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Development of a Comprehensive Management Plan for White-tailed Deer, *Waáwaáŝhkeŝh*, in the Northern Lower Peninsula of Michigan

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and

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EXECUTIVE SUMMARY

This final report describes our study of white-tailed deer (*Odocoileus virginianus*) and vegetation on Tribal lands in the Northern Lower Peninsula of Michigan during 2006-08, as funded by the Tribal Landowner Incentive Program administered by the U.S. Fish and Wildlife Service. This project represents a collaborative effort between the Little River Band of Ottawa Indians (LRBOI; grantee) and the Cooperative Wildlife Research Laboratory at Southern Illinois University Carbondale (subcontractor). We addressed the following 5 objectives: (1) develop a deer abundance monitoring program to allow future tracking of population trends; (2) capture and radiocollar deer to quantify home ranges, habitat use, and survival rates; (3) create a population model to predict deer abundance trends and response to harvest management; (4) quantify deer-vegetation interactions to determine potential deer impact on the ecosystem and at-risk species, and (5) develop a comprehensive management plan consisting of sound management recommendations to balance Tribal needs and those of deer and the ecosystem. Deer density from distance sampling surveys ranged from 4-50 deer/km^2, depending on study region and habitat. The sex ratio was 14 bucks:100 does and the age ratio was 84 fawns:100 does. We radiomarked and monitored 105 does for survival and space use analyses. Annual adult survival was 0.74 ± 0.06, with most mortalities ($n = 8$ of 23) caused by human harvest. Adult survival was the highest during winter (1.00) and lowest in autumn (0.81 ± 0.08). Winter/spring fawn survival was 0.74 ± 0.06, with all mortalities caused by predation ($n = 4$) and starvation ($n = 3$). Cover-type use did not differ seasonally between home ranges and core areas, indicating that deer did not select specific cover types within their home range. Population modeling using empirical demographic data and literature-derived values indicated a slowly growing population at a 4.3% rate of annual increase. Given an even distribution of harvest between the sexes, increased harvests of 4.5% and 9% over current levels would be necessary to meet 5% and 10% population reduction goals, respectively. For all-male harvests, 5% and 10% population reduction goals could not be met; removing all males from the population resulted in only a 2% overall population decline. Given all-female harvests, increased harvests of 5.5% and 11% over current levels would be necessary to meet 5% and 10% population reduction goals, respectively. Data on forb demography, fecundity, and herbivory rates were collected for endemic vegetation within the context of deer density and site-specific environmental factors. Deer densities were highest in lowland conifer stands, vegetated open lands, and heterogeneous landscapes, but herbivory was driven by the density of forb communities, as opposed to deer populations. Deer herbivory targeted specific forb species at the time of seed production and had the greatest impact on forb communities in rich soil conditions. The ability of a forb species to recover from herbivory was also species-specific and was inversely related to the intensity of browse. Forb diversity, density, and fecundity were principally driven by the available water supply and organic matter in the soil. Human presence and deer habitat use were not major factors affecting the distribution of endemic forb diversity on the landscape. The role of soils and land cover components were used to develop a spatial model identifying a gradient of priority-conservation areas across the study area. Management recommendations and a monitoring program were prescribed to focus deer and vegetation management for the LRBOI and throughout Tribal lands in the Northern Lower Peninsula of Michigan.

FORWARD

This project final report is organized as follows. Two M.S. theses via project subcontractor Southern Illinois University Carbondale address 3 of the 5 study objectives (deer abundance estimation; deer capture, radiotelemetry, and associated analyses; and deer herbivory). Theses are provided as appendices, and comprise the bulk of the information for this project final report. Work for the other 2 study objectives (population modeling and management plan) is discussed in the body of the document.

INTRODUCTION

White-tailed deer *(Odocoileus virginianus*), or waáwaášhkešh as known to local Tribal cultures, are among the most visible and ecologically-important wildlife species in North America. Management of deer populations is a complex process and requires the collection of ecological data about deer and subsequent assembly of such information into a management plan. Such a document can then be used as a planning tool to focus deer and vegetation management activities to benefit deer, humans, and the ecosystem. Unfortunately, such a deer management plan does not exist for the Little River Band of Ottawa Indians (LRBOI), despite the considerable cultural and ecological importance of deer to the Tribe. We studied deer and vegetation ecology on LRBOI properties and those ceded to the United States in the Washington Treaty of 1836 (hereafter referred to simply as "Tribal lands") to provide the LRBOI with a comprehensive deer management plan that focuses on deer population status and an understanding of potential impacts of deer on forest vegetation and how that may negatively affect at-risk forb species. In this introductory section, we discuss the cultural importance of deer to the LRBOI and issues pertinent to resource management for deer and ecosystems. Additional introductory information is found in Appendices A (pp. 3-8) and B (pp. 1-5 and 23-26).

Cultural Importance

The current methodology utilized in the science of ecology relies heavily upon the close examination of certain indicator species to effectively monitor the cohesive interrelationship that exists between the fauna and flora types of a particular region or period. Indicator species can also be utilized to model the Cultural and sustainable well-being of a given society and this is especially true to the Woodlands Anishinaabek Culture of the Great Lakes region upon historical investigation of their annual migrations to specific areas that posed the greatest yield of resources. Further indication from this method of investigation provides that regardless of the vast abundance of natural resources the Anishinaabek had within their grasp prior to European contact, they still maintained a conservative approach to their harvesting practices, ever mindful that the balance of nature was (and still is) in a constant state of change with the natural order of environmental causes and effect.

