



Social and Cultural Dynamics of Non-native Invasive Species

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12.1 Introduction

Invasive species and their management represent a complex issue spanning social and ecological systems. Invasive species present existing and potential threats to the nature of ecosystems and the products and services that people receive from them. Humans can both cause and address problems through their complex interactions with ecosystems. Yet, public awareness of invasive species and their impact is highly uneven, and public support for management and control of invasive species can be variable. Public perceptions often differ markedly from the perspectives of concerned scientists, and perceptions and support for management are influenced by a wide range of social and ecological values.

In this chapter, we present a broad survey of social science research across a diversity of ecosystems and stakeholders in order to provide a foundation for understanding the social and cultural dimensions of invasive species and plan more effective management approaches. This chapter also addresses tribal perspectives on invasive species, including traditional ecological knowledge, unique cultural dimensions for tribes, and issues critical to engaging tribes as partners and leaders in invasive species management. Recognizing that natural resource managers often seek to change people's perceptions and behaviors, we present and discuss some promising approaches that are being used to engage human communities in ways that empower and enlist stakeholders as partners in management.

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Humans are a fundamental component of invasive species issues (McNeely 2011). People have long transported species across biogeographic boundaries, both accidentally and intentionally, and this has increased with globalization of the economy and society (McNeely 2011). Humans modify landscapes in ways that precipitate, facilitate, and exacerbate invasions (Rotherham and Lambert 2011). As a result, non-native species, some of which are invasive, are deeply woven into the fabric of modern life (McNeely 2011). Yet, public awareness and knowledge of invasive species remain low even where they are a significant ecological threat (see, for example, Dodds et al. 2014). Only a few invasive species with significant economic and cultural impacts have garnered broad levels of public concern and widespread management attention across different ownership types at the landscape level (Keller et al. 2015; McNeely 2001, 2011; Mooney and Hobbs 2000). Management actions themselves can cause public reactions and objections for a variety of reasons ranging from lack of public acceptance of chemical control methods, to animal rights issues, objections to costs, and cultural preferences for invasive species themselves (McNeely 2011).

Despite this strong human connection, invasive species are not often studied by social scientists, and the existing studies, which generally have examined the issue through particular disciplinary lenses, have produced a fragmented body of knowledge. Anthropologists, historians, and others have analyzed narratives and discourses about non-native species and the ways in which they have affected public opinion in general. Some researchers, using methods of social psychology, have explored the relationships among individuals' knowledge, attitudes, and personal behaviors related to invasive species. Studies of the impacts of educational programs have examined the effectiveness of efforts to raise awareness, increase knowledge, and motivate behavior change. Sociologists have offered insights into social norms regarding invasive species, and have addressed the collective action and institutional challenges that are required for communities and society to address invasive species management. Policy scientists help us understand how invasive species laws and regulations are formed and implemented by governmental bodies, and why environmental and industry groups respond as they do to invasive species management proposals. Ultimately, sustained and interdisciplinary efforts are required to generate the necessary social science understanding to address this issue.

12.2 Understanding the Human Dimensions

A growing community of researchers has recognized that managing invasive species is as much a social issue involving various human factors as it is an ecological or technical

issue (Bremner and Park 2007; Epanchin-Niell et al. 2010; Gobster 2011; Kueffer 2010; Reaser 2001). Invasive species impose huge conservation or economic costs on society (Pimentel et al. 2005; Wilcove et al. 1998). However, when citizens consider the full range of environmental risks, invasive species often do not rank very high. Slimak and Dietz (2006) surveyed members of the public as well as selected U.S. environmental professionals, asking them to rank 24 ecological risk items from climate change to hazardous wastes to sport hunting and fishing. Among the lay public, invasive species ranked 19th, just behind overgrazing and ahead of damming rivers but well below the greatest perceived risks: hazardous waste sites and persistent organic pesticides. Professional risk assessors ranked invasive species ninth, suggesting that beliefs about the threat of invasive species are highly influenced by knowledge and experience. Yet, while general public awareness and concern may be low, there clearly are locations where public interest and knowledge are greater. For example, a survey in Hawai'i found that 96% of respondents were aware of invasion by the coqui frog (*Eleutherodactylus* spp.), and 82% held negative views toward the frogs (Kalnicky 2012).

Geographically, more research has been conducted in Australia, New Zealand, and parts of Europe to assess public attitudes toward invasive species and potential management options using interviews, focus groups, and surveys (e.g., Bardsley and Edwards-Jones 2006; Barr et al. 2002; Bremner and Park 2007; Coates 2015; Fraser 2001; Fischer and van der Wal 2007; Fitzgerald et al. 2007; García-Llorente et al. 2008; Johnston and Marks 1997; Manchester and Bullock 2000; Meech 2005; Nimmo and Miller 2007; Selge et al. 2011; Shine 2015a, b; Veitch and Clout 2001). In contrast, fewer studies have been conducted in the United States to examine public perceptions and behaviors toward invasive species.

12.2.1 Broad Issues and Narratives

People view and relate to the general issue of invasive species in diverse and complicated ways that reflect their underlying values across a range of environmental and social issues. These underlying values, and the narratives in which they are situated, play an important role in shaping perceptions, attitudes, and responses to specific invasive species and their management. Understanding these general issues and the ways they are often discussed, which differ significantly from the ways scientists talk about invasive species, is important for scientists, managers, and policymakers, and can help them avoid major pitfalls, understand why stakeholders may hold different ideas and desires about invasive species and their management, identify mutually acceptable solutions, and determine how to encourage stakeholders to get more involved in control and prevention.

General Attitudes and Stakeholders Relatively few members of the public are likely to see non-native species as inherently problematic. As McNeely (2011) noted, human dietary needs worldwide are largely met by species introduced from elsewhere, and maintaining food production often requires the introduction of non-native species. Many non-native species, including some that are invasive or have deleterious ecosystem impacts, are beloved by people. The ring-necked pheasant (*Phasianus colchicus*), of Asian origin, is a popular upland game bird in the United States and has been adopted as the state bird of South Dakota (Coates 2006). Honeysuckle (*Lonicera* spp.), introduced as an ornamental, for erosion control, and to improve habitat for birds, is valued by gardeners and has been incorporated into Southern culture to the point where it is not widely recognized as a non-native species (Geier 2015; Luken and Thieret 1996; McNeely 2011). Kudzu (*Pueraria* spp.) presents a similar, if more complicated, story. Introduced as an ornamental to shade porches and courtyards, it was later used as inexpensive livestock forage on overgrazed pastures, and then promoted and distributed throughout the South for erosion control before being classified as a weed (Blaustein 2001). Over time, it seeped into Southern culture as “the vine that ate the South,” appearing in band names, logos, festivals, crafts (baskets), and poems at the same time that it triggered economic impacts costing millions of dollars (Blaustein 2001).

People have introduced plants and animals for food, economic gain, aesthetics, and to remind them of the past, and until recently, intentional introductions were generally viewed positively (Borowy 2011). Widespread environmental concern related to introduced species only surfaced in the United States in the 1990s, aside from a few particularly prolific and damaging invasive species such as the chestnut blight (caused by *Cryphonectria parasitica*), sea lamprey (*Petromyzon marinus*), kudzu, and saltcedar (*Tamarix* spp.) (Simberloff 2011). A further complication is that any individual invasive species may affect people and stakeholder groups differently. McNeely (2011) notes that many introductions are beneficial to most people, others benefit some individuals or interest groups while harming others, and a few, generally disease organisms and forest or agricultural pests, are clearly harmful to everyone. When costs and benefits are unevenly distributed across stakeholder groups and over the short and long term, interest groups can be expected to view invasive species issues differently, sometimes to be in conflict, and even to change their positions over time (McNeely 2011). There are numerous examples of stakeholder conflicts over invasive species in the United States. In Chicago, prairie restoration involved removal of large non-native trees that were preferred by some people over prairie, use of herbicides and fire that were seen as risky, and removal of non-native shrubby boundaries that were valued by some for screening and wildlife (Gobster 2011). In San Francisco,

dominant native coastal scrub and dune ecosystems are open and treeless, but fire suppression and afforestation have made non-native eucalyptus (*Eucalyptus* spp.) trees familiar components of the landscape (Coates 2006; Gobster 2011).

Public awareness of invasive species impacts is often limited, and at times public opposition can prove to be an obstacle to invasive species management (Gherardi 2011; Keller et al. 2015; McNeely 2001; Reaser 2001). Groups opposing eradication or control of invasive species, by engaging in protests and lawsuits, can have considerable power to prevent or delay control efforts (McNeely 2001; Sandiford et al. 2015; Simberloff 2011). Examples where opposition has been significant include eucalyptus removals in California, removal of “Australian pine” (*Casuarina* spp.) on the Florida coast, release of a biological control agent for strawberry guava (*Psidium cattleianum*) in Hawai’i, removal of wild parrots in San Francisco, and hunting of wild pigs (*Sus scrofa*) in Hawai’i (Simberloff 2011). Understanding the human dimensions of invasive species is vital for building political and community support to implement policies, laws, and regulations (McNeely 2001).

Lurking beneath many of these issues are questions and debates about what is and what is not native and, ultimately, different views of the fundamental relationship between humans and ecosystems. Particular introduced species have arrived at different times, but it is common to view as non-native only those introduced after Columbus initiated the colonization of the Americas. A number of authors argue that there is no unambiguous point at which an established non-native species is considered native, and thus these distinctions are inherently arbitrary (Chew 2011; Coates 2006; Rotherham and Lambert 2011; Smout 2011). Opponents to control efforts sometimes reference this ambiguity in their narratives, presenting complex challenges to managers. Wild horses and burros (*Equus* spp.) represent a prime example of this. Large non-native mammals are attractive to many people, and horses and burros have particular cultural salience in the Western United States. Furthermore, in spite of ecological and economic costs involved, opponents to their removal have sought to change the underlying basis of the discussion by arguing that wild horses and burros fill an ecological niche once occupied by equine ancestors, some of which may have been eliminated by early humans, and that their introduction should therefore be considered re-wilding (Donlan et al. 2005; Pimentel et al. 2005).

