CHAPTER 5

Dog eat dog, cat eat dog: social-ecological dimensions of dog predation by wild carnivores

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5.1 Introduction

Due to their close relationship with humans, and their ability to adapt to a wide range of social-ecological systems, dogs (*Canis familiaris*) are probably the most numerous carnivores in the world today. As the global human population continues to grow and expand, dogs are more abundant and widely distributed than ever before. This is particularly evident in developing nations, where the majority of the world's human population exists and growth rates are highest (Gompper, Chapter 1). Consequently, although dogs have long been a part of the ecology of many landscapes, they are becoming an even more influential agent of anthropogenic impact on biodiversity, interacting with native wildlife and hence potentially modifying ecosystems to an unprecedented degree (Hansen et al., 2005; Young et al., 2011).

One rarely studied form of interaction is predation on dogs by wild carnivores. As a preliminary step for this chapter, we undertook a review of the scientific literature using Google, Google Scholar, and ISI Web of Knowledge to assess the range of carnivore species recorded as being responsible for killing dogs around the world. We also examined predation studies of potential dog-killing species to find records of dogs being killed or consumed. Most of this literature was in English, but we also accessed some publications from the Spanish and Russian literature. In total 13 species have been documented to kill dogs in 83 studies (Table 5.1, Figure 5.1). The gray wolf (*C. lupus*) occurred most frequently (28 records), largely in Europe but also in North America and Asia, followed by the leopard (*Panthera pardus*; 18 records) in Africa and Asia. Other felids documented were pumas (*Puma concolor*) in North and South America, jaguars (*Panthera onca*) in South America, Amur tigers (*P. tigris altaica*) in Asia (Siberia), and lions (*P. leo*) in Africa. Other canids were coyotes (*C. latrans*) in North America, dingoes (*C. f. dingo*) in Australia, and black-backed jackals (*C. mesomelas*) in Africa. Spotted hyenas (*Crocuta crocuta*) also accounted for a relatively large number of records in Africa. Striped hyenas (*Hyaena hyaena*) regularly scavenge dog carcasses in their African and Asian range and were assumed to prey on dogs by three studies. There was one published record of polar bears (*Ursus maritimus*) killing dogs in Arctic Canada, and another of Asiatic black bears (*U. thibetanus*) killing young dogs in Nepal.

In addition, there were records of other, non-carnivorous species killing dogs. In Africa, adult male baboons (*Papio ursinus*) can kill dogs when villagers use them to repel baboon troops raiding their crops and livestock (Butler et al., 2004), and in Australia southern cassowaries (*Casuarius casuarius*) can

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Table 5.1 Details of the 83 records of wild carnivore species documented in published scientific literature as having preyed upon dogs in different regions and countries of the world. Species are listed in descending order of total records.

Species	Region	Country	Record
Gray wolf	Asia	India	Jethva and Jhala 2004
		Mongolia	Hovens and Tungaslaktuja 2005
		Tajikistan	Bibikov 1988
	Europe	Albania and Macedonia	Keci et al. 2008
		Belarus	Sidorovich et al. 2003
		Estonia and Latvia	Valdmann et al. 2005; Zunna et al. 2009
		Finland	Kojola and Kuittinen 2002; Kojola et al. 2004
		Italy	Boitani 1982; Ciucci et al. 1996
		Poland	Nowak et al. 2005, 2011; Gula 2008
		Portugal	Vos 2000
		Russia	Bibikov 1988; Pozio et al. 2001
		Spain	Salvador and Abad 1987; Cuesta et al. 1991; Llaneza et al. 2000; Cortés 2001; Barja 2009
		Ukraine	Bibikov 1988
	North America	USA	Fritts and Paul 1989; Bangs et al. 2004, 2005; Ruid et al. 2009; Edge et al. 2011
Leopard	Africa	Côte d'Ivoire	Bodendorfer et al. 2006
		Ethiopia	Yirga et al. 2011; 2012
		Kenya	Kock et al. 1998; Kolowski and Holekamp 2006
		Namibia	Dabe 1997
		Tanzania	Kissui 2008
		Zimbabwe	Butler et al. 2004
	Asia	Bhutan	Wang and Macdonald 2009
		India	Johnsingh 1983; Edgaonkar and Chellam 1998; Ramakrishnan et al. 1999; Mukherjee and Mishra 2001; Daniels 2009; Shah et al. 2009; Mondal et al. 2011
		Iran	Sanei et al. 2011
		Nepal	Bhattarai and Kindlmann 2012
		Pakistan	Dar et al. 2009
Puma	North America	USA	Robinette et al. 1959; Aune 1991; Davies 1991; Mansfield 1991; Russ 1995; Sanders and Halfpenny 1991; Torres et al. 1996; Leberg et al. 2004
	South America	Brazil	Mazzolli 2009
		Venezuela	Farrell et al. 2000
Coyote	North America	Canada	Alexander and Quinn 2011
		USA	Howell 1982; Timm et al. 2004; Farrar 2007; Timm and Baker 2007; White and Gehrt 2009
Spotted hyena	Africa	Ethiopia	Atickem et al. 2010; Yirga et al. 2012
		Kenya	Kolowski and Holekamp 2006
		Tanzania	Holmern et al. 2007; Kissui 2008
		Zimbabwe	Butler, du Toit, and Bingham 2004

continued

Table 5.1 *Continued*

Species	Region	Country	Record
Tiger	Asia	Russia	Miquelle et al. 1996; Goodrich and Miquelle 2005; Goodrich et al. 2011; Tkachenko 2012
Lion	Africa	Tanzania	Kissui 2008
		Zimbabwe	Butler et al. 2004
Dingo	Australasia	Australia	Burger and Knowles 1976; Woodall et al. 1996
Striped hyena	Asia	India	Gajera et al. 2009
		Iran	Monchot and Mashkour 2010
Jaguar	South America	Belize	Foster et al. 2010
Black-backed jackal	Africa	Tanzania	Holmern et al. 2007
Polar bear	North America	Canada	Dyck 2006
Asiatic black bear	Asia	Nepal	Stubblefield and Shrestha 2007

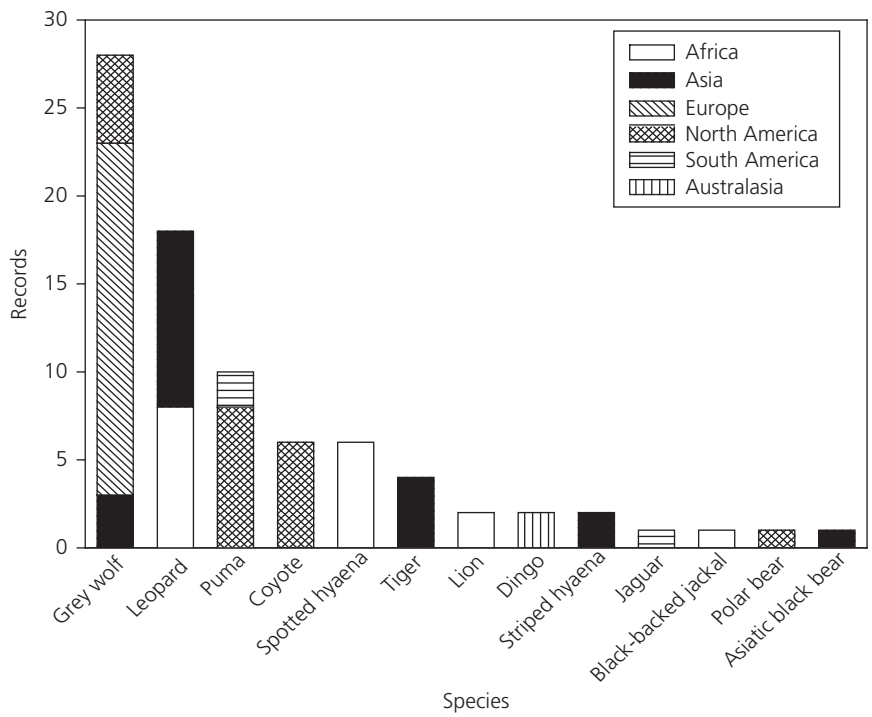

Figure 5.1 Summary of the 83 records of wild carnivore species documented in published scientific literature as having preyed upon dogs in different regions of the world. See Table 5.1 for details.

kill dogs (Kofron, 1999). Also, reptilian carnivores attack and eat dogs, for example saltwater (*Crocodylus porosus*) and freshwater crocodiles (*C. johnstoni*) in Australia (Mawson, 2004).

To augment this review we used email to survey our own contacts, the authors of recent papers or reports on potential dog-killing species, and various electronic mailing lists for records of dogs being killed by predators.

This survey elicited replies from 55 researchers and wildlife managers in Europe, North America, South America, Australia, and Asia. In addition, we used online search engines to review e-newspapers. Responses showed that brown or grizzly bears (*U. arctos*), black bears (*U. americanus*), Eurasian lynx (*Lynx lynx*), and golden eagles (*Aquilla chrysaetos*) have also been occasionally documented killing dogs in Europe and North America. Similarly, there are media reports of amethystine pythons (*Morelia amethistina*) and wedge-tailed eagles (*A. audax*) killing and consuming dogs in Australia, and Burmese pythons (*Python molurus bivittatus*) in Asia. In fact, predation or killing of dogs by a broader range of species is evident from numerous researchers' experiences, management agency records, and media reports, but is rarely mentioned in scientific papers.

These anecdotes imply that records in the scientific literature are unlikely to be an accurate representation of the extent of predation on dogs by the listed carnivores. Numbers of records will be a function of the geographic range of the carnivore concerned, contact rates related to dog and carnivore population densities within the species' overlapping ranges, variable investment in research among countries, and scientists' publication rates and interests. Furthermore, most studies mentioned an isolated incident anecdotally, while only a minority specifically investigated predatory interactions.

