RESEARCH ARTICLE

# Assessing the performance of oribi antelope populations at multiple scales: the limitations of citizen-led oribi conservation

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**Effective monitoring programmes are critical to understand and mitigate declining wildlife populations. In South Africa, the majority of oribi antelope (*Ourebia ourebi ourebi*) occur on private rangelands as broadly distributed and highly-fragmented populations. Thus, to effectively manage such a species, conservation organizations rely on citizen science-led conservation initiatives, whereby members of the public provide data on oribi population demographics and potential threats. Using these data, we estimated the total oribi population size and assessed the population trend of oribi in KwaZulu-Natal, South Africa, over a 14-year period (2001–2014). We found that the oribi population has declined by 30% over the 14 years. However, oribi population estimates were highly correlated with the number of returned survey forms. This relationship makes it difficult to accurately assess population trends and almost impossible to determine if any changes in conservation management have influenced oribi populations. Thus, issues associated with citizen science and data quality (*i.e.* participation levels), may limit the ability of the oribi census to accurately inform oribi conservation and management. We discuss the value and limitations of citizen science in oribi conservation with the ultimate goal of improving citizen-led oribi conservation.**

**Keywords**: census, citizen science, monitoring, population growth, wildlife surveys.

## INTRODUCTION

Anthropogenic disturbances and environmental change have led to the development of ecological monitoring programmes with the goal of assessing how species and ecosystems may respond to such changes (Nichols & Williams, 2006; Lindenmayer & Likens, 2010; Jewell, 2013). The goal of these monitoring techniques is to detect ecological changes at both short- and long-term scales (Siddig, Ellison, Ochs, Villar-Leeman & Lau, 2016). Thus, monitoring free-ranging animals in their natural habitat can be critical to establishing the conservation status of species, setting appropriate recovery targets, and ultimately helping to improve management decisions (Martin, Kitchens & Hines, 2007). While protected areas are the cornerstone of global conservation, the role of private rangelands in conservation is becoming increasingly important (Kamal, Grodzińska-Jurczak & Brown, 2015; Shumba *et al.*, 2020).

A challenge facing conservation biologists globally is obtaining long-term monitoring data from private landowners. This is because these sites occur over large spatial scales, access is frequently limited, and land use and ownership can change, which can influence the relationships between conservation organizations and private landowners (Hilty & Merenlender, 2003). Long-term monitoring programmes are critically important because they can identify population trends and relate observed trends to potential threats to

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elucidate the relative importance of specific threats (Siriwardena, Calbrade & Vickery, 2008; Caro, 2011). Furthermore, in an African context, where funding for species monitoring is limited, low-cost and low-tech monitoring solutions (*e.g.* citizen science) are of great importance (Steger, Butt & Hooten, 2017).

Citizen science has long been incorporated into conservation biology and management (Follett & Strezov, 2015; Dennis, Morgan, Brereton, Roy & Fox, 2017). Despite the popularity of citizen science, concerns remain about the accuracy of the data collected by non-scientists (Bonney *et al.*, 2014; Follett & Strezov, 2015; Aceves-Bueno *et al.*, 2017). Thus, citizen science often involves a trade-off between scientific rigor and mass public participation (Dennis *et al.*, 2017). However, citizen science can address the shortcoming of monitoring populations on widely distributed private land by decreasing the costs associated with monitoring, as well as increasing public engagement in conservation (Bonney *et al.*, 2014; Steger *et al.*, 2017).

In South Africa, a species of conservation concern is the oribi antelope (*Ourebia ourebi ourebi*), of which, a majority inhabit private rangelands in small, highly-fragmented populations (Shrader, Little, Coverdale & Patel, 2016). In response to declining oribi populations (Marchant, 2000), the Oribi Working Group (OWG) was formed in conjunction with the Endangered Wildlife Trust (Coverdale *et al.*, 2006). A primary goal of the OWG is to provide critical monitoring of oribi antelope, *via* an annual citizen-led census, and to consolidate population data into a database that can guide research opportunities and inform management plans. Because the majority of oribi occur on private land and their populations are highly fragmented over large spatial scales, the monitoring and management of oribi populations in South Africa is largely reliant on citizen science where members of the public (*e.g.* private landowners) help in the gathering of data (*e.g.* Belt & Krausman, 2012; Forrester *et al.*, 2017).

