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Review

Challenges and perspectives on tackling illegal or unsustainable wildlife trade

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ABSTRACT

Illegal or unsustainable wildlife trade (IUWT) currently presents one of the most high-profile conservation challenges. There is no "one-size-fits-all" strategy, and a variety of disciplines and actors are needed for any counteractive approach to work effectively. Here, we detail common challenges faced when tackling IUWT, and we describe some available tools and technologies to curb and track IUWT (e.g. bans, quotas, protected areas, certification, captive-breeding and propagation, education and awareness). We discuss gaps to be filled in regulation, enforcement, engagement and knowledge about wildlife trade, and propose practical solutions to regulate and curb IUWT, paving the road for immediate action.

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1. Introduction

Illegal or unsustainable wildlife trade (IUWT) affects numerous species, ecosystems, and human societies (Cardoso et al., 2021; Morton et al., 2021). IUWT can cause direct and indirect harm to target and non-target species, loss of ecosystem services, act as a conduit for potentially invasive species and a pathway for zoonotic diseases, and disrupt and corrupt local and global economies (Cardoso et al., 2021). It is a lucrative illicit activity: estimates range from 7 to 23 billion USD per year excluding logging and fisheries (Nellemann et al., 2016). IUWT permeates the Tree of Life – animals, fungi, plants, and their parts and derivatives, are traded worldwide to be used as food, fuel, for construction and furniture, as pets, medicine, for ornamentation or religious rituals (Fukushima et al., 2020). There is no "one-size-fits-all" strategy for tackling IUWT because the scales and drivers of trade are diverse, from basic subsistence in local communities to high-profit international business. A variety of disciplines and actors are needed for any counteractive approach to work effectively and to guarantee native species persistence, ecosystem function, and human well-being.

People's demand for wildlife and derived products has grown substantially (Zhang et al., 2008) and the internet facilitates wildlife trade, especially illegal. The clear shift in wildlife trade from traditional physical markets towards online platforms (Lavorgna, 2014) has brought additional challenges to curb IUTW. The COVID-19 outbreak has not shown to diminish IUWT: for the pet trade, for example, there is no clear evidence that the volume of online trade decreased during the pandemic (Morcatty et al., 2021), and an increase in illegal hunting has been recorded in some parts of the world (McNamara et al., 2020).

Tackling IUWT and mitigating its impacts requires a complex, multidisciplinary strategy at global, national, and local levels that can address a wide range of challenges. Laws may be insufficient, out of data, ignore relevant science or be inadequately enforced; furthermore, 'legally harvested' does not necessarily mean 'sustainably produced' or 'sustainably managed'. There are concerns that sustainable trade is hard to achieve in many cases, particularly given the systemic lack of scientific data on the status of wild populations and/or the effects of trade (Marshall et al., 2020).

Here, we list challenges, describe some available tools and propose actions to regulate and curb IUWT, paving the road for immediate action.

2. Challenges in tackling IUWT

2.1. Patterns of consumption

Diverse motivations stand behind the consumption of wildlife and its products and derivatives, from subsistence and construction purposes (Fukushima et al., 2020), to medicine (Cheung et al., 2021), spiritual and religious practices (Everard et al., 2019), coming of age ceremonies (Goldman et al., 2013), as pets (Bush et al., 2014), ornamental plants (Hinsley et al., 2018) or as symbols of social status (Lee et al., 2020).

Efforts to change behaviors, some deeply rooted in traditional or cultural practices (Thomas-Walters et al., 2021), in pursuit of a conservation goal can be challenging (Manfredo et al., 2017). Failing to consider deeply held social and cultural motivations may result in conservation policies that are misaligned or conflict with stakeholder needs (Swan and Conrad, 2014). Value alignment can be decisive for the success of conservation programs (Chapman et al., 2019). In particular, it is necessary to understand consumer preferences and motivations (e.g., by demographics), key attributes of species in demand, the influence of price, a willingness to accept substitutes, and the social dynamics of consumption (Challender and MacMillan, 2014; Feddema et al., 2021; Macdonald et al., 2021).

2.2. Local communities

Indigenous people and traditional local communities play a central role in wildlife trade issues, since approximately a quarter of the world's land is owned or managed by them (IIED and IUCN-SULi, 2019). When sufficient revenues from legal and sustainably managed trade accrue to local communities, they can support the survival of traditional knowledge and culture, return equitable benefits, and help finance needs (Cooney et al., 2015). However, this does not always happen, and only a small proportion of revenues from trade may reach the communities involved (Dzvimbo et al., 2018).

