Kurland *et al. Crime Sci (2017) 6:4*
DOI 10.1186/s40163-017-0066-0

Crime Science

RESEARCH Open Access

Wildlife crime: a conceptual integration, literature review, and methodological critique

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Abstract

Wildlife crime, including poaching and wildlife trafficking, threaten the existence of particular species. To date, research on wildlife crime has been primarily conducted by those with backgrounds in the biological sciences, however crime scientists, have much to offer in examining wildlife crimes. With this in mind, we aim to highlight general principals of crime science found through an in-depth review of the conservation literature. More specifically, to determine if, and how, different types of wildlife crimes cluster, to identify the existence of interventions for which the mechanisms mirror those found within SCP, and consider their effectiveness. Our review suggests that various types of wildlife crimes concentrate in time and space, among products, along certain routes, and at particular facilities. Further, some overlap exists between mechanisms used to mitigate more traditional crimes and those used to prevent wildlife crimes and protect threatened species. Of note are the attempts by those in the conservation community to *increase the risk* of crime, *remove excuses* for non-compliance of rules, and *reduce provocations* that contribute to particular types of wildlife crime. Given this overlap crime scientists may be able to collaborate with conservationists to draw on the extensive knowledge base of prevention studies to identify potential interventions, analyze their implementation, and evaluate the overall impact of an intervention.

Keywords: Situational crime prevention, Wildlife crime, Conservation, Poaching, Trafficking, Crime concentration

Background

Wildlife crime is the illegal taking, trading, exploiting, possessing, or killing of animals or plants in contravention of national or international laws. The intensification of wildlife crime, including wildlife trafficking, over the past several years poses a substantial threat to ecological stability, national and local economies, public health, and even security and the criminal justice system. Indeed, only illegal drugs, human, and firearms trafficking eclipse wildlife crime with respect to profits (UNDOC 2015; Zimmerman 2003). For example, recent studies suggest the illegal trade of wildlife is worth an estimated US $20 billion per annum, excluding the illegal timber trade and illegal fishing (Wilson-Wilde 2010; Barber-Meyer 2010). To provide further perspective, consider that conservationists estimate that roughly 20% of African elephant populations have deteriorated over the course of the previous decade to approximately 400,000, while nearly one in 20 wild rhinos were killed just in this past year alone as a result of poaching (Annual Progress Assessment 2015).

To date, much of the empirical research that touches on wildlife crime has originated from conservation biology, which is the scientific study of nature that aims to protect and enhance biodiversity (Kareiva and Marvier 2012). This is not surprising given the explicit relevance of this area of inquiry as it pertains to species populations and protected area management. However, crime scientists also have much to offer in examining wildlife crimes (cf. Moreto 2015). Specifically, it has been suggested that conservation efforts might be improved by analyzing various wildlife crimes in a manner akin to traditional crime types (e.g. how, when, where, and what is targeted) in order to identify patterns and the underlying opportunity structures involved (Kurland and Pires 2017). If the various forms of wildlife crime are indeed concentrated like traditional crime categories, then opportunity-reducing strategies such as situational crime prevention (SCP)

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(Clarke 2009) may be effective at preventing particular types of wildlife crime.

The focus of this paper is to provide an in-depth review of the literature to synthesize and improve knowledge of wildlife crime as it relates to crime science. First, an in-depth review of the conservation and criminological literature is conducted to determine if, and how, different types of wildlife crimes cluster. Second, the mechanisms and techniques that mirror those found within SCP are identified within the conservation literature and their reported effectiveness is discussed. Finally, the various findings are synthesized and recommendations for practitioners and policymakers as well as suggestions for future research are discussed.

Analytic strategy

As this study is not a systematic review, but an exploratory commentary, multiple methods were used to uncover relevant literature for inclusion in this study. Electronic databases, including EBSCO and Google Scholar, were used to search the following terms: wildlife crime, poaching, community-based conservation, animal conservation, fencing AND conservation, poaching AND patrol, protected area(s), compliance AND poaching. Snowballing, or reference and citation tracking, was used to find articles based on literature already familiar to the authors through existing knowledge, previous research, and personal contacts (Greenhalgh and Peacock 2005; Wohlin 2014). One use of this method, termed "backward snowballing," (Wohlin 2014) involved reviewing the reference lists of known relevant literature to find the original sources for each article. Another use of this method, termed "forward snowballing" (Wohlin 2014), employed Google Scholar's "Cited by" tool to discover subsequent, newer studies that cited the known article and led to the discovery of evaluations and systematic reviews that included the article. This method has been found to be just as, or more effective, for discovering hard-to-find articles relevant to a specific research topic, especially for an initial, exploratory review, than methods utilized in a systematic review (Greenhalgh and Peacock 2005).

Study selection

Three reviewers (Pires, McFann, and Moreto) independently assessed study eligibility by examining the title, abstract, and keywords to determine suitability and relevance to our specific study. Bibliographies from existing articles were screened manually. Only fully published articles were reviewed. The publishing journal and author area of expertise were also considered due to the field-specific nature of the research questions of our study. Subsequent full-text analysis was conducted to determine suitability for inclusion. Only peer-reviewed, English language studies were reviewed.

Crime concentration: does illegal wildlife poaching and trade cluster like traditional crimes?

Since Sherman et al. (1989) seminal article, the criminology of place research has consistently found that crime concentrates at the micro-geographic unit (see Weisburd 2015), otherwise known as hotspots. Crime also concentrates among other units of analysis, including victims (Grove et al. 2012; Pease 1998), routes (Tompson et al. 2009), facilities (Eck et al. 2007; Wilcox and Eck 2011), products (Clarke 1999) and time (Haberman et al. 2016). This empirical base suggests underlying reasons for why crime clusters in a variety of ways while offering spatially explicit preventive interventions that seek to mitigate future crime.

