Wolf habitat analysis in Michigan: an example of the need for proactive land management for carnivore species

Thomas M. Gehring and Bradly A. Potter

Abstract Gray wolves (*Canis lupus*) likely will recolonize the northern Lower Peninsula of Michigan (NLP). As such, land managers would benefit from information on the amount, distribution, and quality of potential wolf habitat in this region. We estimated that 2,198–4,231 km^2 of favorable wolf habitat exist in the NLP, supporting an estimated population of 40–105 wolves. Favorable habitat was fragmented by road networks and was predominantly located in the northeastern part of the state on private land. We discuss the management of wolves in the NLP as a case study of wolf recolonization in a landscape that has a relatively high road density and agricultural lands that likely will be sources of conflict with wolves. We provide a hierarchical model for consideration in proactively managing landscapes that already or likely will contain several carnivore species concomitant with human land use. We suggest that this case study and our hierarchical model offer insight into how proactive land management should occur for wolves and other carnivores in the northern Great Lakes Region and other human-altered landscapes.

Key words *Canis lupus*, carnivores, carnivore–human conflict, gray wolf, integrated management, livestock depredation, Michigan, roads

Gray wolves (*Canis lupus*) have made a remarkable recovery in the northern Great Lakes region of Minnesota, Wisconsin, and the Upper Peninsula of Michigan. In response to this regional recovery, the United States Fish and Wildlife Service recently reclassified the gray wolf as a threatened species and has proposed delisting the species (Williams 2004) in the Eastern Distinct Population Segment, which includes the western Great Lakes states as well as the northeastern states of the United States (Williams 2003). Wolves were extirpated from the Lower Peninsula of Michigan by 1911 (Michigan Department of Natural Resources 1997), and the last known breeding wolves occurred in the Upper Peninsula during in the mid-1950s. Since the mid-1990s, the wolf population in the Upper Peninsula of Michigan (UP) has steadily increased. Wolves were downlisted to threatened in Michigan in 2003 and may be delisted in the future. Until recently, no gray wolves had been confirmed in the northern Lower Peninsula of Michigan (NLP) since extirpation, and no population goals were originally established for this region in the wolf recovery plan (Michigan Department of Natural Resources 1997).

Gray wolves have demonstrated the ability to disperse great distances, even in human-developed areas of the Midwest (Mech et al. 1995). For example, a wolf radiocollared in the western part of the UP dispersed and was killed by a hunter in Missouri (Hutt 2002). Also, gray wolves have demonstrated an ability to traverse potential barriers such as large water bodies in the Great Lakes Region. For example, prior to spring 2003, a wolf likely dispersed from the UP into the Door County Peninsula of

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Wisconsin, apparently crossing the ice of Green Bay (Wydeven et al. 2004). The NLP is separated from the UP by approximately 6.5 km at the narrowest part by the Straits of Mackinaw. If wolves do naturally recolonize the NLP, the only viable dispersal route for wolves likely is across pack ice that forms on the Straits of Mackinaw during some winters. Wolves are capable of crossing lake ice, as evidenced by the 24 km of ice on Lake Superior that wolves crossed to colonize Isle Royale (Mech 1966). A report of 2 large canids, presumably wolves, on the ice of the Straits of Mackinaw during 1997 (Williams 2003) indicates that wolves have the potential to recolonize the NLP using this route.

From an ecological standpoint, it is important to maintain populations of large carnivores, such as gray wolves, as they reinhabit the Great Lakes Region. Many carnivore species serve as umbrella species because they have large land-area requirements and thereby incorporate the ranges of other species. By conserving carnivore habitat, managers often can conserve greater amounts of biodiversity. Carnivores also may be used as indicator species that give a warning to ecosystem health because some are sensitive to human-induced disturbances (Gittleman et al. 2001, Noss 2001). In particular, carnivores can be used to assess the scale of fragmentation in human-altered landscapes (Gehring and Swihart 2003). The ultimate goal of conservation biology and wildlife management is to maintain and conserve species in otherwise human-dominated landscapes (Hunter 1996). Central to this goal is the need to assess and predict the distribution patterns of species in order to provide effective long-term management prescriptions. Additionally, it is necessary to prescribe management actions at multiple spatial scales to address complex conservation problems such as wolf-caused livestock depredations. Failure to effectively reduce or prevent carnivore–human conflict (e.g., wolf–human conflict) can lead to an erosion of social tolerance for carnivores and possibly the management agencies involved.

