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Towards Human–Wildlife Coexistence through the Integration of Human and Natural Systems

The Case of Grey Wolves in the Rocky Mountains, USA

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Increasing evidence indicates we face the sixth mass extinction – an extinction largely the result of human activities (Barnosky et al. 2011). The disappearance of wildlife and their habitats has far-reaching consequences on humans, including the degradation of life-sustaining ecosystem services such as the availability of medicines, control of pests and diseases and provision of clean water and air (De Groot et al. 2002). In addition to services, the biosphere also provides *assets* that benefit both society and the natural resources that sustain humankind (Obst et al. 2016). For example, healthy predator populations provide regulation of prey populations that otherwise can overpopulate. Insomuch as wildlife is significantly attributed with aesthetic, cultural, religious, economic and educational values (Manfredo et al. 2009; Carter et al. 2012), their loss also arguably diminishes humans' quality of life. The well-being of humans and wildlife is thus inextricably linked, necessitating the integration of social and natural sciences to understand human–wildlife interactions, and identify means of promoting coexistence (Liu et al. 2007; Carter et al. 2014).

Efforts to understand the interactions between human systems and natural systems increasingly employ a *social-ecological systems* or *human–environment systems* conceptual framework (Walker & Salt 2006; Folke et al. 2010). A social-ecological system (SES) can be defined as an *integrated system of ecosystems and human society with reciprocal feedback and interdependence* (Folke et al. 2010). Because social and ecological systems are interdependent, changes in one component can affect a variety of other components throughout the system, and human-induced changes

directed at a particular outcome (e.g. wildlife management) will almost assuredly have unintended consequences that may ripple throughout the system (Gunderson & Holling 2002). Proponents of systems approaches argue that SESs are characterized by complex, reciprocal – positive and negative – feedback loops spanning spatial, temporal and organizational scales (Liu et al. 2007). An SES approach rejects the idea that systems are characterized by a single state of equilibrium, and uses 'systems thinking . . . to bridge social and biophysical sciences' (Folke et al. 2010, p. 2). Systems thinking focuses on the linkages and interactions between the system components more so than on attributes of the components themselves.

Given their emphasis on complexity and interdisciplinarity, SES frameworks are ideal for understanding and characterizing the interactions among people, wildlife and the broader human and ecological communities. The general framework in Figure 18.1 illustrates the dynamic interplay between macroscopic properties (e.g. governance, ecosystem patterns) and individual actors (both humans and animals) capable of adapting to fluctuating conditions by changing behaviour, learning from experience or pursuing their own agendas (Levin et al. 2012). Individual humans and animals organize at different levels (e.g. groups, populations) and spatial scales (Figure 18.1), with those multiple dimensions interacting to influence the capacity for human societies

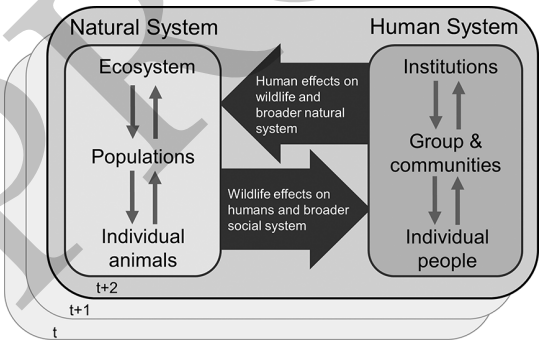

Figure 18.1 A highly simplified, general framework for understanding a social-ecological system (SES). The diagram indicates that individual animals interact with each other and the broader natural system; that individual humans interact with each other and the broader human system; and that the two systems feed back into each other at various spatial, temporal and organizational scales. The SES is at different states at different points in time (e.g. t, t+1, t+2). Based on the overall structure of this diagram, an SES of human–wolf interactions is elaborated in more detail in Figure 18.4.

and wildlife populations to coexist. For example, the behaviours and movements of individual animals can provide individual humans with tangible (e.g. wildlife-viewing opportunities) and other benefits (e.g. spiritual satisfaction), as well as be the source of a diversity of conflicts (Redpath et al. 2013). Those benefits (or costs) influence the shared interests and norms of human groups, which in turn can modify the policies and practices (e.g. through advocacy or litigation) we put in place to manage wildlife and their habitats.

Although a general framework is not well suited for identifying specific policy interventions for different contexts, it is useful for organizing relevant factors identified in theories and empirical research by biophysical and social scientists, and therefore provides a structure for synthesizing data for improving our understanding of human–wildlife interactions in an SES. It also reduces the likelihood that critical human–wildlife interactions are overlooked, which is important when considering that such missed interactions can lead to unanticipated effects, such as increases in illegal killing of wildlife or unexpected increases in livestock losses (Peebles et al. 2013; Chapron & Treves 2016) from large carnivores. Recent work used an SES framework, for example, to pinpoint how and why wildlife anti-poaching interventions differ in their efficacy (Carter et al. 2017).

18.1 SOCIAL-ECOLOGICAL SYSTEMS AND LARGE CARNIVORES

Large-bodied, terrestrial carnivores (hereafter, carnivores) are particularly sensitive to human activities both because of biological characteristics, such as low densities and slow reproductive rates, as well as social factors, such as policies that provide insufficient protection (Linnell et al. 2001) and legal hunting and illegal poaching (Packer et al. 2009; Liberg et al. 2011). Nevertheless, recent attempts to protect and recover carnivores in Europe and North America have resulted in population and range expansions for grey wolves (*Canis lupus*), brown bears (*Ursus arctos*) and other species (Smith & Bangs 2009; Eberhardt & Breiwick 2010; Chapron et al. 2014). These expansions, however, often place carnivores in increased proximity to human populations (Gehrt et al. 2010), prompting more frequent interactions between carnivores and humans, and potentially greater risks for both (Woodroffe 2000; Cardillo et al. 2004). Spatial and temporal overlaps between human and carnivore populations, coupled with continued human population growth, are likely to increase

pressure to minimize the negative impacts of carnivores, highlighting the need to uncover ways for people and carnivores to coexist in human-modified landscapes (Carter & Linnell 2016).