Both crime scientists and conservationists have published a number of studies examining whether wildlife crime is concentrated as it relates to space, time, routes, facilities, and products. 'Hot product' analysis has become a popular line of research in the emerging field of wildlife crime, which examines whether certain taxonomic groups (or species) are poached and/or trafficked more often than others. Not every species of wildlife is equally desired by humans, or even accessible, and as such, there is an expectation that poaching should be unevenly distributed among wildlife species (Pires and Clarke 2012). For example, wildlife seizures made at entry points in Asia (Nijman 2010), the EU (van Uhm 2016), and the US (Kurland and Pires 2017; Petrossian et al. 2016) have found that certain taxonomic groups of wildlife are disproportionately trafficked into major demand markets while others are rarely seized. At the local level, market surveys commonly find particular species disproportionately sold in illicit markets (Gastanaga et al. 2011; Herrera and Hennessey 2007; Lee et al. 2005; Phelps and Webb 2015; Regueira and Bernard 2012) and field research has found certain wildlife is preferred for bushmeat by poachers (Holmern et al. 2007).

More recently, crime scientists have expanded upon this hot product research by explaining why certain products are more frequently taken from the wild and sold in illicit markets with the use of the CRAVED model. The CRAVED model (concealable, removable, available, valuable, enjoyable, and disposable) (Clarke 1999) was originally intended to understand variation in theft of conventional property targets, though its application to wildlife has expanded its general applicability to both animate and inanimate products. Such research has focused on parrot poaching (Pires 2015a; Pires and Clarke 2011, 2012) and trafficking (Pires 2015b; Pires and Petrossian 2016), livestock theft (Sidebottom 2013), and illegal,

unreported, and unregulated fishing (IUU) (Petrossian and Clarke 2014; Petrossian et al. 2015). Specifically, this line of research has found that a mix of opportunity- and demand-side variables explain why certain species of parrots, fish, crustaceans, and livestock are at higher risk of being taken illegally. As a result of studying non-traditional hot products, research has led to the modification of the CRAVED model to include *accessibility* and *abundance* as separate measures of *availability*, or CRAAVED (Pires and Clarke 2012).

While the CRAVED/CRAAVED model is useful, some have suggested that it may not be entirely suitable for trying to understand why wildlife products are more frequently taken from the wild and sold in illicit markets. This is because of the variable nature of their characteristics and fluctuating value at different stages of the trafficking process. As such, Moreto and Lemieux (2015a) proposed a model that more appropriately captures the dynamic nature of the illegal wildlife trade. Combining and adapting the CRAVED/CRAAVED model with other newly recognized product-based characteristics (i.e., whether a product needs to be processed), the CAPTURED framework (*Concealable*, *Available*, *Processable*, *Transferrable*, *Useable*, *Removable*, *Enjoyable*, *and Desirable*) was introduced. Importantly, this product-based framework recognizes and accounts for the influential nature that wildlife products have on who is involved and at what stages are required for a product to be successfully trafficked.

Apart from hot product research, a limited number of studies have begun to analyze spatiotemporal poaching concentrations of elephants, rhinos, parrots, deer, and wildlife more generally. In two landmark studies, Wasser et al. (2007, 2008) applied innovative DNA assignment methods to large seizures of ivory en route to Asia in order to identify the geographic origins of elephant poaching. Results indicated that seized ivory emanated from specific areas in Africa leading the researchers to conclude that criminal syndicates target elephants in spatially concentrated areas. Similarly, Lemieux and Clarke (2009) found only a few sub-Saharan African countries accounted for a disproportionately high number of elephant losses between 1979 and 2007. At the more local level, Maingi et al. (2012) found elephant poaching (i.e. elephant carcasses) was concentrated both in space and time (i.e. dry season) within Southeastern Kenya and was more likely to occur where there were higher densities of elephants, bodies of water, and roads. In Kruger National Park in South Africa, rhino poaching was also found to be spatially concentrated, with 90% of all incidents occurring within 2.5 km of a road (Eloff and Lemieux 2014). As it relates to parrot poaching, a recent study discovered over 80% of poaching was concentrated in small geographic areas within Bolivia and occurred with greater frequency during summer months (Pires et al. 2016). Finally, Haines et al. (2012) found that white-tailed deer poaching in Fayette County, Iowa (U.S.) was spatially concentrated near roads, forests, and riparian areas while being temporally concentrated in the months between October and December during evening hours.

More generally, conservationists have indirectly found that poaching behavior is seasonal. For example, Holmern et al. (2007) found that a significantly greater number of illegal hunters and snares were found during the dry season in Tanzania than during other seasons. One plausible explanation for this pattern is that more herbivores migrate throughout this region during the dry season, thus indicating that poachers are in tune with the seasonal availability of animals. Notably, in addition to seasonal variation, Moreto and Lemieux (2015b) found that poaching activity was also associated with holidays (e.g. Christmas) as poachers would hunt in order to get meat for celebrations, as well as to sell in order to earn money that could then be used to purchase gifts. Similarly, Kurland and Pires (2017) found that a significantly greater number of wildlife contraband seizures occur during the first week of October at U.S. ports, and have suggested that this increase may be related to a week-long Chinese holiday (i.e. Golden Week).

Finally, some macro-level research on the wildlife trafficking and offloading problem has begun to incorporate ideas related to hot routes (Tompson et al. 2009) and risky facilities (Eck et al. 2007) into various studies. Three recent studies took advantage of the U.S. Fish and Wildlife Service (USFWS) Law Enforcement Management Information System (LEMIS) database, compiled by border agents, customs officials, and U.S. Fish and Wildlife Law Enforcement inspectors to track the illicit trade of flora and fauna coming into and out of the United States. Findings from these studies suggest that a small number of export countries account for the majority of wildlife seizures entering the U.S. (Kurland and Pires 2017; Petrossian et al. 2016; Goyenechea and Indenbaum 2015), and that a small number of entry points seize a disproportionate amount of wildlife contraband (Kurland and Pires 2017). Altogether, this research suggests hot routes are being used from particular countries to particular ports (Goyenechea and Indenbaum 2015). While at the meso-level, a Sulawesi wildlife crimes law enforcement unit in Indonesia identified that the majority of wildlife trafficking occurs along a single highway headed in one direction (Lee et al. 2005). Lastly, Petrossian et al. (2015) explored port-level characteristics between those that experienced a greater number of visits from vessels previously identified as having engaged in illegal, unreported or unregulated (IUU) fishing and those that experienced

fewer visits. Results suggested those ports that experienced higher numbers of IUU fishing vessels were larger, experienced more vessel traffic, and were nested within countries that were more corrupt and had less effective fishery inspection.

