frontiers | Frontiers in Conservation Science

TYPE Original Research
PUBLISHED 20 December 2022
DOI 10.3389/fcosc.2022.992621

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Human-Wildlife Interactions, a section of the journal Frontiers in Conservation Science

RECEIVED 12 July 2022
ACCEPTED 15 November 2022
PUBLISHED 20 December 2022

CITATION
Kahler JS, Rivera CJ and Gore ML (2022) Introducing IPOACHED: A conservation criminology-based framework to understand wildlife species targeted by poachers in protected areas.
Front. Conserv. Sci. 3:992621.
doi: 10.3389/fcosc.2022.992621

Introducing IPOACHED: A conservation criminology-based framework to understand wildlife species targeted by poachers in protected areas

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The criminogenic dimensions of conservation are highly relevant to contemporary protected area management. Research on crime target suitability in the field of criminology has built new understanding regarding how the characteristics of the crime targets affect their suitability for being targeted by offenders. In the last decade, criminologists have sought to apply and adapt target suitability frameworks to explain wildlife related crimes. This study seeks to build upon the extant knowledge base and advance adaptation and application of target suitability research. First, we drew on research, fieldwork, and empirical evidence from conservation science to develop a poaching-stage model with a focus on live specimens or *wild animals*- rather than a market stage and *wildlife product*-focused target suitability model. Second, we collected data in the Intensive Protection Zone of Bukit Barisan Selatan National Park (BBSNP), Sumatra, Indonesia through surveys with local community members (n=400), and a three-day focus group with conservation practitioners (n= 25). Our target suitability model, IPOACHED, predicts that species that are *in-demand*, *passive*, *obtainable*, *all-purpose*, *conflict-prone*, *hideable*, *extractable*, and *disposable* are more suitable species for poaching and therefore more vulnerable. When applying our IPOACHED model, we find that the most common response to species characteristics that drive poaching in BBSNP was that they are *in-demand*, with support for cultural or symbolic value (n=101 of respondents, 25%), ecological value (n=164, 35%), and economic value (n=234, 59%). There was moderate support for the *conflict-prone* dimension of the IPOACHED model (n=70, 18%). Other factors, such as a species lack of *passiveness*, *obtainability* and *extractability*, hamper poaching regardless of value. Our model serves as an explanatory or predictive tool for understanding poaching within a conservation-based management unit (e.g., a protected area) rather than for a specific use market (e.g., pets). Conservation

researchers and practitioners can use and adapt our model and survey instruments to help explain and predict poaching of species through the integration of knowledge and opinions from local communities and conservation professionals, with the ultimate goal of preventing wildlife poaching.

KEYWORDS

human-wildlife conflict, CRAVED, CAPTURED, Indonesia, harvesters, song birds, Sumatra, tigers

1 Introduction

Forming robust understanding of species targeted by hunters–legally and illegally, is an interdisciplinary endeavor that ideally considers components of social-ecological systems including but not limited to wildlife ecology and human behavior. Historically, the disciplines of natural resources management and later conservation science (used hereafter) have researched the biological, ecological, and economic consequences of consumptive uses of wildlife (e.g., Gibbs et al., 2010). Conservation science recognizes that the field of conservation must explicitly incorporate the role of humans and the relevant social sciences into conservation efforts (Kareiva and Marvier, 2012). Conservation scientists have attempted to narrow the historical gap between biological and social sciences through recent developments in interdisciplinary frameworks that seek to understand the interactions between ecological and social dimensions of wildlife hunting and trade systems across scales (Carter et al., 2017; Blair et al., 2017).

Conservation criminology brings three distinct yet very relevant bodies of knowledge into conversation with each other, drawing on theories and methods from criminology, conservation, and risk and decision sciences, to investigate environmental crimes and harms (Gibbs et al., 2010). As an interdisciplinary framework, conservation criminology helps generate applied criminological approaches while incorporating the unique context of wildlife ecology and management (e.g., Weekers et al., 2019) with significant growth in research and scholarship over the last decade (e.g., Thomson et al., 2019). Conservation criminology has extended the focus of the conservation sciences to grapple with non-compliance in natural resources management by applying theories and methods from criminology and risk sciences (Thomson et al., 2019), which provides expertise in theories and methods to understand deviant human behavior and decision-making in the context of unknown probabilities of costs and benefits (Gibbs et al., 2010). For example, theories and methods within environmental criminology and crime analysis, which focuses on how opportunities and immediate circumstances influence crime, offers approaches for understanding how the characteristics of theft targets themselves (e.g., wildlife) can affect their propensity to be poached, traded, trafficked, sold, or consumed in illegal markets (Pires et al., 2021).

One approach from crime science are target suitability models. The foundation of contemporary target suitability models is found in Cohen and Felson (1979)'s *routine activity theory*. This theory outlined necessary conditions for a crime to occur, namely that a motivated or potential offender finds a suitable target that lacks a capable guardian. They defined the suitability of the target or victim is in terms of its *value*, *inertia*, *visibility*, and *accessibility* (VIVA), with highly valuable and movable objects with high visibility and accessibility being the most vulnerable (Cohen and Felson, 1979). Clarke (1999) proposed an advancement to VIVA, advocating for deeper consideration of the characteristics of the product stolen. This model, known as CRAVED, defines the target suitability of "hot products" (e.g., cars, electronics) in terms of how *concealable*, *removable*, *available*, *valuable*, *enjoyable*, and *disposable* they are perceived to be by offenders (Clarke, 1999). Rather than a theoretical explanation of target selection by offenders, this crime prevention-based model is grounded in linking vulnerable targets with strategies for protection (Sidebottom, 2012) and has been used to help understand a variety of property-based crimes of "hot products" (e.g., theft of cars, purses, cellphones) (see Pires, 2015 for further discussion). Generally, criminologists have applied CRAVED as an explanation into the disparities of theft risk between targets, as a predictive tool to anticipate shifting preferences for new targets, or to support secondary analysis through crime data (Sidebottom, 2012).

1.1 Evolution of target suitability models in conservation criminology

Taking the model out of its native geography of urban property crimes and into the context of rural landscapes and vast seascapes, a handful of criminologists, most notably Pires

(e.g., Pires & Clarke, 2011; Pires & Clarke, 2012; Pires, 2015), have used CRAVED approach to explain the poaching (i.e., illegal harvest) of fisheries or wildlife (Table 1). This research has made significant advancements in adapting CRAVED components within a non-conventional context. For example, Pires and Clarke (2011) applied CRAVED to analyze what species of parrots were targeted for the pet trade in Bolivia, finding that species most commonly found at the market could be characterized as being *enjoyable* and *available*. Importantly, they adapted the component *available* according to two dimensions more suited to wildlife: the species' relative *abundance* (population size) and its *accessibility* (distance to habitat) to humans (Pires and Clarke, 2011; Pires & Clarke, 2012). Further applications of CRAAVED to explain parrot-poaching behaviors and markets were conducted in Mexico (Pires and Clarke, 2012), Bolivia and Peru (Pires, 2015), and more recently in the vast pet markets of Indonesia (Pires et al., 2021). Beyond parrots, Petrossian and Clarke (2014) found that species most commonly caught illegally by commercial fishing vessels were found to be sold more often in ports of convenience or ports known to have high levels of noncompliance (i.e., *concealable*), more likely caught by longliners (i.e., *removable*), *abundant*, commonly harvested by several known illegal fishing countries (i.e., *accessible*), larger (i.e., *valuable*), found in more recipes (i.e., *enjoyable*), and highly commercial (i.e., *disposable*) (Table 1).

Moreto and Lemieux (2015) advanced a nuanced wildlife product-based model, CAPTURED, to understand how wildlife products progress through illicit markets envisioning applications in understanding repeat targeting of specific wildlife products (e.g., ivory) as well as specific markets (e.g., parrots for pets) (Table 1). The new framework and acronym, CAPTURED, posits that wildlife products that are more *concealable, available, processable, transferrable, useable, removable, enjoyable*, and *desirable* will be trafficked and traded more frequently (Moreto and Lemieux, 2015). Notable changes include the addition of *processable*, recognizing that many wildlife products may necessitate processing to enter a market (e.g., ivory is carved), and *useable* which is related to the perishability of the product (Moreto and Lemieux, 2015). Additionally, CAPTURED reclassified "disposable" as "transferrable," in recognition of the fact that some wildlife products are handed down through generations (e.g., Japanese kanji hanko), and "valuable" to "desirable" to recognize the non-monetary value of wildlife products (e.g., cat skins for traditional ceremonies) (Moreto and Lemieux, 2015). More recently the CAPTURED framework was used to explore the crime symbiosis (e.g., the convergence of crimes) between illegal, unreported, and unregulated fishing and labor trafficking (Moreto et al., 2020). Furthermore, Rivera (2022) adapted the CAPTURED framework to examine the illegal trade of live primates by incorporating concepts and variables from ecology and biological and sociocultural anthropology such as body size, locomotion types, and sociocultural value. Lastly, while VIVA was the antecedent to CRAVED in criminology, this more general model has only recently been examined within the context of conservation criminology research (Table 1). Gluszek et al. (2021) leveraged an application of VIVA to interpret the selection of illegal wild meat species by urban restaurants in Kinshasa (Democratic Republic of the Congo) and Brazzaville (Republic of the Congo) (Table 1).

