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Review Paper

Will legal international rhino horn trade save wild rhino populations?



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ABSTRACT

Wild vertebrate populations all over the globe are in decline, with poaching being the second-most-important cause. The high poaching rate of rhinoceros may drive these species into extinction within the coming decades. Some stakeholders argue to lift the ban on international rhino horn trade to potentially benefit rhino conservation, as current interventions appear to be insufficient. We reviewed scientific and grey literature to scrutinize the validity of reasoning behind the potential benefit of legal horn trade for wild rhino populations. We identified four mechanisms through which legal trade would impact wild rhino populations, of which only the increased revenue for rhino farmers could potentially benefit rhino conservation. Conversely, the global demand for rhino horn is likely to increase to a level that cannot be met solely by legal supply. Moreover, corruption is omnipresent in countries along the trade routes, which has the potential to negatively affect rhino conservation. Finally, programmes aimed at reducing rhino horn demand will be counteracted through trade legalization by removing the stigma on consuming rhino horn. Combining these insights and comparing them with criteria for sustainable wildlife farming, we conclude that legalizing rhino horn trade will likely negatively impact the remaining wild rhino populations. To preserve rhino species, we suggest to prioritize reducing corruption within rhino horn trade, increasing the rhino population within well-protected 'safe havens' and implementing educational programmes and law enforcement targeted at rhino horn consumers.

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1. Introduction

The majority of wild vertebrate populations are in severe decline and one-third of all mammal and bird species are currently under threat by unsustainable subsistence hunting, poaching and wildlife trade (IPBES, 2019; Rivalan et al., 2007; Scheffers et al., 2019). Large-scale poaching operations are taking place all over the world, heavily impacting the remaining number of rhinoceros, elephants, vultures, pangolins and numerous other animal species (Conrad, 2012; Fischer, 2004; Rademeyer, 2016). Their horns, tusks, claws, scales, bones and other body parts are smuggled in large quantities mainly to Southeast and East Asia, where they are processed into products that function as status symbols and traditional medicines (Milliken and Shaw, 2012). Illegal trafficking of animal products, e.g., rhino horn, is often undertaken by international crime groups, which can be both opportunistically formed collectives or structured and organised networks, that may have ties or are involved with conservation, tourism and/or trophy hunting industries (Ayling, 2013; Rademeyer, 2016, 2012; Van Uhm, 2012). Especially rhino horns are extremely valuable on the black market, being sold between US \$ 30,000 and 65,000 per kg in Vietnam, thereby being worth more than gold, heroin or cocaine (Rademeyer, 2016; Van Uhm, 2012). The poachers may be locals that live near nature reserves who can earn between US \$ 500 and 20,000 per poached rhino, depending on the role they fulfil (Rademeyer, 2016). However, there seems to be a trend towards more professionally outfitted and trained poachers (Van Uhm, 2016). Rhino horns are also harvested via 'pseudo-hunting', by using rhino trophy hunting as a cover-up for the illegal killing and trafficking of rhino horns to Southeast Asian markets (Ayling, 2013; Rademeyer, 2016; Van Uhm, 2018a).

The poaching rate of the two African rhinoceros species (the white rhino *Ceratotherium simum* and black rhino *Diceros bicornis*) increased significantly since 2007 (Fig. 1), which has generated substantial global concern (African Wildlife Foundation, 2014; Biggs et al., 2013; Milliken and Shaw, 2012; Rubino and Pienaar, 2017). It has been estimated that African rhinos could already become extinct in the wild around the year 2036 (Haas and Ferreira, 2016). In 2010 it was estimated that South Africa was home to 95% (~19,000) of all remaining white rhinos and 40% (~1900) of all black rhinos (Emslie et al., 2016; Rubino and Pienaar, 2017). The survival of the South African rhino population could therefore likely determine the fate of both African rhinoceros species.

The rhino conservation sector, especially in southern Africa, has responded to this alarming extinction risk in a number of ways. First, intensive patrols with anti-poaching rangers are being undertaken, fences have been built or improved around protected areas, scouting drones have been deployed, horns of living rhinos have been equipped with RFID chips and information technology has been included at various levels to stop poaching (Cambron et al., 2015; Conway-Smith, 2013; Penny et al., 2019; SANParks, 2015; Wildlife ACT, 2014). Second, education and awareness campaigns have been set up to decrease the illegal demand for rhino horn (African Wildlife Foundation, 2014; Greenfield and Veríssimo, 2019; Save the Rhino, 2013; Veríssimo and Wan, 2019; WildAct Vietnam, 2019). Third, synthetic horns have been proposed to replace real ones and with that disturb the illegal market (Save the Rhino, 2016a). Fourth, cargo is being checked more intensively for animal body parts and negotiations with Asian governments are taking place to further enforce the ban on domestic sales of rhino horn in an effort to control the illegal trade (Save the Rhino, 2015, 2013). Fifth, horns of living rhinos have been dyed, poisoned or removed to devalue rhino horn (Ferreira et al., 2014; Rubino and Pienaar, 2017; Save the Rhino, 2016b). All these efforts have not been able to stop rhino poaching from taking place, but have possibly assisted in the decrease of rhino poaching events

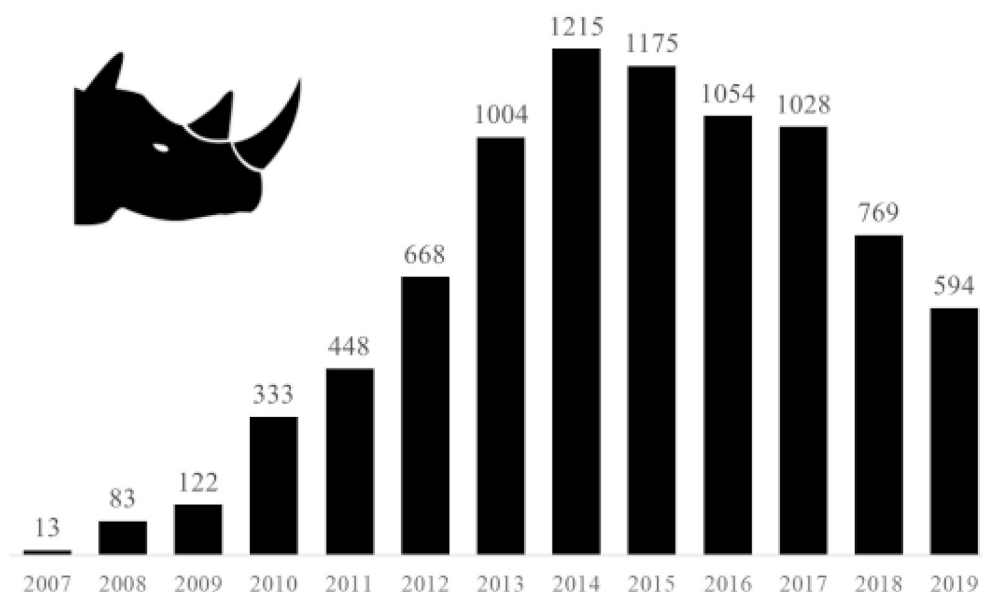


Fig. 1. Number of recorded poached rhinos in South Africa from 2007 until 2019 (Save the Rhino, 2020).