While the collaboration between conservation biologists and the general public can broaden the scope of research and enhance the ability to collect scientific data (Yang, Wan, Huang & Liu, 2019), concerns about data quality can hamper the applicability of citizen science-collected data to wildlife management and conservation. Here, we use citizen science-derived survey data on oribi populations as a case study to identify the benefits and limitations of citizen science in the management of small antelope with the ultimate goal of providing solutions to improve citizen-led oribi conservation. To do this, we used the oribi census data to: 1) determine the total oribi population size and the current population trend of oribi in KwaZulu-Natal, South Africa, 2) assess the performance of oribi populations on both private and protected land in KwaZulu-Natal, and 3) identify potential variables that may influence the performance of oribi populations. We used the above outputs to determine if data obtained from citizen science were suitable for the reliable monitoring of oribi populations.

## METHODS

### *Oribi database*

The OWG maintains a database that contains standardized data on oribi populations in South Africa, which provides spatially explicit analytical capabilities for all oribi-related data. These data are obtained by the OWG through surveys that are distributed to private landowners and protected areas for the annual oribi population counts and includes data on oribi population demographics (*e.g.* age, sex, population trend), perceived threats, and property details (see Supplementary material: Appendix 1 for the 2014 Oribi Survey). Since 2001, oribi population surveys were conducted biennially, but since 2010, these surveys have been conducted annually. Oribi can be relatively cryptic, thus, oribi counts are conducted from September to November when oribi congregate on green flushes provided by spring burns, which makes them more visible (Little & Magwaza, 2014). In South Africa, KwaZulu-Natal is the stronghold for oribi, thus, the populations from KwaZulu-Natal are the focus of this article.

### *Assessing oribi population performance*

It is estimated that the oribi population in KwaZulu-Natal is distributed across 558 sites. However, the paucity in returned oribi survey forms from both private landowners and conservation managers of formal protected areas meant that we were only able to assess the performance of oribi populations from a subset of sites over a 14-year period ($n$ = 100; private land: $n$ = 74; protected land: $n$ = 26; Fig. 1). We only used sites from which we had more than three returns, but were not from three consecutive years, from the 14-year period. For each site, we assessed oribi population