Our objective was to apply the Mladenoff et al. (1995) wolf model to assess the distribution and quantity of potential wolf habitat in the NLP and to estimate the potential size of a wolf population based on available habitat. We used the exact procedure identified by Mladenoff et al. (1995) in order to allow a comparison to assessments of wolf habitat in other parts of the northern Great Lakes region as well as the northeastern United States. Our GIS-based results could be used to target wolf monitoring to areas identified as favorable wolf habitat, thus increasing sampling efficiency. We also discuss management concerns and implications of natural recolonization of the NLP by wolves in part because this area likely will support a smaller population compared to the UP or Wisconsin. Finally, we introduce and discuss the need and opportunity for using integrated and proactive land management of the NLP landscape prior to wolf recolonization. We suggest that the NLP landscape offers a unique opportunity and potentially significant challenges for management of wolves and other resident carnivore species. One significant management challenge will be to maintain large carnivores such as gray wolves in semi-agricultural landscapes. As such, we offer and discuss a hierarchical model for understanding and managing carnivore–human conflict across multiple spatial scales in these landscapes.

Methods

We obtained a Geographic Information System (GIS) coverage of roads (2000 TIGER data) for the NLP from the Michigan Spatial Data Library (Michigan Center for Geographic Information, Lansing, Mich.). We excluded trails and unimproved forest roads from all analyses (Mladenoff et al. 1995). We used the density feature in ArcMap to create a coverage of 1-km^2 cells in which each cell had an assigned road-density value (km/km^2). In accordance with Mladenoff et al. (1995), we did not differentially weight roads based on type or traffic volume. We conducted a moving-window analysis using neighborhood statistics to average cells within a 10-km radius from the center of each focal cell (Mladenoff et al. 1995). Average values for cells were then used to calculate a probability of wolf presence based on the Mladenoff et al. (1995) model created for the Great Lakes Region, in which: $\text{logit}(p) = -6.5988 + 14.6189R$, where p is the probability of wolf presence and R is the road density. We used this simpler model compared to one that also included prey density because we assumed that prey density was relatively high and adequate throughout the NLP.

Given the predicted area of potential wolf habitat in the NLP, we calculated estimates of the number of wolves after Fuller et al. (1992) and Mladenoff et al. (1997) using the following algorithm: N=

$\{AW / [M(1+i)]\} / (1-D)$, where N=estimated number of wolves; A=area of favorable habitat; W= mean midwinter pack size (4.1); M=mean midwinter territory size (179 km^2); i = proportion of saturated habitat in interstitial areas (0.37); and D=proportion of dispersers (0.15). We subtracted the area of lakes from the total available wolf habitat to gain our estimates of total favorable wolf habitat. We calculated estimates for total favorable habitat area and for a reduced area in which all habitat patches <50 km^2 were excluded (Mladenoff et al. 1997). These methods do not explicitly consider the shape of patches, although the neighborhood statistics and moving window analysis we used resulted in few long narrow patches of potential habitat.

