

LETTER

Private rhino conservation: Diverse strategies adopted in response to the poaching crisis

 Hayley S. Clements¹  | Mike Knight^{2,3}  | Pelham Jones⁴ | Dave Balfour³ 

¹ Centre for Complex Systems in Transition, Stellenbosch University, Stellenbosch, South Africa

² WWF in Namibia, Windhoek, Namibia

³ Centre for African Conservation Ecology, Zoology Department, Nelson Mandela University, Port Elizabeth, South Africa

⁴ Private Rhino Owners Association, Muldersdrift, South Africa

Correspondence

Hayley S. Clements, Centre for Complex Systems in Transition, Stellenbosch University, 19 Jonkershoek Road, Stellenbosch 7600, South Africa.

Email: clementshayley@gmail.com.

Funding information

Jennifer Ward Oppenheimer Research Grant; Department of Environmental Affairs, South Africa; Claude Leon Foundation

Abstract

Private landowners in South Africa conserve roughly 40% of white rhinos globally. Given concerns that escalating poaching has caused private-rhino owners to disinvest, we used a national survey to assess 171 private-rhino owners' responses to the crisis. Twenty-eight percent of rhino owners are disinvesting in rhino, 57% are pursuing business-as-usual (largely ecotourism), and 15% are investing in more rhinos. It is currently unclear whether this diversity in private-rhino owners' responses to the crisis is increasing the resilience of the rhino population to poaching. Some rhino investors show signs of financial stress. Most owners support rhino-horn trade to fund conservation, yet international trade remains banned. By contrast, a recent national policy amendment allows rhinos to be managed as livestock, risking a shift from rhino-for-conservation to rhino-for-production on private land. Our findings highlight an urgent need to ensure policies keep pace with dynamic socioeconomic environments that influence the sustainability of wildlife use.

KEYWORDS

poaching, private land conservation, response diversity, rhino horn, South Africa, sustainable use, white rhino, wildlife trade

1 | INTRODUCTION

The supply of lucrative illegal markets with horn through rhino poaching is a high-profile conservation crisis. The rate of poaching of southern Africa's white rhino *Ceratotherium simum* in core populations is close to the species' annual growth rate, with scientists warning of possible extinction of rhino in the wild within decades (Biggs, Courchamp, Martin, & Possingham, 2013; Di Minin et al., 2015; Ferreira et al., 2015). These predictions, together with increasing rhino security costs, have led to calls for an international legal trade in rhino horn, which is currently

prohibited by the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). Proponents argue that nonlethal, sustainable harvesting of horn from live rhinos would shift market control into legal channels; with a steady supply of legal horn substantially reducing the illegal market and generating conservation revenues (Biggs et al., 2013; Child, 2012; Di Minin et al., 2015). Others argue that, given the uncertain effects of legal trade on consumer demand, rhino horn prices, and transaction costs in supply chains, competition from illegal traders would undermine legal trade and worsen poaching of vulnerable populations (Bulte & Damania,

This is an open access article under the terms of the [Creative Commons Attribution](https://creativecommons.org/licenses/by/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2020 The Authors. *Conservation Letters* published by Wiley Periodicals, Inc.

2005; Collins, Fraser, & Snowball, 2013; Fischer, 2004). The conservation success of a legal trade approach has been argued to depend on the existence of appropriate institutional arrangements (Collins, Fraser, & Snowball, 2016).

South Africa conserves about 86% of the world's estimated 18,000 white rhinos (Emslie et al., 2019). The country's success in conserving rhinos has been partially due to its inclusion of private landowners in rhino ownership since the 1960s (Linklater & Shrader, 2017). The opportunity to (a) purchase white rhinos from their last remaining population in Hluhluwe-iMfolozi Park (and more recently from other national parks and reserves) and (b) offer limited trophy hunting at high prices (averaging 90 individuals/year since 2004; Online Appendix 1), incentivized private landowners to conserve and trade rhinos (Cooney et al., 2017; 't Sas-Rolfes, 1995). Private landowners own a growing percentage of South Africa's white rhinos, which is approaching 50% (Online Appendix 2; Emslie et al., 2019). There are increasing concerns, however, that the financial benefits from rhino ecotourism, trophy hunting, and live sales are becoming insufficient to offset increased security costs and financial risks arising from rhino poaching, reducing the live-rhino trade value (Online Appendix 3) and causing private-rhino owners to opt out (Emslie et al., 2019; Ferreira, Pfab, & Knight, 2014). It is argued by some that policy has not kept pace with the changing cost-benefit ratio (Child, 2012), and small-sample surveys of private-rhino owners document support for policy changes to legalize international horn trade (Rubino & Pienaar, 2018; Wright, Cundill, & Biggs, 2016). Despite these concerns, there has not been a nationwide assessment of trends in how private-rhino owners are responding to the poaching crisis, amidst uncertainty regarding trade legalization.

