THE EFFECTS OF HUMAN DISTURBANCE AND HABITAT ON DEPREDATION OF ARTIFICIAL DUCK NESTS

by Rob Olson

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of the Requirements for the Degree
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Natural Resources Institute
University of Manitoba
430 Dysart Road
Winnipeg, Manitoba, Canada
R3T 2N2

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THE EFFECTS OF HUMAN DISTURBANCE AND HABITAT ON DEPREDATION OF ARTIFICIAL DUCK NESTS

By

Mr. Rob Olson

A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfilment of the requirements of the degree of Master of Natural Resources Management.

ABSTRACT

Artificial duck nests were used to determine the effect of human disturbance on duck nest success in the prairie pothole region near Minnedosa, Manitoba. To determine the effect of human visitation on duck nest success, I created nests with and without human trails leading to them. Nests were placed in dense nesting cover, roadside rights-of-way, and native upland habitats during 1993 and 1994. In native uplands, nests with trails were depredated more often ($P < 0.003$) than nests without trails during 1993, but not 1994. During 1993, in roadside right-of-way habitat there was no significant difference in rates of nest depredation between nests with and without trails. However, in two tests within roadside right-of-way habitat during 1994, nests with trails were depredated more often ($P < 0.03$ in test 1, $P < 0.003$ in test 2). Depredation of nests was not affected by the presence of trails in dense nesting cover in either years of the study. Ducks frequently defecate on nests when flushed by humans. I placed nests with and without duck feces in roadside right-of-way habitats during 1994 to determine if the rate of depredation was affected. Nests with duck feces on the eggs were depredated more frequently ($P < 0.03$). To determine the probability of survival for duck nests partially damaged by researchers, I placed nests with and without damaged eggs in roadside right-of-way habitat.

Nests with damaged eggs were depredated more often than nests without damaged eggs ($P < 0.00003$).

Artificial duck nests were used to compare the rates of nest depredation of small patches of native upland to large patches of grain stubble and growing grain. Within stubble fields, I failed to detect a difference between nests placed 5 m into upland native habitat from the edge between stubble and native upland habitat and nests placed 5 m into the stubble field from the edge ($P > 0.05$). Therefore, data from these two nest positions were pooled and compared to nests placed 50 m into the stubble. Nests placed 50 m into the stubble experienced significantly lower rates of depredation than nests placed 5 m from the edge in native upland or stubble habitats ($P < 0.03$).

Within growing grain fields, I failed to detect a difference between nests placed 5 m into the crop and nests placed 50 m into the crop from the edge between the crop and native upland habitat ($P > 0.05$). Data from these two nest positions were pooled and compared to nests placed 5 m into the native upland cover. Nests placed 5 m into the native upland cover were depredated more often than nests placed 5 m and 50 m into the growing grain ($P < 0.03$).

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Without the permission of the private landowners of the Minnedosa area, this study, like so many other studies, would not have been possible. Farmers are the backbone of waterfowl management and research and should be recognized as such.

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GENERAL INTRODUCTION

Habitat loss due to human activities is a major factor causing reduced nesting success and productivity of prairie breeding ducks (Stoudt 1971, Bartonek et al. 1984, Sugden and Beyersbergen 1984, Cowardin et al. 1985, Boyd 1987, Caswell et al. 1987, Hochbaum et al. 1987). Habitat loss in the prairie pothole region is especially critical since this region produces approximately 50% of North American ducks (Smith et al. 1964) even though it accounts for only 10% of all continental breeding range (Klett et al. 1988).

Since the early 1900's, intensified agricultural activity is considered to have been the principle cause of waterfowl habitat loss and habitat fragmentation in the prairie pothole region (Kiel et al. 1972, Boyd 1985). The majority of the prairie pothole region is cultivated, (Sugden and Beyersbergen 1984, Greenwood et al. 1995) leaving relatively small patches of uncultivated nesting cover which is the preferred nesting cover of upland nesting ducks. Concentration of nesting ducks in small patches of cover may result in decreased nest success as a result of an increase in the search efficiency of predators (Tinbergen et al. 1967, Braun et al. 1978, Greenwood et al. 1987, Klett et al. 1988, but see Clark and Nudds 1991)

As the proportion of cropland has grown relative to native habitat, so too has the interest by waterfowl biologists in the use of cropland by nesting ducks. Thus far, research has found duck nesting density to be lower in cultivated land than in native habitat (Higgins 1977, Cowan 1982, Cowardin et al. 1985, Lokemoen et al. 1990, Fisher 1993). However, stubble has been described as an important nesting habitat for northern pintails (Anas acuta) (Milonski 1958, Higgins 1977, Cowardin et al. 1985, Greenwood et al. 1995). Additionally, the extent of duck nesting in growing crop is poorly understood and probably underestimated due to difficulties in searching crops (Duebbert and Kantrud 1987) and timing of previous nest searches when crops were in early growth stages (Kirsch et al. 1978). Waterfowl would not be expected to use short crop growth for nesting because it offers low density nesting cover (Bue et al. 1952, Gates 1965, Kirsch et al. 1978, Cowardin et al. 1985). Furthermore, the high visibility obstruction readings and extensive acreage of mature cropland may attract substantial numbers of late nesting and renesting ducks, especially when high water levels stimulate renesting and initial nesting success is low (Gates 1962, Krapu 1979, Swanson et al. 1979, Hammond and Johnson 1984).

Nest success rate is a critical component of duck production (Cowardin and Johnson 1979, Johnson et al. 1987) and predation is the main factor affecting nest success (Greenwood 1986, Klett et al. 1988, Rondeau and Piehl 1989). If nest predation increases with increasing habitat fragmentation (Gates and Gysel 1978, Andren et al. 1985, Johnson and Temple 1990), one would expect duck nesting success to be elevated in larger patches of habitat such as those provided by agricultural land (but see Clark and Nudds 1991). Supporting this prediction, some research has shown that depredation rates on nesting waterfowl are lower in cultivated land than in native cover (Duebbert and Kantrud 1974, Higgins 1977, Cowan 1982, Rodgers 1983, Duebbert and Kantrud 1987, Fisher 1993), where farmers have avoided tillage of nest sites. Duck production on cultivated land depends in part on the protection of nests from farming operations. Certain non traditional farming techniques may save duck nests from farm operations. Spring sown zero tillage increases the probability of duck nests escaping spring seeding operations from 10% to 50% in Saskatchewan (Sugden and Beyersbergen 1985), while the fall seeding of wheat eliminates nest destruction by spring seeding (Cowan 1982).