However, the literature review and survey results do illustrate the diversity of carnivores that dogs may interact with, which raises questions about the differing characteristics of these ecological relationships. Considering that dogs and native carnivores are potentially members of the same trophic guild, predatory interactions may be considered as intraguild predation, defined as the killing (and sometimes eating) of potential competitors because both species utilize the same prey resources and also benefit nutritionally from preying upon one another (Linnell and Strand, 2000; Palomares and Caro, 1999; Polis and Myers, 1989). Within this broad definition there is a continuum from asymmetrical predation, in which one species kills and eats the other, to symmetrical predation, in which both species may kill each other. There also appears to be a separate, non-predatory dimension where dogs are killed by sympatric species in self-defense (e.g., baboons and cassowaries).

The results also suggest an anthropogenic perspective. Because dog–human relationships vary so greatly between and within social contexts (Serpell, 1995), the loss of dogs to wild carnivore predation may have differing emotional and economic impacts on dog owners and their livelihoods. These impacts may result in diverse responses by humans to dog predation and their perceptions of the carnivores responsible. Unlike other interactions between dogs and wildlife, such as competition for food resources (Vanak et al., Chapter 3) and pathogen transmission (Knobel et al., Chapter 6), predation on dogs may be a more direct driver of conflict between humans and wild carnivores, mediated by complex social and institutional factors.

This chapter explores the nature of dog predation from the published scientific literature collated above, augmented by our own field experience, unpublished data, and wildlife researchers' and managers' anecdotal information. These data illustrate the range of potential predator–prey interactions between wild carnivores and dogs, and their influence on human–carnivore conflict. To synthesize these patterns we present a typology of dog predation based on the theory of intraguild competition. By integrating anthropogenic perspectives we then develop a human impact gradient, and present a hypothetical 'heat map' of ensuing human–carnivore interactions for different social-ecological contexts. We conclude that dog predation is a widespread but poorly understood phenomenon, which has varying impacts for both humans and wild carnivores. Furthermore, because the majority of dogs exist in developing nations, interactions with wild carnivores are likely to result in a new and unique set of challenges as these societies continue their rapid socio-economic development.

5.2 Focal examples of wild carnivore predation on dogs

5.2.1 Wolves in Asia, Europe, and North America

Gray wolves are the most widespread wild carnivore species in the world, and across much of

their range they occur in areas with a substantial presence of humans and dogs. Wolves occupy a diversity of habitats, exploiting an equally large range of prey, and coexisting with human cultures with varied land use and socio-economic status. It is well known that wolves kill dogs throughout most of their area of overlap, although only a few studies have specifically investigated this phenomenon (e.g., Edge et al., 2011; Fritts and Paul, 1989; Kojola and Kuittinen, 2002; Kojola et al., 2004). In some countries, detailed records are kept of domestic animals killed by wolves as part of conflict management protocols, often associated with the existence of compensation programs. Such data are available from several states in the USA (Minnesota, Michigan, Wisconsin, Idaho, Montana, Wyoming) and countries in Europe (Norway, Sweden, Finland, Estonia, Latvia, Poland, Croatia).

There is great variation in the average number of dogs killed each year, both within and between sites. Typical rates are <20 dogs/yr killed within each of these states or countries, with the exception of Croatia where >90 dogs/yr are reported killed. Furthermore, there are a range of anecdotal accounts of wolf–human relationships from across the wolf's range that also document wolf predation. These include Albania, Macedonia, Bulgaria, Slovakia, Germany, Spain, Italy, Mongolia, and Kyrgyzstan, although in some of these areas the extent of killing may be very low. Dog remains have also been recorded in wolf diet studies from Estonia, Latvia, Lithuania, Belarus, Russia, Poland, Italy, Spain, Portugal, Romania, Ukraine, Tajikistan and India (see Table 5.1 and multiple personal communications).

The overall indication is that dog-killing is widespread, occurring wherever wolves and dogs are sympatric. However, the extent of the killing is usually infrequent and irregular. There is little evidence that dogs constitute a major part of wolf diet, although this could often be due to the tendency of researchers to focus on remote study sites with relatively low human (and dog) densities. In studies where dogs do occur in wolf diet, they tend to be represented in <5% of scats or stomachs. In only a handful of cases can dogs be described as a major source of wolf nutrition. Most of these are in areas or periods where natural prey occurs at very low density, such as parts of western Russia, Spain, and Croatia (Bibikov, 1988; Cuesta et al., 1991; Pozio et al., 2001).

There have been several attempts to explain variation in dog-killing by wolves. Three factors are commonly cited. First, there is a broad positive correlation between dog-killing and increasing wolf population size, for example in cases of recovering or reintroduced wolf populations (Ruid et al., 2009). A second correlation is for dog killing to be associated with areas (Cuesta et al., 1991; Kojola and Kuittinen, 2002; Pozio et al., 2001) and periods (Pozio et al., 2001; Sidorovich et al., 2003) of low prey density, implying that dogs can be targeted if natural prey is extremely rare. A third trend is for specific packs to become habitual dog-killers (Kojola et al., 2004). These patterns are also clearly modulated by the local availability of dogs, which depends on how the local human population use and keep them. Throughout Europe, Siberia, and North America dogs are commonly used by recreational hunters. In most cases hunting dogs, either singly or in groups, are released to drive or locate game. Many of the attacks are on free-ranging hunting dogs during the process of training or hunting. Of all lethal attacks on dogs, the percentage involving hunting dogs varies from 30% in Finland (Kojola and Kuittinen, 2002), 47% in Belarus (Sidorovich et al., 2003), 59% in Michigan (Edge et al., 2011), 80% in Sweden (Swedish Wildlife Damage Center unpublished data), to 87% in Wisconsin (Ruid et al., 2009). Most of the remaining cases were dogs killed in yards, and a few while guarding livestock.

This implies that dogs are killed in three contexts. The first is when dogs such as hunting dogs are running free in wolf habitat. This requires no active effort of the wolf to find the dog and the attack may even be provoked by the dog seeking the wolves. The second is where dogs are killed in villages or yards, often when chained to a building, suggesting that the wolf actively sought out the dog and killed it without provocation. The third is when livestock-guarding or herding dogs are killed during a wolf attack on livestock. An additional context concerns wolves killing feral dogs. Although it is widely believed that wolves control feral dog numbers in Spain, possibly through predation (Blanco et al., 1992), there have been no formal studies to confirm this. The extent to which dogs are then consumed

also varies enormously, but occurs in around half the cases.

Hence dog-killing by wolves is a complex ecological phenomenon, involving aspects of predation, defense, or dominance (Karlsson and Jaxgård, 2004). The relative extent to which one of these mechanisms is responsible is likely to vary over space and time, and the mechanisms are not mutually exclusive. Studying wolf predation on dogs is also challenging because it is so poorly reported and is such a rare event when viewed from either the perspective of an individual dog at risk or from an individual wolf. For example, in Scandinavia the Scandinavian Wolf Project (SKANDULV) has been conducting intensive telemetry-based studies of wolf predation since the late 1990s. This project has found more than 800 wolf-killed prey items, but dogs are not among them. However, during the same period the region's wildlife management system has documented 293 dogs killed by wolves (Swedish Wildlife Damage Center; Norwegian Directorate for Nature Management, unpublished data).

Although the number of dogs killed may be statistically insignificant relative to other livestock predation, it can have a dramatic impact on conservation discourses. In some cultures humans and dogs have strong social and emotional links, and dogs are treated as family or team members (Haraway, 2003; Sanders, 1993, 2003; Serpell, 1995). Good hunting and livestock guarding dogs are valuable and cannot be replaced quickly (Lescureux and Linnell, 2010). The loss of such an animal to a wolf triggers strong emotional responses of grief. Finally, the fact that wolves often enter villages and farmyards to take dogs close to houses may induce fear because of the threat that they also pose to human life. All of these mechanisms increase animosity towards wolves and weaken community and political support for their conservation (Bisi et al., 2007; Sjölander-Lindqvist, 2010; Skogen and Krange, 2003; Skogen et al., 2006).

5.2.2 Leopards, lions, spotted hyenas, and jackals in Africa

Most records of dog predation in Africa are incidental within studies focusing on livestock predation by large carnivores (e.g., Atickem et al., 2010; Holmern et al., 2007; Kissui, 2008; Kolowski and Holekamp, 2006; Yirga et al., 2011, 2012). In rural regions where traditional agro-pastoralism co-exists with large carnivores, lions, leopards, and spotted hyenas are the main predators of livestock and dogs. Holmern et al. (2007) recorded an instance of a black-backed jackal killing a dog in Tanzania, and similar records exist in Zimbabwe (where dogs also kill jackals: Butler, 1998; Vanak et al., Chapter 3), but we are not aware of records of side-striped (*Canis adustus*) or golden jackals (*C. aureus*) killing dogs. African wild dogs (*Lycaon pictus*) and cheetahs (*Acinonyx jubatus*) are also predators of livestock but, again, we are unaware of records of either killing dogs. Due to their similar omnivorous ecology brown hyenas (*Hyaena brunnea*) may compete with dogs where their ranges overlap (Vanak et al., Chapter 3), but there are no records of predatory interactions between them.

