EXPERIMENTAL ASSESSMENT OF SHOCK COLLARS AS A NON-LETHAL CONTROL METHOD FOR FREE-RANGING WOLVES IN WISCONSIN

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This thesis is dedicated to my Grandmother, Myrtle Swensen (Mimi), for providing guidance, wisdom, support and love in so many ways for the first 25 years of my life. Although she may not be here to see it, this research would not have been possible without her. I could never begin to thank her for all that she has done for me.

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ABSTRACT

EXPERIMENTAL ASSESSMENT OF SHOCK COLLARS AS A NON-LETHAL CONTROL METHOD FOR FREE-RANGING WOLVES IN WISCONSIN

By Jason E. Hawley

As wolf populations continue to expand in and around human-dominated landscapes throughout the world, so to will the need for new control methods. Lethal control alone has not proven entirely effective in reducing wolf depredations in chronic problem areas. Unsuccessful attempts to implement lethal control can lead to significant economic losses to both the livestock producers and wildlife management agencies. I suggest an integrated management approach to wolf depredation, where lethal control and various forms of non-lethal control are used in concert to control depredating wolves.

If proven effective, non-lethal control could provide an alternative to repeated unsuccessful attempts of lethal control within chronic problem areas, and therefore save management agencies and livestock producers money. Prior to this research, shock collars had not been experimentally assessed on free-ranging wild wolves. I tested shock collars on 5 wolves and maintained 5 control wolves in northern Wisconsin during the summers of 2003 and 2004 using an experimental design. My results suggest that shock collars may significantly reduce wolf visits and time spent in a defined area (i.e., chronic problem area). Treatment wolves reduced their time

spent in the zone by 70% after treatment, which was statistically significant, whereas control wolves did not show a statistically significant change. Visitations to the shock zone by treatment wolves decreased by 50% after treatment, which was also statistically significant, while control wolves showed no change in their visitations after treatment. A significant shift in wolf locations away from the zone of 0.7 km by treatment wolves was also detected.

Between the 2003 and 2004 field seasons I worked on refining and testing shock collar design for efficiency and safety. I developed and tested 3 different collar designs on a total of 12 captive wolves or wolf-dog hybrids at the Wildlife Science Center in Forest Lake, MN. Successful changes made to the shock collars included mounting the shock unit on the back of the radio collar for ease of use, rounded probes rather than the pointed factory probes for safety, a 2-3 month drop off design, and extended battery life. Shock units were directly mounted via drop-off design to the back of the radio collar rather than being fitted on a separate collar under the neck. I found that the new rounded probe design dramatically reduced injuries to the animals, yet still provided adequate probe contact. While more improvements need to be made, this new collar design is a step in the right direction to creating a safe, efficient and practical shock collar for management situations.

I believe that shock collars may hold potential in their use as a non-lethal control method for wolves, and could save both livestock producers and managing agencies valuable time and money. Before they are included in management plans however, more research is needed. Future research should focus on the ability of shock collars to provide long-term conditioning, improving shock collar efficiency, and the effect shock collared wolves have on other pack members.

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CHAPTER I

INTRODUCTION

In the history of the United States, no species has ever been as heavily persecuted as the gray wolf. Early European settlers found it possible to coexist with these predators. Most Native American tribes considered them sacred, even brothers. It was the later settlers that brought with them vast herds of cattle, thereby viewing wolves as a nuisance that held more value dead than alive. Even native game species (i.e., bison (*Bison bison*), elk (*Cervus elaphus*), and deer (*Odocoileus sp*.)) were viewed as competitors of livestock and either eliminated or reduced to minimal numbers to allow for the expansion of cattle grazing pastures. Due to the loss of native prey species, many wolves were compelled to prey upon livestock in order to survive. Increasing wolf depredations on livestock added fuel to the fire (Bailey 1907).

In 1915, the United States Congress gave the U.S. Department of Agriculture's Bureau of the Biological Survey funds with which to eradicate wolves on public lands (Steinhart 1995). The Predatory Animal and Rodent Control Service (PARC, which later became Animal Damage Control, or ADC) was created, which employed full time hunters and trappers to eradicate wolves (Young and Goldman 1944). With government bounties, financial gain, and ingrained hatred as motivation; wolves were trapped, snared, shot, and poisoned to the brink of extinction in the United States.

Similar to what occurred elsewhere in the United States, hunting, trapping, and loss of habitat eliminated the gray wolf from the Lower Peninsula of Michigan and southern Wisconsin by 1910 (Jensen et al. 1986, Thiel 1993). A state-paid bounty extirpated gray wolves from the Upper Peninsula of Michigan by 1960. Aside from a handful of wolves, the species was extinct in the State of Michigan, and northern Wisconsin was not far behind (Shadler and Hammill 1996). Small numbers of wolves did find refuge in Minnesota and across the border in Canada (Mech 1970, Michigan DNR 1997).

By the 1960's, with help from Aldo Leopold's land ethic, an attitude of ecological and environmental awareness began to develop, and with this came a new sentiment towards large predators like wolves (Leopold 1933, Cohn 1990). Instead of merciless killing machines, gray wolves were viewed as an unduly persecuted species and a necessary component of healthy ecosystems (Mech 1970). An animal that had represented a past failure was now viewed as an opportunity to right a moral and ecological wrong.

In 1973, the gray wolf was designated as an endangered species in the northern Great Lakes Region, and given full protection under the Endangered Species Act (ESA 1973). Through dispersal from Canada and Minnesota, wolves have since begun to reestablish resident populations in Wisconsin and the Upper Peninsula of Michigan (Mech and Nowak 1981; Wydeven et al.1995; Schadler and Hammill 1996). Currently, Wisconsin estimates nearly 400 wolves in over 100 packs within its state borders (Wydeven et al. 2004; Appendix D.). The Michigan DNR estimates the gray wolf population in the Upper Peninsula at 350 individuals, with carrying capacities predicted as high as 700 individuals (Michigan DNR 1997).

With greater numbers of wolves, come the unavoidable conflicts with humans (Kellert 1991, Reynolds 1996; Treves et al. 2002). In a natural ecosystem, populations of predators such as wolves would be controlled by disease and prey availability. Historically when wolf numbers exceeded the carrying capacity, there would be a die-off due to disease, or a decrease in prey availability (Packard and Mech 1983). Unfortunately we live in a human (or livestock in some cases) dominated landscape, and wolf numbers cannot always be allowed to naturally fluctuate. Presently the controversy lies in how to successfully manage the gray wolf to avoid human conflicts, thus insuring long-term viability of the species. Wolves were nearly eliminated from the U.S. once, and it could easily be repeated.

Negative attitudes towards wolves can become magnified if it is perceived that agencies are ineffective in preventing livestock depredations. Management prescriptions can be developed and tested that curb depredations and reduce the risk of public attitudes shifting from favorable to unfavorable towards wolves (Mech 1995). Although such a drastic shift in public attitude towards wolves may appear an unlikely event, it has occurred before in human history and has resulted in severe reductions in wolves. For example, public attitude towards wolves in Poland has fluctuated in the past few centuries from protection to extermination back to protection (Mech 1995). The general public is interested in maintaining wolves in Michigan and Wisconsin; thus we must learn and apply the most effective techniques for minimizing wolf-human conflicts (Peek et. al. 1991, Michigan DNR 1997).

Depredation of livestock by wolves is already a major issue in the Great Lakes region (Fritts et. al. 1992, Mech 1998). This problem will undoubtedly worsen as the number of wolves continues to grow (Kellert 1991, Mech 1995, Treves et al. 2002). Chronic problem areas (e.g., farms that suffer livestock losses for 3 or more consecutive years) are developing, and will continue to develop in the Upper Peninsula of Michigan and northern Wisconsin (Fritts et al. 1992, Wisconsin DNR 1999, Mech 2000). If problem wolves are not controlled, individual livestock owners may suffer significant economic losses. Michigan and Wisconsin residents are currently in favor of wolf recovery, but this could change if the population is not properly managed (Dorrance 1983, Mech 1995).

The use of lethal control is and will continue to be an important tool in managing wolf populations (Berryman 1972, Archibald et al. 1991, Mech 2000). It is not however, the answer to all of our problems. Lethal methods are not always effective in controlling wolf depredations (Fritts et. al. 1992, Mech 1995). Implementing lethal control when successful can be expensive, not to mention when it must be repeated annually in chronic problem areas. In Wisconsin, livestock owners are compensated for verified wolf depredations. Between 1982 and 2000, the Wisconsin DNR paid $150,485.00 to compensate livestock owners for wolf depredations. The annual compensation cost within the State of Wisconsin is expected to increase, as the number of wolves continues to increase (Treves et al. 2002). In some cases, such as recovering wolf populations, where numbers are low and each animal is considered valuable, lethal control may not even be an option. This has been the case in the reintroduction of the Mexican gray wolf (*Canis lupus baileyi*) to the southwestern United States, and the red wolf (*Canis rufus*) to the southeastern United States (Peek et al. 1991, Parker and Phillips 1991).

In the United States, Minnesota has the longest history of managing wolf depredations of livestock. The current method used to manage wolf depredations within this State is lethal control (i.e. trapping and shooting) (Mech 1995). To date, lethal control in Minnesota has lead to ambiguous and inconclusive results as a principal management tool for preventing livestock depredations (Fritts et al. 1992). For example, in one year, 34 of 108 Minnesota farms (31%) where wolves were trapped and destroyed were found to suffer wolf-caused depredations the following year. Conversely, 23 of 99 Minnesota farms (23%) where lethal control was not successfully used (i.e., no wolves were destroyed) suffered depredations the following year (Fritts et al. 1992). In other words, repeat depredations were less common on farms where lethal control was not successful. Indeed the trend in Minnesota has been repeated depredations on a handful of farms (i.e., chronic problem areas). These comprise approximately 20% of all Minnesota farms that suffer depredations (Mech 1998; Mech et al. 2000). These data suggest that there may be inherent characteristics of individual farms or neighborhoods that appear to promote livestock depredations. To date, lethal control alone has not been proven successful at reducing depredations within these chronic problem areas.

There are two possible problems occurring within these chronic problem areas: First, when wolves are lethally removed from an area, the territory formerly defended by the recently removed wolves is left open, and new wolves may enter and establish the unoccupied area as their own territory (Bjorge and Gunson 1985). Removing territorial animals like wolves from their territory opens up that formerly defended area to previously excluded wolves (Shivik et al. 2003). The newly established wolves may continue the same habit of killing livestock (Gehring et. al. 1996 a and b). In other words, it may be a problem area that promotes wolf depredation, rather than a problem depredating pack or wolf. Non-lethal methods allow for the continuance of territory defense, and may provide a more long-term solution, as the resident wolves will continue to exclude other wolves from the area. The effects of lethal control often last for only 1 year, while the effects of non-lethal control may last for multiple years (Shivik et al. 2003).

Secondly, regular lethal removal of wolves may in some instances increase depredations by the resident wolves, as remaining wolves may become even more dependent on livestock for food (Bjorge and Gunson 1985). The social disruption caused by the removal of dominant or older pack members may leave young inexperienced wolves no “choice” but to prey on livestock, as they have not yet developed the hunting skills necessary to capture more elusive native prey. This has been directly observed in Montana wolves (Fritts et al 1992). Wolves are highly social predators, and pack structure is extremely important for the transfer of knowledge from one generation to the next (Klinghammer 1975, Shivik et al. 2003). Non-lethal control could possibly be used as a more effective management tool by preserving social and demographic structure, as one would not be dealing with a new group of wolves (or naive young wolves) every time the resident pack is eliminated

(Shivik et al. 2003). It is also possible that older wolves might teach younger wolves to avoid a specific area, if they themselves have been conditioned to do so.

Aside from the possibility of being more effective in certain situations, non-lethal control is publicly more acceptable when compared to lethal control (Reynolds 1996). However, lethal control and non-lethal control should not be viewed as mutually exclusive. Together, lethal and non-lethal control could be used as effective management and conservation tools for wolf populations. Before they can be successfully implemented into wolf management plans, non-lethal control methods must be tested in the field. While many different forms of non-lethal control exist, few have been thoroughly tested on free-ranging wild wolves. Livestock guarding animals, fladry, translocation, electric fencing, Radio Activated Guards (RAGs), scent/taste aversion, hazing, and shock collars are all forms non-lethal control that could possibly be used to control depredating wolves.

Livestock guarding animals have been used for centuries. When ranchers work directly with guard dogs, they have shown to be quite effective (Andelt 1992, Musiani et al. 2003). Training and monitoring, however, can be extremely time-consuming and expensive. It is also not uncommon for even the best guard dogs to be injured or killed by marauding wolves (Musiani et al. 2003). Other possible guard animals include llamas and donkeys, yet neither has proven to be as effective as dogs (Walton and Field 1989, Green 1989, Meadows et al. 2000). Fladry, which consists of flags hung at evenly spaced intervals on ropes, was originally used to hunt wolves in Eastern Europe and Russia (Musiani et al. 2003). It has since been adapted for use as a non-lethal control method to exclude predators from livestock grazing areas. Musiani et al. (2003) found that fladry may work for a period of up to 60 days in small pastures, and then tends to lose its effectiveness at excluding wolves. Hazing, scent/taste aversion, translocation, fencing and RAGs may also have some initial effectiveness at deterring wolf depredation, yet like fladry, tend to become ineffective after a period of time (Linhart et al. 1984, Shivik et al. 2003).

The ultimate goal of all predator control is to provide an efficient, economic and effective method to reduce the existing problem for as long-term as possible (Berryman 1972). While lethal control has proven to be effective in many situations, it often fails to reduce or can even increase wolf depredations (Fritts et al. 1992). Some of the non-lethal control methods mentioned thus far have also shown promise in providing effective relief from wolf depredations in certain situations, yet most of them for short periods of time due to habituation.

I propose that it in order for intelligent animals such as wolves to be truly conditioned (or non-lethally controlled) it may require a significant consequence to a specific behavior. For example, if a wolf approaches a flag on a fence line for the first time and it moves, he may run away. He did not, however, receive a significant consequence to that behavior of approaching the fence, and may not hesitate to attempt it again in a few days. By the tenth time he approaches the fence with the flag, he "realizes" it will not bother him and moves past it. Fear or disruption alone may not be a significant consequence, as it allows for habituation (Shivik et al. 2003). If when the wolf approaches the fence he experiences a burst of pain in the form of a shock, he will run and may remember the consequence. Pain in itself is a significant consequence, and in most cases does not allow for habituation (Coppinger and Coppinger 2001). By the third or fourth time the wolf approaches the fence, the shock is still the same significant consequence, and the wolf may learn to associate the fence with the consequence, and thus avoid the fence. This has been demonstrated in captive coyotes (*Canis latrans*) punished for a specific behavior (predation on rabbits and sheep) by electric shock (Linhart et al. 1976; Andelt et al. 1999).

In order for non-lethal control to be cost-effective and practical, it must provide some measure of long-term aversive conditioning. It should be stated that there is no “fix-all” when it comes to control of wolf-caused livestock depredations. Some methods will work in some situations, where others will not. We must continue to experimentally assess these and other less understood methods of non-lethal control to fully understand their potentials. Shock collars are one of the least understood methods of non-lethal control for wolves. They differ from the previously mentioned forms of non-lethal control in that they result in behavioral conditioning when the animal is able to establish a connection between a specific behavior and a significant negative consequence (pain in this case). Previously mentioned forms of non-lethal control are merely “disruptive” to the animal, and while they may actively “harass” a wolf, alone they do not provide any kind of long-term conditioning (Shivik et al. 2003). If found to be effective, shock collars may create site-specific avoidance by conditioning wolves to avoid livestock pastures, thereby preventing and reducing depredations. Shock collars are regularly used to train or “condition” domestic dogs and the low-impulse “corrective” shock is considered humane.

In 1998, the Wisconsin Department of Natural Resources captured, shock-collared and released a depredating wolf on a beef farm in western Wisconsin (Schultz et al. 2005). This was part of an adaptive management approach to control wolf depredations on the farm at a time when lethal control was not authorized. The wolf was remotely shocked each time it approached the farm. The wolf was monitored via radio telemetry upon receiving a shock and each time moved a significant distance away from the farm. This was repeated on a different wolf with a beeper system in 2001, with similar results. While the Wisconsin DNR did find a decrease in depredations for both wolves, they could not determine if there was any conditioning of the wolves, although the second wolf did continue to react to the beep for some time (Schultz et al. 2005). Schultz et al. (2005) suggested that shock-collars could be effective and even save wildlife management agencies time and money in certain management situations, and that creating conditioned packs of wolves in problem areas, may be a better solution to annually implementing lethal measures. They also suggested further research to assess the efficacy of shock collars as a non-lethal control method. While this research was observational in nature, it did suggest promise in the use of shock collars to control free-ranging depredating wolves.

Shivik et al. (2003) tested shock collars on captive wolves at the Wildlife Science Center in Forest Lake, Minnesota. They reported that shock collars were difficult to use on wolves due to logistical and behavioral variability. Animals reportedly reacted differently to the shock. Some reacted strongly and avoided the shock, while others merely scratched at their neck. Wild wolf behavior will undoubtedly vary greatly from that of captive wolves. While this method of control has shown inconclusive results on captive wolves, it has shown good results in conditioning captive coyotes (Andelt et al. 1999) and promising results on free-ranging wild canids (Andelt et al.1999, Cooper et al. 2005, Schultz et al. 2005). So while captive research is important, it may not tell us much about free-ranging wild wolves.

Captive wolves are acclimated to an unnatural environment, and thus may behave differently than free-ranging wild wolves. It is also possible that variability in the performance of the shock collars themselves was incorrectly attributed to variability in animal response by Shivik et al. (2003). This variability in shock collar performance was clearly demonstrated in the captive research of Chapter 2. It is unclear whether Shivik et al. accounted for this possibility.

