Dabbling Duck Recruitment in Relation to Habitat and Predators at Union Slough National Wildlife Refuge, Iowa

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Abstract. The influence of habitat quality and predation on nesting success and recruitment of dabbling ducks *(Anatini)* was studied at Union Slough National Wildlife Refuge in north-central Iowa, 1984–85. Blue-winged teal (*Anas discors*) and mallards *(A. platyrhynchos)* made up 91–93% of the breeding population. Pair numbers increased from 155 (27/km² of wetland) in 1984 to 336 (58/km² of wetland) in 1985 when local drought conditions prevailed. Water control structures maintained good wetland conditions in both years. Reflooded wetlands were more attractive than continuously and deeply flooded wetlands. We found more nests in 1985 (0.6/ha) than in 1984 (0.4/ha). Nest densities in uplands reflected numbers of pairs using the adjacent wetland. Hens selected nesting sites on the basis of nesting-cover quality. Mallards and blue-winged teal preferred nest sites that were most available in grass–legume fields. Overall nest success (Mayfield 1961) averaged 11.9%. Variation among fields in the quality of vegetation had no effect on nest success variability. Mammals caused most of the nest failures (82%); the primary predator was the red fox (*Vulpes vulpes*). Although nest success was highest in the few areas without red fox, it only occurred in fields with low nest densities. Brood attrition (23% loss from hatching to fledging) was similar to attrition reported for other studies; most losses occurred within 2–3 weeks after hatching. Recruitment rates were below what is needed to replace losses due to mortality. Compared with 1958–61, more mallards and similar numbers of blue-winged teal bred on the refuge despite low recruitment and smaller continental populations. Favorable habitats on the refuge evidently attract pioneering pairs and maintain the refuge's breeding population. However, if flyway populations are to increase, management practices are needed that will increase nest success.

Key words: Dabbling ducks, blue-winged teal (*Anas discors*), mallards (*Anas platyrhynchos*), nest success, recruitment, predation, nesting cover, prairie pothole region, Iowa.

Intensified agriculture and wetland drainage have adversely affected waterfowl production throughout the North American midcontinental breeding range. Land-use alterations have caused major changes in densities and community composition of predators (Johnson and Sargeant 1977; Sargeant et al. 1984). As a result, predation of nests has become a major deterrent to annual waterfowl recruitment, especially in the prairie pothole region (Fig. 1). Thus, future maintenance of waterfowl populations will depend increasingly on areas managed intensively for waterfowl production (Klett et al. 1984).

Only about 1% of the natural wetlands once present in Iowa remain, and marshes today total less than 150 km² (Bishop 1981). Most of the remaining wetlands in Iowa support relatively high densities of breeding waterfowl (Glover 1956; Burgess et al. 1965; Krapu et al. 1970; Weller 1979), but if new management goals established under the North American Waterfowl Management Plan for increasing waterfowl production are to succeed, current

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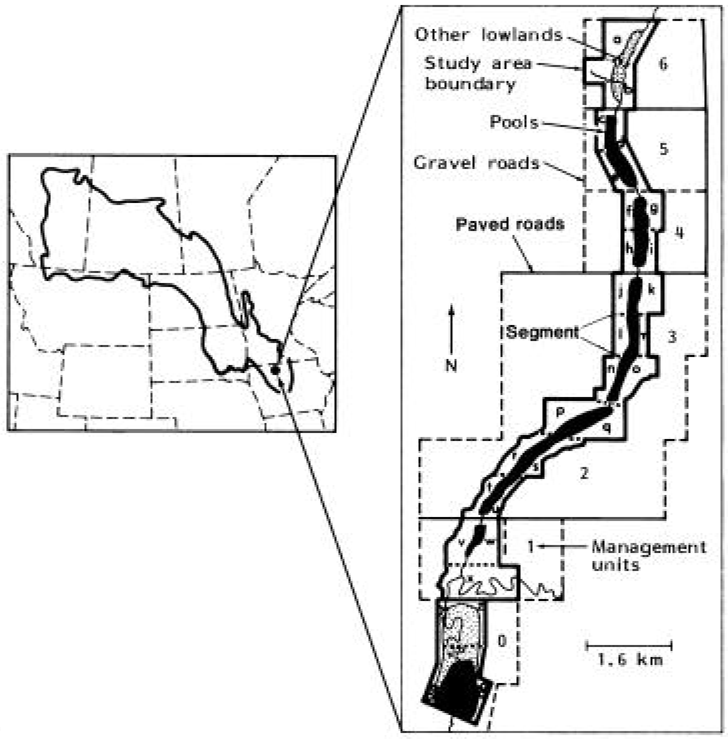

Fig. 1. Map of Union Slough National Wildlife Refuge, Iowa, in relation to the midcontinental prairie pothole region (*outlined*) on the left. The study area was divided into management units (0–6) that included pools, other lowlands, and adjacent uplands. The study area was further divided into 28 segments (a–bb).

conditions and management practices need to be carefully evaluated.

Union Slough National Wildlife Refuge (USNWR) in northern Iowa has long been considered an important waterfowl production area, but recruitment there has not been evaluated in more than 25 years. Burgess et al. (1965) determined that hayfields and moderately grazed pastures provided better nesting habitat for blue-winged teal (*Anas discors*) at USNWR than did ungrazed areas. Since then, however, habitat conditions on and near USNWR have changed substantially.

The objective of this study was to evaluate dabbling duck recruitment at USNWR in relation to current habitat management practices and predator populations.

Study Area

Union Slough National Wildlife Refuge was established in 1937 primarily to assist with the production and management of waterfowl in the Mississippi Flyway. The refuge presently contains 577 ha of upland and 573 ha of wetland (total = 1,150 ha). The refuge extends for 17.5 km along Schwob Marsh, Union Slough, and Buffalo Creek in Kossuth County, Iowa (Fig. 1). Refuge physiography, vegetation, and past land use are described by Burgess et al. (1965). Grazing was discontinued about 1970, and grasslands are now managed by prescribed burning. Farming is now restricted to 62 ha with a 3-year crop rotation (corn or soybean–oats–hay). Idled farmland has been seeded with mixtures of smooth brome (*Bromus inermus* Leyss.) or, rarely, wheatgrasses (*Agropyron* spp.) and legumes (*Medicago sativa*, *Melilotus* spp., *Trifolium* spp.); and with mixtures of switchgrass (*Panicum virgatum* L.), bluestems (*Andropogon* spp.), gramma grasses (*Bouteloua* spp.), yellow indiangrass (*Sorghastrum nutans* L.), needlegrasses (*Aristida* spp.), and porcupinegrass (*Stipa spartea* Trin.). Vegetation is now managed primarily by spring burning. Most of the hayfields and pastures on surrounding private land have been converted to the production of corn or soybeans, causing the refuge to become an island of nesting habitat surrounded by row-crop fields.

Methods

Study Area Divisions

We defined most of the study area by refuge boundaries except for 20 ha of pasture and 30 ha of hay on privately owned land adjoining the refuge. The study area was divided into seven management units (MU), each having a refuge pool or marsh and adjacent uplands (Fig. 1). We subdivided the study area into 28 segments, each about 0.8 km long and located on either side of the water areas (Fig. 1). Segments were additionally subdivided into 110 fields, each 2–28 ha and classified according to vegetative cover, management history, and the MU and segment in which they were located. Idle fields were grouped by vegetation community into six habitats: (1) *Native Grass*—areas with mixed plantings of warm-season native grasses; (2) *Prairie*—areas grazed more than 10 years ago and now covered by an almost equal mixture of warm-season native grasses and forbs and invading cool-season grasses such as Kentucky bluegrass (*Poa pratensis* L.) and smooth brome; (3) *Bluegrass*—areas grazed more than 10 years ago and now covered predominantly by Kentucky bluegrass, small amounts of smooth brome, and few native species; (4) *Brome*—areas grazed more than 10 years ago and now covered predominantly by smooth brome (usually about 95%), (5) *Grass–legume*—areas covered by mixed plantings of a cool-season grass (usually smooth brome, rarely a wheatgrass) and various legume species; and (6) *Reed canary*—lowlands and pool borders where the estimated percent cover of reed canarygrass (*Phalaris arundinacea*) was nearly 100%. Other fields were classified as Hay or grazed Pasture. Hay fields were cut once in July on USNWR and, starting in June, 2 to 4 times each year on private lands.

