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Effects of predator reduction on nest success of upland nesting ducks in low-grassland density landscapes in eastern North Dakota

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EFFECTS OF PREDATOR REDUCTION ON NEST SUCCESS OF UPLAND NESTING DUCKS IN LOW-GRASSLAND DENSITY LANDSCAPES IN EASTERN NORTH DAKOTA

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ABSTRACT

Nest success of upland nesting ducks is the primary driver of duck population growth in the Prairie Pothole Region. Nest success is greatly influenced by nest predation and the amount of available nesting cover on the landscape. The decline in acres enrolled in the Conservation Reserve Program (CRP) in this region has negatively impacted the amount of available nesting cover, making nesting cover sparse and confined to small patches where predation rates are potentially elevated. I evaluated the efficacy of seasonal predator reduction on increasing nest success on low-grassland density ($\geq$10% grassland cover), 93 km^2 landscapes in two different habitat types used by nesting birds, large fields and roadside ditches. Ditches were sampled because they are a major cover source in low-grassland density landscapes. I monitored 1,899 nests during the 2010-2012 breeding seasons. Predator reduction had a significant influence in large fields as nest success was 1.6 times greater in large fields on trapped sites (44% nest success) than on control sites (27% nest success). Predator reduction, however, did not significantly increase nest success in roadside ditches (13% nest success on trapped sites, 12% nest success on control sites). A large majority of monitored nests were located in large fields resulting in the overall effect of predator reduction significantly increasing nest success by 13%. These results indicate that predator reduction is an effective intensive management technique in low-grassland density landscapes and can be used as a management tool in a post-CRP era. Future research should evaluate different trapping techniques in efforts to increase nest success in the roadside ditches.

CHAPTER

INTRODUCTION

Nest success is the primary driver of duck population growth for many prairie nesting ducks (Johnson et al. 1992, Hoekman et al. 2002). High nest success contributes to a high population recruitment rate, making the population growth rate high enough to sustain itself (Sargeant and Raveling 1992). Cowardin and Johnson (1979) found that in order for the population to sustain itself, nest success must be at least 15%. Accordingly, most waterfowl management in the prairies focuses on efforts to increase nest success (Sargeant and Raveling 1992, Williams et al. 1999).

Over the past century, large-scale agriculture has dramatically changed the Prairie Pothole Region (PPR) landscape (Higgins 1977, Stephens et al. 2005), by fragmenting and reducing the available upland-nesting habitat for many duck species (Greenwood et al. 1995, Drever 2006). Since settlement, approximately 67 percent of the grasslands in North Dakota have been converted to agriculture (USDA 1994, Reynolds et al. 2001). Accompanying this habitat loss and fragmentation is the increase of medium-sized mammalian predator populations, such as red fox (*Vulpes vulpes*), raccoons (*Procyon lotor*), and striped skunks (*Mephitis mephitis*) (Stephens et al. 2005), which are the primary nest predators of waterfowl (Johnson et al. 1992). These predators account for approximately 86% of all nest failures in the PPR making predation the leading cause of nest failure in this region (Klett et al. 1988).

In 1985, the Food Security Act was passed, which contained an important element relevant to waterfowl conservation in the PPR; the Conservation Reserve Program (CRP) (Reynolds et al. 2006). The conversion of marginal agricultural and other underutilized lands back to grasslands, in the form of large acreages of CRP, led to a reversal of the long term decline in nest success (Beauchamp et al. 1996) by attaining higher nest success than any other major cover source (Reynolds et al. 2001).

However, more recently, acreage of CRP land cover has been declining, because of increasing prices for grains (USDA 2013b). In North Dakota, CRP acreage peaked at 3.4 million acres in 2007. By 2012, North Dakota CRP acreage has declined to 1.8 million acres (USDA 2013a). Federal deficits and continuing high commodity prices make the future of CRP look bleak. With far less cover, the average nest success in prairie states is expected to decline to levels below the population maintenance threshold (Horn et al. 2005).

Recently, wildlife managers have tried to improve nest success using techniques such as increasing nesting cover (Klett et al. 1988). However, Reynolds et al. (2001) found that the amount of nesting cover on the landscape required to achieve the nest success threshold of 15% for population maintenance in the prairies is approximately 40% grassland on the landscape. This may be an unreasonable goal given the sociopolitical and economic challenges of the area (Rohwer et al, 2004). In low-grassland density landscapes, where nest success is below population maintenance (Horn et al. 2005), predator population reduction may be a viable intensive management technique to enhance nest success.

Garrettson and Rohwer (2001) found that reducing nest predators yielded an average nest success nearly twice as high as areas where no predator reduction was implemented. Pieron and Rohwer (2010) found that by lethally reducing these predators in years 2005, 2006, and 2007 improved nest success by 17.5%, 19.6%, and 35.2% respectively. These studies were conducted in areas where the available nesting habitat was either at or above the amount (40%) needed to achieve the 15% nest success threshold needed for population maintenance.

In contrast, I focused on landscapes where available nesting cover comprised less than 10% of the landscape. In this landscape, the conversion of CRP acres back to agricultural production acres has greatly reduced available fields for nesting and resulted in the use of road right-of-ways for nesting. I implemented seasonal predator reduction to determine if nest success could be elevated on low-grassland density landscapes where nesting habitat patch size is smaller, duck nest success is expected to be below the population maintenance threshold, and predator mobility is increased due to abundant edge habitat. To evaluate the efficacy of the predator reduction, I searched for duck nests in both large CRP fields ($\geq$ 80 acres) and the road right-of-ways (roadside ditches). I hypothesize that (1) the predator reduction treatment will have a similar overall positive effect on nest success as previous predator reduction studies and (2) that the predator reduction treatment will have an equal effect on duck nest success in fields and roadside ditches.