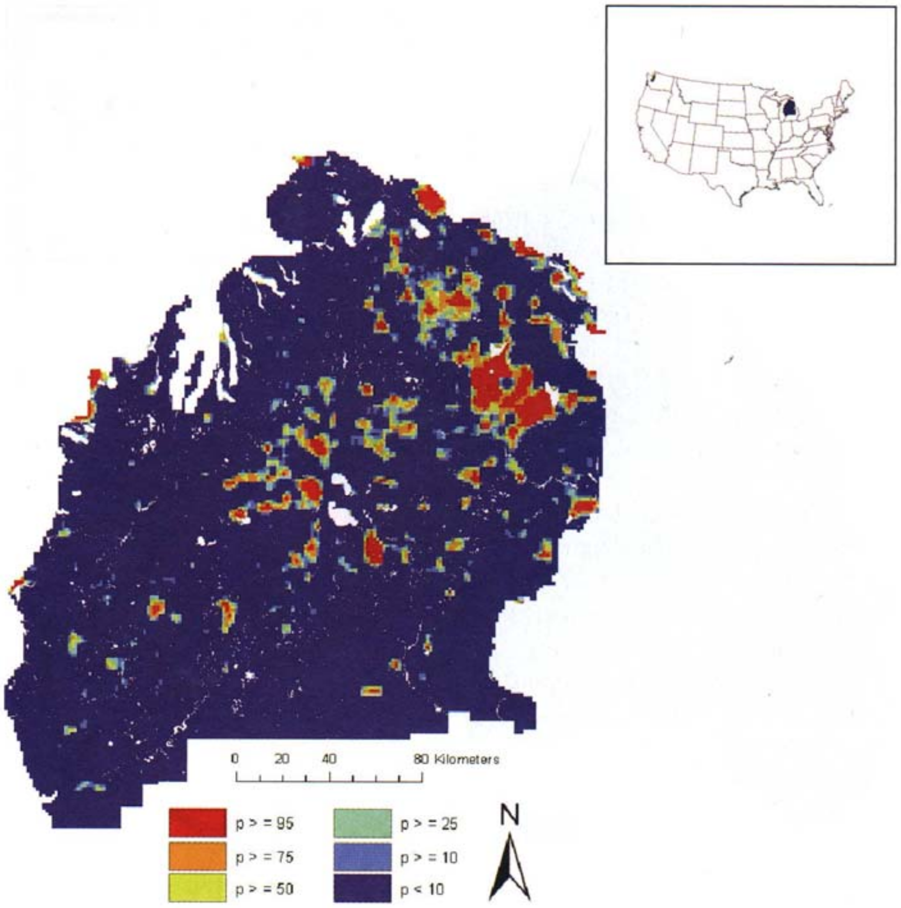

Figure 1. Distribution of potential gray wolf habitat in the northern Lower Peninsula of Michigan based on the road-density model of Mladenoff et al. (1995), 2004–2005. Inland lakes are identified as white polygons. P=probability.

Results

The road-density model predicted 14 patches of potential wolf habitat that were >50 km^2 in the NLP (Figures 1 and 2). The mean distance between patches was 24.0 km (SD=17.4 km). The majority of favorable wolf habitat (i.e., probability level >0.5) was distributed in the northeastern portion of the state on private property (i.e., private hunting club land) with smaller patches located in the north-central region (Figure 2). All 14 habitat patches contained at least 1 livestock farm, whereas only 1% of the total habitat area was comprised of farms. The NLP contained an estimated 4,231 km^2 of favorable wolf habitat. When we excluded all habitat patch isolates <50 km^2, the area of favorable wolf habitat dropped to 2,198 km^2. Thus, 48% of favorable habitat in the NLP was in patch isolates <50 km^2. We found that 61% of favorable wolf habitat in the NLP was in public ownership. We found relatively equal amounts of potential wolf habitat in each probability class except the significant amount of potential habitat in the lowest probability class (Figure 3). Based on our GIS analyses of total favorable wolf habitat in the NLP (i.e., 4,231 km^2), we estimated a potential for 89 wolves (90% CI = 78–105 wolves). However, this estimate dropped to 46 wolves (90% CI=40–54 wolves) when we excluded habitat isolates.

