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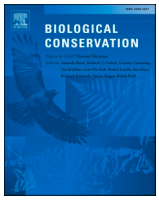

Perspective

Dismantling the poachernomics of the illegal wildlife trade

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ABSTRACT

Persistent poaching fuelled by demand for elephant ivory and rhino horn continues to threaten these species. Despite international trade restrictions operating since the 1970s, limiting poaching has remained a substantial challenge over the last decade. The poaching economy of such storable goods is driven by a combination of persistent consumer demand and market speculation, and enabled by weak governance, lack of adequate resources for species protection, and alienation of local people who pay the costs of living alongside these species. We argue that restricting the legal supply of such wildlife products has created ideal conditions for the poaching economy — 'poachernomics' — to thrive. Strategies that move toward empowering local communities with stronger property rights over wildlife and delivering more benefits to them, including via carefully regulated legal trade, are underused elements in the current fight against the onslaught of the international illegal wildlife trade.

1. Introduction

International trade in wildlife can be a major threat to the conservation of biodiversity when linked to unsustainable harvesting ('t Sas-Rolfes et al., 2019). It is also a potential source of zoonotic diseases (such as COVID-19) that can have devastating impacts on human health and economies (Roe et al., 2020). The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was established as an oversight mechanism to regulate the international trade in wildlife (Abensperg-Traun, 2009). Within CITES, responses to unsustainable wildlife harvesting have focused primarily on restricting trade and enhancing anti-poaching efforts (Challender and MacMillan, 2014). Reducing demand for illegal wildlife products is also widely promoted as a measure to tackle unsustainable wildlife trade (Wallen and Daut, 2018). However, trade restrictions and demand-reduction campaigns have demonstrated questionable conservation success to date (Challender et al., 2015; Veríssimo and Wan, 2019), while unsustainable harvesting of animals and plants is now considered to be one of the biggest threats to biodiversity globally (Maxwell et al., 2016). An important limitation of trade restrictions and demand-reduction campaigns is that they inhibit the potential for local people who bear the costs of living alongside biodiversity to benefit directly from nature conservation (Cooney et al., 2017).

Elephants (African savanna *Loxodonta africana*, forest *L. cyclotis*, and Asian *Elephas maximus*) and rhinoceroses (white *Ceratotherium simum*, black *Diceros bicornis*, Sumatran *Dicerorhinus sumatrensis*, Javan *Rhinoceros sondaicus*, and greater one-horned *R. unicornis*) (hereafter 'rhinos') are some of the most iconic species that are used to raise substantial funds to support biodiversity conservation (Di Minin et al., 2013). They also carry valuable trophies, elephant ivory, and rhino

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horn, which have been in demand historically in Asia and other continents for multiple uses. Commercial international trade in elephant ivory and rhino horn has been essentially banned under CITES since 1989 and 1977, respectively, and many campaigns to reduce demand for elephant ivory and rhino horn have been implemented since. Since banning the trade in rhino horn, at least three rhino subspecies (western black *Diceros bicornis longipes*, northern white *Ceratotherium simum cottoni*, and Vietnamese *R. sondaicus annamiticus*) have already gone extinct in the wild. While demand for elephant ivory and rhino horn is mostly concentrated in Asia, poachers are now mainly targeting African elephants (Wittemyer et al., 2014) and rhinos (Di Minin et al., 2015) for their ivory and horns, respectively.

Commercial poaching for elephant ivory and rhino horn has accelerated from 2007 (Di Minin et al., 2015; Wittemyer et al., 2014) and populations of African elephant and white rhino have started declining (Fig. 1). In fact, nearly one-third of Africa's savanna elephants were exterminated between 2008 and 2012 (Wittemyer et al., 2014), with other forms of human-wildlife conflict and habitat loss contributing. African forest and savanna elephants were recently classified as Critically Endangered and Endangered by the IUCN, respectively (IUCN,

