What is the evidence that counter-wildlife crime interventions are effective for conserving African, Asian, and Latin American wildlife directly threatened by exploitation? A Systematic Map

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Abstract

1. Counter-wildlife crime interventions − those that directly protect target wildlife from illegal harvest/persecution, detect and sanction rule-breakers, and interdict and control illegal wildlife commodities − are widely applied to address biodiversity loss. This systematic map provides an overview of the literature on the effectiveness of counter-wildlife crime interventions for conserving African, Asian, and Latin American wildlife directly threatened by exploitation, including human-wildlife conflicts that trigger poaching.
2. Following our systematic map protocol (Rytwinski et al., 2021a), we compiled peer-reviewed and grey literature and screened articles using predefined inclusion criteria. Included studies were coded for key variables of interest, from which we produced a searchable database, interactive map, and structured heatmaps.
3. A total of 530 studies from 477 articles were included in the systematic map. Most studies were from Africa and Asia (81% of studies) and focused on African and Asian elephants (16%), felids (14%), and turtles and tortoises (11%). Most evaluations of counter-wildlife crime interventions targeted wildlife products (rather than species) and the transfer of those products along the wildlife-crime continuum (40% of cases). Population/species outcomes

were most commonly measured via indicators of threat reduction (65% of cases) and intermediate outcomes (25%).

4. We identified knowledge clusters where studies investigated the links between (1) patrols and other preventative actions to increase detection and population abundance, and (2) information analysis and sharing and wildlife crime/trade levels. However, the effectiveness of most interventions was not rigorously evaluated. Most investigations used post-implementation monitoring only (e.g. lacking a comparator), and no experimental designs were found. We identified several key knowledge gaps including a paucity of studies by geography (Latin America), taxonomy (plants, birds, and reptiles), interventions (non-patrol-based counter-wildlife crime interventions), and outcomes (biological, and the combination of biological and human well-being outcomes).
5. Our map reveals an opportunity to improve the rigor and documentation of counter-wildlife crime intervention evaluations, which would enable the evidence-based selection of effective approaches to improve wildlife conservation and national security.

Keywords: Evidence-based conservation, Evidence map, Evidence synthesis, Illegal trade, Illegal harvest, Law enforcement, Retaliatory killings, Wildlife trade

1. Introduction

One of the main drivers of biodiversity decline (second to habitat loss) is direct exploitation of species (Diaz et al., 2019). To help address species exploitation, a range of conservation interventions have been implemented to directly protect target wildlife from illegal harvest/persecution, detect and sanction rule-breakers, and interdict and control illegal wildlife commodities – here referred to as counter-wildlife crime (CWC) interventions (Fig. 1). Given the

recent emphasis on the use of these CWC interventions (Challender & MacMillan, 2014; Wright et al., 2016), there is a clear need to summarize the available evidence on biological and threat reduction outcomes of such actions to help make evidence-informed policy, management, and funding decisions.

Here, we use a systematic map approach to provide a collated summary of the existing body of literature addressing the effectiveness of CWC interventions for conserving African, Asian, and Latin American wildlife directly threatened by exploitation (including illegal harming of wild animals and plants whether by harvest as a resource or for control/persecution). Staff from the U.S. Fish & Wildlife Service (USFWS) and the Canadian Centre for Evidence-Based Conservation collaborated to develop this question in the context of the plant and animal species targeted by the agency's international grant programmes and law enforcement activities. The aim of this project was to better understand and help build the evidence base that supports grant-making programmes and decisions and to shed light on a topic of increasing policy relevance and attention. Although USFWS initiated the collaboration, this question is of broader relevance as governments and non-governmental organizations (NGOs) worldwide with a focus on nature conservation routinely make decisions about investment of limited resources with goals of having maximal conservation benefit (Brockington & Scholfield, 2010; Waldron et al., 2013). For further details on background, topic identification, stakeholder involvement, and intervention framework development, see our systematic map protocol (stage 1 registered report; Rytwinski et al., 2021a). Through this mapping exercise, we describe the quantity and key characteristics of the available evidence, and we identify knowledge clusters (subsets of evidence that may be suitable for secondary research) and knowledge gaps (topics that are underrepresented in the

evidence base that require future primary research). Specifically, we address the following research questions:

1. What are the frequency and types of CWC interventions used either alone, or in combination with other CWCs or with other non-CWC conservation interventions (e.g. species or land management, legal and policy frameworks) for conserving wildlife directly threatened by exploitation, for which evidence on effectiveness exists?
2. What are the frequency and types of CWC interventions performed by actors with law enforcement authority (i.e. defined here as people with authority to enforce laws in a broad sense e.g. confiscate firearms, spot fine or arrest offenders when encountered, and including criminal justice interventions like prosecuting and sanctioning wildlife crime), non-law enforcement authority (e.g. civil society, industry not trained or given authority to enforce laws), or both?
3. What are the key characteristics of the evidence base addressing the effectiveness of CWC interventions in terms of geographical locations, species or taxonomic groups, outcome measures, study designs, and monitoring/assessment methods?
4. What are the knowledge clusters and gaps in the evidence base?

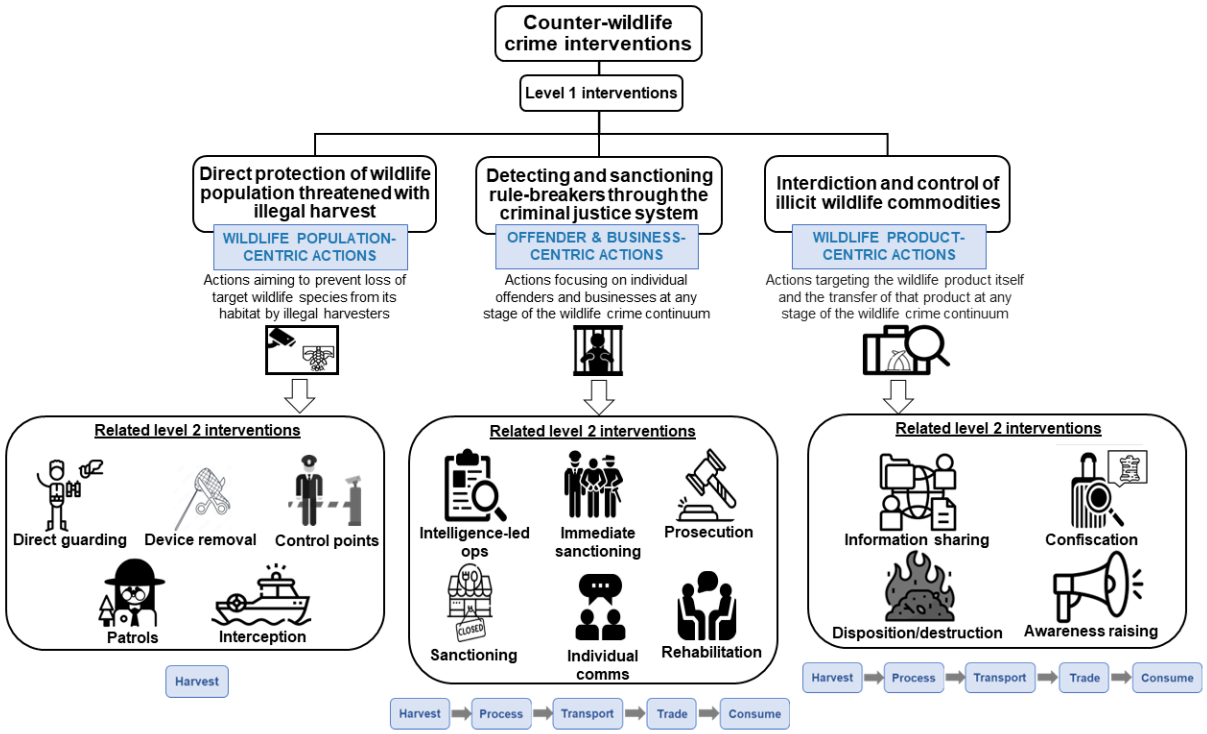

Fig. 1. The three eligible broad groups of counter-wildlife crime (CWC) (level 1) interventions implemented to address wildlife crimes, their associated sub-categories (level 2) interventions, and where these interventions fall along the wildlife-crime continuum (bottom blue boxes). See Table 1 for further details and Table 2 for definitions and examples. Note, icons included here for each CWC intervention are used throughout when presenting map findings.

2. Materials and Methods

This systematic map followed detailed methods described in the stage 1 registered report (Rytwinski et al., 2021a). In doing so, it was performed following, as closely as possible, the guidelines of the Collaboration for Environmental Evidence (CEE, 2018), and conforms to ROSES reporting standards (i.e. detailed forms for ensuring evidence syntheses report their methods to the highest possible standards; see Haddaway et al., 2018; Supporting Information 1).

2.1 Search strategy

This mapping exercise was based on literature searches conducted in 2021 using four publication databases, one web-based search engine (Google Scholar), and 36 specialist websites and online

129 databases (see Supporting Information 2 for full details and search results). Reference sections of
130 66 relevant reviews identified from this mapping exercise were hand-searched to evaluate
131 relevant titles that may not haven been found using the search strategy. We also issued a call for
132 evidence to target sources of grey literature through relevant mailing lists, social media, and
133 distribution to relevant networks and colleagues by the Advisory Team which was a project-
134 specific consultation group composed of 12 stakeholders and scientific experts consisting of
135 wildlife biologists, conservation scientists and criminologists from the USA, Central Africa,
136 México, Indonesia, South East Asia, and the Netherlands.

137 ## 2.2 Article screening and study eligibility criteria

138 Articles found by database searches, the search engine, and specialist websites were screened in
139 two distinct stages: (1) title and abstract, and (2) full text. Articles or datasets found by other
140 means (i.e. searching bibliographies of relevant reviews, social media, etc.) were entered at the
141 second stage of this screening process (i.e. full text). Due to the very large number of search
142 results from database searches alone (i.e. 36,430 records after duplicate removal), we used a
143 semi-automated approach by employing a text-based machine learning algorithm in the EPPI-
144 Reviewer Web software (https://eppi.ioe.ac.uk/EPPIReviewer-Web/home) to prioritize relevant
145 articles. In a deviation from our protocol, in which we proposed to use priority screening to
146 increase efficiency but still screen all database articles, we instead used priority screening to
147 come up with a logical cutoff point (i.e. a plateau where new articles were no longer being
148 included) at which screening was stopped. Specifically, after screening nearly 70% of database
149 articles (i.e. ~25,045/36,430 articles) and having not included a single article in 6,500
150 consecutive articles, we stopped title and abstract screening. This left 11,385 database articles
151 unscreened and assumed irrelevant (see Supporting Information 3 for further details on priority

screening using EPPI-Reviewer). Prior to screening articles, a consistency check was done at each stage on a subset of articles and discrepancies discussed (see Supporting Information 3 for further details on consistency checks).

All of the articles were screened according to the established eligibility criteria developed in consultation with the Advisory Team (Table 1 & 2; see also Supporting Information 3 for further details on eligibility criteria). Articles were included only when all six criteria were met. Given the broad objective and scope of this map, no formal study validity assessment (i.e. study susceptibility to bias) was performed on the included articles. Metadata on aspects of study design were extracted from included studies to provide a basic overview of the robustness and relevance of the evidence. However, the primary purpose of extracting this metadata was to aid with more in-depth synthesis of studies on sub-topics of interest identified from this mapping exercise. A list of articles excluded at the full-text screening stage or during the data extraction stage, with reasons for exclusion, is provided in Supporting Information 4.

165 **Table 1**. Article inclusion and exclusion criteria summarized from the stage 1 registered report (Rytwinski et al., 2021a). Further
166 criteria for consideration that were developed post-publication of the stage 1 report are shown in italic font.