recorded in South Africa from 2014 to 2019 (Fig. 1). However, reduced rates of successfully tracking down rhino, because of their dwindling numbers, may also be invoked as an explanation for the decrease of poaching incidents. Furthermore, some state that the overall decrease of rhino poaching incidents is largely a result of the decrease in poaching in Kruger National Park, where protection was improved in response to the high poaching rate (Rademeyer, 2016). As a response, rhino poaching incidents have increased in other areas (Rademeyer, 2016), notably in Hluhluwe-Imfolozi Park and private game reserves. Unfortunately, the current poaching rate is still so high that it poses a serious threat to the survival of both African rhino species (Haas and Ferreira, 2016).

With the aim to reduce the rapid population decline of vulnerable species, international commercial trade bans of animal products have been implemented through CITES since 1975 (Ayling, 2013). International rhino horn trade has been banned since 1977, which was followed by a decrease in rhino poaching rate at first (Ayling, 2013). However, the increase in the population size of white rhino between 1977 and 2007 was likely not attributed to this trade ban, but to an increase in private ownership and trophy hunting (Leader-Williams et al., 2005) and the protection in the South African National Parks. Furthermore, the population size of black rhino has decreased substantially since the implementation of the trade ban from approximately 65,000 individuals in 1970–2400 individuals in 1995 (Leader-Williams et al., 2005). It is unlikely that the ban directly led to the increase of black rhino poaching, as this was likely caused by rapid economic and population growth in Southeast Asia (Milliken et al., 1993). Moreover, the poaching rate of both African rhino species increased dramatically since 2007 despite the trade ban (Fig. 1).

Given the failure of an international trade ban to fully stop rhino poaching, a substantial number of scientists, policy makers, conservationists and rhino owners have argued to lift the current ban on international rhino horn trade as a potential solution for the ongoing rhino poaching crisis (Biggs et al., 2013; Rubino and Pienaar, 2020; Taylor et al., 2017). This was based on the reasoning of "use it, or lose it", as substantiated by the Principles and Guidelines for the Sustainable Use of Biodiversity by the Convention on Biological Diversity (SCBD, 2004). Rhino horn, which is comprised only of keratin, can be harvested with no ill effect to the animal's health (Biggs et al., 2013; Rubino and Pienaar, 2017). However, others are strongly opposed to lifting this ban for both ethical reasons and concerns about a further increase in rhino poaching (Cheung et al., 2018b; Prins and Okita-Ouma, 2013; Save the Rhino, 2018). This topic has been discussed during several CITES meetings, which led to votes in 2016 and 2019 that twice rejected proposals to lift the ban (CITES, 2019; Save the Rhino, 2018). Furthermore, scientists have been studying the potential effects of a rhino horn trade ban lift for approximately two decades now (e.g., Ayling, 2013; Biggs et al., 2013; Cheung et al., 2018b; Collins et al., 2016; Conrad, 2012; Fischer, 2004; Rivalan et al., 2007; Taylor et al., 2017). Overall, this debate has become polarized, which has led to an apparent deadlock in the discussion (Committee of Inquiry, 2016; Taylor et al., 2017).

The potential conservation benefit of legalizing an animal product market can be divided into two aspects: 1) a legal competing market could offset poaching, and 2) a legal market could provide financial viability to keep, protect and breed animal populations (see Appendix). Past cases show that the legal commercialization of animal products can go both ways regarding the conservation of a species; with a (potentially) positive effect in the case of bison meat, crocodilian skins and trophy hunting, but with a (potentially) negative effect for elephant ivory and lion bones (see Appendix). There are thus situational- and/or context-dependent mechanisms that determine how an animal population responds to a legal animal product trade (Tensen, 2016). It is important to gauge how the rhino populations could respond to a legalization of international rhino horn trade.

Here we present an integrative review on the pros and cons of legalizing international rhino horn trade for the sustained preservation of rhinos in the wild by drawing insight, plausible reasoning, modelling results and empirical data from scientific and grey literature of multiple disciplines (Snyder, 2019). In this review, we discuss four mechanisms (in no specific order) that change or come into play if international rhino horn trade would be legalized and how these mechanisms will potentially impact wild rhino populations (Fig. 2). We identified the following mechanisms as the most frequently occurring ones in scientific literature, in grey literature, and in the arguments of conservationists, policy makers and private rhino owners: 1) financial viability for private rhino owners, 2) rhino horn demand, 3) laundering of rhino horns, and 4) behaviour of rhino horn consumers. These four mechanisms were selected by the authors after thoroughly familiarizing themselves with the topic through past work experience and reading top results from literature search engines about wildlife trade and farming, but without strong *a priori* hypotheses about how each of the mechanisms would influence the study's conclusion. The authors varied in their initial ideas about whether or not rhino horn trade could benefit rhino conservation, thereby limiting a potential researcher bias in the selection of the mechanisms. However, we do not suggest that the selected four mechanisms provide a complete description about what will happen if rhino horn trade is legalized, but we do posit these mechanisms to be of major importance. We collected and studied the literature *ad hoc* to get a thorough understanding about the mechanisms and how these would influence rhino populations in the case of a horn trade legalization. We did this by first reading the top results from literature search engines while searching for keywords related to these mechanisms and wildlife trade and farming. Upon noticing contradictions in views or knowledge gaps, we continued our search by using more specific keywords. These latter search results were often read with the purpose to retrieve an answer on specific questions, in order to get a complete overview of the effects of the mechanisms.

