Predator management and effect on nesting success and recruitment of upland nesting waterfowl

by

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INTRODUCTION

Loss of wetlands and upland nesting habitat have contributed to the reduction of waterfowl populations in the Prairie Pothole Region of North America (U.S. Fish and Wildl. Serv. 1986). Predation on nests, nesting hens and ducklings has also contributed to this decline (Johnson et al. 1989). Limited predator removal has been suggested as an effective way to increase nesting success of ground-nesting waterfowl (Balser et al. 1968, Duebbert and Kantrud 1974, Duebbert and Lokemoen 1980, Greenwood 1986). This study was undertaken to test the effects of controlling the main mammalian nest predators on nest success of ground-nesting waterfowl at Union Slough NWR.

Union Slough NWR is located in north-central Iowa at the southern edge of the Prairie Pothole Region. The refuge, established in 1937, is recognized as an important waterfowl production area in northern Iowa (Burgess et al. 1965, Fleskes 1986). Refuge land provides nesting habitat for 12 species of waterfowl. Ground nesting ducks on the refuge are primarily mallard (_Anas platyrynchos_), blue-winged teal (_A. discors_), green-winged teal (_A. crecca_), northern shoveler (_A. clypeata_), gadwall (_A. strepera_), American wigeon (_A. americana_), and northern pintail (_A. acuta_).

Union Slough's 365 wetland hectares represent approximately 4% of Iowa's remaining 8,689 hectares of natural wetlands (Bishop 1981). Most upland areas are idled hay fields and pastures. The refuge is surrounded by private land, most of which is intensively farmed and provides little nesting habitat. The upland area of the refuge is an island of nesting habitat between plowed land and the marsh lowland.

Fleskes (1986) found that predators, predominantly mammals, caused 89% of nest failures among ground nesting waterfowl. He found overall nest success was 11.9% for 1984 and 1985 seasons, and estimated recruitment rates were not sufficient to increase populations of ground-nesting ducks from one year to the next. He concluded that the breeding population at Union Slough was probably supported by pioneering birds.

In this study, in an effort to raise nest success of ground nesting ducks, the main mammalian predators were controlled. These included red fox (Vulpes vulpes), raccoon (Procyon lotor), Virginia opossum (Didelphis virginiana), and striped skunk (Mephitis mephitis).

The study objectives were to 1) trap and remove opossum, red fox, raccoon and striped skunk immediately prior to and during the nesting season, 2) census numbers and species of breeding waterfowl, 3) measure nesting success and determine the causes of nest failure, 4) measure brood attrition and determine recruitment rates of ground-nesting waterfowl, and 5) evaluate waterfowl production in relation to predator management practices.

METHODS

Weather and wetland conditions

I obtained local weather information on monthly precipitation and temperatures from the John W. Plaiser Weather Station in Titonka, Iowa. Weather and wetland habitat conditions for the prairie midwest were obtained from annual waterfowl status reports (U.S. Fish and Wildl. Serv. and Can. Wildl. Serv. 1988, 1989). I evaluated water levels and wetland habitat on the refuge weekly throughout the nesting season each year.

Predator trapping

An experienced trapper worked an average of 5-6 hours each day at predator trapping. He trapped for predators from 5 March to 14 July 1988 and from 13 March to 14 July 1989. He trapped red fox with double-spring padded jaw #1-1/2 leg-hold traps and off-set jaw #1-3/4 leg-hold traps. Because leg-hold traps could cause injury to young foxes, he used snares at some den sites to catch fox kits. He marked foxes with ear tags and transported them at least 45 kilometers off the refuge and released them. He used 30x25x81 cm box traps to catch opossums, raccoons and skunks. Baits varied between sets and years. These animals were tranquilized with ketamine hydrochloride and euthanized using carbon dioxide gas.

I trapped for ermine (*Mustela erminea*), long-tailed weasels (*Mustela frenata*) and Franklin's ground squirrels

(Spermophilus franklinii) in July of both years to determine if these mammals were present on the refuge. In 1988, I baited traps with whole eggs, synthetic egg extract, or cooked bacon with rolled oats. In 1989, I used uncooked bacon and whole eggs in all traps. All animals caught during this trapping effort were identified and released.

Breeding waterfowl census

I censused breeding waterfowl at 10-day intervals from mid-April through the end of June of each year. Counts were conducted from sunrise to approximately noon on fair weather days with winds less than 16 kilometers per hour. I used binoculars and a spotting scope to observe birds from refuge trails. I followed the same route for each count, covering each management unit (MU) once at approximately the same time in the morning. Pairs, lone males, and groups of drakes of five or less were counted as breeding pairs (Dzubin 1969). The breeding population of each species was calculated as a mean of breeding pairs from 2-6 counts.

Upland waterfowl nest search

Nest search methods closely follow those outlined by Klett et al. (1986). I completly searched upland nesting cover and marsh edges 3 times each year at approximately 18-day intervals beginning in late April. Selected fields were searched a fourth time. A field assistant and I used 2 four-wheel-drive all-terrain vehicles and a 42.7-meter-long, 8-mm chain to flush hens from nests in upland cover.

I marked nests with 1.5 m willow (<u>Salix</u> spp.) stakes with a small piece of survey flagging attached to the end. Markers were placed 4 m north of each nest. I recorded nesting species, incubation stage, egg number, nest site vegetation, nest site visual obstruction measurement (VOM), and location for each nest. After initially locating nests, I checked them at 5- to 10-day intervals until hatch or termination.

I determined the causes of nest failure from "sign" left at the nest. Nest predators were identified for each destroyed nest (Rearden 1951, Fleskes 1986:13). I attributed abandoned nests to observer disturbance if after the first subsequent visit nests were intact and there was no increase in incubation stage or egg number.

<u>Nest success</u>

I calculated daily survival rates (DSR) (Mayfield 1961, Miller and Johnson 1978) using a PC-SAS program (SAS Institute 1985) developed by Northern Prairie Wildlife Research Center, U.S. Fish and Wildlife Service. I express DSR as Mayfield nest success (now on referred to as nest success), where Mayfield nest success = DSR^I and (I) is the interval in days from clutch initiation to hatch. The interval was 35 days for mallard and gadwall, 34 days for blue-winged teal and northern shoveler, and 33 days for American wigeon. Nests were grouped by year, species, refuge management unit (MU), season, field vegetation, nest-site vegetation, and nest-site visual obstruction measurement (VOM). I compared group DSRs using the GLM procedure (SAS Institute 1985) weighted by exposure days. The ratio of the group Type III sum-of-squares/DSR(1-DSR) approximates a chi-square (X^2) distribution with group degrees of freedom. I used this test to detect differences in DSRs among groups ($P < 0.10$). I used z tests to test for significant differences ($P \leq 0.10$) between DSRs of specific group pairs. I selected an alpha level of 0.10 in multiple comparisons and used the Bonferroni method of multiple comparisons (Johnson and Wichern 1988). Probabilities are given at the unprotected (P) and protected (P_b) levels when used.