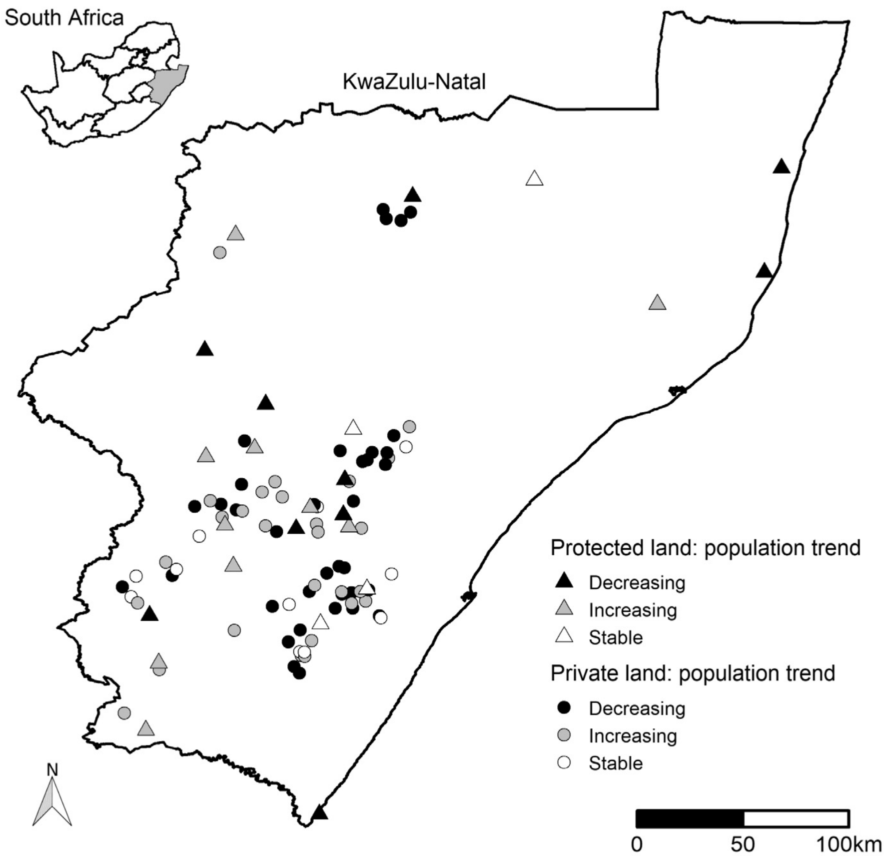


**Fig. 1**. The spatial distribution of oribi population trends for both private rangelands and protected areas ($n$ =100) for KwaZulu-Natal, South Africa, as well as the location of KwaZulu-Natal in relation to South Africa (upper-left).

performance by calculating the finite population growth rate (lambda: $\lambda$), which gives the proportional change in population size from one time period to another. Due to the paucity of the data, we calculated lambda using the first and last survey return for each site. Thus, in this context, lambda does not reflect an annual growth rate, but rather a start and end population change for the oribi population at each site.

We deemed populations as increasing when $\lambda > 1$, decreasing when $\lambda < 1$, and stable when $\lambda = 1$.

*Property-scale variables influencing oribi population performance*

To determine what factors may influence oribi population performance, we contacted landowners that were listed on the OWG database as having oribi on their property. Of the 86 properties listed with contact details, we were only able to contact 25 sites (private land: $n$ = 17; protected land: $n$ = 8). The rest of the sites did not have correct or updated contact details or did not respond to our contact attempts. Once contacted, we asked landowners to provide the following information: land type (private land or protected conservation areas), current oribi population size as well as the population size when the first survey form was submitted, the amount of suitable habitat available to oribi (in hectares), grazing regime of other herbivores (continuous or rotational grazing), average annual rainfall, and information quantifying the impact of predators and dog hunting on oribi (see Supplementary material: Appendix 2). We used the amount of suitable habitat and oribi population size to determine the density of oribi at each site. We included the type of grazing regime because of the differing degree to which rotational and continuous grazing can influence the structural heterogeneity of rangelands (Fuhlendorf & Engle, 2001). Ultimately, we were not able to include the impacts of predators and dog hunting in our analyses because both occurred at all sites and we only received qualitative data (*i.e.* present) because landowners were not able to quantify the effects of predators and dog hunting on oribi populations.

*Statistical analysis*

One concern associated with relying purely on citizen science to assess population sizes of a species is the potential lack of participation by citizens in a given year and how this impacts data quality. To explore this issue, we used a Pearson correlation to correlate the total number of oribi enumerated with the number of oribi surveys returned at each annual oribi population count. Because oribi occur in small populations, a decline in the number of surveys may not necessarily result in a declining population because increasing populations elsewhere may offset the losses associated with a lack of survey responses. Prior to determining what factors may influence oribi population performance, we compared oribi population performance on private and protected lands using a Generalized Linear Model (Gamma distribution and log link function). We found no significant difference in the average population growth of oribi between private and protected lands ($\chi^2$ = 0.937, d.f. = 1, $P$ = 0.333). Thus, we pooled the data and ran a Generalized Linear Model (Gamma distribution and log link function) to determine which property-scale variables may influence oribi population performance. For this model, we included oribi population growth (lambda) as the dependent variable and oribi density (number of oribi/ha), average annual rainfall, and the type of grazing management of other herbivores (rotational grazing or continuous grazing). We used a model selection approach to determine the best fit model from a set of candidate models (Table S1). Model selection was based on Akaike's Information Criterion for small sample sizes (AICc) and Akaike weights with the best model achieving the lowest AICc value (Burnham & Anderson, 1998). All analyses were conducted within the R statistical environment for computing (R Core Team, 2019).