Even though community engagement is already internationally recognized as important in the global effort to tackle IUWT, strategies that involve local communities are complex and take time to execute, resulting in few such initiatives being implemented (IIED and IUCN-SULi, 2019). It is necessary to avoid the most common pitfall in community engagement: the oversimplification or failure to understand the complexity of local views and socioeconomic statuses (Lichtenfeld et al., 2019); and instead, also to consider the balance between individual and community benefits and costs (Biggs et al., 2017a). Although community-based approaches to tackling IUWT may not be a silver bullet that will end the wildlife-trade crisis (IIED and IUCN-SULi, 2019), empowering and engaging communities, and providing local people a motivation to protect wildlife can reduce corruption risk and enhance law-enforcement efforts (Cooney et al., 2017). These motivations can be either financial or non-financial, involving different strategies such as strengthening the sense of stewardship over wildlife, increasing the community ownership rights and/or capacity to use, manage and benefit from wildlife, participation in Payments for Ecosystem Services (PES) schemes, or securing jobs related to ecotourism or wildlife management (Cooney et al., 2017; Roe, 2015). Unfortunately, many of these initiatives have been hampered or interrupted by the COVID-19 pandemic (Golar et al., 2020; Hockings et al., 2020; Rondeau et al., 2020).

2.3. Marketplaces

Traditionally wildlife was exclusively traded in physical areas ranging from city markets, border markets, trading hubs at ports, and stores (Zhang et al., 2008). Physical markets are still prevalent worldwide, especially for the trade of live animals, meat and wildlife-based products for traditional medicine (Zhang et al., 2008). However, the internet is facilitating a rapid increase in the quantity and diversity of traded wildlife (Sung and Fong, 2018; Marshall et al., 2020), connecting traders and buyers in unprecedented ways (Vemuri and Siddiqi, 2009; Siriwat and Nijman, 2020). Wildlife is illegally traded in abundance on publicly accessible websites, surface web platforms, including online auction and social media sites (Sung and Fong, 2018; IFAW, 2018) and on private messaging apps (Sánchez-Mercado et al., 2020) though it remains negligible on dark web marketplaces (Harrison et al., 2016).

Information online is largely unregulated and can be difficult to monitor (Stringham et al., 2020), and the borderless nature of cyberspace means that online wildlife transactions often traverse multiple territories, creating jurisdictional challenges for law enforcement (Lavorgna et al., 2020). Furthermore, statements in online advertisements are often difficult to verify without direct access to the product or documentation (IFAW, 2018; Sharma et al., 2019), and establishing trade legality is problematic unless clear regulations exist (Sung and Fong, 2018).

2.4. Legal aspects

Domestic laws determine the nature, scope and consequences of wildlife offences (UNODC, 2020) and implement compliance with

international treaties (Price, 2017). Although not the reality in many countries, laws should not only confront IUWT but also support demonstrably sustainable use and conservation of natural resources.

Although the Convention on Biological Diversity (CBD) (https://www.cbd.int/) is a widely adopted international conservation agreement aiming to ensure the sustainable use of biodiversity, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) remains the most important international instrument for regulating and documenting international trade in wildlife (Harfoot et al., 2018; Shepherd et al., 2020). However, CITES, like all international agreements, can only be effective when properly implemented by its signatory countries, and compliance and enforcement efforts have not always been consistent (Challender and MacMillan, 2014).

There are a number of regional conventions that address wildlife trade issues (Cooper and Rosser, 2002; Trouwborst et al., 2017), including the Specially Protected Areas and Wildlife (SPAW) Protocol to the Cartagena Convention (https://www.unep.org/cep/what-we-do/specially-protected-areas-and-wildlife-spaw), the Convention on Migratory Species (https://www.cms.int/), the EU Birds and Habitats Directive (Fleurke and Trouwborst, 2014), as well as treaties devoted to specific taxa (e.g. Saladin, 2020). Misinterpretation and lacking of understanding about how these legal instruments work, how they interact, and what their limitations are, are increasingly becoming challenges to overcome (Trouwborst et al., 2017).

2.5. Enforcement aspects

Enforcement of laws against wildlife crime is required at both the domestic and international level. As IUWT is a transnational issue, a global effort is required to address it (Guynup et al., 2020). The shift of actors and legalities along the wildlife trade chain requires special attention, particularly in transnational cases. Formal laws sometimes can conflict with local social norms, and perceptions of the severity of legal violations also vary ('t Sas-Rolfes et al., 2019). Challenges vary among jurisdictions and countries, and enforcement effectiveness may be constrained by available resources, lack of trust, and capacity (Arif-fin, 2015). Unless enforcement officers are trained as specialists – as happens in relatively few countries (Polner and Moell, 2016) – they may lack necessary taxonomic, and legislative knowledge to effectively enforce wildlife protection laws.

