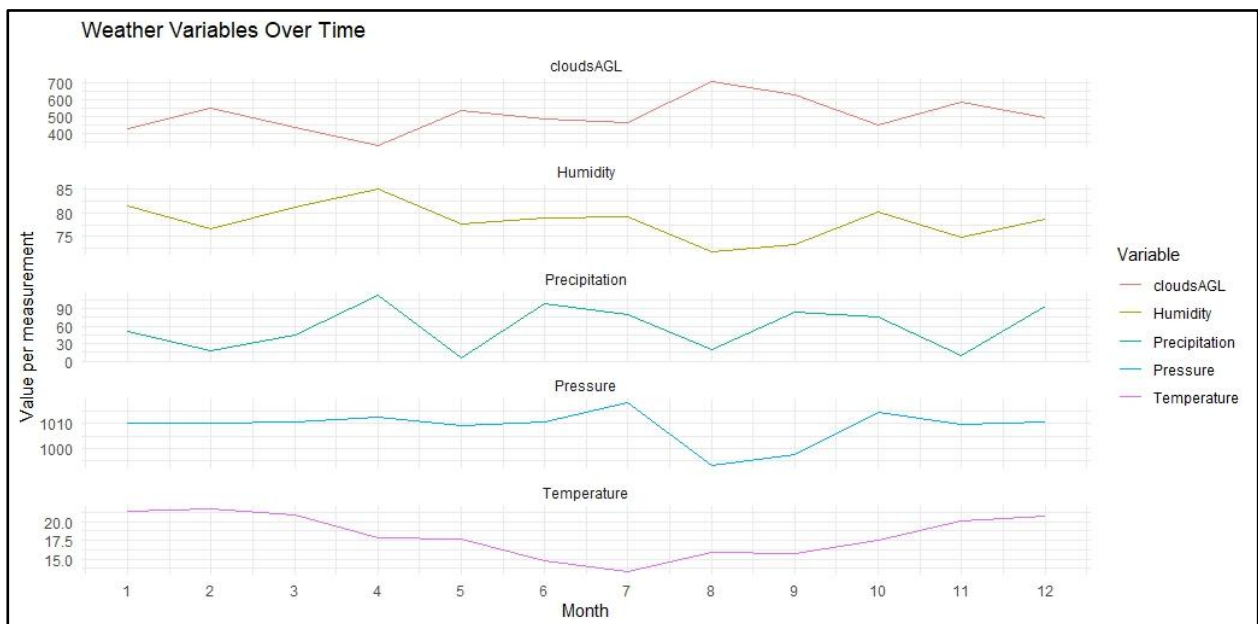


Figure 2-3: Weather variables cloudsAGL (clouds above ground level (m)), Humidity (%), Precipitation (mm), Pressure (air pressure (hPa)) and Temperature (°C) wrapped over Month number from July 2023 to June 2024.

Table 2-2: Possible weather correspondence of each species indicating which weather variable could have a positive, Inverse or no clear influence (NCI) on calling behaviour.

Species	Weather Variable				
	cloudsAGL (m)	Humidity (%)	Precipitation (mm)	Pressure (hPa)	Temperature (°C)
<i>Ametia fuscigula</i>	NCI	NCI	Positive	Inverse	Positive
<i>Afrivalus knysnae</i>	NCI	Positive	Positive	Inverse	Positive
<i>Breviceps fuscus</i>	NCI	Positive	Positive	NCI	Inverse
<i>Cacosternum nanum</i>	NCI	NCI	Positive	Inverse	Positive
<i>Hyperolius marmoratus</i>	NCI	Positive	Positive	Positive	Positive
<i>Sclerophrys capensis</i>	NCI	Positive	Positive	Positive	NCI
<i>Strongylopus fasciatus</i>	NCI	NCI	Positive	Positive	Inverse
<i>Strongylopus grayii</i>	NCI	NCI	Positive	Positive	Inverse

Circadian and seasonal calling activity was measured from data acquired from the Kalandar site. Data from each day between July 2023 and December 2023 was analysed for circadian call patterns and every 10th day from June 2023 to April 2024 between 6PM and 6 AM was analysed for seasonal calling activity. For circadian analysis the average duration of detected calls (s) of each species in every 15-minute recording is plotted over the time of day (24h schedule) (Figure 2-4 & Figure 2-6) followed with a graph presenting chorus energy (dB FS) (Figure 2-8). This measures the loudness of the vocalising chorus (all species) and serves to indicate peak vocal activity of the community. Similarly, for seasonal analysis the average call times of calls detected in 10-minute recordings in each month were used for constructing Figure 2-5 & Figure 2-7. The following results can be seen from the graphs below for each species from Table 2-2, Figure 2-3, Figure 2-4 & Figure 2-5:

- *Amietia fuscigula* (*A. fuscigula*) – Cape river frogs showed calling activity during most hours of the day. Vocalisations of this species are generally soft but fall within the lower frequency spectrum and is easily detectable even during peak chorus activity. Calling hours that appear vacant of *A. fuscigula* calls seem to occur between 7 AM and 11 AM, and 1 PM and 3 PM. Hours during daylight shows lowest calling time with the exception of 10 AM that detected the longest calling times. The lowest calling activity seemed to occur during summer months (between November and February) and gradually increasing until peaking in August/ September. Months of May, June and July detected no calls at the Kalandar site possibly due to file corruptions. Seasonal increase in temperatures and winter rains are weather conditions determining increased calling behaviour.
- *Afrivalus knysnae* (*A. knysnae*) – Little to no calls of the Knysna leaf-folding frog were detected during daylight hours. Calling activity was concentrated from 8 PM to approximately midnight and tapers down as sunrise approaches. Seasonal activity started during the month of August and peaked during September (and could be explained by the increase in rain during that month) after gradually decreasing until January. Vocal activity is completely absent for the remainder of the year [and this agrees with behaviour discussed in Chapter 3 and in De Lange (2019)]. Seasonal increase in temperature, spring rains and abundant winter rains, increasing seasonal humidity and low air pressure are encouraging weather conditions affecting calling behaviour for this species.
- *Breviceps fuscus* (*B. fuscus*) – Plain rain frogs were found to be mostly active during daylight hours with a few exceptions (12 AM, 3 AM, 8 PM and 9 PM). Most calling activity was detected during 5 AM, 5 PM and 6 PM. Vocal activity peaked during August and September, but also remained high during March and April. From October to February

vocal activity became dormant. Increased rain and humidity are the only weather variables encouraging calling behaviour for this species. Decreasing temperatures toward winter discourages this species from calling.

- *Cacosternum nanum* (*C. nanum*) – Bronze dainty frogs (along with the two stream frogs) were the most active calling species during the month of September (the month used for circadian analysis). All hours of the day showed high activity, where 8 PM through to 6 AM showed full recording calling activity (900 seconds). Activity reduces as day breaks and increases as dusk approaches. July proved to be the most active month for this species. January and February showed reduced activity while March and April had no vocal detections. Months after July until December also proved to be active months where September had the most calling activity. Abundant winter rains, low temperatures and decreasing air pressure are considered optimal calling conditions for this species.

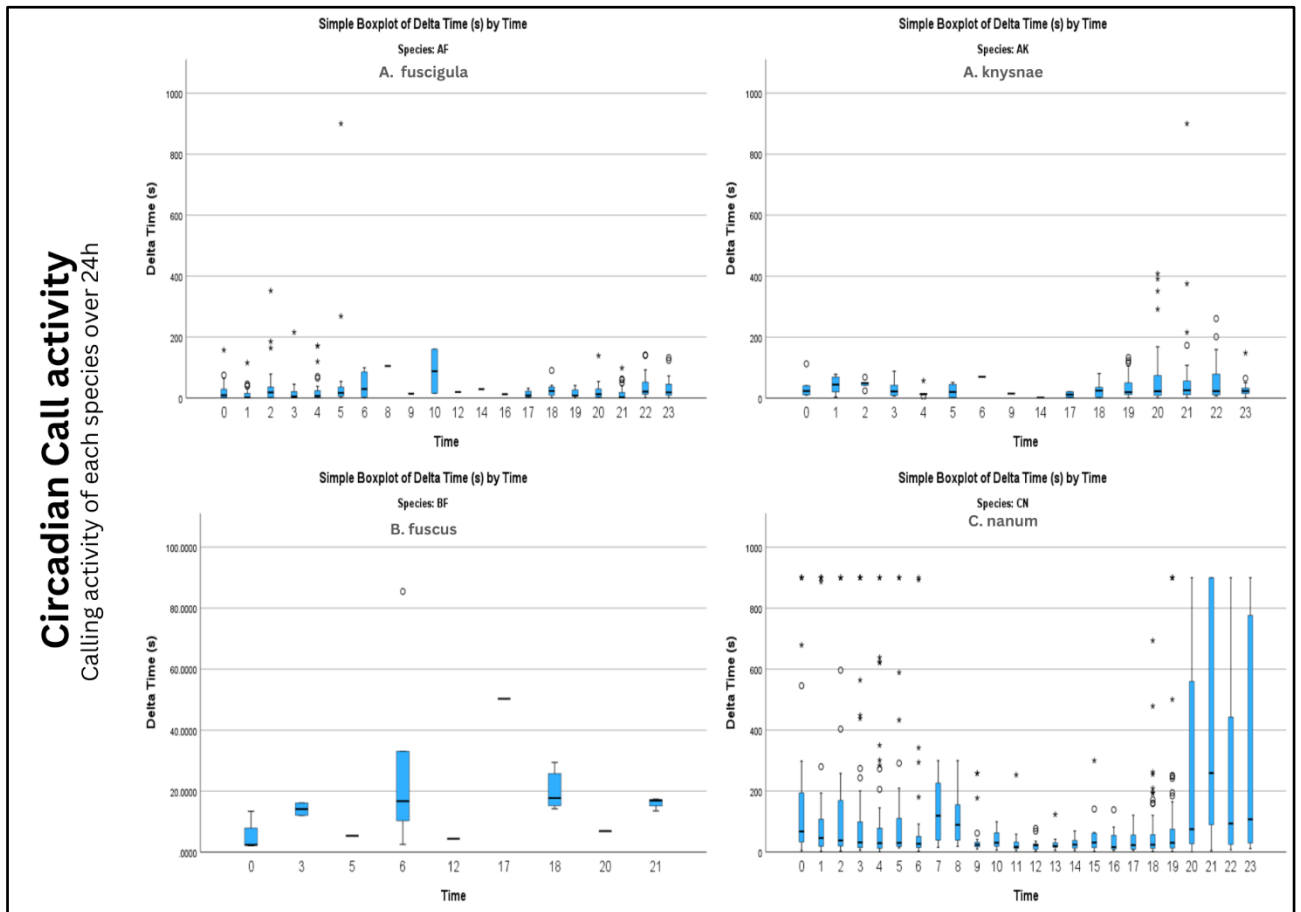


Figure 2-4: Circadian call activity of species *Amietia fuscigula* (*A. fuscigula*), *Afrixalus knysnae* (*A. knysnae*), *Breviceps fuscus* (*B. fuscus*) and *Cacosternum nanum* (*C. nanum*) during the month of September 2023 from the Kalander site (Site A).

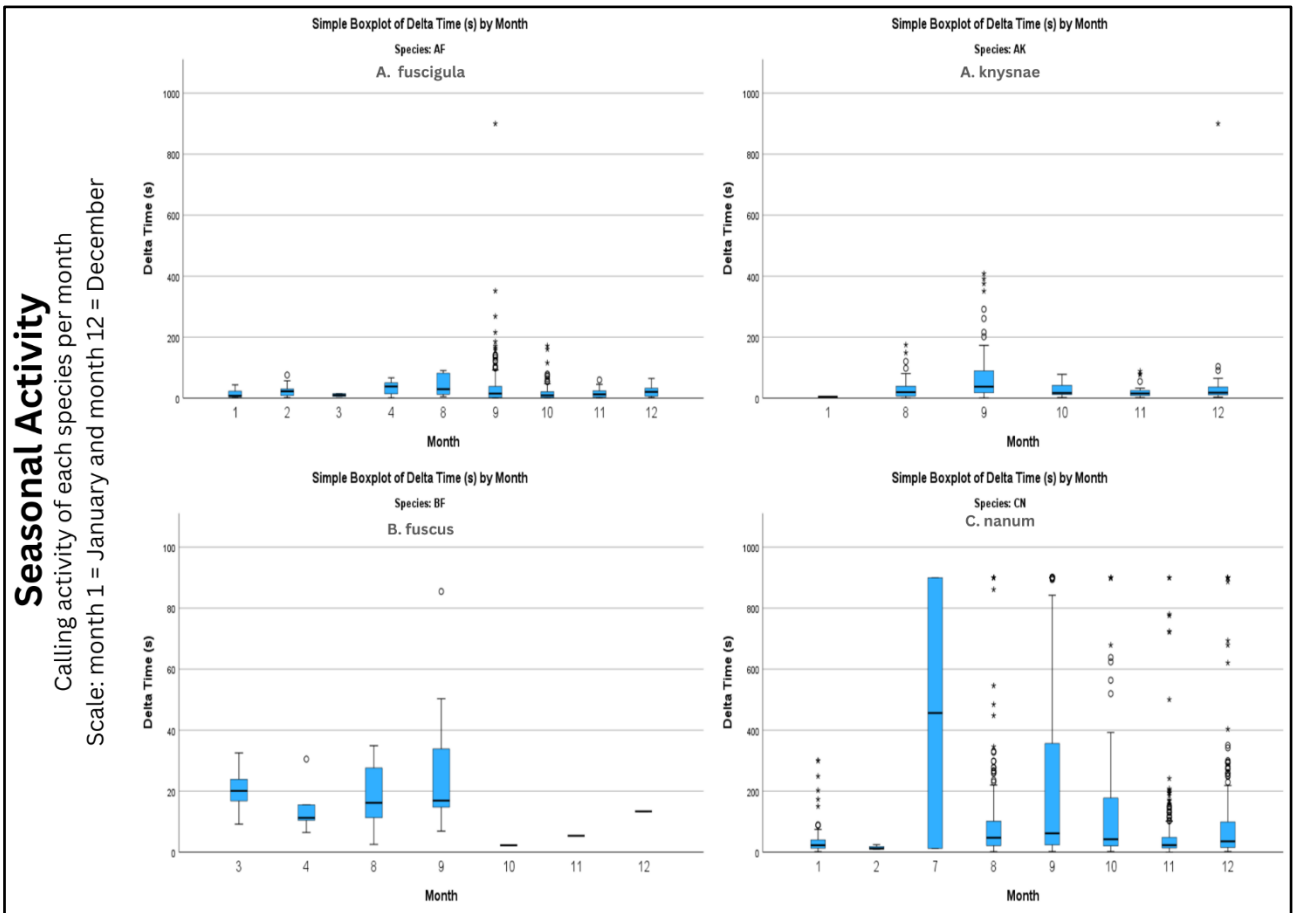


Figure 2-5: Seasonal call (monthly) activity of species *Amietia fuscigula* (*A. fuscigula*), (*A. knysnae*), *Breviceps fuscus* (*B. fuscus*) and *Cacosternum nanum* (*C. nanum*) from the Kalander site (Site A).

The following results can be seen from the graphs below for each species from Figure 2-3, Figure 2-6 & Figure 2-7:

- *Hyperolius marmoratus* (*H. marmoratus*) – Painted reed frogs showed almost no activity during daylight hours. Calling commenced from approximately 6 PM and increased with exceptional outliers to approximately midnight (11 PM or 12 AM) and reduces as dusk approaches. Winter months showed no calling activity from this species where calls were picked up from September through to December and decreasing again from January. Seasonal increase in temperature, humidity, air pressure and spring rains encourage vocalisation in this species.
- *Sclerophrys capensis* (*S. capensis*) – Raucous toads only showed activity after midnight hours and no activity after the sun has risen. Calling only commenced after 12 AM and exclusive to October. Vocalisation of this species corresponds to sudden and abundant

spring rain, high humidity and air pressure. Temperature does not seem to have a direct effect on vocalisation of this species.

- *Strongylopus fasciatus* (*S. fasciatus*) and *Strongylopus grayii* (*S. grayii*) – Both species of stream frog showed high circadian calling activity. Calls of both species were detected during all hours of the day (except 1 PM and 5 PM for *S. fasciatus*). Calling activity showed similar patterns in both species, where lower vocalisations occur during the day but starts to increase from about 6 PM. Peak activity is reached early (8 PM) and tapers down at around 4 AM or 5 AM (*S. fasciatus* shows high calling activity until 6 AM). Both Stream frog species exhibited similar seasonal activity. Full year vocal activity was observed while peaking during July/August and gradually dropping until December. *Strongylopus grayii* showed no activity during December but proved to retain activity a little longer in October than *S. fasciatus*. Correspondence to weather conditions of *S. fasciatus* and *S. grayii* is similar to *C. nanum* though activity of species seem to linger after winter rains and initial low winter temperatures. Henceforth, winter rains, and increasing humidity and air pressure before spring rains are all optimal calling conditions for this species. Increasing temperatures and decrease in precipitation toward summer seems to discourage these species from calling as much.

Circadian Call activity (Continued)

Calling activity of each species over 24h
 Scale: hour 0 = 00h00 and hour 23 = 23h00

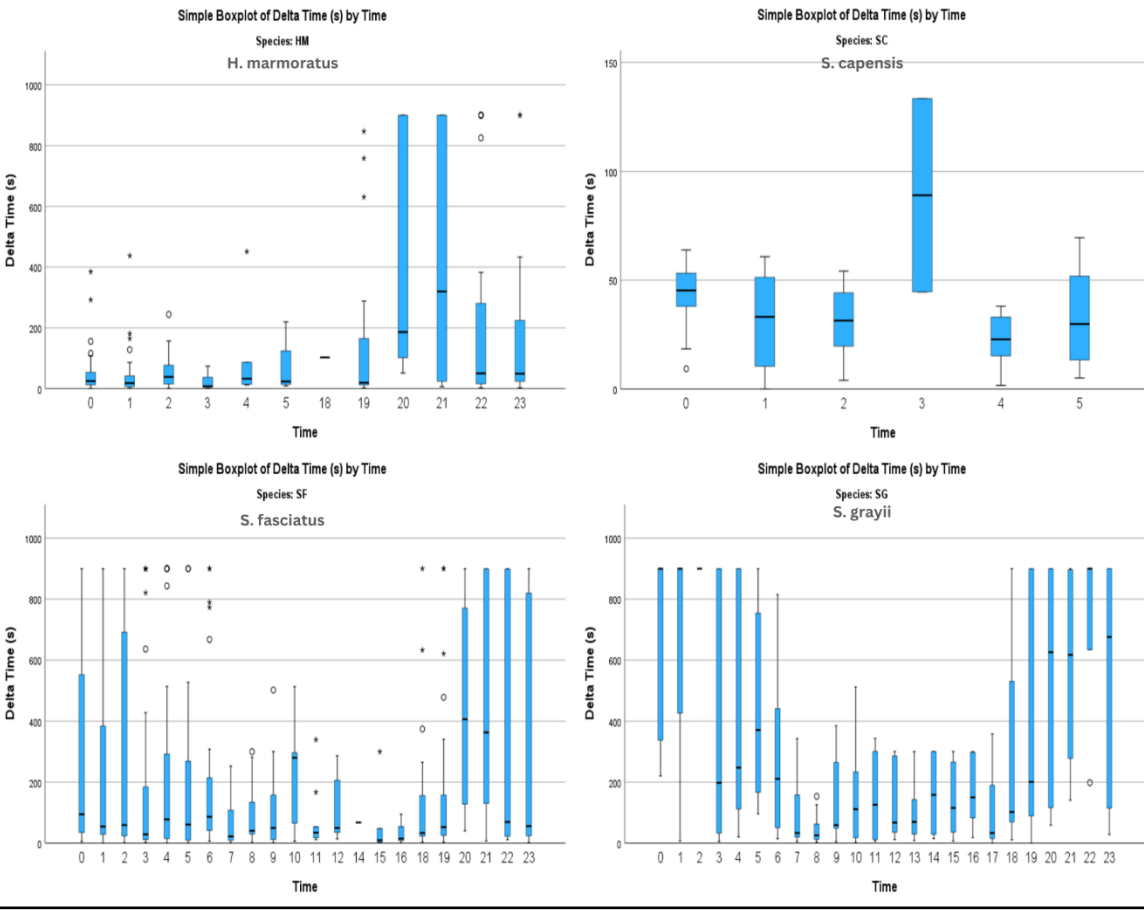


Figure 2-6: Circadian call activity (continued) of species *Hyperolius marmoratus* (*H. marmoratus*), *Sclerophrys capensis* (*S. capensis*), *Strongylopus fasciatus* (*S. fasciatus*) and *Strongylopus grayii* (*S. grayii*) during the month of September 2023 from the Kalandar site (Site A).

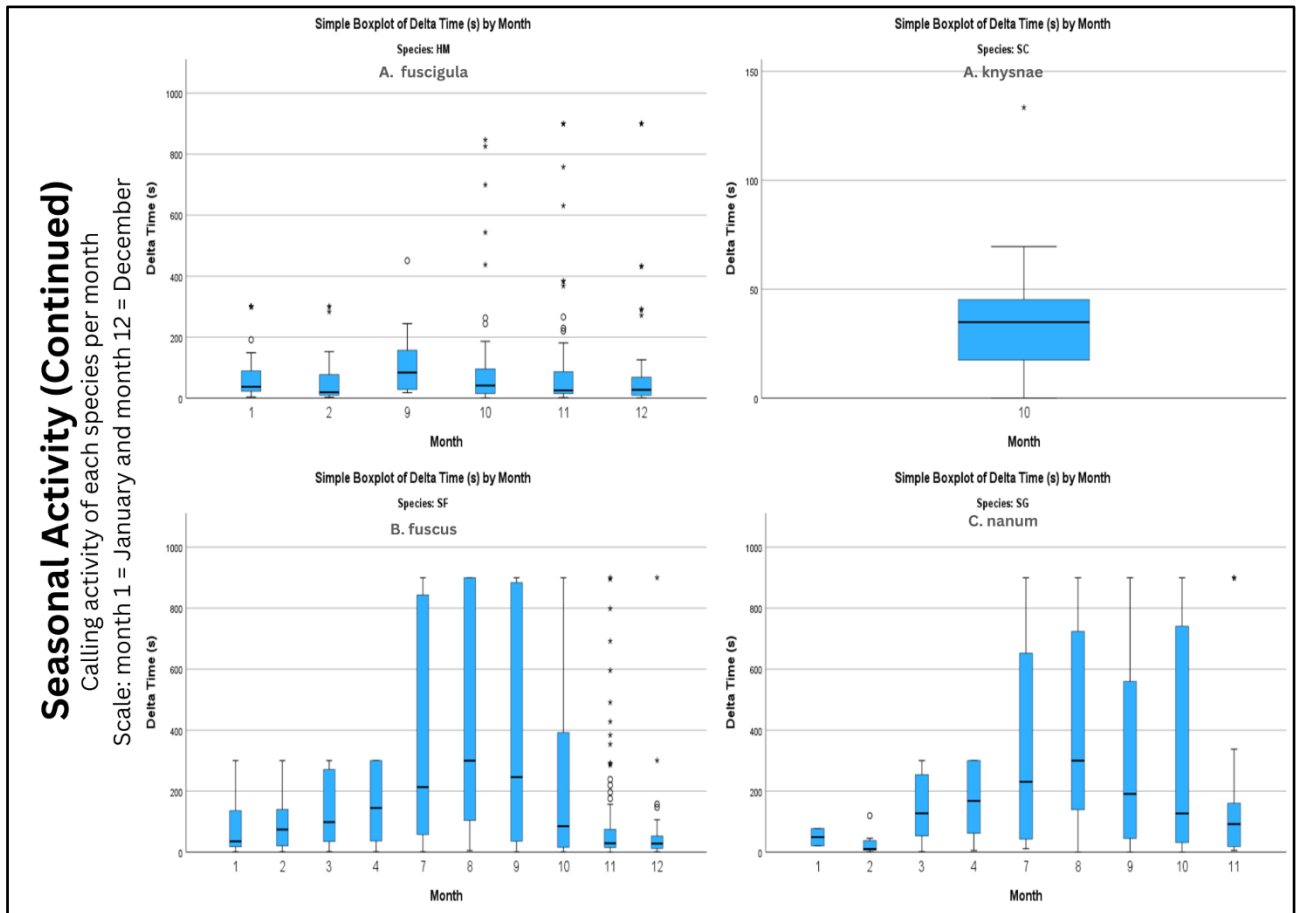


Figure 2-7: Seasonal call (monthly) activity (continued) of species *Amietia fuscigula* (*A. fuscigula*), *Afraxalus knysnae* (*A. knysnae*), *Breviceps fuscus* (*B. fuscus*) and *Cacosternum nanum* (*C. nanum*) from the Kalander site (Site A)

Chorus energy serves as a measurement of the total sound energy produced by the total vocalising frogs per recording. Energy measured in Decibels Full Scale is a logarithmic measurement and representation of a signal's amplitude (loudness). In this case, the chorus energy during September at the Kalander site is lowest between hours 11h and 17h before rising gradually from 6 PM and 7 PM. Chorus energy is highest (therefore calling is loudest) from hours 8 PM to 1 AM (Figure 2-8). Calling activity of *S. grayii*, *S. fasciatus* and *C. nanum* all also falls within these times. Observations from fieldwork conclude that these three species are by far the loudest and chorus *S. grayii*, *S. fasciatus* and *C. nanum* together make it difficult to hear other species.

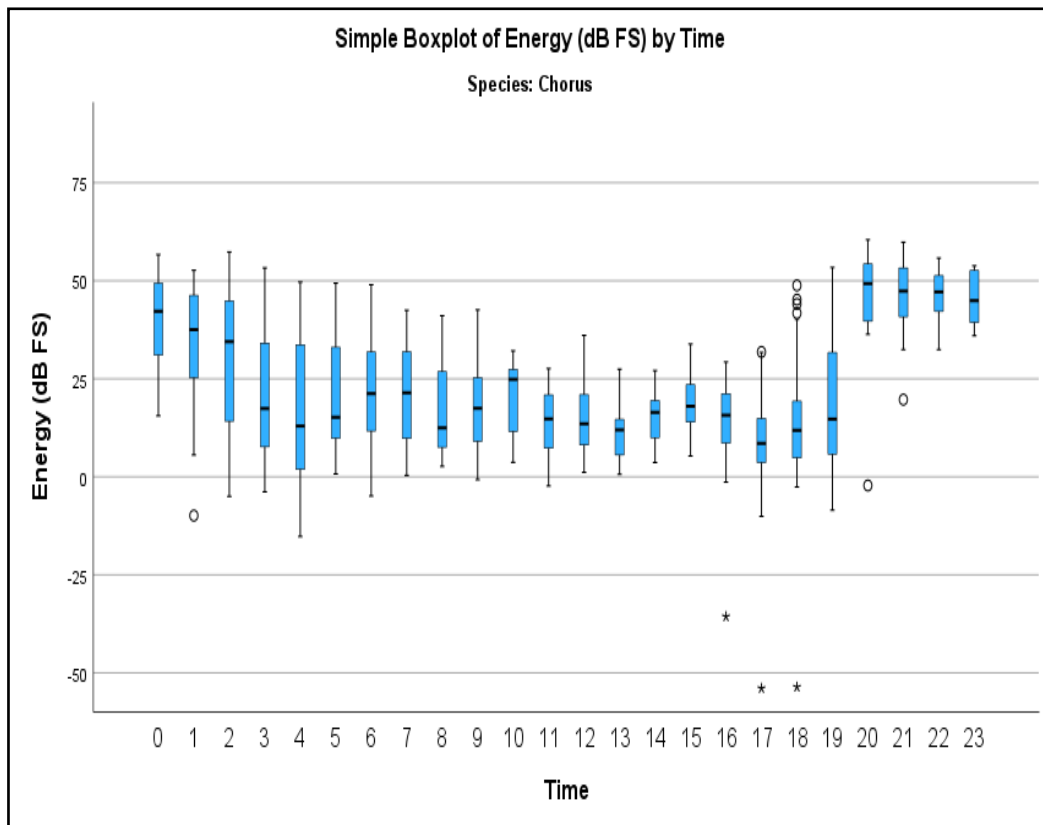


Figure 2-8: Circadian calling energy (dB FS) of the community chorus during the month of September 2023 from the Kalandar site (Site A). Scale: 0 = 00h00, 23 = 23h00.

2.4 Discussion

2.4.1 Responses to abiotic conditions

Vocalisation is an energy expensive activity and it is more efficient to call during conditions conducive to successful breeding, survival and feeding opportunities (Willacy *et al.*, 2015). Results indicate clear association between calling activity and exogenous events in most species in the Nature's Valley area. Abiotic conditions that influence calling activity most included photoperiod, precipitation and temperature with slight variation between species and might be dependent on breeding strategies different species exhibit (prolonged vs explosive or summer vs winter breeding). Most amphibians start calling at the onset of sunset and stop as day breaks as a result of lowered light intensity and possible decreased background noise from birds and other diurnally active animals. Lowered light contributes to camouflage effectivity towards visually orientated diurnal predators, and quieter calling conditions increase males' vocal reach in (possibly) large and (definitely) small spatial scales (Oseen & Wassersug, 2002). Nevertheless, trends are witnessed among species that peak in activity during the same months of the year. Species that show higher activity from early spring to late summer (late August – end of February) (i.e. *A. fuscigula*, *A. knysnae*, *H. marmoratus* and *S. capensis*) also peaked in activity at the onset

of sunset but reduces activity after midnight. Similarly, winter peaking species, *C. nanum*, *S. fasciatus* and *S. grayii*, show sustained diurnal activity with greatly increased nocturnal calling activity. The only fossorial species in this area, *Breviceps fuscus*, showed no definitive pattern towards photoperiod, but remained dormant throughout winter and remains reactive towards rain, hence the genus's name.

Nature's Valley's climate and weather conditions are characterised by high rainfall with moderate temperatures (Joubert, 2021). Rainfall in this area is not persistent across time yet occurs on a regular basis as explained by being in the transitional zone between winter rainfall (Cape of Good Hope) and summer rainfall (East London) areas. Temperature rarely exceeds or falls below extremes of 28 °C or 10 °C respectively with gradual (and expected) decrease towards winter and increase towards summer. Sudden air pressure drops in spring could be explained by a climatological response called "Cutt-off low" (Singleton and Reason, 2007). This causes heavy rain, thunderstorms, and strong winds – cause and effect in September 2023 for one of the highest coastal surges in the western and southern Cape regions of South Africa have experienced in history. Nevertheless, air pressure remains relatively constant throughout the year - characteristic of coastal zones.

Precipitation has the most profound effect on calling activity of all-weather variables, regardless of winter or summer breeding. Though this area is considered temperate (with rainfall distributed evenly throughout the year), high rainfall periods are recorded over winter and throughout spring (Figure 2-3), but not in autumn. As such, calling activity is greatly reduced across all species between April and May but increases as rains approach from June to end of October. In addition to precipitation, temperature acts as an important facilitating variable for calling activity. Winter breeders, understandably, seem to prefer colder temperatures and increased humidity. These winter breeding species generally breed in shallow, thick vegetated areas (*S. fasciatus* and *C. nanum*) or lays eggs on the riparian zone (*S. grayii*), leaving eggs exceptionally vulnerable to desiccation. Lower temperatures, consistent rain, higher humidity and air pressure reduces the risk of drying out. On the contrary, spring-summer breeders are selective of warmer temperatures. Knysna leaf-folding frogs (*A. knysnae*) and Painted reed frogs (*H. marmoratus*) tend to utilise leaves and reeds to lay eggs close to the water surface or even exposed to the outside elements. This could suggest that a required temperature and water abundance thresholds has been met for successful breeding. Explosive breeders, such as *S. capensis*, utilise conditions in abundance for successful, quick reproductive turnover. High rains (or shortly after), high temperatures, air pressure and humidity guarantee longest persistence of adequate breeding grounds. For this species, this means shallow ponds and puddles that form after prolonged rains. Toad eggs are

generally black and should aid in heat absorption – something that is in abundance for quick tadpole development in shallow pools.

2.4.2 Differences between locations and overall diversity

Initial statistical comparison between the three study sites and species occurrence indicated a strong positive association. This supports the hypothesis that species variability occurs between the three sites, i.e. across different habitat types. Statistical analysis of the recordings do not entirely reflect what is seen during field visits and should be interpreted with care: it only serves to give an initial indication whether or not noteworthy differences occur. Though the southern site presented highest species richness, field visits revealed that the only species present there, and not at the other two sites, is *C. boetgerii*. Results also reveal that species *A. fuscigula* and *S. capensis* occur at the Kalandar site, but not the others. This is surprising, and also highly unlikely, as these two species are one of the largest, and also most frequent visually encountered species in the entirety of The Craggs region and Western Cape. *Hyperolius marmoratus* also showed a definitive presence at the Kalandar site (Site A), and not just at the Sout site (Site B). Field work also revealed presence of vocally active *Semnodactylus wealii* at one of the fynbos sites monitored for Chapter 3 but not at any of the other frequently visited locations. *S. wealii* called frequently for approximately a week, right before the September rains. It wasn't heard for the remainder of the year thereafter. Figure 2-9 displays one of the vocalisations made from a calling *S. wealii* male (Recorded 17 September 2023). Table 2- presents the differences of species composition between the three sites.

Table 2-3: Comparison of the species list between study sites. This species list contains the scientific and common names of species that was found to be present (✓), absent (X), or probably present (•) in the three study sites.

Scientific name	Common name	Study sites		
		Kalandar site (A)	Sout Site (B)	Forest Site (C)
<i>Amietia fuscigula</i>	Cape river frog	✓	X	X
<i>Afrivalus knysnae</i>	Knysna leaf-folding frog	✓	✓	✓
<i>Breviceps fuscus</i>	Plain rain frog	✓	✓	✓
<i>Cacosternum boetgerii</i>	Common dainty frog	X	✓	X
<i>Cacosternum nanum</i>	Bronze dainty frog	✓	✓	✓
<i>Heleophryne regis</i>	Southern ghost frog	•	•	•
<i>Hyperolius horstockii</i>	Arum lily frog	X	X	X
<i>Hyperolius marmoratus</i>	Painted reed frog	✓	✓	✓
<i>Semnodactylus wealii</i>	Rattling frog	X	✓	X
<i>Sclerophrys capensis</i>	Raucous toad	✓	✓	✓
<i>Sclerophrys pardalis</i>	Eastern leopard toad	•	•	•
<i>Strongylopus bonaespei</i>	Banded stream frog	X	X	X
<i>Strongylopus fasciatus</i>	Striped stream frog	✓	✓	✓

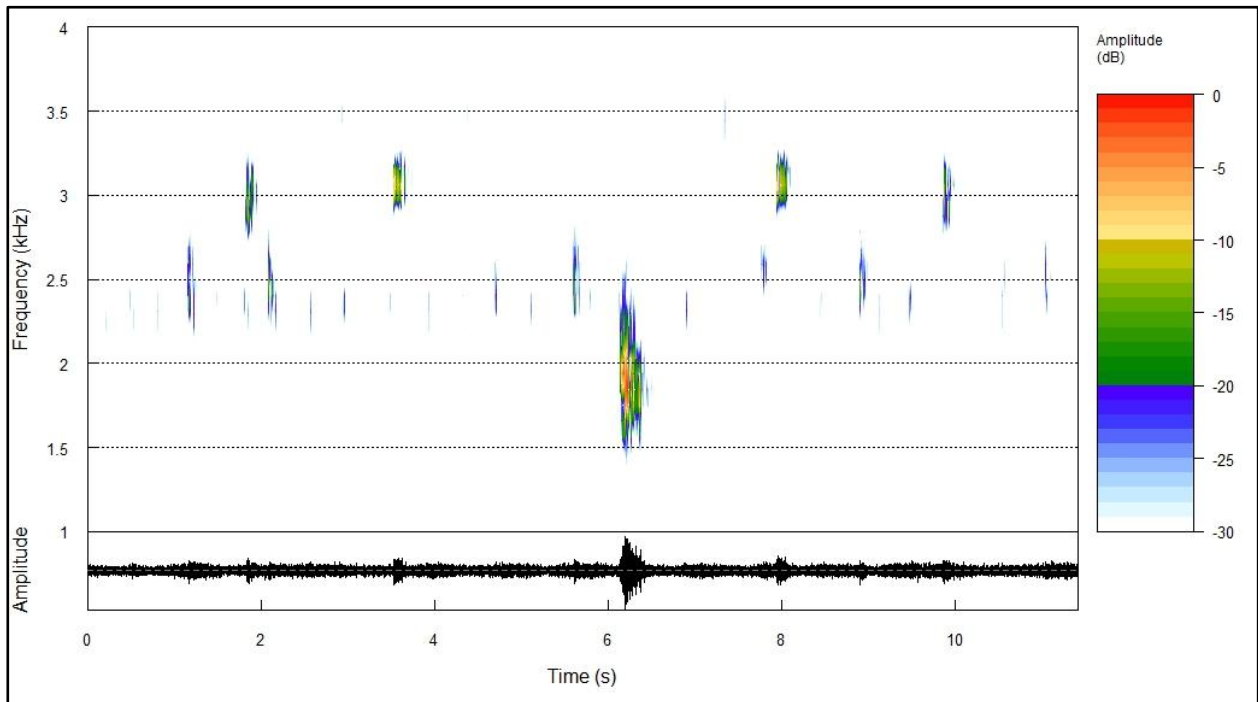


Figure 2-9: Spectrogram (top) and oscillogram (bottom) of a single *Semnodactylus wealii* call at approximately 6 seconds in the recording during September. Graph drawn through R-studios and the function `spectro()` from package TuneR.

