Biological Conservation 311 (2025) 111456

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Review

The present status of knowledge on the global use of rhinoceros dehorning: A systematic review

Lucy C. Chimes [a,b], Timothy Kuiper [c], Colleen T. Downs [a,*]

[a] Centre for Functional Biodiversity, School of Life Sciences, University of KwaZulu-Natal, Private Bag X01, Scottsville, Pietermaritzburg 3209, KwaZulu-Natal, South Africa
[b] Wildlife ACT Fund Trust, 25 Commaille Road, Melkbosstrand 7441, Western Cape, South Africa
[c] Department of Conservation Management, George Campus, Nelson Mandela University, George, Western Cape, South Africa

ARTICLE INFO

Keywords:
Rhinoceros
Dehorning
Anti-poaching
Legal wildlife trade
Wildlife management
Conservation intervention

ABSTRACT

Poaching remains a major threat to rhinoceros (hereafter rhino) species, particularly in southern Africa. In response, the use of dehorning (removing the horns of live rhinos) is increasing. We systematically reviewed 120 publications (44 % peer-reviewed) published prior to June 2024 to assess the present knowledge regarding rhino dehorning. The use of dehorning has increased across southern Africa, with no records of its use in eastern black rhinos or Asian rhino species, while the cost of dehorning per rhino and mortality rates associated with the dehorning procedure have decreased. The discussion of legal trade in relation to dehorning was the most common theme (56 %, n = 67), followed by biological/ecological impacts (24 %, n = 29) and anti-poaching effectiveness (23 %, n = 27). However, only 45 % and 37 % of the latter two themes were peer-reviewed, respectively, most of which only focused on one site and so were not generalisable to other areas. Publications discussing potential legal trade supplied through dehorning presented mixed views, with questions surrounding the potential conservation benefits of trade and the difficulty in predicting market responses. We found little evidence of any dehorning impacts on rhino reproduction, although there was some indication of changes to social structure and ranging behaviour, which warrant further investigation. The present peer- and non-peer-reviewed literature suggests dehorning is effective in reducing poaching on a site-specific scale. However, large-scale, peer-reviewed studies with robust counterfactual analyses, including on possible poaching displacement from dehorned to horned sites, are needed to inform global rhino conservation.

1. Introduction

Unsustainable harvesting of wildlife products for illegal trade is threatening wildlife populations globally (Scheffers et al., 2019). Illegal hunting (poaching) of rhinoceros (hereafter rhino) species (family Rhinocerotidae) to supply horns for Yemeni daggers – although this has declined in recent years – and Traditional Chinese Medicine has caused declines in all five extant species (Leader-Williams, 1992; UNODC, 2020). Between 1960 and 1995, poaching was initially widespread but later concentrated in Namibia, Zimbabwe and eSwatini ('t Sas-Rolfes et al., 2025), with black rhinos (*Diceros bicornis*) – the most abundant species at the time – declining by ~98 % (Emslie, 2020). Despite the 1977 international rhino horn trade ban (CITES, 1977), high poaching persisted until the mid-1990s before temporarily subsiding (Vigne et al., 2025). However, sustained demand for rhino horn in the Far East caused poaching to increase from 2008 and, despite a peak in 2015, is still ongoing at relatively high levels (Ferreira et al., 2022). Southern Africa, home to 84 % of the global rhino population in 2007 (including all five extant species), accounted for 97 % of global rhino poaching mortalities between 2013 and 2021 (Ferreira et al., 2022). This led to a 22 % decline in the white rhino (*Ceratotherium simum*) population, the most abundant species, between 2015 and 2021 (Ferreira et al., 2022). Despite this, southern Africa still accounted for 76 % of the global and 90 % of the African rhino population in 2021 (Ferreira et al., 2022).

In an attempt to reduce poaching, numerous conservation strategies and tactics have been implemented globally, including heightened security, intensive monitoring, demand-reduction campaigns, increased law enforcement, community engagement and development programmes and international policy changes (Cheteni, 2014; CITES, 1977; Ferreira et al., 2022; Kuiper et al., 2025). Despite these efforts, persistent

* Corresponding author.
E-mail addresses: lchimes@outlook.com (L.C. Chimes), timothykuiper@gmail.com (T. Kuiper), downs@ukzn.ac.za (C.T. Downs).

https://doi.org/10.1016/j.biocon.2025.111456
Received 11 February 2025; Received in revised form 7 May 2025; Accepted 20 August 2025
Available online 2 September 2025

poaching has caused many sites to adopt dehorning. This involves the controlled removal of most of a rhino's horns by trained individuals, reducing the mass and, therefore, financial value of the remaining horn. This aims to reduce the perceived "reward" (value of horn) to the poacher below a threshold whereby it is outweighed by the risk of being caught (Corné and Lemieux, 2014), thus reducing poaching incentive. Dehorning is used alongside other anti-poaching tools, such as security measures, as without these, the poacher may perceive the risk to be sufficiently low to still poach dehorned rhinos.

Between 1989 and 1995, dehorning was limited to Namibia, Zimbabwe and eSwatini (Lindsey and Taylor, 2011); however, since the surge in poaching since 2008, dehorning has become increasingly widespread (Ferreira et al., 2022). In 2010, South Africa's Department of Environmental Affairs commissioned a study to determine the viability of dehorning as an anti-poaching strategy (Lindsey and Taylor, 2011). The study was primarily based on dehorning experiences and observations in the 1990s, but there were not enough studies available for a systematic literature review. Since then, the use of dehorning has grown substantially, including in Kruger National Park (2019), Botswana (2020), and Hluhluwe-iMfolozi Park (2024) (Pfannerstill et al., 2023; SANParks, 2019; WWF, 2024). Therefore, field experience and knowledge have also increased, and the data generated has enabled new peer-reviewed research. Finally, there is growing advocacy from some stakeholders for the legalisation of international rhino horn trade, sourced through dehorning, natural mortalities and stockpiles, in an attempt to fund conservation efforts and security (CITES, 1992a,b,c, 1994, 1997a, 2016, 2019, 2022a; DFFE, 2021, 2024a; Ferreira et al., 2014; Rubino and Pienaar, 2020). An updated review of the rhino dehorning literature (including its relation to legal trade) is therefore warranted to inform decision-making.

To help contextualise our review, we developed a conceptual framework of the potential impacts and implications of dehorning based on the literature and field experience (Fig. 1). We used this framework to develop the questions that were addressed here.

2. Methods

2.1. Literature search

We conducted a comprehensive literature search following Pullin and Stewart's review protocol for conservation management (Pullin and Stewart, 2006). Searches were performed in Google Scholar®, Web of Science®, JSTOR® and Scopus® using the phrase "rhino* AND dehorn*" to identify dehorning-related literature published before 1st June 2024.

The Google Scholar® search returned 1040 unique results, while the same search through Publish or Perish (Harzing, 2007) – which ranks results based on relevance – provided 996. We used the Publish or Perish output because the least relevant results had no mention of rhinos or dehorning, making it unlikely that the additional publications found through Google Scholar® were relevant, and because of the ability to export results. The number of relevant publications asymptoted as results from Web of Science®, JSTOR® and Scopus® were added, with no new results found through the Scopus® search.

We conducted additional searches through Google Scholar® Publish or Perish – as this returned the highest number of relevant papers in the

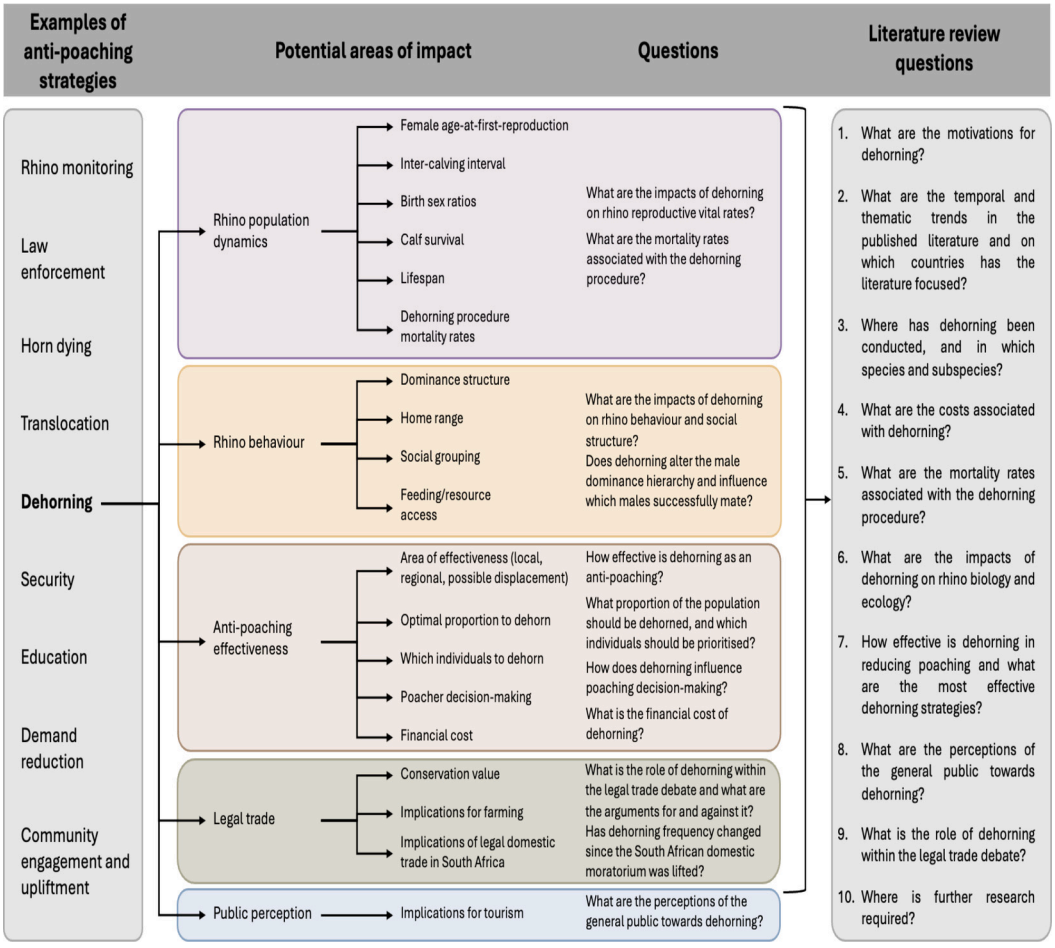

Fig. 1. The conceptual framework developed in this systematic literature review to summarise and highlight the potential implications of dehorning and the questions to be addressed here.

first search – for "rhino* AND horn* AND" with the following additional terms; "behaviour", "ecology", "reproduction" and "anti-poaching". Due to the growing advocacy for legal rhino horn trade sourced through dehorning, we also searched for "rhino* AND horn* AND trade* AND legal*". Twelve additional relevant publications were found, all through the legal trade search term.

We searched for "dehorn" in Rhino Resource Centre – an open-access database of rhino-related publications – to capture grey literature. Additionally, two reports, one peer-reviewed study, one webpage and eight CITES proposals were manually included. One of the reports has since been accepted for publication and so was classified as peer-reviewed (Kuiper et al., 2025). The draft "Biodiversity Management Plan for Black and White Rhinoceros in South Africa" was published on 18th June 2024 (DFFE, 2024a), and was included because of its relevance and having been released less than one month after the literature search cut-off date.