After discussing the four aforementioned mechanisms, we combine our insights into a conclusion where we evaluate each mechanism and whether it will have a positive, negative, or still unknown effect on the future wild rhino population size. We weigh the relative importance of these mechanisms and their potential effect on the wild rhino population through plausible reasoning to come to an overall recommendation about legalizing international rhino horn trade. We conclude by giving

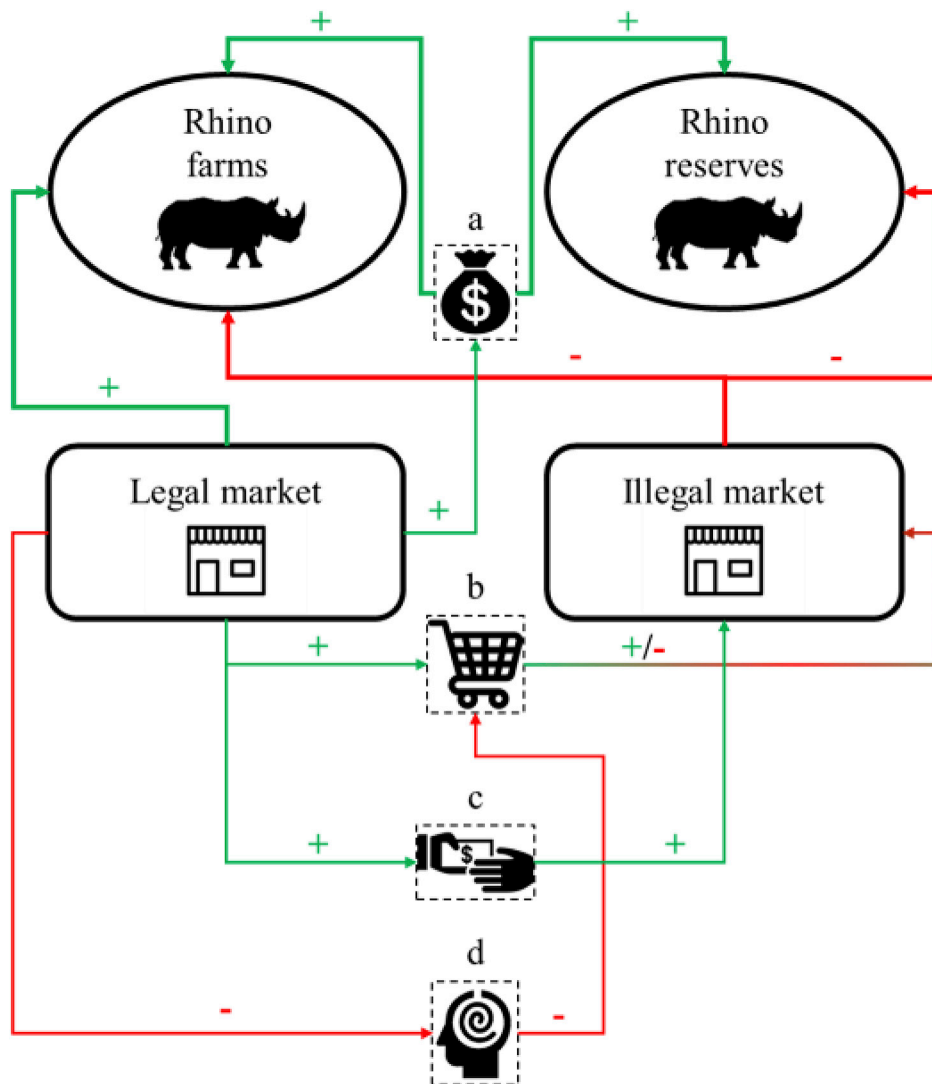


Fig. 2. Conceptual diagram of the international legal rhino horn trade scenario with farmed and wild rhino populations, legal and illegal markets, and four identified mechanisms (as discussed in the four main sections of this study): a) financial viability for private rhino owners, b) rhino horn demand, c) laundering of rhino horns, and d) behaviour of rhino horn consumers. Green arrows represent a potential positive effect (higher/larger source leads to a higher/larger destination), red arrows a potential negative effect (higher/larger source leads to a lower/smaller destination) and green/red arrows both a potential positive and negative effect. An improved financial viability for private rhino owners has been hypothesized to benefit both farmed and wild rhino populations, rhino horn demand has been hypothesized to increase with a legal market, laundering has been hypothesized to allow for an increase in illegal horn trade with a legalized market, and it has been hypothesized that programmes aimed at changing the behaviour of rhino horn consumers will be less effective with the existence of a stigma-removing legal rhino horn market. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

suggestions for future research and for a policy agenda that would benefit rhino conservation the most according to our study. In our study we focus primarily on the two African rhino species and often in the setting of South Africa (as South Africa harbours the majority of all rhinos on Earth at present), even though we acknowledge the importance of other countries with rhino populations and the situation of the more rare Asian rhino species. Nevertheless, since illegal wildlife trade is an interlinked and global system, we posit that our review provides a valid overview for the situation of all rhino species by primarily considering the world's largest rhino population as a case study.

2. Financial viability of private rhino ownership

The majority of South African rhinos (both black and white) currently live in either government-owned national parks or privately owned game reserves and farms (Child et al., 2012; Knight et al., 2015). In national parks, large amounts of money are often spent on wildlife protection, paid for by revenues from tourism as well as by affluent external donors and the state

(Annecke and Masubelele, 2016). Privately owned game reserves and farms on the other hand, need to be financially viable as a business model. For private rhino owners, the revenue from keeping rhinos on their lands traditionally comes from tourism, trophy hunting and live animal sales. When in the early 1990s the subsidy to agricultural commercial farmers stopped in South Africa, a large number of farmers reverted to game farming as South African law allowed for private ownership of wildlife (Child et al., 2012; Taylor et al., 2015). Private wildlife ownership is currently only allowed in South Africa, Namibia and Zimbabwe (Muir-Leresche and Nelson, 2000), where private wildlife owners have to abide to the national nature protection laws. Populations of large game animals have increased in southern Africa through this form of farming (Child et al., 2012). As 80% of the land in South Africa is privately owned (Cousins et al., 2008), it is thought that private ownership of rhino on these lands can play a critical role in the recovery and long-term conservation of the species (Collins et al., 2016; Rubino and Pienaar, 2017). It is estimated that 33% of the total rhino population in South Africa is now privately owned (Rademeyer, 2016; Rubino and Pienaar, 2017).

For private rhino owners, the increasing security costs of protecting their rhino from poaching pose a major problem (Rubino and Pienaar, 2020). Income from the traditional sources (tourism, trophy hunting and/or live sales) is in many cases not sufficient to cover the increased costs for protection and at the same time create a financially sustainable enterprise (Minnaar and Herbig, 2018; Rubino and Pienaar, 2017). It is estimated that in 2016, 70 of the approximate 400 private rhino owners in South Africa have removed rhinos from their land due to financial difficulties and the personal security risks posed by poachers, amounting to a loss of about 200,000 ha of land available for rhino conservation (CITES, 2016).

The problem sketched above has fuelled the plea for a lift on the trade ban and legalization of the market, with private rhino owners being prominent advocates (Private Rhino Owners Association, 2017; Rubino and Pienaar, 2020). Lifting the trade ban could enable private rhino owners to exploit an extra way of gaining revenue from keeping rhinos by selling sustainably harvested horns (Rubino et al., 2018). This increased revenue could in turn be used to pay for extra anti-poaching measures by private rhino owners. An additional advantage that is to be expected when legalizing the trade is that the viability of rhino farming will get an impulse, leading to more entrepreneurs and land-owners being interested in keeping rhinos. This will increase the population of captive rhinos, which benefits the global population of this threatened species. Although the conservation value of a captive population of rhinos is less than that of a healthy wild population (Redford et al., 2011), a captive population could be an important buffer in case rhinos become extinct in the wild.

