CONTRIBUTED PAPER

Killing of orangutans in Kalimantan - Community perspectives on incidence and drivers

Emily Massingham[1,2] | Erik Meijaard[2,3] | Marc Ancrenaz[3,4] |
Dino Mika[5] | Julie Sherman[6] | Truly Santika[7] | Lengga Pradipta[8] |
Hugh P. Possingham[1,2] | Angela J. Dean[1,2,9]

[1]School of the Environment, The University of Queensland, Brisbane, Queensland, Australia

[2]Centre for Biodiversity and Conservation Science, The University of Queensland, Brisbane, Queensland, Australia

[3]Borneo Futures, Bandar Seri Begawan, Brunei Darussalam

[4]HUTAN—Kinabatangan Orangutan Conservation Programme, Kota Kinabalu, Malaysia

[5]Yayasan Tambuhak Sinta, Central Kalimantan, Indonesia

[6]Wildlife Impact, Portland, Oregon, USA

[7]Natural Resources Institute (NRI), University of Greenwich, Kent, UK

[8]National Research and Innovation Agency (BRIN), Universiti Brunei Darussalam Gedung, Jakarta Pusat, Brunei Darussalam

[9]School of Agriculture and Food Sustainability, The University of Queensland, St Lucia, Queensland, Australia

Correspondence
Emily Massingham, School of the Environment, The University of Queensland, Brisbane, QLD 4072, Australia.
Email: e.massingham@uqconnect.edu.au

Abstract

Despite decades of conservation management, many orangutan populations are on the brink of extinction. This is primarily due to habitat loss and direct killings. A study from 2008/2009 suggested that killing was impacting orangutan populations at a rate sufficient to cause local extinctions. As an illegal and taboo behavior that is difficult to measure, killing has been severely understudied since. We conducted 431 interviews in 79 villages across Kalimantan in 2020/2021. Ours is the first quantitative field study in more than 10 years to assess the state of killing of orangutans. We aimed to: (1) assess the current state of killing of orangutans in Kalimantan and compare this to the previous study; (2) determine whether conservation projects are affecting killing; and (3) explore drivers of killing. We examined killing of orangutans across villages with forest conservation projects, orangutan conservation projects, and no conservation projects. We assessed the existence of killing and used scenarios to examine perceived norms about illegal behavior relating to orangutans. We then used matching techniques to assess whether projects have any impact on these indicators. Overall, our findings suggest that killing has occurred in recent times, and our data does not indicate a clear attenuation of the behavior. As such, we argue that killing may still present a substantial threat to Bornean orangutan populations. We also found no statistically significant evidence that conservation projects are reducing killing. Conservation project managers could seek to understand the drivers of killing, and to invest in interventions that address these drivers. Research suggests that current allocation of conservation funding has been ineffective at abating orangutan population decline. We argue that a key part of improving Bornean orangutan conservation practice involves directly addressing killing of orangutans and the underlying drivers of killing.

1 | INTRODUCTION

Orangutans are an iconic species that have attracted more than US$ 1 billion of conservation resources in the past two decades (Santika et al., 2022). There are three species of orangutans, two of which occur on the island of Sumatra (Indonesia) and one on Borneo (Indonesia and Malaysia); all three species are critically endangered (Ancrenaz et al., 2016; Nowak et al., 2016; Singleton et al., 2017). Our study focused on the Bornean orangutan (*Pongo pygmaeus*). Of the three species, the Bornean orangutan has the largest population spread across the greatest range, which overlaps with many human communities. Despite full protection under Indonesian law (Bio Conservation Act, 1990) and concerted conservation efforts (Santika et al., 2022; Sherman, Ancrenaz, Voigt, et al., 2020), recent distribution modeling suggests that the population has declined by >100,000 Bornean orangutans between 1999 and 2015 (Voigt et al., 2018). Such findings reflect estimates of an 80% decline from the 1950 population size over three generations (1950–2025) (Ancrenaz et al., 2016).

Two interlinked and compounding drivers of orangutan decline are forest loss and direct killings (Abram et al., 2015; Davis et al., 2013; Meijaard et al., 2011; Santika, Meijaard, et al., 2017). In the 1990s and 2000s, Borneo experienced some of the highest deforestation rates in the world due to agriculture, infrastructural development, mining, and forest fires (Gaveau et al., 2016), but forest loss rates have decreased significantly since 2015 (Gaveau et al., 2019; Gaveau et al., 2022). Bornean orangutans are a semi-solitary, forest-dependent species with large home ranges, so deforestation leads to loss of critical habitat and food (Ancrenaz et al., 2016). Habitat loss and fragmentation also force orangutans into human populated areas, which may contribute to opportunistic hunting or incidents where orangutans are killed (Meijaard et al., 2011; Rijksen & Meijaard, 1999; Wich et al., 2012). For example, orangutans entering household gardens or farms to raid crops may cause fear and considerable economic loss to farmers, which may lead to retaliatory killing (Davis et al., 2013; Meijaard et al., 2011). People may also encounter orangutans during logging or forestry operations, which can lead to conflict or opportunistic killing (Davis et al., 2013). Further information and efforts are needed to improve our understanding of how to effectively mitigate the risk of orangutans being killed

(Maskulino et al., 2021). Such information could help to prevent negative human social impacts associated with orangutan-human conflict, and could also help prevent killing and illegal behavior toward orangutans. A key part of determining appropriate actions to any conservation problem is to assess the current state of the problem, understand its drivers, and evaluate whether conservation interventions are having a positive influence. As such, further information on the current state of killing of orangutans, the drivers of killing, and whether conservation projects are helping to abate this behavior is needed to inform the implementation of management strategies that promote human–orangutan co-existence and reduce killing of orangutans.

Prior research suggests that killing of orangutans is a much greater threat to their populations than previously understood. For example, Abram et al. (2015) gathered information on local knowledge of threats to the Bornean orangutan from 531 survey locations across Kalimantan. They found that 19% of villages reported human–orangutan conflicts and 23% of villages reported recent orangutan killings. After interviewing 6983 respondents in 687 villages in Kalimantan, Meijaard et al. (2011) estimated that up to 1357 orangutans were killed in 2007 and approximately 2882 ($\pm$500) orangutans were killed on average per year over the lifetime of survey participants. While these rates might not seem extreme in the context of other species, low fecundity and slow reproduction rates (an average of one infant every 8.2 years) means that increased adult orangutan mortality has a disproportionate extinction risk (van Noordwijk et al., 2018). It has been argued that a killing mortality rate of 1% of adults in suboptimal habitat or 2% in optimal habitat will drive populations to extinction (Marshall et al., 2008; Meijaard et al., 2010). According to Meijaard et al. (2011, 2012), estimates of killing rates in 2007 appeared to exceed these percentages, implying that killing rates may well have exceeded viable thresholds at this time (Meijaard et al., 2011; Meijaard et al., 2012). Despite this, the impact of killing on orangutan populations is often underestimated and is rarely considered in conservation planning, with anti-killing efforts receiving nominal funding (Santika et al., 2022). It has been argued that examining ongoing patterns of orangutan killing would enable conservation efforts to tackle mortality more effectively (Abram et al., 2015).