Throughout African agro-pastoralist systems, dogs are kept to deter wildlife from raiding livestock and crops (Atickem et al., 2010; Kissui, 2008; Kolowski and Holekamp, 2006) and also for livestock herding, hunting, and protecting homes (Butler and Bingham, 2000; Knobel et al., 2008). Homesteads are usually open or only partially fenced, allowing dogs to roam and breed freely, while also providing little protection from predators (Atickem et al., 2010; Butler and Bingham, 2000; Kolowski and Holekamp, 2006). The relationship between dogs and humans observed in most rural areas of sub-Saharan Africa has remained largely unchanged since dog immigration with the Bantu 2,000–4,000 years ago (Gallant, 2002). Modern day dog densities have been recorded as ranging between 6 and 21 per km^2 in Kenya (Kitala et al., 1993) and 8 and 53 per km^2 in rural Zimbabwe, and are likely to be increasing rapidly (Butler and Bingham, 2000).

Only one detailed analysis of the predator–prey relationships between wild carnivores and dogs has been undertaken, in a 33 km^2 section of Gokwe Communal Land (GCL) bordering the Sengwa Wildlife Research Area (SWRA), Zimbabwe (Butler and du Toit, 2002; Butler et al., 2004). The study area contained 130 households, 937 people, and 236 dogs, plus 537 cattle (*Bos indicus*), 819 goats (*Capra hircus*), 157 donkeys (*Equus africanus asinus*), and small numbers of sheep (*Ovis aries*) and pigs (*Sus scrofa*). Cattle were the most valuable livestock (US$100 per head

in 1996 values), followed by donkeys ($40), pigs ($25), sheep ($15), and goats ($10) (Butler, 2000). By comparison, dogs were valued at $10. Leopards, lions, and spotted hyenas traveled up to 3 km into GCL at night, while dogs were sighted up to 6 km within the SWRA, and these species were therefore effectively sympatric.

Household surveys revealed that 23 dogs were preyed upon during the study, representing approximately 10% of the population. By comparison, 5% of livestock holdings were taken by wild carnivores (Butler, 2000). For the 19 cases of dog predation where the predator could be identified, leopards were responsible for the most (53%), followed by lions (42%) and spotted hyenas (5%). Eighteen (78%) were killed away from the homestead, and five within the homestead perimeter. Leopards were responsible for taking all dogs killed within homesteads. All incidents took place at night, and all dogs were wholly or partially consumed. There was a seasonality to dog predation, with the monthly rate of kills for all three predators being at least twice as high in the dry season as that for the wet season. In total, the rate of dry season kills (0.75 per month) was almost four times greater than for the wet season (0.19 per month). These patterns were also reflected in livestock predation, with 80% of losses occurring in dry season months (Butler, 2000). Radio-tracking of dogs indicated that they were particularly vulnerable to predation due to their solitary scavenging away from homesteads and human protection (Box 5.1).

Drought potentially escalated predatory interactions between wild carnivores and dogs. The failed wet season of 1994–95 was followed by a sharp increase in dog sightings within the SWRA, partially due to increased illegal hunting within the reserve by GCL inhabitants related to food shortages. Dogs also entered the SWRA independently, perhaps due to a dwindling availability of waste human food in GCL (Butler and du Toit, 2002). This is corroborated by household surveys in seven communal lands that recorded greater incidences of stray or feral dogs during droughts when food became scarce (Butler, 1998). Leopards and lions rely upon vegetative cover to hunt wild prey successfully (Schaller, 1972; van Orsdol, 1984), and therefore may resort to killing livestock more regularly in drier conditions, as also indicated by the higher incidence of livestock predation in dry season months. Hence dogs may become more regular incidental prey during drought years, both within communal lands and adjoining protected areas. However, due to the low economic value of dogs, losses to predators had an insignificant economic effect on GCL households relative to the impact of cattle, goat, and donkey predation.

5.2.3 Leopards in Asia

Leopards are known for being highly adaptable in terms of their habitat and diet requirements, and this is demonstrated clearly in India where they inhabit intact tropical forests, farmlands, and suburban environments. The tendency of leopards to kill and consume dogs has been widely noted in the Indian colonial era hunting literature, with many records of leopards taking dogs from close to, and even inside, human habitation (Daniels, 2009). However, there has been little formal study of dog predation. Most wildlife research in India occurs in the relatively intact ecosystems of protected areas where dogs are not normally present. In such areas it is not surprising that dogs do not register frequently in leopard diet, and predation on dogs by leopards is often only documented in anecdotal footnotes (Johnsingh, 1983), or via occasional occurrence in scats (<5% frequency; Ramakrishnan et al., 1999). In intact ecosystems, leopards show a clear preference for small- to medium-sized ungulates (Hayward et al., 2006). However, the few studies that have occurred in landscapes where natural ungulate prey are rare or absent have frequently found that dogs can be the major prey item. For example, dogs occurred in 25% of scats in Kashmir (Shah et al., 2009), 64% of scats in Sanjay Gandhi National Park (Edgaonkar and Chellam, 1998), and 39% of scats in rural Maharashtra (V. Athreya, unpublished data). No other prey species was more common than dog in these three studies. Farmers and migratory shepherds in Maharashtra have also identified leopards as major predators of dogs (V. Athreya, unpublished data).

Box 5.1 The ranging behavior and vulnerability of dogs to predation in rural Zimbabwe

Radio-tracking of 14 adult dogs from households adjacent to the SWRA enabled an analysis of dog behavior, and hence their potential vulnerability to predation. Dogs had a mean independent home range area (i.e., where they moved freely without their owners) of 97.2 ha (range 0.3–316.0), and males had larger home ranges (mean 145.0 ha) than females (mean 33.5 ha). Seven of these home ranges included areas up to 1 km inside the SWRA. The outer limits of home ranges were often determined by the locations of wild or domestic mammal carcasses which the dogs scavenged, and for males the locations of females in estrus (Figure 5.2). Dogs spent the majority of their time with their owners (76%) and in the immediate vicinity of human habitation (63%). However, they scavenged in their home ranges independently of people and usually alone: 87 and 84% of dogs recorded at experimental carcasses arrived and fed alone, respectively (Figure 5.3).

Of the radio-tracked dogs, one was killed and eaten by a lion within its home range, at night, 400 m from its owner's homestead (Figure 5.2), and another disappeared possibly due to predation. These detailed data suggest that dogs were largely taken opportunistically as prey when ranging independently of people away from their homestead, usually at night. However, leopards appeared to target dogs within homestead perimeters. In contrast to Atickem et al. (2010), who recorded dogs being killed while defending homesteads and livestock against spotted hyena attacks in Ethiopia, none of the cases in GCL involved similar agonistic interactions. The

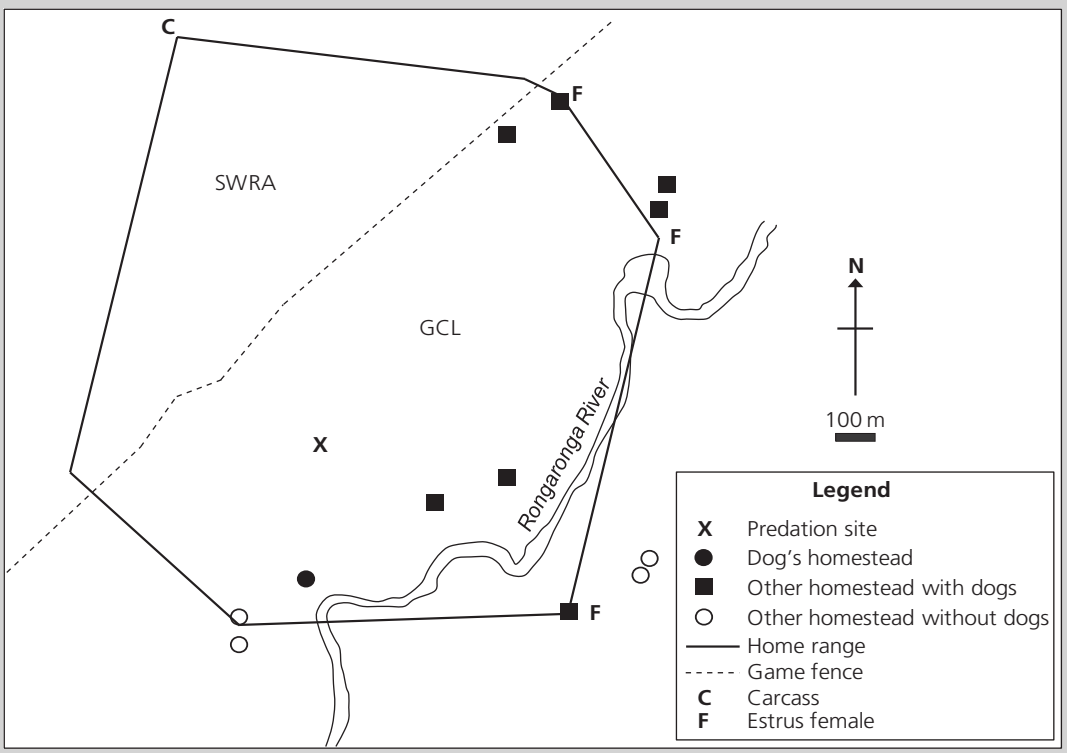

Figure 5.2 Convex polygon independent home range (316 ha) for a 16 kg adult male dog in the Gokwe Communal Land (GCL), relative to the neighboring Sengwa Wildlife Research Area (SWRA), derived from 94 fixes over 188 consecutive days. The dog was killed and consumed by a lion on the night of June 8, 1996 in a field 400 m from the dog's homestead.