Private landowner involvement in conservation in South Africa comes with diverse motivations and management strategies (Child, Peel, Smit, & Sutherland, 2013; Clements & Cumming, 2017; Rubino & Pienaar, 2018). Ecological theory suggests that there is a generally positive relationship between the diversity of elements in a system and system resilience. In more diverse ecosystems, it is less likely that disturbance that causes species losses will cause the loss of entire ecosystem functions, due to diversity in species' responses to the disturbance (Oliver et al., 2015; Tilman, 1999). Although this relationship is less well established in social-ecological systems, it is predicted that systems with diverse people and institutions (e.g.) may be more effective at responding to change because diversity gives rise to higher levels of innovation, adaptation, and resistance (Biggs et al., 2012; De Vos & Cumming, 2019; Leslie & McCabe, 2013). It could, therefore, be hypothesized that the involvement of private landowners in rhino conservation increases South Africa's resilience to the poaching cri-

sis (i.e., the country's capacity to conserve rhinos in the face of poaching). In addition to increasing the extent of rhino habitat and doubling the number of rhinos, if private landowner responses to the crisis are more diverse than on state land alone, they may increase the likelihood of at least one response strategy being effective in conserving rhinos. Although some owners may be disinvesting in rhinos due to growing financial burdens and risks, others may be better equipped to increase antipoaching security or move rhinos out of poaching hotspots.

Private-rhino owners have now had a decade to develop strategies in response to the escalation of poaching. This study makes use of the largest database of private-rhino owners to undertake the first nationwide, quantitative analysis of private-rhino owner responses to the poaching crisis, addressing a key knowledge gap. Three distinct responses by rhino owners emerge: disinvest, business-as-usual, and invest. We discuss the possible consequences and policy implications of this response diversity for rhino conservation going forward, considering rhino-owners' perspectives on legalizing horn trade.

2 | METHODS

Members of the South African Private Rhino Owners' Association (PROA) were surveyed in 2015 and 2018, adapting a previously developed protocol (Hall-Martin et al., 2008). The survey was distributed to 339 (2015) and 285 (2018) rhino owners via email. Participation in all questions was voluntary. Attempts were made to elicit responses from nonrespondents by telephone. The 2015 survey (Online Appendix 4) included questions on property size; involvement in rhino sales, hunting and ecotourism; rhino-security costs; and the number of rhinos and poaching incidents on the property. Owners were asked whether they supported legal-horn trade and intensive-rhino farming, and whether they would participate in these activities should horn trade be legalized.

Owners indicated on a categorical scale by what percentage their security costs had increased since the escalation of poaching in 2008, and what percentage of their rhinos they had sold and intended selling due to poaching risks, or moved to a safer site. They were asked whether they had sold land that once carried rhinos to nonrhino owners, how many hectares of land they had bought on which they have or plan to have rhinos, and how many rhinos they had released onto their property or sold from their property, from 2012 to 2014.

The 2018 survey was a shorter version of the 2015 survey. It omitted questions on the percentage of rhinos sold overall due to poaching risks, security cost increases since the