2.2. Selection criteria

We included peer-reviewed articles, reports, conference/workshop proceedings, books, web pages, theses (Master's or higher), comments and policies. To prevent duplication, workshop/conference proceedings and theses were only included if no formal publication was available. We excluded book reviews, letters, photographs and presentation slides.

We examined each publication's title, abstract and full text. We included literature concerning dehorning in any rhino species, but excluded publications which only used the term "dehorning" to describe illegal horn removal by poachers. Publications related to legal rhino horn trade were included only if they referred to horns sourced through dehorning. To increase reliability, we only included news reports or press releases if they announced a dehorning event, or were a summary of field observations published by specialists or those involved in the operation.

2.3. Data analyses

We categorised each publication by type, theme, country of focus, and species. During literature selection, the main topic(s) of each publication were identified. Similar topics were grouped into eight themes; (1) animal ethics and welfare, (2) anti-poaching effectiveness, (3) descriptions of anti-poaching tools, (4) dehorning announcement, (5) biological/ecological impacts of dehorning, (6) legal trade, (7) public perceptions, (8) other. We did not discuss reports of dehorning impacts on biology/ecology in Section 3.6 if they were duplicate reports of another study or only speculated on potential impacts. Biology/ecology publications were further classified under the following sub-themes: (1) behaviour, (2) calf survival, (3) cause of death, (4) horn regrowth, (5) lifespan, (6) reproduction, (7) stress. Publications on multiple themes, country of focus, or species were included in all relevant categories, giving variable sample sizes. The cost of dehorning per rhino was extracted from all relevant publications, converted to USD using the publication year's exchange rate, and adjusted for inflation to June 2024 values using the US Consumer Price Index.

We conducted all data manipulations, analyses and visualisations in RStudio Version 4.3.3 (R Core Team, 2024). Poisson regression analysis and Chi-Square tests were used to test for differences in the number, type, theme, country and species of study between the two major historical poaching waves (pre- and post-2008). Countries of focus with fewer than five publications were grouped as "other," and a Monte Carlo simulation (2000 iterations) was applied to account for small sample sizes.

3. Results and discussion

The literature search returned 1911 unique results, published between 1718 and 18 June 2024, with 120 publications (published between 1982 and 2024) meeting our inclusion criteria (Supplementary information Table S1). Of these, 44 % (n = 53) were peer-reviewed (46 original studies, seven reviews), while the rest included conference/workshop papers, news articles, reports, books, commentaries and policies. Although the majority of publications were not peer-reviewed, these mainly reported on the implementation of dehorning programmes or were reports authored by specialists, so we felt they should be included. We identified 79 results published after Lindsey and Taylor's (2011) review, including 39 peer-reviewed original studies, thus providing a substantial update.

3.1. What are the motivations for dehorning?

In all cases, dehorning was reportedly conducted to reduce rhino poaching incentive by decreasing the mass of horn on the rhino, aiming to reduce the "reward" (financial value of horn) sufficiently that it is outweighed by the risk to the poacher of being caught. However, although dehorning is generally used to gain a short-term relative advantage against poaching to provide time for other measures to be implemented and improved, it is increasingly being used as a long-term approach. While addressing the drivers of poaching – such as poverty in supply countries and demand in consumer countries – is a long process, the growing reliance on dehorning highlights failures so far in tackling these issues and the insufficiency of alternative strategies to reduce poaching to sustainable levels (~3.6 % annual poaching offtake in African rhinos) (Ferreira et al., 2022).

Presently, there is little financial incentive to use dehorning to produce horns for trade, as there is no known consumer market in South Africa despite domestic trade being legal (UNODC, 2024), and domestic trade in other rhino range states and international trade are both illegal. In recent years, the South African domestic rhino horn trade has increased following the establishment of a private organisation who are developing a sustainable, regulated and legal rhino horn trade model, aiming to provide financial benefits to rhino custodians to support conservation (pers. comm., Anonymous, April 2025). In an attempt to prevent an increase in dehorning frequency as a result of this, the project provides greater economic benefits for horns sourced through natural mortalities of horned rhinos than dehorning. We found no evidence in the literature reviewed here of sites dehorning for the purpose of stockpiling horns in anticipation of trade legalisation. Therefore, presently, the primary motivation for dehorning is to reduce the poaching incentive.

3.2. What are the temporal and thematic trends in the published literature, and on which countries has the literature focused?

The number, type, theme, species and country of focus of publications differed before and after 2008 (Fig. 2, Fig. 3). A Poisson regression revealed a significant increase in publications after 2008, from 35 to 85 (Poisson regression estimate = −0.887, $p < 0.01$). Chi-Square tests showed significant differences in the publication type ($\chi^2 = 36.1$, $p < 0.01$), theme ($\chi^2 = 28.1$, $p < 0.01$) and country of focus ($\chi^2 = 35.4$, $p < 0.01$), but not species ($\chi^2 = 3.54$, $p = 0.06$).

Publications before 2008 were mainly reports or conference/workshop documents based on field observations (54 %, n = 19), with a few peer-reviewed articles (20 %, n = 7). After 2008, literature types were more diverse, although the number of peer-reviewed publications increased to 46 (54 %).

Most publications were categorised under one theme (73 %, n = 87), with 25 % (n = 30) under two and 3 % (n = 3) under three. Anti-poaching effectiveness and biological/ecological impacts were most commonly associated, recorded together in 13 % (n = 15) of results. Discussion of legal trade related to dehorning was the most common theme (56 %, n = 67), including when publications found through the specific legal trade search term were excluded (51 %, n = 55). These publications were skewed towards later years, with 81 % (n = 54)

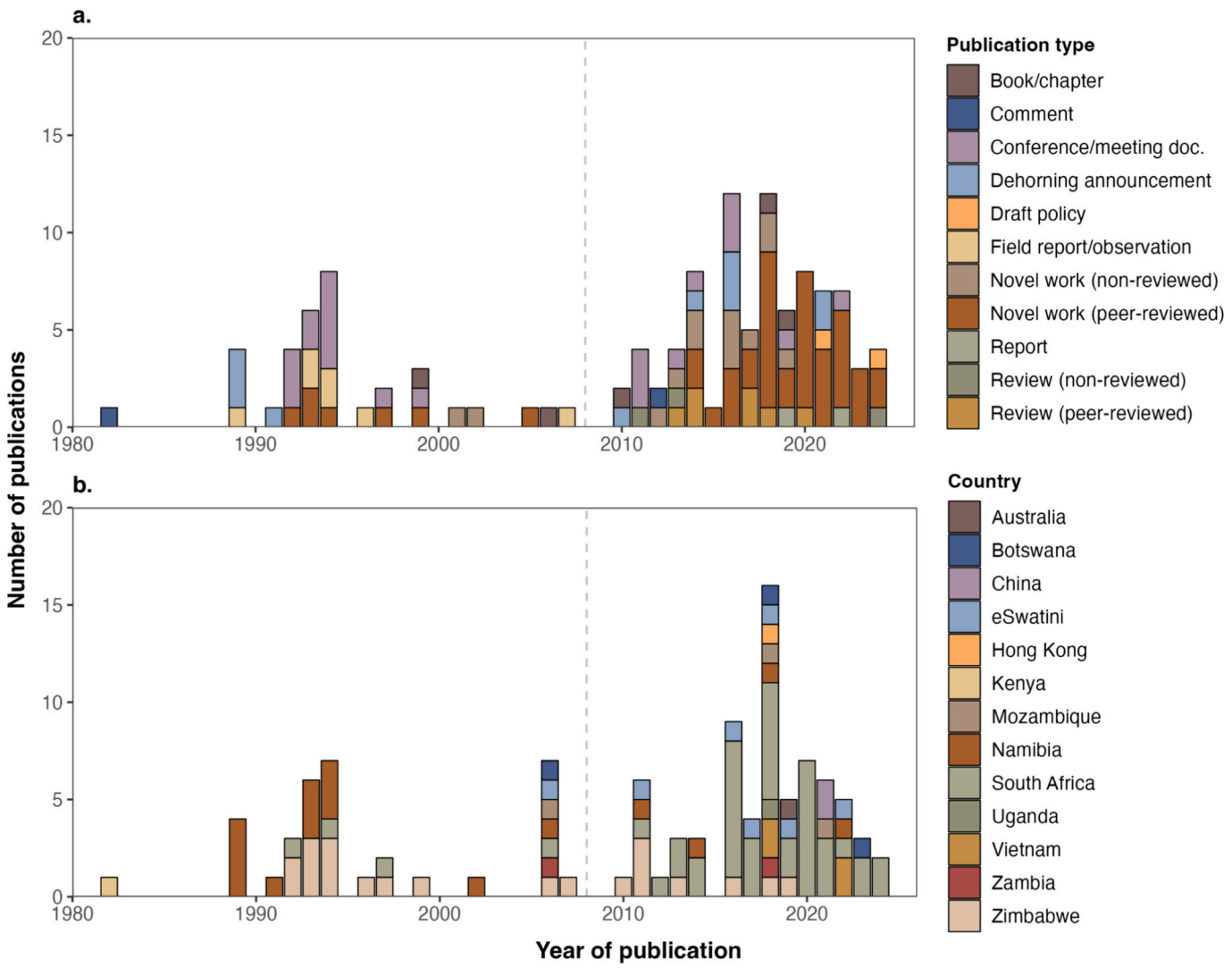

Fig. 2. Annual number of publications on rhino dehorning from 1982 to June 2024, grouped by a) publication type and b) country of study. (Note: Grey dashed line indicates 2008, when rhino poaching pressure began to increase substantially across southern Africa (Ferreira et al., 2022)).

published after 2008 (Fig. 3). Biology/ecology (24 %, n = 29) and anti-poaching effectiveness (23 %, n = 27) were the second and third most common themes, while all others accounted for less than 10 % of publications each. Theme changed significantly over time ($\chi^2 = 28.1$, $p < 0.01$), with pre-2008 publications focused on anti-poaching effectiveness (49 %, n = 17) and biology/ecology (43 %, n = 15), but 64 % (n = 54) of post-2008 publications discussed legal trade.

The country of focus was indicated in 91 publications (28 pre-2008, 63 post-2008), of which 41 % (n = 37) were peer-reviewed. Most publications that specified a country focused on southern Africa (89 %, n = 81), including 76 % (n = 28) of peer-reviewed papers (Fig. 2b). South Africa accounted for the largest proportion of both peer-reviewed (79 %, n = 22) and total (54 %, n = 44) southern African studies followed by Zimbabwe (26 %, n = 21) and Namibia (21 %, n = 17). Country changed significantly before and after 2008 ($\chi^2 = 35.4$, $p < 0.01$). Pre-2008 publications focused primarily on Namibia and Zimbabwe (46 %, n = 13 each), compared with South Africa (14 %, n = 4), however post-2008, South Africa became the primary focus (62 %, n = 39), followed by Zimbabwe (13 %, n = 8) and Namibia (6 %, n = 4). Of the peer-reviewed publications, nine were based outside of southern Africa, while all others were not specific to a particular country.