Other habitats classified were: (1) *Islands*—vegetated dredged material, piled up 1–10m wide × 10–100m long during an attempt in the 1920's to drain Union Slough with a central ditch; (2) *Wetland basins*—emergent vegetation and muskrat (*Ondatra zibethicus*) houses; (3) *Road ditches*—rights-of-way of roads bisecting USNWR.

Pair and Brood Counts

We counted dabbling duck pairs and broods every 5–10 days from late March to mid-August by using a × 15–60 zoom spotting scope to observe from high hills and trails bordering water areas. We followed the procedures of Dzubin (1969) for counting pairs and those of Gollop and Marshall (1954) for brood counts. Pairs, lone drakes, and groups of fewer than six drakes were tallied as breeding pairs. We used nesting data to determine the nesting season and the minimum breeding population. We did not adjust pair–count data by applying prelaying sex ratios (Dzubin 1969) because adjusted data resulted in breeding population estimates below the minimum possible breeding population (number of hens known to be on nests at one time). We compared pair and brood use with the water level and ratios of cover to open water for each wetland. We measured water levels periodically by using permanent gauges, and visually estimated ratios of cover to open water in April.

Predator Assessments

To assess predator populations and distributions, we recorded all mammalian predator sightings, conducted biweekly line transect counts of avian predators, conducted intensive monthly searches for predator nests and ground dens, checked all bare-ground areas for predator tracks in early May, early June, and late June, and live-trapped in July (Fleskes 1988). We determined the presence or absence of a predator species in each segment by using a cumulative assessment of data collected from all techniques.

Nesting Assessments

We used several methods to find nests. We searched about 98% of upland, pool border, and dry wetland areas four times (at 18-day intervals from mid-April to early July) by towing a 0.64-cm chain (17 m long in 1984 and 34 m long in 1985) between two all-terrain vehicles (Klett et al. 1986). We visited 95% of the muskrat houses, and searched on foot (while beating vegetation with switches or dragging a rope [Labisky 1957]) all other idle upland cover and 40% of the emergent vegetation at least twice between mid-April and mid-June. We searched one-third of the privately owned hay with a rope-drag in early June before the hay was cut, and searched all hay for destroyed and hatched nests after swathing and again after swaths were picked up.

Nests were marked 6 m away with flagging (2 cm long) attached to a wire stake. Nest locations were plotted on aerial photographs. We candled eggs to determine their development stage (Weller 1956)and visited nests every 3–10 days until their fate was determined. We determined the cause of nest failure by these criteria: (1) ermine (*Mustela erminea*) or long-tailed weasel (*M. frenata*), if egg loss rate and eggshells were like those described by Fleskes (1988); (2) red fox (*Vulpes vulpes*), if all eggs were missing, no eggshells were found, and the nest material was undisturbed or partly (10% or less) pulled out in one direction; (3) other mammal (striped skunk, *Mephitis mephitis*; raccoon, *Procyon lotor*; mink, *Mustela vison*; badger, *Taxidea taxus*; or opossum, *Didelphis virginiana*) if most eggs were opened at the nest site, and eggshells were crushed or had medium or large holes in them (>50% of the nest material was usually disturbed); or (4) American crow (*Corvus brachyrhynchos*) if eggshells present had definite peck holes in them. We classified pillaged nests not fitting in one of these categories as "unknown mammal" if diggings or crushed eggshells were present. All other pillaged nests were classified as "unknown predator." We used sightings of predators at nests to help formulate the classifications given and check their validity, and compared classifications with predator distribution data. We classified nest failures resulting from abandonment by the female without evidence of depredation or weather influence as "observer-caused" if there was no evidence that the female returned to the nest after we flushed her off (i.e., the number of eggs for incomplete clutches or incubation stage for completed clutches remained the same) or as "unknown cause" if there was evidence that the female returned to the nest after we flushed her off.

Vegetation Assessments

We evaluated nest-site vegetation when nests were first located by measuring visual obstruction (Higgins and Barker 1982) and by estimating the percent cover of the dominant plant species in a circle 1 m in diameter around the nest. Visual obstruction values measured at mallard and blue-winged teal nests were compared with field averages obtained each April, mid-May, and late June. We obtained field averages by measuring visual obstruction at 25 points spaced 15 m apart along a randomly placed transect in two to nine fields from each habitat. We made four sightings to the nearest 0.25 dm at a height of 1 m, 4 m north, south, east, and west from each transect point and averaged the data obtained to calculate a point mean. Field averages were then calculated from the 25 point means. We regressed measurements over time, and combined years because results did not differ. We could not compare nest and field visual obstruction measurements in Hay, Native grass, and Pasture because too few nests were found in those habitats.

Calculations

We calculated daily survival rates (DSR = 1 – [Number of unsuccessful nests divided by total number of exposure days]) and nest success (nest success = DSR^{36}) by the Mayfield method (1961) as applied to duck nests (Miller and Johnson 1978) for all nests except those failing because of observer-caused abandonment by the female. Nests for which DSR's were calculated were grouped for various analyses. The DSR's of groups with 10 or more nests were weighted by exposure period, and total sums of squares (TSS) for differences among groups of DSR's were calculated. The TSS/DSR(1-DSR) ratio is distributed approximately in a chi-square (χ^2) distribution with the degrees of freedom (df) used to calculate the TSS (D. Johnson, personal communication). We used this ratio to determine if DSR's among groups differed significantly ($P < 0.10$). We used z tests to determine if differences between the DSR of specific group pairs were significant ($P < 0.10$) and employed the Bonferroni method of multiple comparisons (Johnson and Wichern 1982) to maintain an alpha level of 0.10. We present P values of multiple paired comparisons at both the unprotected level (P) and the Bonferroni protected level (P_b). We report results of tests made for species separately only when they differ from tests for all species combined. DSR's of all groups, regardless of sample size, were converted to nest success for presentation in tables because nest success is more easily interpreted. Nest success confidence intervals (C.I.) are at the 0.90 level.

We present the number of nests found and nest initiation estimates (number of successful nests found divided by nest success) as indices to nest density. We present nest initiation estimates to allow comparisons with other studies using different sampling procedures (Miller and Johnson 1978). Only annual estimates for the entire study area were possible due to small sample sizes. We used the number of nests found to compare nest densities within our study area because we sampled all areas alike.

We calculated recruitment (number of female young surviving to flight age divided by number of breeding pairs) using equation 5 in Cowardin and Johnson (1979). Because of favorable habitat conditions maintained at USNWR we assumed nesting intensity was high (alpha = 1) and used equation 6 to calculate hen success from nest success (Cowardin and Johnson 1979). We could not detect losses of entire duck broods because we did not mark broods, so we bracketed recruitment estimates by using Cowardin and Johnson's (1979) estimate of entire brood survival (70%) and by assuming no losses of entire broods.

Other statistical methods mainly follow Snedecor and Cochran (1980). We present means ±1 standard error (SE) unless specified otherwise. We used chi-square tests to analyze count data, and used repeated-measure analysis of variance, with conservative degrees of freedom, to compare visual obstruction measurements.

