CAN PREDATOR TRAPPING IMPROVE WATERFOWL RECRUITMENT IN THE PRAIRIE POTHOLE REGION?

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ABSTRACT: We contrasted nest success for control areas and experimental areas in eastern North Dakota where we employed professionals to trap mammalian nest predators from late March to late July. In 1995, dabbling ducks averaged 53% nest success on four treatment blocks of 4,150 ha each; whereas on four control areas upland nesting ducks averaged 24% success. Diving duck nest success averaged 57% on experimental areas and 29% on control areas. American coot (Fulica americana) nest success also improved on experimental areas, but blackbird nesting and fledging success were not affected by the treatment. In 1994, nest success of upland nesting ducks was 52%, which was a striking contrast with upland nest success of 6% on the control area. In 1994 and 1995, brood counts were much higher on the experimental areas than on the control areas. Track counts revealed lower estimates of predator activity on experimental sites compared to control sites. This study provides the first strong experimental documentation that trapping, without the use of poisons, can effectively reduce nest predation and substantially improve waterfowl recruitment.

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Most waterfowl management consists of efforts to alter mortality and recruitment rates so populations remain stable and high. Although this idea is simple, the mechanics of manipulating these vital rates, especially population recruitment, are anything but simple, and have been the subject of extensive research (Batt et al. 1992). Vast fluctuations in population levels over time (Caithamer et al. 1995) attest to the difficulties of achieving stable populations. The dramatic population decline of ducks associated with the very dry conditions of the 1980's prompted a reevaluation of waterfowl management. The North American Waterfowl Management Plan (NAWMP) was initiated in 1986 with the goal of setting management priorities and establishing partnerships to tackle some of the larger problems facing waterfowl (NAWMP 1986).

The NAWMP assigned top priority to management for duck recruitment, and targeted the Prairie Habitat Joint Venture and the Prairie Pothole Joint Venture. These administrative units are a political split of the U.S. pothole habitats of the Dakotas, Minnesota, and Montana and the Canadian pothole and parkland habitats of Manitoba, Saskatchewan, and Alberta. In combination, these regions produce the majority of ducks in North America. The area is united by a triumvirate of problems for waterfowl production: (1) loss of wetlands, (2) loss of upland nesting habitat, and (3) altered predator communities that are detrimental to nesting waterfowl.

Problems For Breeding Ducks

Loss of wetlands is the most serious problem facing breeding ducks. Without wetlands there can be no waterfowl production. Fortunately, drainage on the U.S. side of the 49th parallel has been greatly reduced through legislation protecting wetlands. Recent programs at state and federal levels have provided incentives to recreate drained wetlands. In prairie Canada, drainage continues, but wetland losses have not approached levels seen in the U.S.

The second serious alteration of the prairies has been the conversion of the uplands into agricultural fields. On the northern prairies crop fields do not provide enough cover to adequately conceal nests until very late in the spring. Mallards (Anas platyrhynchos) and other upland-nesting species are limited to nesting in fragments of cover such as fencelines, pond margins, or roadsides. The shortage of nesting cover is not so severe that it influences nesting effort. Many nests can be packed into the fragments of upland cover not usurped by crop production; unfortunately, concentration of nests in small patches of cover makes them highly susceptible to predators.

The least recognized of the threats to production has been the change in the predator community. Humans have altered both the types of predator and their abundance - to the detriment of ducks. The elimination or reduction of large predators and suppression of fire are probably most responsible for the altered predator community. When coyote (Canis latrans) populations decline, red fox (Vulpes vulpes) predominate in the predator community (Sovada et al. 1995). Red fox are serious predators on ducks because they are effective at capturing females on their nests and because they destroy nests by caching eggs (Sargeant et al. 1984, 1993). The second major change in the predator community was the colonization of the prairie region by raccoons (Procyon lotor) (Cowardin et al. 1983, Sanderson 1987). It is unclear whether the lack of large predators, the abundance of trees due to fire suppression, or the availability of anthropogenic food or shelter have been most responsible for the expansion of raccoons. It is clear, however, that raccoons have a very significant impact on duck nest success, especially for the ducks nesting in wetland vegetation, such as canvasbacks (Aythya valisineria) and redheads (A. americana) (Urban 1970, Stoudt 1982, Johnson et al. 1989). The abundance of medium sized mammals, especially red fox, striped skunk (Mephitis mephitis), raccoon, and Franklin's ground squirrels (Spermophilus franklinii) is probably elevated in portions of the prairie because of the availability of agricultural sunflowers during the critical winter periods.