Cross-Over Between Social and Environmental Thought and Language It has been common in U.S. environmental thought and management to draw a sharp line between untrammeled wilderness and human-modified nature (Cronon 1996; Turner 2012), although social scientists today are likely to recognize the social construction of views of

nature (Javelle et al. 2011; Smout 2011). To say that nature is socially constructed does not mean that there is no underlying ecological reality, but rather that our interpretations of what is “natural,” desired states of nature, and management goals are often the result of socio-cultural rather than scientific thinking (Borowy 2011; Coates 2006; Smout 2011). These debates are not limited to the social sciences and humanities. Some biological scientists have argued that notions of pure natural ecosystems have led to exaggeration of the seriousness and breadth of problems caused by introduced species (Allison 2011; Simberloff 2011). Other biologists argue that it is unrealistic to eliminate invasive species and that the focus should be on managing invasive species within novel ecosystems (Hobbs et al. 2013). While a recent trend in ecology may appear to sidestep these questions by merging nature and people into the concept of social-ecological systems (see, for example, Gunderson and Holling 2001; Liu et al. 2016), the notion of “natural ecosystems” is deeply embedded in popular and scientific cultures and difficult to move beyond.

Ecological and social narratives often encode fundamental value differences that affect public acceptance of natural resource management. For example, there may be fundamental differences between worldviews, such as between animal rights perspectives, where the intrinsic right to exist is seen as resting at the level of the individual animal, and ecological approaches to invasive species management, where concern focuses at the level of populations of species within ecosystems (McNeely 2001, 2011). Narratives may also reflect intentional boundary blurring and use of invasive species issues as a means to an unrelated end. Sandiford et al. (2015) give examples where debates over invasive carp (*Cyprinus* spp.) became attached to unrelated agendas, as when a power company framed its proposed increase of wastewater discharge as a way to combat an invasive. Shine (2015b) discusses how an outspoken leader of a naturalist group leveraged invasive species media visibility into a much broader agenda and election to a high public office. Conservation and natural resource management are undertaken by human society and mixing of social and ecological thinking is common.

A common crossover between social and ecological narratives occurs when words and ideas that have strong human associations are used in talking about invasive species. People’s linguistic frameworks contain many assumptions, unarticulated values, implications, and consequences (McNeely 2001), and they are also subject to multiple interpretations and discursive uses. Animals and plants have long been used symbolically by humans (Bloch 1998; Lévi-Strauss 1966). Language use can be a fundamental driver of disagreement in invasive species discussions because it often implies cultural oppositions, such as native/alien, pure/contaminated, harmless/harmful, original/degraded, and diver-

sity/homogeneity. Also, ideals such as ecological integrity and authenticity are frequently associated with opposition to modern forces of social and economic globalization (McNeely 2001).

Two issues, labeling and xenophobia, have been particularly salient drivers of conflict in public discourse about invasive species. Name-calling—a form of labeling broadly defined as using words with common negative associations in social worlds to talk about ecological issues—is rampant in invasive species management and public messaging around the world and is often divisive. Invasive species may be described in ways that are divisive, derogatory, and cause conflicts (Chew 2009; Coates 2006, 2011, 2015; Larson 2005; Sandiford et al. 2015; Verbrugge et al. 2016). Word choice, or labeling more generally, when discussing introduced species can drive larger narratives. Sandiford et al. (2015) notes that when introductions have been promoted, usually by the government or private sector, there is often a historical pattern of rhetoric that begins with an overly optimistic assessment of the species prior to importation and transforms through metaphorical reinvention into a negative narrative through a process in which traits once considered virtues—for example, high reproductive rates and hardiness—become threatening qualities. In the aquatic realm, introduced species such as carp and tilapia have been promoted as the “cheapest food for the greatest number of people” or “poor man’s fish,” later to be disdained by anglers as “trash fish” (Sandiford et al. 2015). Sometimes a narrative seeks to change a previously undesirable species into a valuable addition to the ecosystem. For example, grass carp (*Ctenopharyngodon idella*) have been renamed “white amur” and, tapping into societal fears about herbicides and other chemicals, promoted as a benign “green” tool for cleaning not just fish farm ponds, but thousands of weed-infested lakes, reservoirs, and ditches (Sandiford et al. 2015).

At the extreme, invasive species are referenced using culturally loaded and divisive terms (Coates 2006). This tendency occurs worldwide, perhaps linked to fundamental social and psychological tendencies of humans to distinguish between ingroups and outgroups (Giles and Giles 2012).

Occurrences of inflammatory and derogatory language in reference to invasive species be examples of rhetorical convenience, limited to contrarians, or more common in the past, as Coates (2006) and Simberloff (2011) have maintained. However, when public debates over control of invasive species are characterized as divisive (Coates 2006), the overall cause of invasive species management is likely to be harmed. There has been insufficient research to know the extent to which language issues and nativism have affected public values in general or even in specific cases of invasive species management (Coates 2006; Simberloff 2011). But, language containing negative social associations can be powerful in both positive and negative ways, and there is little

doubt that words and issue framing can significantly influence public opinion (Gobster 2005).

Avoiding Pitfalls and Making Progress This section has reviewed general social and cultural issues and common narratives involving invasive species. The ways in which these issues emerge and play out in individual cases are complex, and subsequent sections of this chapter will examine more specific research. Clearly, the language and imagery used when talking about invasive species matters (McNeely 2011; Smout 2011). There are dangers in ecological purism (Smout 2011), and it is important not to forget that people love and have deep ties to many invasive species (Rotherham and Lambert 2011). Some ecological writing has involved barely disguised racism and xenophobia, and such negative social connotations can distance science and management from the public (Rotherham and Lambert 2011). Pooley (2011) advises, based on past issues, that we should pause and reflect on the values and trends that inform our current thinking and messages about invasive species and their management and how these might differ from the ways that stakeholders think and talk about them. At a minimum, work to date underscores the importance of scientists and managers becoming aware that some individuals and groups often hold different viewpoints and values toward invasive species. In the same ways that our language has evolved to avoid marginalizing people by gender, race, and physical and mental abilities, we must also sharpen the language that we use to discuss invasive species in order to avoid what stakeholders may see as value-laden and potentially offensive terms.

In spite of examples of social opposition to and debate about invasive species control, evidence suggests that when a non-native species becomes highly invasive, destabilizing ecosystems and causing economic harm, control may become more socially acceptable. McNeely (2011) notes that killer bees (or Africanized Honey Bees, a hybrid between *Apis mellifera* and *A. mellifera scutellata*), water hyacinth (*Eichhornia crassipes*), kudzu, spruce budworm (*Choristoneura fumiferana*, *Choristoneura orae*), various pathogens, and agricultural weeds have been sufficiently damaging to generate strong consensus that they should be controlled, bringing together interest groups that might otherwise be in opposition. Gobster (2005) suggests focusing on the more positive term of ecological restoration rather than invasive species control. Rotherham and Lambert (2011) argue for focusing on problem species rather than invasive species in general, recognizing that people value and even celebrate some invasive plants and animals, and accepting that management often involves subjective decisions that require open discussions and stakeholder debates.

12.2.2 Research on People and Invasive Species in Ecosystems

Research on the human dimensions of invasive species is typically carried out in particular ecosystem types. There has been some general research on invasive species that focused on public protected areas. Sharp et al. (2011) surveyed visitors to a national park in Georgia, and their results show that visitor support for invasive species control is associated with their knowledge, perceived threats, age, education, previous experience of visiting national parks, and environmental value orientations. Seidl and Klepeis (2011) interviewed and surveyed residents around the Adirondack State Park in New York, and found a positive attitude toward invasive earthworms (in North America belonging primarily to two families, the Lumbricidae and the Megascolecidae) and their ecological effects, which lead to local residents' casual disposal or use of them. Schlueter and Schneider (2016) surveyed visitors to a State park in Minnesota about emerald ash borer (*Agrilus planipennis*) management approaches, and found that wood regulations, sanitation cutting, and progressive thinning were the most acceptable actions, while complete harvest, chemical treatment, and doing nothing were unacceptable. Light-handed approaches, such as biological control and doing nothing, were most acceptable in natural areas, indicating that landscape context influences social acceptability (Schlueter and Schneider 2016). However, significant bodies of research exist for forest, rangeland, and aquatic ecosystems, and here we present reviews of this literature by ecosystem type. While each of these ecosystem types has unique aspects and issues related to invasive species, they share common issues related to individual behavior and collective action.

Forest Ecosystems In the United States, relatively little has been done to examine the human dimensions of invasive species in forest ecosystems, specifically the role of private forest landowners in preventing and controlling invasive species, even though they control 56% of the forest land (Butler 2008; Steele et al. 2006). Anecdotal evidence has suggested that forest landowners are not always aware of invasive species infestations, and are not actively preventing new invasions or controlling existing infestations. Forestry professionals, based on their own experience interacting with non-industrial private forest landowners, have observed that as an invasive plant species becomes abundant on the landscape, landowner observation of the species and awareness of the associated problems seem to increase, which could potentially motivate landowners to take actions to manage invasions locally (Carlson 2014; Fig. 12.1). Although little research has empirically examined the relationship

between invasion intensity and landowner awareness, anecdotal evidence has also suggested that landowners often fail to recognize and/or act upon such invasions until they are at or near the point where eradication is highly unlikely. Furthermore, less is known regarding how to move the point when landowner awareness typically begins down the curve to an earlier point when eradication or control is still ecologically and financially feasible. Thus, effective invasive species prevention and control require not only an accurate understanding of invasion risks on the landscape, but also a comprehensive assessment of the awareness, attitudes, and behaviors of forest landowners, as well as a better understanding of how they perceive and respond to invasions and invasion risks; how and why they engage in collaborative management; and policy implications.