If ducks are using cultivated land in significant numbers, and nest success is high compared to native cover, then it may be beneficial for conservation agencies to consider developing incentive programs to encourage alternative farming practices such as spring and fall sown zero-tillage. Data on the nesting success of ducks on cultivated land is scarce and needed to evaluate the potential benefits of alternative farming techniques for increased waterfowl production.

Sound waterfowl management is largely based on information gathered through field research. To study nesting waterfowl, biologists typically locate nests by flushing the female from her nest after creating some disturbance (Klett et al. 1986). Traditional methods of nest searching necessitate the investigator approaching the nest with a nest searching vehicle or on foot, thereby disturbing the surrounding vegetation and creating trails to the nest. Additionally, the investigator may spread human scent around the area or cause the hen to defecate on her nest when she flushes.

Since biologists have begun searching for waterfowl nests, they have been curious as to what effect they have on the survival of their subjects. Unfortunately, the effect of investigator disturbance on nesting waterfowl is largely a mystery. To date, the majority of studies examining investigator disturbance on nesting waterfowl and other species of birds have demonstrated that the disturbance associated with nesting studies does not negatively affect nest survival (see Livezey 1980 and Esler and Grand 1993 for review).

Interestingly, most nesting studies in recent years have shown nest success of mallards and other waterfowl to be lower than 15% (Cowardin et al. 1985, Greenwood et al. 1987, Klett et al. 1988, Greenwood et al. 1995), the level of nesting success widely accepted to be the minimum required to maintain populations (Cowardin et al. 1985). With low nesting success across much of the prairie pothole region, one would expect the population of mallards and other waterfowl to decline rapidly. Conversely, the population trend of mallards in recent years (1986-1993) has been fairly stable (United States Department of the Interior, Fish and Wildlife Service, Environment Canada, Canadian Wildlife Service, and Sedesol, Secretaria de Desarrollo Social 1994).

It is possible that, in spite of low nesting success across much of the prairie pothole region, the population of mallards and other waterfowl have remained fairly stable due to infusions of birds from productive boreal or Alaskan habitats (Dickson 1989) or areas of prairie with below average rates of predation. An alternative explanation is that studies of nesting success have been negatively biased by the investigator disturbance inherent in these studies.

Waterfowl conservation programs are evaluated on an ongoing basis to determine their success and cost effectiveness. In an assessment of waterfowl habitat enhancement programs, disturbance of nesting waterfowl by field researchers is inevitable. An understanding of how field researchers influence the survival of ducks and their nests would facilitate more accurate interpretations of nest success data and in turn, improve the evaluation of habitat programs.

In chapter I, the results of my study of the effect of investigator disturbance on the rate of depredation of artificial duck nests are reported. Specifically, the effects of the following three sources of investigator disturbance on artificial duck nest depredation were studied: 1) the creation of a trail to a duck nest when an investigator approaches, 2) hens defecating on their nests when they are flushed during nest searching, and 3) partial damage to a duck nest from nest searching activities or mishandling of eggs.

In chapter II, the rate of depredation of artificial duck nests in cropland relative to nests in adjacent native cover is examined. Additionally, the effect of the proximity of nests to the edge between native cover and cultivated agricultural land is discussed.

Artificial nests were used to determine differences in rates of depredation between treatments and controls as an index to natural duck nesting. No attempt was made to assess the actual nest success of natural duck nests because artificial nests without olfactory clues such as the hen or feathers can overestimate avian predation and underestimate mammalian predation (Dwernychuk and Boag 1972, Gotmark and Ahlund 1984, Willebrand and Marcstrom 1987, Storass 1988). The use of artificial duck nests was critical to this study to allow the control of nest location and sample size.

CHAPTER I

THE EFFECT OF HUMAN DISTURBANCE ON THE DEPREDATION OF ARTIFICIAL DUCK NESTS

INTRODUCTION

Duck nesting studies often require that a human observer approach active nests. Biologists question if their presence has an effect on the survival of a clutch they are observing, thereby introducing bias into nesting data. Depredation is the main source of clutch mortality in the prairie pothole region (Cowardin et al. 1985). Consequently, the possibility that observers are leading predators to nests is a primary concern. An observer may attract predators to a duck nest site by: 1) visually leading a predator to a nest through their presence or markers left behind (Picozzi 1975, Gotmark et al. 1990), 2) flushing a female from the nest (Erikstad et al. 1982), 3) disturbing vegetation at the nest site (Dwernychuk and Boag 1972), 4) causing a female to defecate on a clutch when flushed (Hammond and Forward 1956), 5) creating a trail to a nest consisting of disturbed vegetation and human scent (Esler and Grand 1993), and 6) partially damaging a clutch and spilling egg contents thereby increasing scent at the nest. In this study, I focused on the possible observer disturbance effects of creating a trail to a nest, causing a hen to defecate on her eggs, and partially damaging a clutch on the rate of depredation of artificial upland duck nests.

In the past, researchers have suspected that they attracted predators to nests they were observing (Bach and Stuart 1942, Earl 1950, Snelling 1968). These anecdotal observations led to further investigation of the effect of visiting nests on various species of birds.

Several studies of the effect of visiting nests of colonial birds such as western gulls (Larus occidentalis), black-crowned night herons (Nycticorax nycticorax), and the fulmar (Fulmaris glacialis) have shown that human visitation leads to decreased nest success (Robert and Ralph 1975, Tremblay and Ellison 1979, Ollason and Dunnet 1980). However, colonial birds (unlike ducks) nest in the open and often defend their nests in the absence of abundant mammalian predators. Consequently, the effect of visiting colonial bird nests may not be comparable to ducks.

Studies of tree nesting bird species have provided conflicting results (Willis 1973, Gottfried and Thompson 1978, Nichols et al. 1984, Westmoreland and Best 1985, Major 1989). Most of the predators in these studies of tree nesting birds are different from those that prey on duck nests, thus the results are not strictly comparable to duck nesting studies.

Studies of the effect of human visitation on ducks (Keith 1961) and other species with cryptic plumage and concealed, ground nests such as pheasants (<u>Phasianus colchicus</u>)(Buss 1946, Evans and Wolfe 1967, Gates and Hale 1975) have shown no increase in predation on nests visited by observers. Unfortunately, these studies have only evaluated the effect of visitation in whole; few studies have attempted to isolate and evaluate the mechanisms by which a predator may be attracted to a nest that was visited by a human.

In their attempt to create a control for an unvisited nest in an artificial nest experiment testing the effect of visitation, Hammond and Forward (1956) isolated the effect of creating a trail on nest success. They compared artificial nests placed with a 12 foot (3 m) pole to nests adjacent to researcher trails and found no difference. This experimental approach required that: a researcher was present at all nests, all nests were marked the same way, and actual hens were not flushed from either nest site so that an increase in predation on visited nests would result solely from the creation trails.