These temporal changes reflect the characteristics of the two historical periods of heightened poaching. Publications during the first poaching period (pre-2008) focused heavily on Namibia and Zimbabwe, as the countries facing the heaviest losses at the time (IUCN/SSC African Rhino Specialist Group, 1994) and addressed concerns regarding the biological/ecological impacts and anti-poaching effectiveness of dehorning. In contrast, the particularly heavy losses of white rhinos across southern, and particularly South, Africa after 2008 (Ferreira et al., 2022), combined with improvements in rhino capture efficiency, greater experience and availability of veterinarians and pilots able to conduct dehorning, and cost reductions (Section 3.4) likely contributed to an increase in dehorning, the number of publications and the focus of the literature on southern Africa and white rhinos during this period.

3.3. *Where has dehorning been conducted, and in which species and subspecies?*

The first documented dehorning occurred in Namibia in 1989 (Leader-Williams, 1989), followed by Zimbabwe and eSwatini (Lindsey and Taylor, 2011). Since 2008, with the increase in poaching across southern Africa, dehorning has become increasingly widespread, as documented in the literature in Botswana, eSwatini, Mozambique, Namibia, South Africa and Zimbabwe. ((Supplementary information Table S1).

Dehorning has primarily been used in black (*D. b. bicornis* and *D. b.*

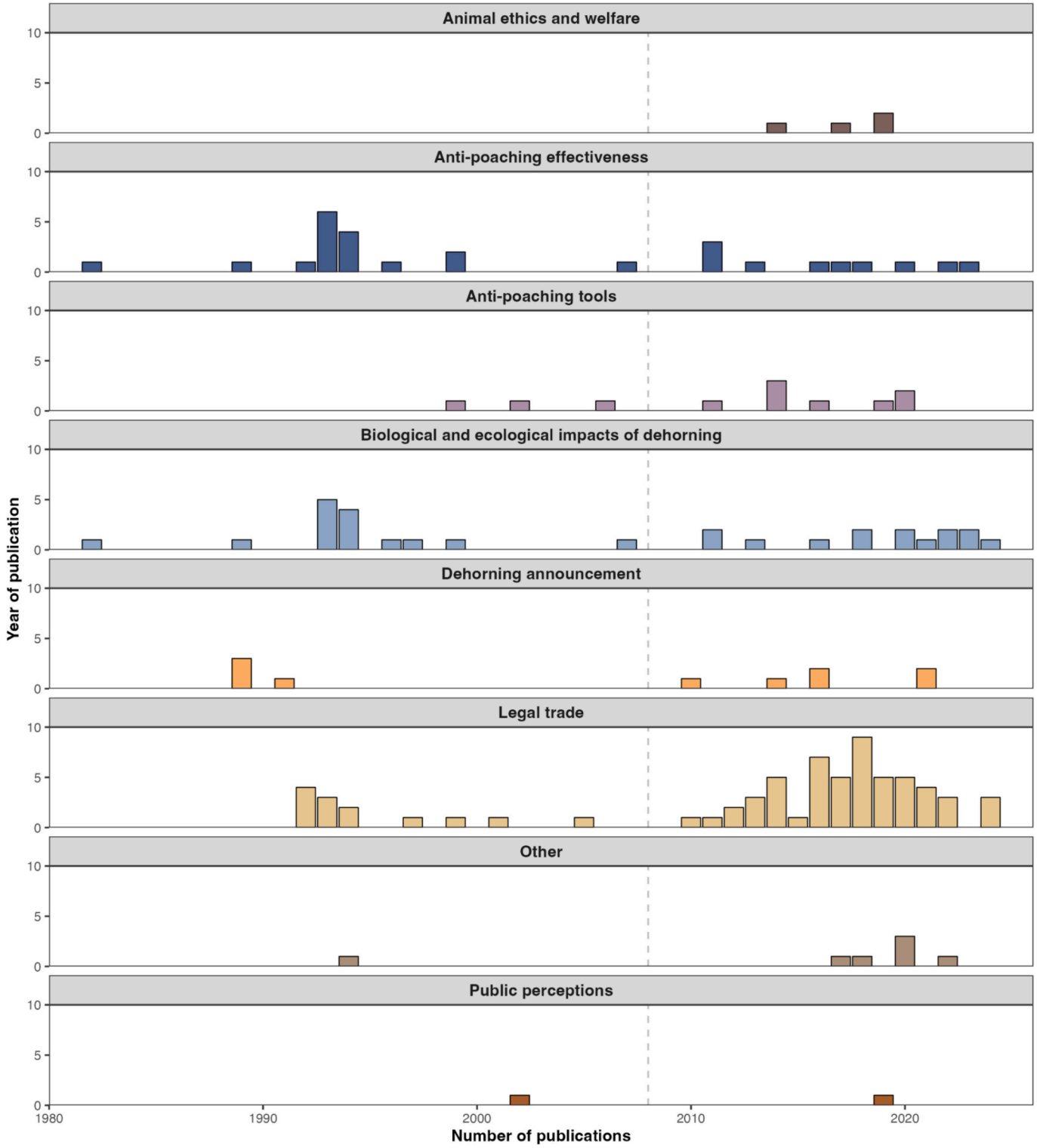

Fig. 3. Annual number of publications on rhino dehorning between 1982 and June 2024 grouped by theme. (Note: Grey dashed line indicates 2008, when rhino poaching pressure began to increase substantially across southern Africa (Ferreira et al., 2022). Y-axis scales match so that both trends and absolute changes in attention to each theme can be compared).

minor) and white rhinos, with no documented cases in eastern black rhinos (*D. b. michaeli*) or any of the Asian rhino species (*Rhinoceros unicornis, R. sondaicus* and *Dicerorhinus sumatrensis*). Outside southern Africa, dehorning was only reported in Uganda, in captive male white rhinos (Patton et al., 2018), and Kenya, in one small population (species unspecified) and the remaining captive northern white rhinos (*C. simum cottoni*) (Lindsey and Taylor, 2011). Despite a slight decrease in black rhino dehorning, total dehornings reported to the African Rhino Specialist Group increased from 285 in 2018 to 1038 in 2021 (Ferreira et al., 2022), although some may not have been reported, so this is likely an underestimate.

3.4. What are the costs associated with dehorning?

The 2024-adjusted dehorning cost per rhino has decreased from $2491–3892 in 1989, to $605–1113 in 2020 (Supplementary information Fig. S1), with costs dependent on the number of rhinos to be dehorned, rhino density and terrain difficulty (Lindsey and Taylor, 2011). Lindsey and Taylor also noted that the cost in 2011 could be as low as $125–250 ($178–357 at 2024-adjusted cost) if the rhino could be immobilised from the ground. As this is uncommon, and as all other reported costs included immobilisation from the air, this was not included in Supplementary information Fig. S1.

As the use of dehorning has increased, the cost per rhino has decreased, which may have contributed to greater use. Despite this, dehorning remains expensive, requires veterinarians and game-capture experts, and is labour-intensive, particularly because of the need to re-dehorn every 12–24 months (Atkinson, 1996; Morkel and Geldenhuys, 1993; Rachlow and Berger, 1997). For example, in 2024, the dehorning of over 1000 rhinos in Hluhluwe-iMfolozi Park took more than three months, and utilised substantial resources, including three helicopters, a fixed-wing plane, four ground teams, four pilots and four veterinarians (pers. comm., Dumisani Zwane, Ezemvelo KZN Wildlife, November 2024). Therefore, despite reduced costs, the substantial resources required make it critical that dehorning is an effective anti-poaching strategy to justify its use.

3.5. What are the mortality rates associated with the dehorning procedure?

The dehorning procedure requires the rhino to be chemically immobilised. Prior to its first use, Western (1982) predicted mortality rates of up to 10 % associated with the procedure. However, despite an initial white rhino immobilisation mortality rate of 7 % (n = 71) in the first phase of Zimbabwe's dehorning programme, adjustments to anaesthesia combinations reduced these to 3.3 % for white and 0.6 % for black rhinos (Kock and Atkinson, 1993). No immobilisation-related deaths were reported in Namibia during their dehorning of 30–40 black rhinos between 1989 and 1991 (Morkel and Geldenhuys, 1993).

Since Lindsey and Taylor's (2011) review, no publications have specifically addressed mortality rates related to the dehorning procedure. However, these low reported rates are reassuring, and they are likely to have further decreased as the use of dehorning has increased and techniques have improved. It would be valuable for more recent reports to be published on mortality rates, particularly to understand whether these differ from mortality rates during immobilisations for other purposes.

3.6. What are the impacts of dehorning on rhino biology and ecology?

The lack of dehorning in eastern black rhinos or the Asian rhino species, or dehorning studies in Northern white rhinos means potential biological/ecological impacts on these groups remain unknown. Southern white rhinos, and south-western and south-central black rhinos use their horns for various functions including fighting for dominance, calf protection, and feeding (Owen-Smith, 1971; Trendler, 2011) and have all been dehorned to some extent (Ferreira et al., 2022), making a strong understanding of the biological/ecological impacts essential. Of the 29 publications addressing this, 13 were peer-reviewed, of which 10 were published since Lindsey and Taylor's (2011) review. Five publications were either duplications of others or speculated on possible impacts, so they are not discussed here. No publications examined differences between black rhino subspecies. The reported impacts and knowledge gaps are summarised in Table 1 and detailed below.

3.6.1. Behaviour

Peer-reviewed studies reported no significant changes in feeding, resting, comfort or avoidance behaviours after dehorning in Botswana (Pfannerstill et al., 2023), or resource access in South Africa (Penny et al., 2021). Anecdotal evidence from Namibia and Zimbabwe similarly reported no behavioural changes, including no displacement of bulls from their home ranges (Atkinson, 1996; du Toit, 2011; du Toit and Anderson, 2013; Pinchin, 1993; Vigne, 1989). However, some peer-reviewed studies reported changes to social dynamics after dehorning. These included significant reductions in black rhino home ranges and social interactions (Duthé et al., 2023), changes to sub-adult white rhino social dominance structure (Penny et al., 2022), reduced fighting frequency in captive white rhino males (Patton et al., 2018) and sex-specific changes in white rhino locomotion and vocalisation (Pfannerstill et al., 2023). These findings are consistent with Berger and Cunningham's (1998) peer-reviewed study that found horn size was positively correlated with dominance in male black rhinos, suggesting that dehorning may affect rhino social dynamics. However, most of these studies were limited to a single site or sites with similar habitats and rhino densities, limiting the generalisability of these findings.

The lack of any studies documenting the frequency and outcomes of fights between dehorned and horned, or two dehorned non-captive rhinos, is a significant gap. For instance, if dehorned individuals are disadvantaged during intraspecific fights, this could affect male dominance hierarchy and thus the demographics of the male breeding population. Fights between two dehorned individuals might also last longer if neither has a horn, potentially increasing stress for longer periods. Additionally, no studies have reported whether dehorning affects diet, which is a particular concern for black rhinos as they use their horns for feeding (pers. comm., Vanessa Duthé, January 2025).

3.6.2. Calf survival

Despite initial concerns that dehorned female black rhinos were unable to defend their calves from predators (Berger et al., 1993), other publications have reported no significant or observed changes in calf survival following dehorning (Atkinson, 1996; Atkinson and Kock, 1999; Chimes et al., 2022). However, two were non-peer-reviewed field observations, and Chimes et al.'s (2022) peer-reviewed study only assessed four populations, without accounting for variables such as predator densities or rainfall. No publications addressed calf survival of dehorned white rhino mothers, highlighting the need for further research in both species.

