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REVIEW

The effectiveness of interventions to manage international wildlife trade

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Abstract

A range of interventions have been established to manage international wildlife trade and protect traded species; however, there is little consensus as to whether, when, and how they are effective. Here, through a comprehensive, systematic review of >8000 articles, we appraise the evidence for the effectiveness of interventions on conservation, biological, and/or socio-economic outcomes. Our systematic review examined four intervention types: "laws and regulations", "detection and enforcement", "efforts to reduce threats to species", and "support local livelihoods". We find that while laws and regulations were most well-studied, with some reported positive outcomes, over half of articles reported unintended consequences including shifting exploitation and trade routes, increased illegal trade, and socio-economic trade-offs. Detection and enforcement efforts appeared effective in protecting target species but limited for high-value species especially when combined with low reproductive rates. Efforts to reduce threats to species (particularly through area protection) had positive biological impacts, but some socio-economic trade-offs were reported. Evidence on community-based approaches was limited but our review indicated positive synergies occurring between conservation and socio-economic outcomes. Overall, socio-economic outcomes were underrepresented, limiting understanding of potentially important socio-ecological feedbacks. This review furthers understanding of relevant conditions, risks and enabling factors around effectiveness of wildlife trade interventions.

KEYWORDS

CITES, conservation effectiveness, evidence review, livelihoods, meta-analysis, sustainable trade, synergies, tradeoffs

1 | INTRODUCTION

The use and trade of wild animals and plants, and their parts or products, is a multibillion-dollar activity involving the harvest and trade of thousands of species including birds, reptiles, mammals, fish, and plants used for both subsistence and commercial purposes (Fukushima et al., 2020). Collection of wildlife for the

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trade occurs predominantly in developing countries where it can form an important component of livelihood strategies particularly for the rural poor (Cooney & Abensperg-Traun, 2013; Roe et al., 2002). However, a growing demand for, and volume and value of, wildlife and wildlife products on a global scale, driven by an increasingly globalized market (Harfoot et al., 2018; Pires & Moreto, 2016), constitutes one of the main biodiversity threats and drivers of species decline (Maxwell et al., 2016; Morton et al., 2021; Scheffers et al., 2019). Unsustainable wildlife trade can undermine and threaten the stability of human livelihoods dependent on these natural resources. In particular, the illegal trade in wildlife and wildlife products is considered one of the most lucrative transnational crimes threatening species with extinction (Challender & MacMillan, 2014; UNODC, 2024) and is progressively characterized by sophisticated and organized criminal networks undermining national and international security (Douglas & Alie, 2014; Wyatt et al., 2020). Thus, concerns over rapid biodiversity loss coupled with security threats and implications for local livelihoods, has propelled international wildlife trade to the top of political and conservation agendas (UNODC, 2024).

Recent work has shown that conservation interventions on the whole are having a positive impact on nature (Langhammer et al., 2024). Among these, a broad range of interventions have been established to promote sustainable international wildlife trade and mitigate potential negative impacts on wild populations and human livelihoods. Regulatory measures, such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), established in 1975, regulates international trade through a system of permits and licenses to ensure the legality and sustainability of trade, have been a principal approach to regulate international wildlife trade (Roe et al., 2002). However, restrictive trade regulations may disregard market dynamics and true drivers of the trade, are weakened by poor governance and corruption (Challender et al., 2015b, 2015a; Douglas & Alie, 2014), and can disproportionately affect local communities dependent on the trade (Roe et al., 2002). Consequently, there has been a growing recognition of and attention to alternative approaches, including addressing demand and consumption (Verissimo & Wan, 2019), market-based incentives to promote sustainable harvest and/or consumption (Arton et al., 2020), and community-based initiatives that offer co-benefits for target species and local livelihoods (Cooney et al., 2015).

Despite increased attention and research, evidence on the effectiveness of established wildlife trade interventions remain scarce and poorly understood (Roe & Booker, 2019; Verissimo & Wan, 2019) and there is a need to better understand the synergies and trade-offs of various intervention types, across biological, conservation and socio-economic outcomes. This is particularly pertinent with the increasing volume of international trade in wildlife and wildlife products, along with growing public and political pressure to combat unsustainable trade and achieve conservation and development goals together. Previous syntheses have examined the impacts of actions targeting consumer demand (Verissimo & Wan, 2019), market-based approaches such as the Marine Stewardship Council certification program (Arton et al., 2020), and engaging local communities (Roe, 2015; Roe & Booker, 2019), but to our knowledge none have attempted to synthesize across multiple intervention and outcome types. Here, we conduct a comprehensive systematic review with supplementary meta-analysis (on a subset of papers) to (1) identify and map the available evidence of impacts of interventions aimed to regulate and manage impacts of international wildlife trade and identify evidence gaps; (2) analyze the impacts and effectiveness of multiple pathways to manage international wildlife trade through trade control and supply-side interventions; (3) evaluate potential synergies and trade-offs between biological, conservation, and socio-economic outcomes; and (4) identify main learning insights and highlight areas warranting further research. This review draws from, and builds on, a previous evidence map by Cheng et al. (2017) and protocol for a systematic map described by Cheng et al. (2022). By conducting a systematic assessment and review with up-to-date information for policy makers, practitioners, and researchers, this review supports evidence-informed funding and management decisions, that can drive more effective interventions to regulate and manage impacts of international wildlife trade.

2 | METHODS

This review followed, as closely as possible based on available time and resources, the guidelines provided by the Collaboration for Environmental Evidence (Pullin et al., 2018) to ensure comprehensive and systematic searching and screening methods. Following screening and data extraction, a narrative synthesis was used to explore trends in impacts reported in the included articles that met our study validity criteria. Direction and magnitude of outcomes were examined more in-depth in a smaller subset of these articles through a meta-analysis (see Supporting Information for methods and criteria).

2.1 | Framework development

The conceptual framework and inclusion criteria were originally developed by Cheng et al. (2017) by an advisory group of experts, practitioners, and researchers in