Another frequently used argument is that tax raised from legally traded horns could flow back to the protection of wild rhino populations and can be invested in livelihood development for communities surrounding these parks, which currently form the cradle of poachers (Di Minin et al., 2015; Rademeyer, 2012). Di Minin et al. (2015) concluded in a modelling study that this reinvestment of profit from legal sales would actually be a prerequisite for a positive effect of legalizing the market on rhino conservation. Given that the black market price for rhino horn is currently between US \$ 30,000 and 65,000 per kg and rhino horn farming is profitable from approximately US \$ 11,500 per kg onwards (Rademeyer, 2016; Rubino et al., 2018), there is ample room for legal sales to yield substantial financial resources to potentially protect rhinos in such a way that poaching becomes less profitable (Collins et al., 2016; Di Minin et al., 2015). However, it is unlikely that most of the tax raised through rhino horn sales will be reinvested in wild rhino conservation, since health care, housing and education of previously disenfranchised people are politically more urgent for many African governments. Capitalist governments have independent processes of harvesting and distributing wealth, meaning that sectors that are taxed for a certain amount are not compensated with an equal amount of governmental funding. Furthermore, it is questionable whether private rhino owners are major stakeholders in wild rhino conservation or not, because they only have an indirect financial incentive to bargain with the government for a reinvestment of taxes to the protection of wild rhinos. Less poached rhino horns could of course lead to more consumers for farmed rhino horns, but the significance of this phenomenon will fade when there would be substantially more farmed rhinos than wild rhinos.

Legalizing the rhino horn trade would thus have two main advantages through the mechanism of increased revenue for rhino owners. First, the owners will have an incentive for sustaining a viable captive population of rhinos. Second, there will be money available for the protection of both private (through sustainably harvested horn sales) and wild rhinos (through taxes), which in turn can discourage poaching. However, it is unclear if a substantial amount of the raised taxes will be reinvested in the protection of wild rhinos.

3. Demand for rhino horn

The debate about whether or not to legalize international rhino horn trade often focuses on what will happen to the market demand (viz., in terms of quantity of rhino horn given current prices or potentially lower or higher prices), i.e., will the overall demand (legal, viz., supplied mainly by farms, and illegal, viz., supplied by poachers, combined) increase and how will the current illegal market respond to a legal market? To adequately answer these questions it should first be known how large the current demand for illegal rhino horn is. Some estimated the overall demand for rhino horn by looking solely at the current illegal supply, concluding that demand for rhino horn can be met with 5000 captive white rhinos through regular non-lethal harvesting of their horns in South Africa alone (Biggs et al., 2013; Milliken et al., 2009). However, there are many concerns about this estimation. First, the current illegal demand is already far greater than the current illegal supply (USAID Vietnam, 2018; USAID Wildlife Asia, 2018). The United States Agency for International Development concluded via interviewing 1400 Vietnamese people that are financially able to buy rhino horn (from five different cities that sustain a black market in rhino horn) that in Vietnam 10% of the people find it acceptable to buy or own rhino, of which 10% are currently

wealthy enough to afford it (USAID Vietnam, 2018). This suggests that there is a demand for rhino horn from about a million people in Vietnam alone. In the 14 times more numerous Chinese population, the USAID surveyed 1800 people (from six different cities that have a rhino horn black market) and concluded that 16% have purchased rhino horn in the past, of which 8% in the past 12 months (USAID Wildlife Asia, 2018). China and Vietnam combined are thus home to millions of potential rhino horn consumers. Second, Kotze (2014) argued that rhino horn farming will produce too few horns to meet the demand in the near future, considering the horn growth rate of only 6 cm per year on average (Pienaar et al., 1991) and the low reproduction rate of one calf per 3–5 years (Patton et al., 1999; Swaisgood et al., 2006). Third, Prins and Okita-Ouma (2013) argued that Biggs et al. (2013) overlooked the demand for the other four rhino species; the suggested yield of legal supply is often based on rhino farming in southern Africa and overlooks Asian rhino species, which are not currently farmed and are desired for their horns nonetheless. To conclude, current illegal demand is likely far greater than current illegal supply, with the current estimation of potential buyers far exceeding the amount a legal supply could realistically meet in the (near) future (USAID Vietnam, 2018).

Current demand for rhino horn will likely not stay the same with a legalization of rhino horn trade and it should thus be estimated how the overall demand will change. First of all, future overall demand is likely to increase with economic and population growth in Asia, regardless of rhino horn trade legalization (Tensen, 2016; Vigne et al., 2007). Furthermore, if the trade ban is lifted new forces will start to influence the demand for rhino horn as well (Fischer, 2004). An important new force is the removal of the stigma that comes with buying illegal products. Although Biggs et al. (2013) assumed that with a legal rhino horn trade *"the demand does not escalate to dangerous levels as the stigma associated with the illegality of the product is removed"*, plenty of other studies argued that the demand will likely increase significantly because of the removal of the stigma (e.g., Collins et al., 2013; Fischer, 2004; Prins and Okita-Ouma, 2013), at least for law-abiding consumers (Fischer, 2004; USAID Vietnam, 2018; USAID Wildlife Asia, 2018). Another market force that could result in an increased demand after legalization is the reawakening of old markets, particularly markets that were active in the 1970s and 1980s in Taiwan, Japan, Singapore and Yemen (Prins and Okita-Ouma, 2013), which could thus reverse the decreased demand in these old markets (Graham-Rowe, 2011). In addition to traditional consumer countries, there are also new (e.g., African) countries that sell Traditional Chinese Medicines in their drug stores and where people start to believe that wildlife products (including rhino horn) can cure diseases (Cyranoski, 2018). These new local markets are often overlooked in the estimation of demand. Moreover, a substantial increase in demand (both legal or illegal) could further promote the tragic positive feedback loop between demand and the rhino extinction rate, which is coined the Anthropogenic Allee Effect (Challender and MacMillan, 2014; Hall et al., 2008). The Anthropogenic Allee Effect indicates that when the abundance of an animal species decreases, the demand for its products will increase due to its rarity (Hall et al., 2008). Accounting for all the aforementioned market forces, the overall demand for rhino horn is expected to grow significantly with a legalized market, although the recent COVID-19 pandemic may affect people's attitudes towards using products of wild animals in unforeseen ways (Lam et al., 2020).