Study Area

I conducted this study in the drift prairie physiographic region of North Dakota from 2010 – 2012 in Benson, Cavalier, and Towner counties. Upland nesting habitat in this area is highly fragmented due to agriculture, leaving nesting cover largely confined to patches of grass provided by Waterfowl Production Areas (WPAs), land enrolled in CRP, hay and pasture land, roadside ditches and wetland margins, and idle/fallow crop fields. Meso-predators such as Coyote (*Canis latrans*), Raccoon (*Procyon lotor*), Striped Skunk (*Mephitis mephitis*), Red Fox (*Vulpes vulpes*), American Badger (*Taxidea taxus*), American Mink (*Neovison vison*), Long-tailed Weasel (*Mustela frenata*), and Franklin's Ground Squirrel (*Poliocitellus franklinii*) were among the most observed mammalian predators.

METHODS

Study Site Selection

In each of the three years of this study, I worked on 4 township-sized (93.2 km^2) study sites. These sites were outlined by the U.S. Fish and Wildlife Service (USFWS) Region 6 Habitat and Population Evaluation Team (HAPET) using a Geographic Information System (GIS) matrix that identifies low-grassland landscapes by producing an "upland accessibility" map that determines breeding pairs of ducks/mi^2 on the landscape, largely based on wetland density. Breeding pair densities were later converted to pairs/km^2. This map was then combined with a "land use" map layer that filtered out areas where the habitat composition was consistent with my objectives. Township-sized areas were then selected based on available nesting habitat, breeding pair density, and upland accessibility.

Trapping Methods

In each year of the study, two of the four study sites were trapped for nest predators from 15 March through 15 July, by professional control trappers hired by the Delta Waterfowl Foundation (DWF). Trappers used an array of legal removal techniques, in accordance with North Dakota Game and Fish regulations, including body-gripping traps and foothold traps. All traps were checked at least once every 48 hours and all trapped predators were killed humanely.

Nest Searching Methods

On each study site, permission was obtained to search for duck nests from private landowners who owned a majority of the land within the site. Private land was typically enrolled in CRP, but some private land was used as hay land or pasture land. Other land where nest searching took place was owned by the U.S. Fish and Wildlife Service in the form of WPA's and sampling occurred under special use permits 62580-10-055, 62580-11-039 and 62580-12-006.

Nest searching was conducted from late-April through early-July each year and was carried out using two different methods. The first method was used in larger tracts of nesting habitat (hereafter known as “fields”) and consisted of a 2-person team dragging a 36.5 m length of 0.47 cm steel chain between two all-terrain vehicles (ATVs) in attempts to locate nests by flushing attending females (Klett et al. 1986, Pieron and Rohwer 2010). The chain had 30 cm lengths of hardened 0.47 cm steel chain attached every 1.5 meters to make extra noise.

The second method, hereafter known as the “boom truck”, was used to search the narrow strips of habitat along the roadside. This method consisted of a truck with a 4.25 m boom (made of 2.85 cm diameter steel pipe) extending perpendicular from the truck (Figure 1.1).

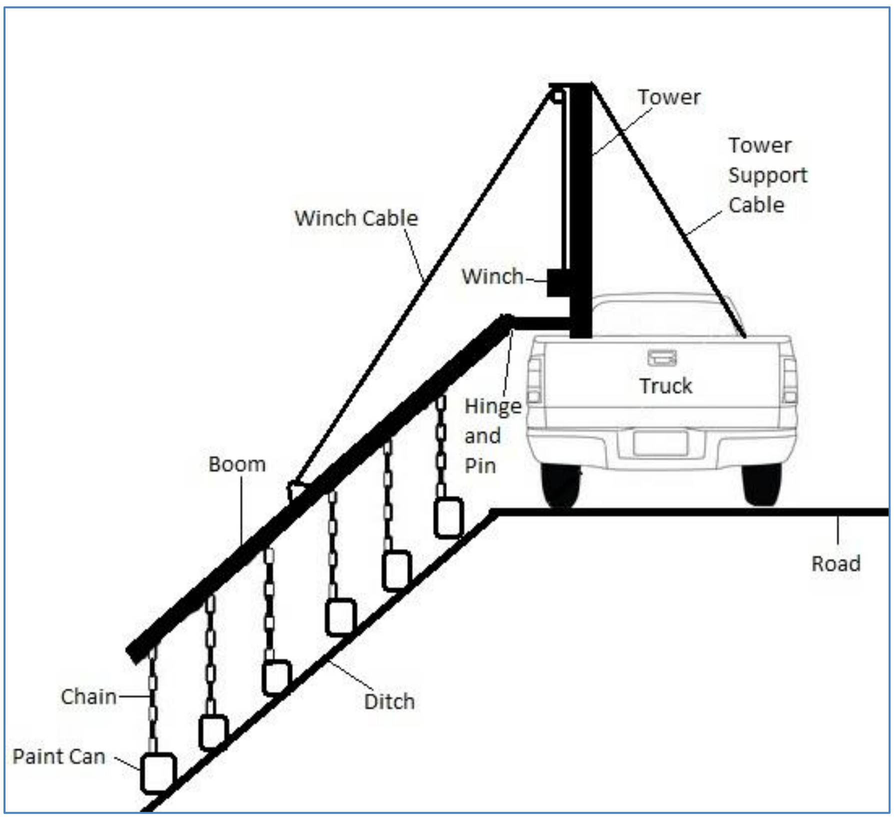

Figure 1. Diagram of boom truck with parts labeled (Ikeskinen, Pick-up line illustration).