2.6. Scientific knowledge

Conservation actions and policies, including those based on curbing IUWT, must have a strong scientific basis. However, basic data on such issues as species' identification and geographical distribution, population trends, and ecological and life-history traits are still missing for many traded taxa – particularly those less charismatic, such as many invertebrates, plants and fungi (after Cardoso et al., 2011). Studies on the effects of exploitation on populations are extremely rare due to lack of resources, yet are crucial to design efficient and sustainable conservation or enforcement strategies. Broad conclusions about wildlife trade, unless fully backed by scientific evidence or based on taxonomic and geographically biased data, can misinform policy makers, misguide conservation efforts and hamper biodiversity conservation ('t Sas-Rolfes et al., 2019; Natusch et al., 2021).

3. Available tools to tackle IUWT

3.1. Bans and quotas

Bans have been used as an emergency brake on unsustainable use, as a response to severe cases of species endangerment (e.g., ban in ivory trade, Underwood et al., 2013), or as a response to disease outbreaks (e.g. Ebola and COVID-19 outbreaks, Bonwitt et al., 2018; Xiao et al., 2021 respectively). Yet, bans or any trade regulation must be accompanied by public education efforts, and when applicable, by appropriate mitigation programs and viable cultural substitutes, while also considering local social and economic aspects (Koh et al., 2021). Some argue that simple trade bans may produce adverse conservation outcomes (Challender and MacMillan, 2014; Weber et al., 2015) by discouraging sustainable harvesting (Biggs et al., 2013), exacerbating poaching and attracting organized crime ('t Sas-Rolfes, 2000), or leading to food insecurities and economic shocks (Booth et al., 2021).

Quotas have been extensively used to avoid over-exploitation and population decline for different species used for several purposes (e.g., harvesting for pet trade, see Natusch and Lyons, 2012; and for hunting, see Booth et al., 2020). Most prominently, fishing quotas are imposed in many regions with mixed results (Melnychuk et al., 2021). Any quotas should be based on robust data and methods (Janssen and Chng, 2018; Bennett et al., 2021), adequately managed (e.g., adoption of bycatch mitigation techniques in fisheries) and transparently operated (Dumenu, 2019) to avoid abuses or exceedance in practice (Nijman and Shepherd, 2015).

3.2. Protected areas, certifications and captive-breeding

Protected areas and indigenous territories can prevent wildlife from being poached, or alternatively be a place for sustainable exploitation. For example, expanding the existing Marine Protected Areas network under effective management and surveillance globally can support sustainable fishing (Cabral et al., 2020) if effectively managed and patrolled, respecting local fishing communities - particularly if these areas include spawning aggregation sites (Grüss et al., 2014). Protected areas under Indigenous control can also result in positive conservation outcomes, with deforestation remaining at low levels while implemented management systems avoid wildlife overexploitation (ICCA Consortium, 2021). Cooperative resource management by countries, legal operators, and nongovernmental organizations, including through Regional Fisheries Management Organizations, can reduce illegal activities (Hutniczak et al., 2019). Understanding the interrelationship between market dynamics and population declines (Milner-Gulland and Clayton, 2002), as well as knowledge of species' biological traits, local harvesting practices and trade regulations, is essential (USAID Wildlife Asia, 2019).

Certification can be a market tool to reduce over-harvesting of resources such as timber (Damette and Delacote, 2011) or to attest to the legality and sustainability of trade in wild-caught or captive-bred specimens. It requires regular monitoring and compliance review, and does not garantee reduced demand (Ebeling and Yasué, 2009).

Providing legal and sustainable alternatives to wildlife sources, such as wildlife farming, can be applicable to multiple species (Wang et al., 2019). Supply-side approaches like captive breeding and propagation have been promoted by some as solutions for alleviating pressure on wild populations (Tensen, 2016; Wang et al., 2019) but can be subject to abuses. Captive-breeding programs may lead to a reduction in prices and reduce the incentives for illegal trade, particularly if markets previously relied only on wild-collected specimens, but only under specific conditions.