Location specific abiotic correlates weren't tested across all sites due to unreliable distance to a proximal weather station, and actual species differences between locations were therefore not effectively investigated. Why *C. boetgerii* was active in the nocturnal acoustic soundscape of Fynbos and not forests clearings remain unknown for this region for now, but it is clear through field work that *C. boetgerii* and *S. wealii* occupy the Fynbos system and not any other system. It is, however, a distinctive feature of *S. wealii* to be associated with shallow, semi-permanent wetlands/marshes in pristine fynbos habitat, but *C. boetgerii* is a known explosive and opportunistic breeder that can be found near *most* waterbodies. Why *A. fuscigula* and *S. capensis* weren't detected at sites besides the Kalandar site is also a mystery, yet iNaturalist observations are saturated with these two species. Nevertheless, though sites are some distance away from each other, they are mostly confined within the same water catchment area, or at least neighbouring catchments. The only obvious boundaries present near each site is the Groot River, Sout River and the R102 "Nature's Valley pass" road. Though connectivity between sites weren't investigated, it is clear that connectivity between sites is most probably still retained and also explains similarity (taking field observations into account) between locations – but this could be beneficial future information for NVT's other forest and estuary related projects.

The amphibian species list of the TCFNP produced by Branch and Hanekom (1987) proved useful to set realistic expectations to what the outcome would be for this study. No automated methods of surveillance or monitoring was used during their study and was completely based on a sight and hearing basis by park personnel. Nevertheless, in a park 40 km east of Nature’s Valley, 13 species was included in their herpetofaunal list from almost four decades ago. This study successfully identified the definitive presence of nine species but estimates that two to three species were accidentally undetected due to unfortunate turn of events throughout the study’s timeline (and is discussed below). Table 2-2 compares findings of Branch and Hanekom (1987) and results from this study.

Table 2-4: Comparison between studies conducted in 1987 and 2024 of sites within the same region. This species list contains the scientific and common names of species that was found to be present (✓), absent (X), or probably present (•) in the two separate studies.

Scientific name	Common name	Year & Location of study	
		1987 – TCFNP	2024 – Nature’s Valley
<i>Amietia fuscigula</i>	Cape river frog	✓	✓
<i>Afrivalus knysnae</i>	Knysna leaf-folding frog	✓	✓
<i>Breviceps fuscus</i>	Plain rain frog	✓	✓
<i>Cacosternum boetgerii</i>	Common dainty frog	X	✓
<i>Cacosternum nanum</i>	Bronze dainty frog	✓	✓
<i>Heleophryne regis</i>	Southern ghost frog	✓	•
<i>Hyperolius horstockii</i>	Arum lily frog	✓	X
<i>Hyperolius marmoratus</i>	Painted reed frog	✓	✓
<i>Semnodactylus wealii</i>	Rattling frog	✓	✓
<i>Sclerophrys capensis</i>	Raucous toad	✓	✓
<i>Sclerophrys pardalis</i>	Eastern leopard toad	X	•
<i>Strongylopus bonaespei</i>	Banded stream frog	✓	X
<i>Strongylopus fasciatus</i>	Striped stream frog	✓	✓
<i>Strongylopus grayii</i>	Clicking stream frog	✓	✓

Shortage of hardware and denial of access by landowners allowed for neglected investigation of other terrestrial habitats in the study area. Fast flowing and cascading river sections flow through and within surrounding privately owned properties and are suitable habitat for Southern ghost frogs (*Heleophryne regis*). Though rivers and water bodies in South Africa aren’t legally allowed to belong to any private party, safe access to adequate cascading habitat is only accessible through privately owned land that denied access. Nevertheless, iNaturalist observations in the area reveal tadpoles of *H.regis* in adequate habitat, suggesting presence in the area.

No Arum lily frogs (*Hyperolius horstockii*) were encountered visually or heard during field visits nor detected during automated acoustic monitoring. This species known for their association with wetlands in coastal fynbos heathland (Measey *et al.*, 2011) that could tolerate disturbances. According to Branch and Hanekom (1897) detection of this species was found in Covie (see Chapter 5 for description of area), close to Nature's Valley, but field visits in October 2023 to marshy habitat in Covie remained silent of this species. Nevertheless, presence of this species is still likely, as an iNaturalist observation positively recorded a specimen in Keurboomstrand, 20 km west from Nature's Valley.

The Eastern leopard toad (*Sclerophrys pardalis*) was the most anticipated species to be detected but only vocalised once between recording sessions at the Kalandar site. During one of the maintenance sessions on the Kalandar site (replenishment of batteries and memory cards) on the 11th of September 2023 a momentary bout was heard with great certainty by researchers from what is believed to be a single *S. pardalis* male. This species is believed to be almost exclusively secluded from the Storms River Eastward. However, in November 2024 one female was found crossing the road in Sedgefield, Western Cape, near an active breeding site, an odd 120 kilometres from the Storms River (Figure 2-9).



Figure 2-10: Female *Sclerophrys pardalis* from Sedgfield, Western Cape, approximately 120 kilometres (west) outside of its expected range (photo: Tiaan Botha)

Banded stream frogs (*Strongylopus bonaespei*) were probably the least likely to be detected during this study as they are positively associated with cold montane streams and ponds. No habitual areas that shared similar characteristics as this species preferences were accessible within the study site or conservation area. Some distance had to be travelled and therefore fell outside the study area. It is worth mentioning that positive identification of this species' call was heard during a day trip to the Formosa Nature Reserve, 22 km northeast from Nature's Valley.

Species presence/absence indices alone, although useful, do not provide conservation efforts much to work with but it does provide a good monitoring baseline. This study provided the first relevant species list since the 90's and also marks the first monitoring event for frogs in this area since the publication of Branch & Hannekom (1987) – monitoring information that was largely absent for some time. Continuous population monitoring is listed as one of the top priority research and conservation areas required for effective conservation of frogs in future (Campbell-Grant *et al.*, 2023). Compilation of species lists should, therefore, be a repeated activity and should be combined with other conservation/research actions. A compilation of recurring species

lists provides population trends and responses to natural events: this provides conservation something to work with.

Habitat selection by animals provides conservation initiatives some insight into proper environmental management as seen in Romano *et al.* (2017) through guided forest management plans. In addition, by knowing habitat preferences of amphibians it makes it possible to assess response behaviours to changes in proximal or immediate environmental conditions (Blomquist & Hunter, 2010) and to prioritise conservation and intensive intervention to areas of highest concern that could result in the most efficient conservation of representative areas (Baldwin *et al.*, 2006). Habitat selection by animals is determined by various environmental cues (be it chemical, physical and social cues) to inform them of a location's resources available for successful reproduction and survivability (Buxton *et al.*, 2020). A combination of species presence and habitat preferences of these species could reveal conservation perspectives that can be explored and implemented for better habitat management, conservation prioritization and habitat assessments. Statistical comparisons imply significant differences between habitats in this study, yet *in vitro* observations reveal that differences are minor, but still present. Connectivity between sites remain retained with little to no barriers and good protection of the landscape within the PA and facilitates homogenous distribution of generalist species, and specialist species in their respective, expected habitat types.

Comparison to the species list conducted in 1987 by Branch and Hanekom has already been discussed above. However, the total number of species found in this understudied area only makes up 17.5% of the expected species amount in the whole of Western Cape. No new species have been detected during this study, but possibilities are not ruled out. Endemicity of Western Cape species across the province continually provides ample possibility for novel, micro-habitat specific species to be discovered all over the hard-to-reach places in the Nature's Valley area. This study is by no means conclusively confirms that all species in this region have been detected, and much work in other areas in this region could provide valuable information regarding present and absent species in harder to reach, isolated habitat. For the Formosa Nature Reserve, however, the species list is largely complete – with the exchange of a species or two that has been discussed above.

2.5 Conclusion

In conclusion, this study focused heavily on updating (or contributing towards updating) knowledge on amphibian diversity of the Nature's Valley conservation area. Herein, location variation of vocalising amphibians has been explored, and concludes that significant statistical

variation occurs, but *in vitro* observations conclude that habitat connectivity ensure expected homogenous distribution of species in their respective habitat types. Abiotic factors influencing calling include photoperiod, temperature and rainfall, but responses to these conditions are species specific. Nevertheless, the anuran species list produced by this study is the first to be generated in three decades and provides a good baseline. Frogs are a very important and easily monitored component of the ecosystem in this area. Detection of species listed above was required some effort yet provides an important confirmation for each species detected (shown in Figure 2-11). How this information benefits NVT and SANPARKS is discussed in more comprehensively in the final chapter.

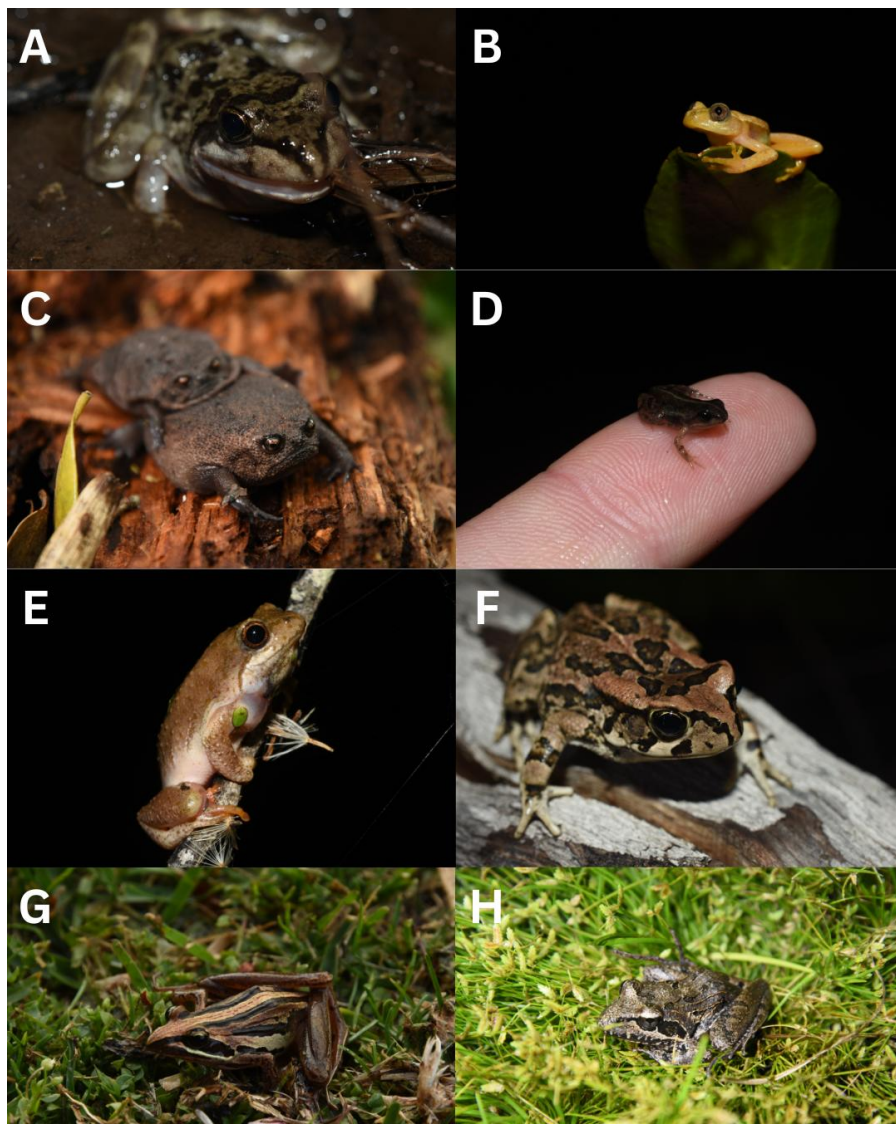


Figure 2-11: Illustrative species list of all visually detected species in Formosa Protected area. (A) *Amietia fuscigula*, (B) *Afraxalus knysnae*, (C) *Breviceps fuscus*, (D) *Cacosternum nanum*, (E) *Hyperolius marmoratus*, (F) *Sclerophrys capensis*, (G) *Strongylopus fasciatus* and (H) *Strongylopus grayii*. Fotos taken by Tiaan Botha.

Chapter 3: Call repertoire of *Afrixalus knysnae* (Loveridge: 1954) (Anura: Hyperoliidae) and associated behaviour relating to inter- and intra-species interactions

3.1 Introduction

Literature on the Knysna leaf-folding frog (*Afrixalus knysnae*) is primarily found in field guides, IUCN Red List assessments, meta-data, specialist reports, and a few descriptive studies on distribution, biology, and behaviour (De Lange & Du Preez, 2018; De Lange 2019). Before 2019, research on the distribution and biology of *A. knysnae* was intermittent over the preceding six decades with no single article focussing exclusively on this species. Literature consisted mainly of short descriptive notes and “box-ticking” of possible presence in herpetological surveys conducted for reserve management plans, conservation recommendations and reports. Features of the species were confined to description in early herpetological field surveys and later in field guides and The Atlas and Red Data Book of the Frogs of South Africa, Lesotho, and Swaziland (Minter *et al.*, 2004) (hereinafter referred to as “The Atlas”). Reports by Poynton (1964), Passmore and Carruthers (1995), and Channing (2002) failed to distinguish between *A. knysnae* and *Afrixalus spinifrons*, which seems to be a common occurrence in older literature (Minter *et al.*, 2004). A survey of the Tsitsikamma Forest and adjacent area reported the occurrence of *A. knysnae* at Covie, on the western boundary of the forest (Branch and Hanekom (1987) and a management plan of the Tsitsikamma National Park (Cole *et al.*, 2009) mentions *A. knysnae* briefly and notes that the species occurs in coastal wetlands between the Park’s most eastern and western borders of Covie and Groenvlei, respectively. However, Minter *et al.* (2004) describes *A. knysnae* and *A. spinifrons* as non-sympatric species. The species occurs on either side of the border between the Eastern and Western Cape provinces (IUCN, 2016). Surveys east and west of the range in the past decade have not revealed any additional records outside of the known range. The Atlas provides some additional information about the life history of *A. knysnae*, conservation recommendations and perceived threats based on what was known about the species at the time. The Red List assessment of 2010 and resultant conservation and research strategy for South Africa’s frogs provided information on the species’ reproductive biology, habitat preference and ecology of the species and mentions the similarity between *A. knysnae* and *A.*

spinifrons. The strategy document recommended the need for further studies to distinguish between the species based on morphology, genetics, and acoustics (Measey, 2011).

In 2019, De Lange completed a full descriptive study of *A. knysnae* covering its range and distribution (with the introduction of a new population locality), bioacoustics analyses, and a preliminary description of its reproductive biology and tadpole morphology (De Lange, 2018). However, comprehensive information on the species behaviour associated with calls, detailed reproductive behaviour, tadpole development and biology and primary survival threats (natural or anthropogenic), has not yet been fully concluded.

Since the recognition of significant global amphibian declines (Stuart *et al.*, 2004; Campbell-Grant *et al.*, 2023; Leudtke *et al.*, 2023), it is widely accepted that gaps in knowledge – and the disconnect between knowledge and applied action – greatly limits the effective translation of research into conservation action (Stuart *et al.*, 2004; Campbell-Grant *et al.*, 2023). The first Global Amphibian Assessment (GAA1) (Stuart *et al.* 2004) found that the key threat to global amphibian population decline was habitat destruction, followed by pollution. The most important emerging threat identified by the GAA1 was the incidence of amphibian pathogens, such as *Batrachochytrium dendrobatidis* (*Bd*) and *Batrachochytrium salamandrivorans* (*Bs*) (or chytrid fungus). The second Global Amphibian Assessment (GAA2, 2015 – 2022) published in 2023 (Luedtke *et al.*) shifted the root causes back to habitat loss and climate change – identified as more long-term threats. These comprehensive overviews of long-term data both highlight the need for ongoing monitoring work to identify patterns in order to guide conservation measures and provide assessments of the effectiveness of these interventions (Grant *et al.*, 2019).

Afrivalus knysnae is one of 16 South African species that are categorised as threatened (CR; n = 6), (EN; n = 9) or (VU = 1) status (IUCN, 2024). The lack of knowledge about this species has been elucidated above, and species-specific conservation interventions, that should take the most precarious short- and long-term threats into consideration – may well be underinformed for *A. knysnae*.

The aim of the current study is to ultimately identify and prioritise research needs that will inform improved and effective conservation action for *A. knysnae*, within its known range. Research on the acoustic behaviour of the species is one area where detailed information is lacking. This study provides a detailed acoustic analysis of call types and/or call classification, call-associated behaviour as it relates to reproductive behaviour as well as inter- and intraspecific interactions.

3.2 Methods and Materials

3.2.1 Study area and study sites

The study took place from the start of August to the end of November 2023 at the De Vasselot Nature Reserve within the Garden Route National Park, Tsitsikamma Forest and Coastal section, near the town of Nature's Valley (Figure 3-1). Five sites were identified and were designated site names A to E – each site representing different habitat types (Coastal afro-temperate Forest, Mesic Proteoid Montane Fynbos, Afromontane Forest Plateau and Proteoid Montane Fynbos), vegetation structure and/or proximity to anthropological activities.

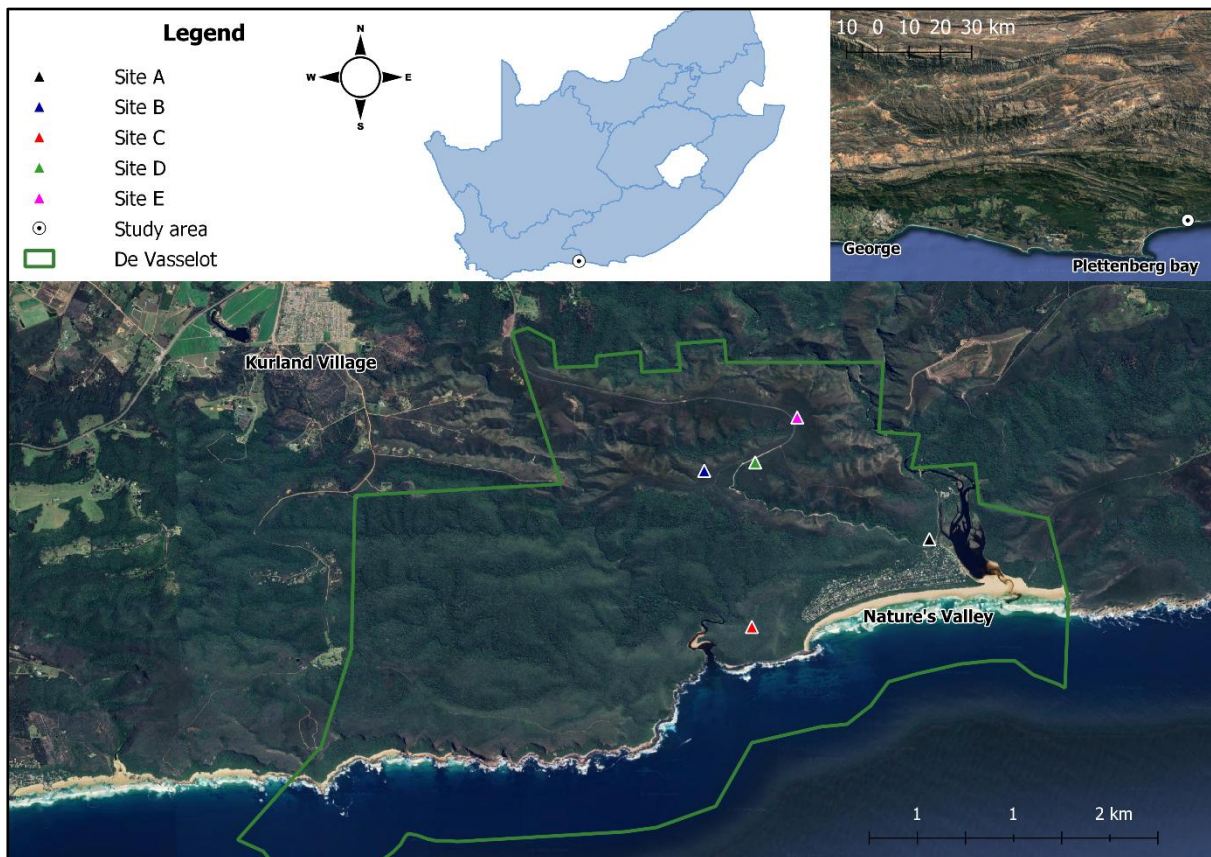


Figure 3-1: Extent of study area in the Eastern extreme of the Western-Cape province of South Africa within the De Vasselot protected area. Research sites are indicated by triangles with miscellaneous colours.

Site A is a small but established meander (muddy, but flowing waterbody) of the Kalandar gorge system across from the Nature's Valley village entrance. It is approximately 1295 m² in size having an overall habitat-type of Coastal afro-temperate Forest. The coordinates of this site are -33.9762, 23.5608 and it occurs five meters above sea level. Site B is a small water body, predominantly sustained by surface runoff, and about 8.7 m² in size within a habitat that has overarching Mesic Proteoid Montane Fynbos vegetation (Rebelo *et al.*, 2006), with locality at coordinates -33.9683, 23.5371. This site is approximately 200 meters above sea level. Site C is located at coordinates

-33.9847, 23.5416 and is symptomatic of Afromontane Forest Plateau habitat and is closely situated to Afromontane Fynbos- and Coastal Afromontane Forest biomes. It being a waterbody with a rounded shape and is found at 100 meters above sea level. Site D situated at coordinates -33.9674, 23.5412 is a (142.1 m²; 200 meters above sea level). Site E (219 m²; 200 meters above sea level) is located at coordinates -33.9622, 23.5459 comprises two well established temporary waterbodies which have identical surrounding vegetation to that found in Site B and is therefore classified as Proteoid Montane Fynbos habitat (Figure 3-2).

Aquatic vegetation of the five sites consists mainly of typical wetland and hydrophyllic vegetation but is differentiated by specific species being present at the various sites. In this instance, Site A have large stands of *Carissa macrocarpa*, *Calochlaena dubia* and *Trichocladus crinitus* beneath the treecanopy while Site B is dominated by *Hydrocotyl bonariensis*, Site C mainly is dominated by grasses, Site D by *Typha capensis* and *Phragmites australis* and Site E is dominated by *Villarsia capensis* and *Hydrocotyl bonariensis*.

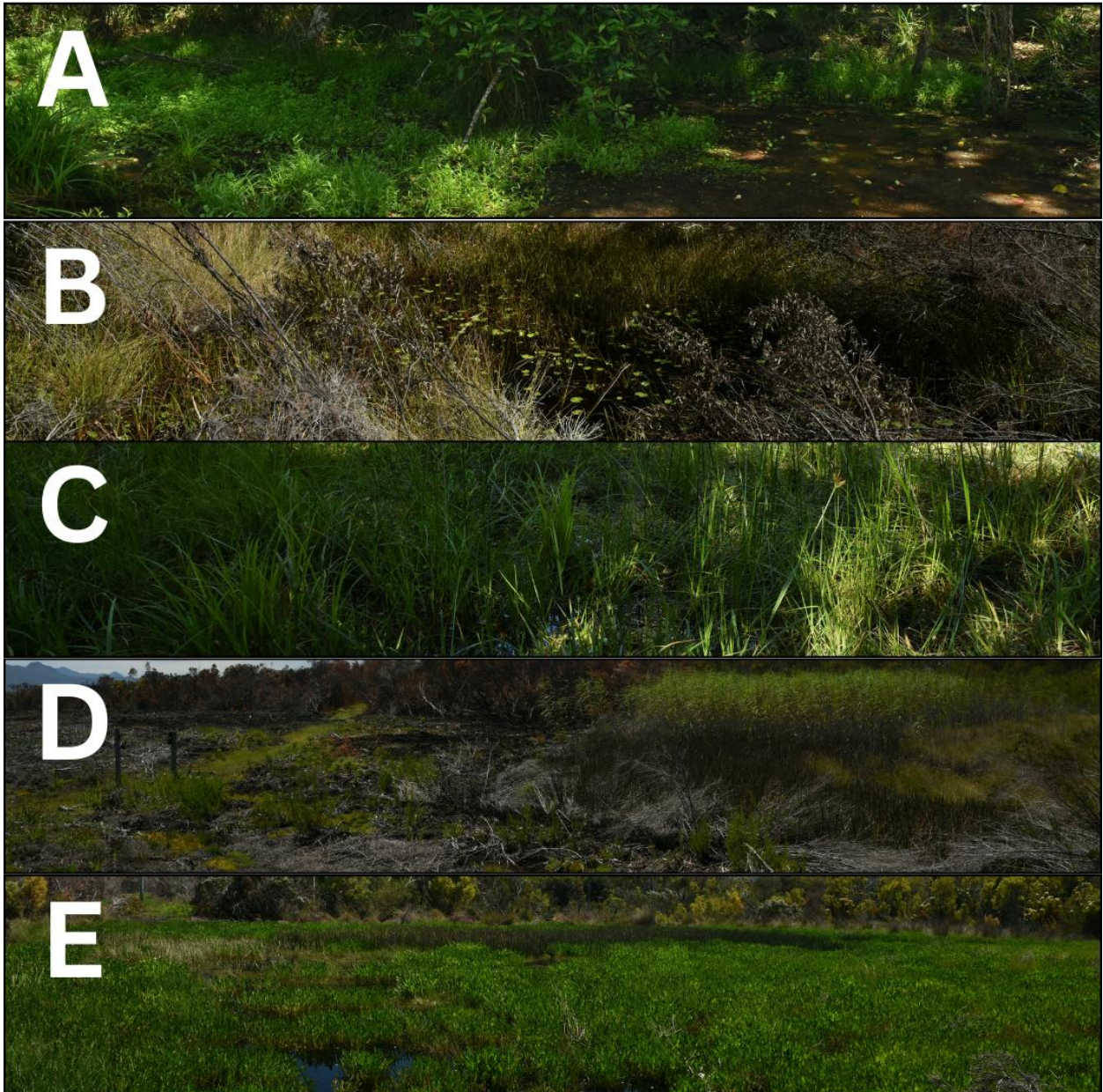


Figure 3-2: Habitat types corresponding to their study sites; (A) Site A – Coastal Afro-temperate forest, (B) Site B – Mesic Proteoid Montane Fynbos, (C) Site C – Afromontane Forest Plateau, (D) Site D - Proteoid Montane Fynbos, (E) Site E - Proteoid Montane Fynbos.

3.2.2 Acoustic monitoring and recordings

Directional Manual Recordings (DMR) of calling males were made while behaviour associated with the various call types were observed. Calls were captured using a Zoom F1® field recorder paired with a ZOOM® S. grayiiH-6 shotgun microphone. Calling males were located audibly and the approximate calling site was approached carefully until the male could be visually confirmed. The recorder was setup on a tripod approximately 1–1.5 m from the calling male for each recording. All calls were recorded at 48kHz sampling frequency (to account for Nyquist

frequencies) and 16-bit precision stereo and stored on an external 1 terabyte solid-state drive in Waveform format (.wav).

Visual observations on behaviour associated with the calls occurred in low light conditions while movement was kept to a minimum to avoid disturbance of calling individuals. Additional observations regarding proximity of males to each other, proximity to conspecifics, call platform and platform preferences, overall environmental and habitat condition during calling bouts and any attempted predation on the calling males were made. These DMR recordings and observations commenced in the early evening, approximately 18:00, and continued into the early mornings, up to approximately 3:00, depending on weather conditions and season.

3.2.3 Acoustic analysis

Analysis of recordings were made using Cornell University's Raven Pro® (v1.6) to isolate specific calls and call patterns. These identified calls were saved as individual .wav files from which oscillograms and spectrograms could be produced and used to identify and analyse the call patterns and call characteristics. Analysis of temporal and spectral properties of the individual call files were entirely conducted using the packages *seewave* and *tuneR* within the R programming platform (Köhler *et al.* 2017; Sueur, 2018). Oscillograms, spectrograms and power spectrums were produced with 1024 (higher frequency resolution) or 512 (higher time resolution) FFT-resolution and 87.5% overlap between discrete fragments.

Calls were classified and described following the protocols, methods and descriptions adopted and explained by Köhler *et al.* (2017). In terms of this approach, a note-centred approach was followed in describing the call types. Descriptive statistics describing the parameters of the call types were performed on the tabular data as produced by the *seewave* package.

3.3 Results

3.3.1 Call descriptions

The vocalisation repertoire of *A. knysnae* consists of two call types, herein referred to as Type A and Type B. Calls recorded using DMR were analysed to determine their temporal and spectral characteristics. The results of this analysis, conducted with R programming software, are presented below. Associated behaviours are discussed in the article's discussion section. Call Type A (n= 5) is a uniform vocalisation consisting of multiple notes produced in rapid succession, resembling a “trill” sound. This call is repeated intermittently with variable call lengths and great variability in silent intervals between call during calling bouts.

Call repetition rate and call intervals of Call A could not be determined and as such is not a characteristic of the *A. knysnae* call. The call comprises a series of transient acoustic signals or notes, each separated by periods of notably reduced amplitude. It primarily consists of various uniform notes that are repeated in rapid succession (Figure 3-3). Figure 4 illustrates call lengths and call structures, as well how they relate to note and pulse duration and length. Each note in turn consists of a number of extremely rapid and variable pulses. Table 3-1 below describes the measured parameters of the different call types, all measured in seconds (s).

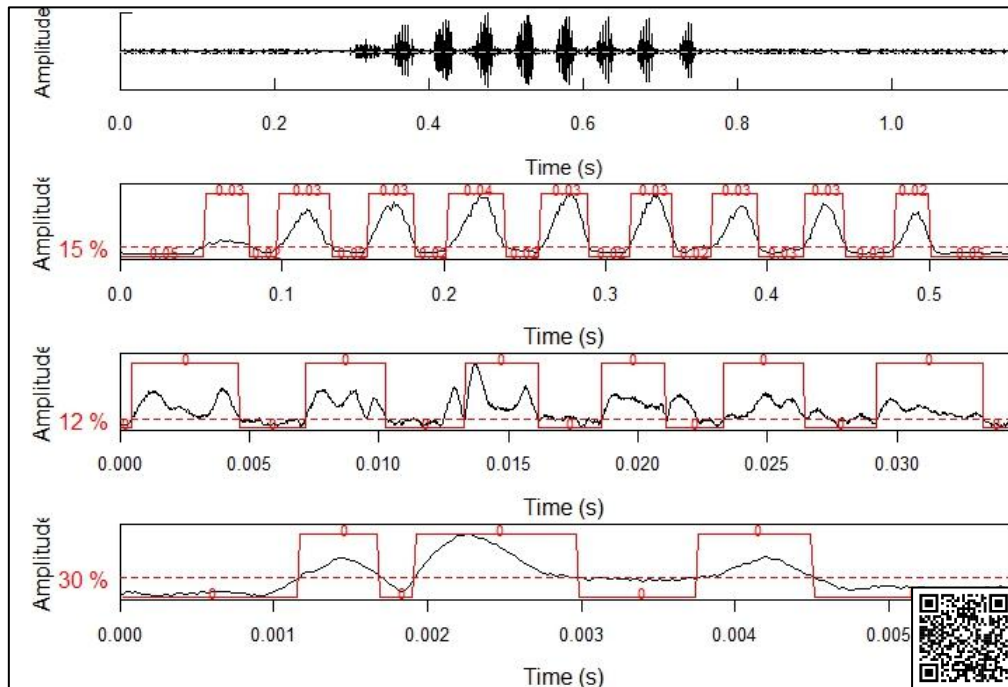


Figure 3-3: Figure plate of (top) Oscillogram ($wl = 1024$; $ovl = 87.5\%$), Hilbert envelope of the notes of one call, (bottom-middle) the pulses of the first note and (bottom) the peaks (echemes) of the third pulse. The QR-code is a link to this call's MP3 file on a cloud storage.

Call Type B ($n = 7$) can be described as a single note call of ascending frequency abruptly ending at a higher frequency. The call is audible and resembles a sudden, brief “zip” sound. Its structure consists of rapidly repeated pulses (Figure 3-4). The call length, like that of Call Type A, varies and cannot be used to determine the call repetition rate for this species. Therefore, pulses are the most relevant measurable element for analysis. This call can occur before or after Call Type A or in isolation. The parameters of the call elements are described in Table 1 below.

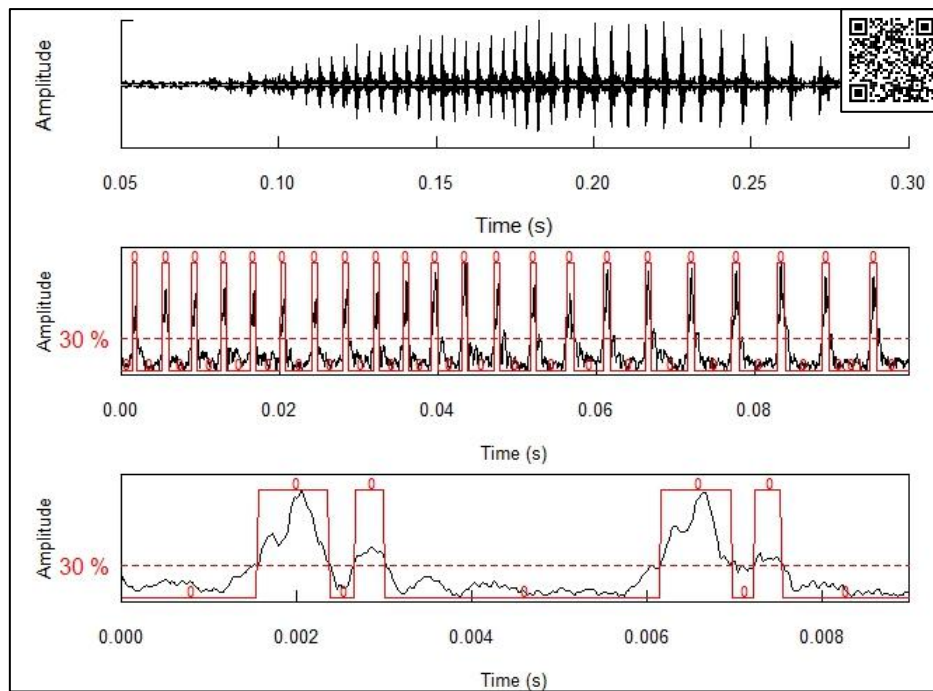


Figure 3-4: Oscillogram of a call ($wl = 1024$; $ovl = 87.5\%$) (top) and Hilbert envelope of the pulses of a call (middle), and the peaks of two pulse (bottom) of Call Type B. The QR-code is a link to this call's MP3 file on a cloud storage.

3.3.1.1 Temporal analysis of calls

Call duration, measured in seconds (s), of Call Type A ranged from 0.14s to just over five seconds in this study. Measurements of the notes revealed a mean note length of 0.0281s ($n = 35$), with a standard deviation (sd) of ± 0.0015 s. The mean inter-note intervals was approximately 0.0256s, with sd of ± 0.0015 s (Table 1). Based on these measurements, the mean note repetition rate was calculated at 20.07 notes s^{-1} (sd of ± 0.25 s).

Table 3-1: Temporal characteristics of Call Type A ($n = 5$) and B ($n = 7$) describing the parameters measured of the components making up these calls.

Call parameters (Temporal)	Call Type A (Mean \pm sd) (Min-Max)	Call Type B (Mean \pm sd) (Min-Max)
Note duration (s)	0.0281 \pm 0.0015	NA
Internote interval (s)	0.0256 \pm 0.0015	NA
Note RR (s^{-1})	20.07 \pm 0.25	NA
Pulse duration (s)	0.00197 \pm 0.00069	0.00147 \pm 0.000333
Interpulse interval (s)	0.00099 \pm 0.00037	0.0027 \pm 0.00104
Pulse RR (s^{-1})	329.32 \pm 33.7	255.28 \pm 46.73

The mean duration of pulses contained within each note was calculated to be 0.00197s and sd of ± 0.00069 s, while the mean inter-pulse interval was 0.00099s, with a sd of ± 0.00037 s. Mean pulse repetition rate was calculated at 329.32 pulses s^{-1} with sd of ± 33.7 s (Figure 3-3, Table 3-

1). Figure 3-4 illustrates the time and amplitude scales of the notes, pulses and acoustic peaks that comprise the structure of Call A.

Call B duration remains variable, but short and the analysed calls was measured to be between 0.088s and 0.17s. Thirty-five ($n = 220$) pulses were analysed across multiple notes. Each note consists of an average of approximately 31 pulses. Pulse analysis indicated the calculated length thereof to be 0.00147s (sd of ± 0.00033 s) and emphasise the extreme short duration scale of this call. Inter-pulse duration was calculated at a mean of 0.0027s (sd of ± 0.00104) leading to a pulse repetition rate mean of 255.28 pulses s^{-1} (sd of ± 46.72). The duration of Call Type B vocalised by one single male, or across different males, does not remain consistent, but durations of pulse and inter-pulses of this single note call remains constant (Figure 3-4).