Understanding the prevalence of orangutan killing and the factors that influence killing is difficult given it is an illegal behavior (Meijaard et al., 2011). Prior research suggests that one of the most common reasons for killing orangutans is for food (i.e., bushmeat) (Abram et al., 2015; Davis et al., 2013). Other studies suggest that orangutans are killed in response to crop raiding (Campbell-Smith et al., 2012; Meijaard et al., 2010). Aligned with this, research has also shown that villages closer to forested regions exhibit greater likelihood of killing (Davis et al., 2013). Killing orangutans to capture infants for the pet trade has also been documented (Davis et al., 2013; Meijaard et al., 2011; Nijman, 2017; Rijksen & Meijaard, 1999; Sherman et al., 2022; Singleton et al., 2017). Individual social factors such as religion, wellbeing and awareness of orangutans conservation status might also influence perceptions of killing. For example, wellbeing may be important for people's capacity to engage in conservation (Shafir, 2014), and religion might represent cultural norms around behaviors, perceptions or reporting of behaviors (Ghazali et al., 2018). A common strategy for conservation engagement focuses on raising awareness of species decline, based on the assumption that awareness of a threat will promote greater engagement in conservation or protective actions (Chua et al., 2021). Within this context, perceptions about orangutan population declines may relate to expectations about killing of orangutans in the community. For example, a lack of knowledge that orangutans are declining could be associated with killing in the community, as people might not know that orangutans are at risk of extinction. Overall, a lack of large-scale studies using quantitative approaches means that our understanding of the current state of killing and its drivers is insufficient to inform targeted management responses (Sherman et al., 2022).

Another gap in our understanding is how conservation projects may directly or indirectly influence rates of killing. A recent study of orangutan conservation investment across Kalimantan found that habitat protection received the largest proportion of total annual investment (31%), followed by rescue and rehabilitation (18%), and public outreach (16%) (Santika et al., 2022). Theoretically, these investments could reduce killing via several pathways. For example, reducing forest loss is likely to reduce the number of orangutans forced to traverse human populated areas. Community outreach programs could potentially discourage behaviors that would harm orangutans. But there are limited data available to specifically assess how program presence influences killing. Understanding drivers of population decline and how effective different conservation strategies are at mitigating those drivers necessitates that the impacts of interventions be measured. Such information will enable the development of evidence-based approaches to halt orangutan population declines (Campbell-Smith et al., 2012).

To address these knowledge gaps, we quantified the current state of killing of orangutans in Indonesian Borneo (Kalimantan) and the influence of conservation projects on reports of killing. We also explored individual factors (such as involvement in palm oil industry, experiences of crop raiding, awareness of orangutan population decline and life satisfaction) associated with expectations of how others in the community would respond to orangutan encounters. Our study is the first in more than a decade to present field-based, quantitative evidence of the state of killing of orangutans. These findings are timely and provide information to direct national orangutan conservation action plan priorities and public and private investment toward interventions that will alter the species' current trajectory toward imminent extinction (Santika, Ancrenaz, et al., 2017; Voigt et al., 2018; Voigt et al., 2021).

2 | METHODS

2.1 | Study area and context

Our study focused on the Bornean orangutan's range in Kalimantan—a region high in biodiversity and endemic species (Koh & Sodhi, 2010; Myers et al., 2000) (Figure 1). Kalimantan's five provinces cover an area of 530,000 km^2 (Santika et al., 2019) of which nearly half (257,400 km^2) remained forested in 2019 (Gaveau et al., 2022). While Indonesia's population is growing rapidly and the country continues to develop (Jones, 2013; United Nations, 2019), the livelihoods and basic needs of many rural communities remain dependent on forests (Bureau of Statistics Indonesia, 2018; Santika et al., 2021).

2.2 | Selection of study villages

The sampling frame encompassed all regions in Kalimantan where orangutans are suspected to occur (Santika et al., 2017). Within these regions, villages surveyed by Meijaard et al. (2011) were considered in the current study if they had reliable reports of orangutan presence in the original study (i.e., at least one respondent from that village reported having seen an orangutan in or around their village). This resulted in a list of 213 villages. Study villages were selected from these previously surveyed villages within the orangutan range, using propensity score matching as described below (Appendix S1).
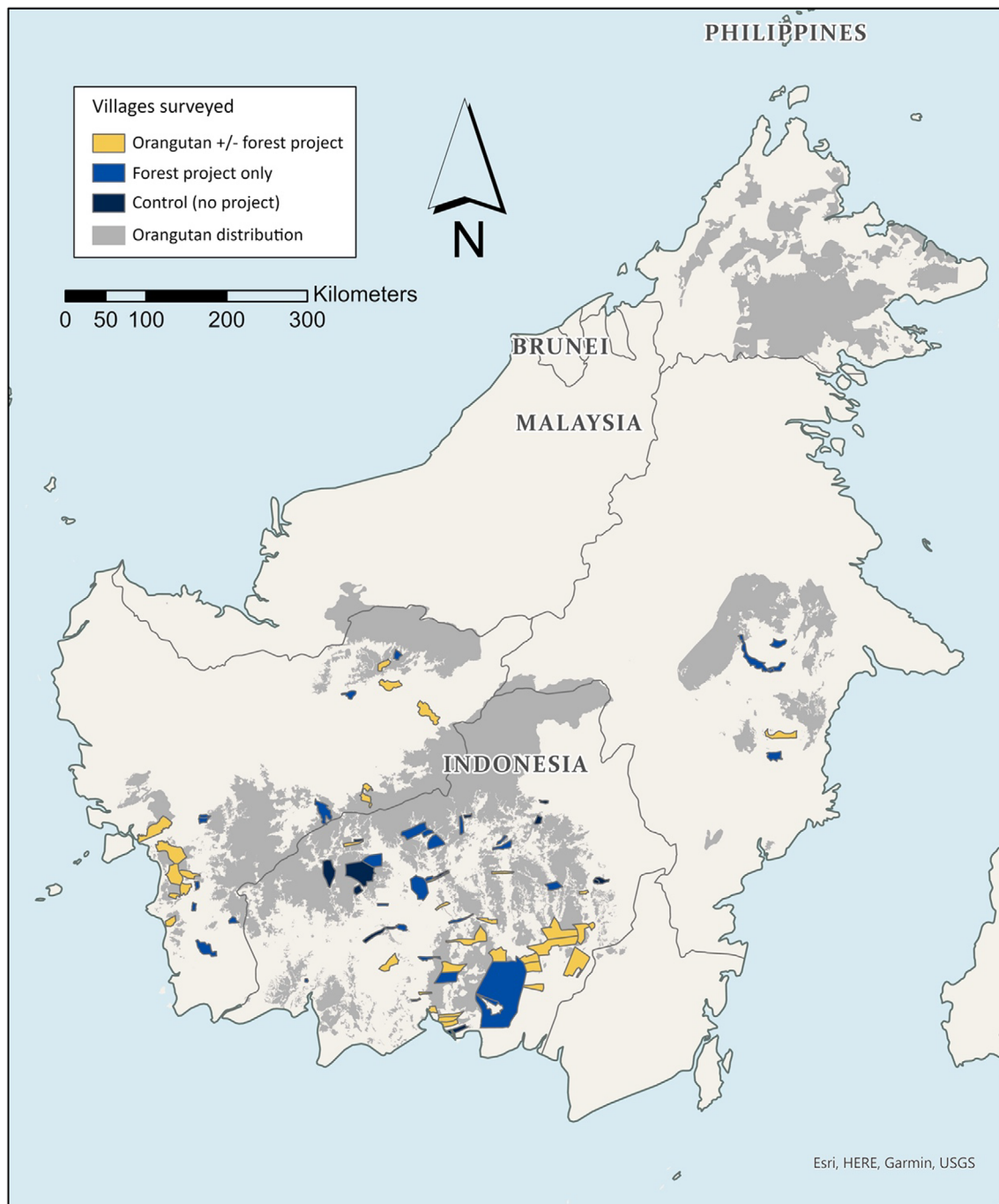
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FIGURE 1 Bornean orangutan range (Santika et al., 2022) and 79 surveyed villages.