Ideally, with a legal market that would be supplied mainly by rhino farmers, the illegal demand for poached horns would disappear or at least become substantially smaller. Unfortunately, how the illegal demand for rhino horn will respond exactly is uncertain (Fischer, 2004). From an economic perspective, illegal traders and farmers can compete with each other in multiple ways that could either benefit or devastate rhino conservation (Damania and Bulte, 2007). From a social perspective, people that fear heavy penalties for consuming illegal products will likely shift from the illegal to the legal market when effective law enforcement is in place. The same applies to people that care about animal welfare or conservation. These three deterrents have been mentioned by 71–76% of the 242 interviewed Vietnamese illegal rhino horn consumers (USAID Vietnam, 2018), so it can be assumed that a substantial portion of the current illegal consumers will consider switching to a legal market. On the other hand, some people have a preference for illegally harvested ('wild') horns, e.g., those that prefer to buy larger horns as a status symbol and those that believe that the suffering of the animal enhances the 'potency' of the medicine (Cheung et al., 2018a; Hanley et al., 2018; Tensen, 2016). It is thus likely that an illegal market will always persist parallel to a legal market and this should not be neglected in the debate around the legalization.

Given the high likelihood of a substantially increasing demand with trade legalization, it is important to consider effective market forces to regulate this increase to avoid it leading to the detriment of wild rhino populations. Price is such a force that many studies proposed to influence the market demand (e.g., Milner-Gulland, 1993). However, the effect of price on the overall demand as well as on the illegal demand is ambiguous and may yield counterintuitive results. For the overall demand, lower prices make on the one hand rhino horn affordable to more buyers, which could lead to an increase in overall demand (USAID Vietnam, 2018). On the other hand, a lower price could also weaken the effect of the Anthropogenic Allee Effect, i.e., a lower price makes it less attractive for people that are after luxurious or rare products. For the illegal demand, Biggs et al. (2013) argued that lower prices in the legal market will likely diminish it. While it is true that a lower legal price can motivate people to move from the illegal to the legal market, it is not always the case. Like with marijuana, a legal market is more likely to reduce the illegal market when its price can compete with the illegal market (Morris, 2018). Wildlife product markets are very different from perfect competition markets, suggesting that lowering the price may not be a good strategy, as it is hard to make sure that the price in the legal market is always lower than the illegal price. For example, farmed tiger bones are 50–300% more expensive than from poached tigers (EIA, 2013). Also, illegal elephant tusks were sold for only a third of the price of legal tusks (Fischer, 2004). As for rhino farming, the minimum price for rhino horn to be profitable is approximately US \$ 11,500 per kg (Rubino et al., 2018). If crime networks are able to supply horns at a lower price it is still likely that consumers will buy illegal products. However, 63% of the 242 Vietnamese illegal rhino horn consumers would be willing to pay more if the product is scientifically tested by a trusted supplier and 72% would still buy rhino horn with a 10%

increase in price (USAID Vietnam, 2018). So a substantial portion of the current illegal consumers is likely to move to the legal market, even if legal prices cannot fully compete with illegal prices. On the other hand, consumers often overstate their willingness to pay a premium (Katt and Meixner, 2020). Furthermore, these results also show that price is only a minor concern to current rhino horn users (USAID Vietnam, 2018; USAID Wildlife Asia, 2018). This is backed up by the notion that demand for rhino horn is inelastic to price changes (Crookes and Blignaut, 2015; Milner-Gulland, 1993). For instance, the demand for rhino horn rose substantially in Yemen despite a 40% increase in price within four years (Vigne et al., 2007) and modelling studies have suggested that reducing the price of rhino horn will not curb rhino poaching (Crookes, 2017). These results suggest that the overall demand for rhino horn is insensitive to an increase or decrease in price.

The improbability of price being able to control the demand urged researchers to look into social instead of economic forces. These social forces turned out to be more effective than price in a modelling study about the rhino horn case (Crookes and Blignaut, 2015). First, the consumption motives of rhino horn buyers in Southeast and East Asia should be known to be able to adequately respond to it. According to results of interviews with 242 Vietnamese illegal rhino horn buyers, the two main drivers of purchase are that rhino horns "are worth their price no matter how expensive" and "indicate wealth, power and social status" (USAID Vietnam, 2018). The status and cultural pride of the elite increases when the prices of 'must-have' status symbol products are high. The way to reduce the demand of these Vietnamese people are for example strategies related to heavy penalties and a focus on animal cruelty (USAID Vietnam, 2018). In a similar study, 140 Chinese illegal wildlife product buyers primarily mentioned that rhino horn "brings good health" and "cures illness" (USAID Wildlife Asia, 2018). In addition, an underestimated driver for buying rhino horn in China is the art and antiques market (Gao et al., 2016). Therefore, eliminating concerns about modern medical practices and increasing public awareness about animal conservation are key to reducing wildlife consumption in China. Understanding and anticipating the underlying consumption motives of rhino horn buyers thus seems more helpful in reducing demand than price changes.

In short, demand for rhino horn is currently much larger than supply and is expected to increase with economic and population growth in Asia (Tensen, 2016; USAID Vietnam, 2018; USAID Wildlife Asia, 2018; Vigne et al., 2007). With legalization of the market, demand is likely to increase further (in current, old and new markets) when the stigma around buying rhino horn is removed and potentially also due to the Anthropogenic Allee Effect (Challender and MacMillan, 2014; Hall et al., 2008). It will most likely be impossible to satisfy the demand with legal horns alone, due to a preference of some consumer groups for illegal ('wild') horns and the potentially lower price of illegal horns (Cheung et al., 2018a; Hanley et al., 2018). The demand for illegal horn could however be reduced through a simultaneous increase in law enforcement combined with severe penalties for buying illegal horn (Tensen, 2016).

4. Laundering of rhino horns

The issues and debates about the demand for rhino horn suggest that legal and illegal markets are likely to co-exist after trade legalization, not only for consumers but also for suppliers (Fischer, 2004). Illegal rhino horn traders are likely to remain in business after trade legalization and could start laundering their products into the legal market (Collins et al., 2013; Fischer, 2004). This is the case with legal ivory trade as well, where 'ghost ivory' (post-1947 ivory being sold as pre-1947 ivory) and 'look-alikes' (e.g., elephant ivory fraudulently mislabelled as mammoth ivory) are being sold to the unsuspecting and uneducated buyers (CITES, 2019; Collins et al., 2017). Under such conditions, a legal market can actually give an incentive to illegal suppliers by lowering the chances of being caught in an illegal exchange, as corruption reduces the rhino horn confiscation rate (Fischer, 2004; Van Uhm, 2018a). For example, corruption amongst government officials, e.g., via threats and commission payments (Collins et al., 2016; Rademeyer, 2012), can allow for the entering of illegal products into legal markets (Bennett, 2015). A similar situation was found for the legal trade of ivory, in which eight of the twelve African countries that are home to the majority of elephant populations belong to the top 40% of the world's most corrupt countries (Transparency International, 2013; UNEP et al., 2013).