Results

Breeding Waterfowl

Annual Populations of Dabbling Ducks

Blue-winged teal and mallards made up 91–93% of the dabbling duck breeding populations each year (Table 1). Less common breeders were northern shoveler (*Anas clypeata*), green-winged teal (*A. carolinensis*), gadwall

Table 1. *Peak numbers and densities (pairs per square kilometer of wetland) of dabbling duck (*Anatini*) breeding pairs at Union Slough National Wildlife Refuge during the 1984 and 1985 nesting seasons.*

	1984		1985	
Species[a]	Number	Density	Number	Density
Blue-winged teal	72	12.5	210	36.6
Mallard	69	12.0	104	18.1
Northern shoveler	5	0.9	7	1.2
Green-winged teal	4	0.7	4	0.7
Gadwall	2	0.3	1	0.2
American wigeon	2	0.3	4	0.7
Northern pintail	1	0.2	6	1.0
Total	155	26.9	336	58.5

[a] Blue-winged teal (*Anas discors*), mallard (*A. platyrhynchos*), northern shoveler (*A. clypeata*), green-winged teal (*A. carolinensis*), gadwall (*A. strepera*), American wigeon (*A. americana*), northern pintail (*A. acuta*).

(*A. strepera*), American wigeon (*A. americana*), and northern pintail (*A. acuta*). Peak density of breeding pairs averaged 42.5/km^2 of wetland for the 2 years of the study.

Blue-winged teal and mallard breeding populations were larger in 1985 than in 1984. Numbers of blue-winged teal pairs differed significantly (χ^2, $P < 0.01$, 1 df) for all counts (n = 8) made during the nesting season. Numbers of mallard pairs differed significantly in 8 of 10 counts (χ^2, $P < 0.05$, 1 df). Only counts of mallards on 22 April and 1 May did not differ.

Wetland Use

During the nesting season each year, mean densities of breeding blue-winged teal and mallard pairs (Table 2) were greater on wetlands that were 25–50% covered by emergent vegetation and were relatively shallow and completely or partly drained before being reflooded (pools 4 and 5 and Schwob Marsh in MU 6), than on deeper (pools 0 and 3) or more open (pools 0, 1, and 2) wetlands (Fig. 2). The mean proportion of the total mallard and blue-winged teal breeding population seen on some wetlands during the nesting season changed between years (Table 2), and corresponded to changes in the relative habitat quality of each wetland. For instance, increased pair use of the large, open pool 2 in 1985 corresponded to a decreased water level in comparison with 1984. Ducks (especially blue-winged teal) were also attracted to reflooded wetlands (pools 4 and 5) in 1985, and away from wetlands that were kept deep both years (pool 3) or that dried up early in the season (pools 0 and 1 and Schwob Marsh in MU 6).

Table 2. *Mean densities of blue-winged teal (*Anas discors*) and mallard (*A. platyrhynchos*) pairs and broods (per square kilometer of wetland) and percent of the total number occurring on wetlands in each management unit (MU) during the 1984 and 1985 nesting seasons at Union Slough National Wildlife Refuge, Iowa.*

	Pairs				Broods			
	Density[a]		Percent[b]		Density		Percent	
MU	1984	1985	1984	1985	1984	1985	1984	1985
0	7 C	1 D	5	*<1	0 C	0 C	0	0
1	5 C	10 C	2	2	0.4BC	0 C	1	0
2	6 C	41 B	8	*28	4.3AB	5.0A	33	48
3	27 B	18 C	25	* 9	5.4AB	1.7ABC	30	*12
4	42 AB	95 A	25	29	9.6A	5.7AB	33	24
5	46 AB	109 A	23	28	1.0BC	4.8AB	3	*17
6	120 A	80 A	12	* 4	0 C	0 C	0	0
Average[c]	21	42			1.5	2.1		

[a] Numbers in the same column with different letter are significantly different ($\chi^2 > 3.84$, 1 df).
[b] Asterisk (*) denotes that the change between years for the MU differed significantly ($\chi^2 > 3.84$, 1 df) compared with the average change for the study area.
[c] Average number of pairs or broods seen on all Union Slough National Wildlife Refuge wetlands (5.73 km^2).

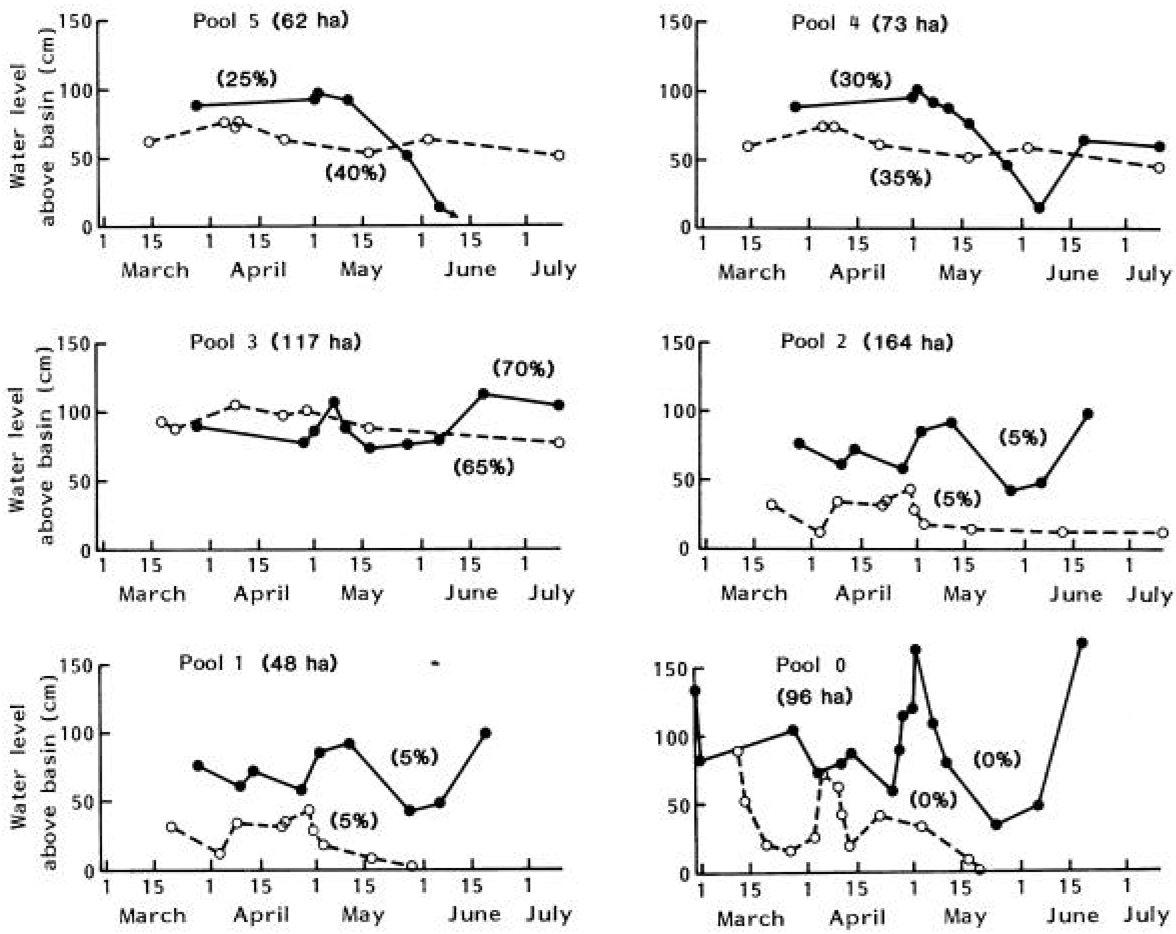

Fig. 2. Water level, size, and percent of basin having emergent cover on 1 April (*in parentheses* next to keys) for Union Slough National Wildlife Refuge pools during the 1984 (*solid line*) and 1985 (*dashed line*) waterfowl breeding seasons. Pool levels were affected by precipitation and prescribed manipulations. Schwob Marsh levels (not shown) in management unit 6 were measured less frequently. Schwob Marsh had no control structures and was dry during much of the 1985 nesting season because of drought.