Although humans attribute carnivores with a range of beneficial values, including material and spiritual, interactions between humans and carnivores have historically been characterized by competition arising primarily from a common interest to eat wild and domestic ungulates. Human societies have responded to this competition by killing large carnivores, removing their habitat and depleting their food sources, resulting in local and regional extirpations of large carnivore species over the last century (Woodroffe 2000). However, we now know that the eradication of large carnivores from ecosystems can trigger trophic cascades that reduce biodiversity and other life-sustaining ecosystem services otherwise provided by healthy large carnivore populations (Crooks & Soulé 1999; Ripple et al. 2014). These reciprocal interactions indicate that human populations and ecological communities are fundamentally linked. Yet social and ecological studies on carnivores are typically conducted independently, constraining our ability to tackle many problems in carnivore management, such as habitat fragmentation and nuisance complaints (Carter et al. 2014).

In what follows, we draw upon existing evidence from one of the most studied populations of large carnivores – grey wolves in the Rocky Mountains, USA – to build a conceptual model of the interactions among humans, wolves and the broader systems upon which both species depend. We focus on wolves because they are a prime example of how human governance systems – through policy, management and individual action – influence where and at what densities carnivores persist, thereby regulating and limiting the impacts of carnivores on both human and ecological communities (Mech 2012; Muhly et al. 2013). The case of wolves illustrates how broad social and ecological forces can influence how humans live with these animals, and underscores the need for governance systems that can adapt to changing social and ecological conditions. For example, policies that protected grey wolves facilitated their expansion and population growth in eastern Washington, prompting actions by some ranchers and wildlife agencies to remove wolves in order to protect their livestock. Governance systems in these areas of wolf expansion need to adapt to address increasing human–wolf interactions and the controversies they create. Wolves are also the foci of many long-standing controversies due to their limiting effect on game species such as deer, moose (*Alces alces*), elk (*Cervus*

canadensis) and caribou (*Rangifer tarandus*). Thus, studying the multi-level, multiscalar interactions between humans and wolves will help provide insights on developing successful coexistence strategies in the Rocky Mountains. Moreover, because co-occurrence between people and wildlife is expected to increase globally, we contend that a social-ecological systems framework can better inform efforts to sustain and recover large carnivore populations while minimizing the negative impacts on human well-being.

18.2 WOLVES IN THE ROCKY MOUNTAINS

In the late nineteenth and early twentieth centuries, government-sponsored eradication programmes designed to protect livestock nearly eliminated wolves from the contiguous USA (Bergstrom et al. 2014). However, in the second half of the twentieth century, wolves became one of the first species listed under the federal Endangered Species Act (ESA) signifying a shift in policy from eradication towards conservation (Mech 1995). Following a reintroduction programme in the mid-1990s, northern Rocky Mountain wolf populations grew by approximately 19 per cent per year (1997–2010; Figure 18.2), and abundance expanded from 100 animals in 1995 to >1,800 in 2011 (Jimenez & Becker 2015).

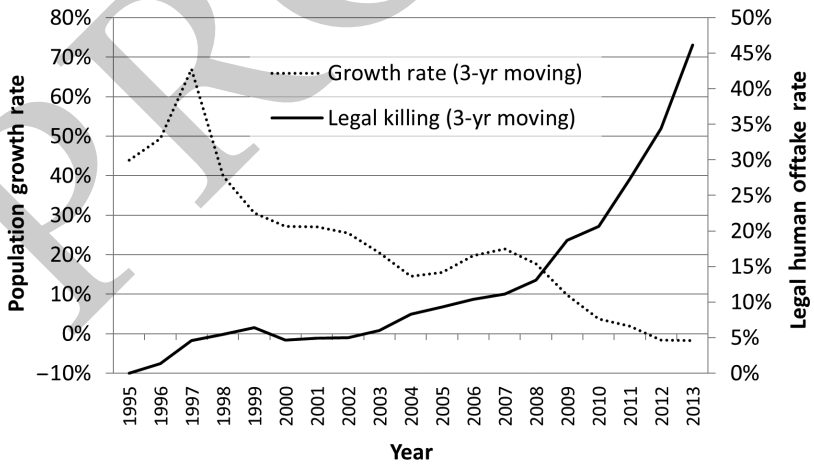

Figure 18.2 Grey wolf population growth rate and legal human offtake rate (legal harvest, plus lethal control) for the northern Rocky Mountain States of Idaho, Montana and Wyoming (1995–2013).
Data from United States Fish and Wildlife Service (UFWS).

Human communities experienced a range of benefits and risks associated with the growing wolf populations. For example, wolf-watching activities in Yellowstone National Park are estimated to bring $35 million annually to Idaho, Montana and Wyoming (Duffield et al. 2006). On the other hand, from 1989 to 2008, nearly 1,000 livestock depredations by wolves occurred in those same three states, and as a consequence 326 partial packs (2.2 wolves on average) and 48 full packs were lethally removed by wildlife agencies (Bradley et al. 2015). Although wolf depredation comprises a small fraction of total livestock mortality each year (Creel & Rotella 2010), in regions where livestock producers and wolf populations overlap, some individual livestock producers experience significant losses (Muhly & Musiani 2009).