Included	Excluded
Subject (population)	
• Any wild animal and plant species and taxonomic groups native to Africa, Asia or Latin America that are targeted by USFWS international activities, including the following broad taxonomic groups: African and Asian elephants, African and Asian rhinos, bovids, felids, pangolins, giraffes and okapi, parrots, ducks, geese and swans, shorebirds, songbirds and other passerines, Old World vultures, hornbills, hummingbirds, primates, turtles and tortoises, crocodiles, boas, pythons, chameleons, typical geckos, monitor lizards, girdle-tail lizards, cycads, succulents, cactus, aloes, elephant trunks, mahoganies, and rosewoods (but see Table S3.1 in Supporting Information 3 for a more complete list of eligible species). • While not comprehensive of all the species involved in USFWS international assistance, this species list is representative of the taxonomic groups targeted by the international activities of the agency's financial assistance programmes, Office of Law Enforcement, Migratory Bird Program, and international wildlife trade programme. • For the purposes of this exercise, Latin America included all the Americas south of the United States (i.e. South America, Caribbean, Central America including Mexico). • *Any study where the intervention was not targeting any species or taxonomic group specifically (e.g. no species were mentioned or only a general list of species in the area was provided) or it was unclear whether it was explicitly targeting a relevant species or taxonomic group, AND the intervention was implemented in Africa, Asia, or Latin America, AND all other criteria were met, were included, and coded as UNCLEAR population.* • *For passerines only, if the species was not listed under one of the eligible families listed in Table S3.1 in Supporting Information 3 BUT was native to Africa, Asia, and Latin America, AND all other criteria were met, we included these studies.*	• Any species or taxonomic group (1) not native to Africa, Asia, or Latin America, or (2) native to these regions but not targeted by USFWS international activities (i.e. not within an eligible Family identified in Table S3.1 in Supporting Information 3). *Captive animals without a direct link to the conservation of the wild population of an eligible species or taxonomic group (e.g. captive animals from pet trade that are then sent to zoos).*
Intervention/exposure	
• Any CWC intervention established, adopted, or implemented to prevent the loss of target wildlife, discourage non-compliance, raising awareness of or enforce compliance with existing laws and policies at all levels performed by actors with and/or without the authority to arrest, prosecute, and/or sanction alleged wildlife crimes. • We proposed three broad groups of CWC interventions primarily implemented to address direct threats: (1) Wildlife population-centric actions; (2) Offender and business-centric actions; and (3) Wildlife product-centric actions (Fig.1; Table 2; Fig. S3.2 in Supporting Information 3). • Eligible articles included an evaluation of a single CWC intervention, combinations of CWC interventions, or the combination of one or more CWC interventions and one or more non-CWC conservation interventions.	• Articles that only implement non-CWC conservation interventions(s) (i.e. any intervention from categories i-ix, with no CWC interventions) to conserve wildlife. *Also, studies that evaluated the effectiveness of a general management/conservation strategy(ies) for a protected area and it was clear (or unclear) that a CWC intervention was not included in this broad management strategy.*

- Non-CWC conservation interventions, when combined with CWC intervention(s) were identified and coded drawing upon the International Union for Conservation of Nature (IUCN) and Conservation Measures Partnership's (CMP) Conservation Actions Classification v2.0 (Salafsky et al., 2008; CMP, 2016), and included the following (level 1 action) categories: (i) Protected Area Management, (ii) Land/Water Management, (iii) Species Management, (iv) Livelihood, Economic, and Moral Incentives, (v) Conservation Designation and Planning, (vi) Legal and Policy Frameworks, (vii) Research and Monitoring, (viii) Education and Training, and (ix) Institutional Development. Note, non-CWC intervention category numbers do not align with those used in the IUCN-CMP Action classification because we consider 'Law Enforcement & Prosecution' and 'Awareness Raising' in our CWC interventions and added a different category 'Protected Area Management' to categorize those studies that address protected area management in general.

Direct threat(s)

- Relevant direct threats (i.e. wildlife crimes) included various forms of exploitation, broadly defined as the collection, harvest, or killing of terrestrial animals or animal products (i.e. hunting and collecting terrestrial animals), plants (i.e. gathering terrestrial plants), or trees (i.e. logging and wood harvest) for a resource or control/persecution reasons (i.e. human-wildlife conflicts).
- Although the word 'crime' implies illegal activities, and that is indeed the focus of our mapping exercise, not all papers clearly identified a threat as being legal/illegal. Furthermore, legality varies across geographical locals, and over time with changes in legislation (see t' Sas-Rolfes et al., 2019). Therefore, we assumed that if a CWC intervention was applied, the threat was considered illegal.
- Our selection and definitions of eligible wildlife crimes primarily drew from the Arizona State University Center for Problem-Oriented Policing's (POP) Taxonomy of Wilderness Problems (https://popcenter.asu.edu/content/resources) and partly from the CMP Direct Threat Classification (CMP 2016 v2.0). Further subcategorization of wildlife crimes was made as the review progressed drawing from the taxonomies of the POP center and the IUCN-CMP level 2 and 3 threats (see Table S3.2 in Supporting Information 3 for further details).
- Activities that are clearly identified as legal but may be associated with unsustainable harvesting. Studies that focus on fishing or harvesting aquatic animals and plants (note, however, bycatch was included).

Outcome

- Measures of change in biological outcomes (e.g. metrics related to abundance, biomass, reproduction, recruitment, behaviour) and threat reduction outcomes [e.g. metrics related to poaching incidence (number of poached animals), changes in wildlife crime levels (number of wildlife products available for sale at markets)], as well as other threat and/or intermediate indicators (e.g. presence of patrols deters poachers evaluated by comparisons of the number of poachers, incidence of illegal activity detected by CWC interventions evaluated by comparisons of the number of snares, gunshots heard or shell casings discovered); for further details see Table S3.3 in Supporting Information 3.
- Intermediate outcomes farther removed from ultimate conservation targets, including indicators related to (1) intervention effort (e.g. total days or distance patrolled), and (2) awareness, attitudes, or knowledge outcomes (e.g. percentage of people that indicate they will consume less bushmeat, change in attitudes towards poaching, number of rangers trained in new techniques). Articles reporting ecological outcomes (e.g. outcomes focusing on change in ecosystem processes and conditions, or community conditions), evolutionary phenomena and

	processes, and exclusively human well-being outcomes were excluded.
Comparator and Study design and type • We included all primary research studies that included a qualitative and/or quantitative evaluation of intervention effectiveness. • Where present, the absence of intervention either over time and/or between sites (hereafter: *true comparators*), associated with the following study designs: (i) Before/After (BA), (ii) Continuous time series (CONT TS; trend over time that includes baseline/before data with no gaps in time), (iii) Interrupted time series (INTER TS; trend over time that includes baseline/before data with gaps in time), (iv) Control/Impact (CI), (vi) Before/After/Control/Impact (BACI); see Fig. 2a. • Also, *alternate intervention comparators* that do not include a comparison to the absence of an intervention, associated with the following study designs that compared: (vii) Spatial locations with the same intervention, (viii) Among groups (i.e. comparing between populations of people or species), or (ix) Interventions (i.e. comparing between alternate levels of the same intervention or different types of interventions) (see Fig. 2b). • Finally, studies that do not include a comparator (*No comparators*), associated with (x) After only study designs (a single or multiple during or after time periods at a single impacted site i.e. no before/baseline data or spatial comparator) (see Fig. 2c). • Studies using an experimental approach (i.e. random assignment of sites/groups to treated [experimental] and untreated [control] sites/groups), quasi-experimental approach (similar to experimental but lacks random assignment), non-experimental approach (non-manipulative or observational studies where researcher takes advantage of changes that have happened [by using existing data] or about to happen [by taking measurements] to understand its effect e.g. correlational, comparative, or longitudinal), qualitative approach (focus almost exclusively on the sampling framework and not statistical power or how exposed and unexposed cases are compared), or theoretical approach (estimating impact of an intervention based on simulation modeling or theory exclusively).	• Comparator: No studies were excluded based on a comparator (or lack thereof). Study design: Review papers and policy discussions.
Language • English at full text	• Any study that was not in English at full text.

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168 **Table 2**. Definitions and examples of eligible counter-wildlife crime interventions.

Interventions	Definition	Examples
Wildlife Population-Centric Actions		
1.1 Direct Protection of Wildlife Threatened with Illegal Harvest	Actions aiming to prevent loss of target wildlife species from its habitat by illegal harvesters (not specifically to detect and arrest a harvester)	
Discouraging and/or removing opportunity structures used by harvesters to enter, extract wildlife products, and leave with the product through…		
1.1.1 Direct guarding of wildlife or key features 	Actions dissuading attempts to harvest by physical presence of guardian	Camping at locations of a nesting bird, camping on beaches during turtle egg laying to dissuade egg theft, directly following individual rhinos
1.1.2 Removal/destruction/control of traps, weapons, tools and infrastructure used by wildlife criminals 	Actions removing from circulation a device or tool that will either directly kill/catch or facilitate that process	Removal/destruction of traps and harvester tools and infrastructure (e.g. snare sweeps to collect abandoned wire used to make snare, destruction of poacher huts, or conveyances) Weapons amnesty (e.g. firearms are exchanged for farming tools)
1.1.3 Control of entry and exit points 	Actions discouraging illegal harvesters attempting to enter the species' protected habitat	Guard posts and checkpoints
1.1.4 Patrols and other actions to increase detection* 	Actions dissuading attempts to illegally harvest wildlife due to offender awareness of the elevated certainty of detection. This includes the deployment of technical sensors, or facilitating tip-offs from community members and tourists via a hotline*	Informant Drone/poacher camp/gunshot detector/geosensor/bioacoustics Patrol team Tourists, workers informing through some form of hotline
1.1.5 Interception of illegal harvest attempt 	Actions confronting illegal harvesters making an attempted incursion (ideally prior to extraction of resource). Here, actions result in a push out of the harvesting team, but no actual sanctioning occurs (cases of detention of individual harvesters, would fall under 1.2 below)	A coast guard patrol vessel intercepting an illegal trawler in a marine protected area
Offender and Business-Centric Actions		
1.2 Detection & Sanction of Rule-Breakers Through the Criminal Justice System	Actions focusing on individual offenders and businesses at whatever stage of the wildlife crime continuum	

Reducing, deterring and/or incapacitating illegal behaviors of offenders and businesses through…

1.2.1 Intelligence-led operations*  	Activities† supporting wildlife investigations. Here, information collection and analysis is used to guide operations	Tip lines Pre-enforcement action plans - deter illegal activity Target exploitation (def. building out threat profile) Link analysis (def: identifying network of individuals or businesses) Financial/Asset analysis Timeline structure Telephone (Toll Analysis) Imagery Interpretation Trend Analysis Short and long-term collection requirements (identifying gaps in information and addressing them to strengthen law enforcement cases) Shipping or database alerts
1.2.2 Sanctioning at time of encounter with offender  	Actions focusing on the immediate sanctioning of an offender at the time of encounter	Detain Arrest Confiscate and/or destroy items Formal Warning Verbal Warning Spot fine (e.g. fines for angling without correct permit) Eviction (e.g. removal of illegal land squatters)
1.2.3 Prosecuting and trying of alleged crimes  	Actions building prosecution cases and trying suspects in court	Holding trials for alleged law breakers
1.2.4 Sanctioning following prosecution and sentencing of offender  	Actions focusing on sanctions following offender prosecution	Incarceration Financial penalty Forfeiture of assets (e.g. conveyances used in commission of crime such as vessels, vehicles)

		Freezing of bank account (e.g. use of anti-money laundering acts to prevent profiting from crime) Repatriate (in cases of foreign criminals) Closure of business (e.g. restaurant repeatedly selling bushmeat, businesses acting as shell companies or legal fronts) Removal of benefits (e.g. conservation credits, vouchers for health clinic, government benefits) Job loss
1.2.5 Individual communications  Individual comms	Actions (communication related) supporting individual offender and potential offender compliance	Verbal communication about legality (e.g. during customs screening or in-person investigations) Targeted communication with repeat offenders Letters to individuals and businesses (e.g. letters sent from U.S. Customs and Border Protection to potential offenders about federal laws and regulations)
1.2.6 Rehabilitation  Rehabilitation	Actions supporting offender rehabilitation	Counseling programs, educational programs
Wildlife Product-Centric Actions		
1.3 Interdiction & Control of Illicit Wildlife Commodities	Actions targeting the wildlife product itself (including wildlife or wildlife parts, derivatives, or by-products) and the transfer of that product from person to person, place to place at whatever stage of the wildlife crime continuum	
Detecting, disrupting, and securing the post-harvest supply chain of wildlife products by...		
1.3.1 Information analysis and sharing  Information sharing	Activities† using information to support interdiction investigations of wildlife and wildlife products	Hotspot and trade analysis Sharing information within and among law enforcement agencies (coordination) CITES species identification guides Training videos to improve identification and detection of wildlife contraband

1.3.2 Detecting and confiscating illegal wildlife products  	Actions detecting and confiscating illegal wildlife products	Inspection Inspection using various tools to enhance procedures to detect, and then confiscate illegal products (e.g. detection dogs, thermo guns, xray machines)
1.3.3 Disposition and/or destructing seized illegal wildlife products  	Actions controlling, disposing, and/or destructing illicit wildlife commodities after detection to remove it from circulation	Disposition of illegal products to remove it from circulation (e.g. returning to country of origin or place of transit, burning of products) Management of stockpiled wildlife products (e.g. ivory, horns, timber)
Reducing the trafficking of illegal wildlife products by…		
1.3.4 Awareness raising related to the transfer of illegal wildlife products  	Actions making people aware of the illegality and/or penalties associated with illegal harvest, transit, trade, purchase, and/or consumption of illicit wildlife products	Reported media (e.g. TV, radio) Electronic media (e.g. social networks, chat platforms) Public service announcements (e.g. voice statements at transit hubs on the legal status of wildlife trade) Displays (e.g. Customs and CITES exhibits at borders, airports, poster or billboard campaigns) Person-to-person awareness engagement (e.g. info booth)

* Modifications to naming conventions and/or definitions that were developed post-publication of the stage 1 report.

† Considered here as activities that enhance CWC intervention execution success rather than as an intervention *per se*.