Programs should present reliable certification that founder populations were legally acquired or collected. Their first organisms can originate from the wild if no other viable alternatives exist, but preferably be sourced from seizures, zoos, aquaria or herbaria. Ultimately, care should be taken to avoid using specimens that might have been laundered through other sources. Special care should be taken for effective regulation of harvesting from the wild for new genetic stock and caution about genetic identity and health of released farmed individuals. Selectively-bred variants can lead to a higher desirability of commercially produced individuals (Evers et al., 2019); promotion of appealing traits or health may be vital to attract consumers who otherwise see captive-bred specimens as lower value than their wild counterparts. However, any pressure towards alternatives must be

presented in culturally acceptable ways (Davis et al., 2016). As captive breeding and propagation may "legitimize" the demand for wildlife products (Rizzolo, 2021), raising public awareness can help to avoid its unsustainable increase. Educational activities can be held in captive breeding/propagation facilities. Uniquely tagging specimens or providing reliable documentation to end-users are necessary to avoid laundering of wild-collected specimens (Tensen, 2016; Janssen and Chng, 2018). Although captive breeding and propagation regulations may need to be made simpler to promote an economically rewarding activity that benefits both local economies and wildlife, they should implement rigorous biosecurity standards to avoid zoonotic disease transmission.

Production costs, including certification fees, vary widely depending on the species involved. Hygiene and welfare issues must also be considered by regulated facilities (Bush et al., 2014). Together, such issues can result in uncompetitive prices compared with wild-sourced and/or illegal alternatives (Bennett et al., 2021). The potential value of captive breeding for conservation has been undermined by fraudulent practices (Lyons and Natusch, 2011), and harvest from the wild may continue despite captive-bred alternatives (Macdonald et al., 2021).

3.3. Technology

Some tools that could be more widely developed and adopted include user-friendly aids for border officers such as online ID guides (CEC, 2021) and apps such as Wildlife Alert (for helping identification of illegal wildlife products) or iNaturalist (for automated or community-driven species identification via photography of lifeforms or their traces) (Kretser et al., 2015; iNaturalist, 2021; Wildlife Conservation Society, 2021). Forensic DNA databases optimised towards endangered and traded species (Ahlers et al., 2017), such as the Barcode of Wildlife Project (http://www.barcodeofwildlife.org/) can identify species, trace the origin of traded products (Mwale et al., 2016), and detect counterfeits (Hellberg et al., 2019). The geographical provenance of traded individuals may be discernable from phylogenetic signals (i.e., DNA markers), which can be particularly useful when subpopulations are subject to differing levels of trade regulation (Ogden and Linacre, 2015). In the absence of physical specimens, environmental DNA (eDNA) can aid wildlife trade surveillance, including for species posing high biosecurity risks (e.g., alien fishes; Roy et al., 2018). Non-DNA based biochemical methods are also of relevance for addressing IUWT include the profiling of ivory volatilomes via gas chromatography (Ueland et al., 2020), carbon dating of derived products to determine time lags between killing and product seizure (Cerling et al., 2016), and the identification of provenance (i.e., wild or captive/farmed) by comparing stable isotope ratios (Hill et al., 2020).

Imaging technologies (e.g., satellite, thermal, and radar) can track wild populations and detect poaching (Kamminga et al., 2018). Satellite imagery and LIDAR surveys can measure illegal logging across vast areas and time (Achard et al., 2002; Wedeux et al., 2020). Unmanned Aerial Vehicles can detect poaching efforts by obtaining high-resolution real-time images in often-inaccessible areas (Mulero-Pázmány et al., 2014). "Smart" shipping containers can be adapted to detect illegal wildlife products inside (Royal Society, 2018). As aspects of wildlife trade transition to online marketplaces, natural language processing and web scraping can record wildlife trade on the internet and facilitate large-scale digital surveillance (Lavorgna et al., 2020; Stringham et al., 2020). Machine learning techniques can automate image processing (e.g., counting animals in an image) (Shaffer and Bishop, 2016) and the detection of species traded online using pictures or text (Di Minin et al., 2019), plus the latter can be used by enforcement agencies to analyse irregularities in wildlife trade documents more accurately and rapidly (Royal Society, 2018). Facial recognition software for the identification of species (e.g., LemurFaceID, see Crouse et al., 2017) can help understand demographics and trace wildlife trafficking routes. For species difficult to detect using X-rays or other common surveillance techniques at borders due to their size and bodily constitution (e.g., fungi, some plants and invertebrates), surveillance of online wildlife markets using artificial intelligence techniques can be helpful to track and seize illegal traded specimens before reaching the borders. However, technological solutions are not without ethical challenges and criticisms, and require ethical guidelines to prevent serious harm (Sandbrook et al., 2021).