The real and perceived risks from wolves can motivate some people to illegally kill them. Poaching is likely the single biggest cause of adult wolf mortality in the USA (Bangs & Shivik 2001; Treves et al. 2017). The heterogeneous distribution of costs and benefits from wolves to human society, and the consequences of these interactions on both natural and social systems, has contributed to a polarizing public discourse about wolf conservation and made it very difficult to develop non-controversial legislation. After a highly contentious process including numerous lawsuits, wolves in the American West were removed from federal protection several years ago (Bruskotter et al. 2014), and now some states allow legal hunting while others do not.

In its recent attempts to remove wolves from federal ESA protections, the USFWS acknowledged the importance of human behaviour towards wolves and the policy mechanisms that govern behaviour:

> . . . attitudes toward wolves is the main reason the wolf was listed under the [ESA] . . . [p]ublic hostility toward wolves led to the excessive human-caused mortality that extirpated the species from the [northern Rockies] . . . Because of the impact that public attitudes can have on wolf recovery, we are requiring adequate regulatory mechanisms to be in place that will balance negative attitudes toward wolves in the places necessary for recovery
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> (74 FR 15175)

In this brief passage, the USFWS argues that the successful conservation of wolves depends upon adequate *regulatory mechanisms* (i.e. public policy and enforcement) that limit human behaviours (i.e. both legal hunting and illegal poaching of wolves) that negatively impact wolf populations. In other words, the USFWS recognized that human communities, through their collective actions, substantively impact wolf

populations. Indeed, wolves were quickly and systematically eliminated in the Western USA (Riley et al. 2004), yet when policies shifted towards protection and restoration, the reintroduction and restoration of wolves to parts of the West proved successful, attesting to their ability to thrive with a sufficient prey base and under sufficiently low human-caused mortality (Smith et al. 2010). In contrast, despite an adequate prey base, legal (mostly control actions) and illegal killing of wolves has essentially prevented the species from occupying suitable habitat in Utah, eastern Wyoming, eastern Montana and western Colorado. Even in the northern Rockies, human killing of wolves from 2003 to 2010 rose sharply, and wolf populations stabilized or declined (Bruskotter et al. 2010, Figure 18.2).

Our history with wolves in the western USA demonstrates that government policies were largely effective both at eradicating and re-establishing wolves. It also serves to illustrate the ability of public policy to directly determine where wolves will be present and where they will remain absent. In this sense, public policy helped achieve legal restoration of wolves, but also prevents wolves from reaching ecologically functional densities in much of the contiguous USA. Moreover, because human and ecological communities are so tightly interconnected, seemingly unrelated policies may have unintended consequences for large carnivores, as well as other species. For example, under current federal policy large portions of federal public lands managed by the USA Forest Service and Bureau of Land Management allow grazing of domestic livestock, which places livestock in proximity to wolves, instigating conflicts (both real and perceived) that often result in the lethal removal of wolves (Thrower 2009). Removal of wolves, in turn, can impact wolf pack structure and behaviour (Brainerd & Andrén 2008; Borg & Brainerd 2015) and, under some conditions, might actually *increase* livestock depredation rates (Wielgus & Peebles 2014; Bradley et al. 2015; Treves et al. 2016). Lethal removal of wolves and other apex predators can also potentially result in increased populations of smaller mesopredators that are suppressed by top carnivores (Prugh et al. 2009). Similarly, regulated human hunting of wild ungulates can influence the abundance of wolves' primary prey (Vucetich et al. 2005), which, in turn, is likely to impact wolf populations and densities. Even water policy may impact the availability and quality of forage for both wild and domestic ungulates, thereby affecting wolves' use of habitat (for evidence, see Muhly et al. 2013). Land-use policies related to forestry, agriculture and the development of transport and energy infrastructure can also have dramatic

impacts on landscape structure and habitat quality. These examples illustrate how human policies and the behaviour they regulate can both directly and indirectly impact wolves and the ecological communities they inhabit. But what social and ecological mechanisms determine wolf management policy?

18.3 PEOPLE AND WOLVES: THE ROLE OF INDIVIDUAL BEHAVIOUR

Policies directed at carnivores are, in part, a function of broad socio-cultural forces (e.g. incentives, sanctions, shared knowledge/beliefs) that impact individuals' attitudes and behaviour – that is, their *tolerance* for wolves (Bruskotter & Fulton 2012; Treves 2012). Though studies examining individual-level correlates of behaviour directed at wolves are few, research generally suggests perceptions of risks (or costs) and benefits associated with wolves and one's affect (or emotional) reaction towards wolves explain the majority of variance across a suite of politically relevant behaviour (Slagle et al. 2012).

Research in the fields of environmental and conservation psychology leads to the general expectation that the physical environment itself also shapes how people think and behave (Clayton & Myers 2009), which in turn, may affect public policy and political clashes over how wildlife populations are managed. We currently know very little about how wolf population dynamics and anthropocentric ecosystem changes affect human attitudes, behaviours and support for management policies. However, we expect that these conditions will impact how individuals perceive wolves, and we anticipate that how they respond behaviourally will be based, at least in part, on those perceptions (Slagle et al. 2012; Bruskotter & Wilson 2014). For example, decreases in wild ungulates may create conditions (e.g. reduced opportunity for harvesting ungulates) that impact hunters' attitudes and behaviour (Ericsson & Heberlein 2003); drought and other environmental disturbances may increase the perceived risks associated with wolves (if such disturbances increase stress on livestock or hunted ungulates, for example); spatial distribution and density of wolves relative to human communities may impact how wolves are collectively perceived (i.e. as novelty or nuisance, Ericsson & Heberlein 2003), all of which potentially heighten individuals' perceptions of risks associated with wolves, and lead people to advocate for (or take) actions intended to reduce wolf populations (e.g. sign petitions, attend legislative hearing or poach) (Slagle et al. 2012). In such cases, the management of wolves is

likely to focus on reducing negative interactions rather than on increasing positive interactions, which limits opportunities for achieving conservation-related goals (Frank 2016).

