2003

Experimental predator removal: a response in small mammal communities and relations to duck nest success

Jeremy Paul Adkins
Louisiana State University and Agricultural and Mechanical College

EXPERIMENTAL PREDATOR REMOVAL: A RESPONSE IN SMALL MAMMAL COMMUNITIES AND RELATIONS TO DUCK NEST SUCCESS

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in
The School of Renewable Natural Resources

by
Jeremy Paul Adkins
B.S. Louisiana State University, 2001
May, 2003

ACKNOWLEDGEMENTS

I start by thanking my advisor, Dr. Frank C. Rohwer for hiring me to work for Delta Waterfowl and Wetlands Research Station and for accepting me as a graduate student at Louisiana State University. I also graciously thank him for all his patience, guidance, editorial comments, and available spots in the duck blind during the past few years. I also thank my advisory committee members, Dr. Mike Chamberlain and Dr. Vernon Wright for their comments and advice during my graduate studies.

This project was funded by the Delta Waterfowl Foundation. I would like to thank all the staff at Delta for their help and for providing me with this wonderful opportunity. I especially thank Scientific Director, Dr. Serge Lariviere, and Delta Trustee Mark Mattox for their support thorough my project.

A big thanks goes to Kristen Chodachek for allowing me to work on her field sites. Without her, my thesis would not exist. I also thank her for the predator and nest success data that follows in this text. I also thank Kristen and Andrea Hoover for keeping me fed during the two summers I spent collecting data.

Last but not least, I thank my parents Charlie and Jackie Adkins, my sister Christie, and fiancée Megan Smith for all the years of love, support, and encouragement that they have provided to me.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Reducing predator populations in the prairie pothole region can greatly increase nest success of both over water and upland nesting ducks. However, little is understood about impacts of predator removal on other wildlife within the same area. I conducted a field experiment to test whether small mammals, primarily mice (*Peromyscus sp.*) and voles (*Microtus sp.*), responded to seasonally reduced predator abundance. I compared small mammal abundance on 10 experimental (259 ha) sites in North Dakota during 2001 and 2002 with intensive, seasonal predator trapping with 10 control sites (259 ha) also monitored in both years. Small mammals were more abundant on sites where predators had been removed ($F_{3, 132}$= 44.45, P<0.001), suggesting that small mammals responded numerically to a reduction of medium-sized carnivores. However, levels of small mammals were comparable in both springs, suggesting that enlarged populations of rodents in summer and early fall were not sustained through winter. I also observed a strong positive relationship between small mammal abundance and duck nest success (r = 0.84, P = 0.002 in 2001; r= 0.82, P = 0.004 in 2002), suggesting a possible buffer effect small mammals may have on predation of waterfowl nest.

INTRODUCTION

Low nest success, which largely reflects high nest predation, is viewed as the most important limitation on waterfowl productivity in the Prairie Pothole Region (PPR) (Cowardin et al. 1985, Greenwood et al. 1987, Johnson et al. 1989). Intensive cultivation has reduced grassland habitat so that remaining nesting patches are relatively easy for predators to search (Cowardin et al. 1985, Greenwood et al. 1987, Klett et al. 1988). Medium sized predators such as striped skunk (*Mephitis mephitis*), red fox (*Vulpes vulpes*), and raccoon (*Procyo*n *lotor*) have increased due to eradication or reduction of populations of large predators such as wolves (*Canis lupus*) and coyotes (*Canis latrans*), intensification of agriculture, and increased numbers of trees on the prairies (Stoudt 1971, Cowardin et al. 1983, Sargeant et al. 1993). Cowardin et al. (1983) estimated that 70% of duck nest failures were due to predation, which are compounded by loss of adult ducks to predators on the breeding grounds.

One of the most common management techniques used to increase nest success is planting cover. However, nest success from managing planted cover alone has provided variable results and limited benefits (Clark and Nudds 1991, Sargeant et al. 1995, McKinnon and Duncan 1999). Improved nest success associated with the Conservation Reserve Program (CRP) suggests that landscape-level additions of nesting cover improve recruitment (Reynolds et al. 2001), but habitat improvement on this scale is not economically feasible for waterfowl conservation groups (Kantrud 1993). Intensive management efforts to make nests inaccessible, such as construction of islands and predator barrier fences, can increase nest success, but costs are high (Lokemoen et al. 1982, Greenwood et al. 1990, Lokemoen and Woodward 1993).

Recently, some waterfowl management on the prairies has focused on directly reducing local predator populations to increase nest success. Early studies demonstrated that reducing predator numbers could dramatically increase nest success (Balser et al. 1968, Lynch 1972, Duebbert and Kantrud 1974). However, these studies used poisons as a removal technique, which is no longer legal or acceptable to managers or the public. Recent work provided evidence that predator population reduction by trapping without the use of toxicants can greatly improve nest success in upland nesting ducks (Garrettson et al. 1996, Garrettson and Rohwer 2001). Recent studies of effects of predator control on duckling survival suggest that trapping also improves this component of production (Zimmer 1996, Pearse 2002). Direct predator control remains highly controversial, partially because effects on other wildlife within the ecosystem are not known (Sovada et al. 1995, Leopold and Chamberlain 2002). Dion et al. (1999) hypothesized that removing meso-carnivores would allow release of small mammal populations (Wade-Smith and Verts 1982) and negatively impact songbirds (Maxon and Oring 1978, Bayne and Hobson 1997). However, data from songbird nests and experiments with artificial eggs did not show any effect of predator trapping on songbird success (Dion et al. 1999).

I conducted an experimental, multiyear study to determine how small mammals, primarily mice (*Peromyscus sp.*) and voles (*Microtus sp.*), respond to seasonally reduced predator numbers. I compared small mammal abundance on areas where predators were intensively trapped to areas where predator populations were not altered. I also examined relationships between small mammals, duck nest success, and predator activity on all sites.