Interdisciplinary and multi-agency collaborative networks such as the International Consortium on Combating Wildlife Crime (ICCWC) (UNODC, 2020) can connect enforcement personnel, scientists and other experts to promote data sharing on investigative techniques, criminal behavior, illegal trade networks, species of concern, known trafficking routes, and regional threats (Patel et al., 2015; Smith et al., 2019; World Bank, 2018). Software tools for collecting and communicating wildlife trade data (Hötte et al., 2016), and cross-jurisdictional platforms such as WEMs (https://wems-initiative.org/) can also assist.

3.4. Awareness and education

Awareness and education are key factors for addressing IUWT. Interventions to tackle IUWT have been traditionally focused on regulation and enforcement (Veríssimo and Wan, 2019), however, there is a growing recognition that this is insufficient. Although they do not provide a quick and easy solution (Thomas-Walters et al., 2020), additional approaches such as demand-side interventions are urgently needed (Rosen and Smith, 2010; Veríssimo et al., 2012), but assessing their full impact will require more research (Shao et al., 2021).

Campaigns to reduce demand for wildlife and derivatives (e.g. by making consumption of wildlife unnecessary due to the presence of synthetic products or by making it socially unacceptable) can contribute to change behaviors towards traded taxa, shift social norms, and increase compliance with environmental laws (Greenfield and Veríssimo, 2019). When well-planned and conducted they can overcome purely economic incentives for decreasing the consumption of wildlife products (e.g., consumption of wild meat in Brazil, Chaves et al., 2018). When they do not take into account social and cultural aspects, they can be ineffective in changing behaviors (e.g., "nail biters" campaign to reduce the consumption of rhino horn) or be perceived as unreliable or driven by profit (Dang Vu et al., 2020).

Developing culturally-nuanced conservation solutions requires scientists and practitioners to understand relevant activities, engage with actors along the wildlife-trade chain, use and respect local language and traditions, and build rapport (Nekaris et al., 2010; Margulies et al., 2019). For instance with traditional medicine, addressing demand for wildlife products requires knowledge of its principles and practices (Cheung et al., 2021), and is necessary to ensure that the needs of local stakeholders are reflected in decision-making (Swan and Conrad, 2014).

As for other types of recommendations, awareness and education campaigns need, although they often lack it, political and societal support. We emphasize the importance of involving local communities and stakeholders since the planning phase to maximize the chances of success and effectiveness, avoiding waste of resources or, worse, social backlash. This is particularly important when campaigns are made together with measures of regulation and enforcement, as many might see any increase in regulatory procedures as a limitation to their livelihood development.

4. Recommendations

4.1. Regulation and enforcement

As pointed out previously, regulations, and enforcement to tackle IUWT are in general not considered priorities by entities responsible for enforcement agencies. In many countries, reform of legal and regulatory domestic systems will be a necessary first step towards regulating wildlife trade (UNODC, 2020). The establishment of environmental courts can be a step in this process (White, 2013), with committed

judiciaries willing and able to impose deterrent penalties (Da Silva and Bernard, 2016). Many Latin American and Caribbean countries are going in this direction (Pring and Pring, 2016). Stringent penalties should be applied to profiteers including middlemen and syndicate operators, but may be less effective in deterring those at the bottom of the supply chain. Poachers may respond better to other measures including reduction of human-wildlife conflict and provision of alternate livelihoods (Travers et al., 2019; Wilson and Boratto, 2020). Empowering and protecting whistleblowers could be an extra element to support law enforcement in some cases. Laws such as the US Lacey Act —that reflects the legal status of imported species from relevant laws of their origin countries—could be adapted for domestic legal systems elsewhere (Slobodian and Chatziantoniou, 2018). Nuanced legislative and judicial reforms should be combined with targeted ant-corruption efforts coupled with outreach to local communities (Faulkner et al., 2018), capacity-building and poverty alleviation (Kideghesho, 2016). Systematic domestic wildlife trade management systems are essential.

Regarding CITES, criticisms have been raised about its general effectiveness (Challender et al., 2015a) and its capacity to respond to the complex and dynamic wildlife trade, hence reforms in its species listing process and general system have been recently proposed (Andersson et al., 2021; Cooney et al., 2021; Macdonald et al., 2021) although these have yet to win broad support. To date, CITES remains as the primary mechanism for regulating international wildlife trade, and addressing issues of compliance or misuse of the treaty by the Parties is a vital to tackle international IUWT (Challender et al., 2015a; Foster and Vincent, 2021).