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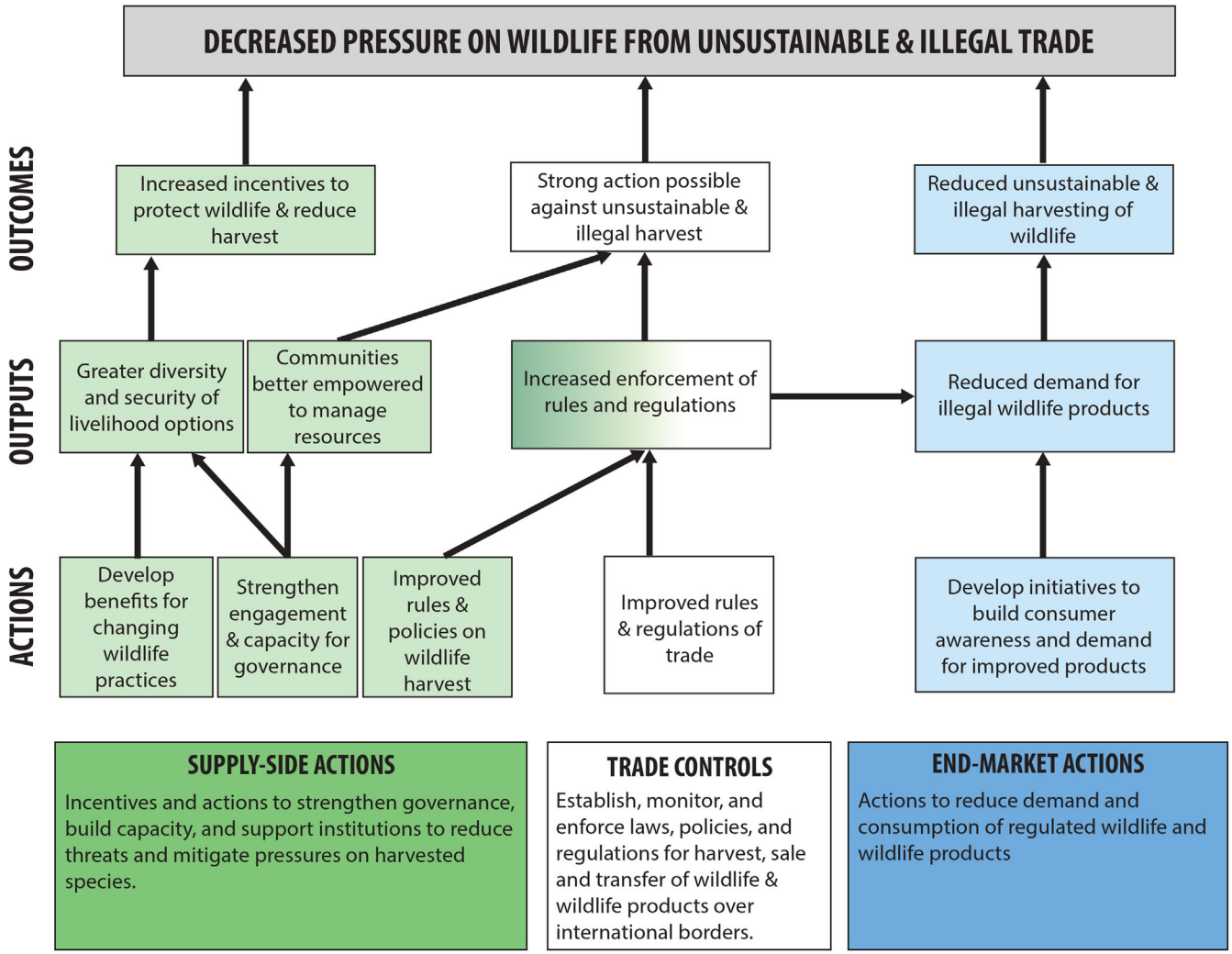


FIGURE 1 Generic conceptual model of primary pathways of action to manage international wildlife trade adapted from Cheng et al. (2022).

international wildlife trade and conservation. Previous frameworks around the drivers of wildlife trade and impacts of trade on species and communities are varied. It is broadly recognized that the interactions between people, environment and international wildlife trade are complex and affected by a range of enabling conditions and factors. However, synthesis across existing conceptual models (Biggs et al., 2017; Cooney et al., 2015; Roe et al., 2002; USAID, 2017; Wallen & Daut, 2018), and the IUCN-CMP Actions Classification (version 2.0) (Conservation Action Measures Partnership, 2016), highlight common key areas that can be incorporated into an analytical framework to understand impact. Specifically, all three models indicate pathways to impact through (1) *regulation and enforcement over the entire supply chain*, (2) *incentive-based action at both end-market and supply sides*, and (3) *awareness-based action at the end-market side*. Within this broad framework, a review team composed of topic-relevant experts, stakeholders and academics specializing in wildlife trade and evidence synthesis, defined key intervention types and pathways focused on international wildlife trade and achieving co-benefits for harvested species and human well-being (Figure 1).

2.2 | Search strategy

Relevant articles were identified through four strategies: (i) search string in Web of Science Core Collection; (ii) Google Scholar search with a simplified version of the Web of Science search string; (iii) searches on topical databases and organizations; and (iv) direct contact with experts on international wildlife trade issues. "Articles" include both peer-reviewed and gray literature sources which can contain insights or data from multiple studies. We used an English search string developed by Cheng

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TABLE 1 Search string used to search for relevant literature on the Web of Science Core Collection.

Trade terms	TS = (((“trade” NOT “trade-off*”) OR “traffic*” OR “poach*”)
Wildlife terms	(“wildlife” OR “conservation” OR “fauna” OR “flora” OR “endangered species” OR “threatened species” OR “fish*” OR “aquarium” OR “aquaculture” OR “ornamental” OR “pet” OR “timber” OR “ivory” OR “elephant” OR “rhino*” OR “tiger” OR “shark” OR “ray” OR “plant” OR “medicinal” OR “bushmeat” OR “ape” OR “bear” OR “turtle” OR “reptile” OR “leopard” OR “deer” OR “primate” OR “coral” OR “non-timber forest products”)
AND	
Intervention terms	(“reserve” OR “protected area” OR “park” OR “fencing” OR “harvest*” OR “community based” OR “patrolling” OR “ranger” OR “manage*” OR “quota” OR “regulat*” OR “*sustainable” OR “zoning” OR “selective logging” OR “hunting” OR “ranching” OR “breeding” OR “propagation” OR “cultivation” OR “aquaculture” OR “mariculture” OR “awareness” OR “campaign” OR “CITES” OR “Convention on International Trade in Endangered Species” OR “moratorium” OR “ban” OR “IUU” OR “suspension” OR “Endangered Species Act” OR “Marine Stewardship Council” OR “Forest Stewardship Council” OR “compliance” OR “property rights” OR “legislat*” OR “whaling” OR “enforc*” OR “Convention on Biological Diversity” OR “law” OR “policy” OR “substitut*” OR “incentive” OR “alternative” OR “certification”)
AND	
Outcome terms	(“recovery” OR “abundance” OR “protection” OR “income” OR “poverty” OR “livelihood*” OR “security” OR “asset” OR “stewardship” OR “awareness” OR “behavior” OR “behavior” OR “benefit” OR “impact” OR “value” OR “effectiveness” OR “effective”))

et al. (2022) through a scoping exercise on the Web of Science Core Collection (Table S1) to check for sensitivity of alternate terms and wildcards. The comprehensiveness of the final search string (Table 1) was tested using a test library consisting of 18 relevant articles complied through solicitation of relevant literature from an expert advisory panel (Appendix S1), which resulted in ~80% of documents being found. To capture unpublished and gray literature, in an attempt to minimize possible publication bias (Leimu & Koricheva, 2005), we also searched Google Scholar using a simplified and shortened version of the original search string: “wildlife trade” OR “wildlife traffic*” OR “wildlife poach*”. Capturing gray literature is particularly pertinent for reviews on wildlife trade as much of the evidence is not formally documented or readily accessible (Roe & Booker, 2019). In addition, searches were conducted on topical online databases and organizations (Table S2) and opportunistically through direct contacts with experts on international wildlife trade issues within our network over email and by issuing calls for potentially relevant literature by the authors on their respective LinkedIn profiles.