STUDY AREA

My study was conducted during 2001 – 2002 on 20 sites in Cavalier, Ramsey, and Towner counties in north-central North Dakota that were each 259 ha. This area is commonly referred to as the Northeastern Drift Plain sub-region of the Prairie Pothole Region (PPR) of North Dakota. This region has little topographic relief and is dominated by small-grain agriculture (Garrettson et al. 1996). I used the same 20 sites both years. All sites had numerous wetlands and at least 25% of the land at each site was grassland created by the Conservation Reserve Program (CRP) or managed as Waterfowl Production Areas (WPA's) by the United States Fish and Wildlife Service. Each site was assigned to either removal or non-removal treatment, which were repeated both years on each site. Removal sites were subjected to intensive predator trapping, whereas non-removal sites were not trapped (Garrettson et al. 1996).

METHODS

Predator Removal

One experienced trapper was hired to remove skunks (*Mephitis mephitis*), red foxes (*Vulpes vulpes*), raccoons (*Procyon lotor*), and mink (*Mustela vison*) from removal sites both years using body-gripping traps, snares, foothold traps, and shooting. Due to logistic constraints, trapping in 2001 did not begin until mid-April and ended in late July. In 2002 trapping began in late March and ended in late July. Predator removal was conducted under United States Fish and Wildlife special use permit DLWMD-02-002 and approved by the Louisiana State University Animal Care and Use Committee (A01-03).

Indexing of Predator Activity

Linhart and Knowlton (1975) suggested that the scent-station technique developed by Cook (1949) and Wood (1959) to monitor gray and red fox was the best way to assess trends in abundance of many predators. Twelve randomly distributed stations were distributed on each site. Each scent station consisted of a circle of sifted soil or sand 1 m in diameter. Synthetic fatty acid scent (FAS) tablets were used as an attractant, and placed in the middle of each circle. Stations were checked in the morning for 3 consecutive days coinciding with each small mammal sampling period. A visit was defined as a track or tracks of 1 or more individuals at a station. Only coyote, red fox, raccoon, skunk, mink, and badger tracks were used in analyses. All were grouped into a general carnivore category for analyses. Total number of visits per station per site per treatment was used to give a general idea predator activity on removal and non-removal sites.

Small Mammal Sampling

Small mammals were monitored during four sampling periods each year on all sites. There are several species of mice and voles present in the study area, however only *Peromyscus sp.* and *Microtus sp.* were used in analyses. Three samples were taken during the summer (May, June, and July) coinciding with the trapping of predators and one sample was taken in October 2 months after predator trapping has ceased and just prior to the onset of winter. Sherman live-traps were placed in a 5 x 5 grid with ten m spacing between each trap. Each site had 3 trapping grids for a total of 75 traps per site. Traps were baited with rolled oats in peanut butter (Birney et al. 1976, Healy and Brooks 1988, Sullivan et al. 1998, Jorgensen and Demarais 1999). Traps were checked each morning and closed, then reset in the afternoon for 3 consecutive nights, which gave 225 trap nights per site per sampling period. Species of each captured animal was recorded and animals were toe-clipped for individual identification and released. Any animal genus captured other than *Peromyscus* or *Microtus* was released without being marked. Small mammal sampling protocol was approved by the Louisiana State University Animal Care and Use Committee (A01-03).

Waterfowl Nest Searching

Nest searching was conducted 3 times on each site between late April and early July. Sites searched varied in size from 65-259 ha of actual nesting habitat. Nests were located using a 2-person crew using all-terrain vehicles to drag a 50m chain (Klett et al. 1986). Nest searching occurred between 0800 and 1400 to increase the chance of finding a female on her nest (Gloutney et al. 1993). Nests were marked with white lathe 15m north of the nest with an orange 3mm welding rod placed at the nest. Upon nest

discovery, time, date, species, clutch size, and incubation stage (Weller 1956) were recorded. Nests were revisited every 7-10 days to determine nest fate (Klett et al. 1986). A nest was categorized as abandoned, destroyed, or successful if one egg hatched (see Chodacheck 2003).

STATISTICAL METHODS

Small Mammal Abundance

Small mammal abundance was calculated as a catch per unit effort index. Since trapping effort on small mammals was constant over all sites and trapping periods, the total number of rodents caught on all three grids per night per site per sampling period were averaged by treatment and used in analyses. I used a MIXED (PROC MIXED, SAS Institute 1999) model in a completely randomized design to determine if small mammal abundance differed between treatments (removal and non-removal) replicated over all time intervals. The model tested was small mammal index as the dependent variable and treatment, year, and time (month) as the independent variables. All interactions were included but only those significant were retained in the final model. LSmeans and standard errors were calculated for total small mammal indices by treatment and year using the LSMEANS statement (Proc Mixed, SAS Institute Inc. 1999) adjusted by the Tukey-Kramer method (Fruend and Wilson 1997). This model was treated as a repeated measures design for site and time because multiple samples were taken from the same sites.

Predator Activity

I used a MIXED (PROC MIXED, SAS Institute 1999) model in a completely randomized design to examine effects of treatments on small mammal captures. In this model my dependent variable was my index of predator activity and treatment, year, and time (month) were independent variables. The same effects and interactions in my small mammal model were present in this analysis.

Nest Success

To estimate nest success, total exposure days were converted to daily survival rates (DSR) for nests using the Mayfield method (Mayfield 1961) as modified by Johnson (1979). To test for differences in DSR between trapped and non-trapped sites, an analysis of variance (ANOVA, Proc Mixed, SAS Institute Inc. 1999) weighted by exposure days with the interaction between site and treatment as the random effect was used. Nests were excluded from the analysis if they were abandoned due to investigator activity, included only infertile eggs, or resulted in no fate determination (Greenwood et al. 1995). Species included in this analysis were mallards, northern pintails, gadwall, blue-winged teal, and northern shoveler.