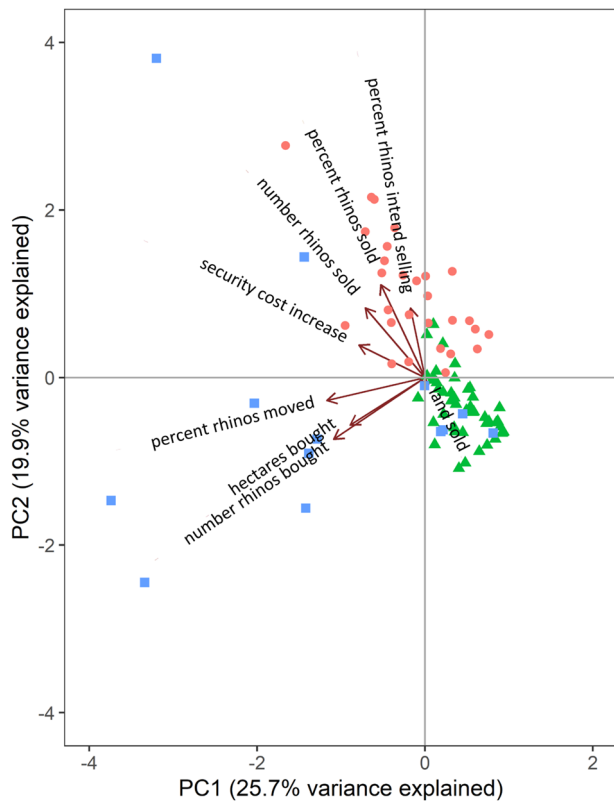


FIGURE 1 Biplot depicting the relative scores of eight response variables on the first two principal components (PCs), depicting rhino-owner responses to the poaching crisis. Data points indicate the scores of 99 rhino owners, with shapes corresponding to the three identified clusters (● Disinvestors; ▲ Business-as-usual; ■ Investors). High similarity in arrow direction indicates high positive correlation between corresponding variables, while high dissimilarity in arrow direction indicates high negative correlation between variables; perpendicular arrows represent unrelated variables

escalation of poaching, and owner support for intensive-rhino farming.

A principal component analysis was performed, followed by a cluster analysis, to investigate diversity in rhino-owners' responses to the poaching crisis, employing Euclidean distance and Ward linkages (R package: *vegan*; functions: *rda*, *vegdist*, *hclust*) (Oksanen et al., 2015; Ward, 1963). A Mantel-based comparison was used to determine the number of distinct clusters of owners (R package: *cluster*; functions: *daisy*, *silhouette*) (Maechler et al., 2015). Only respondents who completed all questions regarding their responses to poaching were included in the analysis. Responses of owners in each cluster were compared with Kruskal–Wallis H tests (continuous, nonnormal data) or Fisher's exact tests (count data). We then compared the average and aggregate characteristics of properties and owners in each distinct cluster.

The shorter 2018 survey prevented a thorough comparison with the 2015 survey responses. We compared the num-

ber of rhinos bought and sold, land area bought, and rhino-security costs (Kruskal–Wallis H tests), and the number of owners who intended selling rhinos due to poaching risks, participate in hunting, and support and would participate in legal-horn trade (Chi-square tests).

3 | RESULTS

Of the 171 responses to the 2015 survey, 132 landowners collectively owned 4,458 white rhinos across 1.3 million ha in 2014 (33.8 ± 8.7 rhino/property). An additional 18 respondents owned rhinos in 2012 or 2013 but no longer in 2014. A total of 345 rhinos were poached between 2012 and 2014 (2.7 ± 0.6 rhino/property; $2.9 \pm 0.6\%$ of rhinos/year). The 77 respondents to the follow-up survey collectively owned 4,226 rhinos in 2017 (54.9 ± 20.0 rhino/property), with 74 rhinos poached in 2017 (1.0 ± 0.4 rhino/property).

Three distinct clusters of owners emerged, based on their responses to poaching (Mantel $r = 0.53$, $n = 99$; Figure 1). The first cluster (28% of owners; Figure 1 “Disinvestors”) was characterized by owners who responded to the crisis by selling a percentage of their rhinos (Table 1), with a third of owners selling $> 67\%$ of their rhinos. Two thirds of owners intended selling more rhinos due to poaching risks. Two thirds of owners had increased their security costs by $> 67\%$, while few had moved rhinos to a safer location or purchased more land.

The largest cluster (57% of owners; Figure 1 “Business-as-usual”) tended to have neither sold rhinos (none selling $> 33\%$ of their rhinos) nor bought rhinos or land in response to the crisis, nor did they intend selling rhinos (Table 1). Only 4% of owners had moved rhinos, moving $< 33\%$ of their rhinos. A quarter of owners had not increased their security costs.

The smallest cluster (15% of owners; Figure 1 “Investors”) tended to have moved a percentage of their rhinos to an alternative safer site (Table 1), with a third of owners moving $> 67\%$ of their rhinos, usually within South Africa. No owners had sold $> 33\%$ of their rhinos in response to poaching risks. Many had purchased more rhinos and land. All owners had increased their security costs, with the majority increasing costs by $> 67\%$.