Waterfowl brood census

I cenused waterfowl broods weekly from the onset of hatching until early August each year. Counts were conducted from sunrise to approximately noon on fair weather days with winds less than 16 kilometers per hour. I also recorded broods observed during other field operations. As with breeding pair counts, I counted broods in MUs systematically to avoid duplicate counting. Species, brood size and brood age (Gollop and Marshall 1954) were recorded. I calculated a mean observed brood size for each age class from all sightings in which all young were observed. To help eliminate gang broods, I excluded broods larger than 12 from mean brood-size calculations. No successful nests larger than 12 were known to exist in this study.

Recruitment and production estimates

Recruitment and production estimates for ground nesting ducks were made using the second method described by Cowardin and Johnson (1979) and an assumed brood survival of 70%.

Habitat evaluation

I used 100% visual obstruction measurement (VOM) transects (Higgins and Barker 1982) to evaluate nesting cover in refuge fields. I conducted transects 3 times during each field season at early, mid, and late nesting season. I selected 3 to 4 fields of each major cover type for sampling. Major cover types were similar to those of Fleskes' (1986) analysis of refuge habitat. These types were characterized by the dominant species as follows: 1) **Brome** (*Bromus inermus* Leyss), 2) **Bluegrass** (*Poa pratensis* L.), 3) **Native Prairie** (*Andropogon* spp., *Bouteloua* spp. and others) 4) **Planted Native** (*Panicum virgatum* L., *Sorghastrum nutans* L. and others), 5) **Hay** (*Bromus inermus* L. and legumes including *Medicago sativa*, *Meliotus* spp., and *Trifolium* spp.) and 6) **Reed Canary** marsh edges and lowlands (*Phalaris arundinagea* L. and other wetland species including *Scirpus* spp. and *Typha* spp.). I placed the starting points of transects randomly within 100 m from field corners. I spaced 25 transect points either 7.5 m or 15 m apart depending on field size, along the length of the field.

I took 4 readings at each transect point from a height of 1 m and a distance of 4 m. I measured to the nearest 0.25 dm at heights below 2 dm and to the nearest 0.5 dm above 2 dm. A mean VOM was calculated for each field. I used repeated measure analysis (Snedecor and Cochran 1980) to test VOM differences between the classification variables of year, cover type, season, and field.

RESULTS

Weather and wetland conditions

Drought conditions existed in many of the north-central states and prairie Canada during the spring and summer of 1988. July pond counts in the Dakotas and Montana were 33% below normal and 38% below normal in Prairie Canada (U.S. Fish and Wildl. Serv. and Can. Wildl. Serv. 1988). In 1989, weather and wetland habitat conditions improved in many areas but drought conditions remained in southern South Dakota, southern Minnesota and northern Iowa (U.S. Fish and Wildl. Serv. and Can. Wildl. Serv. 1989). At Union Slough NWR, rainfall for May-July 1988 was 14 cm below normal. Similar conditions existed in 1989 with the May-July total rainfall more than 15 cm below normal.

Early-season water levels in refuge pools were at normal or near normal levels both years. In 1988, hot and dry weather accelerated normal water level reduction in pools. By the end of July exposed mud flats were present in most refuge pools, and emergent vegetation was free of standing water in many pools. Rains in early August totaling nearly 4.5 cm improved late season water conditions on the refuge. The 1989 season began with a 14.5-cm deficit in April resulting from below normal winter precipitation. Above normal April rainfall improved early season water conditions. Water levels in refuge pools receded at a faster rate in 1989 due again to low rainfall and perhaps to the overall moisture deficit. Pools in MUs 2, 4 and 5 were nearly dry by early August. Most emergent vegetation had no standing water. Water levels remained fair in MU 3, and most emergent vegetation had standing water until mid-August.

Predator trapping

The trapper set leg-hold and box traps for a total of 7067 trap-nights in 1988 and 7522 trap-nights in 1989 (Tables 1 and 2). The trapping period extended from 6 March through 13 July in 1988 and from 13 March through 14 July in 1989. Numbers of animals caught did not vary appreciably from 1988 to 1989 (Tables 1 and 2). The trapper caught raccoons, striped skunks, red foxes, Virginia opossums, house cats (*Felis domestica*), badgers (*Taxidea taxus*), and mink (*Mustela vison*). The raccoon was the most commonly caught species each year followed by opossum and striped skunk (Tables 1 and 2). The trapper caught 5 adult and 4 kit red foxes in 1988, and 5 adults and 6 kits in 1989. Of the 5 adult foxes caught in 1988, 4 were female; the sex of the kits was undetermined. In 1989, 2 of 5 adults and 3 of 6 kits captured were female. Badgers were caught only in 1989. I commonly saw mink near refuge wetlands both years but only 1 was caught. Trapping success was greatest in April each year. Skunk activity peaked in April with 16 caught in 1988 and 24 caught in 1989. Raccoon captures were fairly constant from April through July. Coyotes (*Canis latrans*) were known to have denned near refuge

Table 1. Summary of trapping effort and mammals captured at Union Slough NWR, March-July 1988

	March	April	May	June	July	Total
Days Trapped[a]	21	25	31	25	13	115
Trap-Nights						
Box	782	796	1461	1138	611	4788
Leg-hold	296	133	575	820	455	2279
Total	1078	929	2036	1958	1066	7067
Number Captured						
Red Fox	6	1	1	1	0	9
Raccoon	11	22	34	27	17	111
Skunk	6	16	9	10	5	46
Opossum	8	9	20	8	11	56
House Cat	2	2	6	2	3	15
Badger	0	0	0	0	0	0
Mink	0	0	0	0	0	0
Other	9	6	16	12	14	57
Captures[b] per trap-night	0.031	0.054	0.034	0.025	0.034	0.034

[a]Trapping period extended from 6 March to 13 July.

[b]Predators only, does not include Other category.