Though wolf–human interactions are often categorized as negative (i.e. as conflicts, risks or impacts), this characterization discounts the fact that positive interactions also arise from the presence of wolves, such as increased viewing opportunities, tourism, spiritual happiness or satisfaction, and other psychological benefits. Additional positive outcomes include limiting the abundance of ungulates with populations so large they cause significant damage to human property, as well as reducing disease transmission, and providing a number of other ecological services (Ripple et al. 2014; Gilbert et al. 2016). The perceived potential beneficial impacts of wolves on human communities (e.g. their symbolic value and the value of their ecological services) were used to justify wolf restoration, and continue to be used as justification for wolf preservation (Duffield et al. 2008; Mech 2012).

The picture that emerges from this brief summary is one of a reciprocal relationship, whereby carnivore populations under various environmental conditions impact humans and their perceptions, which, in turn, affect human actions towards the species – including the policies we put in place to manage carnivores. Reciprocal relationships are central features of social-ecological systems (Figure 18.1) as well as a fundamental concept in ecology: density regulation within and between species which also includes trophic cascade effects such as mesopredator release. Importantly, the relationships between ecological conditions, human perceptions and public policy are likely to be moderated by a variety of factors. For example, perceptions may be influenced by the social or interest groups one belongs to (Lute et al. 2014); likewise, the relationship between perception and public policy is likely to be impacted by the level of influence that individual actors and special interest groups have with policy-makers. For example, in the western USA, hunting and agricultural interest groups have long held disproportionate influence with state wildlife management agencies (Nie 2004). Such influence mediates the influence of individual perceptions on public policy.

18.4 ECOLOGICAL IMPACTS OF WOLVES AND PEOPLE: WHO IS THE TOP CARNIVORE?

Wolf reintroduction to Yellowstone and central Idaho created an opportunity to study the direct and indirect effects of predation in an ecological

system where human presence is minimal. One question of some importance is: how do wolves impact populations of their prey? Temporal (but not spatial) correlational data show a strong negative association between wolf abundance and elk abundance in the Northern Range of Yellowstone National Park (Peterson et al. 2014). In addition, when wolves were absent from Yellowstone, growing elk populations degraded plant communities and required additional human intervention (in the form of mass culls and increased human hunting). From this one might infer causation; however, such inference is too simplistic. Indeed, evidence suggests that hunter harvest of elk and natural fluctuations in climate provide a better explanation of changes in elk density across the Northern Range (Vucetich et al. 2005). In other words, changes in the densities of wolf prey species can be influenced by a variety of factors – predator abundance, abiotic factors (such as climate), human-caused mortality, disease and potentially competitors like bison (*Bison bison*).

The extent to which wolves and other top carnivores indirectly impact ecological communities is the subject of intense debate among ecologists (Peterson et al. 2014). There appears to be general consensus that top carnivores precipitate a variety of effects on ecological communities (e.g. mesopredator release or vegetative response to reduced herbivore densities; Estes et al. 2011). However, such effects are likely to be conditional – that is, to depend on other factors (Peterson et al. 2014), including human-caused mortality. Indeed, where wolf populations are held artificially low by high rates of human hunting (legal and illegal), we should not expect wolves to have strong direct effects on ungulate populations nor strong indirect ecological effects (Mech 2012). Consequently, we would expect the indirect effects of wolves on lower trophic levels (i.e. trophic cascades), such as vegetation, to be geographically limited to those regions where humans allow wolves to attain ecologically functional densities (Mech 2012), such as protected areas. However, whether wolves are exerting a strong indirect effect on lower trophic levels is very difficult to detect. In part this is because their effect on lower trophic levels may shift over time in a single region, due to dynamic changes in both biotic and abiotic factors, making the attribution of causation extremely difficult. However, the fact that indirect effects of wolves (and other carnivores) might be negligible or difficult to detect under some circumstances does not significantly influence most arguments in favour of wolf presence in the landscape.

Our collective experience with wolves in the western USA reveals that even in some of the wildest parts of North America – places where

human population densities are extremely low and human impact on ecological systems appears minimal – human communities and the policies we enact have both direct and indirect impacts on carnivores and the ecological communities they occupy. Viewed from this perspective, the ecological effects proximately associated with large carnivores are *ultimately* determined by human communities, our collective tolerance for these species and the policies we put in place to manage and conserve them. Because these ecological effects are closely tied to human communities, in the following section we describe some broad-scale social and economic forces that appear to be fundamentally changing how human communities interact with and perceive large carnivores, like wolves, and consequently how we manage them. The effects of these forces are felt across the American West and also other large regions occupied by both people and wolves, such as in Europe (Chapron et al. 2014). Exploring the effects of these social and economic forces enables us to anticipate likely future scenarios of human–wolf interactions.

18.5 SOCIAL AND ECONOMIC FORCES SHAPING HUMAN–WOLF INTERACTIONS

Previously, we have discussed interactions between humans and wolves at relatively fine degrees of resolution on both spatial and temporal scales. However, it is important to note that the socio-economic and biophysical conditions underlying those interactions have gradually changed over the last few decades, with implications for understanding future patterns of human–wolf interactions. One such major change involves economic modernization, which is fundamentally altering how human societies perceive and behave towards wildlife generally, and carnivores, specifically (Bruskotter et al. 2017; Chapter 1). Research indicates that economic modernization is driving a shift in societal values from survival-based, *materialist* values towards those that emphasize self-expression or *post-materialism* (Inglehart & Welzel 2005). Accordingly, one way modernization may affect perceptions of wolves is by promoting more egalitarian or *mutualist* value orientations in which nature and wildlife are viewed as an important part of individuals' moral communities rather than *domination* value orientations, which are expressed in human actions that attempt to subdue nature and put natural resources to instrumental human uses (Figure 18.3; Manfredo et al. 2009, 2016; Teel & Manfredo 2010; Chapter 2). Manfredo et al.