continued

Box 5.1 *Continued*

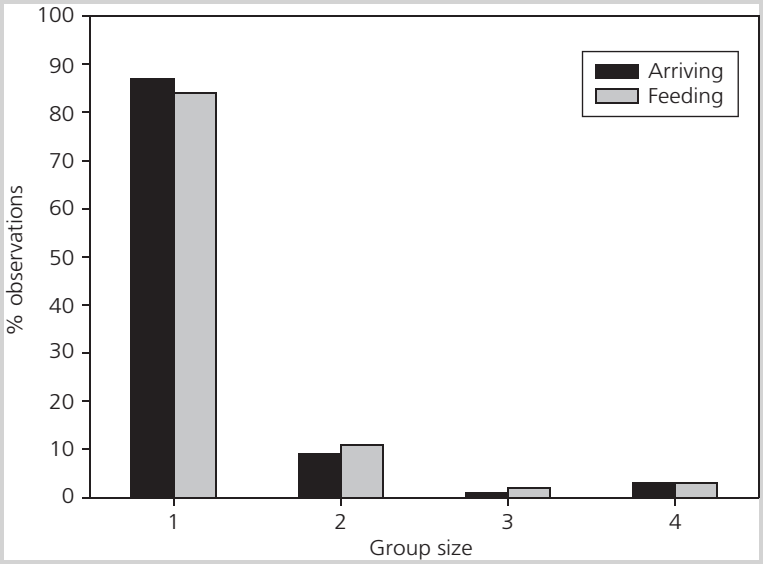

Figure 5.3 Group sizes of dogs arriving and feeding at 12 experimental carcasses in the Gokwe Communal Land and Sengwa Wildlife Research Area, determined from 229 separate observations of dog meals.

tendency of dogs to forage and feed alone may render them particularly vulnerable to predation. This is most likely to occur at carcasses, which also attracted leopards, lions, and spotted hyenas on the GCL–SWRA boundary at night. Human activity is known to be at its lowest between 18:00 and 04:00, providing little interference to nocturnal wild carnivores or protection to dogs during this period (Butler and du Toit, 2002).

The implication is that in the presence of preferred natural prey, dog-killing remains a widespread but uncommon activity, but that in the absence of wild prey, leopards can sustain themselves on a diet of dogs, supplemented with livestock. In India, dogs weigh approximately 15 kg, are usually owned but unrestricted and therefore largely unprotected, and are found throughout the landscape at high densities (30–50 per km^2; V. Athreya, unpublished data; Punjabi et al., 2012). The deliberate targeting of dogs by leopards is illustrated by the frequent cases of leopards pursuing owned dogs into houses (V. Athreya, unpublished data). In some areas, feral dogs are also targeted by leopards. Similar situations probably exist elsewhere in the region, as indicated by the presence of dog remains in leopard diet in Bhutan (Wang and Macdonald, 2009), Nepal (Bhattarai and Kindlmann, 2012), Iran (Sanei et al., 2011), and Pakistan (Dar et al., 2009).

5.2.4 Pumas and jaguars in the Americas

There are only a few published records in the scientific literature of pumas killing dogs, and dogs are rarely reported in scats or among kills found (Aune, 1991; Davies, 1991; Dettmann, 1991; Leberg et al., 2004; Mansfield, 1991; Russ, 1995). However, our survey of online sources, including newspapers

Box 5.2 The challenges of documenting rare events: the case of the puma in the Americas

Reviewing the extent of large carnivore predation on dogs is a challenging task for a number of reasons. First, although our review indicates that it is a widespread phenomenon, it does not appear to be frequent. This implies that within any project researching wild carnivore diet it is highly unlikely it will document many, if any, kills of dogs or scats containing dog remains. Second, the study of pet predation falls between an ecologically relevant focus on predation of wild prey, and the economically relevant issues related to predation on livestock. This leads to a reporting bias, such that even if data exist they do not find their way into the published literature.

Our search for records of predation on dogs by the puma illustrates this challenge. Initial searches using Google Scholar and ISI Web of Knowledge, and keywords associated with 'puma,' 'dog,' 'pet,' and 'predation' led us to only a few articles that either mentioned in passing that pets are occasionally killed by pumas (Torres et al., 1996), record the occurrence of dog hair in a single puma scat (Leberg et al., 2004 (in Louisiana, USA); Farrell et al., 2000 (in Venezuela)), or report anecdotally a single event (Mazzolli, 2009 (in Brazil)). We then searched manually through all relevant publications in our library collections, including data-based scientific articles, technical reports, books, and conference proceedings. We searched for records of dogs as prey species, which led to one record (Robinette et al., 1959), and a few anecdotes in papers dealing with human–wildlife conflict (Aune, 1991; Dettman 1991; Davies, 1991; Mansfield, 1991; Russ, 1995; Sanders and Halfpenny, 1991), with almost all coming from a single conference proceedings. We then sent emails to researchers and wildlife managers who had published on pumas in either scientific articles or conference proceedings during recent years. This elicited many replies that reported records of pumas killing dogs in eight US states and two Central American countries. The information was based on results from research projects, interviews with local people, and public records concerning wildlife damage and depredation reports. As a final line of enquiry we used Google to search English language newspapers and newsfeeds in the USA and Canada. This revealed 38 individual cases of dogs being attacked and killed in 10 US states and 2 Canadian provinces between 2000 and 2012 (Table 5.2).

Table 5.2 The regional coverage of records of pumas killing dogs in North and South America as reflected by sourcing different types of information: scientific papers data-based; manual search of articles and proceedings; email survey of researchers and managers; Internet search of online newspapers and newsfeeds.

State, province, or country	Scientific papers[1]	Articles and proceedings	Email surveys[2]	Online media[3]
United States and Canada				
Alberta	0	0	0	2
Arizona	0	0	0	1
British Columbia	0	0	0	6
California	0	2	1	8
Colorado	0	3	0	6
Florida	0	0	1	0
Idaho	0	0	0	3
Louisiana	1	0	0	0
Montana	0	1	0	2
Nevada	0	0	1	0
New Mexico	0	0	0	1
Oregon	0	0	1	2

continued

Box 5.2 *Continued*

Table 5.2 *Continued*

State, province, or country	Scientific papers[1]	Articles and proceedings	Email surveys[2]	Online media[3]
South Dakota	0	0	1	0
Texas	0	1	0	1
Utah	0	0	1	2
Washington	0	0	1	4
Wyoming	0	0	1	0
Latin America				
Brazil	1	0	0	
Guatemala	0	0	1	
Mexico	0	0	1	
Venezuela	1	0	0	
TOTAL	3	7	10	38

[1] Number of articles.
[2] Number of respondents giving a positive reply.
[3] Number of unique cases mentioned by diverse media. Only North American media were searched.

Hence the peer-reviewed scientific literature only gives limited insight into the extent and frequency of pumas killing dogs, especially when searches are confined to the use of keywords in database searches. Secondary information from publications, the gray literature, media comment, and local experts reveal a different picture. Pumas appear to kill dogs at low frequency in most places where pumas occur (Table 5.2). While there is nothing to indicate that dogs are of dietary importance for pumas anywhere, the occasional killing of a pet has potentially large repercussions for public tolerance of puma presence, an issue that emerges clearly in the media coverage.

This example has fundamental implications for the way that we review information related to wild carnivore conservation. As scientists we like to insist on the use of peer-reviewed material because it is easy to access and has been quality-controlled. However, as shown above, this insistence can lead to a bias and underestimation of the importance of certain issues. While the recent focus on evidence-based conservation is laudable, we must not ignore other forms of knowledge, including unpublished data and media reports. Furthermore, the mutual recognition and integration of local knowledge and expert opinion is particularly important because conflict over large wild carnivores must be resolved through multi-stakeholder co-management processes (Butler, 2011; Young et al., 2012).

and news reports from wildlife management agencies, indicated that predation on dogs is widespread, but occurs at low frequencies (Box 5.2). We found reports of pumas killing dogs in 15 US states and 2 Canadian provinces during recent years, with California, Colorado, and British Columbia contributing the most records. The dogs were often killed in close proximity to houses, with pumas frequently taking dogs from the yard or veranda, and in one case even entering the house in pursuit of the dogs. The houses tended to be on the suburban–forest interface. Dogs varied in size from Miniature Poodles to German Shepherds, and many were consumed. In a few cases the pumas were apparently injured and emaciated, although this did not seem to be a general pattern (Box 5.2). Pumas

also kill and occasionally eat coyotes, implying that dog killing is likely to have both nutritional and intraguild competitive motivations. In South America there is only one published report of a puma killing a dog (Brazil; Mazzolli, 2009), and one other of dog hair occurring in a scat (Venezuela; Farrell et al., 2000).

Similarly, there is limited published scientific information on dog predation by jaguars in South America. In Belize, jaguars preyed on dogs and other livestock on the periphery of a protected area where wild prey was scarce, while sympatric pumas avoided these areas and were not recorded preying on dogs, perhaps due to competitive interactions with jaguars (Foster et al., 2010). Our online search and survey among researchers for anecdotal information also revealed occasional incidents of jaguar predation on dogs in many parts of Central and South America.

5.2.5 Coyotes in North America

The last few decades have seen a shift in North American research on conflict between coyotes and humans. From early concern about the role of coyotes as predators of livestock, there is an emerging focus on direct conflict between coyotes and humans. These interactions occur frequently in suburban areas, especially at the suburban–wildland interface. In many parts of North America, coyotes have shown an ability to occupy these suburban habitats and exploit human food sources. This includes attacking and killing dogs and cats (*F. catus*), and coyotes are often killed by dogs (Kamler et al., 2003). The fact that coyotes kill and occasionally consume pet dogs has been reported in many studies (Alexander and Quinn, 2011; Farrar, 2007; Lukasik and Alexander, 2011; Timm and Baker, 2007; White and Gehrt, 2009), although little quantitative data has been published because pet attacks are overshadowed by the controversy caused by coyote attacks on humans (Timm and Baker, 2007). The development of problem behavior in suburban coyotes has been hypothesized to follow a habituation gradient, whereby coyotes begin to lose their fear of people, then begin to exploit human foods, and ultimately try to attack pets or people (Schmidt and Timm, 2007). The focus of these studies has been to use pet attacks as an early warning for situations of potential danger to humans. Dog-killing by suburban coyotes therefore appears to only begin once coyotes have become sufficiently habituated to human presence. However, once they have overcome this fear, it seems that dog-killing may be motivated by both predation and territorial defense.