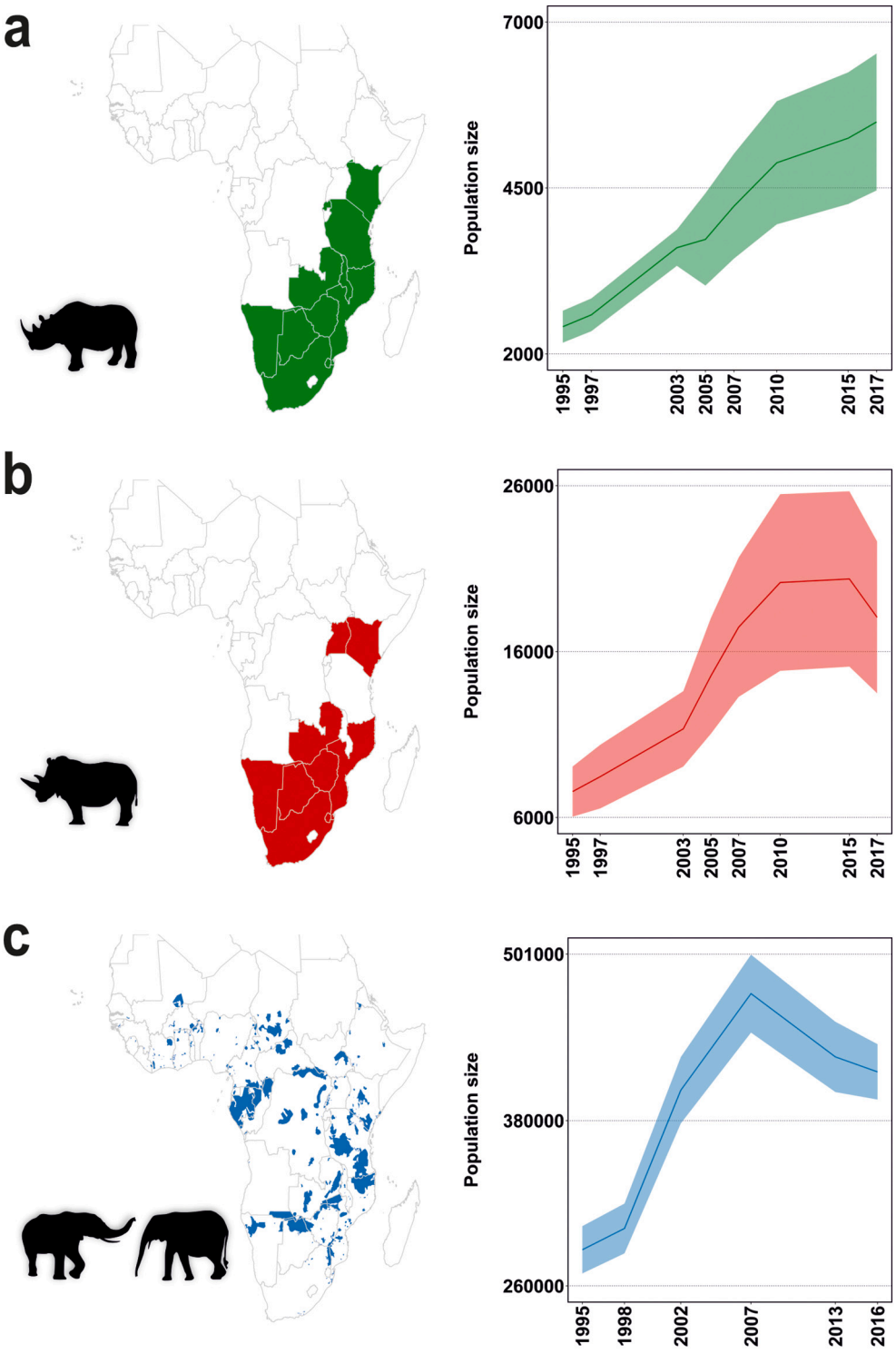

Fig. 1. Distribution of and population trends of (a) black (*Diceros bicornis*) and (b) white (*Ceratotherium simum*) rhinoceros and (c) African elephants (*Loxodonta africana* and *Loxodonta cyclotis*) in Africa. Distribution maps available as range maps from the International Union for the Conservation of Nature (iucnredlist.org) show where rhinoceroses and elephants are 'extant' and 'extant and reintroduced'. For black and white rhinoceroses, distribution is at the country level to avoid revealing locations of rhinos. Population size data were available from the IUCN African Rhino (rhinos.org/research-publications/iucn-african-rhino-specialist-group) and Elephant (africanelephantdatabase.org/report/2016/Africa) Specialist Groups for different years for black and white rhinoceros and African elephant, respectively. Silhouette images are from phylopic.org and in the public domain.