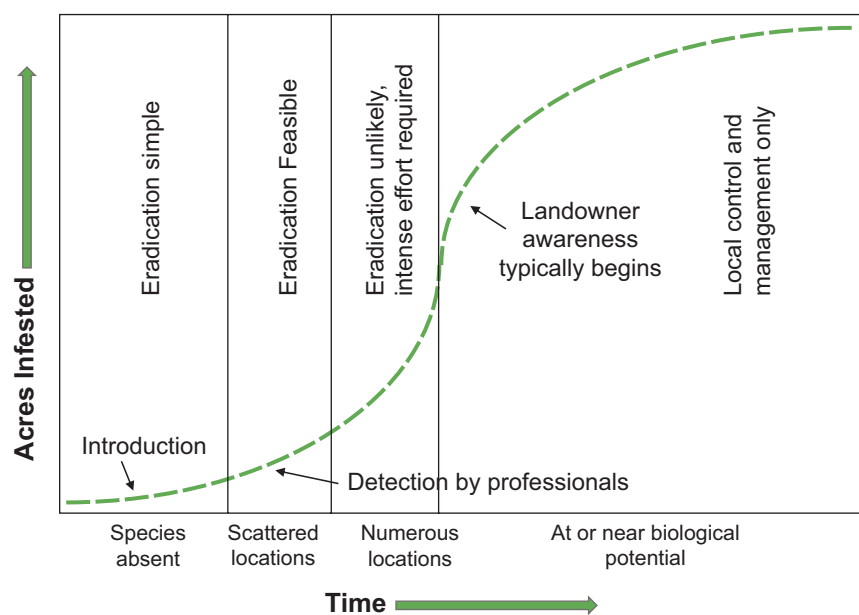
There have been few studies that explicitly examine the human dimensions of invasive insects in forest ecosystems in the United States. Cartwell (2007) mentions the importance of engaging the public in eradicating Asian longhorned beetles (*Anoplophora glabripennis*) and emerald ash borer by increasing public reports of sightings. Several studies were found to assess landowner awareness of invasive plants and their adoption of prevention and control practices. Steele et al. (2006) found that the issue of invasive plants was moderately salient among private forest landowners in West Virginia, but that many landowners could only identify a limited number of invasive plant species. A majority of landowners who recognized certain invasive plants as undesirable had used mechanical methods to remove them, while placing less emphasis on applying herbicides or establishing desirable plants. In a subsequent study, Steele et al. (2008) found that private forest landowners who farmed on their property, held recreation

objectives, and lived in the local area were more likely than their counterparts to have received outreach information about invasive plants; however, a majority of these landowners had not heard or received such information. More recently, Fischer and Charnley (2012) surveyed private forest owners in Oregon's ponderosa pine (*Pinus ponderosa*) zone and found that they had widely different perceptions of invasion risks, ranging from a lack of concern, to the opinion that non-native plant invasions have discrete causes and controllable consequences, to the opinion that invasions have gone out of control. All three studies discussed the importance of raising landowner awareness and the need for communicating invasive plant information in a way that resonates with landowners and that is consistent with their management objectives.

Thus far, there has been limited research on how forest landowners perceive and make decisions about invasive species management, specifically minimizing invasion risks and adopting effective strategies to control and eradicate already established invasions. In addition to this knowledge gap, research has shown that only a small segment of forest landowners is committed to active management (Kittredge 2004). This suggests that there is a significant need and justification for using social science research to inform effective engagement of various stakeholders, especially forest landowners, in controlling invasive species in forest ecosystems.

Because invasive species generally occur at the landscape level and easily cross property boundaries, their management requires coordinated and collective action. For example, as forest land in the United States becomes increasingly fragmented and parcelized, any one public or private entity may assume responsibility for only a small portion of the total damage caused by invasive species, per-

Fig. 12.1 Four stages of invasive plant infestation and possible treatment at each stage. For a given invasive plant species, ease of treatment declines and cost of treatment increases from left to right. (Adapted from Hobbs and Humphries (1995) and Indiana Division of Forestry (2010))



ceive that the management of invasive species—particularly wildlife species—is the responsibility of others, or not feel motivated or adequate to tackle an invasive species problem because the extent of the problem goes beyond their own properties. However, an entity opting not to control invasions will increase control costs for neighboring private and public entities by allowing their land to act as a source for invader propagules (Epanchin-Niell et al. 2010; Simberloff et al. 2005). Thus, invasive species threaten a public good—the health of forest ecosystems—which makes invasive species management a problem that requires collective action. Invasive species management as a collective action problem has been more commonly discussed in grassland and rangeland systems than in forest ecosystems (e.g., Epanchin-Niell et al. 2010; Yung and Belsky 2007). Niemiec et al. (2016) investigated landscape-scale invasive species control in Hawai'i and noted the importance of reciprocity in promoting a community good and the presence of social norms as motivators of invasive species control, and suggested that these are important complements to approaches that focus on individuals like education campaigns and subsidies.

In the forestry context, a significant body of literature has been developed to examine landowner cooperation in forest management in general. For example, Kittredge (2005) reviewed and analyzed private forest landowner cooperation in temperate nations with developed economies, including the United States. He emphasized the need and potential for enhanced landowner cooperation to increase individual ownership benefits, as well as the greater public benefits that may result from better managed forest landscapes. Despite the importance of landowner cooperation, previous research has shown a relatively low level of interest in cooperation among private forest owners (e.g., Erickson et al. 2002; Jacobson 2002; Jacobson et al. 2000; Rickenbach and Jahnke 2006). Researchers have identified various factors that influence landowner willingness to cooperate with one other. These include environmental values, stewardship ethics, concerns about maintaining control and property rights, ability to see immediate outcomes from cooperation, using neighboring properties for non-consumptive recreation activities, trust, existing social networks among landowners, time constraint, demographics, and various dimensions of the institutional environment that supports landowner cooperation (e.g., Blinn et al. 2007; Finley et al. 2006; Rickenbach and Kittredge 2009; Rickenbach and Reed 2002; Rickenbach et al. 2011; Vokoun et al. 2010; Wagner et al. 2007; Wolf and Hufnagl-Eichiner 2007).

In contrast to the literature on cross-boundary cooperation in the context of timber harvesting and other forest management activities, little has been done to apply this collective action approach to manage invasive species in forest ecosys-

tems. There is much to be learned about forest landowner attitudes and willingness to prevent and control invasive species that travel and spread across property boundaries collectively. There may also be opportunities to innovate on the areas of outreach and policy to facilitate the formation of a collective invasive plant management norm within larger forest landowner communities.

Invasive Species and Rangelands Invasive species, particularly plants, have impacted rangelands at increasing rates, causing significant economic and ecological impacts (Vasquez et al. 2010). Human roles in the rangeland invasive species issues include transporting and introducing invasive species and disturbing and fragmenting ecosystems in ways that facilitate their invasion, and thus coordinated management actions are required (Vasquez et al. 2010). Rangeland communities may have a greater level of awareness of invasive species than those in other ecosystem types. Tidwell (2005) surveyed residents in the Southwest United States about their beliefs regarding invasive forbs and their management and found that 94% of respondents were concerned about invasive species. A 2010 survey in the Great Basin found that more than 83% of respondents believed annual invasive grasses pose a threat to healthy rangelands (Gordon et al. 2014).

Management of rangeland invasive species requires both awareness and acceptable control methods. Ambivalence about invasive species control can be common, because it may involve methods considered potentially risky to humans. Norgaard (2007) examined a controversy over control of spotted knapweed (*Centaurea maculosa*; syn. *Centaurea stoebe* L. ssp. *micranthos* (Gugler) Hayek) in northern California and found that natural resource managers considered herbicide application to be safe while community members did not. Similarly, Shindler et al. (2011) reported that residents of rural parts of the Great Basin were more than twice as likely as urban respondents to believe herbicide application is an appropriate management tool on public lands. Tidwell (2005) found that chemical control of invasive plants was judged to be more acceptable for use on multiple-use or agricultural lands than on protected or residential lands. However, he did not find similar differences in support for other forms of management.

Invasive species program managers often seek to heighten awareness and concern about invasive plants with the intention of promoting willingness to support or engage in control activities. It is therefore useful to learn what influences changes in attitudes toward invasive species. However, findings have been somewhat disappointing. Gordon et al. (2014) measured attitudes toward invasive species control methods in 2006 and again in 2010, and found that attitude change was less affected by changes in awareness than by changes in

trust of the government agencies that would be applying those methods.

Efforts to detect, manage, and control invasive species typically involve a combination of top-down measures (e.g., laws and ordinances) and grassroots volunteer action. Legal measures directed against invasive species are reviewed in Chap. 15 and are not repeated here. However, it is worth noting that the absence of legal support for invasive species control can pose a barrier to management effectiveness. Kelley et al. (2013) found that the fact that cheatgrass (*Bromus tectorum*) was not designated as a noxious weed in Wyoming was seen as a barrier to management by 34% of ranchers and 39% of natural resource professionals. As one manager stated in a focus group that Kelley et al. conducted, “One interesting thing with regard to cheatgrass for me is that my budget is such that, I get money to treat noxious weeds and as of yet, cheatgrass isn’t a noxious weed.” The same study found that 77% of ranchers felt other weeds were a higher priority than cheatgrass.

Because volunteers are an important tool in the battle against invasives, Tidwell and Brunson (2008) queried respondents about their willingness to volunteer for weed management activities including control, monitoring, education, and restoration. Ten percent of respondents said they had engaged previously in weed-related volunteer activities, and 43% expressed their willingness to participate. Among those willing individuals, more were interested in directly participating in control activities (57%) or monitoring (55%) than education (39%) or restoration (38%).

Collective action is important, because individual actions are not sufficient to control invasive species (Epanchin-Niell and Wilen 2014; Yung et al. 2015). The nature of collective action needed has received some attention in the rangeland literature. Graham (2013), based on interviews with landholders and agency personnel, suggests there are three ways that communities can encourage greater weed control: sharing information, providing support, and applying pressure on other landowners. Analyzing the case of yellow star-thistle (*Centaurea solstitialis*) in the Sierra Nevada foothills of California, Epanchin-Niell et al. (2010) suggest that no single management regime will control invasive species and suggest multi-level approaches. These levels include bottom-up—public and private landowners, middle-level—cooperative weed management areas and weed districts, and top-down—regulatory and financial support from local, State, and Federal governments (Epanchin-Niell et al. 2010). Researchers also have emphasized the need for socioecological research and data in these cooperative and landscape-level management programs (Epanchin-Niell et al. 2010), bringing together collaborative and scientific efforts (Miller and Schelhas 2008; Schelhas et al. 2012). Weed districts and Cooperative Weed Management Areas have been particularly effective platforms for these efforts in the Western

United States (Forcella and Harvey 1988; Schelhas et al. 2012).

A number of collaborative groups have arisen in recent years to address invasive plant management. These volunteer groups (e.g., Arizona’s Sonoran Desert Weedwackers) typically involve multiple public agencies as well as citizen groups that collaboratively engage volunteers in mapping, monitoring, and controlling invasive plant infestations. Some groups focus on all species in a specific locale while others are organized around particular taxa, but nearly all are geographically limited and supported by a combination of public and private funds. Such groups are increasingly popular because they can accomplish tasks that are not supported by limited tax revenues, can inform management decisions with stakeholder perspectives, and can breach communications barriers between groups of people (e.g., ranchers and environmentalists) to achieve goals of common interest. Fernandez-Gimenez et al. (2004) identified more than 100 collaboratives working in Arizona’s rangelands alone, although only a small subset of those focused on invasive plants.