This boom was attached (using a hinge and pin) to a 3.3 m tower (made of 7.62 cm steel pipe), which was mounted in the bed of the truck. Mounted to the side of the tower was an electronically controlled winch (3,000 lb. pull) that controlled the pitch of the boom by running a cable to the top of the tower, then to the middle of the boom. As the winch wound cable in, the boom would pivot up and as the winch let cable out, the boom would pivot down. Being able to control the pitch of the boom is essential for avoiding obstacles in the roadside such as utility poles, road signs, and trees. A 4.7 mm cable connected the top of the tower to bed of the truck to prevent the weight of the boom from bending the tower. The boom had eight-one gallon paint cans, containing a handful of medium-sized rocks, hanging off of it by eight-1.2 m sections of chain at 0.5 m intervals. As the truck traveled down the road, between 8 and 11 km/h, the combination of the rocks hitting the inside of the paint cans and the cans hitting the ground produced a loud disturbance that would flush attending hens allowing nests to be located.

Nest searching efforts occurred between the hours of 0800 and 1400 to maximize detection of nests by flushing the attending hen (Loos and Rohwer 2004, Pieron and Rohwer 2010). Once a nest was found, nest searching teams placed an orange rod (3mm in diameter, 0.95m in length) directly at the nest and placed a numbered piece of wooden lathe 10m north of the nest to allow for easy re-location. The orange rod was the only marker used for nests in roadside ditches to avoid having the wooden lathe draw unwanted attention to the nest from vehicles on the road. Observers recorded number of eggs present in the nest and used egg candling to estimate incubation stage. I used incubation stage as an indicator of nest initiation date (Pieron and Rohwer 2010). By estimating incubation stage when the nest is found, I can use incubation stage and number of eggs to determine initiation date using the following equation:

Initiation Julian Date = Current Julian Date – (Incubation Stage + 1) – Number of Eggs

The Universal Transverse Mercator (UTM) coordinates of the nest were also recorded using a GPS unit (Garmin eTrex). Nests were re-visited every 5 – 7 days until the nest was either successful or failed. I classified a nest as being successful if ≥ 1 egg hatched. Common causes of nest failure included; depredation, which was determined by visually inspecting the nest for cues consistent with a depredation event (i.e. absence of eggs, egg shells with bite marks, large egg shell fragments, and/or destruction of nest bowl); abandonment (from either investigator activity or unknown causes) which was determined by hen absence with little or no progression of incubation; and farm machinery (less common than previous two). To avoid misinterpreting investigator activity as the cause of nest abandonment, two small sticks from nearby nesting cover were arranged in an "X" pattern on the nest at the end of each visit. This allowed investigators to know whether the female returned to the nest after the investigators had left because the "X" would no longer be present had the female returned.

Statistical Analysis

I used the logistic-exposure method (Shaffer 2004) to model nest Daily Survival Rate (DSR) as a function of continuous, categorical, and time specific explanatory variables (Shaffer and Thompson 2007). I chose to convert DSR into nest success percentages when reporting values because nest success percentages are more meaningful to wildlife managers than DSR (Arnold et al. 2007, Pieron and Rohwer 2010). I used the logistic-exposure method because it allows the addition of explanatory variables to produce less biased and more precise estimates of nest survival than Mayfield methods, as it does not assume that DSR is consistent between nests and within an individual nest over time (Shaffer and Thompson 2007, Allison 2010). Based on previous waterfowl literature, I selected a set of variables that may affect DSR of nests including treatment (trapped vs. non-trapped), year (2010, 2011, and 2012), habitat (field vs. roadside ditch), and species (Blue-winged Teal [*Anas discors*], Gadwall [*Anas strepera*], Mallard [*Anas platyrhyncos*], Northern Pintail [*Anas acuta*], and Northern Shoveler [*Anas clypeata*]) as my categorical explanatory variables. I also included nested site-within treatment as a categorical variable to account for variation between sites. I included nest age and nest initiation date as my continuous explanatory variables in the model. Nest age is calculated as an interval-specific value unique to each visitation. I included the quadratic term for nest initiation and nest age to allow for possible non-linear effects of these variables. Finally, I included interactions between treatment and both continuous variables (treatment x initiation and treatment x nest age) along with their quadratic terms to determine if treatment had an effect on the continuous variables. I also included an interaction between treatment and two categorical variables (habitat and year) to determine if the effects of the treatment varied between either year or habitat type.

I used a generalized linear model (PROC GENMOD, SAS ver. 9.3, SAS Institute, Inc.) to determine the effects of my explanatory variables on DSR of nests in this study. The generalized linear model transformed the models by a log link function, and estimation was based on the Poisson distribution following comparison of competing links and natural exponential distributions (e.g., normal, negative binomial: Bolker et al. 2009) by observing changes in my selected objective function, chi-square/degree of freedom or $\hat{c}$, during selection to ensure that the link and distribution choice was supported. Because sufficient time passed between nest visits to establish temporal independence (Pieron 2010), I treated each nest visit as an individual observation. Beginning with a fully saturated model containing all explanatory variables, I used manual stepwise selection to eliminate non-significant variables from the model, starting with the lowest F-value (i.e., least explanatory). I classified a variable as being non-significant if $P > 0.05$ based on Type III likelihood-ratio statistics. I removed the least explanatory, non-significant variable at each step until all remaining variables were statistically significant. Parameter estimates were derived from programmatic statements (LSMEANS and ESTIMATE) which I then inverse-link transformed into DSR estimates (Pieron 2010) and then into nest success percentages using a 35-day exposure period (Klett et al. 1988). To assess management impacts of habitat and treatment, weighted means ((nest success of habitat, treatment, and combination of habitat and treatment type) x (% of nests found in that habitat, treatment, and combination of habitat and treatment type)) were estimated.

RESULTS

Trapping Results

Trappers removed a total of 834 predators from a total of six trapped sites over the three years of this study (Table 1.1). Raccoons and Striped Skunks were the two most commonly trapped predators, consisting of 51.3% and 40.4% of the total catch, respectively. Trappers caught small numbers of other predators including; American Badger (3.3%), Red Fox (2%), Mink (1.4%), Weasel (0.8%), and Coyote (0.5%).