Emerging evidence thus far suggests wildlife crime is concentrated in space, time, among products, routes, and at particular facilities much like traditional crimes. As a result, approaches to mitigate traditional crimes, such as Situational Crime Prevention (SCP) (Clarke 1980), may be applicable to reducing wildlife crime. SCP can be particularly useful to practitioners and academics (Farrell 2010) involved in wildlife crime projects as it is a low-cost, effective, and empirically-based strategy that can be implemented in the short-term to reduce crime. Based on the theories of rational choice (Cornish and Clarke 2014) and routine activities (Cohen and Felson 1979), SCP aims to reduce criminal opportunities through various techniques that take advantage of five crime reducing mechanisms: (1) making it harder; (2) less rewarding, (3) riskier to commit crime (Clarke 2009), (4) reducing provocations (Wortley 2001), and (5) removing excuses (Homel and Clarke 1997). Crime scientists have already suggested ways in which SCP might be applied to reduce poaching of elephants (Lemieux and Clarke 2009), rhinos (Eloff and Lemieux 2014), parrots (Pires 2012), tigers (Clarke et al. 2014) and wildlife more generally (Lemieux 2014; Petrossian et al. 2016; Pires and Moreto 2011; Schneider 2008, 2012). Yet, these suggestions have not been applied in the field. To see how the various mechanisms that underpin SCP have been applied, and what specific techniques might be most suitable for the prevention of various wildlife crime, we must turn to the conservation literature. However, it should be noted that although efforts to reduce wildlife crime have included manipulation of the immediate environment, as shown in the review that follows, to the best of our knowledge, they have not been formulated in awareness of SCP.

How situational crime prevention has been applied in the field of conservation

Various strategies adopted by conservationists to protect environmental biodiversity align with principles of SCP, differing only in terminology (Pires and Moreto 2011). While conservationists use an environmental protection framework for interventions, the objective of such an approach is reflective of the objective of crime science in that prevention is the motivation. SCP mechanisms include those that alter the physical (and in some instances the immediate social) environment in which crimes occur in the five ways described above. In the sections that follow, the intervention literature related to protected area management and community-based conservation, law enforcement, and compliance will be discussed and situated within a SCP framework (see Additional file 1: Appendix for a summary of all studies).

Opportunity-reducing conservation

Protected areas (PAs) have historically been the cornerstones of conservation efforts around the world, which includes national parks, nature reserves and community conserved areas dedicated and managed through legal authority or an equivalent enforceable mechanism (IUCN 2013). PAs have been regarded as the most important and effective strategy for worldwide conservation efforts, so much so that the international body for environmental conservation, the State Parties to the Convention on Biological Diversity (CBD), has pledged to increase global land coverage of PAs (Juffe-Bignoli et al. 2014). While effective PA management is critical, few evaluations have been conducted to assess management efficacy within the field of conservation (Juffe-Bignoli et al. 2014). In theory, the creation and management of PAs is supposed to include the SCP mechanism *increasing the effort* to protect threatened animals, plants, and ecosystems. More specifically, the technique employed typically involves setting boundaries and physical barriers such as fences.

The creation of fenced enclosures and the strategic placement of fence barriers are meant to *reduce provocations* between animals and neighboring communities. This is commonly referred to as "human-animal" conflict in the conservation literature and efforts meant to reduce this problem hope to decrease retaliatory killing frequently associated with wildlife destroying crops, consuming livestock, or killing people. More specifically, farmers in these communities often have livestock (or crops) that are preyed upon (or eaten) or by protected species and in turn retaliate by killing the offending animals. Conventional forms of fencing such as wire, chain-link, or electrified fences have been widely used in conservation, both within and outside of PAs. In a 4-year study of elephant poaching and retaliatory killing prevention strategies that took place between 1991 and 1995 across 14 villages in East Caprivi Namibia, crop and stock economic damages were calculated to evaluate the overall success of electric fencing, trip alarms, and elephant warning calls (O'Connell-Rodwell et al. 2000). Results suggested that electric fencing had the largest impact for reducing economic losses due to elephant crop raiding. In 1994 a village where permanent, long-term electric fencing was placed—as opposed to temporary, seasonal electric fencing—no claims for economic loss due to elephants were made, compared to 1992 when 14 claims were made ($843 in losses) and 1993 when 17 claims were made ($1025 in losses). A cost-benefit analysis further suggested that the electric fencing would pay for itself by preventing economic losses in 4 years.

Other forms of fencing have also been used to prevent human-animal conflict with the goal of reducing killing of protected animals. Live fencing is the use of living plants, such as a hedge, to create boundaries around or between areas, or the use of shrubbery that is unpalatable to animals, and can be effective at deterring crop-raiding herbivores (Hayward and Kerley 2009). In a two-year trial study of a various types of live fencing a communal farm community in Kenya, beehive fencing was found to be more effective at preventing elephant farm invasions than thorn bush barriers. Elephants entered crop fields at locations blocked by thorn bushes 31 times during the study compared to a single time where a beehive barrier was in place (King et al. 2011).

Metaphorical fencing refers to a suite of approaches that make use of alternative barriers to repel animals and humans that does not involve the construction of a physical fence. More specifically, it includes use of loud noises to scare away animals, embedding guard dogs within herds of livestock, or burning chili plants to create repellant fumes. Davies et al. (2011) conducted a 3-year assessment of seven identified prevention methods used by local farmers in India to prevent elephant crop-raiding. Electric fences and fences made from ground chili plants mixed with oil spread on a rope reduced the probability of crop damage better than the other methods, which included noise, fire, spotlights, elephant drives,[1] and chili smoke. Interestingly, the effectiveness of fencing, which is a static, directional method, was reduced when paired with noise, which may be due to the non-directional nature of sound that can disorient the elephants and cause them to panic. Among the fencing studies meant to reduce provocations, other situational factors such as proximity to highly populated elephant areas, seasonal migration corridors, dense vegetation as well as fence maintenance and upkeep contributed to the efficacy of fencing (Davies et al. 2011; Kioko et al. 2008; Hayward and Kerley 2009; Slotow 2012).