3.6.3. Cause of death

Poaching-related deaths are discussed in Section 3.7. One peer-reviewed study reported no fighting-related deaths in dehorned black rhinos (n = 11) compared with 12 in horned individuals (n = 69) (Chimes et al., 2022). Another non-peer-reviewed publication documented only one fighting-related death from >100 dehorned rhinos, which was killed by another dehorned rhino during post-release fighting, so the confounding influence of the release means conclusions cannot be made regarding the role of dehorning here (du Toit and Anderson, 2007). Additionally, Duthé et al.'s (2023) peer-reviewed study reported a reduction in overall natural mortalities following the implementation of dehorning programmes, though the causes of this were not assessed.

While the lack of literature on the impacts of dehorning on the cause of death warrants further research, the possibility that dehorning may reduce fighting-related deaths, supported by Patton et al.'s (2018) findings that fighting frequency reduced post-dehorning, suggests potential unintended benefits for rhino population growth.

3.6.4. Horn regrowth

Lindsey and Taylor's review (2011) summarised horn regrowth rates for black and white rhinos. Black rhino anterior horns reportedly regrew at 6–8 cm p.a. (although up to 8.9 cm in sub-adults), and posterior horns at 2.7–5 cm p.a. (Berger et al., 1993; Morkel and Geldenhuys, 1993). White rhino anterior horns regrew at 6.7–7 cm p.a. and posterior at

Table 1
Biological/ecological impacts of dehorning on black and white rhinos, summarised from peer-reviewed studies (underlined) and other publications, and remaining knowledge gaps.

Sub-theme	Summary of reported impacts of dehorning		Remaining knowledge gaps
	Black rhinos	White rhinos	
Behaviour	● Significant reduction in home ranges and social interactions ● No observed change in behaviour or displacement of dehorned bulls from their home ranges	● Changes to social hierarchy, locomotion and vocalisation behaviours ● Reduction in fighting frequency in captive individuals ● No significant change in feeding, resting, comfort, avoidance or resource access ● Increase in horn rubbing behaviours ● No observed change in behaviour or displacement of dehorned bulls from their home ranges	● Is there an impact on: ● Diet? ● Feeding/foraging? ● Interactions with other species (e.g. elephants)? ● Fighting frequency and outcomes? ● Home range size in white rhinos? ● Home range location? ● Male dominance hierarchy and the demographics of the breeding males in the population? ● Is the increase in horn rubbing behaviours in white rhinos detrimental in any way? ● Is the change to home range and social interactions in black rhinos observed across all habitats? Does it vary with resource availability?
Calf survival	● No change in *D. b. bicornis* calf survival and no deaths from predation in calves of dehorned mothers ● Decreased calf survival ● Calf survival between 70 and 100%		● Is there an impact on calf survival in white rhinos? ● Are the reported findings on black rhino calf survival observed between different subspecies, habitat types, predator densities and rainfall years?
Cause of death	● Intraspecific fighting-related deaths were only reported in horned populations ● Reduction in the overall number of natural mortalities ● Only one dehorned individual injured or killed through fighting		● Is there an impact on cause of death in white rhinos? ● Are the changes to black rhino cause of death consistent across different subspecies, habitat types, predator densities and rainfall years? ● Why is there a reported reduction in natural mortalities in black rhino populations after dehorning programmes are implemented?
Horn regrowth	● Anterior horns regrow faster than posterior ● Average annual growth for anterior horn 5–8 cm ● Average annual growth for posterior horn 3–5 cm	● Rate of horn regrowth decreases with age ● Adult male horn regrowth is approximately twice that of females ● Anterior horns regrow faster than posterior ● Average annual anterior horn growth 6.7 cm ● Average annual posterior horn growth 2.9 cm ● Male horns regrow faster (2.36 ± 0.082 g/day) than females (1.74 ± 0.073 g/day) in captive individuals	● Does horn regrowth rate vary with resource availability or habitat condition? ● Does the horn regrow to the same shape? E.g. does the horn become wider? ● Does horn strength change?
Lifespan	● No significant difference in *D. b. bicornis* lifespan		● Is there an impact on: ● Lifespan? ● Are the results in black rhinos consistent across different subspecies, habitat types and with larger sample sizes and when considering only individuals who have lived their entire life within either a dehorned or horned population, with no overlap?
Reproductive vital rates	● No significant difference in *D. b. bicornis* inter-calving interval ● No evidence of impact on *D. b. bicornis* birth sex ratios in two sites ● Reduction in proportion of male *D. b. Bicornis* births from 100 % to 62.5 % in a reintroduced site	● Decrease in mean ICI ● Small decrease in average female age-at-first-reproduction (AFR)	● Is there an impact on AFR in black rhinos? ● Are these results consistent across different subspecies, habitat types and with larger sample sizes?
Stress	● Reduction in traumatic nasal damage from knocking horns off against the side of the crate during translocation	● No significant change in stress during translocation ● Significant short-term increase in stress but returns to baseline after approximately three days	● Is there an impact on stress levels during and after the dehorning procedure in black rhinos? ● Is elevated stress/feeling of vulnerability contributing to the reported reduction in home range sizes in black rhinos?

2.9–3.4 cm p.a. (Kock and Atkinson, 1993; Rachlow and Berger, 1997). Male white rhinos had faster horn regrowth than females, and regrowth rate decreased with age in both sexes (Rachlow and Berger, 1997). Since Lindsey and Taylor's (2011) review, only one publication has assessed horn regrowth, reporting that, in a game-ranched white rhino population, male horns regrew at an average of 2.36 ± 0.082 g/day, compared to females at 1.74 ± 0.073 g/day (Ververs, 2018).

3.6.5. Lifespan

Only one peer-reviewed study examined the impacts of dehorning on lifespan (Chimes et al., 2022), finding no significant relationship between dehorning and lifespan, with the mean lifespan being 7.38–13 years for horned, and 7.5–12.5 years for dehorned individuals. However, this study did not account for individuals dehorned later in life, where survival age was likely influenced by factors unrelated to dehorning.

To robustly analyse the relationship between dehorning and lifespan,

future studies should focus exclusively on individuals that have either been consistently dehorned throughout their lives, or have never been dehorned and have not lived in a population where dehorning is used.

3.6.6. Reproduction

Peer-reviewed studies reported that female white rhino inter-calving intervals (ICI) decreased after dehorning, although this was only measured in six individuals (Penny et al., 2020a), and that average white rhino female age-at-first-reproduction (AFR) was slightly lower in those dehorned before their first calf (7.30 and 7.12 years, n = 2) than those that were horned (8.30 and 7.22 years, n = 2) (Penny et al., 2020a). In another peer-reviewed study, the mean AFR for black rhinos ranged between 7.11 and 9.31 years; however, no post-dehorning information was available (Chimes et al., 2022).

One peer-reviewed and one non-peer-reviewed study, respectively, found no significant change in ICI between dehorned and horned black rhinos in Namibia and Zimbabwe (Chimes et al., 2022; du Toit, 2011). The mean ICI for horned and dehorned individuals was 2.75–3.41 years and 2.25–3.41 years in Namibia (Chimes et al., 2022) and 2.76 years and 2.6 years in Zimbabwe (du Toit, 2011), respectively. Mixed results were reported for black rhino birth sex ratios, with two populations showing no change after dehorning, and a third decreasing from 100 % to 62.5 % male births (Chimes et al., 2022). No publications were found on white rhino birth sex ratios.

While dehorning may still have potential detrimental impacts on reproductive parameters, if it decreases poaching mortalities to a level where populations grow despite this, dehorning might still be advantageous for rhino conservation. Therefore, future studies assessing dehorning's anti-poaching effectiveness should also consider the implications for population growth rates.

3.6.7. Stress

In white rhinos, peer-reviewed studies reported short-term increases in stress after dehorning, but with levels returning to baseline within 72 h (Badenhorst et al., 2016; Penny et al., 2020b). No significant changes in stress were detected during translocation post-dehorning (Metzinger et al., 2024).

For black rhinos, Duthé et al.'s (2023) peer-reviewed study reported significant reductions in home range sizes following dehorning, which they suggested was potentially because of an increased feeling of vulnerability. This could imply heightened long-term stress, although further evidence is needed to test this hypothesis. Only one publication (non-peer-reviewed) discussed stress linked to dehorning in black rhinos, noting the importance of dehorning before translocation to minimise the risk of injury and stress from knocking horns off against the inside of the transport crate (du Toit, 1994). Given the limited and mixed findings in both species, more research is necessary to better understand the short- and long-term effects of dehorning on stress, particularly in black rhinos.

The present literature provides limited evidence of detrimental effects of dehorning on rhino biology/ecology, giving some reassurance regarding its continued use. However, fewer than half of the publications were peer-reviewed, and many had small sample sizes, often limited to a single site, meaning these results should be interpreted cautiously and cannot be generalised across all populations. Moreover, substantial knowledge gaps still remain as outlined in Table 1.

The long generation time of rhinos presents challenges for biological research, as many years of data are required to observe meaningful effects post-dehorning. Additionally, environmental factors like habitat type, rainfall and rhino density significantly influence population dynamics (Dunham and du Toit, 2003), and other potential confounding factors, such as translocation and black rhino subspecies, must be considered.

In their 2011 review, Lindsey and Taylor emphasised the need for biological studies across multiple sites where dehorning has been used to varying extents and where detailed reproductive and mortality data are available. With 35 years having passed since dehorning was first used, and considering its widespread implementation across various habitats and subspecies and the growing availability of long-term monitoring data, this research should now be feasible.

3.7. How effective is dehorning in reducing poaching, and what are the most effective dehorning strategies?

The anti-poaching effectiveness of dehorning was addressed in 24 % (n = 27) of publications. However, only ten papers were peer-reviewed, eight of which used simulation modelling rather than empirical data. Challenges which may explain this include the need for long-term data before and after dehorning and the reluctance of custodians to share data because of poaching-related security concerns. Furthermore, all cases reported dehorning being used alongside other anti-poaching strategies, making it difficult to quantify its effectiveness. Findings on the anti-poaching effectiveness of dehorning are summarised in Table 2 and detailed below.

3.7.1. Overall effectiveness

The aim of dehorning is to reduce annual poaching mortality rates at least below the ~3.6 % threshold that still enables population growth (Ferreira et al., 2022), although preferably as low as possible. While several publications documented poaching of dehorned rhinos, these were typically small numbers or the rhinos had substantial horn regrowth (Chapman and White, 2020; Chimes et al., 2022; Dean, 2011; du Toit and Anderson, 2007; Duthé et al., 2023; Kuiper et al., 2025; Leader-Williams, 1993; Morkel and Geldenhuys, 1993). Some of these also occurred soon after dehorning programmes were first implemented, meaning poachers may have been unaware that dehorning had occurred, highlighting the need for media campaigns surrounding dehorning programmes.