1.2 Further integration of conservation sciences in target suitability models

Scientific advances have provided analytical tools in a variety of contexts. In line with the foundation of conservation criminology, we continue to build on CRAAVED and CAPTURED through the explicit incorporation of species vulnerability from the conservation sciences, and risk and decision sciences. The field of conservation science offers systematic methods, theories, and knowledge about natural ecosystems, including wildlife system dynamics and human

TABLE 1 Evolution of target suitability models use in conservation criminology.

Model (Proponents)	Components	Conservation crime applications
VIVA (Cohen & Felson, 1979)	Value, Inertia, Visibility, Accessibility	Urban wild meat trade (Gluszek et al., 2021)
CRAVED (Clarke, 1999)	Concealable, Removable, Available, Valuable, Enjoyable, Disposable	Parrot poaching (Pires and Clarke, 2012)*
CRAAVED (Pires & Clarke, 2011)	Concealable, Removable, Accessible, Abundant, Valuable, Enjoyable, Disposable	Illegal parrot trade (Pires et al., 2021), illegal commercial fishing (Petrossian and Clarke, 2014)
CAPTURED (Moreto & Lemieux, 2015)	Concealable, Available, Processable, Transferrable, Useable, Removable, Enjoyable, Desirable	Labor trafficking and Illegal, Unreported, and Unregulated (IUU) fishing (Moreto et al., 2020)
IPOACHED (proposed)	In-demand, Passive, Obtainable, All-purpose, Conflict-prone, Hide-able, Extractable, Disposable	*Proposed utility in examining multiple markets and species, particularly those implicated in human-wildlife conflicts in protected areas*

* Findings in this study warranted splitting "Available" into two components "Accessible and Abundant," which is the most common conceptualization of availability in conservation crime studies.

interactions with and behavioral responses to wildlife species (Gibbs et al., 2010). Traditionally, conservation science has focused on identifying how life-history traits and ecological characteristics of wildlife species increase their vulnerability to legal hunting and poaching by humans. For example, species body mass has been widely used as a proxy for hunting vulnerability when focusing on hunting of mammals (e.g., Benítez-López et al., 2019). Animal behavior research has identified other key individual characteristics of wildlife species that may also increase hunting vulnerability, including socialization, sex, age, personality, and habituation (as reviewed by Carter et al., 2017). Additionally, conservation science research has revealed broader landscape factors, including population size, spatial distribution, and prey abundance, that may enhance poaching vulnerability for some species (Carter et al., 2017).

Further, conservation sciences have drawn on risk and decision sciences for over two decades with relevant insights regarding how human-wildlife conflicts may influence the tolerance of, attitudes towards, and risk of retaliation and other illegal activities (e.g., Kahler et al., 2013; Kahler and Gore, 2015; Moreto, 2015; Carter et al., 2017). Literature in the conservation sciences establishes the connection between human-wildlife conflicts (e.g., crop damage, livestock depredation) and increased likelihood of poaching in the form of a method of conflict avoidance, direct retaliation for damage, or support for poaching by outsiders (e.g., Kahler and Gore, 2015; Carter et al., 2017). Conflicts with wildlife can inflict direct and indirect costs through ecological and economic systems (Kahler and Gore, 2015). For example, in two Namibian conservancies hippopotamuses were a common target of poachers, were perceived to be ecologically risky as potential disease vectors (e.g., anthrax), responsible for a quarter of the wildlife-related human deaths in the conservancies and were perceived as economically costly as they were responsible for 15% of total annual crop damage estimates (Kahler and Gore, 2015). However, many conflict-prone species also have positive economic or subsistence values on illegal markets, making their poaching an "added-value" kill and with dual benefits of reducing risks while increasing income or consumption (Kahler and Gore, 2015).

Lastly, there is a sizable literature in conservation sciences that how people 'value' wildlife species extends well beyond traditional economic models. For example, researchers have demonstrated how wildlife species can be 'transvalued' or how they simultaneously have ecological, economic, and symbolic values (Remis and Hardin, 2009). For example, in northeastern Namibia local conservancy members perceived the most vulnerable species to poaching were characterized as exacting high ecological (e.g., disease vector to livestock) and economic risks (e.g., crop damage) yet were simultaneously valuable for local subsistence and trade (Kahler and Gore, 2015). The symbolic value of wildlife, such as the socially constructed significance to social status, power or control (Van Uhm, 2018) or as a manifestation of diverse stakes in conservation and development (Remis and Hardin, 2009) may amplify or attenuate ecological and economic costs and benefits. These transvalued benefits and costs can result in increased vulnerability of poaching for some species that transcend pure, rational economic calculations (Kahler and Gore, 2015).

1.3 Proposing a poaching stage area focused approach

Research herein advances target suitability model research in conservation criminology by drawing on interdisciplinary research, and empirical field-based data to advance a model adapted for the poaching stage, where illegal harvest is a predatory-style offense, within diverse conservation areas (Figure 1 *see IPOACHED*). Based on this research, we introduce a poaching-stage area-focused (PSAF) target suitability model specifying that wildlife species that are *in-demand, passive, obtainable, all-purpose, conflict-prone, hideable, extractable*, and *disposable* (IPOACHED) will be more vulnerable to poaching (Figure 2). We acknowledge the negative connotations the term *poaching* may hold, particularly as it relates to local and Indigenous peoples, and the substantial debates around *poaching* and *poachers*. However, a review of this literature is beyond the scope of this paper, which focuses on characteristics of *the hunted* or *the poached* wildlife species. We use the term *poaching* to mean hunting in contravention of traditional or local rules or norms or state-authored laws with no intention to stigmatize or pass judgement on poachers or the act of poaching. The focus on the poaching stage for model development has two interrelated implications and this research seeks to build upon the extant knowledge base and advance application of target suitability research in a number of ways.

First, our research seeks to develop a model for explanation and prediction of "hot species" targeted by poachers in a given location or conservation area rather than wildlife products in a specific use-defined market such as pet, food, or medicinal wildlife markets (Figure 1). It is worth noting that non-governmental organizations (NGOs) may act directly or indirectly in the protection of wildlife, which may include employing new tools to detect and respond to poaching in the specific protected areas where they often work in collaboration with governmental agencies or local communities (e.g., Nurse, 2013). These organizations may focus on specific species but, in general, there is a goal of increasing environmental stewardship and overall livelihood sustainability. Findings on what characteristics are driving local species-specific vulnerability can be used to develop strategies to reduce poaching opportunities in the short- or long-term (e.g., Pires, 2015). Conservation organizations have also taken on the task, in many conservation spaces, of providing training for government-based rangers and law enforcement (e.g.,

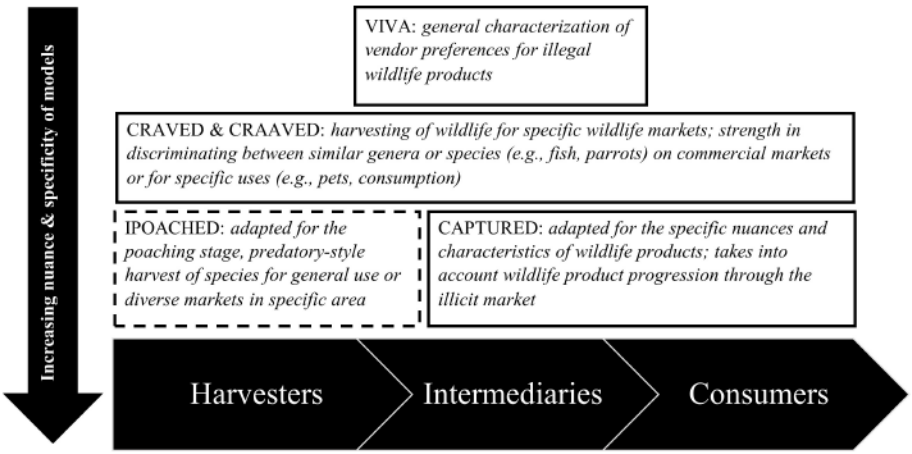

FIGURE 1
Mapping the strengths and uses of various target suitability models in conservation criminology along the illicit supply chain for wildlife species and products.

Warchol and Kapla, 2012), which means that any development of new methods and models are more likely to be adopted if they incorporate the knowledge, language, and experiences of conservation practitioners.

