11

Estimating Poaching Opportunity and Potential

Most governments today protect wolves, bears, and big cats from unregulated killing (Epstein, 2013). Such protections for large carnivores (LC) can be controversial for people who perceive they are sacrificing safety, recreation, or economic opportunity (Nie, 2003; Treves et al., 2015). Perceptions of these risks appear strongly influenced by both the costs and the benefits of living with LC and other wild animals (Bruskotter & Wilson, 2014). Public discourse and media representations of the balance of benefits with costs may play a large role in diverse audiences' actions and reactions to LC and their management. Opponents of LC protection sometimes aim to reduce LC numbers legally or illegally by poaching (Banse, 2011; St. John et al., 2012; von Essen, Hansen, Kallstrom, Peterson, & Peterson, 2015). Legal opposition to LC protections has been studied extensively; this chapter is focused on lesser known illegal opposition (Gavin, Solomon, & Blank; 2010; Muth, 1998).

Regarding illegal killing of wildlife (i.e., poaching, or the illegal taking of wildlife in violation of a codified law and sometimes a normative rule), we know more about poachers' motivations to poach than we know about the attitudes of poachers and the behaviors they show before, during, and after attempted poaching activities. Motivations for poaching seem to include a complex mix of impulsive and rational factors, including commercial gain, household consumption, recreational satisfactions, trophy poaching, thrill killing, protection of self and property, rebellion, traditional right, disagreement with specific regulations, and gamesmanship (Muth & Bowe, 1998). Kahler & Gore (2012) provided a broader list of motivations which have been empirically tested in Namibia. Although one can debate the utility of these typologies, it is difficult to deny the diversity of motivations. Even for situations involving LC only, people have been documented to kill for profit, as a symbolic protest, to protect livestock or valued game, to gain status, or out of fear or hatred (Kahler, Roloff, & Gore, 2013; Knight, 2003; Pohja-Mykrä & Kurki, 2013; Sharmaa, Wright, Joseph, & Desai, 2014; St. John et al., 2012). Economic costs of coexisting with LC have a long history of discussion and but recent reviews have cast doubt on the potency of this explanation as a motivation to poach LCs (Dickman, Marchini, & Manfredo, 2013; Treves & Bruskotter, 2014). For one thing, economic costs may be used to legitimize other motivations to poach LC, testified to by evidence that wealthier individuals are more involved in promoting or implementing poaching of jaguars (Marchini & Macdonald, 2012). Fear may play a role (Flykt et al. 2013), as has resistance to perceived dominant social groups (Browne-Nuñez, Treves, Macfarland, Voyels, & Turng, 2015; Filteau, 2012; von Essen et al., 2015). Personal profit is also a major cause of LC poaching when wildlife parts or live animals have great financial value on international black markets. Overall, however, the attitudes and behavior underlying LC poaching are not as well understood (Browne-Nuñez et al., 2015; St. John et al., 2012).

Poaching warrants more systematic study given that LC poaching is a major source of mortality that has slowed or reversed several population recoveries (Goodrich et al., 2008; Liberg et al., 2012; Treves et al. in press); poaching may also finance illegal activities and

insurgents or undermine biodiversity protections (Gavin et al., 2010). LC are generally charismatic and as such their population declines attract widespread media and policy attention (Houston, Bruskotter, & Fan, 2010). The United Nations deemed poaching to be part of a broader global environmental crime crisis in 2015 (Nellemann, Henricksen, Raxter, Ash, & Mrema, 2015). Poaching can cast suspicion on the other opponents of LC conservation who are law-abiding. Thus poaching may also exacerbate sociopolitical conflicts dividing those who coexist with carnivores from those who wish to see LC populations recover. Effective remedies for LC poaching are hampered by our current lack of information about who poaches, where, and the why of conservation crimes more generally (Gavin et al., 2010). Only recently has the conservation community begun to incorporate and synthesize insights from criminology and criminal justice in an effort to test and improve the effectiveness of anti-poaching initiatives. Here we add to that effort by advancing understanding of the proximate mechanisms leading to poaching and the attitudes of various implicated interest groups.

Understanding attitudes and behaviors of realized and potential poachers

In order to predict and prevent poaching, scientists can study its antecedents, both contextual and cognitive, and communicate bidirectionally with law-enforcement agents. The reliability of social science research on poaching behavior is complicated by concealment of the activity and the difficulty of documenting true intentions to poach (St. John et al., 2012) and how and where poachers act (Kahler et al., 2013). Therefore we turned to criminology and social psychology theories for testable hypotheses to explain poaching opportunity and poaching potential, which we define below. Criminology and social psychology provides theories to link motivations – both impulsive and rational – causally to actions. We turned particularly to rational choice and routine activity theories (Bouhana, 2013; Clarke & Felson, 1993).

Rational choice theory (RTC) tells us people make rational decisions about whether or not to engage in illegal behavior, such as tiger poaching, based on a benefit – cost calculation. A rational choice hypothesis for poaching would suggest the perceived probability of benefiting multiplied by the magnitude of that benefit would be weighed against the perceived probability of punishment multiplied by the severity of punishment. The attitudes and perceptions of would-be poachers are therefore relevant for estimating how they perform this internal, mental calculus or if they do at all (i.e., acting impulsively). Routine activity theory (RAT) tells us crime depends on "a motivated offender with criminal intentions and the ability to act on these inclinations, a suitable victim or target, and the absence of a capable guardian who can prevent the crime" (Review of the Roots of Youth Violence: Literature Reviews, 2013). The estimates of poacher's intentions and inclinations combined with events and circumstances surrounding suitability and guardians would inform conservation and law-enforcement efforts to combat wildlife poaching. However empirical evidence has cast doubt on at least two major assumptions of these theories that are relevant to LC poaching.

First, efforts to increase arrests or punishments for other sorts of crimes have proven ineffective partly because offenders acted irrationally or impulsively, or for immediate instead of long-term net gain (Exum, 2002; Wright & Brookman 2006; Wright & Rossi,

1983). Perpetrators in those studies reported that they assumed they would not be caught or failed to consider long-term repercussions. When LC poaching results from anger, fear, or impulsive response, irrational poaching may arise from ignoring or discounting the consequences that generate costs. A second challenge to applying RTC to LC poaching may arise when subgroups reward offenders for resisting the broader society. Rewards might manifest as elevated social status after (s)he is caught and punished or inducements such as financial prizes. For example, predator-killing contests have often awarded prizes for the largest coyote killed within wolf range, raising the likelihood of poaching protected wolves 'accidentally' (Ketcham, 2014). Organized crime or secret societies may accrue benefits from LC poaching in a different currency than broader society, thereby rewarding criminal acts and offering protection from punishment. The RCT and its simple calculation of benefits - costs seems incomplete when one considers several costs and benefits in different currencies traded within both the broader legal society and the narrower illegal society. For LC poachers, we might expect those associating in an anti-establishment subgroup to calculate the benefits and costs differently so as to ignore the out-group sanctions in favor of their in-group incentives that favor killing a wild animal. Indeed, poachers are sometimes viewed as folk criminals within their communities that tolerate or even encourage poaching because of romantic ideas, (e.g., Robin Hood's daring pursuits in English folk tales and related action films from Hollywood) (Kahler et al., 2013; Marchini & Macdonald, 2012; Pohja-Mykrä & Kurki, 2013). Similarly poachers may believe that they are behaving just like many others in their community, a phenomenon referred to as 'false consensus.' For example poachers perceiving the false consensus may estimate lower risks and costs of punishment, which has been documented in at least one study of LC poaching (St. John et al., 2012). Also poachers may receive intentional or unintentional signals from law enforcement authorities that certain LC have low value to society or that poaching will not be punished, which in turn may promote the behavior (Chapron & Treve, 2016; Pohja-Mykrä & Kurki, 2013; Treves & Bruskotter, 2014). Although RCT may not adequately account for a sub-culture's differential estimation of costs and benefits as described above, the RAT assumptions that inclination, capability, and opportunity can help to predict deviant behavior still deserve attention by those concerned with poaching. Furthermore, these notions complement social psychology's Theory of Planned Behavior, which provides a useful starting point for examining poaching inclinations and their connections to actions.