Further studies have found that fences provide a better environment for lion population growth, reduced poaching, and decreased human-animal conflicts than non-fenced areas. For example, Packer et al. (2013) conducted a comparative analysis of management practices in 42 PAs and found that fenced areas held African lion populations significantly closer to their maximum population potential than unfenced areas, while populations in nearly half of the unfenced areas decreased and were projected to go extinct in the next 20–40 years. In another study, Schwab and Zandbergen (2011) note that after the construction of high fencing and roadway underpasses along a major highway in Florida in 1992, there were no reported vehicle-related deaths of the Florida Panther through the end of the study period in 2004. This finding further suggests the effectiveness of fencing for reducing human–animal conflict, as there was complete prevention of vehicular mortality for this particular species along a stretch of a roadway that had previously experienced high levels of vehicular deaths. While fences appear to be a somewhat effective intervention for the prevention of certain wildlife crimes and reducing human–animal conflict, they may also pose considerable risks. For example, they may cause habitat and population fragmentation, restrict movement, limit food sources, or cause death by electrocution or entanglement, making it crucial to analyze the potential costs and benefits associated with interventions intended to reduce human-caused population decline (Di Minin et al. 2013; Hayward and Kerley 2009; Schwab and Zandbergen 2011).

While PA creation can be an effective conservation approach for improving some threatened animal populations, it is not always the most suitable intervention due to the variability of threats to a given species. In a study on the efficacy of various conservation actions implemented for 144 species of threatened mammals with declining populations, PA creation was not the most successful strategy for improving populations. Indeed, 92% of these threatened species were living within PAs. Comparatively, PA creation was only half as successful as species reintroduction, captive breeding, and hunting restrictions for improving threatened animal populations (Hayward 2011). These results indicate that while PAs can potentially be an effective tool for conservation, other interventions that employ different SCP-related mechanisms such as increasing the risk associated with illegal hunting on non-protected land with fines for overhunting may be equally, or more, effective techniques for improving threatened species populations. Much like preventing traditional crime, effective mechanisms (e.g. removing excuses and reducing the rewards) for the prevention of poaching and human-wildlife conflict is context dependent.

In some instances, humans can *reduce provocations* of human-animal conflict by using various techniques to accommodate features of the natural environment. Retaliatory killings of protected species can be a major contributor to population declines. For some species in certain regions, including cheetahs, Eurasian Lynx, and tigers, retaliatory killings represent 46–50% of population mortality (Inskip and Zimmermann 2009). In a systematic review of literature on human-animal conflict involving large feline species ($n = 349$), a wide range of situational determinants of conflict were identified in the literature, including habitat availability, wild prey

[1] Elephant drives, or *kunkies*, use trained domesticated elephants to wrangle and herd wild animals out of crop fields.

availability, livestock management, and spatiotemporal factors (Inskip and Zimmermann 2009). While only 31% of the studies were scientific evaluations of implemented strategies,[2] conflict was successfully reduced using improved livestock husbandry, livestock guarding by either people or dogs, and construction of barriers such as fencing, while case-specific spatio-temporal patterns were found including concentrations in time (time of day or year) and space (proximity to habitats that provide natural cover for predators) of attacks. The study also identified cattle, goats, and sheep to be the most predated livestock among thirteen types of livestock included in the literature. These findings suggest that interactions between humans and large cats can be reduced by mitigating situational factors that lead to provocations.

Zarco-González et al. (2012) found that various aspects of the livestock farmland landscape and farming practices, in part, explained the high rate of livestock predation by pumas and the retaliatory killings carried out by farmers. Interviews were conducted with 52 livestock owners to assess levels of livestock predation and retaliatory killing of pumas, in addition to livestock management practices such as the degree of livestock supervision and nighttime shelter. Additionally, topographic data was collected on the areas surrounding livestock grazing sites such as distance to human settlements, roads, vegetation, and steep cliffs, and in-field verification of killings. By using a combination of analytical techniques, including spatial modeling and parametric methods, livestock losses due to puma predation were found to cluster in space. Further, the physical attributes of an area were found to significantly influence the likelihood of livestock being predated by pumas. Predation hotspots were located at high altitudes, close to cliffs and dense vegetation, and far from roads or human settlements. Farmers also exhibited ineffective livestock management practices, including routinely leaving animals unsheltered at night, allowing them to graze in large groups making them more susceptible to puma predation, and sheltering newborn animals minimally or not at all. While this was not an evaluation of an intervention, the authors suggested, based on their models, that moving grazing lands as little as two kilometers away from areas characterized by these features would reduce predation. In addition, building shelters for livestock and avoiding forested areas were identified as potentially effective measures.

Economic-based community conservation programs incorporate strategies that incentivize locals to support conservation goals while improving the available economic opportunities within the community (Lindsey et al. 2007). The rules and restrictions placed on new PAs affect lands that in some cases were previously accessible for farming, bushmeat hunting, or other activities integral for survival and economic sustainment. A more comprehensive type of community-based program, economic programs, seek to remove provocations not only between locals and the PA staff, but also between locals and protected animals, such as snow leopards and their wild prey (Mishra et al. 2003). The community is encouraged to consider live predators as income generators rather than pests that eat their livestock, and consequently wild prey such as antelopes are deemed necessary as an alternative food source for predators. Lewis et al. (1990) found that a revenue-sharing program outside of a PA in Zambia created a "protectionist attitude" about surrounding land and wildlife, which curbed unauthorized use and increased the risks of poaching through 'extended guardianship' much like a neighborhood watch. As a result, the number of elephant and black rhino killings was reduced by tenfold over the course of the 2-year study.

Compensation-based models (or relief schemes) are a popular economic-based community conservation program that involve providing payments to local farmers to offset the cost of livestock killed by protected predators such as lions. Such programs aim to *reduce provocations* between farmers and wild animals, while simultaneously *reducing the rewards* for retaliatory killing by imposing fines for killing predators. In Kenya, a compensation program resulted in an 87–91% reduction in lion killings over an 8-year period based on a parametric model that compared the expected number of lion killings in the absence of the intervention to the observed numbers during and after the intervention (Hazzah et al. 2014). A snow leopard conservation program in the Spiti Valley in India implemented a combination of economic incentives and spatial alterations to land use among local herders, which resulted in no killings of large carnivores in the four years following program implementation (Mishra et al. 2003). This program reduced provocations in two ways: first, by offering a livestock insurance plan to farmers to encourage better care and protection of their livestock, fewer livestock were hunted by snow leopards, and farmers saw direct economic benefits of better farming practices; and second, by designating land to increase the availability of wild prey in the area, snow leopards appear to have turned their attention to the abundance of wild animals such as deer and antelope that were available.