Second, given our focus is the poaching stage, it is therefore live specimen- or *wild animal*-based rather than market focused and wildlife product-based (Figure 1). One important distinction between consumer products of theft, such as electronics and cars, is that wildlife species can cause assessed and perceived risks, and direct (e.g., crop damage) or hidden (e.g., increased labor demands) costs. Motivations for poaching are complex and poachers may experience more proximate motives, such as human-wildlife conflicts, that provoke direct action (Kahler and Gore, 2012; Kahler and Gore, 2015). As discussed above, this literature suggested that any PSAF model consider wildlife values, broadly construed, taking into account that wildlife may provoke poaching through ecological, economic, and symbolic costs (e.g., Moreto, 2015; Moreto and Lemieux, 2015). Additionally, Cohen and Felson, 1979 VIVA idea was aimed at understanding the suitability of targets for predatory crime, and discussed the target's *inertia* or the relative ease of disabling or moving the target (Pires and Clarke, 2012). During the poaching stage, wildlife species are animate, sentient targets with "routine activities" or movements independent of the humans that seek to capture, disable, or kill them. Species vary widely as to their *inertia* upon first contact and depending on if their use requires capture and removal of a live specimen. The poacher's judgments as to the differences in species' ability to resist capture and to inflict potential harm *(inertia)* is therefore relevant to targeting and has been revisited by IPOACHED with the component of *passive* (Figure 2).

The overall goal of this research was to develop a target suitability model with strengths at understanding harvesters and first-line intermediaries within a defined area of conservation interest and value (Figure 1). Equally important was that this conservation criminology-based model would be corroborated by the knowledge and opinions of local residents and conservation practitioners living and working in proximity to a poaching-impacted conservation area. To this end, in this paper we describe the elaboration of our poaching stage area focused (PSAF) target suitability model IPOACHED (Figure 2).

2 Methods

2.1 Study area and research approach

Poaching poses risk to species conservation and human livelihoods in many southeast Asian countries and is a primary driver behind the region's dramatic wildlife declines (Steinmetz et al., 2014). Indonesia, the island nation with the world's fourth largest human population, is one such Southeast Asian country with high levels of illegal wildlife trade. Wildlife crimes in Indonesia vary from the high volume, high visibility illegal markets, such as Jakarta's infamous Pramuka Bird Market (Chng. et al, 2015), wildlife laundering through captive breeding farms (Lyons and Natusch, 2011), to the emergence of online trade through social media sites such as private Facebook groups (Igbal, 2015). For example, one comprehensive study of three illegal wildlife markets in Jakarta over the course of three days found over 19,000 individual birds from 206 distinct species for sale (Chng. et al, 2015).

Sumatra, Indonesia's western-most island, has high biodiversity and is threatened by habitat conversion and poaching. Bukit Barisan Selatan National Park (BBSNP) is the island's third largest protected area (3,568 km^2) stretching along

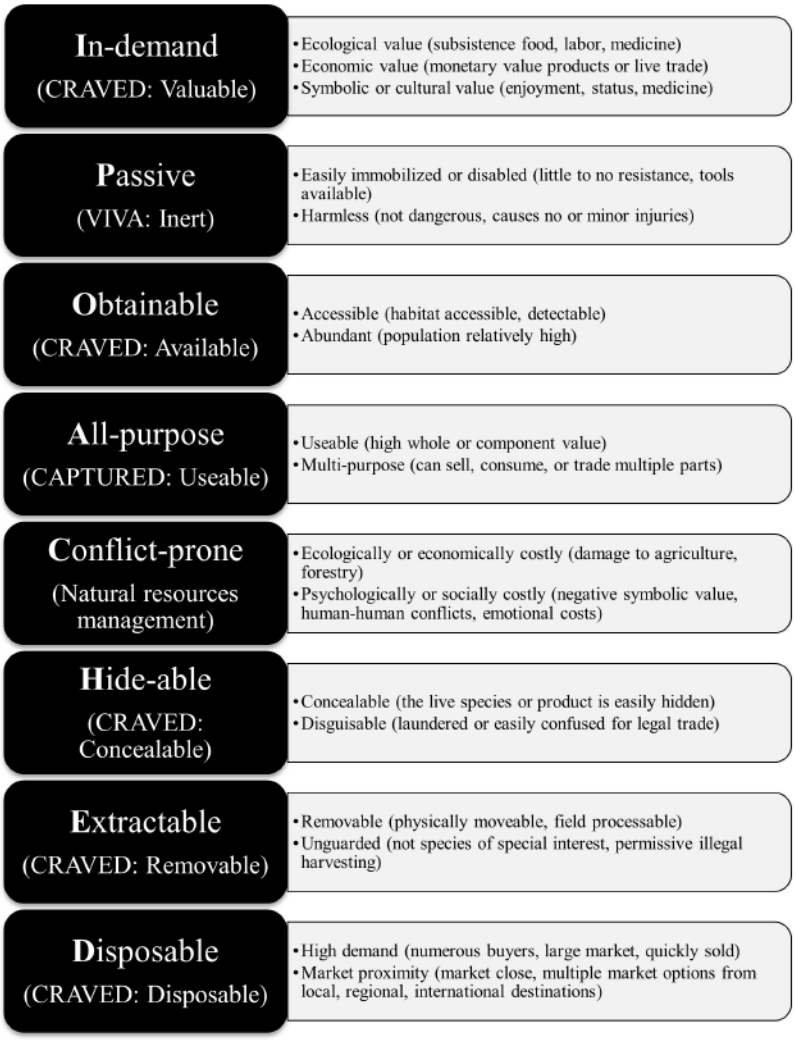

FIGURE 2
Empirically supported elements of the IPOACHED poaching-stage area-focused (PSAF) model.

150 km of the Barisan Mountain range (Anggraini et al., 2000). This park is home to some of the largest tracks of remaining lowland rainforest (O'Brien et al., 2003) and a number of 'hot species' including large mammals, Malayan sun bear (*Ursus malayanus*), Asian elephants (*Elephus maximus*), Sumatran tiger (*Panthera tigris sumatrae*), and at least 277 bird species including all species of hornbills (Anggraini et al., 2000). The park has an Intensive Protection Zone (IPZ) which is bounded in the north and south by a major highway lined with agricultural, commercial, and residential development.

Wildlife crime poses risks to the conservation of biodiversity in BBSNP (Kinnaird et al, 2003). Successful control efforts are complicated by the park's narrow linear shape that includes over 700 km of boundary edge where agricultural encroachment, illegal logging, and illegal hunting occurs frequently (O'Brien et al., 2003). Poaching of species such as the critically endangered Sumatran tiger (O'Brien et al., 2003), Asian elephants (Hedges et al., 2005), and Sumatran rhinoceros (*Dicerorhinus sumatrensis*) (Nardelli, 2014) occurs within the park (Table 1). It is likely that other forms of wildlife crime, such as commercial and subsistence wild meat hunting, wild songbirds trade (e.g., Jepson et al., 2011) and Helmeted hornbill "ivory" poaching (e.g., Beastall et al., 2016), are also happening within BBSNP. For example, illegal hunting of wild boar (*Sus scrofa*) to meet growing demand by Chinese and Christian Bataks has been documented in Jambi, which is northeast of BBSNP on the island of Sumatra (Luskin et al., 2013). This research is focused on BBSNP, which is understudied in terms of wildlife crime given the protected area's size, biodiversity, and complex social-ecological dynamics.

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Prior to collecting data, we reviewed the criminology (e.g., VIVA, CRAVED, CAPTURED) and conservation sciences literature to inform a preliminary target suitability model. This preliminary model was used to quantify and describe the characteristics of the most predominantly poached species within the Intensive Protection Zone (IPZ) in BBSNP during a focus group with local conservation representatives from community, governmental, and non-governmental conservation organizations. Further empirical evidence was gathered through open-ended questions during surveys with residents living in and around BBSNP's IPZ. Data analysis helped inform final articulation of the proposed IPOACHED model (Figure 2).

2.2 Sampling and data collection

Peer-reviewed literature and organizational reports were reviewed for incidents of species poaching within BBSNP. Data on notable Indonesian seizures and prosecutions were recorded from TRAFFIC's Bulletin publications numbers Volume 25 Number 1 (2013) through Volume 29 Number 1 (2017) which covers years 2012 through 2016 (http://www.traffic.org), more closely aligning with the field season that occurred May-August, 2015. The TRAFFIC Bulletin data were chosen because the description often provides where in the island archipelago wildlife originated or was confiscated. Further data were collected using surveys in 10 villages around the IPZ and during a three-day focus group held in Gisting, Lampung Province, Sumatra with community, governmental, and non-governmental conservation organizational representatives from BBSNP from May through August of 2015.