Verification of the above statement regarding the ecological practices of the Anishinaabek is further proven when looking to the various seasonal Ceremonies initiated to appeal to their Manito's (higher powers) through the profound reverence of their songs, prayers, fasting, and personal sacrifice for the bounty that would sustain them throughout the coming year. Waste of life and resources was highly discouraged and is still believed by the Anishinaabek to bring shame and misfortune upon those responsible for these acts. With this in mind, it is not difficult to imagine the level of disgust the Anishinaabek certainly must have felt to bear witness to the ravenous demise of the species that they had relied upon since the beginning of time. Compounding this emotional turmoil even farther, was being forced (through the necessity of survival), to competitively participate in the demise of their own cultural indicators through the means of hunting, trapping and fishing to provide for their respective families and community. Since that time, Cultural indicator species such as the woodlands caribou, the elk, the buffalo, the wolverine, the timber wolf, and many more wildlife and fish species have sadly been overharvested to the brink of extinction and beyond so that only a handful of the Anishinaabek Cultural indicator species still exist with barely enough viable abundance to sustain the Anishinaabek according to their historical proportions. The upshot to this unfortunate situation is that despite the continuing and detrimental effects of pollution, irresponsible hunting, fishing and gathering practices, the introduction of exotic species, depleted habitats, and ineffectual management of resources, a few of the

Anishinaabek's cultural indicator species still *do* in fact, continue to exist. It is believed that if these remaining Cultural indicator species for the Anishinaabek are allowed to become extinct that the Anishinaabek Culture too, will cease to be. Therefore, it is with the solemn intent of the LRBOI to embark upon a cooperative revitalization scheme with Tribal, State, and Federal agencies and special interests groups through proper management initiatives to positively enhance the health and abundance of waáwaášhkešh on Tribal lands to the greater benefit of *all* who rely upon this species for both Cultural and sustenance proposes.

Prioritizing the management of these cultural indicator species is important and essential to the LRBOI Natural Resources Department. In fall 2003, the LRBOI Natural Resources Department sent out a natural resource survey to all Tribal members. This survey was designed, in part, to gather current information about inland resource use as well as the current Tribal resource management perspective. Results from this survey of tribal membership revealed that deer are one of the highest priorities for tribal membership. The importance of waáwaášhkešh to tribal membership was indicated as a top priority both for cultural as well as subsistence use. Survey results revealed that of all game animals, deer are the most targeted game species for tribal subsistence living. Results indicated that 96.4% of LRBOI membership reported deer as the game animal tribal members most often hunted. This staggering percentage is a clear indicator of the importance of deer to tribal membership and the traditional ways of subsistence living. Survey results also indicated that 51% of tribal membership considered deer a culturally significant species that needs to have increased active management by the Natural Resources Department. Deer ranked the highest among tribal members as a culturally significant species that needed increased management. These survey data clearly reveals the desires of the LRBOI membership and the need to increase deer management on Tribal reservation lands. The increased research and management of deer on

Tribal lands will meet the needs of Tribal membership for both subsistence and cultural use. Management and monitoring recommendations derived from this project will assist the tribe in balancing the needs of the membership with the needs of the resource and the ecosystem.

Resource Management

Although deer are one of the most important species on the North American landscape, no deer-specific information exists for focusing deer and forest management on Tribal lands. Deer populations are largely managed by hunter harvest and habitat management, with a goal to either decrease, maintain, or increase deer numbers. Unfortunately, the LRBOI lacks baseline information to understand whether deer populations are too abundant or relatively sparse. This project quantified basic ecology of deer on Tribal lands and contributes to the development of a comprehensive deer management plan that focuses, in part, on assessing potential impacts of deer on forest ecosystems and associated at-risk species.

Management of deer populations while considering human needs and those of the environment is of utmost important to the Tribe. As a keystone herbivore, deer can impact forest ecosystems in dramatic fashion (McShea et al. 1997). Still, other studies have reported that deer impacts to ecosystems are relatively minor (Russel et al. 2001). This research provided the LRBOI with information regarding whether deer may be impacting forest biomass and biodiversity, thereby negatively affecting other at-risk plant and wildlife species.

Deer are also important to humans as food and for the recreational benefits enjoyed by millions; in fact, white-tails are the most hunted big game species on the continent (Halls 1984). Non-hunters and hunters alike enjoy observing these graceful animals in fields and forests. To many Tribal members, knowledge that the deer population is healthy and in balance with the ecosystem is as important as minimizing damage or ensuring huntable numbers. This project provided the means by which to determine current status of the deer population on Tribal lands and management techniques to achieve multiple human desires regarding deer and the habitats in which they live.

Study Objectives

We addressed the following 5 objectives intended to improve the deer and forest management capacity of the LRBOI on Tribal lands:

1. Develop a deer abundance monitoring program to allow future tracking of population trends.
2. Captured and radiocollar deer to quantify home ranges, habitat use, and survival rates.
3. Create a population model to predict deer abundance trends and response to harvest management.
4. Quantify deer-vegetation interactions to determine potential deer impact on the ecosystem and at-risk species.
5. Develop a comprehensive management plan consisting of sound management recommendations to balance Tribal needs and those of deer and the ecosystem.

STUDY AREA

Our study was conducted in the Northern Lower Peninsula of Michigan within Manistee and Mason Counties, primarily on 1836 Reservation and Tribally-owned lands. The 1836 Reservation study area is approximately 69,000 acres (280 km^2) and borders the eastern shoreline of Lake Michigan. Reservation lands are comprised primarily of deciduous, evergreen, and mixed forested landscapes (69.2%), woody and emergent wetlands (14.8%), and herbaceous upland and grassland (7.0%). Other land cover types occurring within Tribal lands include herbaceous planted and cultivated land (3.1%) (i.e. pasture/hay, row crops, recreational grasses); developed land including residential, commercial, industrial and transportation land (2.3%); barren land (0.5%) (i.e. bare rock, sand, gravel pits, quarries); and 3.1% open water.