5.2.6 Tigers in Asia

Dietary studies have not identified dogs as prey of tigers in most regions of Asia, largely because tiger research there tends to occur in protected areas with low human densities. However, Amur tigers in Siberia exist in multi-use landscapes and dog-killing and their consumption as prey is well documented, both as remains in scats and among recorded kills (Miquelle et al., 1996; Tkachenko, 2012). The main data source is reports of tiger–human conflicts recorded by researchers and wildlife management authorities. Dogs are by far the most commonly killed domestic animal. For example, in one study they constituted 63% of the 254 documented domestic animal kills (Goodrich et al., 2011). The dogs were often killed in the middle of villages and when chained outside houses, implying that the tigers were deliberately targeting the dogs rather than killing them following chance encounters. However, there were also cases of predation on free-ranging hunting dogs in the forest. Because these dogs are often highly valued, their death triggers considerable negative feelings and retaliatory killing by their owners (Goodrich et al., 2011). Ironically, Tkachenko (2012) found that in some cases the tigers responsible for attacks on dogs were injured and/or emaciated as a direct result of such human persecution. The tiger–dog relationship is especially interesting considering the evidence for competitive exclusion of wolves by tigers. Existing data indicate that Amur tigers have a dramatic effect on wolf distribution (Miquelle et al., 2005); hence it is possible that dogs are also viewed as intraguild competitors and killed.

5.2.7 Dingoes in Australia

In Australia, dingoes and feral 'wild dogs' (dingo x domestic dog hybrids) are a cause of major economic losses for the sheep and cattle industry, resulting in specific legislation in some states requiring landholders to control themon their property using lethal measures, such as trapping with cage or padded-jaw traps, shooting, and/or poisoning with 1080 (sodium monofluoroacetate) or strychnine baits (Fleming et al., 2001). Dogs are kept by Australians primarily as pets, but in rural areas they are highly valued as working dogs, and for hunting feral pigs (ACAC, 2010). Consequently dogs, dingoes, and wild dogs come into regular contact, particularly in rural areas (Allen and Fleming, 2004), but there are surprisingly few scientific records of dog predation. Burger and Knowles (1976) reported dogs being killed by dingoes on Fraser Island, and Woodall et al. (1996) noted dogs being 'lured' away from human habitation by a female dingo in estrus, and then being attacked by the other members of the dingo pack. Box 5.3 highlights one such study in the Wet Tropics bioregion of Queensland that may be representative of the growing conflict between dingoes, domestic dogs, and people in suburban and peri-urban regions of Australia.

Box 5.3 Conflict between dingoes, domestic dogs, and people in the peri-urban Wet Tropics of Australia

The Wet Tropics bioregion of north-east Queensland is characterized by native rainforest covering the coastal escarpment, and much of the region is protected by the Wet Tropics World Heritage Area (WHA). Following European settlement in the late nineteenth century, the coastal floodplains and inland tablelands were cleared for timber and agriculture. Today this landscape is a mosaic of diverse habitat types, including remnant coastal rainforest and mangroves, interspersed with sugar cane, horticultural production, and cattle grazing (Pert et al., 2012). The Wet Tropics has a rapidly-growing human population which has been forecast to increase from 216,000 in 2004 to 300,000 in 2024 (McDonald and Weston, 2004). This growth is driven by immigrants from large southern Australian cities seeking an idyllic tropical lifestyle (Bohnet and Pert, 2010). The resulting suburban expansion is encroaching on surrounding agricultural land and protected areas, which brings owned dogs into increasing contact with dingoes and wild dogs.

Dingoes in the Wet Tropics maintain home ranges of up to 120 km^2, moving between peri-urban areas and WHA forest (D. Morrant, unpublished data). When roaming dingoes move into human-populated areas, their territorial and predatory behaviors bring them into direct conflict with humans. While they primarily prey on small to medium-sized wild animals (50 g–19 kg), they also occasionally attack and kill domestic animals. In 2011, a questionnaire survey of 3000 households across all land use types was undertaken to assess the frequency and characteristics of such attacks on owned dogs. Records of attacks were also obtained from Pest Management Officers from Cairns Regional Council, the most populous council in the Wet Tropics, and AgForce Queensland, the representative body for the state's cattle industry.

Twelve respondents (6%) reported attacks on their dogs by dingoes. An additional nine incidents were reported by the Pest Management Officers, and three during discussions with farmers. Of the 24 incidents, 10 (42%) occurred on suburban fringes and 13 in rural agricultural areas (Figure 5.4). Five of the seven interactions that were witnessed by respondents involved packs of up to six dingoes. Domestic dogs were injured in twenty incidents, and killed in four, but not consumed. Witness descriptions often emphasized the determination of the dingoes to attack the dogs concerned. One cattle grazier fought off three dingoes with a stock whip when they attacked his dog within 50 m of his house. Another farmer reported that a "pack of wild dogs" returned on three consecutive nights to attack her dog. Another respondent claimed that a male domestic dog was "lured from [the] yard by a female in heat," and then mauled by six other dingoes. This owner physically separated the animals to protect his dog.

The responses revealed a strong emotional reaction and a willingness on the part of dog-owners to protect their pets. Owners of attacked dogs were angry and upset, and were also concerned for the safety of local children and other pets, prompting dingo and wild dog population control. Legal

continued

Box 5.3 *Continued*

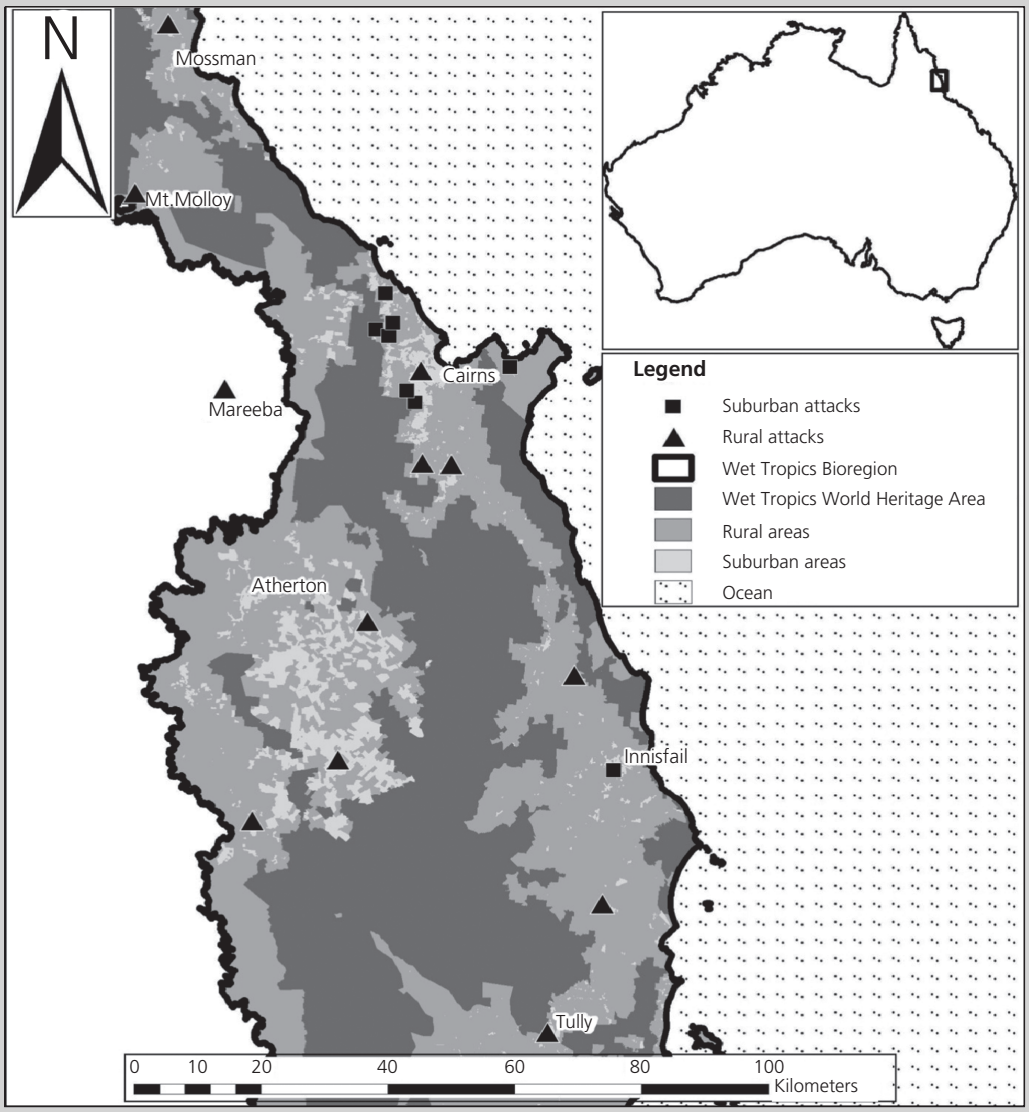

Figure 5.4 The location of 20 dingo attacks on domestic dogs in the Wet Tropics of Queensland, Australia, relative to land use. Four records are not shown because locations were not provided by respondents.

retaliatory control measures followed six of the incidents. Approximately 10% of the landholders surveyed had engaged in lethal control of dingoes and wild dogs in the past 12 months. However, Pest Management Officers admitted that they intentionally avoided killing suspected 'pure' dingoes, in the belief that dingoes with a stable pack structure pose less of a threat to pets and livestock than wild dogs, and exclude wild dogs from their home ranges.