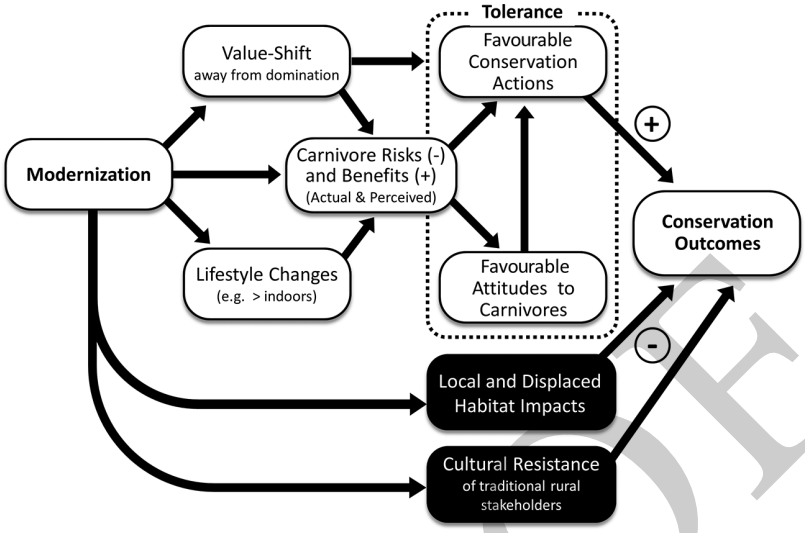

Figure 18.3 Conceptual model outlining how modernization can impact the conservation of large carnivores. Arrows represent proposed causal influences. Figure adapted from Bruskotter et al. (2017).

(2009) found that modernization forces (i.e. urbanization, increasing affluence, education) explained much of the geographic variation in wildlife value orientations across states in the western USA. For example, in the northern Rocky Mountain States of Idaho, Montana and Wyoming, the percentage of respondents with a domination value orientation ranged from 43.8 per cent to 48.6 per cent compared to the 17.9–18.9 per cent of respondents who expressed a mutualist value orientation. In contrast, the percentages of respondents in nearby Washington and Oregon with domination or mutualist value orientations were approximately equal (~33–37 per cent). Value orientations, in turn, were strongly correlated with people's judgements regarding the trade-offs between wildlife protection and human interests (Dietsch et al. 2016; Manfredo et al. 2016), including judgements about carnivores (Dietsch et al. 2016). For example, respondents in Idaho classified as having a domination value orientation were more likely to accept a *reduction in the number of wolves to produce more elk and deer for hunting* than those respondents with a mutualist value orientation (Teel & Manfredo 2010). The high human population growth rate in the Intermountain West region, with many of the in-migrants from other regions

throughout the USA (Hansen et al. 2002), is likely facilitating changes in the wildlife value orientations of people in the region.

In addition to having an impact on value orientations, modernization might act to physically separate human populations from wolves, ultimately reducing risks associated with these animals (Figure 18.3; Bruskotter et al. 2017). For example, by moving jobs and people out of rural areas into cities, agricultural mechanization reduces the risks associated with wolves at a societal level, although livestock losses to wolves can still be quite significant at local levels or on specific ranches (Muhly & Musiani 2009). Furthermore, modernization is associated with technological innovation and the subsequent proliferation of modern technological conveniences (e.g. air-conditioning, passenger cars, electricity, internet) that serve to promote indoor professions and lifestyles, which can further reduce the risks associated with wolves. Recent work has found that variation among nations in large carnivore conservation outcomes was related to modernization forces believed to reduce the risks associated with large carnivores (Bruskotter et al. 2017). However, some aspects of modernization (e.g. increased affluence, habitat modification) have long been viewed as important drivers of biodiversity loss and species endangerment (Czech et al. 2000). Certainly growth of urban areas, the expansion of subdivisions and the proliferation of transport, energy and recreational infrastructure contributes to habitat loss and fragmentation (Woodroffe 2000). Furthermore, the relationships between modernization and value orientations or behaviours towards carnivores are likely heterogeneous over broad geographic areas. For example, in contrast to our example in the American West, some cultures in India and Mongolia apparently have traditional rural attitudes that are more tolerant of carnivores than the emerging modern attitudes (Athreya et al. 2013).

Societal values do not change uniformly across societies. While the majority of the urban populations in the USA appears to increasingly embrace mutualistic and post-materialistic values, more traditional materialist values are retained among some – especially those in rural communities. These communities are associated with the activities (agriculture, ranching, hunting, rural lives) that potentially face the greatest costs of wolf conservation. All of these changes might drive cultural resistance to outside influences, such as nature-protective policies, and lead to intergroup conflict in human communities by associated social and economic changes (e.g. increasing unemployment in certain areas and sectors) that impact livelihoods, and ultimately, human well-being (Nie 2001; Skogen et al. 2017).