To conduct village surveys, five Sumatran research assistants were hired and met the following criteria: (1) fluent in English, Bahasa Indonesia (lingua franca and hereafter Indonesian), and other relevant local languages (e.g., Lampungese, Javanese); (2) completed secondary school and were currently enrolled in an undergraduate program at a local college; (3) agreed to work the duration of research activities; and (4) completed a three-day training session before data collection commenced. The surveyed villages were clustered along the southern and the north, north-eastern boundary villages of Kubu Perahu, Pekon Mon, Pemerihan, Serdang, Suka Marga, Sukabanjar, Sukabumi, Sukaraja, Sumberagung, and Sumberejo. Villages were selected based on (1) recommendation of the facilitating conservation organization, which had a long-term presence in the area and relationships with communities, (2) permission of local and relevant community authorities, and (3) close proximity to or location within the IPZ of BBSNP. Surveys were conducted in five villages along the southern corridor of the IPZ prior to the start of Ramadan in 2015 and five villages on the west and northern boundary of the IPZ after Ramadan in 2015. Cluster sampling with probability proportionate to size (Bernard, 2006) was used as there were no reliable lists (e.g., addresses, property tax records) of residents in the villages.

Forty surveys were conducted in each village due to time constraints and financial feasibility, resulting in a total of 400 surveys. In each village, population clusters were identified (e.g., sub-villages) and then the proportion of surveys in each sub-village were allocated based on the best estimate of population in those areas. Each sub-village zone was sampled and convenience sampling was used within each village zone (Bernard, 2006). Survey participants were 18 years or older and were not excluded from participation based on ethnic affiliation, educational attainment, gender, religion, or socio-economic status. Only one participant per household was eligible to participate. Research assistants were flexible in terms of timing of face-to-face surveys to accommodate work schedules and cultural and religious considerations (e.g., prayer times).

Survey participants were asked two open-ended questions relevant to IPOACHED: (1)

"Some wild animals are poached more often than others. In your opinion, what are the three most often poached wild animals in BBSNP?" and, (2) "What characteristics make these animals the most likely to be poached?" In order to reduce desirability bias the assistants were not associated with the facilitating NGO and were not residents of the sampled villages. Additionally, as the full survey focused on a variety of poaching-related questions we repeatedly stated "We will not ask you about whether you personally break poaching rules or if you know someone who breaks poaching rules." The survey guide was translated from English to Indonesian prior to arrival in Indonesia, back-translated, and a final revised translation was reached by consensus of research assistants (Gore and Kahler, 2015). All surveys were conducted in Bahasa Indonesia, translated into English, and quality checked both in the field and after fieldwork by research assistants.

Focus group participants (n=25) were selected from academic institutions (University of Lampung's Indonesian Environmental Information Center), BBSNP-based communal organizations (e.g., Forum Samabat Gajah (FSG) "Sumatran Elephant Patrols", Community Mahout Forum), governmental (e.g., Balai Konservasi Sumber Daya Alam (BKSDA), Bukit Barisan Selatan National Park), and non-governmental (e.g., Tambling Wildlife Nature Center, WWF Lampung, Yayasan Badak Indonesia (YABI) Rhino Patrol Unit) organizations based on (a) the fact that the organization is currently active in BBSNP conservation activities, (b) willingness of representatives to attend the entire focus group, and (c) recommendation from World Wildlife Fund (WWF) Lampung (the facilitating organization).

The focus group participants were divided into five mixed groups (e.g., different organizational members) that each conducted a species target ranking activity, creating five posters, with a predetermined set of species relevant to conservation. Species were selected based on literature on BBSNP and discussions with BBSNP conservation

practitioners. Cards were printed on adhesive mailing labels to ease physical ranking. Ranking was conducted by consensus and characteristics were written describing why each species was a target of poachers. After the ranking was finished, each group completed two preliminary target suitability surveys for different species. After implementation in additional countries (e.g., Cameroon, Zambia) by the first author and further review of relevant research, we provide a revised IPOACHED survey instrument in the Supplementary Material. Participation was voluntary and in compliance with Michigan State University's Institutional Review Board's Human Subjects standards (IRB# x13-237e Category: Exempt 2).

2.3 Analysis

2.3.1 Descriptive and validity statistics

Survey data were analyzed using SPSS 24 and focus group data were analyzed in Excel. Descriptive statistics were used to characterize the survey respondents in terms of demographic variables. Gender, organization, length of work, role in organization, age, and educational information was collected *via* a demographic survey at the start of the focus group. Data were not weighted due to the non-parametric nature of sampling and the unknown nature of the demographics in BBSNP (Vaske, 2008).

2.3.2 Target species in BBSNP

Recorded incidence of illegal wildlife seizures associated with Sumatra, Indonesia were compiled by searching TRAFFIC's Bulletin volumes 25-29 from the years 2012-2016 (www.traffic.org). Simple frequencies are reported for species or genera provided by survey respondents during free-listing question. Due to local differences in common names (e.g., Murai songbird vs, White-rumped Shama) and differing levels of specificity of reporting (e.g., deer versus Sambar versus muntjac), species are reported in their respective scientific Orders (Infraclass for birds) to aid in interpreting more general trends. The species or genera ranked during the posters focus group activity (n=5) were analyzed by calculating an importance index (I) (Kahler and Gore, 2015) that reflects the ordinal rank the groups assigned to a particular species or genera in relation to the other species. The value ranges from 0 to 1 (1=most often poached), r is the rank, and n is the total number of species ranked (n=10):

$$I = \left[\frac{r-1}{n-1}\right](-1) + 1$$

The species or genera were reported in the final ordinal ranking determined by the importance index *I*. The mean rank was calculated based on the range of their ranking, which provides general insight as to how consistent the rankings were between the five subgroups (lower range=more consistence in opinions on ranking).

2.3.3 Characteristics of species targeted by poachers in BBSNP

Conceptually related responses from the open-ended face-to-face survey questions were initially recorded in Bahasa on paper-based surveys, entered into Excel by the respective assistant, quality checked against the paper-based survey, and translated. Where text or translations were unclear, the assistants discussed and came to a consensus (Gore and Kahler, 2015). Translated responses were grouped together through an iterative process and anchored on important PSAF target suitability dimensions (Gore and Kahler, 2015). Focus group participants provided opinions on the general characteristics that are important for each species poached in an open-ended format on the species ranking posters and filled out species accounts surveys for select species. Qualitative answers were collated and reported for six species, the top-three species poached according to participants and the three flagship species in the park (e.g., elephants, rhinoceroses, tigers), and select results from the species account surveys were reported.

3 Results

3.1 Demographic and descriptive statistics

Of the 400 surveys, 156 (39%) were women, 244 (61%) were men, and ages ranged from 18 to 88 years old with a mean of 37 years. Most respondents were Muslim (97%) and married (89%). There were 12 ethnic groups represented from three different islands: Bali 2.3% (n=9), Java 76.5% (n=306), and Sumatra 21.3% (n=85). Only 2% (n=6) of respondents had no education, 40% (n= 156) had attended elementary school, over a quarter had attended senior high school (26%, n=103), and 8% (n=38) had completed some sort of post-senior high education or training. The majority of people reported agriculture as their primary source of livelihood 61% (n=245) and among those that did not list agriculture as their primary livelihood activity 9% (n=35) listing a secondary activity.

All but one of the 25 focus group participants were men. The average age of participants was 34.4 years (range = 24 to 64 years). Participants worked at their organizations on average 8.5 years (range = 2 months - 32 years). Focus group participants had a variety of roles at their organizations with 44% (n=11) having some responsibility for patrolling within BBSNP. Educational background ranged from junior high (0.08%, n=2) to bachelor's degrees (0.08%, n=2), with the majority of participants having a high school or vocational high school education (52%, n=13).

3.2 Species targeted by poachers in BBSNP

The literature and organizational reports highlight a number of 'hot species' targeted for poaching in BBSNP (Table 2). The TRAFFIC Bulletins contained 24 terrestrial or fresh-water species or genera seized at various locations around Indonesia; marine fisheries related seizures are not reported here. The TRAFFIC Bulletins (Volumes 25-29: www.traffic.org) listed a number of seizures on the island of Sumatra or having originated from Sumatra but seized elsewhere in Indonesia (Table 3). Of these Sumatran-related seizures, the highest volume (i.e., individual animals) were reptiles with seizure of 2,000 pythons and 800 monitor lizard skins (i.e., unspecified species) (Table 3). Greater Green Leafbirds (*Chloropsis sonnerati*) were the most frequently seized songbirds followed by White-Rumped Shamas (*Copsychus*

TABLE 2 "Hot-species" in Bukit Barisan Selatan National Park, Sumatra, Indonesia.