In the late 1970's and early 1980's nest success had declined to rates lower than required for population maintenance for many ducks species (Cowardin et al. 1985, Klett et al. 1988, Beauchamp et al. 1996). It became apparent that there were wetlands that could support breeding pairs, yet the habitat was underutilized (Johnson and Grier 1988). Nest success over much of the prairie region of Canada was below 10% and the overwhelming cause of nest failure was mammalian predation (Greenwood et al. 1987, Sargeant and Raveling 1992).

Indirect Management of Predation

NAWMP was initiated just as it was becoming clear that nest success was the weak link in production. Accordingly, the majority of management effort was expended on techniques to improve success, especially for upland nesting species such as mallards. The Prairie Habitat Joint Venture, which covers prairie Canada, placed an overwhelming emphasis on the establishment of additional grassland acreage. The hope was that larger (>60 ha) blocks of upland nesting cover would disperse nests and improve success. The most intensive form of grassland management was the purchase of blocks of land to establish dense nesting cover (DNC) (Duebbert et al. 1981). Other programs to increase nesting cover included delayed hay cuts, leases to establish DNC, and incentive programs for pasture improvement via rotational grazing (Barker et al. 1990). Unfortunately, establishment of DNC resulted in only moderate improvements in nest success (Clark and Nudds 1991, Clark et al. 1991). As in unmanaged areas, nest predation is still the primary cause of nest failure on plots of DNC.

An alternative to these efforts to conceal nests is management designed to make nests less accessible to predators. In this approach a barrier separates the nest from mammalian predators. Creation of nesting islands in large wetlands, artificial nest structures placed in prairie potholes, and construction of predator exclusion fences around prime nesting habitat all have dramatically improved nest success in at least some situations (Greenwood et al. 1990). Unfortunately, each of these techniques has its drawback. Mallards are the only ducks that routinely use nest structures and use can be highly variable across regions. Islands are expensive to build and can have poor duck nest success if mink (Mustela vison) populations are high (Lokemoen 1984). Electric fences are costly and have had limited effects on production due to brood exodus problems (Lokemoen and Woodword 1993, Trottier et al. 1994).

Predator Reduction

The obvious alternative to management of nesting sites is to take a more direct approach and alter the predator populations. Predator reduction efforts have a long history in wildlife management, especially waterfowl management. Many studies have documented that intensive predator reduction effort will improve duck nest success (Table 1). Unfortunately, these studies are of limited value to managers today. Most of these studies were not replicated, though the same area may have been examined in several years. More important, most of the older studies employed poisons as a primary tool for reducing populations of predators. Poisons are no longer an option for predator reduction efforts because they cannot be targeted to particular species and they are illegal for use in most areas. Two studies that only used trapping and shooting as methods to control mammalian nest predators did not produce a substantial improvement in duck nest success (Sargeant et al. 1995, C. Madsen, pers comm). This was likely a result of several factors, including: (1) small study blocks that could be overwhelmed by emigration; (2) restrictions on how much time trappers could be in the field; and (3) regulations prohibiting snares on some areas. These studies have led many people to believe that it would be impossible to conduct a spring trapping effort and reduce predator population size enough to detect an improvement in duck nest success.

In 1994, we initiated a study to see if we could improve upland duck nest success by using trapping and shooting to reduce the population size of medium sized mammals. Our removal efforts targeted red fox, raccoon, and striped skunk. To avoid the problems of prior studies we designed an experiment that was replicated over several study sites. We chose large study blocks, and we hired professional trappers and placed no restrictions on their work time. Unlike prior studies, we examined the effects of predator removal on several bird groups, including upland nesting ducks, overwater nesting birds, and upland songbirds. In this paper we report primarily on the waterfowl research.

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METHODS

Study Sites

In 1994, we did a pilot project with only one treatment site, where predators were removed, and one control site, where there was no trapping. Both sites were in Towner County in northeastern North Dakota in prairie pothole habitats with high waterfowl production potential. Study sites were square blocks that were 16 square miles (4,150 ha), which was primarily private farmland used for cereal grain production. We selected areas with high wetland densities and about 20% of the upland acreage in grassland, typically cover established under the Conservation Reserve Program (CRP). A coin flip was used to assign treatment in 1994.

In 1995, we expanded to 4 treatment and 4 control sites. The 1994 treatment and control sites remained unchanged, and we added 6 new sites that were randomly assigned to treatment or control. Study areas in 1995 were in northeast North Dakota in Towner, Ramsey, Cavalier, and Nelson counties. Water conditions were excellent in 1994 and in 1995, with water levels well above the long term regional average.