2.3 | Classifying presence of conservation program

Before we were able to perform matching to select our study villages, we first had to determine whether any conservation projects were active within these 213 villages. This in turn allowed us to assess the potential effects of an orangutan or forest conservation project on orangutan killing. To do this, we conducted desktop searches of available scientific and grey literature, supported by expert consultation and ground truthing via village surveys (Appendix S1). Final classifications were shared with orangutan conservation experts in Kalimantan for verification. In addition, data on the location of Reducing Emissions from Deforestation and forest Degradation (REDD+) (Jagger & Rana, 2017) and Community Forestry projects (Santika et al., 2019) was overlaid with village boundaries to identify the presence of those forest conservation projects in villages. The final classifications of project presence in villages included three village types: Orangutan (Villages with

orangutan projects [with or without forest projects]), Forest (Villages with forest projects only), and Control (Villages with neither orangutan nor forest projects).

2.4 | Propensity score matching and final village selection

To assess the influence of projects on killing of orangutans, we aimed to reduce bias by ensuring control villages had similar characteristics to villages with projects in them. To identify a subset of villages with similar characteristics, we used propensity score matching (Rosenbaum & Rubin, 1983). By using matching techniques, control populations can provide a proxy for what the intervention site might look like in the absence of intervention. In preparation for matching, a range of data was collated on each village. Potential confounding variables that were included in the matching process represented geographic accessibility, indicators of market value associated with the village, factors that support agricultural productivity, and forest cover (Appendix S1, Table S2).

In total, 79 control and treatment villages were selected by the matching process (Figure 1), which comprised the following village types:

> Orangutan: Villages with orangutan projects (with or without forest projects) (N = 35);
> Forest: Villages with forest projects only (N = 31);
> Control: Villages with neither orangutan nor forest projects (N = 13).

2.5 | Surveys of key informants and ethical clearance

We conducted face-to-face interviews with 431 respondents between October 2019 and November 2020 (Appendix S3). Institutional ethical clearance was attained to conduct the survey in compliance with the Australian National Statement on Ethical Conduct in Human Research (approval number 2019001703). A research permit (permit number S/241/E5/E5.4/2019) was also attained from the Indonesian government. Data were collected by Indonesian researchers from our research partner organization, Yayasan Tambuhak Sinta (YTS). YTS is an Indonesian social development and research organization with a history of working in our study region. Interviews were conducted in local languages and translated to English for analysis. Participant selection was non-random, with interviewers seeking 5–10 male and female adult respondents per village with knowledge of local wildlife (Appendix S1).

2.6 | Dependent variables: Evidence of killing and expected behavior of others

Evidence of killing—village level: Four questions measured evidence of killing orangutans at the village level over time (Appendix S1):

- How many people do you know who have killed an orangutan before? (coded as: indicator of killing in any village in any time frame)
- When was the last time someone in your village killed an orangutan? (coded as: indicator of killing in any time frame/ indicator of killing in last 10 years)
- How many orangutans have been killed in your village in the last year? (coded as: indicator of killing in any time frame/ indicator of killing in last 10 years)*
- How many people you know who have eaten orangutan in the last year? (coded as: indicator of killing in any time frame/ indicator of killing in last 10 years)*

*NB some open answers to this question revealed killing had happened within timeframes greater than a year, and they were coded accordingly (Appendix S1, Table S3).

A positive response to any of these questions provided an estimate of killing (any evidence = 1, no evidence = 0), in any village ever and within the last 10 years in the respondent's village (Appendix S1, Table S3).

This resulted in two "*evidence of killing*" variables:

1. Killing within your village in the last 10 years
2. Killing in any village at any time

It was beyond the scope of our study to detect the rate of killing, due to our smaller sample size and our decision to avoid direct questioning about illegal behavior. Multiple reports of killing from the same village did not contribute to multiple recorded incidents of killing, instead killing was recorded as detected in a village or not.

Expected behavior of others—individual level: Direct questions about illegal behaviors might elicit dishonest responses (Knapp et al., 2010; Razafimanahaka et al., 2012; St. John et al., 2010). Following Meijaard and colleague's (2011) recommendation, we used sensitive question techniques in the form of vignettes to complement our "evidence of killing" questions. Prior research suggests that vignettes are useful in eliciting responses to sensitive topics. Vignettes have been used to ask sensitive questions in conservation, particularly around the topics of illegal hunting and wildlife crime (Chang, 2017; Rizzolo, 2021; Travers et al., 2019). Vignettes are useful in this context, as they can provide a neutral reflective

space to consider and discuss sensitive issues (Spalding & Phillips, 2007), can help elicit responses that reflect what respondents expect would occur in reality (Hainmueller et al., 2015; Rizzolo, 2021) and can reduce social desirability bias (Brahm, 2001; Hughes & Huby, 2012; Rizzolo, 2021).