The study area as a whole is made up of mostly federal, state, tribal and private property. Hydrological features play an important role in this landscape. Rivers, lakes, ponds, streams and swamps are common throughout the area. The 1836 Reservation is bisected by the Big Manistee River which runs east to west from Tippy Dam on the eastern side of the reservation flowing west into Manistee Lake and then into Lake Michigan. Large bodies of water within the study area include Manistee Lake on the western side of the Reservation and Tippy Dam Pond on the eastern side of the Reservation. Most of the study area is accessible through secondary, 2-track or retired logging roads; however, certain sections of the study area are restricted only to foot travel. The average annual rainfall in the study area is 30-32 in while the average annual snowfall in the area is 80-100 in. The mean annual temperature in Manistee County ranges from 61° F in the summer (Apr-Sep) to 34° F in the winter (Oct-Mar). Summers are generally short (3-4 months) while winters can last up to 7 months. Further description of the study area are found in Appendices A and B.

RESEARCH ACCOMPLISHMENTS AND INTERPRETATIONS

Objectives 1 (Abundance Estimation), 2 (Radiotelemetry), and 4 (Herbivory)

Research accomplishments and interpretations for Objectives 1, 2, and 4 are found in Appendices A and B.

Objective 3: Population Modeling

Methods.—We developed a straightforward, accounting-based model (Nielsen et al. 1997, Grund and Woolf 2004) in Microsoft Excel to forecast current percent annual growth of the deer population on the study area. We modeled 1 year of population growth to be conservative given the short-term nature of data collection in this project and because model assumptions may not hold in the long term (i.e., for 4 years; Grund and Woolf 2004). Due to the short modeling time frame, density-dependence was not incorporated into the model.

Population growth was modeled according to the following equation:

$$N_{\mathrm{t}} + [\mathrm{Recruitment}(N_{\mathrm{t\ adult\ females}})] + [\mathrm{Adult\ Survival}(N_{\mathrm{t}})] = N_{\mathrm{t+1}}$$

The model timeline began in the fall with an assumed initial pre-hunt abundance of 1,000 deer (N_{t}). We chose this hypothetical abundance, rather than one based on density estimates from the present study, to provide percentages of population growth and harvest levels. Such percentages could then be applied to any true abundance level, depending on management objectives and scale of area considered. N_{t} consisted of adult (>1 yr) males and females as proportionately observed during fall spotlight surveys (Appendix A, p. 11). Recruitment was added to the population at this time, assuming the fawn:doe ratio observed during fall spotlight surveys (Appendix A, p. 11); a 1:1 M:F sex ratio was assumed for recruits. Adult Survival for females was estimated from empirical data to be 0.74 ± 0.06 (Appendix A, p. 18). The standard error was used to set the minimum and maximum values for stochastic variance of female Adult Survival (i.e., between 0.68 and 0.80) during 500 model iterations. Adult Survival for males was estimated from published literature for Michigan deer (VanDeelen et al. 1997) to be between 0.12 and 0.33 (i.e., incorporating SE estimates); these values were used in the model as maximum and minimum rates, respectively, for stochastic variance incorporated during the 500 model iterations. For simplicity, we assumed emigration equaled immigration into the population. N_{t+1} was then the predicted deer abundance in the following fall.

We modeled deer harvest levels (assuming harvest was completely additive to other mortality sources) in the fall of N_t (immediately following the initial population growth simulations and entry of N_t into the model) to reach several potential management objectives; each expressed as a percentage of N_{Y1}. Specific management scenarios simulated included increased harvest over current levels to maintain zero population growth (i.e., removal of the sustained yield) and increased harvest over current levels to decrease deer abundance by 5% and 10%. Additional harvest to current levels (i.e., additional to that already present in Michigan) was applied: (1) evenly between males and females, (2) to males only, and (3) to females only. We reasoned it was unlikely that reduced harvests (i.e., below current State and Tribal levels) resulting in increased deer populations were desirable given large-scale management goals in Michigan.

Results.— Based on spotlighting data, the initial deer population consisted of 51% adult females, 7% adult males, and 42% fawns. We applied these percentages to the initial 1,000 deer, yielding a herd structure of 510 adult females, 70 adult males, 210 fawn females, and 210 fawn males in N_t

Upon projecting the population forward given current harvest level, the fall N_{t+1} population estimates following 500 model iterations ranged from 1,038 to 1,050, yielding a mean annual growth rate of 4.3%; this level of increased harvest over current levels would result in zero population growth. Given an even distribution of harvest between the sexes, increased harvests of 4.5% and 9% over current levels would be necessary to meet 5% and 10% population reduction goals, respectively. For all-male harvests, 5% and 10% population reduction goals could not be met; removing all males from the population resulted in only a 2% overall population decline. Given all-female harvests, increased harvests of 5.5% and 11% over current levels would be necessary to meet 5% and 10% population reduction goals, respectively.

Objective 5: Management Plan

The management plan consists of 3 primary sections. Section 1 uses information gained from field research; such as demographic rates, habitat use, and deer-vegetation interactions, to assess the current status of the deer herd and forb communities. This section also provides predictions about future deer population growth and potential resultant impacts of deer on forest vegetation. Section 2 provides a monitoring program that will enable Tribal biologists to quantify deer population and forest vegetation trends by following standardized survey techniques developed in this project. Section 3 includes management recommendations for deer harvest, research, and habitat management practices to benefit deer and vegetative species.

Section 1.—We provide information on deer herd status, habitat use, and impacts on forb populations on Tribal lands.