Table 1. Mammalian predators removed from 93.2 km^2 trap sites in eastern North Dakota from 15 March through 15 July 2010-2012.

Trapper	Year	Raccoon	Skunk	Fox	Badger	Coyote	Mink	Weasel	Total
1	2010	164	71	4	3	0	1	0	243
2	2010	70	69	1	5	0	2	0	147
1	2011	66	48	1	3	0	1	1	120
2	2011	20	36	2	9	2	2	1	72
1	2012	71	58	5	3	1	6	4	148
2	2012	37	55	4	5	2	0	1	104
Total		428	337	17	28	5	12	7	834

Nesting Results

In total, 1951 nests were found, of which 1,899 were used for analysis yielding 5,509 observations. Over the three years of the study, 557 nests were found in trapped fields and 144 nests were found in trapped ditches constituting 82% and 18% of the total trapped site nests, respectively. Conversely, 995 nests were found in control fields and 103 nests were found in control ditches constituting 91% and 9% of the total control site nests, respectively.

Following model selection, the final model included; the intercept, treatment (predator removal), site-within treatment, habitat (field vs. roadside ditch), nest age, initiation date, nest age^2, initiation date^2, and the habitat by treatment interaction (Table 1.2). Underdispersion was negligible ($\hat{c}$ = 0.9943) indicating that this is an appropriate model for this data set.

The effects of the trapping treatment had an overall positive significant effect on DSR (X^2 = 6.3, P = 0.0121). Overall nest success on trapped sites averages 38% while overall nest success on control sites averaged 25%. Habitat type (field vs. ditch) had a highly significant effect on DSR that varied by treatment (X^2 = 5.55, P = 0.0185). Model-based mean (LSMEANS; $\bar{X}$) estimates of nest success indicated that trapping increased nest success by 17% in larger fields ($\geq$80 acres) but did not have a significant effect on nest success in roadside ditches (Figure 1.2). The quadratic term of nest age had a distinct effect on DSR (X^2 = 8.05, P = 0.0046) but did not vary by treatment, habitat type, or the habitat type by treatment interaction. DSR appears to slowly decline during the egg laying stage, but then increases as the nest gets further in incubation (Figure 1.3). The quadratic term for nest initiation date also had a noticeable effect on DSR (X^2 = 12.27, P = 0.0005) but, like nest age, did not vary by treatment, habitat type, or the habitat type by treatment interaction. Nest success appears to be low for early initiated nests, then rises until the middle of the nesting season (just before the average initiation date), then slowly declines for the remainder of the nesting season (Figure 1.4).

Table 2. Variables affecting duck nest success during the 2010 - 2012 breeding seasons on both trapped and non-trapped 93.2 km^2 study sites. Variables with their respective F-Values, X^2 Values, and P-Values are shown.

Variable	**F-Value**	**Pr > F**	**Chi-Square**	**Pr > ChiSq**
Treatment	6.3	0.01	6.3	0.01
Site(Treatment)	26.74	<0.01	267.38	<0.01
Habitat	50.23	<0.01	50.23	<0.01
Habitat x Treatment	5.95	0.01	5.95	0.01
Nest Age	0.61	0.43	0.61	0.43
$(\text{Nest Age})^2$	7.84	<0.01	7.84	<0.01
Initiation Date	11.24	<0.01	11.24	<0.01
$(\text{Initiation Date})^2$	12.46	<0.01	12.46	<0.01

DISCUSSION

Results from the logistic-exposure model supported my first hypothesis that implementing the predator reduction treatment on low-grassland density landscapes had a positive effect on overall duck nest success. However, results did not support my second hypothesis in that the predator reduction treatment was not equally effective in both large fields and roadside ditches.