Predator Trapping

We hired one professional trapper to remove predators from each treatment block. The trappers were local residents of North Dakota and made initial contacts with private landowners to secure permission for land access and trapping. Trapping began in late March and continued through July. Trapping was done with body gripping traps placed in baited wooden boxes, leghold traps, and snares. All trapping was under permit from the North Dakota Game and Fish Department. A small number of predators were opportunistically removed by shooting.

Nest Success

We used traditional nest searching techniques in upland areas to flush females from active nests (Klett et al. 1986). Nests were marked and revisited every 7-14 days to monitor success. To locate nests in overwater cover we searched on foot through emergent vegetation and located nests by flushing females or observing unattended nests. Nests of American coots and diving ducks, primarily canvasback, redhead, and ruddy duck (Oxyura jamaicensis) were checked on a 7-10 day schedule, but nests of red-winged blackbird (Agelaius phoeniceus) were checked on a 4 day schedule. All nest success measures are calculated as Mayfield estimates (Mayfield 1961, Johnson 1979).

Duck and Predator Surveys

We counted pairs during May and broods during late June and July on 16 randomly selected quarter sections (65 ha) on each study area. To index predator activity we did track counts (Sovada et al. 1995) during June in both 1994 and 1995, on 32 randomly chosen quarter sections (65 ha) on each study site. On each of these quarter sections we selected a site (2-4 ha) with mud or soft soil and recorded presence or absence of mammalian predator tracks a minimum of two days after a major rainfall.

RESULTS

In 1994, nest success for upland nesting ducks was 52% on the experimental site, and 6% on the control block. In 1995, upland nest success averaged 53% on experimental sites and 24% on control sites, but was quite variable on individual control sites (Table 2). Diving duck nest success, averaging 57% on experimental sites, compared to 29% on control sites. American coots had 67% nest success on control sites, and 86% success on experimental sites (Table 2). In contrast to ducks and coots, red-winged blackbirds showed no difference in nest success or fledgling success between the control and experimental sites (Table 2).

In 1994, the pair counts of ducks were twice as high on experimental sites as on control sites, but the brood counts were ten times higher on experimental sites. In 1995 the pair counts were marginally greater on control compared to experimental sites, yet the brood counts were nearly three times greater on the experimental sites.

In 1994, the experimental site had higher track counts than the control site for red fox, raccoon, and skunk, but the difference was not significant for raccoon and skunk. Tracks of coyote, mink, and badger (Taxidea taxus) were rare on both control and experimental sites in 1994 and 1995. In 1995, experimental sites had fewer track count plots with at least one visit by red fox and striped skunk than did the control sites (Table 3). For raccoon, 33% fewer plots contained tracks on experimental sites relative to control sites, but that difference was not significant (Table 3).

In 1995 we removed an average of 291 ± 62 (1 S.D.) predators on each 16 square mile block. Raccoon, striped skunk, and red fox were the major species trapped, comprising 42%, 29%, and 26% of the trapped animals, respectively. Most red fox were snared (70%), whereas the box sets with body gripping traps were the most effective technique for trapping raccoons (76%) and skunks (71%). In 1994, 282 raccoon, fox and skunk were removed on the experimental site. In 1995, 212 predators were removed from the same experimental site.

DISCUSSION

The preliminary results of this study strongly suggest that trapping on large blocks of land can substantially improve duck nest success. Brood count data showed that improved nest success caused dramatic improvements in local recruitment of waterfowl. We attribute most of the improvement in brood counts to improved nest success, but its possible that predator reduction also improved brood survival. About half of all duckling loss occurs when entire broods are killed (Rohwer 1985, Rotella and Ratti 1992, Sargeant and Raveling 1992). These catastrophic brood losses may occur when females lead their brood overland to different wetlands (Rotella and Ratti 1992). It is plausible that reduction of mammalian predators would reduce risks of such brood losses.

This study is the first to document that trapping without use of poisons can be effective at substantially improving nest success of prairie nesting waterfowl. We believe that the key to successful predator reduction was the use of large treatment blocks and contracted employment of professional trappers. Waterfowl researchers who have attempted to reduce populations of the entire suite of mammalian predators on large tracts of land have seen substantial improvements in nest success (Table 1). In contrast, studies that have used smaller plots of land have only seen limited improvements in nest success, probably because of emigration from surrounding areas. It is also apparent that limiting removal to only one species in a diverse predator community, even if that species is a major nest predator, will not improve nest success (Table 2). It is likely that compensatory predation by other species makes such selective predator removal impractical for waterfowl management.