Small Mammals and Nest Success

Correlations (Proc Corr, SAS Institute Inc. 1999) were used to examine relations between duck nest success and indexed small mammal abundance by year and treatment. Only small mammal indices from the summer months (May, June, and July) coinciding with waterfowl nesting were used.

RESULTS

Predator Removal

The trapper removed 330 predators in 2001 and 344 in 2002 throughout the study (Table 1). Skunk, raccoon, and mink were the most commonly taken predators, comprising 49, 26, and 17 percent respectively. Badger accounted for 7 percent of the total, whereas red fox only accounted for 2 percent. The remaining 1 percent consisted of coyote (*n*=4) and Franklin's ground squirrel (*n*=2).

Table 1. Number and species of mammalian predators trapped on removal sites in Cavalier, Ramsey, and Towner Counties, North Dakota 2001 and 2002.

Species	2001	2002	Total
Badger	18	15	33
Coyote	1	3	4
Franklin's Ground Squirrel	1	1	2
Mink	56	58	114
Raccoon	95	83	178
Red Fox	12	4	16
Skunk	147	180	327
Total	330	344	674

Small Mammal Sampling

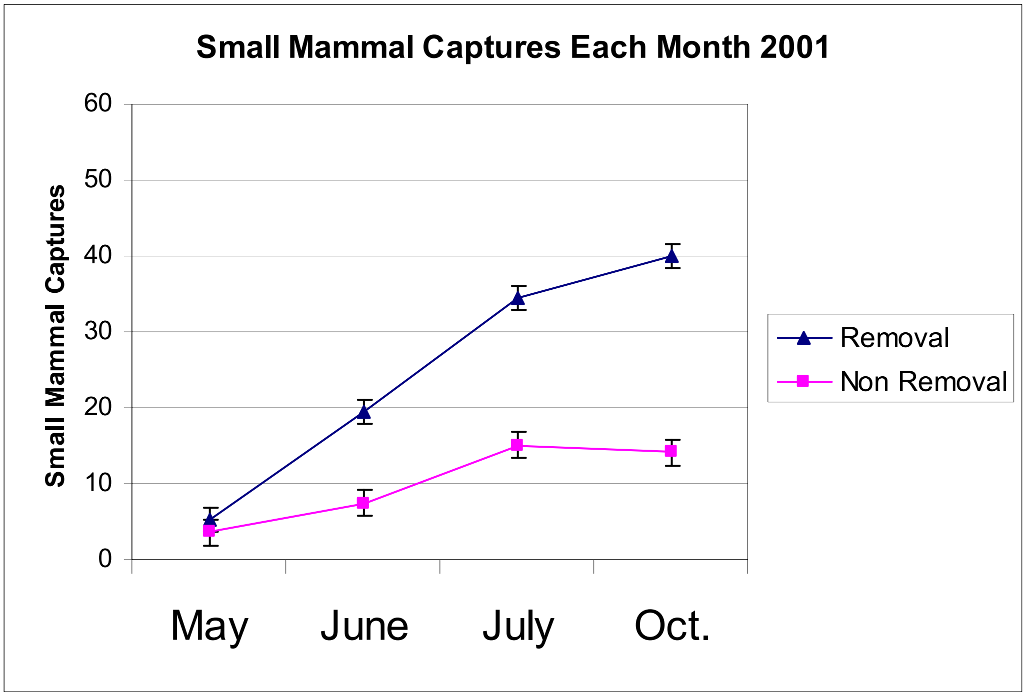
A total of 3,271 mice and voles were caught and released in this study. Voles constituted 72% (*n*=2355) of our sample, with mice taking up the remaining 28% (*n*=916). In 2001, 1,392 small mammals were captured, of which, voles represented 58% (*n*=812) and mice accounting for 42% (*n*=580) of the sample. In 2002, 1,879 voles and mice were captured with voles being 82% (*n*=1543) and mice being 18% (*n*=336) of the sample. I recaptured very few animals; however recaptures were not recounted and

added to the index. Trap mortality was minimal and restricted to the hotter days in July. Trap killed animals were not included in analyses.

My indices of small mammals showed a treatment effect ($F_{1, 18}$ = 216.38, P<0.001), a year effect ($F_{1, 18}$ = 55.43, P<0.001), and a time effect ($F_{3, 126}$ = 197.26, P<0.001), but the only interaction present was a treatment by time effect ($F_{3, 126}$ = 44.13, P<0.001). I caught more small mammals on predator removal sites compared to sites where predators were not trapped during June, July, and October (Figure 1). Small mammals increased on both removal and non-removal sites over trapping periods, however, the increase on removal sites was greater than control sites (Table 2) (Figure 1). Small mammal captures did not differ in May both years and both May 2001 and 2002 indices were at comparable levels (Table 2).

Table 2. Average number of small mammals (LSmeans) ± SE caught during sampling periods for removal (n=10) and non-removal (n=10) sites for 2001 and 2002.

