NATURE'S *letters*



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Journal's focus and scope

Nature's Letters is a multi-disciplinary journal aimed at documenting, describing and critically reflecting on applied social (e.g. historical) and/or ecological research topics that contribute to understanding and conserving Nature's Valley and its surrounds.

The journal is published online and in print format by the NVT TSITSIKAMMA, a not-for-profit company that focuses on conservation, conservation education, applied research and community engagement in the Western Cape, South Africa.

Manuscripts for review can be submitted by anyone working on or who has worked on any social and/or ecological topics in and around Nature's Valley within the past five years.

Guidelines for submissions are available at https://nvt.org.za/natures-letters/.

Contributors to April 2024 issue:

- Brittany Arendse (Woodrow Sustainable Solutions)
- Sky Beveridge (NVT)
- Dr Margaret Bryer (University of Wisconsin)
- Prof Hendri Coetzee (NVT)
- Dr Sandra du Plessis (independent consultant)
- Sophie Kurilla (Tufts University)
- James McCulloch (University of Oxford)
- Jane Mclleleron (Nature's Valley resident)
- Lauren Moriarty (NVT)
- Dr Micheal Powell (Rhodes University)
- Dr Nick Riverse-Moore (Bioassets)
- Nicholaus Huchzermeyer (Rhodes University)
- Dr Kris Sabbi (Harvard University)
- Dr Wynand Vlok (Bioassets)
- Kayla Webster (NVT)

External reviewers:

- Prof Henk Bouman (North-West University)
- Dr Mark Brown (University of KwaZulu-Natal & Discover Eden)
- Dr Bianca Greyvenstein (North-West University)
- Prof Klaus Kellner (North-West University)

Language editing:

- Daleen Groenewald

Graphic design:

- Lauren Moriarty
- Brittany Arendse (Cover page)

FROM THE EDITOR'S DESK

Over the past two years, my awareness of the astounding biodiversity found in and around Nature's Valley grew with leaps and bounds thanks to some very perceptive residents and, of course, my dedicated colleagues at and the trustees of the NVT as well as the incredible people we partner with.

As much as the Valley's astounding biodiversity had me in awe, truth be told, it also had me tossing and turning many a night.

What keeps me awake at night is what is nowadays referred to as the "shifting baseline syndrome".

No, this is not some or other sleeping disorder: Rather, this syndrome is a type of cognitive bias that occurs when people no longer notice the seemingly insignificant changes that occur over time – habitats change, species disappear...

In essence, instead of being concerned about these changes, people are lulled into simply accepting that the altered state of the environment is now the norm.

During one of my sleepless nights, I had a brainwave: To counter cognitive bias, why not create a forum where our residents can share their observations of how they perceive the Valley's ecological state to be altering ever so slightly?

An observation shared, I argued, is a potential threat that can be studied more closely and countered if need be.

But then it occurred to me that all NVT's stakeholders are also deserving of sharing in the "good news": We are duty bound to offer them a glimmer of hope that everything possible is being done to keep habitats from changing and to prevent species from disappearing.

That glimmer of hope stems from the social and ecological data we, as a team, have collected over the years as part of our broader conservation, education, community engagement and research mandate. Also of note is the "big data" currently being generated via our forest programme which, in all likelihood, will be surpassed by even bigger data sets stemming from the recently commissioned marine programme.

To merely gather data, though, is of little consequence unless the results and findings are shared and, eventually, published in reputable scientific journals that can be consulted by environmentalists the world over to inform and refine their own studies.

This need to share and publish research results triggered yet another train of thought: As much as the NVT can consider itself fortunate to have so many budding scientists who wish to complete an internship with us, we not only have an obligation to afford them every opportunity to gain valuable first-hand experience in their chosen field of study but also to hone a rather specialised skill set: The ability to deliver an academic paper in a manner that will satisfy the rather fastidious scientific fraternity.

To afford our current interns the opportunity to learn from the "experts" (i.e. their predecessors), I thought it would be meaningful and insightful to share some of the papers delivered by the latter on the results and findings of the studies they conducted in and around the Valley in recent times.

Having burnt the midnight oil for quite a while, I decided the best way to “package” all of the above would be to let the NVT's very own journal see the light.

And here it is: The inaugural issue of *Nature’s Letters*.

The intention with this journal is two-fold:

1. To counter the shifting baseline syndrome by sharing observations and alerting all interested and affected parties to potential threats; and,
2. To share knowledge and expertise in the interest of facilitating and stimulating scientific studies in areas that would not only be beneficial to Nature's Valley but also to conservationists the world over.

In this issue, Jane Mclleleron shares her very insightful observation of the changes to the marine environment she noted over the past twenty years. Those with a keen interest in the results and findings of studies conducted by former interns/visiting scholars in and around the Valley will find the seven featured papers highly informative, not to mention the summary of three of the Sout (Oos) River studies NVT outsourced to external service providers.

By way of conclusion, I will attempt to contextualise the content covered in this issue by providing a brief synopsis of what we have uncovered, what we are attempting to uncover and what we believe warrants further uncovering.

I trust you will find this issue of Nature’s Letters insightful and look forward to receiving your feedback, inputs and suggestions.

Sincerely



Prof Hendri Coetzee
Executive Director: NVT
hendri.coetzee@nvt.org.za

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SCHOLARLY PAPERS

To follow are seven papers submitted by former visiting post-graduate students/interns, current and former staff and some of our partners covering a whole array of subjects ranging from baboons, birds, bushbuck, invertebrates and invasive alien plants.

Combined, these papers cover just about every habitat common to the Valley: estuaries, forests, fynbos, rivers and shores, not to mention the built environment.

To peak your interest, here's a brief overview of what you can expect to learn from each of the papers organised per subject:

Baboons

1. One of the interesting field observations reported in the first paper by Dr Kris Sabbi (Harvard University), Dr Margaret Bryer (University of Wisconsin) and Sky Beveridge (NVT's forest programme) is that of a young chacma baboon (*Papio ursinus*) snacking on wild mushrooms. Apparently, this is referred to as mycophagy (i.e. fungal feeding), a phenomenon that I found rather novel.

2. In the second paper by Sophie Kurilla (Tufts University), who joined NVT during her senior thesis research data collection in 2023, findings on the spatial use and ranging patterns of the Valley's local troop are reported in collaboration with Dr Sabbi and me. This information will be used to refine the Nature's Valley baboon programme in collaboration with SANParks in the coming months, especially given that human-baboon conflict has seemingly shifted to the NV rest camp. Another interesting development is that now that the baboons have departed, the vervet monkeys (*Chlorocebus pygerythrus*) are all too keen to take their place – an emerging challenge NVT plans to address via experimental research in partnership with our new colleagues from Harvard and Wisconsin and in collaboration with the Nature's Valley Ratepayers' Association (NVRA)/Special Rating Area (SRA) NPC and the Bitou Municipality.

Birds

3. Who would have guessed that the Cape white-eye (*Zosterops virens*) is the most common ringed bird in the Phyl Martin Park? The paper by Brittany Arendse (a former colleague who now works in Ireland) and Kayla Webster (NVT's coastal programme and Nature's Valley's very own bird expert) focuses on bird-ringing efforts in the park over a period of six years and highlights the importance of our botanical garden as an open space/conservation area. Both seasoned and novice "twitchers" might also want to study this paper to learn exactly how many species (including visitors) have made an appearance through the years.

4. In her paper, Lauren Moriarty (who is currently laying the groundwork for a PhD at Nelson Mandela University and works on NVT's rivers and estuaries as well as education programmes.) focuses on the water birds recorded at the Groot (Wes) River estuary over a period of 20 years as

part of one of NVT's long-term ecological monitoring projects in partnership with BirdLife Plettenberg Bay. Even though the bird population seems to be stable, the seasonal fluctuation in species and their numbers sparked Lauren's interest and, as a next step, she wants to determine what this phenomenon can be ascribed to.

Bushbuck

5. The second article by Moriarty deals with the movement patterns of bushbuck (*Tragelaphus scriptus*) in the Valley and provides a baseline against which changes can be measured in future. In this article, the importance of photographic identification is highlighted and, as part of NVT's urban conservancy project, we are most definitely going to ask residents and visitors to help us monitor their movements.

Invasive alien plants

6. The paper by Sky Beveridge (who works on NVT's forest programme and also contributed to one of the baboon studies referred to above) focuses on the occurrence of invasive alien plant species in the Nature's Valley village. Thanks to his research, we now know that at least sixteen such species are present in the Village. We also know where they are located (around a third of all properties are affected), implying that we are now in a position to develop an intervention plan in collaboration with the NVRA/SRA NPC to combat this challenge before it creates a serious problem.

Invertebrates

7. Epigaeic invertebrates (in other words those that neither burrow nor swim nor fly) are generally regarded as good ecological indicators because they play an important role in maintaining ecosystem processes (e.g. nutrient cycling) and rely almost entirely on the resources provided by the organic leaf litter layer. Given that they are also known to be sensitive to environmental changes, James McCulloch (a 2023 intern from the University of Oxford's Merton College) provides some insight into the preliminary effects attempts to restore the fynbos had on the abundance and diversity of these invertebrates compared to primary fynbos. The results and findings reported in his paper will serve to inform NVT's follow-up research on invertebrates.

A rare treat: Young chacma baboon (*Papio ursinus*) observed by NVT researchers snacking on wild mushrooms

Authors:
Kris H. Sabbi [1]
Sky Beveridge [2]
Margaret A. H. Bryer [3]

Affiliations:
[1]Harvard University, Department of Human Evolutionary Biology, Cambridge, MA, United States of America
[2]NVT, Nature's Valley, South Africa
[3]University of Wisconsin, Department of Anthropology, Madison, WI, United States of America

Corresponding author:
Kris H. Sabbi
ksabbi@fas.harvard.edu

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In recent years, mushrooms have emerged as versatile resources across sectors from fine dining to technological innovations to forest regeneration. Despite this recent shift to prominence, mushrooms have been used for centuries across the globe as both food and medicine (Yamin-Pasternak 2011). However, consuming raw mushrooms is relatively rare among animal species, even our closest relatives, the other primates. During routine behavioural observations with the baboons in December 2023, we witnessed a rare event: a juvenile female chacma baboon (*Papio ursinus*) feeding on a fully mature mushroom (Fig. 1). We later identified the mushroom as belonging to the genus *Pluteus* (Goldman & Gryzenhout 2019). Species of this wood-loving fungi are colloquially referred to as deer or fawn mushrooms because they are commonly eaten by deer (antelope) species wherever they are found.

Mycophagy, or eating mushrooms, is relatively rare among primates, having been observed at least once in just 10-15% of species (Hanson, Hodge & Porter 2003; Sawada 2014). For those species that do eat mushrooms, most of the time mycophagy is infrequent, but the level of detail on how often it occurs or even what species are consumed varies widely in the literature (Hanson, Hodge & Porter 2003; Sawada 2014). Many studies simply refer to a small percentage of the diet consisting of "mushrooms."

However, there are a few species of primates that, just like us, feature fungi more prominently. For example, small-bodied South American Goeldi's monkeys (*Callimico goeldii*) consume the sporocarps (fruiting bodies) of four fungus species, including *Auricularia auricula* (commonly known as wood ear) and *A. mesenterica* (tripe fungus) (Hanson 2000; Porter 2001; Hanson et al. 2006), devoting up to 63% of feeding time to eating mushrooms during certain times of the year (Porter 2001). Though Japanese macaques (*Macaca fuscata yakuide*) on Yakushima Island devote only 2% of their annual feeding time to mushrooms, they consume an impressive 67 species from 31 genera – including a species of deer mushroom like that consumed by the Nature's Valley baboons (Sawada et al. 2014). Another conspicuous example is consumption of a previously undescribed species of truffle by wild bonobos (Pan paniscus) in the Democratic Republic of Congo, a species that has since been aptly named *Hysterangium bonobo* (Elliott et al. 2020).



Figure 1: Juvenile female chacma baboon feeding on a fully mature mushroom.

When it comes to their diets, baboon species are usually considered quite generalist, and eating mushrooms has been documented in several species. However, as with other primates, mushrooms are consumed rarely compared to other foods and many descriptions of mycophagy lack detail. For example, sometimes otherwise detailed accounts of baboon diet include mushrooms in the food category "other." One study of olive baboons (*Papio anubis*) in Uganda mentions "mushrooms were encountered seasonally and were their favourite when encountered" (Okecha & Newton-Fisher 2006:69) but does not identify these favoured foods with any additional details. Similarly, although mushroom eating has been documented among other populations of chacma baboons in South Africa, previous work indicates that mushrooms make up a small percentage of the diet and researchers do not tend to identify mushrooms eaten.

Among Altmann's (1998, 2009) detailed accounts of young yellow baboon (*Papio cynocephalus*) diet and nutrition, he observed a yearling baboon eat "the fruit caps of a white mushroom (*Agaricus* prob. *bukavuensis*)" (Altmann 2009:621). Likewise, Byrne and colleagues (1993) observed adult male and juvenile individuals in one group of chacma baboons consuming "field mushrooms," the implication being fungi of the genus *Agaricus*. To the best of our knowledge and according to the published record, this is the first time that chacma baboons have been documented consuming a species of deer mushroom.

As primate mycophagy is both rare and understudied, it is unclear exactly what it is that baboons and other primates are getting from these foods. However, regardless of how often mushrooms are consumed by any species, they still hold health and ecosystem service implications. Given the diversity of mushroom species and the resulting diverse nutritional (Wallis, Claridge & Trappe 2012; Wasser 2014) and medicinal (Yamin-Pasternak 2011; Wasser 2014) composition of

mushrooms, fungi can potentially play diverse roles in primate ecology.

Additionally, primates, like other mushroom-eaters such as rodents and marsupials (Frank et al. 2009; Johnson 1995), can serve as spore dispersers, playing a key ecosystem role. Identifying and analysing mushroom species that are consumed by primates, including baboons, can provide important insight into understudied primate-fungi relationships, with implications for macronutrient, micronutrient, and medicinal gains for baboons and baboon ecosystem roles in spore dispersal.

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Spatial use and ranging patterns among chacma baboons (*Papio ursinus*) in Nature's Valley, South Africa

Authors:
Kurilla, S.E.[1,2]
Coetzee, H.C.[3,4]
Sabbi, K.H.[5]

Affiliations:
[1]Tufts University, Departments of Anthropology and Biology, [2]Boston, MA, United States of America
[3]North-West University, COMPRES, Faculty of Health Sciences, Potchefstroom, South Africa & [4]NVT, Nature's Valley, South Africa
[5]Harvard University, Department of Human Evolutionary Biology, Cambridge, MA, United States of America

Corresponding author:
Sophie Kurilla
Sophia.Kurilla@tufts.edu

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Abstract

Variation in chacma baboon (*Papio ursinus*) ranging behaviour is driven by factors such as habitat type, group size and food resources, the latter of which seasonally fluctuates in quality, distribution and availability. In this study, we aim to provide an initial assessment of the winter ranging patterns and space-use for a small female-only troop of chacma baboons (n=12) that resides around Nature's Valley, South Africa. Spatial data, including GPS coordinates and terrain type, were collected on the troop using instantaneous scan sampling at ten-minute intervals. Our preliminary estimate of the Nature's Valley troop's home range was 4.31 km^2, and the troop travelled a mean daily distance of 1.66 km (sd = ± 0.72). Compared to previously reported data on other chama baboon groups, the Nature's Valley troop had a relatively small range and shorter daily path length. Further, we found that the Nature's Valley troop spent most of their time in the forest (> 60%). Within the forest, the baboons tended to use forest edges that were near human-settled areas, including Nature's Valley village and the rest camp. This may be due in large part to the terrain, as much of the forest further from human areas includes steep cliffs without much vegetation. However, one additional factor is that easily accessible human trash bins near several picnic areas along the road also draw the baboons toward human spaces. We expect these preliminary results to change with seasonal shifts in food availability.

Introduction

As habitat generalists with eclectic diets, baboons (*Papio* spp) range across the African continent, from savannas into desert, mountain, urban and forest biomes (Kopp et al. 2023). Wherever baboons live, they must contend with seasonal variation in temperature and weather, terrain and the availability of the foods they eat. However, the chacma baboons (*Papio ursinus*) of southern Africa face some of the harshest environments across baboon species (Henzi & Barret 2003). Southern Africa features low rainfall and low temperatures, particularly in areas of high altitude, imposing unique ecological pressures such as extremely low seasonal food availability that shape group dynamics and behaviour (Henzi et al. 1992; Henzi & Lycett 1995; Henzi & Barrett 2003).

Like other animals, the relationship between home range and distances travelled by chacma baboons strongly depends on seasonal changes of food resources. Herbaceous leaves and grasses generally comprise the majority of chacma baboons' diets, but other natural foods include fruits, flowers and nuts and seeds (Johnson et al. 2013; Codron et al. 2006). During winter, high-quality natural food items, such as fruit, are least available in the forest (Von Maltitz et al. 2003). In response to seasonal resource availability, previous research on chacma baboon troops in central and eastern South Africa have shown that chacmas either change their home range size or shift their spatial use within their home ranges (Henzi et al. 2011; Slater et al. 2018; Hoffman & O'Riain 2012).

In addition to ecological factors, human land-use patterns also contribute to chacma baboon ranging patterns (Hoffman & O'Riain 2011). In many areas where baboon ranges overlap significantly with human communities and settlements, access to indigenous plants and foraging items is limited (Hoffman & O'Riain 2011). Under these conditions, baboons flexibly adjust their diets to include introduced and/or invasive species including agricultural products (Hoffman & O'Riain 2011). Additionally, they will also forage from trash bins for discarded human-derived resources (Altmann & Muruthi 1988). Studies have reported mixed results on the health implications for this shift. However, it is clear that sourcing human-introduced foods substantially affects baboons' foraging and ranging behaviour (Hoffman & O'Riain 2011; Felmann et al. 2016). For instance, baboons overlapping a human settlement spent 20% of the time foraging and had shorter and more predictable daily ranges compared to neighbouring non-overlapping troops (Altmann & Muruthi 1988). In response, humans often intervene to prevent access to important human agricultural resources (Felmann et al. 2016). Both processes shape baboon movement, altering habitat use and contributing to home range size.

Here, we present the first assessment of ranging patterns among the Nature's Valley baboon troop as part of a long-term project which aims to better understand whether and, if so, how chacma baboons respond to seasonal fluctuations of food availability and/or rely on human-derived resources in the area. We quantify, describe and contextualise the troop's range and spatial use patterns during winter – the season when high quality food items such as fruit are least available in the forest and human presence in the valley is lowest (Von Maltitz et al. 2003).

Methods

Study site and subjects

Our study was conducted around Nature's Valley in the Tsitsikamma Protected Area, Western Cape, South Africa. The environment is characterised as an Afrotemperate forest (Von Maltitz et al. 2003). At a mean altitude of 575 m, the habitat experiences a mean temperature of 8.9°C in winter to 23.8°C in summer with rainfall peaking in autumn and early summer (500-1200 mm annual rainfall) (Von Maltitz et al. 2003). Nature's Valley includes a mosaic of forest, marine, fynbos and urban spaces (Lubke 2010). As a coastal forest, Nature's Valley is dominated by both canopy (including Pterocelastrus tricuspidatus, Olea capensis macrocarpa and Apodytes dimidiata) and subcanopy trees (including Gonioma kamassi) as well as a dense shrub layer dominated by Trichocladus crinitus

(Von Maltitz et al. 2003). Few large predators range in the area such as leopards (*Panthera pardus pardus*) that have rarely been spotted in recent years (Sky Beveridge personal communication).

We followed one small troop of chacma baboons (n=12). At the time of the study, the local Nature's Valley baboon troop encompassed five adult females and seven subadults ranging from weaned infants to older juveniles (females = 5, males = 2). Six months prior to the study, the alpha male died of unknown causes. The rest of the males likely dispersed (for unknown reasons), and no adult males joined the troop over the course of the study.

Data collection

Ranging data on the Nature's Valley troop of baboons were collected from May to August 2023 using a hand-held Garmin eTrex 10 GPS unit. Following prior studies, the troop was habituated to researcher presence at a distance of 7-10 metres (Hernandez Tienda et al. 2022). To collect ranging data, SEK located the troop early in the morning near their roosting location from the previous night whenever possible. If this was not possible, baboons were located by searching for them in nearby forest patches, utilising tips from local baboon monitors and villagers as they became available. On each data collection day, SEK followed baboons for as long as possible until they either began bedding down for the night, or travelled toward a location where they could not be followed (e.g. up a cliff face). While with the baboons, SEK recorded GPS coordinates marking the troop's location at ten-minute intervals and then created a waypoint in the GPS (also noting the time, date, spread and activity of the group) within 7-10 m from the troop.

Analyses

To calculate home range and mean daily distance travelled for the Nature's Valley study troop, we used ArcGIS Pro (Version 3.2). Using the minimum bounding geometry geoprocessing tool, we used Minimum Convex Polygons (MCP) that incorporated every GPS point collected from group scans (Slater et al. 2018). We then identified the shape area to determine the area in square kilometres that reflected the troop's home range.

To calculate the mean daily distance travelled, we included GPS coordinates from days where group scans were collected on the troop for a minimum of six hours in order to get a more accurate reflection of the baboons' space use (McCann et al. 2021). Using the directional distribution geoprocessing tool, we created standard deviation ellipses to one standard deviation divided by day. We then recorded each day's shape area in kilometres and the standard deviation for each day and calculated a total average. We visualised the baboon's habitat utilisation using the kernel density geoprocessing tool to make a heat map of GPS points collected over the study period

Results

We collected 312 hours of ranging data on the Nature's Valley baboon troop over 52 observation days. Over the course of the study, the troop's estimated home range was 4.31 km^2, encompassing a mosaic of forest, montane and urban terrains (Table 1, Figure 2a). Data were collected an average of 6.23 (sd = ± 5.48) hours per observation day (range = 0.75 – 11.71 hours). On average, the Nature's Valley troop travelled 1.66 km (± 0.72) per observation day (range = 0.44 – 3.43 km).

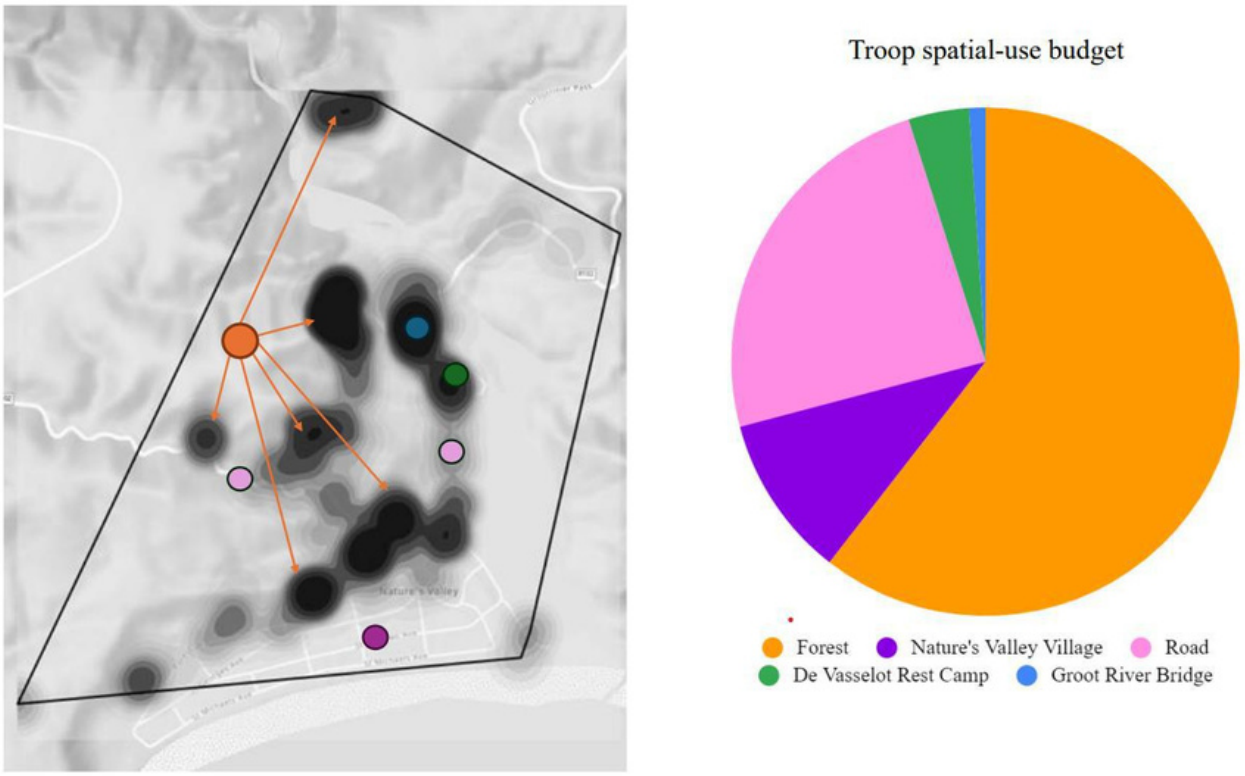


Figure 1: Kernel density map displaying GPS coordinates of the Nature's Valley study troop: Area shade corresponds with the frequency that the troop was reported there. The outline represents the troop's estimated home range. Coloured dots correspond with the space/terrain type.

The baboons spent most of their time in the forest (60.5%) and far less time in human spaces, including the village (10.4%) and rest camp (3.9%) (Figure 2b). They spent nearly a quarter of their time on the road (24.2%). Within these general areas, the baboons concentrated their time on some specific sites more than others.

Discussion

The chacma baboons at Nature's Valley used a winter home range of around 4.3 km^2 and travelled between 1.5 and 2 km per day on average. While these figures do overlap with the lower ranges estimated for other chacma baboon troops, both measures are less than half of previously reported averages.

At first glance, our findings seem at odds with previous research reporting that home range and path length usually increase during times of low food availability (e.g. winter), as animals must travel farther to obtain adequate

Table 1: Mean group size, home range and daily range of chacma baboon troops compiled from the literature and calculated for the Nature's Valley study group (standard deviation included when possible).

Data source	Group size	Home range (km^2)	Daily range (km)
Other chacma baboon troops (n=51)*	49.18 ± 30.15	13.73 ± 9.98	5.00 ± 3.45
Nature's Valley Troop	12	4.31	1.66 ± 0.72

*Anderson 1980; Collet et al. 2022; Hamilton 1985; Hamilton et al. 1976; Henzi et al. 1992; Lewis & O'Riain 2017; Melnick & Pearl 1987; Slater et al. 2018; Stoltz & Saayman 1970

nutrition (Markham & Gesquiere 2017; Johnson et al. 2015). However, chacma baboons exhibit highly variable home and daily ranges that largely depend on troop size, with larger troops having larger home range sizes and vice versa (Table 1; Hoffman & O'Riain 2012; Slater et al. 2018). In line with their small range size, the Nature's Valley troop is much smaller compared to the average chacma baboon group. Small group size may also contribute to the baboon's short daily path length, as fewer group members must compete for resources (Majolo et al. 2008, Johnson et al. 2015).