Table 2. Summary of trapping effort and mammals captured at Union Slough NWR, March-July 1989

	March	April	May	June	July	Total
Days Trapped[a]	19	30	31	19	14	113
Trap-Nights						
Box	148	1148	1394	845	630	4165
Leg-hold	331	794	1384	358	490	3357
Total	479	1942	2778	1203	1120	7522
Number Captured						
Red Fox	0	4	7	0	0	11
Raccoon	6	23	22	24	27	102
Skunk	4	24	8	6	3	45
Opossum	2	21	16	1	3	43
House Cat	0	7	6	0	0	13
Badger	0	2	1	0	0	3
Mink	0	0	1	1	0	2
Other	1	5	17	8	4	35
Captures[b] per trap-night	0.025	0.041	0.022	0.027	0.029	0.029

[a]Trapping period extended from 13 March to 14 July.

[b]Predators only, does not include Other category.

land in 1988 and were found denning on MU 1 of the refuge in 1989. Coyotes were not targeted for removal during this project; however, 3 coyote pups were caught at 1 den site. One pup sustained an injury when trapped and was euthanized. The other 2 pups were ear tagged and released at the den site.

July trapping for long-tailed weasels, ermine and Franklin's ground squirrels yielded 2 captures of ermine in 168 trap-nights in 1988 and no target species in 238 trap-nights in 1989. I commonly saw weasels on the refuge both years. No Franklin's ground squirrels were caught either year but I observed one in MU 2 in 1989.

Breeding pair counts of dabbling ducks

Blue-winged teal and mallard comprised 94% of all breeding pairs counted in 1988 and 89% in 1989 (Table 3). I also observed breeding pairs of northern shoveler, American wigeon, green-winged teal, gadwall, northern pintail, and wood duck (*Aix sponsa*).

The mean number of breeding pairs of dabbling ducks was greater ($t = 9.50$, $p < 0.001$) in 1989 than in 1988. Mallard breeding pairs increased significantly ($t = 2.35$, $p < 0.05$) from 1988 to 1989. Pairs of blue-winged teal also increased significantly ($t = 5.20$, $p < 0.001$) from 1988 to 1989. Northern shoveler breeding pairs showed the greatest increase ($t = 4.75$, $p < 0.005$) from 1988 to 1989. Few pairs of other

Table 3. Estimated numbers of breeding pairs of dabbling ducks at Union Slough NWR

	1988	1989
Mallard	112	151
Blue-winged Teal	83	162
Northern Shoveler	5	25
Gadwall	3	3
American Wigeon	1	4
Northern Pintail	1	1
Green-winged Teal	2	5
Total	207	351

dabbling ducks were present. Increases of these less common species were also noted.

The overall 72% increase of breeding dabblers from one season to the next was probably due to poor water conditions in marshes and wetlands elsewhere in Iowa and southern Minnesota. Burgess et al. (1965) and Fleskes (1986) also noted increases of the breeding population at Union Slough of most dabbler species due to drought in the region.

I noted increases of mallard breeding pairs in late May through mid June both years. In 1988 this increase was 29% above the season mean and 24% above the mean in 1989. Fleskes (1986) observed similar increases. Mallard pairs moving into Union Slough in late season may have been unsuccessful in their first attempts at nesting on temporary wetlands affected by drought.

I probably underestimated breeding pairs on MU 1 and MU 3 both years due to dense emergent vegetation. The density of breeding pairs averaged 56 pairs/km^2 in 1988 and 96 pairs/km^2 in 1989 (Table 4).

<u>Composition of nesting species</u>

I found 293 nests of dabbling ducks in 1988 and 344 in 1989. Of the 637 total nests, 574 were suitable for computing DSRs, 261 in 1988 and 313 in 1989. Blue-winged teal comprised 53% (304), mallard 44% (250), northern shoveler 3% (18), gadwall < 1% (1), and American wigeon < 1% (1) of nest

Table 4. Density of breeding pairs of dabbling ducks and duck nests per Km^2 of wetland by management unit (MU), Union Slough NWR 1988 and 1989

			1988		1989		Overall	
MU	ha Wet[a]	ha Dry[b]	Pair Den.[c]	Nest Den.[d]	Pair Den.	Nest Den.	Pair Den.	Nest Den.
1	27	81	55	16	48	27	52	21
2	140	92	50	42	80	84	65	63
3	88	126	33	53	23	60	28	56
4	61	47	61	133	170	166	116	150
5	47	46	97	150	187	102	142	126
6	2	93	550	44	750	44	650	44
	365	484	56	61	96	71	76	69

[a]Hectares of wetland.

[b]Hectares of upland nesting cover, excluding woodlands.

[c]Breeding pairs/hectare of wetland.

[d]Nests found/hectare of available upland cover, excluding woodlands.

records used in DSR calculations. I excluded 63 nests from the DSR analysis because they were found after they were terminated (33), abandoned due to observer disturbance (27), their fate was unknown (2), or all eggs were addled (1).

Nest initiation

The mid-point for nest initiations for all species and years combined was 18 May (n=628, S.E. 0.57 days) (Table 5). Nests were initiated from 3 April through 8 July in 1988 and 12 April through 28 June in 1989. Mallards began nesting earlier than blue-winged teal both years (3 April and 12 April, respectively) and continued until the end of June. Blue-winged teal began nesting on 27 or 28 April; however, initiations continued 26 days longer in 1988 than 1989. All observed initiations for blue-winged teal took place in a 45-day period in 1989 compared to 72 days in 1988. This shorter nesting season is probably due to fewer blue-winged teal renesting. It is also an indication of high nest success observed in this species (Table 6). The mid-initiation date did not vary significantly between mallards (16 May) and blue-winged teal (19 May, $t = 3.07$, $P = 0.2$) with years combined or within years (1988, $t = 3.15$, $P > 0.10$ and 1989, $t = 1.08$, $P > 0.4$). The mean date for northern shoveler nest initiations was the same as the overall mean of 18 May. The mean initiation date for northern shovelers did not differ from that of mallards ($t = 1.17$, $P > 0.40$) or blue-winged teal ($t =$

Table 5. Mean nest initiation dates of dabbling ducks at Union Slough NWR 1988 and 1989

Species	1988 Mean Date (range[a]) S.E.[b]	1989 Mean Date (range) S.E.	Combined Mean Date (range) S.E.
Mallard	16 May (3 Apr-30 Jun) 1.16	16 May (12 Apr-28 Jun) 1.35	16 May (3 Apr-30 Jun) 1.1
Blue-wing Teal	21 May (27 Apr-8 Jul) 0.91	17 May (28 Apr-12 Jun) 0.65	19 May (27 Apr-8 Jul) 0.57
Northern Shoveler	30 May (19 May-23 Jun) 8.1	14 May (4 May-1 Jun) 2.16	17 May (4 May-23 Jun) 2.8
Gadwall	-	19 May - -	19 May - -
American Wigeon	-	30 May - -	30 May - -

[a]Range in day/month.