## RESULTS

### The oribi database and citizen science

Overall, we found that the citizen science participation in the oribi population monitoring programme was inconsistent. Out of the 558 sites in the OWG database that monitored oribi populations in KwaZulu-Natal over the last 14 years (2001–2014), 64% of these sites only provided data for one survey, whereas, only 2% of the sites provided data for five or more surveys. Moreover, the majority of the sites that participated in only two surveys did so in consecutive years. This short temporal scale makes assessing long-term population trends impossible. In addition, critical information on oribi demographics (*i.e.* number of males, females, and offspring) and potential threats to oribi populations was missing from 69% and 92% of sites, respectively, despite this information being requested on the oribi population monitoring forms.

### Oribi population performance at the provincial scale

Since the inception of the oribi population surveys in 2001, the overall oribi population trend in KwaZulu-Natal has been declining (Fig. 2a). Over a 14-year period, the number of oribi have declined by approximately 700 individuals, which represents a 30% reduction in abundance. However, we found that the total oribi population abundance was highly correlated with the number of survey forms that were returned for each sampling period (Fig. 2b). Such that in years with high return rates, oribi populations increased, and in years with low returns, oribi populations declined. We found this relationship for both private ($n$ = 74 sites; $r$ = 0.99) and protected sites ($n$ = 26 sites; $r$ = 0.91) (Fig. 2b). Overall, participation by landowners, as measured by the number of surveys returned per year, has declined by approximately 45%. Across their distribution, oribi populations are performing slightly better on protected lands (61% of sites are increasing or stable and 39% are decreasing) compared to private lands (51% of sites are increasing or stable and 49% are decreasing) (Fig. 2c). Across their distribution, we did not observe any spatial patterns in oribi population trends (*i.e.* large-scale patterns do not appear to be driving population trends; Fig. 1). Different sites within close proximity to each other can either show an increasing, decreasing, or stable population trend, suggesting that property-scale variables are stronger drivers of population trends for oribi compared to large-scale environmental variables.