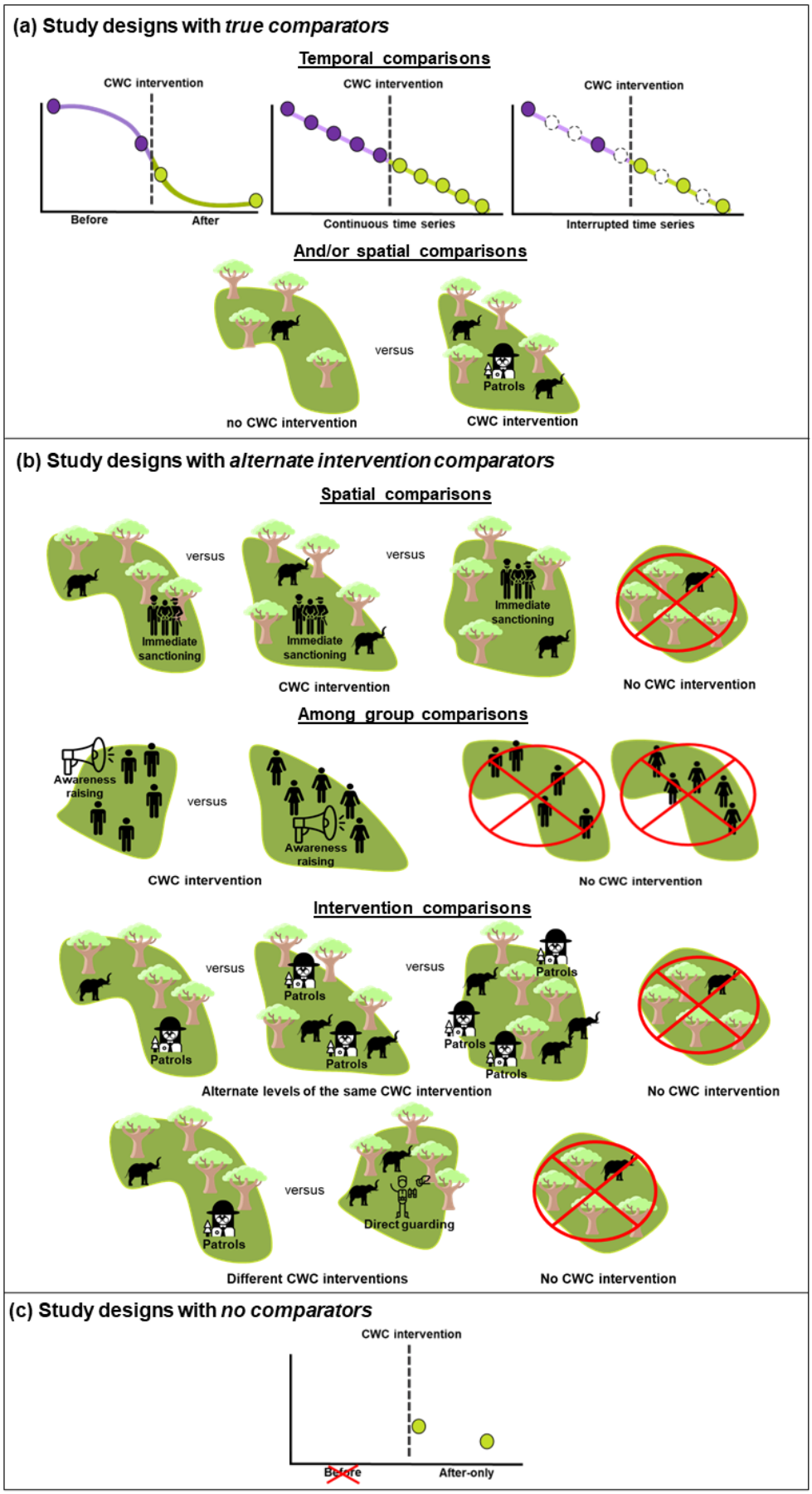

(a) Study designs with *true comparators*
Temporal comparisons
CWC intervention
Before
After
CWC intervention
Continuous time series
CWC intervention
Interrupted time series
And/or spatial comparisons
versus
no CWC intervention
Patrols
CWC intervention
(b) Study designs with *alternate intervention comparators*
Spatial comparisons
versus
Immediate sanctioning
versus
Immediate sanctioning
CWC intervention
Immediate sanctioning
No CWC intervention
Among group comparisons
Awareness raising
versus
Awareness raising
CWC intervention
No CWC intervention
Intervention comparisons
Patrols
versus
Patrols
Patrols
versus
Patrols
Patrols
Patrols
Alternate levels of the same CWC intervention
No CWC intervention
Patrols
versus
Direct guarding
Different CWC interventions
No CWC intervention
(c) Study designs with *no comparators*
CWC intervention
Before
After-only

Fig. 2. Eligible comparators and study designs, including: (a) *true comparators*: designs that include a comparison (of outcome data) with the absence of intervention either over time (baseline/before data) and/or between sites (spatial control site(s)), associated with Before/After, Continuous time series (no gaps in time), Interrupted time series (gaps in time), Control/Impact, or Before/After/Control/Impact designs; (b) *alternate intervention comparators*: designs that lack a comparison with the absence of an intervention (denoted with red circled Xs) but instead compared the impact of a particular CWC intervention across locations (spatial comparisons not treated as replicates in a study), between populations of people or species (among group comparisons), or between alternate levels of the same intervention (e.g., regular patrols versus intelligence-led patrols) or different types of interventions (patrols versus direct guarding of wildlife) (i.e., intervention comparisons); or (c) *no comparators*: study designs completely lacking a comparison such as After only designs where a single or multiple during/after time periods at a single impacted site i.e. no before/baseline data or spatial comparator).

2.3 Data coding and extraction strategy

Following full-text screening of articles, relevant studies were extracted from the included articles (i.e. where multiple studies were reported within one article they were entered as independent lines in the database). We defined a study (case studies) to be an investigation/experiment of a single CWC intervention, or a combination of CWC interventions conducted at a specific study location (but could include multiple study sites) over a similar specified time period. Studies were separated by line when separate relevant comparisons were reported for the same or different species and different: (1) CWC interventions (level 1 or 2), and/or (2) outcome categories and/or subcategories.

In developing the data extraction form and codebook (i.e. code sheet for all codes used in extraction form), the following key variables were identified through scoping activities and discussion with the Advisory Team: (1) bibliographic information; (2) geographical location (e.g. country, latitude/longitude); (3) species (or taxonomic group) information; (4) direct threat information; (5) intervention details [e.g. CWC intervention type (see Table 2), actor(s) implementing CWC intervention (law enforcement actors, non-law enforcement actors, both),

whether a CWC intervention was combined with a non-CWC intervention]; (6) study design and comparator information; (7) outcome details [e.g. outcome category (biological, threat reduction, intermediate), and subcategories within (e.g. abundance, biomass, behaviour, poaching incidents, wildlife crime/trade levels, evidence of illegal activities, incidence of offender arrests), whether human well-being outcomes were also measured (Y/N), and if Y, which human well-being outcomes[1]]; (9) assessment method details (e.g. outcome data collection in the field or court, via interviews/surveys). Coding options within these key variables were then compiled in a partly iterative process, expanding the range of options as they were encountered during extraction. To ensure that data were being extracted in a consistent and repeatable manner, the Review Team conducted a consistency check on a subset of articles and discrepancies were discussed (see Supporting Information 3 for further details on consistency checks). The finalised extraction form and codebook for this review (along with descriptions of each meta-data/coding field) is shown in Supporting Information 5.

2.4 Data synthesis and presentation

Our primary outputs from this systematic map are a searchable, coded database (MS-Excel) along with an interactive map (evidence atlas) of studies, created using the open access, open-source software tool EviAtlas (https://estech.shinyapps.io/eviatlas/) (Haddaway et al., 2019). The software accepts input data as spreadsheets (e.g. .csv format). This evidence atlas plots the location of all studies in geographical space, allowing the user to interrogate and filter datasets according to categories of interest (e.g. country, taxonomic group, CWC intervention, threats)

[1] Given the importance of conservation interventions striving for not only biological but also human well-being objectives (e.g. Biedenweg & Gross-Camp, 2018; Kaplan-Hallam & Bennett, 2018), information on human well-being outcomes were coded from studies when these were reported in addition to relevant direct and/or indirect measures.

and see their summary information. The input file for viewing the studies as an evidence atlas using the online EviAtlas portal is in Supporting Information 6. Descriptive statistics were used to describe the overall amount (e.g. number of articles, number of studies) and key characteristics of evidence available (e.g. geographic locations, species, interventions, wildlife crimes, outcome measures, study designs, and monitoring/assessment methods). Key knowledge gaps (areas that are under-represented in the evidence base and could warrant further research) and knowledge clusters (areas of evidence that may be suitable for secondary research) were identified using structured heatmaps showing linkages between examined CWC interventions (rows) and measured outcomes (columns). As studies within individual articles can examine links between more than one CWC intervention and outcome type, individual studies were mapped to more than one cell when applicable (i.e. referred to as cases). Note, these heatmaps do not quantify or validate the effectiveness of CWC interventions for protecting and conserving wildlife but rather aim to describe the distribution of research efforts and were used to identify knowledge clusters and gaps.

3. Results and discussion

3.1 Review descriptive statistics

A total of 530 studies from 477 articles met our inclusion criteria and were subsequently included in the systematic map, corresponding to 3183 outcome lines (see Fig.S7.1 in Supporting Information 7, for a ROSES flow diagram depicting the full review process). Article publication dates ranged from 1965 to 2021, with relatively few articles published prior to 1996, and the majority in the last ten years (74% of articles). The observed increase in publications in the last decade tracks with other related reviews (e.g., Cheng et al., 2017; Mirin & Klinck, 2021), and

coincides with the timeline of growing attention on biodiversity loss and widespread illegal trade in political and conservation agendas (e.g. U.S. National Strategy for Combating Wildlife Trafficking, wildlife crime made a priority in 2014 by the United Nations Office on Drugs and Crime, Declaration from the 2014 London Conference on Illegal Wildlife Trade, Declaration from the 2015 International Conference on Illegal Exploitation and Illicit Trade in Wild Flora and Fauna in Brazzaville). Additionally, in the overall evidence base, commercially published literature accounted for a higher frequency of included articles than grey literature (72% versus 28%, respectively), and this pattern remained relatively consistent among years over the last two decades (see Fig. S7.2 in Supporting Information 7).

3.2 Summary of the evidence base

3.2.1 Study location

Studies on the effectiveness of CWC interventions were most often conducted in Africa and Asia (41% and 40% of studies, respectively), with relatively fewer in Latin America (13%). While we acknowledge that this geographical imbalance could be due in part to a language bias in the map (see *Limitations of the mapping methods* below), we believe this does represents a 'real' imbalance in knowledge. Indeed, a general lack of attention, data, and funding for CWC investigations and interventions in Latin America has been noted previously by others (e.g., Reuter et al., 2018; UNODC 2020; Gluszek et al., 2021). In a few studies, CWC interventions were implemented in other regions (e.g. inspections at North American or European airports), reporting relevant outcomes for species or taxonomic groups native to Africa, Asia, or Latin America (7% of studies). Of the 34 included African countries, most studies were from Tanzania, Uganda, Cameroon, and South Africa (>20 studies each; Fig. 3). For Asia, 32 countries were captured in our database, with most studies from Indonesia, China, Thailand, and

Malaysia. Comparatively, 24 countries were included from Latin America, with studies predominantly from Brazil (Fig. 3). An exemplary screenshot of the interactive evidence atlas showing the locations of all CWC intervention investigations can be seen in Fig. 4.

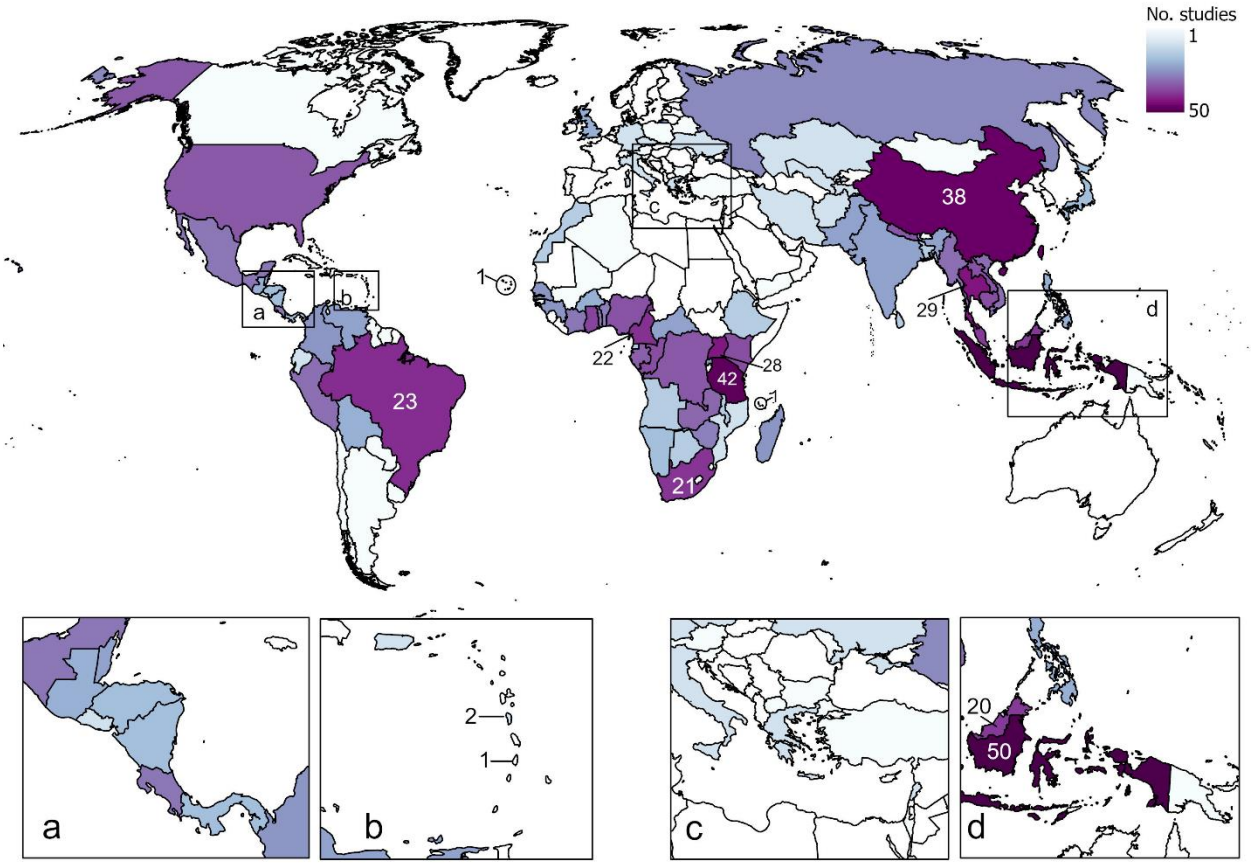


Fig. 3. Geographical distribution of evidence, displaying the number of studies per country. Studies undertaken across more than one country are counted within each study country.