The original search was conducted between July to October 2016 (Cheng et al., 2017) and the updated search between May and August 2020. No date restrictions were placed on publication year during the search; however, due to time and reviewer limitations, only articles published in English were assessed for inclusion.

2.3 | Screening

All search results from Web of Science and the first 50 pages on Google Scholar (cut-off point justified by declining relevance of results) were imported into Colandr, an open-access review platform that assists in the screening process by using machine learning (Cheng et al., 2018). The user must still make the final decision whether to include or exclude articles, minimizing potential sources of bias. First, titles and abstracts were screened for relevance against the inclusion and exclusion criteria using the PICO (Population, Intervention, Comparator, Outcome) framework (Table 2). Articles that met our inclusion criteria at the title and abstract stage were then reviewed at full text. Articles with ambiguous and/or uninformative titles and abstracts were also included for full text screening. To ensure consistency in applying the inclusion criteria, a random 10% and 20% of articles were screened at both title and abstract and at full text respectively by at least two reviewers. Any discrepancies and differences in screening approach were discussed to ensure a consistent approach and minor adjustments to the inclusion criteria were made accordingly through an iterative procedure.

2.4 | Inclusion criteria

We applied the PICO framework (Pullin et al., 2018) to all articles captured by the search to assess whether an article met our inclusion criteria. Articles could include multiple interventions, comparators and/or outcomes. Following the framework development described above to categorize intervention types, we disaggregated interventions into three main pathways: *Trade controls*, *End-market actions*, and *Supply-side actions* (Table 3). Impacts on biological, conservation, and socio-economic outcomes were

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TABLE 2 Inclusion and exclusion criteria with the PICO components (Population, Intervention, Comparator, Outcome) applied to articles captured by the search to identify relevant evidence.[a]

PICO component	Inclusion criteria	Exclusion criteria
Population	Studies conducted in any country, documenting effectiveness of local, subnational, national, regional, and international scale efforts, explicitly aimed to regulate the international trade of wild animal or plant resources (wildlife trade), including but not limited to efforts directed at the collection, management, sale or exchange or wildlife and wildlife products. These include, but are not limited to, products such as pets, skins, medicinal ingredients, timber, fish, and other food products from hunting, harvesting, fisheries, aquaculture	Sale or exchange of domesticated or captive-bred species were excluded (when not directly linked to an intervention to regulate trade of wild populations). Studies not specifying target species were excluded
Intervention	Interventions explicitly aimed at or affecting *international* wildlife trade (i.e., sale across national boundaries). Drawing from previous synthesis on wildlife trade frameworks (Biggs et al., 2017; Cooney et al., 2015; Roe et al., 2002), three broad intervention groups were identified: (1) Trade Controls; (2) End-Market Actions; and (3) Supply-Side Actions (see Table 3). Efforts could be implemented at any point along the supply chain (supply, harvest/trade, and end-market)	The following interventions were excluded: species re-introduction, captive breeding (when not directly linked to an intervention to regulate trade of wild populations), domestication, and criminal syndicate control. Related efforts, such as natural resource management which may include actions affecting trade, though while relevant, were beyond the scope of this review
Comparator	We only included studies that used an appropriate comparator, classified as temporal, spatial or between groups. Temporal comparators examine effects over time (before/after or interrupted/continuous time series). Spatial comparators compare effects between sites over distance. Group comparators compare effects between populations of affected people or target species, including comparisons between presence/absence of an intervention	Studies only evaluating impacts post-treatment with no comparator were excluded
Outcome	We included studies that explicitly evaluated impacts of interventions on conservation, biological and/or socio-economic outcomes (see Table 4)	Studies evaluating impacts on ecological outcomes, e.g., habitat stability, ecosystem integrity, species diversity, were excluded

[a]Studies could include multiple interventions, comparators, and/or outcomes.

included (Table 4). Eligible outcomes included both direct measures of the impact from an intervention (i.e., positive impacts on conservation target, e.g., increased abundance of target species) and indirect measures or outputs (i.e., intermediate outcomes or threat reduction outcomes, e.g., level of enforcement effort or changes in national protection legislation). Intermediate outcomes often tend to be used to measure the effectiveness of conservation interventions and can indicate a potential or perceived change and whether direct outcomes are likely to be achieved (Muir & Byler, 2014; Rytwinski et al., 2024; Sosnowski et al., 2021). Meanwhile, threat reduction outcomes indicate whether the intervention is effective in reducing key threats (e.g., reduced poaching levels). A conceptual model on the primary pathways of actions focused on international wildlife trade and their potential impacts on target species and people was originally developed by Cheng et al. (2022), and further developed here, helps visualize the interactions between key interventions and outcomes relevant for this review (Figure 1).

Primary research studies, gray literature, and systematic reviews were considered for inclusion if they met the PICO inclusion criteria set out in Table 2. We included articles that used either quantitative or a combination of quantitative and qualitative impact measurements, excluding those with purely qualitative data. Theoretical or modeling studies, editorials and commentaries, and articles not explicitly measuring impacts were excluded.

2.5 | Study validity assessment

We critically appraised articles to assess the validity and reliability of study methodology (Pullin et al., 2018), rating them as having high, medium, or low risk of bias based on methodological quality and susceptibility to

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TABLE 3 Intervention framework: Categories and subcategories of programs and polices ('interventions') to manage international wildlife trade considered for inclusion during screening.