Common name (Scientific name)	IUCN status	Description of illegal wildlife trade associated with species	Approximate value	Population status
Dark-handed gibbon (*Hylobates agilis*)	EN	In BBSNP deforestation for coffee markets lead to opportunistic capture for pet trade; one of most common gibbons in illegal markets: CITES Appendix I	USD 50 to USD 150 (2003; Traffic report)	Decreasing
Malayan tapir *(Tapirus indicus)*	EN	Localized poaching occurs in Sumatra; not likely systematic but rather off-take from accidental snaring, retaliation for crop damage may also occur on Sumatra. In past, Indonesian zoos or private collectors would pay for tapirs: CITES Appendix I	Unknown	Declining in Sumatra; population anticipated to be below 400-500 individuals
Siamang *(Symphalangus syndactylus)*	EN	Opportunistic collection for illegal pet trade on Sumatra within national parks; one of the heavily traded gibbon species: CITES-Appendix I	USD 60 to USD 220 (2003) (Traffic report)	Decreasing, estimate of 22,390 individuals in BBSNP (2004)
Sumatran elephant *(Elephas maximus sumatranus)*	CR	Killed for conflicts with humans, hunted for ivory, food, hide (leather) and other products; live trade used for forestry or ceremonies: CITES Appendix I	Whole $28,200; Tusks $1,800 (Vietnam); Ivory $850/kg (Asia); Carved ivory $3,000/kg	Decreasing: estimated 498 individuals (2005) in BBSNP
Sumatran rhinoceros *(Dicerorhinus sumatrensis)*	CR	Poaching for horn and medicinal products driving species to extinction: CITES Appendix 1	Horn dagger $14,000; Horn $65,000/kg; Crushed powder $10 (Vietnam)	Very severe declines of greater than 80% over 20 years; ~30 mature individuals
Common name (*Scientific name*)	IUCN status	Description of illegal wildlife trade associated with species	Approximate value	Population status
Sumatran tiger *(Panthera tigris sumatrae)*	CR	High level of conflict and illegal-trade in tiger parts (bones, meat, skins) primarily for domestic markets drives poaching: from 1998-2002 51 tigers per year were killed in Sumatra with 76% for trade and 15% due to conflict	Dead $5,000; live $50,000; baby $3,200; bone $2,000; bone wine $88; penis $1,300; remains $70,000; skin $35,000	Decreasing: severely fragmented; estimated 40-43 individuals in BBSNP (2003)
Sunda pangolin *(Manis javanica)*	CR	Hunting for skins, scales, and meat for local, subsistence-level consumption, and international trade; traded live and dead; scales used for medicinal purposes; targeted hunting is biggest threat on Sumatra: CITES Appendix I	Live $1,000; meat $300/kg; scales $3,000/kg	Likely in severe decline in Sumatra by evidence of magnitude of trade
Helmeted hornbills *(Rhinoplax vigil)*	CR	Heavily targeted by poachers and illegal trade for solid horn or "casque" sold internationally (China largest market); large numbers of illegal hunters of this species found in Sumatra: CITES Appendix I	$1,000/horn (Beastall et al., 2016)	Severe decline almost disappeared from areas previously abundant on Sumatra (2015)
Straw-headed bulbul *(Pycnonotus zeylanicus)*	EN	Huge demand for species for domestic and international songbird trade, including rural areas; wild caught birds considered superior and very little enforcement on illegal trade: CITES Appendix II	Average US$483 in Borneo for wild-caught untrained birds; (2015-16); Medan (Sumatra) US$ 1,300 for champion singers	Rapidly decreasing; possibly extinct in Sumatra and Java now; extirpation from wild in Indonesia likely imminent
Black-and-white laughingthrush *(Garrulax bicolor)*	EN	Captured for live bird trade which is the species primary threat; international imports of sister species G. *leucolophus* were stopped in 2005 due to risk of avian flu and resulted in increase in this species; since likely population dropped rapidly	Two birds for US$100 (2016)	Considerable decline in Sumatra and becoming locally extinct in some areas: small population in BBSNP

A description of the illegal trade, value and population trends of Endangered (EN) or Critically Endangered (CR) species found in BBSNP from peer-reviewed literature, the IUCN's Red List, and organizational reports.

TABLE 3 Seizures of terrestrial wildlife species and products found in Sumatra, Indonesia from 2012-2016 (Source TRAFFIC Bulletin Volumes 25-29: www.traffic.org).

Species	Amount	Origin	Comments & Destination (if known)
Australian Larks (Mirafra javanica)	*20*	East & South Kalimantan (2015)	Seized at Tanjung Perak Port (TPP), Surabaya, Java
Crested Jays (*Platylophus galericulatus*)	2		
Greater Green Leafbirds (*Chloropsis sonnerati*)	2019		5 separate seizures at TPP, Surabaya, Java via passenger vessel from South Kalimantan
Hill Mynas (*Gracula religiosa*)	581		
Hornbills (unspecified species)	248 beaks	Unknown/ unreported origin (2013)	Hong Kong via international airport (Jakarta, Java)
Red-eyed Bulbul (*Pycnonotus brunneus*)	1	Kalimantan (2015)	Seized at TPP Surabaya, Java 1192 birds died, 308 returned
White-Rumped Shamas (*Copsychus malabaricus*)	1180	Kalamatan (2015)	2 seizures at TPP, Surabaya, Java via passenger vessel
Pangolin (*Manis spp.*)	189 scales	Unknown/ unreported origin (2013)	Hong Kong via international airport (Jakarta, Java)
	91	Belawan Port, North Sumatra (2015)	Malaysia via boat, 9 died, 4 crew memebers arrested
	657	Unknown/ unreported origin (2016)	Jombang district, Java via house raid, found in freezers
	2.5 tonnes (meat) 279 kg (scales)	Jambi, Sumatra (2016)	Warehouse raid; China (meat, scales), Malysia, Singapore Taiwan (meat)
Sambar deer (*Rusa unicolor*)	13 antlers	Pekanbaru, Sumatra (2012)	Found in house of a tanner with tiger skins; DNA tested skins to determine origin
Slow Lorises (*Nycticebus javanicus*)	238	Sumatra (2013)	En route in Port of Merak, Java to markets in Jakarta
	34	Unknown/unreported (2016)	Bandung, West Java via online sale (social media)
Sumatran Orang-utans (*Pongo pygmaeus*)	3	Aceh, Sumatra (2015)	Suspect jailed for 2 years and fined USD 3,700
Sun bears (*Helarctos malayanus*)	4 skins	Pekanbaru, Sumatra (2012)	Found in tanner's house; DNA tested to determine origin
Tigers (*Panthera tigris*)	11 skins		
	> 100 stuffed skins	South Sumatra (2015)	Sold to buyers in Sumatra, Kalimantan, Sulawesi and Jakarta (over 10 year period)
Python (species not given)	2,000 skins	Palembang, Sumatra (2016)	East Java via currier truck
Monitor lizards (species not given)	800 skins		

malabaricus) (Table 3). Both species are found in BBSNP. The majority of seizures of mammal species in Indonesia originated in Sumatra with the most numerous seizures being of the pangolin (Manis spp.) (Table 3). There was one seizure with direct implications for BBSNP, a 10-year multi-organizational investigation into a dealer in South Sumatra that had sold over 100 tigers (*Panthera tigris*), which had been stuffed in Lampang among other provinces in Sumatra (Table 3).

A total of 27 species or genera were listed by survey respondents, while 11.3% (n=45) of respondents provided no species when asked about those targeted in BBSNP (Figure 3 presents the top 10; see Supplement 1 for detailed list). Community survey respondents (n=400) stated birds (n=245, 61.0%) were common targets for poachers as were Sambar deer (n=169, 42.3%), Asian elephant (n=92, 23.0%), and Sunda pangolin (n=72, 18.0%) (Figure 3). When considering taxonomic Orders, the most commonly targeted were Artiodactyla (e.g., Sambar deer, antelope, wild swine; n= 319, 80%), Infraclass Neognathae (unspecified birds, songbirds, White-Rumped Shama; n=245, 61%), and Order Proboscidea (Asian elephant; n=92, 23%)(Figure 3). Two of BBSNP's flagship species, the Sumatran rhinoceros (n=10, 2.5%) and Sumatran tiger (n=38, 9.5%), were not considered prominent targets of poachers by community survey respondents (S1).

Focus group participants were broken into five subgroups during the ICRAVED activity each ranking 18 predetermined species, genera, or guilds. There was a high level of agreement that songbirds, sambar/muntjacs, and pangolins were the most common targets of poachers in BBSNP (Figure 4). There was a high level of disagreement in regard to the vulnerability of some

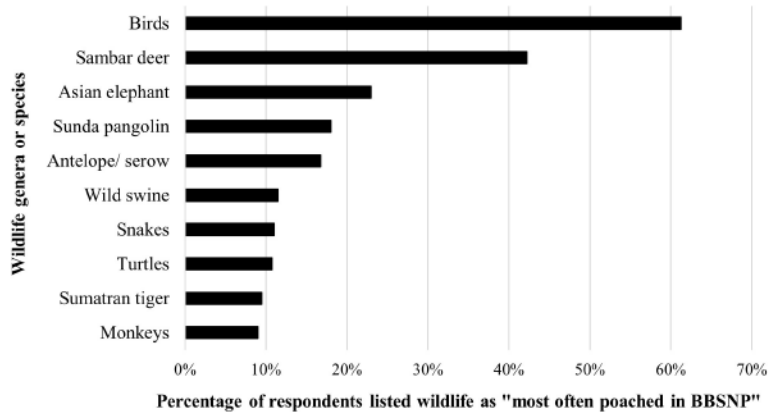

FIGURE 3
Top ten species or genera reported as "most often poached in Bukit Barisan Selatan National Park by community respondents (N=400) living in and around the Intensive Protection Zone, Sumatra, Indonesia (see S1 for full genera or species list).