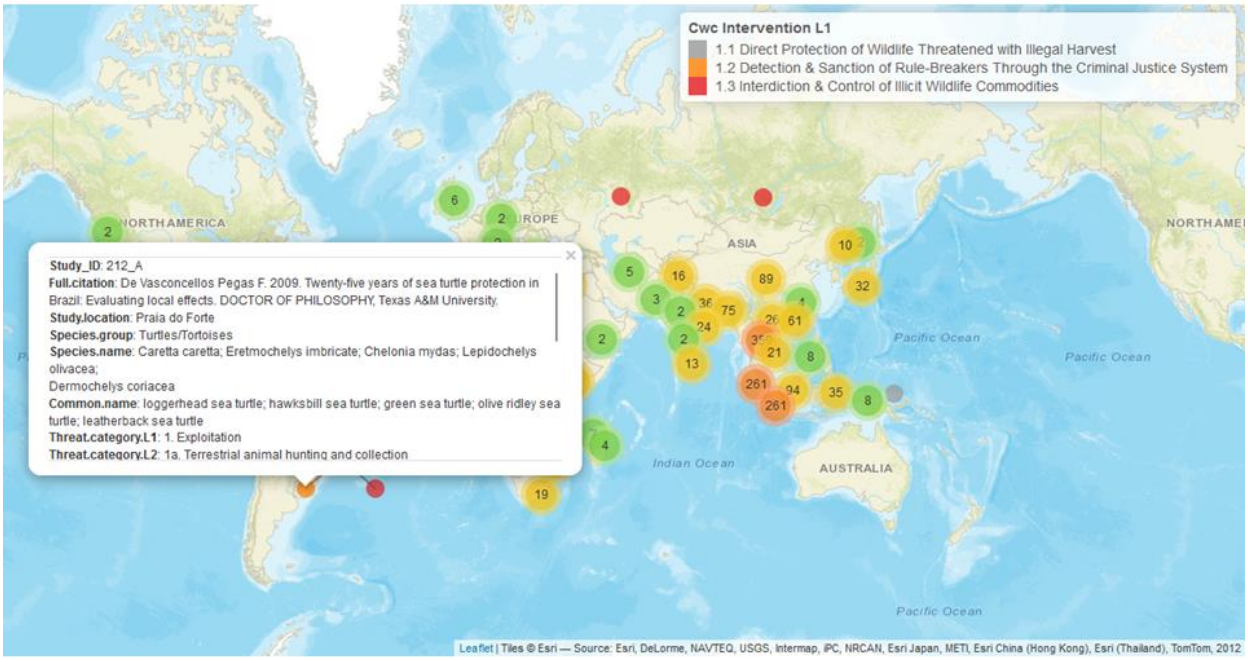


Fig. 4. Screenshot of the interactive evidence atlas showing the location of all CWC intervention investigations in the 530 included studies (from 477 articles) across the 3183 outcome cases. The popup contains descriptive meta-data and a link to the article on Google Scholar.

3.2.2 Study designs

Most studies (82%; 435/530) used a non-experimental study type to investigate the effectiveness of CWC interventions (see Table 1 for definitions). There were no experimental studies captured in the evidence base (i.e. those using random assignment of the intervention to different sites or groups). Only 59 unique studies (11% of the evidence base) employed a study design that included a *true comparator*. Comparatively, many studies used an *alternate intervention comparator* (Fig. 5; see Fig. 2 for examples and descriptions). While designs that use an alternate intervention comparator may show a difference in CWC intervention effectiveness between the comparisons, our ability to infer intervention effectiveness is limited in the absence of a true comparator (i.e. a comparison with the absence of intervention either over time and/or between sites). Overall, the vast majority of studies used an After-only design (i.e. no before/baseline

intervention data or spatial comparator; Fig. 5). Without employing an appropriate temporal or spatial comparator, a study is unable to attribute any observed changes in an outcome to the studied CWC intervention because changes in the outcome could have occurred without the intervention (e.g. due to natural seasonal changes, changes in land-use, market fluctuations, impact of education strategies; Christie et al., 2020). See *Limitations of the evidence base* below for further discussion.

Approximately 73% of studies collected relevant direct and/or indirect outcome data from the field (e.g. biological surveys in protected areas) or the courtroom/police station (e.g. cases of CWC intervention related to prosecuting and trying alleged crimes), whereas fewer studies measured outcomes via social science (i.e. interviews or surveys with people; 16%), or both in-field and social science (4%). Remaining studies used theoretical modelling to obtain (predicted) outcome data.

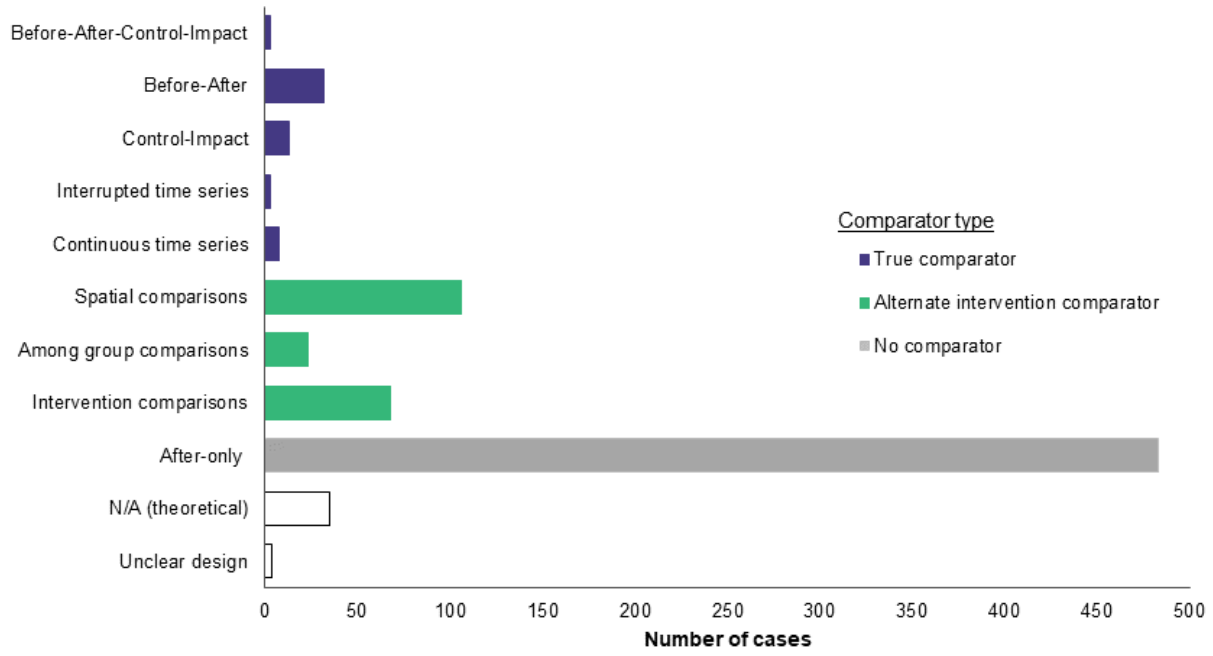


Fig. 5. Frequency of cases in relation to study design and comparator type. The total number of cases exceeds the number of studies since some studies used more than one study design.

3.2.3 Population

Nearly three quarters of the studies evaluating CWC intervention effectiveness targeted at least one relevant wildlife species (i.e. 380/530 studies reported at the species level; see Table S3.1 in Supporting Information 3 for a complete list of eligible species), of which most (49%) targeted a single species (range: 1 to 145 target species). For the remaining studies, there was either (1) no mention of target species and no indication of which species were found in the study area, but the intervention was implemented in Africa, Asia, and/or Latin America, or (2) a list of species found in the study area was provided, with at least one relevant to this map, but no direct link was made stating that the intervention was specifically implemented to target all or some of those species. This was common for cases where the study was, for instance, evaluating anti-poaching efforts such as the removal/destruction of traps with studies reporting outcomes such as the number of snares destroyed, or actions focusing on the sanctioning of an offender and reported outcomes were the number of poachers arrested but, in either case, without mention to species (here termed *Unclear population*).

When studies reported a relevant wildlife species or taxonomic group, the most common group of conservation focus overall were African and Asian elephants (16% of studies), followed by felids (14%), and turtles and tortoises (11%). All remaining taxonomic groups were included in fewer than 8% of the evidence base. There was an overall paucity of studies on plant groups, with only a few studies on relevant rosewoods (1% or 10 studies), mahoganies (2 studies), and cycads (1 study), and no studies on relevant succulents, aloes, or elephant trunks. This finding is not surprising given the lack of attention (research, policy, funding related) for flora noted previously by others in the illegal wildlife trade space, otherwise known as “plant blindness” (Wandersee & Schussler 1999; Margulies et al., 2019, Pires & Marteache, 2023).

Sixteen taxonomic groups were captured in the evidence base for CWC interventions implemented in Africa, with the majority of studies focusing on conserving African elephants (*Loxodonta africana*, *Loxodonta cyclotis*) (Fig. 6a). There were also relatively similar numbers of studies for African rhinos (*Ceratotherium simum*, *Diceros bicornis*), bovids (e.g. *Syncerus caffer*, *Tragelaphus scriptus*, *Aepyceros melampus*), felids (e.g. *Panthera pardus*, *Panthera leo*, *Acinonyx jubatus*), and primates (e.g. *Pan troglodytes*, *Gorilla beringei beringei*, *Gorilla gorilla*). In all such groups, while all three broad groups of CWC interventions were implemented, most studies focused on evaluating the effectiveness of interventions aimed to prevent the loss of target wildlife species from its habitat by illegal activities by directly protecting the wildlife (Fig. 6a).

Asia had the largest number of taxonomic groups represented in the evidence base (21 groups), with the highest concentration of studies focused on felids (e.g. *Panthera tigris*, *Prionailurus bengalensis*, *Panthera pardus*), Asian rhinos (*Rhinoceros unicornis*), and turtles and tortoises (e.g. *Amyda cartilaginea*, *Geochelone elegans*, *Cuora amboinensis*). For Asian felids, rhinos, and bovids, all three broad CWC interventions were implemented in relatively equal proportion among studies; however, for all other taxonomic groups, most studies evaluated the effectiveness of interventions aimed to target illegal wildlife products (wildlife or wildlife parts, derivatives, or by-products) and their removal from circulation by interdiction and control (Fig. 6b).

Only 12 taxonomic groups were captured in the evidence base for Latin America, with most studies focused on conserving parrots (e.g. *Ara macao*, *A. militaris*, *Amazona farinose*) and turtles and tortoises (*Lepidochelys olivacea*, *Chelonia mydas*, *Podocnemis unifilis*). For both taxonomic groups, studies evaluating the effectiveness of CWC interventions were captured for

all three broad CWC intervention groups. For all other taxonomic groups, most or all the studies focused on evaluating interventions related to the interdiction and control of illicit wildlife commodities (Fig. 6c).

When CWC interventions were implemented in other regions, 17 taxonomic groups were included with wildlife native to Africa, Asia, or Latin America. Most of these studies were evaluations of interventions related to the interdiction and control of illicit wildlife commodities, primarily for elephants, felids, rhinos, and turtles/tortoises (Fig. 6d).


(a) Africa
African & Asian elephants
African & Asian rhinos
Aloes
Boas
Bovids
Cactus
Chameleons
Crocodiles
Cycads
Ducks, Geese & Swans
Elephant trunks
Felids
Giraffes & Okapi
Girdle-tail lizards
Hornbills
Hummingbirds*
Mahoganies
Monitor lizards
Old World Vultures
Pangolins
Parrots
Primates
Pythons
Rosewoods
Shorebirds
Songbirds & other passerines
Succulents
Turtles & Tortoises
Typical geckos
Unclear population
0 20 40 60 80 100 120
Number of studies
(b) Asia
African & Asian elephants
African & Asian rhinos
Aloes
Boas
Bovids
Cactus
Chameleons
Crocodiles
Cycads
Ducks, Geese & Swans
Elephant trunks*
Felids
Giraffes & Okapi*
Girdle-tail lizards*
Hornbills
Hummingbirds*
Mahoganies
Monitor lizards
Old World Vultures
Pangolins
Parrots
Primates
Pythons
Rosewoods
Shorebirds
Songbirds & other passerines
Succulents
Turtles & Tortoises
Typical geckos
Unclear population
0 20 40 60 80 100 120
Number of studies
(c) Latin America
African & Asian elephants*
African & Asian rhinos*
Aloes
Boas
Bovids
Cactus
Chameleons*
Crocodiles
Cycads
Ducks, Geese & Swans
Elephant trunks*
Felids
Giraffes & Okapi*
Girdle-tail lizards*
Hornbills*
Hummingbirds
Mahoganies
Monitor lizards*
Old World Vultures*
Pangolins*
Parrots
Primates
Pythons*
Rosewoods
Shorebirds
Songbirds & other passerines
Succulents
Turtles & Tortoises
Typical geckos
Unclear population
0 20 40 60 80 100 120
Number of studies
(d) Other regions
African & Asian elephants
African & Asian rhinos
Aloes
Boas
Bovids
Cactus
Chameleons
Crocodiles
Cycads
Ducks, Geese & Swans
Elephant trunks
Felids
Giraffes & Okapi
Girdle-tail lizards
Hornbills
Hummingbirds
Mahoganies
Monitor lizards
Old World Vultures
Pangolins
Parrots
Primates
Pythons
Rosewoods
Shorebirds
Songbirds & other passerines
Succulents
Turtles & Tortoises
Typical geckos
Unclear population
0 20 40 60 80 100 120
Number of studies
Wildlife population-centric interventions
Offender & business-centric interventions
Wildlife product-centric interventions

Fig. 6. Number of studies by taxonomic groups in each relevant broad region where CWC interventions (level 1) were implemented. Unclear population: the CWC intervention was not targeting any species or taxonomic group specifically or it was unclear whether it is explicitly targeting a relevant species or taxonomic group, but the intervention was implemented in Africa, Asia, or Latin America. Note, all the same taxonomic groups are included for each broad geographical region panel regardless of whether relevant native species exist for that group in each region; however, asterisks beside groups for a given geographical area were used to indicate such cases where taxonomic groups would not be expected to have relevant native species for that region, yet it was possible a CWC intervention was implemented there (e.g. seizures at ports). The number of studies shown exceeds the number of included studies because many studies considered multiple taxonomic groups.