Social psychological approaches for understanding the potential to poach

The Theory of Planned Behavior (TPB) helps frame the antecedents of a behavioral outcome such as poaching. TPB predicts individual beliefs about actions, social norms, and perceived behavioral control shape individual intentions to act. In Ajzen's (1991) refinement of the TPB, he noted the difference between perceived behavioral control, which is a belief about one's ability to act and succeed, and 'actual control,' which is affected by external events (hereafter 'opportunities') (Ajzen, 1991, p. 191). The distinction between perceived and actual control is particularly relevant for human-wildlife interactions because human behavior interacts with animal agency as well as chance events. For example, animals move deliberately across a landscape and stochastic events affect where they move and when so the vicissitudes of a poacher's own movements combine in complex ways to increase or reduce the number and duration of opportunities to poach. If we consider chance external events and animal behavior jointly as presenting opportunities, or not, for a poacher, then

intention might equate to a cognitive readiness if given the opportunity. Intention in this sense resembles 'inclination,' a critical element of RAT (Ajzen, 1991). Likewise, 'capability' in RAT would correspond to perceived behavioral control in TPB. Putting the concepts together in a temporal sequence of cause-and-effect, we might frame the events leading to poaching as follows: a potential poacher starts with a set of attitudes that may produce an intention to act, and if (s)he has the capability when the opportunity arises, then (s)he may manifest poaching behavior (Figure 11.1A). We apply this general framework to a specific case involving wolf-human interactions in the remainder of the chapter using a composite measure of attitudes and intention that we refer to as inclination (Figure 11.1B).

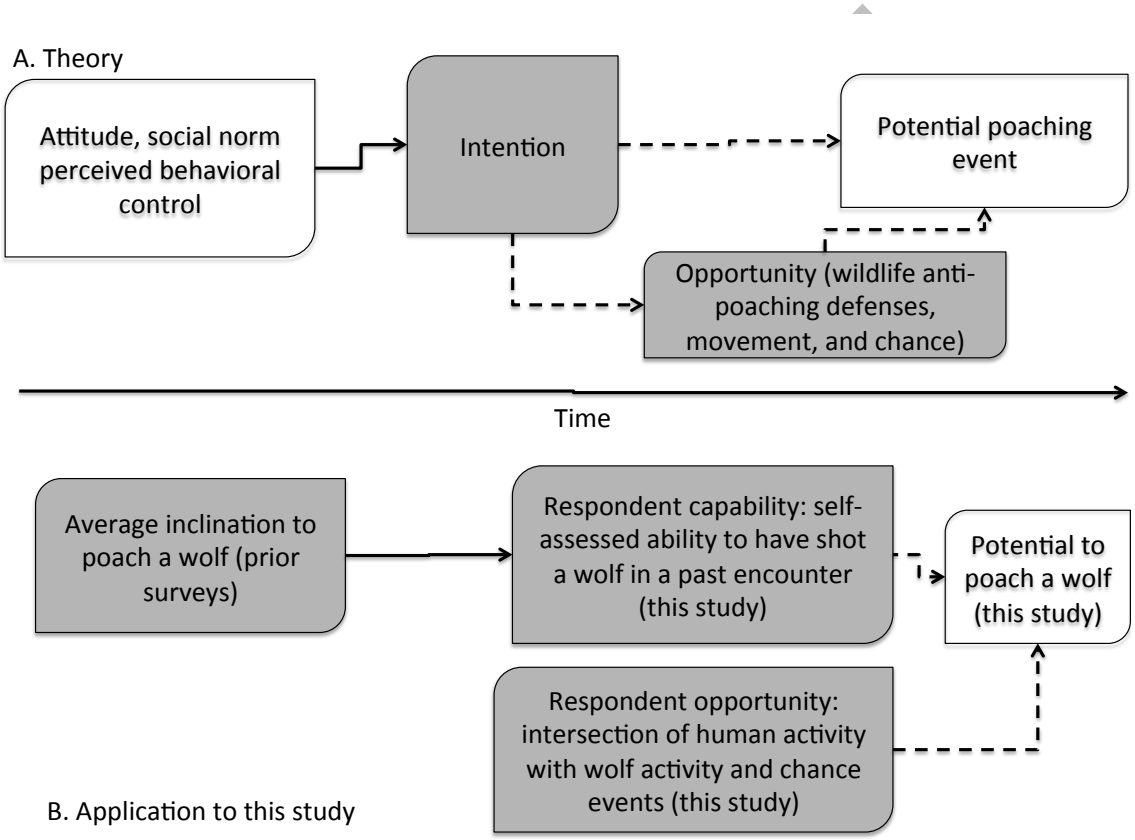

Figure 11.1. (A) Theory for causal connections among a time axis connecting cognitive antecedents preceding the intention to act. And hypothetical (dashed lines) connecting intention to external opportunities and to potential poaching events. External opportunity (the movements and sensory abilities of an animal that bring it into a position or state of vulnerability to poaching) and potential poaching event are probabilistic but influenced by intention in theory. B: We depict a practical application to wolf-poaching. We replace intention with inclination, which is a construct that combines attitude with intention and draw two samples of respondents to examine external opportunity (see Methods). We combine estimates of each to model the potential to poach a wolf among two samples and several classes of respondents. Note the dotted lines indicate hypothetical interaction between intention and opportunity because strong intentions may lead to preparatory

behavior that increases opportunity (lower dashed arrow) but intention may be opportunistic in the sense of awaiting chance events (upper dashed arrow).

Case Study on Wolf poaching

Theoretical approach and sampling

We integrated TPB and RAT to understand poaching of a controversial LC – gray wolves. Previously we investigated attitudes toward wolf policy and individual inclinations to poach wolves in Wisconsin, U.S. (Browne-Nuñez et al., 2015; Hogberg, Treves, Shaw, & Naughton-Treves, 2015; Treves & Martin, 2011; Treves, Naughton-Treves, & Shelley, 2013). We found our estimates of inclination to poach were better predicted by competitiveness by hunters over white-tailed deer than an individual's direct experience with wolf damages or fear for personal safety. We also found that individuals' inclinations to poach increased over time among residents resampled over several years. Many possible causes of this longitudinal change were confounding so we could not elucidate the direct causes of attitude change. However we could rule out that government policies liberalizing wolf-killing did not reverse declining tolerance for wolves. Also a recent study identified themes providing a more nuanced understanding of changing attitudes toward wolves and inclinations to poach them, including fear for personal or family safety, powerlessness to prevent threats, and a lack of trust in the wolf management agency (Browne-Nuñez et al., 2015). Here, we use our attitudinal measures of inclination to poach a wolf as a starting point. However in our region and many others, the motivations and intentions of poachers (i.e., the why) are better understood than the events and behaviors that precede poaching (i.e., the how). Therefore, we integrated information on poaching potential (i.e., probabilities that poaching would manifest) among deer-hunters and among people who had experienced verified, wolf-related threats to personal safety, pets, farm animals (e.g., livestock and farm dogs), or hunting dogs.