Sampling Period	Removal Sites 2001	Non-removal sites 2001	Removal Sites 2002	Non-removal sites 2002
May	5.3 ± 2.66	3.6 ± 1.58	9.5 ± 1.96	5.9 ± 2.23
June	19.6 ± 5.89	7.4 ± 1.89	27.6 ± 4.50	12.6 ± 4.27
July	34.4 ± 8.68	15.1 ± 5.87	44.4 ± 5.52	19.0 ± 6.87
October	40.1 ± 7.74	14.2 ± 3.88	48.6 ± 8.99	20.3 ± 5.25



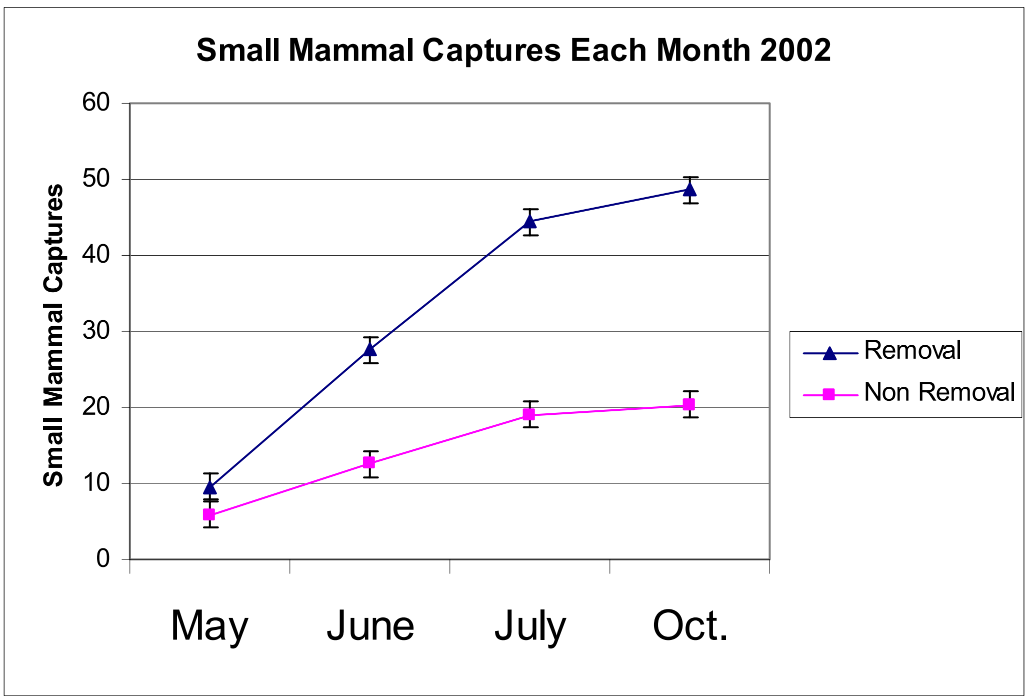


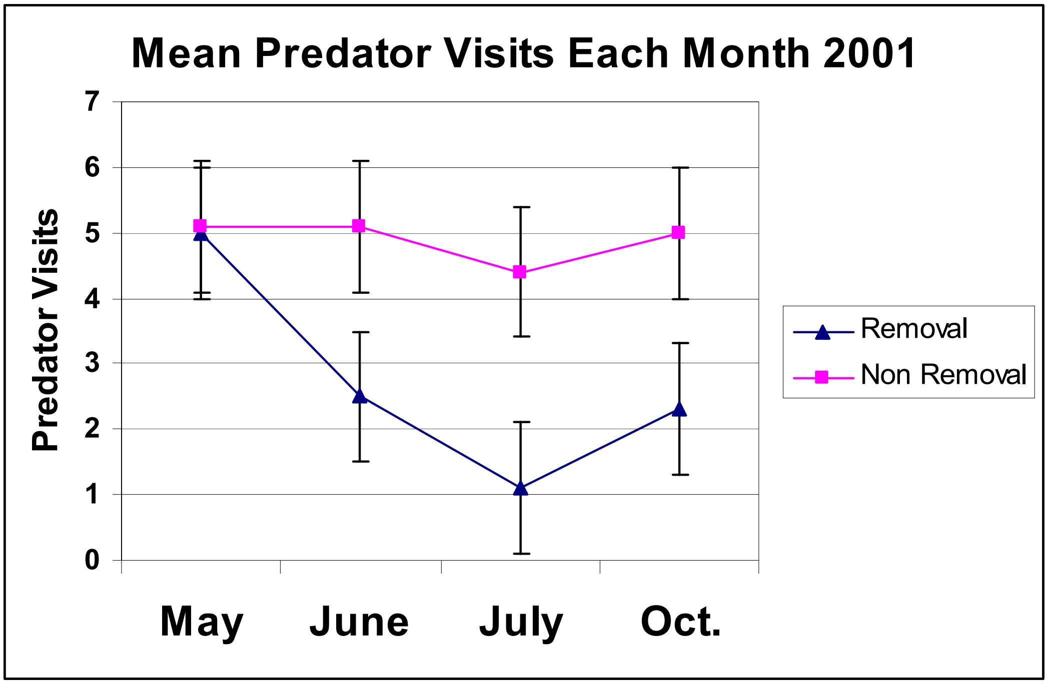
Figure 1. Number of small mammals captured on removal (n=10) and non-removal (n=10) sites (LSmeans with SE bars) for 2001 (top figure) and 2002 (bottom figure) plotted by sampling period.

Predator Activity

Predator activity showed a treatment effect ($F_{1, 18}$ = 156.38, P<0.001), a year effect ($F_{1, 18}$ = 61.13, P<0.001), and a time effect ($F_{3, 126}$ = 168.22, P<0.001), but the only interaction present was a treatment by time effect ($F_{3, 126}$ = 39.74, P<0.001). The number of predator visits at scent stations decreased from May to June (Figure 2) and then remained comparable throughout July and October on removal sites both years. Predator visits also differed between treatments in June, July, and October ($F_{3, 126}$ = 39.74, P<0.001), but not May, during both years. Predator visits to scent stations did not differ on non-removal sites throughout sampling periods either year (Table 3) (Figure 2).

Table 3. Average number of predator visits (LSmeans) ± SE to scent stations during sampling periods for removal (n=10) and non-removal (n=10) sites for 2001 and 2002.