One peer-reviewed study found that poachers did not discriminate between rhinos based on horn size, suggesting they may still target dehorned rhinos (Berger et al., 1993). However, several non-peer-reviewed publications reported reduced poaching of dehorned individuals (Atkinson, 1996; Atkinson and Kock, 1999; du Toit, 2011; du Toit and Anderson, 2007, 2013; Kock and Atkinson, 1993, 1994; Leader-Williams, 1993; Martin, 1994; Milliken and du Toit, 1994; Morkel and Geldenhuys, 1993; Vigne, 1989). For instance, in Zimbabwe over six years, dehorned rhinos had a lower mortality rate (~3.6 %) than horned individuals (~6 %) within the same population (du Toit and Anderson, 2013). In contrast, 95 % of Hwange National Park's white rhinos were poached in the 1990s (n ≈ 100), despite 90 % having been dehorned (Lindsey and Taylor, 2011). However, this was attributed to other factors, including reduced security, highlighting the importance of combining dehorning with other measures to maintain sufficient risk to outweigh the reward of a horn from a dehorned rhino.

While several publications reported reductions in poaching mortalities following dehorning, Kuiper et al. (2025) study was the only one to statistically assess dehorning's effectiveness using empirical data while accounting for other security measures. The study found that dehorning was the only strategy tested that showed strong statistical evidence for reducing poaching in the Greater Kruger, measured over varying time frames (2–4 years) at different sites. For instance, in Kruger National Park (KNP) – which accounted for 53 % of African rhino poaching mortalities between 2010 and 2019 – annual mortalities decreased from a peak of 827 in 2014 (SANParks, 2014; Save the Rhino, 2019; TRAFFIC, 2015, 2018), to 78 in 2023 (DFFE, 2024b), following the implementation of a dehorning programme in 2019.

Since 2020, as KNP's poaching mortalities declined, these increased in Namibia (IRF, 2023, 2024) and particularly in KwaZulu-Natal, rising from 93 in 2020 to 325 in 2023, with 95 % occurring in Hluhluwe-iMfolozi Park (HiP) in 2023 (DFFE, 2022, 2024b). Coordinated international rhino poaching trends have already been reported between South Africa and India (Lopes, 2019). Therefore, although we found no

Table 2
Anti-poaching effectiveness of dehorning summarised from peer-reviewed studies (underlined) and other publications, and remaining knowledge gaps.

Topic	Summary of present knowledge	Remaining knowledge gaps
Site-specific anti-poaching effectiveness	● Reductions in poaching of dehorned individuals ● Some reports of dehorned rhinos being poached ● Significant reduction in poaching linked to dehorning	● Is the significant reduction in poaching linked to dehorning also observed at other sites with different characteristics? ● Does the poaching rate of horned individuals also decrease proportionately with dehorned individuals within the same population? ● If poaching decreases, is this reduction sustained beyond the end of the dehorning operation (during which security may be higher with helicopters and planes flying more regularly looking for rhinos to dehorning, thus potentially temporarily increasing risk to poachers)?
Species-level anti-poaching effectiveness		● Does dehorning reduce poaching at a species-level? ● Does dehorning displace poaching to horned populations? ● Is dehorning a cost-effective anti-poaching strategy at a species-level?
Optimal proportion to dehorn	● Recommend dehorning at least 50 % of the population ● Ideally dehorn as much of the population as possible	● Is dehorning only a proportion of the population sufficient to reduce poaching sufficiently? ● Does selectively dehorning only a proportion of the population provide unfair advantages to some individuals and have detrimental impacts on: ● Behaviour (fighting, mating)? ● Genetic diversity (by altering the demographics of the male breeding population if some are horned and thus have higher chances of mating or many males are killed by poachers if only females are dehorned)? ● Do optimal proportions to dehorn vary by: ● Species? ● Site size? ● Rhino density? ● Proximity to other dehorned sites? ● Sex?
Optimal dehorning strategies		● What is the most effective dehorning strategy (e.g. mass dehorning, regular dehorning of a few individuals at a time as needed based on horn regrowth)? ● Does prioritising the dehorning of cows better contribute to population growth rates than dehorning both sexes? ● Is collaborative dehorning between neighbouring sites more effective than sites conducting their own independent programmes?

literature assessing whether poachers relocated to other sites following dehorning, this might explain the rise in HiP's poaching mortalities following KNP's dehorning, particularly as HiP was one of the largest horned rhino populations in southern Africa at the time. This raises significant concerns about the anti-poaching effectiveness of dehorning at a meta-population scale. This is particularly concerning as dehorning is an interim measure and must be effective across the meta-population to allow time for the underlying drivers of poaching to be addressed.

If poaching displacement from dehorned to horned sites does occur, dehorning might be adopted more widely, as highlighted by HiP's decision to begin dehorning in April 2024 (WWF, 2024). It is difficult to predict the potential implications if most sites were to implement dehorning programmes, particularly as no publications assessed how dehorning affects poacher decision-making. If poachers perceive the low reward of dehorned rhinos to be insufficient to justify the risk, poaching might be reduced across southern Africa. However, as it is unfeasible for all rhinos to be dehorned at any given time because of horn regrowth or because some sites might not want or be able to dehorn, this might still provide sufficient poaching incentive.

On balance, dehorning appears to be an effective anti-poaching strategy on a site-specific scale; however, the lack of knowledge regarding poacher decision-making and the long-term effectiveness as more sites implement dehorning programmes presents significant challenges when predicting its effectiveness at a species level.

3.7.2. Optimal dehorning strategies

Dehorning practices vary, including mass dehorning of the majority of the population in one operation, regular dehorning of a few individuals at a time, or selective dehorning of specific groups (Lindsey and Taylor, 2011; Patton et al., 2018; WWF, 2024). If dehorning a proportion of the population is a sufficient poaching deterrent, selective dehorning may be preferable, particularly if there are detrimental effects to some groups, such as female reproductive rates. With the exception of Kuiper et al. (2025), the publications reviewed here that reported reduced poaching post-dehorning did not address whether this reduction was extended to the entire population, including horned individuals, meaning the knowledge in this area is extremely limited. It is also possible that selective dehorning could provide an unfair advantage to some individuals, with potential negative implications such as in fighting and mating, highlighting the need for a robust understanding of the ecological and behavioural impacts of dehorning on different groups.

A survey of rhino specialists by Lindsey and Taylor (2011) found that 27.9 % of respondents felt the proportion to dehorn depended on the level of threat, rhino population size and security, although 90 % recommended dehorning the entire population. Other peer-reviewed studies using simulation modelling suggested dehorning at least 50 % of the population (Milner-Gulland, 1999) but ideally as many as possible (Milner-Gulland et al., 1992, 1993; Milner-Gulland, 1999). Kuiper et al.'s (2025) more recent study, similarly found that dehorning 100 % of the population reduced the annual poaching rate from ~8.3 % to ~2.0 % (average across five implementing reserves over 4.5 years), but that poaching rates only dropped below the 3.6 % threshold required for population growth (Ferreira et al., 2022) when >50 % of the population was dehorned. Conversely, another peer-reviewed study suggested that dehorning would only reduce poaching if the remaining horn value were almost zero (which is impossible without substantial rhino risks), or trade was legalised to fund security (Lee and Roberts, 2016).

None of these studies considered potential protection through dehorning at neighbouring sites or in other species. For instance, dense habitat and/or rugged terrain can make black rhinos in certain areas challenging to locate and dehorn, whereas white rhinos within the same population may be easier to dehorn because they live in more open areas (pers. obs.). The largely dehorned white rhinos might, therefore, indirectly provide some protection to the horned black rhinos. Similarly, white rhinos might be more vulnerable to poachers as they prefer more

open habitat, live in larger groups and are more docile (Owen-Smith, 1974), meaning a higher proportion may need to be dehorned than black rhinos. Dehorning of a large nearby population or a high proportion of sites in the area with dehorning programmes might also provide some protection. Additionally, protecting females may be more important than protecting males as they contribute more to population growth, so selectively dehorning females might be more beneficial to population growth rates. Although the available literature suggests dehorning as much of the population as possible, given the complexities outlined above, further research is needed to determine optimal dehorning strategies and proportions to dehorn, using empirical data and considering species-specific and site-specific factors.

3.8. What are the perceptions of the general public towards dehorning?

Wildlife tourism, of which rhinos are a major attraction, is vital to many African economies. Therefore, understanding public opinions on dehorning is important to avoid negatively impacting the country's or site's image. While some anecdotal complaints from tourists about dehorning were noted in the early 1990s, no studies have directly interviewed tourists to assess their views.

Two studies assessed public perceptions of dehorning and legal rhino horn trade among residents of non-rhino range states. A non-peer-reviewed UK-based study reported that 77 % of respondents supported dehorning as a conservation strategy (Swanson et al., 2002), while an Australian peer-reviewed study found increased support for legal trade, including horn supplied through dehorning, when information about poaching, dehorning and legal trade was provided (Brown et al., 2019), highlighting the importance of educating the public on conservation interventions. However, Brown et al. (2019) also found that individuals with stronger animal welfare values were significantly less supportive of legal trade. Some South African private rhino owners expressed concerns that dehorning interrupts trophy-hunting income, as hunters prefer horned rhinos, and that applying for dehorning permits could heighten poaching risks, as permitting offices might leak information to poachers (Claus, 2017; Rubino and Pienaar, 2018, 2020).

The evidence from the UK and Australia suggests that photographic tourists may accept dehorning programmes for conservation if they are informed about their purpose; however, the lack of studies directly interviewing tourists highlights the need for further research to explore these preferences and consider differences between tourist groups, e.g., international vs national, hunting vs photographic.

3.9. What is the role of dehorning within the legal trade debate?

International rhino horn trade was banned in 1977 (CITES, 1977); however, legal trade sourced through dehorning has been proposed numerous times since as a conservation strategy (CITES, 1992a,b,c, 1994, 1997a, 2016, 2019, 2022a). Therefore, while we do not aim to review the arguments for or against legal trade, we include this section to highlight its relevance to the present and future use of dehorning.

Dehorning related to the potential legal horn trade was the most common theme in our review (56 %, n = 67), including when results found using the specific legal trade search term were excluded (51 %, n = 55). Of these, 79 % (n = 53) focused on international trade, 10 % (n = 7) on domestic trade in consumer countries, 9 % (n = 6) on South African domestic trade and one that did not specify. Only 49 % (n = 33) of publications were peer-reviewed. However, the total number of publications has grown over time, with 81 % (n = 54) published since 2008 and 22 % (n = 15) since 2020, indicating increasing interest. Although the high prevalence of these publications in our results may have been biased by the search phrase "rhino* AND horn* AND trade* AND legal*", we felt their relevance justified their inclusion. This decision was reinforced after the publication of the Draft "Biodiversity Management Plan for Black Rhinoceros (*Diceros Bicornis*) and White Rhinoceros (*Ceratotherium simum*) in South Africa" in June 2024 (DFFE, 2024a) and the "South African Policy Position on the Conservation and Ecologically Sustainable Use of Elephant, Lion, Leopard and Rhinoceros", which was gazetted on 24 April 2024 (DFFE, 2024c), which outline South Africa's intentions to work towards the potential legalisation of international rhino horn trade, partly supplied through dehorning.

Legal trade was supported in 52 % (n = 35) of publications and opposed in 13 % (n = 9), while 18 % (n = 12) presented mixed views and 12 % (n = 8) gave no opinion. Support was higher in non-peer-reviewed (76 %, n = 26) than peer-reviewed publications (27 %, n = 9).