2021). Poaching of rhinos (mostly white rhino) in South Africa escalated exponentially from an average loss of 0.17 rhinos day^{-1} in 2007 to 3.32 rhinos day^{-1} in 2014 (Di Minin et al., 2015). Even though a decline in poaching rates occurred after 2014 due to enhanced law enforcement, it is likely that this decline also arose because the rhino population in Kruger National Park — the largest and worst-affected rhino population — has decreased (SANPARKS, 2020), and it was more difficult for poachers to locate rhinos. The black rhino population has been slowly recovering over the last decade, primarily because of substantial investment in the protection of small populations within militarized and fenced conservation areas (Emslie et al., 2019); however, there are still fewer than 6000 individuals in the wild (Fig. 1a). A resumption of high poaching rates is certainly a concern and strategies are needed to avoid future negative impacts on the conservation of these species.

African elephants and rhinos typically occur in areas where poverty, inequality, and governance are such that poachernomics can thrive. We define poachernomics as a poaching-based economy driven by persistent consumer demand and market speculation, which is aggravated by trade restrictions that perversely empower organized criminals, to the detriment of species conservation. This study provides an overview across academic disciplines of the complexity of poachernomics. We start by synthesizing information on the supply chain, demand complexity, and enabling factors of the illegal trade in elephant ivory and rhino horn throughout the conservation, geography, economics, and criminology literature, and then we explore ways to alleviate the rising threats to the conservation of these species. We also present a framework that could be used to enhance the conservation of these species and their contribution to local people with whom they co-exist.

2. Poachernomics in a nutshell

The flow of goods in poachernomics is unidirectional, from source countries (e.g., South Africa) where the elephants and rhinos are poached for their ivory and horns, respectively, through a transit country (e.g., Mozambique), and finally to a consumer country (e.g., Vietnam) ('t Sas-Rolfes et al., 2019). Evidence suggests that poaching rates of elephants across Africa are correlated with proxies of ivory demand in the main Chinese markets, and corruption and poverty at the local scale (Hauenstein et al., 2019). Similarly, poaching rates of rhinos in South Africa correlate with proxies of demand in Far East Asia and lack of effective protection effort in South Africa (Di Minin et al., 2015). Below, we discuss the reality of poachernomics in supply countries, the complexity of demand for ivory and rhino horn, and the enabling factors.

2.1. Reality in supply countries

Protecting high-value species such as elephant and rhino is expensive. The number of rangers and the budget required to counteract poaching are currently inadequate, even in the best-funded African countries (Di Minin et al., 2015). In South Africa, one third of private rhino owners, who conserve >50% of white rhinos globally, have disinvested in rhino conservation partly because they could not afford increased anti-poaching costs (Clements et al., 2020). Elephant and rhino conservation imposes additional costs on local people. Opportunity costs, which refer to the cost of lost access to natural resources or opportunities for socio-economic development, are exacerbated when military interventions put in place to protect elephants and rhinos further alienate local people from conservation (Duffy et al., 2019). Militarization of conservation can also violate human rights and inhibit economic growth in conflict areas (Lunstrum, 2014). Elephants impose other costs by killing people and raiding crops (Hoare, 2015). Financial losses due to crop raiding can be substantial and compensation schemes are typically deficient (Hoare, 2015). Non-material costs of crop raiding include negative physical or psychological effects, trauma, fear, and anxiety that can lead to human ill-being (Thondhlana et al., 2020). Additional costs of crop raiding include food insecurity, higher rates of self-reported human and livestock diseases, and poorer scholastic achievement (Mackenzie and Ahabyona, 2012). Without adequate mitigation strategies, human-elephant conflict will likely increase in the future (Di Minin et al., 2021b).

In addition to bearing so many costs, local people have few positive incentives to conserve elephants and rhinos. One important problem is that in most supply countries, elephants and rhinos are state property and perceived as a symbol of colonial authority (Hübschle and Shearing, 2018; Naughton-Treves, 1999). In many parts of contemporary Africa, cultural and religious beliefs that enhance tolerance for wildlife can be weaker than elsewhere (e.g., in Asia), with positive socio-economic incentives playing an important role in enhancing co-existence between humans and elephants and rhinos. Campaigns to devolve wildlife-property rights, especially to local communities to create incentives to protect wildlife, have long been promoted in many African countries, but have mostly failed to be implemented (Nelson and Agrawal, 2008). Countries in southern Africa such as Namibia and South Africa are exceptions because they have altered their legal regimes to give substantial control over the use of wildlife to private and communal landowners. As a result, private and communal landowners have been able to reap benefits from wildlife-based tourism and the sustainable uses of elephants and rhinos. In turn, this has resulted in the recovery of elephant and white and black rhino populations in these countries (e.g., Leader-Williams et al., 2005).