Pathway	Intervention category	Definition	Example actions[a]
Trade controls			
Establish and refine laws and regulations	This category includes interventions related to establishing laws, policies, and regulations that regulate the sale and transfer of wildlife species and products over international borders		
	Establish laws, regulations, and codes	Laws and regulations refer to official legal code governing the sale and transfer of regulated wildlife and associated products. Codes include formal or voluntary agreements between organizations in the private sector and civil society on sale and transfers of wildlife and associated products	Trade bans, CITES regulations, codes required by certification schemes such as Marine Stewardship Council, national laws, trade quotas
	Define/refine policies and guidelines for implementation	Policies and guidelines govern how laws and regulations are implemented	Agency plans regulating trade, task forces, trade commissions
Increase trade enforcement and compliance[b]	This category includes interventions aimed to monitor and enforce existing laws and policies and compel compliance regarding import and export of wildlife and wildlife products		
	Detection and enforcement of trade laws, policies, and codes	Detecting, directly stopping, and/or deterring trade violations	Monitoring trade and trafficking, surveillance, informer networks
	Prosecution of trade violations	Deterring unallowed trade and trade practices through legal punishment	Trials, convictions, legal penalties and fines in trade violation related cases
	Civil Action regarding trade violations and practices	Deterring unallowed trade and trade practices through civil legal proceedings	Civil lawsuits, penalties, and fines
End-market actions			
Reduce demand and consumption[b]	This category includes interventions aimed at reducing demand and consumption of regulated wildlife and wildlife products on the consumer side of the supply chain to reduce pressure on harvested wildlife		
	Promote substitutions	Developing, promoting and/or providing alternative products or practices to substitute for overharvested and/or threatened species	Drugs for traditional medicines, synthetic replicas of wild products
	Awareness raising and building	Promoting awareness and/or emotions and behavior change by providing information to target consumer audiences through various channels	Organization campaigns, outreach, informative lectures, social media
	Market-based incentives	Creating incentives to change behavior and attitudes through market mechanisms	Promotion of purchase of certified product, educating consumers on sustainably harvested products
Supply-side actions			
Increase harvest enforcement and compliance	This category includes interventions aimed to monitor and enforce existing laws and policies and compel compliance regarding harvest of species of concern		
	Detection and enforcement of harvest laws, policies, and codes	Detecting, directly stopping, and/or deterring violations of harvest laws, policies, and codes of species of concern	Poacher control actions (including patrolling), law enforcement at landing sites, payment for informing on poaching
	Prosecution of harvest violations[b]	Deterring unallowed harvest and harvest practices through legal punishment	Trials, convictions, legal penalties and fines regarding harvest violation related cases
	Civil action regarding harvest violations and practices[b]	Deterring unallowed harvest and harvest practices through civil legal proceedings	Civil lawsuits, penalties, and fines regarding harvest laws and codes

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TABLE 3 (Continued)

Pathway	Intervention category	Definition	Example actions[a]
Reduce threats by supporting local livelihoods	This category includes community-based actions and other interventions aimed to reduce local scale threats to harvested species of concern by using social, or positive livelihood and economic incentives to directly influence attitudes and behaviors		
	Strengthen community-based management and protection of wildlife	Actions that strengthen community capacity and engagement in management and protection of species	Training local guards in patrols and surveillance of wildlife activities, community conservation agreements, promote societal pressures and economic incentives to not engage in illegal behaviors
	Increase incentives for stewardship of wildlife	Actions that develop and support initiatives that can generate local benefits from wildlife	Ecotourism enterprises, provide training as nature guides, increase local stakeholders in management, allocate rights/ownerships over wildlife to community groups, promote and/or educate on sustainable use methods
	Decrease human-wildlife conflict[b]	Actions mitigating costs from human-wildlife conflict	Provide fencing for livestock, compensation for losses
Reduce threats to harvested species of concern	This category includes interventions aimed to reduce direct threats/mitigate stresses to populations of specific taxa		
	Establish spatial areas of protection	Actions that protect key habitats, ecosystems, and/or areas for harvested species	Wildlife reserves, protecting breeding, and feeding grounds
	Regulate harvest of species of concern	Actions that establish laws, policies, and codes for harvest practices and promote and implement sustainable harvest practices	Harvest laws and policies, harvest management plans, harvest quotas, seasonal closures, allowed gear type, population management
	Culturing of species to reduce pressure on wild species[b]	Actions that promote raising of desired species in captivity as an alternative to capturing from the wild. This does not include domestication or captive breeding not related to the conservation of wild populations	Culturing, ranching

[a]The example actions listed are representative and not exhaustive.
[b]Interventions pathways and categories not included in the narrative review or meta-analysis due to insufficient evidence (i.e., least number of linkages between categories of intervention and outcome types).

bias (Table S3). We only included articles having low or medium risk of bias in the narrative synthesis to be able to reliably attribute outcome(s) to intervention(s). A total of 13 articles were rated as having high risk of bias and thus excluded. See Appendix S2 for a list of articles excluded from the narrative synthesis.

2.6 | Data coding and extraction

We used a standardized data extraction form to extract descriptive data from articles included at full text, including but not limited to bibliographic details, geographic location(s), study design, target species, and intervention type and details of action(s), scale of intervention, comparator used, if the article included a control, outcome type and indicator(s) used to measure outcome. When coding the data, we only included interventions specifically identified and assessed by the article and outcomes measured (as per our inclusion criteria). The full data extraction form used to extract data from articles included at full text is found in Table S4. A subset of 10% of articles included at full text were coded by three reviewers as a consistency check to ensure that data were recorded in a consistent manner.

2.7 | Data synthesis and analysis

Descriptive statistics were used to analyze the overall body of evidence and synthesize project characteristics. We quantitatively summarized included articles into a structured matrix ("evidence map") visualized as a heap map using Rstudio ggplott2 package (Wickham, 2016). Each cell in the evidence map represents the number of unique articles documenting a linkage between

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TABLE 4 Categories and subcategories of direct and indirect outcomes considered for inclusion during screening.

Outcome category	Subcategories	Example outcomes[a]
Conservation	Management	Utilized harvest/trade/hunting quotas, harvest practice, compliance enforcement effort (e.g., total days or distance patrolled, rate of incidence of illegal activity detected/deterred), sustainable/unsustainable use, poaching levels
	Protection	Endangered species listing (e.g., listed as protected species on a national/subnational level), National biodiversity strategy, Conservation action plan
	Trade	Change in trade levels, new trade policies
	Behavior change	Chang in attitudes towards harvesting practices, valuation of wildlife, consumer preference for products
Biological	Species/population	Density, relative abundance, presence/absence, distribution, biomass
Socio-economic[c]	Economic living standards	Income, livelihood, jobs, employment opportunities, wealth, savings, payments
	Material living standards	Basic infrastructure, food security, resource use (both sustainable and unsustainable), assets owned
	Health[b]	Physical and/or mental health, access to health care, maternal/child health, nutrition, occurrence of diseases
	Education[b]	Access to school, training, informal education, transfer of skill
	Social relations[b]	Ability to work together, conflicts, relationships, connectedness
	Security and safety[b]	Physical security, recourse security, tenure security, rights to access, use and/or benefit from resources
	Governance and empowerment[b]	Including both formal and informal rules; participation and control in decision making, accountability, justice, transparency
	Subjective well-being[b]	Measures of happiness, quality of life, satisfaction
	Culture & spirituality[b]	Cultural, societal, and traditional values of natural resources and nature to the community, sense of home, cultural identity and heritage, spiritual or religious beliefs and/or values
	Freedom of choice & action[b]	Ability to choose and pursue what you value doing and being

[a]The example outcomes listed are representative and not exhaustive.
[b]Outcome categories not included in the narrative review or meta-analysis due to insufficient evidence (i.e., least number of linkages between categories of intervention and outcome types).
[c]Adapted from McKinnon et al. (2016).

intervention categories and outcome types. Articles can appear in multiple cells.