In addition to group size, habitat type and structure also play important roles in shaping both the local ecology and the places that baboons can access (Henzi et al. 1995, 2011). Around Nature's Valley, geological formations (e.g. tall cliffs and river systems) may limit the ranging areas of local baboons. Conversely, human alterations to the landscape (e.g. settlements and roads) may also shape home range size and space use. A study of chacma baboons living on the Cape Peninsula also reported smaller home ranges of around 9-10 km^2 for up to 115 individuals, resulting in a population density of 12 baboons per km^2 (Hoffman & O'Riain 2011, 2012). In Nature's Valley, the population is much less dense (2.78 per km^2). Though the group size prior to the study period is uncertain, home range size in Nature's Valley might be similarly affected by human activity and settlements as seen in other areas.

Roads may also affect animal space use. While we often consider roads as dangerous boundaries or territorial borders (Eloff et al. 2008; Quintana et al. 2022), they can make animal travel easier and/or provide open areas to warm in the sun during cold winter months (Hill et al. 2021). Indeed, the Nature's Valley baboons spent nearly a quarter of their time on the roads during winter data collection. Further data collection on activity and feeding budgets will aid our understanding of how the Nature's Valley troop utilises different spaces within their home range.

Another way chacma baboons cope with seasonal variation in food availability is by feeding on alternative resources and reducing daily distance travelled (Slater et al. 2018). For example, coastal populations of chacma baboons in South Africa's Cape Point Nature Reserve utilise marine resources by foraging in the intertidal zone for protein-dense shark eggs and marine shellfish (Davidge 1978; Lewis et al. 2018; Lewis & O'Riain 2019). Within their winter home range, the Nature's Valley troop preferred ranging in several distinct areas, mostly relying on a few specific sections of the forest. According to Lewis and O'Riain (2017), like other animals, chacma baboons dedicate a large portion of their activity budgets (> 40%) to searching for and consuming food, especially in the winter. In our study, higher density of baboon observations in certain forest spots likely reflects preferred feeding patches on natural resources (Barton et al. 2012). Indeed, most of the time that the baboons spent feeding on natural resources was observed within these forest patches.

However, the troop's forest spatial use may also be shaped by human-derived resource usage (Fehlmann et al. 2016). Previous research has shown that primates (including baboons) rely on human-derived resources more often when forest fruit availability is low (Naughton-Treves et al. 1998). During winter, high-quality natural food items, such as fruit, are least available in the forest (Von Maltitz et al. 2003). Like other baboon groups, the Nature's Valley troop may be drawn toward human areas and/or areas where human food resources or food waste is easily accessible during times of low food availability. This form of adaptive foraging often results in the

consumption of calorically dense and high sugar human-derived resources (such as fruit, bread and meat) that allows baboon troops to expend less time and energy on foraging natural resources, equating to shorter daily ranges and a smaller home range (Johnson et al., 2015; Hoffman & O'Riain 2012).

Though the baboons spent little time in human spaces such as the village and rest camp, they did seem to prefer areas of the forest that bordered human spaces or trails. One possibility is that our findings are at least partly explained by observer bias, as the baboons were often easier to track in these areas. However, our results align with previous research reflecting adaptive space use by baboons in response to human presence (Hoffman & O'Riain 2011, 2012; Fehlmann et al. 2016). When baboons did spend time in human spaces, they tended to remain close to the forest edge and, on multiple occasions, we observed the baboons retreating to forested refuge when they came into conflict with humans. This suggests that a risk-reward trade-off underlies habitat utilisation of baboons overlapping human spaces (Fehlmann et al. 2016). In other words, while the draw toward food resources shapes this preference, it may also be due to the security of those spaces as well as being physically easier to navigate and travel in.

Importantly, the results we present here are preliminary and include several specific limitations. In particular, we are unable to directly evaluate the pulling forces of wild versus human food resources on baboon ranging and space use. While natural food availability is expected to decline in colder, wetter months, future work must quantify these shifts to determine how impactful they could be on baboon diet and behaviour. Further, while there were a limited number of places that baboons could and did interact with human trash, it is unclear how much this type of foraging actually contributed to their diets. This is especially important as winter also coincides with the low human population density around Nature's Valley including low rates of tourism and, in turn, low availability of food waste in trash receptacles. Further data quantifying both types of food resources are required to determine how natural versus human food resources shape baboon space use at Nature's Valley.

Our results provide important preliminary work toward understanding chacma baboon socioecology and the potential for tensions between baboons and human residents in and around Nature's Valley. As we work toward building this understanding and finding solutions to problems that arise between humans and baboons, our research will further document and compare the ranging patterns across seasons. This will allow us to measure both fruit availability in the forest as well as the nutritional impact of tourist/human presence in the area. Understanding the drivers of the Nature's Valley troop's habitat utilisation, ranging patterns and foraging behaviour will better inform troop-specific management interventions to more effectively reduce negative human-baboon interactions in the area.

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Discovering the birds of Phyl Martin Park: Ringing results from 2017 to 2023

Authors:
Brittany Arendse[1]
Kayla Webster[2]

Affiliations:
[1]Woodrow Sustainable Solutions, Sligo, Ireland
[2]NVT, Nature's Valley, South Africa

Corresponding author:
Kayla Webster
kayla.webster@nvt.org.za

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Abstract

Bird ringing can be an incredibly useful tool for monitoring birds. When used alongside effective capture techniques, such as mist-netting, researchers can use bird ringing data to estimate species population sizes, assess survival, understand movement patterns and monitor the effects of environmental changes. This information can aid our understanding of avian ecology and guide conservation efforts. This study used mist-netting and bird ringing as techniques to conduct a long-term census of bird species that occur in the Phyl Martin Park, Nature's Valley, South Africa. The ultimate purpose of this research was to monitor the ecological health of the Phyl Martin Park as a resource for local forest and fynbos passerine bird species. A total of 434 individuals comprising 33 species were captured and ringed, which were mostly forest specialists, but also those with mixed feeding and habitat preferences. Of these, 12 species were recaptured, equating to 20.7% of all captured individuals. This study highlights the need to continue monitoring birds in the area.

Introduction

Bird ringing data and especially recapture rates provide a wealth of information about bird populations and their dynamics within an area. Researchers use this information to estimate population size, assess survival, understand migration patterns, monitor the effects of environmental changes (Parmesan 2006) and so many more, contributing significantly to our understanding of avian ecology and conservation efforts. This information is crucial for designing effective conservation strategies.

Bird ringing has been practiced in South Africa for the last 75 years (Brown & Oschadleus 2009) and initially evolved as a tool for monitoring bird movement. Birds are fitted with uniquely numbered leg bands which allow researchers to track individuals over time. For specific studies, where necessary and when funding allows, researchers may also fit additional coloured/coded markers, which can aid in recognising certain individuals in the field, or transmitters, which send updates on an individual's location (Phalan 2007; Davis & Fisher 2009; Kendall & Virani 2012). These rings were arguably a most profound way of providing insights into both small and large-

scale movements of birds across the landscape (Brown & Oschadleus 2009). Today, mist-netting is a common used by ornithologists to capture and study birds, not only to understand movements and migration, but for studies on longevity (Lebreton 2001; Clarke et al. 2004), morphological variations (Brown et al. 2001; Morgan 2004), moult (Oschadleus & Underhill 2006a, 2006b), population dynamics (Hjort & Lindholm 1977; Osterlof & Stolt 1982; Peach et al. 1999), bird-plant interactions such as pollinator studies (Johnson & Brown 2004) and presence/ absence species data (Brown 2006).

Peach and colleagues (1999) stated that bird ringing is the only way to monitor bird survival rates and to obtain an effective way of monitoring population dynamics and productivity. Hjort and Lindholm (1977) used bird ringing data to demonstrate its usefulness when studying both long-term trends and short-term fluctuations in different species of migratory birds even when trapping methods are not standardised. Osterlof and Stolt (1982) examined the ringing numbers of 34 passerine species for long-term trends and found that 25% of species showed either an increase or decrease in numbers over 19 years. There are also various studies conducted on climate change and how this affects species, some examples include changes in phenology, the arrival and departure dates of migrating species, (Jonzen et al. 2007; Miller-Rushing et al. 2008), potential changes in moulting or breeding seasons due to temperature changes (Coppack & Both 2002; Visser et al. 2004; Dawson 2005; Hedenstrom et al. 2007), body mass changes (Yom-Tov et al. 2006; Millien et al. 2006), and species range shifts (Crick 2004; Jonzen et al. 2007).

Brown (2006) used bird ringing data and census data to investigate annual and seasonal trends in bird species richness in coastal lowland forests which was found to be significant and useful when monitoring changes in bird populations.

Using mist nets to capture birds is noted as a useful supplement to census techniques as it assists in the detection of otherwise extremely cryptic species that would not have been recorded otherwise. For instance, the white-starred robin (*Pogonocichla stellata*) was only ever recorded by mist-netting.

The aim of the study was to monitor the ecological health of the Phyl Martin Park as a resource for local forest and fynbos passerine bird species. This was to be achieved by determining the presence of bird species through multiple mist-netting and bird ringing surveys over the course of six years.

Methods

Study area

The Phyl Martin Park (33°58'43.44"S 23°33'47.16"E) is a botanical garden in Nature's Valley, a village surrounded by the Garden Route's Tsitsikamma National Park on the southern Cape coast of South Africa. The Phyl Martin Park was established in the 1980s and has since been utilised by residents and visitors as a botanical hub. The plant species found in the park are predominantly a mixture of fynbos species, specifically those of Tsitsikamma Sandstone Fynbos, as well as a small, young patch of Southern Afrotemperate Forest species on the periphery (Mucina & Rutherford 2007).

Study design

The method used to assess passerine bird presence during this study was mist-netting (de Beer et al. 2001). Mist nets are made of fine nylon or polyester mesh that is nearly invisible to birds. They consist of vertical panels that are suspended between poles. Considering the size of the park and the movement of birds through it, eight nets were set up along the pathways of the Phyl Martin Park. The nets were typically 12 m in length, except one, which was 9 m and placed on a shorter pathway.

The nets were set up before sunrise to ensure minimal disturbance to birds in the study area. The nets were then deployed at first light and remained open for several hours during the morning when birds are typically more active. Nets were usually set up in a series along the length of the pathway being used. They were strategically placed at heights and angles that were likely to intercept birds flying across pathways from or towards vegetated areas. Surveys were conducted sporadically between 2017 and 2023, with no surveys being conducted in 2021.

Procedure

Once the mist nets were set up, they were monitored closely and checked every 20 minutes, on average. The frequency of checks depended on factors such as weather conditions and the presence of birds in the area. During cold or hot temperatures, nets were checked every 10-15 minutes, and during rain spells, nets were closed.

When a bird became entangled in the net, it was extracted quickly and carefully to minimise stress and avoid injury. Extraction of birds was conducted with a set methodology and monitored closely by a permitted Safring ringer. Each disentangled bird was then placed in its own soft cloth bag to provide a sense of calm until they could be weighed, measured and ringed, if necessary.

Data collection

Once at the processing table, the birds were removed from the bags and held in a way that minimised stress and prevented them from flapping their wings. A uniquely coded Safring ring was added to the leg of each bird unless they were already ringed. Various data were collected, such as species, age, sex, body measurements (wing and tail length, weight, etc.), and any existing markers (such as leg bands or tags) were noted. For this study, we only focussed on species presence/absence data, however, all data were uploaded to the Southern Africa ringing database (Safring: http://safring.adu.org.za/afring) to aid in present and future studies and investigations.

After data collection, the captured birds were released at the capture site, ensuring that they were in good condition before doing so. Birds were released gently from a cupped hand, allowing them to fly away when they were ready.

Data analysis

The data were analysed for species presence, the number of individuals caught related to different times of year, and survey effort. Data was stored, consolidated and analysed using Microsoft Excel (2018).

Results and discussion

Over six years, a total of 21 surveys were done during which 434 individuals comprising 33 species were captured and ringed in the Phyl Martin Park (Figure 1). Of these, 12 species were recaptured at least once. As the park has a mixture of fynbos and forest vegetation, the species caught were predominantly passerine birds, specialised to these two vegetation types. The one exception is the water thick-knee (*Burhinus vermiculatus*), which is classified as a wader, but spends a substantial amount of time in Nature's Valley village after dusk. The most commonly caught species were Cape white-eyes (*Zosterops virens*), which is not surprising as they were the 13th most commonly ringed species in southern Africa in a study by Oschadleus and Underhill (1999). The recapture data has many singly caught birds over the six year period, most of which are forest specialists or, at the very least, have mixed feeding and habitat preferences. Some rare captures included the olive bushshrike (*Chlorophoneus olivaceus*), blue-mantled

crested flycatcher (*Trochocercus cyanomelas*) and green-backed camaroptera (*Camaroptera brachyura*). All three are very inconspicuous birds, with the crested flycatcher and camaroptera often being very rambunctious when spotted.

The three species with the highest number of recaptures over the six years of surveying were the greater double-collared sunbird (*Cinnyris afer*) (29), Cape white-eye (20) and Cape batis (*Batis capensis*) (8). This is not surprising as the park and surrounding habitat, including gardens, have many Erica species as well as nectar-feeders that the sunbirds target and are specialised in. Cape white-eyes, other than being extremely common in the area, are also generalist species that do very well in most habitats because they have such a wide range of food resources,

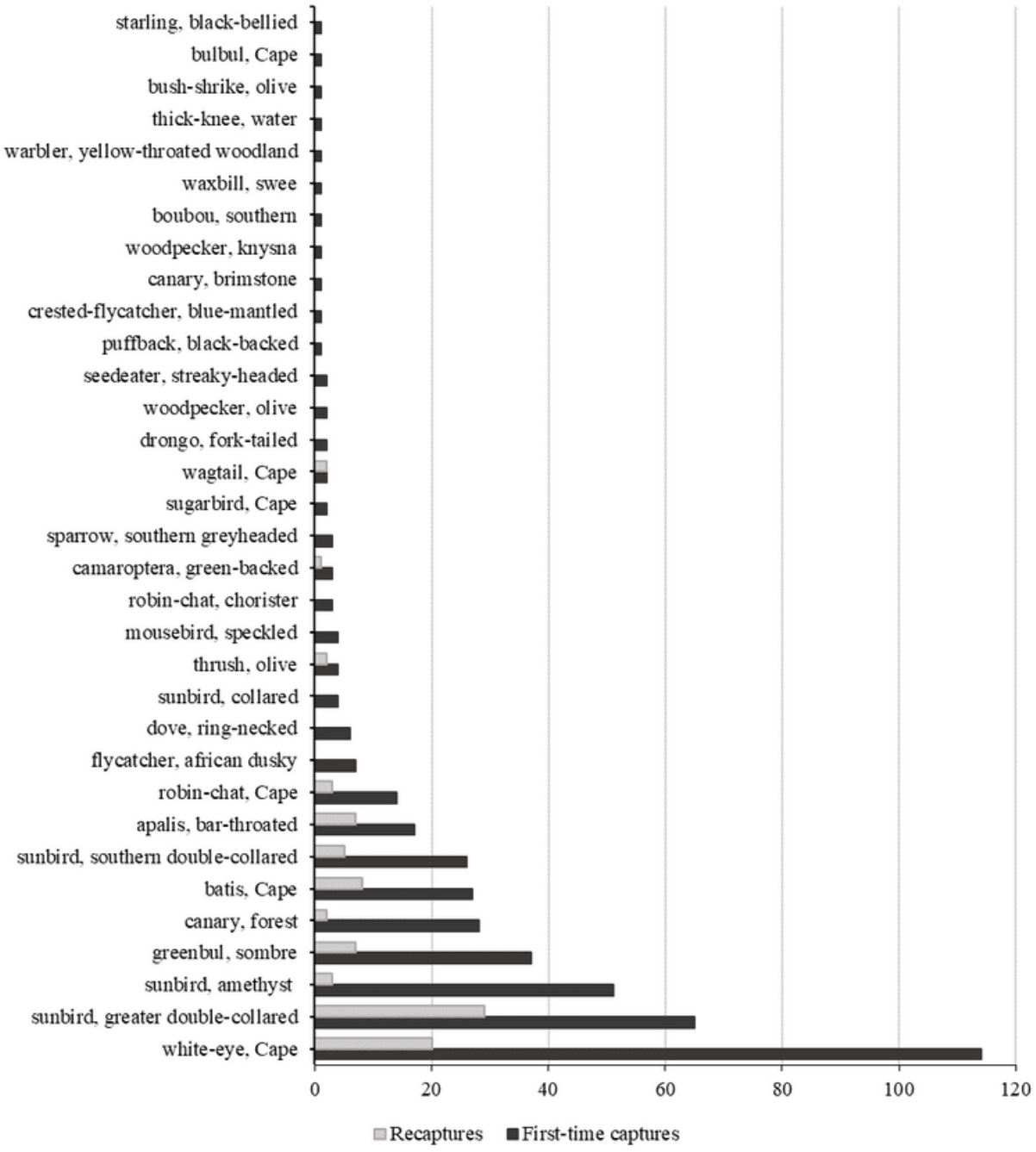


Figure 1: The species and number of individuals processed from 21 bird ringing surveys over six years (November 2017 to July 2023, excluding 2021 where no bird ringing surveys were completed): Dark grey bars indicate first-time captures and light grey bars recaptures.

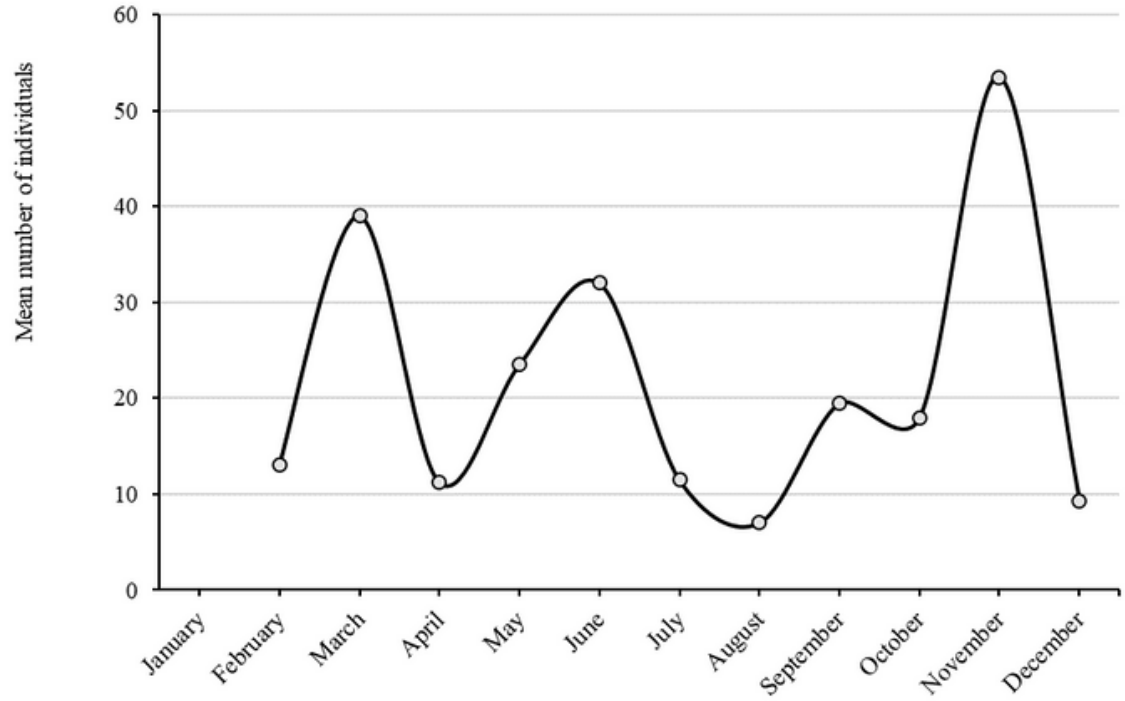


Figure 2: The mean number of individual birds caught in mist nets per month: Note that bird ringing was not conducted in January for any year.

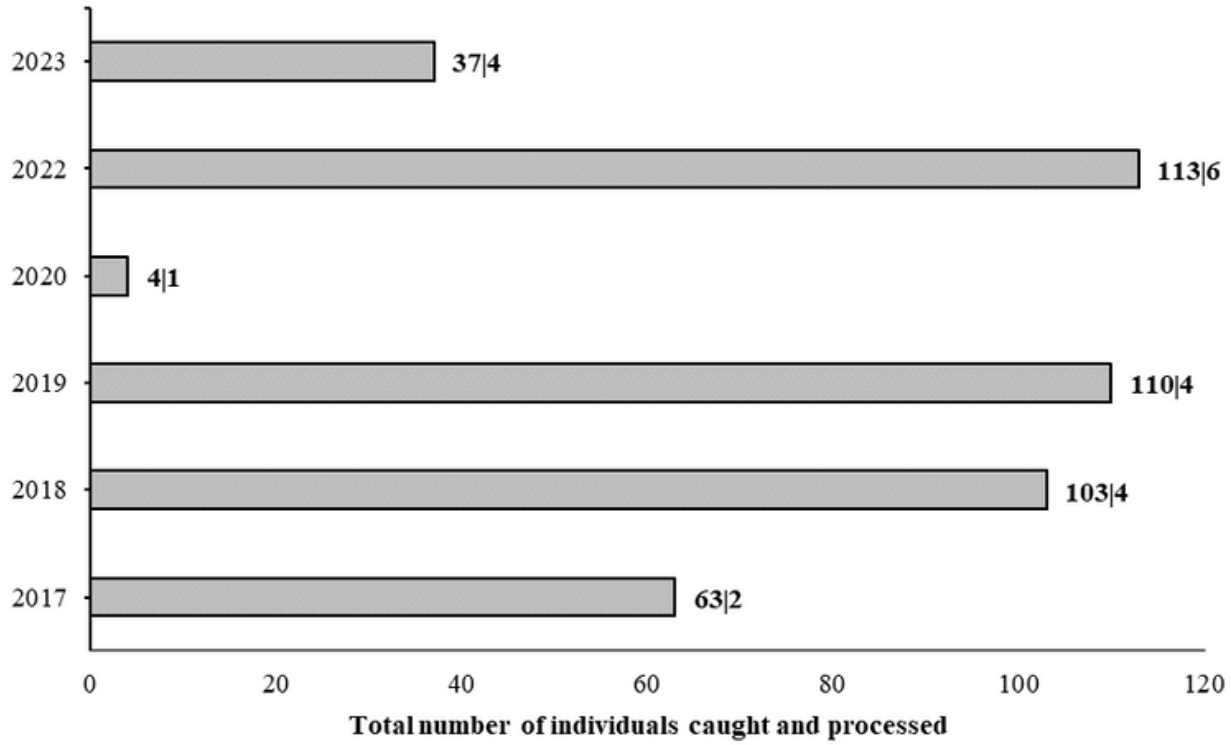


Figure 3: Number of species caught in mist nets and processed for each year in the Phyl Martin Park: The total number of individuals (a) and the number of surveys per year (b) are noted at the end of each bar as a|b.

such as nectar, insects and fruit (Brown & Downs 2003).

The overall percentage of recaptures for passerine birds in the Phyl Martin Park was 20.7%, which was relatively high within the expected range of 5% to 25% for passerines (Whitehead 2018). Specific factors can influence the recapture rate, such as species behaviour, habitat and location, seasonality, bird ringing frequency and levels of disturbance (Peach et al. 1999). Different passerine species will have different levels of site fidelity. Some species may be highly territorial while others are more nomadic and have larger ranges. The habitat and location of the study area are also significant in recapture capabilities, where in more densely vegetated areas it may be more challenging to capture birds at all.

Time of year or seasonality affects recapture rates as it determines activity rates as well as territorial breeding behaviour which confines birds to a specific area close to their nests (Peach et al. 1999).

Lastly, environmental factors such as food availability, weather and disturbance levels can influence bird behaviour and consequently recapture rates.

The variability in number of individuals and species captured could very well be affected by all the aforementioned factors, especially seasonality (Figure 2). Clear peaks in the average number of individuals captured can be seen in early summer (November), mid-autumn (March) and mid-winter (June). The highest capture rate was in November, averaging at 54 birds per survey. Apart from seasonality, surveying effort can also affect variability in the number of individuals and species caught. The number of ringing surveys over the six years varied (Figure 3) due to equipment losses as well as ringing excursions occurring at other sites not included in this study.

Conclusion and recommendations

The Phyl Martin Park houses a healthy population of fynbos and forest specialist birds with a recapture rate within the expected range. Data collection should be conducted consistently over the long-term to account for seasonal fluctuations in species presence. Ringers should also consider supplementing other ringing census techniques to capture birds in higher levels of the park or use techniques like spring traps or walk-in traps to target understory or ground-dwelling species. There is much still to be discovered: Topics pertaining to the understanding of species movements and migration, morphological variations, population dynamics, pollinator studies and more. This research undoubtedly provides important insights into the world of birds but also a valuable context for awareness and education about the conservation of birds and the habitats they thrive in.

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Bird species recorded along the Groot (Wes) River estuary over the past twenty-five years (1998-2023)

Author:
Lauren Moriarty

Affiliation:
NVT, Nature's Valley, South Africa

Corresponding author:
Lauren Moriarty
lauren.moriarty@nvt.org.za

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Abstract

This study, a collaboration between BirdLife Plettenberg Bay members and the NVT looks at the intricacies of avian ecology within the Groot (Wes) River estuary, South Africa, spanning from 1998 to 2023. Birds, good indicators of environmental change, play an important role in reflecting biodiversity and the health of ecosystems. Over the course of twenty-five years, we looked at the bi-annual data collected of waterbirds across the estuary. Noteworthy patterns emerged as we observed distinct seasonal fluctuations in species distribution, with winter populations showing obvious contrasts to their summer counterparts. These findings signal an interesting change between waterbird diversity and seasonal change. This study, integral to NVT's long-term monitoring strategy, constitutes a comprehensive effort to catalogue the avian inhabitants of the Groot (Wes) River estuary which has, in the period from 1998 to 2023, displayed overall stability in bird numbers and a diverse array of species, with a significant total record of 7,313 bird sightings and seasonal (summer-winter) counts of 4,837, totalling 41 different species.

Introduction

The southern Cape region of South Africa boasts a network of rivers and estuaries supporting local ecosystems and communities. Due to the country's warm-temperate nature, freshwater supply to these water systems is limited (James et al. 2013; Western Cape Government 2019). These systems serve as biodiversity hotspots, with estuaries providing important habitats for various species (Adams et al. 2020; James et al. 2013). However, the combined pressures of human activity and onset of climatic and seasonal shifts threaten their water quality and associated species. NVT is actively engaged in research and conservation efforts centred on the Sout (Oos) and Groot (Wes) rivers and estuaries. These efforts encompass monitoring water quality and local water birds, investigating the impact of invasive species on native flora and fauna and evaluating the overall ecological health of these ecosystems. Through research and targeted conservation, the aim is to safeguard the long-term sustainability of these southern Cape rivers and estuaries, preserving their natural resources.

The Groot (Wes) River, a natural asset in the southern Cape with high ecological importance and recreational opportunities, is deserving of conservation to ensure its preservation for future generations. The Groot (Wes) River estuary highlighted in this study is characterised as a temporary open-close system, becoming closed off from the sea periodically by a sandbar at the mouth when freshwater input and tidal influence is low (Morant et al. 1983; Western Cape Government 2019). The Groot (Wes) River Estuary Monitoring Project, conducted in collaboration with Bitou Municipality, SANParks and Garden Route District Municipality, involves collaborative sampling and data collection, ensuring the continued health of this estuary.