Nesting

Use of Nesting Habitats

Overall, an estimated 89 (90% C.I. = 79–118) nests per km² of upland were initiated annually 1984–85 at USNWR; about half were mallard and half were blue-winged teal. We found the highest densities of mallard nests on *Islands* (37/km²) and in *Grass–legume* fields and the lowest densities in *Pasture* and *Prairie* (Table 3). We found the highest densities of blue-winged teal nests in *Grass–legume* and *Bluegrass*; none were found on *Islands*.

Upland Use Reflected Pair Distribution

Nest densities in uplands of each MU corresponded to the number of pairs counted on wetlands in each MU (Fig. 3). The correlation between blue-winged teal nest densities and pair counts was fairly strong ($r^2 = 0.71$; Fig. 3). Thus, the amount of high quality wetland habitat in each MU greatly influenced blue-winged teal use of adjacent nesting cover. For example, even though the amount and relative quality of nesting cover in MU 5 did not change between years, the density of blue-winged teal nests increased to the highest of any MU in 1985, corre-

Table 3. *Dominant vegetation at dabbling duck nests in Union Slough National Wildlife Refuge, 1984–85.*

Dominant nest-site vegetation[a]	All ducks		Blue-winged teal		Mallard	
	Number of nests	Percent of total	Number of nests	Percent of total	Number of nests	Percent of total
Smooth brome	200	44	102	41	92	50
Reed canarygrass	93	21	44	18	48	26
Bluegrass	73	16	61	26	5	3
Native grasses	30	7	20	8	8	4
Sedges	12	2	8	3	4	2
Cattail–bulrush	17	4	1	1	14	8
Legumes	28	6	8	3	13	7

[a] Smooth brome (*Bromus inermis* Leyss.); reed canarygrass (*Phalaris arundinacea* L.); bluegrass (*Poa pratensis* L.); native grasses (*Panicum virgatum* L., *Andropogon* spp., *Bouteloua* spp., *Sorghastrum nutans* L., *Aristida* spp., *Stipa spartea* Trin., *Urtica* spp.); sedges (*Carex* spp., *Cyperus* spp., *Eleocharis* spp.); cattail (*Typha* spp.); bulrush (*Scirpus* spp.); legumes (*Medicago sativa, Melilotus* spp., *Trifolium* spp.).

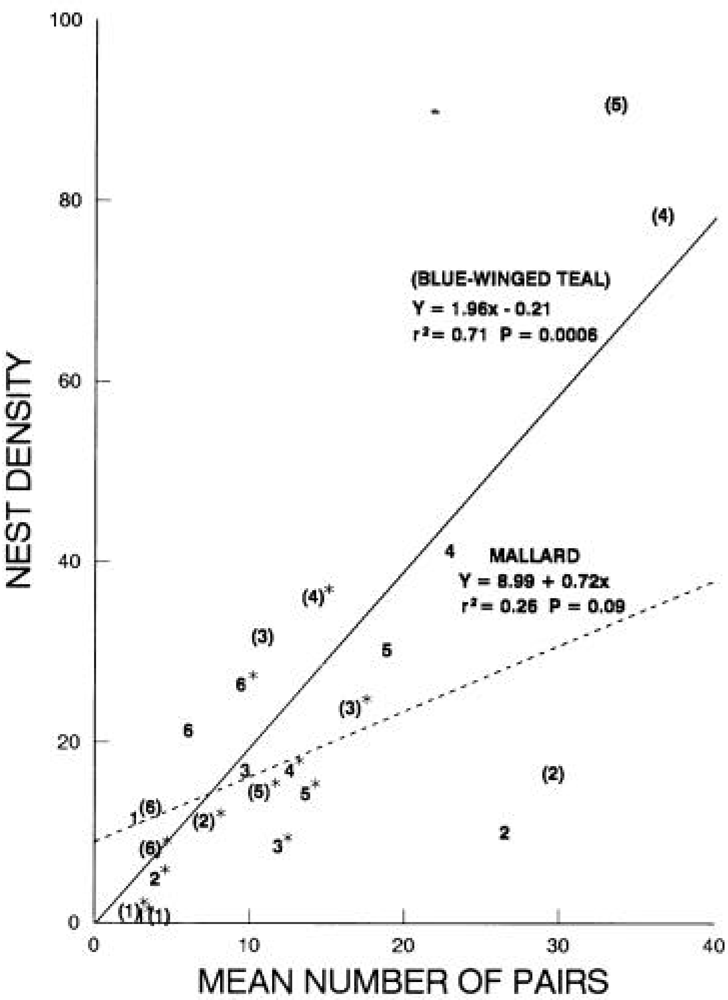

Fig. 3. Correlation between nest densities (number of nests found per square kilometer of upland) in each Union Slough National Wildlife Refuge management unit (numbers correspond to each unit shown in Fig. 1) and the mean number of breeding pairs counted on wetlands in each unit, for blue-winged teal, *Anas discors*, (*in parentheses*) and mallards, *A. platyrhynchos*, during the 1984 (*asterisk*) and 1985 nesting seasons.

sponding to the positive response by blue-winged teal pairs to the reflooding of the MU 5 wetland. The correlation between mallard nest densities and pair-counts in each MU was weak ($r^2 = 0.26$; Fig. 3). Evidently, a high percentage of mallard females nested in MU's other than those in which the wetland that they primarily used was located.

Because nest densities were highest in uplands adjacent to high-quality wetlands and the location of fields greatly affected their use by nesting females, nest density indices (mallard, blue-winged teal, and total duck) for habitats averaged over the entire study area were not correlated ($r^2 \leq 0.32$, $P \geq 0.18$) with April, mid-May, late-June, or mean seasonal habitat visual obstruction measurements. For example, the mean density of nests in *Brome* was very low in relation to the mean density of nests in *Grass–legume* (Table 4) even though mean visual obstruction measurements for the two habitats were similar (Fig. 4). Differences in nest densities for the two habitats occurred because most (86%) *Brome* area was adjacent to the MU 1 wetland, which received low pair use, whereas most *Grass–legume* fields were next to wetlands that were highly attractive to pairs.

Nest Site Selection Related to Cover Quality

Although nest densities in each MU were greatly affected by the number of pairs using adjacent wetlands, females selected nest sites on the basis of nesting-cover quality. Nesting hens of the same species tended to select sites where vegetation provided similar visual obstruction (Fig. 4). Mallard hens tended to select nest sites where the vegetation was taller and thicker than the average vegetation in the field. This trend occurred throughout the nesting season but was less evident early in the season because early cover had low variability. Blue-winged teal hens nesting in dense habitats tended to select sites at which cover was more sparse than average; in other habitats, nest-site cover tended to match vegetation in the fields. The mean visual obstruction measurement at mallard nest sites (3.4 ± 0.12, $n = 137$) was greater ($t = 7.00$, $P < 0.001$) than at blue-winged teal nest sites (2.5 ± 0.06, $n = 222$). Mean nest-site visual obstruction measurements at nest sites of other species were 4.0 ± 0.40 for gadwall ($n = 2$), 2.4 ± 0.38 for green-winged teal ($n = 3$), 2.5 ± 0.39 for northern shoveler ($n = 4$), and 2.7 for northern pintail ($n = 1$).