A challenge in studying poaching potential is to identify sufficient numbers of incidents in which the opportunity to poach was verified. Without verification, people may claim they saw a wolf but it may have been a coyote or free-running dog. A smaller relative, coyotes can easily be confused for wolves under many field conditions. We interviewed individuals who had experienced verified encounters with wolves. The encounters were verified by a federal agency that examines evidence such as tracks, scat, or other sightings in the vicinity (Treves et al., 2002). Because all of our respondents had actually encountered wolves as verified by the agency, we were able to examine their inclinations and capabilities to poach in a more controlled fashion than the typical self-report of a wolf encounter. Lack of verification plagues many studies of wildlife and poaching. Therefore our work helps to shed light onto how to design, implement, and even evaluate interventions in the face of such data deficiencies. Importantly, our sample was unrepresentative of human-wolf encounters because threats or damages leading to a complaint have been a small minority of all reported encounters with wolves (Treves, Martin, Wydeven, & Weidenhoeft, 2011; Treves et al., 2013). Also our sample was to some extent self-selected in that respondents had reached out to and complained to authorities about the wolves and as far as we know, none of our respondents actually poached a wolf. Therefore study respondents may differ from those who actually poach wolves. Self-selection is not necessarily considered a source of bias under

RAT, because the theory holds anyone has the potential to poach. Regardless, our sample provides the first estimate for the U.S. of the maximum numbers of wolves that might die if people killed a wolf during each type of verified encounter (Backeryd, 2007).

For comparison, we also interviewed randomly sampled respondents who hunted white-tailed deer in wolf range. Deer are a very popular game species is hunted by ~500,000 hunters per year in Wisconsin and the pursuit of deer takes some of the hunters into wolf range with an elevated capability, or readiness, to poach a wolf. In this sample, some respondents reported they had encountered wolves whereas others did not. We were unable to verify either report and recognize such reports may be inaccurate cite Dex here. Nevertheless, the deer-hunter sample allowed us to estimate the frequency of perceived opportunities to kill a coyote or a wolf based on a random sample of people who had been engaged in an activity that involves many hunters each year. From this sample we estimated opportunity and capability to poach independent of the likelihood of encounters.

In sum, we had a small sample with verified encounters, where opportunity was equal to 100%, per our definition in Figure 11.1 to estimate self-perceived capability in a rare situation. We also had a large sample with unverified encounters to estimate self-perceived capability and opportunity in a common situation. Although we had no true control, the two samples help us estimate the consequences if policy-makers legalized wolf-killing in different situations (Backeryd, 2007). Comparisons between identity groups such as our subsamples and comparisons between high-risk and lower-risk situations should focus research and prevention efforts more precisely (Clarke & de By, 2013; Haines et al., 2012; Marquez, Vargas, Villafuerte, & Fa, 2013; Treves et al., 2011).

Methods

Due to space considerations additional information about methods are presented in a permanent online archive at Treves (2015). The interested reader can review the archive for additional citations, data, and methodological descriptions.

Study site

Wisconsin extends over 138,644 km^2 with human population density of 41.1 per km^- and 18.7 housing units per km^2. Many private lands and 75% of public lands were open to hunting for at least one season annually during the first decade of the 2000s. These seasons included the autumn white-tailed deer hunt involving approximately 500,000 hunters on public and private lands. Wolf range in Wisconsin contains no vast wilderness and few strictly protected areas. Wolves use areas of the state with relatively less agriculture and human use than expected by chance. Human residents are engaged predominantly in agriculture, timber, rural recreation, and other natural resource uses. In the summer of 2011, Wisconsin's gray wolves were federally protected as an endangered species. At that time, wolves had never been a legal game species and bounties had been discontinued since 1957. Coyotes could be shot on sight in much of the state most of the year.

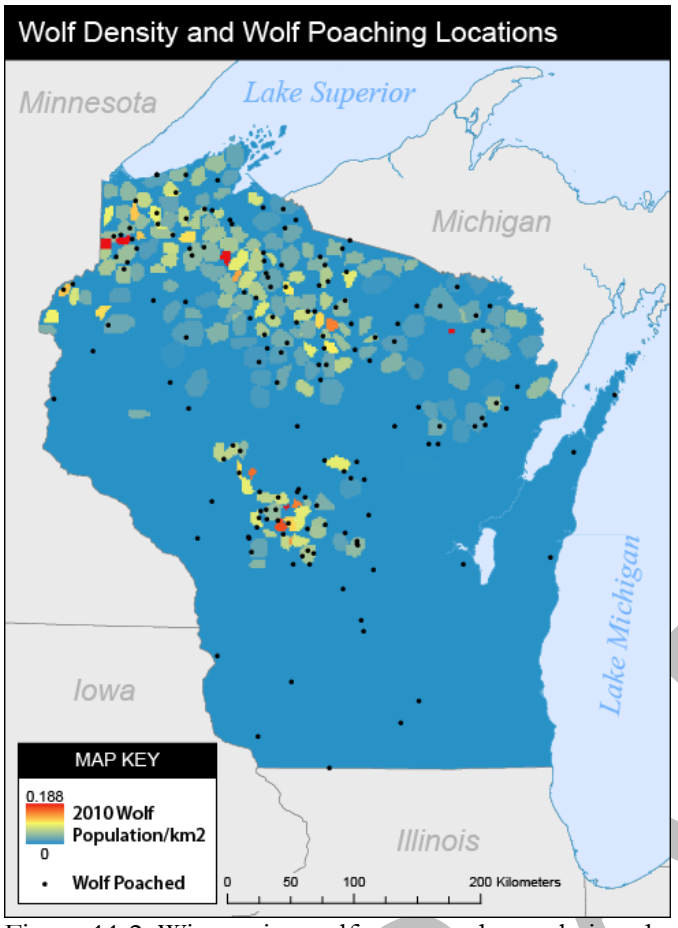

Figure 11.2. Wisconsin, wolf range and population density in 2010, and poaching locations 1979–2011.

Study respondents

We replicated as closely as possible the methods used in Backeryd (2007), achieved human subjects protection program approval and obtained informed consent of individuals at least 18 years of age. Complaints of property loss to wolves were verified; approximately 50% of claims were unverifiable (Ruid et al., 2009). The final respondent sample was drawn from the remainder deemed probable or confirmed and previously estimated the latter error rate in livestock incidents as <9% false positives (Treves et al., 2011). We conducted telephone interviews to record respondents' memories of the circumstances surrounding their experiences with wolves and the respondents' self-reported appraisals of their capability to shoot the wolf or wolves. We sent an advance-notice letter to the complainants so as to avoid surprise, improve the legitimacy of the survey (Salant & Dillman, 1994), and maximize response rates. Deer hunters were reached at random without advance warning by dialing telephone numbers in the same municipalities as the former complainant sample. Questionnaire items analyzed are reproduced verbatim below.

Survey items

We did not ask respondents if they were inclined to poach a wolf because we were concerned that the telephone interview would not be perceived as confidential enough to assure high rates of truthfulness. We were ultimately interested in respondents' perceived capability to act given the opportunity. After recording respondents' descriptions of the conditions during the encounter with wolves, we asked "Did you see the wolf/wolves immediately before, during, or immediately after the incident?" Of the subset with eyewitness encounters we then determined if they had been armed with a loaded weapon. Then we asked, "Playing the scene back in your memory, do you think you might have been able to shoot the wolf or wolves that you saw immediately before, during, or immediately after this incident?" We assumed respondents, not researchers were the best situated to estimate their own capability to kill the wolf they encountered, taking into account their recollections of their internal condition at the time and external conditions (e.g., light, visual obstructions, distance) at the time of the encounter.

Inclination to poach

Following methods detailed in the online archive (Treves, 2015), we set the bounds of our respondents' inclinations to poach wolves at 17–29% among deer hunters and 23–43% among bear hunters. We estimated inclination to poach wolves when their domestic animals were threatened among general pet owners and livestock owners as 30-44% and 29-39% respectively. We did not have a questionnaire item relating to threats to health and human safety.

Modeling potential to poach

We multiplied the three frequency estimates as in Eq. 1 to model the potential to poach a wolf, treating *inclination* and *capability* as independent variables because the former was estimated from our mail-back surveys from 2001–2009, whereas *capability* was estimated from our telephone interview samples of individuals in 2011, both described above. We also treated *opportunity* as independent because it reflected the frequency with which encounters with wolves occurred; they were not necessarily visual and thus as set at 100% for verified complainants but self-reported by the deer hunter sample reporting on visual encounters and taking into account time spent in the field (see Eq. 2). Our assumption of independence (multiplying the probabilities) is reasonable given our sources of data but may not hold under other conditions. First, a would-be poacher with strong intentions may seek additional opportunities (e.g., deliberate search for wolves to poach) or those who encounter many opportunities may change their attitudes (e.g., finding wolves more or less valuable as a result of experiences). We discuss the implications of this theoretical non-independence between intention and opportunity below.