Wolves can be an important symbol of outside influences, which can motivate interested groups to respond in dramatically different ways (Bruskotter et al. 2009; Lute et al. 2014). According to social identity theory, intergroup conflict is driven, in large part, when out-group members take actions that threaten the identity of in-group members (Tajfel & Turner 1979; Tajfel 1982). Broad social changes due to economic modernization might aggravate intergroup conflict, with group members adopting prototypical attitudes and beliefs reinforced through interactions with in- and out-group members (Schneider 2004). Those who strongly identify with groups and regularly interact with in-group members are likely to express different views about the wolf-related risks and benefits to those who identify with *outside* groups. Indeed, tensions over impositions from external groups have exacerbated conflicts over wolves in the United States, as farmers and ranchers feel that the animals are imposed upon them by remote, urban governments and elites unconcerned with the costs incurred by farming communities. In Yellowstone National Park, wolf reintroduction was seen by some rural communities as the controlling, domineering, intrusive federal government overriding the freedom and self-determination of local people (Scarce 1998), and exerting external control over people's private property (Wilson 1997). Wolf-related impacts and human–human conflicts over wolf management can lead to illegal killing of wolves, lawsuits, ballot initiatives and political action to weaken conservation goals in general (Nie 2003; Treves et al. 2016; Carter et al. 2017). By accounting for the various effects of broad social and economic forces on human–wolf interactions as well as the dynamic feedbacks between humans and wolves (Figure 18.4), managers can tailor actions that best accommodate the priorities and goals of a diverse constituency including in those areas where wolves are expected to expand in the future.

18.6 NAVIGATING THE CHALLENGES OF WOLF MANAGEMENT

The political landscape for wolves is in a near-constant flux and defies simple solutions and sustainable outcomes. Although many factors affect wolf policy development (Clark et al. 1996; Primm & Clark 1996), a social-ecological systems framework can be a useful heuristic tool for identifying key levers at the individual, group and societal levels (Figure 18.4) that influence, and are influenced by, decision-making

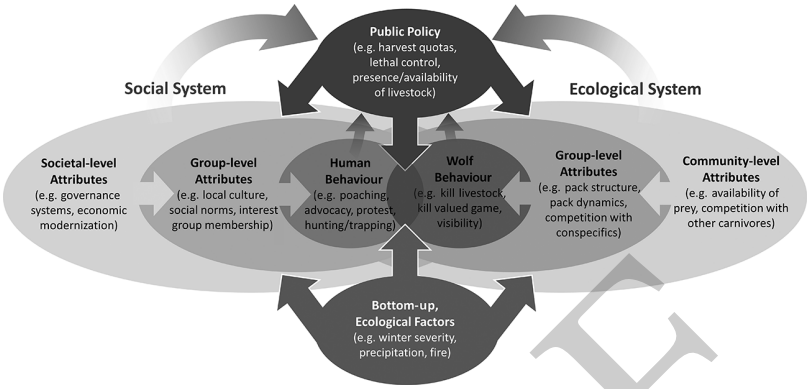

Figure 18.4 A depiction of the social-ecological system of human–wolf interactions in the Northern Rockies, USA. Although not shown here, it is also important to note that behaviours of individual humans and wolves are related to individual-level attributes. For humans, these can include attitudes, emotions, perceived risk, social identity and social trust. For wolves, these can include size, age, health and sex. For the sake of simplicity, other important model actors (i.e. livestock, wild ungulates) and interactions (e.g. human modification of ecological factors) are not depicted in this model.

about wildlife, such as wolves. In the following, we provide a brief and non-exhaustive treatment of some of these levers.

One lever that strongly affects how carnivore conservation policies and practices are created and implemented is political power within governance systems (Clark & Rutherford 2014; Lute & Gore 2014). Configurations of power, wealth and culture in the organizations charged with carnivore management can lead to considerable partiality for a relatively narrow set of special interests (Mattson 2014). To counterbalance the disproportionate effects of a narrow set of special interests, some authors suggest that different degrees of power over various species or resources should lie at different hierarchical levels of government depending on their ecological, social and economic characteristics (Linnell 2015). For example, overall conservation goals could be defined at the national level, while state and local actors are empowered to develop specific, locally adapted policies and practices that are constrained by those broader-level goals and limitations (Redpath et al. 2017). This model is not unlike the model of the ESA, in which federal scientists determine the recovery goals and work with state or local interests to achieve those goals. However, setting overall goals for wolf conservation at regional or national scales, especially in situations where

costs are disproportionately borne at the local scale, will often be controversial (Skogen et al. 2017). Indeed, as noted earlier, the extent to which voters in urban areas are seen as dictating wolf policy in rural communities has been a consistent source of tension in the greater Yellowstone region (Wilson 1997; Nie 2001).

On the other hand, in the USA, state wildlife management agencies receive substantial funding from fees and excise taxes paid by consumptive users (i.e. hunters, trappers, gun owners; Williams 2010) and therefore may be more likely to implement wolf policies that maximize benefits (hunting opportunities) for those users rather than for those of non-consumptive users (i.e. wildlife tourists). For that reason, some authors suggest creating opportunities for both consumptive and non-consumptive users of wolves to meaningfully participate in, and fund, wildlife management programmes, as doing so may lead to greater compromise at local and regional levels (Olson et al. 2015). For example, the state of Montana considered issuing a wolf stamp that would have been available for purchase to anyone, and used to fund non-lethal management of wolves – this would have empowered non-consumptive users to help fund wolf conservation efforts aimed at reducing conflicts. However, successful examples of these types of initiatives appear to be rare as illustrated by *Teaming with Wildlife*, a failed initiative started in the 1990s that proposed taxing outdoor recreational equipment to support non-game species conservation (Spidalieri 2012).

Balancing these disparate priorities among stakeholder groups is a major challenge for management agencies, particularly as stakeholder values change and diversify (Smith et al. 2016). The field of conflict resolution (management) offers useful insights on how to reconcile differences among people (Maser & Pollio 2011). Practitioners advocate the use of deliberative, participatory processes (e.g. collaborative learning, structured decision-making), which assist stakeholders in separating empirical premises (and supporting factual information) from values (desired outcomes). These processes also facilitate joint exploration of consequences of different actions (Maxwell et al. 2015). Participatory processes, characterized by bottom-up representation and legitimization, have also proven successful at negotiating outcomes that are viewed as acceptable, although they work best at small local levels (Daniels & Walker 2001; Young et al. 2013), and there is still a long way to go to fully understand when, and how, they bring benefits (López-Bao et al. 2017; Sterling et al. 2017). Ensuring that participatory processes improve decision-making necessitates that information flows across

management levels (e.g. local to national and vice versa), between sectors and that some form of upward and downward accountability exists (Linnell 2015).