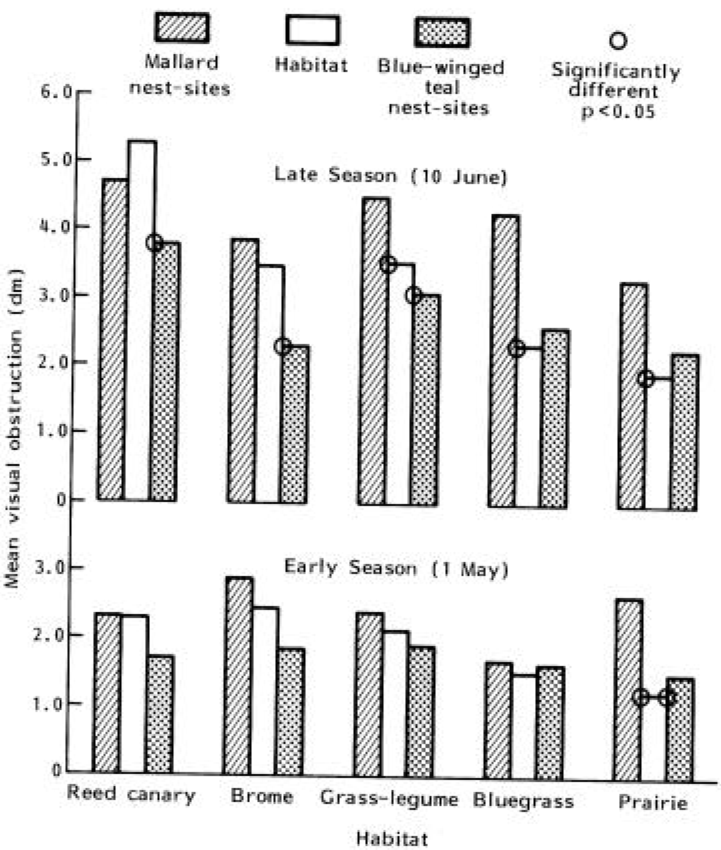

Fig. 4. Mean 1984–85 visual obstruction measurements predicted for 1 May and 10 June by regression of actual measurements taken at mallard (*Anas platyrhynchos*) and blue-winged teal (*A. discors*) nestsites and at transect points in fields where nests were found.

The most common nest-site vegetation at both teal and mallard nests was smooth brome (Table 3). Smooth brome was the dominant grass in *Grass–legume* and *Brome* fields and also occurred as monotypic clumps in *Bluegrass* and *Prairie* fields. Nests (especially mallard) in *Bluegrass* and *Prairie* fields were often in these brome clumps.

Upland Use Reflected Habitat Availability

The availability of preferred nest sites differed among habitats. Wherever *Grass–legume* occurred within an MU, mallard and blue-winged teal nest densities were higher than in other habitats in the same MU (Table 4). This indicates that the different kinds of nest sites preferred by mallards and teal were both readily available in *Grass–legume* habitat. In contrast, *Prairie*, a sparse habitat, provided few nest sites that were attractive to mallards, and nest densities of mallards there were usually low in relation to other habitats.

The availability of preferred habitats differed among MU's and affected the use of nesting habitats within each MU. For example, Reed canary was extensively used by nesting teal only when preferred nesting habitats (i.e., *Grass–legume* or *Bluegrass*) were not readily available in the same MU (Table 4). According to comparisons of visual obstruction measurements between nest sites and habitats, late-season *Reed canary* may be taller and denser, on the average, than what is normally selected by most nesting females (Fig. 4). Reduced availability of nest sites sparse enough to attract blue-winged teal may have limited the use of *Reed canary* during the late nesting season.

Nest Success

Annual Nest Success

Nest success for all dabbling ducks in 1984–85 averaged 11.9% (Table 5). Daily survival rate of blue-winged teal nests was greatest ($z = 2.84$, $P = 0.005$) in 1984 when pair populations and nest densities were lowest. The daily survival rate of nests of other species did not differ between years ($z \leq 1.36$, $P \geq 0.17$). The daily survival rate of nests differed among species only in 1984, when survival of blue-winged teal nests was significantly greater ($z = 2.94$, $P = 0.003$) than mallard nests.

Table 4. *Density of blue-winged teal (*Anas discors*) and mallard (*A. platyrhynchos*) nests found per square kilometer (1984–85 mean) for habitats in each management unit (MU) at Union Slough National Wildlife Refuge, Iowa.*

	Management unit						
Habitat	MU1	MU2	MU3	MU4	MU5	MU6	Mean[a]
				Blue-winged teal			
Reed canary		17	21	44	139	8	25
Brome	0	10	29				15
Grass–legume		(0)[b]	58	71			52
Native grass	(0)	(21)	(31)	(22)			20
Hay		3	29	(27)		2	30
Bluegrass		21	51	47	(170)	(24)	38
Prairie	4	21	61		36	(0)	26
Pasture			37		(0)		18
				Mallard			
Reed canary		11	21	12	30	27	24
Brome	10	15	15				12
Grass–legume		(11)	26	43			33
Native grass	(0)	(42)	(10)	(0)			18
Hay		3	34	(0)		12	14
Bluegrass		10	13	24	(34)	30	23
Prairie	13	2	16		7	(0)	7
Pasture			5		(21)		5

[a] Does not include MU0 where no nests were found.
[b] *Parentheses* denote that the habitat in the MU was less than 5 ha, and densities were calculated from four or more nests.

Table 5. *Mayfield (1961) nest success (percent ± 90% confidence intervals, C.I.) of dabbling ducks at Union Slough National Wildlife Refuge, Iowa, 1984–85.*

	1984		1985		Both Years	
Species[a]	Number of nests	Nest success (C.I.)	Number of nests	Nest success (C.I.)	Number of nests	Nest success (C.I.)
Blue-winged teal	84	23.4 (16.4–33.2)	165	10.1 (7.1–14.1)	249	13.7 (10.7–17.6)
Mallard	79	5.6 (2.7–11.5)	105	11.1 (7.3–16.9)	184	9.0 (7.2–11.2)
Other dabbling ducks	8	23.7 (7.1–76.0)	4	9.1 (0.9–82.7)	12	17.6 (5.9–51.0)
Total	171	15.3 (11.1–21.1)	274	10.3 (7.9–13.5)	445	11.9 (9.7–14.6)

[a] Blue-winged teal (*Anas discors*); mallard (*A. platyrhynchos*); other dabbling ducks include three green-winged teal (*Anas carolinensis*), two gadwall (*A. strepera*), and three northern shoveler (*A. clypeata*) nests in 1984, and two northern pintail (*A. acuta*) and two northern shoveler nests in 1985.

Causes of Nest Failure

The major cause of failure for dabbling duck nests was predation by mammals (Table 6). The red fox was the most important predator species in most areas. Red fox were abundant (≥ six families in 1984 and ≥ five families in 1985) and fox or their sign were found in all but a few segments. American crow, raccoon, striped skunk, mink, and ermine were also abundant and occurred throughout the refuge. Of 98 nests that hatched, 20 had eggs missing before hatching. Most of these eggs were probably taken by ermine (Fleskes 1988). Long-tailed weasel, Virginia opossum, and badger were less common. Coyote *(Canis latrans)* and Franklin's ground squirrel *(Spermophilus franklinii)* were absent.

Severe weather also caused failure of some nests. On 30 April 1984, 15.4 cm of snow fell, accompanied by high winds. The blizzard and subsequent flooding of lowlands caused nest abandonment and may have exposed additional nests to predators, thereby lowering the success of early (all mallards) nests (Table 7). A series of tornados crossed USNWR on 7 June 1984, causing two nests to be abandoned. A storm on 31 May 1985 pelted parts of USNWR with hail about the size of golf balls. The hail destroyed all 14 active nests (13 blue-winged teal) in the affected areas and lowered nest success for that period (Table 7). Although these weather-caused failures lowered the mean nest success for mallards in 1984 and blue-winged teal in 1985, losses were still minor in comparison with predation.

Table 6. *Causes of dabbling duck nest failure at Union Slough National Wildlife Refuge, Iowa, 1984–85.*

Cause of nest failure	Percent of all failures (n = 328)[a]	Percent of predator-caused failures (n = 292)
Red fox[b]	30.2	33.8
Other mammals[c]	35.3	39.8
Weasels	9.1	10.3
Unknown mammal	7.7	8.6
Mammal subtotal	82.3	92.5
American crow[d]	5.2	5.8
Unknown predator	1.5	1.7
Predator subtotal	89.0	100.0
Hail, flood, snow	6.7	
Unknown cause	3.7	
Thistle spraying	0.6	
Total	100.0	

[a] Not including 26 nests abandoned because of observer.
[b] Red fox (*Vulpes vulpes*).
[c] Striped skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), mink (*Mustela vison*), opossum (*Didelphis virginiana*), or badger (*Taxidea taxus*).
[d] American crow (*Corvus brachyrhynchos*).