Hershendorfer et al. (2007) surveyed coordinators of 53 local weed programs in Arizona, Colorado, New Mexico, and Utah to determine how attributes of the programs were linked to performance of control, education, monitoring, and integrated weed management. They found that programs that used volunteers did more monitoring but less direct control than those that relied entirely on paid employees. Contrary to the researchers’ expectations, more regulatory action did not translate to better control. In fact, groups that had regulatory authority but generally refrained from punitive enforcement treated more infestations, partly because staffs are typically small and enforcement takes time, and partly because a gentler approach with private landowners seems to yield better results.

Invasive Species in Aquatic Ecosystems There have been very few general studies of aquatic invasive species in the United States. Weber and Ringold (2015) studied people’s preferences for river and stream features in an arid landscape in Arizona and found that there was concern about both invasive plants and animals. Responses were generally linked to positive concern or threats to native species (Weber and Ringold 2015). There are a number of invasive species studies that focused on aquatic vertebrate and invertebrate species. For example, Limburg et al. (2010) surveyed four homeowner communities near Lake Ontario. They found that most respondents noticed and valued improved water clarity, which in fact reflected the loss of ecological functions due to invasive zebra and quagga mussels (*Dreissena polymorpha* and *D. bugensis*) lowering phytoplankton biomass and pelagic production in the lake. Luizza et al. (2016) modeled potential spread of Alaska’s first freshwater inva-

sive plant (*Elodea* spp.) with climate change, and combined these results with subsistence use by Alaska Natives and concerns related to Chinook salmon (*Oncorhynchus tshawytscha*) and whitefish (*Coregonus nelsonii*). This highlighted the positive contribution of community involvement to risk assessment and incorporating stakeholder concerns into management.

Aquatic invasive species often arrive unintentionally through shipping and recreation vectors, although they can also be associated with pet and landscape trades or through deliberate introductions (Cambray 2003; Pyšek and Richardson 2010). Recreational transport of aquatic invasives represents a significant risk. Cambray (2003) emphasized the significance of deliberate and accidental introductions of sport fish as a problem that is increasing due to globalization. Anderson et al. (2015), while noting the existence of limited literature on recreation and aquatic invasive species, note that there are several publications on transport by recreational boaters between rivers and lakes and by yachts in marine environments (Rothlisberger et al. 2010; Thresher 1999; Willette et al. 2014). Studies indicate that the diversity of aquatic non-native species, including plants, algae, and invertebrates is higher where recreational boating or yachting took place than at control sites, with vectors including hulls of boats, ballast and bilge water, and anglers (Anderson et al. 2015). Waterkeyn et al. (2010) showed that aquatic invertebrates could be dispersed among wetlands at very local scales by footwear and vehicles. Pradhananga et al. (2015), studying boaters in Illinois, found nature- versus human-oriented values had predicted environmental concern but had little impact on behavior; behavioral intentions were most influenced by habit and concern about aquatic invasive species. Overall management recommendations include raising awareness and bio-security measures for tires, boots, boats, and other equipment (Anderson et al. 2015; Pradhananga et al. 2015). Sharp et al. (2016) found that recreational boaters understood the importance of managing aquatic invasive species and supported inspections and regulations. The Cornell Human Dimensions Research Unit has published a series of integrated reports on aquatic invasive species in the Great Lakes region that examines human dimensions across a range of vectors, stakeholders, and issues. This research addresses vectors, such as anglers, boaters, and other recreationists (Lauber et al. 2015a), the role of bait dealers and boating facilities, and angler and boating organizations (Connelly et al. 2014a, b, c; Heck et al. 2013; Lauber et al. 2014), aquarium and plant trades (Lauber et al. 2015b), and factors affecting communication success and outreach capacity in recreational communities (Lauber et al. 2015a).

Intentional fish introductions can have negative impacts. McNeely (2011) notes the harmful effects of introduced trout (*Oncorhynchus* and *Salvelinus* spp.) on amphibian populations. Varble and Secchi (2013) analyzed the results of the first national survey on the attitudes of U.S. fish consumers toward invasive Asian carp, and suggested harvesting Asian carp for human consumption as a potentially promising strategy for controlling this invasive species. However, Nuñez et al. (2012) cautioned policymakers, practitioners, and researchers that controlling invasive species through human consumption should be carefully examined to avoid creating a market that engenders pressure to maintain that problematic species. Sandiford (2015) discusses the long history of rhetoric, both positive and negative, around introductions of different species of carp in the Mississippi River Basin. Various species of carp, which have been promoted by fish farmers and for weed control in ponds, have caused impacts on recreational fishing and other aquatic species. Moreover, Carlson and VonDracek (2014) acknowledged a “dearth of sociological research on Asian carps represents a barrier to predictive management.” They further stated that human dimensions research in the prevention and control of Asian carp can contribute to understanding public attitudes, enhancing stakeholder engagement, fostering harmony between agencies and stakeholders, and gaining social knowledge for effective management.

12.3 Tribal Perspectives and Engagement

Native peoples of North America have millennia of experience adapting to social and ecological change. Among these changes, indigenous communities in the United States and its territories have been responding to the presence of non-native species, some of them satisfying the definition of invasives, at least since the beginning of the Columbian Exchange in the late fifteenth century (Crosby 1972). This experience and traditional ecological knowledge are reflected in indigenous attitudes toward and approaches to invasive species, and are essential to the development of invasive species management programs that honor the U.S. trust responsibility to Native peoples.

There are over 560 federally recognized tribes in the United States (Bureau of Indian Affairs 2016). Each tribe has distinct cultures, histories, and lands. Additionally, within each tribe, members hold multiple perspectives, attitudes, beliefs, and relationships to the natural environment. While tribal governments may take many forms, they are responsible for managing tribal natural resources. The U.S. Government has a trust responsibility to ensure proper management of tribal resources as well as Federal lands. The Federal trust responsibility is codified in treaties, the

U.S. Constitution, case law, Presidential Executive Orders, United States Department of Agriculture (USDA) Regulations, and the USDA Forest Service Handbook. The Federal trust responsibility includes the legal responsibility to consult with individual tribal nations on a government-to-government basis on programs and actions that may impact or are important to federally recognized tribes. This includes a requirement to consult with tribes on planning and actions related to invasive species management and control (see Donoghue et al. 2010; Haskew 1999).

Tribal governments are modern institutions. One of their many responsibilities is to manage, conserve, and protect tribal lands. Tribes approach this in various ways. Some tribes maintain large natural resource, forestry, environmental, and fish and wildlife departments which operate with Federal and tribal funding, while other tribes have smaller departments directly supported by the Bureau of Indian Affairs staff. Most, if not all, of these tribal institutions are concerned about the impacts invasive species are having or could have on tribal ecosystems, tribal resources, tribal enterprises, tribal communities, the Federal Government's trust responsibility, and tribal sovereignty.

Tribal natural resource management staff and tribal community members have indicated that invasive species are one of the most important issues facing tribal natural resources, especially in conjunction with climate change and integrated forest management (see, for example, Gordon et al. 2013; Sustainable Development Institute 2012). While there is no one national group that works exclusively with tribal invasive species management, tribes have formed partnerships with local, State, and Federal institutions to manage invasive species. There are also intertribal organizations that coordinate and share information about invasive species at national, State, and local levels. These partnerships strive to manage invasive species on lands and waters with reserved treaty rights, as well as lands that have the potential to impact tribal resources. Often, non-tribal institutions learn valuable perspectives from tribal partners concerning management, control, and social and cultural impacts.

Because invasive species impact tribal communities on environmental, social, spiritual, and economic levels, tribes throughout the country are actively working on invasive species management. For example, the Menominee Nation in Wisconsin is a leader in sustainable forest management and has established their own forest health department. They are actively working on control of invasive species including garlic mustard (*Alliaria petiolata*), oak wilt (*Bretziella fagacearum*), beech bark disease (*Neonectria* spp.), and emerald ash borer. These, and other invasive species management projects, are important projects for the Menominee Nation and are related to maintaining high quality saw timber for the tribal saw mill, a diversity of species within the tribal forest, and culturally important species for traditional

and contemporary use. Another example is the Shoalwater Bay Tribe in Washington State, which is working on several invasive species control projects including control for the aquatic invasive plant *Spartina* (*Spartina alterniflora*). This plant impacts native plant species, hydrology, bird habitat, and fish communities, which in turn affects many aspects of tribal life including subsistence fishing, recreation, and spiritual practices. Tribes in the Midwest and East are working on projects related to the ecological and cultural impacts of emerald ash borer. Tribes in the Pacific Northwest, including the Confederated Tribes of Warm Springs, the Yakama Nation, and the Colville Confederated Tribes, are working on white pine blister rust (*Cronartium ribicola*) in collaboration with the Forest Service.

Invasive species can have important cultural impacts and meanings for Native people. While recognizing there is no single Native culture but, rather, many sovereign nations with distinct cultures, there are common teachings about the roles, responsibilities, and relationships between human beings and the rest of the biotic and abiotic world (hereafter, "Creation"). These teachings are grounded in the spiritual traditions and lived experience that form the basis for traditional ecological knowledge (Emery et al. 2014). This traditional ecological knowledge teaches that all elements of Creation are relatives and each has roles and responsibilities. The right relationship between humans and Creation is one of mutual respect and caring. The relationship between people and Creation becomes out of balance when humans cease to honor their responsibilities to care for and behave in a respectful way toward their non-human relatives, which includes active stewardship and respectful use. When this happens, the plants and animals that provide for humans may cease to be present, pushed out by or replaced by other aggressive species. In some cases, these species may have the capacity and responsibility to repair damage done by human's poor treatment of the land.

Recent and historical experiences also inform Native perspectives on invasive species and what should be done about them. In their review of 70 case studies of the socio-cultural implications of invasive species around the world, Pfeiffer and Voeks (2008) note that the impacts of invasive flora and fauna on indigenous communities are far from uniform. In some cases, especially where recently arrived biota result in the rapid reorganization of landscapes and/or replacement of culturally important native species within two human generations or less, invasive species may be culturally impoverishing. Effects can include loss of access to cultural keystone species for food, medicinal, ceremonial, and other purposes (Garibaldi and Turner 2004) and interruption of place-based traditions that literally ground indigenous identity (Pretty 2002). Such impacts are especially acute for indigenous groups already struggling to revitalize their cultures.