Efforts to ensure the inclusion of neglected groups in the CITES Appendices are needed, including a call to Parties to propose such species and a candidate review of poorly-represented but heavily-traded taxa (e.g. invertebrates and fungi) (CITES, 2021a). The substantial international trade in non-listed species could be addressed by an increased use of Appendix III, which allows countries to list species unilaterally and expeditiously. Parties listing species on Appendix III should follow the recommendation in CITES Resolution Conf. 9.25 (Rev. CoP18) by ensuring that their national regulations are adequate to prevent or restrict exploitation and to control trade (CITES - Convention on International Trade in Endangered Species of Wild Fauna and Flora, 2021b). Follow-up assessments are needed to determine effectiveness of a listing in controlling trade or contributing to a species' conservation (Challender et al., 2019). The use of the precautionary principle when listing species under CITES may avoid overexploitation before legal protection (Frank and Wilcove, 2019). The adoption of positive lists for trade (Macdonald et al., 2021) may reduce the illegal trade, particularly in cases where there is a high number of traded species that are not regulated by international agreements – as in reptile trade, for example (Marshall et al., 2020).

The linkage between wildlife trade and the emergence of zoonotic diseases (Borsky et al., 2020; UNEP-WCMC and JNCC, 2021) has led to suggestions that CITES should regulate trade in species suspected of carrying zoonotic pathogens (Valdivia-Granda and Richt, 2020; End Wildlife Crime, 2021). Domestic legislation should ensure biosecurity when trading live wildlife. Focus on potentially invasive species and unintentionally introduced species ("hitchhikers") associated with traded species and transportation vectors are needed as well; some countries have taken steps towards identification and prioritization of some prominent invasive alien species (Early et al., 2016). Regulations on international wildlife trade must take into account the interactions between the key dimensions of wildlife trade: the diversity of the species involved in trade, their geographic origin, and the form and nature of the products in the trade (Roberts and Hinsley, 2020). Coordinated efforts among supply, demand and transit areas can be beneficial to tackling IUWT (Esmail et al., 2020). Specialists on the target taxon should be consulted when discussing the best approach in curbing IUWT. Conservation decisions should be based on the best relevant available scientific information (biological, social and economic) (Cooney et al., 2021) and their implementation should also consider enforcement aspects and socioeconomic context to avoid unintended conservation outcomes.

Since CITES does not deal directly with wildlife crime, and because a great deal of IUWT involves organized crime syndicates operating internationally (van Uhm, 2019), there is a new global campaign to add a protocol on wildlife crime to the United Nations Convention Against Transnational Organized Crime (UNTOC). Additionally, countries should invest in transnational enforcement and cooperation, especially with neighboring countries, such what is happening in North America (CEC, 2021) and it is proposed for China and Southeast Asian countries (Jiao et al., 2021). Improving national monitoring and reporting, especially regarding non-CITES-listed species for which trade is generally poorly documented (Janssen and Leupen, 2019; Andersson et al., 2021) is necessary for properly measuring legal and illegal trade. More targeted investigations are needed to identify why regulations are not adhered to, whether the right tools are applied, which enforcement techniques have the greatest impact (Kurland et al., 2017) and are more used by local enforcement officers (Moreto et al., 2018). Translation of wildlife trade documentation into additional languages could ease usage and accessibility. Countries should be prepared to deal with confiscated live animals (Macdonald et al., 2021). Financial Intelligence Units should be used to uncover illegal flows of money and actors in trade, and the recovery of criminal gains and assets (Manzi, 2020; ECOFEL, 2021), with a focus on any links to organized crime and convergence with other serious organized crime, such as drug and human trafficking (UNODC, 2020). Salaries for law-enforcement officials need to be adequate to avoid corruption, which contributes to a lack of trust in law enforcement authorities and can undermine efforts to curb IUWT (Biggs et al., 2017b).

Due to the complexity and diversity of online trade, enforceable legal and regulatory reforms are needed to facilitate collaboration among wildlife trade specialists, species experts, technology companies, and law enforcement (Lavorgna, 2014; Stringham et al., 2020), and to address the borderless nature of cyberspace and the transnational aspect of potential crimes (Lawson and Vines, 2014). Additionally, self-regulation is necessary by e-commerce and social media companies in order to ban the IUWT on their platforms (WWF et al., 2020). Stronger efforts should be made to enforce rules, share data on users engaging in trade with law enforcement agencies (ACCO, 2020), and in curbing illegal trade of less charismatic organisms.