All publications supporting legal trade cited the potential generation of funding for rhino conservation and/or reduced poaching by providing a sustainable supply to meet demand. Of the peer-reviewed publications, two used economic modelling (Di Minin et al., 2015; Doyle et al., 2024), one used expert-based risk-benefit analysis (Ferreira et al., 2014), four interviewed private rhino owners (Chapman and White, 2020; Clements et al., 2020; Rubino and Pienaar, 2018, 2020), one developed a framework to assess animal welfare implications of trade (Derkley et al., 2019), and one was a review (Biggs et al., 2013). Despite the international trade ban, all of the CITES proposals highlighted that poaching has persisted, and in some cases worsened. However, despite seven out of these eight proposals being rejected and one withdrawn, South Africa's plans to potentially submit a new proposal (DFFE, 2024a,c), alongside the 33 other publications reviewed here that supported trade, indicate growing advocacy for international policy change. Despite this, voting at CITES meetings shows the opposite trend, with votes favouring legal rhino horn trade, including through dehorning, decreasing from 65 % in 1997 (CITES, 1997b) to 12 % in 2022 (CITES, 2022b).

Publications against trade (seven of nine of which were peer-reviewed) raised concerns about insufficient supply to meet demand, potential reductions in the stigma associated with using rhino horn leading to increased demand, ethics, that the remaining horn value would still provide poaching incentive, and that the high price of horn would need to be sustained to be economically viable to fund security which could sustain poaching (Aguayo, 2014; Collins et al., 2016, 2020; Crookes, 2017; Crookes and Blignaut, 2015; Eikelboom et al., 2020; Maas, 2016; Milner-Gulland, 1999; Murcott, 2017). Therefore, while advocacy from some for legal trade is growing, these publications highlight that there is also substantial opposition and uncertainty because of the lack of robust evidence regarding its conservation value.

Domestic rhino horn trade, including horns sourced through dehorning, is legal in South Africa. However, only six of the 64 publications discussing legal trade mentioned this, all discussing lifting the 2009–2015 trade moratorium. Despite nearly a decade since the moratorium was lifted, we found no reports on its impact on dehorning rates. The limited focus on domestic trade may be because South Africa has no known consumer demand for rhino horn (UNODC, 2024). However, in recent years, a private project has been established developing models for sustainable trade in rhino horn sourced through dehorning, natural mortalities and stockpiles, resulting in increased domestic trade in South Africa (pers. comm., Anonymous, April 2025). Close monitoring and evaluation of dehorning rates as this project progresses will be critical.

Animal ethics and welfare concerns regarding dehorning for legal rhino horn trade were directly addressed in four publications. Two non-peer-reviewed studies emphasised the importance of considering rhinos' inherent value when debating trade legalisation (Bowles, 2014; Scholtz, 2019), while Derkley et al.'s (2019) peer-reviewed paper concluded that legal trade, as the scenario most likely to reduce poaching, would be most beneficial to rhino welfare. In contrast, Murcott's (2017) peer-reviewed paper criticised the lack of welfare considerations during South Africa's domestic trade moratorium trial. One additional peer-reviewed paper found that individuals with stronger animal welfare values were significantly more likely to oppose trade (Brown et al., 2019).

Understanding consumer preferences for lethal (i.e. the rhino is killed to remove the horn) versus harvested (i.e. sourced through dehorning or natural mortalities) horn is an important consideration.

Peer-reviewed studies in Vietnam and Hong Kong revealed that consumers and Traditional Chinese Medicine practitioners felt there was no potency difference between lethal and harvested horns, and some reported a slight advantage for harvested horns (Cheung et al., 2018; Dang Vu et al., 2022; Dang Vu and Nielsen, 2018; Hanley et al., 2018). However, some consumers still preferred horn sourced from wild rather than farmed rhinos, believing it to be more potent, meaning legal trade in dehorned horns may not satisfy demand unless it is sourced from wild populations.

The ongoing debate surrounding legal trade remains complex, with uncertainty about market responses and the potential implications of these for rhino conservation. It is also important to consider that although some advocate trade as a conservation strategy, it is an opportunity that arises only if conservation has been successful enough for rhinos to persist in numbers sufficient to supply horns for trade (Taylor et al., 2017). Finally, it must also be highlighted that trade alone is unlikely to stop poaching, and instead, numerous strategies must be used to complement each other, particularly the disruption of criminal networks throughout the rhino horn trafficking chain, and providing economic opportunities for communities surrounding protected areas (Haas and Ferreira, 2016). Although this emphasises that there is no single conservation solution, the increasing advocacy for legalisation means it is essential to understand the implications through robust, peer-reviewed research to ensure that continued and potentially wider-scale dehorning is not detrimental to rhino conservation.

3.10. *Where is further research required?*

Our review showed that while the number of publications on dehorning has increased, substantial knowledge gaps remain, particularly in large-scale, peer-reviewed studies. This research is essential to guide conservation efforts, particularly with the growing advocacy for legal international rhino horn trade supplied through dehorning.

Based on these analyses and the questions identified in Fig. 1, we recommend that peer-reviewed research is needed in the following areas:

a. General:
   a. Surveys to understand motivations for dehorning (e.g. as an anti-poaching strategy or to stockpile horn for potential future legal trade)
b. Population dynamics:
   a. Large-scale, multi-site studies assessing the biological and ecological impacts of dehorning, including comparisons between subspecies and considering factors such as habitat, rainfall, rhino density, and other immobilisation events
c. Rhino behaviour:
   a. Large-scale studies assessing impacts on diet, home ranges and social dominance structure
   b. Observational studies on fighting events and outcomes
d. Anti-poaching effectiveness:
   a. Large-scale analyses of the effectiveness of different dehorning management strategies (e.g. optimal proportion to dehorn, frequency of dehorning, which individuals to prioritise) while considering variations in species and habitat types
   b. Studies on possible poaching displacement between dehorned and horned sites
   c. Interviews with poachers to understand risk-reward decision-making related to dehorning
e. Legal trade:
   a. Assessment of whether the legalisation of domestic rhino horn trade in South Africa affected dehorning frequency
f. Public perception:
   a. Social studies on public perceptions of dehorning, comparing differences between tourist groups.

Finally, despite the widespread use of dehorning, we found no evidence of collaborative dehorning between sites of different ownership. We therefore recommend that once the impacts of dehorning are better understood, collaborative dehorning management plans be developed to improve anti-poaching effectiveness.

4. Conclusions

Dehorning has become increasingly common in southern Africa. Yet, despite progress in understanding its implications, and limited evidence of negative biological or ecological impacts, substantial knowledge gaps remain, particularly regarding the most effective dehorning strategies and their biological/ecological consequences. While the present literature suggests that dehorning is effective on a site-specific scale, its benefits to rhino conservation globally remain unclear. Although there is a substantial lack of peer-reviewed literature on dehorning, the non-peer-reviewed publications included here provided important insights, particularly as many were published by specialists and experts, and so should be considered in decision-making. Further large-scale, peer-reviewed studies are needed, particularly when considering the growing possibility of legal international rhino horn trade sourced partially through dehorning.

Ultimately, dehorning is one of numerous rhino conservation strategies and tactics, and its continued use indicates a failure so far in resolving the underlying drivers of poaching and highlights the need for sustained and improved efforts to combat these to ensure that dehorned rhinos do not become the norm for future generations.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2025.111456.

CRediT authorship contribution statement

Lucy C. Chimes: Writing – original draft, Investigation, Methodology, Funding acquisition, Data curation, Formal analysis, Conceptualization. **Timothy Kuiper:** Supervision, Conceptualization, Writing – review & editing, Investigation. **Colleen T. Downs:** Supervision, Conceptualization, Funding acquisition, Writing – review & editing, Project administration.

Funding

This work was supported by Oppenheimer Memorial Trust (ZA, grant number 2024-4056); and Fossil Rim Wildlife Center, USA [donation]. We are grateful to the University of KwaZulu-Natal (ZA), and the National Research Foundation (ZA, grant 98404) for funding.

Declaration of competing interest

The authors declare no competing interests.

Acknowledgements

LC would also like to thank Wildlife ACT Fund Trust, Somkhanda Game Reserve and the Protected Area Management Company (PAMCo) for providing logistical support throughout this study. The authors would also like to acknowledge the incredible dedication and perseverance of all those working across the world in support of rhino conservation efforts. We are grateful to the reviewers whose constructive comments improved our manuscript.

Data availability

Data will be made available on request.

References

Aguayo, F., 2014. Assessing the risks of rhino horn trade. In: A Journal of Arguments Presented at the April 2014 Conference in South Africa. Presented at the OSCAP International Rhino Conference, International Rhino Coalition, Pretoria, South Africa.

Atkinson, M., 1996. Dehorning. IRF Spec. Feature.

Atkinson, M., Kock, M., 1999. Calf recruitment and survival in a population of black rhinoceros, *Diceros bicornis*, in Zimbabwe following immobilization and dehorning. In: Presented at the Proceedings of the Wildlife Disease Association Annual Conference, p. 84.

Badenhorst, M., Otto, M., van der Goot, A., Ganswindt, A., 2016. Stress steroid levels and the short-term impact of routine dehorning in female southern white rhinoceroses (*Ceratotherium simum simum*). Afr. Zool. 51, 211–215. https://doi.org/10.1080/15627020.2016.1261002.

Berger, J., Cunningham, C., 1998. Natural variation in horn size and social dominance and their importance to the conservation of black rhinoceros. Conserv. Biol. 12, 708–711. http://www.jstor.org/stable/2387253.

Berger, J., Cunningham, C., Gawuseb, A.A., Lindeque, M., 1993. "Costs" and short-term survivorship of hornless black rhinos. Conserv. Biol. 7, 920–924. https://doi.org/10.1046/j.1523-1739.1993.740920.x.

Biggs, D., Courchamp, F., Martin, R., Possingham, H.P., 2013. Legal trade of Africa's rhino horns. Science 339, 1038–1039.

Bowles, W., 2014. A Rights Perspective on the Global Trade in Rhino Horn (MSc Thesis). University of Johannesburg, Johannesburg.

Brown, A., Dean, A., Possingham, H., Biggs, D., 2019. The role of animal welfare values in the rhino horn trade debate. Conserv. Sci. Pract. 1. https://doi.org/10.1111/csp2.104.

Chapman, L., White, P., 2020. Anti-poaching strategies employed by private rhino owners in South Africa. Pachyderm 61, 179–183. https://doi.org/10.69649/pachyderm.v61i.9.

Cheteni, P., 2014. An analysis of anti-poaching techniques in Africa: a case of rhino poaching. Environ. Econ. 5, 63–70. https://mpra.ub.uni-muenchen.de/59031/.

Cheung, H., Mazerolle, L., Possingham, H., Biggs, D., 2018. Medicinal use and legalized trade of rhinoceros horn from the perspective of traditional Chinese medicine practitioners in Hong Kong. Trop. Conserv. Sci. 11. https://doi.org/10.1177/1940082918787428.

