Regulating Hunter Baiting for White-Tailed Deer in Michigan: Biological and Social Considerations

Article *in* Wildlife Society Bulletin · June 2006

DOI: 10.2193/0091-7648(2006)34[314:RHBFWD]2.0.CO;2

6 authors, including:

Brent Rudolph
MDNR Michigan Department of Natural Resour…
22 PUBLICATIONS **270** CITATIONS
SEE PROFILE

Shawn J. Riley
Michigan State University
53 PUBLICATIONS **1,308** CITATIONS
SEE PROFILE

Graham J. Hickling
University of Tennessee
240 PUBLICATIONS **2,816** CITATIONS
SEE PROFILE

Mark S. Garner
United States Department of Agriculture
2 PUBLICATIONS **67** CITATIONS
SEE PROFILE

Peer Reviewed

Regulating Hunter Baiting for White-Tailed Deer in Michigan: Biological and Social Considerations

BRENT A. RUDOLPH,[1] *Michigan Department of Natural Resources, Wildlife Division, Lansing, MI 48909, USA*
SHAWN J. RILEY, *Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48824, USA*
GRAHAM J. HICKLING, *Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48824, USA*
BRIAN J. FRAWLEY, *Michigan Department of Natural Resources, Wildlife Division, Lansing, MI 48909, USA*
MARK S. GARNER, *Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48824, USA*
SCOTT R. WINTERSTEIN, *Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48824, USA*

Abstract

*Eradication of bovine tuberculosis (TB) from free-ranging white-tailed deer (*Odocoileus virginianus*) requires mortality rates of infected deer exceed the rate of new infection. Efforts to reduce TB transmission in Michigan, USA, are based on 2 assumptions: 1) deer mortality may be increased through recreational hunting, and 2) encounter rates between infected and noninfected deer may be reduced by prohibiting baiting and supplemental feeding. Spatial correlation of TB-infected deer and supplemental feeding sites detected using aerial surveys validated a ban on artificial feeding in Michigan. Similar analysis could not be used to evaluate the effects of a baiting ban because bait distribution was unknown. Furthermore, a ban on deer baiting could confound attempts to increase deer mortality through reduced hunter participation or efficacy. We reviewed the process used to evaluate a strategy for regulating bait use by hunters. This review included an assessment of 5 factors: statewide spatial analysis of apparent TB prevalence, deer intraspecific interactions at bait sites, effects of bait on hunter harvest rates, impacts of disease presence and practice of eradication efforts on hunting participation in the infected area, and input from law enforcement personnel. Our analysis suggested that restricting baiting to a limited, consistent region incurred less biological risk than allowing bait to be used statewide and less political risk than a statewide ban.* (WILDLIFE SOCIETY BULLETIN 34(2):314–321; 2006)

Key words

baiting, bovine tuberculosis, hunter participation, Michigan, Odocoileus virginianus*, policy, risk analysis, white-tailed deer*.

Initial experiences with bovine tuberculosis (TB) in free-ranging deer (*Odocoileus* spp.) suggested that documented cases were isolated infections, which could not be sustained in wild populations (Essey and Vantiem 1995). Whereas TB was thought to be a livestock disease, evidence now exists that sustained infection of deer populations and related species can occur (Clifton-Hadley and Wilesmith 1991). Diagnosis and management of TB infections in free-ranging populations are more complex than addressing infection of captive wildlife or domestic animals (de Lisle et al. 2002). Self-sustaining TB infections of free-ranging wildlife create risks to public health through potential zoonotic transmission (Fanning and Edwards 1991), economic risks through the potential of reintroducing infection to livestock (Robinson et al. 1989, Lugton et al. 1998), and financial burdens to agencies for disease surveillance and management, in addition to compromising the overall health of the infected host population.

The Michigan Department of Natural Resources (MDNR) documented in 1975 what was believed to be an isolated instance of a TB-positive white-tailed deer (*O. virginianus*) in the northeast lower peninsula of Michigan, USA (44°52′N, 83°51′W). Following discovery of a second infected deer in 1994 (approx 13 km from the location of the original case), a surveillance program was initiated (Schmitt et al. 1997, O'Brien et al. 2001), which consisted mostly of voluntarily submitted hunter-harvested animals (O'Brien et al. 2002). Analyses concluded that these initial cases were located near the center of a self-sustained area of TB infection in white-tailed deer (Hickling 2002). Although surveillance has identified a variety of mammals infected with TB, it appears that deer are the only wildlife species currently acting as a reservoir host in Michigan (Bruning-Fann et al. 2001). Management of TB in Michigan's wildlife, therefore, depends on intervention through deer management practices.

We provide a case study of deer management activities that addressed TB in Michigan. Our review highlights multiple efforts that addressed key uncertainties regarding the effects of regulating use of bait by hunters. These uncertainties arose from a lack of knowledge about how bait concentrated deer locally, whether bait accelerated rates of TB infection by increasing encounter rates, or whether use of bait could reduce rates and sources of infection by sustaining high hunter participation and harvest rates. We conducted a retrospective analysis to define the risk involved with regulating bait under these uncertainties.

Formulating and Initiating a Management Strategy

Deer Management in Michigan: Authority, Policy, and Processes

The mission statement of MDNR commits the agency to "the conservation, protection, management, use, and enjoyment of the State's natural resources for current and future generations." This mission statement recognizes the influence of public trust doctrine on the management of wildlife in the United States (Bean 1983).

The Natural Resources Commission (NRC) is a 7-member governor-appointed panel that establishes general policies for MDNR and is vested with exclusive authority to regulate the taking of game in Michigan. The Wildlife Division of MDNR provides technical expertise to formulate recommendations to the NRC for

[1] *E-mail: rudolphb@michigan.gov*

enacting regulations. The NRC Policy 2007, issued 14 April 1994, established the MDNR policy for deer management that required practices based on scientific research to maintain healthy animals within limits dictated by carrying capacity of the range.