With limited or no devolution of property rights over wildlife, elephants and rhinos currently hold limited or no value to local people in most supply countries. The main economic value of these species derives from their direct use, namely from sustainable, harvest-based extractive uses (e.g., trophy hunting) (Di Minin et al., 2016, 2021a) and non-extractive uses (e.g., from wildlife-based tourism) (Di Minin et al., 2013). The revenue generated from wildlife-based tourism can be substantial and potentially used to offset anti-poaching costs (Naidoo et al., 2016). However, large-scale wildlife-based tourism is viable only in countries with good governance and in more accessible areas, with limited potential in many other areas where elephants and rhinos currently occur. Moreover, wildlife-based tourism often produces limited employment, and the mostly modest cash benefits accrue to a small proportion of the community, while larger benefits often accrue to foreign-owned companies (Kiss, 2004). Even in the case of trophy hunting, there are weaknesses in how it is managed and how revenues are distributed to local communities (Di Minin et al., 2016, 2021a; Koot, 2019).

2.2. Demand complexity

The use of rhino horn in traditional Chinese medicine dates back at least 1800 years (Graham-Rowe, 2011). Similarly, ivory trade has occurred for at least several thousand years (Walker, 2009). There are several motivations for the use and consumption of rhino horn and elephant ivory (Thomas-Walters et al., 2020a, 2020b). Both products have distinct aesthetic properties and have been used in various ornamental applications throughout history (Vigne and Martin, 2018; Walker, 2009). Consumer research in Vietnam revealed that rhino horn has social significance as a symbol of wealth and power strongly associated with success (Milliken and Shaw, 2012), and rhino horn remains in demand for traditional Chinese medicine and ornamental uses (Cheung et al., 2018, 2021; Gao et al., 2016). Being storable goods, both rhino horn and ivory are also stockpiled as an investment for speculative reasons (Gao and Clark, 2014; Stiles, 2015).

Along with various supply factors (e.g., costs, quantity, quality, and reliability), purchasing motivations are central components of poachernomics that determine market size and persistence. The latter also influence product prices that incentivize profit-driven illegal activity. Attempts to discourage product purchase through legislative and coercive means (i.e., bans) will only succeed to the extent that such

restrictions have social legitimacy, create product stigma, and cause increases in black-market prices that buyers are unwilling or unable to afford ('t Sas-Rolfes et al., 2019). However, if consumers do not accept bans as legitimate, are largely unwilling to switch to substitute products, and are therefore insensitive to price increases (i.e., demand is price-inelastic), the efficacy of bans is severely undermined — they can in fact *raise* total market value and the profitability of illegal supply rather than reduce it (t Sas-Rolfes, 2012). This challenge can be compounded over time by rising relative affluence of consumers (as has happened in East Asian markets in the last two decades), indicated by rising prices and sales volumes of both ivory and rhino horn during that period (Gao and Clark, 2014; Sosnowski et al., 2019; Vigne and Martin, 2018). Perversely, bans and illegality of a product can also make it more desirable for certain types of consumers, providing an added incentive to purchase (Hinsley and 't Sas-Rolfes, 2020).

To counteract growing consumer demand, conservation groups have implemented various behaviour-change initiatives, ranging from simple awareness-raising through advertising and public stockpile destructions, to more targeted and nuanced approaches (Veríssimo and Wan, 2019). However, indiscriminate awareness-raising can backfire by alerting new consumers to the existence of the products (Veríssimo et al., 2020) and without social stigma, raising awareness of rarity and creating further perceived supply scarcity (by intensifying restrictions and destroying product stocks) can perversely raise the desirability and therefore prices of these products through a so-called 'snob' effect (Chen, 2016). For rare, wild species, this can create further poaching pressure as a feedback loop, causing a potential extinction vortex called the anthropogenic Allee effect (Courchamp et al., 2006). This effect is exacerbated by market speculation ('t Sas-Rolfes et al., 2014). For example, market speculators, who might have started investing in raw ivory during the global financial crisis (Stiles, 2015), would have likely started stockpiling in anticipation of future increases in black-market prices arising from supply scarcity induced by trade restrictions. Indeed, the black-market price of ivory skyrocketed between 2008 and 2014 (Sosnowski et al., 2019), and there is evidence that prices for rhino horn responded similarly to tighter restrictions (t Sas-Rolfes, 2012). In the case of rhino horn, market speculators may even face incentives to subsidize poaching until wild populations are extinct or nearly extinct in order to gain monopoly power (Mason et al., 2012).