Similarly, Esler and Grand (1993) and MacIvor et al. (1990) used 3 m and 5.5 m poles to place "unvisited" artificial nests. In both studies, no difference was found between unvisited nests and nests visited once, although Esler and Grand (1993) found that predation on artificial nests increased with increased frequency of visitation.

Ducks frequently defecate on their nests when they are flushed by human researchers (Bennett 1938, Hochbaum 1944, Kear 1963). Hammond and Forward (1956) determined that the presence of duck feces on a nest decreased the chance of clutch survival. However, Keith (1961) and Townsend (1966) found that the presence of duck feces on a nest had no effect on the survival of the eggs. Furthermore, studies have shown that eider (*Somateria mollissima*) feces has repelled ferrets (*Putorius furo*), Norway rats (*Rattus norvegicus*) (Swennen 1968), and crows (Corvus carone) (McDougall and Milne 1978).

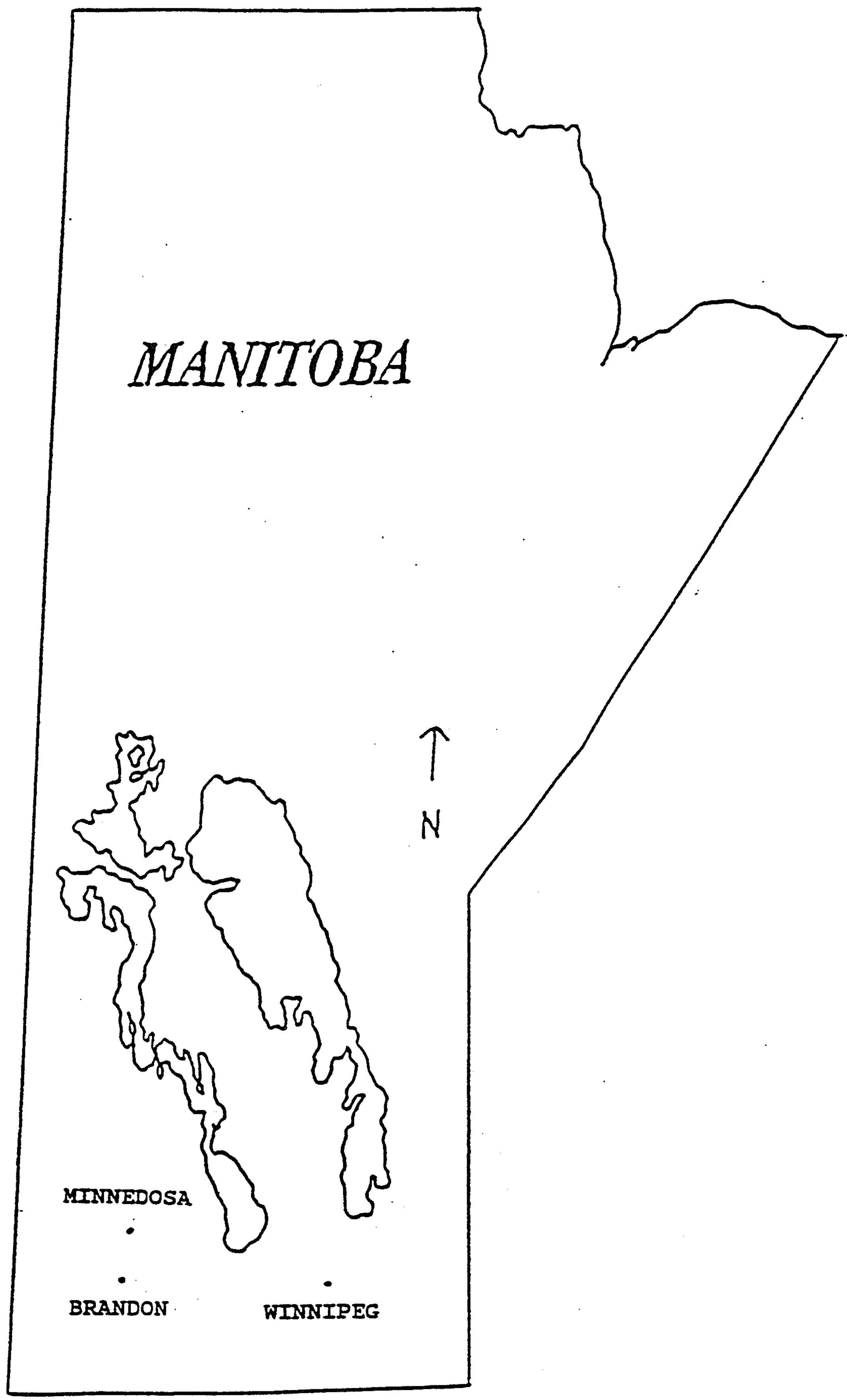
The objectives of this study were to determine if observer trails leading to nests, duck feces on a clutch, or partially damaged clutches affected artificial duck nest survival.

METHODS

Study Area

The study was conducted from mid-May to mid-August 1993-94 within a 80 km radius of the town of Minnedosa (50^0 10' N, 99^0 47' W), located in southwestern Manitoba, Canada (Figure 1). The study area is situated in the aspen parkland portion of the prairie pothole region. Topography is gently undulating and characterized by a high concentration of wetlands that support a dense population of breeding waterfowl (Stoudt 1982). Although intensively farmed, the area is interspersed with small stands of

Figure 1. Map of the Minnedosa study area.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forest, native grasses and forbs. Species of common duck nest predators in this area include the coyote (*Canis latrans*), red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), Franklin's ground squirrel (*Spermophilus franklinii*), and American crow (*Corvus brachyrhynchos*) (Sargeant et al. 1993). The area is described in detail by Kiel et al. (1972).

Experimental Design

Artificial nests were created by making a nest bowl on the ground, adding 6 brown chicken eggs, and partially concealing the eggs with surrounding vegetation. Nests were marked by placing an inconspicuous wire at the nest bowl and a wooden lath 10 m away. Nest marking procedures and the number of people at artificial nests were kept constant because these may be factors influencing nest predation (Picozzi 1975, Livezey 1980). Nests were checked after 10 days to determine their fate. Nests were considered depredated if 1 egg or more was destroyed or removed but were discarded from analyses if they were damaged by human activities. To avoid exceptionally high nest depredation resulting from high nest numbers, the density of artificial nests was limited to < 1 nest / ha.

To test the effect of creating a trail on depredation, I established for comparison two types of artificial nests: nests with trails leading to them (treatment), and nests with no trail leading to them (control). An apparatus was created that allowed the placement of artificial nests onto the ground without a trail leading to them. This apparatus was mounted in the back of a truck and consisted of a ramp which could be extended 7 m from the edge of the truck and lowered near the ground to allow an artificial duck nest to be constructed (Figure 1).