Prior to this research, shock collars had not been tested on free-ranging wolves using an experimental design. Here, I present an experimental assessment of shock collars as a non-lethal control method for free-ranging wild wolves in Wisconsin. The objective of this research was to determine whether shock collars could be effective in altering free-ranging wolf movements away from a desirable site.

Study Area

The study area for this research consisted of a 9,000 km^2 section of north central Wisconsin (Appendix D, Appendix E). This area was made up of 7 different counties including Ashland, Forest, Iron, Lincoln, Price, Oneida and Vilas. It bordered the western edge of the Upper Peninsula of Michigan. The majority of the study area was an ecological landscape type classified as Northern Highlands by the Wisconsin DNR (Wisconsin DNR 2000). It was characterized by pitted outwash plains and kettle lakes mixed with extensive forests and large peat lands. In general, the topography was relatively flat, with a few rolling hills. Aspen (*Populus sp.*) was the dominant forest vegetation, mixed in with some white (*Pinus strobus*), red (*Pinus resinosa*), and jack pine (*Pinus banksiana*). Northern hardwoods did occur, but were less common. Lowland conifers such as black spruce (*Picea mariana*) occupied the low-lying swamp and peat lands. Sixty-four percent of this area was forested. Recreation and timber production are extremely important to the local economy in this area, in fact, over 17% of it is owned by timber industries (Wisconsin DNR 2000).

The remainder of this study site and the areas that surround it were made up of an ecological landscape type classified by the Wisconsin DNR as the North Central Forest (Wisconsin DNR 2000). The topography was similar to that of the Northern Highlands, yet it was dominated by the northern hardwood forest, made up of sugar maple (*Acer saccharum*), American basswood (*Tilia americana*), and red maple (*Acer rubrum*), and also included some scattered hemlock (*Tsuga canadensis*) and white pine. Aspen was also abundant, along with spruce and fir (*Abies balsamea*). This landscape was 80% forested, the highest percentage in the state of Wisconsin. Recreation and timber production were also important in the area (Wisconsin DNR 2000).

The study area as a whole was made up of federal, state, county, timber, and private property. Hydrological features play an important role in this area. Rivers, lakes, ponds, streams, swamps, and peat bogs were common throughout the landscape. Most of the study area was accessible through secondary, two-track, or retired logging roads. A portion of the public and private land was gated and restricted to foot travel for the general public, yet much of it was completely open to any sort of travel. Horse, ATV, truck, bicycle, and foot travel were all common. Hunting and fur-trapping were also prevalent in the area. Agriculture, while not abundant, is present principally as cranberry, potato, and soybean production. Beef and dairy cattle occur at a combined density of 12.8 head/km^2 in northern Wisconsin (Treves et al. 2002). The mean snowfall in the study area was approximately 200 cm per year, while the mean rainfall was approximately 80 cm per year. The mean annual temperature was 4.5 degrees Celsius. Summers were generally short (3-4 months), while winters could last up to 7 months.

An estimated 40 wolf packs with an average of 3.5 animals per pack occur within this area (i.e. 140 wolves) with a mean density of 1.5 wolves per 100 km^2 (Wydeven et al. 2004; Wydeven and Wiedenhoeft 2004). White-tailed deer (*Odocoileus virginianus*) occur at approximately 1,800 per 100 km^2 within this study area (Wisconsin DNR 2000). This equals about 1,200 deer per wolf. According to the Wisconsin DNR, deer make up approximately 55% of wolf diet in the state. Beaver (*Castor canadensis*) are also important, contributing to about 16% of wolf nutrition throughout the state. Snowshoe hares (*Lepus americanus*) contribute about 10%. Moose (*Alces alces*) and elk (*Cervus elaphus*) populations were rare in the area, and neither species was a component in the wolf diet. The average home range size of wolf packs within the study area is 150 km^2 (Wisconsin DNR 2000; Wydeven et al. 2004). Other large predators occurring in this area include the black bear (*Ursus americanus*), coyote, and bobcat (*Lynx rufus*).

CHAPTER II

METHODS

Prior to commencing, this research was approved by the International Animal Care and Use Committee (IACUC, 27-January-2003). Wolf packs occurring within the study area of northeastern Wisconsin were scouted extensively via scat and track surveys. This included both driving and walking two-track roads within wolf pack territories and visually observing tracks and scat. Packs were selected for inclusion in this study based on 3 main criteria. First, packs with accessible roads within their territories were considered top choices because vehicles were necessary to both gain access to the center of pack territories, and to allow transport of equipment and bait in and out of each site. Secondly, packs that readily used roads were also considered top choices. This was because the nature of this research required accessibility to the areas used regularly by the wolves. Within this area, two-track roads were the only viable option to fulfill this requirement. I also tried to select packs with at least 3 adult animals, as they tended to be more established, and less apt to move or disperse. More animals in the pack may also allow for an increased success rate when trapping.

Within each treatment pack a minimum of 1 wolf was captured and chemically immobilized with 10mg/kg of ketamine hydrochloride and 2mg/kg of xylazine hydrochloride via an intramuscular (IM) injection (Kreeger 1996). Wolves were captured using either a modified Newhouse number 14 foot-hold trap (Kuehn et al. 1986) with McBride springs and breakaway pan device, a Cable Restraining

Device (similar to a neck snare with a stop), or a McBride number 7 foot-hold trap with Kevlar padded jaws.

Once chemically immobilized, all wolves were monitored via temperature, respiration, and pulse. Wolves were then sexed, weighed, measured and pit-tagged. Age was defined based on tooth eruption and wear patterns (Van Ballengerghe and Mech 1975). Blood samples were collected from all wolves for health and genetic analysis conducted by the Wisconsin DNR. Healthy adult wolves (> 1 year) were fitted with a 400-g radio collar with a 2-hour mortality sensing (Telonics, Inc., Mesa, AZ) and an Innotek (Invisible Fence Technologies) Training Shock Collar. During the 2003 field season, shock-collar units with factory probes were fitted on a separate collar with the probes on the under side of the neck, which was shaved down to the skin to insure probe contact (Appendix F). During the 2004 field season, the shock units were fitted with custom rounded probes and mounted on the back of the radio collar (thus on the back of the neck) via a custom drop-off design (Chapter 2; Appendix G).

Study Design

Adult wolves found to have significant health problems (i.e., sarcoptic mange) that were captured as a possible treatment sample were fitted with a radio collar but not with a shock collar. Pups (< 1 year) that were less than 20 kg were physically restrained rather than chemically immobilized, and not fitted with a radio collar. Pups that were more than 20 kg were physically restrained and fitted with a radio collar but no shock collar before being released. All chemically immobilized wolves were intravenously administered 0.15mg/kg of yohimbine hydrochloride as a reversal agent before being released (Kreeger 1996).

Control wolves were selected from wolves that had been previously collared with a Telonics radio collar by the Wisconsin DNR when possible. Captured wolves that could not be shock collared and used as a treatment were radio collared and used as a control if possible. Within treatment packs, a second animal was captured only if the first proved unusable in the experiment.

Upon completion of collaring (both treatment and control) wolves, regularly-used (by the wolves) two-track road intersections within each wolf's territory were identified as "shock sites" (Appendix H). These sites were selected based on historic telemetry location data, and track/scat surveys. An inner "shock zone" (extending 30 meters from the center of the intersection) and an outer "detection zone" (extending from 30 to 75 meters from the center of the intersection) was defined for each site (Appendix I). The centers of the sites were then baited with road-killed deer every 2-3 days.

Radio data loggers (H.A.B.I.T. Ltd., Vancouver, British Columbia) were set up to monitor wolf movements at each site. Deep-cycle marine batteries were used to power the data loggers and lasted for approximately 2 months. The data loggers were mounted in trees with antennas extending approximately 3 meters from the ground. Only trees with thick cover were used in order to conceal the data loggers from the wolves and humans. Data loggers scanned defined VHF frequencies for percent signal strength, and recorded the date and time the animal spent in the area. I was able to calibrate the percent signal strengths representing each zone by testing 10

Telonics radio collars held at 50-cm high in the field. I found that when the data logger began picking up a signal (> 1%) the collar was approximately 75 meters from the center of the zone (which was set at 75 m for this reason), or at the start of the detection zone. When the signal strength reached 20% (Variance = 1.5%), the collar was approximately 30 meters from the center of the zone, or at the start of the shock zone (which was set at 30 m for this reason). Simply stated, a wolf recorded at 1 to 19% signal strength was considered in the detection zone, and a wolf recorded at 20-100% signal strength was considered in the shock zone (Appendix J). With these data loggers, I was able to monitor all of the radio-collared wolves for time of visit to the shock and detection zone, length of visit, and distance from the center of the zone.

As soon as it was established that collared wolves were regularly frequenting these pre-selected sites, experimentation began. Innotek shock towers were placed at the center of each treatment site in close vicinity to the data logger (Appendix I). The shock towers were mounted in a 65 x 100 cm wooden box containing a deep-cycle marine battery power source, and custom shock timer (Schultz et al. 2005). Timers allowed for the shock unit to remain on for 13 seconds, then off for 13 seconds, continuously. The purpose of this timer was to allow the wolves time to react, while not being shocked continuously. Antennas were removed from the shock transmitters to maintain a shock zone with a 30 m radius. Wolves wearing an Innotek shock unit would receive a low-impulse shock every 13 seconds, for 13 seconds upon entry into the shock zone (30 m from the center of the site). The outer detection zone served as a monitoring zone only, no shock was ever administered (treatments or controls) while in this outer zone. Controls did not receive a shock collar or transmitter, yet were still monitored via data logger in both zones.

The research design for this study included: 1) 14-day before-shock period during which wolf movements were recorded at the site (no shock) for both treatments and controls; 2) 14-day during-shock period during which treatment wolves were shocked upon entry into the shock zone; and 3) 14-day after-shock period during which wolf movements were recorded at the site (no shock) for both treatments and controls. The amount and extent of researcher visitations to drop bait and check equipment was consistent between treatments and controls (every 2-3 days).

All wolves included in this research were located via aerial telemetry at least once a week by the Wisconsin DNR. All treatment wolves were also located at least every 2 days via vehicle-mounted ground telemetry. Control wolves were only located via ground telemetry 1-2 times per week, or when time allowed. Our vehicle-mounted telemetry system consisted of a 5-element Yagi VHF antenna mounted 1-meter above the roof of a 2003 Dodge Ram 1500 and a 1998 Ford Ranger. The antennas were fastened via heavy-duty conduit, which passed through the roof of each vehicle, and mounted directly to the floor board. A compass rosette and marine electronic compass were also mounted in the interior of the vehicle to provide accurate directional readings (Lovallo et al. 1994). Communication Specialist VHF telemetry receivers were used for all ground telemetry. At least 3 bearings were taken on each animal from established waypoints. Locate II was used to perform the triangulations and gather estimated animal locations. I used the

Maximum Likelihood Estimation (MLE) system within Locate II, which weights all bearings as equal.

Data loggers were collected at each site at the end of the 42-day monitoring period. Data were then downloaded to a laptop computer via a H.A.B.I.T. Ltd. program. Excel was used to sort out any “static” (wolf radio-collar recordings were at 50 pulses per minute, whereas static recordings were usually over 1,000 pulses per minute) recordings such as those caused by lightning, airplanes, radio-towers, etc. A “dummy” frequency was also scanned to insure that recordings of wolf visitations were legitimate. Only recordings on the specific VHF collar frequency were included. All recordings were then sorted in Microsoft Excel by chronological order of each visitation event.

Mean Visits per Day

The data logger recordings were used to calculate 2 different datasets for each treatment and control wolf. The first of these was mean visitations per day. A visitation was counted as an entry into either zone (detection or shock). The animal then had to leave the zone for 2 minutes before returning and registering a second visitation. Visitation events were totaled for each wolf, during each period (before, during and after), and in each zone (shock and detection). Each total was then divided by the number of days in the time period, giving a mean amount of visitations per day for that time period in each zone, for each wolf (the time period was 14 days for all except for the after period for Pine Lake and Somo River which was 7 days. Due to the presence of bear hunting hounds in the area, 7 days were excluded).

These data were then turned into proportional data (proportion of mean visitations per day that occurred in each time period), and a paired t-test was used to compare before-treatment proportions with the after-treatment proportions, where t = mean difference/standard error. Alpha was set at 0.05 for all statistical procedures in this research (Zar 1996).

A meta-analysis was also done to measure any treatment effect and its size going from before treatment to after treatment. The effect size was calculated by dividing the difference of the 2 data set means (before and after) by the pooled standard deviation of both datasets (Fernandez-Duque 1994). Cohen (1977) defined 0.2 as a small treatment effect, 0.5 as a medium treatment effect and 0.8 as a large treatment effect. This was done the same for all controls and treatments.

Mean Time Spent per Day

The second dataset collected with the data loggers was mean time spent in the combined zone per day, for each of the 3 time periods (before-during-after). In order to minimize potential error for this dataset, the shock zone was pooled together with the detection zone. The combined zone for this dataset then, was from 0 to 75 meters from the center (Appendix I). The reason for this pooling was that it was difficult to decipher which zone the wolf was spending time in between the data logger recordings, which usually occurred every 3-12 seconds. A wolf may simply turn his head, causing the data logger to pick up a weaker signal, thus causing a change in the percent signal strength, which may then be misrepresented as time spent in the wrong zone. This problem was avoided when recording individual visits to the separate zones, as the wolf had to leave for an extended period of time and then return before it could be considered a separate visit. Each visit was counted as a discrete moment in time. This was not possible when trying to estimate the amount of continuous time the wolf was spending in each zone. Thus, by pooling the 2 zones together for this dataset, I minimized this possible source of error.

This data set was analyzed in a way similar to that of visitation events. Time spent in the zone was totaled for each wolf, during each period (before, during and after). Each total was then divided by 14; giving a mean time spent in the zone per day for each wolf (the time period was 14 days for all except for the after period for Pine Lake and Somo River which was 7 days. Due to the presence of bear hunting hounds in the area, 7 days were excluded). These data were then turned into proportional data (proportion of time spent that occurred in each time period), and a paired t-test was used to compare before-treatment proportions with the after-treatment proportions (Zar 1996). A meta-analysis was also done to measure any treatment effect on time spent in the zone per day and its size going from before treatment to after treatment (Fernandez-Duque 1994). This was done the same for all controls and treatments.

Mean Distance from the Zone

Flight and telemetry locations were combined and used as a third dataset. As stated earlier, emphasis was put on treatment animals when obtaining telemetry locations, therefore adequate control data was not collected for this dataset. Locating treatment animals was considered a priority, which left little or no time for location of control animals. For treatments, relocation was attempted every 2 days. Animals that could not be located within 4 km of the site were counted as ≥4 km from the site. I used ArcMap to plot all wolf locations on Digital Ortho-Photographs (DOP's) provided by the Wisconsin DNR. Distance from the center of the site was then measured for each location, and mean distance from the center of the zone was calculated for each time period. I used a one-way ANOVA for correlated samples to detect variation of mean distance from the zone between the time periods. I used the Tukey test to decipher where significant differences occurred, if at all (Zar 1996). I used an ANOVA in place of the before-after paired t-test to measure how wolf movements changed before, during, and after shock treatment, rather than just before and after. Wolf distance from the site before, during and after, may be important for management situations.

CHAPTER III.

RESULTS

During the 2003 field season, a total of 9 wolves were captured (Appendix A). Of these, 5 fit the criteria for treatment animals, and these were fit with an Innotek shock collar and Telonics radio collar. These 5 wolves included a 39-kg adult male (M994) of the Ranger Island Pack in Lincoln County, 2, 39-kg adult males (M996 & M482) of the North Willow Pack in Oneida County, a 39-kg adult male (M469), and a 36-kg male (M481) of the Murray's Landing Pack in Iron County. Ranger Island M994's collar malfunctioned before the end of the after-treatment period, and therefore was not included in the sample. Both North Willow wolf M996 and Murray's Landing wolf M469 never localized enough for experimentation, and thus were also not included in the sample. North Willow wolf M482 and Murray's Landing wolf M481 both localized within or near the study site which had been previously selected within their respective territories, and were thus included as treatment samples. The other 4 wolves captured during the 2003 season included a 24-kg adult female (F466) of the Bootjack Lake Pack in Oneida County, a 21-kg male pup (P479) of the Ranger Island Pack in Lincoln County, a 29-kg adult female (F485) and 17-kg male pup (P489) of the Averill Creek Pack in Lincoln County. Bootjack Lake wolf F466 was radio-collared and included in the sample as a control. Ranger Island wolf P479, Averill Creek wolf F485 and Averill Creek wolf P489 did not fit the criteria for inclusion in this research, and were simply radio collared and released. A 40-kg adult male (M355) of the Little Rice River Pack that was collared in 2001 by the Wisconsin DNR was included in the research as a second control sample. Thus, my total research sample for 2003 was 4 animals (2 treatments and 2 controls).

During the 2004 field season, a total of 7 wolves were captured (Appendix B). Of these, 3 fit the criteria for treatment animals, and were fitted with the new combined shock-radio collar design (see methods). These 3 wolves included a 25-kg adult female (F505) of the Bootjack Lake Pack in Oneida County, a 27-kg adult female (F508) of the Pine Lake Pack in Iron County, and a 33-kg adult female (F514) of the Somo River Pack in Lincoln County. Somo River F514 was the only wolf included in this study captured with a Cable Restraining Device (CARD) rather then the modified Newhouse # 14. All 3 of these treatment animals localized within or near the study site which had been previously selected within their respective territories.