2.3. Trafficking and enabling factors

Wildlife trafficking — the illegal procurement, transportation, and distribution across international borders of protected species and products — has become a substantial enterprise (Nellemann, 2016). Trafficking is structured and has evolved in the context of a globalizing marketplace to involve criminal networks (Warchol, 2004). Criminal networks play an important role therein because they provide the trade routes and means of transporting goods from source to consumer countries (Nellemann, 2016). Their involvement in the trade has escalated mainly because of poor governance (see below) throughout the supply chain, weak sentencing for convicted criminals, the affordability of fines, the negligible risk of getting caught and receiving punishment, and high profitability of the crime (Milliken and Shaw, 2012). Wildlife criminals can be classified into (*i*) disorganized criminal networks; (*ii*) organized crime groups, and (*iii*) corporate crime groups (Wyatt et al., 2020 provide detailed definitions for each category). At each node of the supply chain, there is a possibility that one or more of these types might be involved in the trade in elephant ivory and rhino horn (Hübschle, 2016; Titeca, 2019). Disorganized criminal networks include local poachers who are familiar with the terrain and sell ivory and rhino horn collected in one or more countries via an intermediary (Titeca, 2019). Ivory and rhino horn then make their way to international markets via an organized crime group. Organized crime groups are often multifaceted and involved in several illegal activities (e.g., wildlife trade and narcotics) and offer the logistics for the trade to operate successfully from source to consumer countries (van Uhm and Nijman, 2020). Corporate crime groups are then mostly involved in consumer countries such as China where carving of trafficked ivory and rhino horn is done by legal businesses and trafficked rhino horn is also sold by legal medical supply chains (Moneron et al., 2017; Patton and Ammann, 2016; van Uhm and Wong, 2019).

Corruption is an important enabling factor of poachernomics (Van Uhm and Moreto, 2018). For example, supply countries with more effective governance have performed better in terms of protecting elephants and rhinos (Hauenstein et al., 2019). Corruption plays an important role throughout the supply chain of the illegal wildlife trade, from source to consumer countries (Underwood et al., 2013). Low-level corruption in source countries includes rangers in protected areas accepting bribes in exchange for providing patrol information to poachers, and/or themselves poaching elephants and rhinos and/or stealing ivory and rhino horn from stockpiles (Moreto and Lemieux, 2015). High-level corruption in source, supply, and consumer countries involves top police officials, judges, politicians, and diplomats facilitating the activities and obstructing investigations of crime organizations that trade elephant ivory and rhino horn across international borders (Van Uhm and Moreto, 2018).

Poverty is another important enabling factor of poachernomics. Poverty, and especially economic inequality, in source states are central drivers of elephant and rhino poaching (Lunstrum and Givá, 2020). Wealth disparity created along the supply chain of the trade from demand to supply countries is also problematic. While local poachers experience the highest risks (e.g., being fined, incarcerated, or even killed by the authorities or by the animals they target), the promise of atypical recompense makes these risks acceptable (Haas and Ferreira, 2016). As the incentives are so high, even when anti-poaching activities are effective in apprehending poachers, there are many other poachers ready to replace them. Furthermore, poverty is a multifaceted problem encompassing more than lack of alternative economic opportunities. In fact, poverty should also be considered in light of lack of power, prestige, voice, and an inability to shape one's future (Duffy et al., 2014). As such, poaching elephants and rhinos might not only be driven by the need for an income, but could instead be a means of seeking and affirming identity, status, lifeways, custom, and local prestige (Duffy et al., 2016).

2.4. Solutions

Dismantling poachernomics requires a multi-faceted approach to address the complexity of the underlying drivers. Influencing consumers of ivory and rhino horn remains an important tool (Veríssimo et al., 2020); however, evaluations of past attempts to reduce consumer demand reveal many limitations and even perverse outcomes (Greenfield and Veríssimo, 2019). Changing human behaviour is challenging and campaigns need to be well-resourced, persist over sufficient intervals to establish behavioural shifts, avoid unintended consequences, and carefully consider cultural aspects (Thomas-Walters et al., 2020a, 2020b). Although recent declines in wholesale prices for ivory and rhino horn have been recorded (Sosnowski et al., 2019; Vigne and Martin, 2018; Wildlife Justice Commission, 2017, 2020), both theoretical (Lopes, 2015) and empirical (Schlossberg et al., 2020) research suggests that these declines are inadequate to remove the poaching threat. Illegal markets for ivory and (especially) rhino horn appear to share a fundamental characteristic with product markets for which bans typically fail as policy measures, i.e., a combination of inelastic supply and demand (t Sas-Rolfes, 2012; Chen and 't Sas-Rolfes, 2021; Do et al., 2020). For such markets (e.g., narcotics), bans are typically undermined by corruption and economists advocate regulation supported by taxation as a preferred policy measure (Becker et al., 2006; Thornton, 1991, 2007).