Chimes, L.C., Beytell, P., Muntifering, J.R., Kötting, B., Neville, V., 2022. Effects of dehorning on population productivity in four Namibia sub-populations of black rhinoceros (*Diceros bicornis bicornis*). Eur. J. Wildl. Res. 68, 58. https://doi.org/10.1007/s10344-022-01607-5.

CITES, 1977. Appendices to the Convention. Presented at the CITES 1st Meeting of the Conference of the Parties, CITES, Bern, Switzerland.

CITES, 1992a. Amendments to appendices I and II of the convention prop. 16. In: Presented at the CITES 8th Meeting of the Conference of the Parties, Kyoto, Japan.

CITES, 1992b. Amendments to appendices I and II of the convention prop. 17. In: Presented at the CITES 8th Meeting of the Conference of the Parties, Kyoto, Japan.

CITES, 1992c. Amendments to appendices I and II of the convention prop. 18. In: Presented at the CITES 8th Meeting of the Conference of the Parties, Kyoto, Japan.

CITES, 1994. Amendments to appendices I and II of the convention prop. 17. In: Presented at the CITES 9th Meeting of the Conference of the Parties, Fort Lauderdale, USA.

CITES, 1997a. Amendments to appendices I and II of the convention prop. 28. In: Presented at the CITES 10th Meeting of the Conference of the Parties, Harare, Zimbabwe.

CITES, 1997b. Summary report of the Committee I meeting. In: Presented at the CITES 10th Meeting of the Conference of the Parties, Harare, Zimbabwe.

CITES, 2016. Amendments to appendices I and II of the convention prop. 7. In: Presented at the CITES 17th Meeting of the Conference of the Parties, Johannesburg, South Africa.

CITES, 2019. Amendments to appendices I and II of the convention prop. 8. In: Presented at the CITES 18th Meeting of the Conference of the Parties, Geneva, Switzerland.

CITES, 2022a. Amendments to appendices I and II of the convention prop. 3. In: Presented at the CITES 19th Meeting of the Conference of the Parties, Panama City, Panama.

CITES, 2022b. Summary record of the tenth session for Committee I. In: Presented at the CITES 19th Meeting of the Conference of the Parties, Panama City, Panama.

Claus, J., 2017. Valuing the Rhino: Where Is their Worth? (MBA thesis) University of Cape Town, Cape Town.

Clements, H., Knight, M., Jones, P., Balfour, D., 2020. Private rhino conservation: diverse strategies adopted in response to the poaching crisis. Conserv. Lett. 13, e12741. https://doi.org/10.1111/conl.12741.

Collins, A., Fraser, G., Snowball, J., 2016. Issues and concerns in developing regulated markets for endangered species products: the case of rhinoceros horns. Camb. J. Econ. 40, 1669–1686. https://doi.org/10.1093/cje/bev076.

Collins, A., Cox, C., Marire, J., 2020. On the judicial annulment of the "domestic" trade moratorium in South African rhinoceros horn: a law and economics perspective. Eur. J. Law Econ. 49, 361–372. https://doi.org/10.1007/s10657-020-09648-4.

Corné, E., Lemieux, A., 2014. Rhino poaching in Kruger National Park, South Africa: aligning analysis, technology and prevention. In: Lemieux, A. (Ed.), Situational Prevention of Poaching. Routledge, London, England, pp. 18–43.

Crookes, D., 2017. Does a reduction in the price of rhino horn prevent poaching? J. Nat. Conserv. 39, 73–82. https://doi.org/10.1016/j.jnc.2017.07.008.

Crookes, D., Blignaut, J., 2015. Debunking the myth that a legal trade will solve the rhino horn crisis: a system dynamics model for market demand. J. Nat. Conserv. 28, 11–18. https://doi.org/10.1016/j.jnc.2015.08.001.

Dang Vu, H.N., Nielsen, M.R., 2018. Understanding utilitarian and hedonic values determining the demand for rhino horn in Vietnam. Hum. Dimens. Wildl. 23, 417–432. https://doi.org/10.1080/10871209.2018.1449038.

Dang Vu, H.N., Nielsen, M.R., Jacobsen, J.B., 2022. Conserving rhinos by legal trade: insights from a choice experiment with rhino horn consumers. Ecol. Econ. 193, 107287. https://doi.org/10.1016/j.ecolecon.2021.107287.

Dean, C., 2011. Back to the trenches: the bloody battle against rhino and elephant poaching. In: Presented at the International Elephant and Rhino Conservation and Research Symposium, Rotterdam, The Netherlands, pp. 65–125.

Derkley, T., Biggs, D., Holden, M., Phillips, C., 2019. A framework to evaluate animal welfare implications of policies on rhino horn trade. Biol. Conserv. 235, 236–249. https://doi.org/10.1016/j.biocon.2019.05.004.

DFFE, 2021. Draft Policy Position on the Conservation and Ecologically Sustainable Use of Elephant, Lion, Leopard and Rhinoceros.

DFFE, 2022. Rhino Poaching in South Africa in 2021 [WWW Document]. Dep. For. Fish. Environ. URL. https://www.dffe.gov.za/RhinoPoachinginSouthAfricain2021. (Accessed 21 August 2024).

DFFE, 2024a. Draft Biodiversity Management Plan for Black Rhinoceros (*Diceros Bicornis*) and White Rhinoceros (*Ceratotherium simum*) in South Africa, 50829.

DFFE, 2024b. KwaZulu-Natal Carried the Brunt of Rhino Poaching in 2023, Says Creecy [WWW Document]. Dept. Forest. Fish. Environ. URL. https://www.dffe.gov.za/mediareleases/creecy_relasesrhinopoachingstats2024feb27. (Accessed 5 June 2024).

DFFE, 2024c. Policy Position on the Conservation and Ecologically Sustainable Use of Elephant, Lion, Leopard and Rhinoceros, p. 50541.

Di Minin, E., Laitila, J., Montesino-Pouzols, F., Leader-Williams, N., Slotow, R., Goodman, P.S., Conway, A.J., Moilanen, A., 2015. Identification of policies for a sustainable legal trade in rhinoceros horn based on population projection and socioeconomic models. Conserv. Biol. 29, 545–555. https://doi.org/10.1111/cobi.12412.

Doyle, H., Champagne, K., Rajpal, D., Seebeck, G., Gerberry, D., 2024. A coupled model of population, poaching, and economic dynamics to assess rhino conservation through legal trade. Spora 10, 15–23. https://doi.org/10.61403/2473-5493.1088.

du Toit, R., 1994. Management of Black Rhino in Zimbabwean Conservancies. Presented at the Proceedings of a Symposium on Rhinos as Game Ranch Animals, Onderstepoort, Republic of South Africa.

du Toit, R., 2011. Zimbabwe Lowveld: Dehorning Experience. Presented at the Perspectives on Dehorning and Legalised Trade in Rhino Horn as Tools to Combat Rhino Poaching. Proceedings of a Workshop Assessing Legal Trade in Rhino Horn as a Tool in Combating Poaching As Well as a Detailed Assessment of the Efficacy of Dehorning as a Deterrent to Poaching. Endangered Wildlife Trust, Johannesburg, South Africa, p. 13.

du Toit, R., Anderson, N., 2007. Zimbabwe: dehorning rhinos in the Lowveld. In: The Horn Newsletter.

du Toit, R., Anderson, N., 2013. Dehorning Rhinos. Wildlife Ranching.

Dunham, K., du Toit, R., 2003. SADC RMG Black Rhino Carrying Capacity Model Version 1.0: A Review. SADC Regional Programme for Rhino Conservation.

Duthé, V., Odendaal, K., Van der Westhuizen, R., Church, B., Naylor, S., Boshoff, S., Venter, M., Prinsloo, M., Ngwenya, P., Hanekom, C., Kelly, C.P., Walker, T.W.N., Rasmann, S., Defossez, E., 2023. Reductions in home-range size and social interactions among dehorned black rhinoceroses (*Diceros bicornis*). Proc. Natl. Acad. Sci. 120, e2301727120. https://doi.org/10.1073/pnas.2301727120.

Eikelboom, J.A.J., Nuijten, R.J.M., Wang, Y.X.G., Schroder, B., Heitkönig, I.M.A., Mooij, W.M., Van Langevelde, F., Prins, H.H.T., 2020. Will legal international rhino horn trade save wild rhino populations? Glob. Ecol. Conserv. 23, e01145. https://doi.org/10.1016/j.gecco.2020.e01145.

Emslie, R., 2020. *Diceros bicornis* [WWW Document]. IUCN Red List Threat. Species. URL. https://www.iucnredlist.org/en. (Accessed 4 June 2024).

EWT, 2010. Frequently Asked Questions: Rhino Dehorning. Endangered Wildlife Trust's Rhino Security Project, Report. Afr. Indaba 14–16.

Ferreira, S., Pfab, M., Knight, M., 2014. Management strategies to curb rhino poaching: alternative options using a cost-benefit approach. S. Afr. J. Sci. 110, 1–8. https://doi.org/10.1590/sajs.2014/20120055.

Ferreira, S.M., Ellis, S., Burgess, G., Baruch-Mordo, S., Talukdar, B., Knight, M.H., 2022. African and Asian Rhinoceroses: Status, Conservation and Trade: Report From the IUCN Species Survival Commission (IUCN SSC) African and Asian Rhino Specialist Groups and TRAFFIC Commissioned by the Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Pursuant to Resolution Conf. 9.14 (Rev. CoP17). Presented at the CITES 19th Meeting of the Conference of the Parties, Panama City, Panama.

Geldenhuys, J., 1994. Dehorning Black Rhino: The Namibian Experience. Presented at the Proceedings of a Symposium on Rhinos as Game Ranch Animals, Onderstepoort, Republic of South Africa.

Haas, T.C., Ferreira, S.M., 2016. Combating rhino horn trafficking: the need to disrupt criminal networks. PLoS One 11, e0167040. https://doi.org/10.1371/journal.pone.0167040.

Hanley, N., Sheremet, O., Bozzola, M., MacMillan, D.C., 2018. The allure of the illegal: choice modeling of rhino horn demand in Vietnam. Conserv. Lett. 11, e12417. https://doi.org/10.1111/conl.12417.

Harzing, A., 2007. Publish or Perish. https://harzing.com/resources/publish-or-perish.

IRF, 2023. State of the Rhino. International Rhino Foundation.

IRF, 2024. State of the Rhino. International Rhino Foundation.

IUCN/SSC African Rhino Specialist Group, 1994. Conservation of Rhinoceros in Asia and Africa Doc. 9.35 Annex 1. Presented at the CITES 9th Meeting of the Conference of the Parties, CITES, Fort Lauderdale, USA.