Another type of payment-based program is the Payments for Ecosystem Services (PES) incentive program in which local people are hired to carry out various conservation-related activities at the local level for immediate, direct monetary compensation, which *extends*

[2] Measures of success in studies vary widely and therefore cannot be easily compared. Success generally involves a decrease in attacks by felines on livestock and humans and a decrease in the number of cats killed in retaliation.

guardianship and *assists compliance* with the rules. By directly involving the local population in monitoring of the rules and benefiting from compliance, PES assists compliance with conservation rules. One such program in Cambodia for the conservation of endangered large birds offered direct contracts to individuals to monitor and protect nests from human disturbances, particularly egg and chick collection by wildlife traders, to ensure the eggs hatch safely, for a payment of $1 a day while monitoring the nest, and an additional $1 per day spent once the hatchlings successfully mature. In an evaluation of this PES program, Clements et al. (2010) found that the program was extremely successful in terms of the number of nests and eggs protected. Over the study period between 2002 and 2008, an increase of 36% in the number of nests protected each subsequent year culminated in a total of 1200 nests protected, from 13 in 2002 to 410 in 2008. This increase is attributed to an increase in the number of nests of certain species found, which suggests that nest collection had previously been a substantial population-limiting factor. By preventing nest collection through added guardianship, the program contributed to increases in populations of protected species in the project area.

Law enforcement

While still relatively limited, there is a growing body of literature on law enforcement strategies developed specifically to help reduce poaching within PAs. Despite challenges associated with patrolling vast landscapes (Moreto 2016), research suggests that frontline law enforcement presence is necessary to curb wildlife crimes (Hilborn et al. 2006). The large majority of this research relates to patrolling effort and more specifically it has focused on *increasing the risk* of committing wildlife crime and *strengthening formal surveillance*.

Retrospective studies, for example, have demonstrated that severely diminished (or eliminated) law enforcement and park management resources, results in significantly decreased animal populations due to poaching (Jachmann and Billiouw 1997; Hilborn et al. 2006; Leader-Williams et al. 1990). Conversely, when budgets increase along with anti-poaching patrols,[3] the opposite is sometimes true. That is, animal populations significantly increased or their rate of decline slowed when the associated risk of poaching these particular species increased (Jachmann and Billiouw 1997; Hilborn et al. 2006; Leader-Williams et al. 1990; Steinmetz et al. 2010). For example, in the Luangwa Valley in Zambia, increased patrolling effort, particularly in heavily patrolled areas, was significantly related to reduced poacher sightings, camps, and fresh elephant and rhino carcasses. In addition, heavily patrolled areas saw significant increases in elephant abundance and a slower decline in rhino numbers (Leader-Williams et al. 1990). While peer-reviewed anti-poaching patrol studies have shown to be effective in reducing poaching, peer-reviewed studies may be biased towards significant results. There are several examples found in NGO and governmental websites and reports, which demonstrate that increased patrols may not lead to poaching reductions, and in some instances, have led to increases (see Milliken and Shaw 2012).

Within the patrolling literature, several studies have established a link between patrol effort and patrol success (Ford 2005; Gandiwa et al. 2013; Jachmann 2008; Jachmann and Billiouw 1997; Leader-Williams et al. 1990; Martin 2010; Moreto et al. 2014). That is, the more man-hours patrolling in the field, the more effective anti-poaching officers become at increasing the risk of poaching through strengthening formal surveillance. More specifically, they discover more snares, poacher camps, poachers, and illicit wildlife products, which translates into more confiscations and arrests. Moreover, it has been found that rangers routinely target areas within PAs that are perceived to be hotspots (Moreto and Matusiak 2017) to ensure that problem areas are monitored and surveilled at a higher rate. If patrol efforts are indeed successful, there should be an accompanying increase in animal abundance within protected areas (see Ford 2005; Leader-Williams et al. 1990).

To further strengthen formal surveillance and patrol effectiveness, performance management techniques (e.g. cash reward systems) have also been developed. Using performance management strategies, such as intelligence-led policing, hot spot policing, and monthly COMPSTAT-like meetings (Jachmann 2008), led to more motivated staff as they were competing with other PAs on patrol success metrics.[4] Controlling for patrol effort (i.e. patrol man days per unit time), patrol staff performance in the six experimental sites improved by 59% on average compared to 11% experienced by the two control sites. This enhanced performance by patrol staff in experimental sites translated into a greater risk of apprehension for offenders as it led to more arrests and

[3] Anti-poaching patrols are often on foot "under remote and difficult conditions", but vehicle patrols are also used in some contexts for investigative purposes (Leader-Williams et al. 1990, p. 1055). The size of patrol teams vary depending on the PA, which can be as small as three scouts (Jachmann 2008) and up to 10 scouts (Jachmann and Billiouw 1997) who are based in camps scattered throughout PAs.

[4] In this study, patrol success metrics included: "poachers arrested, poachers observed, weapons and illicit wildlife products confiscated, gunshots heard, poachers' camps found, cartridges and carbide ashes found" (Jachmann 2008, p. 92).

observations of poachers in the field. Apart from performance management techniques, patrol effectiveness may potentially be improved by employing a bonus system for patrol rangers. For example, Jachmann and Billiouw (1997) found cash rewards for discovering a gun, trophy, or information that led to an arrest improved staff performance in Zambia. However, Ford (2005) found bonuses were unrelated to better performance for the limited years in her Tanzania based study.

Apart from patrols, law enforcement strategies have also taken advantage of *increasing the effort* associated with poaching and wildlife trafficking by utilizing the technique of deflecting offenders via road blockades. For example, Lee et al. (2005) established road blockades on a high-trafficking highway in North Sulawesi, Indonesia based on prior research in the field, and as a result, the trafficking and sale of protected species over a two-year period was reduced. While others have taken advantage of *reducing the associated rewards* by disrupting illicit markets. More specifically, Martin (2010) found the raid of an ivory illicit market in Ghana appeared to deter market sellers from dealing with ivory in one follow-up market survey. While this study was observational, it suggests that market vendors were less willing to openly sell ivory after arrests and confiscations had been made at the market, if at all.