Discussion and management implications

Natural recolonization of the NLP would provide a possible second relatively disjunct wolf population in the northern Great Lakes Region. This population would be isolated from Wisconsin by urban development in the southern region of Michigan, Indiana, Illinois, and Wisconsin. It would be isolated from the UP wolf population by the Straits of Mackinaw, which likely would lower the frequency

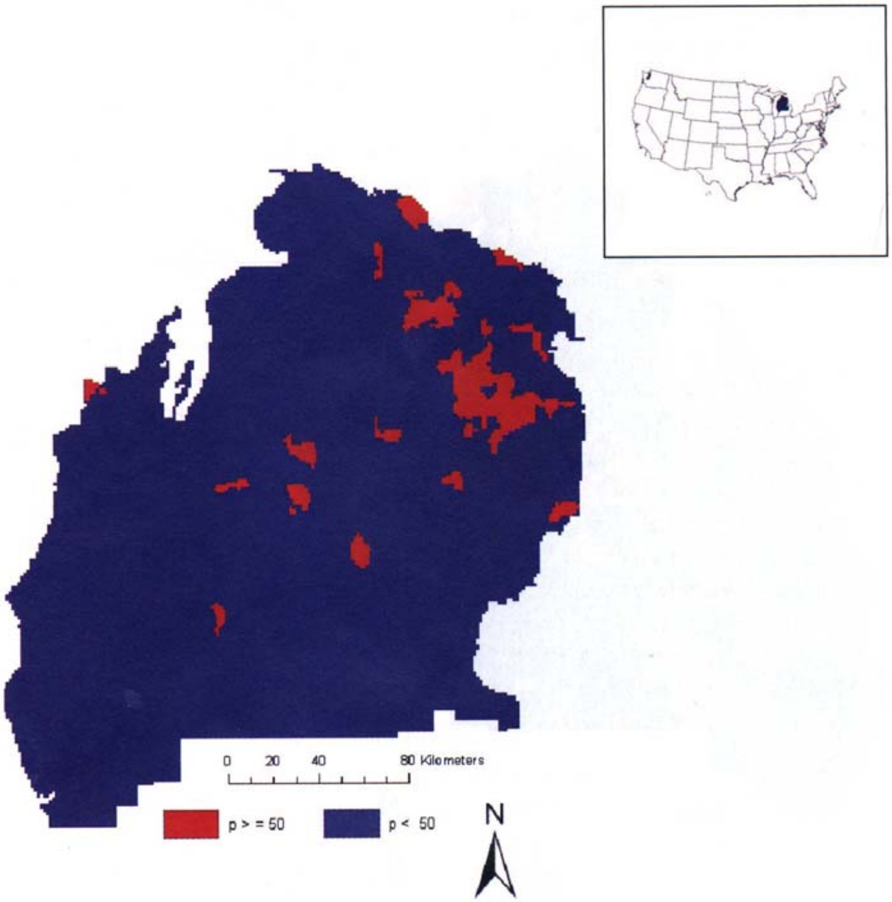

Figure 2. Distribution of potential favorable gray wolf habitat (probability, $P > 0.5$) in the northern Lower Peninsula of Michigan based on the road-density model of Mladenoff et al. (1995), 2004–2005.

of dispersal events. The amount of favorable habitat in the NLP (2,198 km^2) is significantly less than the UP (29,348 km^2) and Wisconsin (15,248 km^2; Mladenoff et al. 1995) and is most similar to estimates for New Hampshire (5,472 km^2) and Vermont (3,624 km^2; Mladenoff and Sickley 1998). Favorable habitat patches in the NLP are disjunct; however, they are well within the dispersal capabilities of wolves (Mech et al. 1995).

During the early stages of recolonization, this population would benefit from additional state-level protections. Our estimates are probably conservative and likely underestimate the potential favorable habitat and potential population size because wolves can use areas of higher-than-expected road densities (Mech 1989, Mech et al. 1995). Given current land-use patterns and road patterns, the NLP may never support a significant, large wolf population given the likely reduced dispersal rate from a source population. Further, although wolves will readily use roads with lower traffic volume (Gehring 1995), wolf packs in areas with higher road densities likely will experience higher mortality rates (Thiel 1985). A reduction in road density in more areas or adjacent to existing favorable habitat would increase overall amount and distribution of favorable wolf habitat. Road density might be initially reduced using road closures on public lands or through cooperative agreements or incentive programs with private landowners. This is par-