Before suggesting predator removal as a management technique, several questions should be addressed. First, is it possible to reduce predator populations enough to improve recruitment? This study was designed to address this question, and we believe the answer for prairie ducks is clear. Another important issue is whether there is alternative management that is more efficient. To evaluate efficiency we must know how effective our management can be at improving recruitment, in that we must have a measure of the time and expense associated with such management. Lokemoen (1984) did an excellent efficiency analysis of waterfowl management to enhance fall flights. That analysis showed predator removal to be the most cost effective production method available. We have not yet updated Lokemoen's (1984) analysis, but it seems apparent that the dramatic improvement in nest success and the moderate costs of trapping will assure that predator reduction will remain efficient waterfowl management.

Measures of cost efficiency require that management goals be clearly articulated (Messmer and Rohwer 1996). Grassland habitat created by wildlife groups may show little improvement in duck nest success when applied on a relatively small scale. These habitat programs can, however, benefit a variety of other species, especially grassland passerine birds (Hartley 1994). Prior to any analysis of efficiency we must decide who the stakeholders are for any management action and what value they place on various types of wildlife. Predator management is controversial even when it is an efficient way to manage for waterfowl recruitment. Lethal control would be disavowed by groups that oppose any consumptive wildlife use.

Predator reduction is also opposed by those who believe in a balance of nature concept (Messmer and Rohwer 1996), which suggests that nature can take care of itself and humans should refrain from intervention. This approach ignores the obvious and overwhelming influence that people already have had on most environments, especially prairie regions. Intensive agriculture in the prairies has been detrimental to waterfowl recruitment. It is naive to believe that ducks breeding in the prairies can maintain high populations without some management to improve nest success.

Many traditional waterfowl managers argue against direct predator management because they prefer to emphasize upland habitat creation as the cure for low nest success. We question this adherence to habitat management for two reasons. First, habitat creation on a small scale, which is all that wildlife groups can expect to be able to finance, has only shown marginal improvements on nest success. Second, other government agencies have a greater ability to produce upland cover than do wildlife groups and can produce enough cover to substantially improve nest success. CRP is the result of one Department of Agriculture program that created 2.5 million hectares of upland cover in the U.S. prairie pothole region. This habitat dwarfs all grassland habitat delivered by wildlife groups in both the U.S. and Canada in the entire history of wildlife management.

Wildlife groups should target funds to areas with excellent duck production potential (Reynolds et al. 1996). Perhaps wildlife managers should use their scarce management funds to improve nest success on habitat already created by the Department of Agriculture. Predator management is particularly suited to such targeted management efforts. Predator reduction is annual management that could be used in areas or years when it could offer the greatest benefits. Several years of excellent water resulted in the recent recovery of duck population, which in 1995 was well above the NAWMP goal. However, excellent widespread water levels are the exception (Lynch 1984), so we will have declining and low populations again in the future. Typically the prairies show patchy water conditions with some areas wet and some completely dry. Predator removal efforts could be targeted to wet areas that attract many ducks. In contrast, habitat management does not have such flexibility for application over space or time. The costs of habitat management remain the same when the ponds are dry, as in the mid 1980's, or when the prairie region is covered with water, as in 1995. We are not arguing against habitat management, we simply believe that if duck production is the primary management goal then we should consider a mix of management that can most cost effectively produce ducks, especially given the spatial and temporal variation in wetland conditions. We believe that predator reduction is an effective tool to enhance duck recruitment and should be reconsidered as a management tool.

LITERATURE CITED

Barker, W. T., K. K. Sedivec, T. A. Messmer, K. F. Higgins, and D. R. Hertel. 1990. Effects of specialized grazing systems on waterfowl production in southcentral North Dakota. Trans. N. Am. Wildl. Nat. Resour. Conf. 55:462-474.

Batt B. D. J., A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu. 1992. Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis. 635pp.

Beauchamp, W. D., R. R. Kolford, T. D. Nudds, R.G. Clark, and D. H. Johnson. 1996. Long-term declines in nest success of prairie ducks. J. Wildl. Manage. 60:247-257.

Caithamer, D. F., J. A. Dubovsky, J. P. Bladen, F. A. Johnson, J. R. Kelley, Jr., C. T. Moore, and G. W. Smith. 1995. Waterfowl population status, 1995. Can. Wildl. Serv. and U. S. Fish and Wildl. Serv. Report. 45pp.