Sampling Period	Removal Sites 2001	Non-removal sites 2001	Removal Sites 2002	Non-removal sites 2002
May	5.0 ± 1.24	5.1 ± 1.72	4.8 ± 1.75	4.8 ± 1.98
June	2.5 ± 1.84	5.1 ± 2.18	2.50 ± 1.51	5.1 ± 1.79
July	1.1 ± 0.87	4.4 ± 1.07	1.20 ± 0.78	5.1 ± 2.02
October	2.3 ± 0.94	5.00 ± 2.00	2.1 ± 0.73	5.1 ± 1.72



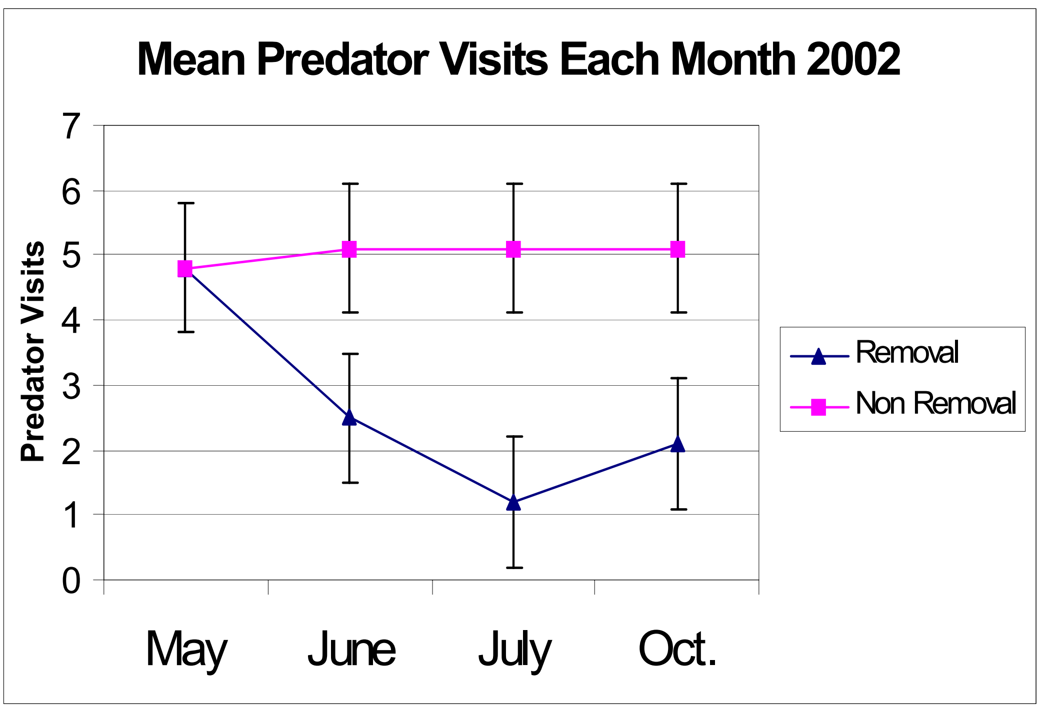


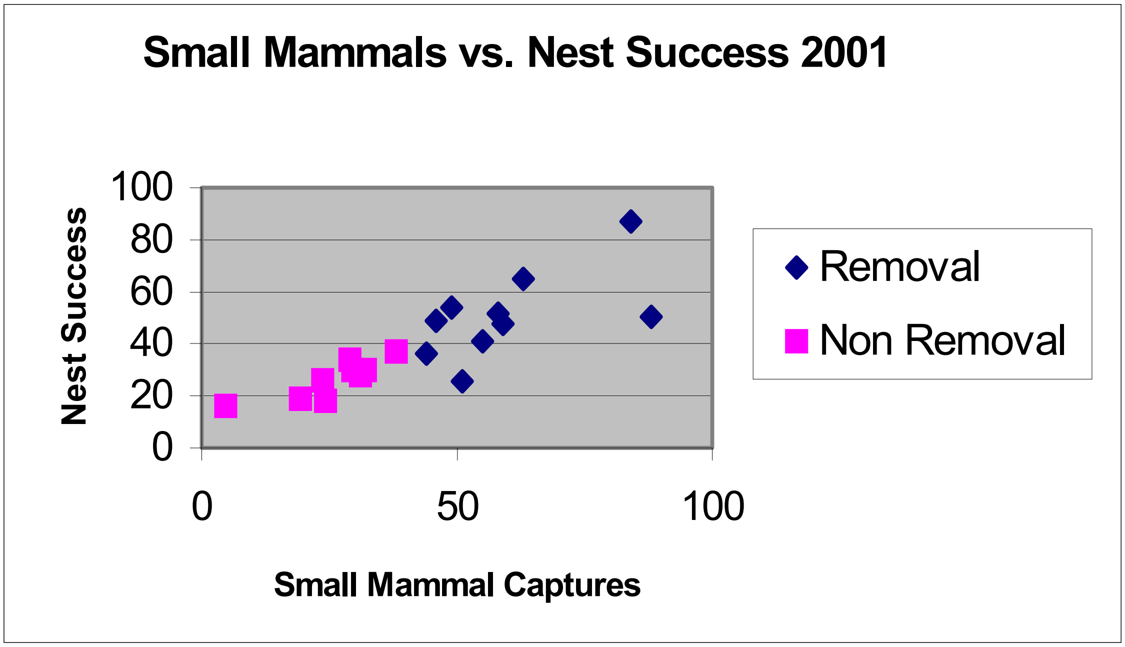
Figure 2. Number of predator visits at scent stations on removal (n=10) and non-removal (n=10) sites (LSmeans with SE bars) for 2001 (top figure) and 2002 (bottom figure) plotted by sampling period.

Nest Success

Overall, 4,389 nests were located, with 4,240 (97%) appropriate for analysis. Daily survival rate was greater on trapped sites (0.982 ± 0.002) than non-trapped sites (0.965 ± 0.003) for years combined ($F_{1, 18}$ = 21.92, P<0.001); however, no year or year by treatment effects were found. Mean Mayfield nest success on trapped sites (53.4%) was nearly double that of non-trapped sites (28.7%) for both years combined.