3.2.4 Threats

The most frequent direct threat (i.e. wildlife crime) reported resulting in the need for CWC interventions was *Exploitation* (91% of cases). Most studies involving *Exploitation* identified *terrestrial animal hunting and collection* as the main (level 2) threat (440/489 *Exploitation* cases). Considering there were relatively few studies focused on plants captured in the evidence base, *logging/wood harvest* and *gathering terrestrial plants* made up a small proportion of the *Exploitation* crimes (21 and 2 unique studies, respectively). There were only four studies that reported *Human-wildlife conflicts* as the main direct threat, all from Africa, and related to conflicts with elephants, felids, and primates. This relatively low prevalence of *Human-wildlife conflicts* as a main threat is likely due to an information gap in linking retaliatory killings from *Human-wildlife conflicts* and opportunistic attempts to sell wildlife products derived from those animals. Indeed, most of the studies captured in our search focused on preventing or reducing *Human-wildlife conflicts* by implementing interventions related to species management actions (i.e. actions directly managing or restoring specific species or taxonomic groups; and these were excluded from the map) rather than reporting on CWC implications of retaliatory killings (i.e. the

386 subsequent illegal trade) and/or CWC intervention effectiveness (but see Nowell et al., 2016).
387 Lastly, the combination of *Exploitation* and *Human-wildlife conflicts* threats was reported in 42
388 unique studies, with most focusing on conserving felids, elephants, and primates.

389 ### 3.2.5 Interventions

390 The most common broad group of CWC interventions implemented to address direct threats was
391 wildlife product-centric actions (274 cases), followed by wildlife population-centric actions (235
392 cases) and offender and business-centric actions (178 cases). Overall, 48% of cases implemented
393 a single CWC intervention, whereas the remaining cases were either combinations of CWC
394 interventions (43%; at any intervention level) or it was unclear whether a single or multiple
395 interventions were implemented (9%). When CWC interventions were combined, most frequent
396 combinations involved direct protection of wildlife (e.g. through patrols) and detection and
397 sanctioning of rule-breakers (e.g. sanctioning at time of encounter with offender) (68/231
398 combination cases; 29%), followed by combinations of interdiction and control of wildlife
399 commodities (e.g. hotspot and trade analysis and inspections) (18%), and combinations of direct
400 protection of wildlife (e.g. patrols and removal of traps) (15%). CWC interventions were often
401 implemented with non-CWC interventions (67% of cases), primarily simultaneous with, for
402 example, protected area management, species management, legal/policy frameworks, and/or
403 livelihood, economic, and moral incentives.

404 With respect to wildlife-population-centric actions, most cases involved one or more forms
405 of patrols or other actions to increase detection (Fig. 7). These actions were performed most
406 frequently by actors with law enforcement authority, although there were a few interventions
407 also implemented by non-law enforcement authorities (e.g. direct guarding of wildlife,
408 informants).

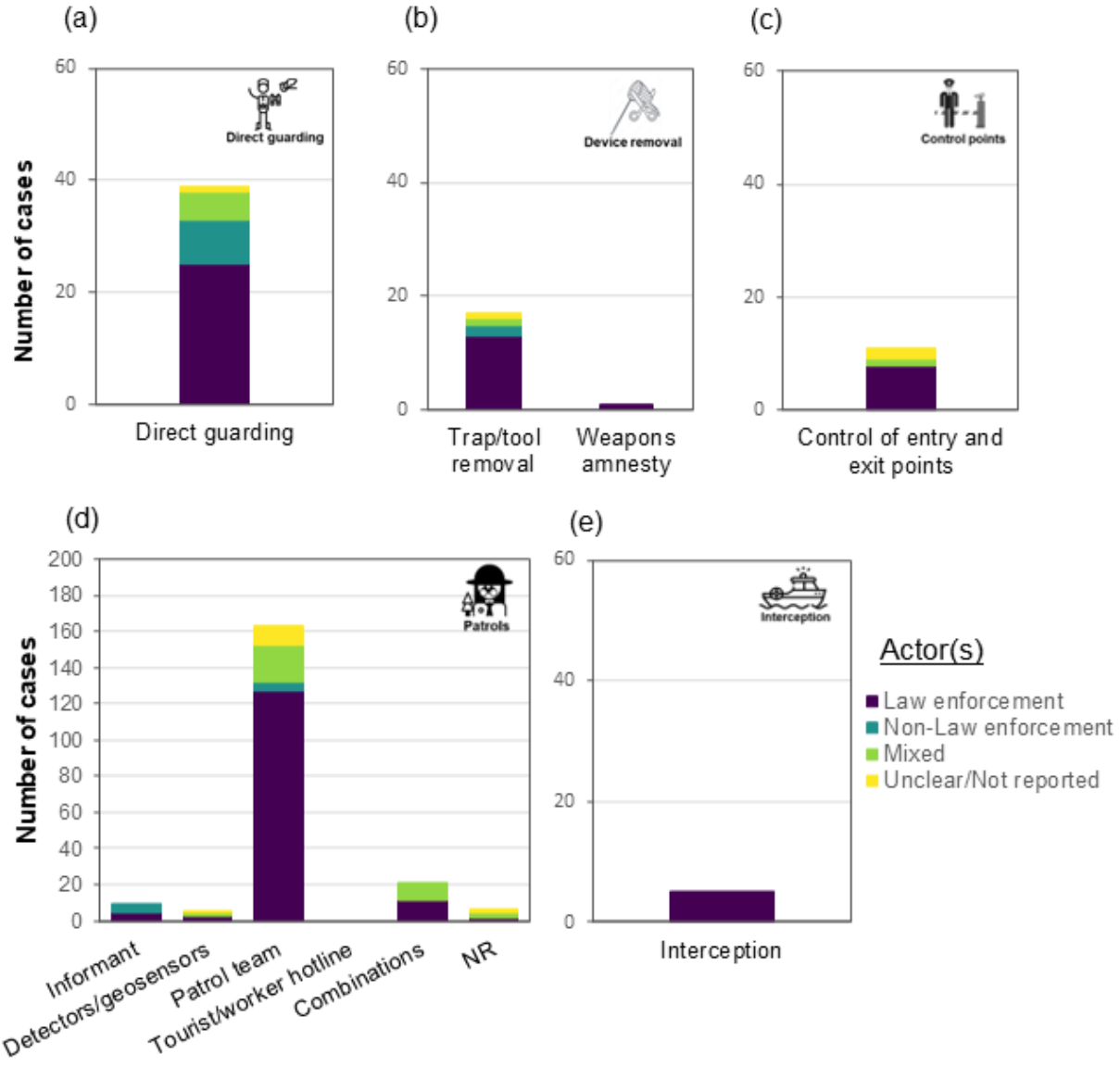


Fig. 7. Number of cases in relation to level 2 (panels) and 3 (columns within panels) wildlife population-centric actions by the actors involved in implementation: (a) Direct guarding of wildlife or key features; (b) Removal/destruction/control of traps, weapons, tools and infrastructure used by wildlife criminals; (c) Control of entry and exit points; (d) Patrols and other actions to increase detection; (e) Interception of illegal harvest attempt. NR: not reported. Note the difference in scale for (d) compared to other panels.

For offender and business-centric actions, most cases involved one or more forms of sanctioning at the time of encounter with offenders, most commonly, arrests and confiscation of items (Fig. 8). There were relatively fewer cases of activities related to intelligence-led operations and actions related to sanctioning following prosecutions/sentencing of offenders, and no studies that investigated the effectiveness of individual communication (e.g. verbal communication about legality, target communication with repeat offenders) or offender rehabilitation actions. Similar to wildlife population-centric actions, most actions were performed by actors with law enforcement authority.

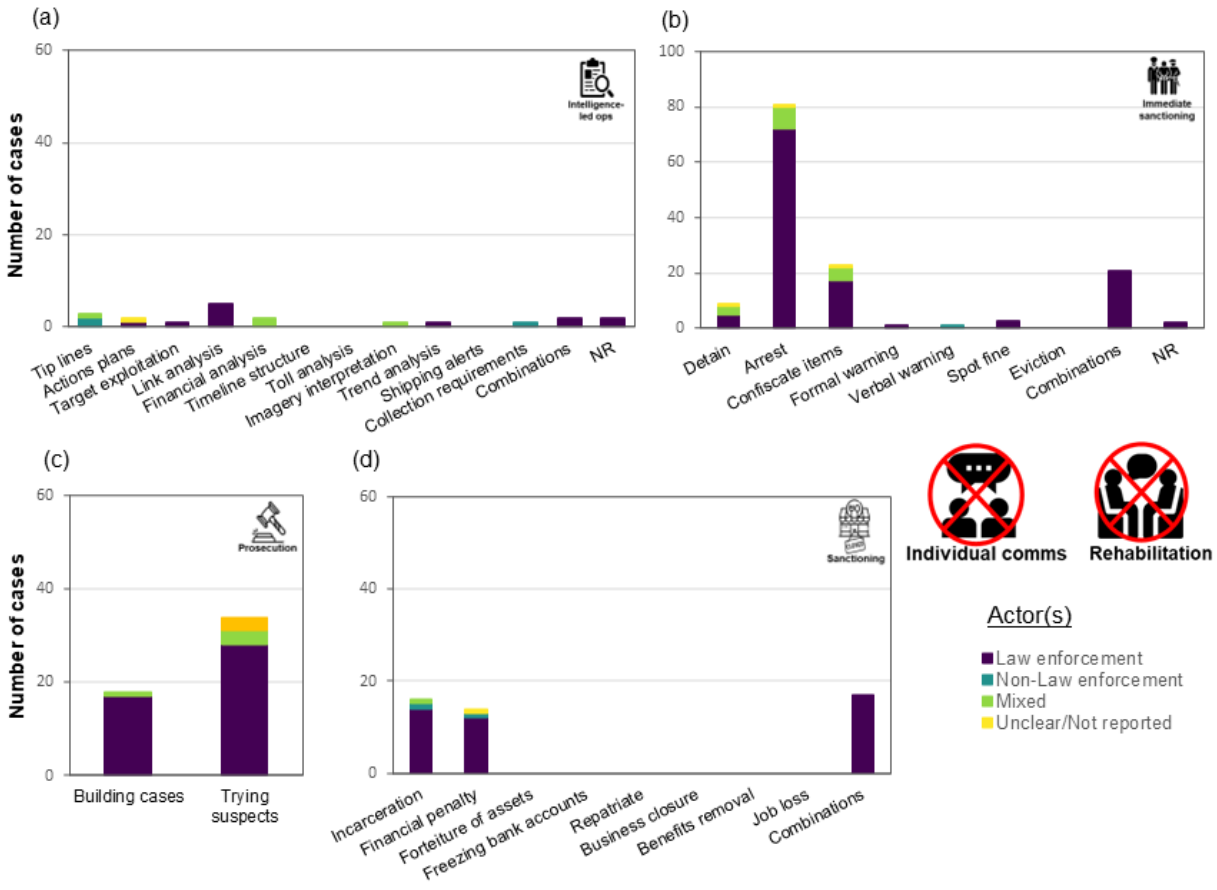
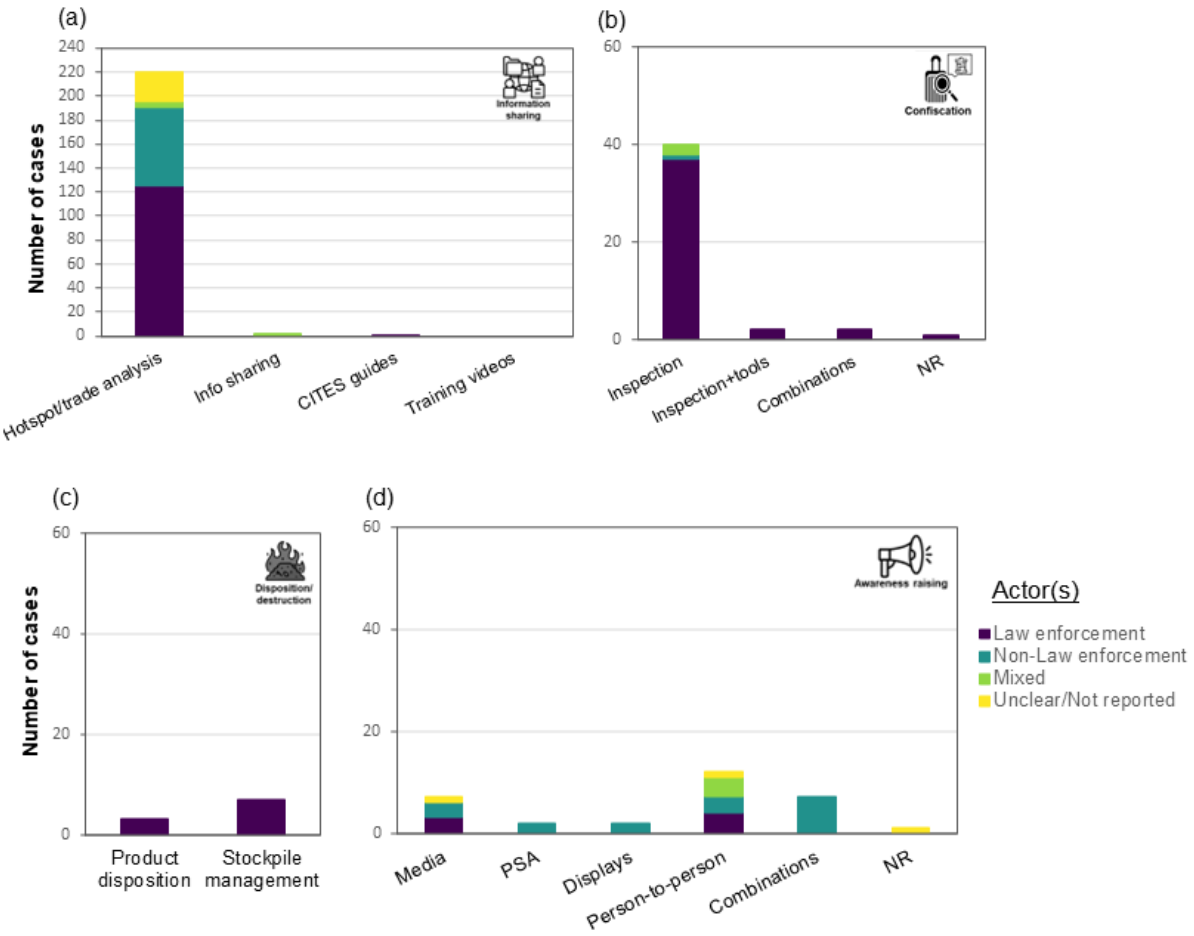