### Property-scale variables influencing oribi population performance

For the 25 sites that we collected site-specific

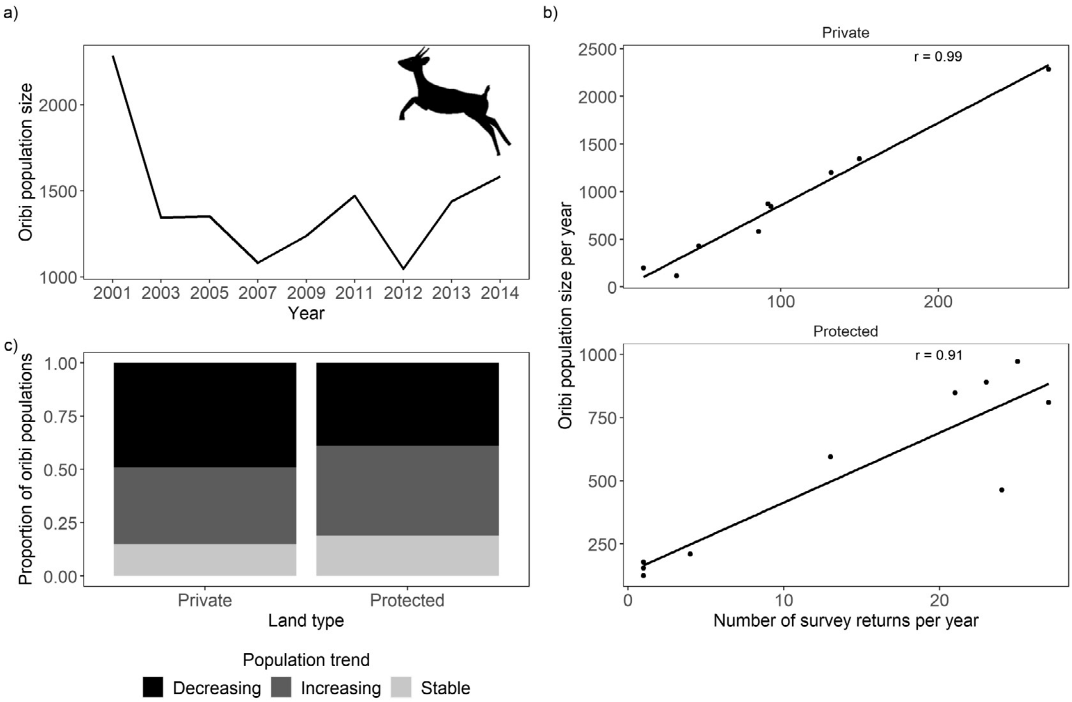


**Fig. 2**. We used the Oribi Working Group (OWG) database that contains oribi census data collected from conservation managers and citizen science to (**a**) determine the total oribi population size and overall population trend since the inception of oribi population counts, (**b**) illustrate that oribi population size is highly correlated by the number of survey returns for both private and protected areas, and (**c**) determine the proportion of oribi populations that are increasing, decreasing, or stable on private rangelands and protected areas.

variables that could influence oribi population performance, we found that 56% of sites had declining oribi populations (private land: $n$ = 10; protected land: $n$ = 4), 32% of sites had increasing populations (private land: $n$ = 6; protected land: $n$ = 2), and 12% of sites maintained stable oribi populations (private land: $n$ = 1; protected land: $n$ = 2). Our best fit model found that only oribi density influenced oribi population growth (Table S1). We found a significant negative relationship between oribi population growth as oribi density increased ($\chi^2 = 20.437$, d.f. = 1, $P = 0.002$). On average, oribi had the highest population growth when oribi densities were less than 0.04 oribi/ha (4 oribi/km$^2$).

## DISCUSSION

In South Africa, the majority of data regarding oribi population dynamics are provided through citizen science because of the predominance of oribi populations that occur outside of protected areas. In KwaZulu-Natal, a stronghold of oribi populations in South Africa, oribi populations are declining, and have done so over a 14-year period. However, these population trends are highly correlated with the number of oribi census returns that are provided by citizen scientists. Furthermore, critical information about factors that are threatening oribi populations were not provided by private landowners, making threat assessments for oribi populations difficult. When we used an additional survey to determine what factors may be influencing oribi populations at the site scale, we found that only oribi density influenced oribi population performance. However, despite these surveys having very direct questions, useable information about site-specific details were generally not provided by landowners (*e.g.* amount of suitable habitat for oribi and quantitative estimates of the frequency and impact of illegal hunting with dogs). With the above in mind, how useful is citizen science with regards to oribi conservation?

### Citizen science and data quality

The goal of citizen science is to provide reliable data that can be used for scientific purposes (Kosmala, Wiggins, Swanson & Simmons, 2016).

However, despite the many benefits of citizen science (Tulloch, Possingham, Joseph, Szabo & Martin, 2013; McKinley *et al*., 2017), the ability of volunteers to collect high-quality data is a frequent concern (Kosmala *et al*., 2016; Lukyanenko, Parsons & Wiersma, 2016; Balázs, Mooney, Nováková, Bastin & Arsanjani, 2021). These concerns are valid because science and policy are frequently derived from data collected from citizen-science projects. Among ecologists and environmental managers, issues of data quality pertain to data accuracy, the degree to which data are correct overall, and bias within the dataset, which refers to systematic error in the data (Kosmala *et al*., 2016).

In the oribi census dataset, data accuracy and the lack of expert validation is a major concern. For example, the correlation between total oribi abundance and the participation of citizen-led oribi conservation by private landowners suggests that oribi numbers are directly influenced by participation levels. This relationship, and the variability in participation between annual oribi counts, makes it difficult to accurately assess population trends and almost impossible to determine if any changes in conservation management have influenced oribi populations. Moreover, in our analysis, we found that oribi performance was negatively influenced by oribi density at a site. The metric, oribi density, was calculated off the amount of suitable habitat for oribi, which was determined by each landowner. There are two problems with this approach. Firstly, there is no standardized measurement for suitable habitat across sites. Secondly, Louw, Pienaar & Shrader (2021) found that many private landowners had little knowledge about oribi and their habitat requirements, thus, it is unlikely that they are able to accurately assess the amount of suitable habitat available to oribi. However, understanding the relationship between oribi performance and their density is critically important for oribi conservation and management. On private rangelands, land-use change and inappropriate land management such as poor fire management and overstocking of livestock can reduce the structural heterogeneity of grasslands, ultimately reducing suitable habitat for oribi (Coverdale *et al*., 2006; Little, Hockey & Jansen, 2013; Neke & Du Plessis, 2004; Stears & Shrader, 2020).