Investors owned the largest properties on average, while business-as-usual owned the smallest properties, though high variability meant the difference was not significant (Table 2). Business-as-usual collectively owned 40% of the land area supporting rhinos; disinvestors owned 36% of the land. On average, investors owned significantly more rhinos than the other clusters, owning 45% of all rhinos. Disinvestors owned 30% of all rhinos. Investors and disinvestors had higher rhino densities on their properties than business-as-usual. Investors had on average lost the most

TABLE 1 Responses of rhino owners in three distinct clusters to the poaching crisis

Responses	Disinvestors	Business-as-usual	Investors	Significance test
Proportion of owners who sold rhinos from 2012 to 2014 due to poaching risks	0.71	0.39	0.47	Fisher's $p < .001^*$
Average number of rhinos sold from 2012 to 2014	7.0 (± 1.6)	0.9 (± 0.2)	4.3 (± 1.7)	$H = 14.9, df = 2, p < .001^*$
Proportion of owners who intend selling rhinos due to poaching risks	0.68	0.13	0.20	Fisher's $p < .001^*$
Proportion of owners who moved rhinos to an alternative safer site	0.07	0.04	0.47	Fisher's $p < .001^*$
Average hectares bought from 2012 to 2014 on which the owner has/plans to have rhinos	137 (± 93)	216 (± 76)	6,015 (± 276)	$H = 16.8, df = 2, p < .001^*$
Average number of rhinos released onto property from 2012 to 2014	2.3 (± 0.9)	1.4 (± 0.4)	41.9 (± 22.0)	$H = 3.2, df = 2, p = .2$
Proportion of owners who increased their security costs by $>67\%$ since the escalation of poaching in 2008	0.68	0.38	0.93	Fisher's $p < .001^*$
Proportion of owners who had not increased security costs since 2008	0.07	0.23	0	Fisher's $p = .035^*$

*Significant.

TABLE 2 Summary statistics of the characteristics of rhino owners and properties in each response cluster

Characteristics	Disinvestors	Business-as-usual	Investors	Significance test
Average property size 2014 (ha)	14,223 ($\pm 4,256$)	8,109 ($\pm 1,494$)	17,317 ($\pm 6,191$)	$H = 3.9, df = 2, p = .1$
Total area 2014 (ha)	384,018	437,907	259,750	NA
Average number of rhinos 2014	38.7 (± 9.3)	16.3 (± 4.3)	109.9 (± 70.1)	$H = 8.2, df = 2, p = .016^*$
Total number of rhinos 2014	1,083	915	1649	NA
Average number of rhinos per 1,000 ha	33.1 (± 28.7)	5.2 (± 1.4)	16.7 (± 10.5)	$H = 3.6, df = 2, p = .2$
Average number of rhinos lost to poaching 2012–2014	1.2 (± 0.4)	1.6 (± 0.5)	4.8 (± 1.8)	$H = 3.7, df = 2, p = .2$
Total number of rhinos lost to poaching 2012–2014	34	89	72	NA
Average rhino security costs 2014 (ZAR1,000)	598 (± 262)	143 (± 39)	366 (± 248)	$H = 1.6, df = 2, p = .4$
Proportion of owners in support of hunting	0.85	0.49	0.93	Fisher's $p < .001^*$
Proportion of owners in support of horn trade	0.93	0.77	0.93	Fisher's $p = .1$
Proportion of owners in support of intensification	0.75	0.69	0.79	Fisher's $p = .7$
Proportion of owners who participate in hunting	0.30	0.13	0.33	Fisher's $p = .07$
Proportion of owners who would participate in horn trade	0.86	0.70	1.00	Fisher's $p = .02^*$
Proportion of owners who would participate in intensification	0.46	0.29	0.60	Fisher's $p = .045^*$

*Significant.

rhinos to poaching, but the business-as-usual cluster had the highest total number of rhinos poached.

Support for legal trophy hunting, horn trade, and intensive rhino farming was generally high among owners (Table 2). Horn trade received more support than hunting or intensive farming and was highest among investors and lowest among business-as-usual. More owners would participate in trade than intensification, with the highest participation among investors and lowest among business-as-usual.

Investors tended to generate a higher proportion of their revenue through rhino-trophy hunting than the other two clusters (Figure 2). Business-as-usual generated a higher proportion of revenue through rhino ecotourism and disinvestors were most dependent on live-rhino sales. Business-as-usual was the only cluster with owners located across all nine provinces (Figure 3). More than two thirds of disinvestors and investors were in three and two provinces, respectively.

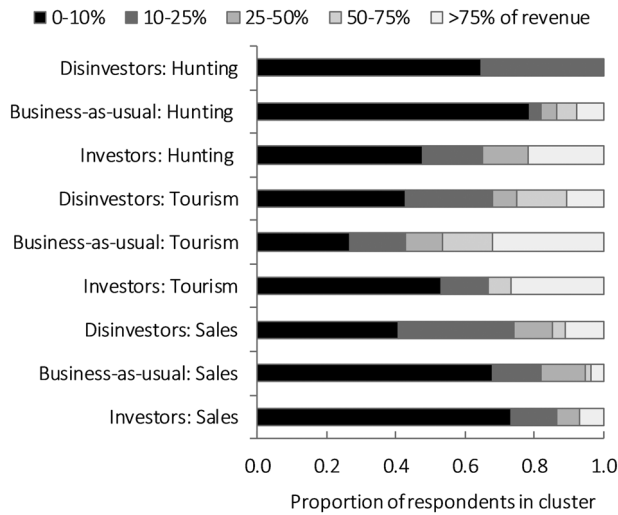


FIGURE 2 The proportion of respondents in each response cluster of private-rhino owners, who generated categorical percentages of property revenue from rhino hunting, ecotourism, and live sales, across the three clusters of private-rhino owners