Fig. 8. Number of cases in relation to level 2 (panels) and 3 (columns within panels) offender and business-centric actions by the actors involved in implementation: (a) Intelligence-led

operations; (b) Sanctioning at time of encounter with offender; (c) Prosecuting and trying of alleged crimes; (d) Sanctioning following prosecution and sentencing of offender. Individual comms: Individual communications; NR: not reported. Note the difference in scale for (b) compared to other panels.

Lastly, for wildlife product-centric actions, cases were dominated by hotspot and trade analysis activities, a form of information analysis and sharing (Fig. 9). There were also several cases related to detecting and confiscating illegal wildlife products via inspections, but relatively fewer cases of actions related to disposition and/or destruction of seized illegal wildlife products or awareness raising related to the transfer of these products. Most wildlife product-centric actions were performed by actors with law enforcement authority, except for hotspot and trade analysis and awareness-raising actions which were also implemented by non-law enforcement authorities.



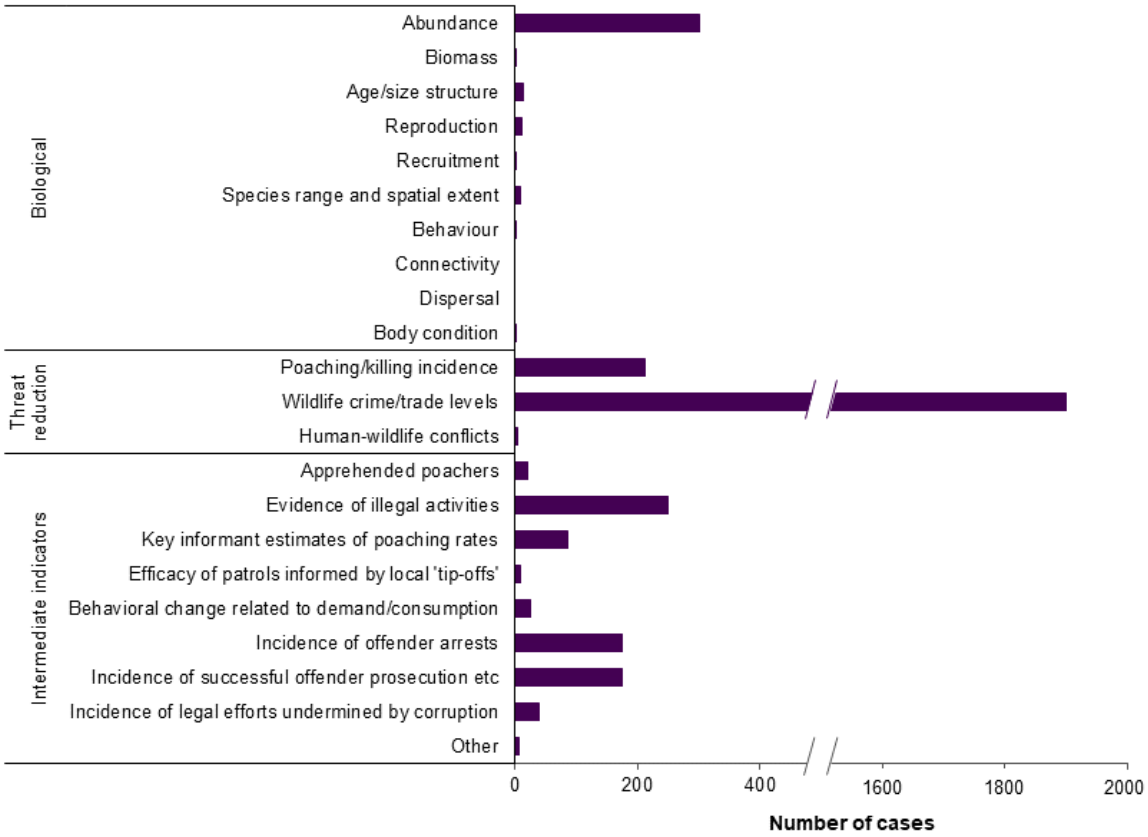
443

444 **Fig. 9**. Number of cases in relation to level 2 (panels) and 3 (columns within panels) wildlife
445 product-centric actions by the actors involved in implementation: (a) Information analysis and
446 sharing; (b) Detecting and confiscating illegal wildlife products; (c) Disposition and/or
447 destructing seized illegal wildlife products; (d) Awareness raising related to the transfer of illegal
448 wildlife products. CITES: Convention on International Trade in Endangered Species of Wild
449 Fauna and Flora; PSA: personal service announcement; NR: not reported. Note the difference in
450 scale for (a) compared to other panels.

451 ### 3.2.6 Measured outcomes

452 Only 11% of all cases used a direct (biological) measure to evaluate CWC intervention
453 effectiveness. Most often, threat reduction or intermediate outcomes were used as indicators of a
454 potential or perceived change in population/species outcomes (65% and 24% of cases,

455 respectively). When a biological measure was used, outcome metrics related to abundance were
456 the most frequently studied (Fig. 10). There were relatively few articles evaluating other
457 biological measures (e.g. biomass, recruitment, behaviour, dispersal). For threat reduction
458 measures, outcome metrics related to wildlife crime/trade levels dominated in terms of sub-
459 categories (Fig. 10). Most outcomes of wildlife crime/trade levels related to (i) the number or
460 price of wildlife products available for sale in markets/online shops and/or spatial/temporal
461 trends in such metrics (~45% of cases), (ii) the number or weight of wildlife contraband
462 confiscated/seized (~34%), or (iii) the number/volume of wildlife/wildlife products from
463 export/import records and/or spatial/temporal trends in such metrics (~18%). Within
464 intermediate outcomes, most studies measured outcomes associated with evidence of illegal
465 activities (e.g. number of poacher camps or snare traps encountered, number of confiscated
466 guns), incidence of offender arrests (e.g. number of arrests), and successful offender
467 prosecutions/sentences/fine payments (e.g. number or length of prison sentences, number and
468 amount of fine payments).
469 Articles that only reported on human well-being outcomes were excluded from this
470 evidence synthesis; however, we identified articles that provided a measure(s) of human well-
471 being outcomes in addition to reporting on relevant direct and/or indirect measures. We found
472 few studies that examined both forms of outcomes (i.e. 16%; 83/530 studies also included human
473 well-being outcomes). When studies did evaluate human well-being outcomes, most related to
474 economics (e.g. employment and livelihoods and/or income and assets), either alone (41 studies)
475 or in combination with other human well-being domain impacts (21 studies; e.g. health, social,
476 culture and cognition).
477



478

479 **Fig. 10**. Number of cases in relation to outcome categories and sub-categories used to evaluate
480 CWC intervention effectiveness.

481

482 ## 3.3 Intersection of CWC interventions and measured outcomes

483 Fig. 11 presents a heatmap of the distribution and frequency of all cases regardless of study
484 designs used in evaluating the effectiveness of CWC interventions on biological, threat reduction
485 and intermediate outcomes for Africa, Asian, and Latin American wildlife directly threatened by
486 exploitation and human-wildlife conflicts.

487 Focusing on wildlife-population-centric actions (i.e. direct protection of wildlife), most
488 cases investigated outcome metrics related to wildlife abundance (biological), poaching/killing
489 incidents (threat reduction), evidence of illegal activities and key informant estimates of

poaching (intermediate), especially for surveillance interventions. Out of the three broad groupings of CWC interventions, overall, wildlife-population-centric actions had the most even distribution of cases among outcome types (Fig. 11).

Cases examining offender and business-centric actions (i.e. detection and sanctioning of rule-breakers) focused heavily on intermediate outcomes, with clear concentrations of evidence for sanctioning at the time of encounter with offenders and incidents of offender arrests, and prosecuting and trying of alleged crimes and incidence of successful prosecutions, with comparatively few cases exploring relationships between offender and business-centric actions and biological and threat reduction outcomes (Fig. 11).

Focusing on wildlife product-centric actions (i.e. interdiction and control), cases were dominated by wildlife crime/trade level metrics, in particular in relation to information analysis and sharing (Fig. 11). Overall, relatively few studies focused on examining changes in biological and intermediate outcomes for all level 2 wildlife product-centric actions.

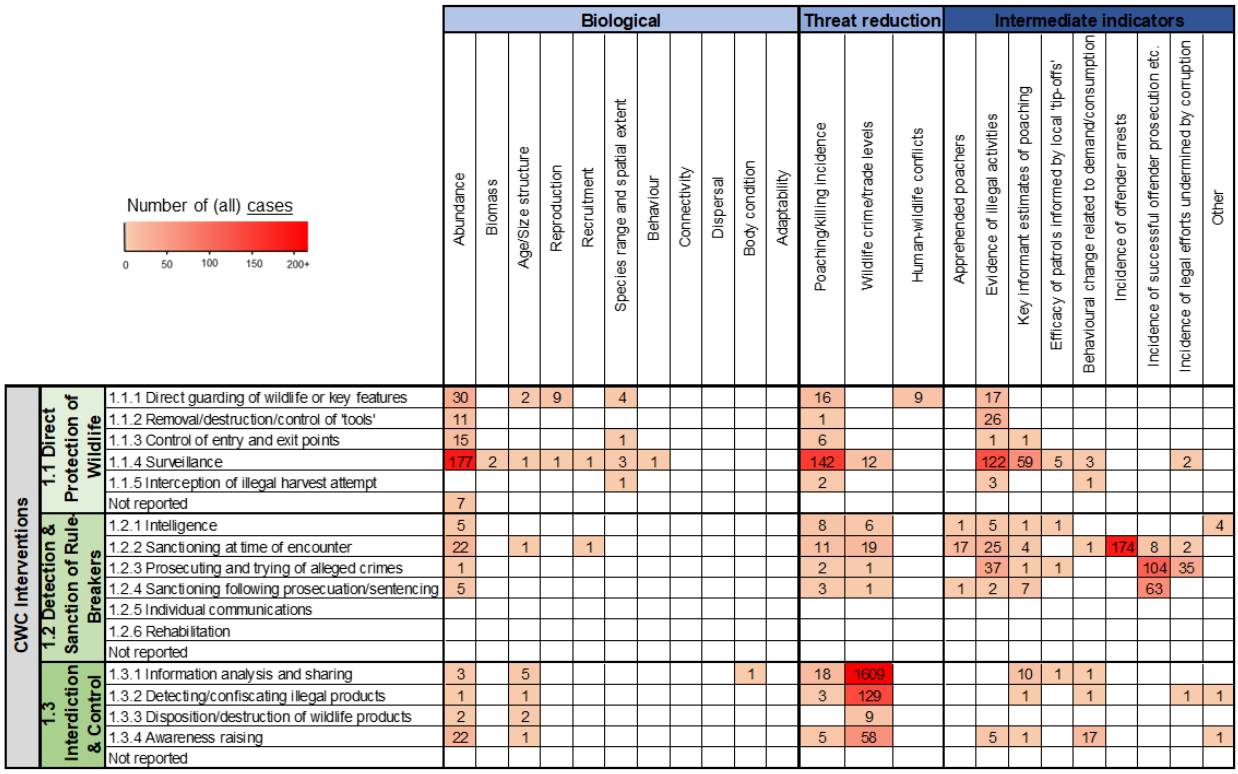


Fig. 11. Distribution and frequency of all cases (regardless of study designs used) examining the effectiveness of CWC interventions (level 1 and 2s) on biological, threat reduction and intermediate outcomes (and sub-categories therein). In this matrix of counts, darker coloured cells indicate a higher frequency of occurrence of the evidence, while lighter colours indicate a lower occurrence.