Regulations for managing TB in deer must, therefore, consider both current and future generations, address the mission statement mandate, and meet the expectation of NRC Policy 2007 for scientific management intended to maintain healthy animals. A goal of MDNR is eradication of the disease from deer populations in Michigan. This objective was established through a 1998 Governor's Executive Directive (Michigan Executive Directive 1998–1).

Identifying the Source of Infection and Sustaining Factors

Data collected as part of the U.S. Bovine TB Eradication Program identified that the initial crossover infection of deer likely occurred in the 1950s, when Michigan had the most TB-positive cattle in the United States (Frye 1995). This likely timeline of infection is supported through reconstruction of the rate of TB transmission among deer in Michigan, which suggested that the origin of the outbreak likely occurred around 1955 in northeast Michigan (McCarty and Miller 1998).

Deer Management Unit (DMU) 452, encompassing approximately 1,480 km^2 in northeast Michigan (Fig. 1), was created to focus management activities on the "core area" of infection, or the area containing the highest apparent prevalence (% of deer in surveillance program testing positive) of TB (Hickling 2002). Approximately 93% of DMU 452 was privately owned, whereas only 64% of the remainder of the 5-county area that was the focus of TB management activities (Fig. 1) was held in private ownership.

DMU 452 was unique in that much of the private land in the area consisted of large holdings owned primarily for use as deer hunting clubs. Members of these clubs commonly protected does and provided supplemental food throughout the winter. Michigan DNR efforts to manage TB were initiated with an assumption that high population densities sustained by these practices, especially the deer concentrated at winter feed sites, contributed to sustaining the disease in free-ranging deer.

An Overall TB Management Strategy

The TB eradication program was based on achieving 3 objectives: 1) mitigation of conditions that concentrate deer, 2) reduction of deer densities in the TB area, and 3) removal of infected animals from the population. Managers believed that achieving the combined objectives would reduce TB prevalence and transmission rates in the northeast lower peninsula of Michigan. A reduction in concentrations and densities of deer should decrease direct and indirect intraspecific encounter and TB transmission rates.

Nevertheless, individual animals are not uniformly infected with TB (O'Brien et al. 2002). Efforts to reduce infection rates through reductions in deer concentrations and densities should not overlook a necessity to reduce sources for infection through removal of infected animals. For example, increasing the harvest of adult does, thereby reducing the productive portion of the population, is the most effective means to reduce deer densities. Pursuit of this sole objective, however, would overlook the importance of removing older male deer, the segment of the population at greatest risk of TB infection (O'Brien et al. 2002). This example illustrates the need to address all 3 objectives of the TB management strategy to avoid confounding results.

Liberalization of Hunting Regulations

A reduction in deer densities and removal of infected animals from the population were pursued through liberalized hunting regulations that included increased availability and ease of obtaining antlerless deer licenses. Antlerless deer harvests in Michigan are primarily regulated through allocation of antlerless licenses by quotas pertaining to individual DMUs. Additional hunting opportunities were offered through the creation of special antlerless deer-hunting seasons before and after the traditional Michigan firearm deer-hunting season and liberalization of antlerless license quotas, available in unlimited numbers in some DMUs. The most substantial increase in hunting opportunity occurred through regulatory changes between the 1997 and 1998 hunting seasons, and resulted in the greatest number of hunters purchasing antlerless deer licenses and highest harvest of antlerless deer in the northeast lower peninsula (Frawley 2002*b*).

Supplemental Feeding Ban

Regulations banning supplemental feeding of deer, or placement of feed for other wildlife in a manner accessible to deer, were enacted in the northeast lower peninsula of Michigan in 1998. These regulations are still in place. The NRC justified the ban by citing the conspicuous effects it had on creating large concentrations of deer, as well as the potential that feeding might increase deer winter survival (Lewis and Rongstad 1998) or productivity (Ozoga and Verme 1982) and sustain deer populations above what the habitat would ordinarily be able to support. Maintaining a ban on supplemental feeding was further supported by a spatial analysis conducted by the MDNR that indicated a positive linear relationship between the presence of feeding operations identified through aerial surveys and the documentation of TB-positive deer (Hickling 2002). Supplemental feeding of deer has been prohibited throughout most of Michigan since 1999 and is regulated to some extent even where it is still allowed.

Approaches to Baiting Regulations

Baiting regulations contrast sharply to the ban on supplemental feeding, which was broadly applied across most of Michigan. Baiting regulations changed each year 1998–2001, but baiting has never been completely banned (Table 1). Implementation of standard baiting regulations have been more tenuous as decision makers struggled to balance the potential role of bait in either helping or hindering the ability to meet TB management objectives. Key uncertainties arose from a lack of knowledge about how bait concentrated deer locally, whether bait accelerated rates of TB infection by increasing encounter rates, or whether use of bait could reduce rates and sources of infection by sustaining high hunter participation and harvest rates.

The role of baiting in creating concentrations of deer was less obvious and more difficult to document. Most bait sites, in contrast to feeding sites, are not visible through aerial surveys. Uncertainty existed about the role baiting alone had played in spreading or maintaining the disease because supplemental feeding had been practiced in much of the area where bait had been used.