Similarly, landowners view predators (predominantly jackal, *Canis mesomelas*) as a significant threat to oribi (52% of sites listed predators as a threat). However, when these results were validated in a follow-up study, the percentage of occurrence of oribi in jackal scats was less than 2% for both summer and winter, which was lower than the occurrence of other wild ungulates (*e.g.* common reedbuck, *Redunca arundinum*, and grey duiker, *Sylviacapra grimmia*) in jackal scats (Humphries, Ramesh & Downs, 2015). Thus, the role of natural predators in driving the overall decline of oribi populations is unfounded, although the role of predators in regulating oribi populations is likely to be site-specific. Accurately identifying a declining population is the first step in species conservation with the next step being able to pinpoint the potential drivers of decline (Martin *et al*., 2007). However, the lack of consistent returns, inaccurate data, and missing population demographics that we observed in the census data may limit the ability of conservationists to understand how disturbances may influence oribi population dynamics (Beissinger & McCullough, 2002; Coverdale *et al*., 2006).

Data bias that is specific to citizen science is the high degree of variability associated with the ability, effort, and commitment of participants (Snäll, Forslund, Jeppsson, Lindhe & O'Hare, 2014; Kosmala *et al*., 2016). For the oribi survey, the participation of landowners was highly variable. Thus, the overall oribi population trend, and the factors that influence oribi population performance, were assessed using a subset of the total data set (sites with multiple survey years). This can be problematic if sub-sampled areas are not representative of the entire area in which oribi exist (Williams, Nichols & Conroy, 2002). For example, we selected sites that had the highest quality data in the population surveys (*i.e.* the best monitored populations). While it is important to understand oribi population dynamics in well-monitored sites, it is critically important to also determine oribi dynamics for sites that are less well monitored and where data are deficient. Thus, without taking this bias into account, the focus of these oribi surveys should be on identifying population trends rather that estimating actual oribi numbers (Martin *et al*., 2007).

## Improving citizen science for oribi and wildlife conservation

Considering the broad distribution of highly-fragmented oribi populations across privately owned rangelands, relying on citizen science is the only realistic and cost-effective method to obtain population demographic data for oribi. Ultimately, the effectiveness of citizen science depends on the quality of the project design, in this case, the design of the oribi population survey form. This survey form follows the correct format by being short and to-the-point, which is meant to improve participation and the quality of data obtained by citizen scientists (Callaghan, Rowley, Cornwell, Poore & Major, 2019). However, the census forms can be further improved by including evolving questions that change as new and different threats to oribi emerge under current conditions of global change (Lindenmayer & Likens, 2010). Relevant questions are central to effective monitoring and should result in quantifiable objectives for measuring progress (Nichols & Williams, 2006; Lindenmayer *et al*., 2007). The overall lack of participation by landowners is partly due to how the survey forms are disseminated – the OWG database that contains landowner contact details. Unfortunately, contact details frequently change and the database is plagued with outdated details. The lack of participation can also be explained by the frequent distrust between private landowners and conservation organizations, which stems from the concern that land-use restrictions could be imposed on private landowners by conservation organizations (Louw *et al*. 2021). Ultimately, this distrust can limit the participation of private landowners in conservation efforts (Miller, Bastian, McLeod, Keske & Hoag, 2010; de Vries, Aarts, Lokhorst, Beunen & Munnink, 2015). Moreover, Louw *et al*. (2021) found that, despite the willingness of many private landowners to protect oribi, they had little knowledge about oribi and their habitat requirements and did not know what land management practices would benefit oribi conservation. Thus, improving participation in oribi population counts may lie in partnership-building and improving current relationships between private landowners and conservation organizations.