Table 7. *Mayfield (1961) success (percent ± 90% confidence intervals, C.I.) of dabbling duck nests grouped according to when the nests were found at Union Slough National Wildlife Refuge, Iowa, 1984–85.*

	Years combined		1984		1985	
Date found	Number of nests	Nest success (C.I.)	Number of nests	Nest success (C.I.)	Number of nests	Nest success (C.I.)
Before 9 May	50	11(6–20)	10	0(0–4)	40	15(9–26)
9–24 May	146	11(7–15)	38	13(7–23)	108	10(7–15)
25 May–14 June	120	13(9–19)	54	22(14–34)	66	8(4–14)
After 14 June	76	14(9–21)	36	17(9–31)	40	12(6–22)

Cover Quality Effects on Nest Success

Nest success did not differ ($P > 0.1$) when grouped by visual obstruction measured at nest sites (Table 8) or by dominant nest-site vegetation. Similarly, overall success of nests grouped by habitat type did not differ, except that mean success was significantly lower for nests found on *Islands* than in *Brome* fields (Table 9).

Fox Distribution and Nest Density Effects on Nest Success

Nests in segments where red fox or their sign were never seen (without fox) survived at a higher rate ($z = 1.96$, $P = 0.05$, nest success = 17% [C.I. = 12–24]) than nests located in segments where fox or sign were seen (with fox; nest success = 10% [C.I. = 8–13]). However, when nests were grouped further by habitat type, this trend was evident only in habitats without fox and having low nest densities (*Brome*, *Prairie*, and *Hay fields* in Table 10). Nest success was low in habitats that had high nest densities even without fox (*Reed canary*, *Grass–legume*, Bluegrass; Table 10). In habitats with fox, nest success was low regardless of the density of nests. This explains the high nest success in *Brome* in relation to other similar habitats (Table 9) because, unlike other habitats, nearly half of all nests in *Brome* occurred at low densities outside of fox territories (Table 10).

Differences in nest success among habitats without fox were related to differences in nest densities but not differences in vegetative structure. Differences in nest success were evident between *Brome*, *Grass–legume* and *Reed canary* even though mean visual obstruction for these habitats was similar (Fig. 4). Also, success did not differ among nests grouped by nest-site visual obstruction measurements in areas with or without fox ($P \geq 0.1$).

Table 8. *Mayfield (1961) success (percent ± 90% confidence intervals, C.I.) of dabbling duck nests grouped by visual obstruction measurement (VOM) of vegetation at the nestsite at Union Slough National Wildlife Refuge, Iowa, 1984–85.*

	All ducks		Blue-winged teal[a]		Mallard[b]	
Nest site VOM	Number of nests	Nest success (C.I.)	Number of nests	Nest success (C.I.)	Number of nests	Nest success (C.I.)
<2.0	90	12(8–18)	67	15(10–23)	21	5(2–15)
2–2.9	131	14(10–20)	92	14(9–20)	35	15(8–29)
3–3.9	72	12(8–20)	41	11(6–21)	29	13(6–27)
>3.9	57	13(8–23)	13	23(9–57)	43	10(5–20)

[a] Blue-winged teal (*Anas discors*).
[b] Mallard (*Anas platyrhynchos*).

Broods

Production in Relation to Pairs and Nesting

Although study area nest densities reflected changes in pair populations between years, overall brood production did not (Table 11). We found about twice as many blue-winged teal nests in 1985 as in 1984, corresponding to a threefold increase in the local breeding population in 1985. Similarly, we found 30% more mallard nests in 1985 and counted 50% more mallard pairs. However, brood production in 1985 was similar to 1984 because teal nest success was lower in 1985.

Wetland Use

Mean densities of dabbling duck broods differed among MU wetlands each year and brood use was similar to pair use (Table 2). As with pairs, most broods used wetlands that were relatively shallow, were drained and later reflooded, and contained substantial emergent cover (Fig. 2). However, broods extensively used the large, open

Table 9. *Mayfield (1961) success (percent ± 90% confidence intervals, C.I.) of dabbling duck nests grouped by habitat at Union Slough National Wildlife Refuge, Iowa, 1984–85.*

Habitat	Years combined		1984		1985	
	Number of nests	Nest success (C.I.)	Number of nests	Nest success (C.I.)	Number of nests	Nest success (C.I.)
Reed canary	97	14(10–21)	20	8(3–22)	77	16(11–21)
Brome	28	25(14–43)	10	15(4–53)	18	30(16–54)
Grass–legume	100	12(8–18)	40	21(13–35)	60	8(4–14)
Native grass	7	13(2–67)	3	42(10–100)	4	2(0–71)
Bluegrass	67	10(6–17)	33	10(5–22)	34	10(4–21)
Prairie	61	11(7–19)	23	25(13–47)	38	6(3–13)
Hay	5	23(6–91)	2	33(5–100)	3	18(2–100)
Pasture	9	3(0–20)	1	2(0–100)	8	3(0–23)
Islands	8	1(0–12)	4	0(0–26)	4	2(0–42)
Wetland basin	7	4(0–40)	1	100	6	4(0–38)
Road ditches	3	0(0–17)	1	0(0–100)	2	0(0–100)

Table 10. *Mayfield (1961) success (percent ± 90% confidence intervals, C.I.) of dabbling duck nests grouped by habitat and by presence or absence of red fox (*Vulpes vulpes*) at Union Slough National Wildlife Refuge, Iowa, 1984–85.*

Habitat	Red fox absent[a]			Red fox present		
	Number of nests	Nests found per km^2	Nest success (C.I.)	Number of nests	Nests found per km^2	Nest success (C.I.)
Reed canary	25	74	12(5–27)	72	40	15(9–23)
Brome	11	11	62(39–97)	15	64	10(3–27)
Grass–legume	22	89	14(6–31)	78	80	12(8–18)
Native grass	0			7	35	13(2–67)
Bluegrass	19	74	14(6–34)	46	52	8(4–17)
Prairie	13	35	29(15–59)	48	31	8(4–14)
Hay	1	27	100	4	9	8(1–82)
Pasture	0			9	23	2(0–20)
All habitats	91	40	17(12–24)	279	43	10(8–13)

[a] Fox not seen, no fox dens in area, and fox tracks not found.

pool 2 both years even though few nests hatched from adjacent uplands. Also, the Schwob Marsh in MU 6 received no brood use because it dried early in the season. Brood use of the deep and heavily vegetated pool 3 decreased in 1985, similar to pair use, when reflooded pools 4 and 5 were available.

Brood Attrition

The mean number of Class III ducklings per brood was 23.2% less than the mean number of eggs that hatched from a nest (Table 12). The greatest loss of ducklings occurred between the time of hatch and the time that they reached age Class II (14–19 days; Gollop and Marshall 1954).

Recruitment

Annual Recruitment Rates

Less than one female mallard was recruited for each female nesting at USNWR (Table 13). Blue-winged teal recruitment was greater than that of mallards, but even under the unrealistic assumption of no entire brood losses, only slightly more than one female was recruited for each nester.