To operationalize Eq. 1 for our random deer hunters, we used Eq. 2, where the first parenthetical product represented capability, and the second parenthetical product represented opportunity. Capability was modeled as the product of A and C. Opportunity for deer hunters was modeled as the product of V and F. We estimated (see also Treves [2015]):

- A using the questions: (1) did you have access to a weapon when you saw the wolf/wolves, (2) if yes, were you carrying it at the time you saw the wolf/wolves, and (3) if yes, was it loaded?
- C using the question: playing the scene back in your memory, do you think you might have been able to shoot the wolf or wolves that you saw immediately before, during, or immediately after this incident?
- V using the question: have you ever seen wolves while deer hunting or preparing your hunting site?
- F using the questions: (1) if yes to V, on how many different days have you seen wolves while you were deer hunting and/or preparing your site, (2) when was this sighting/the most recent sighting, and (3) how many years have you been hunting deer?

The online archive (Treves, 2015) provides the full details for the modeling steps we took to estimate potential to poach following a series of additional equations (i.e., Eq. 1-5).

Results

Potential to poach

We modeled the potential of different stakeholders to poach. Following Eq. 2, deer hunters' potential to poach ranged from 5.4- 9.2%. Other conditions surrounding the self-reported encounters are reported in Treves (2015. Following Eq.3, 1-1.5% of pet owners with verified wolf complaints had the potential to poach. When asked if they were concerned for their personal safety, 6% responded in the affirmative. Figure 11.3 depicts potential-to-poach by random deer hunters and by pet owners with a verified compliant, with different parameters for the two very different groups. Although a pet owner with a verified encounter had more than twice the opportunity (1.0 vs. 0.45) and a higher inclination to poach a wolf (median 0.37 vs. 0.23) than a random deer hunter by our estimates, the self-reported readiness and capability of the random deer hunters (0.71) so far exceeded the pet owner's self-reported capability (0.035) that the random deer hunters posed a higher potential-to-poach by our model (Fig 11.3). Many of the respondents with verified encounters self-assessed their capability of shooting a wolf as zero because they did not see the wolves or there were other impediments to action. This substantiated our assertion that opportunity could be separated from capability (Figure 11.1). Following Eq. 4, we predicted 0.01- 0.2% of livestock owners with verified wolf complaints had the potential to poach; following Eq. 5, we predicted 0.4–0.7% of bear hunters who used hounds and had verified wolf complaints had the potential to poach. We did not model potential to poach for those registered as complaining about health or human safety because we did not have an estimate of inclination for such respondents (see Treves [2015]). Other conditions surrounding the verified attacks are presented in Treves (2015).

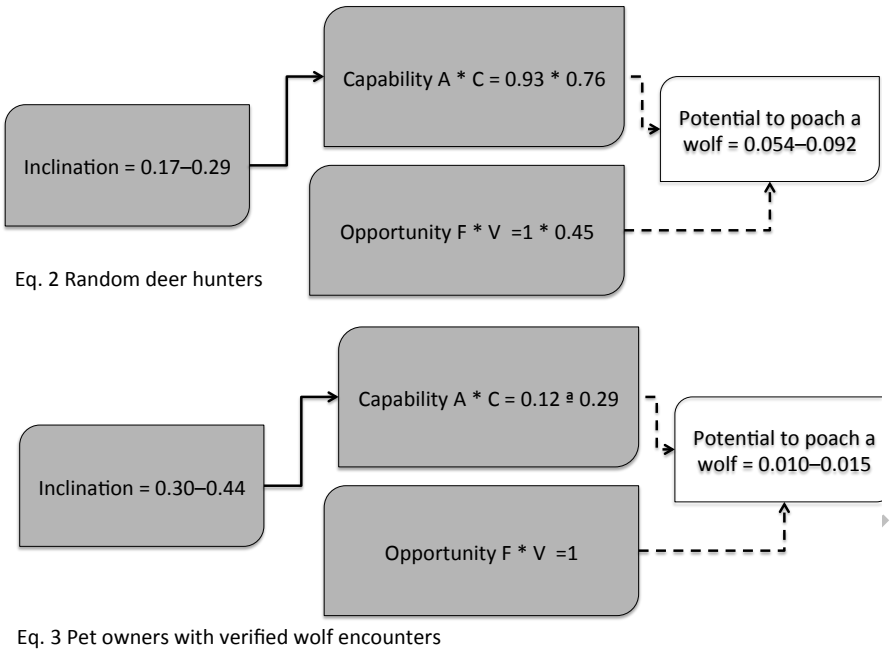

Figure 11.3: Quantifying the potential to poach for two groups of respondents. Random deer hunters were asked to self-report encounters with wolves generating the estimate of opportunity whereas pet owners we interviewed had had verified encounters. In both groups capability was estimated from self-reports of readiness to kill the wolf they encountered. For both groups, inclination was estimated independently from mail-back surveys of much larger samples done in prior studies reported in online archive (Treves, 2015).

Effects on wolf population

Between 15 March 2007 until 3 October 2011 (the time window we asked complainants to recollect), the State of Wisconsin verified 233 complaints about wolf attacks or threats to farm animals, 72 threats or attacks on hounds, 32 threats or attacks on pets, and 17 health and human safety concerns (WDNR database). If these incidents conformed to our respondents' self-reports, we expect that legalizing the killing of wolves under those complaint situations would result in approximately 1.5 wolves killed every 5 years. That estimate might double if one considered companions of respondents and their capability to poach more than one wolf per incident. These very low rates of mortality resemble those estimated in Sweden under similar hypothetical changes in rules (Backeryd, 2007).

Implications for theory and practice

The proximate mechanisms leading to LC poaching remain under-studied. Therefore we know little about encounter rates, the inclination of humans to react lethally to such encounters, and the probabilities that lethal reactions will indeed succeed. As a result, law enforcement actions that enhance guardianship (e.g., direct interventions aimed at

preventing harm to wildlife) and actions that identify would-be poachers (e.g., indirect interventions aimed at markets, communications, and routes used by poachers) are entirely reactive. This chapter profiles our work aiming to build understanding for a controversial, endangered LC that is poached without a financial profit motive in a human-dominated ecosystem. By combining estimates of ordinary people's inclinations to poach a wolf with their self-reported capability to do so, and estimated probabilities of encounters with wolves, we were able to estimate relative frequency of wolf-poaching by different categories of people, and estimate a rate of wolf-killing in situations that are common in human-wolf coexistence in Wisconsin, USA. We synthesized social psychology's Theory of Planned Behavior and criminology's RAT to construct our model of potential for wolf-poaching. Our model highlights individual human readiness and self-reported capability to shoot a wolf as more important than inclinations to poach, which we defined as a construct of motivations, attitudes and intentions to poach.

This work may help advance efforts to unify and reconcile different terminologies in the two sets of theories. From a theoretical standpoint, we argued for separation of opportunity to poach into independent components of readiness and capability to poach on the one hand, and the unpredictable movements of a wild animal that avoids people, on the other hand. That argument builds on RAT predicting that potential victims or guardians should act to reduce vulnerability to crime, largely independent of the actions and intentions of the criminal.

Readers are reminded that animal behavior theory is highly advanced in modeling predator-prey encounters, which resemble human-wildlife poaching interactions. Thus, we borrowed from psychological theory to model inclination and capability of a would-be poacher, or intentions and perceived behavioral control respectively, to use Ajzen's (1991) terms. We believe the union of these bodies of theory will improve understanding of poaching. Beyond theory, we provide information we believe will be useful to law enforcement in our region and perhaps beyond; we discuss these implications below.