Estuaries, as defined by the National Biodiversity Assessment (Van Niekerk et al. 2018), are unique coastal ecosystems characterised by intermittent openings and closings, containing brackish water that links to rivers, streams and tributaries, ultimately connecting with the ocean at the lower reaches. These environments are significantly influenced by natural processes, including tides, wave actions, saline water influx from the ocean and the inflow of freshwater and sediment from upstream rivers and tributaries. The blending of seawater and freshwater in estuaries creates a rich source of nutrients, making them some of the most productive natural habitats globally (Gillanders et al. 2003; Murray et.al. 2018; Van Niekerk et al. 2018; Van Niekerk & Turpie 2012).

Estuaries play an important role in providing refuge, feeding areas, and nurseries for diverse aquatic organisms, such as birds, mammals, and fish (Van Niekerk et al. 2020, 2022). Birds frequently rely on estuaries during migration for resting and feeding. Birds are not only a notable part of freshwater ecosystems but are also important to wetlands and riparian zones surrounding them, reflecting the fundamental importance and productivity of water across various biomes (Browder 2014; Green & Elmberg 2013; Reynolds et al. 2021; Van Niekerk et al. 2022). Freshwater ecosystems and their catchments undergo natural and human-induced changes, impacting both the physical and chemical aspects, making monitoring essential for conservation efforts.

Waterbirds are sensitive to changes in their habitat, such as water quality, food availability and vegetation structure (Kopij & Paxton 2019; Li et al. 2021). Monitoring their populations can provide valuable insights into the overall health of estuarine ecosystems where birds act as indicators of change (Ormerod & Tyler 1993; Stolen et al. 2005; Van Niekerk et al. 2022). The presence or absence of various waterbird species can be used to indicate the health of an estuarine system (Kopij & Paxton 2019; Li et al. 2021; Van Niekerk et al. 2022). A diverse range of species usually suggests a healthy and balanced ecosystem. However, certain waterbird species are particularly sensitive to changes in water quality. Waterbirds often rely on specific habitats for breeding, foraging and roosting. Changes in their distribution or behaviour may signal alterations in these habitats due to factors like seasonal shifts, pollution or habitat destruction (Haig et al. 2019; Van Niekerk et al. 2022). In addition, the presence and timing of migratory waterbirds can indicate seasonal changes in estuarine conditions, implying that their arrival and departure can serve as seasonal markers for ecological monitoring (Rehfisch & Austin 2006).

Birds, as bioindicators, are valuable for monitoring both flowing and standing waters due to their responsiveness to environmental changes at various temporal scales and their reproductive parameters, providing insights into aquatic ecosystem health (Amat & Green 2010; Browder 2014; Kushlan 1993; Stolen et al. 2005). Breeding colonies of waterbirds can mirror wetland conditions, influenced by factors like water levels at foraging sites (Amat & Green 2010; Browder 2014). Conservation efforts have prioritised migratory shorebirds that winter in estuaries, benefiting from abundant invertebrate prey in intertidal mudflats, with seasonal variables, especially precipitation, significantly affecting waterbird distribution and behaviour in estuaries by impacting river flows, salinity, water clarity and primary productivity (Haig et al. 2019; Li et al. 2021).

This study investigates the waterbird community structure in the Groot (Wes) River estuary, South Africa, over a twenty-five-year period, aiming to understand seasonal shifts and potential impact of water quality on waterbird presence.

Methods

Study site

The Groot (Wes) River is a perennial river, that together with the Bobbejaans River, flows out of the Tsitsikamma Mountains, draining a catchment area of 88 km^2. The total combined length of these rivers is 35 km (Morant et al. 1983). The lower catchment area falls under SANParks' jurisdiction. The catchment consists mainly of fynbos and indigenous coastal forest, apart from pine plantations at the lower eastern and western extremities. In the southern African context, the following is a generally accepted definition of an estuary: "It is a partially enclosed, coastal body of water which is either permanently or periodically open to the sea and within which there is a measurable variation of salinity due to the mixture of sea water with fresh water derived from land drainage" (Day 1981).

The Groot (Wes) Estuary is a small to medium size (39 ha) temporarily open/closed estuary, entering the sea at Nature's Valley, and falls within the Tsitsikamma Section of the Garden Route National Park (Morant & Bickerton 1983; Western Cape Government 2019). The Groot (Wes) and Bobbejaan Rivers feed into the Groot (Wes) Estuary, which is approximately 2 kms in length (Morant & Bickerton 1983; Western Cape Government 2019). The average depth of the estuary is about 1 metre, but depths of 2 - 3 metres can be found in the middle and upper reaches. Higher rainfall levels occur in the winter seasons (June-August) and spring (September-November), and lower rainfall levels in autumn (March–May) and in summer (December–February). The western shore is low-lying and prone to flooding, while the eastern shore is bounded by hills dropping steeply to the water's edge (Morant & Bickerton 1983; Western Cape Government 2019).

The geographical boundaries, as presented by the Estuarine Functional Zone (EFZ), are represented in Figure 1 and geo-referenced as follows (Western Cape Government 2019): Downstream boundary: Estuary mouth: 33°58'53.41"S 23°34'8.32"E; Upstream boundary: 33°57'49.27"S 23°33'23.77"E; Lateral boundaries: 5 m contour AMSL along each bank.



Figure 1: The Groot (Wes) River estuary project study site.

According to studies done by Morant et al. (1983) and McLachlan (1991), the system has been seen to be healthy and unpolluted, apart from intermittent lagoon contamination from the residential area and South African National Park De Vasselot campsite sewage.

Data collection

Data on waterbirds was collected through systematic observations during boat or canoe surveys. Observers on the boat or canoe used binoculars and their naked eye to spot waterbirds, visually identifying different bird species based on distinctive characteristics such as size, plumage, coloration and behaviour. Observers recorded their observations in real-time, noting the species of waterbirds, the number of individuals in each species and their specific behaviours or activities (e.g. feeding, nesting, flying). In some cases, photographs were taken to provide additional documentation of the observed waterbirds, which was useful for verification and record-keeping. Along with bird observations, environmental data (such as water quality parameters) was collected monthly over a two-year period between 2022 and 2023. This contextual information helped in understanding the conditions in which the birds were observed. Initial data collection of this study occurred bi-annually between 1998 and 2016, after which data collection commenced once a month, every month, to track changes in waterbird populations over time.

Data analysis

For this project, we conducted extensive data analysis on waterbird populations over a twenty-five-year study period, focusing on species counts, average abundance and species richness. We compared these metrics seasonally, contrasting summer and winter months. Statistical analysis involved testing under the Shannon-Wiener diversity index and unpaired t-tests to assess differences in species abundance and richness. Additionally, we correlated waterbird data with water quality measurements (temperature, salinity, dissolved oxygen) over a two-year period between 2022 and 2023 where monthly water quality parameters and CWAC data was collected simultaneously. We further analysed these correlations seasonally, including *Escherichia coli* measurements, to understand the relationship between water quality and waterbird presence.

Results

Bi-annual waterbird monitoring from 1998 to 2016, followed by monthly data collection from 2017 to present, has provided a reliable dataset and view of the local birdlife in the Groot (Wes) River estuarine habitat. Over the twenty-five-year period from 1998 to 2023, a total of 41 different bird species were observed, with a combined seasonal (Summer-Winter) count of 4,837 individuals.

Figure 2 visually presents the cumulative sightings of waterbird species along the Groot (Wes) River estuary over the past twenty-five years. Kelp gulls (*Larus dominicanus*), Reed cormorants (*Microcarbo africanus*), White-breasted cormorants (*Phalacrocorax lucidus*), Yellow-billed ducks (*Anas undulata*), Cape cormorants (*Phalacrocorax capensis*), Egyptian geese (*Alopochen aegyptiaca*), Water thick-knees (*Burhinus vermiculatus*) and Cape wagtails (*Motacilla capensis*) emerged as the most commonly spotted among the 41 species, with a significant number of Greater crested terns (*Thalasseus bergii*) predominantly found in winter months that coincided with breeding periods.

Figures 3 and 4 illustrate the species abundance and richness trends observed throughout the study period. The Shannon–Wiener diversity index, which estimates the diversity of species within a community, considers both the number of species

(richness) and their relative abundance (evenness). In this study, the richness values were 34 and 29 for summer and winter respectively, with corresponding evenness values of 0.75 and 0.574 for summer and winter.

The Simpson's index value reflects the diversity and evenness of species distribution within a community. A higher value indicates lower diversity. In this study, the Simpson's index values were 0.11 and 0.25 for summer and winter respectively, suggesting higher diversity during the summer months.

The results of the unpaired t-test for abundance showed a two-tailed p-value of 0.9675, indicating that the difference in abundance between summer and winter months was not statistically significant. The results of the unpaired t-test for species richness showed a two-tailed p-value of 0.6458, indicating that the difference in abundance between summer and winter months was not statistically significant.

Figures 5 and 6 indicate peaks in waterbird counts during autumn and especially winter, suggesting a higher abundance of birds during the wintering periods. Initially, this peak was thought to be due to the significant number of Greater crested terns recorded over the winter months throughout the study period. However, after excluding the tern data to mitigate potential bias, the abundance of waterbirds remained at a peak during the winter months, as depicted in Figures 5 and 6.

Physico-chemical parameters, such as salinity (ppt), temperature (°C) and dissolved oxygen (measured in both percentage and mg/l), are monitored systematically at seven sites along the estuary. A distinct variation in these parameters is observed between summer and winter, with lower average temperatures and higher dissolved oxygen levels noted during the winter months (see Figure 7).

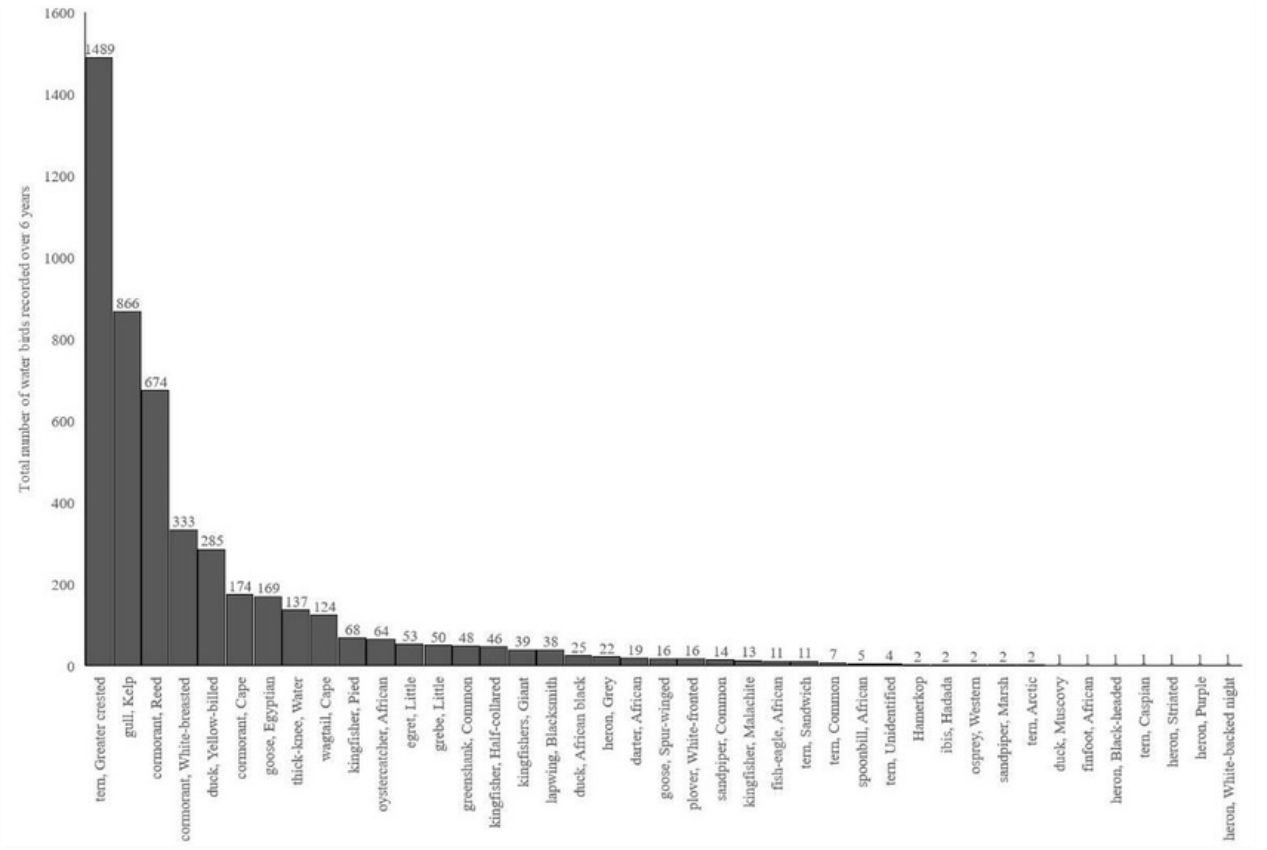


Figure 2 illustrates the total number of sightings per waterbird species recorded along the Groot (West) River estuary over the past 25 years.

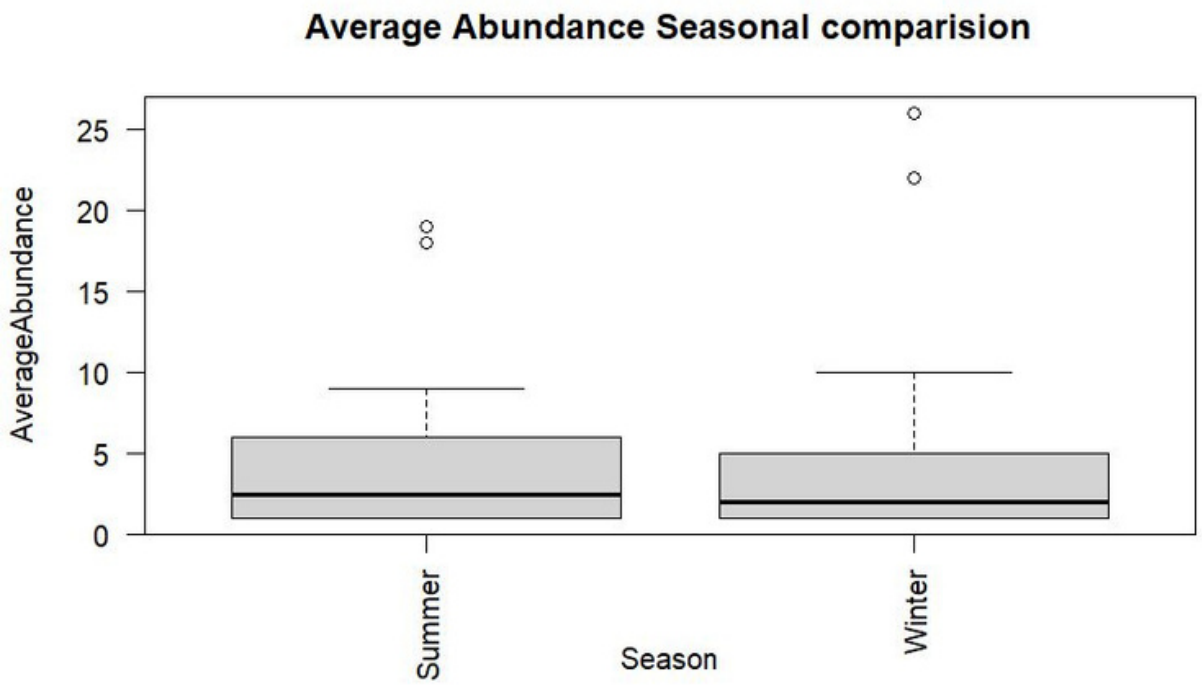


Figure 3 illustrates the average abundance of species across a summer-winter seasonal comparison.

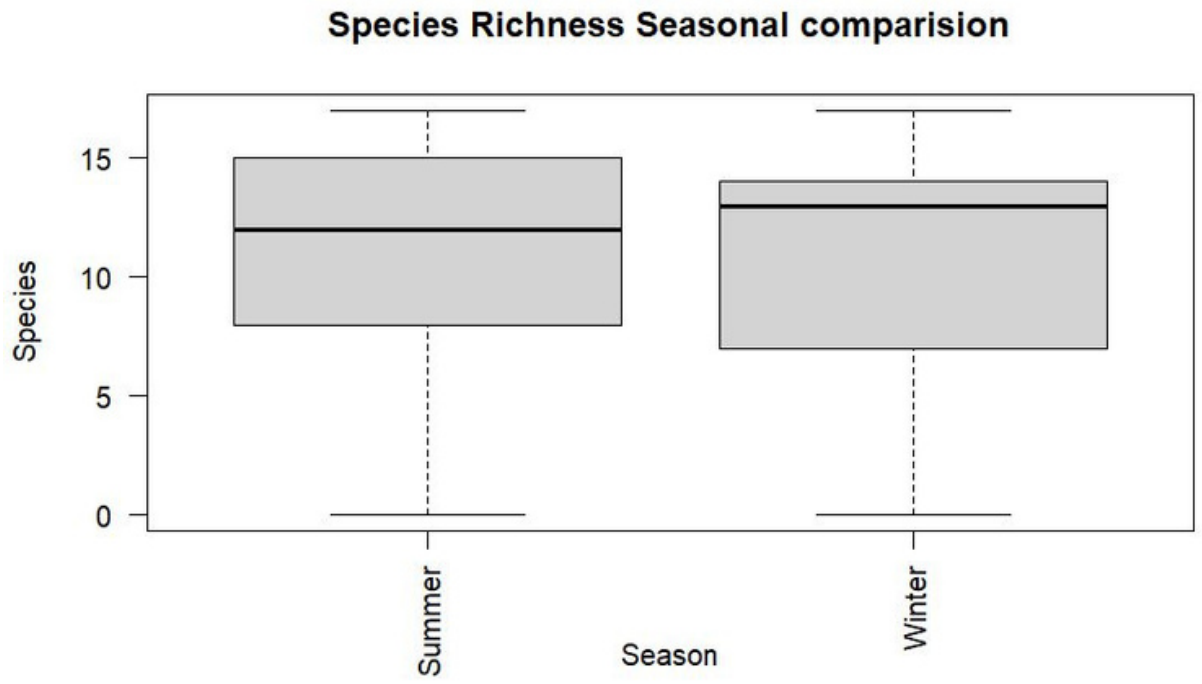


Figure 4 illustrates the species richness across a summer-winter seasonal comparison.

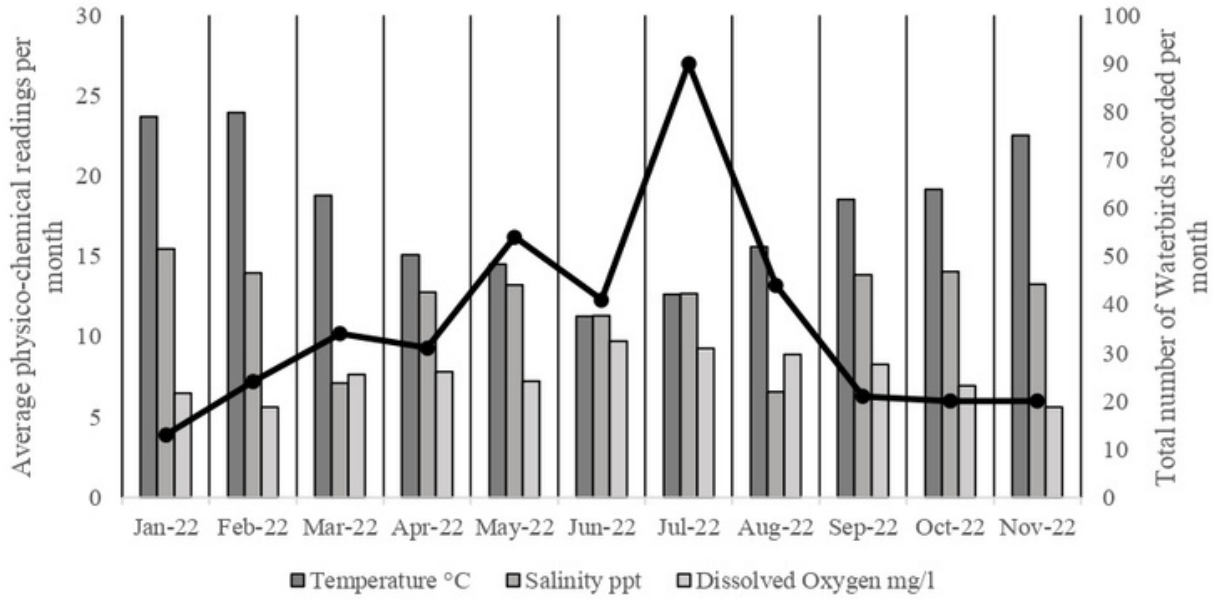


Figure 5: Total number of waterbirds recorded across 11 months in 2022 and compared with in situ water quality recordings.

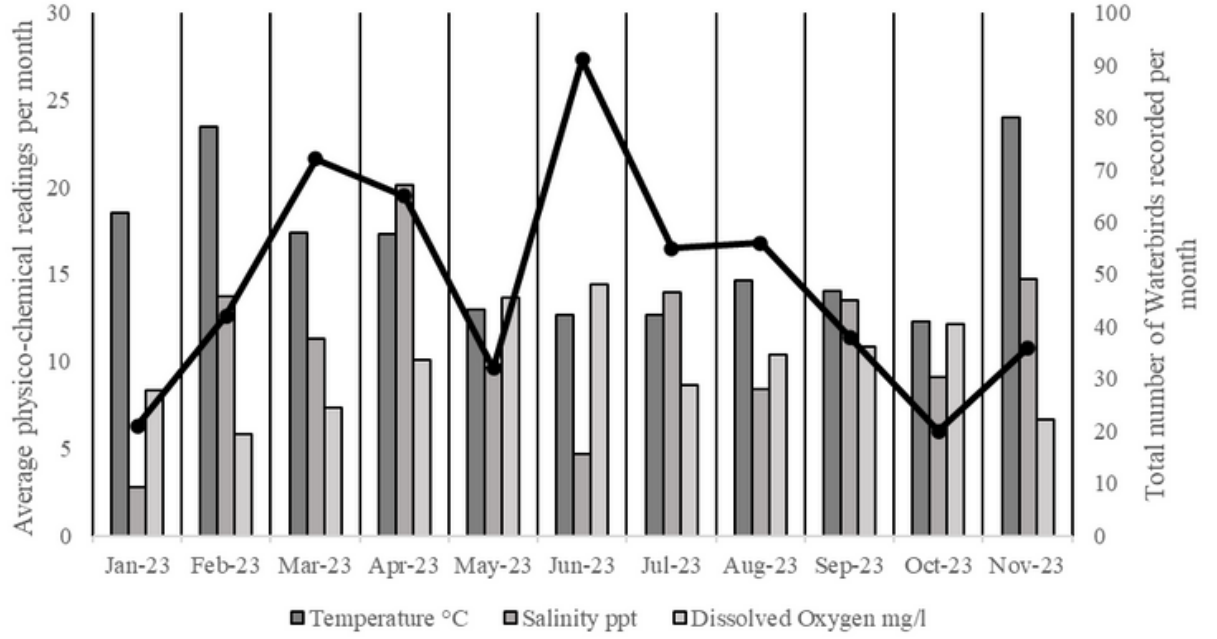


Figure 6: Total number of waterbirds recorded across 11 months in 2023 and compared with in situ water quality recordings.

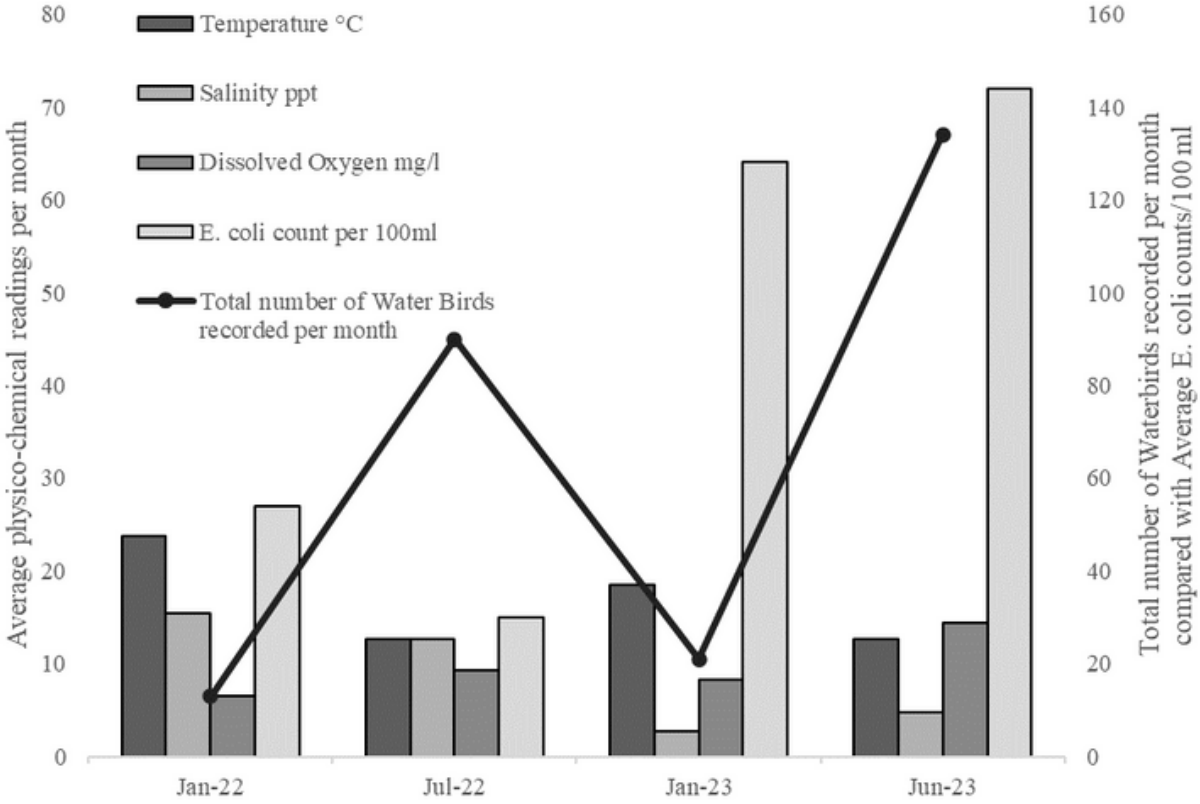


Figure 7: Seasonal (summer and winter) variation indicating changes between waterbird counts, water quality parameters and bacteriological samples.

Despite these seasonal variations, no significant correlation has been found between the changes in physicochemical parameters and the *Escherichia coli* counts for the corresponding months. Similarly, there is no apparent correlation between *E. coli* counts and waterbird abundance, even though the *E. coli* counts remain within natural and acceptable limits.

Discussion

The results of the bird monitoring in the Groot (West) River estuary over a twenty-five-year period reveal several noteworthy findings. The transition from biannual monitoring (1998-2016) to monthly monitoring (2017-2022) provides a more detailed and comprehensive understanding of the birdlife in the estuary over time. This shift in monitoring frequency offers a more dynamic view of species presence in changing seasons and environmental conditions.