The remaining 5 wolves captured in 2004 included a 39-kg adult male (M499) of the Nine Web Pack in Vilas County, a 41-kg adult male (M507) of the Burrows Lake Pack in Oneida County, and a 15-kg male pup (P495) and 2 other pups that were too small to collar of the Averill Creek Pack in Lincoln County. Nine Web M499 was fitted with a Telonics radio-collar and included in the research as a control sample. Burrows Lake M507 did fit the criteria for a treatment animal and was fitted with a combined shock-radio collar, but died shortly after release due to capture-related complications. Averill Creek P495 did not fit the criteria for inclusion in the research. He was radio-collared and released on site. Averill Creek wolf F485 which was captured during the 2003 season, was included in the research as a control sample in 2004. A 40-kg adult male wolf (M726) of the East Firelane Pack which had been previously collared by Michigan DNR personnel and moved to Wisconsin was also included as a control sample for 2004. The total sample size for 2004 was 6 (3 treatments and 3 controls). The total combined research sample size was 10 (5 treatments and 5 controls; Appendices C and K). Although we used different collar designs for the 2 field seasons, we pooled our results for the seasons, and justified this after finding no significant differences between visitation data for the before-treatment or after-treatment periods using a paired t-test between designs.

Mean Visits per Day

For the 5 control samples, 37%, 32%, and 32% of mean visits per day to the detection zone occurred in the before, during, and after treatment periods, respectively (Appendix L). I found no significant difference between the before and after mean visits per day ($t=0.37$, $P = 0.73$). A meta-analysis of the before and after time periods revealed a treatment effect size of 0.0, or no treatment effect (Appendix L). Also for the controls, 30%, 35%, and 36% of the mean visits per day to the shock zone (Appendix I) occurred in the before, during, and after treatment periods, respectively. There was no significant change detected in mean visits per day going from before to after treatment ($t = 1.08$, $P = 0.34$). A meta-analysis of the before and after time periods revealed a treatment effect size of 0.3, which was previously defined as a small effect size (Appendix L).

For treatment wolves, 34%, 27%, and 39% of the mean visits per day to the detection zone (Appendix I) occurred within the before, during and after treatment periods, respectively. The paired t-test of the before and after time periods revealed no significant difference ($t = -1.15$, $P = 0.32$). A meta-analysis of the before and after time periods revealed a treatment effect size of 0.0, or no effect size (Appendix M). Also for treatment wolves, 56%, 15%, and 28% of mean visits per day to the shock zone occurred during the before, during, and after treatment time periods, respectively. This represented a 50% decrease going from before to after treatment, which was significant ($t = 3.88$, $P = 0.02$). A meta-analysis of the before and after time periods revealed a treatment effect size of 0.75, which was previously defined as a large treatment effect size (Appendix M).

Mean Time Spent per Day

For the 5 control samples, 41% (77 minutes per day), 34% (63 minutes per day), and 25% (47 minutes per day) of the mean time spent per day in the combined zone occurred during the before, during, and after treatment periods, respectively. There was no significant change detected in mean time spent in the zone going from before to after treatment ($t = 0.46$, $P = 0.67$). A meta-analysis of the before and after time periods revealed a treatment effect size of 0.35, which was previously defined as a small to medium effect size (Appendix N).

For the 5 treatment samples, 65% (79 minutes per day), 16% (19 minutes per day), and 19% (23 minutes per day) of the mean time spent per day in the combined zone occurred in the before, during, and after treatment periods, respectively. This represented a 70% decrease going from before to after, which was significant ($t = 2.89$, $P = 0.045$). A meta-analysis of the before and after time periods revealed a treatment effect size of 1.0, which was previously defined as a large effect size (Appendix O).

Mean Distance from the Zone

Flight and ground telemetry locations detected a shift in the mean wolf distance from the center of the site between the before, during and after treatment time periods for treatment animals (ANOVA results). The treatment sample size for this dataset was n = 4, instead of 5, as one treatment animal (Bootjack Lake) did not have sufficient location data to be included. Before treatment, wolves averaged a distance of 1.5 kilometers from the center of the site (approximately 9 locations each period). During and after treatment, wolves averaged a distance of 2.2 kilometers from the center of the site. This equaled a shift of 0.7 kilometers or 32%, going from before treatment to after treatment (Appendices P and Q). An analysis of variance (ANOVA) for the average distance in the 3 time periods revealed a significant difference in the mean distances ($F = 7.29$, $P = 0.02$). A Tukey test detected significant differences between the before and during, and between the before and after. No significant difference was present between the during and after time periods.

CHAPTER IV.

DISCUSSION

Prior to this research, no experimental assessment had been done on the possible use of shock collars as a non-lethal control method for free-ranging, wild wolves. It is therefore difficult to compare this research with past research, as only captive, or observational studies of free-ranging wolves have been published. My results suggest that shock collars may alter free-ranging, wild wolf behaviors in and around a specific site. When wolves were shocked at a specific site they avoided the site, spent less time at the site, and shifted movements away from the site, while there were no significant before-and-after treatment changes in the controls for any of these 3 datasets.

Mean wolf visits per day to the shock zone by treatment wolves dropped by 50% going from before treatment to after treatment, which was considered a large treatment effect using meta-analysis. Conversely, control wolves showed no change in mean visits per day to the shock zone going from before treatment to after treatment. This means treatment wolves were twice as likely to visit the shock site before treatment, than after treatment. If this is applied to a true management situation, a depredating wolf would be considered 50% less likely to even enter a livestock pasture after being conditioned with a shock collar for 14 days. If the wolf did enter the pasture after having received a shock, there would likely be a strong chance he will be much more wary than before (Andelt et al. 1999). So while there is a 50% reduction in visits to the area, there could be an even higher reduction in attempts to harass or kill livestock.

While attack and kill behaviors should be considered separate from consumption behaviors in wolves, it may also be suggested that a dead deer (which I used for bait) in a wolf's home territory with which he is very familiar, may be considered an "easier" target than a domestic cow in a human settlement (Shivik et al. 2003). In fact, most of my study packs remained in relative proximity to the baited sites in the pre-treatment period, and would fully consume each deer within 2-3 days. The length of my before-treatment monitoring period gave the wolves 14 days to become comfortable feeding within the shock zone. In a true management situation, wolves would not be given this acclimation period, as the shock would be turned on immediately. In most cases, livestock pastures will occur on the edge of a wolf's territory, or at least a less familiar part of their territory (Fritts et al. 1992). It is possible that most free-ranging wild wolves will never feel completely confident around a human settlement. Adding to this is the fact that the wolves will in most cases have been trapped on or near the pasture in question before being fitted with the shock collar. This increased level of fear and awareness of humans could potentially increase the efficacy of shock collars within a livestock pasture (Fritts et al. 1992).

Recall that wolves in this study were no longer receiving a shock upon entry of the shock zone during the after treatment period, yet they still reduced their visits by 50%, while the control wolves increased their number of visits. It is possible that this demonstrates some level of site-aversive conditioning, yet we cannot predict much about the length this conditioning would be resident in memory. Two weeks of conditioning would likely not be sufficient in a management situation. Future research should be done to assess the possibility of long-term conditioning with shock collars.

It should also be noted that I found a substantial reduction in visits per day to the shock zone and time spent in the combined zone for treatment wolves going from the before-treatment period to the during treatment period, while the control wolves showed no significant change. If the shock collar battery life could be extended from 50 days to even 100 days, this reduction during treatment could prove highly significant in protecting cows, calves, and young stock during the growing season. Treves et al. (2002) reported that 83% of all verified wolf depredations in Minnesota, and 61% of all verified wolf depredations in Wisconsin occurred between the months of May and September. If wolves could be excluded from livestock pastures during that period, I predict that most wolf depredations could be avoided (Gehring et al. 1996). Conditioning may not be necessary if shock collars could actively exclude wolves from a pasture for an extended period of time. Any long-term conditioning would then be considered bonus protection. In chronic problem areas, even 1 year of protection could be considered just as effective as lethal control (Fritts et al.1992, Bradley et al. 2003). If there is any aversive conditioning carrying over to the following year, this could potentially save agencies the time and money of implementing lethal control measures on an annual basis.

No significant change was found in mean visitations per day to the detection zone (Appendix I) for either treatments or controls, which may show that both treatment and control wolves were frequenting the area surrounding the shock zone (detection zone), yet the treatment wolves were less likely to enter the shock zone after treatment than were the controls. This demonstrates the potential of shock collars to allow wolves to remain in their territory and defend it from other wolves, yet possibly exclude them from a chronic problem area within their territory. This has also been demonstrated in island foxes (*Urocyon littoralis*), where shock collars were used to successfully exclude the foxes from endangered San Clemente logger-head shrike (*Lanius ludovicianus mearnsi*) nests, yet remain within their territory (Cooper et al. 2004). This could also be viewed in a way to suggest that the shock collars were not effective in truly moving wolves out of an area, although in a management situation, the shock zone would be extended to the size of a livestock pasture, much larger than 60 m in diameter (Appendix I). Yet creating too large of a "shock zone" might confuse wolves (and possibly affect pack structure), as they may not be able to determine the boundaries of the zone. If the area is too large, or indistinguishable from the surrounding area, the animal may not be able to associate the shock with a specific area or landmark, and thus may not be conditioned to avoid a specific site. The determination of an optimal shock zone size should also be included in future research.

Mean time per day spent in the combined zones by treatment wolves dropped by 71% going from before treatment to after treatment. This is important for a few obvious reasons. First, if the wolf is not spending time in the area, then there is less time for a depredation to occur. These data have shown a significant change in where the wolves are spending their time after 14 days of treatment. Secondly, it is important to recall that this is a combined zone, so mean time spent decreased for both the shock zone and the outer detection zone (Appendix I). The treatment that occurred within the shock zone may have indirectly affected the behavior of the wolves in the detection zone, where no treatment ever occurred. This could be important when considering the idea of a buffer zone around a livestock pasture. By setting up the pasture as the shock zone, it may be possible to create an outer buffer zone (i.e., detection zone in this study) where wolf activity would decrease as an indirect effect of the treatment occurring within the pasture or shock zone.

There is a strong possibility that mean time spent in the zone per day is directly correlated with mean distance from the zone. Treatment wolves shifted a significant distance away from the center of the zone after treatment occurred. If the animal's mean distance is shifted away from a pasture, there is a good chance it is going to spend less time in and around the pasture. While 0.7 km may not seem substantial, it could be critical during a sensitive calving season. Along with the significant shift in mean distance from the center of the site going from before to after, treatment wolves tended to cluster their locations in a mostly forested, low-road areas away from the shock site in the during and after treatment periods. The Somo River Pack wolf F514 provided an example of this behavior (Appendix R). It would be difficult however, if not impossible to quantify these localizations, as the wolves did not localize within a specific habitat type, or at a consistent distance from the site. The only consistent quality of these localizations was that wolves tended to cluster for a while in a low-road area away from human activity. This localization behavior could be important when considering management situations. This may be a display of human avoidance by wolves, which could be important in excluding wolves from an area. Fear of humans should never be underestimated as a non-lethal control tool in itself. Some wolves, possibly a good portion of depredating wolves, may lose their natural fear of humans (Mech 1995). Shock collars, other forms of non-lethal control, or even trapping alone, could restore this natural fear, and cause wolves to again avoid human-dominated habitats such as livestock pastures (Boitani 1992). It should also be noted, that the 1st and 2nd locations of treatment wolves after the shock unit was turned on, averaged 4 km from the center of the site (Appendix R). The mean distance from the site before treatment was 1.5 km. A similar movement pattern was documented following a shock of a free-ranging wild wolf in Wisconsin (Schultz et al. 2005). These movements demonstrated a rather large initial response to the shock and apparent disruption in wolf movements.

Subsequently, wolves slowly resumed their normal movement behavior and began moving back to the shock site. I believe the key is the 2nd, 3rd, and 4th shocks and that there must be consistency in the correction for conditioning to take place. Most domestic dogs will not learn to avoid a specific behavior with 1 initial correction (Coppinger and Coppinger 2001). It is possible the same applies to wolves, and there may have been a lack of consistency in the performance of my collars in delivering a shock (Chapter 2). Without consistency, the animal may not learn a site-specific avoidance behavior.

In a study done at the National Wildlife Research Center's Predator Research Facility, shock collars were tested on 5 coyotes to evaluate the effectiveness of the collars in averting attacks on lambs. The collars averted all of the initial 13 attempted attacks by coyotes. This treatment also greatly reduced the risk of further attacks. The treatment caused the coyotes to avoid the lambs for the final 4 months of the study (Andelt et al. 1999). The researchers conducting this study believed there was great potential in shock collars for reducing depredation by coyotes as well as other predators (Andelt et al. 1999).

While Andelt et al. (1999) and other research has demonstrated shock collars effectively deterring attacks on sheep by captive coyotes, research on captive wolves has reported them as "difficult to use" due to logistical, safety, and collar maintenance issues (Andelt 1999, Shivik et al. 2002, Shivik et al. 2003). It is unclear why these 2 closely related species have shown such variation in their reaction to shock collars in captivity. Similar to Shivik et al. (2003), I found variability in wolf response to the shock units during captive trials discussed in Chapter 2. I believe that much of this could be attributed to technological variation within the shock collars themselves, rather than behavioral differences (Chapter 2).

Inconsistency in shock delivery to treatment wolves may have slightly affected my results. During the first field season with the original collar design (Appendix F); I was assured by the manufacturer that battery life would extend past 2 months. After the first field season I performed extensive field tests and discovered that the batteries began to die or were already dead halfway through the treatment period, or 20-22 days. While this may add more support to the effectiveness of the collars, as the wolves were only being shocked for an average of 7 days for the first field season, it is also a possible source of inconsistency in the delivery of the treatment. The new collar design (Appendix G) used in season 2, also had sources of inconsistency (Chapter 2). During captive trials (Chapter 2), it was noted that the collars would frequently shift or even flip completely (Appendix BB), before correcting themselves upon further wolf movement (Chapter 2). I believe that if a shock collar with a higher degree of consistency is developed and tested, the results will show a greater reduction in both wolf visits and time spent in an area. Within the field of non-lethal wolf control, it should be considered a priority to develop and test a more consistent shock collar.

Although my results demonstrated a significant shift in wolf movements away from a specific site, there are some potential confounding factors that should be reported. First, for 2 of my treatment wolves (Pine Lake and Somo River) bear-hunting hounds were observed or heard on several occasions running in close proximity to the study site in the after-treatment periods, yet not in the before treatment periods. While I have no evidence to suggest that wolves actively avoid bear dogs, I attempted to minimize any effect this may have had on my results by removing the days where dogs were observed or suspected of running in the area from our sample. Days removed from the after-treatment periods totaled 7 for each wolf.

Human scent in and around the sites could have acted as a deterrent to wolves visiting the area. I attempted to minimize any bias of this nature by frequenting the treatments and controls for similar lengths of time, and by performing tasks (equipment maintenance) consistently at all sites. However, only data loggers were placed at the control sites, while both a data logger and a shock transmitter were placed at the treatment sites. Although it is not probable, as the shock transmitters were highly camouflaged and less visible than the data loggers, it is possible they may have acted as a visual deterrent that was not present at the control sites. These factors should be noted when considering the results of this research, although I do not believe they had a major impact on wolf behavior in and around our sites.

Management Implications

The first step in the research of shock collars as a non-lethal control method for free-ranging wild wolves was to simply determine if they could alter behavior in and around a specific site. The results from this research show that it is possible. By administering treatment for 14 days, however, I did not expect to see long-term conditioning. Future research should first focus on measuring the ability of shock collars to provide long-term conditioning by administering treatment for the full extent of the battery life (50 days at present), and on the improvement of collar design for consistency. I believe the effectiveness of the collars in actively excluding and conditioning wolves could be greatly increased if a consistent collar is developed.

Future research should also attempt to quantify the effects shock-collared wolves may have on other pack members. This may depend on the social status of the shock-collared animal. High-ranking animals may make more movement decisions in the pack, and thus indirectly alter the behaviors of non-shock-collared wolves. If this is true, it may be possible to condition an entire pack through learned behavior from 1 shock-collared animal. It may also be possible to extend the conditioning effect of shock collars by including an audible sound at the moment of the shock, which may then become associated with the shock, and provide a level of avoidance in itself. Lastly, shock-collars must be tested in an adaptive management situation, with depredating wolves. As with anything, if we are to truly assess the effectiveness of shock collars as a site-specific non-lethal control method, we must test them in a real-world situation.

When considering non-lethal control, the problem of practicality and cost are usually involved. Some non-lethal control methods can be extremely time-consuming and expensive. They might work in some situations, and not in others. Yet the same can be said of lethal control; sometimes it works, sometimes it doesn't. Thus, lethal control also can often be very expensive and therefore impractical. Lethal removal of wolves from a pack may even worsen the problem, as discussed earlier. Other times it is not even an option, as in the early stages wolf recovery. We must continue to test different forms of non-lethal control if we are to find useful alternatives to lethal control.

The results of this study suggest that shock collars hold potential value in their use as a non-lethal control method for free-ranging wild wolves in certain situations. They should not be viewed as a possible replacement to lethal control or other forms of non-lethal control. Instead, they should be viewed as another potential tool to aid in integrated wolf depredation management especially when lethal control has either proven ineffective or is simply not an option, such as in early wolf recovery (Gehring et al. 2003a). Shock collars may provide a useful alternative to the lethal control of depredating animals when each individual is considered valuable to a species recovery. I also believe they could save managing agencies money, especially if long-term conditioning is proven possible. Before they are included in management plans however, I suggest additional research is needed. The potential that shock collars hold as a non-lethal control tool for wolves is worth the expense of further research. If we can continue to identify specific situations when lethal control is not effective, not practical, or not an option, then we will begin to define the need for non-lethal control. By experimentally assessing different forms of non-lethal control, we are simply adding more tools to our toolbox, or removing those that have no use. Lethal control will always be an important tool for controlling wolf depredations, yet we must attempt to fill the open gaps with new methods of non-lethal control.

EXPERIMENT #2 – TESTING AND REFINING SHOCK COLLAR DESIGN FOR EFFECIENCY AND SAFETY ON WOLVES (CAPTIVE TRIALS)

CHAPTER I.