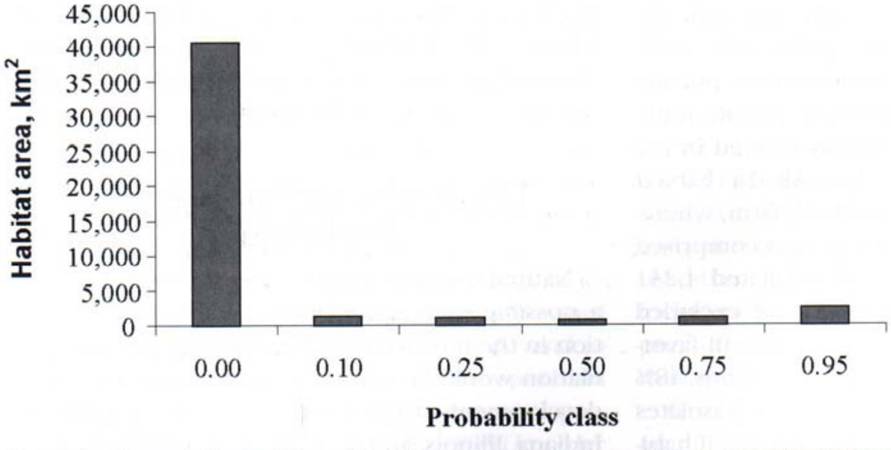

Figure 3. Amount of potential wolf habitat in probability classes from 0–1 for the northern Lower Peninsula of Michigan based on the road-density model of Mladenoff et al. (1995), 2004–2005.