Deer hunters

Estimating the potential rate of poaching in various situations is important to conservation, law-enforcement, and organizations interested in preventing illegal activities. Our model of the potential rate of poaching among different groups of people suggests that deer hunters had a more than 5 times higher relative potential to poach than other categories of respondents in the study. Deer hunters had relatively lower opportunity than other complainants because 100% of the latter had verified encounters (Figure 11.3). By contrast 45% of deer hunters self-reported encounters with a median of one or more species they perceived to be wolves every 2 years, during deer-hunting or hunting-site preparation. Furthermore, deer hunters had lower inclination to poach wolves as measured in prior surveys of different individuals (Treves et al., 2013). Nevertheless deer hunters had the highest relative potential to poach wolves because of their self-reported capability to shoot a wolf successfully. Those deer-hunters reporting an encounter with animal(s) they perceived to be wolves were usually carrying a loaded weapon in a frame of mind and place conducive to shooting. Yet this potential to poach apparently did not manifest.

Consistent with our model predictions, the plurality of reported poaching, 30%, between 1979–2012 occurred in November, when most permitted deer hunting occurs in Wisconsin (Treves, Langenberg, López-Bao, & Rabenhorst, in press). But does the absolute number of poaching events match our deer hunter respondents' self-reports? In November each year, approximately 500,000 hunters stalk deer in Wisconsin statewide. Even if only 10% of these hunters hunt in the range of the 880 wolves that roamed the state in 2012, and only 5.4% of hunters poached 1 wolf (our study minimum estimate potential-to-poach), every wolf in the state would be poached three times over. Because deer hunters have not done so thus far, one or more of the estimates used in our model must be inflated. Inclination measured might be lower in reality than claimed in our questionnaire surveys, capability to shoot a wolf might be lower than deer hunters claimed in our interviews, or deer hunters who also own livestock or pets they perceive at risk from wolves may be a large proportion of the deer hunter community. Another possibility is that large coyotes are being misperceived as wolves at high rates. Whatever the reason, deer hunters have the potential to poach many more wolves than they have done thus far. Therefore our estimate of potential-to-poach should not be confused with realized poaching rate nor confused with attempted poaching. Because we do not know how many deer hunters move within wolf pack areas and how accurately they identify wolves or shoot them, we cannot translate our potential-to-poach estimate into a percent of wolves likely to be poached.

One should not read our results so as to blame poached wolves on the average deer hunter. For one, more poaching goes unreported than is reported (Treves et al. in press). Also, bear hunters who used hounds had higher inclinations than others in the hunting community. Social media from 2011–2015 have been full of evidence and claims of wolf poaching by bear hunters. Further, the role of deliberate search by a handful of repeat offenders cannot be ruled out. The conservation and law enforcement communities might be able to identify would-be poachers using informants within groups suspected of harboring poachers. Anti-wolf organizations interested in preventing illegal activities might self-police. This study also draws attention to relative differences between categories of people in inclination to poach.

Complainant sample

Our second sample of complainants (i.e., people with verified complaints of threats to domestic animals) illuminates further the potential to poach. Because the sample of livestock owners, pet owners, and bear hunters who use hounds had verified encounters with wolves, we were able to set opportunity at 100% and focus our analyses on inclination and capability to poach. This complainant sample self-reported lower capabilities to shoot a wolf, partly because loaded weapons were not accessible or the wolves had not been visible during the verified encounter. Therefore, our finding that deer hunters had a higher potential to poach is consistent with predictions of RAT because our respondents had been engaged in activities that either predisposed them to poaching a wolf (e.g., deer hunter sample) or hindered them from poaching a wolf (e.g., complainant sample). Despite complainants having a higher inclination and a verified encounter, they had far lower self-reported capability to poach, resulting in a lower potential to poach.

Among our sample respondents, we estimated pet owners had a higher potential to poach than bear hunters who used hounds. Livestock owners had half the relative potential to

poach wolves as did bear hunters. Much of the difference between pet owners, livestock owners, and bear hunters lay in their self-reported capability to poach a wolf. Although bear hunters who used hounds were engaged in a hunting-preparation they reported low capability to poach a wolf because their activity with hounds did not seem compatible with carrying a rifle. By contrast, pet owners rated their capability to shoot a wolf higher than the other two groups. This seemed to reflect a lengthy visual encounter with wolves, perhaps prolonged by the presence of their pet dog, and locations near weapons in some cases. Livestock owners reported the lowest capability, as few had weapons at hand and few saw the wolves. Given the low capability to shoot a wolf among the complainants, we predicted that few wolves would be killed each year if the government legalized a lethal reaction to imminent threats. This finding is consistent with work from Sweden (Backeryd, 2007). However, if the government liberally defined 'imminent threat' or did not enforce its definition, we anticipate future complainants might shoot at wolves that pose no threat, shoot at non-wolves, or otherwise create public safety hazards. Liberalized wildlife harvest has been inferred to increase poaching in some instances (Chapron & Treves, 2016). Therefore we recommend no change in the current prohibitions on shooting at wildlife of any species.

Theoretical considerations on the causes of poaching

Theory leads us to expect that poaching requires ability, intent, and opportunity. Intent and opportunity are probably not independent and may interact in important ways. Someone with strong intent can try to make encounters more frequent or more opportune. This would include deliberate search for poaching opportunities. Such deliberate search might arise if the poached animal has high value for its parts or negative value so its destruction brings value to the poacher. Under such circumstances, we predict the rate of poaching would be determined by would-be poachers' search efficiencies and animals' anti-predator efficiencies interacting with the relative abundances of both poachers and animals.

But not all poaching is deliberate search with high motivation. Some poaching may be retaliatory so it is triggered by the actions of the animal. Then deliberate search might ensue where it otherwise would never have arisen. Alternately, the intent to poach might intensify yet rely on chance encounter not retaliatory search. An important difference between retaliation and untriggered poaching is the rate of triggers. We predict the rate of retaliatory poaching would be best predicted the frequency and distribution of triggering events interacting with animals' anti-predator efficiencies rather than the abundances of either poacher or animal directly. Also we might expect the motivation to retaliate might taper off with time or with an initial success in retaliating.

At the other extreme, people with low motivation might be inclined to poach only if the opportunity arises yet make no particular effort to seek out the animal nor require a triggering event other than encounter. Under such conditions, we predict the rate of poaching would depend on the probability of a would-be poacher and animal intersecting in space and time, which would be dictated by their movements and abundances. The three preceding models of poaching make different predictions for the mechanisms and the best predictors of poaching.

In the present paper, we simply assumed no interaction existed between inclination and opportunity. Our efforts to model potential-to-poach were structured so as to treat opportunity as independent from inclination and capability (so we could multiply probabilities rather than treating them as conditional probabilities). In most other studies, the estimates of opportunity, inclination, and capability may all come from the same individuals. In that case, one cannot operationalize the potential to poach by multiplying probabilities because the three probabilities would be statistically dependent. Instead one has to address whether encounters and reactions result from a random encounter pattern or from a focused, deliberate search pattern by putative poachers. If a substantial number of poachers engage in deliberate search, then potential-to-poach estimates should be based more on inclination than capability or opportunity because would-be poachers would search for opportunities with the capability to act. In sum, the scientific models marshaled to address poaching will differ depending on the motivations of would-be poachers, their search behavior, and the triggering events.

Future researchers should interview confirmed poachers, and test the above causal mechanisms with data on search, opportunistic encounter, and triggering events. Also, we recommend that the designers of anti-poaching interventions consider if poaching occurs by chance encounters, deliberate search, or retaliatory killing. Policy and management interventions that aim to prevent poaching tend to cluster into three types. Those that address the cognition of would-be poachers (e.g., improving attitudes to promote compliance with rules), those that address their behavior (e.g., interdiction and prosecution as a form of deterrence to promote compliance), and those that address the technology involved in poaching or anti-poaching efforts (e.g., firearm controls). Cognitive and behavioral interventions can be combined strategically to address different motivations and inclinations, just as behavioral and technological interventions can be combined to counter different search methods and capabilities of poachers.