We used vignettes to examine perceptions about how others would respond to encountering an orangutan (Appendix S1): "For the hypothetical scenarios below, please try and put yourself in Kevin's shoes. 'Kevin' has a wife and two children. He works in the forest."

- Forest encounter scenario: Kevin finds a mother with her baby orangutan the forest. What do you think he will do?
- Forest infant scenario (follow-up to forest encounter scenario): If he happens to kill the female orangutan, what do you think he would do with the infant?
- Crop raiding scenario: Kevin sees a lone orangutan in a tree close to his village. Orangutans have harmed his crops before. He has a weapon and thinks he could easily kill the orangutan. What do you think he will do?
- Bushmeat scenario: It has been a while since Kevin and his family have eaten meat. He sees a lone orangutan in a tree close to his village. He has a weapon and thinks he could easily kill the orangutan. What do you think he will do?

For each scenario, response options included: leave it, kill it, eat it, sell it, keep it or other.

2.7 | Independent variables— Village level

- *Presence of orangutan conservation project or forest conservation project* (classified as described above): (i) any orangutan projects (with or without forest projects); (ii) forest projects only, or (iii) control (Appendix S1, Table S1).

2.8 | Independent variables— Individual level

- *Awareness of population decline*: two items assessed whether respondents thought orangutan populations were declining ("How many orangutans live in your area, compared to 10 years ago" and "How many orangutans do you think will be here in 10 years?") Response options included "more," "about the same," "less," "none," "do not know." Responses were binary

coded for analysis, where those who answered "less" or "none" to either question were coded as 1 = aware of decline, and all other responses coded as 0 = no.
- *Crop raiding*: one item assessed whether people had experienced orangutans coming into their gardens or fruit trees (binary response, yes/no).
- *Involvement in palm oil*: one item measured whether respondents or their family were involved in palm oil agriculture (binary response, yes/no).
- *Life satisfaction*: a single item was adapted from the World Values Survey (Inglehart et al., 2014) to assess whether participants felt satisfied with their life as a whole, (1 = completely dissatisfied, 5 = completely satisfied).
- *Demographics*: we assessed age, gender, and religion.

2.9 | Statistical analysis

Firstly, we conducted descriptive analysis outlining percentages of villages with evidence of killing, across all villages and within village types (i.e., project type or no project). We then examined whether the presence of a conservation project in a village influenced reporting of killing by respondents in that village, including reporting of killing both in that village in the last 10 years, and in any village at any time. To assess the impact of project presence on killing, we performed two binomial logistic regressions (Model 1: killing within the village in the last 10 years; Model 2: killing in any village at any time). Type of conservation project was dummy coded to create two independent variables: any orangutan project (1 = yes/0 = no), and presence of forest project only (1 = yes/0 = no). Models included participant characteristics (age, gender, and religion) as covariates.

We then conducted descriptive analysis outlining the percentage of respondents who selected a response to scenarios that involved killing or other illegal behavior. We assessed factors associated with responses to scenarios using a multinomial regression. We created a single dependent variable by coding responses to scenarios: evidence of illegal response in one or more scenarios (kill, eat, sell, keep), (coded as 2), "other" (coded as 1), with the reference group being "leave the orangutan" in all scenarios (coded as 0). Independent explanatory variables included in the model were village type (i.e., presence of a project and project type within a village), awareness of decline, orangutans raiding garden, involvement in palm oil production and life satisfaction, with gender, age and religion included as covariates. Several village characteristics were controlled for via their inclusion in the process of propensity score matching (Appendix S1, Table S2). Variables were checked for correlations

(Appendix S2) and for multicollinearity (all tolerance levels >0.9). See Appendix S2 for correlations between variables. As expected, there is a positive relationship between responses to scenarios and the two "evidence of killing" outcomes (evidence of killing within your village in the last 10 years and evidence of killing in any village at any time). We examined these scenarios and "evidence of killing" variables as separate outcomes; however, we note that there are relationships between these outcomes of interest (Appendix S2). Models were also checked for normality assumptions by inspecting normality of residuals. No overdispersion was detected.

3 | RESULTS

Reported result outputs include *p* values, confidence intervals and odds ratio. Odds ratios (OR) enable us to compare the relative odds of the occurrence of killing, given the presence of a conservation project (Szumilas, 2010). An OR greater than one suggests that exposure (e.g., presence of a project) is associated with higher odds of killing, and an OR of less than one suggests that exposure is associated with lower odds of

killing (Szumilas, 2010). The 95% confidence interval (CI) indicates the precision of the OR, with a larger CI representing low precision, and a smaller CI representing high precision (Szumilas, 2010).

3.1 | Sample characteristics

Interview participants included 431 residents across 79 villages in Kalimantan. Respondent ages ranged between 20 and 80 years with an average of 43.19 ± 0.54 years. Most respondents identified as male and Muslim (75.17% and 58.47%, respectively) (Appendix S1, Table S4).