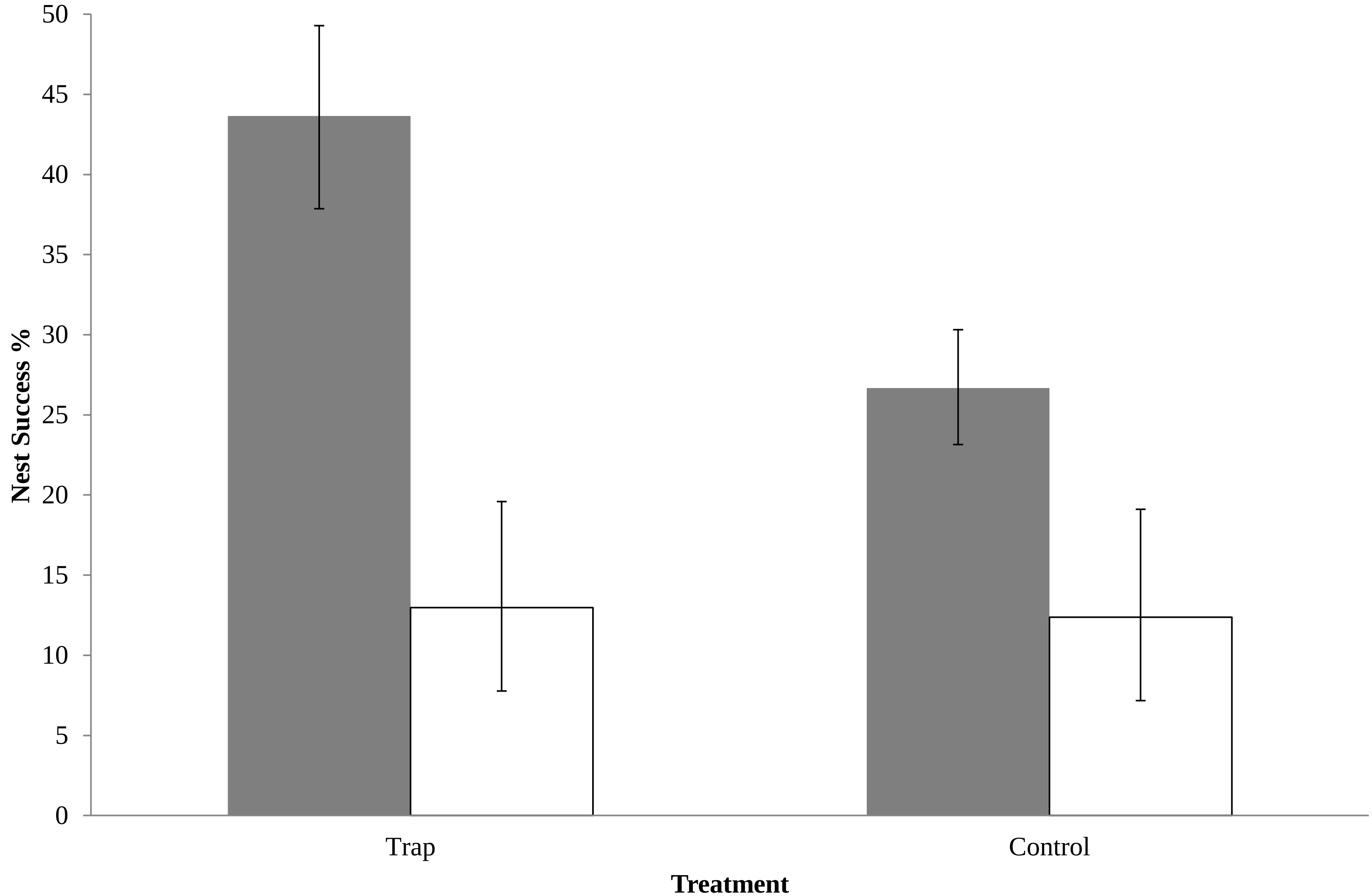

Figure 2. Model-based mean (LSMeans: $\bar{X}$) nest success with 95% confidence limits for nests in fields (grey bars) and roadside ditches (white bars) on trapped and control sites over 3 years on 93.2 km^2 study sites in eastern North Dakota.