Predicted Population Changes

We based our predictions on female adult survival of 0.559 from Minnesota banding data, a differential (young vs. adults) survival rate of 0.85 (Anderson 1975), an adult

Table 11. *Relation between the peak number of breeding pairs (PP) counted during the nesting season, and the number of nests found (NF), nests hatched (NH), and different broods (DB) seen at Union Slough National Wildlife Refuge, Iowa, 1984–85.*

	Year											
	1984				1985				Mean			
Species[a]	PP	NF	NH	DB[b]	PP	NF	NH	DB	PP	NF	NH	DB
BWT	72	84	30	33	210	165	29	22	141	124	29	28
MAL	69	79	14	26	104	105	24	34	66	92	19	30
All	155	171	46	59	336	274	54	57	245	222	50	58

[a] Species: BWT = blue-winged teal (*Anas discors*), MAL = mallard (*A. platyrhynchos*), All = blue-winged and green-winged teal (*A. carolinensis*), mallard, northern shoveler (*A. clypeata*), gadwall (*A. strepera*), American wigeon (*A. americana*), and northern pintail (*A. acuta*).
[b] Number of different broods determined by comparing the number of broods of specific ages between counts, accounting for growth and eliminating any possible duplicates, regardless of the number of young in the brood or the brood's location.

Table 12. *Mean number of eggs hatching from nests and mean number of young seen in waterfowl broods of each age class at Union Slough National Wildlife Refuge, Iowa, 1984–85.*

Species[a]	Nest Mean SE (*n*)[b]	Class I Mean SE (*n*)	Class II Mean SE (*n*)	Class III Mean SE (*n*)
Blue-winged teal	10.4	8.3	7.7	7.5
	0.31(59)	0.72(15)	0.58(26)	0.76(14)
Mallard	9.6	7.7	6.8	8.5
	0.38(38)	0.46(31)	0.48(21)	0.80(8)
Northern pintail	9.0	7.0	5.0	5.0
	(1)	(1)	(1)	(1)

[a] Blue-winged teal (*Anas discors*), mallard (*A. platyrhynchos*), northern pintail (*A. acuta*).
[b] n = number of nests hatched or number of different broods of species i seen multiplied by all age j broods of species i seen divided by all broods of species i seen. Different broods determined by comparing the number of broods of specific ages between counts, accounting for growth and eliminating any possible duplicates, regardless of the number of young in the brood or the brood's location.

Table 13. *Recruitment rates (number of fledged female young per 100 adult females) of dabbling ducks at Union Slough National Wildlife Refuge, Iowa, 1984–85.*

Species[a]	Assuming 70% entire brood survival			Assuming no broods lost entirely		
	1984	1985	Mean[b]	1984	1985	Mean[b]
Blue-winged teal	107	62	76	153	89	109
Mallard	35	54	49	50	77	70
Other dabbling ducks	74	36	61	106	52	87

[a] Blue-winged teal (*Anas discors*); mallard (*A. platyrhynchos*); other dabbling ducks include northern shoveler (*A. clypeata*), green-winged teal (*A. carolinensis*), northern pintail (*A. acuta*), and gadwall (*A. strepera*).
[b] 1984–85 mean, calculated by using pooled nesting and brood survival data.

summer survival rate of 0.738 from similar nesting habitat in North Dakota and South Dakota (Cowardin and Johnson 1979), and the recruitment rate of 49/100 (Table 13). We predicted annual change in the mallard population of the study area, without any influx of pioneering birds into the study area, at –12.6%. Only if no entire broods were lost and the recruitment rate was 70/100 rather than 49/100 (Table 13), would the predicted change in the study area mallard population exceed 0 % (+0.1%).

If the Mayfield (1961) success of mallard nests was increased to 15% and if all other rates remained the same, then the predicted annual change in the mallard population of the study area, without any influx of pioneering birds and with 70% and 100% total brood survival, would be 2.9% and 123%, respectively. Predicted population changes for other species were not calculated because summer survival estimates for hens are lacking.

Discussion

Annual Pair Populations

The size of the local dabbling duck breeding population undoubtedly was affected by habitat conditions in other areas of the prairie pothole region. Breeding pairs were more numerous in 1985, when drought conditions existed over much of the southern half of the prairie pothole region (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1984, 1985). At USNWR, water levels were nearly normal throughout the breeding season and probably attracted breeding pairs displaced from drought-stricken areas. Burgess et al. (1965) observed an increase in the number of breeding dabbler pairs (especially blue-winged teal) at USNWR during years that drought occurred in prairie pothole areas outside Iowa. Bishop et al. (1979) found that blue-winged teal and mallard populations were largest in Iowa when May pond counts in the rest of the prairie pothole region were lowest. Jackson et al. (1985) found that local drought conditions caused mallards that otherwise used small "satellite" wetlands in northern Iowa to concentrate their activities at a larger, more permanent wetland.

Despite poor recruitment, favorable habitat conditions attract many breeding ducks to USNWR. We counted more mallard (mean = 71, range—48 to 94 vs. mean = 45, range—17 to 67) and similar numbers of blue-winged teal pairs (mean = 133, range—64 to 203 vs. mean = 159, range—56 to 252) at USNWR than Burgess et al. (1965) counted in 1958–61 (data only from MU's 1–5, areas counted during both studies) even though continental mallard breeding populations were 42% lower and blue-winged teal populations were 24% lower during our study (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1985). With low recruitment and high loss of nesting females to predators at USNWR (Fleskes 1986), net production of dabbling ducks from this attractive habitat is negligible at best.

Pair Use of Wetlands

Breeding pairs at USNWR concentrated on wetlands that had been drawn down and reflooded within the past year, had slowly decreasing water levels, and were one-fourth to three-fourths covered by emergent vegetation. Our observations agree with findings of other researchers who observed higher breeding pair densities on newly flooded rather than on older marshes (Bishop et al. 1979; Weller 1979), and on wetlands that contained many patches of emergent vegetation rather than more open wetlands (Weller and Spatcher 1965; Weller and Fredrickson 1974). However, shallow wetlands in which water levels decreased slowly, regardless of the amount of emergent vegetation present in the basin, received greater use at USNWR than did wetlands maintained at a deeper level.

Drewien and Springer (1969) and Kirsch (1969) have shown that conditions of upland habitat can affect the density of breeding duck pairs in adjacent wetlands. However, the quality of USNWR uplands did not vary greatly among MU's (most were idle uplands), and any effect from adjacent uplands probably was minor compared with the effect of each unit's wetland habitats.

Nest Densities

Biologists may assume that habitats receiving the greatest use by nesting hens are the ones most hens prefer. However, we found that factors other than the quality of the nesting cover (e.g., size of the local pair population, quality of adjacent wetlands, availability of habitats) measurably affects the use of individual nesting fields. For instance, we found that the largest and smallest mean nest densities for all idle upland habitats were in two habitats that provided nearly identical cover. Thus, we recommend that nest density estimates be corrected for any outside influences that may bias use of the habitats, before density estimates are used to infer hen preference.

Nest Success

Current vegetation management at USNWR has created idle cover that is highly attractive to nesting dabblers. However, we agree with Byers (1974) and Wheeler et al. (1984) that high-quality cover may not reduce predation, at least within the range of cover quality and predator densities we observed. The results of other studies (Duebbert and Kantrud 1974; Kirsch et al. 1978; Livezey 1981) have differed, but the habitats compared and methodology used also differed. Also, the researchers did not measure predator populations, which we found can vary locally and can cause differences in nest success that are unrelated to cover differences.

Recent analysis of long-term data indicates that mallard recruitment may be inversely related to the size of the breeding population (Kaminski and Gluesing 1987). Our data suggest that one mechanism causing this relation is density-dependent predation. Inverse relations between nest densities and mammalian predation rates such as we observed have been reported previously (Martz 1967; Weller 1979; Hill 1984). Similarly, success of nests occurring in high densities in heavy cover have been reported to be lower than success of nests occurring in sparser cover but at lower densities (Holm 1984; Klett et al. 1988). Sugden and Beyersbergen (1986) found that density-dependent predation may occur only when nest density reaches a threshold (e.g., 1/ha for crows). At USNWR, density-dependent predation was detected only in fields where red fox was absent.