Small Mammals and Nest Success

My indices of small mammal abundance and nest success on sites where predators were untrapped were positively correlated both years (r = 0.85, P = 0.002 in 2001; r = 0.82, P = 0.004 in 2002) (Figure 3). There was a correlation between small mammal abundance and nest success on predator removal sites in 2001 (r = 0.63, P = 0.051), but not in 2002 (r = 0.47, P = 0.21).



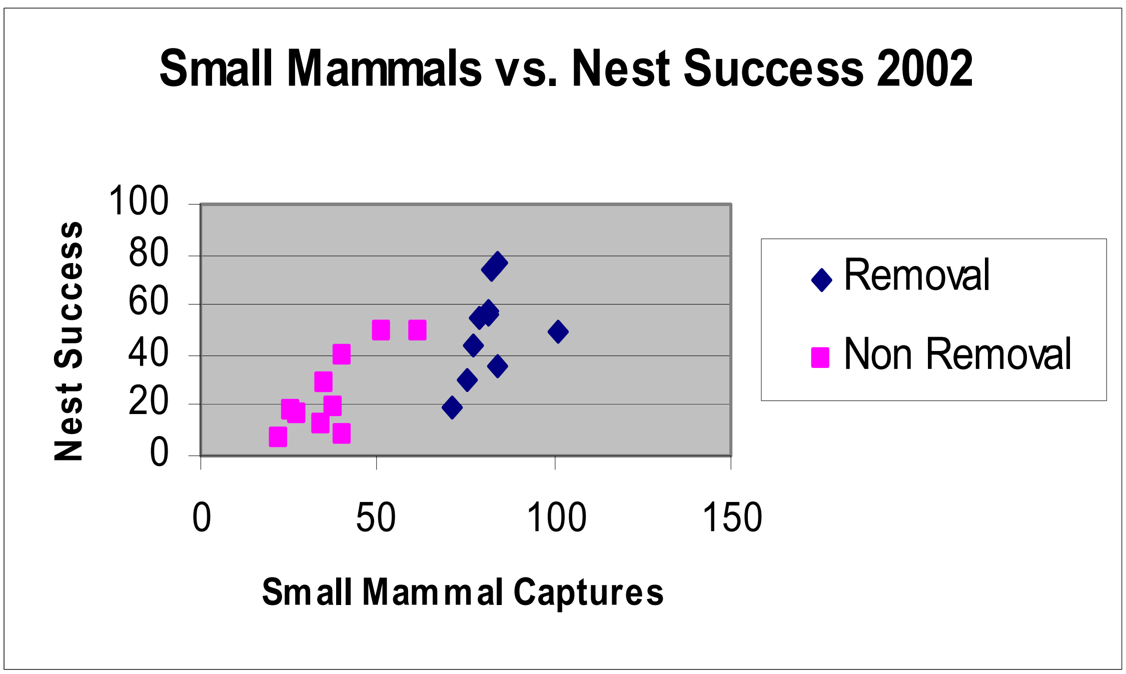


Figure 3. Number of small mammals caught during summer months (May, June, July) on predator removal (n=10) and non-removal (n=10) sites correlated with nest success estimates from 2001 (top figure) and 2002 (bottom figure).

DISCUSSION AND IMPLICATIONS

These results provide evidence from a replicated study that small mammal populations in the prairie pothole region respond with increased population growth due to trapping of medium-sized predators within a short period of time. Marcstrom et al. (1989) studied effects of experimental reduction of red fox and pine marten (*Martes martes*) on mountain hare (*Lepus timidus*) populations and found similar results. However, their study was conducted on an island and the results may not apply to mainland habitats with greater potential for animal movement (Kauhala et al. 1999).

The May small mammal indices did not differ between removal and non-removal sites in both years. These samples were taken only a month after predator trapping had started and the lack of a difference probably reflects predators that were not affected by trapping plus a time lag in small mammal response on removal sites. I detected differences in small mammal abundances in our June and July samples from both years. Mice and voles are able to produce young rapidly and small mammals on removal sites probably responded to a carnivore void while small mammals on non-removal sites were kept at moderate levels due to direct predation by carnivores. This artificial increase in small mammal numbers may cause concern among farmers, though the high October 2001 populations did not remain elevated after winter. Number of small mammals captured in May 2002 were comparable to May 2001 levels, presumably due to mortality caused by winter weather or predation by emigrant predators that filled voids after trapping of resident predators ceased on removal sites.

Mice and voles are important in the diet of the predators we removed (Wade-Smith and Verts 1982, Lariviere and Pasitschnick-Arts 1996) and they can have

substantial impacts on songbird nests (Maxon and Oring 1978, Bayne and Hobson 1997). My data shows that predator trapping leads to an increase in small mammals, which might negatively affect songbird nest success. However, Dion et al. (1999) did not demonstrate such negative effects of predator control on grassland songbird nest success on large plots (2560 ha) that were trapped for one season. Unfortunately, sample size of actual nests was low (Dion et al. 1999).

The impact of coexisting prey species on predation rates of duck nests is poorly understood, but it is possible that small mammals may buffer bird nests (Byers 1974, Dunn 1977, Angelstom et al. 1984, Summers and Underhill 1987). For instance, Blue-winged Teal (*Anas discors*) nest success was positively related with rodent densities (Byers 1974) and Oldsquaw (*Clangula hymealis*) duckling production was positively related to rodent population size (Pehrsson 1985). In this study nest success was highest on sites with the most small mammals, except on non-removal sites during 2002. There was still a positive relationship on non-removal sites in 2002, however that relationship was not statistically significant. The positive relationship suggests that high densities of small mammals may enhance success of duck nests. Duck nest predators might be encountering more small mammals than duck nests, and subsequently feeding on small mammals and not duck eggs.