Overall, the observation of 41 different bird species and the total bird numbers along the Groot (Wes) River estuary seem stable with a varied assortment and good biodiversity, enforcing the ecological significance of this habitat when compared to other estuarine systems such as the Groot Brak with 52 species, Gouritz with approximately 39 species and Knysna with 67 species (Martin et al. 2000; Western Cape Government 2018, 2019, 2021). Monitoring these populations serves as an indicator of the ecosystem's overall health which, at the Groot (Wes) River estuary, seems stable and diverse, with 4,837 bird sightings recorded between 1998 and 2023.

It underlines the importance of the Groot (Wes) River estuary as a habitat for a wide range of waterbirds. Local species including reed and White-breasted cormorants, Yellow-billed ducks and Kelp gulls dominated the numbers along the estuary. These species likely play important roles in the ecosystem and reflect the estuary's suitability as a habitat

for them.

The data indicates clear seasonal variations in bird abundance. The spike in bird numbers during the winter months is intriguing because migrants are typically absent during winter. This could suggest that the estuary serves as an important wintering habitat for many local waterbird species. The sustained peak in abundance could be linked to water conditions during this period, which indicates optimal water quality. Specifically, stable oxygen concentrations, median temperatures and lower salinity values during winter may contribute to this higher number of species present. These increased counts may also correspond to periods when the estuarine system exhibits an open-mouth state. During these phases, characterised by temporary opening and closing, the system undergoes significant temporal variations in water levels and, consequently, water depths. Such fluctuations are expected to impact the availability of food resources (Heÿl & Currie 1985; Russell et al. 2014). The increase in the number of species and individuals during winter months compared to summer months emphasises the value of seasonal monitoring. This data provides important insights into the estuary's ecological dynamics and its role as a seasonal refuge for waterbirds.

This study also seeks to evaluate water quality, ensuring the optimal condition of the estuarine system and the potential role of aquatic birds as indicators of water quality. Physico-chemical parameters, including salinity (ppt), temperature (°C) and dissolved oxygen (% and mg/l), were systematically monitored at seven different sites along the estuary. Notably, there is a distinct variation in physicochemical parameter readings between summer and winter, with reduced average temperatures and elevated dissolved oxygen readings observed during the winter months (refer to Figures 5, 6 and 7). The peak in bird counts over winter months indicates that waterbirds could act as an indicator for certain water parameters along the estuary (Russell et al. 2014).

There was also no apparent correlation between *Escherichia coli* counts and waterbird abundance, even though the *E. coli* counts over the monitoring period remained within natural and acceptable limits. It is worth noting that factors such as the state of the river mouth and breaching periods may play a role in influencing the levels of *E. coli* which could potentially have an impact on the birdlife.

Overall, the results highlight the significance of the Groot (Wes) River estuary as a habitat for a diverse range of waterbirds and its importance as a seasonal destination. Incorporating data from water quality measurements plays an important role in ensuring the long-term preservation and sustainable utilisation of the system that benefits both the ecological integrity and the local community's well-being. The data collected through these extensive monitoring efforts is invaluable for conservation and management strategies to protect this important local ecosystem and its avian inhabitants.

Conclusion and recommendations

The bird monitoring in the Groot (Wes) River estuary over a twenty-five-year period has provided some understanding of the avian diversity and ecological dynamics of this estuarine habitat. The transition from biannual to monthly monitoring has allowed for a more detailed understanding of seasonal variations as well as comparisons with the estuary’s water quality which emphasised the importance of the estuary as a refuge for waterbirds. The presence of 41 different bird species underscores the estuary's ecological significance, particularly for local waterbird species.

The Groot (Wes) River estuary should be (and is) recognised as an ecologically significant water source area. Conservation efforts should prioritise the preservation of this estuarine ecosystem to maintain its role as an important refuge for its species. The data underscores the importance of managing the estuary with seasonal variations in mind. Conservation strategies should focus on protecting and maintaining the estuary's integrity, especially during the winter months when it has been shown to host a higher abundance of waterbirds. Monthly monitoring has also proven to be highly valuable in understanding the estuary's dynamics related to water quality and comparison with waterbirds during each survey. It is recommended to continue these regular surveys to track long-term changes and identify any potential threats to the waterbird population.

Creating awareness among the local community and visitors about the ecological importance of the estuary and the birdlife it supports can further foster a sense of stewardship and responsible interaction with the habitat. In addition, collaborative efforts between conservation organisations, governmental bodies and local communities remain essential to ensure effective protection and management of the Groot (Wes) River estuary.

In conclusion, the Groot (Wes) River estuary plays an important role as a habitat for waterbirds, and the data generated from this extensive monitoring should guide ongoing conservation efforts to preserve its ecological integrity and protect the range of birdlife it supports.

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Bushbuck (*Tragelaphus scriptus*) photographic identification and population estimate in Nature's Valley - an initial assessment

Author:
Lauren Moriarty

Affiliation:
NVT, Nature's Valley, South Africa

Corresponding author:
Lauren Moriarty
lauren.moriarty@nvt.org.za

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Abstract

A population estimate of bushbuck (*Tragelaphus scriptus*) in Nature's Valley was conducted using photographic identification initiated by NVT and local wildlife enthusiasts. Concerns over declining numbers, potentially due to poaching, prompted this study. Systematic photography of bushbuck's left flanks was conducted weekly between 2021 and 2023, supplemented primarily by citizen science contributions using digital camera and cell phone images. Individual animals were categorised by gender and age based on horn presence and size and cross-referenced with previous photographs for identification. Out of 11 verifiable individuals, two were males, seven females and two calves. A species richness curve showed a decline in sightings, mainly due to limited sampling. These limitations despite, the study serves as a foundation for future population estimates and highlighted the importance of continued monitoring and community involvement. Further methods are being explored to track bushbuck population estimates and distribution in Nature's Valley.

Introduction

Bushbuck (*Tragelaphus scriptus*) is an even-toed ungulate (Anderson 1997) native to sub-Saharan Africa that can be found in habitats ranging from forests to savannas and grasslands (Smithers 1983; Frustenburg 2010; Meintjies 2012). Despite their adaptability in terms of habitat, bushbuck seem to favour forested and woodland environments often near water sources (Jacobsen 1974; Sinshaw & Tamene 2020) where they feed on leaves, shrubs and fruits, depending on availability (Jacobsen 1974; Okiria 1980). These animals play a vital role in the ecosystems they inhabit and efforts should be made to protect their habitats and to ensure their well-being.

Renowned for its rich biodiversity and lush forests, Nature's Valley – a coastal area located within the Garden Route National Park, Western Cape, South Africa – offers the ideal habitat for bushbuck given the ample availability of food and cover as well as its proximity to water sources. Despite their characteristic shy and elusive nature, bushbuck are known to venture into the Nature's Valley village and, even in this urbanised environment, they fulfil an important ecological role.

By browsing on certain plant species and participating in natural food chains, they contribute to preserving local biodiversity and maintaining the ecological balance (Jacobsen 1974; Meintjies 2012). Given that they can be more readily observed by residents and visitors, they undoubtedly add aesthetic value and instil an appreciation of local wildlife as well as afford many an educational opportunity to raise awareness of local biodiversity and the importance of conservation efforts to preserve the latter.

Where present in urbanised environments, careful management is required to prevent potential human-wildlife conflicts and health risks that could pose serious threats to the well-being of these animals (Meintjies 2012; Sinshaw & Tamene 2020). To mitigate negative interactions and to promote bushbuck's positive contributions to local ecosystems, urban planners, local authorities and conservationists should consider measures such as wildlife corridors and fencing as well as educate the public on how to co-exist with these magnificent animals so that they can thrive alongside human communities.

To ensure that an urbanised environment such as the Nature's Valley village is conducive to the survival of bushbuck, it is first and foremost necessary to develop a means to reliably identify individual animals so as to gain an understanding of their distribution and basic behaviour. Despite its ecological significance, the bushbuck is relatively underrepresented in scientific research, especially when compared to more charismatic species like marine mammals and wild cats (Jackson et al. 2006; Frainer et al. 2022; Urian et al. 2014). To follow is a brief description of bushbuck's basic behaviour and distinguishable characteristics, the latter being of particular importance for this study.

Basic behaviour and distinguishable characteristics of Tragelaphus scriptus

Although generally solitary and less sociable than other antelope species, bushbuck can sometimes form small family groups consisting of a mother and her offspring (Allsopp 1978; Anderson 1997; Okiria 1980). They are primarily nocturnal (i.e. most active during the night and early morning) which aids in avoiding daytime predators and in regulating their body temperature in warmer climates/during hotter seasons (Frustenburg 2010; Jacobsen, 1974; Okiria 1980). Bushbuck are prey for large predators such as caracals and leopards (Frustenburg 2010; Jacobsen 1974; Sinshaw & Tamene 2020) and have evolved various strategies to evade these (e.g. cryptic colouration, alertness and agility) (Downs & Coates 2005; Frustenburg 2010; Okiria 1980; Sinshaw & Tamene 2020).

Bushbuck have a life span of around 10-12 years and a relatively low reproductive rate where mating generally results in a single calf that is typically hidden in thick vegetation for protection (Anderson 1997). During the mating season, male bushbuck may become more territorial and engage in conflicts with other males to establish dominance and access to females. Both male and female bushbuck can, however, be territorial and are known to scent-mark their territories to communicate with other bushbuck and potential rivals (Allsopp 1978; Okiria 1980). These scent markings may include secretions from glands around their eyes and under their tails (Anderson 1997).

In terms of distinguishable characteristics, this small antelope typically reaches a shoulder height of between 69 and 94 cm, weighs between 63 and 73 kg and is distinguished by its prominent broad ears, short bushy tail and vibrant chestnut to dark-brown coloration with vertical white stripes

and spots on both sides of its body that can vary in intensity. Only rams have relatively short, nearly straight horns with a subtle spiral and ridge (Anderson 1997).

Since this study relied on photography as a means to conduct an initial assessment of the bushbuck population in Nature's Valley, identification was predominantly based on individuals' coat patterns since, as Miththapala et al. (1989) pointed out, distinct variations in stripes and spots among mammals can serve as a tool to recognise unique individuals.

Photographic identification as a viable means to estimate the size of bushbuck populations

To assist with the compilation of a species-specific management plan, Coates and Downs (2007) undertook an estimation of the bushbuck population in the valley thicket and coastal bushveld-grassland habitats of the Shongweni Dam Game Reserve in KwaZulu-Natal and employed mark-resighting methods for this purpose. Eight bushbuck were fitted with radio-collars to study home range and habitat usage, and these animals served as marked individuals to derive abundance estimates. However, the researchers found that mark-resighting seemingly underestimated the density and abundance of bushbuck, possibly due to too few animals being marked and sighted during certain seasons, particularly spring and summer.

In another study by Koivuniemi et al. (2019), photo-identification and mark-recapture techniques were evaluated for estimating the population size of the endangered Saimaa ringed seal (*Phoca hispida saimensis*). Photo- identification data based on unique pelage patterns were collected using camera traps and boat-based surveys during the moulting season. This approach provided minimum population estimates and indicated high survival rates and site fidelity among adult seals. The study suggested that increasing surveying efforts spatially and temporally could improve accuracy in future estimates, advocating for a non-invasive mark-recapture method for reliable population monitoring under changing climatic conditions.

Throughout the realm of field biology, natural markings have been a reliable means to identify individual animals and, as highlighted by Dougherty and Bowman (2012), camera surveys have been widely used to estimate wildlife abundance and presence. The effectiveness of photographic identification, however, hinges on the prerequisite that individuals within a given population exhibit distinctive and consistent natural markings throughout the study period. The permanence of these markings is critical, and any alterations or mark losses should be readily visible to researchers (Meintjies 2012; Dougherty & Bowman 2012).

Additionally, the quality of photographs is crucial, and lower-quality images should be excluded to ensure accurate recognition of marked individuals. The relationship between photographic quality and mark distinctiveness is significant, with subtle marks often requiring higher-quality photographs (Dougherty & Bowman 2012; Jackson et al. 2006; Miththapala et al. 1989).

As is evident from the literature, integrating mark-resighting and photo-ID techniques can enhance population estimation accuracy and contribute to effective wildlife management and conservation efforts.

Objectives of this study

This study emerged from discussions with residents of the Nature's Valley village that raised concerns regarding a perceived decline in the bushbuck population compared to previous years. These concerns prompted the formulation of four key objectives:

- to assess the feasibility of establishing a method for identifying individual bushbuck to lay a foundation for future studies;
- to compile a comprehensive catalogue of individual bushbuck that would offer insights into the approximate number of these animals within the area;
- to extrapolate data in an attempt to estimate the overall population of bushbuck in the area; and
- to create a baseline population reference for future comparative purposes.

Collectively, these objectives address the need to monitor and understand the bushbuck population in Nature's Valley, thereby providing a foundation for ongoing research and conservation efforts.

Methods

Study area

This study was conducted in Nature's Valley (-33.976205°, 23.561555°), a coastal area within the Western Cape Province of South Africa and nestled within the Garden Route National Park. It is surrounded by pristine Tsitsikamma forests and is home to a rich diversity of wildlife, with the likes of bushbuck, baboons, genets and caracals freely roaming amidst the indigenous vegetation. The region is also renowned for its abundant birdlife.

Nature's Valley boasts a moderate climate that is characterised by relatively consistent rainfall patterns throughout the year, although precipitation may fluctuate from season to season (Western Cape Government 2019). On average, the annual rainfall in Nature's Valley ranges from 700 to 900 millimetres. The rainy season typically unfolds during the winter months, spanning from May to August, with precipitation peaking in June and July (iWeathar SA 2024). Conversely, the summer months, from December to February, are generally drier, occasionally interspersed by rainfall. However, precipitation during this period is notably less than what is observed in the winter months.

The Nature's Valley village consists of just over 400 houses of which, according to the Nature's Valley Ratepayers Association, around 70 are occupied year-round. The remaining properties are utilised as holiday homes, particularly during peak seasonal periods since Nature's Valley's abundant sunny days make it a popular year-round holiday destination, attracting a substantial influx of tourists.

Data collection

Initially, various techniques to collect data were considered, including photographs taken with ordinary cameras and/or cell phones, camera traps and direct observations, or a combination of these. In the end, data collection involved capturing a large number of photographs of individual bushbuck sighted throughout Nature's Valley that, preferably, focused on the animal's left side or 'flank'. Sampling was conducted at various times on weekdays, augmented by additional random sightings on weekends. Each photograph included in the dataset was annotated with the date, time and location of the sighting.

Photographed bushbuck were categorised as male, female or calf based on visual indicators such as appearance, size and the presence or absence of horns. These sightings were then cross-referenced with previous photographs to determine whether they represented new captures or recaptures. Initially, primary features such as stripe and spot patterns on the flank were compared to identify potential matches, followed by further identification of secondary features including cheek spots, facial markings, socks and any visible scars or injuries.

This data was logged on a dedicated WhatsApp citizen science group tailored to

the bushbuck study, along with individual reports documented accordingly.

Data analysis

Data management was a crucial aspect of this study and involved the organisation of a comprehensive database of photographs. Each bushbuck sighting was documented by creating individual folders for each animal. An identification key was developed to facilitate the recognition of individual bushbuck, relying on distinctive coat patterns and other features such as facial markings, horn shape or scars. This analysis included monitoring of individual's distribution within Nature's Valley and deriving an overall population estimate. Sightings have also been plotted on a map in ArcGIS to illustrate the bushbuck's spatial patterns, while a cumulative species richness curve based on sightings indicates increases/decreases in observations over the three-year period.

Results

The map (Figure 1) illustrates the distribution of several bushbuck within Nature's Valley and was compiled based on weekly surveys and citizen science sightings to determine any distribution patterns and areas where specific bushbuck spend most of their time within Nature's Valley. From this, we have been able to identify certain bushbuck individuals in the Nature's Valley area and to create a baseline population estimate for the area consisting of 11 verifiable individuals (two males, seven females and two calves).

Figures 2 and 3 illustrate the comparison between male and female bushbuck respectively. These images were captured by NVT staff during surveys utilising Canon cameras. The photographs provide clear views of the left flank, enabling the identification of markings and patterns for future surveys.

Figure 4 illustrates male bushbuck sightings, revealing the presence of only two known male bushbuck (photo catalogue individuals A and I) within Nature's Valley during the study period. Individual A was sighted 12 times during the study, while



Figure 1: Bushbuck sightings in Nature's Valley between 2021 and 2023.

individual I was sighted only twice later in the study.

Figure 5 illustrates the number of female bushbuck sightings. We identified a total of seven well-represented female individuals (photo catalogue individuals B, C, E, F, G, H, J) during the study period. The highest number of sightings was of individuals F and G. The spatial patterns depicted in Figure also indicate that these two individuals were observed across the Valley.

Figure 6 presents sightings of bushbuck calves, with two individuals identified (photo catalogue identification D and K). During the survey period, these calves were sighted between eight and three times respectively.

Figure 7 displays a cumulative species richness curve which is utilised to illustrate trends in bushbuck sightings over the study period. This curve is employed because it provides a clear visual representation of the accumulation of unique individuals observed over time, indicating changes in species richness. In this case, the curve demonstrates a notable decrease in observations from ten to three individuals across the three-year period.



Figure 2: Male bushbuck (T. scriptus).
Photo courtesy Brittany Arendse.



Figure 3: Female bushbuck (T. scriptus).
Photo courtesy Lauren Moriarty.

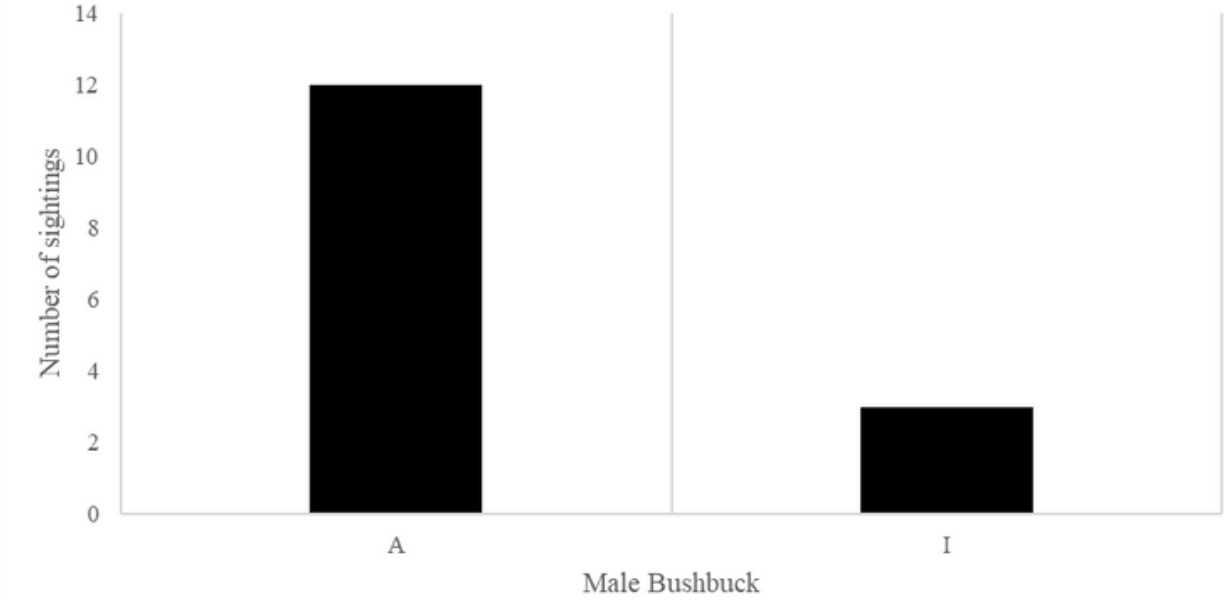


Figure 4: Male bushbuck sightings, revealing the presence of only two known male bushbuck (A and I) within Nature's Valley during the study period.

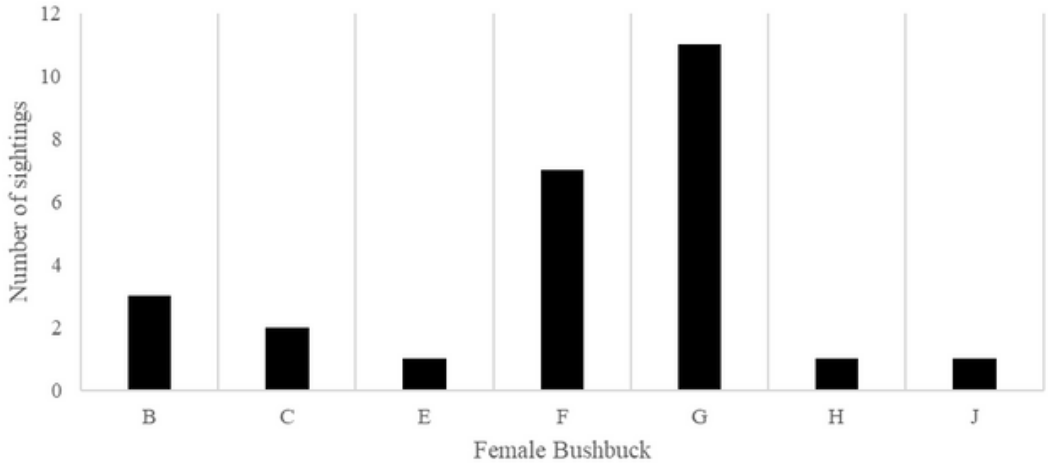


Figure 5: Number of female bushbuck sightings, identifying a total of seven (B, C, E, F, G, H, J) well-represented female individuals during the 2021 - 2023 study.

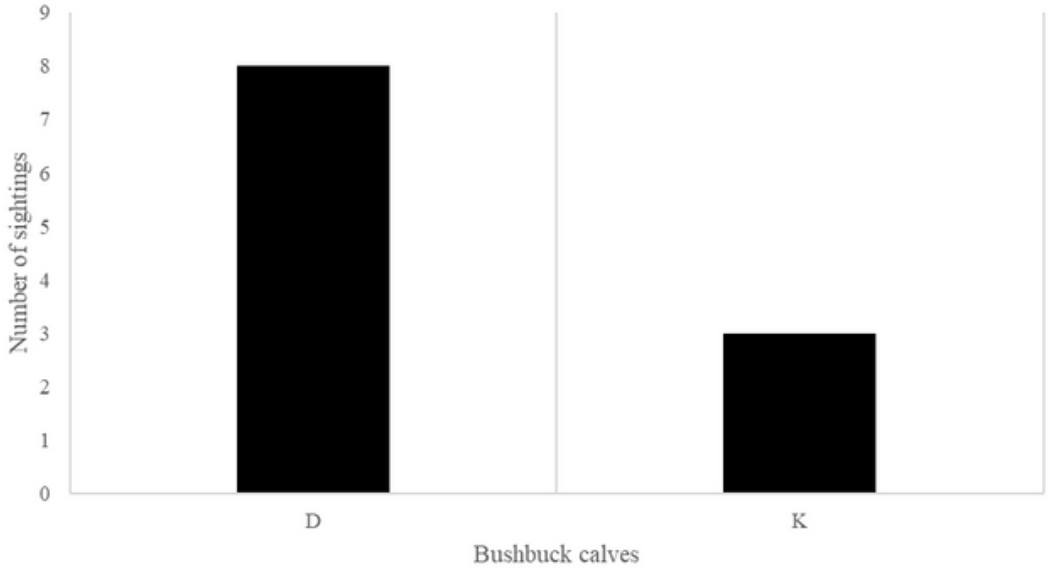


Figure 6: Bushbuck calves sighted, with two individuals identified between 2021 and 2023.

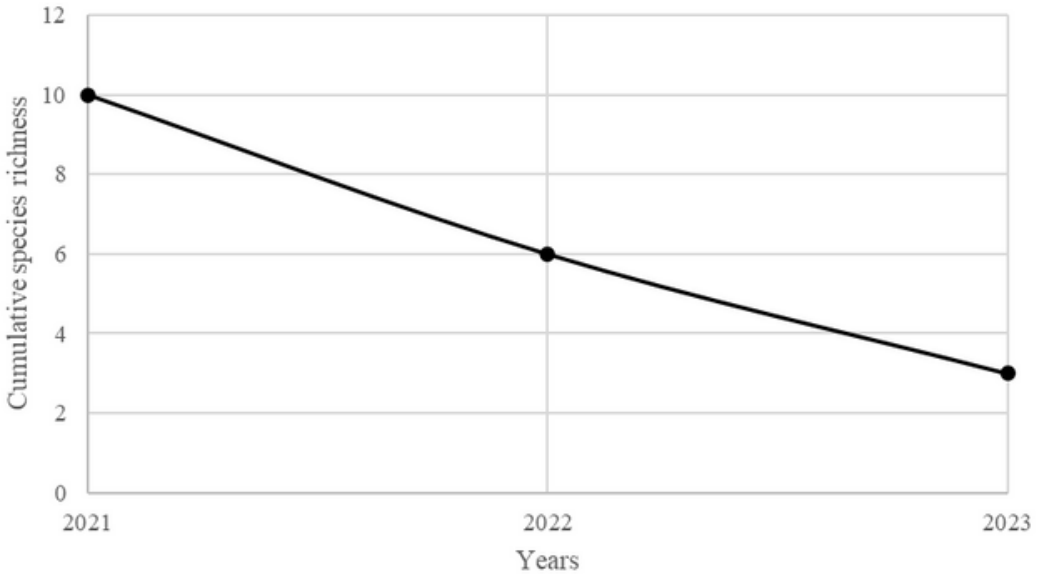


Figure 7: Cumulative species richness curve of bushbuck sightings between 2021 and 2023.

As discussed below, the results stemming from this study seem to indicate a decline in Nature's Valley's bushbuck population that could have implications for genetic diversity and reproductive success.

Discussion

Approximately 45% of the local bushbuck population was identified during the study period. From an analysis of the data, it is evident that only 27% of all photographed animals had a single capture event, with no subsequent re-captures. The cumulative species richness curve (Figure 7) illustrates a decline in sightings, with the majority of animals identified in the first year of sampling, featuring ten animals identified and 38 sightings. In contrast, the second year with a total of 21 sightings yielded fewer results, identifying only five known animals and one new individual.

In keeping with the results of the studies conducted by Addy in 1993 and Bayih & Yihune in 2018, the adult sex ratio was biased towards females. Nevertheless, the observation of only two known male bushbuck (Figure 2 and 4) within Nature's Valley raises questions regarding the population dynamics of this species in the area. As Bayih and Yihune (2018) pointed out, understanding the reasons for the relatively low number of males is important since this could have implications for breeding and genetic diversity. Albeit in low numbers, the sighting of bushbuck calves (Figure 6) does, however, suggest successful reproduction. Monitoring the survival and growth of these calves is essential to assess the reproductive success of the population. This could involve tracking the calves' growth rates, survival rates and overall health over time, allowing researchers to understand the factors influencing the species' reproductive success and population growth within the area given that the overall population estimate suggests that the habitat may be suitable for supporting a sustainable population.