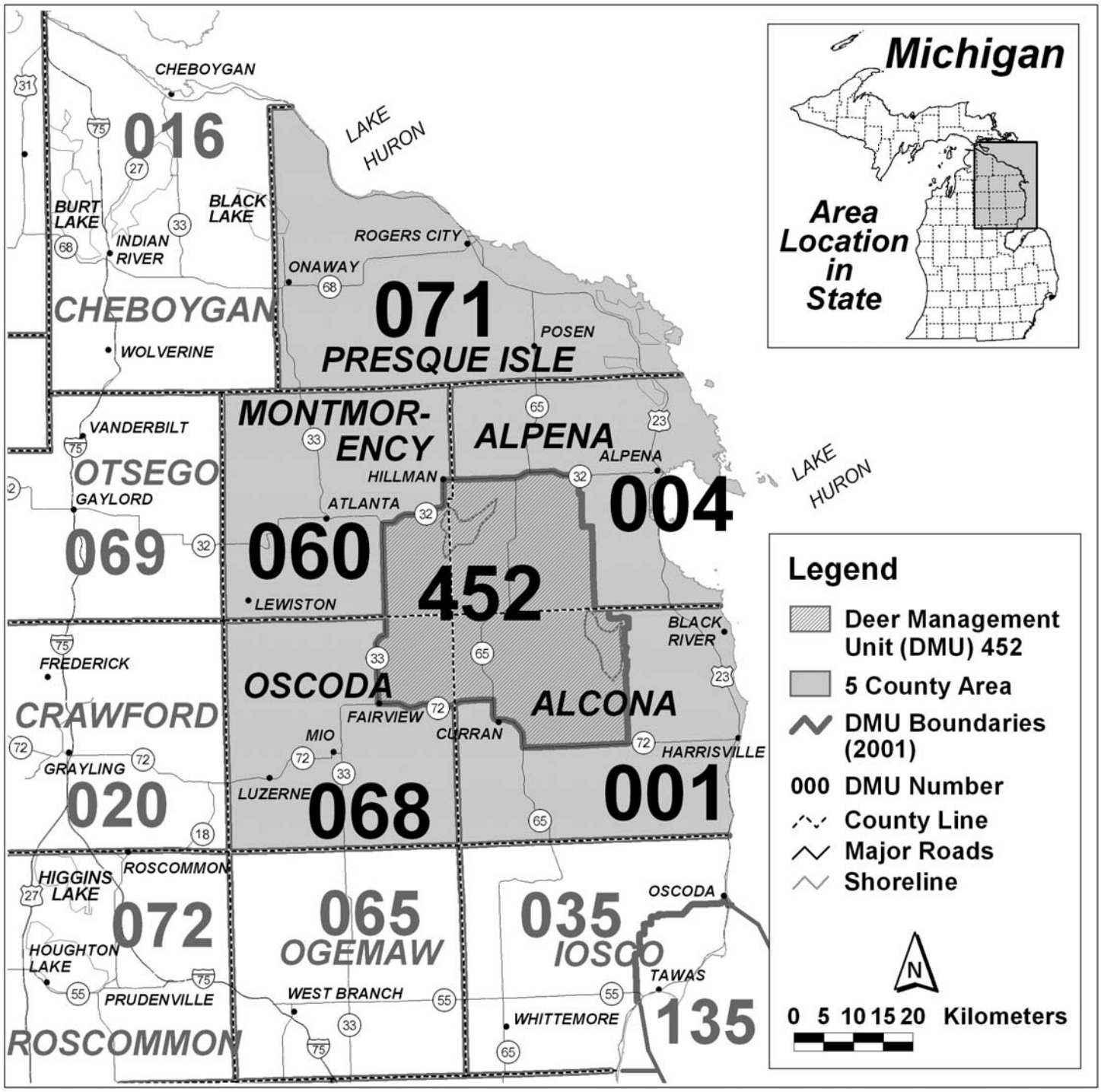

Figure 1. The northeastern Lower Peninsula of Mich., USA, highlighting Deer Management Units that have received the primary focus of bovine tuberculosis management activities.

An additional concern was related to the negative relationship between deer density and the effort investment required per deer killed (Van Deelen and Etter 2003). Reduction of deer densities and removal of infected animals from the landscape was dependent on the ability and willingness of hunters to harvest deer. If either hunter harvest rate or continued hunting participation was substantially reduced through restrictions on baiting, the possibility existed that this influence would confound any benefit of reduced intraspecific deer encounter rates. The cultural significance of deer hunting and hunting camp traditions in the TB area of Michigan, which included the use of bait and historical avoidance of killing antlerless deer, required careful consideration of this dilemma.

Wildlife staff with MDNR were primarily concerned with the potential biological risk (the likelihood that actions might lead to or fail to prevent an increase in prevalence or geographic extent of

Table 1. Annual restrictions on the quantity of bait allowed to use for hunting deer in Mich., USA, including a description of each area regulated, the amount of area (km^2) encompassed, and the quantity allowed.

Year	Area	km^2	Restriction
1998	NELP east of I-75 and north of M-55	14,038	5 gallons per hunting location
1999	NELP east of I-75 and north of M-55	14,038	Illegal to bait
1999	Remainder of Michigan	136,472	5 gallons per hunting location
2000	Counties with TB documented	16,662	Illegal to bait
2000	Remainder of the lower peninsula	90,314	2 gallons per hunting location
2000	Upper peninsula	43,534	5 gallons per hunting location
2001	Counties with TB documented	16,432	Illegal to bait
2001	Deer Management Unit 452	1,480	1 gallon per hunting location
2001	Remainder of the lower peninsula	90,543	2 gallons per hunting location
2001	Upper peninsula	43,534	5 gallons per hunting location
2002–2004	7-county area	10,867	Illegal to bait
2002–2004	Remainder of Michigan	139,643	2 gallons per hunting location

TB infection) associated with continuing to allow use of bait, whereas the NRC had concerns over political risks (e.g., the likelihood of losing regulatory authority over baiting through legislative intervention) associated with increased regulation of baiting. Attitudinal surveys were used to assess social factors that could potentially contribute to political risk. Successive surveys from the mid-1980s through the late 1990s indicated that the percentage of hunters using bait increased from 29% in 1984 to nearly 48% in 1999 (Frawley 2000*b*). Rates of approval for the practice of baiting were even higher than the rates at which bait was used and increased from 33% in 1984 to 61% in 1999 (Frawley 2000*b*). Yet, 50% of Michigan deer hunters surveyed indicated they would support regulations of baiting under the condition of protecting the health of deer populations, and an additional 22% believed baiting should be banned due to ethical concerns (Frawley 2000*b*). Fifty-five percent of statewide hunters approved of the ban on baiting established in the TB area during the 1999 hunting season, and only 25% disapproved. Support for the ban among hunters within the affected area was only 38%.