3.3.1.2 Spectral analysis of calls

Spectral properties measured the call frequencies in hertz (Hz), with the mean dominant frequency (DF) of Call A being 3223.67 Hz, and sd of ± 430.87 Hz and fundamental frequency (FF) at 1591.04Hz and sd of ± 356.06 Hz. These measurements are visualised in Figure 3-5 and Figure 3-6. Figure 3-5 illustrates the call structure spectrally through a spectrogram and associated amplitude peaks at various frequencies, as produced by *spectro()* and *spec()* functions of the *seewave* package. For this particular call the highest amplitude energies are detected at approximately 3500 Hz. Figure 3-6 presents a spectrogram of the same recording analysed with *dfund()* and *fund()* functions of the *seewave* package. This figure indicates correlation of dominant frequency points at around 3.5kHz, but fundamental frequency points were arbitrary and determined to have a mean of approximately 1.7 kHz. Approximate prevalent bandwidth of Call A remains uniform between the limits of 4258.18 (sd of ± 399.95) Hz and 1719.80 (sd of ± 179.25) Hz (Figure 3-4) and can be seen as the total range of frequencies present in the call.

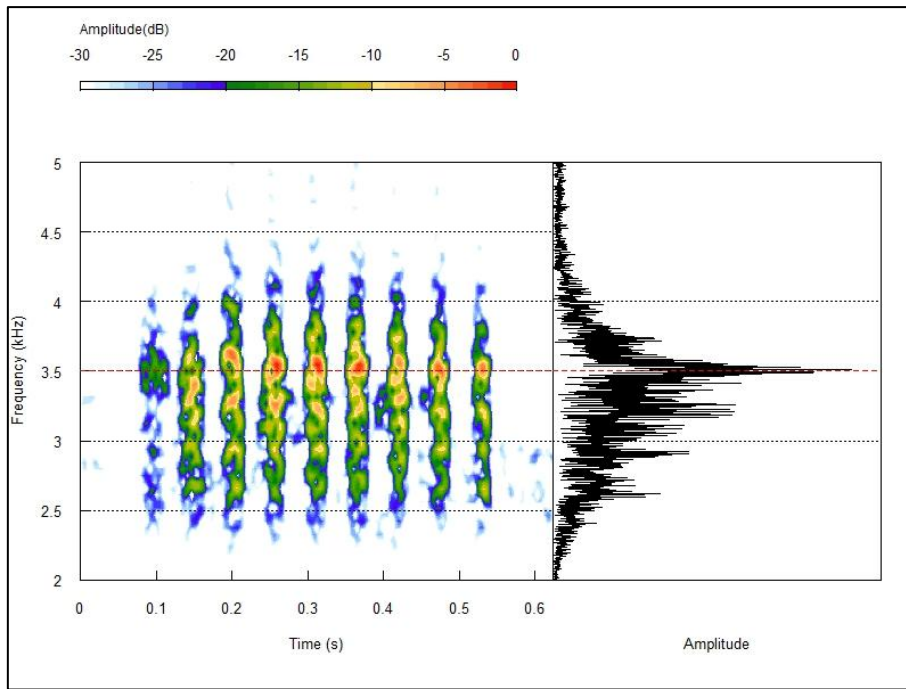


Figure 3-5: Spectrogram and frequency spectrum ($wl = 512$; $ovl = 87.5\%$) of Call Type A that indicates the waveform and amplitude peaks with regard to the spectrographic pattern.

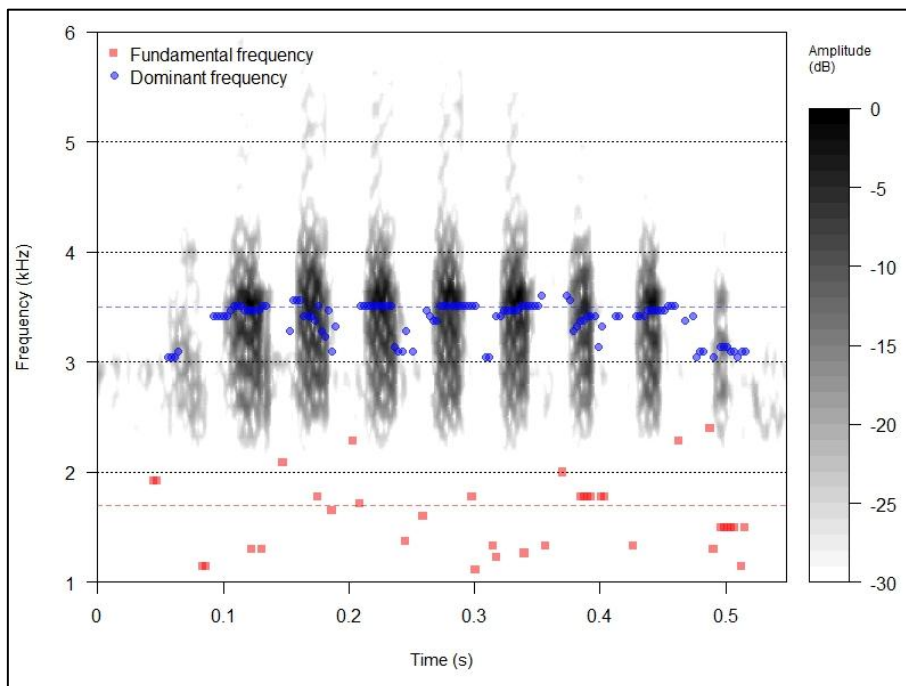


Figure 3-6: Spectrogram ($wl = 512$; $ovl = 87.5\%$; Threshold = 12%) with overlaid dominant (blue circles and dotted line) and fundamental (pink squares and dotted line) frequencies and means of Call Type A.

Spectral components of Call B (measured in Hz) show harmonisation, but dominant frequencies could be difficult to identify (Figure 3-7). Dominant (3178.81 ± 472.11 Hz) and fundamental

(1457.2 ± 330.3 Hz) frequencies (Figure 3-7) were also calculated (Figure 3-8). Figure 3-7 was produced by *spectro()* and *spec()* functions of the *seewave* package. Figure 3-6 was produced by *dfund()* and *fund()* functions of the *seewave* package.

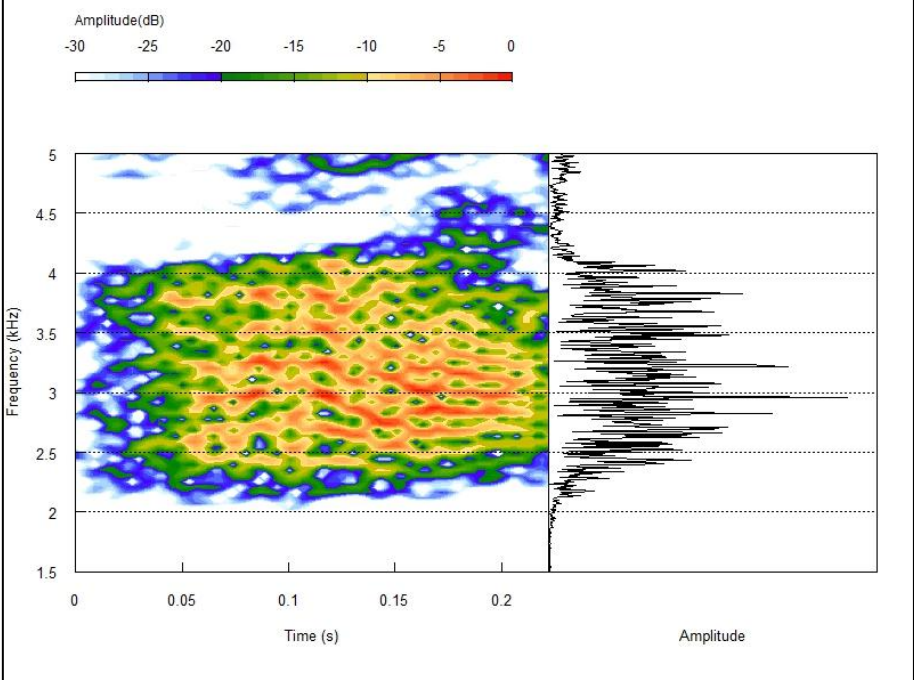


Figure 3-7: Spectrogram (left) and frequency spectrum (right) (*wl* = 1024; *ovl* = 87.5%) of Call Type B that gives an indicates the waveform and amplitude peaks with regard to the spectrographic pattern.

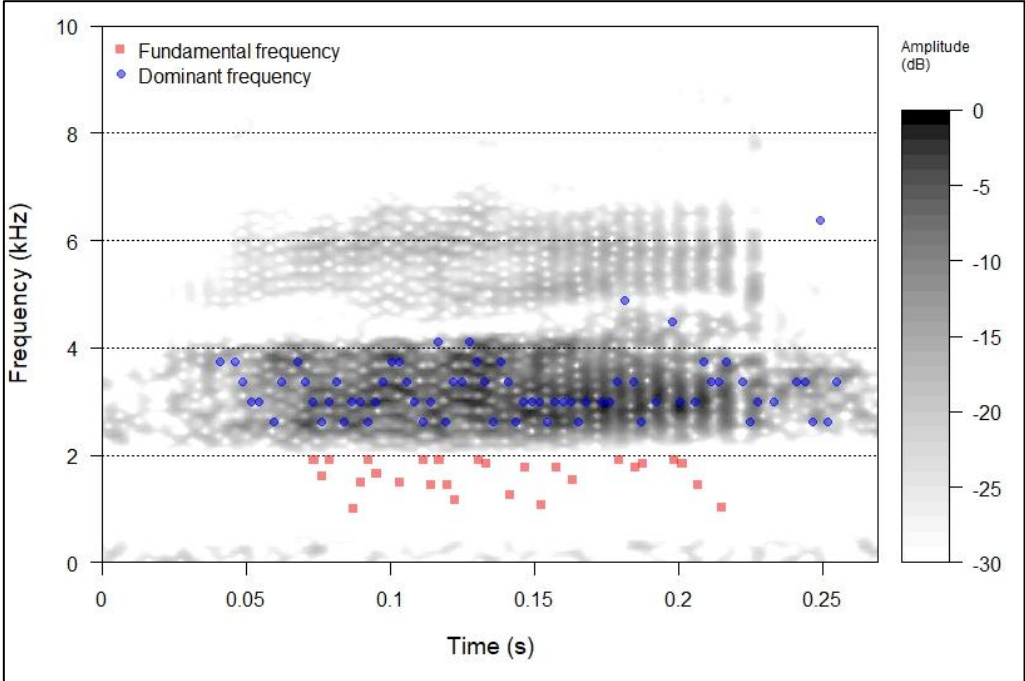


Figure 3-8: Spectrogram (*wl* = 512; *ovl* = 87.5%; *Threshold* = 12%) with overlaid dominant and fundamental frequencies of Call Type B.

3.3.2 Field observations

All three habitat types were observed to have reproductive and acoustic presence of this species. Though in an overall Fynbos biome, each site acted as an ambassador for microbiomes within the overall study area. Aquatic and terrestrial vegetation of each site differed, but some overlap in species was present. Despite these variations, *A. knysnae* in these habitats made use of resources and topography that was available to ensure reproductive success. Though these sites fall within Coastal fynbos biomes, it is evident that this species also utilises Montane Forest, Montane Proteoid and Coastal Forest habitats (Figure 3-2).

Males began calling bouts shortly after (or during) sunset (as early as 16:00 but especially from 18:00 to 19:00), which started with very short bursts of Call A and gradually increased in length as males remained undisturbed on their calling platforms. During this time, males searched for and selected their calling territory at which they displayed for an appropriate mate. Call-podium selection appears to favour open areas at water level with a significant presence of *Villarsia capensis* (Figure 3-9A) and *Hydrocotyl bonariensis*, but also very little to no low hanging overhanging vegetation that would otherwise conceal calling males. This is believed to limit any muffling effect that covering and/or large leaves would have on the call of males. At site A where overhanging vegetation forms part of the microhabitat, most males would call from vegetation overhanging a water source. Call Type A will be instigated at increasing call lengths, and Call B will only be called when other males come into close proximity to each other. Choruses of males typically consist of two to three actively calling males with up to 13, but an average of seven, satellite males around the calling males.

The process of amplexus, however seems straight forward and is initiated when females come in close proximity to calling males. Actively calling males would attract females using their advertisement call, in which females approach the area that is attained by the male. Amplexus is encouraged when the interested female is 50 mm and closer from the male when he starts to approach her cautiously while still calling. Females that seem uninterested would evacuate before the approaching male has the chance of clasping on. Interested females would stay put and allow amplexus to be completed (Figure 3-10C). It is observed that females select appropriate material (leaves to lay eggs on), while the male remains in amplexus. One pair was observed for six-and-a-half hours on a *Villarsia capensis* leaf before failing to complete spawning. Other plant species utilised for leaf-folding include *Hydrocotyl bonariensis* and some water-tolerant sedges. Leaf selection seems largely favoured towards a balance between pliability (ease of folding), strength and buoyancy. Egg clumps were mostly observed to be partially submerged, but tadpoles have

been observed to hatch successfully from fully submerged, or completely unsubmerged egg clumps, but not from leaves that were not folded.

Metamorphs emerged approximately one and a half months after the first detected egg clump. Emerging metamorphs are substantially smaller than mature frogs and tend to be found on the highest tips of aquatic vegetation (Figure 3-10B). It was also observed that calling activity of males abruptly decreased from the date of the first detected tadpole (20th October) onward to the end of the study (end of November 2023).

Interactions between *A. knysnae* and other species within its habitat were observed. The first account was that calling males would call from positions generally occupied close to calling *Strongylopus fasciatus* and *Hyperolius marmoratus* males. On one account, the *H. marmoratus* approached an *A. knysnae* male calling from his advertisement position. When the *H. marmoratus* male was too close for the *A. knysnae* male's comfort, the tone of his call, and calling orientation changed. The call observed was audibly higher pitched than its documented advertisement call but sounds similar temporally (no recordings were made). During this call, the *A. knysnae* simultaneously orientates himself towards the approaching *H. marmoratus* male, and advances aggressively. Physical conflict over calling positions by *A. knysnae* is much more likely towards dissimilar species than towards his own species. The defending *A. knysnae* male jumps towards, or on the crusader, and would push with his snout, or kick with his hind legs until the *H. marmoratus* would abandon his approach (Figure 3-10D). No interactions with other dissimilar species were observed. No predation was observed on *A. knysnae*, however, each night researchers found at least one Brown-water snake (*Lycodonomorphus rufulus*) moving among the aquatic vegetation.

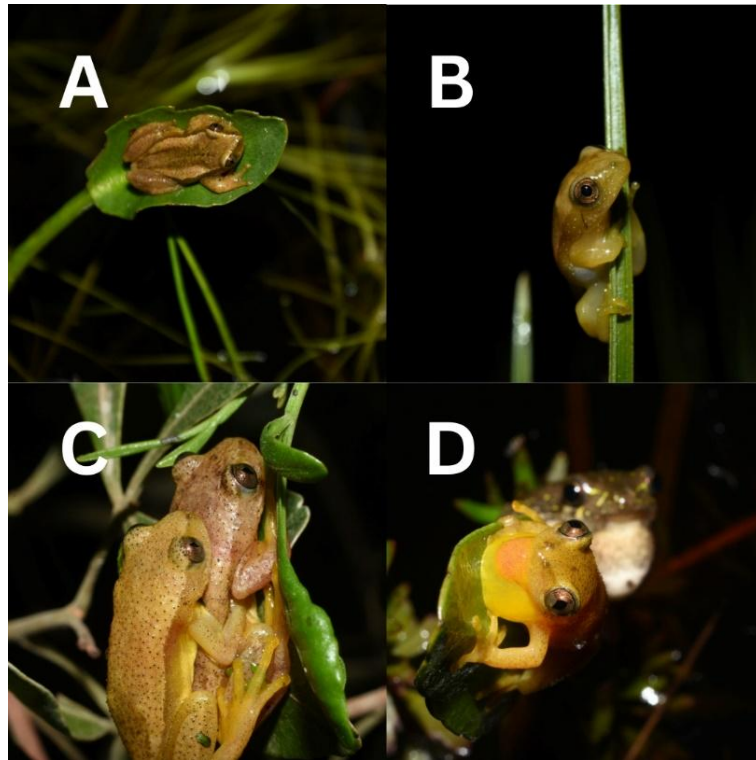


Figure 3-9: Behavioural observations of *A. knysnae*: Emerging male from low vegetation (*Villarsia capensis*) (A), newly metamorphosed froglet (B), Male and female in amplexus (C) and male interaction with dissimilar species (D) (Photographs by Tiaan Botha)

3.4 Discussion

3.4.1 Call structure

Information provided in Köhler *et al.* (2017) categorises Call A and B into designated call types or sound categories. These categories refer to the general characteristics of the sound that are independent of the vocalisation subunits (e.g. calls and notes) of the sound (except for pulse definitions), but calls could differ slightly from these categories and puts emphasis on the variability of anuran calls globally. Call A can be described as a “pulse-repetition” sounding call. These sounds are a series of energy bursts (pulses). Pulses are temporary disturbances in the medium (with limited time), and in bioacoustics can be defined as short spurts of sound energy. Pulse calls are common among frogs, and Köhler *et al.* (2017) extends the definition of this category, because the pulses can be separated by a significantly reduced amplitude, but not necessarily by 100% resulting in no complete silent intervals between pulses (Beeman, 1998; Köhler *et al.* 2017). The call structure of Call Type A follows complete amplitude modulation between notes. Although call lengths have large variability, the duration of notes, and pulses within notes remain constant. Call intensity measurements indicate lower amplitude notes as the call starts and ends. Pulses were found to have three absolute amplitude peaks (Figure 3-3), Call duration of Call A is highly variable with no repeated pattern or sequence. The number of notes

per call differs across each call (and is determined by call lengths). Pulses are emitted at an extremely rapid rate making it inaudible to the human ear. The duration of pulses contained within each note have very short lengths and durations of inter-pulse lengths even shorter. Negligible frequency modulation occurs within the approximate prevalent bandwidth of 2538.38 Hz and a sd of 220.7 Hz and therefore remains at the same audible pitch as the call progresses.

Sound classification of Call B follows a “spectrally structured pulsatile” sound. Such calls are emitted over a wide frequency band with one or more spectral peaks and without clear and visible harmonics. In oscillograms, alternative amplitude modulation can be detected, but usually without a discrete energy peak, which can be clearly called a pulse. However, Call B shows clear and distinct pulse structure while harmonic structure is uncertain (Dominant frequencies are difficult to identify). This call shows strong, audible ascending frequency modulation. Call B duration remains variable, but shorter than that of Call A overall. Note duration, as well as inter-note intervals and note repetition rate could not be measured as the intrinsic character of this call prohibits such calculations. It was found that the largest measurable unit of Call B was notes (Call B being classified as a single note call) followed by pulses that make up the acoustic profile of this single note. Therefore, although notes (and therefore calls) vary in length, the pulses and inter-pulse durations remain constant. Repetition rate of pulses is slower than that of Call A but is also too rapid for the human ear to discern. The amplitude of Call B increases and decreases at the start and end of the call, respectively. Amplitude modulation (not entirely 100% modulation) between pulses and amplitude peaks can be observed in the oscillogram depicted in Figures 3-3. Call Type B seems to have amplitude vacillation within the pulses and throughout the note (Figure 3-3) and giving the illusion that amplitude peaks are “waving” up and down throughout the note. Three amplitude peaks have also been detected within the pulses above the background-noise threshold, although this is difficult to analyse due to the absolute peak durations merging together as result of the extremely high pulse repetition rate. (Figure 3-3). Frequency modulation from start to end of Call B results in differing audible pitches as the call progresses.

Both calls A and B can be called independently by the calling male or used as a combined Call as clarified by De Lange (2019) (Figure 3-11). Figure 3-11 illustrates a spectrogram with an oscillograph as a sub-figure produced in R through the *seewave* package. In this figure two type B calls can be identified before 0.5 s and after 2.45 s – preceding and following Call A between times 0.6 s to 2.4 s.

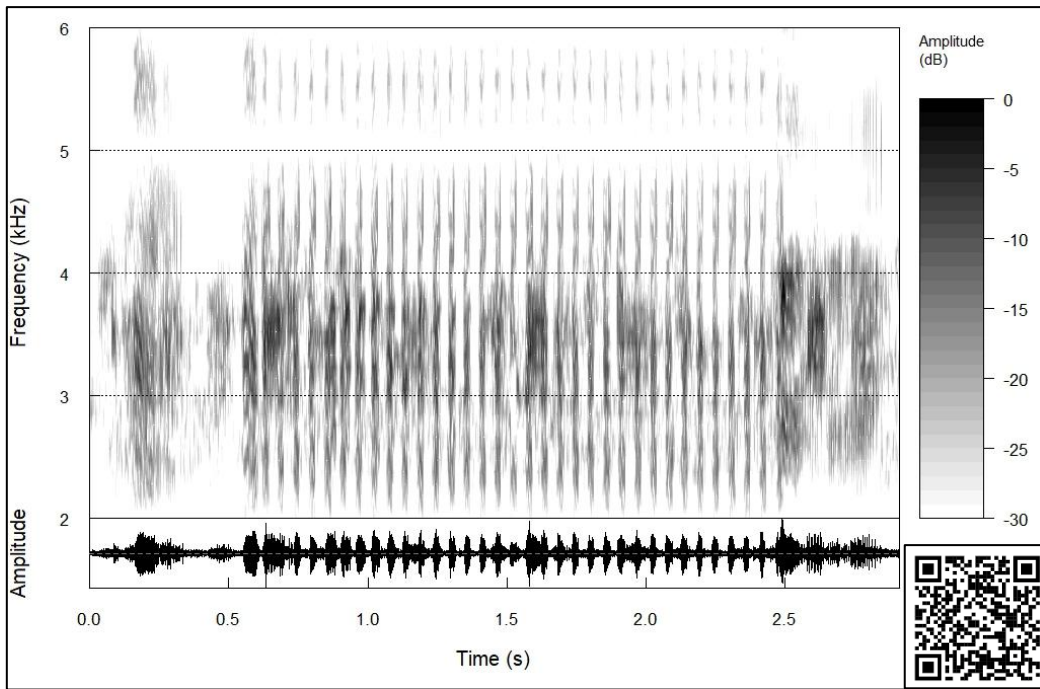


Figure 3-10: Spectrogram and oscillogram ($wl = 512$; $ovl = 87.5\%$) over time that shows combination of Call B before ($t = 0$ to $0.5s$) and after ($t=2.45$ to $3s$) Call A ($t=0.6$ to $2.45s$). A short pause (approximately $0.1s$) occurred after the first B-type call in this recording. The QR-code is a link to this call's MP3 file on a cloud storage.

Variation in calls was observed. It is unclear at this stage whether or not variation can be considered as their own respective calls, or if the same behaviours reported above are associated with these calls. Call A is typically described as a “trill” sound with rapid successive repeats of very short notes that have equal frequencies but show amplitude modulation. A variation observed of Call A ($n = 4$) showed a similar structure in terms of amplitude and amplitude modulation, note length, frequency and frequency modulation, however, is audibly and temporally retarded. Note length calculated to be similar, but inter note intervals are substantially lengthier, resulting in a repeated precipitous “chuck” sound. Figure 3-12 compares the atypical call, and the typical call of Call type A. Males only presented with this call during very early mornings (between 3 AM and 4 AM) in November.

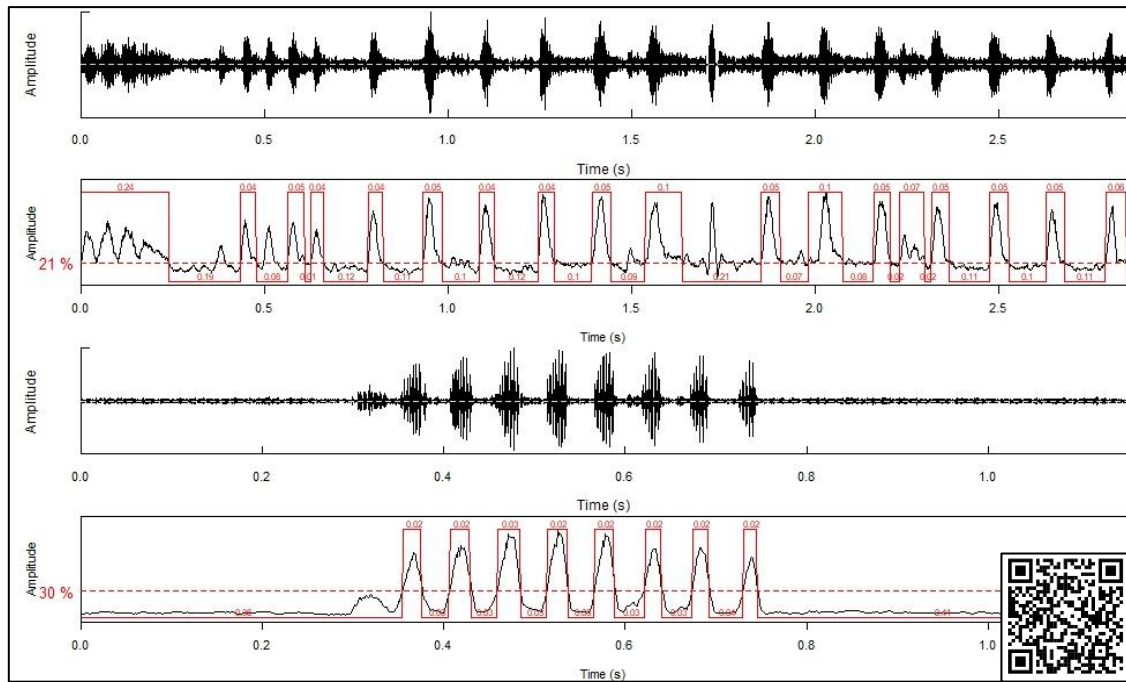


Figure 3-11: Layout of Call A variation. The first two plates illustrate the oscillogram and measured call note lengths of the atypical call above the background noise threshold. The bottom two plates illustrate the typical call and note lengths. The QR-code is a link to this call's MP3 file on a cloud storage.

An alternate form of Call B also emerged. Figure 3-13 illustrates the variability of Call B as a vocalising male audibly prolongs the call duration. The typical form of Call B is a gradual increase in frequency and amplitude with an abrupt termination at a higher frequency than the start frequency. The alternative call form follows a similar form, except dips in frequency and amplitude momentarily (Figure 3-14). As a result, two amplitude peaks (0.13s and 0.1s) are formed, both varying in duration, with an amplitude-valley between (0.04s). No significantly different behavioural change was observed during the vocalisation of this alternate call. Although it occurred less frequently than the usual version of this call, it occurred several times during fieldwork.

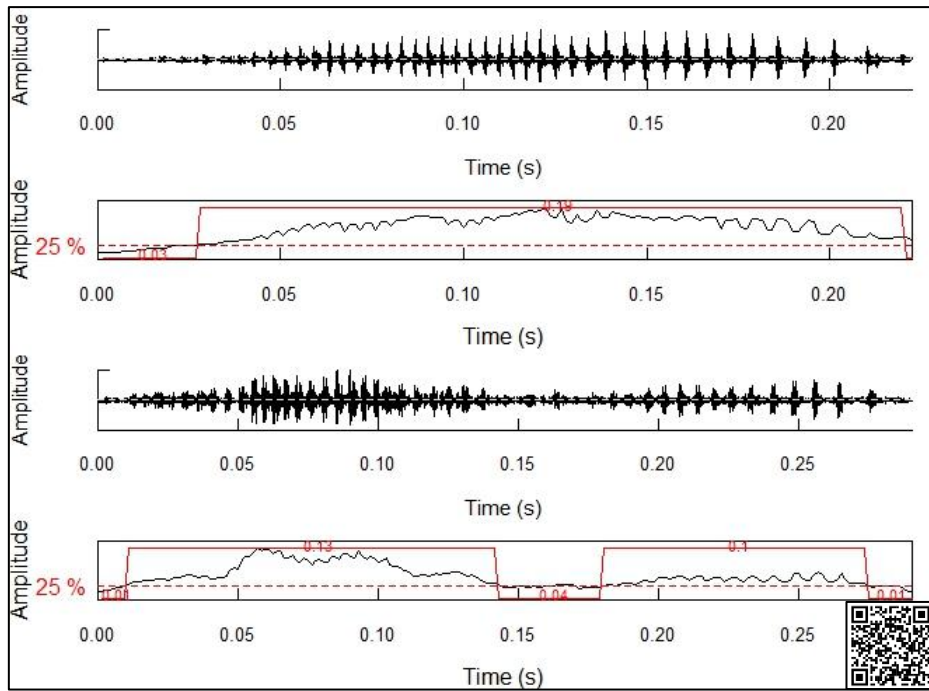


Figure 3-12: Layout of Call Type B vocalised at two different lengths. The first two plates illustrate the oscillogram and measured call length (0.19s) of the Call Above the background noise threshold. The bottom two plates illustrate the alternative form in which a brief, audible, lowering in amplitude (intensity) takes place as the call is prolonged.

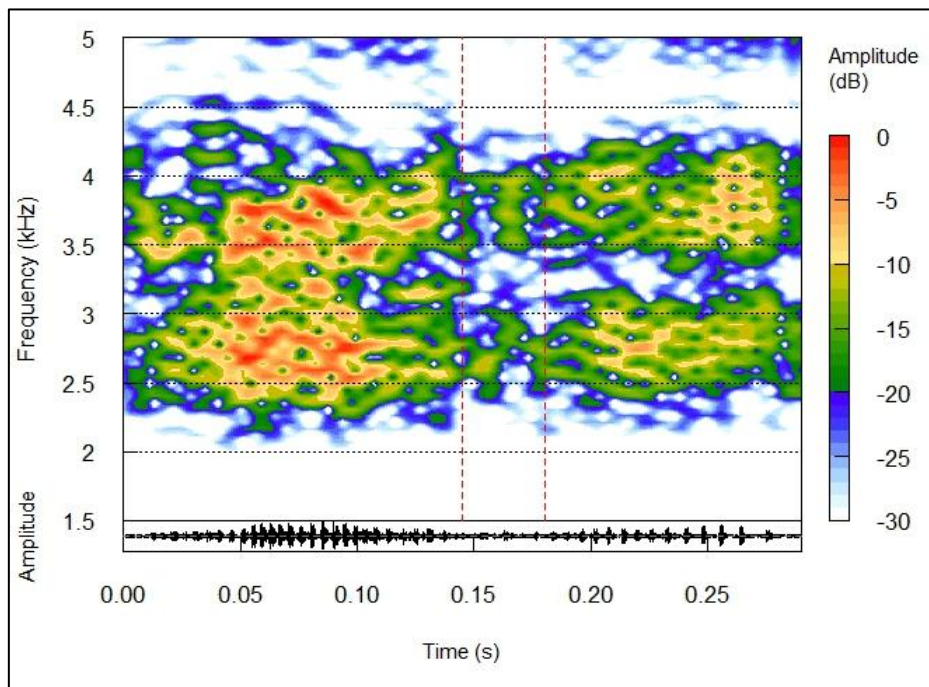


Figure 3-13: Spectrogram ($wl=1024$; $ovl = 87.5\%$) of the alternate, extended call of Call Type B. the Red vertical lines at time 0.14s and 0.17s indicate the start and end of the dip in frequency and amplitude.

3.4.2 Behaviour related to call types

The breeding season of the species usually starts after the first Spring rains, which can be as early as August in this region (De Lange, 2019). Calling commenced on 15th of August 2023 when the first calling male was heard during the late hours of the day. The first chorus activity started

after extensive precipitation in the region during Spring following approximately 100 mm of rain was recorded in mid-September.

Call A is observed to be utilised in majority of the cases for mate attraction (advertisement call) and annexation of calling territory. This call increases in frequency and intensity when a female is nearby. Call B (the “zip” call) however was observed to be used exclusively when other males are within 30 centimetres of each other, and the call would be used in isolation, or paired before and/or after Call A. Males that approach each other were rarely observed to engage in physical conflicts (but is not unlikely) but would rather compete audibly for territory acquisition and calling rights by “zipping” to each other.

Existing literature indicates that signalling intentions through different call types appears to be a characteristic feature of the genus, likely due to similarities in call structures (Blackwell, 1988; De Lange, 2019). Congeneric species such as *Afrivalus fornasini* (Bianconi, 1849), *A. crotalus* (Pickersgill, 1984) and *A. aureus* (Pickersgill, 1984), show differentiation in call types spectrally and temporally, but overall call structures follow the same patterns as *A. knysnae*. *Afrivalus fornasini*, shows a difference acoustically. The frequency of calls for *A. fornasini* seems much lower and it lacks a two-part structure. This species also presents several other clearly distinguished morphological differences (size and color), and together with acoustics, researchers can help make clear taxonomical findings in this regard (De Lange, 2019).

Call signature of *A. knysnae* is easily identified within the soundscape but can be easily masked spectrally. Species such as *C. nanum* and *H. marmoratus* vocalise at frequencies within the range of *A. knysnae* (Figure 3-15). The former species occur in much larger numbers, and thus choruses of these species become deafening.

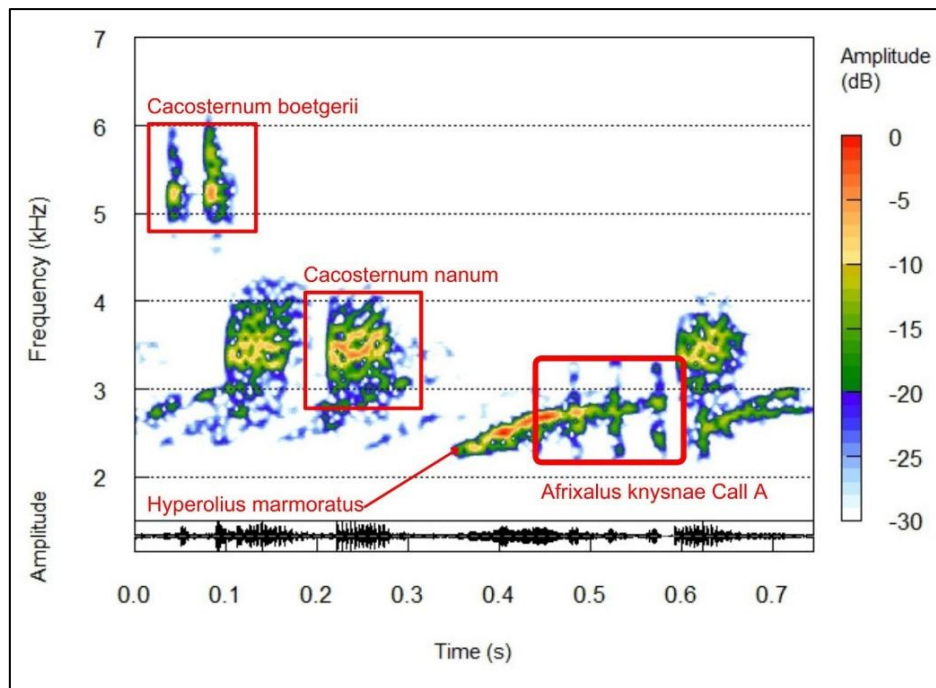


Figure 3-14: Spectrogram ($wl=1024$; $ovl = 87.5\%$) indicating the calls of certain sympatric species of a common habitat during a chorus of various species.

The breeding behaviour and biology of this species have not been fully documented. It is not known whether female frogs vocalise at all, and there is a lack of long-term, systematic data on breeding activity for this threatened species that would otherwise inform the literature on climatological effects on breeding behaviour. Gaps in inter- and intraspecific interactions remain open. Predation and predator evasion have not been documented at all (besides the leaf-folding characteristics) with respect to this species, as well as disease and pathology. Research remains limited to the Western Cape area and little range expansion work has been done in the last 5 years. Novel research remains a very lush, yet untouched field of research in Herpetology (Gray & Karlson, 2022). New initiatives, such as the use of ultraviolet (UV) screening as a means to identify micro-evolution between geographically isolated populations, or UV-biofluorescence of individuals to identify adequate mates (for instance), has proved valuable in understanding ecology, behaviours and evolutionary significance of various other taxa and is by no means irrelevant to this species, or other amphibians in South Africa.

3.5 Conclusion

3.5.1 Shortcomings

The most time-consuming aspect of this study was familiarisation of the statistical software R and its relevant packages for acoustic analysis. Although advanced acoustic monitoring packages exist in R, such as MonitoR (Katz *et al.*, 2016), WarbleR (Araya-Salas and Smith-Vidaurre, 2017),

Raven (Araya-Salas, 2022) and ohun (Araya-Salas *et al.*, 2023), a clear and substantial foundational understanding of the basics of R is needed. Packages *tuneR* and *seewave* are sufficient for baseline acoustic analysis, as presented in this article, but more advanced acoustic investigation can be achieved through utilisation of other packages – given the foundational expertise of and knowledge of the relevant code among biologists and ecologists are in place. It was also found that effective analysis (especially when analysing fundamental and dominant frequencies) was strongly reliant on the quality of recordings with regard to background noise, distance to targeted vocalising male, and recording equipment. Successful, accurate analysis of these spectral properties was challenging and required extensive revision.

3.5.2 Conservation considerations and monitoring implications

This study did not reveal any threats at the study sites (specifically alien invasive species, disease and pathogens, or illegal harvesting), but passive, encroaching pressures (such as agricultural expansion and real-estate development) may prove to be devastating. As discussed by De Lange (2019), habitat destruction and urban encroachment prove to be a direct threat to *A. knysnae*, but also other species that utilise similar habitat. Climate change constantly gleams over our shoulders and is by no means a threat to be ignored. The Fynbos biomes is considered to be most susceptible and sensitive habitat types to drastic and persistent changes, and this species depends almost exclusively on coastal Fynbos habitat.