5.2.8 Striped hyenas in Africa and Asia

Striped hyenas occur from the Horn of Africa through the Middle East and into Asia, and throughout their range are noted as being omnivorous and generalist carnivores with a predilection for scavenging, particularly human waste around settlements (Kruuk, 1976; Kuhn, 2005; Monchot and Mashkour, 2010). They also regularly prey upon small livestock such as goats and sheep (Gajera et al., 2009; Leakey et al., 1999). Monchot and Mashkour (2010) have suggested that their close association with humans may even qualify as a commensal relationship. Consequently striped hyenas are likely to come into regular contact with dogs and compete with them, particularly since in many of the regions within their range dogs are likely to be free-ranging and also scavenge human-derived food (Vanak et al., Chapter 3).

In spite of the likelihood of interactions there are relatively few records of hyenas preying upon dogs. There is evidence of hyenas feeding on dogs in India (Gajera et al., 2009), Kenya (Leakey et al., 1999), and Jordan (Kuhn, 2005), and Monchot and Mashkour (2010) state that in Iran sick dogs are likely to be preyed upon, and hyenas interact aggressively with dogs over carcasses. Hence the relationship between dogs and hyenas appears to be driven by direct interference competition for shared food resources, although hyenas may opportunistically prey upon and consume young or sick dogs. However, we could find no evidence of dogs killing striped hyenas.

5.3 Synthesis

5.3.1 Ecological dimensions

The examples of dog predation reviewed above reveal a wide range of ecological relationships between dogs and wild mammalian carnivores along the continuum of intraguild predation. At the asymmetrical extreme dogs are killed and eaten by lions, leopards, tigers, jaguars, and pumas as food. Records suggest that in many cases dogs are specifically targeted as prey and eaten, for example by leopards in India and Zimbabwe and tigers in Siberia. In other cases predation may be more opportunistic, for example with lions and spotted hyenas in Zimbabwe. At the symmetrical extreme dogs are attacked and killed as competitors but rarely eaten, for example by dingoes in Australia. At this extreme, dogs are equally likely to attack but not necessarily consume competitors (see Vanak et al., Chapter 3).

In addition, there are intermediate relationships which involve elements of both. This is most evident for wolves, which exhibit a complex range of behaviors towards dogs, both targeting them as competitors, preying upon them for food, and also killing them when challenged by hunting or livestock guard dogs. Given some evidence that they kill wild canids, predation of dogs by tigers and pumas may also contain elements of competitive exclusion. Spotted hyenas may also compete with dogs in Africa for carrion and human refuse (Butler and du Toit, 2002; Vanak et al., Chapter 3), and hence a similar mix of predatory and competitive elements could exist. Striped hyenas in Africa and Asia may have a similar relationship, but with a greater emphasis on competition for human-derived food.

By considering the adult body mass of the wild carnivores concerned relative to dogs and then mapping these specific relationships along the continuum of intraguild predation, a typology emerges (Figure 5.5). This indicates that predators that have a body mass at least twice that of dogs, such as lions, leopards, pumas, jaguars, and tigers, have a predominantly asymmetrical, predatory relationship with dogs. This is to be expected since dogs fall within the prey range of all of these carnivores, and for leopards in particular, which are known to favor small- to medium-sized mammals of 5–20 kg (e.g., Bodendorfer et al., 2006; Hayward et al., 2006). Those with a smaller or equivalent body mass to dogs may have exclusively symmetrical relationships involving competitive killing, for example among black-backed jackals, coyotes, and dingoes. Given their similar size, dogs are capable of killing these species in agonistic interactions (Vanak et al., Chapter 3). Wolves, spotted and striped hyenas occupy an intermediate position, having a range of predatory and competitive killing interactions with dogs. In the case of wolves and striped hyenas, this is perhaps because their body sizes overlap and also exceed those of dogs.

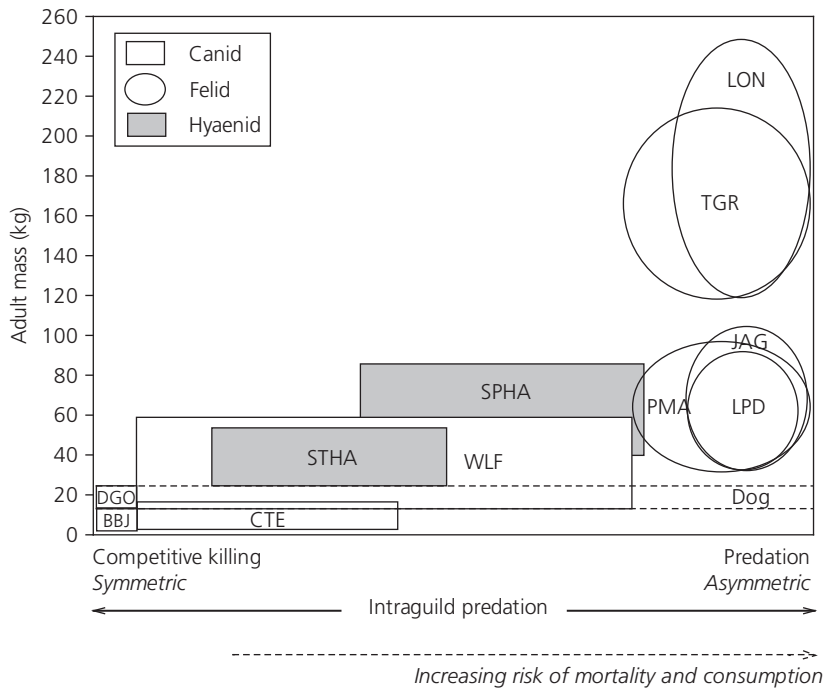

Figure 5.5 A typology of intraguild relationships between wild mammalian carnivores and dogs, assuming an adult dog body mass of 15–25 kg. The wider the symbol along the intraguild predation axis, the broader the range of intraguild relationships possible. The greater the body mass relative to dogs, the more likely the relationship will involve predation, and the risk of mortality for dogs in interactions will increase. Abbreviations (and sources for adult body mass data) are: BBJ black-backed jackal (Loveridge and Nel, 2004); DGO dingo (Letnic et al., 2011); CTE coyote (Kennedy-Stoskopf, 2003); WLF grey wolf (Kennedy-Stoskopf, 2003); SPHA spotted hyena (Ramsay, 2003); TGR tiger (Slaght et al., 2005); PMA puma (Wack, 2003); LPD leopard (Wack, 2003); JAG jaguar (Wack, 2003); LON lion (Wack, 2003); STHA striped hyena (Monchot and Mashkour, 2010).

Polar, brown/grizzly, and black bears in North America are among the largest carnivores in the world and would therefore be expected to have an extreme predatory relationship with dogs. However, reports of dog killing by bears are rare, which is consistent with brown/grizzly and black bears' more omnivorous ecology and the specialization of polar bears as predators of marine mammals, plus their very low levels of sympatry with dogs. Consequently we have omitted these species, plus the Asiatic black bear, from our typology.

This analysis is highly simplified, since all wild carnivores considered have a wide range of body masses that may influence relationships with dogs under different circumstances. These body masses also ignore their immature life stages. Equally, dogs vary in size depending on their breed and age: adult Chihuahuas may only weigh 1–2 kg, while Bull Mastiffs can weigh 50–60 kg. Also, the social behavior and feeding strategy of wild carnivores may vary between and within species, influencing their ability to prey upon or dominate dogs. Furthermore, we have not included reptilian and avian carnivores, which could distort the influence of body mass. In spite of these shortcomings, the typology highlights two fundamental principles. First, carnivores that prey on dogs for food are most likely to be large felids, while those involved in competitive killing are most likely to be canids of a similar size to dogs. Second, a dog's risk of mortality during an intraguild interaction increases with the body mass of the carnivore, because it is more likely to be taken as prey (Figure 5.5).

5.3.2 Social dimensions

Since their domestication from wolves, dogs have become part of human society and culture, providing benefits including transport, companionship, livestock protection and herding, hunting aides, and a source of food. Dogs can be perceived to

have crossed the barrier between animality and humanity, but their status varies widely between and within cultures (Serpell, 1995). In Western occidental cultures, dogs are often referred to as 'man's best friend.' They can be given human names, which contribute to their individuality and personality in anthropomorphic terms (Haraway, 2003; Sanders, 2003). In addition, they contribute significantly to human wellbeing (Hart, 1995; Wells, 2007, 2009).

Beyond cultural differences, it appears in several countries that the number of dogs owned is correlated with socio-economic status and livelihood profile. Hence, in Tanzania, wealthier and better educated households tended to own more dogs, and rural households keeping livestock were also most likely to own dogs (Knobel et al., 2008). A similar correlation is evident in more developed countries such as the United Kingdom (Westgarth et al., 2007). Furthermore, an owners' investment in dog husbandry and health may increase with socio-economic status. In Zimbabwe, dog condition score, frequency of rabies vaccination, and rates of neutering were correlated with indicators of rural households' affluence (Butler, 1995, 1998).

Generalizing these dog–human relationships assists in anticipating the impacts that predation on dogs by different wild carnivores could have on humans, and thus the potential for conflict. The Human Development Index (HDI) is commonly used to measure the standard of living amongst different nations, based on indicators of education, health, and per capita income (UNDP, 2011). Assuming that there is a correlation between HDI and the nature of a society's relationship with dogs, a logical parallel may be a notional 'dog development index' (DDI). Dogs with a high DDI typically have clear ownership, high levels of husbandry and selective breeding, and contribute significantly to their owners' wellbeing. These dogs have higher or similar economic value relative to other domestic animals, and their owners have disposable income to invest in their health, resulting in high life expectancy (Table 5.3). Examples of such animals include urban pet dogs or rural hunting, herding, and livestock guarding dogs in nations with a very high HDI, such as Norway, Australia, the United States, and Canada.