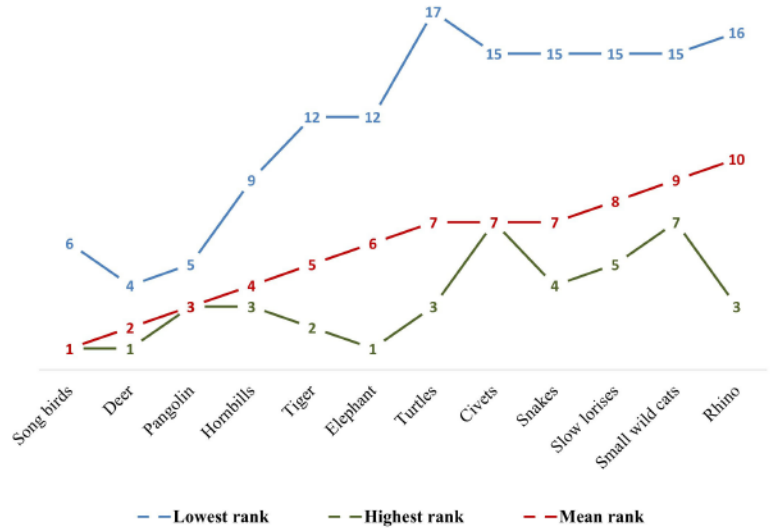

FIGURE 4
Top ten of the most commonly targeted species by poachers in Bukit Barisan Selatan National Park according to the ranking of focus group participants (N=27) (see S2 for full species list). Focus group participants were broken into five subgroups and the lowest rank (blue), highest rank (green) and the compiled or mean rank (red) given by subgroups is displayed for each wildlife genera or species.

of BSSNP's flagship species with Sumatran tigers (mean =7.2, range 10) ranked as fifth, Sumatran elephant (mean=8.2, range 11) sixth, and Sumatran rhino (mean 10.8, range =13) tenth (Figure 4).

3.3 Characteristics of poached species in BBSNP

The IPOACHED (Figure 2) PSAF model was created upon reviewing the results of community-based surveys and the focus group activities related to target suitability. This model expands on (e.g., *passive, conflict-prone*), revises some (e.g., *in-demand, extractable*), and retains essential components of CRAAVED (e.g., *obtainable, hideable, disposable*) and CAPTURED (e.g., *all-purpose*) (Figure 2). The previous component of *enjoyable* was absorbed in this PSAF model into cultural or symbolic value under *in-demand* (Figure 2).

Community member (n=400) perceptions of target suitability were fit to the developed IPOACHED model (Table 4). Frequencies do not add up to 100% as participants were allowed to list a single reason or multiple reasons. The most common

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TABLE 4 Community perceptions based on surveys (n=400) of what characteristics drive poaching of particular species in Bukit Barisan Selatan National Park, Sumatra, Indonesia as fitted to proposed IPOACHED framework.

Concepts	Characteristics that drive poaching	Freq. (n)	Percent
	IN-DEMAND (CRAVED: Valuable)		
Cultural or symbolic value	As a hobby or pet	98	24.6
	Entertainment (1), Cute (1), Species is unique (1)	3	0.8
Ecological value	Consumed	139	34.8
	Daily necessities	14	3.6
	Medicine (e.g., turtle oil)	11	2.9
Economically valuable	To sell [products]: ivory (n=9, 2.3%), snake skin (n=2, 0.6%)	155	39.0
	High economic value (e.g., leather, meat, tusks)	79	20.1
	PASSIVE (VIVA: Inert)		
Harmless	They are not dangerous	3	0.8
Easily Disabled	Easy to catch	1	0.3
	OBTAINABLE (CRAVED: Available)		
Accessible	Easily accessed	1	0.3
	CONFLICT-PRONE (Natural Resources Management)		
Ecological or economic costs	Pests	10	2.6
	Damage to agriculture (e.g., crops, farms)	51	13.1
	Danger to livestock	3	0.8
Socially contentious	Dangerous, disturbing or threat	5	1.3
	Danger to pets	1	0.3
	EXTRACTABLE (CRAVED: Removable)		
Removable	Easily removed	1	0.3
	DISPOSIBLE (CRAVED: Disposable)		
Market size	High market demand	2	0.6

When asked this open-ended question 45 respondents (11.3%) gave no answer or stated they did not know.
No participants mentioned characteristics that fit with the dimension of all-purpose (CAPTURED : Useable) or Hideable (CRAVED: Concealable).

response to species characteristics that drive poaching was they are *in-demand*, with support for cultural or symbolic value (n=101, 25.3%), ecological value (n=164, 35.2%), and economic value (n=234, 58.5%) (Table 4). There was moderate support for the *conflict-prone* dimension (n=70, 17.5%) and nominal presence of the dimensions of *passive* (n=4, 1.0%), *disposable* (n=2, 0.6%), *obtainable* (n=1, 0.3%), and *extractable* (n=1, 0.3%). No community-member gave a response that fit to the dimensions of *all-purpose* (né useable) or *hideable* (né concealable) (Table 4).

Data from focus group participants were compiled from the species poaching vulnerability ranking exercise and the species surveys, and IPOACHED elements were summarized for the top three most targeted species or genera (songbirds, Sambar deer and muntjacs, pangolins) and the 'big three' critically endangered species (Sumatran elephants, rhinoceros, and tigers) (Table 5). All six species were considered valuable in at least one or all three *in-demand* considerations with estimated economic value provided (Table 5). The three most frequently poached species were characterized by compounding dimensions that make these species vulnerable to poaching, with few (if any) limiting IPOACHED dimensions (Table 5). The 'big three' species were the most economically valuable, displayed high symbolic value, but were each limited by three or more IPOACHED dimensions (Table 5).

4 Discussion

Understanding the characteristics that drive and hamper species targeting at the initial poaching-stage in a particular locale is vitally important to direct intervention efforts to the most vulnerable species. The examination of longer-term trends in these characteristics may help in forecasting changes in vulnerability of local species based on the dynamics of markets, obtainability of species, and relative risk to poachers. There is a need to develop practitioner-ready tools to conduct rapid assessments and relevant analysis with locally available data. Our interdisciplinary research advances applied conservation criminology, providing a complimentary tool to explain differential vulnerability of wildlife species targeted by poachers. Further, our study contributes to answering the call to gather information from community members, and local conservation practitioners (Moreto and Lemieux, 2015). Additionally, this study represents a methodological contribution by creating a

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TABLE 5 IPOACHED elements that drive and limit poaching of the top 3 most frequently poached species or genera and the "big 3" (elephants, rhinos, tigers) species of Bukit Barisan Selatan National Park, Sumatra, Indonesia according to focus group participants[a] (n=27).