3.4 Knowledge clusters and gaps

3.4.1 Knowledge clusters

This mapping exercise identifies a number of subtopics that warrant further evidence synthesis (Fig. 11). While many of the subtopics identified in Fig. 11 have sufficient numbers to permit further review, the majority relate to evidence that, in general, is susceptible to bias. Specifically, our ability to infer CWC intervention effectiveness is hindered by study designs that lack *true comparators*. As such, we provide additional heatmaps that include only those linkages between

CWC interventions and outcomes for cases (noting there could be more than one case from a given study if there were linkages for multiple species; Fig. 12a) and unique studies (Fig. 12b) that include *true comparators* (e.g. BA or CI designs). We used the heatmaps in Fig. 12 to identify the following subtopics perhaps most suitable for further synthesis (defined here as linkages with >25 cases that include *true comparators* from at least three unique studies):

1. The effectiveness of surveillance interventions on population abundance (46 cases from 16 studies)
2. The effectiveness of information analysis and sharing on wildlife crime/trade levels (46 cases from 3 studies)

3.4.2 Knowledge gaps

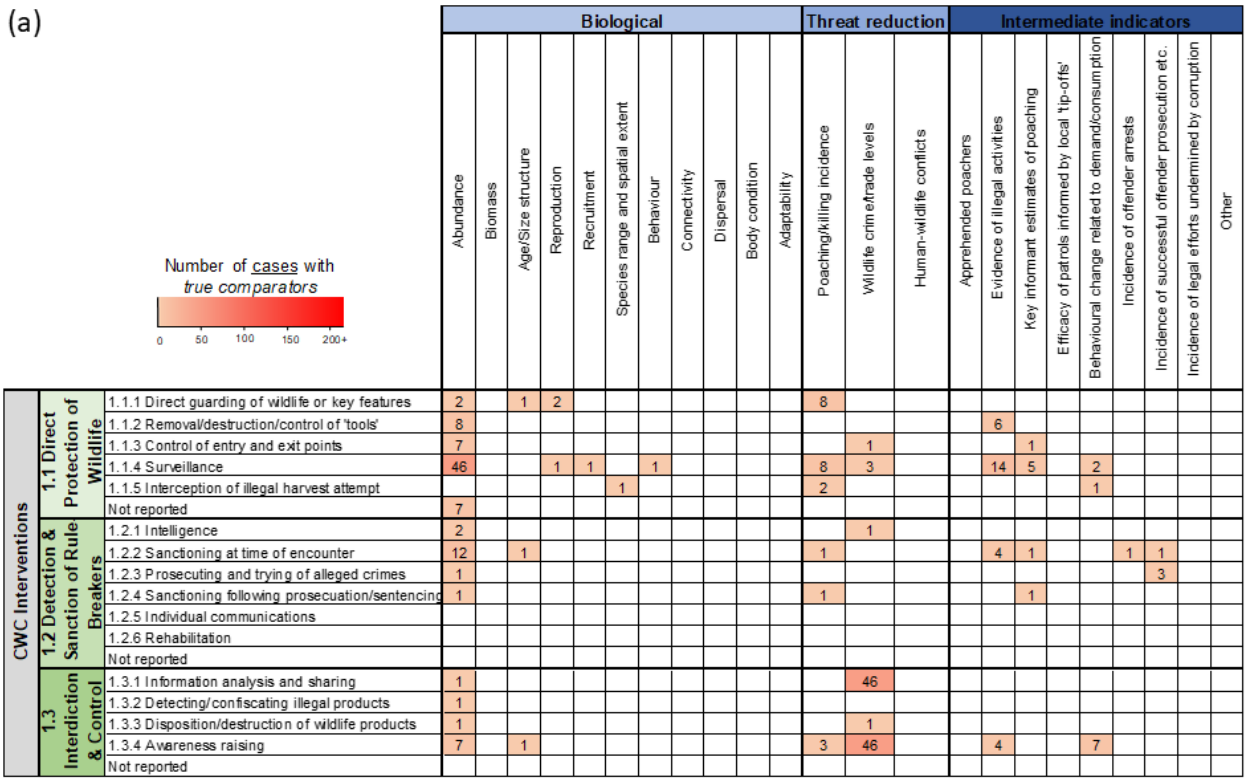
Based on our analysis of the evidence base, we suggest the following knowledge gaps, which could benefit from primary research (presented in no particular order):

1. Geographical coverage for studies in Latin America.
2. Research on the effectiveness of CWC interventions for relevant plant groups (i.e. rosewoods, mahoganies, cycads, succulents, aloes, elephant trunks).
3. Research on the effectiveness of CWC interventions for relevant bird (e.g. hummingbirds, old world vultures, shorebirds) and reptile groups (e.g. boas, chameleons, girdle-tailed lizards), especially related to wildlife population-centric actions (rather than wildlife product-centric actions).
4. Research on the effectiveness of individual communication (e.g. verbal communication about legality, target communication with repeat offenders) or offender rehabilitation interventions.

5. Biological outcomes at the population and species levels (i.e. ultimate conservation targets, e.g. abundance, biomass, reproduction).

Given that most investigations of intervention effectiveness lacked true comparators, and no experimental designs were found, we emphasize that more rigorous study designs are needed when addressing these knowledge gaps to ensure we are building a strong evidence base (see Christie et al., 2019 & 2020, and the *Conclusions* section below for further recommendations).

(a)



(b)

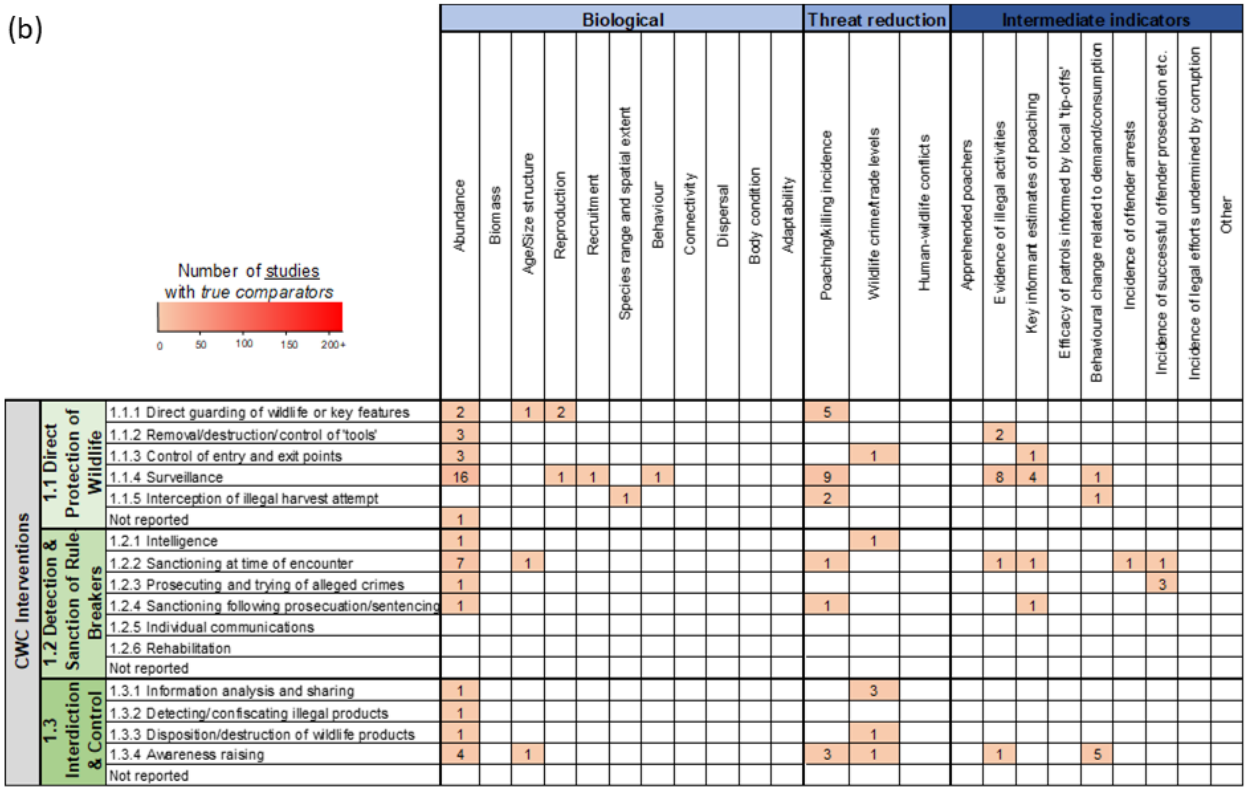


Fig. 12. Distribution and frequency of cases examining the effectiveness of CWC interventions (level 1 and 2s) on biological, threat reduction and intermediate outcomes (and sub-categories

therein) including (a) only cases that include *true comparators* (e.g. BA or CI designs), and (b) the number of studies that include *true comparators*. In this matrix of counts [cases for (a) or studies for (b)], darker coloured cells indicate a higher frequency of occurrence of the evidence, while lighter colours indicate a lower occurrence.

3.5 Systematic map limitations

3.5.1 Limitations of the mapping methods

There were a few potential limitations of our mapping methods. First, the search strategy used to generate this map may not have captured all relevant investigations on CWC intervention effectiveness. To identify the grey literature and/or articles that might have been missed with our search strategy despite our extensive scoping efforts (see supporting information in Rytwinski et al., 2021a), we issued evidence call-outs (e.g. via mailing lists, social media, networks) and undertook supplemental bibliographic and website searching, screening the reference lists of nearly 70 relevant reviews, and 36 specialist websites and online databases. This supplemental searching proved well worth the effort, representing 34% (i.e. 234/695 articles) of the captured evidence base included at the full-text screening stage. However, through these supplemental searches and discussions with our Advisory Team members, it was evident that there were other projects and datasets that had not been documented and made publicly available. This failure to document or share knowledge on past efforts is not unique to our review topic (e.g. Davies et al., 2008; Ramstead et al., 2012; Rytwinski et al., 2019 & 2021b) but limits the insights of our synthesis. Indeed, many management practitioners and NGOs implementing CWC interventions are not provided support to evaluate (rigorously or otherwise) the effectiveness of an intervention(s) (Ferraro & Pattanayak, 2006). This gap highlights the need for making such

information available so that it can be used by others to avoid duplicated research (Buxton et al., 2020) and be included in evidence syntheses about the effectiveness of CWC interventions.

Second, our search was limited to English language literature, presenting a potential language bias (Konno et al., 2020). We acknowledge that additional evidence likely exists in other languages, however, we did not have the resources to conduct these searches. Only seven non-English articles were identified by our search strategy (i.e. had English abstracts) but were excluded (Spanish, 2; German, Russian, Portuguese, Chinese, French, 1 each respectively). It is unclear how many of these articles would have met all the inclusion criteria; however, the ability to include these untranslated articles, as well as to conduct searches in other languages, would add strength to the accuracy of the map and any resultant syntheses.

Third, we were unable to source 20 articles because (i) the articles were not accessible with our institution's subscriptions (10), or (ii) there was insufficient bibliographic information to locate them (10). This is a relatively small number of papers, and here too, it is unclear how many of these articles would have been eligible for inclusion.

Lastly, we encountered some challenges in coding the CWC interventions and outcomes into our pre-defined classification framework. Our interventions classification framework and codes were developed in consultation with the Advisory Team during the protocol development stage of this systematic map. Although coding was scoped and tested on a subset of the evidence base during framework development and when checking data extraction consistency, as with any attempt to classify a heterogeneous data set into predefined categories, we encountered some difficulties. For example, when studies reported the confiscation of a wildlife product(s) as an outcome (e.g. X number of tusks seized) and the confiscation was carried out by a patrol regime, it was at times difficult to differentiate whether the patrols were targeting the offender (relating

to an offender and business-centric action, i.e. *1.2.2 Sanctioning at time of encounter with offender* from Table 2 but also see Supporting information 5) or the wildlife product itself (relating to a wildlife product-centric action i.e. *Detecting and confiscating illegal wildlife products*). Unless the patrol regime was explicitly described by authors as focused on detecting and confiscating illegal wildlife products, we consistently coded these cases as an offender-centric action. Relatedly, due to a lack of descriptive reporting of CWC interventions in many studies, we sometimes used reported outcomes to help distinguish between interventions. For instance, author(s) frequently used offender apprehensions synonymously with making arrests in describing sanctions at the time of encounter with an offender. If the outcome was reported as apprehensions, rather than arrests, we coded the intervention as *Detain* (coded as 1.2.2A from Table 2) and the intermediate outcome as *Apprehended poachers*; however, if the indicator was reported as arrests, the intervention was coded as *Arrest* (coded as 1.2.2B from Table 2) and the outcome as *Incidence of offender arrests*. These challenges were a normal part of this subject matter, and we handled them as consistently as possible to reduce bias and variability.

3.5.2 Limitations of the evidence base

Due to the scope of the topic and the highly heterogeneous nature of the studies, this systematic map did not conduct a formal in-depth critical appraisal of the included studies (i.e. assessment of study reliability or susceptibility to bias). Instead, meta-data on aspects of study design were extracted from included studies to provide a very basic overview of the robustness of the evidence. From this meta-data extraction, a few aspects of the evidence base were highlighted.