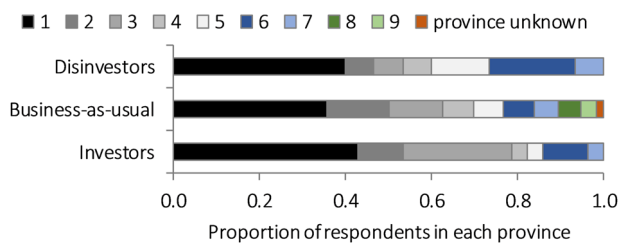


FIGURE 3 The proportion of respondents in each response cluster of private-rhino owners, whose properties were located in each of South Africa’s nine provinces. Provinces are kept anonymous to protect sensitive information on property locations

Trends in the responses of owners to the poaching crisis in the 2015 and 2018 surveys were largely similar (Table 3). Significant differences were only apparent in the increased average land area purchased and increased spending on rhino security.

4 | DISCUSSION

Response diversity was evident in the strategies adopted by private-rhino owners in the face of an escalating poaching crisis. Twenty-eight percent of owners in our sample, who collectively owned roughly a third of both the rhinos and the land (Table 3), were actively disinvesting in rhinos, supporting concerns that poaching will cause private-rhino owners to opt out (Emslie et al., 2019; Ferreira et al., 2014). By contrast, 15% of owners were purchasing land and rhinos in response to the poaching crisis. Although one rhino owner has gained media attention for this strategy (Stoddard, 2019), the extent of this response has not previously been documented.

Disinvestors increased their security costs and were selling rhinos, suggesting that they cannot afford rhino losses to poaching and the growing costs of mitigating this risk (>ZAR1.5 million/property on average in 2017). This finding supports predictions that if the financial costs of conserving rhinos on private land outweigh the financial benefits, landowners will disinvest (Child, 2012; Ferreira et al., 2014). The 75% drop in live-rhino auction price, coupled with the dramatic reduction in live-rhino sales in recent years (Online Appendix 3), is likely to be at least partly driven by this disinvestment in rhino, as well as further disincentivizing owners from keeping rhinos. Most disinvestors would participate in legal-horn trade, suggesting that such trade opportunities may curb disinvestment.

Investors, who owned 45% of all rhinos, had increased their rhino-security costs considerably and were buying rhino and land despite experiencing the most poaching incidents. Investors thus appear better-equipped financially than disinvestors to cope with the growing costs of owning rhino. Although these owners show resilience to poaching thus far, possibly benefitting from the reduced rhino prices and the supply from disinvestors, whether this strategy will result in resilient rhino conservation in the long term remains unknown. All owners in this category would participate in legal-horn trade, and some have

TABLE 3 Comparison of rhino-owner responses to surveys issued in 2015 (for year 2014) and 2018 (for year 2017)

Responses	2014	2017	Significance test
Average number of rhinos sold from the property that year	1.12 (±0.24)	2.28 (±0.57)	$H = 3.3, df = 1, p = .07$
Proportion of owners who intend selling rhinos due to poaching risks	0.32	0.37	$X^2 = 0.3, df = 1, p = .6$
Hectares bought that year on which the owner has or plans to have rhinos	481 (±295)	764 (±634)	$H = 44.6, df = 1, p < .001^*$
Average number of rhinos released onto property that year	2.72 (±1.16)	1.09 (±0.37)	$H = 0.2, df = 1, p = .7$
Average rhino security costs (ZAR1,000)	301.55 (±82.83)	1,558.70 (±458.35)	$H = 44.6, df = 1, p < .001^*$
Proportion of owners who participate in hunting	0.20	0.28	$X^2 = 1.0, df = 1, p = .3$
Proportion of owners in support of horn trade	0.84	0.80	$X^2 = 0.3, df = 1, p = .6$
Proportion of owners who would participate in horn trade	0.80	0.74	$X^2 = 0.6, df = 1, p = .4$

*Significant.

invested in rhinos in anticipation of horn-trade legalization (see, e.g., Stoddard, 2019; some landowners are understood to be banking on benefitting from legal sales of rhino horn at ~USD23,000/kg, P. Jones, personal communication). There is thus uncertainty regarding how long these owners can finance their investments should live-rhino prices continue to fall and horn trade remain illegal. The largest investor in rhino claims that he is approaching bankruptcy (Stoddard, 2019).