3.2 | Evidence of killing

Overall, 43 out of 79 villages (54.43%) had one or more respondent indicate evidence of killing in any village at any time, and 24 villages (30.38%) had at least one respondent report orangutan killing within that village in the last 10 years (Figure 2). While response options for this question went up to 5 years, one respondent offered
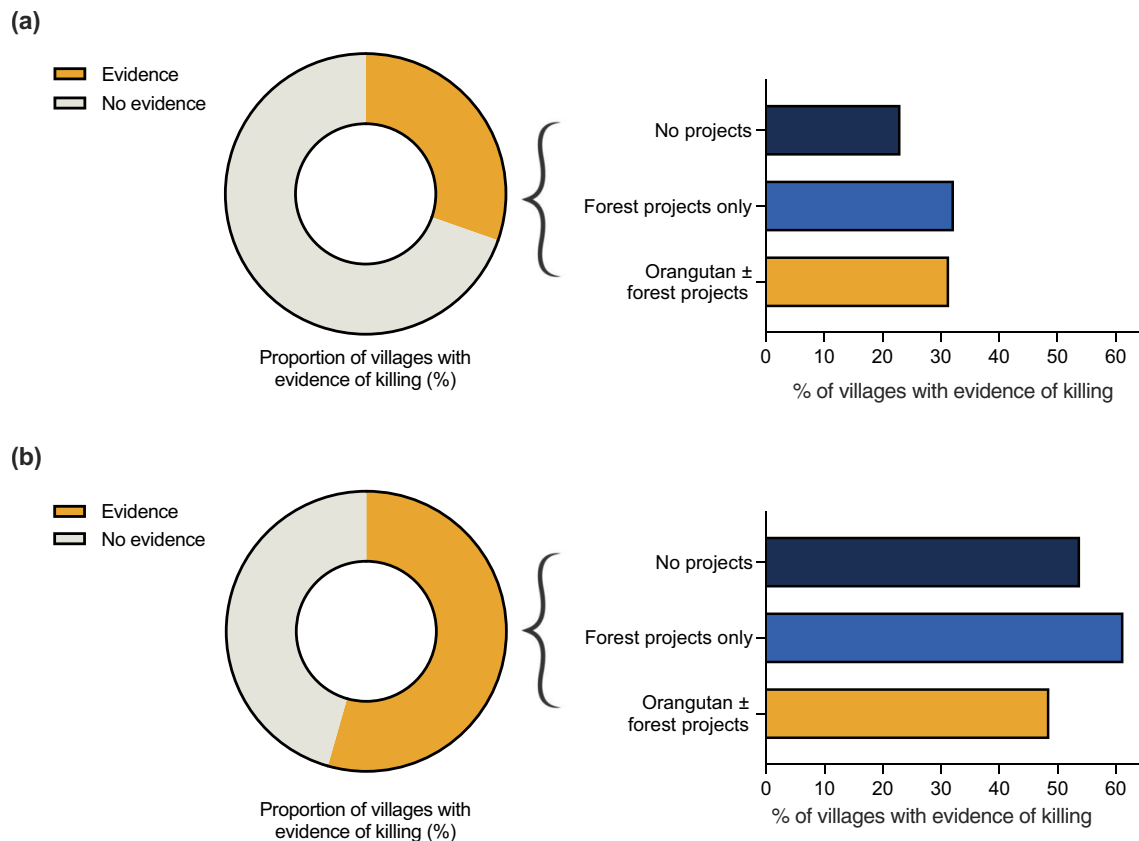

FIGURE 2 Evidence of killing (a) in village in last 10 years and (b) in any village at any time.

additional information about killing occurring in a broader time frame (5–10 years). As such, we took a cautious interpretation of this and classified responses as killing within their village in the last 10 years (see Table S3). The greatest number of reported killings (in total and within the last 10 years) was reported from villages with recent or ongoing forest conservation projects (Figure 2, Appendix S1, Tables S4 and S5). We note the lower proportion of killing in the "last 10 years" (compared to "ever") reflects a smaller window for occurrence to be detected, rather than a reduction in killing. Specifically, given the high age of participants (mean 43 years, upper age 80), the time period covered by "ever" may include a period exceeding 50 years (including the last 10) for many respondents. While not included as a variable in our analysis, it is notable that 11.39% (nine villages) of villages had evidence of killing in that village in the year prior to survey.

3.3 | Influence of village characteristics on killing reporting

Regression analyses indicated the presence an orangutan conservation project compared to no project was not significantly associated with reports of killing within a village in the last 10 years (B = −.05, p = .92, 95% 0.39–2.36) or of killing in any village at any time (B = .29, p = .41, 95% 0.67–2.67) after controlling for gender, religion and age (Table 1). Similarly, the presence of a forest project alone as compared to no project was not significantly associated with reports of killing within their village in the last 10 years (B = .05, p = .92, 95% 0.43–2.56) or of killing in any village at any time (B = .11, p = .76, 95% 0.55–2.24) after controlling for gender, religion and age (Table 1). Respondents who identified as Muslim were less likely to report killing in their village in the last 10 years (B = -0.67, p = .04, 95% 0.27–0.98) or in any village at any time (B = -0.66,

p = <0.05, 95% 0.32–0.84). Older respondents were more likely to report killing in any village at any time (B = .03, p = .02, 95% 1.00–1.05) (Table 1).

3.4 | Expected behavior of others in scenarios

Based on individual responses to scenarios, 4.41% of survey respondents suggested the character would kill in one or more scenario and 42.69% of respondents suggested the character would have an illegal response to the orangutan encounter (sell, keep, eat, kill) in at least one scenario (Figure 3). Less than half (40.14%, 173 respondents) said "Kevin" would leave the orangutan in all scenarios, and 17.17% (74 respondents) said he would do something "other" than kill, eat, sell, keep or leave. Text responses were not provided for what "other" referred to. Looking at the response to specific scenarios (Appendix S3), the most frequent response relating to illegal behavior occurred in the scenario where an infant orangutan was encountered.

3.5 | Drivers – Expected behavior of others in scenarios

Regression analysis indicated that the presence of conservation projects did not have a detectable effect on illegal responses to scenarios (Table 2). Selection of an illegal response in the scenarios was higher in respondents who perceived that orangutan populations were declining (B = .91, p = .001, 95% 1.43–4.30) (Table 2). People involved in the palm oil industry and those with higher life satisfaction were more likely to suggest the character would "leave" an orangutan (compared to selecting "other" as a response in any of the hypothetical scenarios) (B = −1.11, p = <0.001, 95% 0.18–0.61 and B = -0.39, p = <0.05, 95% 0.46, 0.99, respectively).

TABLE 1 Results of logistic regression assessing the effect of conservation projects on the reporting of orangutan killing within villages in the last 10 years and within any village at any time.

	Killing reported within village—last 10 years			Killing reported in any village—Anytime		
	Coefficient (±SE)	95% CI	Odds ratio	Coefficient (±SE)	95% CI	Odds ratio
Orangutan project versus control	−0.05 ± 0.46	0.39, 2.36	0.96	0.29 ± 0.35	0.67, 2.67	1.34
Forest project only versus control	0.05 ± 0.46	0.43, 2.56	1.05	0.11 ± 0.36	0.55, 2.24	1.11
Age	0.01 ± 0.02	0.98, 1.04	1.01	0.03 ± 0.01*	1.00, 1.05	1.03
Gender (M vs. F)	−0.23 ± 0.37	0.38, 1.66	0.80	−0.37 ± 0.28	0.40, 1.22	0.70
Religion (Islam Y vs. N)	−0.67 ± 0.33*	0.27, 0.98	0.51	−0.66 ± 0.25**	0.32, 0.84	0.52

*$p < .05$; **$p < .01$.