Kock, M., Atkinson, M., 1993. Report on dehorning of black and white rhinoceroses in Zimbabwe. J. Wildl. Dis. 29, 10–11.
Kock, M., Atkinson, M., 1994. Dehorning of Black (*Diceros bicornis*) and White rhinoceros (*Ceratotherium simum*): The Zimbabwean Experience. Presented at the Proceedings of a Symposium on Rhinos as Game Ranch Animals, Onderstepoort, Republic of South Africa.
Kuiper, T., Haussmann, S., Whitfield, S., Polakow, D., Dreyer, C., Ferreira, S., Hofmeyr, M., Shaw, J., Bird, J., Bourn, M., Boyd, W., Greef, Z., Hartman, Z., Lester, K., Nowak, I., Olivier, I., Pierce, E., Rowles, C., Snelling, S., van Tonder, M., Worth, E., Zowitsky, H., Milner-Gulland, EJ., Altwegg, R., 2025. Dehorning reduces rhino poaching. Science 388 (6751), 1075–1081. https://doi.org/10.1126/science.ado7490.
Leader-Williams, N., 1989. Desert rhinos dehorned. Nature 340, 599–600. https://doi.org/10.1038/340599a0.
Leader-Williams, N., 1992. The World Trade in Rhino Horn: A Review. TRAFFIC.
Leader-Williams, N., 1993. The Pros and Cons of Dehorning Rhinos. Presented at the Workshop on Rhino Conservation for Tanzania, Department of Wildlife, Dar es Salaam, Tanzania.
Lee, T., Roberts, D., 2016. Devaluing rhino horns as a theoretical game. Ecol. Model. 337, 73–78. https://doi.org/10.1016/j.ecolmodel.2016.06.009.
Lindsey, P., Taylor, W., 2011. A Study on the Dehorning of African Rhinoceroses as a Tool to Reduce the Risk of Poaching. Endangered Wildlife Trust, Johannesburg.
Lopes, A.A., 2019. Transnational links in rhino poaching and the black-market price of rhino horns. Aust. J. Agric. Resour. Econ. 63, 95–115. https://doi.org/10.1111/1467-8489.12286.
Maas, B., 2016. Pointless: A Quantitative Assessment of Supply and Demand in Rhino Horn and a Case against Trade. NABU International.
Martin, E., 1994. Rhino poaching in Namibia from 1980 to 1990 and the illegal trade in the horn. Pachyderm 18, 39–51.
Metzinger, A., Meyer, L., Buss, P., Hooijberg, E., Huber, N., Viljoen, F., Leiberich, M., Pohlin, F., 2024. Dehorning does not alter the stress response in southern white rhinoceroses (*Ceratotherium simum simum*) during transport: a preliminary investigation. J. Wildl. Dis. 60, 490–495. https://doi.org/10.7589/JWD-D-23-00061.
Milliken, T., du Toit, R., 1994. Rhino dehorning in Zimbabwe: an update. TRAFFIC Bull. 14, 45–46.
Milner-Gulland, E., Leader-Williams, N., Beddington, J., 1993. Is dehorning African rhinos worthwhile? Pachyderm 18, 52–58.
Milner-Gulland, E.J., 1999. How many to dehorn? A model for decision-making by rhino managers. Anim. Conserv. 2, 137–147. https://doi.org/10.1111/j.1469-1795.1999.tb00059.x.
Milner-Gulland, E.J., Beddington, J.R., Leader-Williams, N., 1992. Dehorning African rhinos: a model of optimal frequency and profitability. Proc. Biol. Sci. 249, 83–87. https://doi.org/10.1098/rspb.1992.0087.
Morkel, P., Geldenhuys, L., 1993. Dehorning of Black Rhinoceros (*Diceros bicornis bicornis*) in Namibia. Presented at the Rhinoceros Biology and Conservation: Proceedings of an International Conference, San Diego, USA.
Murcott, M., 2017. Transformative environmental constitutionalism's response to the setting aside of South Africa's moratorium on rhino horn trade. Humanities 6, 84. https://doi.org/10.3390/h6040084.
Owen-Smith, N., 1971. Territoriality in the white rhinoceros (*Ceratotherium simum*) burchell. Nature 231, 294–296. https://doi.org/10.1038/231294a0.
Owen-Smith, N., 1974. The social system of the white rhinoceros. In: Geist, V., Walther, F. (Eds.), The Behaviour of Ungulates and Its Relation to Management. IUCN, Morges, Switzerland, pp. 341–351.
Patton, F., Campbell, P., Genade, A., 2018. The effect of dehorning adult male rhinos on the frequency of fighting at Ziwa Rhino Sanctuary. Pachyderm 59, 114–115. https://doi.org/10.69649/pachyderm.v59i.91.
Penny, S., White, R., MacTavish, D., MacTavish, L., Scott, D., Pernetta, A., 2020a. Does dehorning lead to a change in inter-calf intervals in free-ranging white rhinoceros? Pachyderm 61, 191–193. https://doi.org/10.69649/pachyderm.v61i.13.
Penny, S., White, R., MacTavish, D., MacTavish, L., Scott, D., Pernetta, A., 2020b. Negligible hormonal response following dehorning in free-ranging white rhinoceros (*Ceratotherium simum*). Conserv. Physiol. 8. https://doi.org/10.1093/conphys/coaa117.
Penny, S., White, R., Scott, D., MacTavish, L., Pernetta, A., 2021. No evidence that horn trimming affects white rhinoceros horn use during comfort behaviour and resource access. Anim. Biol. 71, 243–259. https://doi.org/10.1163/15707563-bja10037.
Penny, S., White, R., MacTavish, D., MacTavish, L., Scott, D., Pernetta, A., 2022. Changes in social dominance in a group of subadult white rhinoceroses (*Ceratotherium simum*) after dehorning. Afr. Zool. 57, 32–42. https://doi.org/10.1080/15627020.2022.2046155.
Pfannerstill, V., Härdtner, R., Maboga, O., Balkenhol, N., Bennitt, E., Scheumann, M., 2023. Dehorning impacts white rhinoceros behaviour less than social events: evidence from Botswana, 321, 249–259. https://doi.org/10.1111/jzo.13115.
Pinchin, A., 1993. Zimbabwe's rhino dehorning programme. Int. Zoo News 40, 9–13.
Pullin, A.S., Stewart, G.B., 2006. Guidelines for systematic review in conservation and environmental management. Conserv. Biol. 20, 1647–1656. https://doi.org/10.1111/j.1523-1739.2006.00485.x.
R Core Team, 2024. R: A Language and Environment for Statistical Computing.
Rachlow, J.L., Berger, J., 1997. Conservation implications of patterns of horn regeneration in dehorned white rhinos. Conserv. Biol. 11, 84–91. https://doi.org/10.1046/j.1523-1739.1997.95523.x.
Rubino, E., Pienaar, E., 2018. Understanding South African private landowner decisions to manage rhinoceroses. Hum. Dimens. Wildl. 23, 160–175. https://doi.org/10.1080/10871209.2018.1402971.
Rubino, E., Pienaar, E., 2020. Rhinoceros ownership and attitudes towards legalization of global horn trade within South Africa's private wildlife sector. Oryx 54, 244–251. https://doi.org/10.1017/S0030605318000030.
SANParks, 2014. Media Release: Rhino Poaching Update [WWW Document]. SANParks. URL. https://www.sanparks.org/news/media-release-rhino-poaching-update-20. (Accessed 30 September 2024).
SANParks, 2019. SANParks and Greater Kruger Partners' Innovate to Minimise Impact of Rhino Poaching [WWW Document]. South Afr. Natl. Parks. URL. https://www.sanparks.org/news/media-release-sanparks-and-greater-kruger-partners-innovate-to-minimise-impact-of-rhino-poaching. (Accessed 1 July 2024).
Save the Rhino, 2019. 769 Rhinos Poached in South Africa in 2018 [WWW Document]. Save Rhino. URL. https://www.savetherhino.org/africa/south-africa/769-rhinos-poached-in-south-africa-in-2018/. (Accessed 30 September 2024).
Scheffers, B.R., Oliveira, B.F., Lamb, I., Edwards, D.P., 2019. Global wildlife trade across the tree of life. Science 366, 71–76. https://doi.org/10.1126/science.aav5327.
Scholtz, W., 2019. Trading rhinoceros horn for the sake of conservation: dehorning the dilemma through a legal analysis of the emergence of animal welfare. In: Scholtz, W. (Ed.), Animal Welfare and International Environmental Law. Edward Elgar Publishing, Cheltenham, UK, pp. 235–268.
Swanson, T., Mourato, S., Swierzbinski, J., Kontoleon, A., 2002. Conflicts in conservation: the many values of the black rhinoceros. In: Pearce, D., Pearce, C., Palmer, C. (Eds.), Valuing the Environment in Developing Countries: Case Studies. Edward Elgar Publishing, Cheltenham, UK, pp. 169–205.
't Sas-Rolfes, M., Rademeyer, J., Vigne, L., Emslie, R., Knight, M., Gaymer, J., Talukdar, B., 2025. The Impact of Poaching on Rhino Conservation. In: Melleti, M., Talukdar, B., Balfour, D. (Eds.), Rhinos of the World: Ecology, Conservation and Management. Springer Nature, Switzerland, Cham, pp. 367–392. https://doi.org/10.1007/978-3-031-67169-2_15.
Taylor, A., Balfour, D., Brebner, D.K., Coetzee, R., Davies-Mostert, H., Lindsey, P.A., Shaw, J., 't Sas-Rolfes, M., 2017. Sustainable rhino horn production at the pointy end of the rhino horn trade debate. Biol. Conserv. 216, 60–68. https://doi.org/10.1016/j.biocon.2017.10.004.
TRAFFIC, 2015. South Africa confirms 2014 worst on record for rhino poaching - Wildlife Trade News from TRAFFIC [WWW document]. URL. https://www.traffic.org/news/south-africa-confirms-2014-worst-on-record-for-rhino-poaching/. (Accessed 30 September 2024).
TRAFFIC, 2018. 2017 South Africa rhino poaching figures [WWW document]. URL. https://www.traffic.org/news/south-africa-rhino-poaching-in-2017-almost-matches-2016-figure-with-kwazulu-natal-now-bearing-the-brunt/. (Accessed 30 September 2024).
Trendler, K., 2011. Dehorning Rhino: Welfare, Ethics and Behavioural Issues. Presented at the Perspectives on Dehorning and Legalised Trade in Rhino Horn as Tools to Combat Rhino Poaching. Endangered Wildlife Trust, Johannesburg, South Africa, p. 7.
UNODC, 2020. World Wildlife Crime Report. United Nations Office on Drugs and Crime.
UNODC, 2024. World Wildlife Crime Report. United Nations Office on Drugs and Crime.
Ververs, C., 2018. Breeding on the Brink of Extinction: What Can We Learn From Game-ranched White Rhinoceroses (*Ceratotherium simum simum*)? (PhD thesis) Ghent University, Ghent, Belgium.
Vigne, L., 1989. Dehorning rhinos in Damaraland - a controversial issue. Pachyderm 12, 47–48. https://doi.org/10.69649/pachyderm.v12i1.695.
Vigne, L., 't Sas-Rolfes, M., Milliken, T., Rademeyer, J., Talukdar, B., 2025. The impact of rhino horn trafficking on conservation. In: Melletti, M., Talukdar, B., Balfour, D. (Eds.), Rhinos of the World: Ecology, Conservation and Management. Springer Nature Switzerland, Cham, pp. 393–422. https://doi.org/10.1007/978-3-031-67169-2_16.
Western, D., 1982. Dehorn or not dehorn? Swara 5, 22–23.
WWF, 2024. Ezemvelo KZN Wildlife Extends Dehorning to Contain High Levels of Poaching [WWW Document]. WWF. URL. https://www.wwf.org.za/?47943/Ezemvelo-KZN-Wildlife-extends-dehorning. (Accessed 1 July 2024).