Nests were established in pairs; a pair consisting of one nest with a trail leading to it and another nest without a trail. Pairs of nests were placed in three different types of cover: 1) right-of-way native grass (roadside drainage ditches), 2) dense nesting cover plots (seeded grasses and/or legumes [see Duebbert and Lokemoen 1976]), and 3) native grass plots adjacent to wetlands and surrounded by cultivated land. I was restricted to placing nests from the edge of each habitat type into the cover because vehicle access was required to place treatment nests. Nests were placed the same distance from the edge (7 m) to avoid the potential confounding factor of edge effect on predation rates (Andren et al. 1985, Anglestam 1986).

Paired nests were separated by 100 m along the edge of cover and pairs were separated by 400 m. Nests were placed in all available dense nesting cover and native grass plots within the study area wherever vehicle access was feasible in 1993 and 1994. A minimum of 60 pairs of nests were placed into native grass and dense nesting cover plots in

Figure 2. Photograph of the apparatus used to place artificial nests onto the ground without creating a trail.

each year. A minimum of 100 pairs of nests were placed into roadside right-of-ways in a 120 km^2 plot per test, with one test in 1993 and two tests in 1994. All nests were partially concealed except for nests placed into roadside right-of-way habitat in test 2 during 1994 where they were completely concealed to determine the magnitude of avian depredation.

To assess the effect of presence of duck feces on the rate of depredation I established pairs of artificial nests, one nest with duck feces (treatment) and one without (control), in roadside right-of-way habitat. Treatment nests were covered with 100 ml of mallard feces which was collected from captive mallards. Paired nests were spaced 100 m apart, placed 7 m into the roadside cover from the road, and pairs were separated by 400 m. One hundred pairs of nests were placed into roadside right-of-way cover in 1994 within a 120 km^2 plot. All nests were completely concealed with vegetation.

To determine the effect of partial clutch damage on the rate of depredation of artificial nests I established pairs of 6 egg nests, one with 2 eggs broken open and one with no broken eggs, in roadside right-of-way habitat. Eggs were broken by puncturing the shell to create a 2 cm hole and were subsequently left sitting upright in the nest with their contents exposed but not spilled. In 1994, 60 pairs of nests were placed and separated in the same way as all other experiments in the study. Nests were completely concealed with vegetation.

When artificial nests were checked, I measured the minimum height at which I could see a 5-cm wide pole from a distance of 4 m to obtain an index to vegetation density (Robel et al. 1970), also known as a visual obstruction measurement.

Statistical Analyses

The frequency of depredated and undisturbed treatment and control nests were compared for each experiment in each habitat type using the McNemar test for two related samples (Conover 1971, Daniels 1978). Nests were paired to encourage equal exposure of treatment and control nests to any individual predator.

The McNemar test compared the number of instances where either the treatment or control nest of a matched pair was depredated; instances where both or neither nests were depredated were not included in the procedure. An estimate of the difference in depredation between treatments and controls was calculated to give some indication of the magnitude of the differences (Agresti 1990). The margin of error was calculated for each estimate of the difference between treatment and control to provide an indication of the potential variability of the data given the current sample size (Agresti 1990). Mean visual obstruction (vegetation density) was compared between paired nests only when one nest was depredated, to determine if depredation occurred as a result of the treatment or significant differences in vegetation between the two nests. Means of vegetative visual obstruction were compared using a paired t-test.

RESULTS

During 1993, nests without a trail leading to them were depredated more often than nests with a trail in roadside habitat (Table 1), with the difference (8% ± 9 percentage points) approaching statistical significance ($P = 0.07$). In 1994, nests with trails were depredated more often than nests without (Table 1) in roadside habitat during test 1 (7% difference ± 6 percentage points, $P < 0.05$) and test 2 (14% difference ± 9 percentage points, $P < 0.005$). Nests with a trail were depredated more often than nests without in native upland habitat (21% difference ± 9 percentage points, $P < 0.005$) during 1993 (Table 1). In native habitat during 1994, more nests with a trail were depredated than nests without (Table 1), however the difference (2% ± 4 percentage points) was not statistically significant ($P > 0.05$). During 1993 and 1994 I detected no significant differences in the number of depredated nests with and without trails (3% difference ± 7 percentage points, 0%, $P > 0.05$) in dense nesting cover habitat (Table 1). Vegetative

Table 1. Number of pairs where both nests, neither nests, or one nest of a pair were depredated in three habitats during the trail effect experiment, Minnedosa study area, Manitoba, 1993-94.

Nests depredated within pairs	Habitat type						
	Dense Nesting Cover		Native		Roadside		
	1993	1994	1993	1994	1993	1994	
						Test 1	Test 2
Both nests	2	58	17	77	41	106	36
Neither nest	88	36	24	11	47	18	35
Trail nest	6	9	14	3	8	15	16
No trail nest	9	9	2	1	17	5	3
P*	-0.44	1	0.003	0.3	-0.07	0.025	0.003
D**	3	0	21	2	8	7	14
ME***	7	0	9	4	9	6	9
T****	9(210)	60(224)	44(114)	86(184)	47(226)	81(288)	51(180)

* P= results of McNemar test for differences in depredation between nests with and without trails, for each habitat and year.

** D= percent (%) estimate of the difference in depredation between nests with and without trails.

*** ME= percent (%) margin of error for D** based on a 95% confidence interval.

**** T= proportion (%) of total nests depredated and (total number of nests).

visual obstruction did not differ between depredated and undisturbed nests of pairs where one nest was destroyed ($P > 0.05$) in all habitats and years (Table 2).

Nests with duck feces were depredated more frequently than nests without (table 3) (9% difference $\pm$ 7 percentage points, $P < 0.025$). The effect of damaged nests was dramatic, with higher depredation than undamaged nests (table 4) (39% difference $\pm$ 15 percentage points, $P < 0.005$).

Table 2. Differences in visual obstruction measurements (cm) between depredated and undisturbed nests of pairs where one nest was depredated, Minnedosa study area, Manitoba, 1993-94.

	Habitat			
	Native Upland	Dense nesting cover	Roadside	
	n=16	n=15	n=25	n=20
	1993	1993	1993	1994
D*	0.17	0.32	0.53	0.06
SD**	2.69	2.34	1.79	0.95
P***	0.40	0.29	0.11	0.39

* D= mean of differences in visual obstruction (cm) measurements between disturbed and undisturbed nests.

** SD= standard deviation of the differences in visual obstruction between depredated and undisturbed nests.

*** P= results of paired t-test procedure comparing differences in visual obstruction between depredated and undisturbed nests of pairs with one nest depredated.