INTRODUCTION

As wolf populations continue to expand into human-dominated landscapes, conflicts with humans are increasing in the form of livestock depredations (Kellert 1991, Mech 1995, Treves et al. 2002), and so to is the need for wolf control. In the United States and elsewhere, lethal control has been and often still is the most frequently used form of wolf control. Lethal control however, has not proven to be effective in all situations. Chronic problem areas exist, and continue to develop where repeated implementation of lethal control has not had its desired effect in lessening wolf depredations (Fritts et al. 1992). When wolf depredations are not controlled, individual livestock producers may suffer significant economic losses (Mech 2000). Repeated attempts at lethal control can also be costly to the management agencies implementing the control, and providing compensation to livestock producers for their losses (Treves et al. 2002). While lethal control is and will always be a valuable tool, new methods of non-lethal control need to be explored. If found to be effective, various forms of non-lethal control could be used in situations where lethal control has proven ineffective (Shivik et al. 2003).

In chapter 1 I examined a specific method of non-lethal control, site-specific aversive conditioning (via shock collars). During this research, 5 wolves were fitted with Telonics VHF radio-tracking collars and Innotek Free Spirit Training collars identical to those used on domestic dogs. The five shock-collared wolves were monitored before, during, and after treatment (shock), and were found to reduce visitations to and time spent in a designated shock zone. This research provided results that suggest shock collars could be an effective tool in altering wolf activity away from specific areas, which could then be applied to a livestock pasture suffering chronic wolf depredations.

In the past, one of the major obstacles to using shock collars as a non-lethal form of control for free-ranging wild wolves has been the efficiency and safety of shock collar design. Past shock-collar research with captive wolves, has described problems such as short battery life, animal safety concerns, shock consistency, and practicality of properly fitting collars in the field (Shivik et al. 2003). Similar to this past research, I also encountered problems with the shock-collar design in field tests (Chapter 1), and therefore developing a safer, more efficient shock collar became my research objective for this chapter.

The issue of greatest concern when considering non-lethal control should always be that of animal safety. Shivik et al. (2003) found unaltered factory Innotek shock collars to cause mild to moderate pressure necrosis on the necks of captive wolves that had been wearing the collars for a short time period. Schultz et al. (2005) recaptured a free-ranging wild wolf that had been fitted with a factory shock-collar the previous year. While the wolf appeared healthy, and the collar was no longer present, they did note 2 small scars on the neck where the probes made contact. Both of these injury types described are a direct result of either probe shape and/or collar tightness.

If shock collars are to be used effectively and safely as a method of non-lethal control for wild wolves, improvements in the collar design must be made. Innotek factory shock collars fitted as specified by the manufacturer (for dogs) include a tightened vinyl collar strap with the shock unit placed under the neck of the animal (Appendices S and F). Original factory probes included with the shock unit are sharp and pointed, to allow for probe contact through the fur. I believe fitting tight collars with sharp probes on wild animals that cannot be visually monitored is not in the best interest of the animal. This feeling was compounded by injuries described in past shock collar research (Shivik et al. 2003, Schultz et al. 2005). The factory shock collars are designed for domestic dogs which can be closely monitored for any possible neck damage. Wildlife managers will not have this option when fitting shock collars on free-ranging wolves, and therefore I believe the shock collar design must be improved both for the safety of the wolves, and the practicality of using shock collars as a non-lethal control method for wild wolves.

The objectives of the development of this new shock collar were as follows: 1) to reduce the risk of injury to the animal by creating a design that did not require a tight collar; 2) to create a safer probe design that would not damage the skin; 3) to measure and refine the efficiency of the shock units in delivering a shock; 4) to measure and extend battery life; and 5) to combine the shock unit and the radio collar into one collar that would release the shock unit after a period of time. Here, I present the development and refinement of this new shock collar design which was tested in 3 trial periods on captive wolves or wolf-dog hybrids.

CHAPTER II.

METHODS

Battery Life

Following my 2003 field research season (chapter 1), I tested the battery life of 5 unaltered Innotek factory shock collars which were placed outdoors in a similar habitat to which wolves might occur in (hung from trees within wolf territories). All 5 collars were powered by 1, 3-volt lithium battery. The manufacturer specifications suggested a battery life of nearly 60 days for the shock units under normal environmental conditions. The collars were checked daily to determine the exact battery life. Batteries were considered expired when the light discontinued flashing, and a shock was no longer delivered.

Shock Consistency

Ten Innotek unaltered factory shock units were tested for consistency in their ability to deliver a shock. This was done by hanging the collars approximately 50 cm from the ground and triggering the shock unit with a hand-held Innotek shock transmitter. These collars present a flashing red light while shocking. I monitored the pulse of the red light, while listening to the consistency of the audible pulse of the shock. The shock was also tested physically on my hand for all 10 collars. I tested all 10 shock units for overall consistency with these 3 methods for 2-3 trials of 10 seconds each.

Trial #1

I suspected that 2 serious health risks existed while using the unaltered factory shock collars on free-ranging wolves. First, the possibility of developing pressure necrosis on the neck from the shock probes, and second, partial asphyxiation due to the tightness of the collar. Innotek shock collars came from the factory fitted with 1.5cm pointed probes (Appendix S), and 2cm backup probes were also included. For the first captive trial, I replaced the 1.5cm factory probes which were used in the 2003 field season (chapter 1) with the 2cm probes on 3 shock units and ground the tip of the probe off to create a smooth surface for probe-skin contact (Appendix T). The 3 shock units with the new rounded probes along with 1 shock unit with the original 1.5 cm pointed probes were removed from the factory vinyl collars (Appendix T). These 4 shock units were then mounted on the back of a Telonics VHF radio collar via 2 metal brackets on a custom plastic mount designed to drop off in 2-3 months. The idea was that the weight of the VHF unit of the radio collar itself, would hold the unit to the dorsal side of the animal's neck, and correct it when it swayed from side to side. This eliminated the need to fit a tight collar on a free-ranging wild animal. Holes were drilled through the back of the radio collar for probe contact with the skin (Appendix U).

I tested these collars on captive animals at the Wildlife Science Center in Minnesota. I used 4 wolves or wolf-dog hybrids in this first trial. The animals were anesthetized and shaved to the skin on the back of the neck underneath the shock units to insure probe contact. Collars were fit like regular radio collars would be fit on a wild wolf, with enough space to fit 4 fingers snugly under the collar (Appendix

V). Once recovered from the drug, the wolves were then released into their captive facilities. Two days after fitting the 4 collars, the shock units were remotely triggered via a hand-held Innotek shock transmitter to determine if the shock unit was functioning properly and in contact with the skin. An observable physical reaction (i.e. running, jumping, scratching) of the animal was used to gauge if the unit was functioning. All animals were visually checked for neck damage each day.

Trial #2

In the second trial, I used a 0.5-20 acorn nut as replacement probes in an attempt to improve animal safety. I manufactured a threaded metal sleeve to fit over the shock unit probes in order to fit these new probes. This sleeve was made by cutting the 2.5 cm long threads off of a 0.5-20 strike anchor, and then drilling through the center of the threaded section with a #36 drill bit. The now hollow interior of the sleeve was threaded with a 6-32 fluted tap using a table lathe, then screwed onto the factory shock unit, allowing for the 0.5-20 acorn nut to be directly fastened to the custom sleeve. The surface of the acorn nut was similar to a ball-bearing, providing a wider, smoother surface for probe contact with the skin (Appendix X).

For this second captive trial, I also attempted to increase the battery life of the shock collars. I did this by externally wiring 2 extra 3-volt lithium batteries that were connected to each other in a parallel circuit, which I predicted would extend battery life to 50 days. These batteries were then externally soldered onto the side of the shock unit, and the unit and batteries encased in high-density polymer to provide protection and water-proofing (Bio-Plastic). This new design with the rounded acorn nut probes and externally mounted batteries was then mounted to the back of 4 radio-collars and fitted on four anesthetized wolves, identical to the way they were fitted in trial #1 (Appendices V and Y). At 2 days into trial #2, the shock units were manually triggered via a hand-held Innotek shock transmitter to determine if the shock unit was functioning properly and in contact with the skin. An observable physical reaction (i.e. running, jumping, scratching) of the animal was used to gauge if the unit was functioning. All animals were visually checked for neck damage each day.

Trial #3

Four collars identical to those used in trial #2 were used in trial #3. Only minor adjustments were made. Interior edges that made contact with the animal were rounded off and sanded smooth with a Dremel Tool. The entire collar was then wrapped in 3 layers of electrical tape to provide a smooth surface. Shock units with the new probe design and extra batteries encased in a slightly thicker layer of high-density polymer (BioPlastic) were then fit on the drop-off mount design of the 4 collars. These 4 collars were then fit on 4 more anesthetized wolves for this final captive trial (Appendix G). At two and again at 18 days into trial #3, the shock units were manually triggered via a hand-held Innotek shock transmitter to determine if the shock unit was functioning properly and in contact with the skin. An observable physical reaction (i.e. running, jumping, scratching) of the animal was used to gauge if the unit was functioning. All animals were visually checked for neck damage each day.

CHAPTER III.

RESULTS/DISCUSSION

Battery Life

I found the single 3-volt lithium batteries to last between 18-22 days in the shock units. This raised questions about the ability of shock collars to have any long-term effect on a wolf's behavior after only 20 days of treatment. Extending battery life then became a high-priority goal in refining the shock collar design for trial #1.

Shock Consistency

Six out of 10 (60%) shock units delivered a consistent shock (10-20 pulses per second). The other 4 collars (40%) shocked intermittently or sometimes not at all. By testing and removing the faulty collars from my sample, I was able to eliminate some of the variability between the collars. Shivik et al. (2003) described a large variation in captive wolf response to the shock collars. While it is unknown if the collars were tested for consistency in the Shivik et al. (2003) study, some of the variability they considered to be "behavioral", may have actually been variability in the shock collars themselves. This is not to say, however, that variability in individual behavior and response did not exist in our trials. It is possible that wolf personality played a role in response. In my captive trials, most wolves reacted moderately to the shock (58%), a few reacted severely (17%), and some were simply irritated or showed no reaction to the shock (25%; we believe animals showing no reaction were not receiving a shock due to lack of probe contact or unit malfunction).

Trial #1

While the collars tended to sway from side to side with movement of the animal, they did appear to remain in good contact with the shaved portion of the back of the neck. When the shock units were triggered 2 days after collaring, all 4 animals showed a moderate reaction to the shock (yelping, running, or attempting to bite the collar). Six days into this first trial, all 4 animals began showing neck damage in the area of probe contact on the back of the neck. The wolves were physically restrained, and all 4 collars removed. Of the 3 collars with rounded probes, 1 showed moderate neck damage (light necrosis), while the other 2 with rounded probes along with the collar fitted with the pointed probes showed severe neck damage (deep necrosis) in the area of probe contact (Appendix W). I believe this damage was caused by the rocking motion of the probes due to the looseness of the radio collar on which they were mounted. While the original collar design used in the 2003 field season (chapter 1) was too tight, and had been shown to cause pressure necrosis (Shivik et al. 2003) in the area of probe contact, the looseness of this design, caused the probes to slowly wear away at the skin by swaying back and forth. All 4 animals were administered medical treatment and penicillin, and made full recoveries in a few days.

While successful improvements had been made in the overall ease-of-use in the collar design during the first captive trial, animal health and safety became my first priority for trial #2. The problem with this first design was a combination of probe shape/design, as well as the back and forth motion of the loose collar. I did not want to go back to a tight collar fitted separately from the radio collar, so I set out to make improvements in the shape and design of the probe. I believe the problem with this original probe design is that it was too narrow, and therefore put a lot of pressure into a small point on the neck. The probe was designed this way by the manufacturer so it would penetrate through the hair to provide contact with the skin. Since I was shaving the animals in the area of probe contact, and felt the radio collar would prevent fur from ever fully growing back underneath anyway, I developed the new probe for trial #2 that was larger in width, and would thus spread the force of the probes over a larger surface area.

Trial #2

Two of the 4 shock-collared animals in trial #2 showed a moderate reaction to the shock (yelping, running, or attempting to bite the collar). One animal showed a severe reaction (i.e. jumping, spinning, biting, and barking). It was believed that the 4th animal's collar had shifted so far over to one side, that it was not making contact with the skin. Eight days into trial #2, 3 of the 4 wolves began showing neck damage to the shaved area on the back of the neck. All 4 wolves were physically restrained and the collars removed. While not as severe as the neck damage in trial #1, there was some visual necrosis neck damage on 3 of the 4 animals. However, it appeared that the damage was caused not by the shock probes, but the edge of the radio collar rubbing on the shaved skin of the animal (Appendix Z). The problem is the animal's fur usually provides a barrier between the radio collars and the skin. Since I shaved the back of the animal's neck, this barrier was no longer present. It was also noted that one of the external batteries had been broken off of the 4th animals shock unit, and was the probable cause of its failure.

Trial #3

Two of the 4 shock collared animals showed a moderate reaction (yelping, running, or attempting to bite the collar) to the shock in trial #3. One animal showed a severe reaction (i.e. jumping, spinning, and barking). The 4th animal did not react to the shock, and it was unclear why. This animal had been previously shock-collared in trial #1, and it is possible the thickened scar tissue on the back of his neck had decreased sensitivity to the shock. This collar was removed and found to be functioning properly. Sixteen days later, the 3 remaining shock collars were manually triggered via an Innotek hand-held shock transmitter. Two of the 3 animals showed a moderate reaction to the shock. The third animal showed no reaction. The 3 wolves were physically restrained and collars removed. It was later discovered that the 3rd wolf that did not show a reaction was wearing a collar that had been turned off. Although it is unclear how this happened, the collars are turned on and off via a magnet, and is possible some sort of contact with the metal cage caused the unit to shut off. All 3 animals showed no significant neck damage, and the collars and shock units were also intact (Appendix AA).

CHAPTER IV.

CONCLUSION

Overall, this new shock collar design can be considered an important step in the direction of using shock collars to control free-ranging wild wolves. The new shock collar design provided 50 days of battery life (compared to 20 days), and can be considered safe for the animals wearing it as the probes were not abrasive, the collar itself did not require a tight fit, and the shock unit was designed to drop off in 2-3 months. The new collar design was used exclusively in the 2004 field season (chapter 1). While the results of the 2004 field season were virtually identical to 2003, the one concern was still with the consistency of the collars, due to their tendency to shift from side to side, and thus lose contact with the shaved area of the neck. I believe that avoidance of shock sites by shock-collared wolves could be greatly increased if the consistency of the shock could be increased. This problem of shifting collars was actually observed on one of our wild wolves in 2004 (chapter 1). Upon completion of treatment, the wolf was observed standing alongside the road with the collar completely flipped over. This was also observed numerous times in our captive trials (Appendix BB). While the collars usually corrected themselves after a couple of seconds, this could still reduce the consistency and therefore reduce the effectiveness of the collars in conditioning an animal to avoid an area.

In order for an animal to learn to avoid a specific behavior (i.e., entering a pasture), it must have a consistent consequence to that behavior. This may be the one remaining obstacle in the way of using shock collars as an effective non-lethal management tool. If the weight and high profile (which in itself can draw the "chewing" of other wolves) of the shock unit on the back of the neck can be reduced, it is possible this problem would be reduced our even eliminated. It would be possible to reduce the weight and profile of the shock unit, and therefore its imbalance, by powering the unit from the same source as the radio collar, which is under the neck of the collar. This would eliminate the need to externally mount the batteries in a high-density polymer on the shock unit, and thus greatly decrease its size and weight. Adding weight to the underside of the collar (near the VHF battery) might also help to counteract the tendency to shift to the side. The new probes do not seem to irritate the back of the neck and the entire unit is designed to drop off in 2-3 months, leaving the animal with a fully-functional radio collar.

While this new shock collar design should be considered a success, I do suggest further design improvements are necessary. The new design should then be further tested on both captive and free-ranging wolves before being included in management plans. Aside from the design improvements mentioned, further research should focus on the ability of shock collars to permanently "condition" a wolf to avoid an area, as well as the effect a shock collared wolf has on the rest of the animals in the pack. I also suggest further testing be done in an adaptive management situation, where the shock collars are tested on actual depredating wolves in the wild. I believe that if these small design improvements are made, shock collars could be used as an effective form of non-lethal control in limited situations. While lethal control will always be our most widely used form of control, non-lethal control could provide an alternative in situations where lethal control has not proven effective (chronic depredation areas), or is not an option, such as genetically valuable animals (Mexican gray wolves), or when low numbers occur within recolonizing populations (i.e., Northern Lower Peninsula of Michigan).

APPENDICES

Appendix A

Capture data, collar placement information and status of wolves captured during the 2003 season of shock collar research in northeastern Wisconsin.

Wolf	Sex	Age	Weight	Capture Date	Status as of 1/05	Pack	Collar Placement
M482[b]	Male	Adult	36kg[a]	June	Unknown	North Willow	VHF + Shock[f]
M996	Male	Adult	36kg[a]	June	Unknown	North Willow	VHF + Shock[f]
F466	Female	Adult	24kg[a]	June	Alive	Bootjack Lake	VHF
M994	Male	Adult	39kg[a]	July	Unknown	Ranger Island	VHF + Shock[f]
M469	Male	Adult	39kg[a]	July	Dead[d]	Murray's Landing	VHF + Shock[f]
M481[b]	Male	Adult	36kg[a]	August	Alive	Murray's Landing	VHF + Shock[f]
P479	Male	Pup	21kg	August	Alive	Ranger Island	VHF[e]
F485[c]	Female	Adult	25kg	August	Alive	Averill Creek	VHF
P489	Male	Pup	17kg	Sept.	Dead[d]	Averill Creek	VHF[e]

[a] Estimated.
[b] Included in sample as a treatment.
[c] Included in sample as a control (2004).
[d] Illegally shot and killed.
[e] Collar fitted with foam.
[f] Original shock collar design (shock collar separate from VHF collar).