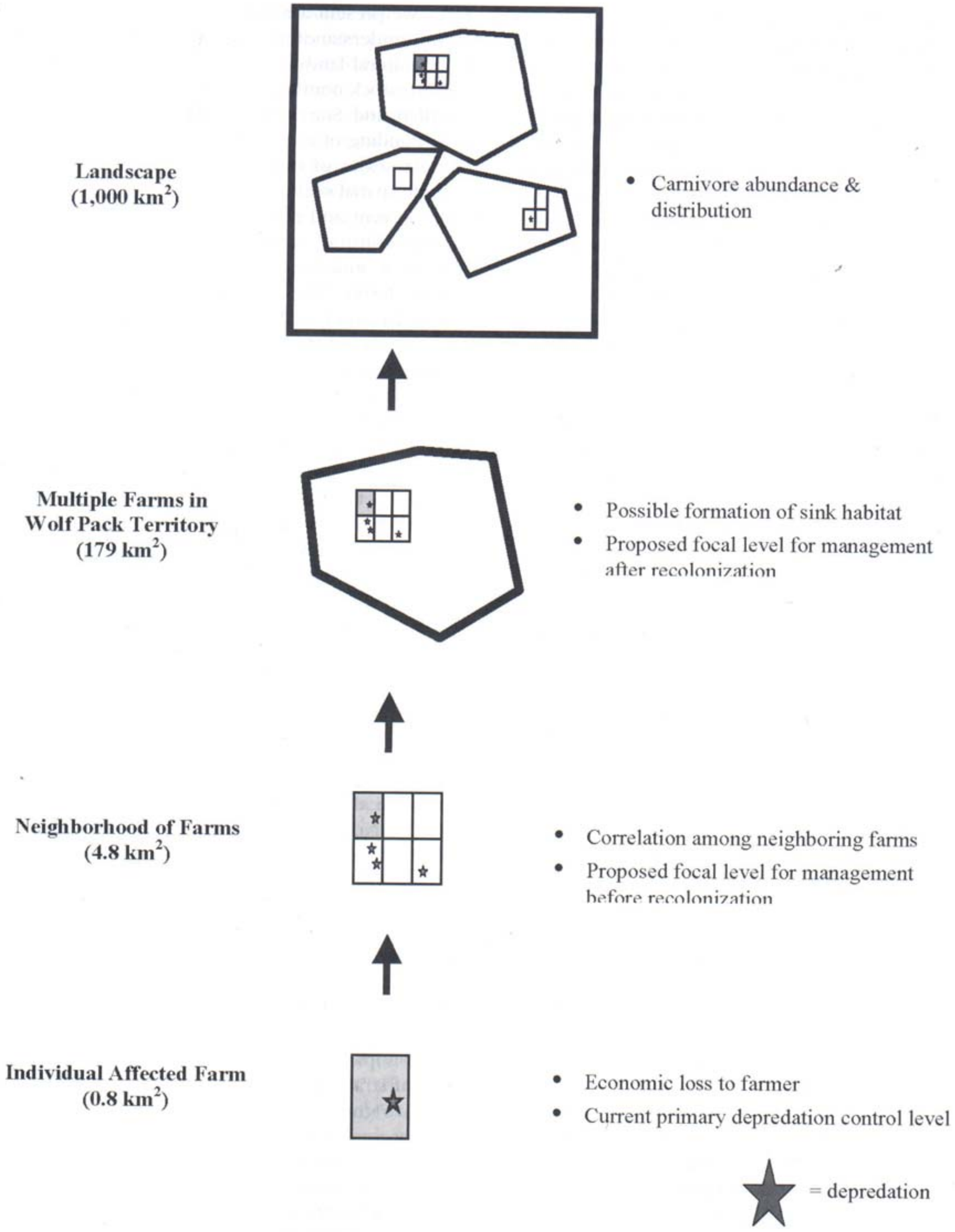

Figure 4. Hierarchical model for understanding wolf-caused livestock depredation and management at multiple spatial scales, 2004–2005.

ticularly relevant to the NLP because nearly 40% of favorable wolf habitat is on privately owned lands. Additional planning of road expansion projects would be needed to reduce and mitigate the long-term impacts of roads on wolf and other carnivore populations (Saunders et al. 2002). The likely reduced dispersal of wolves into the NLP from a source population may be of some conservation concern particularly with a relatively small founder wolf population and possible small to moderate carrying capacity based on the road-density model. Further, a small population in the NLP could succumb to genetic swamping if the few, new dispersing wolves may not find a mate other than resident coyotes (Wydeven et al. 1998).

Our results identified key patches of favorable habitat that might be recolonized first. For example, Mladenoff et al. (1997, 1999) found that wolves in Wisconsin colonized low-road-density areas first rather than areas with higher road density. We suggest that these favorable habitat areas should receive priority for howl and track surveys conducted to detect wolf presence and distribution, thereby improving the cost-effectiveness and efficiency of a large-scale monitoring program (Peterson and Dunham 2003). The favorable wolf habitat patches we have identified are characterized by lower road densities. As such, they also may serve as important habitat for other carnivores such as bobcats (*Lynx rufus*) and American martens (*Martes americana*) that are sensitive to roads and landscape fragmentation (Lovallo and Anderson 1996; Saunders et al. 2002). We suggest that further exploration should investigate the use of the wolf road-density model for general application to other carnivore species.

As the wolf population continues to increase in the Upper Peninsula of Michigan and more wolves become dispersers, we suggest that the NLP could begin to be recolonized. In fact, recent evidence suggests that several wolves have dispersed into the NLP (D. Beyer, Michigan Department of Natural Resources, personal communication). We suggest that wolf recolonization into the NLP serves as a case example of future carnivore management challenges in the northern Great Lakes Region and other human-dominated landscapes that contain some remaining wild lands. In particular, preventing and reducing wolf-human conflict (e.g., wolf-caused livestock depredation) and thereby maintaining human tolerance of carnivores in the NLP will be necessary to support a wolf population there. We present a hierarchical model for gaining a better understanding of the scale of management of agricultural lands needed to adequately address wolf-livestock conflicts (Figure 4). Hierarchy theory (Allen and Starr 1982) allows one to gain an understanding of complex systems that operate at multiple scales of organization. We propose that multiple spatial scales must be considered to effectively prevent and reduce wolf-human conflict in semi-agricultural landscapes because predators operate at multiple spatial scales (Gehring and Swihart 2003). The current primary tool used to manage livestock depredations is lethal removal of wolves from individually affected farms following a verified depredation (Figure 4). However, lethal control of wolves often is only a temporary solution and livestock depredations typically resume within 1 or 2 years (Fritts et al. 1992, Gehring et al. 2003). The concentration of management activities only at the scale of the individual farm fails to incorporate the influence of adjacent neighboring farms. That is, neighborhoods of farms are collections of individual farms that are not independent entities since they can influence one another depending on attributes such as livestock type and animal husbandry practices. For example, an individual farm with poor animal husbandry such as a livestock carcass dump can negatively influence neighboring farms (Gehring et al. 2003). As such, wolf-livestock conflicts are related to neighborhoods of farms within a given wolf pack's territory (Figure 4). Further, in the northern Great Lakes Region and much of North America, individual farm size is much smaller than the territory of a wolf pack, and territories may be comprised of neighborhoods of farms (Figure 4). Removal of entire packs of wolves following depredations at 1 or several farms within a territory can lead to the formation of sink habitat into which dispersing wolves may move to occupy (Gehring et al. 2003). At the landscape scale, wolf and other carnivore abundance and distribution can be impacted by the type and extent of management strategies used to reduce livestock depredations (Figure 4).