[b]Standard error in days.

Table 6. Mayfield nest success (%) of dabbling ducks at Union Slough NWR, 1988, 1989 and combined

Species	1988 n	1988 Success (90% C.I.)	1989 n	1989 Success (90% C.I.)	Combined n	Combined Snccess (90% C.I.)
Blue-winged teal	147	21.8 (16.8-28.2)	157	34.9 (28.5-42.6)	304	28.0 (23.8-32.9)
Mallard	110	11.3 (7.5-17.0)	140	18.5 (13.6-25.0)	250	15.1 (11.8-19.3)
Northern shoveler	4	28.8 (8.5-92.0)	14	13.8 (4.9-38.1)	18	17.5 (7.8-38.4)
Gadwall	0		1	100	1	100
American Wigeon	0		1	0	1	0
Total	261	17.7 (14.2-22.0)	313	26.5 (22.4-31.4)	574	22.2 (19.4-25.4)

1.25, P > 0.4).

Nest density

Observed nest density for years combined was 66 nests/Km^2 for 484 ha. of available nesting cover. Nest density was greater in 1989 (71 nests/Km^2) than in 1988 (61 nests/Km^2) (Table 7). The highest nest density was observed in MU 5 (150 nests/Km^2) in 1988 and in MU 4 (166 nests/Km^2) in 1989. Estimated nest initiations (number of successful nests/ Mayfield success rate) (Miller and Johnson 1978) for 1988 was 107 nests/Km^2 and 128 nests/Km^2 for 1989 for all refuge land. There was a significant correlation ($r = 0.64$, $P = 0.04$) between breeding pair density in wetland pools and observed nest density in adjacent uplands in refuge MUs (Table 4) with years combined.

Nest success

Overall mean nest success (90% CI) was 22.2% (19.4-25.4) for all dabbling ducks during 2 seasons with predator management (Table 6). Overall nest success (26.5%) in 1989 was greater ($\underline{z} = 2.55$, $P = 0.011$) than in 1988 (17.7%).

Nest success for years combined differed among species ($X^2 = 73.3$, $P < 0.001$) and was greater ($\underline{z} = 3.21$, $P < 0.002$, $\underline{z} = 1.91$, $P \leq 0.06$, respectively) for blue-winged teal (28.0%) than either mallard (15.1%) or northern shoveler nests (17.5%). Nest success did not differ significantly between mallard and shoveler nests ($\underline{z} = 0.184$, $P > 0.85$). Success of

Table 7. Density (nests/Km^2) of dabbling duck nests and Mayfield nest success (%) in management units (MUs) of Union Slough NWR, 1988 and 1989

	1988			1989		
MU	# Nests	Nests /Km^2	%	# Nests	Nests /Km^2	%
1	13	16	43.3	22	27	50.3
2	39	42	11.0	78	84	39.8
3	63	53	19.0	71	60	36.3
4	68	133	8.2	85	166	24.1
5	69	150	19.8	47	102	6.5
6	41	44	35.7	41	44	13.3
Total	293	61	17.7	344	71	26.5

blue-winged teal nests was greater ($\underline{z}$ = 2.38, P < 0.02) in 1989 (34.9%) than in 1988 (21.8%) but annual differences of shoveler or mallard nest success were not significant ($\underline{z}$ = 0.76, P > 0.40, $\underline{z}$ = 1.58, P $\geq$ 0.11, respectively). Nest success of mallards compared to blue-winged teal differed within years. Blue-winged teal nest success in 1988 (21.8%) and 1989 (34.9%) was greater ($\underline{z}$ = 2.05, P < 0.05, $\underline{z}$ = 2.71, P < 0.007) than mallard nest success (11.3%, 18.5%, respectively). Meaningful comparisons of American wigeon and gadwall nests could not be made, though the 2 nests are included in the overall nest success estimates.

The date on which a nest is found is partly dependent on when nest searches are conducted, and partly on the nesting chronology of the species present. For years combined, most nests (75.5%, n = 433) were found between 9 May - 14 June. Nest success of mallard or blue-winged teal (years combined) did not differ by date found (P_b > 0.10).

Differences in nest success occurred among refuge management units (MUs) and between years within MUs ($X^{2,\ P < 0.05)}$. Nest success increased in MUs 1-4 and decreased in MUs 5 and 6 in 1989. Overall nest success was seemingly greater in MUs 1, 2, 3, and 6 than MUs 4 and 5 (Table 7) though none of the paired comparisons of individual MUs tested significant (P_b > 0.10). However, the results are highly significant ($\underline{z}$ = 3.76, P < 0.0002, $P_b \leq$ 0.008) if the pooled nest success from MUs 1, 2, 3 and 6 (27.5%) is compared to the pooled nest success from MUs 4 and 5 (13.9%). The combination of high nest density and high fox activity was associated with lower nest success in MUs 4 and 5. Breeding pair densities and the observed nest densities of MUs 4 and 5 were greater than that of the other MUs (Table 4). Eight of the 10 adult foxes caught during the 2 seasons of trapping were caught in MUs 4 and 5. The other 2 foxes were caught in MU 6 adjacent to MU 5. Three of the 4 active fox dens found were also found in MUs 4 and 5. The other den was found near MU 6 within 0.5 km of MU 5.

Waterfowl broods

I observed broods of mallard, blue-winged teal, northern shoveler, pintail, wood duck, redhead (Aythya americana), hooded merganser (Lophodytes cucullatus) and ruddy duck (Oxyura jamaicensis) on refuge pools. Gang brooding was common among blue-winged teal and, to a lesser extent, in mallards. Gang broods as large as 60 were observed. Brood size decreased with age for blue-winged teal and mallards in 1988 (Table 8). In 1989 class III brood size was larger than class II for mallards. Generally, fewer class III broods were seen compared to other age classes, resulting in a larger standard error associated with the estimate of the mean. Most duckling losses for all species occurred in the interval between hatching and the time a brood was observed as a class I brood. Losses for all classes and species ranged from 2% to 51%.