4 | DISCUSSION

Our study suggests that killing of orangutans is still happening and is still in people's memories. Respondents from almost one third of villages reported evidence of killing in their village within the last 10 years. In addition, scenario analyses revealed a high proportion of respondents suggested the character would take an illegal action that would likely lead to the death of an orangutan. Neither forest nor orangutan conservation projects were found to have a significant effect on orangutan killing nor on illegal responses to scenarios. While we were not able to identify clear drivers of killing, we did find the perception that orangutans are declining was associated with illegal responses to scenarios. These findings highlight a range of challenges and insights for conservation practice.
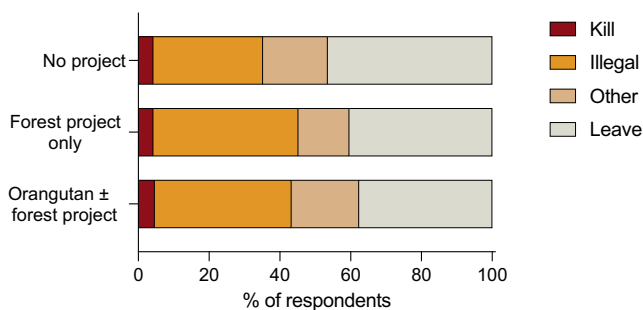

FIGURE 3 Responses show percent of respondents indicating killing, illegal or other responses in at least one of the scenarios.

4.1 | Killing remains a threat

Our findings reveal that killing is being reported and has occurred in recent times. At the village level, more than half of villages (54%) had one or more respondents report at least one orangutan had been killed at any time. Regarding recent incidences of killing, 30% of villages had at least one respondent reports the evidence of killing in that village within the last 10 years. We also note that the majority of reports of killing within the last 10 years were reported in the last 5 years. One response suggested that the actual occurrence was between 5 and 10 years, hence we selected the more cautious interpretation. Situating these findings in the context of Meijaard and colleague's (2011) prior study provides useful insights and highlights various challenges. Their findings suggested between 630 and 1357 orangutans were killed in the year prior to their study (Meijaard et al., 2011, 2012). According to their estimates, this reflects a loss rate of between 1.48% and 3.19% (Meijaard et al. 2011, 2012). This was greatly concerning, as orangutan population viability analysis suggests these rates would likely drive populations to extinction (Marshall et al., 2008; Meijaard et al., 2010; Meijaard et al., 2012). Determining orangutan loss rates as Meijaard et al. (2011) did was beyond the scope of our study; they calculated this using a large sample size, and directly asking people whether they had killed orangutans before. We chose not to ask direct questions about participants' killing behavior, based on advice from local experts around culturally appropriate practice, and literature suggesting that direct questions are

TABLE 2 Results of binomial logistic regression assessing effects of conservation projects and respondent characteristics on responses to scenarios—illegal responses (kill, eat, sell or keep) compared to reference group "leaving orangutan" (Model 1).

	Illegal versus leave			"Other" versus leave		
	Coefficient (±SE)	95% CI	Odds ratio	Coefficient (±SE)	95% CI	Odds ratio
Village level variables						
Orangutan project versus control	0.48 ± 0.34	0.83, 3.16	1.62	0.30 ± 0.41	0.60, 3.03	1.35
Forest project only versus control	0.39 ± 0.35	0.75, 2.94	1.48	0.07 ± 0.44	0.46, 2.54	1.08
Individual level variables						
Awareness of decline	0.91 ± 0.28**	1.43, 4.30	2.48	0.07 ± 0.33	0.56, 2.06	1.07
Orangutans raiding garden	−0.61 ± 0.31	0.29, 1.00	0.55	−0.15 ± 0.38	0.41, 1.82	0.87
Involvement in palm oil	−0.34 ± 0.23	0.45, 1.12	0.71	−1.11 ± 0.32***	0.18, 0.61	0.33
Life satisfaction	−0.15 ± 0.15	0.64, 1.14	0.86	−0.39 ± 0.19*	0.46, 0.99	0.68
Age	0.02 ± 0.01	1.00, 1.04	1.02	0.02 ± 0.01	0.99, 1.05	1.02
Gender (M vs. F)	0.06 ± 0.27	0.62, 1.80	1.06	0.06 ± 0.35	0.54, 2.12	1.07
Religion (Islam Y vs. N)	−0.44 ± 0.24	0.40, 1.04	0.65	0.32 ± 0.32	0.73, 2.56	1.37

Note: Because of the high rates of "other" responses, we also examine drivers of "other" responses (reference group "leaving orangutan").
*$p < .05$; **$p < .01$; ***$p < .001$.

ineffective at detecting the presence of sensitive behaviors (Hinsley et al., 2019). Drawing direct comparisons between the two studies regarding evidence of killing is also challenging, due to barriers associated with detecting the rate of sensitive behaviors over time. Two questions in our study were identical to that used by Meijaard et al. (2011), but the responses do not indicate a clear pattern of change. For example, we found more than half of villages had evidence of killing in any village at any time. In terms of proportion, this is more than double what was found in 2008/2009 by Meijaard et al. (2011), who reported 26% (179/687) of villages had one or more respondent report an orangutan had been killed at some time. This contrasts to the proportion of villages with evidence of an orangutan killed in that village in the year prior to each survey, with our findings (11%, nine villages) being around half of Meijaard and colleague's proportion (23% [$n = 116$]). These contrasting findings highlight the complexity of studying such a rare and sensitive behavior over time. In addition, any trends in temporal patterns could also reflect shifting social norms about killing and sharing information about the behavior. Nonetheless, we posit that our data does not indicate a clear attenuation in killing of orangutans in Kalimantan. As such, we argue that conservation investment should be directed toward abating killing of orangutans as a key and ongoing threat to the Bornean orangutan.

Scenario findings also revealed insights about expectations of others' behavior toward orangutans. Prior studies recommend that orangutans should be left alone to optimize their chances of survival (Sherman, Ancrenaz, & Meijaard, 2020). Nonetheless, 43% of respondents suggested the character would take an illegal action (kill, sell, eat, or keep) in one or more scenarios, and 17% said he would do something other than kill, eat, sell, keep or leave the orangutan. Only 40% of respondents said that the character would leave an orangutan alone in all scenarios. This suggests that norms about expected community responses during encounters with orangutans may involve an action that results in loss of orangutans. It is important to note, while very few responses to scenarios involved actual killing, choosing to keep or move an orangutan is likely to lead to incidental death. Keeping wild orangutans as pets is not conducive to their survival and adult females are almost always killed in the process of capturing an infant (Freund et al., 2017). Translocation has a potentially negative impact on the viability of the broader meta population (Ancrenaz et al., 2021; Fischer & Lindenmayer, 2000) and limited data available suggests translocated individuals struggle to survive or return to capture sites (Sherman, Ancrenaz, & Meijaard, 2020). As such, the "leave" response could be

interpreted as the response most consistent with law and ecological advice (Sherman, Ancrenaz, & Meijaard, 2020). Despite this, authorities and NGOs commonly translocate individuals, with affected residents calling a "hotline" to request their removal (Sherman et al., 2022). While we did not detect an effect of conservation projects on scenario responses, it is possible that translocation programs inadvertently promote acceptability of responses that involve moving orangutans.