Like much of the situational crime prevention literature, the conservation literature on wildlife crime mentions displacement as a possible consequence. Gandiwa et al. (2013) suggest that the increased use of snares may be a consequence of greater patrol efforts and points to a displacement of methods by poachers. As opposed to guns, snares are simple, effective, and less detectable, and do not require the motivated offender to be present in time and space when the suitable target is trapped by the snare (Moreto and Lemieux 2015b). In studying whether anti-poaching patrols deter poaching, Ford (2005) suggests even if patrols find less evidence of poaching activities over time, it may not indicate a net reduction in poaching. Instead poaching may have simply shifted spatially or temporally to avoid ranger patrols. Finally, implementing road blockades on a major highway to reduce wildlife trafficking of protected species led to increased transportation of non-protected species such as bats, rats, and squirrels (Lee et al. 2005), which is a form of target displacement. While these examples demonstrate different types of displacement may occur post-intervention, it is not suggestive that net displacement follows situational-based interventions. Indeed, Guerette and Bowers' (2009) meta-analysis of all situational-based interventions found that the majority of interventions did not lead to displacement and that no study has ever recorded net displacement.

Compliance

An increasingly studied topic in the conservation literature is whether individuals are willing to comply with local wildlife regulations and what types of incentives can increase compliance. As it relates to SCP, the compliance literature often focuses on *removing excuses* in the form of setting rules or assisting compliance, sometimes in conjunction with *increasing the risk* via formal surveillance. For example, community based conservation programs may simultaneously educate locals on conservation objectives, set rules, disincentive poaching with direct and indirect economic benefits, assist compliance, as well as having active patrols to enforce such rules that in turn strengthen formal surveillance.

The compliance literature is commonly divided into regulatory and normative approaches (Kahler and Gore 2012). Regulatory approaches come in the form of setting regulations and laws, fines and punishments, and implementing various law enforcement tactics such as anti-poaching patrols and making arrests. Such approaches are the most widely used tactics to increase compliance with conservation objectives (Hauck 2008) despite the limited resources for enforcing regulations and laws in underdeveloped countries (Rowcliffe et al. 2004). Conversely, normative approaches "focus on moral obligations such as standards of personal morality, moral development, social influences such as peer opinion and influence, and perceived legitimacy of laws implemented by authorities such as procedural fairness" (Kahler and Gore 2012, p. 105). Increasing compliance via normative approaches has the potential to reduce rule-breaking, particularly in countries that have few resources to expend on the enforcement side of the issue (Jones et al. 2008). While normative approaches do not fall under the domain of situational-prevention, regulatory approaches often do, and both approaches in combination can lead to better conservation results (Hauck and Kroese 2006).

It is increasingly evident that normative models in combination with regulatory models may have the greatest effect on increasing compliance (Hauck and Kroese 2006; May 2005; Stern 2008; Kahler and Gore 2012; Nielsen and Meilby 2013). Community-based interventions such as awareness campaigns and educating locals on conservation goals is linked with increased compliance (Kahler and Gore 2012; Nielsen and Meilby 2013). In Tanzania, for example, the Joint Forest Management (JFM) reduced bushmeat hunting by 79% between 2001 and 2008, which can be attributed to both normative and regulatory interventions. Within the JFM study, normative explanations such as an education campaign, local participation in conservation efforts, trust in local leaders, and a belief locals would economically benefit from JFM was significantly related to compliance. Along with

this, anti-poaching patrols (i.e. regulatory approach) deterred locals from poaching because of the perceived risk of being apprehended (Nielsen and Meilby 2013). Such management programs use a combination of situational techniques—setting rules, assisting compliance, and strengthening formal surveillance—to incentivize compliance via carrots and sticks.

Setting rules and regulations, a common SCP technique to *remove excuses* for undesired behavior, has the potential to increase compliance by informing citizens of what is right and wrong. There is mixed evidence on whether awareness of rules and regulations increases compliance. Using focus groups and interviews, Kahler and Gore (2012) found that awareness of rules was associated with compliance in Namibia. This study found a high percentage of respondents complied with wildlife rules because of normative explanations, i.e. "it was the right thing to do" and they respected local authorities, in combination with regulatory measures, such as fearing apprehension and the severity of punishment. While in another study, Blank and Gavin (2009) found recreational fishers in northern California (U.S.) had the same likelihood of illegally fishing red abalone (i.e. non-compliance with daily take limits, minimum size limits, licensing laws, and annual take limit) regardless of their awareness of its illegality. Such illegal fishing practices may have also been a result of not fearing apprehension or the severity of punishment, however, this study did not examine such questions. Apart from regulatory incentives, awareness of rules and its corresponding relationship to compliance may be better understood by whether a poacher is a local or outsider. Locals may be more cognizant of wildlife rules because they have been specifically targeted and informed by conservation practitioners while outsiders may be less knowledgeable. As a result, such outsiders may be less likely to comply with wildlife regulations (Keane et al. 2011).

The importance of *removing excuses* cannot be overlooked or ignored when attempting to reduce wildlife crime at the local level. Long-standing traditions of trapping or killing local wildlife may not come to an abrupt end even after the implementation of regulatory approaches such as preventive patrols (see also Infield 2001). Consequently, practitioners and local authorities need to engage the community by educating them on regulations and explaining why it is morally correct to follow the rules. Engaging the community can be made more effective by micro-targeting certain people within the community that can assist NGOs' objectives (Fairbrass et al. 2016). For example, in a study on bird trappings and killings in Portugal, people with certain demographics, such as being a hunter and locally born, made them more likely to comply with rules. As such, these individuals may be more receptive to working with NGOs to increase the compliance of others (Fairbrass et al. 2016). In sum, engagement with locals can raise awareness of conservation issues and rules, and simultaneously increase the trust between residents and authorities in charge of conservation (Lovrich et al. 2005). In doing so, such normative approaches can lead to higher compliance.