Table 8. Mean clutch size of hatched waterfowl nests and mean of observed broods by age class, Union Slough NWR 1988 and 1989

	1988				1989			
	Hatched nests	Brood age class I	Brood age class II	Brood age class III	Hatched nests	Brood age class I	Brood age class II	Brood age class III
	x S.E. (n)	x S.E. (n)	x S.E. (n)	x S.E. (n)	x S.E. (n)	x S.E. (n)	x S.E. (n)	x S.E. (n)
Blue-winged Teal	9.5 0.31(52)	6.8 0.33(50)	6.8 0.34(46)	5.6 0.29(56)	9.8 0.26(83)	6.2 0.33(62)	6.1 0.33(56)	6.0 0.41(22)
Mallard	7.5 0.47(35)	6.9 0.28(70)	6.5 0.35(36)	6.3 0.54(10)	8.3 0.26(57)	6.1 0.28(77)	5.2 0.42(46)	7.7 0.99 (7)
Northern Shoveler	8.0 - (1)	6.9 - (1)	7.0 - (1)	-	10.3 0.48 (4)	5.0 4.0 (2)	6.0 1.0 (2)	-
Northern Pintail	-	6.5 0.50 (2)	-	-	-	-	-	-
Gadwall	-	-	-	-	12.0 - (1)	-	-	-

An observed class III brood size has been commonly used in recruitment estimates (Cowardin and Johnson 1979) although this number may be subject to a large error. Applying derived attrition rates to class I brood sizes (Cowardin and Johnson 1979:22), real class III brood sizes for 1989 mallards were probably closer to 5.

Nest success before predator management and after

Overall nest success for this study (22.2%) with 2 seasons of predator management was significantly larger ($\underline{z}$ = 3.54, $P \leq 0.0004$) than was observed in 1984 and 1985 (11.9%) without predator management (Fleskes 1986). Nest success in 1988 (17.7%) was not significantly different ($\underline{z}$ = 1.59, P = 0.11) than 1984-1985; however, nest success in 1989 (26.5%) was significantly greater ($\underline{z}$ = 4.38, $P < 0.0001$). Nest success with years combined for blue-winged teal and mallard (28.0% and 15.1%, respectively) were also significantly greater ($\underline{z}$ = 3.47, $P \leq 0.0004$ and $\underline{z}$ = 1.7, $P \leq 0.09$, respectively) than observed by Fleskes (1986), 13.7% and 9.0%, respectively.

Recruitment and production estimates

Recruitment estimates for ground nesting dabbling ducks (Table 9) ranged from 0.6 in mallards (1988) to 1.1 in blue-winged teal (1989). Calculations used Mayfield nest success for each species, an assumed brood survival rate of 0.7, and the observed (Table 8) or calculated class III brood size (Cowardin and Johnson 1979) for each species.

Table 9. Recruitment and production estimates of dabbling ducks, Union Slough NWR 1988 and 1989

	1988		1989	
Species	Recruitment[a]	Production[b]	Recruitment	Production
Mallard	0.6	123	1.0	293
Blue-winged Teal	0.8	131	1.1	363
Northern Shoveler	0.8[c]	5	0.4	21
Pintail	?	5[d]	-	-
Total production of ground nesters		264		677
Ground nester production/km^2 wetland		72		185

[a]Fledged female young/adult female, from observed class III brood size (Table 8.)

[b]Production = (2 x recruitment) x estimated breeding population (Table 3).

[c]Northern shoveler recruitment based on calculated class III brood size of 4.9.

[d]Pintail production estimated by calculating a class III brood size of 5 from an observed mean class I brood size of 6.5.

Recruitment rates increased for mallard and blue-winged teal during the second season of predator control. A lack of sufficient nest records or brood observations for other species prevents an accurate estimation of their recruitment.

Total production of ground nesting ducks was greatest in 1989 with an estimated 677 fledglings produced. This represents a 156% increase from 1988 when an estimated 264 ducklings fledged.

Causes of nest failure

Despite the predator control measures carried out in 1988-89, mammalian predation accounted for nearly 75% of the 390 failed nests. The proportion of failures attributed to each predator group was similar to that observed by Fleskes (1986) in the same study area (Figure 1). Most failures (57%) could be attributed to either red fox or other large mammal (striped skunk, raccoon, opossum, mink, and badger). Weasel predation caused 15% of all nest failures. Nest failures continued throughout each nesting season indicating that the trapping effort did not remove all individuals or that there was a continual movement into the refuge by new individuals.

Hen loss and predation

The remains or carcasses of a total of 30 waterfowl were found during field activities. In 1988, 9 waterfowl were found and in 1989 21 were found on or near refuge land. Predation accounted for 57% (n = 17) of these losses.