Adaptive and active management provides an approach to effective amphibian conservation and is achieved through research, including continuous population monitoring. Ongoing monitoring is recommended for future amphibian conservation initiatives (Campbell-Grant *et al.*, 2023). Successful acoustic analysis of amphibian calls are generally a by-product of surveys and monitoring of a particular species in the field. As such, these monitoring events lead to real time, updated insights into *in situ* conditions of species under investigation. Acoustic analysis of calls of understudied species enables further use of effective monitoring and empowerment of the scientific (as well as citizens) communities. Priority research needs in species and communities (identified by the ninth World Conference on Animal Sciences) and their conservation priorities are limited by knowledge gaps, the gap between knowledge and action, and the challenge of scaling research results to regional, national or global coordinated actions. Call analysis contributes toward the realisation of future conservation hurdles and resistance to effective conservation of *A. knysnae* populations and relevant communities found in Fynbos habitat threatened by major threats, such as climate change. Conservation prospects and implications relevant to acoustic monitoring and *A. knysnae* are discussed in full in the final chapter of this dissertation.

This study provides information of species-specific call-associated behaviours correlating to behaviours and interspecific and intraspecific interactions obtained through continuous research via population monitoring. It contributes to a body of priority research that will inform the effective future conservation [as outlined by Campbell-Grant et al. (2023)] of *A. knysnae*. This study recommends that similar research methods be continued in the near future to address all gaps necessary for effective short-term conservation and monitoring, with potential for scalability to longer-term, holistic solutions. A reinvestigation on this species' conservation status is suggested, as several known populations of this species have been replaced (De Lange 2019). As such, continuous monitoring could be the most effective method that informs conservation of this species, able to be scaled up or down based on requirements in the field. It will allow any required action to be based on relevant evidence-based information: informing monitors of any trends, tipping points, emerging threats and/or potential opportunities interminably.

Chapter 4: Predator and ecosystem influence on the development of *A. knysnae* tadpoles

4.1 Introduction

The developmental trends of *A. knysnae* tadpoles remains largely unknown. Anatomical dimensions have recently been studied and reported and opened doors to further studies on this species at different developmental stages. Knowledge IUCN gaps in regarding the Endangered *A. knysnae* pose a potential threat towards successful conservation and rehabilitation initiatives. This chapter reports on the effects of different simulated environmental conditions on the outcome of developmental process and success of *A. knysnae* tadpoles. The succeeding study was conducted in terms of the research agreements with SANPARKS following ethics clearance (NWU-01317-23-A9) from the North-West University.

4.2 Materials and methods

Four 100 litre incubation tubs were setup to house approximately 200 tadpoles (Figure 4-1). Two of the four tubs were setup in such a way that near natural conditions were mimicked – All non-similar species (arthropods, tadpoles of other species, any adult frogs, etc), vegetation, and physical cover was kept. In the remaining two tubs all predators, tadpoles of other species, and other animals were removed (including biological cover such as aquatic vegetation and organic structure). The latter tubs were isolated from probabilities of introducing such animals by covering the tubs with 80% nylon shade cloth and inspected at regular intervals. This in turn produced two treatments in which tadpole populations would develop – a near natural treatment (treatment 1) and unnatural, predator and competition-less treatment (treatment 2).



Figure 4-1: Four 100 litre tubs setup to house tadpoles. Two tubs are setup in near natural conditions (closest to photographer) and two are isolated from introduction of predators, dissimilar species, and other animals (closest to researcher) (Photo: Giorgio Lombardi).

Tadpoles were introduced into the tubs while still incubating in leaf-folds as egg clumps. Five sites were visited daily for a period of 5 days until a total of four egg-clumps per tub were introduced. Egg clumps were harvested in such a way that maximum survivability was ensured, therefore as much as possible of the utilised plant is harvested and as little physical damage as possible was ensured on the utilised plant. Egg clumps were submerged in respective tubs.

After tadpoles hatched, a week was allowed to ensure tadpoles successfully emerged and acclimated to their surroundings. The tubs were visited twice a week to measure tadpoles total body length, tail length and body width and score developmental stage (Gosner, 1960). This was achieved by gently fishing out (at most eight ($n = 8$)) tadpoles from one tub at a time and momentarily housing them in a container containing water from their respective tub. Tadpoles were then sedated with a 0.025% ethyl-4-aminobenzoate (MS-222) solution (Appendix A). Once the sedated tadpoles show little reactivity, they were placed two at a time in a transparent petri-dish on top of 1 mm graph-paper (Figure 4-2), and measures, and a high-resolution picture was taken with a Nikon D7200 fitted with a 40mm f2.8 Macro lens. Following measurements, tadpoles were placed in a separate recovery container containing water from the respective tub until full reactivity was restored and they were then returned gently to their original tubs.

Statistical analysis included basic descriptive analysis followed by an experimental Chi-Square Association Test with Effect Size between Treatment and Gosner stage. Sample size was, however, not big enough to conduct trustworthy and reliable Association and Effect size tests. This only serves to investigate whether statistical differences between the two treatments might occur.

4.3 Results

Approximately two-hundred-and-eight (n=208; Mean = 15.25 per clump; SD = 5.4) (Table 4-1) hatched tadpoles were counted between the 4 tubs (Tub A = 50 tadpoles; Tub B = 52 tadpoles; Tub C = 48 tadpoles; Tub D = 58 tadpoles). Hatching success calculated to average at 86.14% where treatment 1 showed higher hatching success than treatment 2 (Table 4-1).

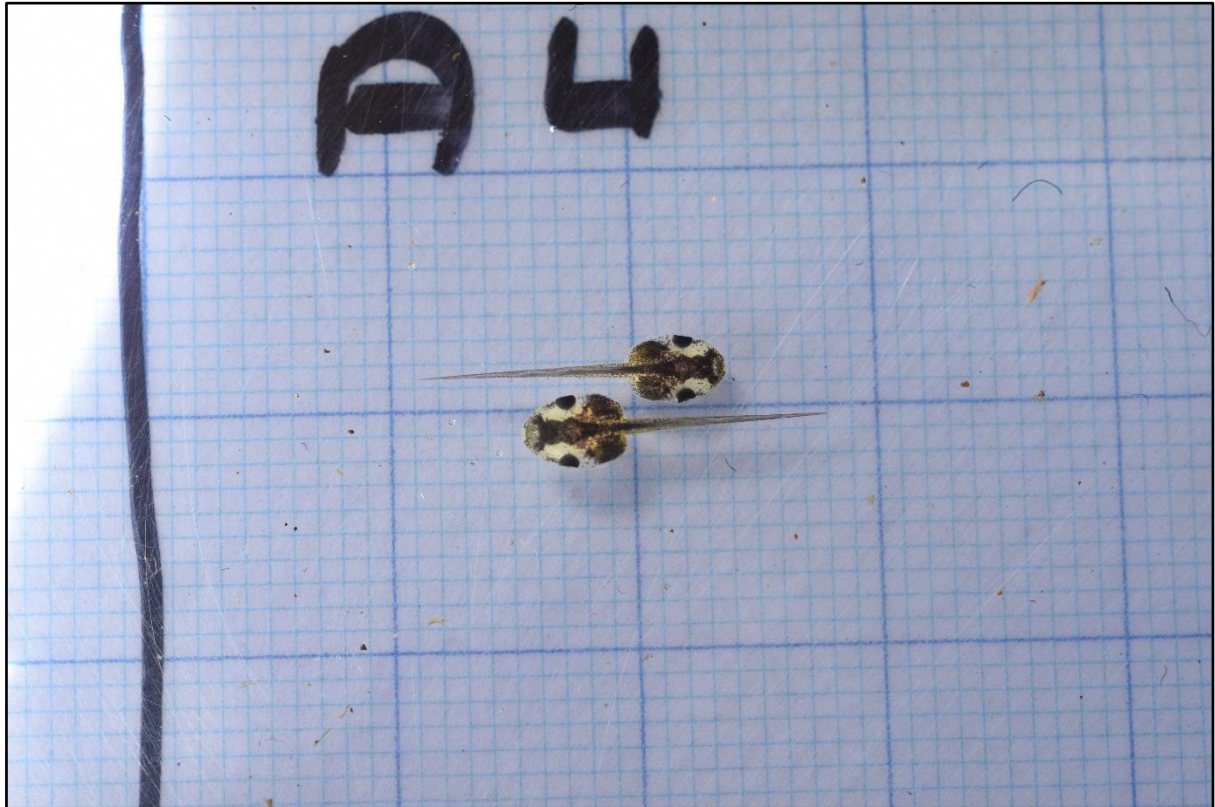


Figure 4-2: Sedated *A. knysnae* tadpoles in a transparent petri-dish over 1 mm graph paper (Photo: Tiaan Botha).

First emergence of tadpoles from eggs was observed 2 weeks after eggs were laid and collected. A total of twenty-five eggs failed to hatch from clumps and started to deteriorate sometime after all other tadpoles hatched. They were respectively removed from the tubs.

Table 4-1: Descriptive data of egg distribution among all four tubs.

Tub number	Egg clump number	Number of hatched tadpoles	Number of unhatched eggs	Mean (Min-Max)	Std. Deviation	Hatching success (%)
Tub A	AkA1	9	-	16.6	5.5	100
	AkA2	19	-	(9-22)		100
	AkA3	22	3			82.6
	AkA4	-	-			-
Tub B	AkB1	11	-	17.3	4.9	100
	AkB2	-	-	(11-23)		-
	AkB3	18	-			100
	AkB4	23	2			91.3

Tub C	AkC1	20	6	12	4.8	70
	AkC2	8	1	(8-20)		87.5
	AkC3	12	4			66.6
	AkC4	8	4			50
Tub D	AkD1	18	2	14.5	6.9	88.9
	AkD2	24	1	(6-24)		95.8
	AkD3	10	1			90
	AkD4	6	1			83.3
Total	All	208	29	15.25 (6-24)	5.4	86.14%

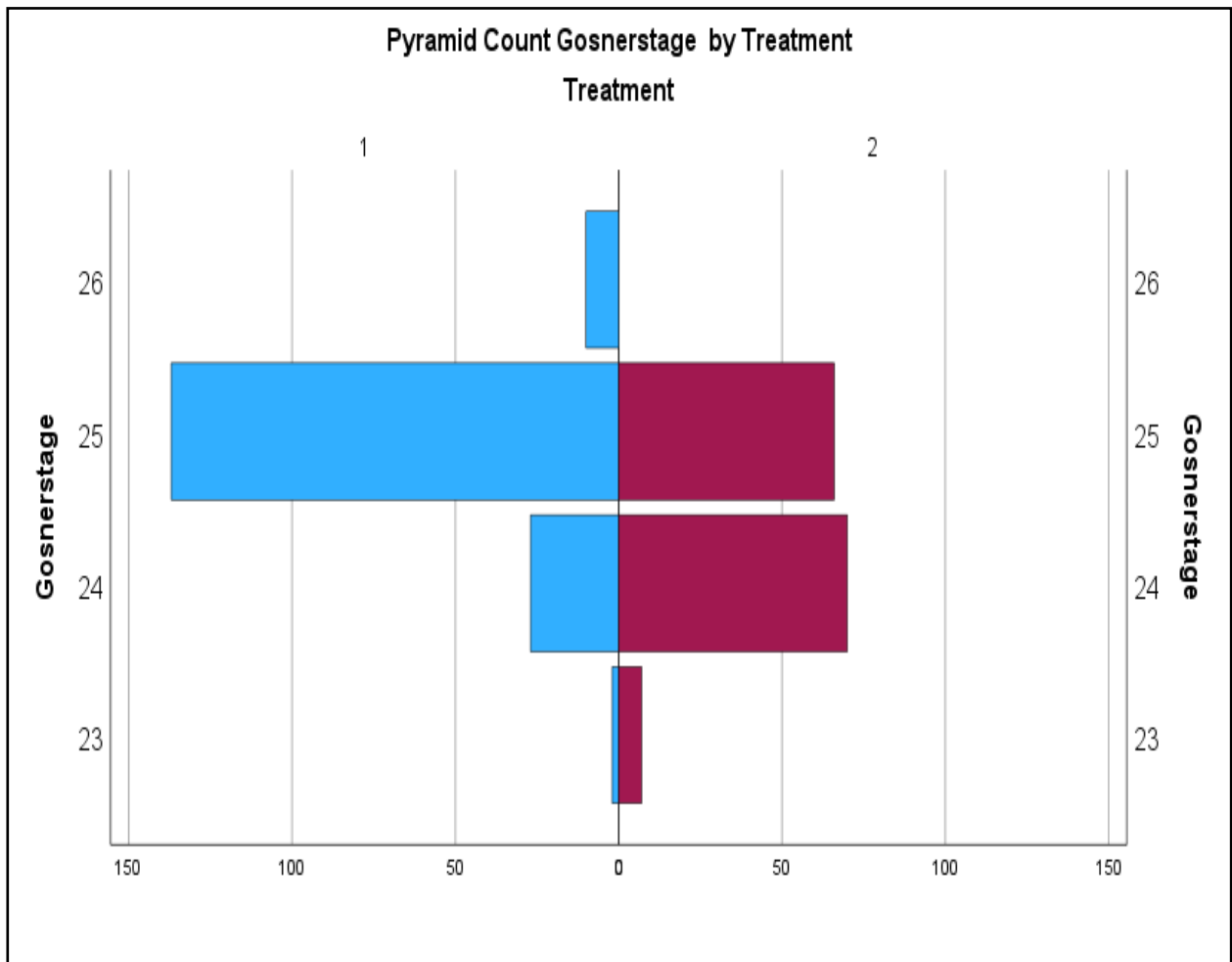


Figure 4-3: Bar graph comparing Gosner stages (tadpole development category) of tadpoles of the two treatments – Natural treatment (treatment 1) and unnatural treatment (treatment 2).

Throughout the study it was evident that tadpoles sampled and measured from treatment 1 were larger, better coloured and further along in development. Gosner stages of tadpoles from treatment 1 were almost always one or two stages ahead of treatment 2 (this could mean the difference between visible external gills and the initial formation of hind legs) (Figure 4-3). All measurements made on tadpole body measurements from the natural treatment were longer and

wider (tadpoles were bigger) than that of the treatment 2. Figure 4-4 illustrates the differences between the two treatments in all body measurements.

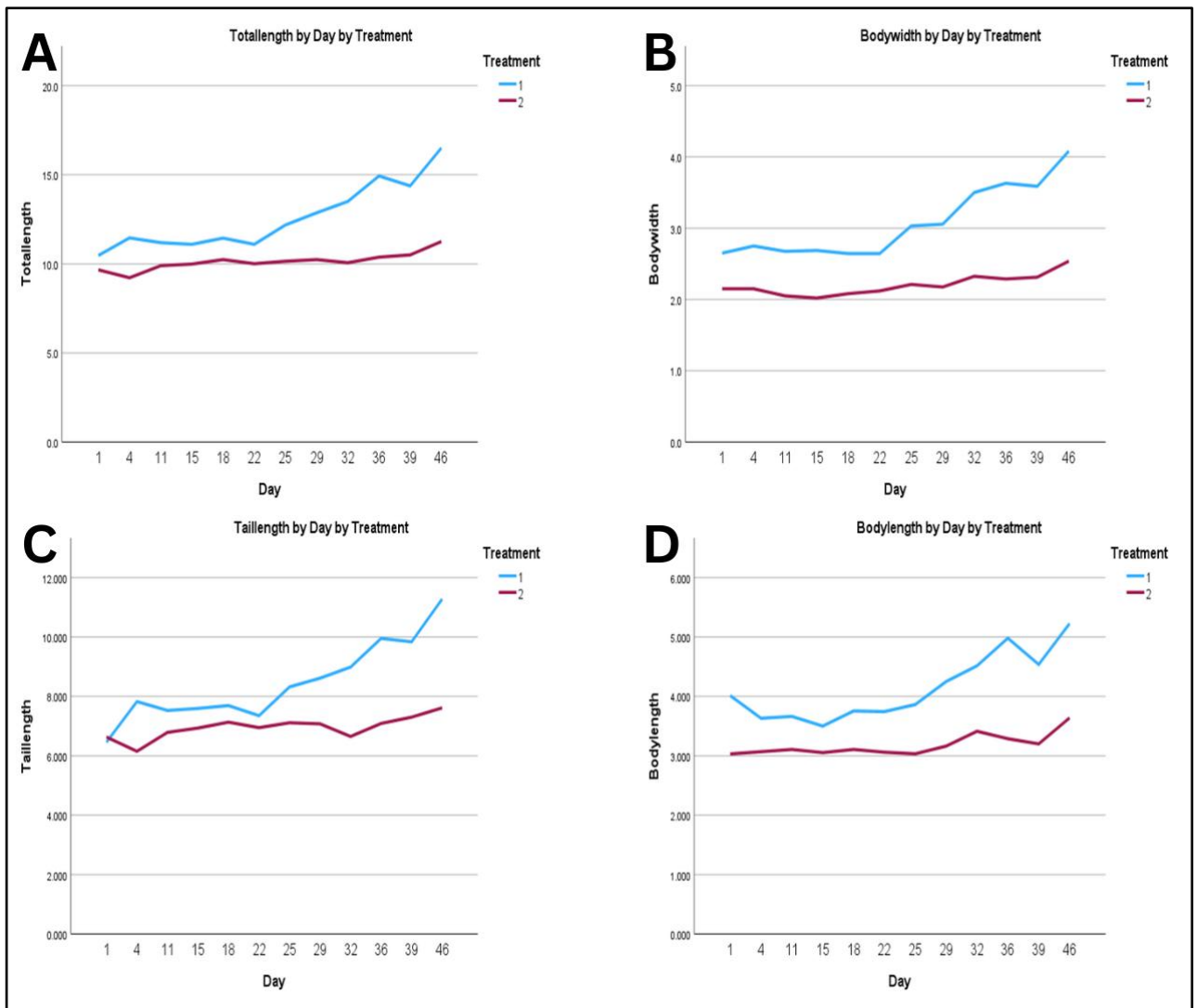


Figure 4-4: Line graphs of measurements made across the study time. Trendlines indicate change in measurements per day of (A) Total length, (B) Body width, (C) Tail length and (D) Body length.

Association and Effect size between treatment type and Gosner stage indicates a statistically significant difference ($p < 0.05$) with moderate association (Cramer's $V = 0.411$) between Gosner stage and Treatment type. Post-hoc test revealed a statistically insignificant difference between Treatment 1 and Treatment 2 across Gosner stages and the null hypothesis should therefore be rejected. However, in a test where dataset has 319 total cases, for a Chi-test and Effect size to be reliable, at least 80% of the expected cell counts should be ≥ 5 and (this dataset has 37.5% cells ≥ 5) (Park, 2018). This Chi-squared test is therefore considered borderline valid with

expected false positives to emerge, while Cramer's V is still useful but should be interpreted with care.

4.4 Discussion and conclusion

Although statistical analysis, through Nominal Association and Post-Hoc tests, did not indicate significantly different results between Treatment 1 and Treatment 2 across Gosner stages, developmental difference was observed between the two treatments. Tadpoles from the natural treatments were larger, more observed to be more colourful and were one to two Gosner stages ahead in development than those in the unnatural treatment. Considering that egg-clumps were harvested at exactly the same time, eggs hatched on approximately the same day (some hatching one day later than the first) and first measurements on all tubs were made on the same day, exactly one week after all eggs hatched. Initial and final measurements of treatment 1 were more than that of treatment 2 and suggests that developmental conditions dictate developing rate and possibly quality of the tadpoles.

All biological cover, predators and competition were removed from treatment 2 and refugia by shade-netting. Natural tubs weren't altered in any way. Water temperature was not measured, but it could be a possibility that unshaded, natural tubs experienced higher water temperatures than that of the covered, unnatural tubs – facilitating increased growth rates. This is expected as tadpole growth rate is directly influenced by developing temperature (Herreid and Kinney, 1967). Moreover, presence or absence of predators serves as differing developing pressures. Mortality rates of tadpoles during early stages of development (smaller sizes) are particularly high, and the presence/absence, amount and size of predators in both treatments could affect tadpole survival, mass and age at metamorphosis (development rate) – as discussed by Babbit and Tanner (1998). In the natural tubs, various other, larger tadpole species (*Amietia fuscigula*, *Strongylopus fasciatus* and *Strongylopus grayii*) were found at varying development stages. Competitive niche overlap is also believed to influence development rate. Benar and Maher (2010) found that phenotypic variation of similar and dissimilar species decreases competition and facilitates faster growth rates.

It should be mentioned that, although developmental pressures increase growth rate for faster metamorphosis, emergence of tadpoles into froglets could negatively influence metamorph survival if driven too quickly (Reading, 2010) and in return negatively influence swimming performance of tadpoles in late development and survivability of froglets and adult frogs (Watkins and Vraspir, 2005).

This study successfully identified conditions that influence developmental trends of *A. knysnae* tadpoles. Future studies should isolate variables that could have possible influence on the development of this endangered species – such as temperature, presence/absence of predators, cover and other dissimilar tadpole species. Understanding development trends and optimal growth conditions of this species provides important information for *ex situ* conservation practices – in case it becomes necessary in future.

Chapter 5: A mixed-methods study on human-frog interactions in Nature's Valley, South Africa

This chapter has been published: See Appendix A

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5.1 Introduction

The importance of frogs and their usefulness as indicators of environmental health cannot be denied (Şişman et al., 2021), but despite being the world's most threatened group of vertebrates (IUCN Red List, 2024; Leudtke *et al.*, 2023), they are not afforded commensurate research and/conservation attention (Gillespie et al., 2020). This is presumably because frogs are not as appealing (i.e. visible or likable) as other groups of animals (Botts et al., 2011). And indeed, people in some cultures fear or actively dislike herpetofauna. Such attitudes can strongly influence conservation effectiveness (Ceríaco, 2012). Consequently, soliciting public support for conservation efforts is difficult, and research interest and funding often lacking (Tarrant et al., 2016).

During the past decade, frog-related research has focused mainly on historical data evaluations (Escalona Sulbaran et al., 2019), predictive and niche modelling (Sopniewski et al., 2022), genetic analyses (Shaffer et al., 2015), and the effects of various spatial- and temporal variables on the genetic integrity of specific frog species and populations (Hu et al., 2019). Frog-related conservation efforts, on the other hand, typically focused on built- and natural-habitat management (Simpkins et al., 2021), conservation prioritisation programs (Gillespie et al., 2020), species interactions (Sabagh et al., 2017), amphibian pathology (Fisher & Garner, 2020), and species-focused conservation (Lewis et al., 2019). Despite these efforts, frog populations continue to decline globally with almost 60% falling into extinction-risk categories (IUCN, 2024), which is a clear indication that more adaptive approaches to understanding and conserving frogs need to be developed and tested.

Some authors are of the opinion that the main reason why conservation efforts are not as successful is because not enough attention is paid to human-frog interactions, specifically how people think (cognition and perceptions), feel (emotions and attitudes) and, ultimately, behave

(intentions and actions) towards frogs (Tarrant et al., 2016; Brom et al., 2020; Soga & Gaston, 2020).

Studies that have focused on this aspect reveal that several socio-demographic variables impact human-frog interactions. Vergara-Ríos et al. (2021) found that positive and negative perceptions varied across the urban-rural gradient of the Columbian Caribbean and concluded that education specifically plays an important role in human behaviours and attitudes towards frogs. Prokop et al. (2016) found that young females in Turkey, Chile, South Africa, and Slovakia are normally more tolerant of frogs than their male counterparts. In the South African context, Brom et al. (2020) found a strong correlation between childhood experience (significantly impacted by the opinions and behaviours of caregivers) and how children think, feel, and behave towards frogs later in life.

Behaviour towards frogs also appears to be influenced by their aesthetic appeal (Vergara-Ríos et al., 2021). In other words, people's liking of frogs is influenced by their "looks" with reference to a frog's skin texture, colour and size. For example, in Turkey, Chile, South Africa, and Slovakia it was found that even though high school learners view frogs with a particular level of disgust, they displayed non-lethal tolerance towards "prettier" frogs (Prokop et al., 2016; Taylor, 2018).

On a behavioural level, people also seem to display certain reactions when they encounter frogs. In some regions amphibians are persecuted and killed for social and ethnic reasons; because they are perceived to be uglier (and less useful) than fish, birds, and mammals; and due to people's phobias (Brom et al., 2020; Rabbe et al., 2021). Aversion behaviours are also witnessed widely as people commonly believe that touching frogs would result in the contraction of skin warts (Jiménez, 2014), that they are filthy (Rabbe et al., 2021), or that they will cause infections (Brom et al., 2020). Other behaviours towards frogs include getting rid of the frog by either taking it outside or covering it with salt to inevitably kill/get rid of it (Brom et al., 2020) or to combat beliefs regarding bad omens. Non-lethal behaviour includes rescuing frogs from domestic pets, dousing them with water to prevent dehydration, using them to scare people, and taking them to a pond/dam or natural habitat "where it belongs" (Kruger, 2014).

On a cognitive level, in general, people's knowledge regarding frogs is strongly influenced by cultural beliefs, such as "knowing" that frogs cause warts or that all frogs are dangerous and poisonous/venomous. Recognition of frogs also seems to be culture-specific, for example in China, participants could correctly name and recognise most toad/frog species used to test their knowledge of frogs (Jiménez, 2014), while in the Columbian-Caribbean study, participants' knowledge was poor and they could not recognize or name more than two local frog species

according to local or scientific standards (Vergara-Ríos et al., 2021). In the highlands of KwaZulu-Natal, the easternmost province of South Africa, knowledge regarding frogs was so limited that people failed to recognise vocalising frogs at night and identified them as chirping insects (Phaka et al., 2019), despite that province having the highest frog diversity in the country. Knowledge on frogs is determined by a culture's utilisation and experience of frogs (Jiménez, 2014; Brom *et al.*, 2020).

Given that how people think, feel, and behave towards frogs is often underpinned by their beliefs, another important factor to take into consideration is cultural beliefs and religion (e.g. superstitions and folklore). In the literature, this is the human-frog related topic that has been well explored. Studies in South American countries such as Argentina, Brazil, and Uruguay, for example, showed that cultural beliefs and local folklore (e.g. frogs are evil/venomous/dangerous) strongly impacted human-frog interaction, while in Asian countries such as Bangladesh, ancient misconceptions and myths hold that killing a frog/toad will cause night terrors (Rabbe et al., 2021). Perhaps, some of the strongest links between cultural beliefs and behaviour towards frogs occur on the African continent:

- In north-east Ethiopia, superstitions and associations with bad omens lead to the unnecessary killing of frogs (Kassie, 2020);
- In Tanzania, local farmers use frog activities and calling behaviours as environmental predictors of rainfall events to aid agricultural practices (Elia et al., 2014);
- Local communities in northern Mozambique believe that the African bull frog (*Pyxicephalus edulis*) is more dangerous than the Mozambique spitting cobra (*Naja mossambica*) (Farooq et al., 2021);
- In the highlands of Lesotho, communities believe that specific species can communicate with humans (Mokuku & Mokuku, 2004);
- In South Africa, many IsiZulu speaking communities believe grass frogs (*Ptychadena*) call or attract rain and that the Africa clawed frogs (*Xenopus leavis*) fall from the sky during rains (Phaka *et al.*, 2019).

Interestingly, Botts et al. (2011) found that people's interactions with frogs appear to be more prominent in countries where species richness strongly correlates with higher human population densities. Given that approximately 135 frog species (Du Preez & Carruthers, 2017) co-exist with a population in excess of 60 million, South Africa is an ideal place to study human-frog interactions to understand how people think, feel, and behave towards frogs.

The aim of this mixed-methods study on human-frog interactions was to quantify and verify how people interact with frogs in an attempt to derive new knowledge that could ultimately benefit the conservation of frogs and unlock new research opportunities, especially from a human/social/behavioural perspective.

5.2 Methodology

5.2.1 Study area

The study was conducted in Bitou, a municipality within the Western Cape, South Africa, with a specific focus on an area known as “The Crags” situated approximately 30 kilometers from Plettenberg Bay. Three different communities within this area were targeted: Covie (a small, isolated rural village with 30 households), Kurland (a small township with approximately 1 050 households), and Nature’s Valley (a predominantly tourist village with 70 out of 400 houses occupied on a permanent/semi-permanent basis) (Figure 5-1).

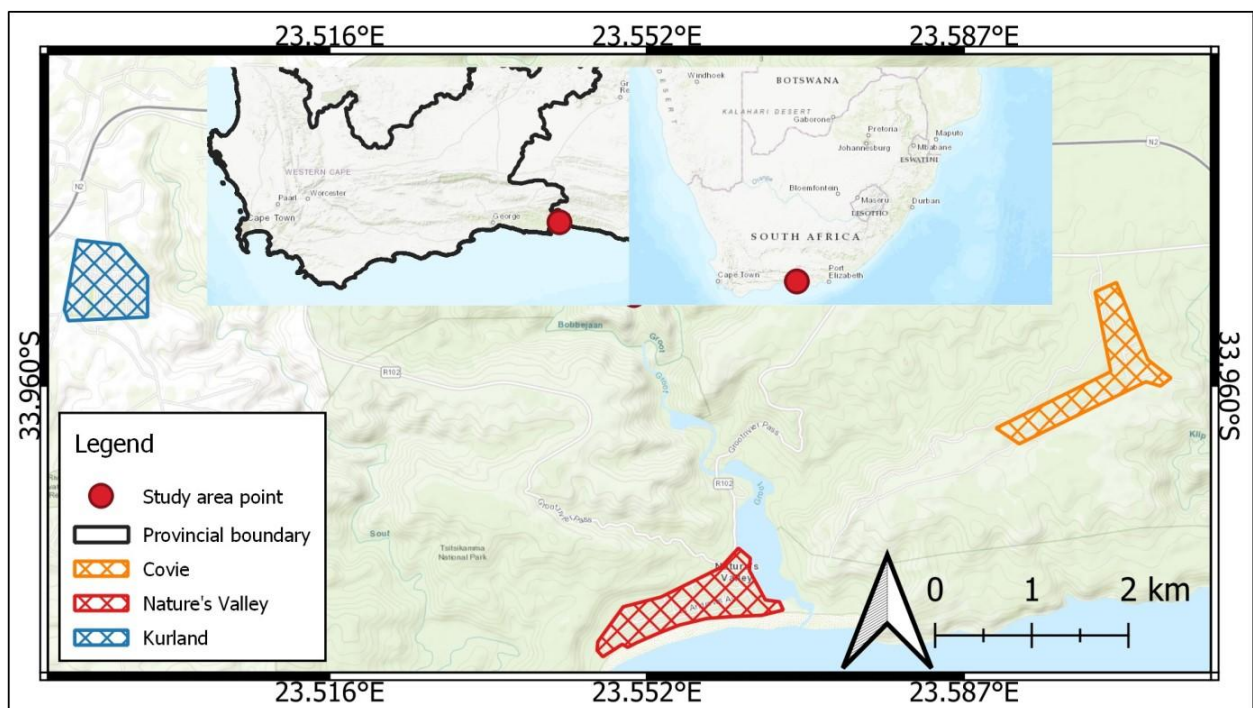


Figure 5-1: Map of overall study area. Coloured polygons represent the area of each studied communities – being Nature’s Valley (red), Covie (orange) and Kurland (blue).

5.2.2 Approach and strategy

A concurrent, embedded mixed-methods research design (Figure 5-2) guided this study. As demonstrated by Fetters et al. (2013) and Gelo et al. (2008), this approach to sampling and analysis is desirable since more insight and understanding towards the matter under investigation

can be gained as opposed to simply sampling, analysing, and interpreting quantitative and qualitative data in isolation.

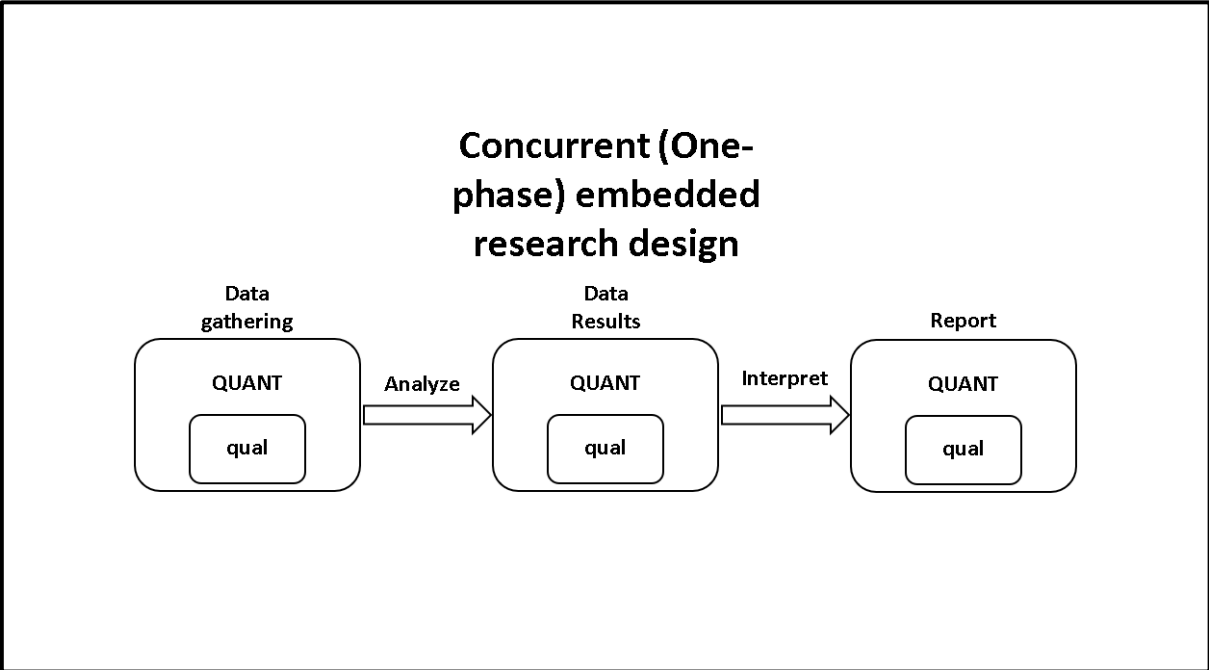


Figure 5-2: Study design of a concurrent, embedded mixed-methods approach. Qualitative data serves as secondary subsets (descriptive nature) of quantitative data but is collected simultaneously with each other.

Accordingly, embedded refers to quantitative, and qualitative data being collected simultaneously where the latter was used as an embedded secondary subset to describe the overall characteristics of the initial quantitative data and to provide clarity and context in relation to emergent findings stemming from the survey.

5.2.3 Procedure

Having obtained ethical clearance from the North-West University (NWU-01317-23-A9), goodwill permission to conduct the study in the three communities was obtained from their local leadership, who also acted as gatekeepers to the communities. Questionnaires were deployed with the aid of three remunerated, trained fieldworkers, and care was taken to ensure that no overlap or duplication occurred during fieldwork.

Most interviews lasted no more than an hour and were conducted at participants' place of residence and followed all protocols with regards to obtaining informed consent, explaining the nature and aims of the study, and informing participants about potential risks/benefits and their rights to withdraw without penalty.

Quantitative data gleaned from questionnaires that met the researcher's standards for completeness and correctness (sober answers and completed questionnaires) was captured and sent to the North-West University's Statistical Consultation Services for analysis. Following analysis and interpretation of the data, findings from the quantitative and qualitative phases of the study were integrated and will be presented below. Qualitative answers were written down by the interviewer.

5.2.4 Data gathering

A questionnaire designed and developed with the intent to cover four themes that might have a bearing on human-frog interactions was used to gather quantitative and qualitative data simultaneously. The themes were mostly adopted from Tarrant et al. (2016) and Brom et al. (2020); however, some questions were modified or added based on studies conducted by Phaka (2020) and Kruger (2014). All questionnaires were administered verbally by fieldworkers who recorded the responses.

In an attempt to reveal any cultural beliefs, superstitions, and understandings participants have towards frogs that might not be revealed in their responses, an open-ended question was included: "*Would you be willing to share any existing knowledge, beliefs, or superstitions you have regarding frogs?*" According to Tarrant et al. (2016), underlying beliefs dictated or determined by memories of childhood experiences can significantly impact perceptions and behaviour towards animals in later life. Therefore, as per the study conducted by Brom et al. (2020), respondents were also asked whether they have any strong memories of coming into contact with frogs when they were children as well as whether they have any memories from their childhood of a teacher or parent that told them something specific about frogs that they want to share.

The four themes broadly dealt with participants' (1) fondness and toleration ("Liking") of frogs, (2) frequency of encounters with frogs and typical response to such an event ("Encounters"), (3) knowledge of and willingness to learn more about frogs ("Knowledge"), and unrecorded superstitions that might impact participants' attitude towards frogs ("Culture, beliefs, and myths") (see Table 2).

With the exception of statements E1, E2, E3, and K7 to K13 (See table 5-2 for descriptions), participants were required to answer questions on a five-point Likert scale (1 = Completely disagree; 5 = Completely agree).

In the case of questions K10–12, participants were shown a picture of a painted reed frog (*Hyperolius marmoratus*), endangered *A. knysnae*, and a plain rain frog (*Breviceps fuscus*),

respectively, and asked to indicate whether they think the specific frog species is “likable”, “scary”, “gross” or “other”. Since Ceríaco (2012) holds that negative values, such as unsightly appearance, directly influence the conservation prospects of herpetofauna, a modified approach as proposed by Brom et al. (2020) was used to inquire whether participants had seen the frogs before, and which frogs they are most likely to conserve (support conservation efforts) to test this hypothesis. The qualitative component involved asking participants after each question to explain/add details as to why they think, feel, and behave towards the species in a certain manner.