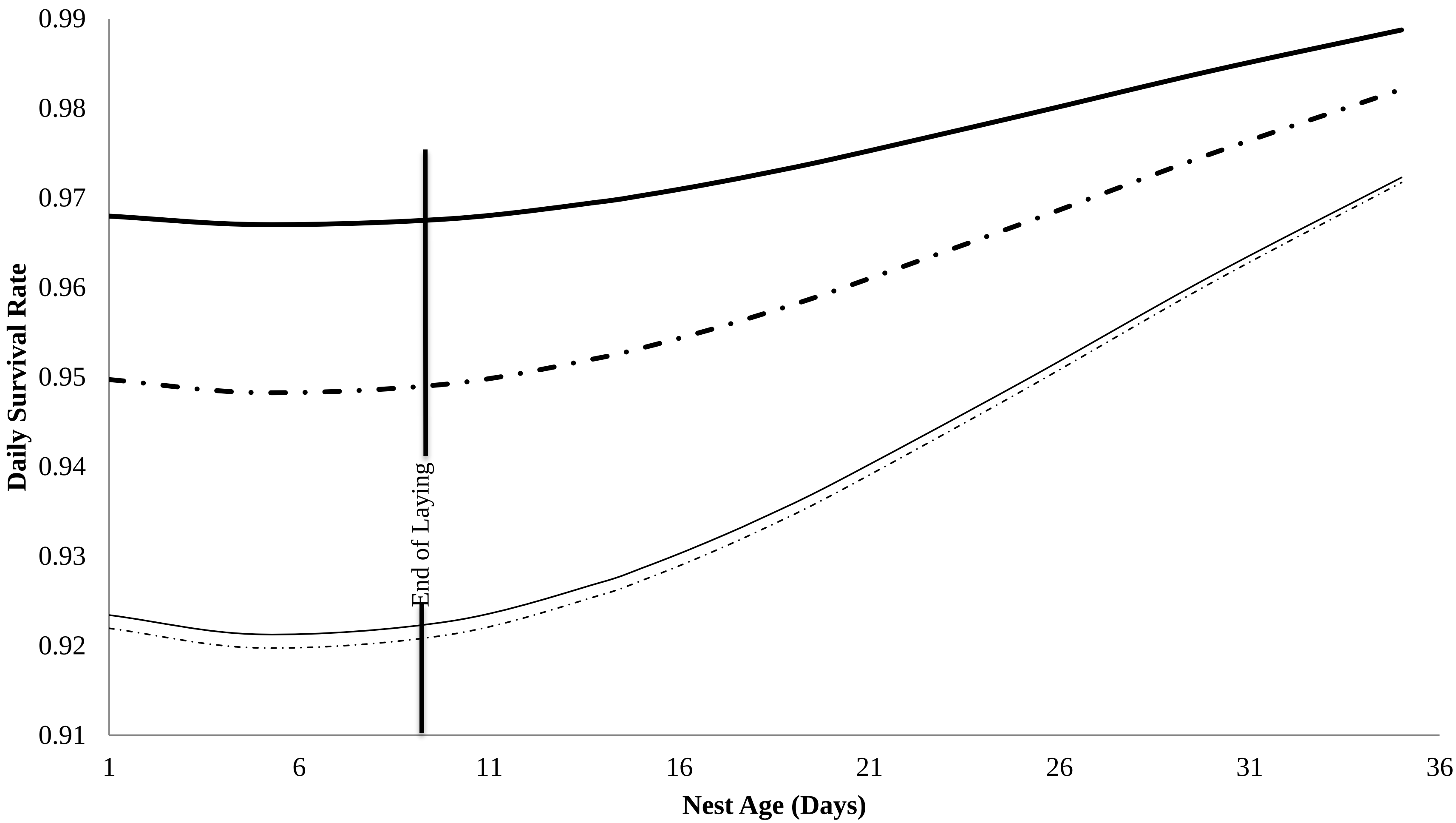

Figure 3. Model-based estimate of Daily Survival Rate in relation to nest age. This figure shows both the estimated DSR for trapped sites (solid lines) and control sites (dashed lines) as well as in fields (bold lines) and roadside ditches (thin lines). I weighted sites equally and held all other covariates at their means. The vertical solid line represents the end of the egg laying period, derived from the average clutch size of all nests. Although these relationships begin at different points, the overall trends (curves) are similar across the different treatments and habitat types which may be visually significant to wildlife managers.

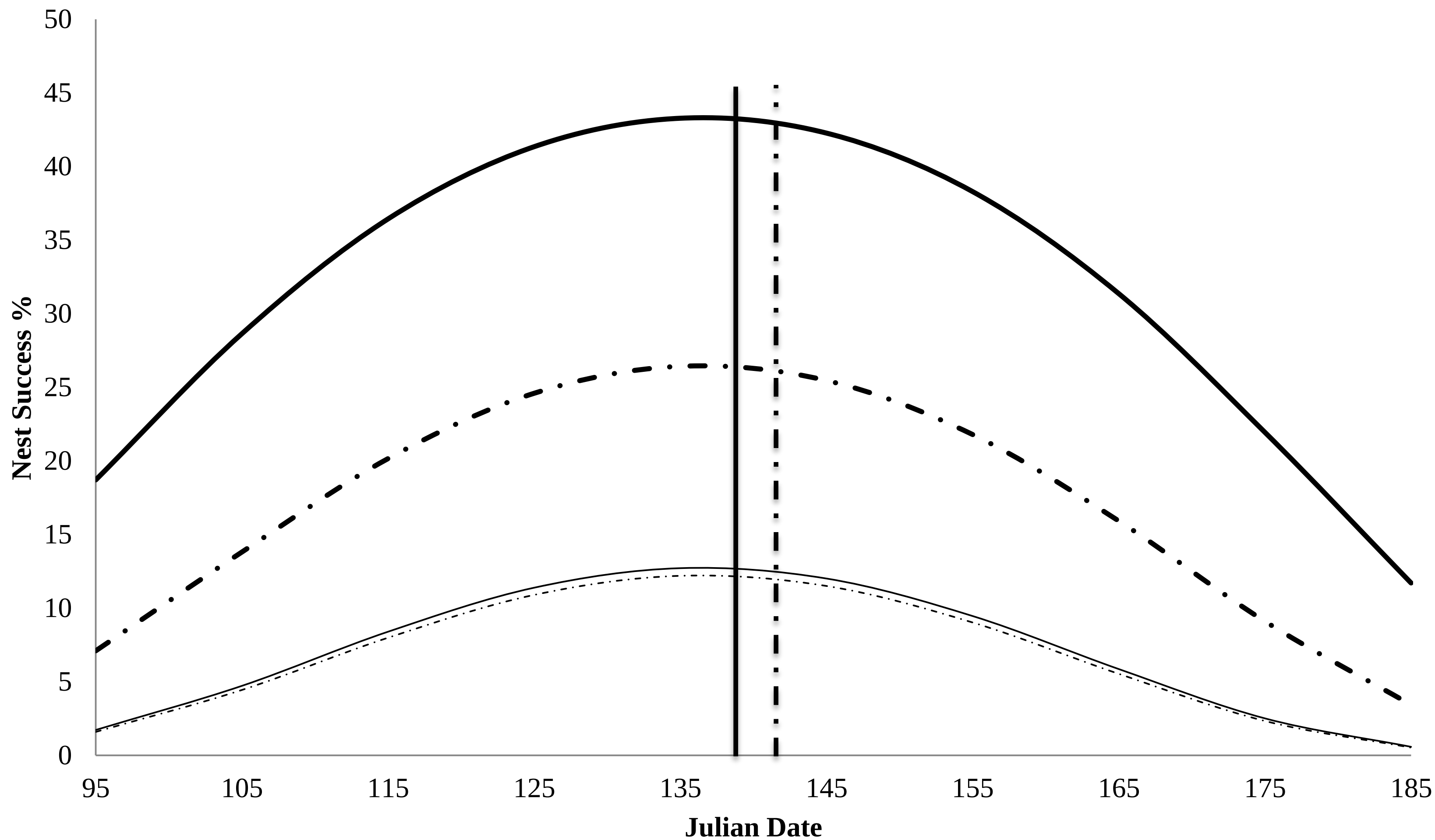

Figure 4. Model-based estimate of nest success in relation to nest initiation date. This figure shows both the estimated nest success on trapped sites (solid lines) and control sites (dashed lines) as well as in fields (bold lines) and roadside ditches (thin lines). I weighted sites equally and held all other covariates at their means. The vertical solid line represents the mean trapped initiation date and the vertical dashed line represents mean control initiation date. Although these relationships begin at different points, the overall trends (curves) are similar across the different treatments and habitat types which may be visually significant to wildlife managers.

My results indicated that nest success was higher in the trapped fields compared with their respective control fields, however, this pattern was not evident in the roadside ditches. Potentially, differences in methodology could explain the different outcome. However, although one method was ATV-based and one method was truck-based, each habitat type was searched with the same effort and frequency, suggesting that methodological differences were unlikely explanations. Access differed between habitats because I was unable to conduct searching efforts on all of the fields on each site due to being unable to attain permission from some private landowners. I was able to search all roadside ditches on each site because roadside cover is not owned by private landowners. Nesting hens also use wetland margins (narrow grass buffer surrounding wetland) (Klett et al. 1988, Reynolds et al. 2001). However, this type of habitat was not searched during this study due to lack of accessibility and availability. Therefore, the effects of predator reduction in wetland margins are unknown.