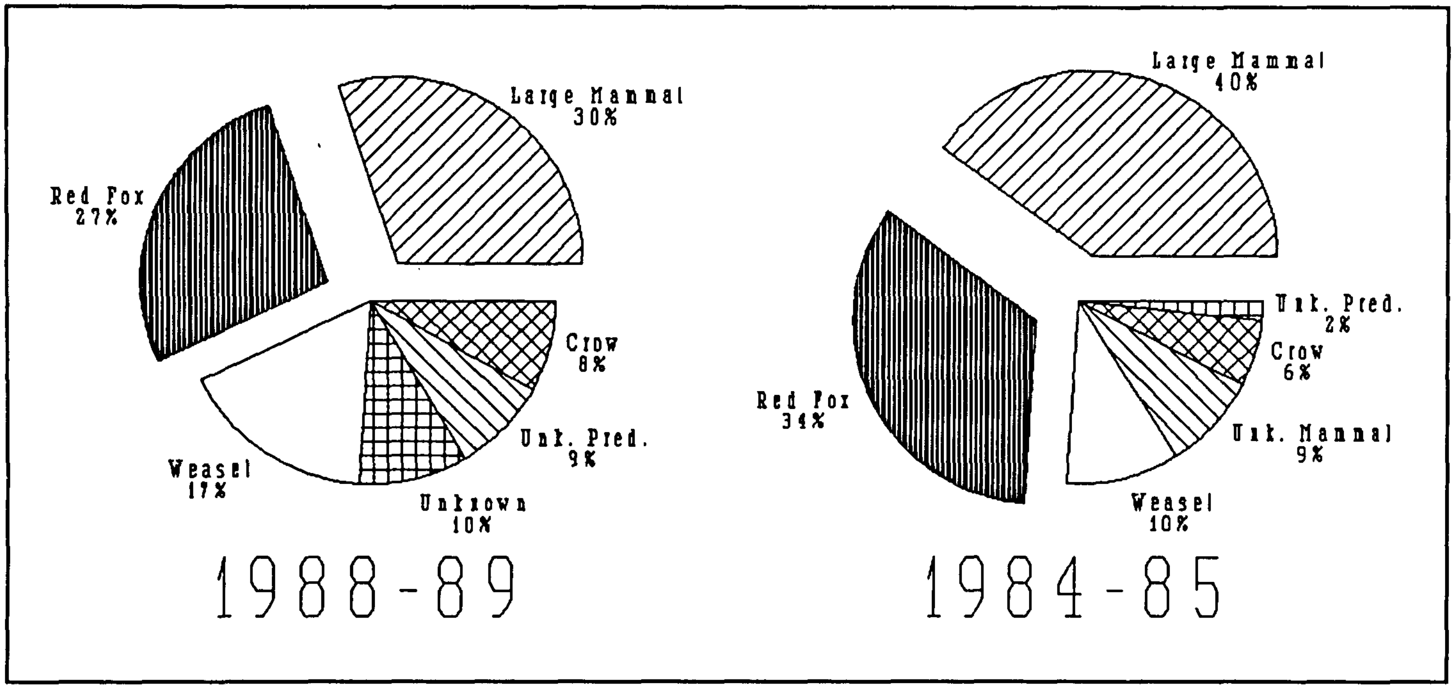

Figure 1. Comparison of predator caused nest failures of dabbling ducks at Union Slough NWR between 1988-1989 and 1984-1985 (Fleskes 1986)

Of these, 25 were dabbling ducks and 5 were geese. The dabbling ducks consisted of 11 mallards, 10 blue-winged teal and 4 wood ducks and were predominantly female (76%, n = 19). Six hens were found killed at nest sites and an additional 20 hens were known or suspected to have been taken from nest sites but carcasses were not found. I found most of these known or suspected hen predations (n = 23) during the 1989 field season. Often only a few feathers were present at the nest site. I found several hens dead near undisturbed nests, whereas at other nests all eggs were missing with evidence that the hen was taken.

The remains of 4 wood ducks were found at the surface or within excavated fox dens. No other dabblers were represented at fox dens. In mid-June 1989, haying operations in MU 1 killed 4 hen mallards and destroyed a total of 7 mallard nests. Other losses include 1 attributed to a raptor, 1 road kill, and 4 of unknown causes.

Vegetation density

There were significant differences in mean visual densities among the 6 major vegetation types (F = 27, P = 0.0001), years of the study (F = 9.34, P = 0.0029), seasons of vegetative growth (F = 59, P = 0.0001), fields within a vegetation type (F = 2.05, P = 0.02), and vegetation type by season interactions (F = 11.79, P = 0.0001) (Table 10).

Table 10. Least square means of visual obstruction measurements (VOM dm) for major grassland vegetation types, Union Slough NWR 1988 and 1989

	Season			
Vegetation Type	Early	Mid	Late	Overall
Blue Grass	0.7	1.6	1.6	1.3
Smooth Brome	1.0	2.6	2.8	2.1
Hay	0.4	2.0	1.9	1.4
Prairie	0.7	1.1	1.6	1.1
Planted Native	1.4	1.5	2.7	1.9
Reed Canary	1.3	2.5	6.4	3.4
Seasonal Means	0.9	1.9	2.8	1.9

The mean VOM for years, seasons and vegetation types combined was 1.9 dm (S.E. 0.11, n = 126) (Table 10). Overall mean VOM for the major vegetation types ranged from 1.1 dm for Prairie to 3.4 dm for Reed Canary. I observed the lowest VOM (0.4 dm) in Season 1 Hay fields. This low measurement was caused primarily by the absence of residual cover due to haying operations of the previous season and the growth character of the legume cover crop. I observed the highest observed VOM (6.4 dm) in Reed Canary (Late Season). Planted Native had the highest Early Season VOM (1.4 dm) indicating the presence of taller residual cover. This type comprises less than 5% of available nesting cover (Figure 2). Smooth Brome had the highest mid Season VOM (2.6 dm). Smooth Brome dominates most upland fields and comprises approximately 31% of available nesting cover. Of all the upland cover types (excluding Reed Canary) Smooth Brome provides the most area of upland nesting cover (table 11) and the densest cover overall (2.1 dm). The availability of Reed Canary as nesting habitat is variable from year to year depending on precipitation. Dry conditions during this study allowed searching of most Reed Canary habitat and presumably also allowed nesting to take place in these areas. Hay provides little nesting cover early in the season but is nearly as tall and dense as Smooth Brome by mid Season. Hay fields are cut mid-June to mid-July on the refuge and provide no cover after cutting.