Embracing emerging technologies, such as mobile applications can engage broader participation, motivate volunteers, and ultimately improve data collection (see Newman *et al*., 2012 and references therein). Such platforms already exist (*e.g.* iNaturalist, eBird) and current technology is making it easier than ever to build citizen-science projects with online components (Kosmala *et al*., 2016). These digital app-based platforms eliminate the need for contact details and allows for location-based, real-time dissemination of data to landowners that collect the data. Furthermore, important information about oribi habitat requirements and management can be made available to landowners on such platforms.

A common feature of the oribi census data, and large-scale citizen-science projects in general, is the spatial and temporal patchiness of data (Beck, Böller, Erhardt & Schwanghart, 2014; Callaghan *et al*., 2019). Because one of the main goals of the oribi census is to produce reliable population trends, the census should focus less on collecting data over large spatial scales, and focus more on obtaining longer timeseries data from fewer sites (Dennis *et al*., 2017; Callaghan *et al*., 2019). Focussing on protected areas seems like the logical solution because animal censuses are conducted frequently and are collected by trained observers, thereby improving the quality of the data. However, because the majority of oribi occur outside of protected areas, this approach should also be implemented in key areas where landowners are willing and interested in oribi conservation.

Finally, an alternative to the annual oribi census is to obtain data using large-scale camera grids. The rapid development and improvement of camera traps, as well as analytical frameworks to process data generated from cameras, makes them an important tool to inform conservation decision-making (Gilbert, Clare, Stenglein & Zuckerberg, 2021). For example, camera-trap data can be used to estimate the density and relative abundance indices of a given species even if individuals are unmarked (Palmer, Swanson, Kosmala, Arnold & Packer, 2018; Gilbert *et al*., 2021). Volunteers can identify oribi captured in images and selected images can be verified by experts, akin to Snapshot Serengeti (Swanson, Kosmala, Lintott & Packer, 2016). Such camera grids can be used at key sites, mentioned above, to validate the data obtained from the citizen-led oribi census to further improve data quality.

Ultimately, the oribi census raises awareness and helps inform oribi management and conservation. Despite the limitation of the current census, data obtained from the census has resulted in important research that has benefitted oribi conservation (see Stears & Shrader, 2015; Manqele, Selier, Hill & Downs, 2018; Stears & Shrader, 2020; Louw *et al*., 2021). To fully take advantage of the potential of citizen-science, the solutions provided above can be used to refine data collection techniques with the goal of providing high-quality data in support of furthering public education, resource management, and conservation monitoring.

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**Supplementary material to:**

Tamanna Patel, Keenan Stears, Ian T. Little & Adrian M. Shrader

Assessing the performance of oribi antelope populations at multiple scales: the limitations of citizen-led oribi conservation

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## Supplementary material

## Assessing the performance of oribi antelope populations at multiple scales: the limitations of citizen-led oribi conservation

Tamanna Patel, Keenan Stears, Ian T. Little, Adrian M. Shrader

## Appendix 1: Oribi census form

**ORIBI SURVEY FORM**

**Threatened Grassland Species Programme**
**2014 ANNUAL ORIBI SURVEY**
Endangered Wildlife Trust

The Annual Oribi survey helps the Oribi Working Group make informed decisions about the conservation of the species. Please fill in this user-friendly survey during September every year

**Oribi Survey Information – please count Oribi anytime on your property between 1 and 30 of September 2014**

| | | | |
|---|---|---|---|
| Date Oribi counted: | | No. of Male Oribi | |
| No. of Oribi counted (total): | | No. of Female Oribi | |
| No. of groups counted: | | No. of Juvenile | |

Is your Oribi population (please circle): Stable Increasing Decreasing Not Sure

Are your Oribi under threat? YES NO

What factors are affecting your Oribi population?
Habitat loss – agriculture ☐ Habitat loss – afforestation ☐ Snaring ☐
Illegal shooting ☐ Organized dog hunting ☐ Stray dogs ☐
If other, please specify: ______________________________