Table 3. Number of pairs where both nests, neither nests, or one nest was depredated during the duck feces experiment, Minnedosa study area, Manitoba, 1994.

Nests depredated within pairs	Number of pairs
Both nests	65
Neither nests	15
Feces nest	12
No feces nest	3
P*	0.02
D**	9
ME***	7

* P= results of McNemar test for differences in depredation between nests with and without duck feces.

** D= percent (%) estimate of the difference in depredation between nests with and without duck feces.

*** ME= percent (%) margin of error for D** based on a 95% confidence interval.

Table 4. Number of pairs where both nests, neither nests, or one nest was depredated during the damaged egg experiment, Minnedosa study area, Manitoba, 1994.

Nests depredated within pairs	Number of pairs
Both nests	17
Neither nests	11
Damaged egg nest	25
No damaged egg nest	3
P*	0.00003
D**	39
ME***	15

* P= results of McNemar test for differences in depredation between nests with and without damaged eggs.

** D= percent (%) estimate of the difference in depredation between nests with and without damaged eggs.

*** ME= percent (%) margin of error for D** based on a 95% confidence interval.

DISCUSSION

I determined that the presence of human trails in native upland habitat during 1993, and roadside rights-of-way habitat in 1994 increased depredation of artificial duck nests. I was unable to find a published study of real or artificial nests of species sharing duck nest characteristics (cryptic coloration, concealed, ground location) that did not contradict these findings. However, studies of the effect of human visitation on nest depredation have differed from this study in the species composition of predators on study areas. Very little is known about how various predators of duck nests react to human cues such as research trails leading to nests. MacIvor et al. (1990) found that the proportion of piping plover (Charadrius melodus) nests depredated increased as the distance from which researchers observed increased; depredation was lower for nests monitored from < 3 m. Moreover, in all 15 instances of fox predation, MacIvor et al. found that foxes approached along a route that neither followed or crossed researcher's trails. MacIvor's results support testimony of trappers who claim that minimization of human scent is critical in successful red fox trapping (George Laing, Manit. Trappers Assoc. Zone Dir., pers comm.). Trappers claim that scent minimization is not as important for catching raccoon or skunk, as it is for fox trapping. Perhaps human scent at nest sites deters fox depredation, therefore the species composition of predators in a study area may be an important factor in determining if human cues such as researcher's trails increase nest depredation. Keith (1961) found no difference between depredation of visited and unvisited waterfowl nests in southeastern Alberta but raccoon and Franklin's ground squirrels are considered scarce in that area (Sargeant et al. 1993).

Esler and Grand (1993) found that artificial duck nests that were visited 2 or 4 times were not depredated more often than unvisited nests, but nests with daily visitation received higher rates of predation than unvisited nests. Red foxes were the major mammalian nest predators on Esler and Grand's Alaskan study site. It is not surprising that 2 or 4 visits did not increase nest depredation because foxes may be averse to certain human cues. In the apparent absence of mammalian predators investigating human cues, higher rates of depredation on nests visited daily compared to unvisited nests may reflect adaptive foraging behaviour among avian predators such as mew gulls (*Larus canus*) and common ravens (*Corvus corax*) which were nest predators on the Alaskan study site (Croze 1970, MacInnes and Misra 1972, Picozzi 1975, Reynolds 1985).

My study of the effect of visitation, specifically the creation of human research trails, is the only such study in the eastern prairie pothole region where the duck nest predator community is diverse and large. Moreover, the ramp apparatus allowed me to create a nest without any human footprints nearby, whereas other studies using poles to create "unvisited" nests could only place eggs 4 m or less from the nearest human footprint (Hammond and Forward 1956, MacIvor et al. 1990, Esler and Grand 1993).

Although I found that the creation of human trails to nests increased nest depredation, these results were inconsistent between habitats and years of the study. The creation of trails increased nest depredation in native upland and roadside habitats but not in dense nesting cover. It is unknown why this variation between habitats occurred. However, if the effect of human visitation is dependent on the predator species composition of a given patch of habitat, perhaps areas of dense nesting cover possessed different types of predators than native upland or roadside habitat. Unfortunately, I have no information about predator species abundance in the various habitats of this study and attempts to identify predators from clues at the nest site were inconsistent.

During 1993, nests without trails were depredated more often in roadside habitat with a difference bordering on statistical significance, contradicting data collected in 1994. I do not know why these contradictory results occurred.

I detected an effect of trails on nest depredation in native uplands during 1993, but not during 1994. The difference between treatment and control nests may have been overwhelmed by the substantial increase in overall predation between 1993 and 1994. High rates of depredation may have resulted in relatively few instances where one nest of a pair was depredated, reducing the likelihood of detecting a statistical difference with the McNemar test for matched pairs.

During 1994, completely concealed nests in the roadside test 1 were depredated less than partially concealed nests in roadside test 2. The drop in nest depredation on totally concealed nests suggests that crows may have been responsible for much of the depredation on artificial nests because crows predominantly use sight during foraging (Willebrand and Marcstrom 1987, Storass 1988) and readily find unconcealed nests (Picozzi 1975, Gotmark and Ahlund 1984). I suspect that crows were major predators in the study area and that between 1993 and 1994 they may have learned to forage in areas where they could easily find and depredate partially covered nests. This may partially explain why overall depredation rates increased in all habitat types between 1993 and 1994 during trail effect experiments. Alternatively, the overall increase in depredation between years may have been due to seasonal changes in predator behaviour, as opposed to learning by crows, because trail effect experiments in all habitat types were conducted at least 10 days earlier in the 1994 season, compared to 1993.

Dwernychuk and Boag (1972) found that crows depredated 34% of concealed artificial duck nests, suggesting that crows may have used human visitation cues such as disturbed vegetation, nest markers, or the presence of a researcher to find the concealed nests. I watched a crow fly directly to an artificial nest, search on foot, and consume the eggs less than 5 minutes after the nest was placed. However in this study, nest marking procedures and the amount of time spent at nest sites was constant between treatment and control nests. Additionally, vegetative visual obstruction did not differ between treatment and control nests of pairs where one nest was depredated, demonstrating that differences in depredation did not result from differences in concealment. Accordingly, I would expect crow depredation to elevate total nest depredation and to influence rates of depredation only in response to the creation of trails at treatment nests.

I found that the presence of duck feces increased artificial duck nest depredation. Hammond and Forward (1956) also found that duck feces increased artificial duck nest depredation. However, more recent studies have shown that the presence of duck feces does not influence nest depredation (Keith 1961, Townsend 1966, Livezey 1980). Again I propose that variability among studies of the effect of visitation, specifically the presence of duck feces, may be attributed to differences in predator communities.