In other cases, invasive species have enriched Native peoples' diets and pharmacopoeias, particularly where a species originating elsewhere has been present for 100 or more years, providing time for its absorption into individual and group practices (Pfeiffer and Voeks 2008). For example, the weedy northern European species English plantain (*Plantago major*) was widely adopted into North American indigenous healing practices (Crosby 1986).

Forced relocation and voluntary moves also are common in North American indigenous communities. In such cases, highly cosmopolitan species that were used in the home territory and also are present in the new location may assist displaced Native peoples in maintaining cultural practices. Indeed, it has been noted that disturbed habitats that create the conditions necessary for the establishment of invasive species tend to be readily accessible and rich in plant species with medicinally useful secondary compounds (Voeks 2004).

It has been noted that biological invasions and responses to them have social and political histories, as well as biotic roots (Crosby 1986; Robbins 2004), a process with which indigenous peoples around the world have abundant experience. For example, Pretty Paint-Small (2013) notes that the Dawes Act of 1887, which resulted in privatization and ownership of land by non-Indians inside the boundaries of reservations throughout the Western United States, set the stage for the contemporary invasion of Russian-olive (*Elaeagnus angustifolia* L.) on the Crow Indian Reservation in Montana. The cessation of traditional land management practices due to loss of sovereignty and control over ancestral territories likely is a component in other instances (see, for example, Long et al. 2016; Ortiz 2008a).

Indigenous communities also have suffered negative impacts from programs designed to address invasive species, including the use of toxic chemicals and escaped biocontrol agents (Pfeiffer and Voeks 2008). When chemical applications affect culturally important foods, entire communities may suffer, with children and elders at particular risk. Likewise, cultural practices such as those involved in processing basket materials may present increased risks of exposure (Norgaard 2007).

There are numerous examples of collaborative efforts between indigenous communities and government agencies, which are designed to replicate traditional resource management practices in order to control invasive species and support biocultural diversity (Pfeiffer and Voeks 2008). Yet there is relatively little published scientific literature on tribes and invasive species, in spite of the fact that many tribes are faced with invasive species issues. In the following discussions, two tribes, the Eastern Band of Cherokee Indians and the Kashia Band of Pomo Indians, present their perspectives on and experiences with invasive species.

Cherokee Perspective of Invasive Species¹

Through art, subsistence, and culture, the Cherokee people have relied on the great biodiversity of the Southern Appalachians for thousands of years. However, this biodiversity is threatened by invasive species. The Eastern Band of the Cherokee, therefore, considers invasive species one of the greatest threats to cultural and economic stability (EBCI 2013). Because some non-native species have taken the place of native organisms as cultural resources throughout American society, appropriately defining an invasive species as more than exotic is paramount, especially when the term invasive is often confused with nuisance or exotic species.

In accordance with Cherokee priorities and modern scientific designations, we believe that invasive species are most appropriately defined as species that causes net harm to our economic or cultural resources. We are still in the early stages of species census and evaluation of impacts, but we have categorized several organisms that we plan to manage as potential invasive species. We plan to list plants and animals that can cause either direct or indirect harm to our resources. For example, the hemlock woolly adelgid (*Adelges tsugae*) has nearly eliminated culturally and ecologically important eastern hemlocks (*Tsuga canadensis*) from our area, and the newly arriving didymo algae (*Didymosphenia geminata*) can choke out stream bottoms that in turn influence trout food, which would be detrimental to our fishing industry.

With our definition of a "net harm to economic or cultural resources," some situations will require evaluation. We do not consider a non-native designation as equivalent to invasive. There are many examples of non-native or exotic species that are used for horticultural and agricultural purposes that become naturalized, leaving a net positive benefit to people, ecosystems, or communities (Brown and Sax 2004; Colautti and MacIsaac 2004). For example, Japanese honeysuckle (*Lonicera japonica*) is deemed an invasive species by many Federal and State agencies, but the Cherokee people have adopted this East Asia native as culturally important for making baskets. Therefore, we require an economic and cultural impact assessment before we would deem this species invasive. As our census efforts progress, we will consider each species with a Federal or State invasive listing on a case-by-case basis for our own listing process. Feral hogs (*Sus scrofa*) represent another example of a species that can have both positive and negative impacts but is almost universally listed as invasive among State and Federal agencies. People in our region have long used these animals as livestock as well as game. Groups have intentionally released hogs to hunt, which creates a difficult dynamic when manag-

¹This perspective was written by Caleb R. Hickman, Michael J. LaVoie, and Tommy Cabe of the Eastern Band of Cherokee Indians Natural Resources program.

ing for eradication versus for a sustainable resource. Based on Federal and State designations as invasive, and a level of damage on our lands, we have implemented feral hog management by creating an open hunting season and supporting research to understand hog and disease movement.

Some species with potential to be invasive might have a higher net economic benefit to people. Trout are native to the Southern Appalachians and a culturally important organism to the Cherokee. Native to Cherokee lands, brook trout (*Salvelinus fontinalis*) populations declined over the past century due to unregulated harvesting and habitat changes. In order to restore this harvesting connection, brook trout were replaced in many areas by a non-native game fish, rainbow trout (*Oncorhynchus mykiss*). Although rainbow trout are considered invasive in certain situations (i.e., western States when hybridizing with native trout), we do not have sufficient information to deem them invasive on tribal lands. Despite a lack of designation, we are committed to careful stocking so that we only manage areas where naturalized rainbow trout exist and preserve reaches with only native brook trout.

Compared to neighboring State and Federal agencies, we might have a different designation for a species based solely on its impact on culturally important organisms. For example, we are describing coyotes (*Canis latrans*) as invasive because of their potential to reduce populations of culturally important white-tailed deer (*Odocoileus virginianus*), which occur in small densities on tribal lands. Even though they are native to the United States, coyotes are new to our area and their predation pressure can cause decreases in deer populations. We consider deer culturally significant because they represent one of the Cherokee clans and serve as a focal point in stories and history. To assess coyote impacts on deer, we are currently leveraging a bounty system to understand their movement and diet.

Our management process consists of these particular areas: assess, monitor, mitigate, and manage. First, we need to determine if a species is invasive by targeting those listed as invasive by State and Federal designation or determining if they produce a net cost to Cherokee economic or cultural resources. In addition to biological surveys, our assessments will include rigorous scientific review and professional research from our staff and experts in the field. If we deem a species invasive, we monitor for prevalence and attempt to decrease impacts by creating management plans with expert involvement. Our actions for invasive species will be within larger management plans. We are currently finishing both a Wildlife Action Plan and Forest Management Plan that will outline strategies to deal with invasive species. Most of the daily challenges will be addressed through eradication treatments of the invasive species, education of people, and enforcement when introductions are a factor. We rely on our tribal municipal code to deal with legal actions and limitations imposed by our enforcement. We feel our program is

poised to exercise our sovereignty goals of protecting our natural resources against invasive species.

The Kashia Band of Pomo Indians Respond to Sudden Oak Death²

We'll be gathering acorns, and they'll teach us how to sing the songs that are appropriate for gathering, and why we're singing those songs. We'll learn language and stories... It's what we call the University of Kashaya. It's our school. *Phytophthora ramorum* is threatening that. (Reno Franklin (Kashaya Pomo) 2007)

In the Kashaya Pomo language, tanoak (*Notholithocarpus densiflorus*) is *chishkale*, meaning beautiful tree (Gifford 1967), so in the late 1990s when unprecedented tanoak mortality was recognized on tribal lands near Stewarts Point and on surrounding traditional gathering areas in western Sonoma County, tribal members became quite distressed (Bowcutt 2013). The tanoaks were dying from sudden oak death, caused by *Phytophthora ramorum*, an invasive, exotic, microscopic pathogen, new to science. The pathogen was introduced to the United States on ornamental nursery plants (Mascheretti et al. 2009); once established, its spores spread through forests by wind-blown rain (Rizzo et al. 2005). Tribal environmental staff, elders, and leaders discussed the issue internally and reached out to plant pathologists for assistance to develop management plans, and to share their concerns, they hosted outreach and education workshops for tribal and non-tribal neighbors.

Thousands of trees died near the 40-acre Stewarts Point Rancheria (Ortiz 2008b). Reno Franklin, former Kashia chairperson, described the loss in 2007 as, "We still continue to pass on our ceremonies, our traditions, our prayers, and our songs, and some of those songs and prayers and ceremonies are centered around tanoak and these acorns. We still have roundhouse ceremonies that celebrate and give thanks for what we're taking from those tanoak trees in the form of acorns. You could have a tanoak that's maybe three or four hundred years-old where five or six generations of Kashaya families go. We've got families whose entire gathering areas have been wiped out. And it's hard to take seven generations of a family and remove something like that, and then try and fill that void" (Reno Franklin, quoted in Ortiz et al. 2008b).

As Franklin explains, the ecological, cultural, and community impacts of this invasive, quarantined pathogen pose a serious threat to the tribe including loss of highly valued acorn-producing trees (tanoak and oak (*Quercus* spp.)) and disruption of traditions. The disease's primary source of inoculum, California bay laurel or pepperwood (*Umbellularia californica*), is also culturally important to the Kashia and

²This perspective was written jointly by Susan J. Frankel, USDA Forest Service, Pacific Southwest Research Station; Janice Alexander, University of California Cooperative Extension, Marin County; and Nina Hapner, Kashia Band of Pomo Indians.

other California North Coast tribes. The berries are collected for food, and other plant parts are used in ceremony and for medicinal and household purposes. While *P. ramorum* infection is not lethal to pepperwood, transporting infected leaves could contribute to disease spread.

Former Kashia Chairman Eric Wilder, when describing the impacts of sudden oak death asked, “What happens when you take that element from your people that is a significant ceremony, and a practice of your people that happened for thousands and thousands of years, and it’s suddenly gone? In our traditional belief, when we go out and we gather these acorns and anything from the land, the Creator has put that here for us.... This is a sacred ceremony that we do.... According to the teachings of our people from thousands and thousands of years, if you don’t respect the creation, and we don’t follow those rules that we were given to gather, this is the kind of thing that will happen.... In the traditional people’s view...creation’s showing us what happens when you don’t respect it..., so we feel like we’re...responsible for what’s happening, too...” (Ortiz 2008a).