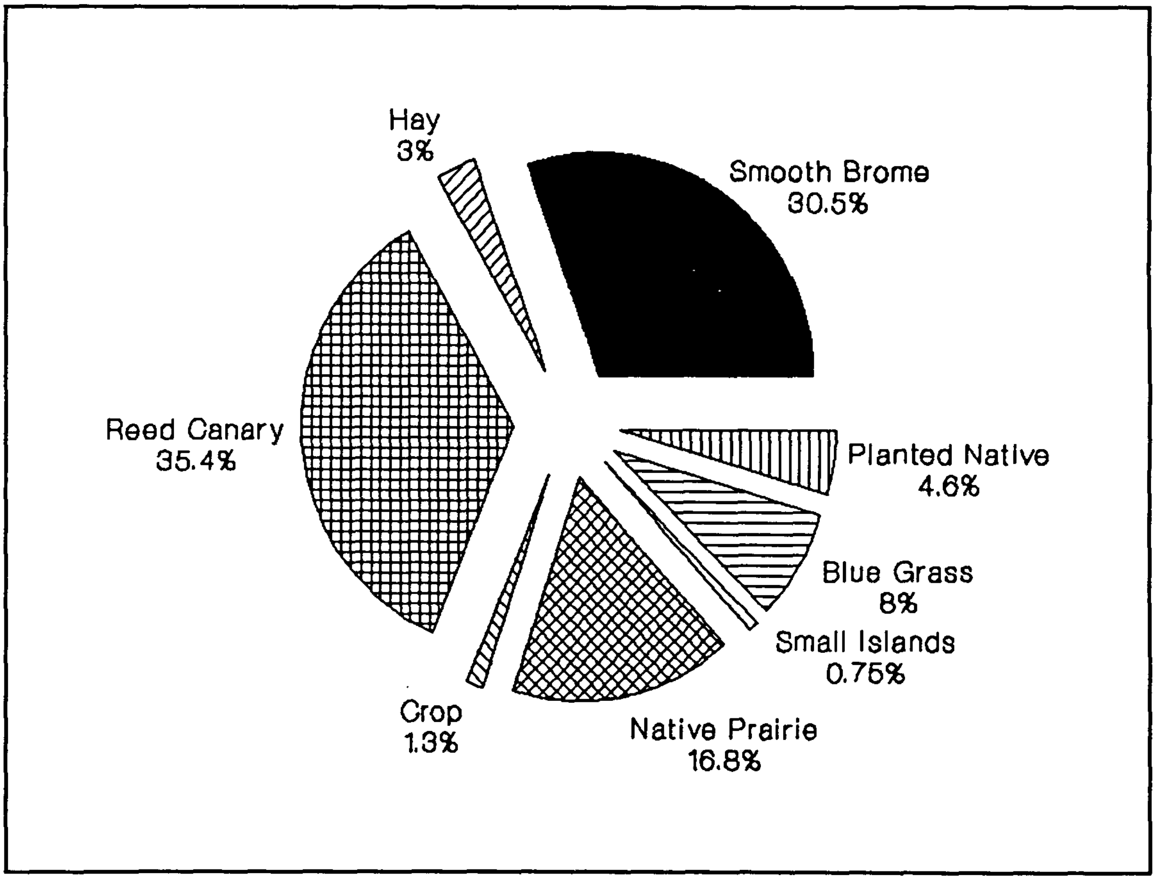

Figure 2. Available upland nesting cover by dominant grass species, land use or land type, Union Slough NWR 1988 and 1989

Table 11. Area (ha) of nesting cover types on refuge land by management unit, Union Slough NWR 1988 and 1989

Habitat	Management Unit						
	1	2	3	4	5	6	Total
Smooth Brome	35	10	38	36	-	29	148
Reed Canary	20	27	51	11	17	47	173
Prairie	8	23	23	-	28	-	82
Planted Native	4	9	6	1	-	3	23
Blue Grass	-	24	1	-	-	14	39
Hay	15	-	-	-	-	-	15
Crop	-	-	6.5	1.5	-	-	8
Small Islands	<1	-	<1	1.2	1.4	-	3
Available Nesting Cover	82	93	119	50.7	46.4	93	484

Vegetation density selection by waterfowl and nest success

With the exception of nests found in Reed Canary and Planted Native grasses, ducks selected nest sites with mean VOM greater ($t \geq 3.10$, $P < 0.005$) than the mean VOM along randomly placed transects in the same vegetation type (Table 12). Nests found in Reed Canary had a lower VOM ($t = 3.18$, $P < 0.001$) than found on average in transects of this type. Nest-site VOM of nests found in Planted Native was not significantly different than found in transects ($t = 1.56$, $P > 0.10$).

Nest success differed among VOM classes ($X^2 = 12.9$, $P < 0.01$). VOMs at most nest sites (370 of 534) were less than 3 dm (Table 13). The greater number and higher success rate in VOM class 1 and 2 are largely due to blue-winged teal selecting sparser vegetation. Of blue-winged teal nests measured, 85% were in VOM class 1 or 2. Mallards did not seem to prefer vegetation of any particular VOM class; nests were nearly evenly distributed among VOM classes and success rates did not differ significantly ($\underline{z} \leq 1.14$, $P \geq 0.25$).

Nest success did not differ significantly between any likely comparisons of field vegetation types ($\underline{z} \leq 1.5$, $P \geq 0.13$). Most nests (74%, n = 427) were found in upland fields dominated by Smooth Brome (34%) or lowlands and marsh edges dominated by Reed Canary (40%). The percentages of nests

Table 12. Mean nest site visual obstruction measurements (VOM) (dm) by season and field vegetation type for ground-nesting ducks at Union Slough NWR, 1988 and 1989

Vegetation type	Season[a] Early		Mid		Late		Overall	
	(n)	(±SE)	(n)	(±SE)	(n)	(±SE)	(n)	(±SE)
Blue Grass	1.8		2.4		2.7		2.5	
	(5)	(0.27)	(13)	(0.48)	(12)	(0.32)	(30)	(0.25)
Brome	2.0		2.7		3.4		2.7	
	(37)	(0.13)	(146)	(0.08)	(34)	(0.21)	(217)	(0.07)
Hay	-		3.7		-		3.7	
			(3)	(1.16)			(3)	(1.16)
Prairie	1.9		2.0		2.7		2.2	
	(11)	(0.28)	(63)	(0.12)	(20)	(0.29)	(94)	(0.11)
Planted Native	2.9		2.2		1.8		2.4	
	(8)	(0.52)	(15)	(0.20)	(3)	(0.04)	(26)	(0.21)
Reed Canary	1.8		2.6		4.4		2.6	
	(54)	(0.12)	(168)	(0.08)	(25)	(0.32)	(247)	(0.08)
Seasonal Mean	2.0		2.5		3.4		2.6	
	(116)	(0.09)	(411)	(0.05)	(95)	(0.15)	(622)	(0.05)

[a]Seasons: early = before 15 May, mid = 15 May - 15 June, late = after 15 June.

Table 13. Mayfield nest success (%) by nest site visual obstruction measurement (VOM), 1988 and 1989 combined, Union Slough NWR

Nest Site	BWT		Mallard		All Dabblers	
VOM	n	%	n	%	n	%
< 2.0	123	32.2	55	14.2	188	27.2
2.0 - 2.9	119	23.9	59	22.5	182	23.2
3.0 - 3.9	39	18.2	64	14.3	106	16.5
> 3.9	4	9.8	52	13.3	58	13.5

found in these vegetation types and the others represented on the refuge are near to the availability of each vegetation type on the refuge (Figure 2).

Nest success did not differ significantly between any likely comparisons of nest site vegetation ($z \leq 1.06$, $P > 0.2$). Most nest sites (79%, n = 453) were located in Brome (47%, n = 267) and Reed Canary (32%, n = 186). Nest success in Brome or Reed Canary (21.7% and 22.6%, respectively) was not significantly different than overall nest success of 22.2%.

DISCUSSION

Nest success relative to predator control

Nest success rates in this study were higher than previous years at Union Slough (Fleskes 1986). Assuming that Fleskes' study is an acceptable experimental control, my results indicate that predator control has been effective. Fewer active red fox dens were found during this study than found by Fleskes (1986). Two active dens were found each year compared to 12 and 15 dens, respectively, for 1984 and 1985. This may indicate a decreased level of fox activity on the refuge during this study. However, assessments of predator activity could not be done because dry conditions resulted in few tracks being found.