For the narrative synthesis, only intervention and outcome (sub)categories from the articles included at full text deemed to have sufficient evidence were included. This was based on the number of unique articles that reported on the impact of an intervention (or interventions) on an outcome (or outcomes), i.e., a linkage. Interventions under the pathway *End-market actions* had a total of 18 linkages, compared with interventions under pathway *Supply-side* actions with 100 linkages and *Trade controls* with 51. *End-market actions* was therefore excluded from the narrative synthesis (excluding a total of nine articles). Further, intervention categories with less than 10 linkages were excluded. These were *Detection*, *prosecution*, and *civil action* under "trade controls" (4, 8 and 0 linkages respectively), *Prosecution* and *civil action* under "supply-side actions" (0 and 4 linkages respectively), *Decrease human-wildlife conflicts* (0 linkages), and *Culturing of species* (5 linkages) (see Table 3 for details on intervention framework and categories). The same criteria were applied to the outcome subcategories (Table 4), i.e., subcategories with <10 linkages were excluded. For the socio-economic outcomes, only subcategories *Economic well-being* and *Material well-being* were included as the other subcategories all had four or less linkages each. This excluded a further two articles. The remaining outcome categories were included in the narrative synthesis. See Appendix S2 for a list of articles excluded from the narrative synthesis.

2.8 | Supplementary analysis: Meta-analysis

To further explore the impact of different interventions, we also conducted a meta-analysis on the subset of articles that provided a quantitative measurement of

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outcome indicator(s) and the comparator (i.e., before or without intervention). However, only 18 articles met the inclusion criteria for meta-analysis, resulting in very small subgroups for comparative analysis. Therefore, we provide the methods and results of the meta-analysis in Appendix S3 and note here that the results of the meta-analysis support the findings of the narrative synthesis, albeit with only a small subset of articles included.

3 | RESULTS

Our search strategy identified a total of 8011 articles (after removing duplicates) which were screened first at title and abstract. Of these, 801 articles were screened at full-text. A total of 87 articles were included based on our inclusion/exclusion criteria presented in Table 2. Of these, 63 articles were included in the narrative synthesis, after excluding a total of 24 articles due to having high risk of bias or insufficient evidence on intervention/outcome types (Figure S1). As mentioned in the methods, we also conducted a meta-analysis on a small subset comprising of 18 articles. However, due to the small sample number these results are presented in the Supporting Information and should be interpreted merely as supplementary to the narrative synthesis.

3.1 | Descriptive analysis of the overall body of evidence

We found no articles prior to 1994 and few until 2009. Thereafter, the rate of relevant articles increased peaking in 2019 with 16 included articles (Figure S2). Articles represented a wide range of geographic regions (Figure S3), with Asia being the most well-studied region (40%, $n = 35$). A large diversity of target species and purposes for trade were represented with an overrepresentation of terrestrial mammals (45%, $n = 39$) (Figure S4). Impacts of establishing laws and policies to regulate international wildlife trade on conservation outcomes were the most well-studied intervention category with highest frequency of linkages in the evidence map (Figure 2). Apart from economic living standards, very few articles examined socioeconomic impacts across intervention types (Figure S5).

3.2 | Narrative synthesis

Of the 63 articles included in the narrative synthesis, virtually half (49%) examined the effectiveness of actions in category *Establish and refine laws and regulations*,

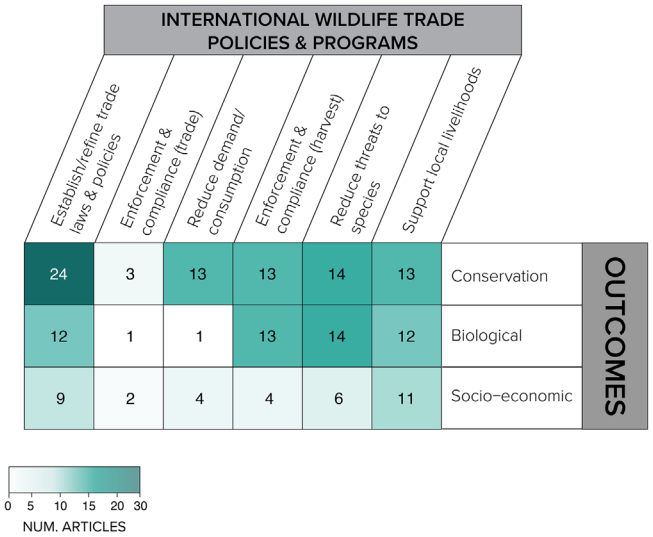


FIGURE 2 Heat map of the impacts of the intervention categories to manage international wildlife trade as presented in Table 3 on conservation, target species (biological) and socio-economic outcomes (Table 4) in a summarized form showing the intervention and outcome categories, including the excluded intervention category *Reduce demand/consumption*. Each cell represents the number of unique articles documenting a linkage. Darker colors indicate where there was more evidence available (i.e., high number of linkages). Articles can appear in multiple cells if they include multiple interventions and/or outcomes.

followed by *Detection and enforcement of harvest laws, policies, and codes* (21%), *Reduce threats to harvested species of concern* (16%), and *Support local livelihoods* (14%) (Figure 2). Although several articles mentioned multiple interventions, we were only able to report on the effectiveness of the intervention the articles specifically evaluated and clearly linked to outcome(s) measured. Although our search strategy aimed to capture a wide range of socio-economic outcomes, only impacts on economic and material living standards were included in the narrative synthesis, as few public articles reported on the other subcategories. See Table S5 for a summary of key information from each of the articles included in the narrative synthesis.

3.3 | Establish and refine laws and regulations

Regulatory measures were the most well-studied intervention category (Figure 2), but articles reported varying efficacy of such interventions. This observation was supported by the supplementary meta-analysis with non-significant effect sizes for this subgroup (seven articles) (Appendix S3). Included articles examined impacts on trade levels, management outcomes, populations of target

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species, or economic living standards. Nearly half of these ($n = 18$) highlighted issues and unintended outcomes in terms of trade dynamics. Four articles reported that observed trade volumes declined in the country or region where regulatory measures were implemented, but unintended outcomes included trade being redirected to other source countries (Carpenter et al., 2005: Dell'Apa et al., 2013) or concentrated to fewer countries while increasing market value (for European eels: Nijman, 2017; and seahorses: Kuo & Vincent, 2018). Two articles found that traders circumvented stricter regulation and enforcement by shifting to alternative trade routes (Raghavan et al., 2013) or to other platforms such as social media websites (Krishnasamy et al., 2016). One article indicated that increasingly restrictive trade measures from the United States on imports of lion trophies inadvertently spawned a new lucrative direct export market of lion bones from South Africa to Asian markets to meet a growing demand (Williams & 'tSas-Rolfes, 2019).