Facilitating information exchange, however, does not resolve the issue that occurs when wildlife management priorities differ across jurisdictions. This challenge becomes especially relevant when wildlife, especially wolves, cross jurisdictional boundaries between agencies or states (Smith et al. 2016). For example, wolves are subjected to high levels of hunting immediately upon leaving Yellowstone National Park, where they are protected, to follow prey species that migrate outside the park in the autumn. This high mortality pressure affects pack structure and wolf populations inside the park and conflicts with the mission of the National Park Service of maintaining *naturalness* and providing non-consumptive benefits to park visitors. In such cases, recognizing and negotiating the different missions and management approaches of state and federal agencies, while considering the ecological scales within which wolves exist, are important steps in developing coordinated management across jurisdictions that mitigates public opposition. One suggested coordinated approach involves delineating a transition zone directly adjacent to Yellowstone National Park, to enable wolves from the park to temporarily migrate outside the park without being exposed to liberal harvests near the park boundary (Smith et al. 2016).

Even where mechanisms exist to coordinate management approaches across agencies, rapid social or environmental changes (e.g. disturbances such as fire), political volatility and uncertainties regarding anticipated social and ecological outcomes are likely to challenge agencies' capacity to adapt policies and practices. The adaptive capacity of institutions has been the focus of much research (Brown 2003). A full treatment of institutional fit is beyond the scope of this chapter, but we highlight one approach that is especially relevant to human–wolf coexistence: adaptive management. It focuses on understanding (through experimentation of different management actions) and responding (through iterative modification of strategies) to rapid and unpredictable changes in management contexts when systematic monitoring data are available (Keith et al. 2011). Adaptive management programmes can enhance institutional capacity to learn what drives human–carnivore impacts and human–human conflicts and adjust those policies and practices that may be ineffective. For example, adaptive management can also be applied to funding mechanisms whereby the cost-benefit ratio of wolf presence can be adjusted. This can enable

revenue from non-consumptive users, such as wolf-watching tourists, to supplement funding for non-lethal methods for deterring wolves from depredating livestock (Olson et al. 2015).

So far we have focused on those landscapes where humans and wolves are most likely to interact and implicitly assumed that the geographic boundaries of protected areas remain unchanged in the future. However, looking ahead to what habitat wolves need and prioritize protecting those areas would allow wolves to occupy the ecological niches they once filled, thereby providing various ecosystem services and benefits on a larger landscape. By giving wolves the space to roam, it would maintain the *wildness* of the western USA amid growing human pressures and simultaneously reduce the likelihood of negative interactions between humans and wolves in the future. Achieving this longer term, strategic vision would likely require innovative public-private institutional arrangements (see Chapter 8 and Chapter 14). For example, a form of adaptive co-management might be needed that provides incentives and enhanced shared learning across different levels of organization (e.g. private landowners, local organizations and federal agencies) and across geographic space (Armitage et al. 2009). In this case, the boundaries of the SES should be carefully re-delineated (e.g. to encompass a landscape extending beyond the Northern Rockies, USA) to sufficiently accommodate the different sets of human and non-human actors that might accrue benefits or costs from newly established wolf populations (Martín-López et al. 2017). This example highlights the importance of changing how we study human–wolf interactions to address the complex and dynamic challenges of wolf management across a gradient of human-influenced landscapes.

18.7 CHANGING HOW WE STUDY HUMAN–WOLF INTERACTIONS

Much can be gained by integrating the disparate fields of research related to wolves. For example, the inclusion of social science can help reveal how actor groups, social networks, governance structures, power relations or ethics limit or enhance coexistence between human societies and wolf populations. Likewise, social scientists can learn from the ecological sciences, for instance, by examining how ecological disturbances impact human attitudes and values. Viewing wolves and humans as fellow actors within an SES (Figure 18.4) dramatically alters how one thinks about the ecological effects that have become so controversial. For

example, viewing human populations as just another member of the ecological community changes the foci of the debate surrounding trophic cascades. Rather than attributing changes in the ecological community to wolves and other top carnivores, we are forced to step backwards along the causal chain and ask – *what factors affect wolf populations, and thereby determine if, when and where trophic cascades will take place*? The answer largely centres on human-induced wolf mortality – a mechanism that is itself highly regulated. Similar questions should be asked for the ways in which human activities directed towards habitat and prey will also modulate wolf-centric trophic cascades. This type of recognition does not challenge the traditional thinking of ecologists in the least; rather, it seeks to better frame humanity's role within the larger realm of ecological processes. Without such recognition, our fundamental understanding of such processes, and especially, our ability to predict when, where and under what conditions they will occur, will suffer.

Of course, analytically disentangling these interactions and feedbacks is a major challenge. For example, it may take several decades (or more) for ecological systems to reorganize after human intervention (Gunderson & Holling 2002); yet our political systems move much faster (e.g. every 2–4 years), challenging our ability to predict ecological dynamics, evaluate management actions and adapt our interventions to achieve desired results. Fortunately, tools that allow scientists to systematically link social and ecological systems are emerging. One example is quantitative models of SESs that incorporate both social and ecological mechanisms of change. Mechanistic models contrast with statistical models that optimize model parameters through the use of correlative data and dependencies between multiple factors which are usually not appropriate to extrapolate the results to unprecedented conditions (Stillman et al. 2015). Rather, mechanistic modelling uses first principles (e.g. animals seek to maximize individual fitness or humans seek to maximize individual utility or well-being) to construct equations and algorithms representing behaviours and interactions that provide the basis for understanding and predicting patterns of interest (Stillman et al. 2015). Mechanistic models have been used separately in the social and ecological sciences to help understand how and why systems change (Drechsler et al. 2007). For example, individual-based ecological models have incorporated adaptive animal-movement ecology in changing landscapes, and investigated wildlife population persistence as a bottom-up process emerging from individual variations and events (Grimm &