Appendix B

Capture data, collar placement information and status of wolves captured during the 2004 season of shock collar research in northeastern Wisconsin.

Wolf	Sex	Age	Weight	Capture Date	Status as of 1/05	Pack	Collar Placement
F505[b]	Female	Adult	25kg	May	Alive	Bootjack Lake	VHF + Shock[h]
F508[b]	Female	Adult	27kg	June	Alive	Pine Lake	VHF + Shock[h]
M507	Male	Adult	41kg[a]	June	Dead[d]	Burrows Lake	VHF + Shock[h]
M499[c]	Male	Adult	39kg	July	Alive	Nine Web	VHF
P495	Male	Pup	15kg	July	Alive	Averill Creek	VHF[e]
Fpup [f]	Female	Pup	15kg	July	Unknown	Averill Creek	NA
Mpup [f]	Male	Pup	15kg	July	Unknown	Averill Creek	NA
F514 [b]	Female	Adult	33kg[a]	August[g]	Alive	Somo River	VHF + Shock[h]

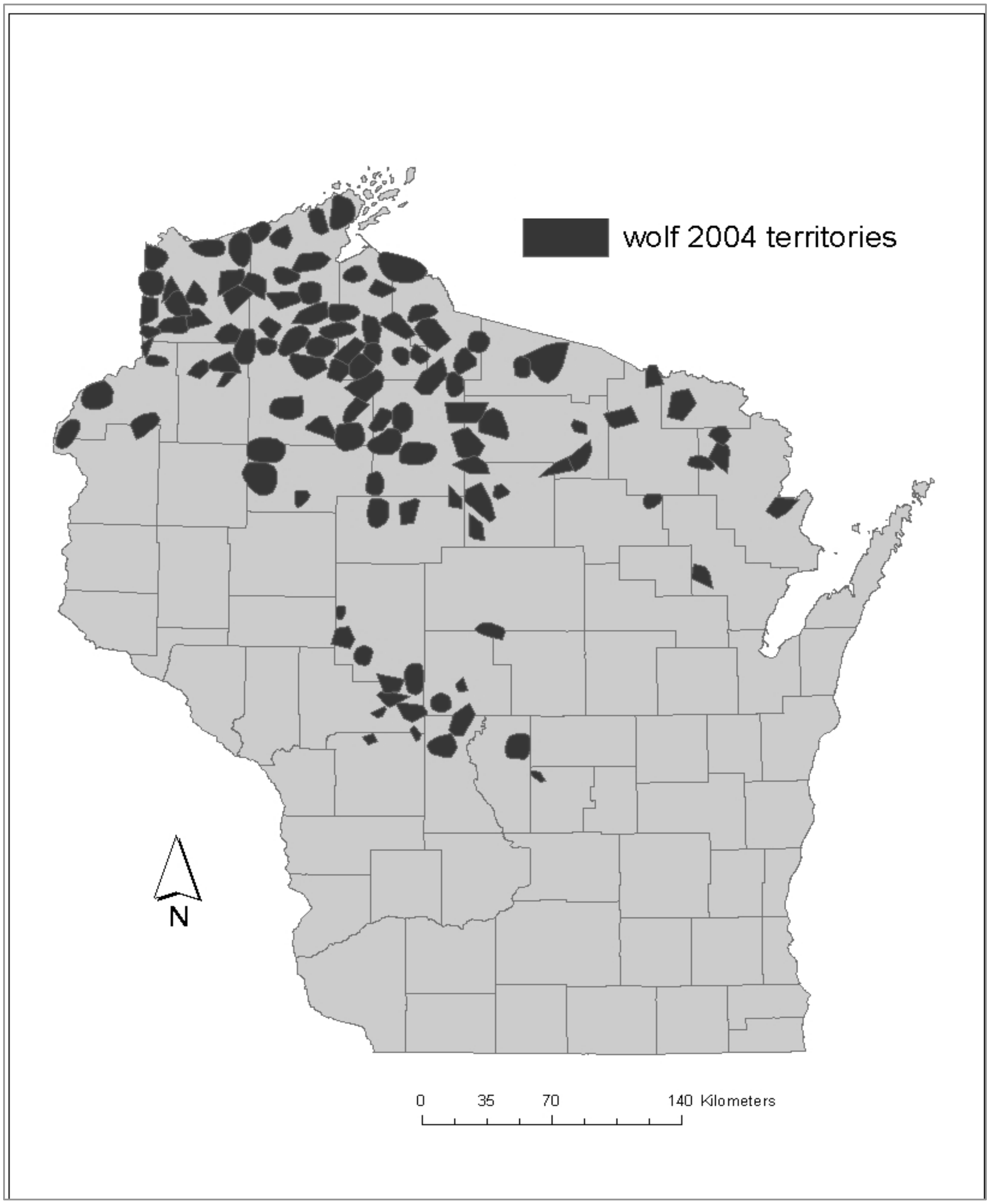
[a] Estimated.
[b] Included in sample as a treatment.
[c] Included in sample as a control.
[d] Capture-related mortality.
[e] Collar fitted with foam.
[f] Too small for collar.
[g] Captured in a Cable Restraining Device (CARD).
[h] New shock collar design (VHF + Shock combined).

Appendix C

Data on all wolves included in shock collar research sample.

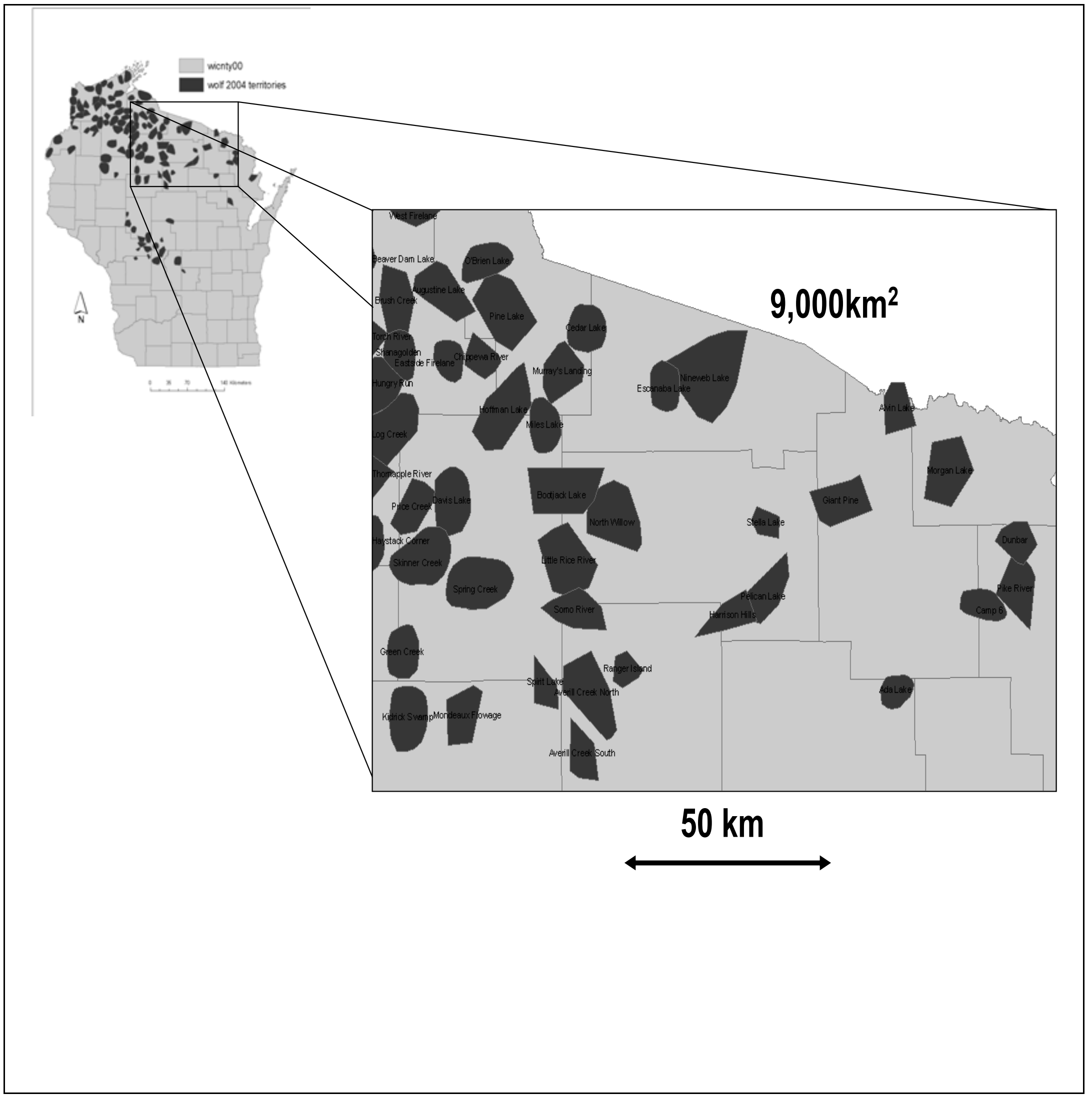
Wolf	Sex	Age	Weight	Control or Treatment	Season	Pack	Collar Design
F505	Female	Adult	25kg	Treatment	2004	Bootjack Lake	New Shock[b]
F508	Female	Adult	27kg	Treatment	2004	Pine Lake	New Shock[b]
F514	Female	Adult	33kg	Treatment	2004	Somo River	New Shock[b]
M499	Male	Adult	39kg	Control	2004	Nine Web	VHF
F485	Female	Adult	25kg	Control	2004	Averill Creek	VHF
M726[C]	Male	Adult	40kg	Control	2004	East Firelane	VHF
M482	Male	Adult	36kg	Treatment	2003	North Willow	VHF + Shock
M481	Male	Adult	36kg	Treatment	2003	Murray's Landing	VHF + Shock
F466	Female	Adult	24kg	Control	2003	Bootjack Lake	VHF
F355[a]	Male	Adult	40kg	Control	2003	Little Rice River	VHF

[a] Previously captured by DNR Personnel.
[b] New shock collar design (shock unit combined on the back of VHF collar).
[c] Previously captured by Michigan DNR Personnel and dispersed to Wisconsin.

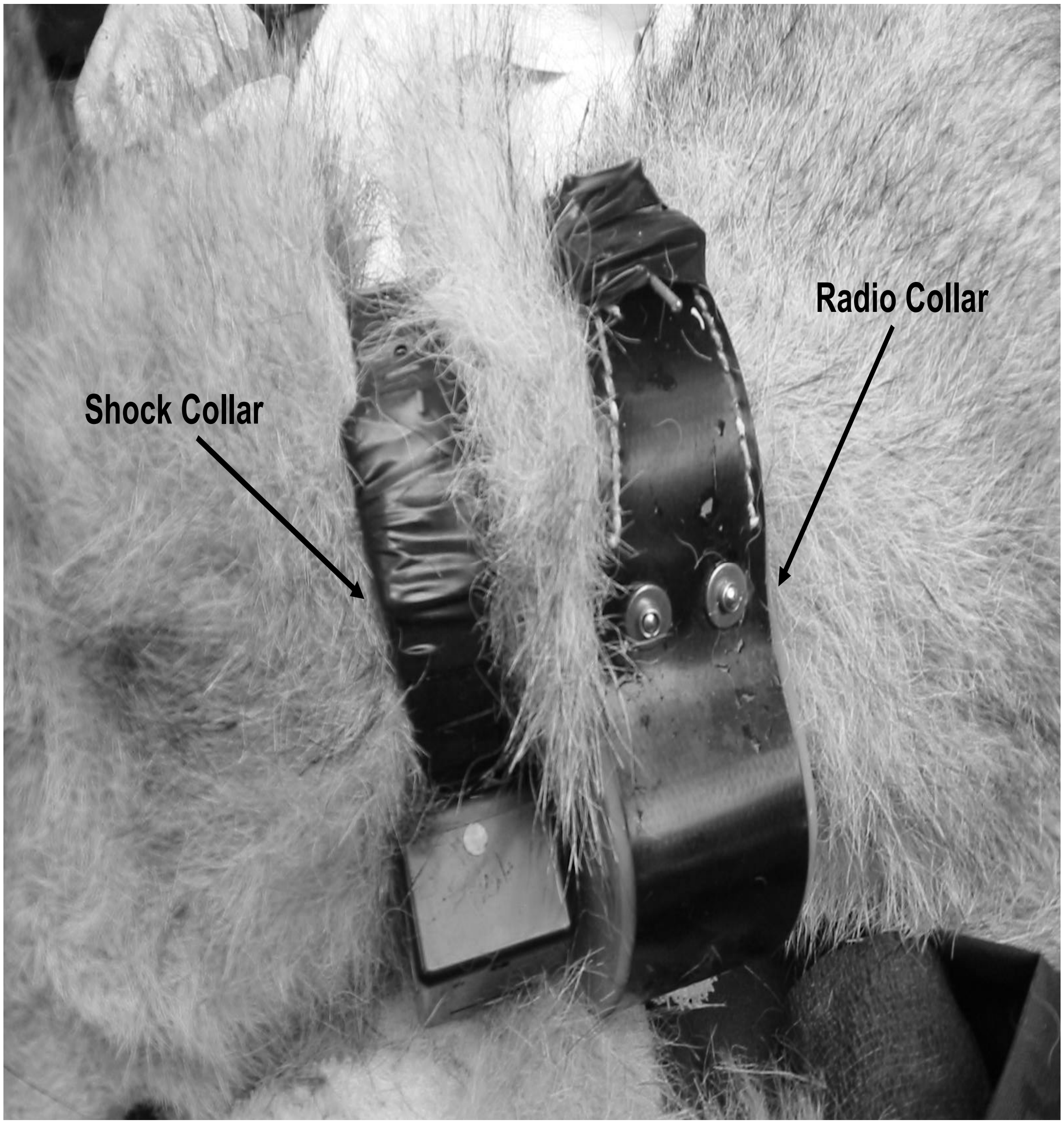


Wisconsin wolf territories in 2004. Known or estimated wolf pack home ranges in the State of Wisconsin in 2004. Home ranges were predicted through aerial telemetry locations displayed as minimum convex polygons, or through estimation by winter track surveys. Home-range data were provided by the Wisconsin Department of Natural Resources (Weidenhoeft 2004).