Conceptual Risk Relationships

The NRC began instituting baiting regulations (Table 1) during various stages of reviewing these preliminary sources of information brought forward by the Wildlife Division. The NRC approached decisions regarding potential restrictions on baiting for deer by considering apparent biological and political risks. In the initial years (1998–2001), information presented by Wildlife Division staff suggested that continuing to allow use of bait statewide represented the greatest biological risk, but the most politically conservative approach, and vice versa with considerations to implement a statewide baiting ban (Fig. 2a). Uncertainty prevented decision makers from defining levels of risk involved with intermediate efforts at which baiting might be regulated. Prior to the 2000 hunting season, the NRC granted authority and provided instruction to the MDNR Director to annually order a ban on baiting in any county where TB was documented. Wildlife Division was asked to provide ongoing considerations for future approaches to restrictions on baiting, as well as to gather more information as to the biological risk associated with baiting and the extent to which the management impact of hunting might be compromised by a baiting ban.

Further Considerations, Deliberations, and Decisions

Deer Interactions and Baiting

A study involving radiomarked deer in northeast Michigan examined movement patterns of deer in the TB area and recorded observations of deer interactions at baiting locations (Garner 2001). Direct encounters between deer at bait sites and visits by a known TB-positive deer to $\geq$3 bait sites were documented. Deer exhibited high fidelity to baiting areas but not to specific baiting locations. This research confirmed that interactions at baiting locations provided a possible avenue of TB transmission, but it was not possible to quantify the influence of baiting on modifying rates of transmission.

Hunter Harvest Rates and Participation

We assessed hunter participation and use of bait in the TB area using a mail survey following the 2001 hunting season. The NRC established an exemption to the baiting ban for TB-infected counties within the core area of infection in 2001 (Table 1), and the Wildlife Division estimated participation (no. of hunters), harvest levels, and harvest rates (days hunted/deer harvested) of hunters who did and did not use bait (Frawley 2002*a*). Thirty-eight percent of all hunters reported using bait. For archery hunters, approximately equal numbers used and did not use bait (Table 2). Although baiting also appeared to improve harvest rates of archery hunters, the difference noted was not statistically significant due to high variation among hunters. Firearm hunters who did not use bait accounted for a greater number of hunters and higher harvest, and we noticed no difference in harvest rates.

The other objective of this hunter survey was to measure changes in participation in the TB area that hunters attributed to the establishment of baiting regulations. Twenty-two percent of archery hunters stated that baiting regulations caused them to stop hunting in the area, whereas 50% indicated they hunted less within the area. Among firearm hunters, 12% stopped hunting within the area, whereas 31% hunted less in the area.

We conducted a second hunter survey after the 2001 hunting season (Frawley 2002*b*). We sent the survey specifically to individuals who had purchased antlerless licenses for the TB area in 1998 (prior to the establishment of a baiting ban), but not in 2001 (after the ban was established). The specific audience of this survey was identified due to concerns that 45% of TB-area 1998

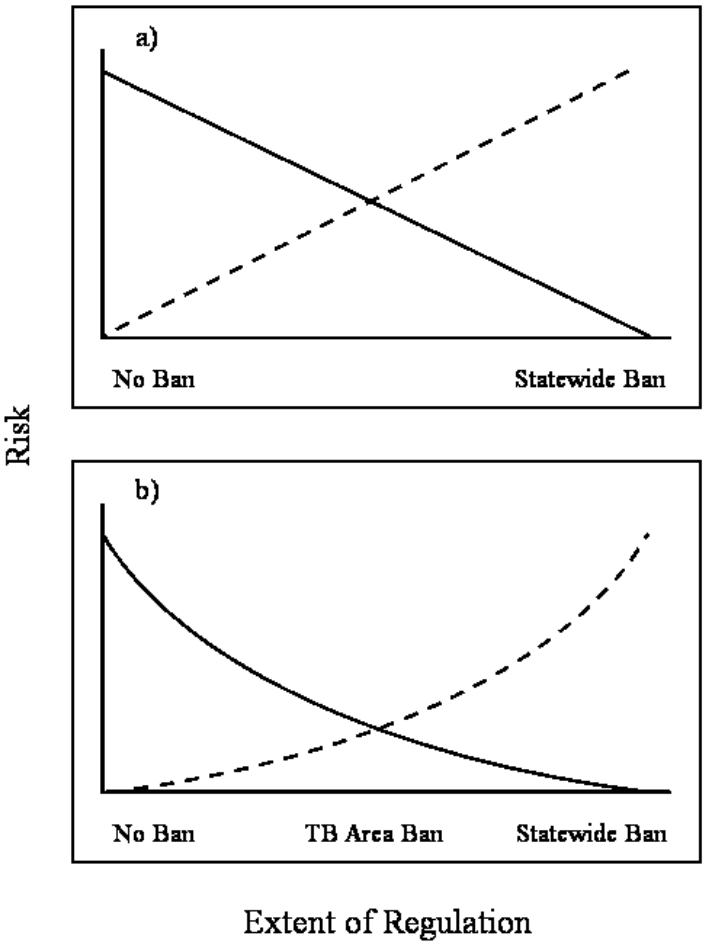

Figure 2. Conceptual diagrams of the amount of risk associated with establishing a ban on the use of bait by Mich. white-tailed deer hunters to varying geographic extent. Regulations were considered as part of deer management activities to manage bovine tuberculosis (TB). Biological risk (solid line) increases with the likelihood of increased prevalence or distribution of TB. Political risk (dashed line) increases with the likelihood of losing regulatory authority over baiting through legislative intervention. Diagrams reflect predictions of risk based on information available at the time of decisions for (a) 1998–2001 hunting seasons and (b) 2002 and later hunting seasons.

antlerless license buyers had not bought an antlerless license in 2001. Over 26% of respondents to this survey believed that the deer population in the TB area was too low to provide an enjoyable hunt in 2001. Only 20% stated that the prohibition of baiting was a factor in their decision. Coincidentally, 17% of these individuals stated they simply lacked time to hunt antlerless deer, and 7% stated the risk of TB in deer caused them to stop hunting in the area.