Limitations

Limitations in this study primarily pertain to data collection. Given that the bushbuck sighted in this study mostly reside in a residential area that forms part of a national park, human presence and activity could have had two notable implications. First, during periods of increased human activity, only the calmer animals may have been visible to observers, potentially skewing the recorded behaviours and population estimates. Second, those animals that remained in proximity for identification may have been more habituated to human activity, creating an unknown bias in the data. Due to differences in capture effort, a mark-recapture population estimate was not conducted (Coates & Downs 2007).

To mitigate potential bias, data collection efforts were extended to various times of the day but then exclusively on weekdays. The assumption was that weekends would witness heightened human activity, possibly resulting in fewer animals being present. Nevertheless, surges in recorded numbers often stemmed from consistent sightings (approximately 50 of the 62) recorded by citizen scientists on the same property and within the same surroundings. This raised the question as to whether certain recordings might have been influenced by some residents/visitors feeding the bushbuck with vegetable scraps. Such feeding practices may have attracted the animals to specific locations, causing these particular individuals to grow more habituated to human presence.

Additionally, the study's requirement to photograph only the left flank of the bushbuck inadvertently led to the omission of

several animals from the survey. Furthermore, the exclusion of some photographs due to poor quality may have influenced the capture rates and overall population estimate.

Its limitations despite, this study laid the foundation for future research endeavours to assess the bushbuck population in Nature's Valley.

Conclusion and recommendations

Concerns over declining numbers of bushbuck (*Tragelaphus scriptus*) in Nature's Valley raised by residents prompted NVT to initiate this project with the intention to assess the bushbuck population in the Valley.

Over a 62-day observation period spanning three years, only 11 bushbuck (seven females, two males and two calves) were identified based on their unique individual markings. The resultant figures are indicative of a rather small (perhaps declining) population and could be a cause for concern, especially in as far as maintaining genetic diversity is concerned.

The use of photography as a means to gather data proved to be both feasible and valuable. However, the resolution (i.e. quality) of photographs submitted by participating citizen scientists will need to be addressed while the inclusion of both left and right flank photographs will allow two identification patterns per animal which could contribute to more accurate population estimates in future (Bouwman & Cronje 2016).

Further research is needed to look more closely into the behaviour, distribution patterns and ecology of bushbuck in Nature's Valley. It is crucial to assess the suitability of the habitat, availability of food resources and potential human-wildlife interactions, while long-term monitoring and genetic studies can provide a more comprehensive understanding of the population's dynamics.

This study provided valuable insights that could help to inform the development of management strategies to ensure the long-term survival of bushbuck in the region. These strategies could encompass habitat protection and initiatives to reduce human-wildlife conflicts by raising public awareness, all of which are imperative for effective conservation efforts.

Despite being subject to various limitations (e.g. potential biases stemming from the bushbuck's familiarity with human activity and selective photographic data collection), the data presented in this study can serve as a reference for ongoing monitoring and future studies. However, when interpreting the findings, it is essential to be mindful of these limitations and to recognise that certain behaviours and population estimates may not accurately represent the overall bushbuck population in Nature's Valley.

In conclusion, it is incumbent on all concerned to make every effort to preserve this species' natural habitat and to use every possible means (especially engagement with communities and education of the general public) to prevent potential human-wildlife conflicts in urbanised areas.

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The occurrence of alien invasive plants (IAPs) in Nature's Valley - a 2023 baseline survey

Author:
Sky Beveridge

Affiliation:
NVT, Nature's Valley, South Africa

Corresponding author:
Sky Beveridge
sky.beveridge@nvt.org.za

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Abstract

Invasive alien plants (IAPs) are plants that have been introduced into areas where they would not naturally occur and where they often have negative impacts on economies, the environment and human well-being. This study was conducted in January 2023 and was aimed at documenting and assessing the extent of IAPs in Nature's Valley. A quantitative survey approach was used to observe and map the presence/absence of IAPs on 400 residential properties. The results indicate that 16 IAPs occur in the Village and that 30% of the properties have been invaded. According to the National Environmental Management: Biodiversity Act 10 of 2004 (NEMBA), owners are required to remove and destroy species that fall in categories 1a and 1b. It is, therefore, recommended that property owners in Nature's Valley work with the Nature's Valley Rate Payers' Association and NVT to remove and control IAP species on their properties.

Introduction

Alien species are organisms that have been introduced (intentionally or un-intentionally) into areas where they would not occur naturally (Beck et al. 2008). IAPs have certain characteristics that enable them to spread very rapidly in environments because they have a high tolerance for disturbance, high seed production and rapid growth rates. These characteristics also make them incredibly difficult to eradicate (Sharma, Raghubanshi & Singh 2005).

Globally, IAPs are having negative impacts on economies, the environment and human well-being due to their ability to outcompete indigenous species, thereby reducing the integrity, functioning and ecosystem service delivery of indigenous ecosystems (Beck et al. 2008). According to a report by the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), more than 37,000 alien species have been introduced into non-indigenous environments across the world. Around 9.5% are harmful IAPs that seriously threaten economies, the environment and human well-being on a global scale (Richardson & Van Wilgen 2004; Sharma Raghubanshi & Singh 2005).

In the South African context, approximately 10 million hectares have been invaded by 750 IA tree species as well as up to 8,000 IA shrubs, succulent and herbaceous species. Of these, 161 species are regarded as IAPs (Van Wilgen et al. 2001). The most problematic genera of IAPs occurring in South Africa include Australian wattles (*Acacia* species), gums (*Eucalyptus* species), pines (*Pinus* species) and hakeas (*Hakea* species) due to their astounding spread rates and impact on water security (Marias et al. 2004). As a result, the South African government has spent considerable funding on the control of IAPs to protect our country's indigenous biodiversity and water resources (Richardson & Van Wilgen 2004). Over the past ten years, for example, the government's contribution to the Working for Water Programme has amounted to over R3 billion (Van Wilgen et al. 2008).

As specified in NEMBA, IAPs have been classified into four categories (i.e. 1a, 1b, 2 and 3) where basic management treatments and control is required (Arendse & Breen 2018; Huntley 2022) (Table 1). IAPs classified as Categories 1a and 1b pose a serious risk to the health of humans or livestock, cause serious financial losses to land users, can invade undisturbed environments, can transform or degrade natural plant communities, use more water than the indigenous plant communities they replace or can be particularly difficult to control. Most of the plants in this category produce copious numbers of seeds, are wind or bird dispersed or have highly efficient means of vegetative reproduction. Whereas some of these plants were introduced accidently, they have no obvious function to fulfil in South Africa and are generally regarded as undesirable, although many are popular garden or landscaping plants. What they do have in common, though, is that their harmfulness outweighs any useful properties they might have. Ornamental species occurring in this category should be reasonably easy to replace with endemic and indigenous species (ARC – RNL 2004).

The NEMBA regulations also state that the seller of any immovable property must, prior to the relevant sale agreement, inform the purchaser of the property, in writing, of the presence of listed invasive species that occur on that property (Arendse & Breen 2018). Importantly, any property containing IAPs is liable to the buyer and must be removed (Huntly 2022).

The invasive status of IAPs corresponds with the degree to which these species invade, persist and alter natural or semi-natural environments (Henderson 2020). The invasive status of species can be either 'transformer' or 'potential transformer'. Transformers are species that can dominate or replace, as a mono-species, any canopy or subcanopy layer of a natural or semi-natural ecosystem, thereby altering the structure, integrity and functioning of natural or semi-natural ecosystems. Potential transformers are species that can invade natural or semi-natural habitats and have the potential to dominate a vegetation layer without having a marked effect on the habitat (Henderson 2020).

Regulations emphasise that only species-specific methods are allowed to control IAPs within a specific ecosystem. One or a combination of the following control methods may be used: felling, uprooting, cutting, ringbarking, burning, treating with registered herbicides and utilising biological control. Repetitive follow-up actions will be mandatory until the required level of control has been achieved (Arendse & Breen 2018).

Finally, the aim of controlling IAPs is to eradicate and prevent them from producing viable seeds or spores, coppicing, sprouting, producing root suckers, reproducing vegetatively, propagating in any other way or spreading into other areas. If this is not

possible, the plants must be contained and their multiplication limited as far as possible (Arendse & Breen 2018).

The invasive status of IAPs corresponds with the degree to which these species invade, persist and alter natural or semi-natural environments (Henderson 2020). The invasive status of species can be either 'transformer' or 'potential transformer'. Transformers are species that can dominate or replace, as a mono-species, any canopy or subcanopy layer of a natural or semi-natural ecosystem, thereby altering the structure, integrity and functioning of natural or semi-natural ecosystems. Potential transformers are species that can invade natural or semi-natural habitats and have the potential to dominate a vegetation layer without having a marked effect on the habitat (Henderson 2020).

Regulations emphasise that only species-specific methods are allowed to control IAPs within a specific ecosystem. One or a combination of the following control methods may be used: felling, uprooting, cutting, ringbarking, burning, treating with registered herbicides and utilising biological control. Repetitive follow-up actions will be mandatory until the required level of control has been achieved (Arendse & Breen 2018).

Finally, the aim of controlling IAPs is to eradicate and prevent them from producing viable seeds or spores, coppicing, sprouting, producing root suckers, reproducing vegetatively, propagating in any other way or spreading into other areas. If this is not possible, the plants must be contained and their multiplication limited as far as possible (Arendse & Breen 2018).

The occurrence of IAPs in Nature's Valley (NV) has never been systematically documented or assessed. The aim of the study was, therefore, to document and assess the occurrence of IAPs throughout NV to serve as a baseline and a guide for future interventions.

Table 1: Legal categories of invasive alien plants occurring in South Africa as per the National Environmental Management: Biodiversity Act 10 of 2004 (NEMBA).

Category	Parameters
1a	- Require compulsory control, removal and destruction - No permits for growing these species will be issued by the national government.
1b	- Require compulsory control (as part of an invasive species control programme), removal and destruction - High invasive potential: Infestations can qualify for inclusion in a government-sponsored invasive species management programme. - No permits for growing these species will be issued by the national government.
2	- Permit required for importation, possession, growing, propagation, selling and purchasing. - Permits will not be issued where these species are to occur in riparian zones.
3	- Species may occur in certain areas across the country, but further planting, propagation and trade are prohibited. - If a species in this category occurs on a property, the owner is not compelled to remove it but is prohibited from planting, propagating or selling the species.

Method

Study area

This study was carried out throughout Nature's Valley's residential area (-33.9807° S, 23.5565° E) (Figure 1). Nature's Valley is located between South Africa's southern Cape coastline and the Tsitsikamma mountain range on the eastern border of the Western Cape. The predominant vegetation type is southern Cape Afrotemperate Forest, but the village is also surrounded by various fynbos, sandy beach, rocky shore and estuarine ecosystem types found within the Tsitsikamma section of the Garden Route National Park. The temperate climate of the study area is moist to warm, which is influenced by orographic rainfall of up to 12,000 mm per year. Coastal winds and mist occur frequently throughout the year.

Data collection

Following the methods used by Henderson (2007), roadside surveys were carried out throughout the NV residential area over three days in January 2023. A driver and one to three observers drove along all the roads occurring within the residential area. The driver stopped at the entrance to each property whilst the observers noted the occurrence of IAPs on that property. Observers could differentiate between indigenous vegetation and IAPs. The legal and invasive status for each IAP species, recorded throughout the NV residential area, was also documented.

Data analysis

The data was captured and processed in Microsoft Excel. Using the count-if function, the total count of sites where IAPs were absent (0) or present (1) was converted to percentages of invasion (Table 2 and Figure 2). Pie charts were produced to visually represent these findings. QGIS software was used to identify and map the extent of invasion of IAPs occurring within the NV residential area (Figure 2).

Results

IAPs were present on 120 (30%) of the 400 properties that were surveyed (Figure 2).

A total of 16 IAP species were recorded (Table 2). Of these, 12.5% were category 1a species, 43.75% category 1b, 18.75% category 2 and 6.25% category 3 (Table 2).

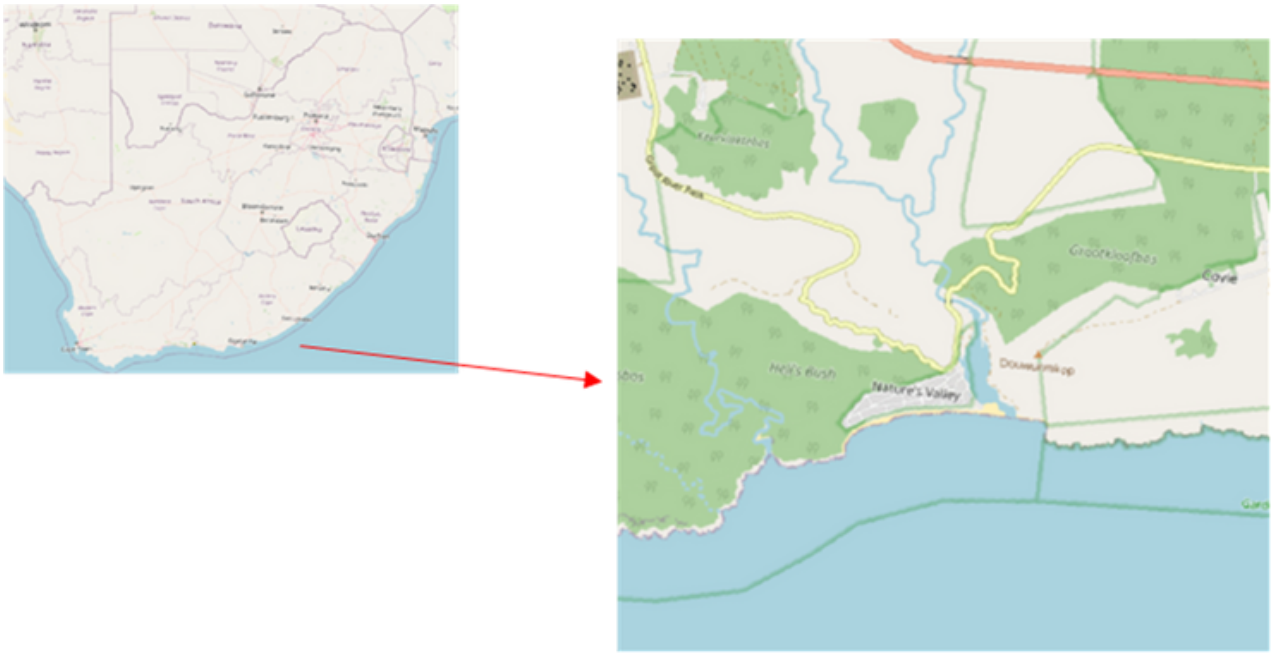


Figure 1: Location of NV within South Africa.



Figure 2: A map representing the presence (green) and absence (red) of IAPs throughout the properties in the NV residential area.

The remaining percentage of IAPs were not classified into any management category since they do not resort under any of these categories. Only ten species (62.5%) were transformers and three species (18.75%) were potential transformers, while the remaining three species (18.75%) do not have an invasive status.

Of the IAP species documented in NV, 93.75% were deliberately introduced into South Africa via ornamental trade only, 12.5% via both ornamental and industrial trade and the same percentage (i.e. 12.5%) via industrial trade only, while the remaining species (6.25%) were introduced accidentally.

Discussion and recommendations

The aim of this study was to document and assess the extent of IAP occurrence in the residential area of Nature's Valley. The results indicate that 16 IAPs were recorded on 30% of the properties. This result is not too alarming given that the Western Cape Province was found to be home to the highest concentrations of IAPs within South Africa (Richardson & Van Wilgen 2004).

Most of the IAPs occurring within NV have predominately arrived via the ornamental and industrial trade and have escaped into suitable surrounding environments. The study found eight species in the NV residential area that resort under the NEMBA category 1b. These species, including sword fern (*Nephrolepis exaltata*), American bramble (*Rubus cuneifolius*), bugweed (*Solanum mauritianum*), white moonflower (*Ipomoea indica*), red ginger lily (*Hedychium coccineum*), Indian shot (*Canna indica*), Madeira vine (*Anredera cordifolia*) and lantana (*Lantana camara*), are also known to be extremely invasive and require compulsory control. As indicated by Arendse and Breen (2018), it is not possible to obtain permits to keep these plants.

Unmanaged, these species are likely to degrade natural ecosystems as they are a threat to native biodiversity (Richardson & Van Wilgen 2004). They also tend to dominate the ecosystems they have been introduced to and to change one or more functional aspect of that ecosystem (Davis 2003; Davis et al. 2009; Nsikani et al. 2018).

Table 2. The species, legal status/category, invasive status and mode of introduction of invasive alien plants occurring within the Nature's Valley residential area.

Species	Legal status/ Category	Invasive status
New Zealand Christmas tree (*Metrosideros excelsa*)	1a	Potential transformer
American bramble (*Rubus cuneifolius*)	1b	Transformer
Bugweed (*Solanum mauritianum*)	1b	Transformer
White moonflower (*Ipomoea indica*)	1b	Transformer
Red ginger lilly (*Hedychium coccineum*)	1b	Transformer
Madeira vine (*Anredera cordifolia*)	1b	Transformer
Lantana (*Lantana camara*)	1b	Transformer
Indian shot (*Canna indica*)	1b	Potential transformer
Sword fern (*Nephrolepis exaltata*)	1b	-
Australian blackwood (*Acacia melanoxylon*)	2	Transformer
Mexican weeping pine (*Pinus patula*)	2	Transformer
European blackberry (*Rubus fruticosus*)	2	Transformer
Aleppo pine (*Pinus halepensis*)	3	Transformer
Australian water pear* (*Syzygium paniculatum*)	-	Potential transformer
Silky hakea (*Syeringe hakea*)	-	-
False dodder (*Cassytha ciliolata*)	-	-

*Important in NV as it attracts baboons and vervet monkeys

Expected impacts could include altered competitive interactions as these species directly outcompete native species (Busch & Smith 1995; Rejmánek et al. 2013), cause changes to water and/or fire regimes (D'Antonio & Vitousek 1992), interfere with plant-soil interactions by changing nutrient cycling and soil nutrient status (Ehrenfeld 2003), alter gene flow between native populations via hybridisation (which affects the responses of vegetation to varying environmental conditions) (Corbin & D'Antonio 2012) and reduce the provision of ecosystem services (Hulme et al. 2012).

Alarmingly, recent observations along the Kalander Trail, a hiking trail leading into the Tsitsikamma protected area from the village, revealed that sword ferns already occur in the water course along the trail and in forest areas bordering the back end of the village. A focused programme to remove and control

these species should, therefore, be launched as soon as possible because these species have the ability to invade undisturbed environments and transform or degrade natural plant communities. To remove as well as to prevent the spreading of these species is particularly important seeing that Nature's Valley is situated right in the middle of the Tsitsikamma section of the Garden Route National Park, a well-known and highly visited protected area in South Africa.

Removal and control will, however, be a challenge seeing that plants in category 1b produce copious numbers of seeds, are wind or bird dispersed or have highly efficient means of vegetative reproduction. Consequently, a longer-term intervention strategy with regular follow-up sessions is required to make sure that all plants are removed.

Three species resorting under NEMBA category 2 were also found in the NV residential area, namely the Australian blackwood (Acacia melanoxylon), Mexican weeping pine (Pinus patula) and European blackberry (Rubus fruticosus). Property owners who have these species in their gardens will need to acquire a permit. However, permits will not be granted to those whose properties occur along riparian zones as these species are thirsty and diminish water sources (Arendse & Breen 2018).

Only one species resorting under NEMBA category 3 was found in the NV residential area, namely the Aleppo pine (Pinus halepensis). If this species occurs on a property, removal is not mandatory, but propagation is disallowed (Arendse & Breen 2018).

The control, removal and eradication of IAPs that occur within NV is not an insurmountable task given that only 30% of residential properties are affected. Nevertheless, given the close proximity of the affected properties to the fynbos reserve, this task should be undertaken in collaboration with the Nature's Valley Residents' Association as a matter of urgency since, as pointed out by Richardson and Van Wilgen (2004), fynbos ecosystems are exceptionally prone to invasion by IAP species.

Conclusion

Although the current invasion of IAP species in the Nature's Valley village does not pose an immediate ecological or economical threat to the area, nor to the well-being of its residents, national legislation nevertheless requires owners to remove and eradicate species that fall in categories 1a and 1b and to have permits for categories 2 and 3. It is recommended that local owners work with the NVRA to acquire the necessary funding and assistance to remove and control IAPs on their properties. To aid with the identification of invasive alien plants on their properties and for advice on how to manage these should they be present, residents can refer to the guide titled Alien Invasive Plants of Nature's Valley accessible via NVT's official website. This guide even suggests alternative indigenous species property owners could consider planting to promote diversity throughout the residential area.

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The preliminary effects of attempted fynbos restoration on epigaeic invertebrate abundance, diversity and similarity to primary fynbos

Author:
James McCulloch

Affiliation:
University of Oxford,
Merton College,
United Kingdom

Corresponding author:
James McCulloch
james.mcculloch@merton.ox.ac.uk

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Abstract

The fynbos biome, the most important constituent habitat of the highly diverse and endemic-rich Cape Floristic Region, is threatened by anthropogenic activity. This comparative study evaluates the success of the fynbos restoration programme in Nature's Valley, using measures of epigaeic invertebrate abundance and diversity. The results of this study indicate that while this fynbos restoration programme has increased both the abundance and diversity of epigaeic invertebrates, the community composition does not yet closely emulate the local primary fynbos.

Introduction

As the smallest of the world's six floral kingdoms, the Cape Floristic Region (CFR) is unparalleled in the distinctness and diversity of its floral assemblages. A review published at the beginning of this century put the number of vascular plant species found in the region at 9,030, with 68.7% of them being endemic (Goldblatt & Manning 2002). To provide some context, despite taking up only 0.5% of the land area of the African continent, which includes the tropical regions typically renowned for their unmatched biodiversity, the CFR encompass approximately a fifth of Africa's plant species (Goldblatt & Manning 2002). A vast majority of the CFR's diversity and endemism is found within the fynbos biome, a Mediterranean-type heathland habitat characterised by a high diversity of Proteaceae, Ericaceae and Restionaceae.

In contrast, the region is claimed not to be as important with regard to the diversity and endemism for invertebrates (Giliomee 2003), despite the generally globally held positive relationship between plant and invertebrate diversity, at least for phytophagous insects (Schuldt et al. 2019). A few explanations have been put forward, mainly centring on the unpalatability of fynbos plants due to their stressful environmental conditions resulting in high sclerophylly (leatheriness as an adaptation to hot and dry conditions) and low nutrient content (Giliomee 2003), but these are not strongly empirically supported (Procheş & Cowling 2006). In fact, in some taxonomic groups, studies have indicated that there has been a relatively high level of diversity and endemism, especially in the leafhopper insect group (Davies 1988a,b). Regardless, invertebrates are a key component of the

fynbos ecosystem and important for preserving the CFR's unique plant assemblage, with about 83% of fynbos plants being insect-pollinated (Steiner 1987) and many non-insect pollinators relying on other invertebrates as a food source (Fleming & Nicolson 2003). Additionally, invertebrates are important for seed dispersal, with about 41% of dioecious angiosperms (flowering plants with separate male and female plants) in the fynbos producing seeds with elaiosomes, fatty and proteinaceous structures which attract ants (Steiner 1987).

Despite the importance of invertebrates for ecosystem functioning, there are still significant gaps in our knowledge of invertebrate communities in the fynbos biome. For example, fire is an integral part of the fynbos ecosystem and a regular fire cycle of approximately one fire every 12-15 years is required for a healthy ecosystem (Van Wilgen et al. 2012), yet our response to the threat of more regular fires (a result of climate change) and our effective use of fire as a management tool are limited by our poor knowledge of the post-fire recovery of invertebrate communities (Parr & Chown 2003). In addition, most comparative studies of fynbos invertebrate abundance and diversity have been limited to communities occurring on vegetation, often sampled by sweep-netting, omitting the epigaeic (soil surface-dwelling) community (Procheş & Cowling 2006). Epigaeic invertebrates perform numerous ecosystem services, such as improving soil health (in turn improving the ecosystem's capacity for carbon sequestration and environmental detoxification) and supporting invertivorous animals (Lavelle et al. 2006), but the properties of this community do not always correlate with those more frequently sampled (Pryke & Samways 2008). This emphasises the need for focused studies on epigaeic invertebrate communities rather than injudicious reliance on other invertebrate communities as indicators.

A particular objective of this study is to evaluate attempted fynbos restoration within a context of human habitation by analysing epigaeic invertebrate abundance and diversity and comparing these to the original vegetation type and local natural fynbos vegetation. This study also aims to provide baseline knowledge on epigaeic invertebrate community characteristics in different broad habitat types of the CFR that can be used in future studies to inform best management practices for conserving invertebrate diversity and the health and functionality of this unique CFR ecosystem.

Methods

Study sites

The sites for this study are in and around Nature's Valley, Bitou, Western Cape. The fynbos restoration programme is located within the Village and comprises an area of one hectare. The fynbos restoration sites, for the purposes of this study, were characterised by vegetation below 1.5 metres in height. The area is surrounded by taller shrubs, a vegetation type like that in the surrounding gardens, and is referred to as the 'surroundings'. The surroundings were used as a control to investigate the influence of the fynbos restoration programme on invertebrate community characteristics.

For the comparison of epigaeic invertebrate communities between natural habitat types of the CFR, and for comparison between the fynbos and surroundings in Nature's Valley with these habitat types, four broad habitat types were chosen. These were recently burnt fynbos, 'primary' fynbos, thicket and forest. The 'primary' fynbos was defined as fynbos vegetation below 1.5 metres in height, not recently burnt and not previously disturbed by human development. In contrast, the thicket was much denser vegetation adjacent to the primary fynbos, with growth characterised by shrubs significantly above 1.5 metres in height.

The forest was a mature forest. The sites chosen for these habitats were along the Groot Rivier Pass, approximately two kilometres from Nature's Valley in the case of the burnt fynbos, primary fynbos and thicket, and approximately 5.5 kilometres from Nature's Valley in the case of the forest (Hebron Private Nature Reserve).

Data collection

The epigaeic invertebrate communities of these six sites were sampled using pitfall traps. These traps were fashioned of plastic pots which were 15 cm in diameter and 15 cm in depth. The traps were sunk into the ground so that the rim of the pot was flush with the surface of the soil, so as not to obstruct any invertebrates from falling into the trap. To minimise the escape of invertebrates from the trap, a 1:1 solution of water and Shiny Star Anti-Freeze and Summer Coolant was added to a depth of 3 cm. Lids, lifted off ground level by thick twigs or rocks to allow invertebrate passage underneath, were placed on top of the traps to reduce the entry of rainwater and vertebrates. The lids were weighed down with clods resulting from the excavation process.

A total of 15 pitfall traps were deployed: three each in the restored fynbos, the surroundings and the forest, while two were placed in each of the burnt fynbos, primary fynbos and thicket habitat. Trap sites were chosen by randomly selecting 20 x 20 m grid squares. The traps in the restored fynbos and surroundings were deployed for six consecutive weeks; those in the forest for five consecutive weeks; and those in the burnt fynbos, primary fynbos and thicket for three consecutive weeks. The first traps were deployed on 1st August 2023 and all traps were collected on 12th September 2023, which is winter in the region. The traps were checked on a weekly basis, with the contents emptied



Figure 1: A map showing the location of the burnt fynbos, 'primary' fynbos, and thicket sites (top left rectangle) and the restored fynbos site and 'surroundings' in the village of Nature's Valley (bottom right rectangle).

into small tubs to be sorted and the trap refilled with the solution. Each invertebrate within the trap was counted and identified to superfamily (most insects) or, in the case of taxa the author was less familiar with such as spiders and crustaceans, to the most precise taxonomic rank possible given the constraint of time and the volume of material collected.