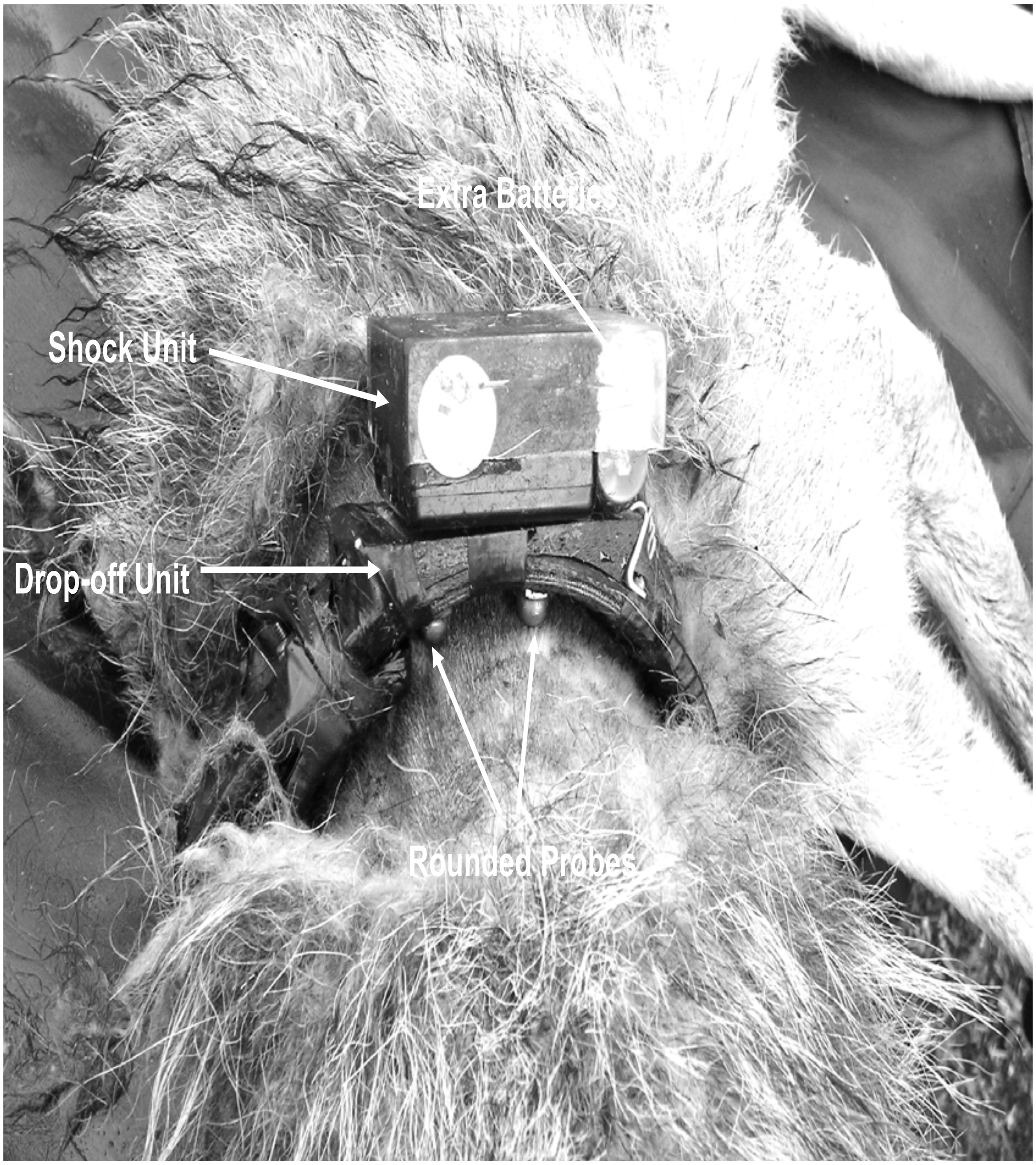
Appendix E



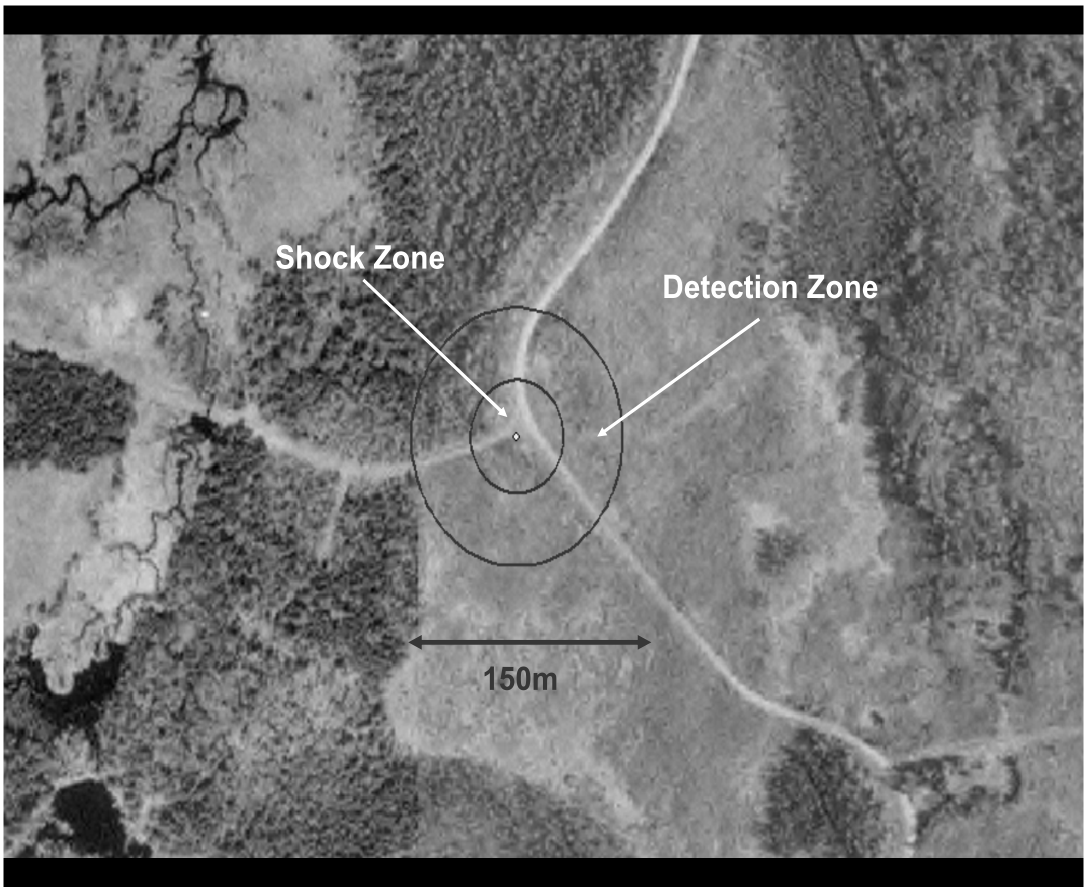
Study Site. Enlarged shock collar research study area during 2003 and 2004 in northeastern Wisconsin. Study area is roughly 9,000 $km^{2,}$ and is made up of 7 different counties including Ashland, Iron, Lincoln, Oneida, Vilas, Forest and Price. Shaded areas indicate wolf pack territories.



Original shock collar design in 2003. Example of shock-collar placement used in 2003 treatment showing a wolf fitted with both Innotek shock collar and Telonics VHF radio-collar. The skin was shaved under the shock unit to insure probe contact.

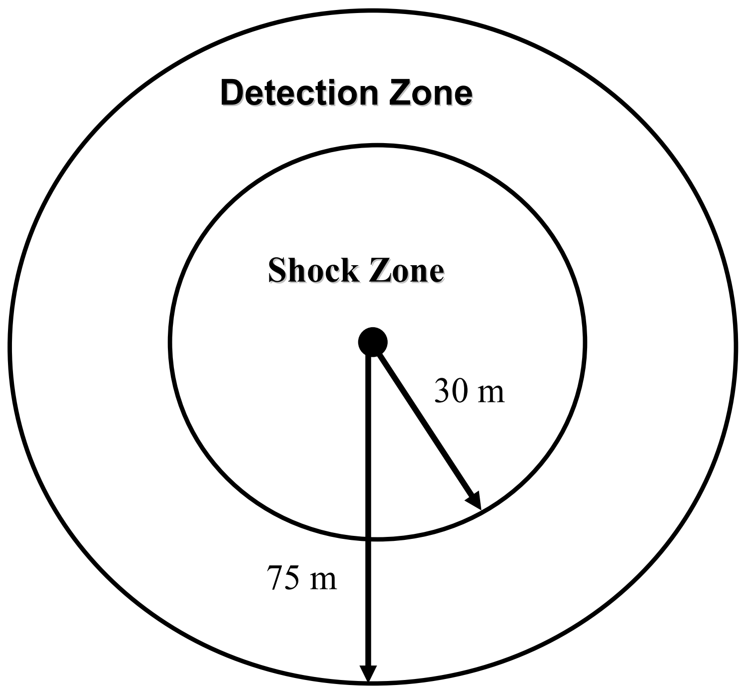


New shock collar design in 2004. Example of shock-collar placement used in 2004 treatment showing a wolf fitted with new shock-collar design with Innotek shock unit mounted on the back of the Telonics VHF radio-collar. New shock collar design included 2 externally mounted 3-Volt lithium batteries encased in a high-density polymer to extend battery life, rounded probes, and drop off designed to released shock unit in 2-3 months time. The back of the wolf's neck was shaved to insure probe contact.

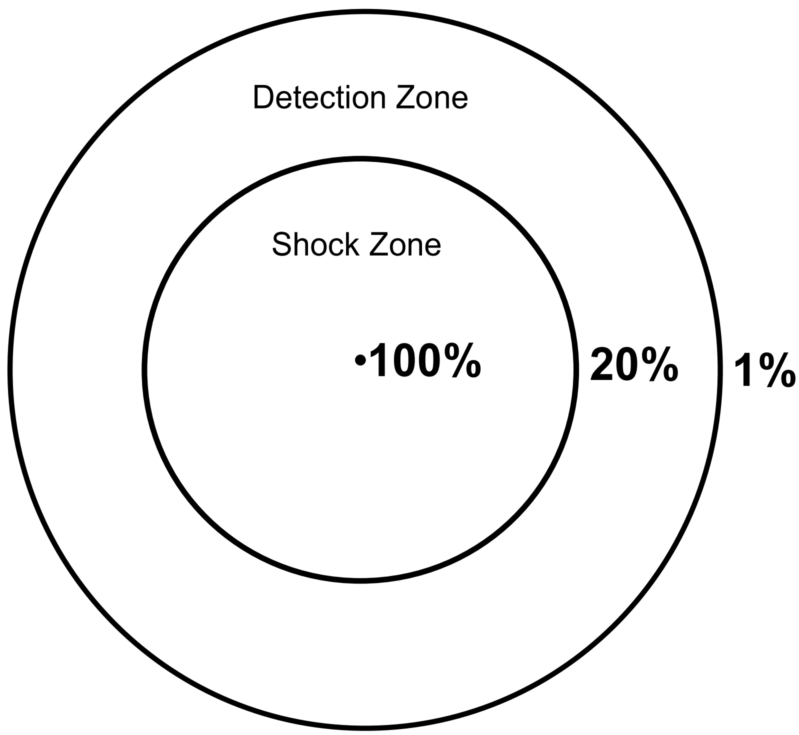


Intersection (study design example). Road intersection with both shock and detection zones overlaid. The shock zone extends 30m from the center of the intersection, while the detection zone starts at 30m and extends to 75 m.

Appendix I

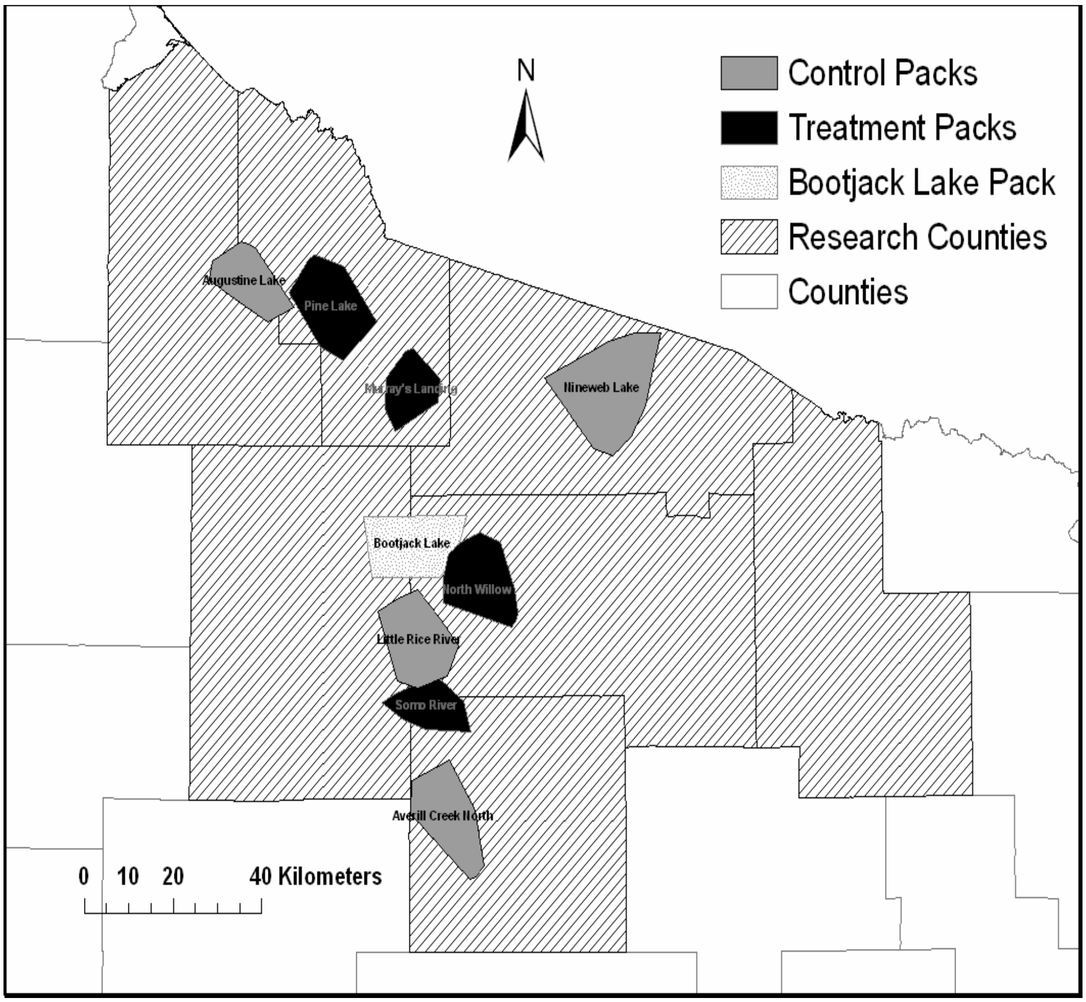


Shock/detection zone dimensions. The shock zone is shown extending 30 m from the center of the site. The detection zone begins at 30 m and extends out to 75 m. The zone structure is identical for both treatments and controls.

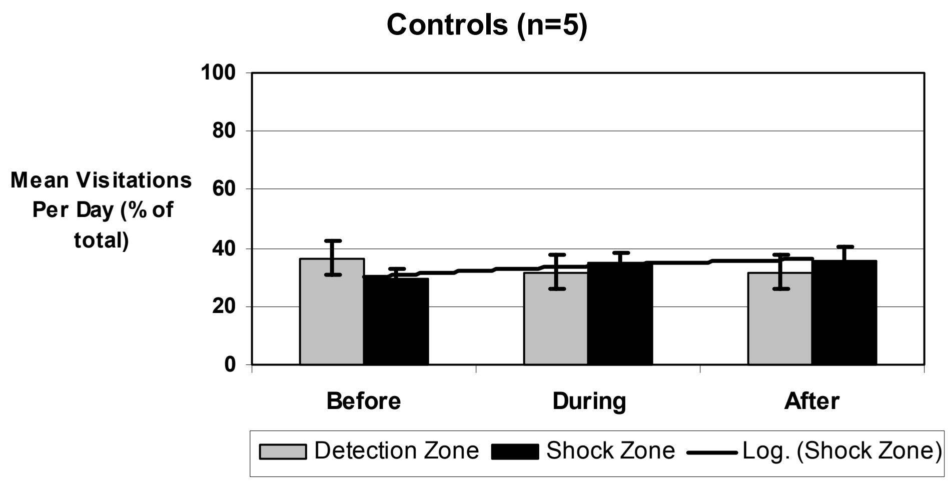


Shock/detection zone percent signal strength. Percent signal strength of VHF collar beacon detected and recorded by the H.A.B.I.T. Ltd. data loggers at the center of the zone, the edge of the shock zone, and the outer edge of the detection zone. Recordings between 1 and 20% signal strength were considered in the detection zone. Recordings between 20 and 100 were considered in the shock zone.

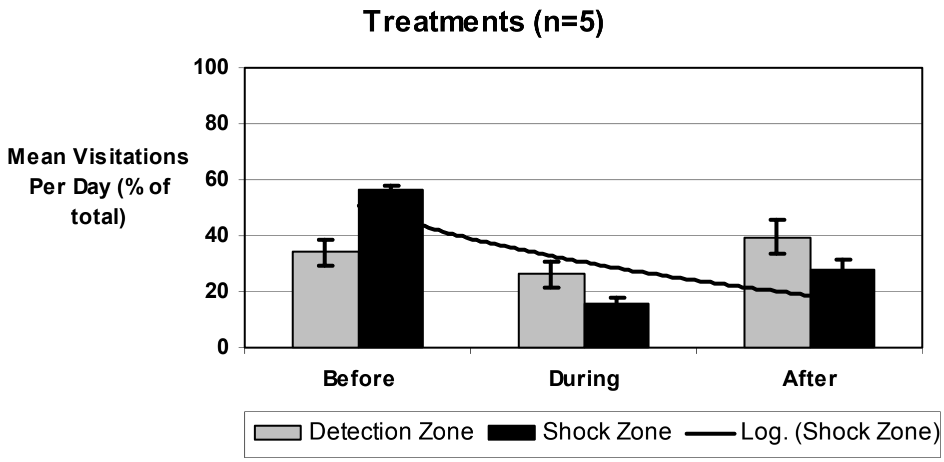
Appendix K



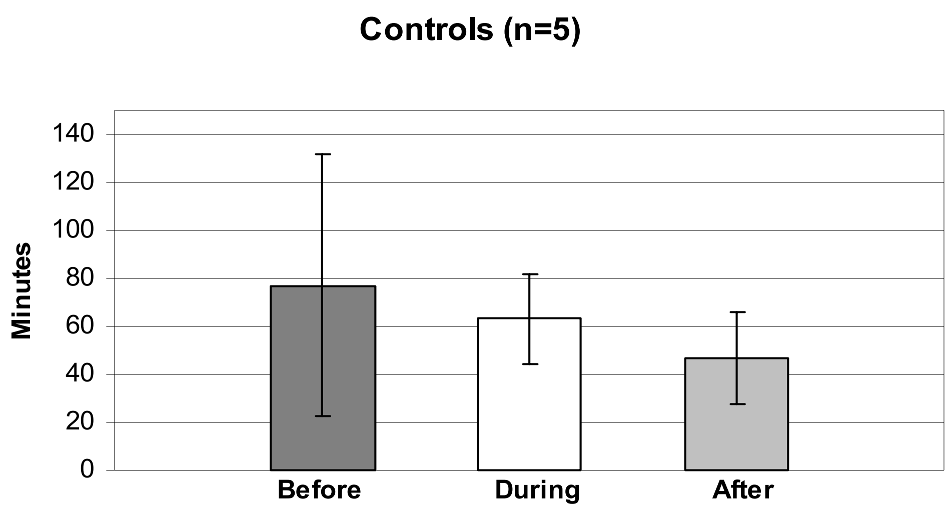
Control/treatment wolf home ranges. Gray polygons represent the home range of control wolves included in shock collar research. Black polygons represent the home ranges of treatment wolves (shock collared) included in the research. The Bootjack Lake home range represents the home range of F466, included as a control in the 2003 season, and F505, included as a treatment in the 2004 season. Polygons were created from Wisconsin DNR aerial telemetry locations.



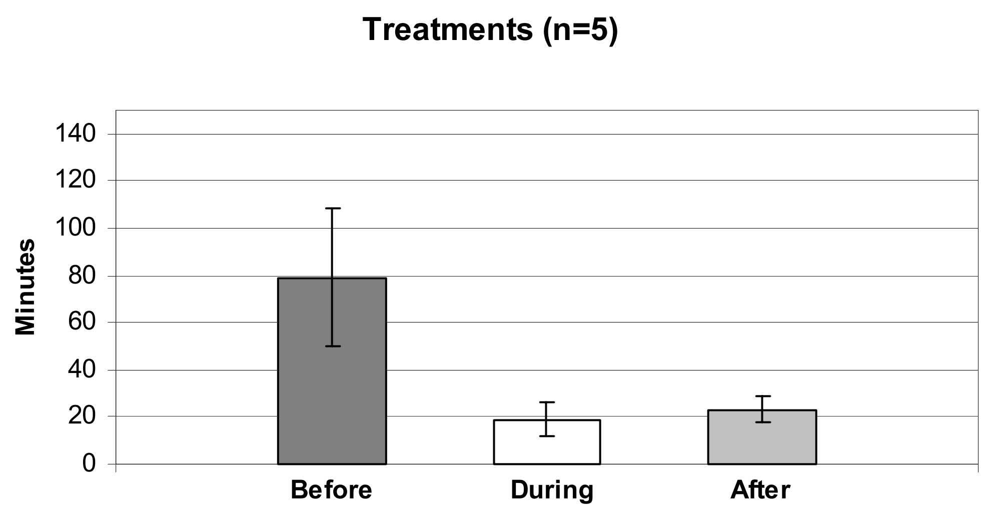
Mean visitations per day for control wolves (percent of total). Gray bars represent percent of mean visits per day to the detection zone in each period (before, during and after). Black bars represent the percent of mean visits per day to the shock zone in each period. Standard error bars and trend line of shock zone included. No significant changes were detected with a paired t-test of the before and after time periods.