Both surveys conducted after the 2001 hunting season (Frawley 2002*a*,*b*) suggested that a segment of hunters decreased or eliminated their hunting activities in the TB area due to the baiting ban. Yet, 1995–2001 trends in the number of people hunting deer during the firearm season throughout Michigan (Frawley 2002*c*) and within only the TB area (B. J. Frawley, Michigan Department of Natural Resources, unpublished data) were very similar. Trends in antlerless harvest at each of these geographic areas closely match the 1995–2001 trends in firearm season participation. Antlerless harvest in both the 5-county area (Frawley 2002*b*) and statewide (Frawley 2002*c*) peaked corresponding with high participation of 1998 and then declined over the next 3 years. These similar trends highlight the management significance of Michigan's firearm deer hunting season, during which nearly 60% of the antlerless harvest occurred 1998–2001 (Frawley 2000*a*, 2001, 2002*c*).

A Shift in Regulatory Strategy

The additional information accumulated about the TB area over several years allowed greater confidence when drawing conclusions about the impact of baiting regulations on meeting the 3 objectives of Michigan's TB management strategy. First, the potential of eliminating opportunities for direct encounters between deer at bait sites was demonstrated, although the actual influence on the rate of disease transmission was still unknown (Garner 2001). Second, concerns over the potential that a baiting ban might reduce hunter harvest rates, thereby compromising the ability to lower deer densities through recreational hunting, were partially alleviated by documentation of little effect on firearm or archery hunters (Table 2). Finally, although some hunters indicated they reduced their hunting activities in response to baiting regulations (Frawley 2002*a*,*b*), trends in the number of hunters and hunter days in the TB area closely resembled trends over a similar period at the statewide level. Furthermore, by the conclusion of the 2001 hunting season, a comprehensive spatial analysis of TB surveillance samples had been completed (Hickling 2002). The analysis revealed that the distribution of TB was stable over space and time since 1995, and the report concluded that a limited region in northeast Michigan was the only self-sustaining area of TB infection.

Experiences in the enforcement of baiting regulations, which had changed each year from 1998 to 2001, compelled decision makers to consider the need for a stabilization of baiting regulations. The previous instability of regulations, coupled with unfamiliarity of county prosecutors with the Director's Order process required to make these annual changes, led to reluctance to prosecute baiting violators. Enforcement officers believed the amount of time required to actively locate baiting violations would be wasted if cases would not be prosecuted, so no more than

Table 2. Number of hunters, number of deer harvested, and harvest rate (days hunted/deer harvested) in Deer Management Unit 452, Mich., USA, during 2001, summarized by hunting method (those who used and did not use bait) and hunting season (data from Frawley 2002*a*).

	Hunters		Deer harvested		Harvest rate	
Hunting method	**Archery**	**Firearm**	**Archery**	**Firearm**	**Archery**	**Firearm**
Baiters	2,865	4,593	1,185	2,337	20.3	12.0
Nonbaiters	3,278	9,121	422	3,603	56.5	13.5

warnings were typically issued to violators. Wildlife Division staff, therefore, recommended an approach to implement a baiting ban in 7 counties in northeast Michigan for a period of at least 5 years, starting with the 2002 hunting season. This action was intended to focus regulations and enforcement actions to have the greatest impact on reduction of bait in the area where it would be most beneficial to TB eradication. The NRC enacted this recommendation, agreeing to not revisit baiting regulations until at least the 2006 hunting seasons (Table 1).

Risk Concepts Revisited

Additional information and further deliberations over regulatory actions suggested a conceptual nonlinear relationship between risk and the extent to which baiting is regulated in Michigan (Fig. 2b). If this revised conceptualization is accurate, Wildlife Division staff may have initially overestimated the biological risk involved with allowing bait to continue in some portions of the state, while considerations by the NRC likely overestimated the political risk during early deliberations over establishing a baiting ban. With relatively high levels of hunter acceptance (50%) for regulations enacted to protect the health of deer, additional support (22%) for a complete ban, and even higher approval of (55%) and relatively low opposition to (25%) a TB-area baiting ban amongst statewide hunters (Frawley 2000*b*), moving from the most politically conservative position of continuing to allow the use of bait statewide to a ban in the TB area likely incurred little additional political risk. Furthermore, the spatial analysis of TB surveillance data suggested that the 7 counties in which baiting was banned encompassed the only area of self-sustaining infection and that eradication of TB from this area would lead to statewide eradication (Hickling 2002). Therefore, it appears that little additional biological risk is associated with continuing to allow the use of bait outside this portion of the state.

Current Status and Remaining Uncertainties

Apparent prevalence of TB within the core area of infection decreased significantly 1995–2000 (O'Brien et al. 2002), coinciding with initiation and early stages of TB management strategies. Ongoing analyses indicate this declining trend has continued. In contrast, reconstruction of the historic rate of TB transmission among deer in Michigan suggested TB prevalence would greatly exceed current apparent prevalence rates if successful intervention did not occur (McCarty and Miller 1998). In addition, population estimates based on reconstruction techniques similar to the sex-age-kill method described by Creed et al. (1984) suggest deer densities in the 5-county area were approximately 30% lower in 2002 than 1998, the year in which liberalization of hunting regulations was initiated. These trends suggest management efforts to date have addressed all 3 objectives of the TB management strategy (preventing conditions that concentrate deer, reducing deer densities in the TB area, and removing infected animals from the population). Yet, key uncertainties persist, especially pertaining to impacts of baiting regulations.