Clark, R. G., and T. D. Nudds. 1991. Habitat patch size and duck nesting success: the crucial experiments have not been performed. Wildl. Soc. Bull. 19:534-543.

_____, _____, and R.O. Baily. 1991. Populations and nesting success of upland-nesting ducks in relation to cover establishment. Can. Wildl. Serv. Prog. Notes 193. 5pp.

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

_____, D. S. Gilmer, and C. W. Shaiffer. 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildl. Monogr. 92. 37pp.

_____, E. T. Jacobson, K. F. Higgins, and E. B. Podoll. 1981. Establishment of seeded grasslands for wildlife habitat in the prairie pothole region. U. S. Fish and Wildl. Serv., Spec. Sci. Rep. - Wildl. 234. 21pp.

_____, A. B. Sargeant, D. H. Johnson, L. M. Cowardin, and T. L. Schaffer. 1987. Mallard nest success and recruitment in prairie Canada. Trans. N. Am. Wildl. Nat. Resour. Conf. 52:298-309.

________, P. M. Arnold, and B. G. McGuire. 1990. Protecting duck nests from mammalian predators with fences, traps, and a toxicant. Wildl. Soc. Bull. 18:75-82.

Hartley, M. J. 1994. Passerine abundance and productivity indices in grasslands managed for waterfowl nesting cover. Trans. N: Am. Wildl. Nat. Resour. Conf. 59:322-327.

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

_____, and J. W. Grier. 1988. Determinants of breeding distributions of ducks. Wildl. Monogr. 100. 37 pp.

______, A. B. Sargeant, and R. J. Greenwood. 1989. Importance of some individual species of predators on nesting success of ducks in the Canadian Prairie Pothole Region. Can. J. Zool. 67:291-297.

Klett, A. T., H. F. Duebbert, C. A. Faanes, and K. F. Higgins. 1986. Techniques for studying nest success of ducks in upland habitats in the prairie pothole region. U.S. Fish Wildl. Serv. Resour. Publ. 158. 24pp.

______, T. L. Shaffer, and D. H. Johnson. 1988. Duck nest success in the prairie pothole region. J. Wildl. Manage. 52:431- 440.

Lokemoen, J. T. 1984. Examining economic efficiency of management practices that enhance waterfowl production. Trans. N. Am. Wildl. Nat. Resour. Conf. 49:584-607.

______, and R. O. Woodward. 1993. An assessment of predator barriers and predator control to enhance duck nest success on peninsulas. Wildl. Soc. Bull. 21:275-282.

Lynch, J. J. 1984. Escape from mediocrity: a new approach to American hunting regulations. Wildfowl 35:5-13.

Mayfield, H. A. 1961. Nesting success calculated from exposure. Wilson Bull. 73:255-261.

Messmer, T. A., and F. C. Rohwer. 1996. Issues and problems in predation management to enhance avian recruitment. Trans. N. Am. Wildl. Nat. Resour. Conf. 61:In press.

North American Waterfowl Management Plan. 1986. Environment Canada. Ottawa, Ontario, Canada. 19pp.

Reynolds, R. E., D. R. Cohan, and M. A. Johnson. 1996. Using landscape information approaches to increase duck recruitment in the prairie pothole region. Trans. N. Am. Wildl. Nat. Resour. Conf. 61:In press.

Rohwer, F. C. 1985. The adaptive significance of clutch size in prairie ducks. Auk 102:354-361.

Rotella, J. J., and J. T. Ratti. 1992. Mallard brood survival and wetland habitat conditions in southwestern Manitoba. J. Wildl. Manage. 56:499-507.

Sanderson, G. C. 1987. Racoon. Pages 487-499 *in* M. Novak, J. A. Baker, M.E. Obbard, and B. Malloch, eds. Wild furbearer management and conservation in North America. The Ontario Trappers Association, Ontario.

Sargeant, A. B., S. H. Allen, and R.T. Eberhardt. 1984. Red fox predation on breeding ducks in midcontinent North America. Wildl. Monogr. 89:1-41.

_____, and D.G. Raveling. 1992. Mortality during the breeding season. Pages 396-422 *in* B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, eds. Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis. 635pp.

________, R. J. Greenwood, M. A. Sovada, and T. L. Shaffer. 1993. Distribution and abundance of predators that affect duck production-prairie pothole region. U.S. Fish Wildl. Serv. Resour. Publ. 194. 96pp.