Railsback 2005). The models have thus been used to quantitatively examine critical habitats from the individual- to population-level (McLane et al. 2011). Furthermore, by representing different modes of human decision-making, agent-based models (similar in concept to individual-based ecological models) have become powerful tools in ecological economics, land-use science, political science and natural resource management (Filatova et al. 2013). However, despite their potential utility, mechanistic SES models for wildlife conservation are much less common. In part, this is because they require a great deal of social and ecological data that are compatible with each other (that is, collected at a comparable level across different scales) in order to represent real-world systems. For example, where wildlife research is generally spatially explicit, social science research is usually spatially implicit. Even those social science studies that do spatially represent their data (Teel & Manfredo 2010; Dietsch et al. 2016) do so at spatial scales (e.g. state or county boundaries) that do not match well with ecological data, such as individual animal movements that are not bounded by geopolitical borders, although some recent research is beginning to tackle these scale mismatches (Behr et al. 2017). Being one of the most-studied organisms in the world, the grey wolf is therefore an excellent candidate for which to construct an SES mechanistic model. Still, more information on the social system is urgently needed to fully parameterize such models.

Another challenge to understanding human–wolf interactions is the uncertainty associated with our knowledge of social and ecological processes and how policies might affect those processes. When unaccounted or inadequately communicated, uncertainties can lead to inappropriate expectations in the public about the benefits and costs of wildlife, detrimentally affect wildlife populations and in general diminish the efficacy of governance structures. For example, recent studies are calling attention to the uncertainties surrounding legal and illegal hunting rates of wolves, and demonstrate the significant implications these unaccounted uncertainties have on wolf populations and management goals (Creel et al. 2015; Treves et al. 2017). A number of approaches (e.g. integrated assessment models, optimization algorithms and multicriteria decision analysis tools) now exist to systematically account for uncertainties in environmental decision-making (Ascough et al. 2008). One such approach is management strategy evaluation (MSE), a relatively recent method for systematically assessing multiple outcomes of different strategies. MSE uses simulation models to test the

future effects of alternative management procedures on species population dynamics (Milner-Gulland et al. 2010; Bunnefeld et al. 2011). Unlike other modelling approaches, MSE incorporates various forms of uncertainty, including process, measurement and structural uncertainty (e.g. resource user compliance with regulations). By engaging different stakeholder groups, MSE can explicitly include a range of realistic human behaviours in shared landscapes and facilitate knowledge exchange. Due to the transparency of the MSE approach, for example, previous studies have shown that it can significantly reduce the time and effort various stakeholder groups need to reach agreement on management decisions (Bunnefeld et al. 2011). For those reasons, MSE offers an exciting way to link research (e.g. from mechanistic SES models) and policy for wolf conservation in the dynamic landscapes of the American West.

18.8 RECOMMENDATIONS AND FUTURE DIRECTIONS

We list below some take-home messages that emerge when using an SES framework to understand and manage human–carnivore interactions, like those between humans and wolves in the Northern Rockies of the United States.

- Viewing carnivores and humans as interdependent fellow actors within an SES is useful for understanding the causes and consequences of ecosystem change, and identifying sources of human–wildlife conflicts. A good starting point for doing so is to evaluate how gradients of anthropogenic landscapes and activities (e.g. livestock grazing, hunting and policies and practices governing these activities) affect the populations and functional roles of large carnivores, like wolves, at various scales.
- Whether coexistence can be achieved (or what coexistence might look like), however, rests not only on the biophysical capacity of a landscape to be shared by humans and wildlife, but also on the capacity for human societies to adjust to and accept some level of conflict with carnivores (Carter & Linnell 2016; Frank 2016). Human tolerance (and intolerance) for carnivores is a function not only of human perception, but also social norms and structures, all of which are undergoing changes due to broad social and economic forces, such as modernization. Increasing our knowledge of how this broad suite of

human factors interacts to regulate human–carnivore coexistence remains an important challenge to sustainably sharing landscapes.

- Because both social and ecological factors shape policy towards carnivores, an SES perspective can highlight ways to navigate the polarizing and challenging issues surrounding carnivore management. In particular, an SES approach could assist in identifying the underlying mechanisms exacerbating human–human conflict over carnivore management, and ways to ameliorate these conflicts, such as through participatory processes or redistribution of costs and benefits between stakeholder groups.
- A large carnivore–human SES is data-rich and could form the basis for successful conservation strategies and outcomes using adaptive management procedures focused on coexistence.
- Through continuing integration of social and ecological sciences and use of ever-advancing computational tools, more and more insights will emerge that help stakeholders and decision-makers maximize positive interactions between humans and carnivores, while minimizing the negative impacts. Maximizing positive interactions will foster a shift towards the neutral to positive side of the conflict-to-coexistence continuum.

The increasing human footprint on planet Earth necessitates a more holistic view of ecological systems – one that explicitly incorporates, rather than ignores, human actors. An important step in learning to live with carnivores is the recognition that even in places where the human footprint is as light as in Yellowstone National Park, carnivores are fundamentally and importantly impacted by people. In a geological epoch dominated by human impacts (the Anthropocene), carnivore persistence is likely to depend upon our ability to coexist with these animals in landscapes altered, and managed, by people. It is time for ecology to recognize and embrace humans, our social systems and institutions as key actors and attributes of ecological systems. Doing so will help reframe human–carnivore interactions from conflict to coexistence.

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