The final and largest group of rhino owners displayed limited changes to their activities in response to poaching. They tended to have low rhino densities and generate revenue from ecotourism. Although rhinos are popular among ecotourists (Hausmann et al., 2018), the revenue generated by ecotourism (compared with rhino sales and hunting) is not directly dependent on rhino numbers. Ecotourism properties may, therefore, be less sensitive to poaching and less inclined to invest heavily in security. Furthermore, the widespread distribution of business-as-usual properties (Figure 3) suggests that many fall outside of current poaching hotspots in the savanna biome near South Africa's north-eastern borders, where many investors and disinvestors are located.

Although the majority of private-rhino owners support horn trade, far fewer would farm rhinos to supply this trade. Those who would intensify tended to be investors and disinvestors, who already had higher rhino numbers and densities than the business-as-usual owners. These findings suggest that, while many private landowners believe that they would benefit from horn trade through its likely effect on the value of live rhinos (Ferreira et al., 2014) and through horn sales, the diversity of landowner business models would reduce the risk that all private-rhino properties become homogenized breeding grounds for intensively managed or "nonwild" rhinos. Interpretation of our results should, however, consider that rhino owners undertaking less acceptable or illegal activities, or those wishing to remain "below the radar," may have been less likely to respond to the survey, possibly biasing these findings.

At this stage, it is unclear whether the response diversity present among private-rhino owners will ultimately increase South Africa's resilience to the poaching crisis, with limited signs of change in either poaching rates or international trade regulations. What is apparent is that enabling private-rhino ownership has diversified conservation options. The primary strategy adopted by state-owned parks in response to poaching (in South Africa and continentally) has been to increase security and promote the growth of rhino populations (Balfour, Barichievy, Gordon, & Brett, 2019). The historic auctioning of rhinos from Hluhluwe-iMfolozi Park, and more recent translocation


of rhinos to private land outside poaching hotspots, represents an additional strategy to spread risk across many, smaller reserves that are potentially easier to secure (Linklater & Shrader, 2017). The former strategy is largely dependent on ongoing conservation funding, while the latter depends on the willingness of (and incentives to) private landowners to purchase rhinos (Ferreira et al., 2014). The combined conservation and financial motives and means of private-rhino owners (Rubino & Pienaar, 2018) enabled diversity in rhino conservation strategies. Although rhino numbers have been declining on state reserves, they were still increasing on private land as of 2017, depicting a growing reliance on private land for white-rhino conservation (Online Appendix 2; Emslie et al., 2019).

South Africa is currently at a crossroad. Regardless of whether private-rhino owners are already opting out, investing or continuing as usual, many are experiencing rising costs. The majority support legalizing international horn trade to equilibrate the cost-benefit ratio. Some owners emphasize the need for government to regulate the intensification that may arise if trade is legalized (Rubino, Pienaar, & Soto, 2018; Wright et al., 2016), given its uncertain consequences for the conservation of wild populations (Sanderson et al., 2008; Taylor et al., 2017). Seemingly contrary to this, the government recently gazetted a list of 33 wildlife species, including white and black rhino, which can now be treated as livestock under the Animal Improvement Act (Kamuti, 2019; Somers et al., 2020). This action risks shifting the focus of private-rhino ownership from rhinos-for-conservation to rhinos-for-production. In 2017, a tightly controlled, domestic rhino-horn trade was legalized in South Africa, but has yielded limited returns given the lack of an international market (Emslie et al., 2019). Our findings highlight the urgent need to (a) keep track of both state- and private-rhino populations and management strategies (which currently is not happening at an appropriate level), (b) track the potential conservation impact of the recent recognition of rhinos as livestock, and (c) adapt and align international and national policies to incentivize rhino conservation over rhino production or rhino disinvestment. These findings speak to a global need for the policies that determine how people and countries can manage and use their wildlife to keep pace with dynamic socioeconomic changes (e.g., increased illegal trade, changing market dynamics, an increasing antihunting lobby, local institutional contexts, and global economic shocks such as that caused by the SARS-CoV-2 pandemic), amidst criticism that international policies, such as CITES, are misaligned with national-level strategies for conserving wildlife (Abensperg-Traun, 2009; Challender, Harrop, & MacMillan, 2015; Frank & Wilcove, 2019).