First, CWC interventions implemented to conserve African, Asian, and Latin American wildlife directly threatened by exploitation have not been subject to rigorous evaluations of their effectiveness. Most investigations evaluated the effectiveness of CWC intervention efforts

through post-implementation monitoring (i.e. After-only designs with no pre-intervention data or spatial comparator), and typically either reported a single value for an outcome (e.g. number of arrests made at time X) or correlated change in an outcome over time or in relation to implementation effort. After-only designs are considered to have the weakest standard of evidence (low scientific inference) because the causal effect of an intervention on an outcome is very difficult to evidence quantitatively without a comparator (Stewart-Oaten & Bence, 2001) and they cannot control over potentially confounding variables (Treves et al., 2016; Christie et al., 2020). The generally high proportion of studies lacking a *true comparator* in this evidence base will restrict the ability of reviews to draw conclusions on the effectiveness of particular CWC interventions, and/or combine studies in meta-analyses.

Furthermore, of the relatively few studies that included a *true comparator* (i.e. only 11% of studies), none were experimental in design, whereby, there was random allocation of the CWC intervention(s) to treatment and control groups/sites (e.g. randomized CI or BACI designs). Randomization is a key element of study design for yielding strong inference results because this technique can avoid confounding biases (e.g. baseline difference among treatment groups/sites — groups/sites that differ initially cannot reveal treatment differences) (Treves et al., 2016; Cooke et al., 2017; Christie et al., 2020). This is particularly concerning here, because most evaluations of a CWC intervention were confounded by the implementation of more than one conservation action (i.e. 430/530 studies combined >1 CWC interventions and/or combined a CWC intervention(s) with a non-CWC intervention(s) either simultaneously or consecutively). Most frequently, uncontrolled observational designs were used in comparative studies instead (e.g. BA designs; Fig.5). However, the paucity of studies employing an experimental design is not unique to our review topic, as this finding has been reported in related reviews (e.g., wildlife

642 trade practices and policies: Cheng et al., 2017; crime prevention in the social sciences: Sherman
643 et al., 1998), other subfields of conservation (e.g., human-wildlife conflict mitigation: van Eeden
644 et al., 2018; road mitigation for wildlife: van der Ree et al., 2015), as well as biodiversity
645 conservation in general (e.g. Christie et al., 2020). Randomised experiments to evaluate CWC
646 intervention effectiveness is challenging because there are often ethical, cultural, logistical, and
647 economic constraints that prevent the use of these designs in this field. Indeed, true
648 randomization of experimental units is more difficult in conservation (and ecology in general)
649 with threatened species and large-scale sites such as protected areas compared to other fields
650 such as health care (Larsen et al., 2019). We also echo statements from Treves et al. (2016) that
651 "Often well-intentioned and highly component researchers encounter flaws in research design
652 because of inescapable challenges presented by field conditions". Furthermore, most often, these
653 interventions are implemented to address wildlife crimes, not necessarily to generate new
654 information that can facilitate learning about the effectiveness of these measures. Therefore,
655 taken together, it was not surprising to observe an evidence base of generally low rigor.
656 Nevertheless, a lack of rigorous evaluations of intervention effectiveness has important
657 implications for the credibility of the results and any decisions that are based on them. Some
658 related fields have made strides in improving intervention effectiveness evaluations. For
659 instance, the evidence-based policing movement is trying to change the status quo of
660 implementing interventions to reduce crime and disorder without checking the effectiveness of
661 interventions (see Center for Evidence-Based Crime Policy, 2024). Given the increasing
662 popularity of CWC interventions and the high-profile nature of wildlife crime, it would be
663 beneficial for both wildlife conservation and national security to invest time and resources in
664 evaluating the effectiveness of intentions to counter wildlife crime.

665 Another limitation of the evidence base is that many studies were poorly documented. In
666 particular, we encountered limited descriptive information for the evaluated CWC interventions
667 [e.g. how and when the CWC intervention(s) was implemented, whether combined with other
668 CWC interventions or non-CWC intervention(s), what actor(s) were involved in the
669 implementation]. These limitations affect the comprehensiveness of our narrative description of
670 the current evidence base. Furthermore, the lack of information reported on these key aspects of
671 the implemented interventions limit further secondary review (e.g. quantitative synthesis) in
672 determining how and why a particular CWC intervention worked or did not work, and in what
673 context (Pawson & Tilley, 1997).

674 ## 4. Conclusions

675 This systematic map provides an overview of the existing English-language literature on
676 the effectiveness of CWC interventions for conserving African, Asian, and Latin American
677 wildlife directly threatened by exploitation. This narrative and visual description of the evidence
678 base provides important first steps towards improving our understanding of CWC intervention
679 effectiveness and helping to make evidence-informed management and funding decisions. The
680 database (Supporting Information 5) and heatmaps (Figs 11 & 12) reveal the distribution of
681 research effort for sub-topics of the evidence base (e.g. particular linkages between CWC
682 interventions and outcomes, geographical locations, taxonomic groups). However, this mapping
683 exercise does not quantify or validate the effectiveness of CWC interventions for conserving
684 wildlife, nor provide a formal, in-depth assessment of the validity of individual studies. Only
685 with further systematic review of the knowledge clusters identified herein, can the full depth and
686 validity of evidence be assessed. Importantly, we identified several understudied topic areas,
687 which can help inform decision-making by managers and funding agencies about the allocation

688 of future funding and resources for research on the effectiveness of CWC interventions.
689 Furthermore, this systematic map highlights important limitations in the current evidence base,
690 which can be used to improve future study design and methods, as well as research reporting and
691 knowledge sharing. Below we highlight some implications for consideration for researchers,
692 management/funding agencies, and policy-makers.

693 A major finding highlighted from this systematic mapping effort is the overall lack of
694 studies that included a comparator. Despite a relatively large evidence base (i.e. 530 studies from
695 477 articles included in the map), only 11% of studies used a design that included an appropriate
696 temporal and/or spatial comparator, and there were no experimental designs. Given this, the
697 evidence base should be treated with caution regarding its strength of evidence. There is
698 considerable scope for improving the rigor of future evaluations of CWC interventions − a
699 responsibility to be shared by researchers, managers, and funding agencies.

700 For researchers, we recommend designing studies to assess the effectiveness of a
701 management intervention (or impact of a threat) by building on the recommendations of prior
702 research. For instance, Christie et al. (2020) found that experimental designs such as randomized
703 Control/Impact (CI) and randomized Before/After/Control/Impact (BACI) designs produced less
704 biased quantitative estimates of intervention effectiveness than simpler observational designs
705 (i.e. CI or Before/After [BA] designs). However, if randomization is not feasible or there are
706 restricted financial resources or ethical issues, researchers should choose a non-randomized
707 BACI design, followed by a CI design (if pre-impact sampling is impossible and as long as
708 control and impact sites are well-matched; see Rytwinski et al., 2016), then a BA design (if
709 appropriate controls cannot be found) (Christie et al., 2019 & 2020). Several studies captured in
710 our map employed a non-randomized BACI design (e.g. Critchlow et al., 2017; Lee, 2018),

711 suggesting that these designs are feasible in some cases. In particular, a BACI design should be
712 considered when prior knowledge exists in the timing of the implementation of a CWC
713 intervention or where there is already pre-intervention data available (De Palma et al., 2018;
714 Christie et al., 2019).

715 For managers and funding agencies, ensuring adequate long-term investments in research
716 effort and funding is critical to building a robust evidence base to support evidence-informed
717 decision making. We observed that most studies (55% regardless of study design) involved <5
718 years of post-CWC intervention implementation monitoring, with the majority of these (32% of
719 studies) for ≤1 year. Therefore, we emphasize the need for investments to include longer-term
720 monitoring to facilitate improved understanding of CWC intervention effectiveness, especially
721 for population-level outcomes (i.e. ultimate conservation outcomes) and the potential for time-
722 lags in responses to management actions. This may be particularly important for species of
723 conservation concern that have longer generation times and/or lower reproductive rates that may
724 be less able to rebound quickly from population declines caused by exploitation (Owens &
725 Bennett, 2000; Kablan et al., 2019; Chichorro et al., 2022). If we continue to support poorly
726 designed and/or executed research, we run the risk of providing incomplete or incorrect
727 information that could lead to ineffective or even harmful decisions (Sells et al., 2018).
728 Therefore, managers and funding agencies should support longer term monitoring (this is good
729 program management) but also evidence building (more robust study designs for making strong
730 inferences on the effectiveness of conservation interventions), two separate but equally important
731 needs to help advance the field.

732 In addition to improving the rigor of CWC intervention evaluations, this systematic map
733 identified the need for improved reporting. To facilitate the knowledge base required for better

734 evaluations of CWC intervention effectiveness, we need to provide comprehensive information
735 on CWC interventions, i.e. how and when the CWC intervention(s) was implemented and by
736 whom specifically, and whether combined with other CWC interventions or non-CWC
737 intervention(s). Where possible, we recommend that this information be reported in publications
738 directly; however, where information cannot fit within published studies, details should be
739 included in supplementary materials and data should be shared in archivers or repositories to aid
740 in future reviews (for further guidance, see e.g., White et al., 2013; Wilkinson et al., 2016;
741 Lowndes et al., 2017).

742 This systematic map also highlights the important need for finding ways to ensure project
743 information is made broadly available in accessible formats so that it can be used by others and
744 included in future evidence syntheses. One approach to help ensure CWC intervention
745 evaluations are documented could be to form collaborations between practitioners or NGOs and
746 scientists from universities, government agencies, or other organizations that may have more
747 time and resources to help disseminate the information (Ramstead et al. 2012). Also, practical
748 field reports or short papers are welcomed by several peer-reviewed journals, including for
749 example, *Environmental Management*, C*onservation Science and Practice*, *Ecological Solutions*
750 *and Evidence, Journal of Fish and Wildlife Management*. Further, to overcome a lack of
751 reporting or documentation to ensure the global conservation community benefits from the
752 investment, funding/permit agencies and/or institutions could consider (i) increasing funding to
753 organizations/salaries to ensure adequate time and monetary support for writing/documentation,
754 (ii) increasing resources to overcome language barriers, (iii) requiring proof that research was
755 adequately shared/reported before further funding is granted, or permits renewed to applicant(s),
756 and/or (iv) requiring data management plans (DMPs) to describe how the data anticipated from a

project will be managed, analyzed, stored, reported, and shared/preserved (e.g. in an online data repository) (Buxton et al., 2020; for further guidance, see also e.g., Michener, 2015; Wilkinson et al., 2016).

There were several knowledge gaps identified from this mapping exercise that deserve further study. First, in general, given the overall low rigor of the evidence base, more robust primary research evaluations on all CWC interventions are needed before we can confidently and accurately say what works and what does not work for conserving African, Asian, and Latin American wildlife threatened by exploitation. However, if management/conservation decisions are urgent for a particular species and/or location (i.e. waiting for more primary studies to allow for such investigations is not an option), the outputs of this systematic map provide managers with a comprehensive evidence base that they can use to assess the available evidence that is relevant to their specific contexts and/or regions. Second, to address geographic and taxonomic gaps, further study is needed focusing on evaluating CWC interventions (i) in Latin America, and/or (ii) for conserving plants (i.e. rosewoods, mahoganies, cycads, succulents, aloes, elephant trunks), birds (e.g. hummingbirds, old world vultures, shorebirds) and reptiles (e.g. boas, chameleons, girdle-tailed lizards), especially related to wildlife population-centric actions. Note, we did not search or collate evidence for amphibians, fungi, arthropods, and fish for this mapping exercise, therefore, it remains unclear whether there are gaps in these taxonomic areas. Third, we found no studies investigating the effectiveness of individual communication or offender rehabilitation actions. Interestingly, these interventions were identified by staff from the USFWS Office of Law Enforcement as commonly used interventions during the development of our CWC interventions framework. As such, further attention and evaluation may be warranted for these action types. Lastly, we identified a clear knowledge gap in evidence for the effect of

CWC interventions on biological outcomes at the population and species levels. We recommend this as a focus area for future primary research efforts, ideally, accompanied with human well-being objectives, as others have encouraged before (e.g. Biedenweg & Gross-Camp, 2018; Kaplan-Hallam & Bennett, 2018).

Author's contributions

Siri LA Öckerman, Jessica J. Taylor, and Trina Rytwinski carried out literature searches. Adrienne Smith, Siri LA Öckerman, and Trina Rytwinski performed screening. Trina Rytwinski, Siri LA Öckerman, Adrienne Smith, and Lisa A. Kelly conducted coding and extraction of articles. Trina Rytwinski and Adrienne Smith performed descriptive statistics. Trina Rytwinski led the writing of the manuscript. All authors assisted in the design of methodology, interpretation of data, contributed critically to the drafts, and gave final approval for publication.

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Conflicts of interest

The authors declare that they have no competing interests.

Data availability statement

All important additional information is provided in Supporting Information. Upon acceptance, the systematic map database (i.e. extraction sheet containing the coding for all articles/studies) will be archived in Figshare.

Supporting information

Supporting Information 1. ROSES systematic map report

Supporting Information 2. Search strategy and results

Supporting Information 3. Consistency checks and study eligibility criteria

Supporting Information 4. List of records excluded at full text screening with reasons

Supporting Information 5. Systematic map database

Supporting Information 6. Input file for evidence atlas

Supporting Information 7. Review descriptive statistics

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