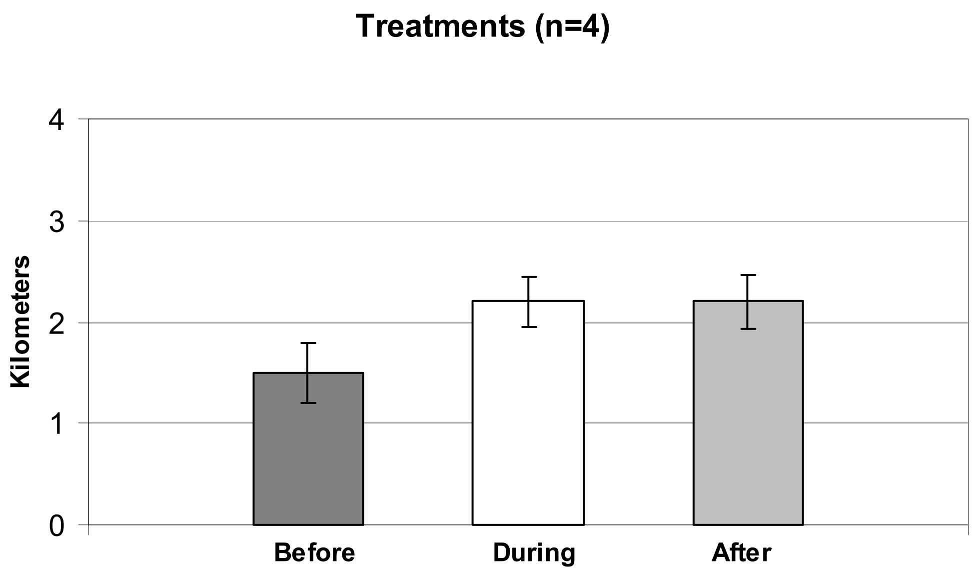
Mean visitations per day for treatment wolves (percent of total). Gray bars represent percent of mean visits per day to the detection zone in each period (before, during and after). Black bars represent the percent of mean visits per day to the shock zone in each period. Standard error bars and trend line of shock zone included. A significant change was detected between the before and after visitations to the shock zone with a paired t-test.



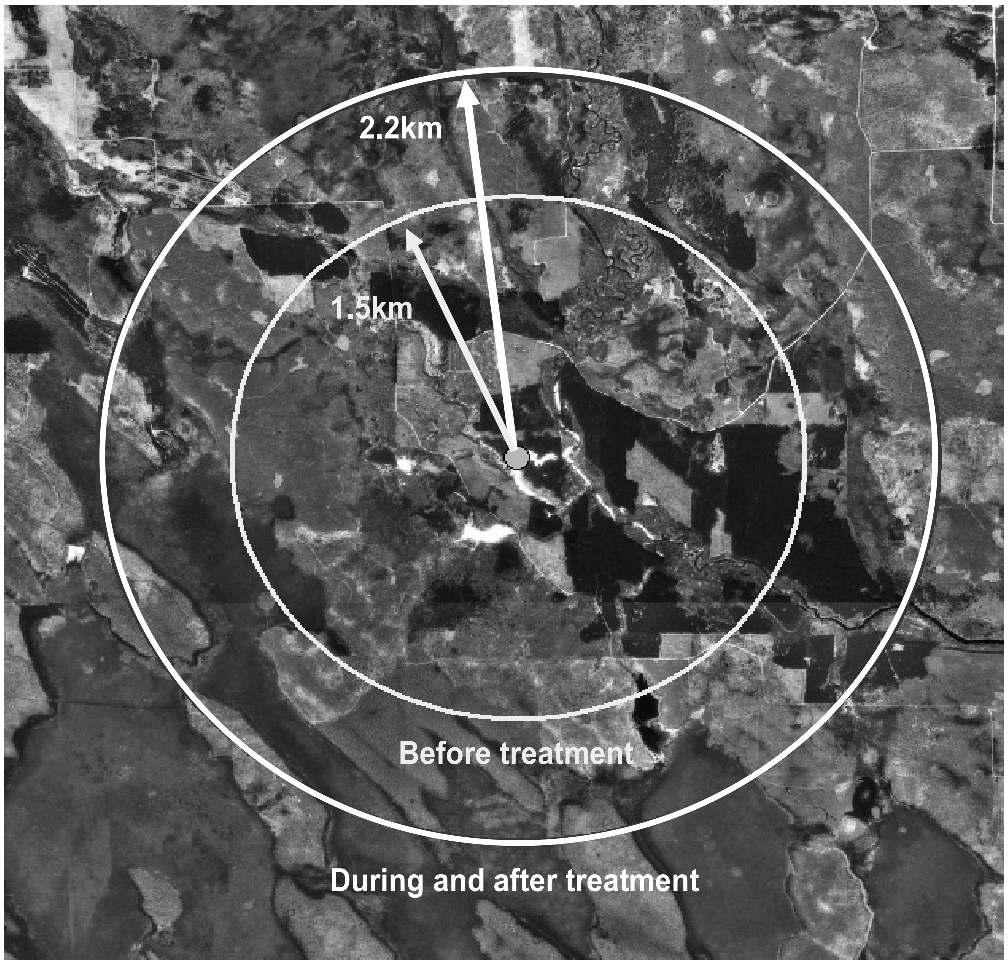
Mean minutes per day spent in the zone by control wolves. Mean minutes per day spent in the combined zones (shock and detection) before, during, and after treatment for controls. No significant change was detected going from before to after treatment with a paired t-test.



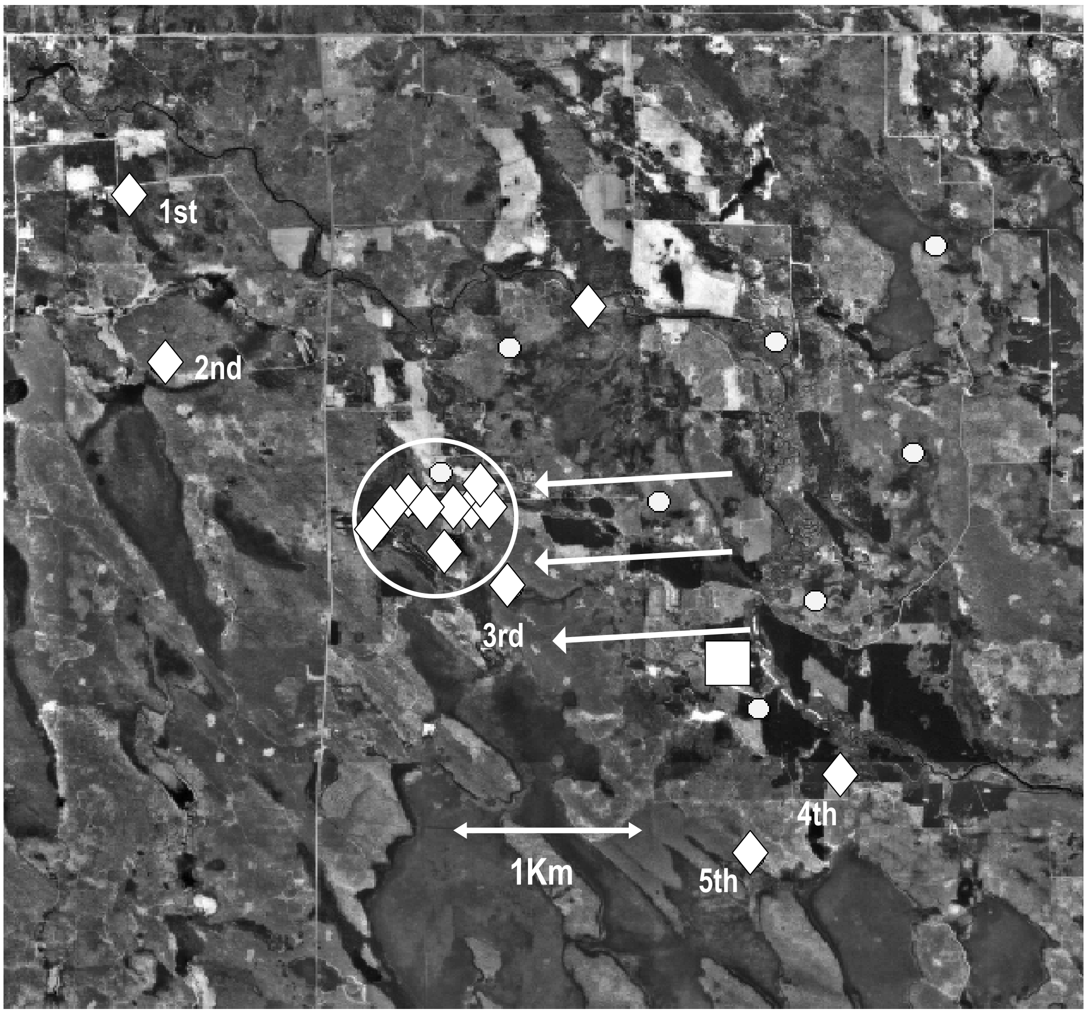
Mean minutes per day spent in the zone by treatment wolves. Mean minutes per day spent in the combined zones (shock and detection) before, during, and after treatment for treatment wolves. A significant change was detected going from before to after treatment by running a paired t-test.



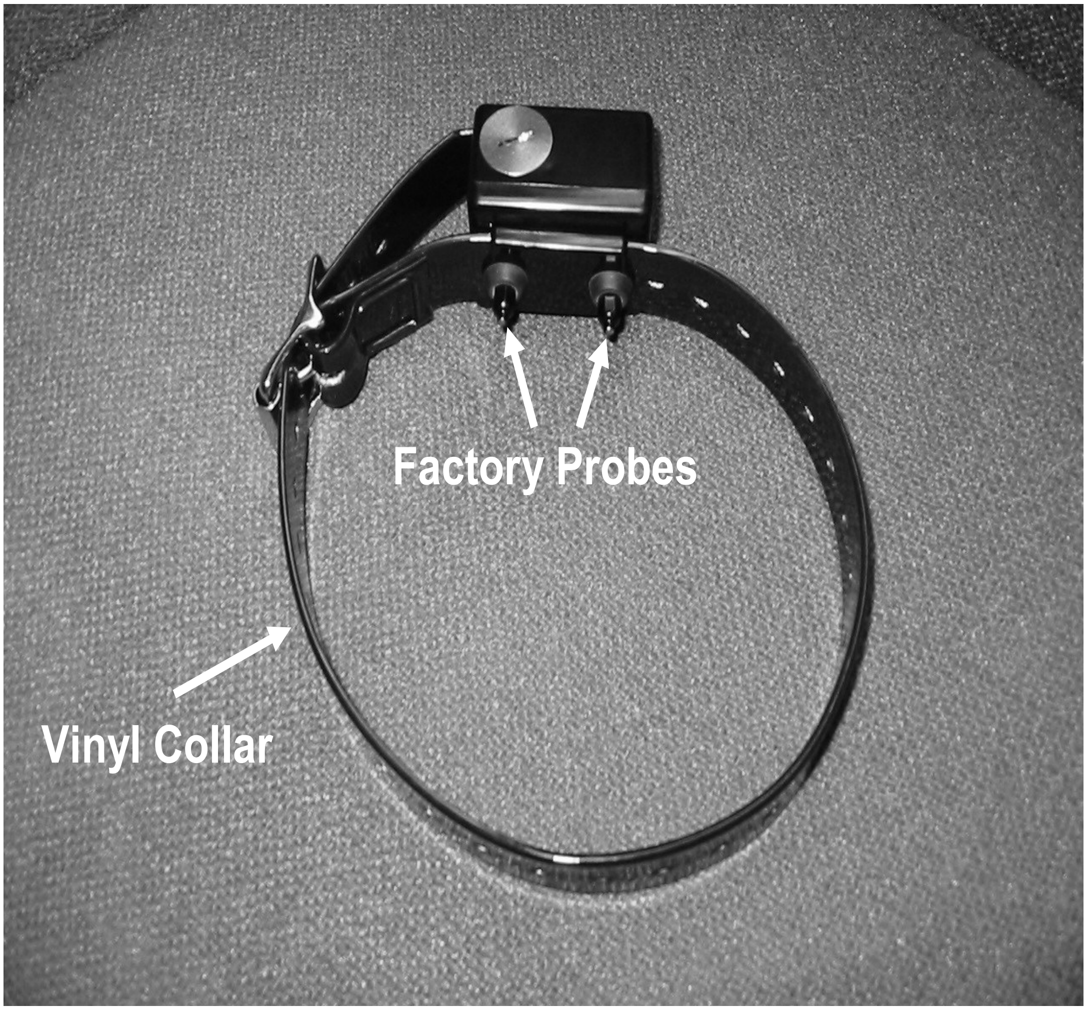
Mean distance of wolf locations from the center of the zone. Mean distance of wolf telemetry locations from the center of the zone (kilometers) before, during and after treatment. A significant change was detected between the before and during, as well as the before and after time periods with a One-Way ANOVA for correlated samples.



Mean distance from the center of the zone before and after treatment. Mean distance of treatment wolf telemetry locations from the center of the zone before and after treatment. Mean distance before treatment was approximately 1.5km. Mean distance after treatment was approximately 2.2km, equaling a .7km shift.

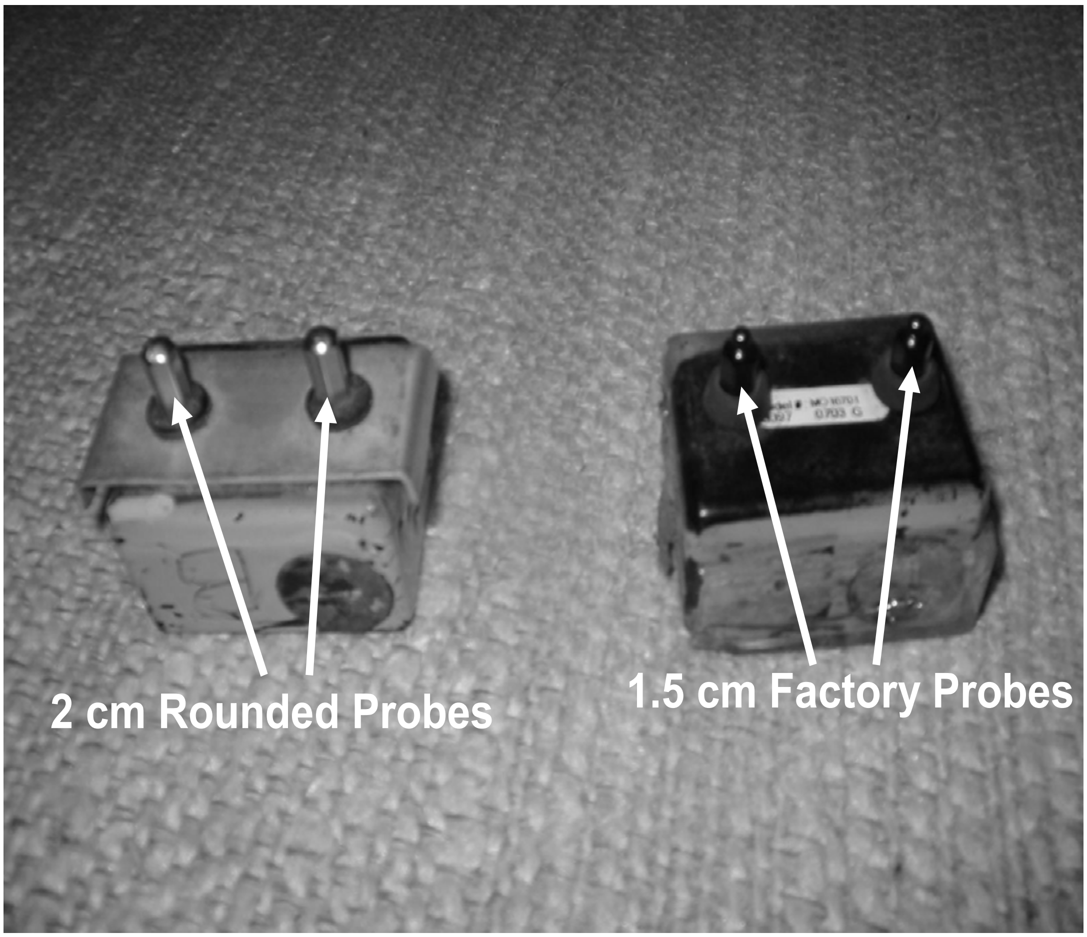


Example of shift in wolf locations before to after treatment (Somo River). Circles represent wolf locations before treatment of a shock collared wolf (Somo River), square represents the center of the shock zone, and the triangles represent locations during and after treatment. Notice the large movement of the first location following the initial shock. The wolf then slowly moves back in the 4th and 5th locations, and then localizes in a heavily wooded area along a river.



Original unaltered factory Innotek shock collar with pointed probes and vinyl collar strap.