4.2. Knowledge

Gaps in knowledge on taxonomy, ecology and behavior of many species traded need to be filled. Scientists from various fields are needed for addressing the multidimensional issue (Bennett et al., 2017), studying the criminal, social and economic aspects of wildlife trade, and developing new techniques and technologies for enforcement and surveillance (Brandis et al., 2018; Stringham et al., 2021). Since the available tools to curb IUWT have been mostly developed for large animals or timber (e.g., Wasser et al., 2018), there is a demand for developing alternatives for smaller, discrete or less charismatic species. More research is needed to understand the role of IUWT as a source of livelihoods, and its impact on social and environmental justice for the local community. Research is essential to propose viable alternatives for subsistence or income, to determine sustainable levels of exploitation, to design interventions tackling IUWT, and to reduce or modify the demand for wildlife products.

4.3. Engagement

Local communities and consumers can be engaged in reducing IUWT by reinforcing disincentives for illegal behavior and increasing incentives for wildlife stewardship (Cooney et al., 2017; Biggs et al., 2017a). They also have to be properly informed about species

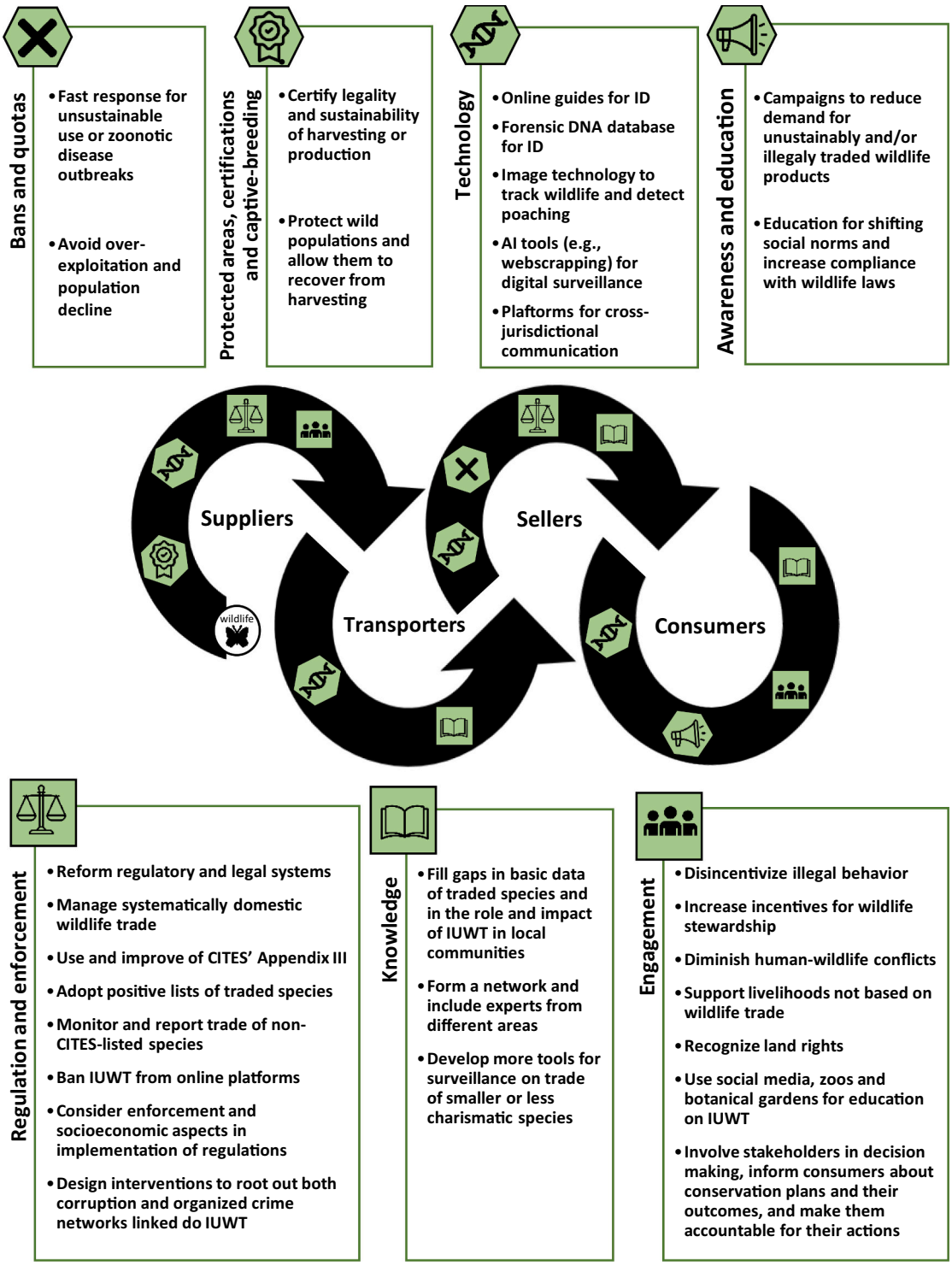

Fig. 1. Simplified wildlife (circle) trade chain presenting some available tools (hexagons) and proposed actions (squares) for tackling some of the current challenges in IUWT. See text for concerns related to the adoption of each mentioned tool.