ACKNOWLEDGMENTS AND DATA

The collection and collation of the PROA members data was undertaken by DB and supported by the Department of Environmental Affairs, South Africa (2015) and the IUCN (2018). HC was funded by a Claude Leon Postdoctoral Fellowship and a Jennifer Ward Oppenheimer Research Grant. Data can be requested from PROA (not open-access due to data sensitivity). Research was approved by Stellenbosch University Human Research Ethics Committee, reference 11333.

ORCID

Hayley S. Clements  <https://orcid.org/0000-0002-7015-6532>

Mike Knight  <https://orcid.org/0000-0001-6685-4269>

Dave Balfour  <https://orcid.org/0000-0002-4613-4069>

REFERENCES

- Abensperg-Traun, M. (2009). CITES, sustainable use of wild species and incentive-driven conservation in developing countries, with an emphasis on southern Africa. *Biological Conservation*, *142*, 948–963.
- Balfour, D., Barichiev, C., Gordon, C., & Brett, R. (2019). A theory of change to grow numbers of African rhino at a conservation site. *Conservation Science and Practice*, *1*, e40.
- Biggs, D., Courchamp, F., Martin, R., & Possingham, H. P. (2013). Legal trade of Africa's rhino horns. *Science*, *339*, 1038–1039.
- Biggs, R., Schlüter, M., Biggs, D., Bohensky, E. L., BurnSilver, S., Cundill, G., ... West, P. C. (2012). Toward principles for enhancing the resilience of ecosystem services. *Annual Review of Environment and Resources*, *37*, 421–448.
- Bulte, E. H., & Damania, R. (2005). An economic assessment of wildlife farming and conservation. *Conservation Biology*, *19*, 1222–1233.
- Challender, D. W. S., Harrop, S. R., & MacMillan, D. C. (2015). Understanding markets to conserve trade-threatened species in CITES. *Biological Conservation*, *187*, 249–259.
- Child, B. (2012). The sustainable use approach could save South Africa's rhinos. *South African Journal of Science*, *108*, 21–25.
- Child, M. F., Peel, M. J. S., Smit, I. P. J., & Sutherland, W. J. (2013). Quantifying the effects of diverse private protected area management systems on ecosystem properties in a savannah biome, South Africa. *Oryx*, *47*, 29–40.
- Clements, H. S., & Cumming, G. S. (2017). Positives and pathologies of natural resource management on private land conservation areas. *Conservation Biology*, *31*, 707–717.
- Collins, A., Fraser, G., & Snowball, J. (2013). Rhino poaching: Supply and demand uncertain. *Science*, *340*, 1167.
- Collins, A., Fraser, G., & Snowball, J. (2016). Issues and concerns in developing regulated markets for endangered species products: The case of rhinoceros horns. *Cambridge Journal of Economics*, *40*, 1669–1686.
- Cooney, R., Freese, C., Dublin, H., Roe, D., Mallon, D., Knight, M., ... Buyanaa, C. (2017). The baby and the bathwater: Trophy hunting, conservation and rural livelihoods. *Unasylva*, *68*, 3–16.
- De Vos, A., & Cumming, G. S. (2019). The contribution of land tenure diversity to the spatial resilience of protected area networks. *People and Nature*, *1*, 331–346.
- Di Minin, E., Laitila, J., Montesino-Pouzols, F., Leader-Williams, N., Slotow, R., Goodman, P. S., ... Moilanen, A. (2015). Identification of policies for a sustainable legal trade in rhinoceros horn based on population projection and socioeconomic models. *Conservation Biology*, *29*, 545–555.
- Emslie, R. H., Milliken, T., Talukdar, B., Burgess, G., Adcock, K., Balfour, D., & Knight, M. H. (2019). *African and Asian rhinoceroses – Status, conservation and trade*. A report from the IUCN Species Survival Commission (IUCN SSC) African and Asian Rhino Specialist Groups and TRAFFIC to the CITES Secretariat pursuant to Resolution Conf. 9.14 (Rev. CoP17). International Union for the Conservation of Nature, Gland. <https://cites.org/sites/default/files/eng/cop/18/doc/E-CoP18-083-01.pdf>
- Ferreira, S., Pfab, M., & Knight, M. (2014). Management strategies to curb rhino poaching: Alternative options using a cost-benefit approach. *South African Journal of Science*, *110*, 1–8.
- Ferreira, S. M., Greaver, C., Knight, G. A., Knight, M. H., Smit, I. P. J., & Pienaar, D. (2015). Disruption of rhino demography by poachers may lead to population declines in Kruger National Park, South Africa. *PLoS One*, *10*, e0127783.
- Fischer, C. (2004). The complex interactions of markets for endangered species products. *Journal of Environmental Economics and Management*, *48*, 926–953.
- Frank, E. G., & Wilcove, D. S. (2019). Long delays in banning trade in threatened species. *Science*, *363*, 686–688.
- Hall-Martin, A. J., Toit, J. G., Hitchins, P. M., & Knight, M. H. (2008). *An exert of the 2008 survey of white rhinoceros, Ceratotherium Simum, on private land in South Africa*. WWF-African Rhino Programme, 1–44.
- Hausmann, A., Toivonen, T., Slotow, R., Tenkanen, H., Moilanen, A., Heikinheimo, V., & Di Minin, E. (2018). Social media data can be used to understand tourists' preferences for nature-based experiences in protected areas. *Conservation Letters*, *11*, e12343.
- Kamuti, T. (2019). South Africa struggles to manage wildlife ranching: Why it's a problem. [WWW Document]. *The Conversation*. <https://theconversation.com/south-africa-struggles-to-manage-wildlife-ranching-why-its-a-problem-126439>
- Leslie, P., & McCabe, J. T. (2013). Response diversity and resilience in social-ecological systems. *Current Anthropology*, *54*, 114–143.
- Linklater, W. L., & Shrader, A. M. (2017). Rhino management challenges: Spatial and social ecology for habitat and population management. In J. P. Cromsigt, S. Archibald, & N. Owen-Smith (Eds.), *Conserving Africa's mega-diversity in the anthropocene. The Hluhluwe-iMfolozi Park Story* (pp. 265–285). Cambridge University Press.
- Maechler, M., Rousseeuw, P., Struyf, A., Hubert, M., Studer, M., & Roudier, P. (2015). *Package 'cluster'*.
- Oksanen, A. J., Blanchet, F. G., Kindt, R., Legendre, P., Minchin, P. R., Hara, R. B. O., ... Wagner, H. (2015). *Community Ecology Package: Vegan. Version 2.3-0*.
- Oliver, T. H., Heard, M. S., Isaac, N. J. B., Roy, D. B., Procter, D., Eigenbrod, F., ... Bullock, J. M. (2015). Biodiversity and resilience of ecosystem functions. *Trends in Ecology & Evolution*, *30*, 673–684.