Deer Demographics, Harvest, and Habitat Use

Status information from this segment of our research is also found in the Discussion and Management Implications sections of Appendix A (pp. 19-42) and population modeling (Objective 3 described above). Deer populations on Tribal lands are currently healthy and productive. Deer populations are growing slowly, at a 4% rate of annual increase, which is further indication of the generally good status of the herd and that harvest levels are not overly restrictive (but could be greater, see below). Deer density on our study area (20 deer/km^2) is higher than estimates from several studies in the northern Midwest region. The fawn:doe ratio (84 fawns:100 does) was similar to that reported 25 years ago (70 fawns:100 adults) for this region (Blouch 1984), and indicative of a healthy deer population. However, the adult buck:doe ratio (14 M:100 F) was less than half the ratio reported by Blouch (1984, 30 M:100 F) or Fuller (1990; 39 M:100 F). A small M:F sex ratio could be attributed to the often higher hunting and non-hunting mortality rates of males than females due to hunter preference of male traits, physiological demands of larger body size, and behavioral patterns during the breeding season (Clutton-Brock et al. 1982, Dusek et al. 1989, Nixon et al. 1991, Van Deelen et al.

1997).

Annual survival of adult females (0.74) on Tribal lands was relatively high for harvested populations, but similar to those in other northern white-tailed deer studies (0.68-0.79; Nelson and Mech 1986, Fuller 1990, Van Deelen et al. 1997, Brinkman et al. 2004). Survival rates for adults were high (100%) during the winter/spring season, which is likely due to the relatively warm winters experienced during our study. The non-restrictive snow depths encountered most likely permitted deer to have greater accessibility to a variety of food sources and be more mobile if chased by predators, conditions which would not exist in deeper snow. These relatively mild winters may become more prevalent in northern Michigan given increased global temperatures.

Causes of deer mortality also indicate the population is healthy and not significantly affected by human-caused mortality on Tribal lands. Twenty-three of 105 deer died during our study: 14 (60%) mortalities were human-caused, 7 mortalities (30%) were natural (only 4 predation and 3 starvation, and all fawns), and the cause of 2 mortalities (9%) could not be determined. Of the human-caused mortalities, 8 were from hunter harvest, and 4 were attributable to deer-vehicle collisions. Hunter harvest was somewhat lower than reported in other studies (Fuller 1990, Van Deelen et al. 1997, DelGuidice et al. 2002), and deer-vehicle collisions were lower than expected given that Michigan has the most reported deer-vehicle collisions in the Midwest (Sudharson et al. 2006).

Information regarding home range sizes and habitat selection of deer indicate favorable habitat conditions exist on Tribal lands. Our composite female home range size of 2.0 km^2 is smaller than reported in other northern deer studies (Kilpatrick et al. 2001, Cobb et al. 2004). Relatively small home range sizes of deer, lack of migration, and lack of seasonal habitat selection indicated that cover types are highly interspersed and evenly distributed (Beier and

McCullough 1990, Kie et al. 2002, Cobb et al. 2004). We originally hypothesized that radiocollared deer would show preference for yarding cover, but winter conditions during our study period were generally favorable for deer, and did not require pronounced seasonal shifts in habitat use.

Deer Herbivory and Other Factors Affecting Forbs

Status information from this segment of our research is also found in the Discussion and Conservation Implication sections of Appendix B (pp. 15-22 and 33-38). We found soil conditions, herbivore selectivity, and forb species' life history characteristics to be driving factors in the forb ecology on Tribal lands, but that deer are currently having a relatively minor impact on forest vegetation.

Common forb taxa tended to have high reproductive potential, in the case of Liliaceae, Asteraceae, and Primulaceae, or occur in dense or clonal groups, as in Rosaceae. However, no environmental factors (including deer) at the community level were capable of explaining the distribution of reproductive effort on Tribal lands. The production of inflorescences at the population-level appears to be related to the morphological conditions of the individuals in the population and the duration of time without being browsed by deer.

The apparent divergence of community densities in vegetative exclosures vs. adjacent reference sites on richer soils may be an indication of mild herbivore-induced forb declines on Tribal lands. However, it is vital to remember that endemic forb diversity patterns at these same sites did not exhibit any significant trends. In this case, it is possible that deer may be acting as agents of intermediate disturbance, a stabilizing force in some contexts (Connell 1978, Anderson et al. 2005), or that the negative effects of browsing at these sites requires a wider spatiotemporal scale to detect.

Soils, more than deer at current densities, appear to drive forb densities and perhaps the potential for increased forb diversity on Tribal lands. Given this, and that the forb densities of reference sites declined on richer soils (while adjacent exclosure densities actually increased), it seems plausible that soil conditions may be influencing the selective browsing of deer in this system. However, our subsequent analyses did not convincingly support this hypothesis. Deer targeted reproductive structures and specific species of forbs, regardless of soil richness. If there is an element of soil richness that encouraged browsing, it was likely overshadowed by the physiological and chemical properties of the vegetation species being selected for.

Section 2.—This section of the management plan includes future deer herd and vegetation monitoring recommendations presented as a series of bulleted items. We suggest Tribal biologists consider the following monitoring techniques, and to utilize methods developed in this study (Appendix A, pp. 10-16; Appendix B, pp. 6-10) for future monitoring:

- Continue annual fall spotlight surveys to determine sex- and age-ratios of the deer herd, utilizing traditional Mason and Manistee survey routes. Use these data to monitor herd responses to changing harvest regulations, should they arise (e.g., increased female harvests), and changes in deer condition as reflected by increasing or decreasing fawn:doe ratios.
- Conduct spotlight- and pellet-based distance sampling and use program DISTANCE (Thomas et al. 2005) to estimate deer density and abundance. Both survey techniques are useful, but pellet surveys should likely be conducted during late-winter/early-spring after snow melt, but before green-up, to maximize pellet detectability. Pellet-based surveys are preferable in areas lacking roads, whereas spotlight-based surveys are recommended for areas containing roads.
- Monitor deer survival, dispersal, and space use using radiotelemetry (see

recommendations for study of males in the next section). From purchases made for our project, the Tribe now has all the infrastructure necessary to capture and radiotrack deer (e.g., nets, traps, radio receivers). Such data could also be used to update the population model.