5.2.5 Data analysis

Captured quantitative and qualitative data were analysed separately, but the results were interpreted as concurrent subsets of one another. Initially, Cronbach’s alpha coefficient for internal psychometric reliability between scales ($0.00 \geq \alpha \geq 1.00$) (Tavakol & Dennick, 2011) was tested before further basic and intermediary statistical analysis to identify scales that could potentially affect uniformity and credibility. Further analysis included the computation of basic descriptive statistics (means, frequencies, and standard deviations), correlations and differences (i.e. ANOVA, t-tests) and effect size (Cohen’s d) for differences between means.

In terms of quantitative data, Cronbach’s alpha was applied to validate internal reliability per section. Measured on a scale of between 0 and 1 (Tavakol & Dennick, 2011), the psychometric internal reliability coefficient attained for the section “Liking” was 0.882; 0.712 for “Knowledge”; and 0.812 for “Folklore” which, according to (Taber (2018), vary between robust (0.81) and good (0.71).

As per Field (2005), ANOVA and t-tests were set at a p-value of $p < 0.05$ to derive inferential deductions on the mean differences between the three communities: Covie, Nature’s Valley, and Kurland. This enabled the investigation of the significant/practical effect demographic variability had on participants’ behaviour towards frogs and to determine which of the means were different based on post hoc tests (Brown, 2005).

Qualitative data was analysed thematically by means of open coding followed by axial coding (Creswell & Poth, 2016; Tracy, 2019). The patterns or groupings based on conceptual similarities thus derived were then each assigned an overarching theme based on their interrelationship.

Note that in this study, data pertaining to demographics were limited to significant variables (i.e. age, gender, culture, language, race, education level, religion, religiosity, and connectedness to nature) as per Tarrant et al. (2016) and Brom et al. (2020), given that Evert et al. (2021) found

variables such as income bracket and political orientation to have no significant bearing on the former.

5.3 Results

To follow is a brief overview of the results derived from the responses to the questions posed under each of the sections as per Table 5-1. In all instances, pertinent quantitative results per section will be presented first followed by supporting data and qualitative responses per question that confirm practical significances (Cohen's d values). Cohen's d value is considered a standardised method of commenting on the differences between the means of two populations (Nature's valley with Covie, Nature's Valley with Kurland, and Covie with Kurland) regardless of statistical significance. In this article, we determine practical significance as a result of differences having small ($d=0.2$), medium ($d=0.5$) and large ($d=0.8$) effect sizes (Steyn, 2003).

T-tests and effect-size calculations confirmed statistical insignificance between male (mean = 3.25) and female (mean = 3.16) ($p < 0.05$; $d = 0.07$) participants with both genders indicating that they are "undecided" regarding frogs. Statistical significance between Colored and White (mean = 2.78 and 4.53) was evident with a strong effect size ($p < 0.05$; $d = 2.01$). White participants showed higher liking towards frogs than Colored participants, and this difference is regarded as practically important. Despite insignificant p -value comparisons between Afrikaans (mean = 3.04) and English (mean = 4.09), Afrikaans speaking participants showed no general liking or disliking towards frogs, while English speaking participants showed some liking towards frogs. Therefore, the practical effect value ($p > 0.05$; $d = 0.95$) is regarded as meaningful.

5.3.1 Participants

Participants were exclusively divided into "White" and "Colored" racial groups while statistically negligible "Black" participants took part in this study. White participants are internationally described as "Caucasian" individuals, while Colored participants are internationally described as multiracial ethnic communities that have ancestry from European, African and Asian forefathers.

Participants aged between 18 and 78 years with an average age of 37 ($SD = 18$). Ninety participants ($n=90$) were systematically and proportionally selected based on the size of the respective communities: 62.2% were from Kurland, 27.8% from Nature's Valley, and 10% from Covie. Of these, 53.3% identified as male, 45.6% as female, and 1.1% as "other" (Table 5-1).

Table 5-1: Demographic variables of the residents participating in this study.

Characteristics of participants (n = 90)			
Item	Options	n	Valid %
Location	Nature's Valley	25	27.8
	Kurland	56	62.2
	Covie	9	10
Gender	Male	48	53.3
	Female	41	45.6
	Other	1	1.1
Race	Black African	9	10
	White	23	25.6
	Colored	56	62.2
	Other	2	2.2
Language	Afrikaans	71	78.8
	English	15	16.9
	Zulu	2	2.2
	Xhosa	1	1.1
Education	Primary	6	7
	Some secondary	14	16.3
	Completed secondary	31	36
	Some tertiary	11	12.8
	Completed tertiary	24	27.9
Religion	Agnostic	6	6.7
	Atheistic	4	4.4
	Christian	75	83.3
	Traditional African	2	2.2
	Other	3	3.3

Most participants indicated that they had completed secondary school (36%) or tertiary education (27.9%). Of the remainder, 16.3% completed some secondary education and 12.8% completed some tertiary education, with 7% indicating that they have at least a “primary” education.

When asked about their connectivity with nature, 26.7% indicated some connectivity and 23.3% complete connectedness. Of the remainder, 22.2% were “Undecided”, with 14.4% indicating that they are either “Disconnected” or “Somewhat disconnected” (13.3%) from nature. The mean connectedness to nature was thus calculated at 3.31 (SD = 1,38).

5.3.2 Section 1: Liking

Below follows detailed univariate and multivariate statistical analysis of all “Liking” items within the three groups. Results can be interpreted by viewing distribution of answers across the Likert scale (Table 5-2), followed by viewing statistical significance between groups and recognition of practical significance through effect size (difference in means) (Table 5-3), and finally confirmation

of differences in means by viewing qualitative reasoning of participants (Table 5-4). This will be the same for “*Knowledge*” and “*Cultural beliefs and myths*”.

Table 5-2: Overall basic descriptive statistics of items intended to measure the Liking of the communities towards frogs/toads.

Internal Reliability = 0.882					
Item Code	Statement	Mean	Std. Deviation	Answer distribution (%)	
L1	You like frogs/toads	2,61	1,56	Completely disagree	36.7
				Disagree	17.8
				Undecided	13.3
				Agree	12.2
				Completely agree	20.0
L2	You are scared of frogs/toads	2,23	1,36	Completely disagree	40.0
				Disagree	30.0
				Undecided	6.7
				Agree	13.3
				Completely agree	10.0
L3	You will pick up and handle a frog/toad	2,69	1,52	Completely disagree	33.3
				Disagree	20.0
				Undecided	6.7
				Agree	24.4
				Completely agree	15.6
L4	Frogs/toads should be killed	2,08	1,13	Completely disagree	38.9
				Disagree	31.1
				Undecided	17.8
				Agree	7.8
				Completely agree	4.4
L5 *	You will consider having a frog/toad picture as wallpaper or screen saver on your mobile/computer	2,56	1,52	Completely disagree	40.0
				Disagree	14.4
				Undecided	7.8
				Agree	25.6
				Completely agree	12.2
L6	You are annoyed by frogs/toads being on your property	3,04	1,53	Completely disagree	28.9
				Disagree	10.0
				Undecided	6.7
				Agree	36.7
				Completely agree	17.8
L7 *	You don't like the sound that frogs/toads make	3,46	1,43	Completely disagree	16.7

Disagree	12.2
Undecided	6.7
Agree	37.8
Completely agree	26.7

The internal reliability coefficient for questions marked with (*) were too low to be deemed reliable and these questions were initially removed from the dataset when determining the reliability coefficient. Results are still reported as the authors believe that valuable insight was found post analysis of these questions

Multivariate statistical analysis can be observed for all items in the “*Liking*” section, as well as the overall correlation of “*Liking*” between the three groups. Overall, participants showed a slightly below-average liking towards frogs (mean = 2.67; SD = 0.46) with significant differences ($F(2,87) = 57.32, p < .05, \text{partial } \eta^2 = 0.569$) between locations: Nature’s Valley (mean = 4.62) showed strong overall liking towards frogs, whereas Covie (mean = 2.78) and Kurland (mean = 2.62) showed slight overall disliking towards frogs (Table 5-2).

Table 5-3: Multivariate statistical analysis of items intended to measure the Liking of the communities towards frogs/toads.

Item	Location	N	Mean	Std. Deviation	ANOVA p-value	Cohen's d Effect sizes	
						Nature's Valley with	Covie with
Liking overall	Nature's Valley	25	4,62	0,44	$F(2,87) = 57.32$		
	Covie	9	2,78	0,78	$p < .05$	2,35**	
	Kurland	56	2,62	0,90	$\text{partial } \eta^2 = 0.569$	2,23**	0,18*
	Total	90	3,19	1,18			
L1	Nature's Valley	25	4,56	0,768	$F(2,87) = 66.58$		
	Covie	9	1,89	0,928	$p < 0.05$	2,88**	
	Kurland	56	1,86	1,086	$\text{partial } \eta^2 = 0.605$	2,49**	0,03*
	Total	90	2,61	1,563			
L2	Nature's Valley	25	1,20	0,500	$F(2,87) = 13.07$		
	Covie	9	3,00	1,323	$p < 0.05$	1,36**	
	Kurland	56	2,57	1,399	$\text{partial } \eta^2 = 0.231$	0,98**	0,31*
	Total	90	2,23	1,366			
L3	Nature's Valley	25	3,96	1,241	$F(2,87) = 16.1$		
	Covie	9	2,22	1,202	$p < 0.05$	1,40**	
	Kurland	56	2,20	1,367	$\text{partial } \eta^2 = 0.27$	1,29**	0,02*
	Total	90	2,69	1,526			
L4	Nature's Valley	25	1,08	0,277	$F(2,87) = 18.87$		
	Covie	9	2,33	1,118	$p < 0.05$	1,12**	
	Kurland	56	2,48	1,112	$\text{partial } \eta^2 = 0.303$	1,26**	0,13*
	Total	90	2,08	1,134			
L5	Nature's Valley	25	1,08	1,578	$F(2,87) = 11.89$		
	Covie	9	1,56	0,527	$p < 0.05$	1,32**	

	Kurland	56	2,23	1,348	partial $\eta^2 = 0.215$	0,89**	0,50*
	Total	90	2,56	1,522			
L6	Nature's Valley	25	1,16	0,624	F(2,87) = 72.32 p < 0.05	1,27**	0,75**
	Covie	9	2,89	1,364			
	Kurland	56	3,91	0,996	partial $\eta^2 = 0.624$	2,76**	
	Total	90	3,04	1,535			
L7	Nature's Valley	25	2,56	1,805	F(2,87) = 11.71 p < 0.05	0,12*	0,99**
	Covie	9	2,78	1,202			
	Kurland	56	3,96	0,990	partial $\eta^2 = 0.212$	0,78**	
	Total	90	3,46	1,431			

▪, Small effect size (Cohen's d) = 0.2

*, Medium effect size (Cohen's d) = 0.5

** , Large effect size (Cohen's d) = 0.8

Qualitative responses such as “Nothing to like about frogs” (Covie Participant #2); “I am not a frog person” (Kurland Participant #34); and “I love them. They are lovely to me. I believe they are a sign of a healthy environment” (Nature's Valley Participant #65) serve as confirmation of the means (Table 5-4) for item (L1) *You like frogs*. Differences in means (Cohen's d) can also be illustrated through the qualitative answers.

Table 5-4: Qualitative responses of participants from respective communities that confirm large/medium/no practical significance for “Liking” towards frogs.

Item code/ statement	Location	Qualitative answer (Location Participant #)	Mean	Std. Deviation	Cohen's d Effect sizes	
					Nature's Valley with	Covie with
Δ L1 <i>You like frogs/toads</i>	Nature's Valley	“I believe they are a sign of a healthy environment” (Participant #65)	4,56	0,768		
	Covie	“Nothing to like about frogs” (Participant #2)	1,89	0,928	2,88**	
	Kurland	“I am not a frog person” (Participant #34)	1,86	1,086	2,49**	0,03*
Δ L2 <i>You are scared of frogs/toads</i>	Nature's Valley	“They are good for the environment and an indicator as health” (Participant #77)	1,20	0,500		
	Covie	“I am not scared; I just don't like frogs” (Participant #8)	3,00	1,323	1,36**	
	Kurland	“Some frogs are pretty, and some frogs are ugly and rough (lumpy)” (Participant #19)	2,57	1,399	0,98**	0,31*
Δ L3 <i>You will pick up and handle a frog/toad</i>	Nature's Valley	<i>I would; to save them if they get lost</i> (Participant #70)	3,96	1,241		
	Covie	“Only if I have to move it” (Participant #9)	2,22	1,202	1,40**	

	Kurland	<i>I am not that comfortable around frogs" (Participant #34)</i>	2,20	1,367	1,29**	0,02•
Δ L4 Frogs/toads should be killed	Nature's Valley	<i>"I don't want to see frogs get killed" (Participant #89)</i>	1,08	0,277		
	Covie	<i>"Just take it outside" (Participant #4)</i>	2,33	1,118	1,12**	
	Kurland	<i>"If they put people's lives in danger, yes" (Participant #51)</i>	2,48	1,112	1,26**	0,13•
Δ L5 You will consider having a frog/toad	Nature's Valley	<i>"They are cute" (Participant #88)</i>	3,64	1,578		
	Covie	<i>"Why would I want to do that?" (Participant #62)</i>	1,56	0,527	1,32**	
	Kurland	<i>"I would rather have a puppy as a wallpaper" (Participant #15)</i>	2,23	1,348	0,89**	0,50*
Δ L6 You are annoyed by frogs/toads being	Nature's Valley	<i>"No, they are welcome and kind" (Participant #77)</i>	1,16	0,624		
	Covie	<i>"It must stay in the forest" (Participant #6)</i>	2,89	1,364	1,27**	
	Kurland	<i>"What do they want in my yard?" (Participant #56)</i>	3,91	0,996	2,76**	0,75**
Δ L7 You don't like the sound that frogs/toads make	Nature's Valley	<i>"It is the sound of Nature's Valley. It is louder than snoring" (Participant #83)</i>	2,56	1,805		
	Covie	<i>"Sometimes they are irritating" (Participant #90)</i>	2,78	1,202	0,12•	
	Kurland	<i>"It sounds uncomfortable and makes me feel creeped out" (Kurland Participant #30)</i>	3,96	0,990	0,78**	0,99**

•, Small effect size (Cohen's d) = 0.2

* , Medium effect size (Cohen's d) = 0.5

** , Large effect size (Cohen's d) = 0.8

Δ, Statistically significant (Table above)

•, Statistically insignificant (Table above)

5.3.3 Section 2: Encounters

Comprised of three questions, each with its own categorical or ordinal scale, this section aimed to investigate how often and where participants encounter frogs and what their attitude towards frogs is in such an event.

E1. *Within a year, how often do you see a frog/toad?* Most (38.8%) stated that they encounter frogs 1-5 times per year, 28.9% encounter them 11-15 times per year, 21.1% 16-plus times per

year, 8.9% 6-10 times per year, and 5.6% never encounter them. Seemingly, participants on average encounter frogs 6-10 times per year (mean = 3; SD = 1.15). ANOVA revealed no statistical significance between localities ($F(2,87) = 10.66$, $p < .05$, partial $\eta^2 = 0.197$), but a large practical effect size was revealed between Nature's Valley (mean = 3.24) and Covie (mean = 4.33) ($d = 0.84$), and between Covie and Kurland (mean = 2.68) ($d = 1.48$), while a medium effect was observed between Nature's Valley and Kurland ($d = 0.43$). These means suggest that within the study area frogs are encountered most often in Covie (around 11-15 times per year), followed by Nature's Valley (6-10 times per year), and Kurland (around 1-5/6-10 times per year).

Males (mean = 3.1) and females (mean = 2.9) both encounter frogs around 6-10 times per year. The calculated effect size for Colored (mean = 2.95) and White (mean = 3.35) participants is statistically insignificant ($p > 0.05$; $d = 0.35$) and of medium practical significance. The same can be said for frequency of encounters by Afrikaans- (mean = 3.11) and English-speaking (mean = 2.73) participants ($d = 0.33$).

Frequency of encounters only showed positive significant correlations at the 0.05 level with age ($\rho = .327$; $p < 0.05$) and connectedness ($\rho = .415$; $p < 0.05$), and no correlation with education level and religious orientation. Older participants seemed more likely to encounter frogs than younger participants, and participants with a strong connection to their natural environment also encounter frogs more frequently than do people who did not feel connected.

Generally, the encounter theme showed significant positive correlations with "liking" ($\rho = .299$; $p < 0.05$) and "knowledge" ($\rho = .383$; $p < 0.05$), but not with "folklore". This suggests that as participants' encounter frequency increases, so would their general liking and knowledge, while folklore remains unaffected.¹

E2. Where do you see frogs/toads most often? Most participants (36.7%) indicated their garden, followed by on the road (24.4%), and at work (8.9%). Of the remainder, 5% stated that they never see frogs and 21.1% preferred "Other". Qualitative probing revealed that "other" mostly implied in the forest [*In the woods*] (Participant #6), followed by in other people's homes [*Other people's properties*] (Participant #51).

¹ Note that E2 and E3 were intended to gather supporting data for E1 only. Since these two questions were not measured on a scale, no correlations and comparisons with other variables are possible.

E3. *What do you do when you see a frog/toad?* Most participants (45.6%) said they will take a frog outside if it is in their home, 16.7% said they would kill it, 15.6% said they would call someone to remove it, 13.3% will ignore it, and 5.6% gave their own responses. Qualitative probing regarding participants' reactions revealed "*Wrong place*" as the overarching theme, implying that participants recognize that frogs belong outside. The second dominating theme involved "*Using tools*", implying that participants will use something like a broom, shovel, or stick to remove the frog from their living space or, in specific cases, kill it [*"I use a broom to remove it because I am scared it lands in the foodstuffs"* (Participant #37)].

5.3.4 Section 3: Knowledge

Measured on a 5-point Likert scale (Table 5-5), this section revealed low knowledge about frog biology and ecology (mean = 2.54; SD = 1.108) across the three locations. Statistical insignificance between all three locations ($F(2,87) = 33.5, p > 0.05, \text{partial } \eta^2 = 0.435$) was observed, indicating that place of residence accounts for 43.5% of the variance. Confirmation of statistical significance ($p < 0.05$) between sites revealed a large practical effect size ($d = 1.03$) between Nature's Valley (mean = 3.16) and Covie (mean = 2.71), between Nature's Valley and Kurland (mean = 2.38) ($d = 1.78$), and between Covie and Kurland ($d = 0.84$): Nature's Valley participants show some knowledge of frogs, while both Covie and Kurland show below-average knowledge (Table 5-6).

Table 5-5: Overall basic descriptive statistics of items intended to measure the Knowledge of the communities towards frogs/toads.

Internal Reliability = 0.712					
Item Code	Statement	Mean	Std. Deviation	Answer distribution (%)	
K1	You want to learn more about frogs/toads	2,74	1,41	Completely disagree	26.7
				Disagree	22.2
				Undecided	14.4
				Agree	23.3
				Completely agree	13.3
K2	You know the difference between a frog and a toad	2,22	1,30	Completely disagree	40.0
				Disagree	26.7
				Undecided	11.1
				Agree	15.6
				Completely agree	6.7
K3	Frogs/toads belong to the most threatened group of vertebrae in the world	2,84	0,88	Completely disagree	6.7
				Disagree	22.2

				Undecided	56.7
				Agree	8.9
				Completely agree	5.6
K4	The conservation of wetlands and freshwater habitat may help to reduce loss of frog/toad species and numbers	4,09	0,85	Completely disagree	2.2
				Disagree	1.1
				Undecided	15.6
				Agree	47.8
				Completely agree	33.3
K5	You think it is important to conserve South Africa's frogs/toads	3,59	1,17	Completely disagree	6.7
				Disagree	12.2
				Undecided	21.1
				Agree	35.6
				Completely agree	24.4
K6	Frogs/toads are important for medical research	2,93	1,11	Completely disagree	10.0
				Disagree	26.7
				Undecided	31.1
				Agree	24.4
				Completely agree	7.8
K7*	For each picture, can you react and say if you think it's likeable, gross, or scary? Frog 1	1,36	0,77	Likeable	76.7
				Gross	13.3
				Scary	4.4
				Other	4.4
K8*	For each picture, can you react and say If you think it's likeable, gross, or scary? Frog 2	1,71	0,92	Likeable	52.2
				Gross	31.1
				Scary	7.8
				Other	7.8
K9	For each picture, can you react and say If you think it's likeable, gross, or scary? Frog 3	2,74	0,89	Likeable	16.7
				Gross	5.6
				Scary	63.3
				Other	13.3
K10	Have you seen frog 1 before?	1,37	0,48	Yes	62.2
				No	36.7
K11	Have you seen frog 2 before?	1,42	0,49	Yes	57.8
				No	41.1
K12	Have you seen frog 3 before?	1,30	0,46	Yes	68.9
				No	30.0
K13	Which of the three frogs are you most likely to conserve (1, 2, or 3)?	3,13	1,59	Completely disagree	32.2
				Disagree	3.3
				Undecided	1.1
				Agree	43.3
				Completely agree	18.9

The internal reliability coefficient for questions marked with (*) were too low to be deemed reliable and these questions were initially removed from the dataset when determining the reliability coefficient.

Results are still reported as the authors believe that valuable insight was found post analysis of these questions

The difference between males (mean = 2.58) and females (mean = 2.69) is statistically insignificant ($p > 0.05$; $d = 0.21$) for the “*Knowledge*” section. However, T-tests confirmed statistical significance between Colored (mean = 2.48) and White (mean = 3.31) participants, with Colored participants showing slightly below-average knowledge about frogs and White participants showing slightly above-average knowledge. This difference is of large practical importance ($p < 0.05$; $d = 1.49$). On the other hand, no statistical significance between Afrikaans- (mean = 2.58) and English- (mean = 2.98) speaking participants came to the fore, but a large practical significance was confirmed after calculation of effect size ($p < 0.05$; $d = 0.81$): Afrikaans-speaking participants show less knowledge about frogs than English-speaking participants do.

Table 5-6: Multivariate statistical analysis of items intended to measure the knowledge of the communities towards frogs/toads.

Item	Location	N	Mean	Std. Deviation	ANOVA p-value	Cohen's d Effect sizes	
						Nature's Valley with	Covie with
Knowledge overall	Nature's Valley	25	3,16	0,44	F(2,87) = 33.5 $p > 0.05$ partial $\eta^2 = 0.435$	1,03**	0,84**
	Covie	9	2,71	0,32			
	Kurland	56	2,38	0,39			
	Total	87	2,54	1,108			
K1	Nature's Valley	25	4,20	0,957	F(2,87) = 30.406 $p < .05$ partial $\eta^2 = 0.411$	2,20**	0,18*
	Covie	9	2,00	1,000			
	Kurland	56	2,21	1,171			
	Total	90	2,74	1,419			
K2	Nature's Valley	25	3,12	1,333	F (2,87) = 14.86 $p < .05$ $\eta^2 = 0.255$	0,17*	0,86**
	Covie	9	2,89	1,364			
	Kurland	56	1,71	1,004			
	Total	90	2,22	1,305			
K3	Nature's Valley	25	3,20	1,155	F (2,87) = 3.081 $p > .05$ partial $\eta^2 = 0.066$	0,56*	0,24*
	Covie	9	2,56	0,726			
	Kurland	56	2,73	0,726			
	Total	90	2,84	0,886			
K4	Nature's Valley	25	4,80	0,408	F(2,87) = 16.224 $p < .05$ partial $\eta^2 = 0.272$	2,27**	0,20*
	Covie	9	3,67	0,500			
	Kurland	56	3,84	0,869			
	Total	90	4,09	0,856			
K5	Nature's Valley	25	4,84	0,374	F (2,87) = 36.262, $p < .05$ partial $\eta^2 = 0.455$	1,77**	0,50*
	Covie	9	3,56	0,726			
	Kurland	56	3,04	1,044			
	Total	90	3,59	1,179			
K6	Nature's Valley	25	3,32	1,345	F (2,87) = 2.206 $p > .05$	0,32*	
	Covie	9	2,89	0,782			

	Kurland	56	2,77	1,009	partial $\eta^2 = 0.048$	0,41*	0,12*
	Total	90	2,93	1,110			
K7	Nature's Valley	25	1,24	0,831	F(2,86) = 1.012		
	Covie	9	1,67	1,323	p > .05	0,32*	
	Kurland	55	1,36	0,620	partial $\eta^2 = 0.023$	0,15*	0,23*
	Total	89	1,36	0,772			
K8	Nature's Valley	25	1,48	1,046	F(2,86) = 1.333		
	Covie	9	2,00	0,866	p > .05	0,50*	
	Kurland	55	1,76	0,860	partial $\eta^2 = 0.03$	0,27*	0,27*
	Total	89	1,71	0,920			
K9	Nature's Valley	25	2,24	1,393	F(2,86) = 6.055		
	Covie	9	2,89	0,782	p < .05	0,47*	
	Kurland	55	2,95	0,448	partial $\eta^2 = 0.123$	0,51*	0,07*
	Total	89	2,74	0,899			
K10	Nature's Valley	25	1,44	0,507	F (2,86) = 0.676		
	Covie	9	1,22	0,441	p > .05	0,43*	
	Kurland	55	1,36	0,485	partial $\eta^2 = 0.015$	0,15*	0,29*
	Total	89	1,37	0,486			
K11	Nature's Valley	25	1,48	0,510	F (2,86) = 0.349		
	Covie	9	1,44	0,527	p > .05	0,07*	
	Kurland	55	1,38	0,490	partial $\eta^2 = 0.008$	0,19*	0,12*
	Total	89	1,42	0,496			
K12	Nature's Valley	25	1,20	0,408	F (2,86) = 6.123		
	Covie	9	1,78	0,441	p < .05	1,31**	
	Kurland	55	1,27	0,449	partial $\eta^2 = 0.125$	0,16*	1,12**
	Total	89	1,30	0,462			
K13	Nature's Valley	25	3,40	1,155	F(2,86) = 6.753		
	Covie	9	4,67	0,500	p < .05, partial	1,10**	
	Kurland	55	2,76	1,721	partial $\eta^2 = 0.136$	0,37*	1,11**
	Total	89	3,13	1,597			

▪, Small effect size (Cohen's d) = 0.2

*, Medium effect size (Cohen's d) = 0.5

** , Large effect size (Cohen's d) = 0.8

Positive significant correlations ($p < 0.05$) between knowledge and demographic variables such as age ($\rho = .595$; $p < 0.05$), education level ($\rho = .414$; $p < 0.05$), and connectedness to nature imply that older participants as well as more educated and more environmentally involved participants (independent of one another) are more knowledgeable but are unaffected by religiosity. Again, correlations between themes suggest that as participants' knowledge increases, so would liking (or *vice versa*) ($\rho = .672$; $p < 0.05$) and encounter frequency ($\rho = .299$; $p < 0.05$) due to a significant positive correlation ($p < 0.05$), but folklore would decrease because of negative significant correlation.

Confirmation of means and support of practical effect size can be read in conjunction of qualitative reasoning of Participants (Table 5-7). For example *You want to learn more about frogs/toads (K1)*: Qualitative responses such as "*It would be very interesting, especially tree frogs*" (Nature's Valley

Participant #77) as opposed to “*It wouldn’t benefit me*” (Kurland Participant #62) and “*It doesn’t serve a purpose in my life*” (Covie Participant #8) support statistical significance ($F(2,87) = 30.406$, $p < .05$, partial $\eta^2 = 0.411$) between participant scores with a significant practical effect between Nature’s Valley (mean = 4.2) and Covie (mean = 2) ($d = 2.2$), and Nature’s Valley and Kurland (mean = 2.21) ($d = 1.7$), but not between Covie and Kurland ($d = 0.18$) (Table 5-6).

Table 5-7: Qualitative responses of participants from respective communities that confirm large/medium/no practical significance for “Knowledge” about frogs.

Item code/ Statement	Location	Qualitative answer (Location Participant #)	Mean	Std. Deviation	Cohen's d Effect sizes	
					Nature's Valley with	Covie with
Δ K1 You want to learn more about frogs/toads	Nature's Valley	“It would be very interesting, especially tree frogs” (Nature's Valley Participant #77)	4,20	0,957		
	Covie	“It doesn't serve a purpose in my life” (Covie Participant #8)	2,00	1,000	2,20**	
	Kurland	“It wouldn't benefit me” (Kurland Participant #62)	2,21	1,171	1,70**	0,18•
Δ K2 You know the difference between a frog and a toad	Nature's Valley	“I'm not sure I know the differences between them at all” (Nature's Valley Participant #70)	3,12	1,333		
	Covie	“I don't really know much about frogs” (Covie Participant #1)	2,89	1,364	0,17•	
	Kurland	“I don't know the difference” (Kurland Participant #45)	1,71	1,004	1,05**	0,86**
• K3 Frogs/toads belong to the most threatened group of vertebrae in the world	Nature's Valley	“No compelling case, but I am not sure” (Nature's Valley Participant #71)	3,20	1,155		
	Covie	“There are many frogs” (Covie Participant #9)	2,56	0,726	0,56*	
	Kurland	“I thought there are a lot of frogs” (Kurland Participant #24)	2,73	0,726	0,41*	0,24•
Δ K4 The conservation of wetlands and freshwater habitat may help to reduce loss of frog/toad	Nature's Valley	“To me wetland areas are typical frog habitat. Conserving their habitat will automatically conserve animals that live in it” (Nature's Valley Participant #72)	4,80	0,408		

species numbers	and	Covie	"They [wetlands] keep nature in place and play an important role in nature" (Covie Participant #1)	3,67	0,500	2,27**	
		Kurland	"If people stay away from animals' natural habitat, then extinction would decrease" (Kurland Participant #25)	3,84	0,869	1,11**	0,20*
Δ K5 You think it is important to conserve South Africa's frogs/toads		Nature's Valley	"Not just SA, but the whole world" (Nature's Valley Participant #88)	4,84	0,374		
		Covie	"We have to conserve what we have that belongs to us" (Covie Participant #3)	3,56	0,726	1,77**	
		Kurland	"I don't know if frogs are important or not" (Kurland Participant #20)	3,04	1,044	1,73**	0,50*
● K6 Frogs/toads are important for medical research		Nature's Valley	"I am unsure if they are used in medical sciences, but probably" (Nature's Valley Participant #72)	3,32	1,345		
		Covie	"I don't know much" (Covie Participant #9)	2,89	0,782	0,32*	
		Kurland	"What can a frog contribute with regards to medicinal research?" (Kurland Participant #25)	2,77	1,009	0,41*	0,12*
● K7 For each picture, can you react and say if you think it's likeable, gross, or scary? Frog 1		Nature's Valley	"What can a frog contribute with regards to medicinal research?" (Kurland Participant #25)	1,24	0,831		
		Covie		1,67	1,323	0,32*	
		Kurland	"He doesn't look pretty. He is big and rough"	1,36	0,620	0,15*	0,23*
● K8 For each picture, can you react and say if you think it's likeable, gross, or scary? Frog 2		Nature's Valley	"Eyes look too gross" (Nature's Valley Participant #89)	1,48	1,046		
		Covie	"Looks slimy" (Covie Participant #8)	2,00	0,866	0,50*	
		Kurland	"Not too bad. I can live with it" (Kurland Participant #64)	1,76	0,860	0,27*	0,27*

● K9 For each picture, can you react and say If you think it's likeable, gross, or scary? Frog 3	Nature's Valley	"Weird. A bit strange. It makes me feel uncomfortable" (Nature's Valley Participant #84)	2,24	1,393		
	Covie	"Big and scary" (Covie Participant #4)	2,89	0,782	0,47*	
	Kurland	"Heart attack-inducing. He (frog) is fat and big" (Kurland Participant #11)	2,95	0,448	0,51*	0,07•
● K13 Which of the three frogs are you most likely to conserve (1, 2, or 3)?	Nature's Valley	"Think they are very sensitive, immobile due to fossorial lifestyle" (Participant #82)	3,40	1,155		
	Covie	"I wouldn't conserve any" (Participant #7); "I can't decide" (Participant #90)	4,67	0,500	1,10**	
	Kurland	"It (frog 1) looks pretty, and our younger generations must still witness these animals" (Participant #18); "They aren't important for me" (Participant #38)	2,76	1,721	0,37*	1,11**

▪, Small effect size (Cohen's d) = 0.2

*, Medium effect size (Cohen's d) = 0.5

** , Large effect size (Cohen's d) = 0.8

Δ, Statistically significant (Table above)

●, Statistically insignificant (Table above)

Reaction to, recognition of, and likely conservation of *H. marmoratus*, *A. knysnae*, and *B. fuscus* (K7-K13). Participants were asked to look at pictures of *H. marmoratus*, *A. knysnae* and *B. fuscus* (all species present in the area) and give their impression of how they feel about the frogs by saying if they are "Likeable", "Scary", "Gross", or "Other". Afterwards they are asked if they recognise the species.

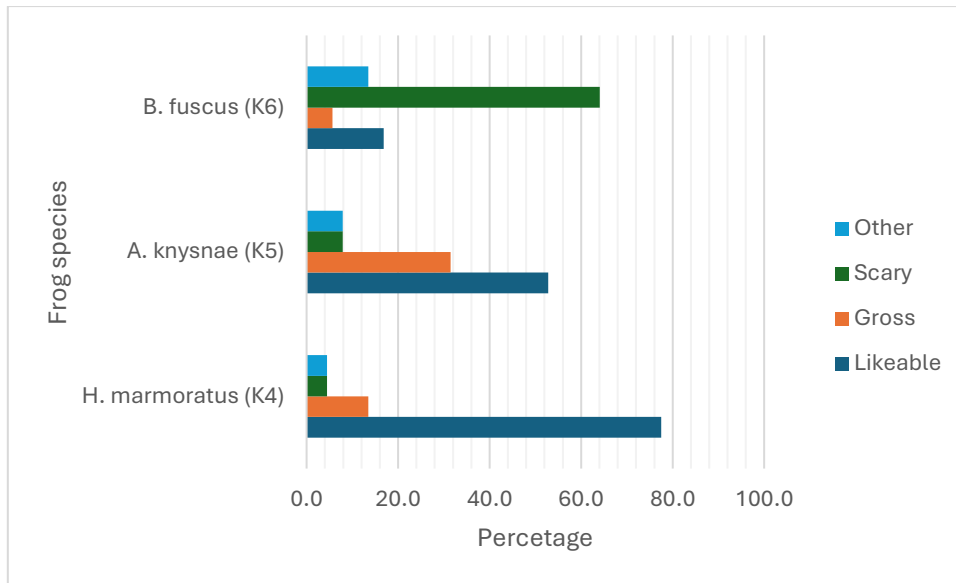


Figure 5-3: Reactions towards frog species: *Breviceps fuscus*; *Afrixalus knysnae* and *Hyperolius marmoratus* (K7-K9).

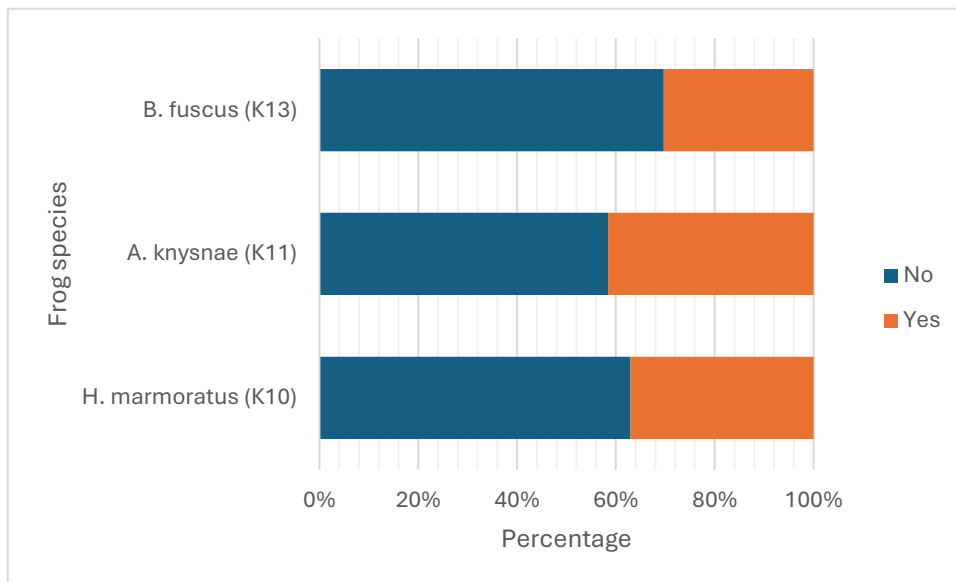


Figure 5-4: Recognition of selected frog species: *Breviceps fuscus*, *Afrixalus knysnae* and *Hyperolius marmoratus* (K10-K12).

As reflected in Figure 5-3, most participants (76.7%) found the reed frog to be “likeable” as opposed to 13.3% who described it as gross: “*He has cool colors*” (Nature’s Valley Participant #71); “*He doesn’t look pretty. He is big and rough*” (Kurland Participant #44). Generally, all communities “liked” this image: Nature’s Valley mean = 1.24; Covie mean = 1.67; Kurland mean = 1.36 ($F(2,86) = 1.012$, $p > .05$, partial $\eta^2 = 0.023$).

As reflected in Figure 5-4 above, most (41.1%) (mean = 1.37; SD = 0.49) participants recognised *A. knysnae* (K11), only 36.7% recognised *H. marmoratus* (K10) (mean = 1.42; SD = 0.5), and 27% recognised *B. fuscus* (K9) (mean = 1.3; SD = 0.46).