Damaged eggs within artificial duck nests increased depredation. Apparently the additional scent of the egg contents greatly enhanced predators' ability to find these nests. It seems that the partial damage of upland duck nests during normal nest searching activities occurs infrequently and poses no serious bias for nesting studies if partially damaged nests are excluded from analysis.

It seems evident that the existence and magnitude of the effect of human visitation on duck nesting may vary with respect to a combination of the following factors: predator community composition (species and abundance), type of human cues involved, and type of habitat. Consequently, the effect of human visitation is probably site and study specific.

I encourage further investigation of the effect of human visitation on duck nesting success in the prairie pothole region where many nesting studies of waterfowl are conducted. Future studies of the effect of human visitation should emphasize identification of predator species in relation to responses towards specific cues, as opposed to human visitation in general. My inability to identify predators and failure to completely conceal nests from avian predators were shortcomings of this study. Future studies using a matched pair design should maximize sample size because high or low rates of nest depredation may result in either both or neither nests being depredated in the majority of pairs. This may substantially reduce one's ability to detect differences between treatment and control.

This study may have underestimated the effect of creating a trail on nest depredation because the trail treatments consisted of 7 m, single trails. In normal duck nesting research, more and longer trails often result from difficulties in locating camouflaged, hidden nests. Further research on the effect of trail creation on duck nest depredation should create realistic trail treatments representative of normal research conditions.

CHAPTER II

THE EFFECT OF HABITAT TYPE AND PROXIMITY TO AN EDGE ON THE DEPREDATION OF ARTIFICIAL DUCK NESTS IN AGRICULTURAL LAND

INTRODUCTION

Uncultivated land is the preferred habitat for upland nesting ducks. However, most uncultivated land in the prairie pothole region has been converted into cropland leaving fragments of native cover (Sugden and Beyersbergen 1984, Greenwood et al. 1995). Consequently, upland nesting ducks are concentrated in relatively small patches of native cover (Higgins 1977, Cowardin et al. 1985, Greenwood et al. 1995), which may increase the search efficiency of predators and decrease nest success (Tinbergen et al. 1967, Goransson et al. 1975, MacFarlane 1977, Braun et al. 1978, Krasowski and Nudds 1986, Greenwood et al. 1995). Nest depredation in small patches may also be increased because predators may use such cover for travel corridors (Fritzell 1978), denning sites (Sargeant et al. 1993), and foraging for other food items (Angelstam 1986). However, there is no definitive answer yet on the relationship between patch size and nest success (Clark and Nudds 1991).

One consequence of reduced patch size is a proportional increase in edge habitat. Studies suggest that proximity of edge habitat to bird nests may decrease nest success (Gates and Gysel 1978, Chasko and Gates 1982, Johnson and Temple 1990 but see Ratti and Reese 1988, Rudnicky and Hunter 1993).

Conservation agencies have sought methods of more wildlife friendly farming to offset decreases in duck production due to shrinking nesting habitat. Alternative farming techniques have shown potential for increased duck production on cropland (Cowan 1982, Sugden and Beyersbergen 1985, Duebbert and Kantrud 1987) mainly because of low rates of depredation on duck nests in cropland and the large amount of cropland available. However, data on the nest success of ducks in cultivated land relative to native habitat are scarce and has been based on small sample sizes.

The objectives of this study were: 1) to compare the rate of nest depredation in native cover with depredation in two types of cropland cover, namely cereal grain stubble and growing cereal grain, and 2) to determine how the rate of nest depredation varied with the distance of a nest to the edge between native and cropland vegetative cover.

METHODS

Study Area

The study was conducted from late May to late August 1993, within a 70 km radius of the town of Minnedosa (50^0 10' N, 99^0 47' W) in southwestern Manitoba, Canada (Figure 1). This area is aspen parkland, with gently undulating topography and a high concentration of wetlands (Stoudt 1982). Species of common duck nest predators in this area include the coyote (Canis latrans), red fox (Vulpes vulpes), raccoon (Procyon lotor), striped skunk (Mephitis mephitis), Franklin's ground squirrel (Spermophilus franklinii), and American crow (Corvus brachyrhynchos) (Sargeant et al. 1993). The area is intensively farmed with the remaining patches of grasses, forbs, and forest tending to be small compared to cropland. The study area was described in detail by Kiel et al. (1972).

Experimental Design

This study consisted of two trials: an early summer trial concerning stubble fields and a late summer trial using growing grain fields. For each trial, sets of 3 nests each were placed in fields with wetlands containing native cover. For each set of 3 nests, one nest was located 5 m into the native cover from the edge between the cropland and native patch (hereafter referred to as the "edge"). The other two nests were located 5 m and 50 m into the cultivated field. The 3 nests of a set were placed perpendicular from the edge into their respective type of cover, and were separated along the edge by 100 m. The first nest of a set was placed 100 m along the edge from a randomly chosen starting point. Nest types were spaced out along the edge in random order.

Predation pressure may vary between patches of native cover within cropland patches. By placing nests in sets, associated with a specific patch of native cover, each type of nest comprising a set is probably exposed to a similar predator community. Usually, a single set of nests was placed in and around a patch of native cover within a segment of a field. Some large native patches (20% of sample in stubble fields and 30% in grain fields) were assigned more than one set to increase sample size. When more than one set was assigned to a patch of native cover the sets were separated by a 200 m gap along the edge.

Between mid-May and mid-June 1993, 120 sets of nests (360 nests) were placed within stubble fields and between late-June and late-July, 100 sets of nests (300 nests) were placed within growing grain fields. Selection of stubble fields depended largely on finding fields that would not be cultivated before the study was completed. Only cereal grain stubble fields were used as opposed to stubble from oilseed crops. The selection of growing grain cropland depended primarily on obtaining landowner permission to walk in mature crops. Only grain fields consisting of barley and wheat crops were included in the study. Fields were > 40 ha of cultivated land and had patches of native cover < 12 ha within stubble and grain cropland patches > 40 ha. To avoid exceptionally high nest depredation resulting from high nest numbers, the density of artificial nests was limited to < 1 nest / ha.

Artificial nests were created by making a nest bowl on the ground, adding 6 brown chicken eggs, and partially concealing the eggs with surrounding vegetation. Nests were marked by placing a welding rod at the edge of the nest bowl and a wooden lath 10 m away. Nest marking procedures and the number of people at artificial nests were kept constant at all nest sites because these may be factors influencing nest depredation (Picozzi 1975, Livezey 1980, Ollason and Dunnett 1980, Reynolds 1985). Nests were checked after 10 days to determine their fate and nests were considered depredated if 1 egg or more was destroyed of removed. Sets with nests damaged by human activities, such as farming operations, were discarded from analyses. When artificial nests were checked, I measured the minimum height at which I could see a 5-cm wide pole from a distance of 4 m to obtain an index to vegetation density (Robel et al. 1970), also known as visual obstruction.