Discussion

What should be clear from this review is the complexity associated with the study of wildlife crime, the various forms it can take, and the limitations of the various interventions that have been implemented to prevent it. To recap, we discussed the relatively small amount of literature that has focused on the concentration of wildlife crime including aspects of space, time, routes, facilities, and products (which in the case of wildlife crime refers to animals, plants, or their constituent parts). In our estimation, this is a severely neglected component of trying to understand both poaching and wildlife trafficking (arguably both a micro- and macro-level problem). While recent efforts by crime scientists have been made to determine where and when poaching concentrates among specific species and to understand wildlife contraband trafficking patterns, much remains unclear about these particular aspects of wildlife crime. And, if crime scientists are going to play a more substantial role in conservation, then an emphasis should be placed on micro-level species-specific studies that provide the underlying foundation for opportunity-driven interventions and their associated evaluations (see also Moreto and Lemieux 2015a).

It is clear that strategies implemented for prevention of wildlife crime have taken advantage of SCP mechanisms but often fail to implement complementary techniques. In other words, some published conservation interventions aimed at reducing wildlife crime, and poaching more specifically, have attempted to increase the effort and risk, reduce rewards and provocations, in addition to removing excuses. However, they frequently rely on non-situational techniques such as educating local communities that have proven difficult in having an immediate impact on reducing crime. That said, there have been some interventions—which we have extracted from the literature—that take advantage of those situational mechanisms integral to opportunity reduction (see Table 1 summary). For example, PAs often find some form of success by *increasing the effort* and *removing excuses*. The former is typically accomplished by controlling access to protected areas, and screening exits from protected areas, as well as by deflecting offenders through the use of physical barriers such as electrified fencing, while the

Table 1 Using situational crime prevention to reduce wildlife crime

Increase the effort	Increase the risk	Reduce the rewards	Reduce provocations	Remove excuses
1. Harden target Collars that allow escape from metal snares	*6. Extend guardianship* WildScan, a mobile app, to report likely illegally sourced or poached animals in markets "Bush Watch" schemes modeled after Neighborhood Watch programs	*11. Conceal targets* Avoid providing location data for potential poachers	*16. Reduce frustration and stress* Eco-tourism provides monetary incentives Business alternatives Boost availability of affordable legal fuel wood and introduce sustainable alternatives	*21. Set rules* Making locals aware of laws and conservation objectives Require third-party evidence of legal procurement for public timber purchases
2. Control access to facilities Screening entrance points into PAs Securing rhino horn and elephant ivory stockpiles Docking protocol at ports to check for illegal fishing gear	*7. Assist natural surveillance* Monetary rewards for whistleblowers who disclose wildlife law violations Publicize contact information (e.g. "hotline") for civic reports of wildlife offenses	*12. Remove targets* Translocation of species Dehorning Tusk trimming	*17. Avoid disputes* Relief schemes to compensate farmers for livestock killed Road mitigation such as guardrail gaps and under/overpasses reduce wildlife-motorist conflict	*22. Post instructions* "Protected area" Road signage warning motorists of wildlife crossing zones "Buyer beware" campaigns using billboards and social media to engage the public
3. Screen exits Departure protocols at ports could include checks for illegal fishing gear License plates recorded upon exit from PAs Manned checkpoints and random investigations on forest area exit roads	*8. Reduce anonymity* Ranger IDs GPS devices for rangers and PA visitors so movement can be tracked Log personnel who access data or evidence relating to wildlife investigations	*13. Identify property* Branding legally sourced timber Marking antique ivory Identifying "captive-bred" animals as wild-caught based on health, behavior, and blood/stool tests	*18. Reduce emotional arousal* Corrals/fences to prevent livestock predation Educate herding communities about best practices	*23. Alert conscience* Public awareness campaigns Social marketing campaigns targeted to wildlife consumers and their networks
4. Deflect offenders Road blockades for car/truck checks along roadways identified as wildlife trafficking routes Automate customs checking systems documentation to reduce corruption	*9. Utilize place managers* Trade show officials must report animals (and vendors selling them) identified as protected Provide equipment, training, and mentoring for park guards	*14. Disrupt markets* Monitoring markets Increasing the availability/affordability of substitute protein (chicken, fish) Surveillance of internet markets and advertisement websites	*19. Neutralize peer pressure* Anti-corruption units and multi-agency taskforces to undermine corruption in police culture Anonymous whistleblowing mechanisms to neutralize peer intimidation and coercion	*24. Assist compliance* Accessible factsheets for tourists identifying region-specific illegal wildlife products Plan tour routes and amenities to direct visitors away from at-risk areas
5. Control tools/weapons Prohibiting the sale of fishing gear prone to by-catch License system for timber processing facilities	*10. Strengthen formal surveillance* Alarms in facilities that house ivory/rhino horn stockpiles CITES identification Guides for state customs officials Spatial monitoring and reporting tool (SMART)	*15. Deny benefits* Disfiguring the carapaces of ploughshares tortoises Dying rhino horn Increase profitability of sustainable harvest through subsidiaries and tax reductions	*20. Discourage imitation* Censure details of modus operandi	*25. Control drugs and alcohol* N/A

latter is achieved through setting rules and assisting compliance by improving the livelihood of local communities.

The *removal of excuses* in these communities is also predicated on a normative approach whereby people are informed of the rules and why they should follow them sometimes in combination with regulatory models, i.e. *increasing the risk*, that include patrol efforts to enforce said rules. Findings from this literature suggest that the combination of these two is optimal for the prevention of poaching. However, unlike the combined approach to prevention, evaluations conducted on interventions that solely make use of normative strategies indicate that they have little effect on reducing wildlife crime. At the same time, but via a different mechanism, some studies have demonstrated that *increasing the risk* of poaching via patrols can be an effective prevention strategy. Indeed, Leader-Williams et al. (1990) argued that having as few as one ranger per every 9–19 km^2 would be enough to save rhinos from being exploited and similar calculations have been expressed for the protection of gorillas (Bell and Clarke 1986; Harcourt 1986). Along this vein, there have been a number of cash rewards systems for patrol rangers that aspire to increase patrol effort through monetary incentives, which in turn should *increase risk* for poachers who will be more likely to meet capable guardians in time and space. However, in our attempt to review the conservation literature on the effectiveness of these systems there is little in the way of evaluations, and of those that have been done, the results have been mixed.