Firearm season hunting participation and antlerless harvest in the 5-county area (Frawley 2002*b*) declined no more substantially than at the statewide level (Frawley 2002*c*) following establishment of a baiting ban. However, further reductions in deer densities may be required to further reduce TB prevalence. A reduction of management impact from any future decline in hunting participation may be compounded by an inverse relationship between deer density and hunting effort required per deer killed (Van Deelen and Etter 2003). Furthermore, it is possible that baiting may elevate the rate at which hunters encounter deer while not resulting in fewer days hunted/deer harvested. This may occur if hunters using bait are more selective (i.e., some harvest opportunities are declined while waiting for a more desirable opportunity). An alternate strategy for achieving further reductions in deer densities may involve allowing bait while encouraging hunters to harvest antlerless deer at their earliest opportunity. However, it would not be feasible to adopt regulations mandating such practices.

The current TB infection appears to be the result of a historic crossover from livestock coinciding with unique conditions capable of sustaining infection in deer. Although TB prevalence among livestock has declined, occasional infections do occur. Should local deer densities occur at elevated levels near such a source of infection, such conditions would represent a scenario not addressed by the broad-scale spatial analyses of TB distribution used to inform decisions regarding the current baiting ban (Hickling 2002). The use of bait at such a place and time would greatly increase the apparently low biological risk associated with bait outside of the current ban area.

The current approach to baiting regulations attempts to enhance enforcement and improve compliance. Nevertheless, complete elimination of baiting is unlikely. Bait is readily available for purchase in the banned areas because it is neither illegal to sell there, nor to use throughout most of Michigan. A continued social acceptance of baiting as a hunting tactic, even in areas where baiting is illegal, is an ongoing challenge. A statewide ban may better enhance enforcement and compliance by creating a single legal standard, increasing social pressure against illegal baiting, and reducing the availability of bait.

Our review demonstrates the application of multiple lines of investigation to reduce uncertainty while conducting TB management activities in Michigan. Uncertainty has not prevented management from proceeding but must continue to be addressed while considering options for further reduction of TB prevalence. The assessments reviewed here rely on information collected at broad scales, such as data attributed to individual counties or DMUs generally $\geq$1,400 km^2 in size. Because the distribution pattern of TB in Michigan reveals fine-scale areas of persistence, these large-scale assessments may be insufficient to address factors critical to disease eradication. Such factors may relate to opinions and actions of a small group of hunt clubs or other property owners in northeast Michigan, which may not match those at the broader levels assessed here. Female deer in forested northern environments exhibit high site fidelity (Van Deelen et al. 1998, Nelson and Mech 1999) and associate in multigenerational social groups (Tierson et al. 1985, Nelson and Mech 1999). Demographics associated with TB-positive deer suggest that infection is sustained among philopatric matriarchal groups and disseminated through the dispersal and movement of bucks (O'Brien et al. 2002). The data reviewed here, and the management strategies employed to date, do not address population dynamics at this scale. Localized management of matriarchal social groups (Porter

et al. 1991, McNulty et al. 1997, Oyer and Porter 2004) may provide an opportunity to tailor deer management efforts and consideration of specific landowner attitudes to areas of TB persistence, although harvest history of female deer in northeast Michigan may be more similar to areas in which localized management appears to be of limited utility (Comer et al. 2005).

Perspective on Risk Management

Many obstacles confound the direct formulation of public policy based solely on scientific information, including an inability to demonstrate effects of management activities on natural systems and limitations to methods for clearly communicating risk (Rycroft et al. 1987). Wildlife management professionals often are frustrated by their perceived peripheral role to inform policy makers on such issues and often believe their input should hold greater weight than public opinion in decision making (Mortenson and Krannich 2001). Wildlife managers in Michigan had great concern over the biological risk of continuing to allow use of bait after discovering a self-sustained TB infection in free-ranging deer. The NRC avoided maximizing the area over which baiting was banned because of apparent political risks and attempted to maximize support for a partial baiting ban by limiting the area affected to the region deemed most critical to eradication.

Convincing arguments exist for developing methods to integrate biological and social considerations in management systems (Riley et al. 2002). In extreme cases, if resource management agencies ignore social considerations while addressing wildlife management issues of great public interest, they risk losing decision-making authority. Although some feasible models of collaborative management exist (Nie 2004), direct intervention by legislators or ballot initiatives has the potential to ultimately transform a high degree of political risk into biological risk. The foundation of legal authority, through either ballot initiatives or legislatures, does not lie in the gathering and application of technical information (Sabatier 1978), and mandates to conform to public trust obligations (Horner 2000) apply less strongly to legislative action. Issues facing a high degree of uncertainty, requiring review of technical information, and dealing largely with future threats to the resource, all of which apply to considering regulations addressing the potential role of bait in influencing disease transmission, are likely to be handled less aptly when they are not under the influence of resource management agencies.

Deer management policy in Michigan mandates a scientific basis for maintenance of healthy animals, and the MDNR mission statement requires interests of current generations not jeopardize those of future generations. Legislative intervention in disease management strategies for Michigan deer would be unlikely to explicitly involve such considerations. The course taken in regulating bait in Michigan appears to be one that avoids the greatest amount of combined biological and political risk (Fig. 2b). Although biologists, policy makers, and external stakeholders may continue to argue the utility of regulating baiting, we believe full consideration of biological and social factors likely has provided benefits to the future health and public enjoyment of deer in Michigan.