Prior literature suggests various explanations for how vignette responses should be interpreted. Some studies suggest that respondents reflect on their own experiences when answering vignettes (Rizvi, 2019), others suggest that vignette responses reflect respondent attitudes (Schoenberg & Ravdal, 2000), and others posit that the further detached a scenario is from a respondent's reality, the more challenging it is to determine the respondent's ability to relate to it (Wilson & While, 1998). Killing is a relatively rare behavior so would not necessarily be close to many respondents' everyday reality, particularly for some people who spend less time in forests. The character being male may have made it more difficult for non-male respondents to put themselves in his shoes. As a result of their hypothetical nature, the degree to which vignette responses reflect reality remains uncertain. It is likely that responses might reflect what respondents believe someone else in their village would do. At the very least, they are likely to provide an indication of social norms (Jasso & Opp, 1997; Rossi & Anderson, 1982).

The four scenarios of orangutan interactions elicited different response trends, hence providing insights into the drivers of illegal and killing behaviors. The crop raiding scenario had the highest "kill" response (3.5%), whereas the forest infant scenario generated the highest rate of non-killing illegal behaviors (keep or sell) (40%). As described in previous studies (Davis et al., 2013; Meijaard et al., 2011; Singleton et al., 2017), these responses suggest that illegal behavior could be driven by financial or livelihood motives, such as protection of oneself or crops, or from selling an infant into the pet trade. "Leave" responses were highest in the bushmeat and forest encounter scenarios, suggesting that these are not perceived as scenarios where someone would harm an orangutan. This is counter to prior studies that suggest that bushmeat consumption is a key driver of killing of orangutans (Davis et al., 2013). The reason for this difference in findings is unclear; potential explanations may include shifts in the social acceptability of killing orangutans or the cultural importance of bushmeat consumption, or improved access to alternative protein sources (Khusun et al., 2022). Importantly, there was a high rate of "other" responses. Unfortunately, we were not able to

ascertain what "other" referred to. One potential "other" action could be calling authorities to move orangutans, which previous studies suggest is a common response (Sherman et al., 2022). More research is required to explore how people act in these scenarios, but our findings provide useful insights and evidence to direct project funding. For example, resources could be invested in providing communities with training to manage orangutans in human areas or providing outreach about the need to immediately report lone infants to authorities.

4.2 | Drivers

With regard to scenarios, we found that people who were aware that orangutan populations are declining were more likely to suggest the character would perform an illegal behavior in scenarios. This association does not prove a causal relationship and could be interpreted various ways. For example, this could suggest that raising awareness around the dire state of orangutan populations might not be a panacea for their protection. Underscoring threats and conservation status of species is a key component of conservation campaigns (Chua et al., 2021). While research suggests that threatened status is an important determinant of public appeal (Barua et al., 2011; Caro & Girling, 2010; Macdonald et al., 2017), it is well established that problem awareness is not sufficient to elicit necessary action (Schultz, 2011; Toomey, 2023). Consistent with this, previous findings show that education is not effective at preventing wildlife crime (Baruch-Mordo et al., 2011; St. John et al., 2018; Travers et al., 2019). Between the years 2000 and 2019, 16% of the total annual orangutan conservation investment across Kalimantan was dedicated to public outreach (Santika et al., 2021). Collectively, these findings suggest that such outreach should extend beyond emphasizing population declines, and actively promote positive behaviors through skills training, removing barriers to suitable actions, and emphasizing the tangible benefits of actions (Cinner, 2018; Reddy et al., 2017). It is also possible that knowing orangutans are declining could demotivate some people; if people think the species' trajectory to extinction is already cemented, they might view efforts to conserve orangutans as futile. Importantly, awareness of decline could come from external sources such as awareness raising campaigns, or it may stem from direct experience where people have observed population declines. Within this context, this association could be interpreted in the reverse direction, where experience or knowledge of killing might lead to the perception that orangutan populations are declining.

Respondents who identified as Muslim were less likely to report killing. Notably, previous studies suggest higher likelihoods of killings by respondents from regions with a higher proportion of Christian residents (Abram et al., 2015). Religion was a covariate and so not a key focus of our analysis. This finding should be interpreted with caution and further study could help to unpack it. It could reflect less frequent killing in and around villages where Islam is the predominant religion. It could also reflect cultural differences where non-Muslims are more comfortable sharing sensitive information. This finding could also signal broader trends in the system, such as relationships between orangutan distribution and socio-demographic factors like religion.

Respondents with higher life satisfaction were more likely to state the character would leave an orangutan over "other" actions in any of the hypothetical scenarios. This finding aligns with prior literature suggesting well-being is important for conservation engagement (Kideghesho et al., 2007; Massingham et al., in press). It should be interpreted with caution, as notably, people with greater life satisfaction were not more likely to suggest the character would leave the orangutan than perform illegal behaviors. Future work could examine the impacts of multi-dimensional constructs of wellbeing on killing of orangutans and other conservation behaviors. A range of other factors could also contribute to killing. For example, the association between scenario responses and the two "evidence of killing" outcomes (Appendix S2) could suggest that social norms or expectations of what others would do reflect greater acceptability of killing in villages where killing occurs.