By contrast, dogs of low DDI have less clear ownership, limited or no selective breeding, and hence less direct benefit for their owners' wellbeing. They are of generally low economic value relative to other livestock, and consequently receive little investment in their health or husbandry, exacerbated by dog owners' limited financial resources—often resulting in unrestricted movements and breeding and low life expectancy—but retaining a high dependence on human-derived resources. Such dogs are typified by 'village' or 'neighborhood' dogs ubiquitous to many rural and suburban areas of countries with low HDIs such as Zimbabwe, Nepal, and Pakistan (Table 5.3). Feral dogs are by definition un-owned and therefore receive no investment in their husbandry, and may also have negative impacts as pests. These animals have been recorded in varying numbers in many different development contexts, such as rural Italy (Boitani and Ciucci, 1995; Boitani et al., 1995), the United States (Causey and Cude, 1980), Australia (Fleming et al., 2001), and suburban India (Oppenheimer and Oppenheimer, 1975). This emphasizes an important point that in any one nation a range of dog–human relationships may exist along a DDI continuum (Table 5.3), which is determined by local variations in socio-economic status and levels of human development.

Table 5.3 A continuum of dog–human relationships and relevant indicators, termed the Dog Development Index.

Indicator	Dog Development Index		
	High	Low	Feral
1. Owner's Human Development Index	High	Intermediate	None
2. Clarity of dog ownership	High	Low	None
3. Dog's selective breeding	High	Intermediate	None
4. Dog's contribution to owner's wellbeing	High	Low	None
5. Dog's economic value relative to other livestock	High	Low	None
6. Owner investment in dog's health and husbandry	High	Low	None
7. Dog's life expectancy	High	Intermediate	Low

5.3.3 Human impact

Combining the ecological and social dimensions presented above allows the characterization of the potential impacts of dog predation on human wellbeing and livelihoods (Figure 5.6). This suggests

an impact gradient ranging from neutral for feral dogs, to highly negative for dogs with high DDIs. Predation on 'village' dogs with low DDIs is of intermediate impact. However, there is a subtle distinction in impact along the intraguild predation continuum, with an increasing risk of mortality for dogs towards the predation extreme, which will potentially result in a greater human impact due to the death of the dog. Although competitive attacks can also result in lethal outcomes, there is a higher probability of dog survival from these interactions. Hence the greatest human impact is likely to occur where dogs with high DDIs are killed by felids and the largest canids as prey.

From the data reviewed and presented in this chapter it is also possible to identify the location of specific wild carnivores on the impact gradient, and the regions of the world where such interactions are most likely to occur. The zone of highest impact is North America, where pumas and wolves prey on hunting or working dogs in rural areas, or pet dogs in the suburban–wildlands interface. Tigers occupy a similar zone when they kill hunting and other dogs in rural Siberia. Wolves also have a widespread impact across Europe due to their broad range of ecological interactions with dogs, ranging from competitive killing to predation. Dingoes in Australia and coyotes in North America have a marginally less acute impact, often in the interface between suburban and rural or protected areas. By comparison, predation on dogs by lions, leopards, spotted and striped hyenas, and black-backed jackals in Africa is likely to generate lesser human impact, largely due to the low economic value of dogs relative to cattle and other livestock. The same is probable for rural or peri-urban areas of India and other parts of Asia (Figure 5.6).

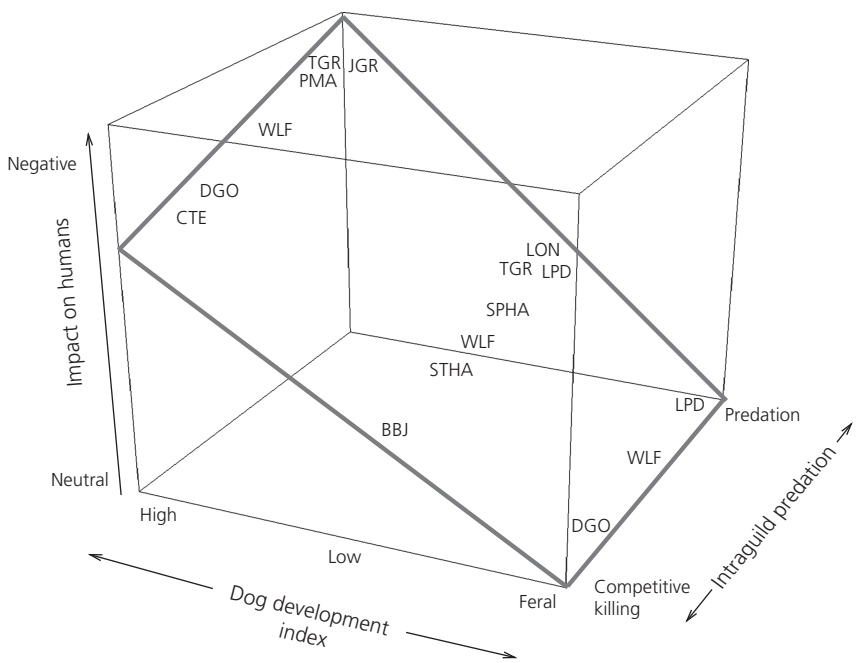

Figure 5.6 A hypothetical human impact gradient resulting from predation on dogs by wild mammalian carnivores in different ecological and social contexts. This combines the dimensions of intraguild predation (see Figure 5.5) and dog–human relationships (see Table 5.3). Note that negative impacts are greatest for predation on high dog development index dogs because the risk of mortality for dogs is higher than in competitive killing. Abbreviations are: BBJ black-backed jackal; DGO dingo; CTE coyote; WLF grey wolf; SPHA spotted hyena; TGR tiger; PMA puma; LPD leopard; JAG jaguar; LON lion; STHA striped hyena.

It is also possible to infer the positions on the impact gradient of these carnivores for other regions where they occur. For example, wolves and tigers in less economically developed regions of Asia (e.g., rural India) are likely to have an intermediate impact due to their predation on village dogs with low DDIs. Also, it is possible that wolf and leopard predation on feral dogs in Europe and Asia, respectively, and the killing or competitive exclusion of feral wild dogs by dingoes in Australia, may have a minor positive impact on humans given the pest status of these animals.

There is a third potentially important variable that may intensify the degree of negative human impact in any given context. Native habitat modification, and related to this the availability of natural prey, appears to drive an increased frequency of dog predation. For example, wolves in Europe are known to kill and consume more dogs when natural food availability is low, as do leopards in India. Related to this is the conflict that occurs along urban interfaces with surrounding forest or modified habitats, for example for pumas and coyotes in North America and dingoes in Australia. Seasonal or climatic factors may also influence the availability of natural prey where dogs and wild carnivores are sympatric. In Zimbabwe, dog predation by leopards, lions, and spotted hyenas escalated in the dry season in parallel with higher levels of livestock predation, perhaps due to a lack of vegetative cover that aided hunting wild prey. Drought also resulted in more extensive ranging by dogs away from homesteads and into the neighboring protected area, increasing their vulnerability to predation by wild carnivores. The availability of wild prey linked to seasonal migrations also influences temporal variations in livestock killing by large carnivores in Kenya (Kolowski and Holekamp, 2006), although this was less evident in Tanzania (Holmern et al., 2007).

5.4 Implications for wild carnivore conservation

5.4.1 Impacts on wild carnivores

To assess the implications of dog predation for wild carnivores and their conservation, it is important to analyze the potential impacts of dog predation on the carnivores themselves. While all mammalian carnivores considered in the intraguild typology (Figure 5.5) must benefit to some extent from the removal of potential competitors, levels of predation on dogs appear to be so low and infrequent that dogs are probably not a primary source of nutrition. However, an exception may be leopards in rural landscapes of India, where dogs clearly form a significant part of their diet, probably due to high dog densities and the relative scarcity of natural prey.

Potential negative impacts can therefore be considered to outweigh these limited benefits. The first route of impact is through direct retaliatory killing by local people. This may occur legally, for example the targeted poisoning of dingoes in Australia under legislation, or illegally through the indiscriminate hunting, snaring, or poisoning of large carnivores, for example the killing of spotted hyenas, leopards, and jackals in the Bale Mountains of Ethiopia (Atickem et al., 2010). Some carnivores may be targeted specifically for killing dogs (e.g., Amur tigers in Siberia; Goodrich et al., 2011), but in many cases retaliation is a reaction to livestock predation more generally (e.g., in Kenya; Kolowski and Holekamp, 2006), which in the case of the Maasai in Tanzania is enshrined within traditional lion-hunting ceremonies (Kissui, 2008). In a more benign form of retaliation, some 'problem animals' may be captured and translocated (e.g., Amur tigers; Goodrich, 2010; Goodrich and Miquelle, 2005), but this is more feasible in economically developed contexts where wildlife management is well resourced. Dog predation may also be such an emotive issue that it becomes a powerful argument against large carnivore conservation, particularly when there is also a threat of attacks on humans, for example in the case of wolf recovery programs in Finland (Bisi et al., 2007).