- Continue use of the population model to assess deer population growth and response to harvest over time. Update as necessary with additional information. This model has the flexibility to input multiple initial population sizes given different scales of interest (e.g., based on Mason County or a portion of Tribal lands of critical importance for which density estimates exist).
- Collect data from deer at Tribal deer-check stations for further assessments of sex- and age-distributions, reproduction, and nutritional condition. Specific items to collect include ovaries/fetuses, jawbones for aging, body mass, and fat measurements such as the kidney fat index.
- Continue annual vegetation data collection within exclosures and reference sites to provide a longer-term data set on the impacts of deer herbivory on forbs. Considerable time and effort was expended to locate these sites and erect enclosures, and we recommend their long-term use.
- Consider establishing a set of permanent transects upon which vegetation measurements can be taken each year. Specific cover types of importance or areas of deer concentration (especially during periods of severe winter) could be targeted.

Section 3.—We provide implications for deer and habitat management on Tribal lands.

<u>Deer Demographics, Harvest, and Space Use</u>

Research and management implications from this segment of our research are also found in the Discussion and Management Implications sections of Appendix A (pp. 19-42) and population modeling (Objective 3 described above). Our study presents information about deer demographics and space-use essential for developing management recommendations for the LRBOI and to benefit wildlife managers elsewhere in the northern Great Lakes ecosystem.

Although deer herds are currently healthy, deer densities on Tribal lands were slightly higher than the current goal levels set by the Michigan Department of Natural Resources (MDNR), the population had a severely female-biased sex structure, and the population was growing slowly. Successful deer management requires attention to basic herd dynamics, including adult sex ratios (Demarais et al. 2000). Female-skewed sex ratios may serve as strong evidence that adult male mortalities and herd relative densities are high (Keyser et al. 2006). If wildlife managers aim to create a more balanced sex ratio on Tribal lands, increased harvest of females will be necessary, especially in light of declining hunter numbers (Frawley 2008a). Currently, harvest incentive programs such as the "earn-a-buck" (EAB) program do not exist in Michigan, but have been used in other state hunting programs (e.g., Wisconsin; WDNR 2008). EAB programs are beneficial in increasing harvest pressures on females while controlling the harvesting of males (Kilpatrick et al. 2005). From a cultural standpoint, deer populations are abundant and there is no fear of appreciable population decline.

Quality deer management (QDM) is another approach for balancing the sex ratio by restricting buck harvest and sustaining antlerless harvest (Miller and Marchinton 1995). Currently, MDNR supports the voluntary implementation of QDM practices on private lands in Michigan (Frawley 2008b), such an approach could be considered for Tribal lands. Mandatory QDM regulations are only imposed in a deer management unit (DMU) when >66% of sampled hunter and landowners support the implementation (Frawley 2008b). Currently, only 1 of 13 DMUs practices QDM within the NLP's northwest management unit (Frawley 2008b).

Recently, a 5-day early firearm antlerless-only hunting season was issued by the MDNR for regions of the southern lower peninsula and 6 northeastern lower peninsula counties in an attempt to increase total harvest levels by 1-2% (MDNR 2008a), which would slow (but not stop) population growth according to our models. If MDNR observes positive outcomes with this additional season, Tribal biologists should consider this management strategy to help increase female harvest, given harvest greater that current levels are necessary. Harvest of males-only, which has fortunately fallen out of practice throughout much of North America, had little ability to reduce deer numbers according to our simulations.

Tribal wildlife managers also should be concerned about relatively high deer densities since overabundant deer can cause severe, long-term ecological effects, as well as negative social and economic impacts on humans (Côté et al. 2004). Although we did not see major impacts of deer on vegetation, the population is growing and may become problematic in the future. Furthermore, high deer densities may increase transmission of infectious disease (Côté et al. 2004), some of which are currently prevalent in the NLP of Michigan (e.g., bovine tuberculosis; Dorn and Mertig 2005). During the end of our field research, chronic wasting disease (CWD) was newly discovered within Michigan in a farmed deer herd approximately 150 km south of our study area (Michigan Department of Agriculture 2008). Although the MDNR has taken immediate provisions to prevent unintentional spread of CWD, Tribal biologists may wish to consider reducing deer densities on Tribal lands, because decreasing population density is one of the few preventative measures that can be taken towards a disease whose biology is not yet fully understood (Gross and Miller 2001).

Adult females on Tribal lands experienced high survival rates including during the over-winter period. Alternatively, some fawns died of predation and starvation during winter/spring. Age-specific differences in over-winter survival is most likely due to related differences between adults and fawns regarding body condition, energy needs, intra-specific competition when acquiring available winter foods, and the capacity to handle winter severity. Winter conditions during our study were relatively mild, but given increasing global temperatures, winter severity may not be as large a factor affecting deer on Tribal lands in the future. The fact that hunting is the primary cause of mortality for adult females validates that manipulation of harvest levels can be a successful tool in controlling survival and maintaining deer populations within goal ranges (McCullough 1984, Brinkman et al. 2004). Male-biased harvest is less effective for population control since the growth of deer populations are primarily driven by females (McCullough 1984); and our harvest simulations agreed with this fact.

Our radiotelemetry research focused on the female segment of the population, given its primary influence on population dynamics. However, study of the male segment of the population on Tribal lands is highly recommended. Our sex ratio of 14 M:100 F clearly suggests that further research regarding this skewed ratio is needed, especially if it is desirable to create a harvest strategy attempting to balance the sex ratio and increase the number of adult males in the population (Keyser et al. 2006). We captured and released 67 males (65 of which were fawns), indicating that a study of survival and dispersal of yearling males would be highly successful and warranted, given the importance of this component of the harvest.