Widespread corruption exists and expands to all nodes in a trade chain (Bennett, 2015). Examples of wildlife trade related corruption exist in justice, economic and political systems (Wyatt et al., 2018), where acts of corruption on an individual level include bribes, patronage, diplomatic cover and permit abuse (Corruption Tracker, 2011; Nshuli, 2013; Walker, 2009; Wyatt et al., 2018). For example, a number of rhinos were actually poached by people who were employed to guard them in Africa during the 1970s and 1980s (Fischer, 2004). More recently in South Africa's Kruger National Park, police officers and rangers were directly involved in poaching (Anderson and Jooste, 2014). Similar situations were discovered in other rhino poaching hotspots in Africa as well (Smallhorne, 2013). For example in Kenya, the stronghold of the eastern black rhino (containing 87% of the subspecies' population), the internal government corruption worsened the problem of population decline (Anderson and Jooste, 2014).

Due to the aforementioned effects of corruption and laundering, legalizing rhino horn trade would at least need a highly regulated trading system if rhinos are to be preserved. A Central Selling Organization, the system with the largest control, was proposed by Biggs et al. (2013). To reduce the effects of corruption, they suggested to shorten the market chain between suppliers and buyers (Biggs et al., 2013). However, an illegal supply can in reality always be present as corruption within the Central Selling Organization could still support laundered poached horns to end up on the legal market (Bennett, 2015; Fischer, 2004). This was the case in the highly controlled diamond trade, where an estimated 5–10% of the world's legal diamond market consisted of 'blood diamonds' (Baker, 2015). Considering the huge demand for rhino horn and the small rhino population (USAID Vietnam, 2018), a potential 5% illegal horns would already be problematic for the survival of the

species. Biggs et al. (2013) also proposed DNA profiling to track the legality of individual horns. However, this will not only inhibit the potential use of synthetic horns, but also that of buffalo horn and wood that circulate as 'rhino horn' and which currently comprise a substantial proportion of the market (Collins et al., 2013; Save the Rhino, 2016a). The demand for genuine rhino horn could therefore increase, together with the negative consequences (Collins et al., 2013). Furthermore, DNA profiling will likely increase the price of legal rhino horns.

In short, corruption is unfortunately a large problem worldwide, also along the rhino horn trade route in Africa and Asia (Emslie and Brooks, 1999; Wyatt et al., 2018). The illegal supply of rhino horn is therefore likely to increase when legalizing international rhino horn trade due to laundering and corruption (Van Uhm, 2018a), even with a highly regulated trading system (Bennett, 2015; Collins et al., 2013; Fischer, 2004).

5. Long-term behavioural change of rhino horn consumers

It is generally thought that the ultimate solution to stop rhino poaching lies in a change of the consumers' behaviour (Litchfield, 2013). The demand can be drastically reduced if not eliminated, by creating a uniform morality that it is wrong to purchase products that have such a clear negative effect on the survival of a threatened species and by providing alternatives to fulfil the need for the product (Litchfield, 2013). This can only be accomplished by a global change in consumer behaviour. Despite the efforts of non-governmental organisations and conservation incentives (Biggs et al., 2013; Holden et al., 2019; St John et al., 2010), this has not been achieved yet, as illustrated by the high poaching rates and large demand for rhino horn and other wildlife products (Save the Rhino, 2019; USAID Vietnam, 2018; USAID Wildlife Asia, 2018).

Environmental awareness programmes are believed to increase knowledge and concern (Sampei and Aoyagi-Usui, 2009), but there seems to be a value-action gap remaining in the general public (Kollmuss and Agyeman, 2002). Furthermore, the outcome of programmes to reduce consumer demand for wildlife products are only known for about 37% of the programmes, and the ecological impact has been reported for only 9% (Veríssimo and Wan, 2019). An extra complication in the rhino poaching crisis is the scale of the problem. While local awareness programmes can have strong positive effects on local environmental problems, e.g., overexploitation by subsistence hunting (Campos-Silva et al., 2017) or human wildlife conflicts (King et al., 2017), the illegal rhino horn trade represents an international conservation crisis that involves many stakeholders other than the local consumers (Milliken and Shaw, 2012; Sutherland et al., 2014). Especially with the current rise in popularity of Traditional Chinese Medicine, as promoted by the Chinese government (Cyranski, 2018; Master, 2019) and supported by the World Health Organisation (Matthews-King, 2019; WHO, 2013), the market for perceived medicinal uses of rhino (and other wildlife) products is increasing (Master, 2019; Tang et al., 2018). Furthermore, half of all planned purchases of rhino horn products in Vietnam were motivated by the advice of a traditional medical doctor (USAID Vietnam, 2018). Current rhino horn buyers in Vietnam indicated that although they were aware of the extinction risk for rhinos, they do not feel responsible for the killing themselves as they "are one of many consumers", "do not kill the animals themselves" or "do not buy products regularly nor in high quantities" (USAID Vietnam, 2018). These beliefs in combination with the commercial and governmental lobby for the use of Traditional Chinese Medicine make it difficult to campaign for the exact opposite. However, the incrimination of pangolins as the origin of the COVID-19 pandemic may put traditional misuse of wild animals in a new unfavourable light (Lam et al., 2020).

In addition to environmental awareness programmes, law enforcement on the consumer side of the trade could also change the behaviour of potential buyers of rhino horn (Olmedo et al., 2018). Buyers of rhino horn in both Vietnam and China indicated that the top deterrents for future purchases are the link of rhino products to organised crime and the personal risk of violating the law (USAID Vietnam, 2018; USAID Wildlife Asia, 2018). When prioritized by the governments of consumer countries, more severe penalties for rhino horn owners could be implemented and effective law enforcement established. This has the potential to change the behaviour of consumers in both the short and long term (Olmedo et al., 2018).

Legalizing the market can be considered the complete opposite of campaigning to reduce consumer demand. By making it legal to sell and buy rhino horn products, the stigma around these products is removed and a signal that it is acceptable and useful to buy rhino horn is implicitly given (Biggs et al., 2017b). This may hamper critical thinking by consumers about their own behaviour and limit the impact of education programmes on the matter. As a comparison, legalization has increased the demand for other products in the past (see Appendix). For marijuana the total consumption rose after legalization due to an increase in new users and extended consumption by regular users (Pacula, 2010). Furthermore, after legalizing crocodilian skin trade, the demand remained robust for the high-end products (alligator and crocodile skins) and increased dramatically for the lower-cost (caiman) products (MacGregor, 2002).

In the long term, involving consumers and informing them about the consequences of their choices is an essential aspect of saving the rhino as a species (Biggs et al., 2017a). This can perhaps best be achieved by emphasizing the lack of efficacy of rhino-based Traditional Chinese Medicine by engaging professional medical doctors in China, who have essentially the same ethical standards as their counterparts in the U.S.A. (Nie et al., 2015). In the long run, such demand-reduction programmes may be more cost-effective and better able to tackle the complexity of the trade than increasing anti-poaching enforcement, independent of the initial price of wildlife products or ecological parameters (Challender and MacMillan, 2014; Holden et al., 2019). However, for demand-reduction programmes to become truly effective, conservationists need to adopt more rigorous impact evaluation strategies ('t Sas-Rolfes et al., 2019; Olmedo et al., 2018; Veríssimo and Wan, 2019). Nevertheless, given the current critical situation of rhino populations, more short-term measures, e.g., law enforcement (Olmedo et al., 2018), should

be implemented as well to ensure the survival of the rhino species. In either scenario, legalizing the rhino horn market will likely hamper any demand-reduction strategy.