Coupled with appropriately targeted interventions to influence consumer behaviour to encourage conscious legal and sustainable purchasing habits, transnational policing aimed at dismantling criminal networks engaged in ivory and rhino horn trafficking should remain a

priority (Haas and Ferreira, 2016). However, transnational environmental-crime markets are resilient and tend to persist over time (Costa, 2021). It is therefore paramount to understand the sources of such resilience better to develop more targeted approaches to dismantling criminal networks (Ayling, 2013). Even so, the efficacy of conservation interventions based on intelligence gathering and criminal investigations without considering the needs of local people remains equivocal (Massé et al., 2020). Another challenge is how to mitigate corruption throughout the supply chain (Smith et al., 2015). Artificial-intelligence approaches can also be used to investigate and monitor digital markets for ivory and rhino horn and thereby assist authorities to dismantle criminal networks (Di Minin et al., 2018, 2019b). However, effectively tackling corruption also requires recognizing and addressing its links to issues of social legitimacy (Hübschle, 2017).

Besides demand-side interventions and transnational policing, we contend that innovative solutions that support enhanced management of protected and other conservation areas — and that better integrate local actors and institutions in conservation efforts — are especially needed. In Fig. 2, we propose a framework that can be used for this purpose. In the short term, adequate funding must be made available for effective management and security of state protected areas that form a core part of elephant and rhino conservation strategies (Di Minin et al., 2015; Pacifici et al., 2020). However, following the COVID-19 pandemic (Lindsey et al., 2020), it is unlikely that these resources can be derived solely from wildlife-based tourism. Therefore, building a more sustainable financial base for state protected areas (Cumming et al., 2021) to support effective management and security is essential (Fig. 2a). This should also be a priority for private and community-owned conservation areas that host rhinos and elephants; in South Africa for example, the number of rhinos on private land is now equal if not greater than on state-protected land. Enhanced resources will also allow implementing management strategies (Di Minin et al., 2021b) that can reduce human-wildlife conflict more effectively.

But enhanced management and protection by themselves cannot successfully arrest poaching unless local actors (e.g., local community members) and institutions are better integrated into conservation decision-making (Cooney et al., 2017). In South Africa, state actors have implemented various strategies aimed at reducing rhino poaching and apprehending offenders, but these efforts could not prevent an important recent decline in the rhino population in Kruger National Park (SANPARKS, 2020). Because of the socio-economic and political complexity of poachernomics, the response must be broadened to include additional actors (e.g., local communities) and institutional factors in the conservation of elephants and rhinos, and to develop conservation policies that account for sustainable development goals (e.g., income generation from conservation) (Muchapondwa and Stage, 2015). Actors should feel more empowered and benefit more directly from the sustainable management of — or otherwise feel a sense of custodianship toward — elephants and rhinos (Fig. 2b). Devolution (e.g., local community proprietorship of the land and its associated biodiversity) should be pursued where the decision context (values, rules, and knowledge) allows it (DeGeorges and Reilly, 2009). However, some African countries would need to alter their legal regimes to devolve control over the use of wildlife, especially to local communities. Local communities, for example, currently contribute the smallest share of rhino ownership in Africa. It is also important for donors to support the establishment of local institutions and entities for the conservation of elephants and rhinos (e.g., community-owned conservancies), but this funding should be carefully allocated to build capacity so that the relevant entities can be self-sufficient in the long term (Newmark and Hough, 2000). Local values, preferences, and motivations must be carefully considered. Participatory planning and decision-making with local actors can reduce social conflict and achieve institutional progress in managing elephants and rhinos (Treves et al., 2009).