Although deer densities on Tribal lands are higher than MDNR goals, the fawn:doe ratio indicated high recruitment which reflects the quantity and quality of available habitat and ultimately the overall health of the herd (Fuller 1990, DePerno et al. 2000). Furthermore, deer experienced little mortality due to natural causes. Tribal wildlife managers should be cognizant that deer populations in the NLP can likely achieve higher densities without concomitant density-dependent changes (i.e., reduced adult survival and reduced natality;

McCullough 1979) occurring, which indicates further population growth is possible if harvest levels do not compensate.

Analyses of home range size and habitat selection also provide management insight for Tribal biologists. Relatively small home range sizes of deer indicated that cover types are highly interspersed and evenly distributed on Tribal lands (Beier and McCullough 1990, Kie et al. 2002, Cobb et al. 2004). This landscape signature is due to diverse soil types, lake-induced precipitation and milder temperatures, land use that is divided between agriculture and multi-use forests, and habitat programs that maintain high quality deer habitat on public and private lands (MDNR 2005).

From a management perspective, are further habitat alterations necessary to improve deer habitat on Tribal lands? Habitat improvement may be a concern if winter yards were limiting, but deer did not seem to yard much or select yarding habitats (i.e., non-mast producing lowland forest) differently during the cold months in winter conditions observed during this study. Habitat quality also appears favorable for deer given high deer survival, fawn:doe ratios, and overall good physical condition of deer. Historically, Michigan has invested in habitat improvements for deer under the 1971 Deer Range Improvement Program (DRIP; MDNR 2008b). Under DRIP, the creation, seeding, cultivation, and maintenance of >28,300 ha of forest openings was achieved as well as an increase in direct and residual timber cuts (MDNR 2008b). Currently, the program seeks to acquire high-quality winter deer habitat in the Upper and Northern Lower Peninsula to provide adequate winter cover and natural food (MDNR 2008c). Further deer habitat improvement on Tribal lands does not appear necessary as past habitat management and current weather patterns are conducive to healthy deer populations. Rather, protection of at-risk forbs and manipulation of deer densities via harvest may be more important foci for tribal wildlife managers (see below).

Deer Herbivory and Other Factors Affecting Forbs

Research and management implications from this segment of our research are also found in the Discussion and Conservation Implication sections of Appendix B (pp. 15-22 and 33-38). By considering multiple ecological scales and a host of proximate factors, our study provides foundational information to support ecosystem-based research and management for endemic forbs on Tribal lands. Several notable trends in forb demography, fecundity, and ecology were exhibited and are worthy of management consideration.

Regarding potential expansion of exotic forb species on Tribal lands, in our surveys, exotic species all belonged to the family Asteraceae and tolerated generally poor soils. While these exotic asters were fairly uncommon, their reproductive potential was notably greater than endemics of the same family (268.8 vs. 71.0, respectively) and merit caution given the potential for future expansion (i.e., Vitousek et al. 1997). Tribal managers should monitor exotic species presence and abundance as part of the vegetation monitoring recommendations suggested above.

We observed some patterns indicative of deer targeting plant sources which maximized nitrogen-acquisition; this has implications for management. Deer selected specific species and reproductive structures in seasonally-available herbaceous species and may have had the greatest impact on forb communities occurring in nutrient-rich sites. Unfortunately, we were unable to separate the species selection factor from the soil nutrient components and, therefore, conclusions are limited. However, vegetation survey data indicated that nitrogen-fixing individuals of the family Fabaceae were browsed 85% of the time. This is supported by other research which has considered deer impacts on Fabaceae legumes and has considerable trophic consequences for sympatric, threatened invertebrates like the Karner blue butterfly, *Lycaeides melissa samuelis* (Anderson et al. 2001, Miller et al. 1992). This evidence and its theoretical foundation point to the potential for nitrogen to act as a predominant limited resource in the herbivore-forb system on Tribal lands (Tilman 1985, Ritchie et al. 1998). Tribal biologists interested in conserving palatable forbs should consider isotopic analysis of structural nitrogen as a ratio of levels in preferred species, such as *T. grandiflorum*. Identifying the resource ratios selected for by abundant keystone herbivores, such as deer, can assist conservationists struggling to preserve forb species despite the limited observability of browsing behavior.

It is interesting that despite a generally positive effect of deer exclusion, browse rates were not related to deer-habitat density on Tribal lands. Deer densities were highest in vegetated open lands (e.g., fields, savannahs) and lowland cover (e.g., northern white cedar, *Thuja occidentalis*). These results are in agreement with numerous regional studies supporting the use of vegetated open lands for feeding and lowland conifer stands as thermal and escape cover (Beier and McCullough 1990; Van Deelen et al. 1996, 1998; Anderson et al. 2001). This increased density did not, however, relate directly to an increase in browsed forbs, as shown in previous studies (Augustine and Frelich 1998). In fact, no community-level factors played a significant role in predicting the occurrence of deer browse. Only at the population level did we observe a selection for specific species and reproductive structures. This makes sense in light of the selective nature of deer diets, but also has conservation implications for Tribal lands when one considers that managing deer densities at the regional level (i.e., using standard harvest management) may do little to conserve impacted forb communities.

One hypothetical explanation for the lack of a deer density effect on forbs is that browsing of certain highly-demanded vegetation species may asymptote at such a low deer density as to be nearly immitigable at modern deer population levels on Tribal lands. If species are targeted by deer 85% of the time, as with Fabaceae species, then significant pockets of periodic deer absence will have to be created via harvest or depredation permits. This may have been conceivable prior to Michigan's colonization and alteration by European settlement, when Tribal hunters, threat of wolf (*Canis lupus*) predation, and forest contiguity may have produced more spatially heterogeneous deer herds (Van Deelen et al. 1996, Brown et al. 1999, Martin and Szuter 1999). Currently, deer exclusion or reduction to such a level is an extremely daunting task on Tribal lands, to say the least.