We present this hierarchical model in conjunction with our GIS analysis to illustrate that if wolves and humans are to coexist in the NLP and other similar landscapes in North America, then agencies must be more rigorous in addressing depredation problems using proactive land management across multiple spatial scales and by collaborating with important stakeholder groups such as the farming community. Our hierarchical model could easily be adapted to other regions where carnivore–human conflict may negatively impact recovering or small populations (e.g., the northeastern United States where favorable carnivore habitat exists; Mladenoff and Sickley 1998). We suggest that proactive management of agricultural landscapes could be initiated before, as well as during, wolf recolonization in order to reduce conflict. This approach should include managing individual farms and neighborhoods of farms, but it also must manage at the scale of wolf territories as well as the landscape scale. We suggest that the focal levels of management, however, should be at the neighborhood level before recolonization and at the territory scale during and after recolonization (Figure 4). For example, in semi-agricultural areas that could likely support wolves, preventative measures such as use of livestock-guarding dogs and standardization of proper animal husbandry practices would be implemented by all farmers in a neighborhood. This management approach should be integrative in the sense that multiple tools are used in concert. An active educational program would be an integral part of this integrated management approach and could target neighborhoods of farms rather than individual farmers. Open communication and cooperation among all stakeholders (e.g., farmers, state and federal agencies, nongovernmental organizations, university researchers) is essential to the successful application of this approach. In particular, active cooperation with and assistance provided to farmers would allow this important stakeholder group to gain a greater role in carnivore conservation.

We envision that a state- or federal-level incentive-based program, as a component of proactive management, could encourage and promote carnivore conservation on private lands. This carnivore habitat incentive program (CHIP), modeled after United States Department of Agriculture programs such as Conservation Reserve Program (CRP) and Wildlife Habitat Incentive Program (WHIP), could provide financial incentives to farmers or other private landowners that promote carnivores on their lands or do not degrade carnivore habitat. For example, a livestock producer enrolled in CHIP would receive a financial incentive for promoting sound animal husbandry and the use of proactive, nonlethal control tools on their property. Thus, livestock producers would become active managers in preventing livestock depredations on their own land (e.g., Cozza et al. 1996), and they would become integrated and a franchise in the management process. Most incentive-based carnivore programs have been implemented across limited spatial scales and generally only compensate for livestock losses (Mishra et al. 2003). Conservation programs that only compensate for livestock losses may not increase social tolerance for carnivores (Naughton-Treves et al. 2003). However, we predict that active land management by farmers and a comprehensive incentive program might increase the social tolerance for wolves and other carnivores. Additionally, nonfarm landowners might receive financial incentives for maintaining vehicle-restricted parcels on their properties. Given the scale at which carnivores operate and the need to manage at multiple spatial scales, CHIP would coordinate land use practices at the landscape scale in addition to local scales. Collectively, these measures may increase social tolerance for wolves and other carnivores.

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