Transitioning from a law enforcement-focused to a more adaptive, resilience-based, management model will enable elephant and rhino conservation to adjust to future drivers of change (Fig. 2c). People's intrinsic motivations (i.e., people are morally committed to the conservation of elephants and rhinos and these species have high non-use values) play an important role in supporting elephant and rhino conservation. In Mali for example, elephant poaching declined when local communities were provided with tangible livelihood benefits from elephant conservation and empowered via management activities rooted in existing practices (Canney, 2019). However, extrinsic motivations (i.e., monetary benefits from illegally killing elephants and rhinos) can outweigh intrinsic motivations for conserving these species in many contexts where people lack alternative economic opportunities and/or are alienated from conservation. Without incentives that outweigh the high costs of conservation, these systems might be less resilient to increasing economic pressure to poach. In Namibia, a wildlife-based tourism program designed and delivered to support local institutions and entities effectively improved the value local people

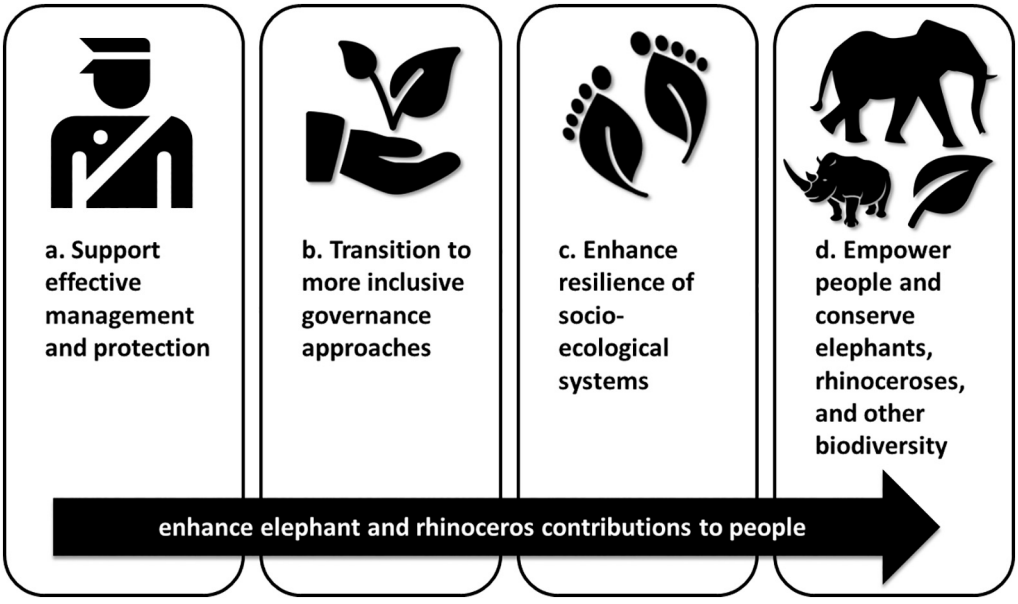

Fig. 2. Framework for disincentivizing poachernomics and enhancing elephant and rhinoceros contributions to people.

attached to saving species such as black rhino (Muntifering et al., 2020). In Nepal, the benefits generated from wildlife-based tourism and community participation in conservation activities have substantially reduced rhino poaching (Aryal et al., 2017). However, the provision of these benefits at the household level remains a major hurdle on the path to erode poachernomics (Galvin et al., 2018).

Following the COVID-19 pandemic, Africa is likely to face reduced funding for biodiversity conservation, and the extent to which conservation can rely on economic incentives related to wildlife-based tourism and trophy hunting in the future is questionable (Lindsey et al., 2020). Furthermore, power dynamics can pose a challenge for these initiatives, aggravated by inequitable distribution of benefits, market challenges, and dependence on tourism investors and trophy-hunting companies (Muchapondwa and Stage, 2015). Therefore, alternative and/or additional sources of funding that can be used to support local livelihoods and make socio-ecological systems (protected and other conservation areas and the broader landscapes around them) more resilient need to be sourced. Allowing for a diversity of land uses that are not detrimental to conservation could provide local actors and institutions with more options for sustaining livelihoods than depending on conservation benefits only. For example, a sustainable land-use allocation in Kenya that also supports land uses other than for conservation (e.g., agriculture and pastoralism) has reinforced socio-ecological systems that are more resilient to poaching and the lack of direct benefits from ecotourism and trophy hunting (Niskanen et al., 2018).