Presently, diverse and dense forb populations are restricted to moisture- and nutrient-rich sites on Tribal lands distributed sporadically on a landscape dominated by arid and hastily-leached soils. As a form of rapid mitigation and conservation triage, protected areas should be established around diverse communities and those rich sites which are apt to support similarly diverse communities with reasonable levels of management. Our models indentify such sites on Tribal lands. In these communities, moderate deer densities (by evolutionary standards, and not based on current densities) may well increase angiosperm diversity as other researchers have found (Connell 1978, Anderson et al. 2005).

In addition to our overall priority-conservation area model for Tribal lands, the subsidiary models developed in this assessment may prove valuable. The deer habitat-density model supports the importance of winter deer cover, meadows, fields, and landscape heterogeneity as driving factors affecting deer density (Alverson et al. 1988, Beier and McCullough 1990, Van Deelen et al. 1998, Lesage et al. 2000). The patch extent of lowland conifers supported increased deer densities, but complex stand boundaries had an inverse effect. One possible explanation for this is that lowland conifer stands, especially white cedar, support overwinter deer herds with reduced snow depths and increased microclimate (Van Deelen et al. 1998), even in times of relatively warm winters. Lowland conifer stands which have extremely complex shapes are more likely to have an increased edge-to-interior ratio and, therefore, would be less effective at reducing snow depths and stabilizing climate. Contiguous vegetated open lands and heterogeneous landscapes also favored increased deer densities. Open land habitats tend to be rich in preferred herbaceous species that make up a vital portion of a deer's seasonal diet (Anderson et al. 2001). The interspersion associated with heterogeneous, upland landscapes offers readily-available and quickly-accessible escape cover to adjacent feeding areas and may draw deer to ecotone-rich areas (Clark and Gilbert 1982). The strong link between habitat components and deer populations supports the use of habitat management as a potentially viable method of naturally manipulating deer densities on Tribal lands (Alverson et al. 1988), but this is less likely to be applicable as harvest management for directly reducing deer numbers.

As further indicated during modeling of priority-conservation areas, deer density and human influence are not currently significant factors affecting forbs on Tribal lands. It is quite possible that species or sites that exhibited the greatest sensitivity to such pressures have already been extirpated or drastically altered and settled into alternate stable states (Van Deelen et al. 1996, Augustine et al. 1998, Rooney et al. 2004). In the event that future research reveals a negative influence on forbs from elevated deer densities or human influence, targeted deer harvest, habitat management, or road removal at optimal sites can assist in mitigating such impacts to diverse forb communities. Even so, it seems probable that the effect of such considerations on the identification of optimal conservation areas would be minimal given the overwhelming effect of bottom-up factors (i.e., soils and nutrients) observed in the distribution of diverse forb communities.

Endemic forb diversity and its relationship to land cover revealed a number of different habitat patterns that can inform Tribal biologists. We observed different degree and direction effects between upland and lowland sites, as well as between conifer and hardwood stands. The patch extent and patch density of lowland conifer stands had a positive influence on forb diversity. Cedar recruitment in these stands is traditionally low for numerous reasons, and preservation efforts may be the most reliable means of retaining this multifunctional land cover type and its associated forb diversity (Van Deelen et al. 1996, 1998). The range of values in lowland conifer patch extent and lowland hardwood contiguity were both negatively correlated with forb diversity. This variable may represent areas of heavily interspersed habitat types or ecotones that can result in variations of microclimate, light availability, soil chemistry, herbivory, competition, and site history (Didham and Lawton 1999, Cadenasso and Pickett 2000, Ries and Sisk 2004). However, caution should be ascribed to interpretations of each of these land cover variables when related directly to forb diversity, given the possibility of an interaction with soil hydrology and organic matter. The interaction between soil richness and land cover features was unobserved in comparison plots, but is ecologically probable; further research and ecological assessments on Tribal lands will want to consider this.

The hydrology and nutrient content of soils (i.e., soil richness) were the strongest factors affecting the distribution of forb diversity on Tribal lands (Rogers 1982). These proximate resources are difficult, if not impossible, to recreate and preservation must be stressed in areas containing considerably rich soils. Given the degree of effect and irreparable nature of these resources, it is essential that Tribal biologists monitor the effects of changes related to climate, soil nutrients, and hydrology (Stephenson 1990). The use of watersheds to delineate our study area is particularly relevant here, as it may allow water chemistry samples to track nutrients leached from the soil and predict the impacts of alterations to the hydrological cycle. It is also important to consider the historical ecology and geology of the landscape to determine if current conditions are the result of anthropogenic influences since the 19th century (Mladenoff and Stearns 1993). Fuels reduction, extensive timber removal, and the major outbreak and subsequent repression of wildfires are all relatively recent (i.e., post-1900

A.D.) events that may have drastically affected local soils (Daubenmire 1936, Whitney 1987). Frequent or intense fires and biomass removal have all been shown to volatize nitrogen and permit rapid losses to the atmosphere or through the highly permeable soils that are common in the area (Vitousek and Howarth 1991). Unregulated herbivore populations can induce an additional decelerating effect on nitrogen cycling over time (Ritchie et al. 1998). Only when similar assessments and monitoring have taken place can Tribal managers be confident that the current soil resource conditions reflect the evolutionary context of endemic biota and its sustainability.

The intent of the modeling portion of our research was to facilitate conservation efforts that maximize site diversity of forbs on Tribal lands. It is important to mention that this does not ensure that conservation priority species or taxa at risk of extirpation are indeed covered (e.g., the low ranking of the critical dune habitat) (Higman and Penskar 1999, Michigan Natural Features Inventory 2007). Adjusting the resolution of the modeling scale or substituting the focal community will alter habitat considerations and spatial patterns to suit the needs of the particular investigation (Reid 1998, Bowker et al. 2008). For example, techniques we employed could also be used to model dispersion corridors for invasive species by establishing cell-to-cell costs of colonization across gradients of habitat potential. Undoubtedly, numerous additional model alterations are possible based upon available data, local pressures, and management objectives. Regardless of its focus, our models provide Tribal biologists with an applicable gradient of conservation priority based upon rapidly acquired field data and landscape metrics.