conservation and the threats posed by IUWT, and about the local law that rules wildlife trade. Local communities can also be engaged by diminishing costs of living with wildlife, and supporting livelihoods not based on wildlife exploitation, sharing responsibility for conservation tasks and ensuring stronger participation on conservation decisions that would affect them such as in CITES' listing process (Biggs et al., 2017a; Cooney et al., 2017). A focus on justice and diversity are need to develop new models of conservation and confront IUWT, including recognition of land rights and indigenous-led approaches to conservation (Domínguez and Luoma, 2020; Wyborn et al., 2020). Detection of economic and non-economic factors that influence and rationalize community engagement in IUWT are valuable in designing more effective plans to curb such trade, ensure social and environmental justice and improve local sustainable development (Strong and Silva, 2020; Paudel et al., 2019; Moneron et al., 2020).

Social media can provide valuable data about consumption patterns (Li and Hu, 2021) and help change perceptions about IUWT through education and awareness. Education could focus on relevant laws

governing wildlife trade and exploitation, negative aspects of trade including wildlife welfare, zoonotic disease (Morcatty et al., 2021; UNEP-WCMC and JNCC, 2021) or buying possibly illegal or unsafe wildlife products and allowing human-wildlife interaction for example in tourist centres (Moorhouse et al., 2017; Ying et al., 2020). Guides for the types of wildlife souvenirs tourists may encounter, including information about applicable regulations, are already available for some countries (European Commission, 2021) and could be developed elsewhere. Zoos, aquaria and botanical gardens may have potential to raise awareness regarding wildlife trade (Clayton et al., 2018). Environmental journalists and NGOs can play a role in consumers' education and in investigation of illicit networks or activities. Citizen scientists can help in surveillance, identification, collecting field data and conducting various analyses to reduce human-wildlife conflicts (Frigerio et al., 2018), yet once synthesised — ideally in collaboration with academics — science communication is crucial to engage, educate and influence the actors involved.

5. Conclusions

It is necessary to measure the scope, scale and impact of IUWT for all the branches of the tree of life (Kumschick et al., 2016; Fukushima et al., 2020). Transparency about philosophical approaches used in research, policy and enforcement is necessary to apply the scarce conservation resources towards those species most threatened by trade (Kolby, 2019; Natusch et al., 2021). Because wildlife trade has diverse drivers and purposes, and different levels of legality, social legitimacy and enforcement, we must better understand consumer demands (Dang Vu and Nielsen, 2018), economic and social aspects along the trade chain (Cooney et al., 2021), and the market dynamics (Challender et al., 2015b) to determine where and how to permit and support legal and sustainable trade, versus where it should be more tightly regulated or even cease (Cooney et al., 2015). Models can help provide a framework that identifies assumptions and estimates probabilities of success for alternative conservation actions for a species based on the best available information (Bennett et al., 2021)

Shortfall of funding and political will is often a constraint for the implementation or long-term permanence of initiatives aimed at curbing illegal trade or promoting sustainable trade or alternative sources (e.g., Nogueira and Nogueira-Filho, 2011). In this sense, higher-income countries should further support scientific and enforcement agencies of less affluent countries and offer financial support or incentives in return for commitments to a reduction in wildlife exports (Liew et al., 2021). Yet, although strong regulations are necessary to control IUWT, the wildlife trade's complex human dimensions should not be entirely reduced into a law enforcement problem (Velázquez-Gomar and Stringer, 2011; Challender et al., 2015a; Hübschle, 2016; Massé, 2020). Visibility and participation of community in IUWT issues are becoming more common as local and national voices pursue greater authority over natural patrimony, sovereignty, and self-determination (Esmail et al., 2020).

IUWT is a complex, dynamic and inter-jurisdictional problem, and finding integrated solutions requires a multidisciplinary approach involving several actors, use of the most recent advances in science and recognition of different viewpoints (Roe et al., 2013). Solutions do exist, but given the inherent global scope of the challenge it will take time, money, and commitment for any integrated approach to be developed and implemented. Here we have proposed a range of measures that we hope will be useful for developing such an integrated roadmap for this complex conservation challenge (Fig. 1).

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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