Johnson et al. (1988) found the red fox to be the principal predator on dabbling duck nests in Canadian prairies. Red fox occurred at much higher densities at USNWR (1.1 families per square kilometer) than those (0.1–0.16 families per square kilometer) reported by Pils and Martin (1978) for Wisconsin and Sargeant et al. (1984) for North Dakota and South Dakota. USNWR has an abundance of well-drained slopes that provide good den sites, and foxes probably were subject to little human disturbance compared with adjacent, cultivated lands. Sargeant (1972) also found high densities of red fox on two refuges similar in habitat to USNWR. He reported fox territories that were small and movements that concentrated on refuge lands. Each fox must draw its food from within its territory (Sargeant 1978) and is able to scent and locate nesting duck hens at distances as great as 30 m (A. Sargeant, personal communication). Thus, nests were destroyed at a high rate within the territory of a fox family even when nests occurred at low densities. Predator searching behavior is believed to be reinforced by success (Tinbergen et al. 1967; Olton et al. 1981), but little is known about the relative ability of other mammals to locate nests and hens. Theoretically, mammalian predators less adept at finding nests than red fox would tend to concentrate searching in areas having high nest densities. This hypothesis is supported by our observation that lower predation rates occur in fields having low nest densities and no foxes.

Duckling Survival

Measuring duckling survival as we did, by using counts of unmarked broods to determine brood attrition, has inherent biases because of visibility (Wheeler et al. 1984) and survey timing problems (Cowardin and Johnson 1979; Figley and VanDruff 1982). However, our attrition estimates were similar to other reports (Jahn and Hunt 1964; Stoudt 1971; Wheeler and March 1979; Bellrose 1980; Duebbert and Frank 1984). Our results agree with other studies, which describe most duckling mortality as occurring within 2 to 3 weeks after hatching (Dzubin and Gollop 1972; Ball et al. 1975; Ringelman and Longcore 1982;

Talent et al. 1983; Orthmeyer and Ball 1990). We did not determine the causes of duckling mortality , but mink and snapping turtles (*Chelydra serpentina*)—both reported to be important duckling predators (Coulter 1957; Talent et al. 1983)—were common at USNWR.

Recruitment

Mean recruitment rate estimates for mallards at USNWR were about twice what Cowardin et al. (1985) reported for mallards in an agricultural environment in North Dakota (27/100) but were lower than mean rates for most other areas (72/100, range = 50–103/100) listed by Cowardin and Johnson (1979). Following Cowardin and Johnson (1979), we assumed that duckling mortality from Class III to fledging was negligible when calculating recruitment rates. However, recent data indicate that mortality of older ducklings may not be negligible (Hestbeck et al. 1989). Thus, our recruitment estimates may be inflated.

Management Implications

Although natural areas are never entirely alike, USNWR probably is typical of many other managed wetland areas in the southern part of the prairie pothole region. We believe the following discussion of possible management solutions to increase waterfowl recruitment at USNWR will assist managers of similar areas to meet waterfowl production objectives.

Lokemoen (1985) examined the economic efficiency of five management practices aimed at increasing survival of duck nests: island construction, dense nesting cover plantings, predator management, barrier fencing, and nest basket installments. We relate these practices to findings in our study, although we did not evaluate fencing or nesting structures.

Islands are already in place at USNWR and, although they had high mallard nest densities, raccoon and mink use (including den sites) on these islands was high and nest success was low. Higgins (1986) reported high nest success on small man-made islands during two periods of less than 20 years after the islands were constructed. Why our results differed from Higgins (1986) is not clear, but USNWR islands are older, larger, and more closely spaced than those described by Higgins (1986)—all factors that may facilitate use by mink and raccoons. Also, some wetlands at USNWR are usually kept flooded, and thus USNWR may support higher populations of mink and raccoons than where water levels of wetlands are allowed to fluctuate from dry to wet in accordance with annual precipitation. We do not recommend constructing islands of the type at USNWR where high populations of mink and raccoons exist unless predator access is restricted.

Conversion of native prairie to dense nesting cover would probably increase mallard nest densities, but prairies are scarce (Smith 1981) and should be protected for their own inherent values.

Predator management, primarily the removal of small carnivores by lethal baits, shooting, or trapping during the waterfowl nesting season, has proved effective at increasing nest success of dabbling ducks in areas where mammals were the main predators (Balser et al. 1968; Duebbert and Kantrud 1974; Duebbert and Lokemoen 1980). Effective predator reduction must be widespread and may have to extend into adjoining farmland (Lokemoen 1985). Because most nest predators are under state jurisdiction, state wildlife agencies must concur (Sargeant and Arnold 1984). Effectiveness of predator removal efforts depends on the composition of the predator community. Greenwood (1986) found that removal of skunks only was not effective in North Dakota if red fox and Franklin's ground squirrels were also abundant. Removal of only red fox should reduce hen mortality, but nests would still be at risk from other predators. Thus, if predator management is adopted, broad scale efforts should be applied to control as many of the major nest predators as possible. Trapping should be conducted throughout the nesting season to remove immigrating animals.

Exclusion of mammalian predators by barrier fences around dense nesting cover has been effective in increasing nesting success when coupled with continual removal of predators within the fence (Lokemoen et al. 1982). Species (e.g., mallards) that show fidelity to previous successful nesting areas (Doty and Lee 1974) would probably exhibit the most rapid and positive response. Maintenance trapping within the fence should include sets for predators not excluded by the fence (e.g., weasels or ground squirrels).

Mallards have nested successfully in open-top baskets on other Iowa marshes (Bishop and Barratt 1970) and probably would at USNWR. Open baskets have potential for increasing recruitment rates of mallards, but data on cost per duckling produced should be considered. Covered mailbox-type nesting structures are not recommended. Those in place at USNWR in 1966–74, and in North Dakota (Sidle and Arnold 1982), received little use (unpublished data, on file at USNWR).

Managing habitat to reduce predator occupancy or to change the species composition of the predator community is another alternative. Reducing the number of den sites by removal of abandoned farm buildings, rock piles, and hollow trees theoretically should reduce population numbers of animals that use these structures. The conversion of adjacent cropland into grassland to enlarge the area of available nesting cover may temporarily increase nest success. However, as nest densities increase, predation rates may also increase unless the habitat is capable of supporting an alternate prey base. Any gain in nest success may be short-lived unless the total area of habitat is large enough to achieve and sustain a reasonable balance in predator and prey populations. We have no information about how large an area must be to obtain acceptable levels of nest success. Clark and Bailey (R. G. Clark, Canadian Wildlife Service, personal communication) reported no increase in nest success when the nesting area of a refuge was increased from 100 ha to 204 ha.

Changes in the composition of the predator community may also reduce predation on nesting ducks. Coyotes exclude red foxes from their territories, and red foxes maintain smaller, exclusive territories in areas frequented by coyotes (Sargeant et al. 1987). Activity indices of red foxes in waterfowl nesting habitat of prairie Canada were negatively correlated with those of coyotes (Johnson et al. 1988). Red foxes are considered more effective predators on waterfowl nests and hens and hunt their territories more thoroughly than coyotes (Johnson and Sargeant 1977). Thus, nesting habitat inhabited by coyotes may be more productive than areas with red foxes.

The general assumption is often made that if the quality of upland nesting cover is improved, nest success rates of ground nesting waterfowl will increase. This assumption has been explicitly incorporated into habitat protection strategies of the North American Waterfowl Management Plan (U.S. Fish and Wildlife Service 1988).

Uplands and wetlands at USNWR have been intensively managed, like many other waterfowl production areas, to provide optimal conditions where waterfowl can breed. The area attracts large numbers of breeding pairs, nest densities are high, and post-hatch survival is similar to that in other areas. However, recruitment remains low because of severe predation on nests. Nest success at USNWR must be increased to more than 15% if the area is to produce a surplus of dabbling ducks. This has not been accomplished by cover management alone. Thus, additional management practices to reduce the effects of predators must be implemented on waterfowl breeding areas similar to USNWR if waterfowl population objectives outlined in the North American Waterfowl Plan are to be attained.

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