5.3.5 Section 4: Cultural beliefs and myths

Intended to uncover undocumented superstitions, misconceptions, myths, and cultural beliefs (i.e. "folklore"), the probing questions posed in this section revealed via a Likert scale (Table 5-8) a somewhat lowered presence of folklore and superstitions overall (Table 9) (mean = 2.14, SD = 0.19) with statistical significance confirmed as $F(2,87) = 23.104$, $p < 0.05$, partial $\eta^2 = 0.374$. The variance of 37.4% between participants' scores explains the d-value of 2.75 between Nature's Valley and Covie, 1.30 between Nature's Valley and Kurland, and 0.39 between Covie and Kurland (Table 5-9).

Table 5-8: Overall basic descriptive statistics of items intended to measure the Cultural beliefs and myths of the communities towards frogs/toads.

Internal Reliability = 0.812							
Item Code	Statement	Mean	Std. Deviation	Answer distribution (%)			
F1	Frogs/toads of South Africa are poisonous	2,69	1,09	Completely disagree	17.8		
				Disagree	22.2		
				Undecided	37.8		
				Agree	17.8		
				Completely agree	4.4		
F2	Touching frogs/toads gives you warts	2,16	1,24	Completely disagree	43.3		
				Disagree	21.1		
				Undecided	15.6		
				Agree	16.7		
				Completely agree	3.3		
F3	It is safe to collect water from rivers or dams where frogs/toads occur	2,94	1,40	Completely disagree	21.1		
				Disagree	18.9		
				Undecided	22.2		
				Agree	20.0		
				Completely agree	17.8		
F4	Frogs/toads cause lightning	1,63	0,94	Completely disagree	61.1		
				Disagree	22.2		
				Undecided	8.9		
				Agree	7.8		
				Completely agree	0		
F5	You should sprinkle salt on a frog's/toad's skin to kill it	2,27	1,27	Completely disagree	38.9		
				Disagree	24.4		
				Undecided	10.0		
				Agree	24.4		
				Completely agree	2.2		
F6	Frogs/toads spread disease to humans	2,24	1,02	Completely disagree	32.2		
				Disagree	20.0		
				Undecided	40.0		

				Agree	6.7
				Completely agree	1.1
F7	Frogs/toads attack humans	1,56	0,80	Completely disagree	57.8
				Disagree	34.4
				Undecided	3.3
				Agree	3.3
				Completely agree	1.1
F8	You should sprinkle salt on a frog's/toad's skin to kill it	2,00	1,27	Completely disagree	52.2
				Disagree	18.9
				Undecided	10.0
				Agree	14.4
				Completely agree	4.4
F9*	Frogs are an important figure in my belief system	1,78	1,25	Completely disagree	62.2
				Disagree	17.8
				Undecided	5.6
				Agree	5.6
				Completely agree	7.8

The internal reliability coefficient for questions marked with (*) were too low to be deemed reliable and these questions were initially removed from the dataset when determining the reliability coefficient. Results are still reported as the authors believe that valuable insight was found post analysis of these questions

Effect size between male (mean = 2.22) and female participants (mean = 2.17) was found to be statistically insignificant ($p > 0.05$; $d = 0.06$) and the practical significance negligible. Colored participants showed elevated levels of folklore and cultural views compared to white participants ($p < 0.05$; $d = 1.44$), while comparisons between English- and Afrikaans-speaking participants confirmed statistical significance ($p < 0.05$) and a medium effect size ($d = 0.56$). Demographic profiles such as age ($\rho = -.392$; $p < 0.05$), education level ($\rho = -.620$; $p < 0.05$), and connectedness to nature ($\rho = -.304$; $p < 0.05$) had a significant negative correlation, inferring that as age, education level, and connection to the environment (independent of one another) increase, a tendency towards superstitions and believing “old-women’s tales” would decrease. Thematic correlations calculated indicate that encounter frequency is not related to presence of folklore; however, significant negative correlations with liking ($\rho = -.624$; $p < 0.05$) and knowledge ($\rho = -.392$; $p < 0.05$) were observed, implying that as folklore increases, liking and knowledge will decrease.

Table 5-9: Multivariate statistical analysis of items intended to measure the Cultural beliefs and myths of the communities towards frogs/toads.

Item	Location	N	Mean	Std. Deviation	ANOVA p-value	Cohen's d Effect sizes	
						Nature's Valley with	Covie with
Folklore overall	Nature's Valley	25	1,50	0,44	F(2,87) = 23.104 p < 0.05 partial η^2 = 0.374	2,75**	0,39*
	Covie	9	2,71	0,23			
	Kurland	56	2,43	0,71			
	Total	90	2,20	0,75			
F1	Nature's Valley	25	2,56	1,227	F(2,87) = 2.48 p > 0.05 partial η^2 = 0.253	0,72**	0,80**
	Covie	9	3,44	1,014			
	Kurland	56	2,63	1,019			
	Total	90	2,69	1,098			
F2	Nature's Valley	25	1,20	0,707	F(2,87) = 14.236 p < .05 partial η^2 = 0.247	2,08**	0,44*
	Covie	9	3,00	0,866			
	Kurland	56	2,45	1,249			
	Total	90	2,16	1,244			
F3	Nature's Valley	25	4,20	1,225	F(2,87) = 19.988 p < .05 partial η^2 = 0.315	1,25**	0,19▪
	Covie	9	2,67	1,225			
	Kurland	56	2,43	1,142			
	Total	90	2,94	1,401			
F4	Nature's Valley	25	1,00	0,000	F(2,87) = 9.291 p < 0.05 partial η^2 = 0.176	1,14**	0,01▪
	Covie	9	1,89	0,782			
	Kurland	56	1,88	1,046			
	Total	90	1,63	0,942			
F5	Nature's Valley	25	1,48	0,823	F(2,87) = 7.668 p < .05 partial η^2 = 0.15	1,19**	0,08▪
	Covie	9	2,67	1,000			
	Kurland	56	2,55	1,334			
	Total	90	2,27	1,270			
F6	Nature's Valley	25	1,44	0,712	F(2,87) = 14.308 p < 0.05 partial η^2 = 0.248	1,61**	0,27▪
	Covie	9	2,78	0,833			
	Kurland	56	2,52	0,972			
	Total	90	2,24	1,020			
F7	Nature's Valley	25	1,32	0,852	F(2,87) = 4.436 p < 0.05 partial η^2 = 0.093	0,93**	0,69
	Covie	9	2,22	0,972			
	Kurland	56	1,55	0,711			
	Total	90	1,56	0,809			
F8	Nature's Valley	25	1,20	0,408	F(2,87) = 7.912 p < 0.05 partial η^2 = 0.153	1,31**	0,02▪
	Covie	9	2,33	0,866			
	Kurland	56	2,30	1,426			
	Total	90	2,00	1,272			
F9	Nature's Valley	25	2,76	1,739	F(2,87) = 7.912, p < 0.05 partial η^2 = 0.153	0,56*	0,46*
	Covie	9	1,78	0,972			
	Kurland	55	1,33	0,668			
	Total	89	1,78	1,259			

▪, Small effect size (Cohen's d) = 0.2

* , Medium effect size (Cohen's d) = 0.5

** , Large effect size (Cohen's d) = 0.8

Qualitative responses such as “I am not sure why, but I don't think South Africa has any poisonous frogs” (Participant #72) confirm overall uncertainty (mean = 2.69; SD = 1.1). Seemingly, both Nature's Valley and Kurland residents slightly disagree: “I believe they secrete poison causing allergy reaction if you swallow it” (Nature's Valley Participant #66); “Because I haven't heard of a person getting killed by a frog before” (Kurland Participant #15). Covie residents, on the other hand, slightly agree: “Certain frogs kill snakes (with poison)” (Participant #4) (Table 5-10).

Table 5-10: Qualitative responses of participants from respective communities that confirm large/medium/no practical significance for “Folklore” about frogs.

Item code/ Statement	Location	Qualitative answer (Location Participant #)	Mean	Std. Deviation	Cohen's d Effect sizes	
					Nature's Valley with	Covie with
F1 Frogs/toads of South Africa are poisonous	Nature's Valley	“I believe they secrete poison causing allergy reaction if you swallow it” (Participant #66)	2,56	1,227		
	Covie	“Certain frogs kill snakes” (Participant #4)	3,44	1,014	0,72**	
	Kurland	“Because I haven't heard of a person getting killed by a frog before” (Participant #15)	2,63	1,019	0,05*	0,80**
F2 Touching frogs/toads gives you warts	Nature's Valley	“My parents told me this when I was young but I don't believe it anymore” (Participant #72)	1,20	0,707		
	Covie	“I don't know or I am not a believer in that kind of stuff” (Participant #3)	3,00	0,866	2,08**	
	Kurland	“I don't think so” (Participant #64)	2,45	1,249	1,00**	0,44*
F3 It is safe to collect water from rivers or dams where frogs/toads occur	Nature's Valley	“Of course, it means it's healthy” (Participant 83)	4,20	1,225		
	Covie	“I use tank water, but it [river water where frogs occur] isn't healthy” (Participant #8)	2,67	1,225	1,25**	
	Kurland	“I enjoy a clean environment to drink water from and frogs	2,43	1,142	1,45**	0,19*

			<i>don't look clean"</i> (Participant #18)				
<i>F4 Frogs/toads cause lightning</i>	Nature's Valley	"Absolutely not true. Impossible" (Participant #70)	1,00	0,000			
	Covie	"Heavy rain causes lightning" (Participant #5)	1,89	0,782	1,14**		
	Kurland	"Lightning is naturally created, not through frogs" (Participant #33)	1,88	1,046	0,84**	0,01▪	
<i>F5 You should sprinkle salt on a frog's/toad's skin to kill it</i>	Nature's Valley	"Shame! Never, ever!" (Participant #68)	1,48	0,823			
	Covie	"This is inhumane" (Participant #6)	2,67	1,000	1,19**		
	Kurland	"I don't think it will work" (Participant #15)	2,55	1,334	0,80**	0,08▪	
<i>F6 Frogs/toads spread disease to humans</i>	Nature's Valley	"Unlikely. Never heard of it" (Participant #79)	1,44	0,712			
	Covie	"I don't know of any frog-flu" (Participant #9)	2,78	0,833	1,61**		
	Kurland	"For as long as I've lived, I have never heard of or seen frog diseases" (Participant #25)	2,52	0,972	1,11**	0,27▪	
<i>F7 Frogs/toads attack humans</i>	Nature's Valley	<i>Frogs I have seen would run away and never approach"</i> (Participant #76)	1,32	0,852			
	Covie	"Frogs are too small and scared of people" (Participant #9)	2,22	0,972	0,93**		
	Kurland	"They are scared of people and are too small" (Participant #46)	1,55	0,711	0,27▪	0,69	
<i>F8 Frog's/toad's skin to kill it</i>	Nature's Valley	"They can sense the change of weather but can't bring rain." (Participant #70)	1,20	0,408			
	Covie	"People say if frogs are killed then it attracts rain" (Participant #5)	2,33	0,866	1,31**		
	Kurland	"I am not myself convinced of this, but my mom says so" (Participant #29)	2,30	1,426	0,77**	0,02▪	
	Nature's Valley	"Not really but I love them! They shouldn't be	2,76	1,739			

<i>F9 Frogs are an important figure in my belief system</i>		<i>in soup!"</i> (Participant #68)				
	Covie	<i>"Not in my religion"</i> (Participant #3)	1,78	0,972	0,56*	
	Kurland	<i>"There is nothing in my culture that makes frogs important"</i> (Participant #21)	1,33	0,668	0,82**	0,46*

▪, Small effect size (Cohen's d) = 0.2

*, Medium effect size (Cohen's d) = 0.5

** , Large effect size (Cohen's d) = 0.8

△, Statistically significant

●, Statistically insignificant

Correlations between demographic variables effects the extent of perceptions and beliefs of participants towards frogs. Significant positive correlations between demographic variables such as age ($\rho = .631$; $p < 0.05$), education ($\rho = .566$; $p < 0.05$), and connectedness to nature ($\rho = .636$; $p < 0.05$) were observed. This suggests that as participants' age, have higher education levels, and connectedness to nature increase, so does their liking towards frogs. In addition, significant positive correlations with general encounters ($\rho = .299$; $p < 0.05$) and knowledge ($\rho = .672$; $p < 0.05$) were observed, and significant negative correlations with folklore ($\rho = -.624$; $p < 0.05$). This indicates that as the level of liking of participants towards frogs increases, so does frequency of encounters as well as knowledge of frogs (and vice versa), while negative correlations suggest that as the liking of participants towards frogs increases, folklore and superstitions towards frogs decrease (and vice versa).

These findings are supported by the responses to the open-ended question that revealed a lack of knowledge [*"I have no knowledge about frogs"* (Participant #50)] and a strong affiliation of frogs with snakes and/or rain [*"I am not really fond of frogs and snakes. Where a frog is, there a snake is too"* (Participant #3); *"If you kill a frog then it is going to rain"* (Participant #11); *"I heard frogs bring rain. Frogs give snakes their venom"* (Participant #40)] as emerging themes.

Responses to open-ended question: "Would you be willing to share any existing knowledge, beliefs, or superstitions you have regarding frogs?". The intention with this question was to uncover any childhood memories and/or opinions and behaviours that might have impacted participants' responses, and, by inference, the results obtained in this study. All responses were captured qualitatively and analysed thematically.

Childhood memories: Most respondents answered "None", yet the following themes emerged post-analyses:

- Playful childhood interaction: *“Caught frogs”, “Looked at frogs”, “Chased frogs”, “I always went with my cousin to look at frogs”; “We always caught frogs and played with them.”*
- Keeping frogs as pets: *“When I was small, we caught bullfrogs in Pretoria. Collected tadpoles and kept them at home”; “They were my pet when I was living on a farm as a child”; “I had a pet frog as a child for a while, but it didn't last for long.”*

Opinions and behaviours of parents/caregivers: Some participants were encouraged to discover nature: *“Parents always encouraged curiosity and zoology lectures with keen interest”* (Participant #79). Qualitative responses, however, also revealed a strong tendency towards upholding cultural beliefs and superstitions:

- Killing a frog will bring rain: *“If a frog dies then it will bring rain”* (Participant #10), *“I heard from my grandma that frogs bring rain”* (Participant #39); *“If people kill frogs, then it brings rain”* (Participant #5); *“I once killed a frog and then it rained that night”* (Participant #21); *“Just that when I killed a frog it started raining”* (Participant #61)
- Frogs attract snakes: *“When you kill a frog it will rain, and where there is a frog, there is a snake”* (Participant #13)
- Frogs cause warts: *“Causes bad omen; they cause warts and kill them with salt”* (Participant #21); *“If I touch them, I will get warts, but I know better now. I found the lifecycle interesting at school”* (Participant #72)

5.4 Discussion

This study on human-frog interactions aimed to quantify and investigate how people within a local area interact with frogs. It followed a concurrent, embedded mixed-methods research design with 90 participants agreeing to partake.

Demographic variables affecting the liking of frogs showed slight contrast to what is found in literature and may be the result of these studies being in different areas/at different scales (e.g. Tarrant et al. was done on a national scale) (Prokop et al., 2016; Tarrant et al., 2016; Vergara-Ríos et al., 2021). Culture and people’s perspectives towards frogs vary spatially and temporally. Gender played no statistically significant role; however, race and language (regarded by Anemone [2019] and Holme [2003] as constructs of culture) did play an important role. Covie and Kurland have similar culture constructs (predominantly Colored and Afrikaans-speaking), while Nature’s Valley is predominantly white and English-speaking. This supports the notion that cultural background strongly influences the tolerance of people towards frogs (Tarrant et al., 2016;

Brom et al., 2020) and can explain the practically significant differences between the disposition of Kurland and Covie residents versus Nature's Valley residents.

Regression analyses support the notion that tolerance of frogs can be improved in South African communities by way of physical encounters and experiential learning (Kruger, 2014; Tarrant et al., 2016). Even though variables between communities might be discouraging for a frog-focused conservation approach, previous endeavours proposed and tested by Tomažič (2011) and Tarrant et al. (2016) provide sufficient substantiation for further exploration and testing, provided certain dynamics are taken into consideration (such as certain community's willingness to learn more about frogs, for example. This is discussed below). It is also possible that liking frogs influences individuals' ability to better recollect memories of encounters with frogs. It is also possible that people who show a higher liking for frogs actively seek out encounters with them. This was not directly investigated in this study and is recommended to be studied in future.

Overall, the three communities showed low interest in learning more about frogs (mean = 2.42; SD = 0.35). Consequently, frog-focused education initiatives might have lower success rates than initially expected. "Connectedness to nature", which positively correlated with "liking" and "knowledge", could be used as a proxy for pro-frog behaviours by initially focusing on pro-environmental intentions (Brom et al., 2020). As Van der Werf et al. (2013) and Brom et al. (2020) pointed out, bio-spherical values determine pro-environmental behaviours, intentions, and preferences. Thus, educating people by increasing their self-identified "connectedness to nature" for the benefit of the environment could benefit frog conservation.

The results of this study support the notion that educational initiatives might have a positive effect: Nature's Valley residents show high "connectedness to nature" (mean = 4.56; SD = 0.69) as opposed to Kurland (mean = 2.61; SD = 1.1). Additionally, Nature's Valley residents show elevated liking towards frogs, while Kurland residents dislike frogs in general. Moreover, even though Nature's Valley residents do not know much about frogs, they are keenly interested in learning more about them which, again, strongly contrasts with Kurland participants' level of interest.

Participants showed strong affinity towards *H. marmoratus*, less affiliation towards *A. knysnae*, and strong aversion towards *B. fuscus*.² These reactions strongly correlate with the literature, namely that the charismatic features (texture of skin, size and color) displayed by frogs will

² *H. marmoratus* is an ornamental species widely spread all along the south and east coasts of South Africa, while *A. knysnae* remains restricted to areas around Knysna (De Lange, 2019). *Breviceps fuscus* looks naturally "grumpy", thereby creating the impression of an ugly frog.

determine how people react towards them (Ceríaco, 2012; Brom et al., 2020; Deutsch et al., 2020; Vergara-Ríos et al., 2021). Inevitably, people's reactions will affect their willingness to conserve certain frog species in appropriate ways. For example, *H. marmoratus* and *B. fuscus* present opposite charismatic features; therefore, participants showed a higher interest in conserving *H. marmoratus* than *B. fuscus*, and even *A. knysnae*.

Even though quantitative results showed a relatively low predisposition towards folklore, myths, and cultural beliefs overall, a thematic analysis of qualitative responses revealed a number of recurring themes of which two are of particular interest: *affiliation with rain* and *affiliation with snakes*. Given that folklore and cultural beliefs reportedly have strong predictive outcomes on frog conservation initiatives (Ceríaco, 2012; Tarrant et al., 2016; Brom et al., 2020; Deutsch et al., 2020; Farooq et al., 2021; Vergara-Ríos et al., 2021), it is of concern that beliefs such as “killing a frog and leaving it outside, belly-up, will call rain” are still being handed down from generation to generation. Furthermore, the common belief that “where there are frogs, there are snakes” may also cause unwarranted, and sometimes lethal, reactions towards frogs.

Interestingly, participants' responses to an open-ended question designed to probe any childhood memories as well as parental biophilia (Brom et al., 2020) that could affect their views and behaviours confirmed exposure to some other common myths that could cause fear: “frogs cause warts” and “a frog is a bad omen and should be killed with salt and left outside”.

Direct interactions with nature can influence and change people's attitudes towards nature, and there is a strong relationship between this and developmental benefits among children when exposed to nature (Soga and Gaston, 2022). A theory termed “nature blindness” could be applicable here, where people showing less liking or knowledge towards frogs have a natural tendency to be “blind” to noticing members of the taxa. The opposite may be true for those that show higher liking and knowledge towards frogs – individuals that like frogs have a higher tendency to hear and see frogs in the environment around them. Even though most participants had positive, playful memories of catching frogs and playing with them, participants from Kurland and Covie ended up disliking frogs. Seemingly, parental views on frogs slightly carried over into their adulthood, suggesting that there might be some dominating influences on participants' views that were not fully covered in this study. In this regard, Bouman et al. (2020) suggested that “the value of what others value” influences individual pro- and, possibly, anti-environmental motivations, beliefs, intentions, and actions. Individual bio-spheric values, and the notion to implement and live out these values, are strongly dependent on how the group individuals surround themselves with endorses their bio-spheric values. This could well be the case in

Kurland and Covie where positive and playful memories are slowly being substituted with the general demeanour of the community as a whole – a demeanour that tends towards amphibian aversion and slight hostility towards frog conservation (Van der Werf *et al.*, 2013; Bouman *et al.*, 2020).

This study adds to the body of evidence that the attitudes and intended behaviours of people towards frogs are largely culture-specific but still follow specific patterns. This confirms the discourse between South Africans' attitudes towards specific environmental concepts: Attitudes affect behaviour; education level, or extent of environmental knowledge affects attitudes; and cultural preconceptions or misconceptions also play a role in shaping beliefs, attitudes and behaviour (Tarrant *et al.*, 2016; Evert *et al.*, 2021; Brom *et al.*, 2020).

5.5 Conclusion

This study not only substantiates earlier findings with regard to human-frog interactions and conflict but also provides a detailed look into the different aspects of said interactions and how they are influenced by demographic profiles, cultural beliefs and myths, memorial background, and location specificity. In addition, the results highlight the importance of variability between community-specific views towards a matter where conservation intervention is required and emphasises the need to focus on how communities feel about proposed interventions. For example, if people are not keen on learning more about frogs, it could be beneficial “to take the long way round” by following a generalist approach to pro-frog behavioural change by focusing first on pro-environmental behaviour in general rather education about frogs as an initial approach.

Chapter 6: General discussion and conclusion

6.1 Introduction

This chapter discusses the study's overall research objectives and aims and summarises the main findings of each chapter that makes up the structure of this thesis. Herein aims and objectives are repeated for convenience, strengths and limitations are mentioned and future research recommendations are considered.

6.2 Research aim

The aim of this research project was to improve frog-focused research in the Nature's Valley area, in the Western Cape province, South Africa, by updating outdated species lists, contributing to knowledge on *A. knysnae* in the area for effective future protection, and investigating the prevalence of an emerging, and ominous topic in amphibian conservation research ; Human-frog interactions.

6.3 Research Objectives

Aims and objectives that were introduced in chapter 1 were successfully met by completion of the following milestones:

- Design and implementation of a Passive Acoustic Monitoring (PAM) plan enhances seasonal ecological investigations
- Improved understanding of the advertisement call of *A. knysnae* through statistical analysis.
- The breeding behaviour and tadpole development of *A. knysnae* is better understood.
- Investigating human-frog interactions and human attitudes to frogs of Nature's Valley communities contributes to conservation in the area.
- Information on the status of frog populations and conservation potential in the Nature's Valley area is provided to guide local conservation custodians.

6.3.1 Anuran community composition, habitat selection, seasonal variation and weather affiliation

This study made use of Passive acoustic monitoring to conduct surveys of amphibian vocalisations at scales from season to the hour. Frogs' primary method of courtship is through vocalisations which can also be correlated to preferred breeding seasons, weather conditions, reproductive fitness, activity and behaviours, etc. (discussed in Chapter 2). Enhancing this by

means of automated audio recordings that can be analysed using software applications such as Wildlife Acoustic's, Kaleidoscope® and Cornell University's Raven Pro®. Raven Pro proved to be extremely user friendly, easy to navigate and basic audio analysis was easily learnt from abundant YouTube videos (provided by K. Lisa Yang Center for Conservation Bioacoustics) and Reddit/GitHub posts. Although only Raven Pro was used to analyse PAM data, these applications allowed for easier analysis of "large" datasets. However, this study produced under 190 000 hours of recording data across three SM-recorders. This totalled over three terabytes (TB) of recording data that contained five- to 15-minute recordings of each hour for 24 hours from June 2023 to June 2024. Although these applications made it easy for large dataset analysis, it remains ineffective for analysis of "largest" datasets. Compromise was required for time-effective and justifiable completion of successful analysis of this dataset and data had to be excluded (but not destroyed) from the analysis process.

Most PAM-focused projects end up with similar complications – seemingly unlimited sets of recordings and no means to analyse them without making it a full-time job. Automated analysis of such datasets has been explored but remains largely limited to bird acoustic analysis. The same principles should be applicable to frog acoustics, given substantial adjustments are made to variables. Such analysis was attempted for this study but required specialist training in this field that sought too much time to complete just one component of this thesis. It should be mentioned that PAM has the ability to produce unmatched bioacoustic resolution (acoustic recordings spanning over time) and automated analysis of large datasets in this instance should become the next discipline to master. Since the emergence of artificial intelligence (AI) in the 90's, this technological advancement has grown more in the last two years than in the past three decades. Countless machine-learning templates exist, compatible with many different coding languages and applications. Prompt engineering is now as simple as giving a verbal instruction, and online assistance on the topic of AI is globally open source. Opportunities for developing automated frog chorus analysis are now more abundant than ever, and greatly overdue. However, hypothesis creation that intend to make use of PAM should take time in familiarising already available automated analysis methods and ask, "I have this hypothesis, what is the best way to analyse it?", rather than "I have this new shiny method, what can I do with it?". Nevertheless, PAM enabled production of updated amphibian diversity lists and calling preferences of different environmental conditions. This proves useful to conservation organisations as discussed later.

6.3.2 Status and future of *A. knysnae*

Afrivalus knysnae is referred to as a cryptic species that shares similar morphological and vocal features as the non-sympatric *Afrivalus spinifrons*. Calling activity of this species remains largely

isolated towards the end of the winter months (August - October) – a chorusing legacy of the first spring rains – and call detection didn't seem to be challenging during these times. Utilisation of R-studios as a means of acoustic analysis deemed successful, yielding results as accurate as dedicated call-analysis software would yield, all while producing visually appealing (and easily interpreted) graphs, spectrograms and oscillograms. From this it was concluded that *A. knysnae* vocalised through a two-part call that is used in isolation and/or in conjunction with each other. Both calls, Call A and Call B, were observed to have differing behavioural purposes and are used under different male-male and male-female interactive conditions – dictating the use of isolated calls or combined calls. Analysis showed that Call A ranged between fundamental (FF) and dominant frequencies (DF) of approximately 1500 Hz and 3200 Hz, and Call B between FF = 1700 Hz and DF = 3400 Hz, conclusions similar to what was found (with minor differences) by De Lange (2019) that used Raven Pro as their primary means of call analysis. Both calls were also described as having their own respective presence and/or absence of amplitude and frequency modulation and being classified as “pulse-repetition” (Call A) and “spectrally structured pulsatile” (Call B) calls based on note/pulse lengths, repetitions rates and structures.

Previous, but recent, studies on this species discussed events of complete habitat destruction where healthy populations of this species occurred in the Goerge and Knysna area. Due to this species showing no activity during months between March and late August (as well as being notoriously difficult to locate when vocally dormant) causes them to easily be overlooked by Environmental Assessment Practitioners (EAPs) and Researchers/Conservationists during non-active months or during dry years. During this study, various specialists of this species and of the area was contacted for insight and guidance. It was quick to realise that one of the larger active populations of this species used in this study was previously dormant (virtually undetectable and thought to be displaced) due to below-average rains – and builds on the crypticity of this species and importance of thorough specialist reports. Furthermore, it was previously thought that this species was primarily a Fynbos-habitat inhabitant but showed great adaptability towards invasive species and novel nesting (leaf-folding) opportunities. During this study it was concluded that, yes, this species makes use of various leaf and vegetative types for leaf-folding (which is primarily determined by pliability, distance relative to water level, and robustness of leaves and not invasiveness), but wasn't confined to Fynbos biomes. Activity was observed and recorded in habitats that formed part of Fynbos-forest ecotones, forest riverine and coastal forest habitats and suggests that this cryptic species might be more abundant than initially thought.

The latest IUCN Red-list assessment placed this species under the Endangered category with the criteria B1ab(i,ii,iii,v)+2ab(i,ii,iii,v) (see Chapter 1) (IUCN 2016) suggesting fragmented, low-

level of occupancy populations across a very limited (less than 5000 km²) range. Despite its Endangered status, this species occurs in several protected areas (PAs) and appears to utilise a variety of available habitat types. A re-assessment of this species' status is currently underway and will contribute to the next National Biodiversity Assessment, which provides an indicator of the effectiveness of PAs for amphibian conservation. Caution must be taken to not use this as a reason to neglect future research and conservation opportunities regarding this wonderful and unique species.

R-studios proved (through trial and error) valuable in call analysis and description of the target species' call in this thesis. As discussed before, graphic outputs are clean, visually appealing and flexibly adjustable to the user's desires. The coding language of R is straight forward and easily deductible for newcomers to the software. All packages used in R are free to use and is installable through a single-line of code and includes "Help" directories for any uncertainties regarding purposes of functions within packages (Example function *spec()* of package *Seewave*). The strength of using this application and language was thorough analysis of the calls of the Knysna leaf-folding frog and producing excellent graphs of spectral and temporal properties of calls. The application used to execute the R coding language is widely referred to as "user friendly". This is true to some degree, given users have (at least) initial and minimum coding experience. Any code in R required for specific purposes users intend to use is a Google search away, but it remains important to understand basic terms, functionality and definitions used in this field of expertise to effectively execute intended codes for its intended purpose. It also occurred that on one day code would work flawlessly, producing excellent, publication grade outputs and the next day returning errors of incompatibility to the device used or unrecognised characters in the codes used – all while no margins of measurements were changed and the exact same code was used as before. In addition, certain code lines are compatible with each other while others aren't and suggests cooperation between bioacousticians and programmers in future work.

Nevertheless, leading bioacoustic analysts in R developed a novel package named *Rraven* (Araya-Salas, 2022) and facilitates the combination Raven Pro software within the interface and analytical power of R-studios. As discussed in Chapter 3, substantial training is required for implementation of this package (and other powerful packages). This package was attempted to be used due to relevance and outstanding analytical potential. Developers of *Rraven* were contacted for support and assistance and agreed to help given a fee of \$250 were to be paid. An unfortunate response that was not considered. It is worth mentioning that once relevant code was mastered further analysis worked smoothly. The limitation with this software was primarily that self-taught skills took much time but was possible without much direct specialist intervention.

6.3.3 Tadpole development and breeding behaviour of *A. knysnae*)

Breeding behaviour of *A. knysnae* showed typical, expected behaviours from the genus (introduced in Chapter 1) – being utilisation of small-leafed vegetation for the formation of small, enclosed egg-clumps believed to protect eggs from predators. Field observations revealed inter- and intra-specific behaviours that contributes to understanding of this species niche positioning. Interestingly, physical bouts of advertising males among each other are extremely rare and wasn't witnessed during this study. Physical encounters do seem more likely towards non-similar species. In this instance one calling *A. knysnae* male was quick to engage a Painted-reed frog (*Hyperolius marmoratus*) male approaching his calling position – a behavioural profile that presented with an audible change in calling pitch (and sounds temporally similar to Call A. see Chapter 4) and hostile orientation towards the intruder that lead to kicks, headbutts and pushes from the *A. knysnae* male towards the *H. marmoratus* intruder. Process of amplexus seems straightforward. Males select calling positions that overhang adequate waterbodies (Forest populations) or are clear of close, overhanging or tall vegetation (Fynbos populations). Most interesting and unexpected behaviour was advertisement calling from within tree canopies at least 10–20 meters high. The process of amplexus is straightforward where females initially approach calling males to investigate. Interested females would hang around until amplexus is complete, but uninterested females move on to the next calling male. Successful egg-sheath formation was not observed and suggests that amplexus could last up to 8 hours or longer.

6.3.4 The rule of thirds of human-frog encounters: Culture, Willingness and the Community

Using a concurrent (one-phased) embedded mixed-methods research design for the investigation of human-frog interactions in the Nature's Valley area it was possible to determine the level of tolerance, existing knowledge, present/absent folklore and cultural beliefs and extent of parental influence on views and feelings local communities showed pertaining to frogs. Quantitative probing enabled establishment of socio-demographic stance, and levels of affiliation (likability, knowledge, encounters and response, folklore) of participating inhabitants. Qualitative probing and open-ended questions allowed for revelation of reasoning behind the way people react the way they do, what they believe, what they do during frog encounters and where, how or why they inherited the beliefs they exhibit. As such, socio-demographic profile, the influence of the aesthetic appeal of frogs, behaviours of people in an encounter with frogs, cognition or what people think they "know" about frogs, and culture and religion are five dominating themes that formed the focus of this chapter and is believed to influence the dynamic of human-frog interactions in South Africa.

The objectives set out for this chapter were successfully met. It was concluded that the socio-demographic profile of all three communities in the area (Nature's Valley, Kurland and Covie) presented cultural polarisation. Race (or ethnicity) and language (any of the 12 recognised languages in South Africa) were the dominant culture-defining constructs (also forms part of socio-demographic stance) used in this instance, where Covie and Kurland showed overwhelming Afrikaans-speaking Colored residents and Nature's Valley showed overwhelming English-speaking White residents. Polarisation presented with statistically significant and strong practical differences between cultures' response to frogs and agrees with what is found in literature. Interestingly, other socio-demographic categories tested statistically insignificant towards views on frogs which comes into disagreement with what is largely available in literature.

From this it was found that both liking and knowledge of participants towards frogs in the three communities differed significantly between each other. Effect size indicated that Nature's Valley showed more liking, knowledge and willingness to learn more about frogs, and Covie and Kurland indicated low scores for these themes. Quantitative scores indicated low to medium, insignificant scores for "Cultural beliefs and myths" between the three communities (effect size suggested Nature's valley with the lowest score and Covie with the highest), yet qualitative probing revealed themes "Killing frogs cause rain", and "Frogs cause warts" – common beliefs among South African citizens. Aesthetic appeal (ease to look at or to behold) of frogs determined participants' willingness to conserve frogs. Three local and indigenous species of differing color vibrancy, skin texture and body size showed differing responses from participants, where smaller, smoother and more colorful frogs (Reed frogs) were most liked than that of big, rough and dull frogs (Toads and rain frogs) for these communities. In instances where people encountered frogs, most participants from Kurland and Covie suggested lethal action towards them (mentioning bad luck, calling rain and presence of snakes) suggesting revulsion, where Nature's Valley expressed sympathy (for being close to humans), admiration and fascination.

It was therefore concluded that, taking other literature into consideration, that human-frog interaction is sensitive to geographic, cultural, and socio-demographic community dynamics. Literature in South Africa suggests conservation-focused intervention at primary-(Middle) school and high-school levels (Prokop *et al.*, 2016; Tarrant *et al.*, 2016; Brom *et al.*, 2020), yet here it is evident that (from qualitative probing) positive childhood memories and beliefs towards frogs are slowly substituted by the belief of the community overall – lethal action expressed as adults (The value of what others value). Willingness of Covie and Kurland (where anti-frog behaviour is most evident) participants to learn more about frogs and to conserve them is low. A holistic approach is necessary to initiate frog conservation in these areas by increasing the communities' fondness

and affiliation towards the natural world that surrounds them – and then focusing on the components that make up this environment, such as frog-focused education and conservation initiatives.

6.4 General Conclusion: Recommendations to SANPARKS and NVT Tsitsikamma NPC

The overall goal of this thesis is to provide SANPARKS and NVT Tsitsikamma NPC information on the status of frog species in the respective PAs. These recommendations aim to support the conservation and management goals of SANPARKS and NVT – representatives and guardians of this area.

The surveys conducted through this study produced an updated amphibian species list, which provides a baseline understanding of frog species diversity and distribution in the area. Knowledge generated on habitat selection offers insight into specific habitat and microhabitat preferences of the various frog species in the area. Circadian call patterns, seasonal activity and weather affiliation opens opportunities to understanding breeding behaviours, peak activity periods and highlights weather influences on the survival of different species – linking to climate change research and intervention opportunities. Conservation value gained from this information includes identification of species of concern (endemic or threatened species) which hopefully promotes conservation action and opportunities for habitat management programs (crucial habitat protection, habitat restoration and areas under anthropogenic threats). Activity patterns assist in timely scheduling of effective population monitoring and data collection, guides timing of conservation interventions that coincide with critical life-cycle events and allows organisations to pre-emptively respond to climate-change crises. Application of these findings could prove valuable for informing data-driven decisions, leading to more effective and sustainable conservation efforts.

Information produced from research conducted on the Endangered Knysna leaf-folding frog could provide NVT and SANPARKS with (a) detailed acoustic characterisation for the improvement of population monitoring, (b) offers critical insight into the species' reproductive ecology (timing, habitat preference and environmental cues for breeding), (c) documents tadpole growth rates, survival rates and requirements (and highlights factors crucial for successful tadpole metamorphosis), and (d) highlights the role of protected areas in threatened species conservation given adequate action is taken by relevant parties. This enables and encourages the use of remote surveys (PAM) for more effective detection of species in areas difficult to reach, contributing to distribution patterns inside and outside PAs. Information generated from this could vouch for adequate habitat restoration and protection, all while identifying threats to the longevity

and validity of breeding populations and already developing juvenile stages (taking water quality, predation and weather into account). Seemingly flourishing populations in PAs demonstrates the effectiveness of conservation measures within PAs (even if focused elsewhere), justifying continued funding and management efforts. The challenge outside PAs, though, are to reveal gaps in species distribution and conservation coverage and to encourage strategies that engage communities and landowners regarding the needs of this species all while the human world continues to expand and develop. Hopefully balance and resource allocation is promoted by focusing on areas where populations continue to rely on conservation intervention.