Species (Rank)	IPOACHED elements driving harvest	IPOACHED elements limiting harvest
Song birds (Rank 1)	In-Demand: *cultural & economic value*	All-purpose: *component value & multi-purpose*
	Passive: *easily disabled & harmless*	
	Obtainable: *accessible & abundant*	
	Hideable: *disguisable*	
	Extractable: *removable & unguarded*	
	Disposable: *high demand & proximate markets*	
Characteristics: High value and high market demand based on song and beauty, increases owners' status, and easily accessible, easy to catch, and relatively abundant (some species). Approximately $145-1,091 (USD [b]) per bird but must be traded live with high mortality reported in TRAFFIC bulletins. Kept at home, traded among household and local, regional, and international markets.		
Sambar deer & muntjacs (Rank 2)	Passive: *easily disabled & harmless*	
	Obtainable: *accessible & abundant*	
	All-purpose: *component value & multi-purpose*	
	Conflict-prone: *economically costly*	
	Hideable: *concealable & disguisable*	
	Extractable: *removable*	
	Disposable: *high demand & proximate markets*	
Characteristics: Easily accessible as they frequent garden areas, relatively large population, meat consumed in home, traded among households or sold on local markets, horns sold or used in home, and meat is easily concealable on the market. Approximate value $7 USD per kilogram (Sambar).		
Pangolins (Rank 3)	In-Demand: *ecological & economic value*	
	Passive: *easily disabled & harmless*	
	Obtainable: *accessible*	
	All-purpose: *whole, component value & multi-purpose*	
	Hideable: *concealable*	
	Extractable: *removable*	
	Disposable: *high demand & proximate markets*	
Characteristics: High value with all parts of the animal sold, medicinal value, easy to catch, handle and disable, and has a large number of buyers. Approximately $364 USD live and $7 USD per kilogram of scales, consumed at home, traded among households and sold on local, regional and international markets.		
Tiger (Rank 5)	In-Demand: *cultural, ecological & economic value*	Passive: *easily disabled & harmless*
	All-purpose: *whole, component value & multi-purpose*	Obtainable: *accessible & abundant*
	Conflict-prone: *economically costly, dangerous*	Hideable: *concealable & disguisable*
	Disposable: *high demand & proximate markets*	Extractable: *removable & unguarded*
Characteristics: High economic value of all body parts (~ $2,909 USD for whole animal), market demand high, including regional cities and international, has cultural value (amulets, customs, raising social status) but difficult to disable because of resistance and severe punishment deters poachers.		
Elephant (Rank 6)	In-Demand: *cultural & economic value*	Passive: *easily disabled & harmless*
	Obtainable: *accessible*	Obtainable: *abundant*
	Conflict-prone: *economically costly*	All-purpose: *component, whole value & multi-purpose*
	Hideable: *concealable*	
	Extractable: *removable*	
	Disposable: *high demand & proximate markets*	
Characteristics: High market demand and value (e.g., cultural value- increases status), easy to locate a group because of noise but not abundant any more due to hunting. Hunting is dangerous as elephants have a high level of resistance. Approximately $255 USD per 15 cm ivory pipe. There are local, regional and international markets.		

(Continued)

TABLE 5 Continued

Species (Rank)	IPOACHED elements driving harvest	IPOACHED elements limiting harvest
Rhino	In-Demand: *cultural, ecological & economic value*	Obtainable: *accessible & abundant*
(Rank 10)	Passive: *easily disabled & harmless*	All-purpose: *whole, component value & multi-purpose*
	Hideable: *concealable*	Hideable: *disguisable*
	Extractable: *removable*	Extractable: *unguarded*
	Disposable: *high demand & proximate markets*	

Characteristics: The horn has a high value and high market demand but difficult to find and very low population numbers. Can reach hundreds of millions of Indonesian rupiah (Rp 100,000 ~ $7,273 USD).

Information was collecting via descriptive ranking exercise, detailed species-based surveys, and translations of notes typed by a professional Indonesian transcriptionist.
[b]*Currency was reported in Indonesian Rupiah (Rp) by participants and converted using OANDA currency converter (www. oanda.com) on October 1, 2017.*

poaching-stage area-focused (PSAF) model with broad application to examine multi-market bound (e.g., pet, trophy, wild meat) species or genera within a conservation management unit such as a protected area.

4.1 Empirical considerations of the dimensions of IPOACHED

First, there was support for the reconceptualization of the dimension *in-demand* or *valuable* to include cultural, ecological, and economic values. It is notable that in the IPOACHED model, *enjoyable* is absorbed into cultural value. This is also consistent with the literature in terms of entertainment or enjoyment being a motivating factor for legal and illegal hunting (Kahler and Gore, 2012). Cultural values, such as the elevated social status and enjoyment of beauty and songs, were listed as prominent in targeting songbirds, likely magnifying the economic value for specific songbird species. Ideally, market-based models, such as CAPTURED, can predict changing market demands and connect with localized IPOACHED models to better predict trends in changing 'hot species' targeted by poachers. In 2005, for example, due to an outbreak of bird flu international imports of the White-crested laughingthrush (*Garrulax leucolophus*), a popular pet songbird species, were halted in Indonesia (BirdLife International, 2022). In Sumatra there was a dramatic increase in domestic trapping of a related species, the Black-and-white laughingthrush (*G. bicolor*), which led to a sharp population decline and local extinction in some areas of the island (BirdLife International, 2022). Developing robust songbird-focused CAPTURED models could aid in alerting conservation areas to use up-to-date IPOACHED models to better anticipate what species, if any, in their conservation area may be vulnerable to increased targeting by poachers.

Second, this study supports the addition of another dimension, *passive* (*inertia* from VIVA), due to the fact that wildlife at the poaching stage is animate, more closely resembling a victim of predatory crime, with varying degrees of ability to resist capture, injure, or even kill would be poachers. *Passive* was added as a target suitability component with predicting species that are easily disabled (little to no resistance, hunted with tools that are available) and not dangerous (causes no or minor injuries) being more likely to be targeted by poachers. This is distinct from whether a species is *removable* once it has been captured, disabled, or killed. There was evidence from conservation practitioners (less so from community surveys) that species vary considerably in how easily immobilized they are once located with diverse risks to inflict serious injury or harm. All three of the species considered most targeted by conservation practitioners were considered easily disabled and unlikely to inflict serious or even minor injuries, while tigers and elephants were considered difficult to disable and able to cause severe injury or even death to poachers.

Further, this study confirms the earlier adaptations of CRAVED to illegal wildlife, such as the two dimensions of *availability*, abundance, and availability (Pires and Clarke, 2011; Pires et al., 2021), as being distinct and equally important in terms of *obtainability*. For example, herds of elephants were cited as being accessible and detectable due to their relatively noisy nature, yet not abundant at present due to excessive hunting and habitat loss. The last reported citing of the critically endangered Sumatran rhinoceros in BBSNP was in 2015, the year of this study, and experts are now divided on whether they have been extirpated from the park (Kusuma, 2021). Sufficed to say this is one of the least abundant species in the park, possibly absent all together. Conservation practitioners confirmed that despite being *passive* and *in-demand*, with high cultural and economic value, poaching was primarily limited by being unobtainable.

This study confirms that legal trade may *conceal* overharvest or illegal wild harvest of species (e.g., Pires, 2015) as is the case with the sale of wild Sambar deer and muntjac meat on markets where other forms of red meat are legally available. There is a great potential that the previously discussed substitute species of songbirds might be *concealable* on legal markets as well to all but those trained in bird identification. Further, there was also support for the concept of *all-purpose* (né useable) at the poaching-stage (Moreto and Lemieux, 2015) with species such as Sambar deer, pangolin, and tigers being valued because the

whole specimen could be used within the household, local trade, sold for cash on markets, or a mixture of uses.

Our case study supports the addition of the *conflict-prone* dimension to account for human-wildlife conflicts that occur within community and conservation areas that may agitate residents or augment motivations for poaching. Human-wildlife conflict is a salient concern in Sumatra, particularly with their flagship subspecies of elephant (e.g., Kuswanda et al., 2022) and tiger (e.g., Lubis et al., 2020). For example, human-tiger conflict grabbed international attention in February and March of 2009 when within six weeks tigers had killed nine people, the majority illegal loggers, in the Jambi Province (Butler, R. 2009). Conservation practitioners cited human wildlife conflicts, especially involving elephants and tigers, as a potential catalyst for individual poachers and as enhancing community tolerance of poaching in BBSNP listing *conflict-prone* as an element driving harvest (Table 5). Additionally, 18.1% of survey participants free-listed species characteristics such as being a pest, damaging to agriculture, or a danger to livestock, pets, or people as driving poaching (Table 4). Focus group participants discussed the importance of developing robust human-wildlife conflict mitigation and management interventions as a situational crime prevention strategy relevant to reducing frustration and stress (Kahler, 2018).

Additionally, there was support in the literature and our case study for a reconceptualization of the dimension of *extractable* (né removable), to attend to two primary considerations: the physical act of extracting or removing the specimen and avoiding detection while doing so. The former dimension has been defined previously as the difficulty of accessing the species, such as parrot nests (Pires, 2015) or access to diverse habitats (Rivera, 2022), but can also be a product of the specimen's mass according to focus group participants. For example, they mentioned a market for elephant feet but noted the extreme difficulty in physically removing, and concealing, these parts of the animal. This relates to how easily the species is field processed, a concept proposed in Moreto and Lemieux (2015) CAPTURED product-based model, where it was a stand-alone dimension of *processable* that was highly variable through the market stage yet not considered a key element during the poaching stage. The concept is still relevant, particularly within the concept of the physical removal of the specimen after harvest, however, it has been absorbed into consideration under *extractable*. There is evidence that there is a discernable difference between the enforcement effort, detection probability, and risk of punitive consequences based on species. In Sumatra, the illegal bird markets and presence of caged birds in virtually every village and roadside restaurant is astonishing in its volume and in its visibility to the public and law enforcement. Focus group participants discussed the permissive environment for songbird poaching in BBSNP and the extraordinary efforts made to safeguard the park's remaining tigers and rhinoceroses, if any. *Unguarded* was added to the *extractable* dimension to capture this disparity in the risk that poachers are detected and face punitive consequences for poaching lower priority species in the area. This finding also highlights the utility of combining official and unofficial data sources to determine species-based poaching trends as official sources may be biased toward heavily guarded, high priority species.