Statistical Analyses

For each trial, rates of nest depredation for the 3 different nest locations were compared simultaneously using the Cochran's Q test for related observations (Conover 1971, Daniels 1978) to determine if any nest location differed from the others. The Cochran's Q test places emphasis on instances when one or two nests of a set are depredated.

When the Cochran's Q test revealed significant, or nearly significant differences in rates of depredation among the 3 nest locations, I compared depredation between pairs of nest locations using a multiple comparison procedure (Daniels 1978). To determine the relative difference in depredation between native upland and cropland, I compared depredation between the nests 5 m from the edge into the native upland interior and nests 5 m from the edge into the cropland interior. To determine the effect of proximity to the edge on rates of nest depredation, I compared depredation between nests 5 m from the edge into the cropland interior and nests 50 m into the cropland interior. Data were pooled where no difference was found between either of the above comparison of pairs of nest locations.

RESULTS

For the first trial, simultaneous comparison of the 3 nest locations revealed a difference bordering on statistical significance (Cochran's Q = 5.69, P = 0.058)(Table 5) that warranted multiple comparison analyses of pairs of nests. A significant difference was not detected between nests placed 5 m from the edge, into native upland cover, and nests placed 5 m into the stubble field (multiple comparison = 0.05 , P = 0.82). Therefore data for nests placed 5 m from the edge into native cover and stubble were pooled and compared to nests placed 50 m into the

Table 5. Proportion (%) of total (n) nests depredated at each nest position, for stubble and crop trials, Minnedosa study area, Manitoba, 1993.

	Stubble nest position*				Cropland nest position*			
	Out 50	Out 5	In 5	All	Out 50	Out 5	In 5	All
n	113	113	113	339	96	96	96	288
%	31	40	39	37	14	18	29	20
P**				0.058				0.002

* Out 50= the nest placed 50 m into the cropland from the edge.
Out 5= the nest placed 5 m into the cropland from the edge.
In 5= the nest placed 5 m into the native upland from the edge.

** P= result of the Cochran's Q procedure comparing depredation among the 3 nest locations.

stubble field. Nests 50 m from the edge into the stubble experienced significantly lower rates of depredation than nests placed 5 m either side of the edge (multiple comparison = 5.64, p = 0.02).

For the second trial, simultaneous comparison of the 3 nest locations revealed significant differences in depredation rates (Cochran's Q = 12.06, P = 0.002)(Table 5). I did not detect a significant difference between nests placed 5 m and 50 m from the edge into growing grain (multiple comparison = 0.43, P = 0.51). Consequently, data for growing grain nests were pooled and compared to nests placed in native upland cover. Rates of depredation for pooled growing grain data were significantly lower than in native uplands (multiple comparison = 5.35, P = 0.02).

DISCUSSION

I evaluated nest depredation in stubble fields in the absence of farm operations as did Cowan (1982) and Fisher (1993). Few other studies have evaluated nest success in stubble fields where nest destruction from farm operations was eliminated. My finding that nests placed in stubble fields 5 m from the edge of native cover did not differ significantly from nests placed 5 m into the upland native habitat, contradicts Cowan's study of duck nest success in stubble fields where nests in stubble were more successful than nests in native uplands. Conversely, Fisher's (1993) findings of no difference in nest success between nests in native uplands and nests in stubble agree with our study. Unfortunately, prior studies were based on small sample sizes (Cowan 1982, Fisher 1993) and natural nests which were not situated at controlled distances from edges between the stubble and native cover. The lack of nest success studies excluding nest destruction by farm operations from their results make it difficult to assess the potential benefits of farming practices that reduce the impact of farming operations on nest survival in stubble fields.

My findings that nests located 50 m from the edge were depredated less often than nests 5 m either side of the edge (pooled data) agree with early studies of field-forest edges that demonstrated higher rates of depredation on nests located close to a forest edge (Gates and Gysel 1978, Chasko and Gates 1982), though more recent studies have not corroborated those results (Yahner and Wright 1985, Rudnicky and Hunter 1993). There have been few examinations of nest success in proximity to the edge between upland grass cover and cropland and none on duck nests.

The pattern of nest depredation was different during the growing grain trial compared to the stubble trial. In growing grain, there was no difference between nests placed 5 m and 50 m from the edge into the crop, supporting recent studies of depredation near field-forest edges (Rudnicky and Hunter 1993). Nests placed in growing grain (pooled data) were depredated less often than nests placed in upland native cover, as seen by other researchers (Higgins 1977, Duebbert and Kantrud 1987). Duck nests are more dispersed in larger patches of habitat, so predator foraging efficiency may be reduced, resulting in greater nest success (Braun et al. 1978, Johnson and Temple 1990, Clark and Nudds 1991). However, studies of patch size have compared nest success between two patches of different size but the same vegetation type. Conversely, my study compared nest depredation between two patches which differed in size and in vegetation type. Predators may make greater use of more productive native habitats where forage is more plentiful than in cultivated habitat (Angelstam 1986). Availability of buffer prey can influence rates of depredation on bird nests (McInvaille and Keith 1974, Pehrsson 1985, Johnson et al. 1989). If buffer prey production was higher in native patches than in growing grain, then predators may have foraged there with greater intensity resulting in elevated incidental contact with nests.

It is possible that lower rates of nest depredation in growing grain simply reflects the tendency of avian predators such as crows to more readily locate nests in sparse native cover (Dwernychuk and Boag 1972, Sugden and Beyersbergen 1987). However, in trial 1, stubble cover was less dense than native cover (Table 6) and stubble nests 50 m from the edge received less depredation, even though crow

Table 6. Mean visual obstruction (cm) at each nest location, for stubble and crop trials, Minnedosa study area, Manitoba, 1993.

Nest location*	Mean visual obstruction (cm)**	
	stubble trial	crop trial
In 5	4.72	6.66
Out 5	2.99	9.39
Out 50	2.93	9.78

* In 5: the nest placed 5 m into the native upland from the edge.
Out 5: the nest placed 5 m into the cropland from the edge.
Out 50: the nest placed 50 m into the cropland from the edge.

** Measured as the minimum visible height on a Robel pole.

predation is supposedly greater in early summer (Sugden and Beyersbergen 1986, Greenwood et al. 1995).