Data analysis

For each trap, abundance was calculated across taxonomic groups as well as the mean abundance across weeks for each trap. Taxonomic richness was used as a proxy for diversity and was calculated for each trap by taking the mean of the number of taxonomic groups which were represented in the sample each week. For comparisons between traps which were out for a different number of weeks, means over only the weeks both traps were deployed were used to control for weather or phenology.

Given the small sample size (number of traps at each site), the statistical power to detect non-normality was low. However, in all cases except one, the Shapiro-Wilk test gave p-values greater than 0.05, indicating that there was no evidence that the assumption of normality was violated, as calculated using the stats package in R (R Core Team 2022). The exception was the abundance data ($p < 2.2e-16$) from the surroundings of the fynbos restoration programme, in which two of the three traps incidentally had the same average weekly abundance. Parametric tests were still used for all comparisons, however, as the tests used (Student's t-tests and one-way ANOVA) are considered robust against even fairly strong deviations from normality.

Epigaeic invertebrate abundance and diversity was compared between the restored fynbos and the surroundings using the Student's t-test (R Core Team 2022). The assumption of equal variances was tested using the F-test (R Core Team 2022), which provided non-significant p-values in both cases, indicating insufficient evidence for unequal variances ($F = 4.0308$, $p = 0.3975$ for the abundance data; $F = 1.9634$, $p = 0.6749$ for the taxonomic richness data). Abundance and diversity was compared between the four



Figure 2: A map showing the location of the forest site (top left, Hebron Private Nature Reserve) relative to Nature's Valley (bottom right).

broad natural CFR habitat types (burnt fynbos, primary fynbos, thicket, and forest) using one-way ANOVA. In this case, the assumption of equal variances was tested using Levene's test, which also provided non-significant p-values, indicating insufficient evidence for unequal variances ($F = 0.6285$, $p = 0.6273$ for the abundance data; $F = 1.0594$, $p = 0.4444$ for the taxonomic richness data) (Fox & Weisberg 2019). Post hoc pairwise comparisons were conducted using Tukey's honest significant difference (HSD) test (R Core Team 2022). Taxonomic richness was also compared between the restored fynbos in the village and the primary fynbos site at the Groot Rivier Pass using the Student's t-test (F-test: $F = 4.5$, $p = 0.3359$). However, the F-test for equal variances was not satisfied by the abundance data to be compared between the restored fynbos in the village and the primary fynbos at the Groot Rivier Pass ($F = 0.000036$, $p = 0.0084$), and so the Welch's t-test was used.

To determine the similarity of the epigaeic invertebrate communities of the different habitats, the Bray-Curtis dissimilarity index was used. In order not to violate the assumption of equal site size (equivalent to an equal number of traps), in cases where a site with two traps was being compared to a site with three traps, the Bray-Curtis dissimilarity was calculated three times in Excel, each time with the data from a different one of the three traps from the 'larger' site removed. A mean was then taken of the three values to provide an overall Bray-Curtis dissimilarity value for that comparison.

Results

Across all traps and weeks, 5168 invertebrates were collected, across 65 taxonomic groups. The taxonomic groups with the greatest number of individuals collected were the poduromorph springtails, ants, and amphipods (1180, 663, and 569 individuals respectively). 37 taxonomic groups had fewer than 10 individuals trapped.

Comparing the fynbos restoration programme with the surrounding vegetation

The mean weekly abundance and mean weekly taxonomic richness values for each of the three traps from both the fynbos restoration programme site and the surrounding garden-like vegetation are given in Table 1 and displayed in Figures 3 and 4.

The data indicate that the fynbos restoration programme has resulted in an increase in both the abundance and taxonomic richness of epigaeic invertebrates. For both measures, the Student's t-test produced significant results, indicating that there is a significant difference in the means of the samples (abundance: $t = 2.2822$; $p = 0.0477$; taxonomic richness: $t = 3.0512$, $p = 0.03798$).

Comparing the four CFR habitat types

The mean weekly abundance and the mean weekly taxonomic richness for each trap in each habitat type (burnt fynbos, primary fynbos, thicket, and forest) are given in Table 2 and displayed in Figures 5 and 6.

The displayed data do appear to show a relationship between habitat type and epigaeic invertebrate abundance, with primary fynbos having the lowest abundance and forest having the highest abundance, while the burnt fynbos and thicket had values in between the latter two habitats. However, the one-way ANOVA did not produce significant results $p = 0.063$). However, the post hoc Tukey's HSD test did produce one significant result between the primary fynbos and the forest ($p = 0.046$) (Table 3).

The displayed data also showed a relationship between epigaeic invertebrate taxonomic richness and the habitat type, with

richness increasing from burnt fynbos to primary fynbos, then to thicket, and finally with the highest taxonomic richness observed in the forest. The one-way ANOVA also indicates a statistically significant effect of habitat type on taxonomic richness ($F = 6.331$, $p = 0.0372$). However, the post hoc Tukey's HSD test indicated only one statistically significant result, between the burnt fynbos and the forest habitat (diff = 6.40, $p = 0.041$) (Table 4).

Comparing the restored fynbos with natural primary fynbos

The mean weekly abundance and mean weekly taxonomic richness values for the three traps from the fynbos restoration programme site and the two traps from the primary fynbos site at Groot Rivier Pass are given in Table 5 and displayed in Figures 7 and 8.

Table 1: The mean weekly abundance and mean weekly taxonomic richness for the three traps in the fynbos restored area as well as the surrounding habitat.

Site	Mean weekly abundance	Mean weekly richness
Fynbos	99.33	14.50
	67.83	13.17
	133.5	13.18
Surroundings	31.00	12.83
	31.00	11.17
	59.33	10.83

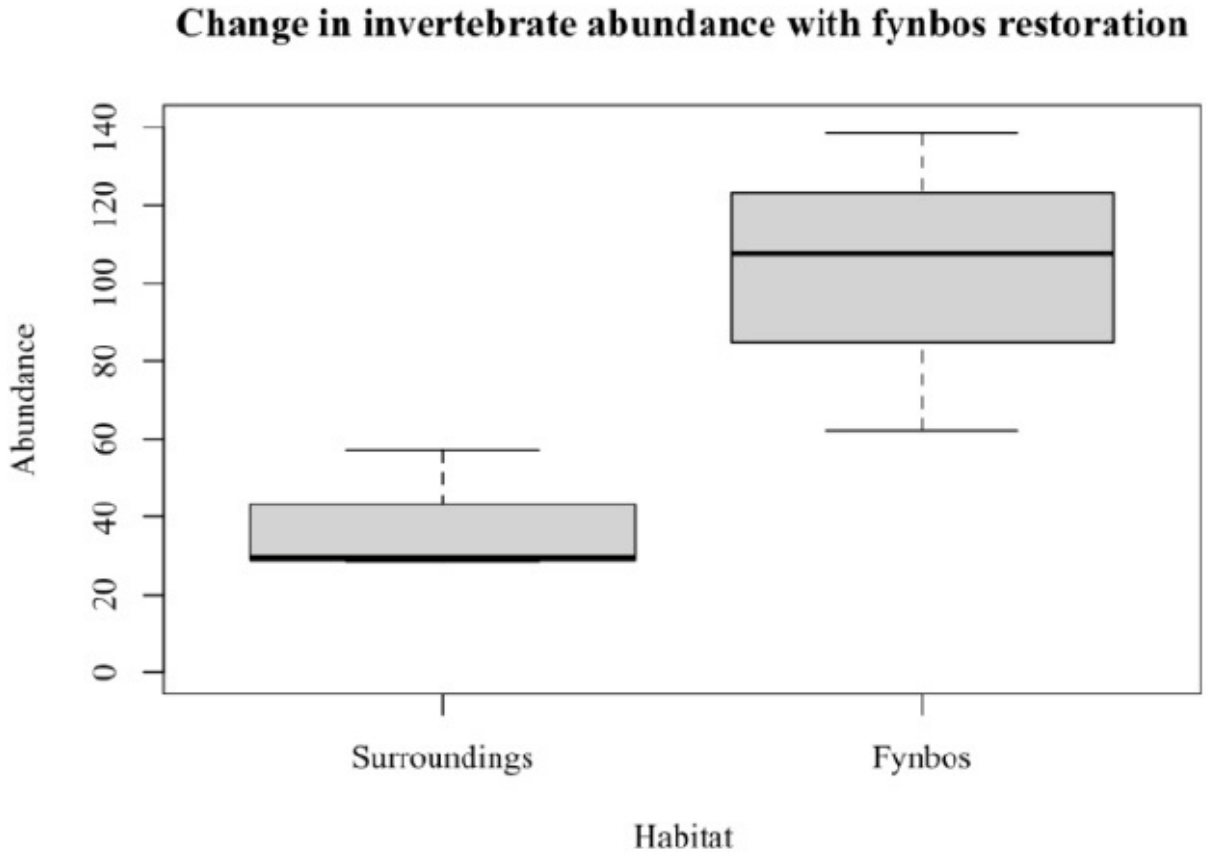


Figure 3: The traps in the restored fynbos site showed a greater mean weekly abundance of invertebrates trapped relative to the surroundings of this site.

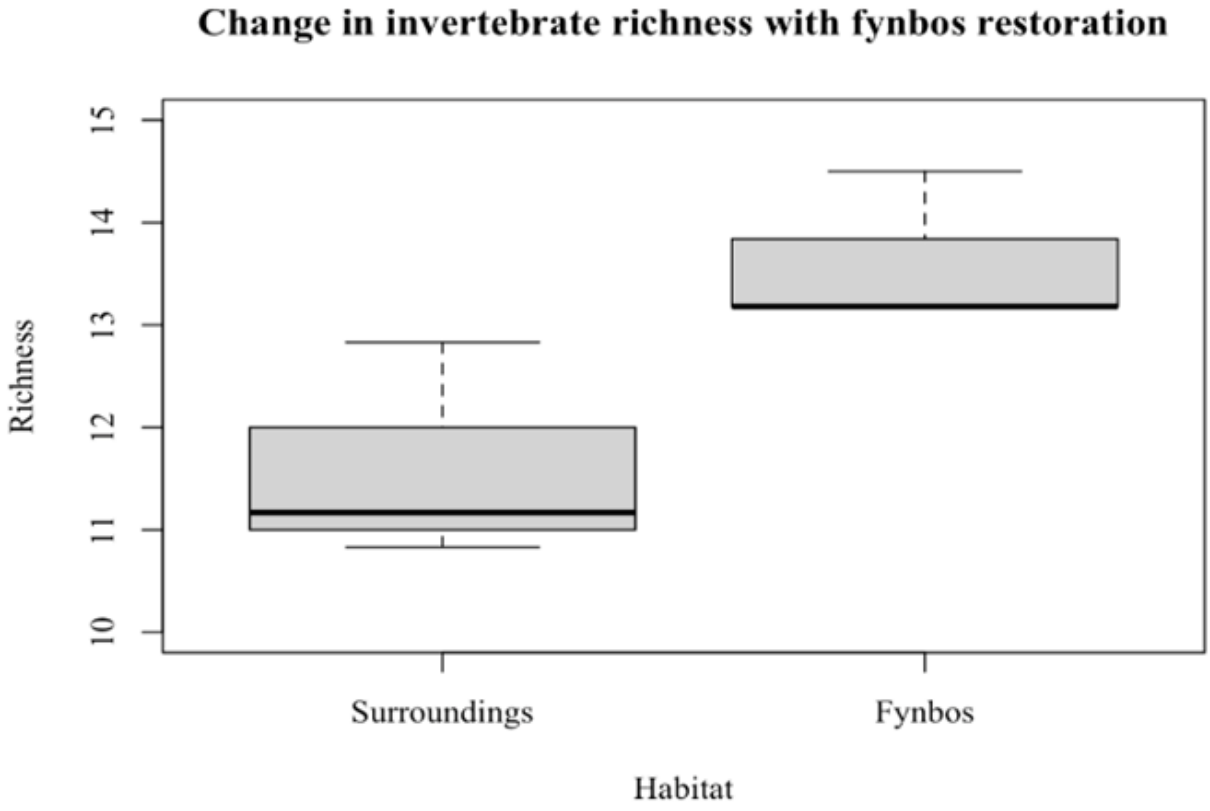


Figure 4: The traps in the restored fynbos site produced a greater mean weekly richness of invertebrates relative to the surroundings of this site. The size of the difference between the two treatments necessitated a truncated y axis.

Table 2: The mean weekly abundance and taxonomic richness for each of the four broad CFR habitat types.

Site	Mean weekly abundance	Mean weekly richness
Burnt fynbos	61.00 67.33	8.67 8.00
Primary fynbos	23.67 23.33	9.33 10.33
Thicket	71.00 59.67	12.67 13.67
Forest	115.6 108.2 57.60	11.80 17.20 15.20

Table 3: Results of the pairwise abundance comparisons from post hoc Tukey's HSD test. * = $p < 0.05$

Comparison	Difference	p
Primary fynbos-Burnt fynbos	-40.65	0.303
Forest-Burnt fynbos	29.65	0.458
Thicket-Burnt fynbos	1.10	0.999
Forest-Primary fynbos	70.30	0.046*
Thicket-Primary fynbos	41.75	0.286
Thicket-Forest	-28.55	0.485

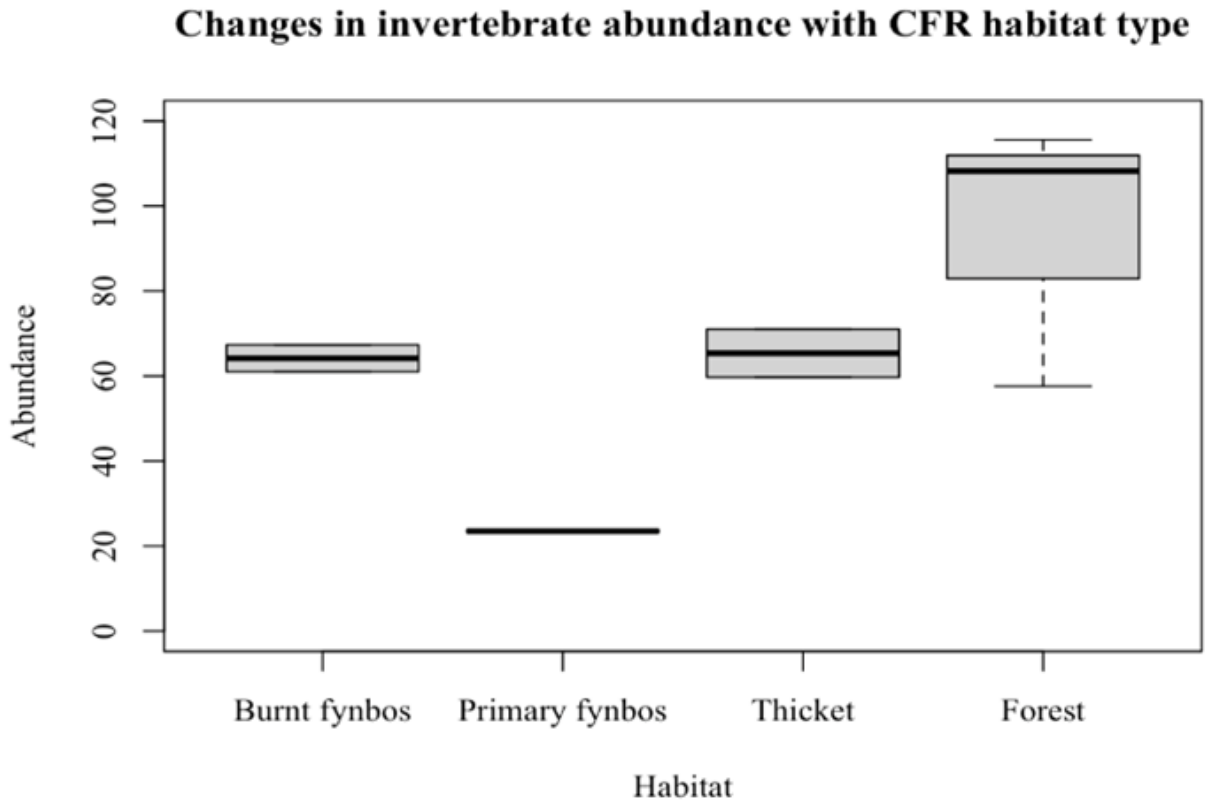


Figure 5: The mean weekly abundance of invertebrates captured across the pitfall traps set in the burnt fynbos, 'primary' fynbos, thicket and forest sites.

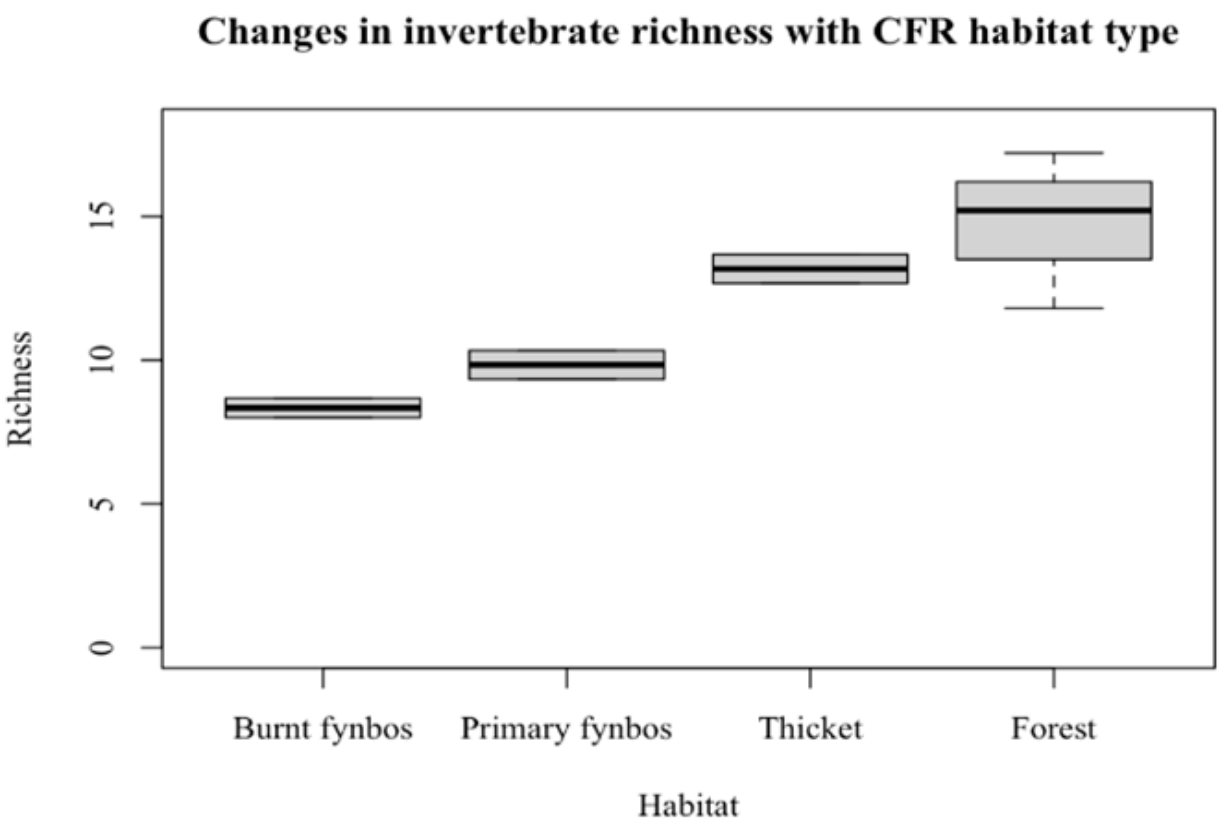


Figure 6: The mean weekly richness of invertebrates across the traps set in the burnt fynbos, 'primary' fynbos, thicket and forest sites: This plot shows an increase in richness along a successional gradient from recently burnt fynbos to the mature deciduous forest.

Table 4: Results of the pairwise richness comparisons from Tukey's HSD. * = $p < 0.05$

Comparison	Difference	p
Primary fynbos-Burnt fynbos	1.50	0.836
Forest-Burnt fynbos	6.40	0.041*
Thicket-Burnt fynbos	4.83	0.142
Forest-Primary fynbos	4.90	0.103
Thicket-Primary fynbos	3.33	0.350
Thicket-Forest	-1.57	0.779

Table 5: The mean weekly abundance and mean weekly taxonomic richness for the primary fynbos at the Groot Rivier Pass and the restored fynbos in Nature's Valley: Note that the data for the restored fynbos is different to previously displayed data as data from traps that were deployed at both sites is used for this comparison.

Site	Mean weekly abundance	Mean weekly richness
Primary fynbos	23.67	9.33
	23.33	10.33
Restored fynbos	73.33	14.00
	72.33	14.67
	141.33	14.33

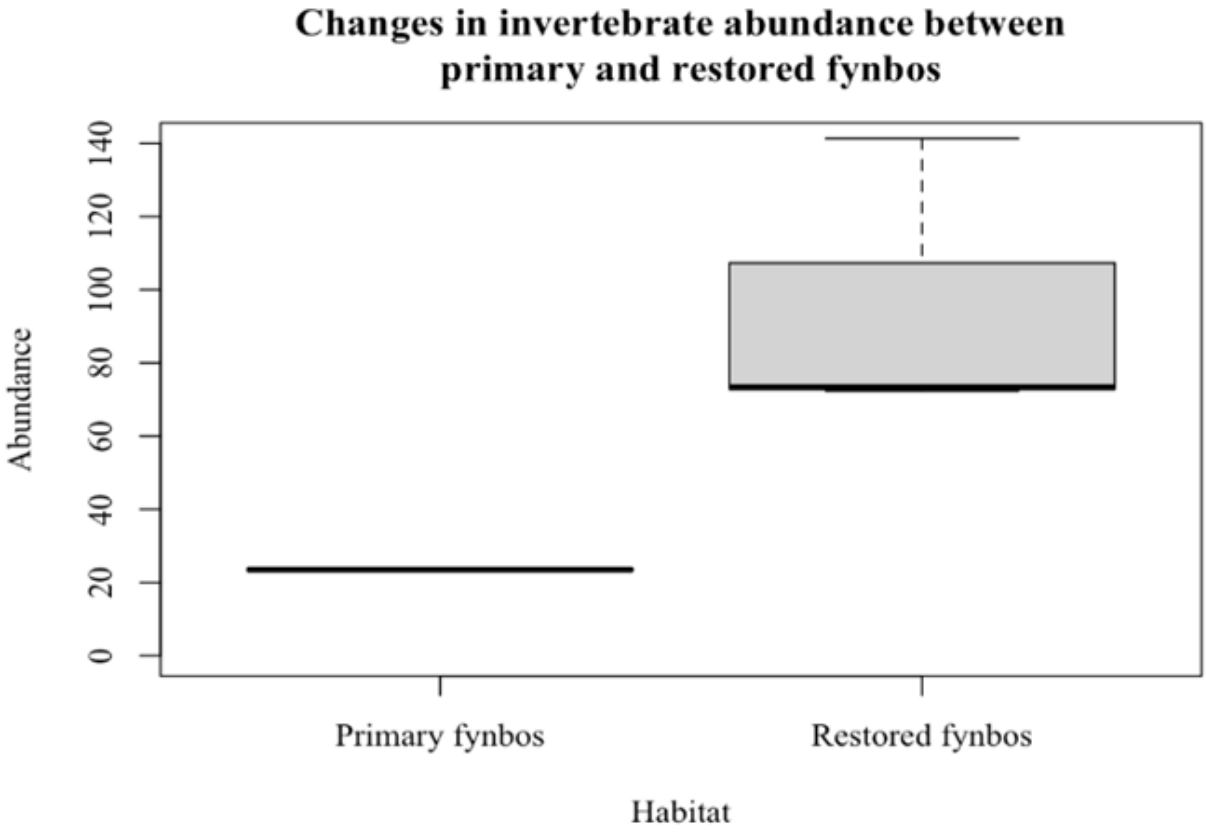


Figure 7: There was a greater mean weekly abundance of invertebrates across the traps set in the restored fynbos site compared to the 'primary' fynbos at the top of the Groot Rivier Pass. This plot only includes data from the weeks in which traps were set in both sites to control for phenology and weather.

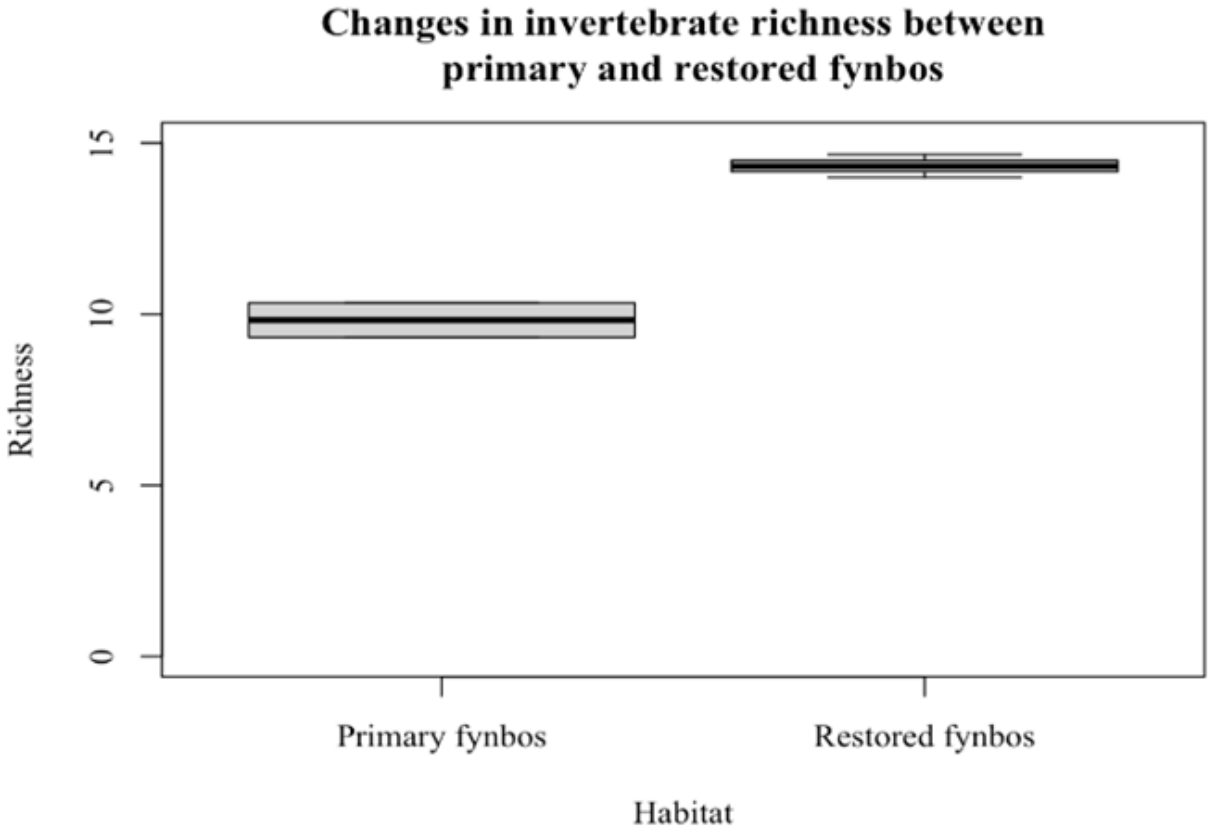


Figure 8: There was greater richness of invertebrates captured in the restored fynbos site relative to the primary fynbos.