4.3 | Impact of conservation projects

We did not detect a significant effect of the presence of conservation projects on evidence of killing, or on killing responses to scenarios, suggesting that conservation projects might not be preventing killing of orangutans. Rather than view this as a failure of conservation projects, it is important to recognize that such programs have diverse goals and may not necessarily be designed to target killing behaviors. While we were not able to include more detailed information about project goals in our study, our findings suggest that the broad benefits of conservation programs do not routinely spill over to reduce killing. As such, it is crucial that projects incorporate in their goals the reduction of orangutan killing—one of the key drivers of orangutan population decline. Prior studies suggest that projects in this space tend to overlook killing as a key contributing factor to orangutan population decline and therefore not directly

address it (Meijaard et al., 2011; Sherman, Ancrenaz, & Meijaard, 2020). This raises several questions around what type of interventions are needed to target and reduce killing of orangutans. For example: are the projects applying the wrong type of interventions? Are the projects applying interventions that could potentially reduce killing, but they are unacceptable to communities? Should projects include more components that specifically target killing? These questions should be at the forefront of Bornean orangutan conservation intervention design. The absence of detectable benefits on killing is consistent with what we see on the ground: declining orangutan numbers despite countless orangutan and forest conservation projects in Kalimantan (Santika et al., 2022). Failure to halt population decline could stem from the haphazard approach to orangutan conservation, where hundreds of independent projects operate at largely local scales with little collaboration or strategic integration at regional and national scales and limited impact assessment (Sherman, Ancrenaz, Voigt, et al., 2020). Ensuring conservation projects have their desired impact at a rate fast enough to prevent the extinction of the Bornean orangutan will require a new approach (Meijaard et al., 2022). This is especially important given that anti-killing laws are not routinely enforced (Sherman et al., 2022). New approaches should include working with communities to design interventions that specifically aim to reduce killing, such as monitoring and law enforcement, wildlife friendly management training, protection of habitat to avoid orangutans impinging on populated areas, and behavioral interventions (Abram et al., 2015). Importantly, integrating programs and evaluating their success is a critical component of developing novel approaches.

4.4 | Limitations and future research

Due to the sensitive nature of the behavior we sought to capture, under-reporting and social desirability bias may have underestimated killing. We took evidence-based measures to avoid under-reporting including sensitive and non-biased questioning techniques, respondent anonymity assurances and interviewer neutrality (Hess & Singer, 1995). We also employed the help of a local contractor (Yayasan Tambuhak Sinta) with community survey experience and existing relationships with many communities we surveyed. Nonetheless, killing may be even more prominent than our data suggests. While our findings did not detect a significant effect of conservation projects, we recommend exploring the impact of projects with a larger sample size of villages using more nuanced data about the type of projects and project goals. Our

project searches might not have captured some projects, particularly informal or undocumented interventions. We focused on drivers of a problematic behavior (killing of orangutans). Another approach could seek to identify and learn from positive deviants or bright spots –villages where conservation interventions, environmental conditions, human behaviors or other socioeconomic circumstances support the attainment of positive outcomes (e.g., reduction or absence of killing) (Cinner et al., 2016). Future research could explore bright spots as an opportunity to identify and scale up solutions to abate killing. This paper did not aim to detect the rate of killing. It would be useful for future studies to use larger sample sizes and seek to capture the rate of killing and whether multiple reports of killing reflected multiple orangutans killed. Another caveat to our study is that we did not capture any detail on what people meant by "other" in the scenarios. It would be useful for future work to examine other responses to orangutan encounters in more detail. Our analysis controlled for a range of other factors, such as forest cover at specific times. It would be interesting for future studies to explore dynamic relationships between biophysical and social variables across time, such as how changes in forest cover over time and space influences killing or other practices. Finally, we were only able to assess a small number of factors that could impact killing reports or perceived norms related to orangutan encounters; it is likely that other non-measured factors, such as livelihood or forest dependence, could contribute to killing. Future research could expand on our findings further by assessing a broader range of potential social and contextual influences (Chua et al., 2022). This will help to improve our understanding of the incidence of killing, what is driving the behavior, and how to address these factors to reduce the behavior.

5 | CONCLUSION

Despite immense funding, orangutans are declining at a rate that current conservation interventions seem unable to abate. Effecting behavioral change at the rate required to protect dwindling orangutan populations requires the use of evidence to inform interventions operating with limited funds. Research indicates that killing is one of the main drivers of orangutan decline (Abram et al., 2015; Davis et al., 2013). Our study reinforces the importance of considering killing as a key driver of orangutan decline. Our data indicate that killing has occurred in recent times and does not suggest a clear attenuation of the behavior. As such, we argue that killing may still pose a substantial threat to Bornean orangutan populations, and that conservation interventions should better address

this threat. Our findings suggest that telling people orangutans are declining is insufficient to stop killing. Existing projects do not appear to be effective at abating killing of orangutans. At the very least, our findings, combined with ongoing orangutan population declines, tells us that projects are not working fast enough. New approaches should be tailored to local social-ecological contexts. This could involve working with communities and seeking to understand what influences practices related to crop raiding, keeping primates as pets, and other potential drivers of killing. Practitioners should work with communities to identify the most acceptable management options, barriers to positive actions, and ways to overcome these barriers. Due to its immediate impact on populations and breeding rates, killing cannot be dismissed as a rare and negligible threat. Our findings suggest that if we are to prevent their extinction, we must address the two key drivers of orangutan decline—forest loss and killing—together, with targeted and strategic resources and energy, and within the social-ecological systems that they exist.

AUTHOR CONTRIBUTIONS

Emily Massingham designed the survey, managed the fieldwork, conducted a significant portion of the data analysis, and wrote the initial draft of the manuscript. Angela Dean contributed to the data analysis, co-designed the survey, and was involved in drafting and revising the manuscript. Julie Sherman, Erik Meijaard, Dino Mika, and Hugh Possingham provided input into the survey design and Hugh Possingham provided input into data analysis. Dino Mika conducted the fieldwork with a team, ensuring the collection of high-quality data, and contributed insights into fieldwork-related aspects of the manuscript. Truly Santika was involved in part of the data analysis, contributing to the robustness of the study's findings. Erik Meijaard, Marc Ancrenaz, Dino Mika, Julie Sherman, Truly Santika, Lengga Pradipta, and Hugh P. Possingham assisted with editing and proofreading the manuscript, ensuring clarity and coherence in the final version. All authors participated in discussions, reviewed, and approved the final version of the manuscript. Erik Meijaard and Emily Massingham conceived the research.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Due to the sensitive nature of the research, supporting data are not available online. Please contact the corresponding author (E. Massingham) to discuss data sharing.

ORCID

Emily Massingham https://orcid.org/0000-0002-9498-2994

Erik Meijaard https://orcid.org/0000-0001-8685-3685

Marc Ancrenaz https://orcid.org/0000-0003-2325-2879

Dino Mika https://orcid.org/0000-0001-6749-199X

Julie Sherman https://orcid.org/0000-0002-9618-8217

Truly Santika https://orcid.org/0000-0002-3125-9467

Lengga Pradipta https://orcid.org/0000-0002-0384-8205

Hugh P. Possingham https://orcid.org/0000-0001-7755-996X

Angela J. Dean https://orcid.org/0000-0003-4017-4809

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