Understanding how frogs and humans interact with each other holds immense conservation potential that could be applied to other ethnobiological-related issue in the area, and more broadly. Information gained through this study provides an improved understanding of which human activities mostly impact frogs in this area – and which actions cause most harm. Cultural and socio-demographic insight highlights possible pro- or anti-frog related behaviours, such as lethal action (as a result of folklore), or dependence on them for pest control. Understanding these dynamics provides opportunity to intervene during conflicting situations – for example where people feel unconsidered due to chorus noise during nights. Considering how these themes interchange between each other could assist in guiding education campaigns based on what the community presents, to enlighten communities in terms of ecosystem services frogs showcase, and to foster/steward coexistence by promoting non-invasive practices that protect both human-interests and frog populations. Stakeholder engagement and policy influences provide practical measures for habitat stewardship and sustainable land use, all while involving local communities, schools and policy makers for frog conservation, given processes are guided by what empirical results provide. Conservation benefits by promoting habitat connectivity in this already highly fragmented area (outside the PA), by prioritising areas based on biodiversity hotspots and encouraging local participation in citizen science programmes – something NVT is already very good at in bird- and coast-related research/conservation. This strengthens local efforts (equips local organisations for intervention), enhances awareness (educates communities on cause and affect) and provides detailed data and actionable plans for grant proposals (further research support). In this regard, the gap between scientific research and practical, community-based conservation is breached and ensures long-term frog benefit while also taking community livelihoods, needs and desires into consideration.

This thesis provides a foundation for initial frog conservation action in Nature's Valley through investigating current amphibian diversity trends, habitat selection (concise yet insightful) and vocal activity across multiple variables affecting frogs of Nature's Valley. Attention is focused on

the only threatened amphibian species in this area, and expanding again towards real-world, anthropogenically relevant problems that cause reason for action in a rapidly changing, nature-neglecting, hostile world. The recommendations emanating from this thesis are data-driven, applicable and achievable so long as they are collaborative . The greater Nature's Valley area, or The Craggs, is highly fragmented by livestock practices, farms and timber plantations. Large stands of Black Wattle (*Acacia mearnsii*) and Bramble (*Rubus sp.*) pollute the natural landscape. Considering that agriculture practices and invasive species are some the most prevalent threats to amphibians in South Africa, gives weight to acting on these threats in the area. Conservation actions will predominantly include notification of local landowners (the private sector) and possible inclusion of political involvement. The situation *A. knysnae* faces could be used as a motivation for local community involvement and upliftment through job creation and/or educational opportunities. These opportunities should explore possibilities of employing – and empowering – surrounding landowners to act as willing stewards for threatened populations within their property boundaries; by facilitating improved grazing and fire management (Kraaij *et al.*, 2013). Politically involved people have the power to implement alien vegetation clearing as job creating opportunities. *Acacia mearnsii* produces good firewood, and cleared vegetation can be used as fuel for local informal communities for heating and food preparation. Improved fire management not only benefits the surrounding fire-sensitive fynbos but also protects rural communities within these systems. Conservation of our unique wildlife isn't a one-sided relationship: hard work is always rewarded. What a reward it will be if we can live in harmony with a biodiverse world!

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Appendices

Appendix A

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 OPEN ACCESS 

A mixed-methods study on human-frog interactions in Nature's Valley, South Africa

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ABSTRACT

Despite their ecological significance, frogs receive far less public support and funding for research and conservation than that afforded to more charismatic animals. An emerging perspective suggests that conservation success is dependent on understanding the cognitive, emotional, and behavioural aspects that impact attitudes and behaviours towards biodiversity. This mixed-methods study attempted to shed light on how three communities in the vicinity of Nature's Valley in the Western Cape province of South Africa, perceive, interact with, and consider the protection of frogs. Overall, the three communities slightly disliked frogs, however, geo-specific variability between demographic profiles, cultural beliefs and myths, and memorial background evidently strongly impact human-frog interaction and willingness to tolerate and protect them. This complex interplay between cultural and personal factors, as well as grouped bio-spherical values, led to the conclusion that to ensure the success of frog conservation efforts, a generalist approach to pro-frog behavioural change should be followed by focusing on pro-environmental behavior in general first rather than attempting to change a specific aspect of human-frog interaction from the outset.

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Introduction

The importance of frogs and their usefulness as indicators of environmental health cannot be denied (Şişman et al. 2021), but despite being the world's most threatened group of vertebrates (IUCN Red List 2024; Leudtke et al. 2023), they are not afforded commensurate research and/conservation attention (Gillespie et al. 2020). This is presumably because frogs are not as appealing (i.e. visible or likeable) as other groups of animals (Botts et al. 2011). Indeed, people in some cultures fear or actively dislike herpetofauna. Such

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attitudes can strongly influence conservation effectiveness (Ceríaco 2012). Consequently, soliciting public support for conservation efforts is difficult, with research interest and funding often lacking (Tarrant et al. 2016).

During the past decade, frog-related research has focused mainly on historical data evaluations (Escalona Sulbaran et al. 2019), predictive and niche modeling (Sopniewski et al. 2022), genetic analyses (Shaffer et al. 2015), and the effects of various spatial and temporal variables on the genetic integrity of specific frog species and populations (Hu et al. 2019). Frog-related conservation efforts, on the other hand, typically focused on built and natural habitat management (Simpkins et al. 2021), conservation prioritisation programmes (Gillespie et al. 2020), species interactions (Sabagh et al. 2017), amphibian pathology (Fisher and Garner 2020), and species-focused conservation (Lewis et al. 2019). Despite these efforts, frog populations continue to decline globally with almost 60% falling into extinction-risk categories (IUCN 2024), which is a clear indication that more adaptive approaches to understanding and conserving frogs need to be developed and tested.

Some authors are of the opinion that the main reason why conservation efforts are not as successful is because not enough attention is paid to human-frog interactions, specifically how people think (cognition and perceptions), feel (emotions and attitudes) and, ultimately, behave (intentions and actions) towards frogs (Tarrant et al. 2016; Brom et al. 2020; Soga and Gaston 2020).

Studies that have focused on this aspect reveal that several socio-demographic variables impact human-frog interactions. Vergara-Ríos et al. (2021) found that positive and negative perceptions varied across the urban-rural gradient of the Colombian Caribbean and concluded that education specifically plays an important role in human behaviours and attitudes towards frogs. Prokop et al. (2016) found that young females in Turkey, Chile, South Africa, and Slovakia are normally more tolerant of frogs than their male counterparts. In the South African context, Brom et al. (2020) found a strong correlation between childhood experience (significantly impacted by the opinions and behaviours of caregivers) and how children think, feel, and behave towards frogs later in life.

Behaviour towards frogs also appears to be influenced by their aesthetic appeal (Vergara-Ríos et al. 2021). In other words, people's liking of frogs is influenced by their "looks" with reference to a frog's skin texture, colour and size. For example, in Turkey, Chile, South Africa, and Slovakia it was found that even though high school learners view frogs with a particular level of disgust, they displayed non-lethal tolerance towards "prettier" frogs (Prokop et al. 2016; Taylor 2018).

On a behavioural level, people also seem to display certain reactions when they encounter frogs. In some regions amphibians are persecuted and killed for social and ethnic reasons; because they are perceived to be uglier (and less useful) than fish, birds, and mammals; and due to people's phobias (Brom et al. 2020; Rabbe et al. 2021). Aversion behaviours are also witnessed widely as people commonly believe that touching frogs would result in the contraction of skin warts (Jiménez 2014), that they are filthy (Rabbe et al. 2021), or that they will cause infections (Brom et al. 2020). Other behaviours towards frogs include getting rid of the frog by either taking it outside or covering it with salt to inevitably kill/get rid of it (Brom et al. 2020) or to combat beliefs regarding bad omens. Non-lethal behaviour includes rescuing frogs from domestic pets, dousing them with water to prevent dehydration, using them to scare people, and taking them to a pond/dam or natural habitat "where it belongs" (Kruger 2014).

On a cognitive level, in general, people's knowledge regarding frogs is strongly influenced by cultural beliefs, such as "knowing" that frogs cause warts or that all frogs are dangerous and poisonous/venomous. Recognition of frogs also seems to be culture-specific. For example in China, participants could correctly name and recognise most toad/frog species used to test their knowledge of frogs (Jiménez 2014), while in the Colombian-Caribbean study, participants' knowledge was poor and they could not recognise or name more than two local frog species according to local or scientific standards (Vergara-Ríos et al. 2021). In the highlands of KwaZulu-Natal, the easternmost province of South Africa, knowledge regarding frogs was so limited that people failed to recognise vocalising frogs at night and identified them as chirping insects (Phaka et al. 2019), despite that province having the highest frog diversity in the country. Knowledge of frogs is determined by a culture's utilisation and experience of frogs (Jiménez 2014; Brom et al. 2020).

Given that how people think, feel, and behave towards frogs is often underpinned by their beliefs, another important factor to take into consideration is cultural beliefs and religion (e.g. superstitions and folklore). In the literature, this is the human-frog related topic that has been well explored. Studies in South American countries such as Argentina, Brazil, and Uruguay, for example, showed that cultural beliefs and local folklore (e.g. frogs are evil/venomous/dangerous) strongly impacted human-frog interaction, while in Asian countries such as Bangladesh, ancient misconceptions and myths hold that killing a frog/toad will cause night terrors (Rabbe et al. 2021). Perhaps, some of the strongest links between cultural beliefs and behaviour towards frogs occur on the African continent:

- In north-east Ethiopia, superstitions and associations with bad omens lead to the unnecessary killing of frogs (Kassie 2020);
- In Tanzania, local farmers use frog activities and calling behaviours as environmental predictors of rainfall events to aid agricultural practices (Elia et al. 2014);
- Local communities in northern Mozambique believe that the African Bull Frog (*Pyxicephalus edulis*) is more dangerous than the Mozambique Spitting Cobra (*Naja mossambica*) (Farooq et al. 2021);
- In the highlands of Lesotho, communities believe that specific species can communicate with humans (Mokuku and Mokuku 2004);
- In South Africa, many IsiZulu-speaking communities believe Grass Frogs (*Ptychadena*) call or attract rain and that the Africa Clawed Frogs (*Xenopus leavis*) fall from the sky during rains (Phaka et al. 2019).

Interestingly, Botts et al. (2011) found that people's interactions with frogs appear to be more prominent in countries where species richness strongly correlates with higher human population densities. Given that approximately 135 frog species (Du Preez and Carruthers 2017) co-exist with a population in excess of 60 million, South Africa is an ideal place to study human-frog interactions to understand how people think, feel, and behave towards frogs.

The aim of this mixed-methods study on human-frog interactions was to quantify and verify how people interact with frogs to derive new knowledge that could ultimately benefit the conservation of frogs and unlock new research opportunities, especially from a human/social/behavioural perspective.

Methodology

Study area

The study was conducted in Bitou, a municipality within the Western Cape, South Africa, with a specific focus on an area known as “The Craggs” situated approximately 30 km from Plettenberg Bay. Three different communities within this area were targeted: Covie (a small, isolated rural village with 30 households), Kurland (a small township with approximately 1 050 households), and Nature’s Valley (a predominantly tourist village with 70 out of 400 houses occupied on a permanent/semi-permanent basis) (Figure 1).

Approach and strategy

A concurrent, embedded mixed-methods research design (Figure 2) guided this study. As demonstrated by Fetters et al. (2013) and Gelo et al. (2008), this approach to sampling and analysis is desirable since more insight and understanding towards the matter under investigation can be gained as opposed to simply sampling, analysing, and interpreting quantitative and qualitative data in isolation.

Accordingly, embedded refers to quantitative, and qualitative data being collected simultaneously where the latter was used as an embedded secondary subset to describe the overall characteristics of the initial quantitative data and to provide clarity and context in relation to emergent findings stemming from the survey.

Procedure

Having obtained ethical clearance from the North-West University (NWU-01317-23-A9), goodwill permission to conduct the study in the three communities was obtained from their local leadership, who also acted as gatekeepers to the communities. Questionnaires

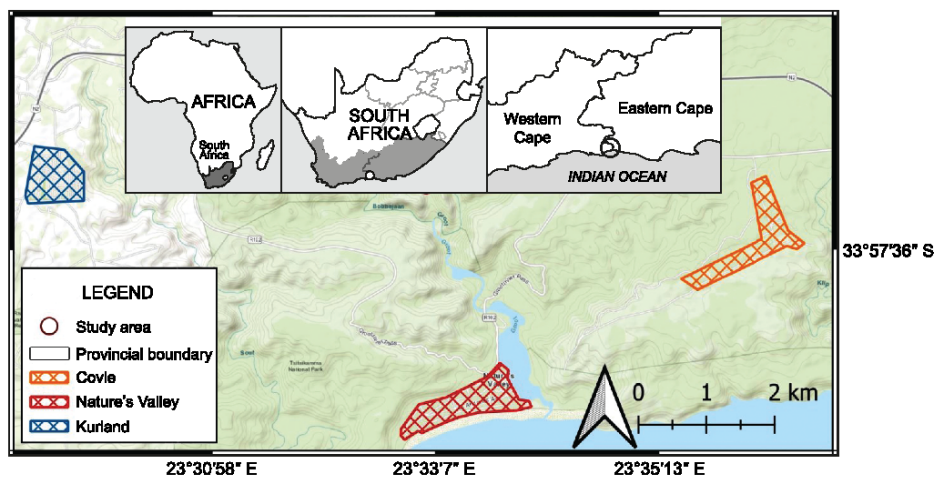


Figure 1. Map of overall study area. Coloured polygons represent the area of each studied communities – being Nature’s Valley (red), Covie (orange) and Kurland (blue).

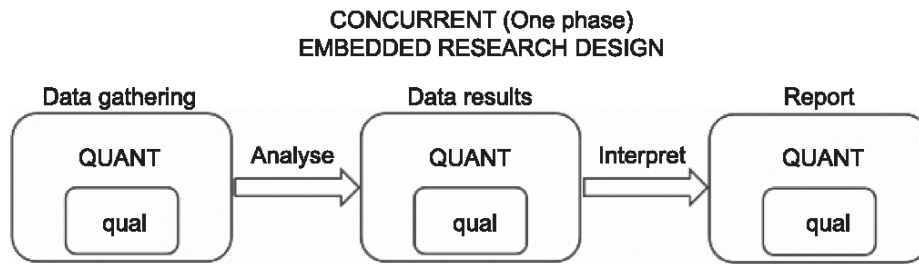


Figure 2. Study design of a concurrent, embedded mixed-methods approach. Qualitative data serves as secondary subsets (descriptive nature) of quantitative data, but is collected simultaneously with each other.

were deployed with the aid of three remunerated, trained fieldworkers, and care was taken to ensure that no overlap or duplication occurred during fieldwork.

Most interviews lasted no more than an hour and were conducted at participants' place of residence and followed all protocols with regards to obtaining informed consent, explaining the nature and aims of the study, and informing participants about potential risks/benefits and their rights to withdraw without penalty.

Quantitative data gleaned from questionnaires that met the researcher's standards for completeness and correctness (sober answers and completed questionnaires) were captured and sent to the North-West University's Statistical Consultation Services for analysis. Following analysis and interpretation of the data, findings from the quantitative and qualitative phases of the study were integrated and will be presented below. Qualitative answers were written down by the interviewer.

Data gathering

A questionnaire designed and developed with the intent to cover four themes that might have a bearing on human-frog interactions was used to gather quantitative and qualitative data simultaneously. The themes were mostly adopted from Tarrant et al. (2016) and Brom et al. (2020); however, some questions were modified or added based on studies conducted by Phaka (2020) and Kruger (2014). All questionnaires were administered verbally by fieldworkers who recorded the responses.

To reveal any cultural beliefs, superstitions, and understandings that participants have towards frogs that might not be revealed in their responses, an open-ended question was included: "Would you be willing to share any existing knowledge, beliefs, or superstitions you have regarding frogs?" According to Tarrant et al. (2016), underlying beliefs dictated or determined by memories of childhood experiences can significantly impact perceptions and behaviour towards animals in later life. Therefore, as per the study conducted by Brom et al. (2020), respondents were also asked whether they have any strong memories of encountering frogs when they were children as well as whether they have any memories from their childhood of a teacher or parent that told them something specific about frogs that they want to share.

The four themes broadly dealt with participants' (1) fondness and toleration ("Liking") of frogs, (2) frequency of encounters with frogs and typical response to such an event ("Encounters"), (3) knowledge of and willingness to learn more about frogs ("Knowledge"),

and unrecorded superstitions that might impact participants' attitude towards frogs ("Culture, beliefs, and myths") (see Table 2).

Except for statements E1, E2, E3, and K7 to K13 (See Table 2 for descriptions), participants were required to answer questions on a five-point Likert scale (1 = Completely disagree; 5 = Completely agree).

In the case of questions K10–12, participants were shown a picture of a Painted Reed Frog (*Hyperolius marmoratus*), the Endangered Knysna Leaf-folding Frog (*Afrixalus knysnae*), and a Plain Rain Frog (*Breviceps fuscus*), respectively, and asked to indicate whether they think the specific frog species is "likeable", "scary", "gross" or "other". Since Ceriaco (2012) holds that negative values, such as unsightly appearance, directly influence the conservation prospects of herpetofauna, a modified approach as proposed by Brom et al. (2020) was used to inquire whether participants had seen the frogs before, and which frogs they are most likely to conserve (support conservation efforts) to test this hypothesis. The qualitative component involved asking participants after each question to explain/add details as to why they think, feel, and behave towards the species in a certain manner.

Data analysis

Captured quantitative and qualitative data were analysed separately, but the results were interpreted as concurrent subsets of one another. Initially, Cronbach's alpha coefficient for internal psychometric reliability between scales ($0.00 \geq \alpha \geq 1.00$) (Tavakol and Dennick 2011) was tested before further basic and intermediary statistical analysis to identify scales that could potentially affect uniformity and credibility. Further analysis included the computation of basic descriptive statistics (means, frequencies, and standard deviations), correlations and differences (i.e. ANOVA, *t*-tests) and effect size (Cohen's *d*) for differences between means.

In terms of quantitative data, Cronbach's alpha was applied to validate internal reliability per section. Measured on a scale of between 0 and 1 (Tavakol and Dennick 2011), the psychometric internal reliability coefficient attained for the section "Liking" was 0.882; 0.712 for "Knowledge"; and 0.812 for "Folklore" which, according to Taber (2018), vary between robust (0.81) and good (0.71).

As per Field (2005), ANOVA and *t*-tests were set at a *p*-value of $p < 0.05$ to derive inferential deductions on the mean differences between the three communities: Covie, Nature's Valley, and Kurland. This enabled the investigation of the significant/practical effect demographic variability had on participants' behaviour towards frogs and to determine which of the means were different based on post hoc tests (Brown 2005).

Qualitative data was analysed thematically by means of open coding followed by axial coding (Creswell and Poth 2016; Tracy 2019). The patterns or groupings based on conceptual similarities thus derived were then each assigned an overarching theme based on their interrelationship.

Note that in this study, data pertaining to demographics were limited to significant variables (i.e. age, gender, culture, language, race, education level, religion, religiosity, and connectedness to nature) as per Tarrant et al. (2016) and Brom et al. (2020), given that Evert et al. (2021) found variables such as income bracket and political orientation to have no significant bearing on the former.

Results

To follow is a brief overview of the results derived from the responses to the questions posed under each of the sections as per Table 1. In all instances, pertinent quantitative results per section will be presented first followed by supporting data and qualitative responses per question that confirm practical significances (Cohen's d values). Cohen's d value is considered a standardised method of commenting on the differences between the means of two populations (Nature's Valley with Covie, Nature's Valley with Kurland, and Covie with Kurland) regardless of statistical significance. In this article, we determine practical significance because of differences having small ($d = 0.2$), medium ($d = 0.5$) and large ($d = 0.8$) effect sizes (Ellis and Steyn 2003).

T -tests and effect-size calculations confirmed statistical insignificance between male (mean = 3.25) and female (mean = 3.16) ($p < 0.05$; $d = 0.07$) participants with both genders indicating that they are "undecided" regarding frogs. Statistical significance between coloured and white (mean = 2.78 and 4.53) was evident with a strong effect size ($p < 0.05$; $d = 2.01$). White participants showed higher liking towards frogs than coloured participants, and this difference is regarded as practically important. Despite insignificant p -value comparisons between Afrikaans (mean = 3.04) and English (mean = 4.09), Afrikaans-speaking participants showed no general liking or disliking towards frogs, while English-speaking participants showed some liking towards frogs. Therefore, the practical effect value ($p > 0.05$; $d = 0.95$) is regarded as meaningful.

Participants

Participants were exclusively divided into "white" and "coloured" racial groups while statistically negligible "black" participants took part in this study. White participants are

Table 1. Demographic variables of the residents participating in this study.

Characteristics of participants ($n = 90$)			
Item	Options	n	Valid %
Location	Nature's Valley	25	27.8
	Kurland	56	62.2
	Covie	9	10.0
Gender	Male	48	53.3
	Female	41	45.6
	Other	1	1.1
Race	Black	9	10.0
	White	23	25.6
	Coloured	56	62.2
	Other	2	2.2
Language	Afrikaans	71	78.8
	English	15	16.9
	Zulu	2	2.2
	Xhosa	1	1.1
Education	Primary	6	7.0
	Some secondary	14	16.3
	Completed secondary	31	36.0
	Some tertiary	11	12.8
Religion	Completed tertiary	24	27.9
	Agnostic	6	6.7
	Atheistic	4	4.4
	Christian	75	83.3
	Traditional African	2	2.2
	Other	3	3.3

internationally described as “Caucasian” individuals, while coloured participants are internationally described as multiracial ethnic communities that have ancestry from European, African and Asian forefathers.

Participants aged between 18 and 78 years with an average age of 37 (SD = 18). Ninety participants ($n = 90$) were systematically and proportionally selected based on the size of the respective communities: 62.2% were from Kurland, 27.8% from Nature’s Valley, and 10% from Covie. Of these, 53.3% identified as male, 45.6% as female, and 1.1% as “other” (Table 1).

Most participants indicated that they had completed secondary school (36%) or tertiary education (27.9%). Of the remainder, 16.3% completed some secondary education and 12.8% completed some tertiary education, with 7% indicating that they have at least a “primary” education.

When asked about their connectivity with nature, 26.7% indicated some connectivity and 23.3% complete connectedness. Of the remainder, 22.2% were “Undecided”, with 14.4% indicating that they are either “Disconnected” or “Somewhat disconnected” (13.3%) from nature. The mean connectedness to nature was thus calculated at 3.31 (SD = 1.38).

Section 1: Liking

Below follows detailed univariate and multivariate statistical analysis of all “Liking” items within the three groups. Results can be interpreted by viewing distribution of answers across the Likert scale (Table 1), followed by viewing statistical significance between groups and recognition of practical significance through effect size (difference in means) (Table 2), and finally confirmation of differences in means by viewing qualitative reasoning of participants (Table 3). This will be the same for “Knowledge” and “Cultural beliefs and myths”.

Multivariate statistical analysis can be observed for all items in the “Liking” section, as well as the overall correlation of “Liking” between the three groups. Overall, participants showed a slightly below-average liking towards frogs (mean = 2.67; SD = 0.46) with significant differences ($F(2,87) = 57.32, p < 0.05$, partial $\eta^2 = 0.569$) between locations: Nature’s Valley (mean = 4.62) showed strong overall liking towards frogs, whereas Covie (mean = 2.78) and Kurland (mean = 2.62) showed slight overall disliking towards frogs (Table 2).

Qualitative responses such as “Nothing to like about frogs” (Covie Participant #2); “I am not a frog person” (Kurland Participant #34); and “I love them. They are lovely to me. I believe they are a sign of a healthy environment” (Nature’s Valley Participant #65) serve as confirmation of the means (Table 3) for item (L1) *You like frogs*. Differences in means (Cohen’s d) can also be illustrated through the qualitative answers.

Section 2: Encounters

Comprised of three questions, each with its own categorical or ordinal scale, this section aimed to investigate how often and where participants encounter frogs and what their attitude towards frogs is in such an event.

E1. *Within a year, how often do you see a frog/toad?* Most (38.8%) stated that they encounter frogs 1–5 times per year, 28.9% encounter them 11–15 times per year,

Table 2. Overall basic descriptive statistics of items intended to measure the Liking of the communities towards frogs/toads

Internal Reliability = 0.882				
Item Code	Statement	Mean	Std. Deviation	Answer distribution (%)
L1	You like frogs/toads	2.61	1.56	Completely disagree 36.7 Disagree 17.8 Undecided 13.3 Agree 12.2 Completely agree 20.0
L2	You are scared of frogs/toads	2.23	1.36	Completely disagree 40.0 Disagree 30.0 Undecided 6.7 Agree 13.3 Completely agree 10.0
L3	You will pick up and handle a frog/toad	2.69	1.52	Completely disagree 33.3 Disagree 20.0 Undecided 6.7 Agree 24.4 Completely agree 15.6
L4	Frogs/toads should be killed	2.08	1.13	Completely disagree 38.9 Disagree 31.1 Undecided 17.8 Agree 7.8 Completely agree 4.4
L5 *	You will consider having a frog/toad picture as wallpaper or screen saver on your mobile/computer	2.56	1.52	Completely disagree 40.0 Disagree 14.4 Undecided 7.8 Agree 25.6 Completely agree 12.2
L6	You are annoyed by frogs/toads being on your property	3.04	1.53	Completely disagree 28.9 Disagree 10.0 Undecided 6.7 Agree 36.7 Completely agree 17.8
L7 *	You don't like the sound that frogs/toads make	3.46	1.43	Completely disagree 16.7 Disagree 12.2 Undecided 6.7 Agree 37.8 Completely agree 26.7

The internal reliability coefficient for questions marked with (*) were too low to be deemed reliable and these questions were initially removed from the dataset when determining the reliability coefficient. Results are still reported as the authors believe that valuable insight was found post analysis of these questions

21.1% 16-plus times per year, 8.9% 6-10 times per year, and 5.6% never encounter them. Seemingly, participants on average encounter frogs 6–10 times per year (mean = 3; SD = 1.15). ANOVA revealed no statistical significance between localities ($F(2,87) = 10.66, p < 0.05$, partial $\eta^2 = 0.197$), but a large practical effect size was revealed between Nature's Valley (mean = 3.24) and Covie (mean = 4.33) ($d = 0.84$), and between Covie and Kurland (mean = 2.68) ($d = 1.48$), while a medium effect was observed between Nature's Valley and Kurland ($d = 0.43$). These means suggest that within the study area frogs are encountered most often in Covie (around 11–15 times per year), followed by Nature's Valley (6–10 times per year), and Kurland (around 1–5/6–10 times per year).

Males (mean = 3.1) and females (mean = 2.9) both encounter frogs around 6–10 times per year. The calculated effect size for coloured (mean = 2.95) and white (mean = 3.35) participants is statistically insignificant ($p > 0.05$; $d = 0.35$) and of medium practical significance. The same can be said for frequency of encounters by Afrikaans- (mean = 3.11) and English-speaking (mean = 2.73) participants ($d = 0.33$).

Table 3. Multivariate statistical analysis of items intended to measure the Liking of the communities towards frogs/toads.

Item	Location	N	Mean	Std. Deviation	ANOVA <i>p</i> -value	Cohen's <i>d</i> Effect sizes	
						Nature's Valley with	Covie with
Liking overall	Nature's Valley	25	4,62	0,44	$F(2,87) = 57.32$ $p < .05$ partial $\eta^2 = 0.569$	2.35**	0.18 [■]
	Covie	9	2,78	0,78			
	Kurland	56	2,62	0,90			
	Total	90	3,19	1,18			
L1	Nature's Valley	25	4,56	0,768	$F(2,87) = 66.58$ $p < 0.05$ partial $\eta^2 = 0.605$	2.88**	0.03 [■]
	Covie	9	1,89	0,928			
	Kurland	56	1,86	1,086			
	Total	90	2,61	1,563			
L2	Nature's Valley	25	1,20	0,500	$F(2,87) = 13.07$ $p < 0.05$ partial $\eta^2 = 0.231$	1.36**	0.31*
	Covie	9	3,00	1,323			
	Kurland	56	2,57	1,399			
	Total	90	2,23	1,366			
L3	Nature's Valley	25	3,96	1,241	$F(2,87) = 16.1$ $p < 0.05$ partial $\eta^2 = 0.27$	1.40**	0.02 [■]
	Covie	9	2,22	1,202			
	Kurland	56	2,20	1,367			
	Total	90	2,69	1,526			
L4	Nature's Valley	25	1,08	0,277	$F(2,87) = 18.87$ $p < 0.05$ partial $\eta^2 = 0.303$	1.12**	0.13 [■]
	Covie	9	2,33	1,118			
	Kurland	56	2,48	1,112			
	Total	90	2,08	1,134			
L5	Nature's Valley	25	1,08	1,578	$F(2,87) = 11.89$ $p < 0.05$ partial $\eta^2 = 0.215$	1.32**	0.50*
	Covie	9	1,56	0,527			
	Kurland	56	2,23	1,348			
	Total	90	2,56	1,522			
L6	Nature's Valley	25	1,16	0,624	$F(2,87) = 72.32$ $p < 0.05$ partial $\eta^2 = 0.624$	1.27**	0.75**
	Covie	9	2,89	1,364			
	Kurland	56	3,91	0,996			
	Total	90	3,04	1,535			
L7	Nature's Valley	25	2,56	1,805	$F(2,87) = 11.71$ $p < 0.05$ partial $\eta^2 = 0.212$	0.12 [■]	0.99**
	Covie	9	2,78	1,202			
	Kurland	56	3,96	0,990			
	Total	90	3,46	1,431			

■, Small effect size (Cohen's *d*) = 0.2

*, Medium effect size (Cohen's *d*) = 0.5

**, Large effect size (Cohen's *d*) = 0.8

Frequency of encounters only showed positive significant correlations at the 0.05 level with age ($\rho = 0.327$; $p < 0.05$) and connectedness ($\rho = 0.415$; $p < 0.05$), and no correlation with education level and religious orientation. Older participants seemed more likely to encounter frogs than younger participants, and participants with a strong connection to their natural environment also encountered frogs more frequently than do people who did not feel connected.

Generally, the encounter theme showed significant positive correlations with "liking" ($\rho = 0.299$; $p < 0.05$) and "knowledge" ($\rho = 0.383$; $p < 0.05$), but not with "folklore". This suggests that as participants' encounter frequency increases, so would their general liking and knowledge, while folklore remains unaffected.¹

E2. *Where do you see frogs/toads most often?* Most participants (36.7%) indicated their garden, followed by on the road (24.4%), and at work (8.9%). Of the remainder, 5% stated that they never see frogs and 21.1% preferred "Other". Qualitative probing revealed that "other" mostly implied in the forest [*In the woods*] (Participant #6), followed by in other people's homes [*Other people's properties*] (Participant #51).

E3. *What do you do when you see a frog/toad?* Most participants (45.6%) said they will take a frog outside if it is in their home, 16.7% said they would kill it, 15.6% said they would call someone to remove it, 13.3% will ignore it, and 5.6% gave their own responses. Qualitative probing regarding participants' reactions revealed "Wrong place" as the overarching theme, implying that participants recognize that frogs belong outside. The second dominating theme involved "Using tools", implying that participants will use something like a broom, shovel, or stick to remove the frog from their living space or, in specific cases, kill it ["I use a broom to remove it because I am scared it lands in the food-stuffs" (Participant #37)].

Section 3: Knowledge

Measured on a 5-point Likert scale (Table 4), this section revealed low knowledge about frog biology and ecology (mean = 2.54; SD = 1.108) across the three locations. Statistical insignificance between all three locations ($F(2,87) = 33.5$, $p > 0.05$, partial $\eta^2 = 0.435$) was observed, indicating that place of residence accounts for 43.5% of the variance. Confirmation of statistical significance ($p < 0.05$) between sites revealed a large practical effect size ($d = 1.03$) between Nature's Valley (mean = 3.16) and Covie (mean = 2.71), between Nature's Valley and Kurland (mean = 2.38) ($d = 1.78$), and between Covie and Kurland ($d = 0.84$): Nature's Valley participants show some knowledge of frogs, while both Covie and Kurland show below-average knowledge (Table 5).

The difference between males (mean = 2.58) and females (mean = 2.69) is statistically insignificant ($p > 0.05$; $d = 0.21$) for the "Knowledge" section. However, t -tests confirmed the statistical significance between coloured (mean = 2.48) and white (mean = 3.31) participants, with coloured participants showing slightly below-average knowledge about frogs and white participants showing slightly above-average knowledge. This difference is of large practical importance ($p < 0.05$; $d = 1.49$). On the other hand, no statistical significance between Afrikaans- (mean = 2.58) and English- (mean = 2.98) speaking participants came to the fore, but a large practical significance was confirmed after calculation of effect size ($p < 0.05$; $d = 0.81$): Afrikaans-speaking participants showed less knowledge about frogs than English-speaking participants did.

Positive significant correlations ($p < 0.05$) between knowledge and demographic variables such as age ($\rho = 0.595$; $p < 0.05$), education level ($\rho = 0.414$; $p < 0.05$), and connectedness to nature imply that older participants as well as more educated and more environmentally involved participants (independent of one another) are more knowledgeable but are unaffected by religiosity. Again, correlations between themes suggest that as participants' knowledge increases, so would liking (or vice versa) ($\rho = 0.672$; $p < 0.05$) and encounter frequency ($\rho = 0.299$; $p < 0.05$) due to a significant positive correlation ($p < 0.05$), but folklore would decrease because of negative significant correlation.

Confirmation of means and support of practical effect size can be read in conjunction of qualitative reasoning of participants (Table 7). For example *You want to learn more about frogs/toads (K1)*: Qualitative responses such as "It would be very interesting, especially tree frogs" (Nature's Valley Participant #77) as opposed to "It would not benefit me" (Kurland Participant #62) and "It doesn't serve a purpose in my life" (Covie Participant #8) support statistical significance ($F(2,87) = 30.406$, $p < 0.05$, partial $\eta^2 = 0.411$) between

Table 4. Qualitative responses of participants from respective communities that confirm large/medium/no practical significance for “Liking” towards frogs.

Item code/ statement	Location	Qualitative answer (Location Participant #)	Mean	Std. Deviation	Cohen's d Effect sizes	
					Nature's Valley with	Covie with
^Δ L1 You like frogs/toads	Nature's Valley	"I believe they are a sign of a healthy environment" (Participant #65)	4.56	0.768		
	Covie	"Nothing to like about frogs" (Participant #2)	1.89	0.928	2.88**	
	Kurland	"I am not a frog person" (Participant #34)	1.86	1.086	2.49**	0.03 [■]
^Δ L2 You are scared of frogs/toads	Nature's Valley	"They are good for the environment and an indicator as health" (Participant #77)	1.20	0.500		
	Covie	"I am not scared; I just don't like frogs" (Participant #8)	3.00	1.323	1.36**	
	Kurland	"Some frogs are pretty, and some frogs are ugly and rough (lumpy)" (Participant #19)	2.57	1.399	0.98**	0.31*
^Δ L3 You will pick up and handle a frog/toad	Nature's Valley	"I would; to save them if they get lost" (Participant #70)	3.96	1.241		
	Covie	"Only if I have to move it" (Participant #9)	2.22	1.202	1.40**	
	Kurland	"I am not that comfortable around frogs" (Participant #34)	2.20	1.367	1.29**	0.02 [■]
^Δ L4 Frogs/toads should be killed	Nature's Valley	"I don't want to see frogs get killed" (Participant #89)	1.08	0.277		
	Covie	"Just take it outside" (Participant #4)	2.33	1.118	1.12**	
	Kurland	"If they put people's lives in danger, yes" (Participant #51)	2.48	1.112	1.26**	0.13 [■]
^Δ L5 You will consider having a frog/toad	Nature's Valley	"They are cute" (Participant #88)	3.64	1.578		
	Covie	"Why would I want to do that?" (Participant #62)	1.56	0.527	1.32**	
	Kurland	"I would rather have a puppy as a wallpaper" (Participant #15)	2.23	1.348	0.89**	0.50*
^Δ L6 You are annoyed by frogs/toads being	Nature's Valley	"No, they are welcome and kind" (Participant #77)	1.16	0.624		
	Covie	"It must stay in the forest" (Participant #6)	2.89	1.364	1.27**	
	Kurland	"What do they want in my yard?" (Participant #56)	3.91	0.996	2.76**	0.75**
^Δ L7 You don't like the sound that frogs/toads make	Nature's Valley	"It is the sound of Nature's Valley. It is louder than snoring" (Participant #83)	2.56	1.805		
	Covie	"Sometimes they are irritating" (Participant #90)	2.78	1.202	0.12 [■]	
	Kurland	"It sounds uncomfortable and makes me feel creeped out" (Kurland Participant #30)	3.96	0.990	0.78**	0.99**

[■], Small effect size (Cohen's *d*) = 0.2

^{*}, Medium effect size (Cohen's *d*) = 0.5

^{**}, Large effect size (Cohen's *d*) = 0.8

^Δ, Statistically significant (Table above)

[●], Statistically insignificant (Table above)

participant scores with a significant practical effect between Nature's Valley (mean = 4.2) and Covie (mean = 2) ($d = 2.2$), and Nature's Valley and Kurland (mean = 2.21) ($d = 1.7$), but not between Covie and Kurland ($d = 0.18$) (Table 6).

Table 5. Overall basic descriptive statistics of items intended to measure the Knowledge of the communities towards frogs/toads.