To estimate the overall effect of predator reduction, I took a weighted mean of the nest success estimates of the fields and the ditches for each treatment. When I took the weighted mean by treatment, trapped sites had a nest success estimate of 38% while control sites had a nest success of 25% indicating that predator reduction increased nest success by 13% overall. This effect size is smaller than that found in other predator reduction studies (e.g. Pieron and Rohwer 2010, 17% - 35% nest success increase with trapping on moderate to high-grassland density landscapes), but I believe this smaller effect size is a result of low-grassland density landscapes having lower nest success in general than moderate to high-grassland density landscapes (Horn et al. 2005).

Despite differences in nest success between habitats, overall 25% nest success was above the population maintenance threshold of 15%. However, I believe that one control site out of six significantly influenced the estimate. Mayfield nest success estimates (as modified by Johnson 1979) on the six control sites are as follows; 7%, 8%, 10%, 11%, 28%, and 64%. The control site with 64% nest success drastically increased the nest success estimate for fields on control sites. On this particular study site, there were two fields in close proximity whose combined area equaled ~ 220 acres. Between these two fields, 320 nests were found and nest success was 72% compared to 15% nest success for the 40 nests found on the remainder of the site. There are a few possibilities as to why these two "hot spots" (Reynolds et al. 2001) experienced higher nest success and higher nest density than the remainder of the site. One is that there were little to no corridors (fence lines, field edges, tree lines) leading into the area, which predators use for mobility (Horn et al. 2005, Frey and Conover 2006). This would essentially turn these two fields into grass islands, which can experience high nest density and success (Duebbert et al. 1983), in a landscape of agricultural fields. Another possibility is that there may have been an abundance of alternate prey (rodents) in these two fields, which has been found to increase duck nest success (Brook et al. 2008). A third possibility is that these fields had high nest density and high nest success purely by chance. Richkus (2002) conducted a three year study in which nest success in grassland habitats (much like these fields) the first year was only 6%. In the second year, there was an unexplained spike in nest success (37%) followed by a decline in nest success the third year (6%). Any of these possibilities, or a combination of them, could explain the high nest success and nest density in these two fields. Unfortunately, these fields were only searched for one year of the study, so it is unclear what may have been the true cause of these "hot spots".

Roadside ditch nest success (12-13%) and nesting effort (9-18% of all nests found) was significantly lower than success and effort in large fields. Klett et al. 1988 and Reynolds et al 2001 found a reduced hen preference to roadside ditches, compared to large fields, and Klett et al. 1988 found lower nest in roadside ditches when compared to large fields. My results were consistent with these studies in that, on both trapped and control sites, a smaller percentage of nests were found in ditches as opposed to fields and nest success was lower in the ditches than in the fields.

Predator reduction was ineffective at increasing nest success in roadside ditches (trapped ditches (13% nest success), control ditches (12% nest success)) and roadside ditches had lower nest success than fields regardless of treatment. I suspect this is due to greater accessibility of nests in the ditches to nest predators. Since mammalian predators use man-made roads as a means of traveling (Frey and Conover 2006) and roadside ditch width ranges only 0.5 m – 10 m in this region, nesting hens are not far from the edge of the road that the predator is using as a travel lane. I suspect a single predator can destroy numerous nests as it travels down a section of road.

Effectively trapping the roadside ditches for predators is a difficult task. On a given study site, there ranged between 80 – 120 km of roadside ditch. As opposed to large fields, where predators travel along edges and trails making it relatively easy for trappers to choose where to place traps, there are a multitude of access points that a predator could use to enter a ditch from the road. Trapping may not have been effective in the roadside ditches. Trapping efficiency is highest when a predator has a high probability of encountering and a high probability of becoming captured by the trap. In roadside ditches, the probabilities of encounter were likely low because of easy avoidance (i.e., predators not restricted to confined access points) and low intensity of trapping because trappers avoided setting traps near highly travelled roads to reduce negative public reaction, theft, and accidental trapping of pets (J. Brice, Delta Waterfowl Foundation, pers. comm). Presumably, once encountered, the probability of capture was the same between fields and ditches, and the lower encounter probabilities were more likely responsible for less effective trapping in ditches and less impact on nest success.

The effects of nest age on DSR in this study were consistent with the findings of Pieron and Rohwer (2010) in that there was a non-linear age effect on DSR. Figure 1.3 shows a slight decline in DSR from initiation until just after the end of the egg laying stage when a more linear relationship between nest age and DSR begins. I believe that the lower DSR early in incubation represents the hens that nest in risky areas, such as near a predator den or near a predator pathway, being detected by predators early in incubation (Garrettson and Rohwer 2001, Pieron and Rohwer 2010). Nests in high-risk areas are more likely to be found early in the nesting cycle and nests in safer areas have an increased chance of survival because they are not as likely to be detected (Klett and Johnson 1982, Pieron 2010). Nest attendance in relation to nest age may also have had an effect on DSR. Hens spend more time on the nest as they transition to incubation from egg laying (Klett and Johnson 1982, Caldwell and Cornell 1975) and begin nocturnal incubation 1-5 days after clutch completion (Afton and Paulus 1992, Loos and Rohwer 2004). Hens are more likely to be present on a late stage nest and therefore attract predators. As incubation stage increases, a nesting hen will allow predators to get closer to the nest before flushing (Forbes et al. 1994) creating a distraction to draw predator attention away from the nest, which may reduce egg depredation (Klett and Johnson 1982). While drawing attention to her may decrease hen survival, the possibility of leading a potential nest predator away from the nest may increase nest survival.