Coyotes are a new addition to the predator community at Union Slough. The effect of coyotes denning near the southern part of the refuge in 1988 and in MU 1 in 1989 is unknown. Activity indices of red foxes in prairie Canada were found to be negatively correlated with those of coyotes (Johnson et al. 1989). Coyotes have been observed exhibiting agonistic behavior towards red foxes (Dekker 1983). Red foxes maintain smaller, exclusive territories (Sargeant et al. 1987) and avoid denning in areas frequented by coyotes (Voigt and Earle 1983). Red foxes are thought to be more effective waterfowl nest and hen predators and hunt their territories more thoroughly than coyotes (Johnson and Sargeant 1977). The tendency of foxes to thoroughly hunt their territories helps explain the high loss rate of nests in MU 4 and 5, units where most fox activity was found. The active coyote den in MU 1 probably caused foxes to avoid using this unit for hunting and denning. Nest success was high both years (43%, 50%, respectively) in MU 1, but nest density was also the lowest of all refuge units.

Predator species composition and numbers caught during each season indicate a continual influx or supply of these animals on the refuge. The linear, high edge to area configuration of Union Slough and scarcity of other habitat makes this refuge attractive to predator species.

I observed a 7% increase in nest failures due to weasels than observed by Fleskes (1986). This is not enough evidence to suggest that weasels responded to the decreased numbers of other nest predators. Other workers in northern Iowa have documented increased weasel activity and decreased nest success in the absence of other mammalian predators within an electric fence exclosure (Hansen et al. 1988). In July live trapping, I caught 2 ermine in 1988 and none in 1989. Fleskes (1988) also noted variable success in trapping efforts for weasels. He concluded that most weasel nest depredations at Union Slough are due to ermine. My capture of only ermine and no long-tailed weasels in the July trapping effort supports the prevalence of ermine at Union Slough.

Habitat quality and nest success

Little has changed in refuge habitat at Union Slough since Fleskes (1986) completed his work. Neither he nor I found habitat type or quality to be a factor in nest success. Upland habitat conditions or availability of nest sites do not seem to be limiting the success of upland nesting waterfowl at Union Slough. Most nesting cover on the refuge is of equal or denser quality than most cover found elsewhere in the Prairie Pothole Region (Johnson et al. 1987). The use of only visual obstruction measurements as a measure of field habitat or nest site quality is perhaps an over-simplified method to evaluate a complex relationship. The use of additional measures such as vegetative penetrability and understory/overstory component analysis (Crabtree et al. 1989) may help to define habitat quality limitations, if any, at Union Slough.

Hen losses

Of all ducks at Union Slough, hens were most at risk to mortality. We confirmed or suspected the loss of 51 ducks during 2 nesting seasons; 88% were female (n=45). Most of these hens (78%, n=35) were lost to predation. Hen losses from nest sites were probably due mainly to red foxes (Sargeant et al. 1984).

The loss of nesting hens and their nests during hay mowing is an avoidable but common cause of mortality and nest destruction in the Prairie Pothole Region. Grass-legume hay fields provide large blocks of attractive, homogenous nesting cover. Delaying haying until after 1 July (Bennett 1938) would help reduce losses of hens and nests.

Brood loss and attrition

Brood and duckling survival estimates are integral components of recruitment and production estimates (Cowardin and Johnson 1979). Ball et al. (1975) found that most duckling losses were associated with overland travel, while Talent et al. (1983) found most losses occur in wetland brood-rearing habitat. Both studies found that duckling losses were greatest in the first 2 weeks after hatching. Losses of ducklings at Union Slough during overland travel are probably minimal; most upland nesting cover is adjacent to the wetland. Losses to predation in wetland cover cannot be accurately estimated from my brood observations though marsh predators such as mink and snapping turtles (*Chelydra serpentina*) were common. The influence of low August water levels on brood survival or attrition is also not known but low water probably increases the vulnerability of ducklings to predation. Few complete class III broods were seen compared to class I or II broods. In part this may be due to some class III broods reaching flying age. Many older ducklings were observed in refuge pools unattached to broods. Ringleman and Flake (1980) found brood visibility to increase with age class in broods of mallard and blue-winged teal. A decline of observable broods in older age classes may also mean that a high number of complete broods die before they reach class III status. If complete brood losses exceeded 30%, a figure commonly used in recruitment calculations (Cowardin and Johnson 1979), recruitment would be overestimated.

Nest success and population change

Nest success of 15% for mallard (Cowardin et al. 1985, Cowardin and Johnson 1979) and 20% for other dabbler species (Klett et al. 1988) have been described as the minimum required for long-term population maintenance in North Dakota. If population requirements are similar in Iowa, the nest success of 11.3% for mallards in 1988 was insufficient to maintain the population. The 1989 mallard nest success of 18.5% may have produced a "surplus" of individuals. Blue-winged teal nest success exceeded 20% each year and a "surplus" of individuals may also have been produced.

RECOMMENDATIONS

Research needs

Limited information is available on waterfowl brood survival from hatching to fledging (Cowardin et al. 1985). Union Slough offers an opportunity to study brood and hen dynamics. There is a ready supply of ground nesting and cavity nesting hens and many broods are produced. The geography and size of Union Slough make it well suited for radio telemetry with narrow marshland surrounded by elevated uplands.

Long-term evaluation of predator control is needed to determine if removal of selected species causes changes in the composition of the predator community and whether short-term gains in nest success can be sustained.

Management recommendations

Based on these short-term results, I believe predator management has been effective in increasing nest success of ground nesting ducks at Union Slough NWR and should be continued. Further predator control efforts at Union Slough should be periodically evaluated in terms of nest success and recruitment. A limited nest search in mid-May through June should provide a large enough sample to make an accurate assessment of nest success. To avoid a biased sample, an effort should be made to obtain nest records from management units with low nest densities as well as those with high densities.

Other methods to increase nest success in addition to predator management could also be considered. Electric fence exclosures (Lokemoen et al. 1982) and nesting baskets (Bishop and Barratt 1970, Ray et al. 1989) have produced high nest success in other areas. Predator exclosures would be most efficient in MUs 4 and 5, because these units seem to attract the highest breeding pair and nest densities. As a long-term approach, increasing the upland area available for ground nesting ducks would be desirable. The refuge's long, linear configuration results in long stretches of edge habitat between cropland and upland that are highly attractive to predators. If one assumes that Union Slough Refuge is a permanent national resource, the cost of a parcel amortized over several hundred years may be money well spent. A long-term plan to purchase parcels adjacent to refuge land as they become available would steadily increase refuge upland area. Fleskes (1986) noted that additions to Union Slough's land base may be ineffective if predation continued to limit waterfowl nest success. Continued predator control described here, in addition to an increased land base, would be effective at increasing the productivity of ground nesting waterfowl at Union Slough NWR.

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