Different management approaches are needed to meet tribal needs. The Kashia’s relationship to tanoaks and pepperwood causes the tribe to be reluctant to use pest management practices commonly used on lands of other ownerships. Recommendations to control sudden oak death include removal of pepperwood trees to protect oaks, and thereby eliminate the inoculum reservoir for spores that spread to highly susceptible oaks (Swiecki and Bernhardt 2013). Favoring oaks over pepperwood is a preference the Kashia do not agree to because both trees are utilized for food and ceremony.

Because Kashia collect and consume acorns, they are also concerned that a systemic pesticide used to prevent *P. ramorum* infection (Lee et al. 2011) may contaminate acorns. A preliminary study of the efficacy of phosphonate to protect tanoak was conducted on Kashia tribal lands, after Kashia staff conducted extensive education and outreach with the tribal community concerning the risks of sudden oak death and the use of phosphonate. Only with agreement from the Kashia community was the application allowed (N. Hapner, personal observation). The chemical composition of tanoak acorns was analyzed (Meyers et al. 2006), but there was insufficient information to determine toxicity. Despite the desire to protect tanoak trees, the Kashia Band of Pomo Indians is reluctant to treat trees because of concerns about pesticide exposure to the acorns (N. Hapner, personal observation).

12.4 Promising Approaches for Changing Awareness, Attitudes, and Behaviors

The preceding review of the social and cultural literature highlights the extent to which public values, opinions, and behaviors related to invasive species and their management

are deeply embedded in larger societal and cultural processes. Incorporating the human dimensions into invasive species programs means that managers endeavor to consider a broad range of relevant social science research and to engage with the public and stakeholder groups to incorporate their diverse perspectives, develop broadly supported priorities, and identify strategies that can promote change. Verbrugge et al. (2013) show how people’s basic understandings of nature and the relationship between humans and nature influence their perceptions of invasive species and their management, and highlight the importance of early stakeholder participation and risk communication. McLeod et al. (2015) find that providing information has been the primary strategy implemented to change attitudes and behaviors toward invasive species, in spite of the fact that research on human behavior has demonstrated that knowledge transfer alone rarely brings about change. Recognizing that there are many behavioral change models in the social sciences, McLeod et al. (2015) developed a tool employing multiple theories to identify key leverage points and apply them through a range of intervention strategies. Notably, they are able to link a broad range of policy and management approaches to these intervention strategies. Several other studies (Dalrymple et al. 2013; Howell et al. 2015) draw on social networks and diffusion of innovation theories to target behavioral change efforts at opinion leaders, who serve as important and respected sources of information, in these cases targeting vendors of fishing supplies to reach the broader recreational fishing population.

While care must be taken to understand stakeholder perspectives and respect cultural differences, education will continue to be an important part of invasive plant management strategies both to increase participation in management efforts (Marler et al. 2005) and to influence policy (Hershendorfer et al. 2007). Forms of public outreach vary, from relatively low-cost options such as printed materials and electronic resources to direct engagement of citizens in activities (DiTomaso 2000). Marler et al. (2005) report using a suite of educational and citizen engagement efforts in Missoula, MT, that included stewardship opportunities (Adopt-a-Switchback on a popular trail; a Prairie Keepers program that organized activities that included weed pulls, seed collecting, and K-12 education); an annual “weed fair” education project that drew significant attention in the community; and a Grow Native project that engaged junior high school students in restoration activities. Strategies that directly engage learners, either through active participation or involvement in discussion, have been shown to work better than unidirectional or rote-learning approaches used for increasing knowledge (DiEnno and Hilton 2005).

The lack of evidence that short-term training increases long-term participation in invasive species control (Crall et al. 2013; Jordan et al. 2011) suggests that more careful

attention must be paid to audience, curriculum design, and desired behavior change. Two curricula were created as part of the Ecologically-Based Invasive Plant Management (EBIPM) program, instituted by the USDA Agricultural Research Service to provide science-based solutions to annual grass invasions (Crall et al. 2013). The university curriculum (Kartchner 2013) provides an example of how an education program can be structured when direct engagement is not always feasible. EBIPM offers a decision-making framework for landowners and managers; therefore, the curriculum covers each of the decision steps in separate modules that include synoptic reading, case studies, in-class and field activities, review questions, additional resources, and a PowerPoint presentation. The modular curriculum was developed with collaborators, including plant ecologists, weed scientists, social scientists, economists, range managers, and media developers.

Public engagement in invasive species monitoring and management can both complement and amplify the work of natural resource professionals, and will be essential if larger cultural changes in the understanding of invasive species and implementation of widespread management actions are to occur. There are a number of promising new public science and engagement techniques that have potential to simultaneously address a suite of human dimension needs for invasive species management, including changing attitudes, engaging stakeholders, instilling a landscape-level perspective, generating a common vision to motivate cross-boundary cooperation, changing behaviors, and complementing and expanding the work of public agencies. Here we review experiences with several of these techniques, while emphasizing the need for them to be accompanied by two-way communication and learning between scientists and the public. Citizen science can improve our scientific understanding of invasive species issues while facilitating attitude and, perhaps, behavior change. Geospatial Participatory Modeling helps engage people to increase their understanding of invasive species issues at landscape and regional scales, envision alternative futures, and establish the conditions for collective action. Social marketing applies marketing principals and strategies to social and environmental issues, and has shown particular promise for developing high profile campaigns with multiple partners to promote behavior changes to limit the spread of invasive species, for example, dispersal by recreationists or the pet trade. These are just a sampling of possibilities, but broad thinking informed by public input, social science research, ecological science, and consideration of the full range of intervention possibilities are the paths most likely to develop successful programs to address invasive species.

Citizen Science Citizen science, which involves members of the public in scientific research, has the potential to drive social change with respect to environmental

issues. Through knowledge and skills training to engage the public in scientific activities, citizen science provides opportunities to facilitate change through improvements in participants' science literacy, knowledge of an issue, attitudes surrounding an issue, and behavior to address that issue (Bonney et al. 2009, 2015; Brossard et al. 2005; Evans et al. 2005; Jordan et al. 2012; Shirk et al. 2012; Trumbull et al. 2000). In addition, it is often suggested that public involvement in research induces social change by building social capital, enhancing community capacity, and promoting trust among various stakeholders (Bonney et al. 2015; Jordan et al. 2012; Kountoupes and Oberhauser 2008; Overdeest et al. 2004; Shirk et al. 2012). However, few studies have empirically supported this (Bonney et al. 2015).

This holds true for citizen science projects that involve invasive species. Jordan et al. (2011) examined knowledge gain and behavior change among participants following participation in a project called "Spotting the Weedy Invasives." As part of the training program, instruction included invasive plant species ecology and implementation of the project protocol. Participation resulted in increased knowledge of invasive plant species, improved skills in recognizing invasive plants, and increased awareness of invasive plant impacts. However, participation did not improve understanding of the scientific process or result in changes in behavior. The authors suggest modifications to the training program that better align project design with its goals and participant motivations to reach desired outcomes.

Crall et al. (2013) examined changes in participants' attitudes, behavior, and science literacy following their participation in a citizen science project that focused on invasive plant species. The day-long training included presentations covering an introduction to invasive species, global positioning systems (GPS), sampling design, and the project's vegetation monitoring protocol. A field component included identification of plant species, marking and navigating with a GPS, and implementing the protocol. Although the study found no changes in general science literacy or attitudes following participation, it did note improvements in science literacy and knowledge using context-specific measures. In addition, participants expressed their intention to engage in more pro-environmental activities following the training which included volunteering for environmental organizations, attending community events, removing invasive species, and educating others about them.

Despite the potential, very little research has focused on outcomes from citizen science invasive species initiatives. Outcomes can be considered to be scientific (such as ecological datasets or publications based on these data) and social (such as abilities, skills, and knowledge). Historically, the study of citizen science programmatic outcomes was focused on verifying data quality and individual benefits.

More recently, however, the field has begun to widen its scope and address larger scale social changes that may result from citizen science programs including the potential for long-term impacts that involve attaining conservation outcomes as well as human well-being (Jordan et al. 2011; Shirk et al. 2012). For example, Jordan et al. (2016) report on preliminary data that suggest that collaboratively structured citizen science can produce social outcomes such as increased involvement in natural resource stewardship.

In a recent review of citizen science programs, Conrad and Hilchey (2011) found that some programs increase in environmental engagement, scientific literacy, and social capital. Direct evidence for benefits to the ecosystem, however, was not well-documented, perhaps because data collected from citizen science are often not shared through the management phase. Furthermore, citizen science impacts on conservation behavior, as opposed to behavioral intentions, have not been well-measured (Gray et al. 2017 is an exception). Perhaps conservation scientists and resource managers, by adopting a socio-ecological or adaptive management perspective, can not only gather essential data with respect to invasive species, but, through carefully structured training and education, also use learning as a management tool that increases conservation behavior and improves decision making (Jordan et al. 2016). A recent review suggests programs consider project design, metrics to measure outcomes, ways to engage new audiences, and new directions for research (Bonney et al. 2015). As the field continues to expand, more evidence will be available on best practices for generating desired outcomes through citizen science.

Geospatial Participatory Modeling Despite the availability of bigger data and better models, many efforts to manage invasive species have not been as effective as we have hoped. For complex systems with multi-scale interactions across ecological, social, and economic domains, even the best applied research will not yield solutions without the addition of sustained and meaningful stakeholder participation. Decisions that comprehensively involve stakeholders in the management of invasive species—from data collection to policy—are more likely to be viewed as legitimate, more likely to be accepted, and more likely to succeed (Groffman et al. 2010; Reed 2008). Yet, most public science projects fail to gain traction in shaping collaborative solutions, because either they do not follow best practices for participatory research or they use abstract or aspatial representations of data and models that fail to engage stakeholders. Advancements in geospatial analytics are helping generate more data and better models, raising the question of how to use geospatial technologies effectively to make a difference.

Geospatial Participatory Modeling (GPM) provides an opportunity to improve the connection between communities and the environment and offers three ways to involve stake-

holders in research better. Dynamic, adaptive geospatial models enable multiple stakeholders to visualize and explore the roles of (1) place; (2) spatial interaction; and (3) multi-scale processes through all steps of a research process. GPM is an umbrella term that combines (1) adaptive modeling of complex multi-scale/multi-domain processes; (2) geospatial tools and technologies to conceptualize and visualize modeled processes; and (3) the principles and best practices of participatory research, where stakeholders are meaningfully involved throughout the research process. Examples of specific models that could be incorporated into a GPM approach include process-based models such as those that model the spread of invasive insects (Fitzpatrick et al. 2012) and plant pathogens (Cunniffe et al. 2016; Meentemeyer et al. 2011).