Acknowledgments

Our thanks are extended to numerous employees of the Michigan Departments of Natural Resources, Agriculture, and Community Health, U.S. Department of Agriculture, and Michigan State University who contributed to various aspects of TB management and research activities reviewed here. We also acknowledge the cooperation of Michigan hunters and landowners that participated in meetings, opinion surveys, and TB surveillance, and provided access to their property for research activities. This paper was developed from a presentation delivered as part of the "Implications of Baiting and Feeding Game Wildlife Species" symposium at the Annual Conference of The Wildlife Society (TWS), 22 September 2004, in Calgary, Alberta, Canada. Our thanks go to symposium organizers J. E. Miller and S. R. Craven and the sponsorship of TWS Wildlife Damage Working Group. G. E. Matthews, D. J. O'Brien, B. C. West, and an anonymous reviewer provided considerable insight during reviews of an earlier draft of this manuscript. M. L. Strong assisted with preparation of figures. This work was supported by the Federal Aid in Wildlife Restoration Act under Michigan Pittman-Robertson Project W-147-R.

Literature Cited

Bean, M. J. 1983. The evolution of national wildlife law. Praeger, New York, USA.

Bruning-Fann, C. S., S. M. Schmitt, S. D Fitzgerald, J. S. Fierke, P. D. Friedrich, J. B. Kaneene, K. A. Clarke, K. L. Butler, J. B Payeur, D. L. Whipple, T. M. Cooley, J. M. Miller, and D. P. Muzo. 2001. Bovine tuberculosis in free-ranging carnivores from Michigan. Journal of Wildlife Diseases 37:58–64.

Clifton-Hadley, R. S., and J. W. Wilesmith. 1991. Tuberculosis in deer: a review. Veterinary Record 129:5–12.

Comer, C. E., J. C. Kilgo, G. J. D'Angelo, T. C. Glenn, and K. V. Miller. 2005. Fine-scale genetic structure and social organization in female white-tailed deer. Journal of Wildlife Management 69:332–344.

Creed, W. A., F. Haberland, B. E. Kohn, and K. R. McCaffery. 1984. Harvest management: the Wisconsin experience. Pages 243–260 in L. K. Halls, editor. White-tailed deer ecology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

de Lisle, G. W., R. G. Bengis, S. M. Schmitt, and D. J. O'Brien. 2002. Tuberculosis in free-ranging wildlife: detection, diagnosis and management. Revue Scientifique et Technique International Office of Epizootics 21:317–334.

Essey, M. A., and J. S. Vantiem. 1995. *Mycobacterium bovis* infection in captive Cervidae: an eradication program. Pages 145–157 *in* C. O. Thoen, and J. H. Steele, editors. *Mycobacterium bovis* infection in animals and humans. Iowa State University Press, Ames, USA.

Fanning, A., and S. Edwards. 1991. *Mycobacterium bovis* infection in human beings in contact with elk (*Cervus elaphus*) in Alberta, Canada. The Lancet 338:1253–1255.

Frawley, B. J. 2000*a*. Michigan deer harvest survey report: 1999 seasons. Michigan Department of Natural Resources, Wildlife Division Report 3314, Lansing, USA.

Frawley, B. J. 2000*b*. 1999 Michigan deer hunter survey: deer baiting. Michigan Department of Natural Resources, Wildlife Division Report 3315, Lansing, USA.

Frawley, B. J. 2001. Michigan deer harvest survey report: 2000 seasons. Michigan Department of Natural Resources, Wildlife Division Report 3344, Lansing, USA.

Frawley, B. J. 2002*a*. Deer baiting in the northeast lower peninsula of Michigan. Michigan Department of Natural Resources, Wildlife Division Report 3372, Lansing, USA.

Frawley, B. J. 2002*b*. Factors affecting the sale of antlerless deer hunting licenses in the northeast lower peninsula. Michigan Department of Natural Resources, Wildlife Division Report 3373, Lansing, USA.

Frawley, B. J. 2002*c*. Michigan deer harvest survey report: 2001 seasons.