In four articles, restrictive trade measures were followed by an observed increase in illegal harvest and trade of species characterized by high market demand and price, such as seahorses (Kuo et al., 2018), wild-caught bears to meet demand for bear bile in Vietnam (Crudge et al., 2020), Asian pangolins following a CITES trade ban (Challender et al., 2015b), and humphead wrasse in Hong Kong (Hau & de Mitcheson, 2019). Weak implementation, ambiguous or limited enforcement, prevailing corruption, and abuse of legal loopholes and permit systems, were identified as key factors facilitating or incentivizing continued exploitation and illegal trade in some cases (Diaz et al., 2012; Nijman, 2019), exemplified by the surge in exploitation of African rosewood in Ghana following national felling and export bans, as well as the inclusion of the species in CITES Appendix II (Dumenu, 2019).

In contrast, eight articles reported positive impacts without clear indications of shift in trade patterns or rise in illegal trade. For instance, national quotas restricting harvest and export of native birds in Peru did not appear to facilitate or stimulate illegal trade (Daut et al., 2015) and strict enforcement such as random testing by custom officials contributed to reduced occurrences of fraudulent caviar trade (Doukakis et al., 2012). In addition, national implementation and enforcement of CITES regulations brought unsustainable snake trade under control in China (Jiang et al., 2013) and the 1989 CITES ban on international ivory trade is thought to have been instrumental in reducing consumer demand in Japan by increasing public awareness on illegal trade and the endangered status of elephants (Kurohata, 2020). Articles also reported higher abundance and density of target species following stricter regulatory trade measures (Brodie et al., 2011; Buzzard et al., 2012; Pain et al., 2006), of which some were implemented in conjunction with habitat protection (Cahill et al., 2006). However, species-specific characteristics influenced recovery potential of target species. Positive effects of restricting otter trade through a listing on CITES Appendix I, as well as a national ban on commercial hunting, on wild populations took a long time to manifest due to slow reproduction rates and limited recruitment (Uscamaita & Bodmer, 2010). Severely overexploited oyster populations failed to recover even after 15 years with an export ban; the slow recruitment of the species may have further been compounded by continued illegal harvesting (Hawes et al., 2011). In instances where trade restrictions were combined with measures to regulate harvest, such as establishing no-take zones, articles reported substantially higher densities of target species compared with areas without (Acosta, 2011; de Mitcheson et al., 2019; Ward-Paige & Worm, 2017).

No articles reported positive socio-economic impacts of regulatory measures, although evidence was limited. Articles that examined socio-economic outcomes reported that regulatory measures led to reduced income among dependent local communities (Weber et al., 2015) and disproportionately affected local collectors whilst concentrating benefits among those higher up in the trade chain (Carpenter et al., 2005; Myers, 2015). Trade-offs were reported as exploitation and trade levels declined following stricter measures but adversely impacted local livelihoods by reducing income opportunities (Booth, 2016). One article reported negative synergies as a shrimp export ban caused some fishers to intensify shrimp fishing activities, or switch to other already exploited fish species, to make up for lost income, compromising future shrimp/fish stocks (Houssa & Verpoorten, 2015).

3.4 | Increase enforcement and compliance of harvest violations

Thirteen articles included in the narrative synthesis examined impacts of actions aimed to detect and enforce harvest laws and policies, which was the second most studied intervention category. The available evidence for this intervention category was limited to interventions aimed at reducing threats from unsustainable collection or poaching of birds and terrestrial mammals, and all but one (Di Vittorio et al., 2018) reportedly took place within the context of a protected area. Two-thirds ($n = 9$) reported largely positive impacts on reducing poaching but impacts on target species varied. The potential efficacy of interventions aimed at increasing enforcement

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and compliance of harvest, was supported by the supplementary meta-analysis on this subgroup (five articles) (Appendix S3). Surveillance, ranger patrols, and anti-poaching efforts contributed to higher abundance of target species compared with before the intervention (of Bonelli's Eagle: Di Vittorio et al., 2018) or areas with little or no detection efforts (of ungulates: Atickem et al., 2011; Ghoddousi et al., 2016). Two articles reported declining poaching incidents over time, which occurred in combination with increasing elephant abundance in heavily patrolled areas (Leader-Williams, 1996) and indications of an increasing tiger population although the article notes that it was too early to draw definite conclusions (Duangchantrasiri et al., 2016).

Four articles examined efforts explicitly involving local communities. Nest protection and surveillance by community members in India (Manchi & Sankaran, 2014) and Venezuela (Briceno-Linares et al., 2011) reportedly resulted in increased bird populations However, despite a decline in observed tiger poaching in Sumatra and Lao PDR respectively (Johnson et al., 2016; Linkie et al., 2015) following enforcement actions conducted by community members, efforts were unable to curtail extirpation of this high-value species due to continued poaching that natural reproduction rates could not compensate for and, to some extent, inconsistent fining and low prosecution and conviction rates. In addition, three articles found limited evidence that detection efforts deterred poaching due to inconsistent patrol quality (Hötte et al., 2016), especially strong incentives to poach high-value species such as rhinos (Barichievy et al., 2017), good infrastructure near ranger stations that attracted poachers and potential ranger involvement, directly or indirectly, in poaching activities (Jenks et al., 2012). Included articles thus help highlight certain factors that may limit the potential positive impacts of detection and enforcement efforts at the supply-side, including species-specific characteristics such as low reproductive rates and sensitivity to human pressures, as observed among chimpanzee populations in Cote D'Ivoire where, despite increased anti-poaching efforts, populations did not recover as observed for other species in the park (Kablan et al., 2019). No articles included in the narrative synthesis examining detection and enforcement interventions on harvest of species reported on socio-economic outcomes.

3.5 | Reduce threats to species

Ten articles examined impacts of spatial protection and included interventions such as National Parks, nest site protection, at times coupled with harvest regulations such as no-take zones and methods to reduce bycatch of endangered species (such as prawn fisheries in Northern Australia adopting methods that more effectively excluded non-target species: Brewer et al., 1998). Articles reported largely positive outcomes for target species, which was supported by the supplementary meta-analysis on this subgroup (four articles) (Appendix S3). Following spatial protection, articles reported increased reproduction rates of green turtles (Mortimer et al., 2011) and a stable, and possibly growing, tiger population in India (Bisht et al., 2019). Ferreira et al. (2017) found contrasting evidence on the effectiveness of the potential for national parks in South Africa to protect three rhino subspecies. Impacts varied across parks and subspecies due to disruptive effects of poaching, particularly high in Kruger National Park which also saw the greatest population declines, and biological factors affecting population growth rates.