Contradictory results between the stubble and crop trials may be explained by the difference in vegetation density between stubble and growing grain. In trial 1, the native cover was more dense and taller than the stubble (Table 6). Predators travelling on the stubble side of the edge, to exploit the path of least resistance (Bider 1968), may have frequently encountered the nests placed 5 m into the stubble field. Whereas denser and taller growing grain in trial 2 may have encouraged predators to travel on the native cover side of the edge, thereby lowering depredation on nests 5 m into the crop. Consequently, 5 m may not have been far enough from the edge to distinguish nests in stubble from native cover. Regardless, this study suggests that ducks nesting in growing grain, and in stubble at least 50 m from the edge of native cover, would be more likely to escape depredation than ducks nesting in native cover.

Studies of duck nesting have consistently shown that density of duck nests in stubble and growing grain is low compared to native cover (Higgins 1977, Sugden and Beyersbergen 1985, Fisher 1993, Greenwood 1995; but see Cowan 1982). Notwithstanding low nesting density, cropland has shown potential to provide significant duck production where field operations avoid destroying nests (Higgins 1977, Cowan 1982, Duebbert and Kantrud 1987) due to low depredation rates and the immense amount of cropland in the prairie pothole region. Alternative farming techniques such as spring and fall sown zero tillage can eliminate much of the damage of farming operations on duck nests (Sugden and Beyersbergen 1985, Duebbert and Kantrud 1987). Spring and fall sown zero tillage offer many potential benefits to farmers (see Fisher 1993 for review) and may represent a rare opportunity for agricultural practice to benefit ducks and farmers.

Although this study suggests that duck nests may experience relative safety in growing crop and in stubble isolated from native cover, much more study is needed on nest success of ducks in cropland. Future studies should emphasize larger sample sizes, more investigation of growing crops in years of substantial renesting, and study of nest success in isolation from destruction by farming. The matched triplet design of this study requires large sample sizes because high or low rates of depredation severely limit the amount of useful data. I recommend that future studies focus on one effect at a time. Attempting to detect edge and habitat effects on nest depredation in one test is a troublesome approach statistically and logistically.

SUMMARY, CONCLUSIONS, and MANAGEMENT RECOMMENDATIONS

Human Disturbance

The creation of human trails increases artificial duck nest depredation. However, results were inconsistent among habitat types and years. Variability of results makes the effect of human trail creation on nest depredation unclear, but suggests that the effect may vary with habitat type and predator community composition. Presence of duck feces and damaged eggs at artificial duck nests increased depredation.

Where statistically significant increases in depredation occurred at treatment nests, the magnitude of the increases ranged from 7% ± 6 percentage points to 39% ± 15 percentage points. Since duck nesting success is below 15% across much of the prairie pothole region, increases in depredation of the magnitude observed in this study are of practical importance to duck nest success data collectors. Consequently, waterfowl researchers should minimize disturbance at duck nest sites to reduce the risk of introducing bias into nest success data.

Based on these conclusions, I propose the following management recommendations:

(1) Researchers studying duck nesting success should;

   (a) limit the number of people approaching a nest to minimize trampling and visibly marking the habitat,

(b) minimize damage to vegetation surrounding nest sites,

(c) in cases where a hen is startled and defecates on the nest, clean duck feces off eggs where possible, and

(d) remove from analyses, data from nests with damaged eggs and spilled egg contents, as this would bias results.

(2) Additional research on the effects of human disturbance nesting ducks should be conducted. Such research should try to answer questions which were not fully addressed by the present study. The nature of human disturbance effects should be investigated with emphasis on;

(a) the prairie pothole region where the predator community is diverse and the majority of North American duck nesting data are collected,

(b) predator identification at depredated nests,

(c) replication in different types of habitats,

(d) study of the combined effect of predator type and habitat type,

(e) identification and study of individual cues causing human disturbance, such as visual cues like trail creation, or olfactory cues like duck feces on a nest, and

(f) study of individual cues with magnitudes of disturbance representative of realistic field research conditions.

Nest Depredation in Agricultural Land

In this study, artificial duck nests in growing grain or in stubble at least 50 m from the nearest native cover, were more likely to escape depredation than nests located in native cover. High nest success on agricultural land, coupled with reduction of nest losses from farming operations facilitated by conservation farming techniques, could provide substantial benefits to duck production. Therefore, I propose the following management recommendations:

(1) Research is required to develop strains of winter wheat that are able to withstand diseases of the prairie pothole region, to facilitate fall sown zero tillage,

(2) Research is required to provide additional information on: (a) duck nesting density in growing crops, and (b) nesting success on agricultural land (growing crop and stubble), emphasizing data collection in isolation of nest mortality from farming activities,

(3) Conservation agencies should encourage the use of conservation farming practices in the prairie pothole region by providing incentives to farmers such as;

   (a) providing demonstration of conservation farming techniques,

(b) providing information concerning the potential benefits of conservation farming techniques to farmers,

(c) subsidizing specialized equipment costs subject to international farm subsidy restrictions.

Aforementioned recommendations concerning the effects of human disturbance are directed towards institutions conducting waterfowl research , such as the Delta Waterfowl and Wetlands Research Station, Ducks Unlimited, the Canadian Wildlife Service, the U.S. Fish and Wildlife Service, and universities. Recommendations regarding nesting of ducks in agricultural land are primarily directed towards organizations participating in the North American Waterfowl Management Plan.

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Appendix I: Start and finish dates for human disturbance and habitat-edge effect experiments.

Human Disturbance Experiments	Year	Date	
		Start	Finish
Trail effect			
Dense Nesting Cover	1993	June 19	July 8
	1994	June 9	July 1
Native Upland	1993	July 14	July 25
	1994	June 3	June 14
Roadside	1993	June 6	July 5
	test 1-1994	May 26	June 7
	test 2-1994	June 21	July 2
Damaged egg effect	1994	June 30	July 10
Duck feces effect	1994	June 28	July 9
Habitat-edge effect experiments			
Stubble trial	1993	May 26	June 14
Growing grain trial	1993	July 10	July 23

Appendix II: Number of blocks where one, two, three or no nests were depredated and the number of nests depredated at each location for both trials, Minnedosa study area, Manitoba, 1993.

Block* type	Nest** location(s) depredated	Trial 1 (stubble)		Trial 2 (grain)	
		Number of blocks per block type	Nests depredated per location(s)	Number of blocks per block type	Nests depredated per location(s)
3	all	26	26	7	7
2	i5, o5	14	7	7	3
	i5, o50		2		4
	o5, o50		5		0
1	i5	18	9	23	14
	o5		7		7
	o50		2		2
0	none	55	0	59	0
P***			0.058		0.002

* The number of nests depredated per block.
** i5: nests placed 5 m into the native upland from the edge.
o5: nests placed 5 m into the cropland from the edge.
o50: nests placed 50 m into the cropland from the edge.
*** Result of the Cochran's Q procedure comparing depredation among the 3 nest locations.