Appendix T



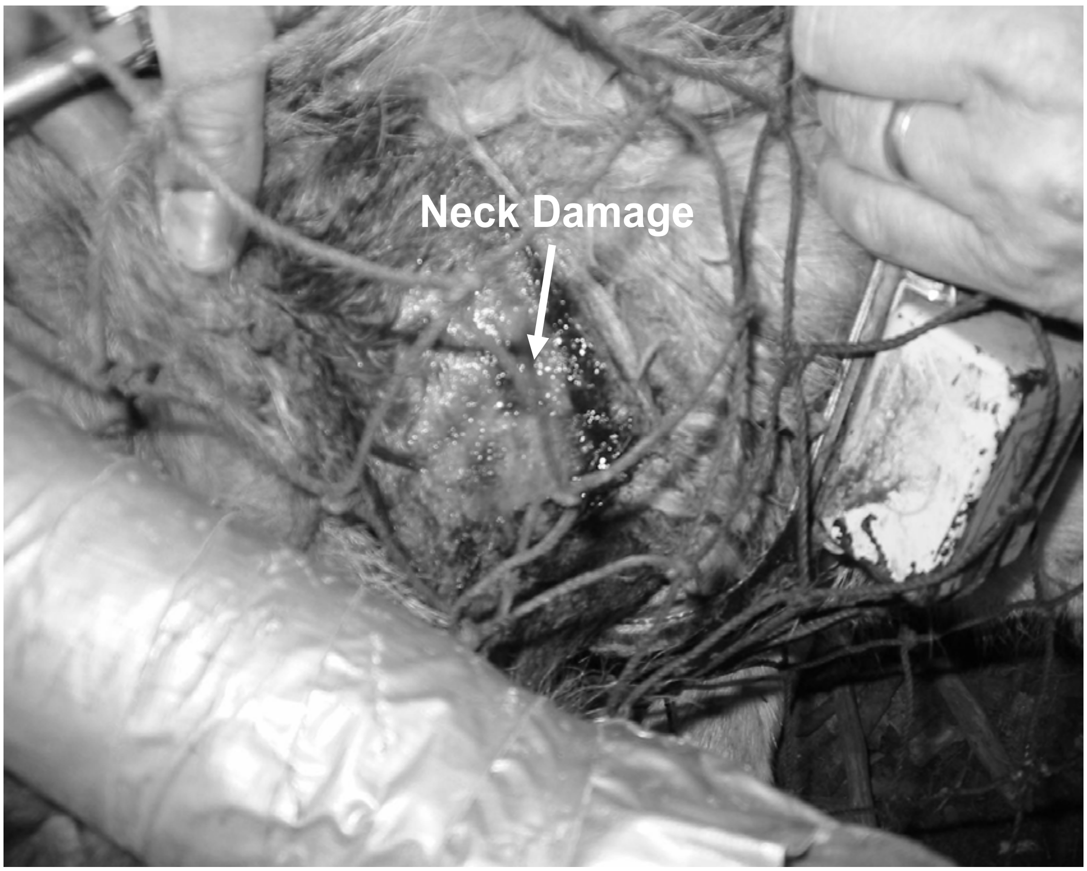
Innotek shock unit fitted with custom 2 cm rounded probes (left). Innotek shock unit fitted with original 1.5 cm pointed probes.

Appendix U

Shock collar design used in trial #3. Includes shock unit with 2 cm probes mounted on the back of a Telonics VHF Radio Collar.

Shock collar being fitted onto a wolf in trial #1.

Appendix W



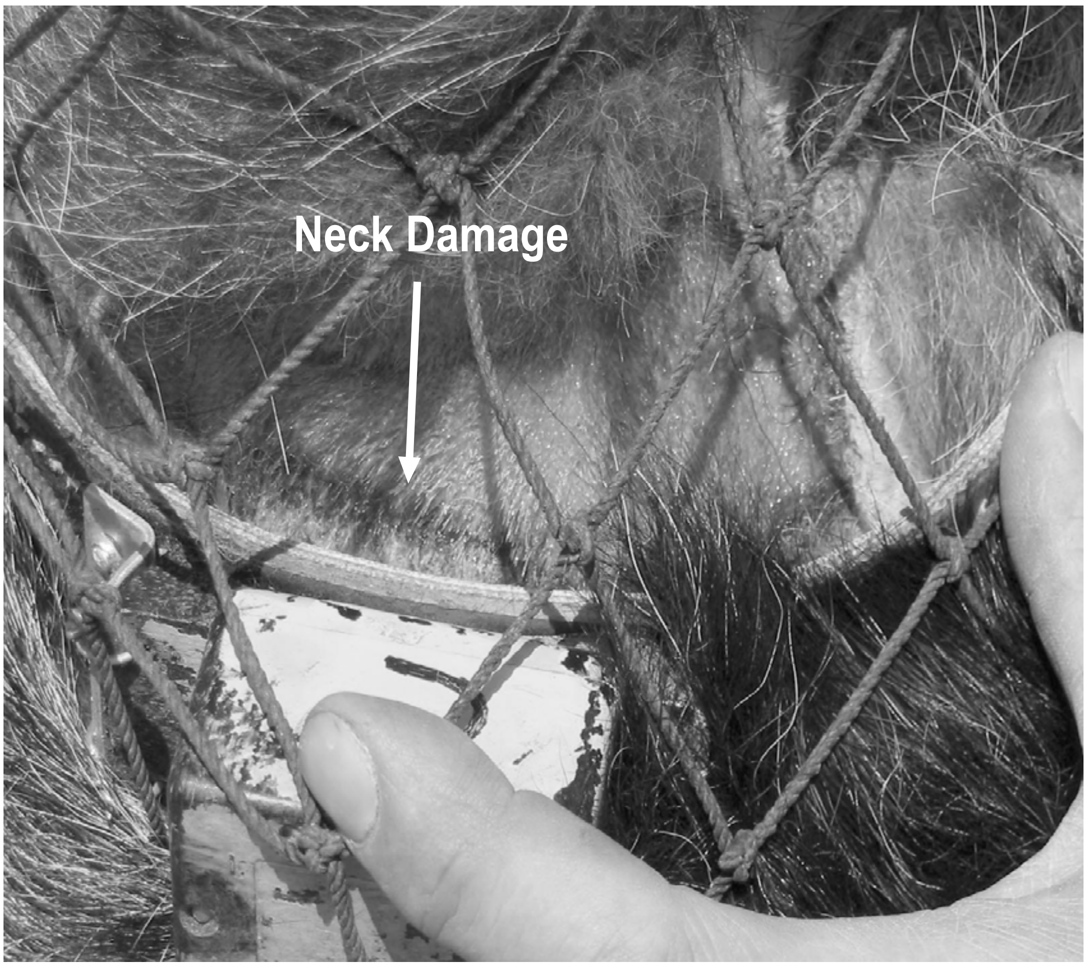
Severe neck damage on back of neck due to probe contact in trial #1.

Appendix X

New probes and drop-off design used in trial #2.

Appendix Y

New collar design used in trial #3 with rounded probes, rounded and taped inner collar edges, externally mounted batteries, and drop-off design.



Neck damage on wolf caused by the edge of the collar in trial #2.

Neck of wolf in trial #3 showing no damage.

Collar shown completely flipped over in captive trials.

BIBLIOGRAPHY

ANDELT, W.F. 1992. Effectiveness of livestock guarding dogs for reducing predation on domestic sheep. Wildlife Society Bulletin 20:55-62.

ANDELT, W.F., R.L. PHILLIPS, K.S. GRUVER, AND J.W. GUTHRIE. 1999. Coyote predation on domestic sheep deterred with electronic dog-training collar. Wildlife Society Bulletin 27:12-18.

ARCHIBALD, W.R., D. JANZ, AND K. ATKINSON. 1991. Wolf control: a management dilemma. Trans. North American Wildlife and Natural Resources Conference 56:497-511.

BAILEY, V. 1907. Directions for the destruction of wolves and coyotes. U.S. Department of Agriculture Biological Survey Circ. No. 55.

BERRYMAN, J.H. 1972. The principles of predator control. Journal of Wildlife Management 36:395-400.

BJORGE, R. R. and J. R. GUNSON. 1985. Evaluation of wolf control to reduce cattle predation in Alberta. Journal of Range Management 38: 483-486.

BOITANI, L. 1992. Wolf research and conservation in Italy. Biological Conservation. 61:125-132.

BRADLEY, E.H., D.H. PLETSCHER, E.E. BANGS, K.E. KUNKEL, D.W. SMITH, C.M. MACK, C.C. NIEMEYER, J.A. FONTAINE, T.J. MEIER, AND M.D. JIMENEZ. 2003. Evaluating wolf control in response to livestock depredation in the northwestern U.S. World Wolf Congress, Banff, Canada.

COHEN, J. 1977. Statistical power analysis for the behavioral sciences. Academic Press, New York.

COHN, J. 1990. Endangered wolf population increases. BioScience 40:628-632.

COOPER, D.M., E.L. KERSHNER, and D.K. GARCELON. 2005. The use of shock collars to prevent island fox (*Urocyon littorali*s) predation on the endangered san clemente loggerhead shrike (*Lanius ludovicianus mearnsi*). Institute for Wildlife Studies, Arcata, CA.

COPPINGER, R., AND L. COPPINGER. 2001. Dogs: a new understanding of canine origin, behavior, and evolution. The University of Chicago Press, Chicago.

DORRANCE, M.J. 1983. A philosophy of problem wildlife management. Wildlife Society Bulletin 11:319-324.

FERNANDEZ-DUQUE, E. AND C. VALEGGIA. 1994. Meta-analysis: a valuable tool in conservation research. Conservation Biology 8:555-561.

FRITTS, S. H., W. J. PAUL, L. D. MECH, and D. P. SCOTT. 1992. Trends and management of wolf-livestock conflicts in Minnesota. United States Fish and Wildlife Service Resource Publication Number 181.

GEHRING, T. M., J. L. GEHRING, M. A. Beckel, and M. A. Callahan. 1996a. Recovering wolf populations. Conservation Biology 10:5-6.

GEHRING, T. M., J. L. GEHRING, B. E. KOHN, M. A. BECKEL, and M. A. CALLAHAN. 1996b. Integrated management of wolf-caused depredation: the Wisconsin-Minnesota depredation option plan. 14^{th} Midwest Furbearer Workshop. Ironwood, Michigan.

GREEN, J.S. 1989. Donkeys for predation control. Proceedings of the Fourth Eastern Wildlife Damage Control Conference. Madison, WI.

JENSEN, W.R., T.K. FULLER, AND W.L. ROBINSON. 1986. Wolf, *Canis lupus* distribution on the Ontario-Michigan border near Sault Ste. Marie, Ontario. Canadian Field-Naturalist 100:363-366

KELLERT, S.R. 1991. Public views of wolf restoration in Michigan. Trans. North American Wildlife and Natural Resources Conference 56:152-161.

KLINGHAMMER, E. 1975. The behavior and ecology of wolves: proceedings of the symposium on the behavior and ecology of wolves held on 23-24 May 1975 at the Annual Meeting of the Animal Behavior Society in Wilmington, NC. New York: Garland STPM Press.

KREEGER, T.J. 1996. Handbook of Wildlife Chemical Immobilization. Laramie WY: International Wildlife Veterinary Services Inc.

KUEHN, D.W., T.K. FULLER, T.K., L.D. MECH, W.J. PAUL, S.H. FRITTS and W.E. BERG. 1986. Trap-related injuries to gray wolves in Minnesota. Journal of Wildlife Management 50(1):90-91.

LEOPOLD, A.S. 1933. Game management. Charles Scribner's Sons, New York.

LINHART, S.B., J.D. ROBERTS, S.A. SHUMAKE, and R. JOHNSON. 1976. Avoidance of prey by captive coyotes punished with electric shock. Proceedings of the Vertebrate Pest Conference 7:302-306.

LINHART, S.B., R.T. STERNER, G.J. DASCH, and J.W. THEADE. 1984. Efficacy of light and sound stimuli for reducing coyote predation upon pastured sheep. Protection Ecology 6:75-84.

LOVALLO, J.L., K.C. VERCAUTEREN, N.C. HEDGE, E.M. ANDERSON, and S.E. HYGNSTROM. 1994. An evaluation of electronic versus hand-held compasses for telemetry studies. Wildlife Society Bulletin 22:662-667.

MEADOWS, L.E., and F.F. KNOWLTON. 2000. Efficacy of guard dog llamas to reduce canine predation on domestic sheep. Wildlife Society Bulletin 28:614-622.

MECH, L. D. 1970. The wolf: the ecology and behavior of an endangered species. University of Minnesota Press, Minneapolis, Minnesota.

MECH, L.D., AND R.M. NOWAK. 1981. Return of the gray wolf to Wisconsin. American Midland Naturalist 105:408-409.

MECH, L. D. 1995. The challenge and opportunity of recovering wolf populations. Conservation Biology 9:270-278.

MECH, L.D. 1998. Estimated costs of maintaining a recovered wolf population in agricultural regions of Minnesota. Wildlife Society Bulletin 26: 817-822.

MECH, L. D., E. K. HARPER, T. J. MEIER, and W. J. PAUL. 2000. Assessing factors that may predispose Minnesota farms to wolf depredations on cattle. Wildlife Society Bulletin 28:623-629.

MICHIGAN DEPARTMENT OF NATURAL RESOURCES (MDNR). 1997. Michigan gray wolf recovery and management plan. Lansing, Michigan. 52pp.

MUSIANI, M., C. MAMO, L. BOITANI, C. CALLAGHAN, C.C. GATES, L. MATTEI, E. VISALBERGHI, S. BRECK., and G. VOLPI. 2003. Wolf depredation trends and the use of fladry barriers to protect livestock in western North America. Conservation Biology 17:1538-1547.

PACKARD, J.M., and L.D. MECH. 1980. Population regulation in wolves. pp. 135-150 in M.N. COHEN, R.S. MALPASS, and H.G. KLEIN, eds. Biosocial mechanisms of population regulation. Yale University Press, New Haven, CT.

PARKER, W.T., and M.K. PHILLIPS. 1991. Application of the experimental population designation to the recovery of endangered red wolves. Wildlife Society Bulletin 19:73-79.

PEEK, J. M., E.E. BROWN, S.R. KELLERT, L.D. MECH, J.H. SHAW, and V. VAN BALLENBERGHE. 1991. Restoration of wolves in North America. Wildlife Society Tech. Rev. 91-1. 21pp.

REYNOLDS, J. C., and S. C. TAPPER. 1996. Control of mammalian predators in game management and conservation. Mammal Society, Mammal Review, 26, 127-156.

SCHADLER, C. L. G., and J. HAMMILL. 1996. Status of the gray wolf in Michigan: a naturally recovering population. Pages 104-110 *in* Wolves of America Conference Proceedings. Defenders of Wildlife, Albany, New York.

SCHULTZ, R.N., K.W. JONAS, L.H. SKULDT, and A.P. WYDEVEN. 2005. Experimental use of dog-training shock collars to deter depredation by gray wolves (*Canis lupus*). Wildlife Society Bulletin 00:000-000.

SHIVIK, J.A., V. ASHER, L. BRADLEY, K. KUNKEL, M. PHILLIPS, S.W. BRECK, and E. BANGS. 2002. Electronic aversive conditioning for managing wolf predation. Proceedings of the Vertebrate Pest Conference 20:227-231.

SHIVIK, J.A., A. TREVES, AND P. CALLAHAN. 2003. Nonlethal techniques for managing predation: primary and secondary repellents. Conservation Biology 17:1531-1537.

STEINHART, P. 1995. The company of wolves. p.84 Vintage Books. New York, New York.

THIEL, R.P. 1993. The timber wolf in Wisconsin: the death and life of a majestic predator. The University of Wisconsin Press. Madison, Wisconsin.

TREVES, A., R.R. JUEWICZ, L. NAUGHTON-TREVES, R.A. ROSE, R.C. WILLGING, AND A.P. WYDEVEN. 2002. Wolf depredation on domestic animals in Wisconsin, 1976-2000. Wildlife Society Bulletin 30:231-241.

TREVES, A., L. NAUGHTON-TREVES, E.K. HARPER, D.J. MLADENOFF, R.A. ROSE, T.A. SICKLEY, AND A.P. WYDEVEN. 2004. Predicting human-carnivore conflict: a spatial model derived from 25 years of data of wolf depredation on livestock. Conservation Biology 18: 114-125.

VAN BALLENBERGHE, V., and L.D. MECH. 1975. Weights, growth, and survival of timber wolf pups in Minnesota. Journal of Mammalogy. 56:44-63.

WALTON, M.T., and C.A. FEILD. 1989. Use of donkeys to guard sheep and goats in Texas. Proceedings of the Fourth Eastern Wildlife Damage Control Conference. Madison, WI.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES 1999. Wisconsin wolf management plan. Madison, Wisconsin. PUBL-ER-099 99. 74pp.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES (WDNR). 2000. A fisheries, wildlife, and habitat management plan for Wisconsin. Madison, Wisconsin.

WYDEVEN, A. P., R.N. SCHULTZ and R.P. THIEL. 1995. Extirpation and recolonization of gray wolves in Wisconsin. Pages 111-122 *in* Wolves of America Conference Proceedings. Defenders of Wildlife, Albany, New York.

WYDEVEN, A.P., J.E. WIEDENHOEFT, R.N. SCHULTZ, R.P. THIEL, S.R. BOLES, E. HEILHECKER, and W.H. HALL Jr. 2004. Progress report of wolf population monitoring in Wisconsin for the period October 2004- March 2004. Park Falls, Wisconsin. 40pp.

WYDEVEN, A.P. and J.E. WIEDENHOEFT. 2004. Gray wolf population, 2002-2003. Wisconsin Wildlife Surveys, 14(5): 125-138.

YOUNG, S.P., AND E.A. GOLDMAN. 1944. The wolves of North America. Dover Publications, New York/American Wildlife Institute, Washington, DC.

ZAR, J. H. 1996. Biostatistical analysis, 3rd edition. Prentice Hall, Upper Saddle River, New Jersey.