**Contact details -**

| | | | |
|---|---|---|---|
| Owners name: | | | |
| Owners telephone: | | Cell phone: | |
| Owners email address: | | | |
| Owners postal address: | | Code: | |

**Property details -**

| | |
|---|---|
| Property name: | |
| Magisterial district: | |
| Province | |
| Main farming activity/s | |

Join the fight against hunting with dogs
**SA CAN: Why as landowner you need SA CAN and their Family?**
BECOME AN SA CAN MEMBER – FREE LIFETIME MEMBERSHIP
SA CAN has launched the first National Community 911 Incident Management Center (IMC) in the country. Comparable to the USA's 911, SA CAN's IMC links to 84 safety and security organizations, including the police, medical emergency services, fire & rescue services, private security and many more. One telephone number, or the push of a speed dial button on your cell phone, is what gains you access to this network of emergency help 24/7. SA CAN Halo Aviation ER24 has the only private Aeromedical Helicopter in KZN which is based at PMB. SA CAN IMC has joined hands with EWT, supported by KZN wildlife and has sponsored 637 Wildlife Officers across KZN. Jointly we are trying to unite SAPS, Wildlife Officers and Landowners into one centralised emergency and concerns communication hub. Whilst the focus is on illegal dog hunting, SA CAN has many others benefits for you the landowner. Given that it costs you nothing; can you afford not to join?
CLICK HERE TO REGISTER

Please return information to: jibam@ewt.org.za
PO Box 1312 Howick 3290
**For more information : 033 330 6982/ 0825706977**

**Please pass on this survey form to your neighbours and advise if you need communication with your labourers/community on illegal hunting with dogs.**

**Appendix 2: Additional Questions for Landowners**

1. Are the historical numbers indicated for your farm correct? Are there any missing years that you could fill in?
2. What is the size of your farm? Estimate in hectares (ha)
3. Has farm size increased/decreased over the years – if so, why?
4. What is the amount of suitable grassland habitat (a mosaic of long and short grass) for oribi? Estimate in hectares (ha)
    - How is your farm divided? Give proportions of grassland, rye grass, sugarcane, forestry, etc?
    - Do oribi use these habitats?
5. What type of farm is it? – dairy, beef, conservation, etc
6. What are the main threats to your oribi population?
7. What is your burning regime? Do you burn annually, every second year? Do you have fire breaks? Do you mow?
8. Do you have other grazers? If so, what species?
9. What type of grazing do you have? – continuous/rotational
10. What are your stocking rates? Has it increased/decreased over the years?
11. What type of fencing do you have? Are oribi able to move in and out of your farm?
12. What is the average rainfall per year? What is your winter rainfall? Is frost a problem?

Other comments

**Table S1**: Results of the model selection procedure to assess which model best predicts oribi population performance.

| Model | AICc | ΔAICc | Model likelihood | AICc weight | Log likelihood |
|---|---|---|---|---|---|
| **Oribi density** | **47.256** | **0** | **1** | **0.423** | **-19.961** |
| Oribi density + rainfall | 48.961 | 1.705 | 0.426 | 0.180 | -19.304 |
| Oribi density x grazing policy | 49.333 | 2.077 | 0.354 | 0.150 | -17.791 |
| Oribi density + grazing policy | 49.885 | 2.629 | 0.269 | 0.114 | -19.766 |
| Oribi density x grazing policy + rainfall | 51.67 | 4.414 | 0.110 | 0.047 | -17.035 |
| Oribi density + grazing policy + rainfall | 51.764 | 4.508 | 0.105 | 0.044 | -19.007 |
| Rainfall | 52.719 | 5.464 | 0.065 | 0.028 | -22.693 |
| Grazing policy | 55.222 | 7.966 | 0.019 | 0.008 | -23.944 |
| Grazing policy + rainfall | 55.735 | 8.479 | 0.014 | 0.006 | -22.691 |
| Oribi density x grazing policy x rainfall | 64.063 | 16.807 | 0 | 0 | -15.531 |