The displayed data indicated that the restored fynbos site has both greater epigaeic invertebrate abundance and taxonomic richness. In terms of the difference in abundance, this was found to be not statistically significant ($t = 3.1602$, $p = 0.0872$), however the Welch's t-test does have a lower power than the Student's t-test. The Student's t-test indicated that between the taxonomic richness of the primary and the restored fynbos, a statistically significant result was recorded ($t = 10.047$, $p = 0.0021$).

The Bray-Curtis dissimilarity was calculated for the primary and restored fynbos, as well as for selected other pairs of sites. The results of these calculations are shown in Table 6.

Given that a value of Bray-Curtis dissimilarity closer to 1 indicates greater dissimilarity between the invertebrate communities, it is suggested that relative to the other selected pairwise composition comparisons, the epigaeic invertebrate communities of the restored fynbos in Nature's Valley and the epigaeic invertebrate communities in the primary fynbos at the Groot Rivier Pass are dissimilar (Table 6). Notably, the restored fynbos site and the forest site have a lower dissimilarity than the restored fynbos and the primary fynbos. The most similar communities are the restored fynbos and the surroundings of the restored fynbos site; the only two site pairs with greater dissimilarity than the restored fynbos and the primary fynbos are the restored fynbos and thicket, and the primary fynbos and forest.

A non-metric multidimensional scaling plot is shown in Figure 9, which shows the six sites in different colours, with each dot representing a trap. The proximity of the dots in the two-dimensional plot represents their proximity in a 65-dimensional Euclidean space, as there were 65 taxonomic groups trapped in total. The 65-dimensional proximities were calculated using the Bray-Curtis dissimilarity index.

Discussion

The results indicated a statistically significant increase in both the abundance and the taxonomic richness of epigaeic invertebrates from the baseline surroundings to the fynbos restoration programme area is preliminarily promising. The greater abundance indicates a greater biomass of invertebrates, which can support more secondary and tertiary consumers elsewhere in the ecosystem, both vertebrate and invertebrate. A greater abundance also suggests more individuals to perform ecosystem services, such as the breakdown of organic matter and the return of nutrients to the soil. The health of the restored fynbos ecosystem is further supported

Table 6: Bray-Curtis dissimilarities between selected site pairs: In both cases, 'surroundings' refers to the vegetation surrounding the fynbos restoration programme in Nature's Valley.

Site pair	Bray-Curtis dissimilarity
Primary fynbos-Restored fynbos	0.6514
Restored fynbos-Surroundings	0.4668
Restored fynbos-Thicket	0.6789
Restored fynbos-Forest	0.6240
Primary fynbos-Surroundings	0.6198
Primary fynbos-Thicket	0.5662
Primary fynbos-Forest	0.7162

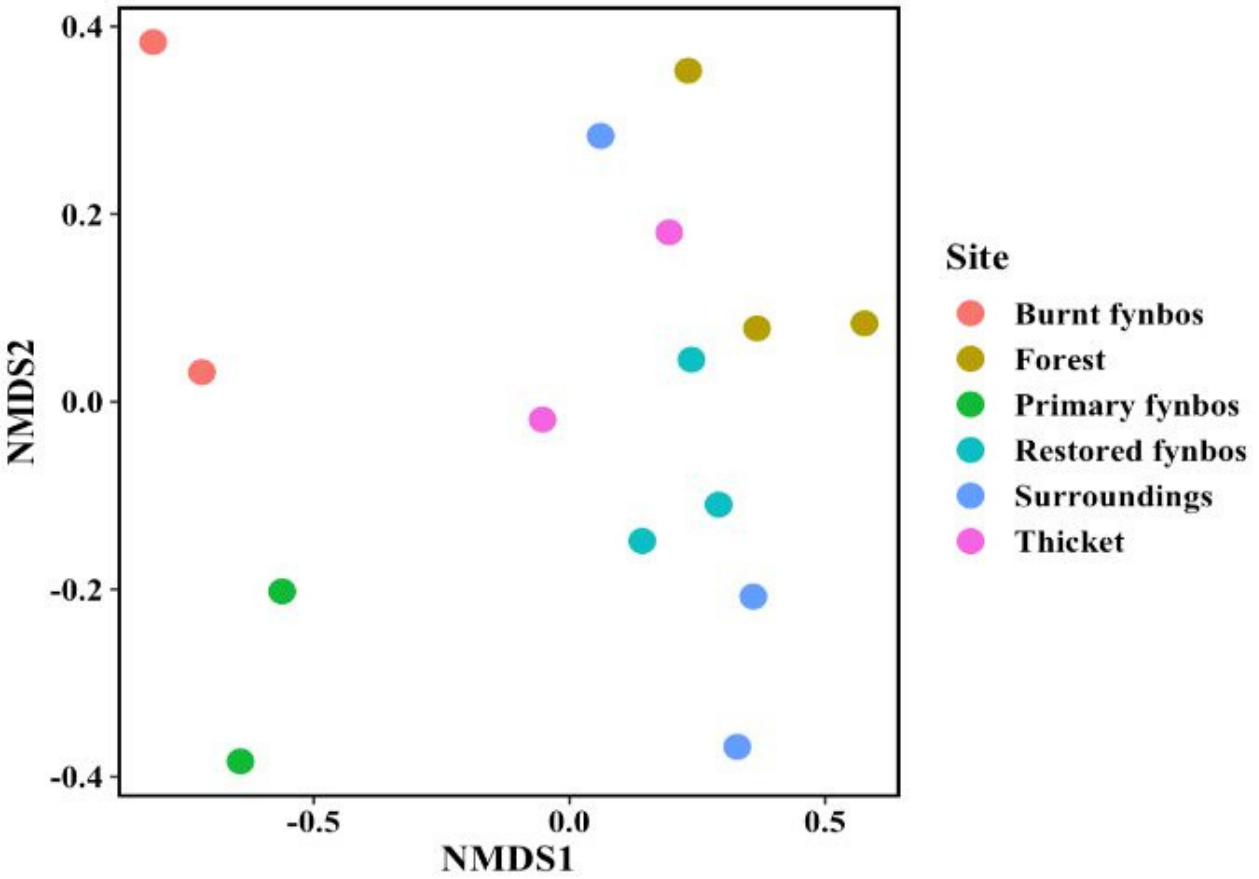


Figure 9: A non-metric multidimensional scaling (NMDS) plot which visually displays the Bray-Curtis dissimilarities between traps, calculated as a distance in a 65-dimensional Euclidean space (on account of the 65 taxonomic groups trapped) and then projected onto a 2-dimensional plane: The traps from different habitats are shown in different colours.

by the increase in taxonomic richness, which ensures that this increase in abundance is not solely due to the inflation of numbers of one particular invertebrate type.

Taxonomic richness can also be used as a proxy for functional diversity; the greater the taxonomic richness the greater the number of functional roles being fulfilled by invertebrates in that ecosystem (Cadotte et al. 2011). Due to the low taxonomic resolution used in this study, it is difficult to accurately state how this observed increase in richness is benefitting the ecosystem, as most models describe the benefits of species-level diversity. Although, if as suggested the taxonomic richness is like the species richness, it is suggested by the results of this preliminary study that it is possible that the restored fynbos area could be benefitting from increased productivity and ecosystem functioning. This is due to a greater number of taxonomic groups increases the diversity of ways in which organisms are extracting resources from the environment, increasing resource-use efficiency (Díaz & Cabido 2001) as well as other ecosystem functions such as pollination. In terms of ecosystem services, soil macro-invertebrates have been shown to increase microbial diversity and consequently increase rates of carbon mineralisation (Bray et al. 2019); increasing the diversity of invertebrates would likely further increase carbon-sequestering microbial diversity.

The trend in epigaeic invertebrate abundance across the four broad CFR habitat types was irregular with no clear patterns emerging from the data. These four habitats could be considered as four stages in the process of succession, with the land initially cleared by fire, developing into fynbos with short vegetation, and then in the absence of fire or any other limiting factor on the growth of vegetation the land will develop into thicket

and eventually forest. Given this, it was expected that abundance would increase along this successional gradient, due an increase in primary productivity with greater plant biomass and thus greater energy in the system.

While the forest did have the greatest number of invertebrates, the lowest abundance was recorded in the primary fynbos, with the burnt fynbos and thicket recording intermediate abundance values. His could be due to the primary fynbos site being fairly rocky, much more so than the thicket site, and with larger rocks than the burnt fynbos site. This may have been one of the factors slowing the process of succession at this site, as opposed to only the natural fire cycle. The large rocks reduce the surface area of soil available for plants to grow, reducing the quantity of organic matter available to support a greater abundance of epigaeic invertebrates.

Alternatively, the abundance values for the burnt fynbos may have been artificially inflated by an abundance of one particular invertebrate group, creating the illusion that the primary fynbos had an unusually low number of invertebrates. This was supported by the calculation of taxonomic richness for each habitat as it suggested that the primary fynbos which had a greater taxonomic richness than the burnt fynbos. Visual inspection of the raw data showed that the inflation of the abundance values for the burnt fynbos was due to the high number of springtails (Collembola: Poduromorpha) in the traps. Poduromorph springtails often form aggregations on the surfaces of pools of water, facilitated by aggregation pheromones (Salmon et al. 2019), which is what may have occurred on the surface of the liquid within the pitfall traps in the burnt fynbos, an otherwise quite dry environment.

To further evaluate the success of the fynbos restoration programme, the characteristics of the epigaeic invertebrate communities were compared between the restored fynbos site in Nature's Valley and the primary fynbos at Groot Rivier Pass. The results indicated there was greater epigaeic invertebrate abundance and taxonomic richness in the restored fynbos site compared to the local primary fynbos. The difference in richness was strongly supported by results of the Student's t-test ($p = 0.0021$), but the unequal variances of the abundance data necessitated the use of the Welch's t-test, which with its lower power was unable to provide a statistically significant result ($p = 0.0872$). It is likely that with a larger sample size – sample size being the main limitation of this study– the difference in invertebrate abundance between the restored fynbos site and the primary fynbos would become statistically significant. Regardless, the apparent strong discrepancy between the sites in terms of both abundance and taxonomic richness suggest that the fynbos restoration programme has not well-emulated the local primary fynbos ecosystem.

The community similarity between the primary fynbos and the restored fynbos and the primary fynbos had fewer shared taxonomic groups and thus a higher dissimilarity. This may be because of the influence of the neighbouring habitats on the community within the study sites (Cantero et al. 1999).

The dissimilarity index indicated that only the restored fynbos and the Groot Rivier Pass thicket as well as the primary fynbos and the forest had greater dissimilarity values that the restored and primary fynbos. Notably, the restored fynbos and the forest had lower dissimilarity than the restored fynbos and the primary fynbos, indicating the restored fynbos had greater community composition similarity with the forest than with the primary fynbos the programme is attempting to emulate. Further, the primary fynbos and the surroundings of the fynbos restoration programme site also had a lower dissimilarity;

this would suggest that the surroundings of the fynbos restoration site are more similar than the actual restored fynbos itself in community composition to the primary fynbos. This suggests that the restored fynbos in Nature's Valley only poorly emulates the local primary fynbos. Visually, there are several characteristics of the two sites which differ; the primary fynbos on Groot Rivier Pass has higher elevation, is more exposed, and is rockier, and the sites have different plant assemblages. It may also be the case that the restored fynbos needs more time to mature and with greater age the invertebrate community may become more similar in composition to the primary fynbos. As a recommendation for further comparative study on these two sites, projects with finer taxonomic resolution (genus- or species-level identifications) would allow better qualitative insight into how the sites differ in terms of community composition and support suggestions as to how the restored fynbos could be better managed so to better emulate the local primary fynbos. Ideally, one would want to achieve as great a similarity as possible to best contribute to the preservation of this threatened ecosystem.

Conclusion

The preliminary evaluation of the fynbos restoration programme in Nature's Valley provided here concludes in both a positive and a negative manner. It is evident from statistical tests comparing the epigaeic invertebrate abundance and taxonomic richness between the restored fynbos area and the baseline surroundings that the restoration has increased invertebrate diversity. This in turn contributes to increased ecosystem functioning and provision of ecosystem services and is thus beneficial for Nature's Valley and the wider environment. However, comparison with the natural habitats in the environs of the Village indicate that the fynbos restoration may not yet be successfully emulating natural primary fynbos, as one would be aiming for to best preserve this localised and threatened habitat. While further investigation with greater sample size, different seasons to combat for variation in temperature and rainfall as well as taxonomic resolution is needed to provide a potentially more informative qualitative evaluation, this study provides a preliminary baseline for further comparison between habitats in the CFR local region compared to Nature's Valley and beyond which can be used to inform habitat management decisions.

Acknowledgements

I am grateful to the NVT for providing the opportunity to carry out this investigation. In particular, I must thank Sky Beveridge for supporting me in my fieldwork and Professor Hendri Coetzee for providing key pieces of equipment. I am also most grateful to Merton College, University of Oxford, and Lord Gerry Grimstone for financing a grant to cover my travel and living expenses.

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SOUT (OOS) RIVER SOURCE-TO-SEA PROJECT

This multidisciplinary research project, funded by the Whitley Fund for Nature, commenced in 2023 and will take around two years to complete.

The preliminary findings of the outsourced carbon risk study, ecological baseline study and social baseline study (with an indication of their implications for NVT) are summarised below.

Note that, as and when they become available, full reports will be accessible via NVT's official website under the "Scientific publications" tab.

Sout (Oos) River Catchment Carbon Assessment

Mr Nicholaus Huchzermeyer and Dr Micheal Powell (Rhodes University) conducted this study. The array of vegetation types identified in the process is truly astounding as, unfortunately, is the level of degradation and the extent of the carbon risks involved. The information derived from this study will not only inform an intervention strategy that encapsulates the Sout (Oos) River in its entirety but will also serve to focus future restoration efforts where the core strategy will be to focus on areas with the highest biodiversity and lowest number of invasive alien plant species.

Ecological Baseline Study

This study was conducted under the leadership of Drs Wynand Vlok and Nick Rivers-Moore. Their preliminary findings offer a glimpse of the water quality as well as the biota (in particular freshwater fish and macro-invertebrates) present in the system. Those who were under the impression that the Sout (Oos) River is still a fishless system are in for a surprise… as are the macro-invertebrates that evolved in the absence of fish.

Social Baseline Study

Dr Sandra du Plessis conducted this study. In addition to pointing to some pressing environmental challenges in the Sout (Oos) River catchment, she highlights some interesting collaborations between Southern Crags, Redford, Kurland and Nature's Valley residents and provides some pointers as to what all of us can do to address some of the challenges in our respective areas.



Sout (Oos) River Catchment Carbon Assessment

Authors:
Nicholaus Huchzermeyer[1]
Michael Powell[2]

Affiliations:
[1,2]Rhodes University, Rhodes Restoration Research Group, Makhanda, South Africa

Corresponding author:
Nicholaus Huchzermeyer
nicky.huchzermeyer@gmail.com

NVT contracted the Rhodes Restoration Research Group (RRRG) to develop a fine-scale carbon baseline for the Sout (Oos) River catchment.

The aim of the study is to:

- Estimate carbon stocks for:
  - different vegetation types
  - different levels of degradation
  - different land-cover classes
  - different land-use classes
- Identify carbon sequestration opportunities related to the above
- Estimate carbon sequestration rates linked to opportunities
- Identify carbon emission risks
- Provide recommendations for carbon sequestration and avoiding emissions related to land-use practices

The Sout (Oos) River catchment is located in the Western Cape Province. The catchment falls within the K70A quaternary catchment. The catchment extends from the foothills of the Tsitsikamma Mountains to the permanently open estuary of the Sout (Oos) River.

According to the National Vegetation Map of South Africa, the catchment is dominated by Tsitsikamma Sandstone Fynbos (61%) and Southern Afrotemperate Forest (37%). The remainder of the vegetation types make up a small proportion of the catchment. The Garden Route Initiative mapped the vegetation (pre-transformation) of the study area at a finer scale and, when clipped to the catchment, it shows that the study area is dominated by fynbos (54%), forest (33%), water sources (10%) and major drainage lines (3%). Marine and thicket biomes make up less than 1%.

Land cover, as defined by the United Nations (2023), refers to the observed physical cover on the earth's surface and describes the distribution of vegetation units, water bodies and built infrastructure. National land-cover datasets are a key component of South Africa's environmental datasets. Changes in land cover can point to degradation (e.g. loss of key ecosystems) or landscape rejuvenation (such as the maintenance or gain of important and functional ecosystems).

Dynamic World is a near real-time global 10-metre pixel resolution land-use and land-cover dataset. Dynamic World uses an automated deep learning approach on 10 m Sentinel-2 satellite imagery for developing a globally consistent, high resolution, near real-time land-use/land-cover classification. The Dynamic World dataset was explored as an option to map out land cover for the catchment, but it was evident that the scale of the spatial accuracy as well as the errors in the defined classes make this dataset not suitable to be used for quantifying carbon within this catchment. Likewise, the South African National Land-cover 2020 dataset with a resolution of 20 metres was explored. The results at a catchment scale, although impressive, when zoomed in have

spatial inaccuracies and the dataset was, therefore. not considered useful to quantify carbon in the catchment.

In order to quantify carbon accurately across the landscape, it was necessary to have a high resolution map of land cover and land use in the study area. To achieve this, an extensive exercise was undertaken to map the entire catchment's land cover and land use at an ultra-fine scale (~1: 500) to create a spatially accurate baseline.

The figure below summaries the relative contributions of the different land covers and land uses to the area of the Sout (Oos) River catchment. Natural forest and fynbos account for 37% and 36% of the catchment area, whereas alien invader plants account for nearly 14%.
Pastures are a significant carbon pool accounting for the fourth largest land cover (5%).

The data was subsequently intersected with the Garden Route Initiative vegetation variants (which is currently the most accurate vegetation map for the area). The result is a spatial dataset of land cover per vegetation variant.

Each land-cover class within each vegetation type was assigned a carbon stock matrix using existing literature. The result is a spatial layer quantifying different carbon stock across the landscape. This spatial dataset can be used to interrogate land tenure and land use to provide mitigation plans (restoration, climate smart agriculture, urban greening, etc.). For each vegetation type, the relative contribution from the various land cover/land uses will help to inform mitigation and restoration strategies.

For the entire catchment, as well as each land cover, land use and vegetation class standing carbon stocks will be calculated using the above spatial data and published literature for the relevant carbon stocks. For example, fynbos occupies 1 974.1 hectares. This will translate to a total carbon pool for the Sout (Oos) River Catchment of 22 899 t C for above-ground biomass, 9 476 t C for litter, 26 256 t C for roots, 165 430 t soil C and a total of 224 060 t C for the catchment. It should be noted that there are many forms of fynbos, forest, alien plants, et cetera. Thus, these figures are the best approximations based on the available literature.





Figure 1: Comparison of land-cover datasets: A. Raw aerial image; B. Dynamic World; C. South African National Land-cover dataset; C. Result of high-resolution land-cover mapping for NVT.

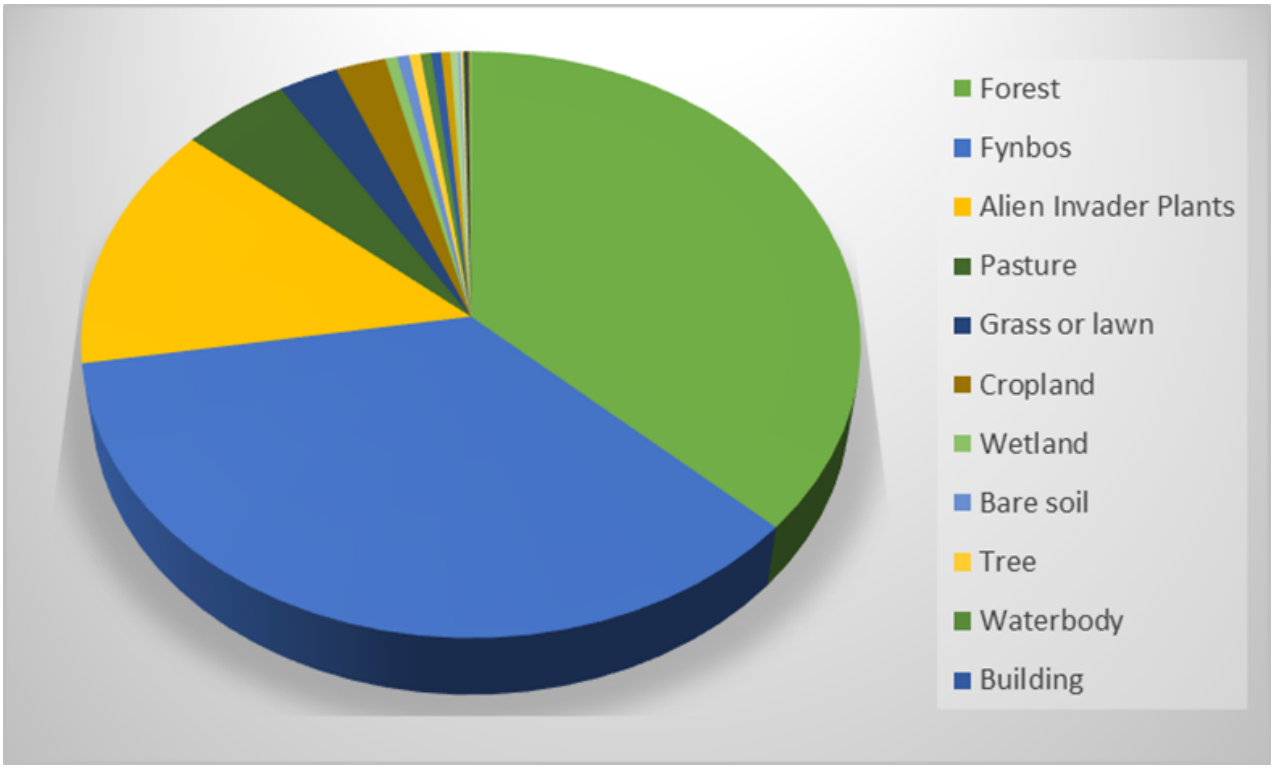


Figure 2: The 1: 500 spatial data for the Sout (Oos) River Catchment for land cover/land use.

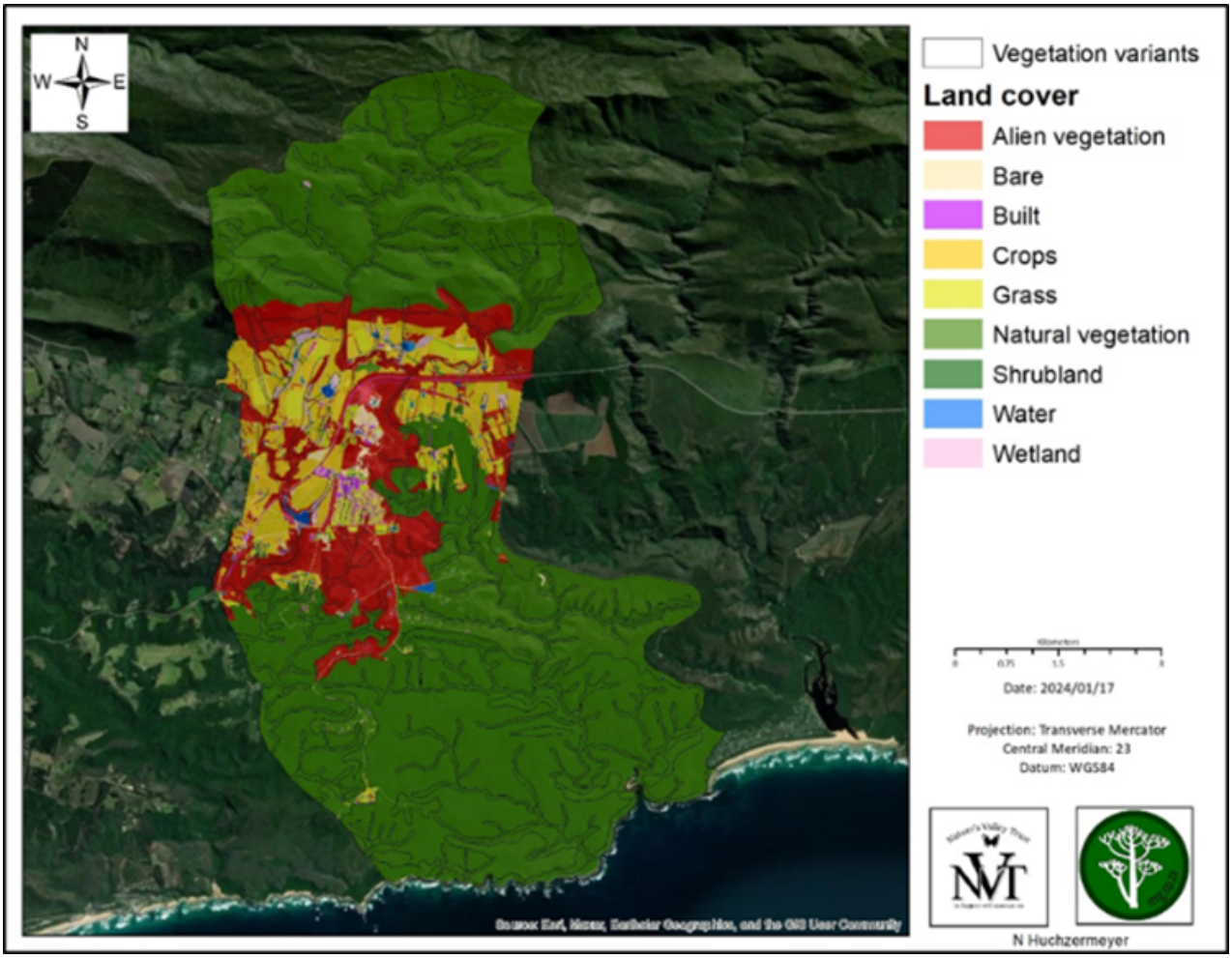


Figure 3: Spatial dataset of land cover per vegetation variant for the Sout (Oos) River Catchment.