By offering a spatial context through maps and interactive spatial media, GPM can evoke and establish stakeholders' sense of place and spatial awareness (Brown and Raymond 2007; Silbernagel et al. 2015). This geospatial framing offers participants insight into how the spaces around them (home, neighborhood, landscape) might be impacted by personal or policy decisions. The first-person positionality and spatial orientation possible with geospatial media can highlight causal relationships between users' behavior and environmental outcomes for locations familiar to or used by participants. Illuminating this causality can be highly persuasive for changing behavior or management practices; stakeholders are more likely to become involved when they recognize that the places they care about are being affected. For example, when citizen scientists were able to contribute data from their own backyards, there was a boost to monitoring efforts in normally under-sampled urban ecosystems (Meentemeyer et al. 2015). Geospatial models and representations can help the world to move away from abstract ideas and vague representations and to bring those problems home. Whether it is pests impacting agricultural commodities and farmer livelihoods, such as the Asian citrus psyllid (*Diaphorina citri*), or the death of species with cultural or spiritual values, such as the oak trees impacted by sudden oak death, making it spatial makes it personal.

Biological invasions and management outcomes are rarely confined to one place. The connections between places can be very difficult to visualize or understand without thinking spatially. Tools from geospatial analytics allow us to examine spatial interactions between invasion and affected people and places, which can catalyze an understanding of the connectedness of our world. For example, geospatial information regarding (1) where; (2) when; and (3) how severe a problem or threat is can shape discussions about management tradeoffs, offering stakeholders improved opportunities to represent their interests. Epanchin-Niell et al. (2010) reported that 75% of interviewed ranchers stated that they were negatively affected, in terms of reduced cattle forage, by the invasion of the rangeland weed yellow star-

thistle from neighboring land parcels. One-quarter of those interviewed also reported that due to the cost associated with continual reinvasion, if their neighbors did not treat for the invasive species, they would reduce their own investment in control efforts. The importance of spatial interactions is clear—what happens on one stakeholder’s property directly affects another stakeholder’s livelihood.

A GPM approach could also accommodate localized stakeholder knowledge and understanding to promote sustainability. Stakeholders have unique and often deep knowledge of both the environment and their community and can offer tremendous insight on the use and management of local resources. Geospatial models can contextualize spatial interactions—what happens here affects there—and stakeholders can contribute iteratively to alternative future scenarios by evaluating options and eliminating non-starters.

Geospatial information can also help stakeholders to better understand multi-scale processes and to know where critical geographic boundaries lie. Complex problems are better assessed, and solutions are more sustainable, when stakeholders consider dynamic cross-scale linkages (Cash et al. 2006). For example, multi-scale scenario exercises can highlight cross-scale interactions that manifest or have strong impacts at one scale but not at others (Biggs et al. 2007). Heavy impacts at a local scale, such as a localized outbreak, may be lost when considering a regional assessment or perspective. Conversely, widespread, but low-level, invasions may not be recognized as a threat at a local level but may be seen as a problem when we scale up and realize that a whole region is impacted. With reference to sudden oak death, Cunniffe et al. (2016) showed that it is no longer feasible to eradicate and probably impossible to significantly slow the geographical spread of this disease. However, countless trees can still be protected locally with careful forest management in high priority landscapes, such as national parks and places of cultural heritage. GPM has the ability to incorporate these scenarios within a spatially explicit framework, making it easier to understand mismatches between scales at which decisions are made and scales at which ecological processes occur.

Socio-ecological systems function at multiple scales; however, stakeholders typically engage and manage within a local or jurisdictional boundary unrelated to the boundaries of biophysical and ecological processes. Rarely is there one scale where optimal, equitable solutions exist for multiple stakeholders. Nevertheless, there is an urge to simplify issues of scale in order to control and manage these complex systems more easily (Cash et al. 2006). Local actions often compound to create environmental and social tradeoffs. For example, land owners may choose to divert resources elsewhere rather than control for invasive species. They would be making a decision based on the perceived damage to their land. However, this may contribute to increased invasion at

a landscape scale and an additional cost to others because the untreated parcel now serves as a propagule source (Epanchin-Niell et al. 2010). In order to understand and manage complex natural resource issues effectively, it is critical to clarify potential effects at multiple scales. Geospatial analytics has become an invaluable tool to visualize geographic boundaries and to understand and contextualize multi-scale processes. GPM offers a method for allowing stakeholders to see themselves in a connected world, with considerations ranging from site-specific to global perspectives.

Stakeholder involvement in the research process will be vital for developing lasting sustainability solutions, and GPM offers three ways to improve stakeholder engagement. Contextualizing “place” in a problem strongly motivates people to explore how an issue affects them; making it spatial makes it personal. Visualizing “spatial interaction” catalyzes new understandings of the connectedness of our world; people learn that what happens here affects there! Defining “spatial scale” helps visualize geographical boundaries of a problem, including knowledge of where policy and funding mechanisms operate at multiple and overlapping levels. We must move beyond specialized computational environments (and so-called “decision-support tools”) that continue to inhibit discussion and co-learning of complex problems between professionals and the public. Technical solutions alone cannot provide sustainable futures for environmental management, rather we need integrated approaches with new tools for envisioning the future and evaluating tradeoffs that arise from multiple social, economic, and environmental drivers.

Social Marketing Social marketing, an approach derived from the applied social sciences, has considerable potential for changing awareness, attitudes, and behaviors of targeted audiences. It provides a method for improving our relationship with the environment and promoting the adoption of a conservation ethic and sustainable behaviors. Social marketing is a discipline that is grounded in education and psychology, and can be combined with other applied social science disciplines, like branding and storytelling, to promote environmental behaviors.

Public engagement in many natural resource management functions can both complement and amplify the work of conservation professionals. While new science and management techniques are addressing invasive species issues, it is also critical to influence citizen behavior to prevent the spread and introduction of invasive species. Kotler and Zaltman (1971) introduced social marketing as a method to influence behaviors for good—those behaviors that improve health, prevent injuries, protect the environment, and contribute to communities. Social marketing does this by applying marketing principles and practices to bring about positive social

change, to improve society and the environment, or to enhance the health and/or social status of individuals within society. In the 1980s, social marketing was used by agencies such as the World Bank to address personal hygiene and sanitation and by the Centers for Disease Control to influence the health behaviors of individuals or the behavior of policymakers.

There are seven steps involved in social marketing: selecting behaviors; uncovering barriers and benefits to the behaviors; researching the target audience's knowledge, attitudes, and related behaviors; developing communication strategies that address these barriers and benefits; combining branding and storytelling; piloting this strategy; and implementing it broadly when it is cost-effective (Goodman 2008; Jiwa 2015; McKenzie-Mohr and Smith 1999). This process can and has been used to foster a wide range of sustainable behaviors, ranging from individual health behaviors like smoking cessation and family planning, to pro-environmental behaviors like recycling, litter prevention, and use of public transportation.

Social marketing provides a voluntary approach that simplifies a very complex resource management issue, makes the issue relevant to a targeted audience, and empowers individuals to become part of the solution. In 2002, the U.S. Fish and Wildlife Service (FWS) created the "Stop Aquatic Hitchhikers!" campaign to elevate the aquatic invasive species issue and empower people with cleaning behaviors that are designed to prevent the introduction and spread of these harmful organisms into other waters. By leveraging social marketing with branding and storytelling, the campaign has created an international community of grassroots organizations that support, engage in, and promote behaviors that inhibit the spread of invasive species. Branding has introduced the need for a consistent message, and storytelling enables people to understand a very complex natural resource issue (Ries and Trout 2001). Branding the issue and the behaviors created an action step that empowers people beyond raising awareness about different non-native invasive species. All 50 State fish and wildlife agencies have joined the campaign, as well as all of the Canadian provinces and the countries of New Zealand, Scotland, England, and Ireland.

The campaign is particularly effective because the grassroots branding strategy enables the campaign to transcend State borders and promote a unified message. The same empowering brand is seen in Florida, Alaska, Maine, and California. After 13 years, the campaign is currently undergoing a brand refresh process and website update. "Stop Aquatic Hitchhikers!" has led to the emergence of different regional initiatives over the years, and the new face of the campaign will include a multi-initiative strategy that will leverage the market-defining impacts of the slogan. Currently, the campaign has been written up as a case study example of

effective grassroots branding in a social marketing textbook written by Kotler and Lee (2011), producing a return on investment of 5:1, leveraging \$5 from external partners for every \$1 of Federal money spent. Over 2000 grassroots organizations have joined the campaign and are using the marketing collateral to promote the same message.

Due to the success of "Stop Aquatic Hitchhikers!," the pet and aquarium industry approached the FWS to develop a similar type of campaign. The high cultural importance of individual rights and identities in the modern United States has led to a considerable increase in the purchase of exotic pets and plants. Unfortunately, many of these species are impulse purchases and consumers may not realize how large they will grow and what other issues might arise. Ultimately, for a variety of reasons, these people may not be able to properly care for these species, and they may end up releasing them into the environment, thinking this is beneficial for the pet. If the pet survives, it has the potential to wreak havoc on the environment; a perfect example is the introduction of Burmese pythons (*Python bivittatus*) in south Florida and the impacts these species are having on the Everglades ecosystem. In partnership, the FWS and pet industry created "Habitattitude," a social marketing campaign designed to promote the environmentally friendly surrender of pets and discourage the spread of aquatic plants.

In addition to these two campaigns, the State of Minnesota's Department of Natural Resources has created the "PlayCleanGo" campaign to target those who recreate on the land. Seeds and plant fragments from non-native, invasive terrestrial plants have the potential to "hitchhike" on hiking boots, tires of off-road vehicles, horses, and other mobile vectors and thereby introduce and spread these harmful species to other areas. While this campaign was initiated by the state of Minnesota, it is seeing a similar growth trajectory as "Stop Aquatic Hitchhikers!" and the people who created the campaign are currently exploring ways to transfer the management of the campaign to a national organization to enhance growing interest.