- Rubino, E. C., & Pienaar, E. F. (2018). Understanding South African private landowner decisions to manage rhinoceroses. *Human Dimensions of Wildlife, 23*, 160–175.
- Rubino, E. C., Pienaar, E. F., & Soto, J. R. (2018). Structuring legal trade in rhino horn to incentivize the participation of South African private landowners. *Ecological Economics, 154*, 306–316.
- Sanderson, E. W., Redford, K. H., Weber, B., Aune, K., Baldes, D., Berger, J., ... Stephenson, B. (2008). The ecological future of the North American Bison: Conceiving long-term, large-scale conservation of wildlife. *Conservation Biology, 22*, 252–266.
- Somers, M. J., Walters, M., Measey, J., Maartin Strauss, W., Turner, A. A., Venter, J. A., ... Moodley, Y. (2020). The implications of the reclassification of South African wildlife species as farm animals. *South African Journal of Science, 116*, 1–2.
- Stoddard, E. (2019). Quo vadis South Africa's rhino rancher supreme? [WWW Document]. *Bus. Maverick*. <https://www.dailymaverick.co.za/article/2019-08-22-quo-vadis-south-africas-rhino-rancher-supreme/>
- 't Sas-Rolfes, M. (1995). *Rhinos: Conservation, economics and trade-offs*. London: IEA Environment Unit.
- Taylor, A., Balfour, D., Brebner, D. K., Coetzee, R., Davies-Mostert, H., Lindsey, P. A., ... 't Sas-Rolfes, M. (2017). Sustainable rhino horn production at the pointy end of the rhino horn trade debate. *Biological Conservation, 216*, 60–68.
- Tilman, D. (1999). The ecological consequences of changes in biodiversity: A search for general principles. *Ecology, 80*, 1455–1474.
- Ward, J. (1963). Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association, 58*, 236–244.
- Wright, O. T., Cundill, G., & Biggs, D. (2016). Stakeholder perceptions of legal trade in rhinoceros horn and implications for private reserve management in the Eastern Cape, South Africa. *Oryx, 52*, 175–185.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Clements HS, Knight M, Jones P, Balfour D. Private rhino conservation: Diverse strategies adopted in response to the poaching crisis. *Conservation Letters*. 2020;e12741. <https://doi.org/10.1111/conl.12741>