The field of conservation has made significant advances in the design of interventions for human-wildlife conflicts (Treves, Wallace, & White, 2009). Some of the lessons learned will be useful to those designing anti-poaching interventions or to conservation criminology generally. For example, conservationists teach that effectiveness should be considered separately and first before cost-efficiency, and the selection of candidate interventions needs to consider unintended consequences such as perverse incentives. For example, cognitive fixes are often touted by policy-makers, but recent empirical evidence about cognitive fixes is consistent, in that inclinations to poach did not change despite policy interventions (lethal control, hunting) that were believed to shape attitudes (Hogberg et al., 2015; Treves et al., 2013). Moreover the cognitive processes that motivate poaching of controversial species may have little to do with economics and more to do with social norms or symbolism and fear attached to the species (Treves & Bruskotter, 2014). Indeed, tight-knit organizations that foster and conceal specialist poachers might have a widespread effect on sensitive wildlife populations (Lute & Gore, 2014). Scholars have long noted the difficulty of changing attitudes, persuading people to behave differently, and the importance of changing social norms as well as individual ways of thinking (Dunwoody, 2007; Heberlein, 2012; Kinzig et al., 2013; Treves & Bruskotter, 2014). Heberlein hypothesized that structural or technological interventions may be more cost-effective in the long run (Heberlein, 1974, 2012).Others recommend combining structural and cognitive fixes to prevent poaching (St.

John et al., 2012). The legalization of wildlife-killing is a commonly promoted combination of a cognitive and structural fix intended to prevent poaching and enhance conservation.

Conferring ownership of wildlife on those who coexist with them, including the right to kill wildlife for profit or other purposes, has commonly been advocated as a way to reduce poaching (reviewed in, Di Minin, Bradshaw, & Leader-Williams, 2016) . For example, in southern Africa, community-based natural resource management has been a popular method for providing locals with rights to use wildlife populations either non-consumptively (via photographic tourism) or consumptively (via culling, harvest, or trophy hunting). In Namibia and Zambia, for example, such schemes provided benefits to communities by creating income to locals via trophy hunting permits sold. The local community owners of wildlife may then be motivated to protect wildlife on their land because they can obtain income from them (reviewed in, Di Minin et al., 2016). Peer-reviewed empirical evidence remains sparse if one scrutinizes the latter study. For example, game surveys suggest this helped Namibian large ungulates, e.g., a pre-conservancy report for one area in Namibia (Rodwell, Tagg, & Grobler, 1995). Carnivore-poaching in particular may not abate if profits are focused on ungulates or if properties are small and easily traversed by individual carnivores (Balme, Slotow, & Hunter, 2009; Balme, Slotow, & Hunter, 2010). Moreover the fundamental idea that liberalizing carnivore-killing will enhance conservation has not found support. In Wisconsin and neighboring Michigan, government policies to legalize wolf-culling as a way to reduce poaching had the opposite result (Chapron & Treves, 2016). We hypothesized that government policy to legalize the killing of problem wolves sent a signal to poachers that wolves were imposing higher costs, or that anti-poaching rules would not be enforced. Therefore we encourage caution with proposed cognitive fixes especially when no data on psychology or criminology are offered in support of an intervention. Given scientific consensus that both compulsory and voluntary regulatory mechanisms are needed to prevent or limit illegal resource use (Kinzig et al., 2013; May, 2005), we recommend renewed study and investment in both. We made recommendations for research above. As for interventions, we recommend the hunting community self-police with third-party verification. as a first step to preventing poaching. We recommend policy-makers set legal lower quotas for wildlife killing; lower by the amount of all other sources of mortality, especially poaching measured transparently and scientifically. Then we recommend deploying effective anti-poaching interventions that incorporate the modern tools of criminology and policing.

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METHODS

Study site

Wisconsin extends over 138,644 km^2 with human population density of 41.1 km^{-2} and 18.7 housing units km^{-2} (http://quickfacts.census.gov/qfd/states/55000.html, accessed 31 January 2016). Many private lands and 75% of public lands were open to hunting for at least one season annually. These seasons included the autumn, white-tailed deer hunt involving approximately 500,000 hunters on public and private lands. Wolf range in Wisconsin contained no vast wilderness and few strictly protected areas (Mladenoff, Clayton, Pratt, Sickley, & Wydeven, 2009; Thiel, Hall, Heilhecker, & Wydeven, 2009; Treves, Martin, Wiedenhoeft, & Wydeven, 2009; Wydeven et al., 2009). Wolves used areas of the state with relatively less agriculture and human use than expected by chance (Mladenoff et al., 2009; Treves et al., 2009). Human residents were engaged predominantly in agriculture, timber, rural recreation, and other natural resource uses. In the summer of 2011, Wisconsin's gray wolves were federally protected as an endangered species. Wolves had never been a legal game species and bounties had been discontinued since 1957. The smaller canid, coyotes *Canis lupus*, could be shot on sight in much of the state most of the year.

Respondents

Complaints of property loss to wolves had to be verified by government agents inspecting the scenes of all encounters. Verifiers dismissed approximately 50% of such claims as non-wolf or unverifiable (Ruid et al., 2009; Treves et al., 2002). We drew our

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respondent sample from the remainder deemed 'probable' or 'confirmed' wolf complaints only. We previously estimated the latter error rate in livestock incidents as <9% false positives (Treves, Martin, Wydeven, & Wiedenhoeft, 2011). We obtained telephone numbers of all complainants from 2007 to the spring of 2011 from the Wisconsin Department of Natural Resources. We conducted telephone interviews to record our respondents' memories of the circumstances surrounding their experiences with wolves and the respondents' self-reported appraisals of their capability to shoot the wolf or wolves. We replicated as closely as possible the methods used in Backeryd (2007). Typically, the more recent and salient an event is, the easier it is to recall (Pearson & Caroline, 1981). Although recall of events beyond even a few months may be limited, we believe the high degree of salience of events involving wild wolves would limit biases and error (Dex, 1995). We sent an advance-notice letter to the complainants so as to avoid surprise, improve the legitimacy of the survey (Salant & Dillman, 1994), and potentially increase the response rate.

Deer hunters were reached at random without advance warning by dialing telephone numbers in the same municipalities as the former complainant sample. We asked whichever adult answered the phone if they hunted deer but were not bear hunters or livestock producers, so as to differentiate the random sample from the complainant samples described above. We sought oral consent by script and used structured interview questionnaires (both available upon request) and guaranteed confidentiality orally. We did not record names of deer-hunters. We interviewed only

those respondents ≥18 years old. One recipient refused. The questionnaire items analyzed here are reproduced verbatim below.

Survey items

We did not ask telephone respondents if they were inclined to poach a wolf because we were concerned that the telephone interview would not be perceived as confidential enough to assure high rates of truthfulness. We were less interested in the respondent's intentions than in their perceived capability to act given the opportunity. After recording respondents' descriptions of the conditions during the encounter with wolves, we asked "Did you see the wolf/wolves immediately before, during, or immediately after the incident?" Of the subset with eye-witness encounters who answered 'yes' to the latter question, we then determined if they had been armed with a loaded weapon. Then we asked, "Playing the scene back in your memory, do you think you might have been able to shoot the wolf or wolves that you saw immediately before, during, or immediately after this incident?" We assumed our respondents were the best situated to estimate their own capability to kill the wolf they encountered, taking into account their recollections of their internal condition at the time and external conditions (light, visual obstructions, distance, etc.) at the time of the encounter. Although people over-estimate or under-estimate their capability, no one else could make a better judgment. Our alternative would be to use the conditions at the scene (light, visibility, readiness, etc.) but that would substitute our judgment for theirs, which we could not justify.