6. Discussion

Evaluating the effects of the four mechanisms separately on the rhino population in the situation of a legalized trade (Fig. 3), we can summarize that 1) an improved financial viability of private rhino ownership will likely have a positive effect on the captive rhino population in countries that allow private wildlife ownership, i.e., South Africa, Namibia and Zimbabwe (Muir-Leresche and Nelson, 2000). However, it is questionable if this will lead to a substantial conservation benefit for wild rhino populations. 2) It will most likely be impossible to satisfy the demand with legal horns alone in the near future (Tensen, 2016; USAID Vietnam, 2018; USAID Wildlife Asia, 2018). Therefore, legal and illegal trade circuits would probably exist in parallel due to a preference of some consumer groups for illegal ('wild') horns and the potentially lower price of illegal horns (Cheung et al., 2018a; Hanley et al., 2018; Rubino et al., 2018). 3) Corruption is widespread and likely to remain present in all nodes of the trade chain and can stimulate the illegal trafficking of poached rhino horns through laundering channels into the legal market (Van Uhm, 2018a), thereby keeping the poaching incentive alive. Furthermore, even in a tightly controlled market system corruption will most likely still allow for an influx of poached horns from African countries, as is the case with blood diamonds and ivory (Baker, 2015; Bennett, 2015; Fischer, 2004; Wasser et al., 2015). 4) Behavioural change of rhino

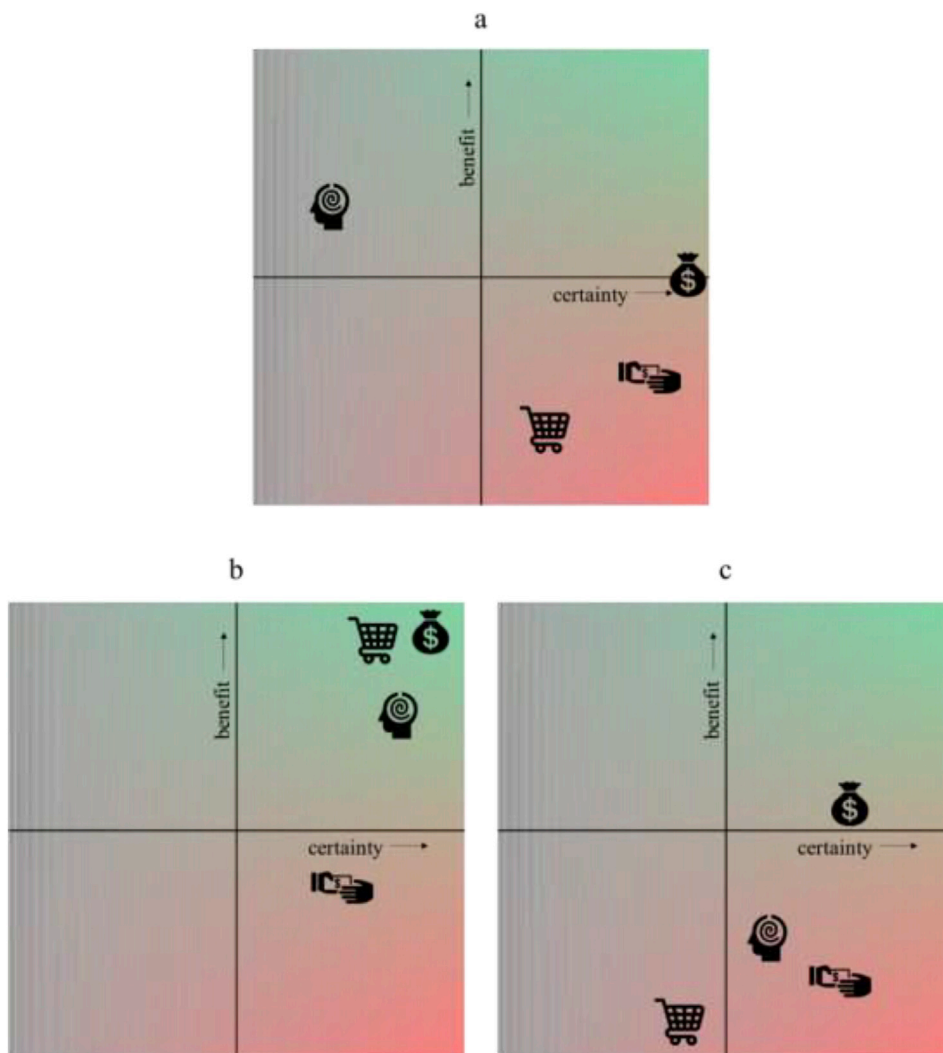


Fig. 3. The mapped conservation benefit (y-axis, from red to green) and certainty (x-axis, from grey to transparent) of the four discussed mechanisms (financial viability for private rhino owners, rhino horn demand, laundering of rhino horns, and behaviour of rhino horn consumers) on rhino populations: a) business as usual scenario for wild rhinos, b) legal trade scenario for farmed rhinos, and c) legal trade scenario for wild rhinos. The symbols are identical to Fig. 2. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

horn consumers has often been suggested as the ultimate solution to stop rhino poaching, but legalizing the rhino horn market could likely negatively affect efforts taken in this direction (Biggs et al., 2017b). By legalizing the rhino horn market the stigma around buying illegal products of poached and threatened animals will be removed, which could cause an overall increasing interest in rhino horn (as happened for crocodilian skins and marijuana) in the future (MacGregor, 2002; Morris, 2018; Prins and Okita-Ouma, 2013).