An oft-proposed (Di Minin et al., 2015; Ferreira et al., 2014) alternative to help raise more funds for anti-poaching activities and to support local people, especially during the COVID-19 pandemic, is legalizing trade in elephant ivory and rhino horn, following similar models already applied to the legal trade of hunting trophies of elephants (Muposhi et al., 2016) and rhinos ('t Sas-Rolfes et al., 2021. A legal trade is an instrument that could potentially both (*i*) depress scarcity-driven black-market prices that make poachernomics profitable and worth the risk (especially for rhino horn), and (*ii*) reduce the incentives to engage in the illegal trade by providing finance and economic incentives at relevant local levels to strengthen anti-poaching efforts (t Sas-Rolfes, 2012). Ivory and rhino horn can be sourced sustainably without needing to kill any animal. Legal ivory can be sourced from animals dying naturally, problem-animal control, and existing stockpiles, which are substantial (recently estimated at >900 t in Africa) (Stiles, 2021). Accumulated rhino-horn stockpiles are similarly substantial, most recently estimated at >75 t in South Africa (The High-Level Panel of Experts for the Review of Policies Legislation and Practices on Matters of Elephant, Lion, Leopard and Rhinoceros Management, Breeding, Hunting, Trade and Handling, 2020), which amounts to ~15 times the most recent estimate of ~5.1 t year^{-1} entering the illegal market (Emslie et al., 2019). In the case of rhinos, horn is a constantly growing keratin appendage that can be removed and regrown on the same animal for many years (like a human fingernail), thereby enabling legal producers to increase production substantially relative to illegal suppliers. According to a recent estimate, South Africa has the capacity to provide a supply of between 5319 kg and 13,356 kg year^{-1} (Taylor et al., 2017) and research reveals that consumers in Vietnam prefer wild-sourced rhino horn, harvested humanely from the least rare species, under a scenario where international trade is legalized compared to the current situation of illegal trade (Hanley et al., 2018).

-However, legalizing the trade in ivory and rhino horn is opposed by influential animal protection groups for ideological reasons (Madzwamuse et al., 2020), and also raises several practical concerns. Regulation and management of a legal trade, for example, are complicated and there are concerns that suppliers would continue to sell ivory and rhino horn outside the legal market (Collins et al., 2013). Recent developments in traceability technology, as successfully demonstrated by South Africa's quota compliance system for the export of lion bone (Williams et al., 2021), suggest that carefully controlled and verifiable supply channels are at least technically possible. The success of any legal trading regime would therefore depend on applying such technology through an institutional framework that creates appropriate incentives on both the supply and demand sides of the market. A legal trade in ivory appears especially challenging (Sekar et al., 2018) and, given ivory supply dynamics, is unlikely to be a panacea (Do et al., 2020; 't Sas-Rolfes, 2016). Being far more numerous and widely dispersed across Africa, elephants are not as carefully monitored and individually protected as rhinos, currently making them weak candidates for a decisive legal-trade solution. Furthermore, there are currently sharp divisions between countries that oppose legal trade (e.g., Kenya, India, and Nepal for rhino horn trade) and are unlikely to trade themselves, and those that want to trade (e.g., countries in southern Africa). In addition, most consumer countries have closed their legal domestic markets for ivory and rhino horn. However, as long as differences among countries remain, and if consumer demand remains high enough, the current status quo might lead (especially for rhinos) to a 'poaching pit' from which legal trade might offer the only viable escape.

3. Conclusion

Africa's human population is projected to grow to nearly two billion by the end of the century (Bradshaw and Brook, 2014) and there is a serious risk that failing to involve local actors and align with local institutions in conservation will transform some of the last remaining areas where elephants and rhinos occur into hotspots of unsustainable harvesting (Di Minin et al., 2019a) and human-wildlife conflict (Di Minin et al., 2021b). Realities in supply countries, demand in consumer countries, and trade restrictions often prevent local people from benefitting from the conservation of African species. Instead, traders in consumer countries maximize their profits while pushing species toward extinction. In the case of an illegal trade in ivory and rhino horn, none of the profit returns to the supply country or is invested to protect elephants and rhinos. Increasing involvement by organized crime in the illegal wildlife trade can have greater degrading effects on society at large.

A practical, long-term approach would be to combine effective consumer-engagement campaigns, dismantle criminal networks, and empower local actors and strengthen institutions in supply countries, potentially even by developing a legal and regulated supply of rhino horn managed through CITES, thereby mitigating the economic forces that further incentivize poachers and reduce resilience of socio-ecological systems. Engaging decision makers and traders in Asia will also be paramount to reduce the purchasing of illegally sourced ivory and horn. Otherwise, potential continued price escalation driven by market speculators will likely reduce source populations even further, increase rarity, and push these species toward extinction in the wild. Socio-ecological research can be used to understand the diverse and dynamic contexts in which local actors and institutions and elephants and rhinos interact, and how these socio-ecological systems can adapt or transform in response to threats such as poaching.

Declaration of competing interest

The authors declare no competing interests.

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