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Inclination to poach

We used the results of three prior mail-back questionnaire surveys (described below) in which respondents living in Wisconsin's wolf range were assured of confidentiality and presented with statements about poaching wolves. Because the surveys and return envelopes were not identifiable and respondents could answer in privacy, we felt the truthfulness would be enhanced. We demonstrated previously in a general sample of respondents that there was internal consistency in the responses to that statement and that individuals who were later resampled remained consistent in their responses over time (Treves & Martin 2011; Treves et al. 2013). For each of three questionnaire items that follow, we offered five response options (strongly agree, agree, neutral, disagree, strongly disagree) and pooled strongly agree and agree for simplicity.

In 2009, 15% of deer hunters living in wolf range agreed with the statement, "If I were out hunting and saw a wolf I might shoot it" (25% of bear hunters agreed). Also we demonstrated that responses to this statement had shifted toward agreement an average of 1% per year from 2001–2009. Assuming the rate of change continued by the time of the present study (2011), the percent agreeing might have increased to 17% (27% among bear hunters). In addition, 24% of deer hunters selected the neutral response option (32% of bear hunters). The neutrals might be considered equally inclined to poach and not to poach. Therefore we set the bounds of our respondents' inclinations to poach wolves at 17–29% among deer hunters ($INCLINATION_{deer\text{-}hunters}$) and 27–43% among bear hunters ($INCLINATION_{bear\text{-}hunters}$). In 2001, the statement "I would

shoot a wolf if it threatened my pets", garnered 20% agreement (26% neutral) from a sample of 152 wolf range residents with high exposure to wolves but who were neither livestock producers nor bear hunters (sampling details in Naughton-Treves, Grossberg, & Treves, 2003). Among 171 livestock producers in that same sample, agreement was 19% (19% neutral) and among 188 bear hunters it was 13% (18% neutral). We never asked this question again in subsequent surveys nor did we ask a comparable question about livestock or hounds. As in the prior item, we assumed a 1% increase per year and a final range of values bounded by those agreeing (minimum) and added that estimate to half of those who had been neutral (maximum). Thus, we had 3 estimates for the inclination to poach wolves when their domestic animals were threatened among general pet owners, and livestock producers respectively, as follows: $\text{INCLINATION}_{\text{pet-owners}}$ = 30–44% and $\text{INCLINATION}_{\text{livestock-producers}}$ = 29–39%. For bear hunters, we had two estimates of inclination to poach a wolf (see above) so we used the minimum and the maximum estimates of both as our bounds for $\text{INCLINATION}_{\text{bear-hunters}}$ = 23–43%. We did not have a questionnaire item relating to threats to health and human safety. Thus we described these respondents' answers only.

Modeling potential to poach

Following the hypothesis in Figure 1 (main text), we operationalized potential to poach as follows:

Eq. 1: POTENTIAL-TO-POACH = INCLINATION • CAPABILITY • OPPORTUNITY

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To model the potential to poach a wolf, we multiplied the three frequency estimates as estimated above. We treated INCLINATION and CAPABILITY as independent because INCLINATION was estimated from our mail-back surveys from 2001–2009, whereas CAPABILITY was estimated from our telephone interview samples of individuals in 2011, both described above. We also treated OPPORTUNITY as independent because it reflected the frequency with which encounters with wolves occurred (not necessarily visual), i.e., it was set at 100% for verified complainants but self-reported by the deer hunter sample reporting on visual encounters and taking into account time spent in the field (see Eq. 2 below).

Our assumption of independence (multiplying the probabilities) is reasonable given our sources of data but may not hold under other conditions. First, a would-be poacher with strong intentions may seek additional opportunities (e.g., deliberate search for wolves to poach) or those who encounter many opportunities may change their attitudes (e.g., finding wolves more o less valuable as a result of experiences). We discuss the implications of this theoretical non-independence between intention and opportunity in the Discussion.

To operationalize Eq. 1 for our random deer hunters, we defined its components as follows:

Eq. 2: $\text{POTENTIAL-TO-POACH}_{\text{deer-hunters}} = \text{INCLINATION}_{\text{deer-hunters}} \bullet (A \bullet C) \bullet (F \bullet V)$

where the first parenthetical product represented CAPABILITY, and the second parenthetical product represented OPPORTUNITY. CAPABILITY was modeled as the

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product of A (the proportion of respondents who reported having access to a loaded weapon at the time of the encounter), and C (the proportion of those who believed they could have shot a wolf had they had a loaded weapon). The questions allowing us to estimate A were, “Did you have access to a weapon when you saw the wolf/wolves?”, “If yes, were you carrying it at the time you saw the wolf/wolves?”, and “If yes: Was it loaded?”. One might argue that some encounters lasted long enough for the respondent to fetch, load, and ready a weapon but we deemed this too speculative to add. The question with which we estimated C was, “Playing the scene back in your memory, do you think you might have been able to shoot the wolf or wolves that you saw immediately before, during, or immediately after this incident?” Although we asked how many wolves they might have shot (median 1, range 1–2), we chose to model poaching of a single wolf, because we assumed the others would usually escape after the first shot. OPPORTUNITY for deer hunters was modeled as the product of V (the proportion of respondents who ever reported a visual encounter with a wolf in response to the following question, “Have you ever seen wolves while deer hunting or preparing your hunting site?”) and F (the median number of visual encounters with wolves during a hunter’s self-reported career). We estimated F by responses to the question, “*If yes,* on how many different days have you seen wolves while you were deer hunting and/or preparing your site?” Because encounters were self-reported we did not restrict the deer hunters to reporting encounters prior to 2007 as in our complainant sample. Instead we asked, “When was this sighting/the most recent sighting?” and “How many

years have you been hunting deer?" so we could account for career effort. Although we report our respondents' assessments of the potential for their companions to have poached a wolf during the same encounter, we did not include that in Equation 2, as it seemed too speculative.

By contrast to our deer-hunter sample whose encounters were *not* verified independently, we treated our second sample as real encounters with wolves (OPPORTUNITY = 1.0) because of the verification procedure described above. Accordingly, we modeled POTENTIAL-TO-POACH for complainants as follows:

Eqs. 3–5: $\text{POTENTIAL-POACHING}_x = \text{INCLINATION}_x \bullet (A \bullet C)$

Where x is pet owners, livestock owners, or bear hunters, and each is presented in Results with its own equation.

RESULTS

Deer hunters

Among our random sample of deer hunters living in wolf range, 27 of 60 (V = 0.45) reported seeing wolves (n = 22 while hunting, n = 5 while preparing their site in the most recent events). The 27 respondents with visual encounters reported 1–42 such encounters in their hunting careers (median 2) and when asked, "When was this sighting/the most recent sighting?", the median response was the previous year (median last year, range 0–55) hence we estimated F = 1 because a median of 2 encounters every other year resulted in a median of 1 encounter per year. There was no

association between the response to, "How many years have you been hunting deer?" and whether they had seen wolves (median 40 years; range 2-49) or had not seen wolves (median 40 years, 6-73)— all were sampled from within wolf range. The durations of visual encounters were estimated at 2–900 seconds (median 30). Almost all of the 27 reported having had access to a weapon during the encounter (n = 3 bows), all said they were carrying it at the time, and almost all reported it had been loaded (including the 3 bow hunters) so we estimated A = 0.93 as the product of the two. When we included a 'maybe' response as 0.5, we found that 20.5 of 27 respondents thought they might have been able to shoot a wolf, so we estimated C = 0.76. The median number of wolves they believed they might have shot was one. Following Eq. 2,

$$\text{POTENTIAL-TO-POACH}_{\text{deer-hunters-minimum}} = 0.17 \bullet (0.93 \bullet 0.76) \bullet (1 \bullet 0.45) = 0.054$$

$$\text{POTENTIAL-TO-POACH}_{\text{deer-hunters-maximum}} = 0.29 \bullet (0.93 \bullet 0.76) \bullet (1 \bullet 0.45) = 0.092$$

In sum, 5.4–9.2% of deer-hunters from wolf range had the potential to poach a wolf each year by our model.