12.5 Using Human Dimensions Research to Inform Invasive Species Policies

At the global and national levels, the World Conservation Union and Convention on Biological Diversity as well as the National Invasive Species Council in the United States have developed guiding principles for the prevention and control of invasive species. However, their guiding principles are largely about what governments should or should not do and thus fall short of utilizing human dimensions research to inform policies that can motivate and direct actions to minimize the spread of invasive species on the ground (Reaser 2001). Researchers have emphasized the need to incorporate

more human dimensions research into invasive species policy development. Warren (2001) argued that it is important to incorporate the management of invasive species within a system of legislation, public policy, and resource management that reflects public interest and is informed by values, cultures, and other human dimensions considerations. Carlson and Vondracek (2014) state that even though some of the current invasive species management approaches in the United States are progressive and anticipatory, they are deficient in human dimensions, and there is a need for predictive models, management paradigms, and human dimensions research to design ecologically effective, economically feasible, and socially acceptable management policies and strategies. This general need for using human dimensions research to inform invasive species policies is further exacerbated by the fact that the management of invasive species is a multi-scalar, cross-boundary problem that requires various stakeholders at different levels to work collaboratively (Stokes et al. 2006).

In the United States, significant public policy efforts have been made to improve the ability of government agencies and the general public to detect, report, and verify suspected new invasive species and to assess and respond to verified new infestations. The Federal Interagency Committee for the Management of Noxious and Exotic Weeds established the National Early Detection and Rapid Response (EDRR) System for Invasive Plants to foster interagency cooperation and public-private partnerships needed to address new and emerging invasive plant species in agricultural, forest, and other ecosystems. Several regional networks were established to coordinate EDRR efforts operating across State lines (e.g., Great Lakes Early Detection Network, Mid-Atlantic Early Detection Network). A number of States also have their own EDRR system incorporated within their State invasive species management plan. Undoubtedly, investment and coordination by Federal, regional, and State officials are important for invasive species prevention and control (Leung et al. 2012; Lodge et al. 2006). These existing public policy efforts strongly rely on the idea that “the best offense is a good defense” (Mehta et al. 2007) because prevention and early detection of invasive species are considered to be more effective than eradication and control (Hobbs and Humphries 1995; Mehta et al. 2007). However, these public policy efforts have been mostly focused on public lands, while relatively little is known about private landowners’ ability and willingness to prevent invasions and detect early infestations. Human dimensions research could provide important insights to address this need.

In addition, communication between government agencies and the general public with respect to invasive species prevention and control has generally focused on discernible terrestrial and aquatic wildlife species (e.g., Burmese pythons, feral pigs, Asian carp, and zebra mussels). Insufficient attention has been directed at communication

between government agencies and private landowners about invasive species in a forestry setting. Understanding how private landowners perceive and respond to invasive species will be critical for informing effective outreach and communication strategies targeting these people who are at the forefront in efforts to control invasive species.

Finally, limited effort has been made to assess the extent to which previous and current public policy efforts effectively address local needs and concerns and motivate individual citizens to engage in invasive species management actions on their own. So far, few studies have evaluated the various public outreach efforts that aim to increase public awareness and willingness to report sightings of, eradicate, and/or control invasive species (Fritts 2007; Hawley 2007; Martin 2007; Reaser and Meyers 2007). The use of human dimensions research to evaluate a broader range of invasive species policies and programs will provide important insights that can be used in the development of future policies and programs to incentivize the public (including private landowners) to engage in invasive species management actions individually or collectively. It can also help policymakers and resource managers to anticipate and minimize conflicts over invasive species management rooted in diverse stakeholder values (Buckley and Han 2014; Estévez et al. 2015; Gobster 2011; Larson et al. 2011).

12.6 Conclusions: Key Findings and Information Needs

12.6.1 Key Findings

Social and cultural research is of fundamental importance in addressing the issue of non-native invasive species. Invasive species can threaten many of the fundamental ecosystem values and services on which society depends. The spread of invasive species is largely through human actions, including intentional introductions, accidental introduction through global movements of products and people, and human disturbances that facilitate their introduction and spread. In spite of the threats that invasive species impose on ecosystems and human well-being, public awareness of their presence and impact is generally low except in a few cases that involve highly problematic species. Broad awareness of an invasive species is generally only achieved once a species is widespread and well-established, but unfortunately this is also the point at which control is most difficult. Invasive species are generally viewed quite differently by the public than by scientists. People have complicated relationships with invasive species, with some being viewed very positively. Public views are further divided among stakeholder groups, who, depending on their relationship with a particular inva-

sive species, may differ in their attitudes and associated interests.

Human dimensions research addresses a wide variety of topics and plays a critical role in informing scientists and managers about the larger social and cultural contexts in which people relate to invasive species. It also provides knowledge of awareness, attitudes and values, behaviors, and management preferences in relation to specific invasive species issues. Public support for management and control of invasive species is variable and often influenced by other values, such as the ways that people think about ecosystems and nature, and by the specific control measure being used. Language employed to call attention to invasive species and support management actions should be chosen carefully, because there is substantial evidence that language that is divisive or offensive to some people can create reactions that hinder efforts to carry out invasive species management activities. Differences in public opinion and interest related to invasive species can create conflict over control and management actions, and stifle efforts to promote widespread behavior changes.

Viewing invasive species from social and cultural perspectives highlights the importance of public dialogue that involves both listening to and educating the public to develop sufficient common understanding and concern to support needed management and policy actions. Collective action to address invasive species across ownership boundaries and at the landscape level is known to be important, yet more research is needed to learn the key motivating factors and steps necessary to promote collective action. Public engagement in invasive species monitoring and management can both complement and amplify the work of natural resource professionals, and will be essential if larger cultural changes in understanding invasive species issues and implementing management actions at landscape levels are to occur. Innovative human dimension techniques often simultaneously address various human dimension issues, including attitude change, stakeholder engagement, instilling a landscape-level perspective, generating a common vision to motivate cross-boundary cooperation, behavior change, and complementing and expanding the efforts of public agencies. Some of the promising new public science and engagement techniques being used for invasive species include citizen science, Geospatial Participatory Modeling, and social marketing.

Relatively little attention has been directed at determining how racial and ethnic diversity in the United States affects invasive species and their management. Structural issues, such as resource rights and environmental justice, and cultural differences, such as the ways that different species and ecosystems are used and are valued, are critical in managing many invasive species. Yet, relatively little is known about these issues. This chapter has highlighted the perspectives of

tribes and invasive species. Tribes bring unique cultural perspectives and traditional ecological knowledge to invasive species management, and their close ties with the land and ecosystems can amplify its importance. Because of tribal sovereignty, the Federal Government relates to tribes on a government-to-government basis, yet overlapping trust responsibilities and common interests have resulted in numerous collaborative efforts to address invasive species issues.

12.6.2 Key Information Needs

Social science research conducted in the United States has been both limited and uneven in addressing general awareness, attitudes, and behaviors toward invasive species and how these are situated in larger social and cultural contexts. There is an obvious need for broad research in these areas. More specific research is also needed on particular invasive species, in the full range of ecological contexts and using a diversity of social science approaches and methods. Currently, research results have been insufficient to support strong decisions and actions by managers and policymakers. More research is needed on all aspects of the human dimensions of forest invasive species in public ownerships, such as national and State parks and forests. For private forest owners, we need to know: (1) how they perceive invasive species problems, particularly how they perceive invasions and associated impacts, both on an individual and landscape scale; and (2) what types of information, assistance, and resources will be most useful for helping landowners detect and manage invasions that have occurred and the potential risk of future invasions. There is also a need for a more explicit focus on the role of scale in landowner perceptions of invasive species and invasion risks, concerns about invasive species and invasion risk, and willingness to take actions.

Public awareness of invasive species in grasslands and aquatic ecosystems may be greater than it is in forest ecosystems, yet there is relatively little published research available for both. There is a clear need for more research on (1) attitudes and behaviors of individuals; (2) mechanisms to generate public concern regarding invasive species and support for their management; (3) collective action responses at the landscape level on both public and private lands; and (4) how laws and policies interact with other human dimensions issues, and how can their effectiveness be improved.

We know that cooperation across land ownerships is of fundamental importance, but we need more research on collective action practice in order to know: (1) what factors determine the likelihood of landowner cooperation and the effectiveness of their cooperation; (2) whether there are tradeoffs between the increased likelihood of landowner coop-

eration (potentially by reducing the scale at which landowners cooperate with one another) and decreased effectiveness of landowner cooperation (e.g., as few landowners cooperate, whether the ability of the group to prevent and control invasive species and affect landscape outcomes could be compromised); and (3) at what scale landowners should cooperate with one another in order to realize invasive species management at a landscape scale.

There is a need for interdisciplinary research to better understand the interactions between biological and social complexities and uncertainties, in order to more effectively manage invasive species and reduce the associated social conflicts among stakeholders (Kokotovich and Andow 2017). An accurate understanding of current and future invasion risks is critical to achieving effective invasive species management and to enhance strategic planning and policymaking at the regional level (Leung et al. 2012; Lodge et al. 2006). Assessing and predicting invasion risks require a holistic understanding of various interacting components of invasions (Catford et al. 2009; Richardson et al. 2000). However, current invasion risk assessments tend to focus on the biological characteristics of invaders, environmental factors that make a recipient system more or less likely to be invaded, and a number of biological, ecological, and (in a few cases) land-use drivers. Considerable research has shown that socioeconomic drivers on both local and regional scales can influence the distribution, abundance, and species richness of invasive plants and animals (Chhabra et al. 2006; Vilà and Ibáñez 2011; With 2002). Therefore, to better predict invasion risks, modeling efforts need to incorporate changing ecological and landscape characteristics, as well as socioeconomic conditions over time. Only by incorporating human dimensions data on landowner willingness-to-manage invasive species into invasion risk models will we be able to achieve a more realistic understanding of future invasion risks.

There is relatively little published literature on tribes and invasive species. There are a number of successful examples of collaboration between tribes and biological scientists to address invasive species, particularly involving tree pests and diseases. There is a need to conduct collaborative research with tribes in order to better document the cultural, traditional ecological knowledge, and sovereignty and other policy issues that are often key factors in invasive species management.

While promising new approaches are being developed to increase public awareness and actions related to invasive species, it is critical that new research focuses on the outcomes and effectiveness of these approaches. We need to know how participation in citizen science projects and geospatial modeling and exposure to story maps and social marketing change knowledge of invasive species, attitudes, and behavior for both the public and sci-

entists. We also know very little about the broader ecological, community, and social impacts of these new approaches.

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