A common argument against using predator control as a management tool is that predator control disrupts the ecosystem. However, the current predator community through much of the northern prairies and plains bears little resemblance to what was present before large scale agriculture dramatically altered the communities. Species that are important nest predators today were historically relatively rare or scattered in

distribution (Sargeant et al. 1993, Ball 1996). I did document that carnivore visits to scent stations was higher on non-removal sites, and that carnivore visits decreased on removal sites. However, the total number of carnivores trapped on removal sites did not differ between years, suggesting only a short-term disruption of carnivore density. Moreover, the increase in seasonal abundance of small mammals I documented in response to predator removal did not carry over to enlarged spring population in the second year of my research. This suggests that effects of predator removal on small short-term.

LITERATURE CITED

Angelstam, P., E. Lindstrom, and P. Widen. 1984. Role of predation in short-term population fluctuations of some birds and mammals in Fennoscandia. Oecologia 62: 199 – 208.

Ball, I. J. 1996. Nest predation and predator control: current perspectives on an old controversy. Proceedings of the International Waterfowl Symposium 7: 197 – 203.

Balser, D. S., H. H. Dill, and H. K. Nelson. 1968. Effects of predator removal on waterfowl nesting success. Journal of Wildlife Management 32: 669 – 682.

Bayne, E. M., and K. A. Hobson. 1997. Comparing the effects of landscape fragmentation by forestry and agriculture on predation of artificial nests. Conservation Biology 11: 1418 – 1429.

Birney, E. C., W. E. Grant, and D. D. Baird. 1976. Importance of vegetative cover to cycles of *Microtus* populations. Ecology 57: 1043 – 1051.

Byers, S. M. 1974. Predator-prey relationships on an Iowa waterfowl nesting area. Transactions of the North American Wildlife and Natural Resource Conference 39: 223 – 229.

Chodacheck, K. D. 2003. Evaluation of Repeated Removal of Mammalian Predators on Waterfowl Nest Success and Density. Thesis, Louisiana State University, Baton Rouge, USA.

Clark, R. G., and T. D. Nudds. 1991. Habitat patch size and duck nesting success: the crucial experiments have not been preformed. Wildlife Society Bulletin 19: 534 - 543.

Cook, A. H. 1949. Fur-bearer investigations. New York State Conservation Department Pittman-Robertson Project 1-R, Suppl. G, Final Report 57pp.

Cowardin, L. M., A. B. Sargeant, and H. F. Duebbert. 1983. Problems and Potentials for prairie ducks. Naturalist 34: 4 -11.

Cowardin, L. M., D. S. Gilmer, and C. W. Shaiffer. 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildlife Monographs 92.

Dion, N., K. A. Hobson, and S. Lariviere. 1999. Effects of removing duck nest predators on nesting success of grassland songbirds. Canadian Journal of Zoology 77: 1801 – 1806.

Duebbert, H. F., and H. A. Kantrud. 1974. Upland duck nesting related to predator reduction. Journal of Wildlife Management 38: 257 – 268.

Duebbert, H. F. and J. T. Lokemoen. 1980. High duck nesting success in a predator-reduced environment. Journal of Wildlife Management 44: 428 – 437.

Dunn, E. 1977. Predation by weasels (*Mustela nivalis*) on breeding tits (*Parus spp.*) in relationship to the density of tits and rodents. Journal of Animal Ecology 46: 644 – 652.

Freund, R. J., and W. J. Wilson. 1997. Statistical methods. San Diego, CA, Acedemic Press Inc. 684pp.

Garrettson, P. R., F. C. Rohwer, B. J. Mense, J. M. Zimmer, and N. Dion. 1996. Effects of mammalian predator removal on waterfowl and non-game birds in North Dakota. Transactions of the North American Wildlife and Natural Resources Conference 61: 94 – 101.

Garrettson, P. R., and F. C. Rohwer. 2001. Effects of predator removal on production of upland-nesting ducks in North Dakota. Journal of Wildlife Management 65: 398 – 405.

Gloutney, M. L., R. G. Clark, A. D. Afton, and G. L. Huff. 1993. Timing of nest searches for upland nesting waterfowl. Journal of Wildlife Management 57: 597 0 601.

Greenwood, R. J., P. M. Arnold, and B. G. McGuire. 1990. Protecting duck nest from mammalian predators with fences, traps, and a toxicant. Wildlife Society Bulletin 18: 75 - 82.

Greenwood, R. J., A. B. Sargeant, D. H. Johnson, L. M. Cowardin, and T. L. Shaffer. 1987. Mallard nest success and recruitment in prairie Canada. Transactions of the North American Wildlife and Natural Resources Conference 52: 298 – 309.

Greenwood, R. J., A. B. Sargeant, D. H. Johnson, L. M. Cowardin, and T. L. Shaffer. 1995. Factors associated with duck nest success in the prairie pothole region of Canada. Wildlife Monographs 128.

Hall, N. E. 1994. Effects of striped skunk removal on duck nest success in the Mission Valley, Montana. Thesis, University of Montana, Missoula, USA.

Healy, W. M., and R. T. Brooks. 1988. Small mammal abundance in northern hardwood stands in West Virginia. Journal of Wildlife Management 52: 491 – 496.

Johnson, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96: 651 - 661.

Johnson, D. H., A. B. Sargeant, and R. J. Greenwood. 1989. Importance of individual species of predators on duck nesting success in the Canadian Prairie Pothole Region. Canadian Journal of Zoology 67: 291 – 297.

Jorgensen, E. E., and S. Demarais. 1999. Spatial scale dependence of rodent habitat use. Journal of Mammalogy 80: 421 – 429.