Four articles examined impacts of harvest regulations and reported largely positive impacts on economic and material living standards although trade-offs on biological outcomes of target species were observed. Following an eight-year fishing moratorium on sea cucumbers in Papua New Guinea to prevent overexploitation, fishing was re-opened during a limited two-month period, despite the populations having not fully recovered (Hair et al., 2019). However, local villagers reported substantial improvements in their economic and material well-being during the two-month fishing period compared with during the fishing moratorium. The establishment of no-take zones led to significantly higher shark abundances in Indonesia, whereas local fishing communities were negatively impacted with reduced income and forced to fish in less productive areas, although impacts varied between sites (Jaiteh et al., 2016). Additionally, two articles that examined harvest regulations permitting more access and harvest of sea cucumbers in Mexico and Belize, when analyzed together, indicate positive outcomes for local households but also declined density and depletion of sea cucumber stocks (Glockner-Fagetti et al., 2016; Rogers et al., 2018). The latter found that declining sea cucumber abundance, due to increased access, caused fishers to harvest at much greater depths, consequently increasing harvest pressure on relatively unexploited populations.

3.6 | Support local livelihoods

Eleven articles examined the effectiveness of interventions aimed at supporting local livelihoods, with most articles reporting positive impacts on measured outcomes. Although this observation was not supported by the supplementary meta-analysis of this subgroup (three

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articles) (Appendix S3). Seven articles evaluated initiatives that promoted sustainable harvest and recognized community rights, and largely reported positive impacts on both target species and socio-economic outcomes by generating income and creating incentives for sustainable management (Kachel et al., 2017; Nawaz et al., 2008; Scholte et al., 2017). The level of impact varied among articles, and between sites within an article as reported by Rasul et al. (2012) that examined plant harvest programs in India and Nepal. Local collectors were provided training, which created new employment opportunities, improved plant quality, and increased market value and household income. However, due to different local contexts, stakeholder engagement and access to markets, contribution to local livelihoods varied.

In Zambia, new harvest regulations requiring sport hunting operators to provide a proportion of game animals harvested each year by hunting clients to nearby villages, with the objective to provide benefits of sport hunting to rural economies and livelihoods, resulted in improved food security for local communities (White & Belant, 2015). Positive synergies were observed when sustainable harvest methods of mushrooms in China also contributed to higher income for collectors (Yang et al., 2009). In the United States, the establishment of ranching programs for alligators potentially reduced, or at least did not increase, incentives for illegal harvest and trade (Moyle, 2013). An article that examined community-based natural resource management and crocodile ranching in Australia was unable to draw clear conclusions on the economic sustainability of the operation (Corey et al., 2018). Although the program contributed to local livelihoods, it was deemed not commercially viable due to low harvesting rates and incubation success, leading to inconsistent supply and quality of skins, making them less attractive across the supply chain. Nonetheless, the ranching program has, and continues to, run for a notable number of years, with social and environmental motivations likely being more important than commercial financial profits.

Two articles examined impacts of providing alternative livelihoods through ecotourism initiatives and reported positive socio-economic impacts. Important enabling conditions identified were close cooperation with, and support by, local authorities, and to clearly identify roles and distribution of revenue early on. A project in the Philippines provided alternative livelihoods to former whale shark fishers by offering employment in ecotourism activities. The article reported improved income for those involved, increased number of former fishers engaged in the project over the years, and improved law enforcement capacity as some of the revenue generated through ecotourism was used to finance training of sea patrol personnel (Lowe et al., 2019). Additionally, a project in Lao PDR emphasized the benefits of using a formal contract directly linking economic benefits and costs with positive conservation outcomes (wildlife sightings) and infractions (poaching incidents) and reported positive synergies between increased village revenue from tourism, reduced poaching incidents, and more wildlife sightings (Eshoo et al., 2018). However, the presence of a formal contract did not seem to influence the effectiveness of incentive-based initiatives to protect crocodile populations in Cambodia, with no significant difference reported when comparing impacts of direct (explicit contract) and indirect (without contract) incentive programs on socio-economic and conservation outcomes (Sony et al., 2009).

4 | DISCUSSION

Here, we present a comprehensive review of the impacts of interventions to regulate and manage impacts of international wildlife trade and report synergies and trade-offs between conservation, biological, and socio-economic outcomes. Regulatory measures aimed at the sale and transfer of wildlife and wildlife products and actions to increase harvest enforcement and compliance were among the most well-studied intervention categories, reflecting the prioritization of using laws, policies, and enforcement actions to regulate harvest and trade (Challender & MacMillan, 2014; Duffy et al., 2019; Roe, 2015). Although several articles reported positive impacts of regulatory measures, negative and unanticipated impacts and trade-offs were a dominating theme. The meta-analysis results, reported in the Supporting Information, are consistent with this observation, echoing the critique that regulatory measures can be an oversimplistic response to a complex problem, disregarding the economic reality and multifaceted drivers of wildlife trade (Challender et al., 2015b, 2015a; Cooney & Abensperg-Traun, 2013; Oldfield, 2003; Roe et al., 2002). Reducing unsustainable harvest and trade of high-value species where demand is largely driven by high prices, perceived rarity, and with a preference for wild-sourced products, appears especially challenging. Regulatory measures may signal a declining supply, consequently increasing the price, demand, and ultimately harvest pressure and rates of illegal trade (Challender & MacMillan, 2014; Crudge et al., 2020). Thus, this review provides further support for more research and robust impact evaluations of interventions that aim to address demand in key consumer countries, drive down market prices, provide market-based incentives to regulate trade, and community-based approaches (Challender et al., 2015b, 2015a;

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Roe & Booker, 2019; Verissimo & Wan, 2019; Thomas-Walters et al., 2020).

The challenge of protecting high-value species was also observed in articles examining detection efforts, although positive impacts dominated, suggesting they can be effective in reducing poaching and protecting target species. However, there is a pervasive publication bias favoring positive findings over negative or mixed findings in the conservation literature (Wood, 2020). Moreover, no articles included here examined the potential displacement effect of poaching efforts, reported elsewhere (e.g., Herbig & Minnaar, 2019), highlighting potential evidence gaps in our review. There was a clear overrepresentation of terrestrial mammals in the included articles harvested for medicinal purposes (e.g., tiger bones, bear organs), food, and e.g., elephant tusks and rhino horns (Figure S4). Despite more than 80% of all CITES-listed species being plants (including timber species), and only approximately 2% being mammals (CITES, n.d.), there was an overall paucity of articles assessing the impacts of interventions focused on plants. This is not surprising given the general lack of attention in research, policy, and funding for trade in plants, particularly the illegal trade (also referred to as "plant blindness", Margulies et al., 2019; Pires & Marteache, 2023; Wandersee & Schussler, 1999), which a recent review on a similar topic also concluded (Rytwinski et al., 2024).