Cases of trade legalization from the past show that the legal commercialization of animal products can go both ways regarding species' conservation; with a (potentially) positive effect in the case of bison meat, crocodilian skins and trophy hunting, but with a (potentially) negative effect for elephant ivory and lion bones (see Appendix). To determine how the rhino populations will respond to the legalization of international rhino horn trade, it needs to be evaluated what makes a legal animal product market sustainable to benefit species conservation (SCBD, 2004; Tensen, 2016). Tensen (2016) determined that wildlife farming (to supply legal products) can benefit species conservation only if five different criteria are met. First, consumers should show no preference for products originating from wild-caught animals. This likely does not apply to all buyers of rhino horn, as larger horns from poached rhinos function better as status symbols and horns from rhinos that suffered are believed by some to increase their medicinal potency (Cheung et al., 2018a; Hanley et al., 2018). Second, a substantial part of the demand should be met and the demand should not increase due to a legalized market. This probably does not apply to rhino horns either, because demand is unlikely to be met by rhino farming in the near future (USAID Vietnam, 2018; USAID Wildlife Asia, 2018). Third, legal products should be more cost-efficient in order to combat the black market prices. This criterion likely does not apply to rhino horn as rhino horn farming was estimated to only be profitable without subsidies when horn is sold at a minimum price of US \$ 11,500 per kg (Rubino et al., 2018). In contrast, poached rhino horn would probably still be profitable at a much lower price if the risks of rhino poaching do not increase substantially compared to the current situation (Conrad, 2012). Fourth, wildlife farming should not rely on wild populations for restocking. This would likely hold true for rhino farming if captive populations are well protected, because already more than 30% of all South African rhinos are privately owned and due to the aridification of farming grounds more area is expected to become available for rhino farming in the near future (Rademeyer, 2016; Rubino and Pienaar, 2017). Fifth, laundering of illegal products into the commercial trade should be absent. This will likely not be the case for rhino horn farming given the enormous value of the product, the trade network that is already involved and the corruption that is present in many African and Asian countries (Collins et al., 2013; Fischer, 2004; Wyatt et al., 2018). In short, the case of rhino horn farming complies with only one of the five criteria that are needed for wildlife farming to benefit species conservation. According to Tensen (2016) even a minor violation of any of the criteria will result in a negative outcome of wildlife farming to species conservation, but even if a minor violation of these criteria could be compensated for by the other criteria then violating four out of five criteria will likely not result in a benefit for rhino conservation from farming rhino commercially. Similar to this prediction for the rhino horn trade, a modelling study deemed sustainable harvesting of elephant ivory to be impossible (Lusseau and Lee, 2016), and an assessment framework study deemed pangolin farming to be unable to yield a conservation benefit (Challender et al., 2019; Phelps et al., 2014).

Providing recommendations about scenarios that have never happened before (viz., legalizing international rhino horn trade) is challenging, as this is inherently coupled with a lack of empirical data. As a consequence, all our conclusions could only be determined with a certain level of certainty (Fig. 3). In order to increase the certainty of inferences that can be made about potential effects of legal horn trade on wild rhino populations, we would suggest to focus future research on three topics. 1) Quantify and describe the current demand for rhino horn and the potential demand for legal rhino horn better. Although recent studies have taken important steps in this direction (e.g., USAID Vietnam, 2018; USAID Wildlife Asia, 2018), there is potential to better clarify the number of (potential) consumers, the amount of rhino horn they (want to) consume per time unit, the amount of money they are realistically willing to pay per unit of legal and illegal rhino horn, their reasons for purchasing rhino horn, and under which circumstances they are willing to switch to a legal market. This can be achieved through surveys and undercover intelligence in Southeast Asia. This information is critical to make more certain conclusions about whether or not there is potential for an illegal rhino horn market to exist in parallel to a legal market. 2) Rhino horn demand-reduction programmes should adopt more rigorous impact evaluation strategies. As demand-reduction is often a long-term process, studies should ideally be designed in such a way that it allows for demand-reducing strategies to be effective over multiple years and that the impact of the strategies are quantitatively evaluated for multiple times during this period. Because these programmes are arguably the only solution to stop the demand for rhino horn entirely and because these are likely to take a long time to take effect, efforts taken in this direction should be properly chosen, evaluated and ultimately optimized. 3) Economic and political avenues should be explored and substantiated about how a legal market of farmed rhino horns could benefit wild rhino populations in national parks and private game reserves. The financial benefit for rhino conservation related to farmed rhinos is clear, but it is not yet clear through which mechanisms this could benefit wild rhino populations. As both a healthy captive and wild population of rhinos could be important in preserving these species during the Anthropocene, the benefit of legal horn trade should be clear for the entire gradient of captive to wild rhino.

7. Conclusion

A legal rhino horn trade will most likely not be able to satisfy demand in the near future and will likely even lead to an increase in demand (Fig. 3c). Omnipresent corruption in countries along the rhino horn trade routes will, together with demand for illegal ('wild') horns, facilitate the co-existence of legal and illegal markets. In addition, legalization will remove

the stigma associated with the consumption of illegal products and will therefore counteract long-term behavioural change programmes targeted at consumers, which is arguably the ultimate solution to wildlife crime. Only one of our four considered mechanisms (an increased revenue for private rhino owners) will likely have a positive impact on rhino conservation, but primarily for the captive rhino populations in countries that allow private wildlife ownership. However, this one minor positive impact for rhino conservation will most likely not be able to offset the other negative impacts of trade legalization (Fig. 3c). Based on this review, we therefore recommend not to legalize an international trade in rhino horn. Instead, we suggest to focus efforts on creating well-protected 'safe havens' for the remaining wild rhino populations to bridge the current period of high demand (short-term approach) and on programmes aimed at reducing rhino horn demand (long-term approach). We acknowledge that this strategy is not perfect, because rhinos are still poached in well-protected reserves and behavioural change programmes still need to improve and prove their effectiveness, which is why our proposed strategy requires substantial (international) effort.

One could argue that rhinos should be preserved as a species, instead of prioritizing rhinos in the wild. Focusing on preserving rhinos in the wild through a legal trade ban has the likely consequence that far less captive rhinos will be kept. Even though healthy wild animal populations are generally thought to have a higher conservation value than captive populations (Redford et al., 2011), if in spite of all efforts rhinos do become extinct in the wild, then it might complicate future reintroduction efforts to have fewer captive rhinos. This is a risk that should not be underestimated, which makes our suggested short-term approach of creating well-protected 'safe havens' for wild rhino populations all the more relevant (e.g., Welgevonden Game Reserve, 2020). Regardless of one's opinion to legalize an international rhino horn market or not, both anti- and pro-trade strategies to save the rhino from extinction are likely only possible after corruption has been reduced, more rhinos have been bred and illegal demand has been reduced (Committee of Inquiry, 2016). The debate about legalizing the rhino horn market should thus not prevent stakeholders from working together to achieve these goals (Sandbrook et al., 2019).

Authors' contributions

B.S., J.A.J.E., R.J.M.N., H.H.T.P., F.v.L. and I.M.A.H. conceived the ideas; J.A.J.E., R.J.M.N. and Y.X.G.W. designed the study; Y.X.G.W., R.J.M.N., J.A.J.E., B.S., I.M.A.H., H.H.T.P. and F.v.L. collected the literature; J.A.J.E., Y.X.G.W. and R.J.M.N. wrote the manuscript; J.A.J.E. led the writing of the manuscript. All authors (J.A.J.E., R.J.M.N., Y.X.G.W., B.S., F.v.L., I.M.A.H., W.M.M. and H.H.T.P.) contributed critically to the drafts and gave final approval for publication. All authors declare that they have no conflict of interest.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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