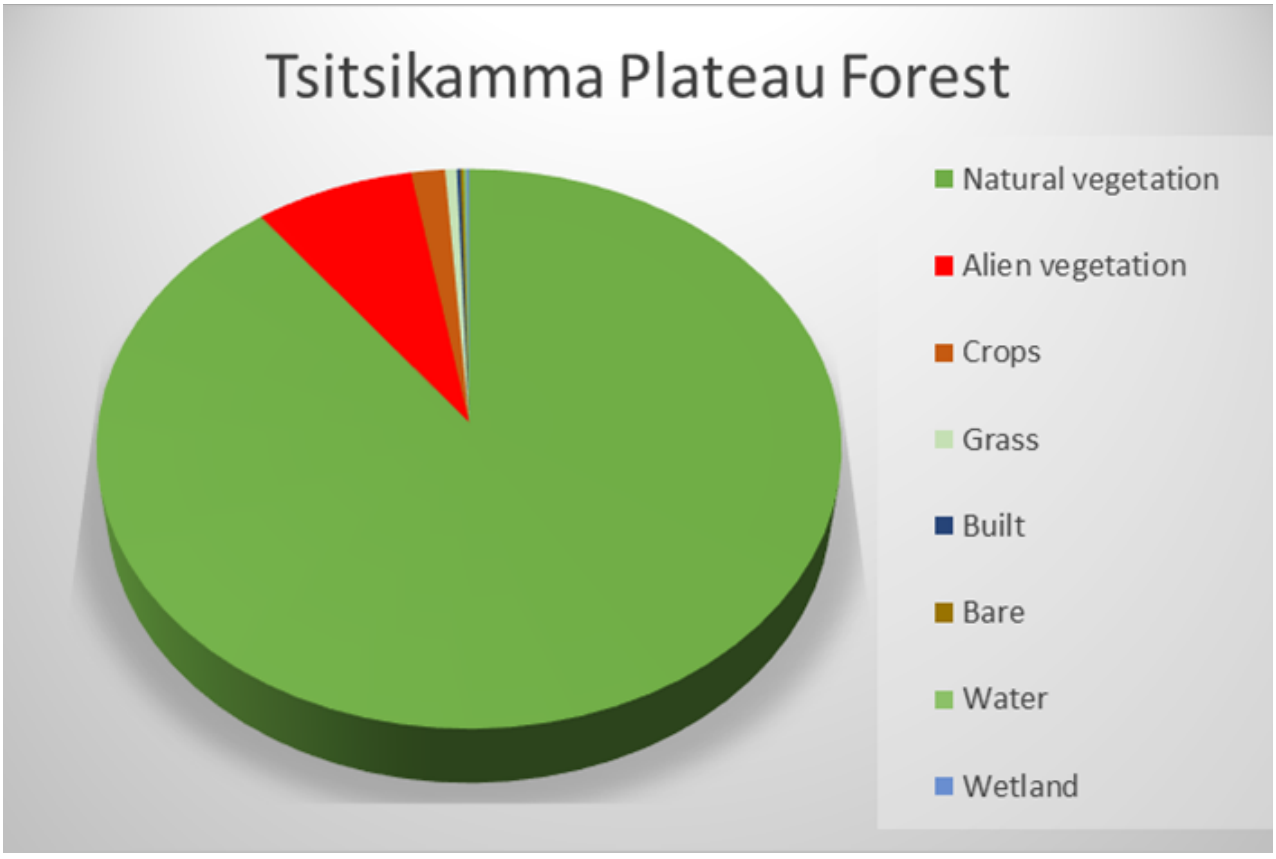


Figure 4: Land cover for the Tsitsikamma Plateau Forest.

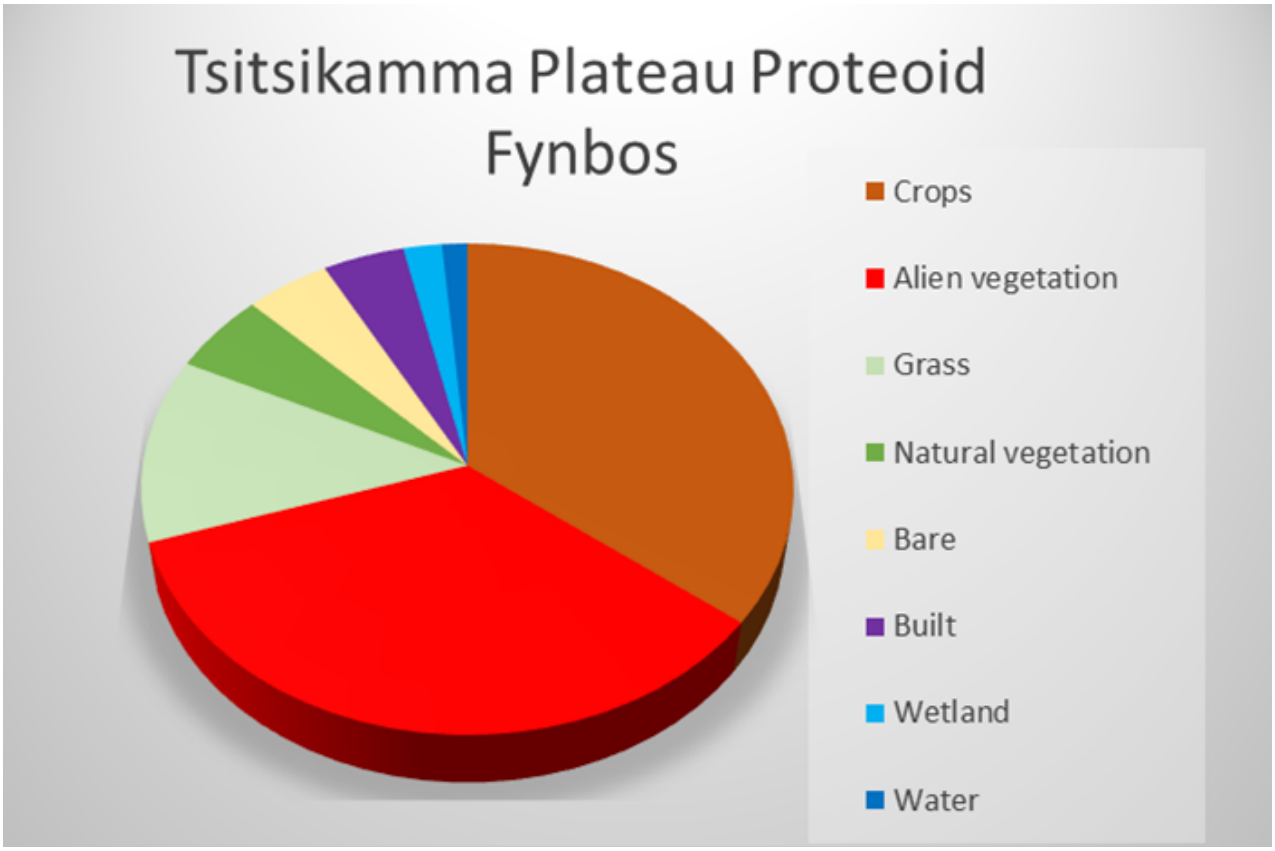


Figure 5: Land cover for the Tsitsikamma Plateau Proteid Fynbos.

Basic Assessment of the Biota and Water Quality of the Sout (Oos) River, Nature's Valley

Authors:
Wynand Vlok [1]
Nick Rivers-Moore [2]

Affiliations:
[1,2] Bioassets,Somerset West, South Africa

Corresponding author:
Wynand Vlok
wynand.vlok@gmail.com

The Sout (Oos) River is a small river (20 km axis) draining through the Bitou local municipality area, approximately 3 km west of Nature's Valley. It is known that the rivers of this region are short and within relatively small catchments draining from the Cape Fold Mountains into the ocean. The lower half of this river flows through the Tsitsikamma (De Vasselot) section of the SANParks Garden Route National Park, while the wider catchment is under the jurisdiction of the Gouritz-Breede Catchment Management Agency (GBCMA). The upper reaches of the catchment area fall within a mix of indigenous and non-native forested slopes above Kurland and Nature's Valley, with the middle reaches passing through the various agricultural and tourism developments associated with the Kurland area. The lower reaches of the river, which include the estuary, experience relatively lower human impacts and twenty years ago were reported as being in an "excellent" ecological condition.

The Sout (Oos) River is typical of the relatively short, deeply incised southern Cape rivers, being naturally oligotrophic and highly acidic. The geology of the region is mainly made up of a bottom layer: the Table Mountain quartzite that is around 250 million years old. The middle layer is a river stone conglomerate (proof of the presence of riverbeds thousands of years ago), and the top layer consists of sandstone which is about 45 000 years old. The geology and associated vegetation contribute to water with low conductivity and nutrient constituents. The tea-coloured water exhibits low turbidity and flows that are highly variable with episodic extreme high flow events with the result that the biotic community structure is linked to event-driven flows. Despite this variability, previous studies on the system (although limited in extent) have indicated that the aquatic macroinvertebrates are of high conservation value, being classified as Gondwana relict populations with no less than 16 previously undescribed species and three undescribed genera recorded. The macroinvertebrates perform a vital role in ameliorating water quality, removing nutrients and pollutants and, in the case of the Sout (Oos) River, ensuring improved water quality supply to vital marine systems.

The Sout (Oos) River is regarded as having evolved as a "fish-free" system, making it unique within the wider catchment setting of other similar rivers. The question arises why the Sout (Oos) River and the nearby Lottering River are referred to as "fishless" systems? Hey (1926) reported that only one species of freshwater fish was collected (*Anguilla mossambica*) from the Sout (Oos) River and this was confirmed by Bok (2000) after two surveys in August and November 2002. Russel (2002) found one freshwater fish (*Anguilla mossambica*) at two sample sites, one just above the estuary (some marine species collected) and a larger tributary of the Sout (Oos) River flowing from the west into the main channel. Recently however, there have been observations of the presence of fish in the middle and lower reaches of the river. Recent observations in the lower Sout (Oos) River have shown that that some freshwater fish are indeed present and this raised the question of the validity of the historic observation. This was confirmed during an assessment in December 2023, and a healthy breeding population was observed.

Samples were collected for genetic analysis to determine the origin of the fish in the Sout (Oos) River. Redfin species expected in the area is *Pseudobarbus afer* where its distribution is described as "present in coastal rivers from Algoa Bay to Mossel Bay but absent from smaller streams of the Tsitsikamma and Outeniqua coasts". However, in the past five years it has been noted that "populations currently assigned to P. afer across the species' distribution range revealed the existence of four deeply divergent taxonomic units.

The water quality, biotic and trophic characteristics of the Sout (Oos) River make this system of high conservation value and contribute to its growing vulnerability to degradation. A growing concern along the length of the river is the rapid current and projected developments happening that will negatively impact the river's sensitive ecology – especially the water quality and the rich endemic biota. The main impacts listed in reports include alien vegetation, the potential of alien aquatic species (including trans-located indigenous species), pollution and abstraction.

All activities in the catchment will affect river resilience and function to a greater or lesser degree. In the case of the Sout (Oos) River, biotic threats include presence of non-native and introduced native fish and growing densities of alien plants in the catchment and the riparian zone. The low pH and oligotrophic ecology present result in specific vulnerabilities to climate change impacts, wastewater pollution and agricultural runoff (fertilisers and pesticides).

A baseline ecological study forms the foundation for a monitoring and management programme and provides the yardstick against which changes, trends and ecosystem resilience can be measured as part of a longer-term monitoring programme. When linked to ecological threshold tipping points, this can be used to trigger appropriate interventions and actions within a broader adaptive management framework. A baseline assessment provides a benchmark of river integrity and ecosystem function against a specific point in time. However, for the baseline to be fully useful, it should be contextualised within any wider knowledge of the system, based on known biogeography, geological patterns and previous studies as this gives insights on whether the baseline has deteriorated over time and whether the river system is in a climax state, or dynamic equilibrium between states.

To understand the ecology and the related baseline of the Sout (Oos) River, it will be important to get a clear understanding of its current water quality, measured against available historic physico-chemical parameters. The process to drive this component will be water quality management consisting of an ongoing monitoring cycle aimed at, firstly, understanding the system and, secondly, at improving and maintaining optimal water quality for a specific body of water. The process will start by determining the baseline water quality parameters and then to determine what standards it needs for the water and biota, as selected health indicators, to accurately determine the integrity of the system. The results of the fish taxonomic analyses will inform the conservation authorities (Cape Nature and SANParks) so that decisions can be reached on what to do about the fish in the river. As mentioned, the macro-invertebrate in the system is considered of high endemic value and, therefore, its conservation is of high priority. Nevertheless, the question remains whether "to be or not to be".

NVT Sout (Oos) River Project – Social Baseline Assessment 2023

Author:
Sandra du Plessis

Affiliation:
Private consultant, Plettenberg Bay, South Africa

Corresponding author:
Sandra du Plessis
treesofgoodness@gmail.com

Introduction

Recognising the vital role of the Sout (Oos) River for local communities and ecosystems, the NVT Sout (Oos) River project aims to proactively address environmental challenges to safeguard the river for the future. This summary highlights the key components of the social baseline assessment as mandated by objective 2 (i.e. "understand challenges and map stakeholders") of the funding agreement for Phase One.

Approach and methods

The social baseline assessment utilised a diverse methodological approach to understand the social dynamics in the Sout (Oos) River region. Methods included semi-structured interviews, focus-group sessions, oral history sessions and participatory workshops.

The participatory workshops employed various techniques to explore the history and current situation of stakeholder groups, conservancies and communities. Stakeholders engaged in participatory activities such as creation of historical timelines, building human Venn diagrams to map stakeholder relationships and utilisation of matrices to document changes in resources over time, while image theatre was applied to explore 'helps and hindrances' to community progress in the region, and vision building. Forum theatre was used for stakeholder scenario-building, addressing current environmental challenges and brainstorming solutions collectively. Semi-structured interviews with key stakeholders in the region gathered insights into stakeholders' perspectives on ecosystem services, interests in the Sout (Oos) River, relationships with other stakeholders, knowledge of NVT projects, regional natural resource trends, possible drivers of change and proposed solutions. Additionally, an influence-interest grid analysed key stakeholders' influence and interest in the Sout (Oos) River project.

Findings

The social baseline assessment provides valuable insights from diverse stakeholders in the Sout (Oos) River region. Stakeholders in wine farming and mixed agriculture highlighted water in the Sout (Oos) River as a critical resource, advocating for sustainable management practices of the river system. Nature tourism was highlighted as a possible avenue for economic growth in the region, with stakeholders in Southern Crags expressing keen interest in further development of hiking trails and eco-friendly lodge developments. Collaborative conservation efforts, positive community engagements and the importance of monitoring infrastructure developments were highlighted. Economic sustainability through business collaboration and eco-tourism, governmental engagement, seasonal considerations for involvement of those stakeholders connected to Polo in conservation initiatives, monitoring progress and educational programmes were identified as crucial aspects. The revival of Southern Crags Conservancy, the problem of fences being erected by property owners and the need for creating wildlife corridors within the conservancies were emphasised as important for long-term environmental health. Addressing

concerns such as river pattern changes and potential conflicts with new landowners emerged as focal points for sustainable development.

Through participatory workshops, stakeholders identified significant trends and drivers impacting the natural resources in the Sout (Oos) River system. Water source and catchment areas were marked by negative trends, with dams, abstraction, pollution and various forms of runoff from agricultural farms and industries posing substantial challenges. Concerns were raised about the proliferation of alien vegetation in the area, the emergence of bug weed in the Crags and the contentious issue of increasing fellow deer. The upward trend of aliens was seen to come with challenges stemming from insufficient funding for clearing efforts.

Oral history with the Covie anglers shows a decline in fish abundance in the Sout (Oos) River estuary spanning decades. According to Covie anglers, in the 1960s, species like shad (*Alosa sapidissima*), blacktail (*Diplodus sargus*) and galjeon (*Dichistius capensis*) were plentiful but dwindled by the 1980s due to trawlers out at sea. Overfishing at sea by trawlers worsened the trend in the 1990s, with further decreases of fish in the estuary in the 2000s, along with an increase in plastic pollution. The decline of fish populations persisted through the 2010s, hitting a low in 2019, impacting key angling species. Covie anglers expressed the desire to be able to access their traditional fishing grounds, provide fish to their families and preserve their cultural heritage.

Further negative trends identified by stakeholders included a decline in wetlands attributed to diverse land uses that relate to developmental issues pertaining to, amongst others, the planting of macadamia trees and vines and the development of polo fields. Wildlife has showed an overall decrease in the region, driven by issues such as snares, poaching and agricultural development. Fynbos, a critical habitat in the region, was also identified as experiencing negative trends influenced by monoculture practices in land use, reduced burning frequency and property owners clearing the vegetation.

Tailored solutions based on economic disparities

Economic disparities impact communities differently: Covie and Kurland communities face challenges with unemployment, low living standards and low nature connectedness. Nature's Valley, Redford and Southern Crags enjoy economic stability and prioritise conservation. This affects resource access, conservation capacity, community dynamics and skill development opportunities. Tailored solutions are crucial, with Covie and Kurland needing initiatives focussing on basic needs, while Redford and the Southern Crags Conservancies have key players who self-initiate conservation efforts, emphasising the need for support and further development of their efforts. Recognising and addressing these economic differences is vital for effective community solutions in the region.

Conclusion

The outcomes of the social baseline assessment provide a foundation for the project's second phase, emphasising the design of nature-based solutions. These solutions, tailored to address identified challenges, aim to achieve resilient ecosystems and community well-being in the Sout (Oos) River region. The social baseline assessment, through its participatory and inclusive methodology, stands as an example for collaborative management of resources and knowledge integration.

CONTEXTUALISATION

In an attempt to contextualise the studies shared in this edition of *Nature's Letters*, to follow is a brief synopsis of what research has already revealed and/or are aiming to reveal as well as to spark interest in those areas that warrant further investigation.

Note that anyone with a keen interest in conducting ecological research that will contribute to understanding and conserving Nature's Valley and its surrounds are also advised to peruse, as a baseline, the report titled "Garden Route National Park: The Tsitsikamma SANParks section state of knowledge" originally produced by Hanekom et al. in 2012 and updated by SANParks in 2014.

Forests

Limited context-specific research and knowledge on Southern Cape Afrotemperate forests are available. For that reason, NVT established a new programme in 2022 that is dedicated to researching, conserving and expanding these forests in our area.

In addition to developing and testing methodologies that can be used to monitor forests, one of our 2024 interns is currently looking at the black ironwood as an indicator of forest health – a project that will also help to understand the impact climate change has on local forests. Given the applied nature of NVT's work, we are also currently experimenting with restoration methods and have identified the need to address the fragmentation of smaller forest patches by finding ways to link them to the larger forest complex so that their functionality can be maintained.

Research on larger forest mammals is ongoing. One of our 2023 interns is focusing on the impact humans have on the behaviour and movement of bushbuck, while our baboon project has already taught us a lot of about baboons' general behaviour and their foraging ecology, all of which contributes to the continuous refinement of our intervention strategies. A lot of work has also been done on forest birds and we will be reporting on our findings in the coming months.

Fynbos

In the past, we did a lot of work on birds, flowering phenology and pollination, while the ground orchids in the area were also surveyed and documented last year. The results and findings of a lot of this work can be perused on NVT's website under scientific publications.

The most recent contribution was made by Dr Daniel Cloete who focused on the impacts habitat fragmentation has on avian nectarivore presence, abundance and pollination. Since pollination is such an important component of fynbos, a variety of different pollination syndromes such as insect pollination (e.g. bees, moths, monkey beetles, etc.), bird pollination, and rodent pollination warrant further investigation.

Now that the fynbos at the top of the pass has burned, we are in a position to gain a better understanding of post-fire succession. James' work on insects already pointed to some differences between burned and unburned areas, while one of our new interns will be focusing on the indirect effects fire has on bird diversity and species richness.

Furthermore, a lot of work also still needs to be done on large and small mammal diversity in fynbos.

Marine & coastal

In as far as the local marine environment is concerned, we have a good (basic) understanding of our sandy shores (e.g. marine debris, shore birds, stranded marine mammals and birds, etc.) and of our local rocky shores (e.g. zonation, gully assessments, profiling, sand deposition, etc.). In NVT's long-term ecological monitoring projects, we focus on all of these aspects and plan to share the results in future issues of *Nature's Letters*.

What we don't really know much about yet is what the situation in our underwater marine space looks like. For that reason, NVT included this crucial aspect in its research proposal where the intention is to gain an understanding of the marine and coastal systems of Plettenberg Bay in its entirety. The intention is to follow a functional, whole-sea systems approach that will be applied in a structural, site-specific manner and encompass seven interlinked research projects:

- ocean floor classification and underwater depth (bathymetry),
- aerial water-quality assessment and monitoring of pollutants,
- habitat mapping (benthic survey),
- a fish population and biodiversity survey,
- a rocky-shore survey,
- a sandy-shore survey, and
- a social baseline study.

Another aspect we also don't fully understand yet is the linkages between our marine and estuarine systems. What we do know is that estuaries are important nursery grounds for local marine fish species, and Lauren plans to focus on this aspect as part of her doctoral studies.

Rivers & estuaries

Overall, we have a relatively good (basic) understanding of the two rivers the Groot (Wes) and the Sout (Oos) River as well as the related estuary systems in our area.

The Sout (Oos) River project is now in its second year and, at this stage, we have gained considerable insight into river health, water quality, water birds, et cetera partially because all of these aspects are covered by rote in some of our long-term ecological monitoring projects. SANParks also produced an estuary management plan for the Sout (Oos) River last year. The latter covers all the basic information about the catchment and also includes information on the function and state/status of the estuary and reserves as well as ecosystem services and impacts.

A similar plan will be produced for the Groot (Wes) River soon. On completion of the Sout (Oos) River project, our intention is to shift our focus to the Groot (Wes) River which will afford us a second opportunity to apply and refine the model we are currently developing – a model that can be used to understand, restore and manage river and estuarine systems from source to sea.

CITIZEN SCIENTIST FORUM

NVT is extremely fortunate that residents and "regulars" take a keen interest in the preservation of the Valley's natural state. All too often, concerns raised by our citizen scientists will alert NVT to the fact that a more thorough investigation may be warranted.

A case in point is the project that was launched to assess the Valley's bushbuck population – a project that relied heavily on citizen science [see page 38].

Of equal importance are the "historical" observations recounted by citizen scientists (be they residents or regular visitors) who were fortunate to observe changes to the ecological state of the Valley over many, many years.

These "historical" observations have the potential to unlock a treasure trove of data that can inform the studies of environmentalists who endeavour to preserve the Valley in the here and now.

Jane Mclleron's recounting of how, in her experience, the marine environment has changed over the past twenty years is, indeed, food for thought.

NVT invites all citizen scientists to share their observations/concerns. Send your contribution to hendri.coetzee@nvt.org.za.

Memories of rock pooling at Nature's Valley

My family used to come to Nature's Valley on holiday at least once a year for two to four weeks – as long as we could get away with. Low tides, especially spring lows, were occasion for rock pooling expeditions – to me magical glimpses into a jewel-coloured, strangely shaped, marvellously intricate and diverse world. This is just a compilation of things I remember off the top of my head, with identification (or not) from books including George and Margo Branch's *Living Shores of Southern Africa*, *The seaweeds of the Tsitsikamma Coastal National Park* by Dr SC Seagriel, *Fishes of the Tsitsikamma Coastal National Park* by JLB Smith and Margaret M Smith, and *Tsitsikamma Shore* by RM Tietz and Dr GA Robinson. These books are not new, so names and classifications may have changed.

The pools then had much more luxuriant life. Seaweeds formed lush fringes and forests down the sides of pools – *Sargassum* especially, and *Ulva* on the more level areas with shallow pools. Lower down the tidal range, I remember particularly *Dictyota* (possibly *naevosa* and also *liturata*) with its iridescence, and the dark lumpy *Codium* (possibly *lucasii*) and fingers of *C. duthieae*. I remember also *Caolpomenia sinuosa* (perhaps more often washed onto the beach than in pools), *Zonaria subarticulata* (small feathery, dark brown weeds) and similarly fine dark weeds but bigger (possibly *A. massesof* or a species belonging to the genus *Gelidium*), as well as a beautiful red *Plocamium* species and the broad, dark leaves of (possibly) *Gigartina paxillata*. I think I remember *Gigartina minima* too. Also, of course, the pink coralline weed still common in the cochlear zone, and many lichen-like encrusting algae. I am sure my list is far from complete.

I remember masses of sea urchins, cushion stars, limpets of different kinds and sea anemones of several kinds (certainly *Bunodactis reynaudii* and *Pseudactinia flagellifera*, but there could have been others too) in many colours – electric blue, greenish cream, raspberry pink, lilac, blackish green, red, greenish ochre, etc. The rocks were liberally encrusted with the grey tubes of polychaete worms (possibly *Pomatolleios kraussii*). There were other quite large polychaete worms too that the fishermen used to look for.

There were many brown and orange crabs (and plentiful octopi hunting them) and hermit crabs too. There were other starfish (while snorkelling recently, I saw *Patiria granifera*, *Henricia ornata* and *Marthasterias glacialis*). There were fan worms (*Sabellastarta longa*) in a range of colours, flatworms of several kinds and, occasionally, a nudibranch (possibly *Hypselodoris capensis* and *Polycera capensis*) or a seahare. Numerous other gastropods were, of course, also spotted (possibly species belonging to the genus *Oxystele*) as well as alikreukel, whelks, etc. In deepish pools, there were sea cucumbers and hydroids (possibly *Theocarpus formosus*). There were numerous sponges, some very brightly coloured. I remember a magenta one (a sponge or perhaps a kind of anemone) at the extreme low edge of the tidal range that was intense "ink purple". For those old enough to remember, the colour was similar to that of those old purple ink pads used to stamp things, just more saturated.

In the shallows of the upper ranges, as well as in the lagoon and at Sout (Oos) River mouth, any part of you dipped in the water would attract transparent shrimps (*Palaemon pacificus*) within seconds.

Apart from leopard shark, striped dogfish and sea snakes washing up quite often, fish in the pools were also diverse. Below is a list of some I can remember:[1]

- blaasop (*Amblyrhynchotes honckeni*)
- blenny (*Bennius cornutus*)*
- butterfish (*Palunolepis brachydactylus*)
- butterflyfish (*Chaetodon marleyi*)
- dassie (*Diplodus sargus*)
- dikkop (*Coryphopterus caffer* and *C. cloatus*)*
- flagtail (*Dules taeniurus*)
- kelpfish (most likely *Caboclinus superciliosus*, *C. robustus*, *Cirrhibarbis capensis*, *Clinus venustris*, *Blennioclinus brachycephalus*, *Blennophis striatus*, *Blenniomimus taurus*, *B. cottoides*, *Fucomimus mus*, *Pavoclinus pavo* and *P. heterodon*) *
- mullet* (smallish and usually in pools with water washing in and out easily)
- musselcracker (*Sparodon durbanensis*)
- rooivlerk (*Cheilodactylus fasciatus*)*
- sand goby /sanddikkop (*Psammogobius knysnaensis*)
- strepie / karanteen (*Sarpa salpa*)
- zebra (*Diplodus trifasciatus*)

[1] ***Editor's note***: Instances where this citizen scientist expressed her reservations about the precise identification of fish species are followed by an asterisk. This list has also been arranged alphabetically for the purposes of aiding inputs by those who wish to add to or, perhaps, provide clarity on the species most likely observed.

Even though I have spotted some of the fish species listed above during recent snorkelling expeditions, I have not done any serious rock pooling recently, being too discouraged by the seeming bareness.

It is possible that some areas are better than others, but I am particularly struck by the lack of seaweeds and sea urchins, as they were so evident previously, and the scarcity of octopi and diverse invertebrates.

Jane Mcilleron
Nature's Valley
mcilleron@gmail.com





Photo courtesy Tiaan Botha



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