Kauhala, K., P. Helle, E. Helle, and J. Korhonen. 1999. Impact of predator removal on predator and mountain hare populations in Finland. Annual Zoological Fennici 36: 139 – 148.

Klett, A. T., H. F. Duebbert, S. A. Fanes, and K. F. Higgins. 1986. Techniques for studying nest success of ducks in upland habitats of the prairie pothole region. U.S. Fish and Wildlife Service Resource Publication 158.

Klett, A. T., T. L. Shaffer, and D. H. Johnson. 1988. Duck nest success in the prairie pothole region. Journal of Wildlife Management 52: 431 - 440.

Lariviere, S, and M. Pasitschniak-Arts. 1996. *Vulpes vulpes*. Mammal Species 537: 1 – 11.

Leopold, B. D., and M. J. Chamberlain. 2002. Predator management: Here we go again? Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies. 56:in press.

Linhart, S. B., and F. F. Knowlton. 1975. Determining the relative abundance of coyotes by scent-station lines. Wildlife Society Bulletin 3: 119 - 124.

Lokemoen, J. T., H. A. Doty, D. E. Sharp, and J. E. Neaville. 1982. Electric fences to reduce mammalian predation on waterfowl nest. Wildlife Society Bulletin. 10: 318 - 323.

Lokemoen, J. T., and R. O. Woodward. 1993. An assessment of predator barriers and predator control to enhance duck nest success on peninsulas. Wildlife Society Bulletin 21: 275 - 281.

Lynch, G. M. 1972. Effects of strychnine control on nest predators of dabbling ducks. Journal of Wildlife Management 36: 436 – 440.

Marcstrom, V., B. K. Lloyd, and E. Engren. 1989. Demographic responses of arctic hares (*Lepus timidus*) to experimental reductions of red foxes (*Vulpes vulpes*) and martens (*Martens martens*). Canadian Journal of Zoology 67: 658 – 668.

Maxon, S. J., and L. W. Oring. 1978. Mice as a source of egg loss among ground-nesting birds. Auk 95: 582 – 584.

Mayfield, H. 1961. Suggestions for calculating nest success. Wilson Bulletin 87: 451 - 461.

McKinnon, D. T., and D. C. Duncan. 1999. Effectiveness of dense nesting cover for increasing duck production in Saskatchewan. Journal of Wildlife Management 63: 382 – 389.

Pearse, A. T. 2002. An experimental test of the effects of predator removal on mallard brood and duckling survival. Thesis. University of Idaho, Moscow, Idaho, USA.

Pehrsson, O. 1985. Duckling production of the oldsquaw in relation to spring weather and small-rodent fluctuations. Canadian Journal of Zoology 64: 1835 – 1841.

Reynolds, R. E., T. L. Shaffer, R. W. Renner, W. B. Newton, and B. D. J. Batt. 2001. Impact of the conservation reserve program on duck recruitment in the U.S. prairie pothole region. Journal of Wildlife Management 65: 765 – 780.

Sargeant, A. B., R. J. Greenwood, M. A. Sovada, and T. L. Shaffer. 1993. Distribution and abundance of predators in the Prairie Pothole Region that affect duck production. U.S. Fish and Wildlife Service Resource Publication 194. 96pp.

Sargeant, A. B., M. A. Sovada, and T. L. Shaffer. 1995. Seasonal predator removal relative to hatch rate of duck nests in waterfowl production areas. Wildlife Society Bulletin 23: 507 – 513.

SAS Institute Inc. 1999. SASOnlineDoc®, Version 8, SAS Institute Inc., Cary, North Carolina, USA.

Sovada, M. A., A. B. Sargeant, J. W. Grier. 1995. Differential effects of red fox and coyotes on duck nest success. Journal of Wildlife Management 59: 1 - 9.

Stoudt, J. H. 1971. Ecological factors affecting waterfowl production in the Saskatchewan parklands. U. S. Fish and Wildlife Resource Publication 99.

Sullivan, T. P., D. S. Sullivan, E. J. Hogue, R. A. Lautenschlager, and R. G. Wagner. 1998. Population dynamics of small mammals in relation to vegetation management in orchard agroecosystems: compensatory responses in abundance and biomass. Crop Protection 17: 1 – 11.

Summers, R. W., and L. G. Underhill. 1987. Factors related to breeding production of brant geese *Branta b. bernicla* and waders (Charadrii) on the Taimyr Peninsula. Bird Study 34: 161 – 171.

Wade-Smith, J., and B. J. Verts. 1982. *Mephitis mephitis*. Mammal Species 173: 1 – 7.

Weller, M. W. 1956. A simple field candler for waterfowl eggs. Journal of Wildlife Management 20:111 - 113.

Wood, J. E. 1959. Relative estimates of fox population levels. Journal of Wildlife Management 23: 53 – 63.

Zimmer, J. M. 1996. Effects of predator reduction on the survival and movements of northern shoveler broods. Thesis, Louisiana State University, Baton Rouge, USA.

VITA

Jeremy Paul Adkins was born on June 7, 1978, in Lake Charles, Louisiana. Early in his childhood, his passion and appreciation for nature and the outdoors were developed and nurtured through frequent hunting trips taken with his father, Charles Adkins, and grandfather, Lon Adkins. Jeremy grew up in Lake Charles, only minutes away from the best hunting and fishing in the country. There he graduated from A. M. Barbe High School in the spring of 1996. The following year he enrolled at Louisiana State University and began pursuit of a degree in Wildlife and Fisheries Science. After a few semesters of course work he met his future master's advisor, Dr. Frank Rohwer, and upon graduation began graduate work for the Delta Waterfowl and Wetlands Research Station in pursuit of the degree of Master of Science in wildlife in the School of Renewable Natural Resources at Louisiana State University. The degree of Master of Science will be awarded in May 2003.