4.2 Limitations and future research

The IPOACHED model has potential to offer new entry points for examining what drives species selection for market-specific poachers, such as songbird collectors, within a particular conservation management landscape. Moreto and Lemieux (2015) discuss the changing importance of CAPTURED components across market types and this study would support the assertion that the same might be said for specific conservation areas. For example, for the poaching of songbirds, dimensions such as *passive*, *conflict-prone*, and *all-purpose* will not likely discriminate between species, while cultural and economic value (*in-demand*), their abundance and accessibility (*obtainable*), whether they can be disguised in terms of legal trade (*hideable*), and *disposability* on local, regional, and international markets will likely determine species harvest in specific areas.

There are several future directions for research into the IPOACHED model. First, Clarke (1999) discussed theft choices involving personal versus commercial use items, which is relevant to subsistence versus commercial use-based poaching. To better anticipate decision-making on the part of the poacher when targeting wildlife species, models that are based on the different modus operandi of the various actors involved in poaching should be explored (Moreto and Lemieux, 2015). During this study, focus group participants created concept diagrams based on the modus operandi of opportunistic, premeditated, and provoked poachers but failed to link considerations of these different poachers to concepts related to IPOACHED. Additionally, Clarke (1999) discussed the displacement of crime when protecting a hot product and states that within the context of stolen goods there is evidence that displacement is not a foregone conclusion as many thieves target specific products for specific reason that other products may not satisfy. We do not know if poachers in BBSNP are primarily focusing on one market, such as pets or wild meat, or are more flexible and opportunistic in their species choices. This is an area of great uncertainty.

Lastly, there are several dimensions and components of dimensions of IPOACHED that warrant further consideration and better definition and quantification to make applicable as a tool for protected area management and conservation law enforcement. For example, this study attempted to quantify cultural, ecological, and economic values but further elaboration is warranted. The component of *unguarded* in regard to a species' extractability, for example, could be quantified based on measures of punitive consequences (e.g., fines), enforcement effort within core habitat zones of particular

species, a scaled response from law enforcement indicating their likelihood to enforce species-specific regulations, or a combination of the above. Official data will be an important empirical test and aid refinement of IPOACHED and any future poacher- (e.g., premeditated) or market-focused (e.g., wild meat) renditions.

Moreto and Lemieux (2015) suggested that in order to empirically evaluate the CAPTURED model it would be necessary to gather information about illegal activities beyond official law enforcement data, which could include interviewing poachers, middlemen, informants, and local law enforcement as to why particular species are more often targeted than others. This research aimed to gather input and knowledge from the perspective of local communities that live with wildlife and local representatives from community-based, governmental, and non-governmental organizations (NGOs) involved with conservation and protection of wildlife species. However, there are several limitations associated with this study. First, although this study answers the call for use of more non-official sources of information *via* surveys with community members and conservation and enforcement representatives (e.g., Moreto and Lemieux, 2015), we failed to secure sources of official data for species poached in BBSNP. Securing enforcement data for protected areas, like Pires et al. (2021), would prove useful in testing this framework. Additionally, community members surveyed were of unknown compliance status with regard to wildlife poaching laws. It would be useful to identify and prioritize community-based informants and current or former poachers to further calibrate the model and quantify some of the concepts. Official records and more purposeful sampling of stakeholders would provide valuable data to test the model, aid in appropriate quantification of the various components of IPOACHED dimensions, and adequately assess the usefulness of this model to detect trends in species-targeting within a given conservation area despite species being destined for differing markets (e.g., pets, trophies, wild meat).

Lastly, this study confirms that one common method of poaching in BBSNP is the use of snares, which complicates the use of target suitability models as poachers may pursue one or more species but catch non-targeted species (i.e., bycatch). These non-targeted species may comprise a substantial volume of wildlife poached from the park and provide smaller economic rewards but be equally likely to be consumed in the home or enter markets. For example, accidental snaring of the endangered Malaysian tapir was reported in BBSNP with participants citing its lack of desirability due to dietary restrictions in Islam as they are perceived to be related to pigs. This assertion is backed up by IUCN data on tapirs in Sumatra, where numbers are thought to be declining and below 500 individuals, and off-take is likely due to accidental snaring and possibly retaliation for crop damage (Table 2). There is evidence elsewhere on Sumatra that pigs are entering the market either through direct targeting or bycatch to be sold to non-Muslims for wild meat (Luskin et al., 2013), therefore it is plausible that tapirs enter illegal markets as well. Bycatch due to snaring is problematic for poaching and market-based CRAAVED, CAPTURED, or IPOACHED models, as results may be an artifact of hunting method rather than characteristics of species being the desired target of the poacher. While species confiscated in snares, sticky rice, and mist nets may correlate to the species overall *abundance* and *accessibility*, these indiscriminate harvesting methods may hamper our understanding of characteristics most sought after by poachers and demands on the market.

4.3 Conclusion

CRAAVED and CAPTURED approaches have become increasingly statistically sophisticated (e.g., Pires et al., 2021) in interpreting the species-specific vulnerability to poaching and trade. These developments provide advancements in interpreting and ultimately responding to the illegal wildlife trade. However, there are a number of limitations that persist in these approaches particularly as they relate to the poaching stage and as a conservation tool sensitive to conservation contexts at a finer scale (e.g., specific protected areas). First, empirical investigations using these existing frameworks are reliant on seizure and market data often compiled across diverse conservation contexts and from various sources (e.g., Pires et al., 2021). Market data, which detects violations often distant from the source wildlife habitats, is likely to underestimate species poached for non-commercial uses (e.g., retaliation, subsistence) or sensitive species with high mortality rates along the illegal wildlife trade chain. Additionally, these approaches are often hampered by data availability. Secondly, while CAPTURED was developed to take into account the unique characteristics and nuances of wildlife products (Moreto and Lemieux, 2015), theoretically giving this framework flexibility to discriminate between diverse genera or species found in diverse use markets, empirical investigations have been restricted to single genera (e.g., fishes, parrots) within specific use markets (e.g., commercial fisheries, pet markets). Lastly, while there are distinct analytical advantages to these increasingly sophisticated target suitability frameworks, these approaches maintain or increase conservation practitioner reliance on academic partnerships to operationalize and interpret framework findings. Our framework seeks to address these limitations, complimenting existing approaches, by creating a conservation criminology-based framework designed to accommodate diverse data that can be leveraged by conservation practitioners to consider disparate species-specific drivers of poaching within conservation areas.

First, recognizing that not all poached species or products end up entering commercial markets, and drawing on diverse data proximate to source habitats, the IPOACHED model is designed to account for species or genera poached under diverse opportunity, demand, and motivational contexts. For example, unmitigated human-wildlife conflicts or *conflict-prone* species may amplify economic or cultural motivations to poach (Kahler and Gore, 2015). Further, the PSAF model can accommodate diverse data

sources within a conservation management unit, allowing conservation law enforcement and practitioners to fill in data and knowledge gaps often present in official law enforcement records with the knowledge and opinions from local communities and conservation practitioners. Triangulating data in this way creates a more holistic picture of what species are most vulnerable under localized conditions (e.g., Kahler et al., 2013; Kahler and Gore, 2015). Secondly, the results of this study show that the IPOACHED model has the potential to serve as an explanatory and predictive tool to understand broad species and genera targeted for a variety of uses. For example, our BBSNP data suggests that species such as songbirds, deer, pangolins, and hornbills are more vulnerable to poaching compared to higher profile species such as rhinoceroses or tigers. Findings from IPOACHED can supplement other data and intelligence to facilitate improved enforcement efforts and aid in directing interventions to the most vulnerable species within a geographically distinct management area. Designed with conservation practitioners in mind, government agencies, environmental NGOs, and community-based conservation programs can use and adapt our IPOACHED model and survey instruments (provided in Supplementary Material) to explain and predict poaching of diverse species in the conservation management areas they are charged to protect.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by IRB at Michigan State University (IRB# x13-237e Category: Exempt 2). The participants provided their written (focus groups) or oral (surveys) informed consent to participate in this study.

Author contributions

JK led concept, data collection and analysis, and writing. CR contributed to writing, revisions, and formatting. MG contributed to data collection, study design, analysis, and written revisions. All authors contributed to the article and approved the submitted version.

Funding

This research was funded by the National Science Foundation's Division of Social and Economic Sciences, Decision, Risk and Management Sciences (NSF Award #1357869).

Acknowledgments

We are grateful for the contribution of World Wildlife Fund – Lampung who provided in-kind support and facilitated research activities on the ground in Sumatra and the services of N. Adji, D. Buhasan, A. Fadila, D. Haryanto, S.A. Saputra, and Pak Zulfadi.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcosc.2022.992621/full#supplementary-material

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