Michigan Department of Natural Resources, Wildlife Division Report 3371, Lansing, USA.
Frye, G. H. 1995. Bovine tuberculosis eradication: the program in the United States. Pages 119–129 in C. O. Thoen, and J. H. Steele, editors. Mycobacterium bovis infection in animals and humans. Iowa State University, Ames, USA.
Garner, M. S. 2001. Movement patterns and behavior at winter feeding and fall baiting stations in a population of white-tailed deer infected with bovine tuberculosis in the northeastern lower peninsula of Michigan. Dissertation, Michigan State University, East Lansing, USA.
Hickling, G. J. 2002. Dynamics of bovine tuberculosis in wild white-tailed deer in Michigan. Michigan Department of Natural Resources, Wildlife Division Report 3363, Lansing, USA.
Horner, S. M. 2000. Embryo, not fossil: breathing life into the public trust in wildlife. Land and Water Law Review 15:23–75.
Lewis, T. L., and O. J. Rongstad. 1998. Effects of supplemental feeding on white-tailed deer migration and survival in northern Wisconsin. Canadian Field-Naturalist 112:75–81.
Lugton, I., P. R. Wilson, R. S. Morris, and G. Nugent. 1998. Epidemiology and pathogenesis of *Mycobacterium bovis* infection in red deer (*Cervus elaphus*) in New Zealand. New Zealand Veterinary Journal 46:147–156.
McCarty, C. W., and M. W. Miller. 1998. A versatile model of disease transmission applied to forecasting bovine tuberculosis dynamics in white-tailed deer populations. Journal of Wildlife Diseases 34:722–730.
McNulty, S. A., W. F. Porter, N. E. Mathews, and J. A. Hill. 1997. Localized management for reducing white-tailed deer populations. Wildlife Society Bulletin 25:265–271.
Mortenson, K. G., and R. S. Kranninch. 2001. Wildlife managers and public involvement: letting the crazy aunt out. Human Dimensions of Wildlife 6:277–290.
Nelson, M. E., and L. D. Mech. 1999. Twenty-year home-range dynamics of a white-tailed deer matriline. Canadian Journal of Zoology 77:1128–1135.
Nie, M. 2004. State wildlife policy and management: the scope and bias of political conflict. Public Administration Review 64:221–233.
O'Brien, D. J., S. D. Fitzgerald, T. J. Lyon, K. L. Butler, J. S. Fierke, K. R. Clarke, S. M. Schmitt, T. M. Cooley, and D. E. Berry. 2001. Tuberculous lesions in free-ranging white-tailed deer in Michigan. Journal of Wildlife Diseases 37:608–613.
O'Brien, D. J., S. M. Schmitt, J. S. Fierke, S. A. Hogle, S. R. Winterstein, T. M. Cooley, W. E. Moritz, K. L. Diegel, S. D. Fitzgerald, D. E. Berry, and J. B. Kaneene. 2002. Epidemiology of Mycobacterium bovis in free-ranging white-tailed deer, Michigan, USA, 1995–2000. Preventive Veterinary Medicine 54: 47–63.
Oyer, A. M., and W. F. Porter. 2004. Localized management of white-tailed deer in the central Adirondack Mountains, New York. Journal of Wildlife Management 68:257–265.
Ozoga, J. J., and L. J. Verme. 1982. Physical and reproductive characteristics of a supplementally fed white-tailed deer herd. Journal of Wildlife Management 46:281–301.
Porter, W. F., N. E. Mathews, H. B. Underwood, R. W. Sage, Jr., and D. F. Behrend. 1991. Social organization in deer: implications for localized management. Environmental Management 15:809–814.
Riley, S. J., D. J. Decker, L. H. Carpenter, J. F. Organ, W. F. Siemer, G. F. Mattfeld, and G. Parsons. 2002. The essence of wildlife management. Wildlife Society Bulletin 30:585–593.
Robinson, R. C., P. H. Phillips, G. Stevens, and P. A. Storm. 1989. An outbreak of *Mycobacterium bovis* infection in fallow deer (*Dama dama*). Australian Veterinary Journal 66:195–197.
Rycroft, R. W., J. L. Regens, and T. Dietz. 1987. Acquiring and utilizing scientific and technical information to identify environmental risks. Science, Technology, and Human Values 12:125–130.
Sabatier, P. 1978. The acquisition and utilization of technical information by administrative agencies. Administrative Science Quarterly 23:396–417.
Schmitt, S. M., S. D. Fitzgerald, T. M. Cooley, C. S. Bruning-Fann, L. Sullivan, D. Berry, T. Carlson, R. B. Minnis, J. B. Payeur, and J. Sikarskie. 1997. Bovine tuberculosis in free-ranging white-tailed deer from Michigan. Journal of Wildlife Diseases 33:749–758.
Tierson, W. C., G. F. Mattfeld, R. W. Sage, Jr., and D. F. Behrend. 1985. Seasonal movements and home ranges of white-tailed deer in the Adirondacks. Journal of Wildlife Management 49:760–769.
Van Deelen, T. R., H. Campa, III, M. Hamady, and J. B. Haufler. 1998. Migration and seasonal range dynamics of deer using adjacent deeryards in northern Michigan. Journal of Wildlife Management 62:205–213.
Van Deelen, T. R., and D. R. Etter. 2003. Effort and the functional response of deer hunters. Human Dimensions of Wildlife 8:97–108.

Brent A. Rudolph (photo, with daughter) is a wildlife research specialist with the Michigan Department of Natural Resources (MDNR), where he coordinates the Wildlife Division's deer research program. Brent holds an M.S. in environmental and forest biology from the College of Environmental Science and Forestry at Syracuse, and a B.S. in biology from Ohio Northern University. His professional interests focus on addressing the biological and sociological challenges to managing wildlife on increasingly human-dominated landscapes. ***Shawn J. Riley*** is an assistant professor in the Department of Fisheries and Wildlife at Michigan State University (MSU). His interests include wildlife ecology and management, systems modeling, and integration of ecological and social science in decision making. Shawn earned B.S. and M.S degrees in wildlife management from Montana State University, and a Ph.D. in wildlife science at Cornell University. In between his studies at Montana State and Cornell, Shawn served 12 years as a research and management biologist for Montana Fish, Wildlife, and Parks. ***Graham J. Hickling*** is an associate professor in the Department of Fisheries and Wildlife at MSU. He completed his Ph.D. in behavioral ecology at the University of Western Ontario in 1987 and then worked as a research scientist with the Animal Ecology Section of the New Zealand Forest Service, where his research focused on the spread of bovine tuberculosis by introduced mammals. From 1993–2001 he was a senior lecturer in wildlife management at Lincoln University, and in 2002 moved to Michigan where he helped develop a Graduate Specialization in the ecology and management of wildlife disease. He is presently undertaking research on bovine tuberculosis in Michigan deer, the spread of Lyme disease by vertebrate hosts in southwestern Michigan, and the wildlife/livestock/human disease interface in Mongolia. ***Brian J. Frawley*** is a wildlife research biologist with MDNR specializing in hunter harvest and opinion surveys. Brian received a Masters degree from Iowa State University and worked for the Indiana DNR for nearly 10 years as a wildlife research biologist before being employed by MDNR. Brian also has served as an officer of the Indiana Chapter of The Wildlife Society. ***Mark S. Garner*** is a wildlife biologist with the USDA Forest Service on the Conecuh National Forest in Alabama. Mark earned 2 B.S. degrees; one in Biology from Freed-Hardeman University and the second from the University of Tennessee at Martin. He earned his Masters degree from the University of Tennessee at Knoxville in fisheries science and a Ph.D. from Michigan State University in wildlife management. While at MSU, his research focused on white-tailed deer in northeastern Michigan and bovine tuberculosis. ***Scott Winterstein*** is a professor in the Department of Fisheries and Wildlife at MSU and a Certified Wildlife Biologist with teaching and research interests in the areas of ecology, ethology, dynamics of wild populations, and wildlife biometry.

Associate Editor: West.