_____, M. A. Sovada and T. L. Shaffer. 1995. Seasonal predator removal relative to hatch rate of duck nests in waterfowl production areas. Wildl. Soc. Bull. 23:507-513.

Sovada, M. A., A. B. Sargeant and J. W. Grier. 1995. Differential effects of coyotes and red foxes on duck nest success. J. Wildl. Manage. 59:1-9.

Stoudt, J. H. 1982. Habitat use and productivity of canvasbacks in southwestern Manitoba, 1961-72. U. S. Fish Wildl. Serv. Pec. Sci. Rep. Wildl. 248. 31pp.

Trottier, G. C., D. C. Duncan, and S. C. Lee. 1994. Electric predator fences delay mallard brood movements to water. Wildl. Soc. Bull. 22:22-26.

Urban, D. 1970. Racoon populations, movement patterns, and predation on a managed waterfowl marsh. J. Wildl. Manage. 34:372-382.

Table 1. Summary of predator removal studies in the prairie pothole region.

Experimental Site			Duck Nest Success[A]			Study Design			
Area (ha)	Treatment	Targeted Species[B]	Experimental[C]	Control[C]	Signif.	Site	Yrs.	Plots[D]	Source
7,700	poison, trap	fox, skunk, rac., crow	59%	29%	N.S.	Minn.	6	2	Balser et al. 1968
176	poison	skunk, rac., grd. sq.	84%[E]	66%[E]	P<0.05	Manit.	1	1	Lynch 1972
200	poison	fox, skunk, rac., badger	72%[E]	46%[E]	P<0.01	N.D.	1	1	Schrank 1972
25,900	poison, trap shoot	fox, skunk, rac., grd. sq.	88%	58%	N.A.	S.D.	3	1	Duebbert & Kantrud 1974, Duebbert & Lokemoen 1980
104-338	live trap	skunk only	15%	5%	P=0.02	N.D.	3	3	Greenwood 1986
36,800	poison trap	fox, skunk, rac., grd. sq.	27%	10%	P<0.01	Minn.	1	1	Doty & Rondeau 1987
1,020	shoot	crow only	11.8%	7.5%	N.S.	Sask.	1	2	Clark et al. 1995

Table 1. Continued.

Experimental Site			Duck Nest Success[A]			Study Design			
Area (ha)	Treatment	Targeted Species[B]	Experimental[C]	Control[C]	Signif.	Site	Yrs.	Plots[D]	Source
142	trap shoot	fox, skunk, rac., grd. sq., badger	13.5%	5.6%	P=0.047	Minn. N.D.	4	12	Sargent et al. 1995

A. Nest success is for all upland-nesting ducks combined. Samples were predominantly blue-winged teal (Anas discors), mallard, gadwall (A. strepera), northern shoveler (A. clypeata), and northern pintail (A. acuta).

B. Fox = red fox; rac. = raccoon; skunk = striped skunk; grd. sq. = Franklin's ground squirrel; crow = American crow (Corvus brachyrhynchos).

C. Apparent nest success is reported for all studies prior to Greenwood 1986. Mayfield (1961) estimates are used in other studies.

D. These are the number of sites used for treatments. Balser et al. (1968) had one treatment and one control site, which were reversed in the second half of their study.

E. These data are from simulated nests using chicken eggs.

Table 2. Mayfield estimates of components of avian productivity on experimental (predator removal) and control sites in North Dakota, 1995.

	Experimental Sites						Control Sites					
	I	II	III	IV	N	Mean	I	II	III	IV	N	Mean
Upland duck nests	66	53	52	41	587	53	36	23	19	18	442	24
Overwater duck nests	47	57	50	65	88	57	41	27	18	44	80	29
American Coot nests	86	91	83	83	122	86	47	59	73	83	111	67
Blackbird nests - eggs	72	87	58	87	73	73	80	80	68	75	78	75
Blackbird nests - young	84	100	86	71	62	87	85	95	78	70	69	82

Table 3. Indices of predator activity expressed as the percent of tracking plots (quarter sections) with any arrival occurrence on experimental and control sites in North Dakota, 1995.

	Experimental Sites						Control Sites					
Species	I	II	III	IV	N	Mean	I	II	III	IV	N	Mean
Red Fox	34	22	19	48	126	38	79	57	72	63	113	60
Raccoon	66	59	26	6	126	40	29	65	78	67	113	60
Skunk	9	3	6	3	126	7	18	22	22	10	113	17