The second more indirect route is through the transmission of pathogens. Predation or agonistic interactions with dogs offer an ideal route of transmission for canid pathogens, such as rabies and canine distemper viruses, due to the opportunity for close contact or consumption of infective tissue (Butler et al., 2004; Knobel et al., Chapter 6). Dogs have been implicated as the reservoir hosts underpinning a canine distemper epidemic in 1994,

which caused widespread mortality of lions in the Serengeti, Africa (Roelke-Parker et al., 1996; Kock et al., 1998), and also underpinning canine distemper and rabies epizootics amongst the highly endangered African wild dog (Cleaveland et al., 2000). Spotted hyenas may play an important role as an intermediate host facilitating the spillover of pathogens from dogs to other wild carnivores in African ecosystems (Butler et al., 2004; Harrison et al., 2004). Similarly, Amur tigers are known to have been exposed to canine distemper virus, probably due to close contact with dogs (Goodrich et al., 2012; Quigley et al., 2010). However, the risk of mortality for carnivores preying upon dogs will vary according to the susceptibility of the species, and the health status of the dog population concerned. In general it can be assumed from our typology of dog–human relationships (Table 5.3) that dogs with a high DDI are likely to have higher levels of investment in their health and vaccination than 'village' dogs in contexts with lower HDIs, and feral dogs will have none. Hence, on a per capita basis, dogs with a low DDI and feral dogs pose the greatest risk of pathogen transmission to wild carnivores, but this will be determined by dog densities and hence contact rates with carnivores.

5.4.2 Potential human–carnivore conflict

By combining the human impact gradient (Figure 5.6) with these impacts on carnivores, it is possible to develop a 'heat map' of potential conflict and the nature of that conflict (Figure 5.7). Based on the evidence for species reviewed here, this suggests that there may be three broad types of conflict (Table 5.4). The first and most intense is 'Pet Predation,' where dogs of high DDI are taken as prey or through intraguild killing, and human retaliation results in the killing or translocation of problem animals and increased opposition to large carnivore conservation. However, the risk of pathogen transmission is relatively low given the generally healthy status of

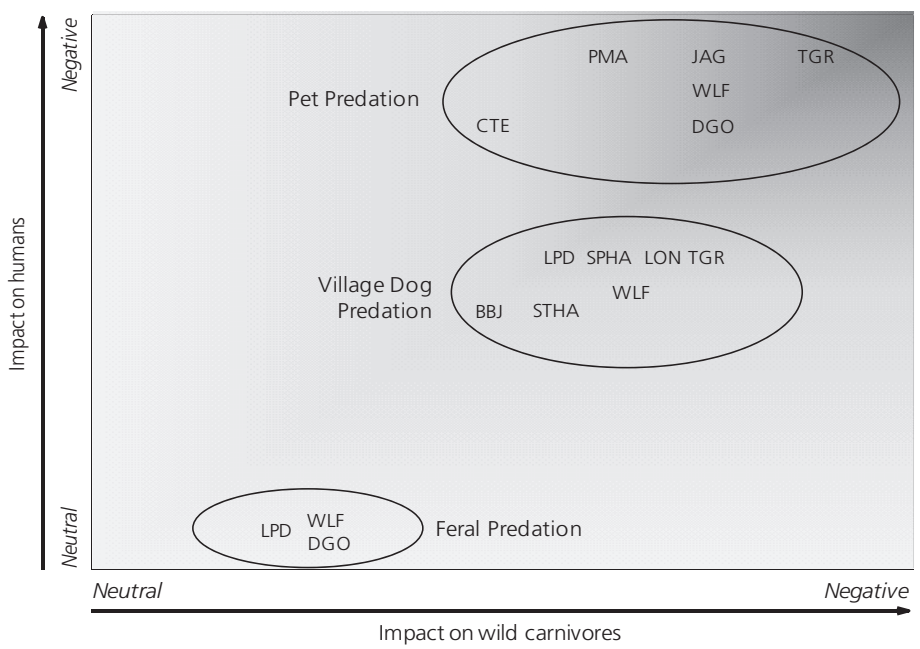

Figure 5.7 A 'heat map' of potential human–wild carnivore conflict as a result of predation on dogs by wild mammalian carnivores. The darker shading indicates greater potential for conflict. Based on the data reviewed, three types are identified: Pet Predation, Village Dog Predation, and Feral Predation. Abbreviations are: BBJ black-backed jackal; DGO dingo; CTE coyote; WLF grey wolf; SPHA spotted hyena; TGR tiger; PMA puma; LPD leopard; JAG jaguar; LON lion; STHA striped hyena.

Table 5.4 Features of the three types of human–wild carnivore conflict generated by predation on dogs (see Figure 5.7).

Predation type	Impact on humans	Impact on wild carnivores	Example and region
Pet	Loss or injury to few valuable pets and working dogs; high impacts on wellbeing and livelihoods; intensified by risk of carnivore attack on people and pets in peri-urban and modified landscapes.	Targeted retaliation, lethal and non-lethal, legal and illegal; decreased support for wild carnivore conservation; some pathogen transmission risk from dogs with lower dog development index.	Amur tiger: Asia (Siberia) Gray wolf: North America Dingo: Australia Puma: North America Coyote: North America
Village Dog	Dogs of low value relative to other livestock; largely in rural areas and on protected area boundaries.	Indiscriminate illegal retaliation against all large carnivores driven by livestock predation; high risk of patho gen transmission from all dogs.	Lion, leopard, spotted hyena: Africa Leopard, tiger, gray wolf: Asia Striped hyena: Africa and Asia
Feral	Dogs of no value or pest status; predation or competitive exclusion provides neutral or positive impact; limited by low dog densities.	No retaliation; high risk of pathogen transmission, mitigated by low densities of feral dogs.	Dingo: Australia Leopard: Asia (India) Gray wolf: Europe and Asia

dogs, although this will be dependent on the densities of dogs with poorer health status. The most extreme example of this is for Amur tigers in Siberia, where hunting dogs are preyed upon regularly and represent a large proportion of livestock kills, resulting in targeted retaliatory killing by local communities and some disease risk from canine distemper. Slightly less intense are situations involving wolves in Europe and North America and dingoes in Australia, which may kill dogs but with less frequency than do Amur tigers. Conflict is also generated by unease amongst communities about the risk of predation on people, combined with their impacts on other livestock, resulting in targeted killing. Puma and coyote predation may have similar human impacts to those of tigers, dingoes, and wolves, but threats of retaliation may be less.

By comparison 'Village Dog Predation' may result in similar levels of carnivore impact, but a lesser degree of human impact due to the generally lower value of dogs, which mitigates the loss of animals. In this type, the per capita risk of pathogen transmission is high, and human retaliation often stems from the cumulative impact of livestock predation, rather than on dogs specifically, and tends to be indiscriminate resulting in a more diffuse impact. Examples include interactions between communities and their dogs with lions, spotted and striped hyenas and jackals in Africa, and leopards and striped hyenas in Asia. 'Feral Predation' occurs where feral dogs of minimal value or pest status are taken as prey or through intraguild killing, and there are neutral or even positive human impacts. Given the limited abundance of feral dogs relative to dogs of higher DDI, the potential for conflict is much reduced (Table 5.4).

Clearly this model is highly generalized, and limited by the paucity of data and case studies of interactions between wild carnivores and dogs. Furthermore, the response of local communities to wild carnivore predation on livestock is likely to vary even between individuals depending on their education, age, and ethnicity (e.g., Marchini and Macdonald, 2012; Thorn et al., 2012). In addition, local responses will be countered or modified by the wider institutional and stakeholder setting, resulting in different outcomes for the same wild carnivore in different locations within its geographical distribution. The specific conservation status of the carnivore concerned will also influence this context. There may also be other locally-specific issues that will influence the nature of the conflict, such as the presence of wolves that specialize in attacking dogs (e.g., Kojola et al., 2004), or reintroduction or recovery programs that instigate wider social conflict (e.g., Skogen et al., 2006).

5.5 Conclusions

Due to the unique relationship between dogs and humans, the study of dog predation requires analysis of both ecological and social dimensions. Our

review shows that, in spite of the importance of understanding this relationship for human wellbeing, livelihoods, and wild carnivore conservation, there is only limited scientific data available. Because of the rarity of the events there are likely to be many challenges to studying them in a systematic manner. Yet there appears to be ample anecdotal information and knowledge amongst researchers, managers, and local experts which show that predation of dogs by wild carnivores is widespread, and the impacts for humans and wild carnivores are varied but often considerable. Given the rapid growth of global human and dog populations, and hence the increasing fragmentation of natural habitats and 'hard edges' between modified and wild environments, the potential for conflict between dogs and wild carnivores can only escalate.

Therefore our review represents a useful starting point for characterizing the nature of these conflicts, and the underlying ecological and social determinants. Utilizing this framework it is possible to design and prioritize appropriate responses, although we acknowledge that there will be context-specific issues that our general models have overlooked. For example, it is clear that within the 'Pet Predation' typology the high value of dogs significantly intensifies the potential for conflict. Consequently, in some cases the only option for reconciling conflict may be to ban dogs altogether, as has been proposed in the Wet Tropics of Australia (D. Morrant, unpublished data). Under the Village Dog Predation typology dogs are of lesser importance relative to other livestock, but pose a greater direct threat to carnivores because of pathogen transmission risk, facilitated by their vulnerability to predation due to their free-ranging, solitary behavior. Clearly, linked improvements in both dog and livestock husbandry are a key to mitigating these risks.

Finally, with socio-economic development, human–dog relationships typical of countries or regions with lower HDIs (and therefore DDIs) are likely to shift towards those that are characteristic of higher HDIs. Hence, in developing and urbanizing regions of the world, the nature of wild carnivore conflict resulting from dog predation may further intensify, amplified by the likelihood that with increased socio-economic status people will own more dogs per capita, and livestock-owning households in particular, and exacerbated by the contraction of carnivore habitat and related availability of wild prey. Our review provides a hypothetical framework that can project the likely characteristics of such future conflict. However, it requires further development, testing, and improvement through more targeted research into the social-ecological systems and typologies presented here.

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