Internal Reliability = 0.712					
Item Code	Statement	Mean	Std. Deviation	Answer distribution (%)	
K1	You want to learn more about frogs/toads	2.74	1.41	Completely disagree	26.7
				Disagree	22.2
				Undecided	14.4
				Agree	23.3
				Completely agree	13.3
K2	You know the difference between a frog and a toad	2.22	1.30	Completely disagree	40.0
				Disagree	26.7
				Undecided	11.1
				Agree	15.6
				Completely agree	6.7
K3	Frogs/toads belong to the most threatened group of vertebrae in the world	2.84	0.88	Completely disagree	6.7
				Disagree	22.2
				Undecided	56.7
				Agree	8.9
				Completely agree	5.6
K4	The conservation of wetlands and freshwater habitat may help to reduce loss of frog/toad species and numbers	4.09	0.85	Completely disagree	2.2
				Disagree	1.1
				Undecided	15.6
				Agree	47.8
				Completely agree	33.3
K5	You think it is important to conserve South Africa's frogs/toads	3.59	1.17	Completely disagree	6.7
				Disagree	12.2
				Undecided	21.1
				Agree	35.6
				Completely agree	24.4
K6	Frogs/toads are important for medical research	2.93	1.11	Completely disagree	10.0
				Disagree	26.7
				Undecided	31.1
				Agree	24.4
				Completely agree	7.8
K7*	For each picture, can you react and say if you think it's likeable, gross, or scary? Frog 1	1.36	0.77	Likeable	76.7
				Gross	13.3
				Scary	4.4
				Other	4.4
				Likeable	52.2
K8*	For each picture, can you react and say if you think it's likeable, gross, or scary? Frog 2	1.71	0.92	Gross	31.1
				Scary	7.8
				Other	7.8
				Likeable	16.7
				Gross	5.6
K9	For each picture, can you react and say if you think it's likeable, gross, or scary? Frog 3	2.74	0.89	Scary	63.3
				Other	13.3
				Yes	62.2
				No	36.7
				Yes	57.8
K10	Have you seen frog 1 before?	1.37	0.48	No	41.1
				Yes	68.9
K11	Have you seen frog 2 before?	1.42	0.49	No	30.0
				Yes	69.0
K12	Have you seen frog 3 before?	1.30	0.46	No	30.0
				Yes	68.9
K13	Which of the three frogs are you most likely to conserve (1, 2, or 3)?	3.13	1.59	Completely disagree	32.2
				Disagree	3.3
				Undecided	1.1
				Agree	43.3
				Completely agree	18.9

The internal reliability coefficient for questions marked with (*) were too low to be deemed reliable and these questions were initially removed from the dataset when determining the reliability coefficient. Results are still reported as the authors believe that valuable insight was found post analysis of these questions

Reaction to, recognition of, and likely conservation of *Hyperolius marmoratus*, *Africalus knysnae*, and *Breviceps fuscus* (K7–K13). Participants were asked to look at pictures of *H. marmoratus*, *A. knysnae* and *B. fuscus* (all species present in the area) and give their impression of how they feel about the frogs by saying if they are “Likeable”, “Scary”, “Gross”, or “Other”. Afterwards they were asked if they recognise the species.

As reflected in Figure 3, most participants (76.7%) found the Reed Frog to be “likeable” as opposed to 13.3% who described it as gross: “He has cool colours” (Nature’s Valley Participant #71); “He doesn’t look pretty. He is big and rough” (Kurland Participant #44). Generally, all communities “liked” this image: Nature’s Valley mean = 1.24; Covie mean = 1.67; Kurland mean = 1.36 ($F(2,86) = 1.012, p > 0.05$, partial $\eta^2 = 0.023$).

As reflected in Figure 4 above, most (41.1%) (mean = 1.37; SD = 0.49) participants recognised *A. knysnae* (K11), only 36.7% recognised *H. marmoratus* (K10) (mean = 1.42; SD = 0.5), and 27% recognised *B. fuscus* (K9) (mean = 1.3; SD = 0.46).

Section 4: Cultural beliefs and myths

Intended to uncover undocumented superstitions, misconceptions, myths, and cultural beliefs (i.e. “folklore”), the probing questions posed in this section revealed via a Likert scale (Table 8) a somewhat lowered presence of folklore and superstitions overall (Table 9) (mean = 2.14, SD = 0.19) with statistical significance confirmed as $F(2,87) = 23.104, p < 0.05$, partial $\eta^2 = 0.374$. The variance of 37.4% between participants’ scores explains the d -value of 2.75 between Nature’s Valley and Covie, 1.30 between Nature’s Valley and Kurland, and 0.39 between Covie and Kurland (Table 8).

Effect size between male (mean = 2.22) and female participants (mean = 2.17) was found to be statistically insignificant ($p > 0.05$; $d = 0.06$) and the practical significance negligible. Coloured participants showed elevated levels of folklore and cultural views compared to white participants ($p < 0.05$; $d = 1.44$), while comparisons between English- and Afrikaans-speaking participants confirmed statistical significance ($p < 0.05$) and a medium effect size ($d = 0.56$). Demographic profiles such as age ($\rho = 0.392$; $p < 0.05$), education level ($\rho = 0.620$; $p < 0.05$), and connectedness to nature ($\rho = 0.304$; $p < 0.05$) had a significant negative correlation, inferring that as age, education level, and connection to the environment (independent of one another) increase, a tendency towards superstitions and believing “old-women’s tales” would decrease. Thematic correlations calculated indicate that encounter frequency is not related to presence of folklore; however, significant negative correlations with liking ($\rho = 0.624$; $p < 0.05$) and knowledge ($\rho = 0.392$; $p < 0.05$) were observed, implying that as folklore increases, liking and knowledge will decrease.

Qualitative responses such as “I am not sure why, but I don’t think South Africa has any poisonous frogs” (Participant #72) confirm overall uncertainty (mean = 2.69; SD = 1.1). Seemingly, both Nature’s Valley and Kurland residents slightly disagree: “I believe they secrete poison causing allergy reaction if you swallow it” (Nature’s Valley Participant #66); “Because I haven’t heard of a person getting killed by a frog before” (Kurland Participant #15). Covie residents, on the other hand, slightly agree: “Certain frogs kill snakes (with poison)” (Participant #4) (Table 9).

Correlations between demographic variables affect the extent of perceptions and beliefs of participants towards frogs. Significant positive correlations between demographic variables such as age ($\rho = 0.631$; $p < 0.05$), education ($\rho = 0.566$; $p < 0.05$), and connectedness

Table 6. Multivariate statistical analysis of items intended to measure the knowledge of the communities towards frogs/toads.

Item	Location	N	Mean	Std. Deviation	ANOVA <i>p</i> -value	Cohen's <i>d</i> Effect sizes	
						Nature's Valley with	Covie with
Knowledge overall	Nature's Valley	25	3.16	0.44	$F(2,87) = 33.5$ $p > 0.05$ partial $\eta^2 = 0.435$	1.03**	0.84**
	Covie	9	2.71	0.32			
	Kurland	56	2.38	0.39			
	Total	87	2.54	1.108			
K1	Nature's Valley	25	4.20	0.957	$F(2,87) = 30.406$ $p < .05$ partial $\eta^2 = 0.411$	2.20**	0.18 [■]
	Covie	9	2.00	1.000			
	Kurland	56	2.21	1.171			
	Total	90	2.74	1.419			
K2	Nature's Valley	25	3.12	1.333	$F(2,87) = 14.86$ $p < .05$ $\eta^2 = 0.255$	0.17 [■]	0.86**
	Covie	9	2.89	1.364			
	Kurland	56	1.71	1.004			
	Total	90	2.22	1.305			
K3	Nature's Valley	25	3.20	1.155	$F(2,87) = 3.081$ $p > .05$ partial $\eta^2 = 0.066$	0.56*	0.24 [■]
	Covie	9	2.56	0.726			
	Kurland	56	2.73	0.726			
	Total	90	2.84	0.886			
K4	Nature's Valley	25	4.80	0.408	$F(2,87) = 16.224$ $p < .05$ partial $\eta^2 = 0.272$	2.27**	0.20 [■]
	Covie	9	3.67	0.500			
	Kurland	56	3.84	0.869			
	Total	90	4.09	0.856			
K5	Nature's Valley	25	4.84	0.374	$F(2,87) = 36.262$ $p < .05$ partial $\eta^2 = 0.455$	1.77**	0.50*
	Covie	9	3.56	0.726			
	Kurland	56	3.04	1.044			
	Total	90	3.59	1.179			
K6	Nature's Valley	25	3.32	1.345	$F(2,87) = 2.206$ $p > .05$ partial $\eta^2 = 0.048$	0.32*	0.12 [■]
	Covie	9	2.89	0.782			
	Kurland	56	2.77	1.009			
	Total	90	2.93	1.110			
K7	Nature's Valley	25	1.24	0.831	$F(2,86) = 1.012$ $p > .05$ partial $\eta^2 = 0.023$	0.32*	0.23 [■]
	Covie	9	1.67	1.323			
	Kurland	55	1.36	0.620			
	Total	89	1.36	0.772			
K8	Nature's Valley	25	1.48	1.046	$F(2,86) = 1.333$ $p > .05$ partial $\eta^2 = 0.03$	0.50*	0.27*
	Covie	9	2.00	0.866			
	Kurland	55	1.76	0.860			
	Total	89	1.71	0.920			
K9	Nature's Valley	25	2.24	1.393	$F(2,86) = 6.055$ $p < .05$ partial $\eta^2 = 0.123$	0.47*	0.07 [■]
	Covie	9	2.89	0.782			
	Kurland	55	2.95	0.448			
	Total	89	2.74	0.899			
K10	Nature's Valley	25	1.44	0.507	$F(2,86) = 0.676$ $p > .05$ partial $\eta^2 = 0.015$	0.43*	0.29*
	Covie	9	1.22	0.441			
	Kurland	55	1.36	0.485			
	Total	89	1.37	0.486			
K11	Nature's Valley	25	1.48	0.510	$F(2,86) = 0.349$ $p > .05$ partial $\eta^2 = 0.008$	0.07 [■]	0.12 [■]
	Covie	9	1.44	0.527			
	Kurland	55	1.38	0.490			
	Total	89	1.42	0.496			
K12	Nature's Valley	25	1.20	0.408	$F(2,86) = 6.123$ $p < .05$ partial $\eta^2 = 0.125$	1.31**	1.12**
	Covie	9	1.78	0.441			
	Kurland	55	1.27	0.449			
	Total	89	1.30	0.462			
K13	Nature's Valley	25	3.40	1.155	$F(2,86) = 6.753$ $p < .05$, partial partial $\eta^2 = 0.136$	1.10**	1.11**
	Covie	9	4.67	0.500			
	Kurland	55	2.76	1.721			
	Total	89	3.13	1.597			

■, Small effect size (Cohen's *d*) = 0.2
 *, Medium effect size (Cohen's *d*) = 0.5
 **, Large effect size (Cohen's *d*) = 0.8

to nature ($\rho = 0.636$; $p < 0.05$) were observed. This suggests that as participants age, have higher education levels, and connectedness to nature increase, so does their liking towards frogs. In addition, significant positive correlations with general encounters ($\rho = 0.299$; $p < 0.05$) and knowledge ($\rho = 0.672$; $p < 0.05$) were observed, and significant negative correlations with folklore ($\rho = 0.624$; $p < 0.05$). This indicates that as the level of liking of participants towards frogs increases, so does frequency of encounters as well as knowledge of frogs (and vice versa), while negative correlations suggest that as the liking of participants towards frogs increases, folklore and superstitions towards frogs decrease (and vice versa).

These findings are supported by the responses to the open-ended question that revealed a lack of knowledge [*"I have no knowledge about frogs"* (Participant #50)] and a strong affiliation of frogs with snakes and/or rain [*"I am not fond of frogs and snakes. Where a frog is, there a snake is too"* (Participant #3); *"If you kill a frog then it is going to rain"* (Participant #11); *"I heard frogs bring rain. Frogs give snakes their venom"* (Participant #40)] as emerging themes.

Responses to open-ended question: *"Would you be willing to share any existing knowledge, beliefs, or superstitions you have regarding frogs?"*. The intention with this question was to uncover any childhood memories and/or opinions and behaviours that might have impacted participants' responses, and, by inference, the results obtained in this study. All responses were captured qualitatively and analysed thematically.

Childhood memories: Most respondents answered "None", yet the following themes emerged post-analyses:

- Playful childhood interaction: *"Caught frogs", "Looked at frogs", "Chased frogs", "I always went with my cousin to look at frogs"; "We always caught frogs and played with them."*
- Keeping frogs as pets: *"When I was small, we caught bullfrogs in Pretoria. Collected tadpoles and kept them at home"; "They were my pet when I was living on a farm as a child"; "I had a pet frog as a child for a while, but it didn't last for long."*
- Opinions and behaviours of parents/caregivers: Some participants were encouraged to discover nature: *"Parents always encouraged curiosity and zoology lectures with keen interest"* (Participant #79). Qualitative responses, however, also revealed a strong tendency towards upholding cultural beliefs and superstitions:
- Killing a frog will bring rain: *"If a frog dies then it will bring rain"* (Participant #10), *"I heard from my grandma that frogs bring rain"* (Participant #39); *"If people kill frogs, then it brings rain"* (Participant #5); *"I once killed a frog and then it rained that night"* (Participant #21); *"Just that when I killed a frog it started raining"* (Participant #61)
- Frogs attract snakes: *"When you kill a frog it will rain, and where there is a frog, there is a snake"* (Participant #13)
- Frogs cause warts: *"Causes bad omen; they cause warts and kill them with salt"* (Participant #21); *"If I touch them, I will get warts, but I know better now. I found the lifecycle interesting at school"* (Participant #72)

Discussion

This study on human-frog interactions aimed to quantify and investigate how people within a local area interact with frogs. It followed a concurrent, embedded mixed-methods research design with 90 participants agreeing to partake.

Table 7. Qualitative responses of participants from respective communities that confirm large/medium/no practical significance for "Knowledge" about frogs.

Item code/ statement	Location	Qualitative answer (Location Participant #)	Mean	Std. Deviation	Cohen's d Effect sizes	
					Nature's Valley with	Covie with
△ K1 You want to learn more about frogs/toads	Nature's Valley	"It would be very interesting, especially tree frogs" (Nature's Valley Participant #77)	4.20	0.957		
	Covie	"It doesn't serve a purpose in my life" (Covie Participant #8)	2.00	1.000	2.20**	
	Kurland	"It wouldn't benefit me" (Kurland Participant #62)	2.21	1.171	1.70**	0.18*
△ K2 You know the difference between a frog and a toad	Nature's Valley	"I'm not sure I know the differences between them at all" (Nature's Valley Participant #70)	3.12	1.333		
	Covie	"I don't really know much about frogs" (Covie Participant #1)	2.89	1.364	0.17*	
	Kurland	"I don't know the difference" (Kurland Participant #45)	1.71	1.004	1.05**	0.86**
● K3 Frogs/toads belong to the most threatened group of vertebrae in the world	Nature's Valley	"No compelling case, but I am not sure" (Nature's Valley Participant #71)	3.20	1.155		
	Covie	"There are many frogs" (Covie Participant #9)	2.56	0.726	0.56*	
	Kurland	"I thought there are a lot of frogs" (Kurland Participant #24)	2.73	0.726	0.41*	0.24*
△ K4 The conservation of wetlands and freshwater habitat may help to reduce loss of frog/toad species and numbers	Nature's Valley	"To me wetland areas are typical frog habitat. Conserving their habitat will automatically conserve animals that live in it" (Nature's Valley Participant #72)	4.80	0.408		
	Covie	"They [wetlands] keep nature in place and play an important role in nature" (Covie Participant #1)	3.67	0.500	2.27**	
	Kurland	"If people stay away from animals' natural habitat, then extinction would decrease" (Kurland Participant #25)	3.84	0.869	1.11**	0.20*
△ K5 You think it is important to conserve South Africa's frogs/toads	Nature's Valley	"Not just SA, but the whole world" (Nature's Valley Participant #88)	4.84	0.374		
	Covie	"We have to conserve what we have that belongs to us" (Covie Participant #3)	3.56	0.726	1.77**	
	Kurland	"I don't know if frogs are important or not" (Kurland Participant #20)	3.04	1.044	1.73**	0.50*
● K6 Frogs/toads are important for medical research	Nature's Valley	"I am unsure if they are used in medical sciences, but probably" (Nature's Valley Participant #72)	3.32	1.345		
	Covie	"I don't know much" (Covie Participant #9)	2.89	0.782	0.32*	
	Kurland	"What can a frog contribute with regards to medicinal research?" (Kurland Participant #25)	2.77	1.009	0.41*	0.12*

(Continued)

Table 7. Continued.

Item code/ statement	Location	Qualitative answer (Location Participant #)	Mean	Std. Deviation	Cohen's d Effect sizes	
					Nature's Valley with	Covie with
● K7 For each picture, can you react and say if you think it's likeable, gross, or scary? Frog 1	Nature's Valley	"What can a frog contribute with regards to medicinal research?" (Kurland Participant #25)	1.24	0.831		
	Covie		1.67	1.323	0.32*	
	Kurland	"He doesn't look pretty. He is big and rough"	1.36	0.620	0.15 ^Δ	0.23 [●]
● K8 For each picture, can you react and say if you think it's likeable, gross, or scary? Frog 2	Nature's Valley	"Eyes look too gross" (Nature's Valley Participant #89)	1.48	1.046		
	Covie	"Looks slimy" (Covie Participant #8)	2.00	0.866	0.50*	
	Kurland	"Not too bad. I can live with it" (Kurland Participant #64)	1.76	0.860	0.27*	0.27*
● K9 For each picture, can you react and say if you think it's likeable, gross, or scary? Frog 3	Nature's Valley	"Weird. A bit strange. It makes me feel uncomfortable" (Nature's Valley Participant #84)	2.24	1.393		
	Covie	"Big and scary" (Covie Participant #4)	2.89	0.782	0.47*	
	Kurland	"Heart attack-inducing. He (frog) is fat and big" (Kurland Participant #11)	2.95	0.448	0.51*	0.07 [●]
● K13 Which of the three frogs are you most likely to conserve (1, 2, or 3)?	Nature's Valley	"Think they are very sensitive, immobile due to fossorial lifestyle" (Participant #82)	3.40	1.155		
	Covie	"I wouldn't conserve any" (Participant #7); "I can't decide" (Participant #90)	4.67	0.500	1.10**	
	Kurland	"It (frog 1) looks pretty, and our younger generations must still witness these animals" (Participant #18); "They aren't important for me" (Participant #38)	2.76	1.721	0.37*	1.11**

^Δ. Small effect size (Cohen's *d*) = 0.2

*. Medium effect size (Cohen's *d*) = 0.5

** . Large effect size (Cohen's *d*) = 0.8

^Δ. Statistically significant (Table above)

●. Statistically insignificant (Table above)

Demographic variables affecting the liking of frogs showed slight contrast to what is found in literature and may be the result of these studies being in different areas/at different scales (e.g. Tarrant et al. (2016) was done on a national scale) (Prokop et al. 2016; Tarrant et al. 2016; Vergara-Ríos et al. 2021). Culture and people's perspectives towards frogs vary spatially and temporally. Gender played no statistically significant role; however, race and language (regarded by Anemone 2019 and Holme 2003 as constructs of culture) did play an important role. Covie and Kurland have similar culture constructs (predominantly coloured and Afrikaans-speaking), while Nature's Valley is predominantly white and English-speaking. This supports the notion that cultural background strongly influences the tolerance of people towards frogs (Tarrant et al. 2016; Brom et al. 2020) and can explain the practically significant differences between the disposition of Kurland and Covie residents versus Nature's Valley residents.

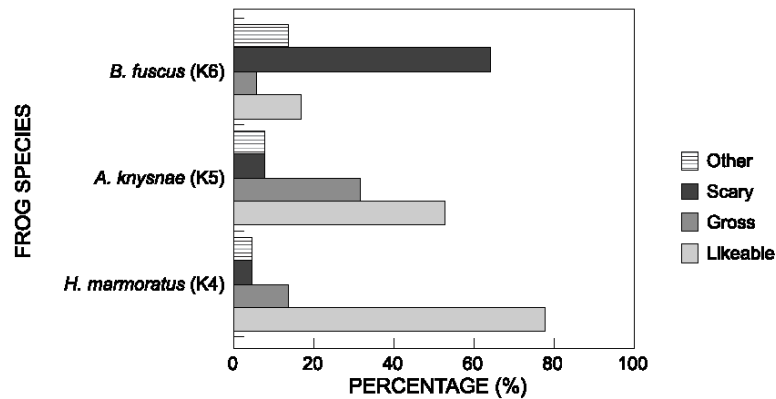


Figure 3. Reactions towards frog species: *Breviceps fuscus*; *Afrivalus knysnae* and *Hyperolius marmoratus* (K7–K9)

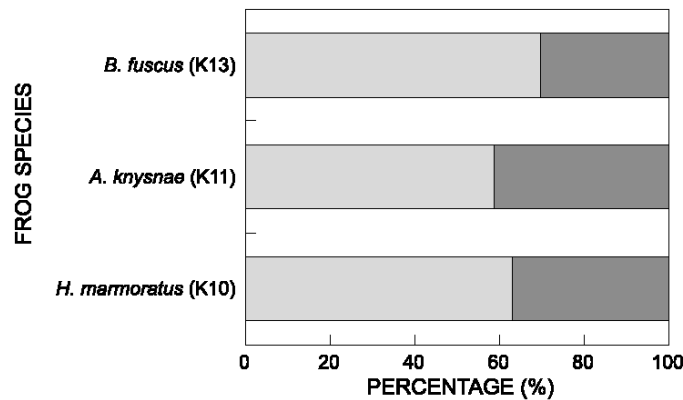


Figure 4. Recognition of selected frog species: *Breviceps fuscus*, *Afrivalus knysnae* and *Hyperolius marmoratus* (K10–K12)

Regression analyses support the notion that tolerance of frogs can be improved in South African communities by way of physical encounters and experiential learning (Kruger 2014; Tarrant et al. 2016). Even though variables between communities might be discouraging for a frog-focused conservation approach, previous endeavours proposed and tested by Tomažič (2011), and Tarrant et al. (2016) provide sufficient substantiation for further exploration and testing, provided certain dynamics are taken into consideration (such as certain community's willingness to learn more about frogs, for example. This is discussed below). It is also possible that liking frogs influences individuals' ability to better recollect memories of encounters with frogs. It is also possible that people who show a higher liking for frogs actively seek out encounters with them. This was not directly investigated in this study and is recommended to be studied in future.

Overall, the three communities showed low interest in learning more about frogs (mean = 2.42; SD = 0.35). Consequently, frog-focused education initiatives might have

Table 8. Overall basic descriptive statistics of items intended to measure the Cultural beliefs and myths of the communities towards frogs/toads.

Internal Reliability = 0.812					
Item Code	Statement	Mean	Std. Deviation	Answer distribution (%)	
F1	Frogs/toads of South Africa are poisonous	2.69	1.09	Completely disagree	17.8
				Disagree	22.2
				Undecided	37.8
				Agree	17.8
				Completely agree	4.4
F2	Touching frogs/toads gives you warts	2.16	1.24	Completely disagree	43.3
				Disagree	21.1
				Undecided	15.6
				Agree	16.7
				Completely agree	3.3
F3	It is safe to collect water from rivers or dams where frogs/toads occur	2.94	1.40	Completely disagree	21.1
				Disagree	18.9
				Undecided	22.2
				Agree	20.0
				Completely agree	17.8
F4	Frogs/toads cause lightning	1.63	0.94	Completely disagree	61.1
				Disagree	22.2
				Undecided	8.9
				Agree	7.8
				Completely agree	61.1
F5	You should sprinkle salt on a frog's/toad's skin to kill it	2.27	1.27	Completely disagree	38.9
				Disagree	24.4
				Undecided	10.0
				Agree	24.4
				Completely agree	2.2
F6	Frogs/toads spread disease to humans	2.24	1.02	Completely disagree	32.2
				Disagree	20.0
				Undecided	40.0
				Agree	6.7
				Completely agree	1.1
F7	Frogs/toads attack humans	1.56	0.80	Completely disagree	57.8
				Disagree	34.4
				Undecided	3.3
				Agree	3.3
				Completely agree	1.1
F8	You should sprinkle salt on a frog's/toad's skin to kill it	2.00	1.27	Completely disagree	52.2
				Disagree	18.9
				Undecided	10.0
				Agree	14.4
				Completely agree	4.4
F9*	Frogs are an important figure in my belief system	1.78	1.25	Completely disagree	62.2
				Disagree	17.8
				Undecided	5.6
				Agree	5.6
				Completely agree	7.8

The internal reliability coefficient for questions marked with (*) were too low to be deemed reliable and these questions were initially removed from the dataset when determining the reliability coefficient. Results are still reported as the authors believe that valuable insight was found post analysis of these questions

lower success rates than initially expected. "Connectedness to nature", which positively correlated with "liking" and "knowledge", could be used as a proxy for pro-frog behaviours by initially focusing on pro-environmental intentions (Brom et al. 2020). As Van der Werf et al. (2013) and Brom et al. (2020) pointed out, bio-spherical values determine pro-environmental behaviours, intentions, and preferences. Thus, educating people by increasing their self-identified "connectedness to nature" for the benefit of the environment could benefit frog conservation.

Table 9. Multivariate statistical analysis of items intended to measure the Cultural beliefs and myths of the communities towards frogs/toads.

Item	Location	N	Mean	Std. Deviation	ANOVA <i>p</i> -value	Cohen's <i>d</i> Effect sizes	
						Nature's Valley with	Covie with
Folklore overall	Nature's Valley	25	1.50	0.44	$F(2,87) = 23.104$ $p < 0.05$ partial $\eta^2 = 0.374$	2.75**	0.39*
	Covie	9	2.71	0.23			
	Kurland	56	2.43	0.71			
	Total	90	2.20	0.75			
F1	Nature's Valley	25	2.56	1.227	$F(2,87) = 2.48$ $p > 0.05$ partial $\eta^2 = 0.253$	0.72**	0.80**
	Covie	9	3.44	1.014			
	Kurland	56	2.63	1.019			
	Total	90	2.69	1.098			
F2	Nature's Valley	25	1.20	0.707	$F(2,87) = 14.236$ $p < .05$ partial $\eta^2 = 0.247$	2.08**	0.44*
	Covie	9	3.00	0.866			
	Kurland	56	2.45	1.249			
	Total	90	2.16	1.244			
F3	Nature's Valley	25	4.20	1.225	$F(2,87) = 19.988$ $p < .05$ partial $\eta^2 = 0.315$	1.25**	0.19■
	Covie	9	2.67	1.225			
	Kurland	56	2.43	1.142			
	Total	90	2.94	1.401			
F4	Nature's Valley	25	1.00	0.000	$F(2,87) = 9.291$ $p < 0.05$ partial $\eta^2 = 0.176$	1.14**	0.01■
	Covie	9	1.89	0.782			
	Kurland	56	1.88	1.046			
	Total	90	1.63	0.942			
F5	Nature's Valley	25	1.48	0.823	$F(2,87) = 7.668$ $p < .05$ partial $\eta^2 = 0.15$	1.19**	0.08■
	Covie	9	2.67	1.000			
	Kurland	56	2.55	1.334			
	Total	90	2.27	1.270			
F6	Nature's Valley	25	1.44	0.712	$F(2,87) = 14.308$ $p < 0.05$ partial $\eta^2 = 0.248$	1.61**	0.27■
	Covie	9	2.78	0.833			
	Kurland	56	2.52	0.972			
	Total	90	2.24	1.020			
F7	Nature's Valley	25	1.32	0.852	$F(2,87) = 4.436$ $p < 0.05$ partial $\eta^2 = 0.093$	0.93**	0.69
	Covie	9	2.22	0.972			
	Kurland	56	1.55	0.711			
	Total	90	1.56	0.809			
F8	Nature's Valley	25	1.20	0.408	$F(2,87) = 7.912$ $p < 0.05$ partial $\eta^2 = 0.153$	1.31**	0.02■
	Covie	9	2.33	0.866			
	Kurland	56	2.30	1.426			
	Total	90	2.00	1.272			
F9	Nature's Valley	25	2.76	1.739	$F(2,87) = 7.912$ $p < 0.05$ partial $\eta^2 = 0.153$	0.56*	0.46*
	Covie	9	1.78	0.972			
	Kurland	55	1.33	0.668			
	Total	89	1.78	1.259			

■. Small effect size (Cohen's *d*) = 0.2*. Medium effect size (Cohen's *d*) = 0.5**. Large effect size (Cohen's *d*) = 0.8

The results of this study support the notion that educational initiatives might have a positive effect: Nature's Valley residents show high "connectedness to nature" (mean = 4.56; SD = 0.69) as opposed to Kurland (mean = 2.61; SD = 1.1). Additionally, Nature's Valley residents show elevated liking towards frogs, while Kurland residents dislike frogs in general. Moreover, even though Nature's Valley residents do not know much about frogs, they are keenly interested in learning more about them which, again, strongly contrasts with Kurland participants' level of interest.

Participants showed strong affinity towards *H. marmoratus*, less affiliation towards *A. knysnae*, and strong aversion towards *B. fuscus*². These reactions strongly correlate with the literature, namely that the charismatic features (texture of skin, size and

Table 10. Qualitative responses of participants from respective communities that confirm large/medium/no practical significance for "Folklore" about frogs.

Item code/ description	Location	Qualitative answer (Location Participant #)	Mean	Std. Deviation	Cohen's <i>d</i> Effect sizes	
					Nature's Valley with	Covie with
F1 Frogs/toads of South Africa are poisonous	Nature's Valley	"I believe they secrete poison causing allergy reaction if you swallow it" (Participant #66)	2.56	1.227		
	Covie	"Certain frogs kill snakes (with poison)" (Participant #4)	3.44	1.014	0.72**	
	Kurland	"Because I haven't heard of a person getting killed by a frog before" (Participant #15)	2.63	1.019	0.05■	0.80**
F2 Touching frogs/toads gives you warts	Nature's Valley	"My parents told me this when I was young but I don't believe it anymore" (Participant #72)	1.20	0.707		
	Covie	"I don't know or I am not a believer in that kind of stuff" (Participant #3)	3.00	0.866	2.08**	
	Kurland	"I don't think so" Participant #64)	2.45	1.249	1.00**	0.44*
F3 It is safe to collect water from rivers or dams where frogs/toads occur	Nature's Valley	"Of course, it means it's healthy" (Participant 83)	4.20	1.225		
	Covie	"I use tank water, but it [river water where frogs occur] isn't healthy" (Participant #8)	2.67	1.225	1.25**	
	Kurland	"I enjoy a clean environment to drink water from and frogs don't look clean" (Participant #18)	2.43	1.142	1.45**	0.19■
F4 Frogs/toads cause lightning	Nature's Valley	"Absolutely not true. Impossible" (Participant #70)	1.00	0.000		
	Covie	"Heavy rain causes lightning" (Participant #5)	1.89	0.782	1.14**	
	Kurland	"Lightning is naturally created, not through frogs" (Participant #33)	1.88	1.046	0.84**	0.01■
F5 You should sprinkle salt on a frog's/toad's skin to kill it	Nature's Valley	"Shame! Never, ever!" (Participant #68)	1.48	0.823		
	Covie	"This is inhumane" (Participant #6)	2.67	1.000	1.19**	
	Kurland	"I don't think it will work" (Participant #15)	2.55	1.334	0.80**	0.08■
F6 Frogs/toads spread disease to humans	Nature's Valley	"Unlikely. Never heard of it" (Participant #79)	1.44	0.712		
	Covie	"I don't know of any frog-flu" (Participant #9)	2.78	0.833	1.61**	
	Kurland	"For as long as I've lived, I have never heard of or seen frog diseases" (Participant #25)	2.52	0.972	1.11**	0.27■
F7 Frogs/toads attack humans	Nature's Valley	"Frogs I have seen would run away and never approach" (Participant #76)	1.32	0.852		
	Covie	"Frogs are too small and scared of people" (Participant #9)	2.22	0.972	0.93**	
	Kurland	"They are scared of people and are too small" (Participant #46)	1.55	0.711	0.27■	0.69
F8 Frog's/toad's skin to kill it	Nature's Valley	"They can sense the change of weather but can't bring rain." (Participant #70)	1.20	0.408		
	Covie		2.33	0.866	1.31**	

(Continued)

Table 10. Continued.

Item code/ description	Location	Qualitative answer (Location Participant #)	Mean	Std. Deviation	Cohen's <i>d</i> Effect sizes	
					Nature's Valley with	Covie with
F9 Frogs are an important figure in my belief system	Kurland	"People say if frogs are killed then it attracts rain" (Participant #5)	2.30	1.426	0.77**	0.02■
	Nature's Valley	"I am not myself convinced of this, but my mom says so" (Participant #29)	2.76	1.739		
	Covie	"Not really but I love them! They shouldn't be in soup!" (Participant #68)	1.78	0.972	0.56*	
	Kurland	"Not in my religion" (Participant #3)	1.33	0.668	0.82**	0.46*
		"There is nothing in my culture that makes frogs important" (Participant #21)				

- . Small effect size (Cohen's *d*) = 0.2
- *. Medium effect size (Cohen's *d*) = 0.5
- ** . Large effect size (Cohen's *d*) = 0.8
- Δ. Statistically significant
- . Statistically insignificant

colour) displayed by frogs will determine how people react towards them (Ceríaco 2012; Brom et al. 2020; Deutsch et al. 2020; Vergara-Ríos et al. 2021). Inevitably, people's reactions will affect their willingness to conserve certain frog species in appropriate ways. For example, *H. marmoratus* and *B. fuscus* present opposite charismatic features; therefore, participants showed a higher interest in conserving *H. marmoratus* than *B. fuscus*, and even *A. knysnae*.

Even though quantitative results showed a relatively low predisposition towards folklore, myths, and cultural beliefs overall, a thematic analysis of qualitative responses revealed a number of recurring themes of which two are of particular interest: *affiliation with rain* and *affiliation with snakes*. Given that folklore and cultural beliefs reportedly have strong predictive outcomes on frog conservation initiatives (Ceríaco 2012; Tarrant et al. 2016; Brom et al. 2020; Deutsch et al. 2020; Farooq et al. 2021; Vergara-Ríos et al. 2021), it is of concern that beliefs such as "killing a frog and leaving it outside, belly-up, will call rain" are still being handed down from generation to generation. Furthermore, the common belief that "where there are frogs, there are snakes" may also cause unwarranted, and sometimes lethal, reactions towards frogs.

Interestingly, participants' responses to an open-ended question designed to probe any childhood memories, as well as parental biophilia (Brom et al. 2020) that could affect their views and behaviours, confirmed exposure to some other common myths that could cause fear: "frogs cause warts" and "a frog is a bad omen and should be killed with salt and left outside".

Direct interactions with nature can influence and change people's attitudes towards nature, and there is a strong relationship between this and developmental benefits among children when exposed to nature (Soga and Gaston 2022). A theory termed "nature blindness" could be applicable here, where people showing less liking or knowledge towards frogs have a natural tendency to be "blind" to noticing members of the taxa. The opposite may be true for those that show higher liking and knowledge towards frogs –

individuals that like frogs have a higher tendency to hear and see frogs in the environment around them. Even though most participants had positive, playful memories of catching frogs and playing with them, participants from Kurland and Covie ended up disliking frogs. Seemingly, parental views on frogs slightly carried over into their adulthood, suggesting that there might be some dominating influences on participants' views that were not fully covered in this study. In this regard, Bouman et al. (2020) suggested that "the value of what others value" influences individual pro- and, possibly, anti-environmental motivations, beliefs, intentions, and actions. Individual bio-spheric values, and the notion of implementing and live out these values, are strongly dependent on how the group individuals surround themselves which endorses their bio-spheric values. This could well be the case in Kurland and Covie where positive and playful memories are slowly being substituted with the general demeanor of the community as a whole – a demeanor that tends towards amphibian aversion and slight hostility towards frog conservation.

This study adds to the body of evidence that the attitudes and intended behaviours of people towards frogs are largely culture-specific, but still follow specific patterns. This confirms the discourse between South Africans' attitudes towards specific environmental concepts: attitudes affect behaviour; education level, or extent of environmental knowledge affects attitudes; and cultural preconceptions or misconceptions also play a role in shaping beliefs, attitudes and behaviour (Tarrant et al. 2016; Evert et al. 2021; Brom et al. 2020).

Conclusion

This study not only substantiates earlier findings regarding human-frog interactions and conflict, but also provides a detailed look into the different aspects of said interactions and how they are influenced by demographic profiles, cultural beliefs and myths, memorial background, and location specificity. In addition, the results highlight the importance of variability between community-specific views towards a matter where conservation intervention is required and emphasises the need to focus on how communities feel about proposed interventions. For example, if people are not keen on learning more about frogs, it could be beneficial "to take the long way round" by following a generalist approach to pro-frog behavioural change by focusing first on pro-environmental behavior in general rather education about frogs as an initial approach.

Notes

1. Note that E2 and E3 were intended to gather supporting data for E1 only. Since these two questions were not measured on a scale, no correlations and comparisons with other variables are possible.
2. *H. marmoratus* is an ornamental species widely spread all along the south and east coasts of South Africa, while *A. knysnae* remains restricted to areas around Knysna (De Lange 2019). *Breviceps fuscus* looks naturally "grumpy", thereby creating the impression of an ugly frog.

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