We asked deer-hunter respondents, "Did anyone else see the wolf/wolves before, during, or after the encounter?" and "*If yes,* were they armed with a loaded weapon?" The median number of armed companions who also saw the wolf was one (n = 18) whom they deemed capable of shooting the wolf in 8 cases (44%). When asked, "Were you concerned for your personal safety during your encounter?", 33% said 'yes'. Although the 27 deer hunters who had seen wolves appeared to be more likely to use concealments (100%) than those who had never seen wolves (87%), the role of

concealment is ambiguous in our data. At the time of the sightings, 38% of 27 deer hunters were not concealed *"…*when you sighted the wolf/wolves?" When asked, "*If concealed*, did the wolf/wolves seem to be aware of you presence?" 80% of deer hunters answered 'yes'. Also addressing conspicuousness of deer hunters, 33% answered 'yes' when asked, "Were you hunting alone or in a group?" (median 1, range 1–9 companions). "*If in a group,* was everyone in your group together, or within earshot of each other, during the wolf encounter?" (no = 2, yes = 6). "How would you describe your/your group's noise level immediately before seeing the wolf/wolves – quiet, moderate, or loud?" (n = 24 of 27, 88% reported 'quiet'). "Were there other hunters besides you/your group in the area that day?" (no = 9, yes =15, ? = 3). "Had you/anyone in your group/nearby fired a shot before the sighting?" (no = 26, yes = 1). "Did you harvest/wound any deer at that site in that season prior to seeing the wolf/wolves?" (no = 23, harvest = 3, wound = 0). "Were there any dead deer, dear gut piles, or deer skeletons in the area prior to that sighting?" (no = 21, yes = 3, ? = 1). "Were you aware of the wolf/wolves living nearby prior to the sighting?" (no = 3, yes = 21). "Was the land public access or private land?" (public = 10, private = 16).

Pet owners

We estimated A as 0.12 and C as 0.29. Following Eq. 3, we modeled

$$\text{POTENTIAL-TO-POACH}_{\text{pet-owners-minimum}} = 0.30 \bullet (0.12 \bullet 0.29) = 0.010$$

$$\text{POTENTIAL-TO-POACH}_{\text{pet-owners-maximum}} = 0.44 \bullet (0.12 \bullet 0.29) = 0.015$$

Hence 1–1.5% of pet owners with verified wolf complaints had the potential to poach as we have defined it.

When asked, "Were you concerned for your personal safety?", 1 of 17 (6%) of the pet owners answered 'yes'. Among pet-owners, 16 of 17 reported a single pet involved (n = 24 dogs total) in response to "How many of your pets were directly involved in this incident?" and six responded, 'yes' to "Were any other pets, yours or someone else's, in the vicinity during this incident?". Four respondents reported the incident took place on another property. These respondents believed that other persons might have shot the wolf in 22% of cases.

Livestock owners

For 61 livestock-owner respondents, A = 0.05 and C = 0.11. Following Eq. 4, we modeled

$$\text{POTENTIAL-TO-POACH}_{\text{livestock-owners-minimum}} = 0.29 \bullet (0.05 \bullet 0.11) = 0.0016$$

$$\text{POTENTIAL-TO-POACH}_{\text{livestock-owners-maximum}} = 0.39 \bullet (0.05 \bullet 0.11) = 0.0021$$

Hence our model predicted 0.2% of livestock owners with verified wolf complaints had the potential to poach.

For 61 livestock-owners responding to, "Where was/were the animal(s) located at the time of the incident?", we found refusal to respond = 1, barn = 1, enclosure = 6, pasture = 53, all three = 1. Livestock owners believed that other persons might have shot the wolf in 6% of cases. Among the livestock owners: "Were there any carcass dumps, including those used for road-kill deer, on your property or the surrounding

properties when this incident occurred?" (no = 55, yes = 5, ? = 2). "Were you on the farm at the time of the incident? (no = 15, yes = 40, ? = 6). "Were there dog(s) in the vicinity of the attack site?" (no = 40, yes = 20) and "I*f yes*, how many?" (one = 12, two = 4, three = 2, four = 1, twelve = 1) and "*If yes,* does it/do they usually bark when wildlife enter your property?" (no = 3, yes = 17) and "*If yes,* did they bark at the time of the incident?" (no = 2, yes = 17) and "If yes, did this warn you of trouble?" (no = 5, yes = 2). "Were there any signs or warnings [*other than dogs*] just prior to the incident?" (no = 49, yes = 9, ? = 3) and "Did you observe the animals' behavior change before the wolf appeared?" (no = 48, yes = 10, ? = 4).

Bear hunters

For the 29 bear-hunter respondents, A = 0.10, and C = 0.17. Following Eq. 5, we modeled

Eq.4: $\text{POTENTIAL-TO-POACH}_{\text{bear-hunters-minimum}} = 0.23 \bullet (0.10 \bullet 0.17) = 0.004$

Eq.5: $\text{POTENTIAL-TO-POACH}_{\text{bear-hunters-maximum}} = 0.43 \bullet (0.10 \bullet 0.17) = 0.007$

Hence our model predicted 0.4–0.7% of bear hunters who used hounds and had verified wolf complaints had the potential to poach.

For 29 bear-hunter respondents asked, "Did you see the wolf/wolves immediately before, during or immediately after the attack?", we found 'never' = 20, 'before' = 1, 'during' = 2, 'after' = 3 (multiple responses accepted). Additional situational details are presented in Supporting Information 1. 1.5 of 29 (5%) were concerned for their personal safety. These respondents considered that their companions might have

shot the wolf in 7% of cases. "Was the land public access or private land?" (public = 21, private = 4, mix = 3, ? = 1). "Did you (or your group) use bait at this site?" (no = 15, yes = 14). To the question, "Did this incident take place while training or hunting?" (training = 16, hunting = 13) and "*If hunting:* Which game animal(s) were you hunting?" (bears = 23, other = 3). "Were you hunting/training alone or in a group?" (alone = 2, group = 27). Were any other dogs, yours or someone else's, in the vicinity during this incident?" (no = 10, yes = 19, median 4 dogs, 1–78). "How much time had elapsed from when the dog was released to when it was attacked?" (15–30 minutes = 6, 30–60 = 9, >60 min = 12, ? = 2).

Complainants of health and human safety

For 8 complainants, A = 0.13 and C = 0.40. We did not model POTENTIAL-TO-POACH because we di not have an estimate of INCLINATION for these respondents (see Methods above). Five of eight complainants with health and human safety concern reported concerns for personal safety during our telephone interviews (63%). Apparently in the remainder, the verifier interpreted the incident as a threat to human health or safety or the respondent had forgotten that concern, although the official record we received was mute on the source of concerns. For these 8 situations, respondents answered the following question, "What activity were you engaged in during the incident?", husbandry (n = 3), by house (n = 3), other (n = 2). Of the six engaged in husbandry or by the house, four incidents occurred within 50 m of the complainant, and two occurred further away. Two respondents affirmed that pets or

livestock were involved in this incident (3 dogs, 1 chicken), suggesting half of these cases might be modeled as pet- or livestock-owners. The respondents believed that other persons might have shot the wolf in 16% of cases.

Effects on wolf population

From 15 March 2007 until 3 October 2011 (the time window we asked complainants to recollect), the State of Wisconsin verified 233 complaints about wolf attacks or threats to farm animals, 72 threats or attacks on hounds, 32 threats or attacks on pets, and 17 health and human safety concerns (WDNR annual records accessed through a Memorandum of Understanding with AT). If these incidents conformed to our respondents' self-reports, we expect that legalizing the killing of wolves under those complaint situations would result in approximately 1.5 wolves killed every 5 years. That estimate might double if one considered companions of respondents and their capability to poach more than one wolf per incident.

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Methods and Results (unabridged) accompanying the following article:

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