Tribal biologists can apply the priority conservation model and its developed subsidiary models to mitigate for regional conservation challenges. Overlaying current ownership by Federal, State, and Tribal entities reveals that much of the region has already been afforded some degree of protection. However, high-priority sites remain unprotected and increasing the continuity of protective status around species-rich sites can help buffer communities from degrading influences (Yamaura et al. 2008). In addition, identifying locations for protective status is only the first step in conservation, with possible threats to species diversity and sustainability persisting even after legal and social support is established. Likewise, all conservation is not created equal and various degrees of protection and monitoring are afforded to different locations within a conservation holding. The status of high-priority areas within current conservation areas on Tribal lands should be adjusted appropriately to ensure that current diversity is maintained.

CONCLUSIONS

This project has been highly successful and the amount of information generated has far exceeded expectations. The benefits of this project to the LRBOI and neighboring Tribes are numerous given the importance of deer to humans and the ecosystem alike. First, the management plan provides the Tribe with a necessary document to forward management of its own natural resources. Second, our work serves as a guide for Tribal wildlife biologists to conduct deer work that will be essential to future deer management. Third, 2 M.S. theses, 10 presentations and posters at professional and public meetings, and several publications in preparation for scientific journals have resulted from this research; thus, results will be shared with other Tribes and the entire wildlife community. We envision that management that will follow this work will bring humans, deer, and the forest into the proper balance that should exist on Tribal lands.

Our project met specific U.S. Fish and Wildlife Service goals as follows:

Sustainability of Fish and Wildlife Populations.—Our work will help improve the sustainability of deer populations and at-risk forb species on Tribal lands. The LRBOI has gained information on deer population dynamics, response to harvest, and habitat use through this research, thereby providing baseline data for understanding deer sustainability on Tribal lands. These analyses have yielded science-based data for management decisions that should extend to the entire northern Great Lakes ecosystem.

Habitat Conservation.—Our project provides the Tribe with knowledge of deer impacts on their habitat, which is integral to habitat conservation and protection measures. Assessments of deer browsing, as well as other ecological factors, indicate that deer are not as important as bottom-up pressures in affecting habitat. Our model of priority-conservation areas provides targeted areas to protect for endemic forb diversity.

Public Use and Enjoyment.—Deer are likely the most "enjoyed" species in North America (and of critical cultural importance to the LRBOI), with millions participating in hunting and viewing activities pertaining to deer. Proper management of deer populations that will stem from this project will allow for enhanced use and enjoyment of deer populations on Tribal lands well into the future.

Partnership in Natural Resources.—This project was a collaborative effort between LRBOI Tribal biologists and faculty/staff of the Cooperative Wildlife Research Laboratory at Southern Illinois University Carbondale. Cooperative Wildlife Research Laboratory personnel knowledgeable in deer research and management techniques trained Tribal biologists in monitoring the deer population and forest vegetation during this study.

As originally proposed, this project thoroughly addressed U.S. Fish and Wildlife Service initial project ranking criteria for the Tribal Landowner Incentive Program as such:

Benefit.—We provide substantial benefits to the LRBOI in regards to providing knowledge of deer and forest vegetation on Tribal lands and developing a deer management plan. Our project provides substantial benefits to the deer population as well as the habitats in which it resides. This information will allow Tribal wildlife biologists to better manage not only deer populations but also the habitats they occupy. It will assist Tribal biologists in identifying habitats important to deer and help to identify areas in which habitat restoration and improvement may be necessary.

Performance Measures.—This project obtained quantifiable performance measures. Population models, survival and habitat analyses, vegetation measurements, and models of priority-conservation areas produced through this research yielded baseline conditions that were not yet known for deer and vegetation on Tribal lands. The management plan recommends applied management options that biologists can employ to meet Tribal goals, both now and in the future. The monitoring program, using methods employed in this study, will allow Tribal biologists to evaluate the deer population and vegetation status, thereby allowing for an adaptive management approach for managing resources over time (Holling 1978, Nielsen et al. 1997). Given the importance of deer to Tribal culture and the ecosystem, few higher priorities exist than the appropriate management of deer on Tribal lands, and this project enabled such a program to begin and flourish.

Capacity Building.—The LRBOI has gained a much greater capacity to manage its own wildlife and habitat as a result of this project and the management plan produced therein. Deer and vegetation management guidelines developed as a part of the management plan will affect and amend Tribal wildlife ordinances through science-based management recommendations. Furthermore, equipment and the vehicle purchased for this project has developed significant infrastructure for future wildlife work. Finally, this project resulted in the creation of a population model and monitoring program that will aid Tribal wildlife biologists in future deer management.

Contributions and Partnerships.—This project has built a collaborative relationship between the LRBOI and Southern Illinois University Carbondale. Undoubtedly, other local tribes will benefit from this research, which will significantly contribute to their knowledge of deer ecology and management. The management plan created via this project serves as a valuable example to other Tribes and likely result in partnerships among Tribes to manage deer populations. The development of a comprehensive deer management plan by the Little River Band will be incorporated into the management strategy currently being developed by the Little River Band, the Grand Traverse Band of Ottawa Indians, and the Little Traverse Bay Bands of Odawa Indians. Furthermore, the U.S. Forest Service supported this grant proposal and served as an active partner in data collection and technical assistance, and they will benefit from our forb research.

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Appendix A. J. Stroud M.S. thesis.

Appendix B. C. Hester M.S. thesis.