Generally speaking, conservation strategies aimed at preventing wildlife crime are not evaluated rigorously enough to best determine "What works for whom in what circumstances and in what respects, and how" (Pawson and Tilley 1997). For example, there have been numerous attempts to modify farming practices to prevent retaliatory killings that appear to have focused on different predators who may exhibit different hunting behaviors, across contrasting landscapes, with potentially different kinds of fences, and ultimately different outcomes. Hence, the objective is to eliminate predation of livestock and thus *reduce provocations* between humans and animals that often lead to retaliatory killing. Unfortunately, many of the key principles to conducting a proper evaluation such as a thorough understanding of: (1) *context*, the setting in which an intervention is implemented; (2) *mechanisms*, how the planned intervention is meant to work; and (3) *outcomes*, the practical effects produced by causal mechanisms that have been triggered are largely absent from the conservation research that has focused on crime. While it is difficult to operationalize these three concepts within an impact evaluation, Johnson et al. (2015) recently developed mnemonic, EMMIE, seeks to organize the various evidential components required for decision makers to optimize the selection of interventions (see also Sidebottom and Bullock 2017). As outlined by Johnson et al. (2015), the EMMIE framework refers to:

E the overall *effect* direction and size (alongside major unintended effects) of an intervention and the confidence that should be placed on that estimate

M the mechanisms/mediators activated by the policy, practice or program in question

M the moderators/contexts relevant to the production/non-production of intended and major unintended effects of different sizes

I the key sources of success and failure in implementing the policy, practice or program

E the economic costs (and benefits) associated with the policy, practice or program (p. 463).

In general, the EMMIE framework would be useful in providing a realist assessment (Pawson and Tilley 1997) of conservation initiatives through a holistic understanding of the mechanisms, costs-benefits, context, and outcomes of such strategies. In particular, given the necessity of understanding the uniqueness of different conservation settings (e.g. Parks compared to markets) and the potential role of various stakeholders (e.g. Park management, local villagers, etc.), the EMMIE framework is well suited to assess SCP approaches specifically tailored for wildlife crime.

There are a number of caveats related to all of the abovementioned studies that need particular consideration if crime scientists are going to successfully collaborate with conservationists and the government and non-governmental organizations (NGOs) that conduct these studies. The most pressing of these limitations relates to the metrics most commonly utilized in conservation research. Often wildlife crime research, regardless of the type of intervention, focuses on surveying communities and their perceptions, attitudes, and activities, often neglecting to obtain population estimates of the species of interest prior to and after these interventions. The motivation for this evaluation approach is the growing recognition among some in the conservation community that these problems are inherently people-based. Consequently, projects themselves are seen as being unsustainable if the local community either suffers some loss from an intervention, rejects a project, or both. While, the value of community surveys is undeniable, it is equally true that the victimization and fear of crime surveys conducted in criminological research are simply not possible to do in the conservation context because the

victims are animals or plants. This represents an inherent challenge for those interested in evaluating the perceived effectiveness of particular types of wildlife crime interventions where the target cannot be surveyed in the more traditional criminological sense. Thus, we recommend a combination of surveys with local communities, population estimates of the species of interest, and other metrics such as the number of poaching incursions captured by either CCTV be used to evaluate whether situational-based interventions work in the field.

We feel strongly that interventions meant to curtail poaching must whenever possible aim to quantify the population of a target species. Unlike many urban crime problems where there is an underlying denominator (e.g., number of houses and number of residents) that can be used to calculate a crime rate for comparison to similar areas, test for potential displacement, or a change in the rate over time, to evaluate intervention effectiveness, it is exceedingly difficult to do with animals primarily because they are mobile and in most instances cannot all be tracked.

Fortunately, since the early 2000s, there has been a concerted effort on the part of governmental and NGOs towards electronically-based data collection. With conservation software like the Management Information System (MIST) and Spatial Monitoring and Reporting Tool (SMART), a better approach to the collection of population data and also patrol metrics such as catch-per-unit effort (CPUE) are becoming more prevalent. The combination of this all-purpose measure of patrolling effort and population estimates can provide some of the spatial and temporal data necessary to enrich our understanding of the numerous poaching problems that persist and in turn will help us in collaboration with conservationist to implement more effective evidence-based interventions.

Conclusions

This in-depth review of the conservation literature sought to determine if, and how, different types of wildlife crimes cluster and to identify the existence of interventions for which the mechanisms mirror those found within SCP and assess their effectiveness. The conservation literature, while scant, suggests that there are various types of wildlife crimes that concentrate in time and space, among products, along certain routes, and at particular facilities, in a manner that is similar to what has been found among more traditional crime categories.

In addition, it became evident that there is some overlap between the mechanisms instrumental for the success of SCP on preventing crimes and those used to protect threatened species. Notably, those in the conservation community have attempted to *increase the risk* of crime, *remove excuses* for non-compliance of rules, and *reduce provocations* that often contribute to the retaliatory killing of protected species. Unfortunately, the general lack of impact and outcome evaluations of programs, policies and interventions has hindered our understanding of what works, and what might work in different contexts, for the design and implementation of cost-effective interventions (see Baylis et al. 2016).

In the future, whether studying tiger poaching behavior in a protected area in India or conducting a port-level analysis of wildlife contraband trafficking patterns, evaluation needs to, and should be, integrated into the overall design of a study when prevention is the objective. And, while we know the lure of working with NGOs is strong for those crime scientists interested in wildlife crime—as obtaining data continues to be a great challenge—we urge those among us to seek out collaborations with conservation scientists who are open to evaluations.

Additional file

Additional file 1: Appendix. Summary of all studies.

Authors' contributions

JK contributed to the introduction and discussion sections while significantly revising the entire manuscript. SP contributed to the sections on 'crime concentration', 'law enforcement', and 'compliance'. SM contributed to the section on 'protected area management and community based conservation'. WM participated in shaping the paper's objectives, along with JK and SP, and wrote 'the dynamics of the illegal wildlife trade' section. All authors read and approved the final manuscript.

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Acknowledgements

We would like to thank the reviewers for their insightful comments and suggestions which have significantly improved this paper.

Competing interests

The authors declare that they have no competing interests.

Publisher's Note

Received: 3 June 2016 Accepted: 25 March 2017
Published online: 28 April 2017

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