Most articles explored impacts on biological and conservation-related outcomes, where impacts on the former were greater. A possible explanation may be the varied set of methods and data used to measure trade and management related outcomes (e.g., CITES trade data, national export data, market surveys), compared with biological impacts where methods used are typically more standardized (e.g., measuring population density). No socio-economic outcomes met the criteria for inclusion in the supplementary meta-analysis, reflecting the dearth of evidence in this area, but also highlighting the complexity of measuring outcomes, identifying relevant conditions and confounding factors, and possibly less systematic methods used. The paucity of evidence on socio-economic outcomes limits our ability to have a more nuanced understanding of the synergies and trade-offs of trade control interventions across different types of outcomes. Only negative impacts on local livelihoods were reported from articles examining regulatory measures, which risk compromising potential positive outcomes on target species outcomes as some articles reported increased exploitation or that people turned to sourcing other already pressured resources. The lack of evidence on socio-economic impacts of detection and enforcement interventions warrants attention, considering the potential negative impacts of curtailing local livelihoods dependent on wildlife as it may reduce incentives to tolerate animals and support conservation (Challender & MacMillan, 2014), and the increasing use of militarized forms of anti-poaching considered repressive and coercive (Duffy et al., 2019).

Indeed, these concerns have led to growing emphasis and support for community-based approaches to regulate and manage impacts of international wildlife trade and support local livelihoods (Cooney et al., 2016; Roe & Booker, 2019; Wilson-Holt & Roe, 2021). Articles reviewed here almost exclusively reported positive impacts and synergies between socio-economic outcomes and conservation of target species. However, effect sizes for this subgroup in the complementary meta-analysis were not significant, suggesting that caution should be taken in interpreting the efficacy of such interventions. Impacts of community-based projects often take long time to manifest (Roe et al., 2002) and vary greatly in terms of local context, project design, governance factors (e.g., property rights), and end-market factors (e.g., market and demand dynamics), all of which interact and influence potential outcomes (Cooney et al., 2015; Roe & Booker, 2019). In addition, impacts on communities can be heterogenous – affecting different groups and individuals within a community in different ways, with tradeoffs potentially occurring between different domains of well-being within an individual (e.g., improvements to income but at the expense of quality of life; Gill et al., 2019). As such, they should not be viewed as a panacea but rather one approach among many, as regulating and ensuring a sustainable wildlife trade while contributing to local livelihoods requires careful consideration.

Protected areas, both terrestrial and marine, have long been a central part of global conservation efforts (UNEP-WCMC et al., 2018). Our analysis provides evidence of the effectiveness of spatial protection, particularly when combined with harvest restrictions, in terms of protecting target species. However, important trade-offs were reported with negative impacts on local communities when harvest was restricted, and the opposite with less strict harvest regulations as local people reported increased income, but species abundance/density declined. How to balance conservation and development goals remains a challenge.

This comprehensive review of wildlife trade interventions moves beyond a description of the evidence base, to also examine the intersectionality of outcomes across biological and socio-economic spheres. However, whilst we have attempted to categorize articles according to our intervention framework to allow systematic coding and analysis, we recognize that this could lead to an oversimplification. Of the included articles, we only report on the effectiveness of the intervention articles specifically

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evaluated and clearly linked to outcomes(s) measured (as per our inclusion criteria). Included articles did not necessarily explore all possible outcomes, or report the full range of interventions that may have contributed to the outcome measured. For example, if a positive outcome was reported (e.g. reduction in poaching), this does not necessarily mean that the threat overall has decreased, or that the positive effect can be seen on the population as a whole. Likewise, it was not possible to conclude whether a positive impact e.g., on conservation outcomes, led to positive outcomes on e.g., local livelihoods (and vice versa), if this was not assessed/reported by the article. Wildlife collection and trade takes place in inherently complex socio-ecological systems where identifying causality and confounding factors is challenging, and this limits the appraisal of indirect outcomes. Indeed, outcome(s) are always likely a result of a mix of factors ranging from conservation measures over time and space, socio-ecological and socio-economic context as well as political and cultural factors. This exemplifies the challenges of understanding the full suite of impacts from conservation interventions.

Furthermore, the exclusion of interventions under the pathway *End-market actions*, due to limited evidence available, means that we were unable to evaluate the effectiveness of those types of interventions compared with other pathways focused on international wildlife trade. However, a recent synthesis examined efforts to reduce demand and consumption of wildlife products, but they were unable to conclude their effectiveness or magnitude of impact on behavioral or biological outcomes due to lack of robust study design and impact evaluations (Verissimo & Wan, 2019). Indeed, in our study, only 18 papers met the criteria for meta-analysis. Although our meta-analytical approach was designed to overcome such problems as high variance among articles, we present this in Supporting Information only because to appraise different interventions, we had to further divide the sample, in effect producing several even smaller meta-analyses. Although in most cases these analyses supported the conclusions of our review, we see this as primarily useful in drawing attention to the lack of appropriate articles, that we hope may stimulate such future research. This research only included interventions explicitly aimed at managing international wildlife trade, and therefore future research may wish to explore interventions targeting national trade and utilization. We also note that the limited number of articles relating to large industries, (e.g. fisheries and timber) is likely due to our strict inclusion criteria, for example they were not focused on international trade or were not taxon specific.

Our review captured both published and unpublished literature evaluating the effectiveness of interventions to regulate and manage impacts of international wildlife trade. By searching for relevant literature on topical websites in addition to publication databases, and issuing a call for evidence among relevant research networks, we attempted to capture a wide range of both published and gray literature and minimize possible publication bias (Leimu & Koricheva, 2005). It was beyond the scope of this review to include non-English language articles, but we recognize this can limit and bias results (Nuñez & Amano, 2021) and encourage inclusion of additional languages in future syntheses.

4.1 | Implications for conservation practice and policy

Our review shows the clear need for more and better-quality evidence and impact evaluations across intervention and outcome categories. This need is particularly pertinent for investigating socio-economic impacts across interventions, and the need to expand impact evaluations of human well-being outcomes beyond economic and material living standards, as noted by McKinnon et al. (2016) and Cheng et al. (2019). In turn, this will help identify the most appropriate intervention(s) and mitigate for potential unintended consequences or trade-offs identified a priori, for example negative livelihood impacts following more restrictive trade regulations. To address potential unintended consequences of trade interventions and improve the evidence base we suggest the following: (1) using relevant frameworks or theory of change (e.g., Biggs et al., 2017; Cooney et al., 2015) to guide policy makers and conservation practitioners to identify the relevant socio-ecological context, key enabling and disabling conditions, and underlying assumptions; (2) creating interdisciplinary project teams who can advise across conservation and socio-economic domains creating a holistic view of possible impacts of wildlife trade interventions; and (3) long-term impact evaluations utilizing rigorous research designs to facilitate concerted monitoring and assessment of a range of potential benefits and impacts associated with different interventions.

Finally, our study will better equip future synthesis efforts to tease apart the impacts of multiple intervention types and outcomes in one article and assess their effectiveness and how they interact and influence measured outcomes. This can help guide funding and management decisions towards effective interventions to regulate potential negative impacts of international wildlife trade, and enhance positive synergies between the trade, conservation and socio-economic outcomes.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

For access to the raw data, please contact the corresponding author.

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