Results on the effects of nest initiation date on DSR were also consistent with the findings of Pieron and Rohwer (2010) in that there was a non-linear initiation date effect on DSR. Figure 1.4 shows a low DSR at both the beginning and the end of the breeding season.

However, DSR is high in the middle of the nesting season, which coincides with both the average initiation date on trapped sites, 19 May (Julian date 139), and the average initiation date on control sites, 23 May (Julian date 143). I believe that the abundance of nests in the middle of the breeding season diluted the percentage of nests destroyed by predators which ultimately led to higher DSR. Distribution of nests by initiation date between treatments was examined, but there was no noticeable trend that would indicate a difference in initiation pattern between the two treatments.

While mean estimates of nest success indicated a 13% increase in nest success as a result of predator reduction, I believe that this effect size would have been larger had the red fox population been higher. Red foxes have a major impact on nest success of upland nesting ducks (Sargeant et al. 1984) as they are known to be responsible for 27% of all nest depredation events (Sovada et al. 1995). Red foxes constituted only 2% of the total predators removed over the three years of this study. Removing 17 red foxes during the study equated an average of 0.03 red foxes removed/km^2 which is significantly less than Garrettson and Rohwer (2001) (1.9 foxes removed/km^2) and is comparable to Pieron and Rohwer (2010) (0.049 foxes removed/km^2) (Figure 1.6).

Chodachek and Chamberlain (2006) and Pieron and Rohwer (2010) noted that during their studies the red fox population in this area had been drastically reduced by an outbreak of sarcoptic mange, which would decrease the number of depredated nests due to red fox predation. It appears, from comparing my results with Pieron and Rohwer (2010), the red fox population has yet to recover from the mange outbreak. If/when the population does recover, I expect that nest success on non-trapped sites will considerably decrease and the effect size between nest success on trapped sites versus non-trapped sites will increase.

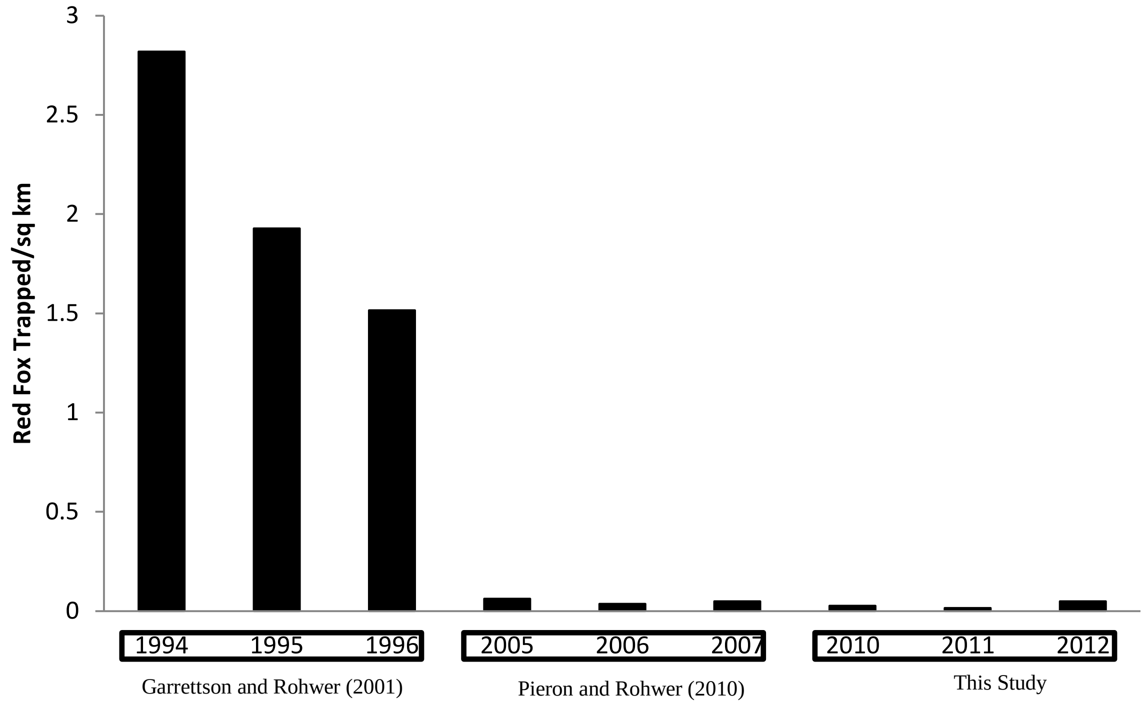

Figure 5. Average numbers of red fox removed/km^2 during the Garrettson and Rohwer (2001) study, the Pieron and Rohwer (2010) study, and this study.

MANAGEMENT IMPLICATIONS

Predator reduction is an effective management tool that can be implemented on township sized, low-grassland density landscapes. Even though predator trapping did not significantly increase nest success in roadside ditches, it had an effect in the larger grass fields, which had far more nests than roadside ditches. Breeding duck populations were higher in 2012 than they have ever been on record (USFWS 2012), so there is no need for immediate intensive management, such as predator reduction, to increase nest success. However, if land enrolled in CRP in the PPR continues to decline at its current rate, a drought hits the PPR, and/or red fox populations recover from the mange outbreak, then intensive management may be a valuable tool to increase nest success. As a result of this study, I recommend that wildlife managers, whose goal is to increase duck nest success, implement predator reduction on landscapes with low-grassland densities and high breeding pair densities. I also recommend that future predator reduction research be conducted to evaluate the efficacy of alternative trapping techniques in roadside ditches to determine if the predator reduction treatment can be effective at increasing nest success in roadside ditches.

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