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Spring distribution of ring-necked pheasants (*Phasianus colchicus*) following cattail reduction with glyphosate herbicide

H. J. Homan[A], *G. M. Linz*[A], *R. C. Carlson*[B] *and W. J. Bleier*[C]

[A]US Department of Agriculture, 2110 Miriam Circle, Bismarck, ND 58501-2502, USA.
[B]Department of Entomology, North Dakota State University, Fargo, ND 58105-5346, USA.
[C]Department of Biological Sciences, North Dakota State University, Fargo, ND 58105-5517, USA.

Abstract. To reduce blackbird (Icteridae) damage to field crops in the north-central United States, dense stands of cattail (*Typha* spp.) are thinned with glyphosate herbicide. The stands become unusable as roosting and loafing sites, which helps to protect susceptible crops nearby, particularly sunflower (*Helianthus annus*). Landscape-level impacts of cattail management on non-target avian species have not been studied. We measured use of upland breeding territories by male ring-necked pheasants (*Phasianus colchicus*) following cattail reduction in wetlands used by pheasants for overwintering. In August 1992, glyphosate was applied to all wetlands with ≥70% cattail coverage in four 23-km^2 study blocks in south-eastern North Dakota. Four other blocks were used for controls. Habitat use was inferred from territorial crowing counts. No treatment effect or treatment*year interaction (all $P \geq 0.05$) was evident during 2 years of post-treatment observations. Although the herbicide eradicated large contiguous stands of cattail that pheasants had used for winter cover, surface water levels rose in 1993, which created additional cattail growth in untreated wetlands within the blocks. The additional cattail may have lessened the effect of the herbicide treatments. During drier periods, when cattail growth slows, cattail reduction could affect use of upland breeding sites. We recommend more research to assess the effects of glyphosate during drier periods.

Introduction

Sparse stands of hardstem bulrush (*Scirpus acutus*) and common cattail (*Typha latifolia*) occupied prairie wetlands before narrow-leaved cattail (*T. angustifolia*) invaded the northern Great Plains in the 1950s (Kantrud 1986). A species native to Europe, narrow-leaved cattail crossed with common cattail to create a robust hybrid, *T.* × *glauca*, the dense canopies and luxuriant growth of which altered the physiognomy and ecological processes of prairie wetlands (Kantrud 1986). Native plant species (including *T. latifolia*) were competitively excluded by aggressive growth of *T. angustifolia* and *T.* × *glauca* (Beule 1979). Wetlands that were formerly mosaics of open water and sparse stands of emergents were overgrown with cattail, causing a loss of spatial heterogeneity and declines in avian diversity and abundance (Kantrud 1986; Solberg and Higgins 1993). Agencies within federal and state governments and private groups have become actively involved in managing dense stands of hybrid cattail. Although mechanical methods for managing cattail (e.g. burning, mowing, cultivating, and grazing: Kantrud 1986; Payne 1992) are used, these approaches may be ineffective because of cattails' rhizomatous growth, which allows it to quickly recolonise mechanically managed sites (Solberg and Higgins 1993). The best long-term control in many cases is provided by glyphosate, a non-selective, post-emergent herbicide (Messersmith *et al.* 1992; Leitch *et al.* 1997). Glyphosate is widely used in the United States (US) and has been used to (1) prevent cattail (and other invasive emergents, e.g. *Phragmities* spp.) from clogging navigable waterways, (2) promote recolonisation of wetlands by less competitive native plant species (Comes and Kelley 1989), (3) create open water areas for waterfowl in closed-canopied wetlands (Beule 1979; Linz *et al.* 1996*a*), and (4) reduce agricultural damage through dispersal of nuisance blackbird (Icteridae) roosts located in cattail-dominated wetlands adjacent to susceptible crops (Linz *et al.* 1995).

In the northern Great Plains, the US Department of Agriculture (USDA) applies glyphosate in an effort to help agricultural producers reduce blackbird damage to the commercial sunflower (*Helianthus annus*) crop. The damage is caused during the late-summer/early-fall migratory period, when large flocks of blackbirds amass in the sunflower-growing regions and use cattail-dominated wetlands for roosting and loafing. Single roosts of more than 750000 have been observed during migration (Besser *et al.* 1981). The birds leave their roosts in early morning to feed in sunflower fields nearby (Otis and Kilburn 1988). Sunflower is a preferred food of blackbirds because it is a high-caloric, easily available food resource that allows for rapid acquisition of energy reserves needed for migration

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(Homan *et al.* 1994). Within areas containing high densities of cattail-dominated wetlands, production losses of 20–100% can occur (Besser *et al.* 1981; Linz and Hanzel 1997). A random survey of sunflower producers in North Dakota indicated an average individual loss of US$6296, yielding an estimated statewide annual loss of US$3 million (North Dakota Department of Agriculture 1990). Management of cattail vegetation may provide an effective non-lethal approach that will reduce blackbird damage to sunflower. Since initiation of a cattail-management program 10 years ago, the USDA has treated >16000 ha of wetlands with glyphosate. Most treatments are applied in North Dakota, the prime region of sunflower production in the US (Homan *et al.* 2001*a*). Some regions of the state have received more applications than others. For example in south-eastern North Dakota, about 3800 ha out of a total 39000 ha of semipermanent wetlands have been treated. While representing <10% of the semipermanent wetland area in this region, the management guidelines of the USDA target only large contiguous stands of cattail >6 ha; this bias in wetland selection has led to treated wetlands that, on average, are 4 times larger than the average-sized semipermanent wetland in south-eastern North Dakota. This could produce negative impacts for some non-target species that use cattail for cover, especially those species that may be area-dependent and inclined to seek only the larger-sized wetlands.

Extensive research has been conducted on non-target impacts of glyphosate (Sullivan 1990). In the north-central US, studies of environmental impacts on wetlands have focused mainly on water quality, aquatic invertebrate populations, and avian species (Solberg and Higgins 1993; Henry *et al.* 1994; Linz *et al.* 1999). Most of the avian research has involved migratory species that use wetlands for reproduction during spring and summer. Passerine species that preferred dense stands of emergent cover for nesting [e.g. marsh wrens (*Cistothorus palustris*) and red-winged blackbirds (*Agelaius phoeniceus*)] declined in abundance following cattail reduction with glyphosate (Linz *et al.* 1996*b*). In contrast, black terns (*Chlidonias niger*), northern pintails (*Anas acuta*), mallards (*A. platyrhynchos*), and some rallids (e.g. *Fulica americana*) increased in numbers after cattail reduction, suggesting a preference for more open wetlands (Linz *et al.* 1994, 1996*a*, 1997; Linz and Blixt 1997). Cattail management has provided several ecological benefits to wildlife, particularly to those species using wetlands from late spring (after thaw) through autumn. However, it could have unintended consequences for non-migratory resident species that use residual cover of cattail-dominated wetlands for refuge over the winter months. Prior to our study, no research had attempted to investigate this aspect of cattail management.

The ring-necked pheasant (*Phasianus colchicus*) is a resident of the north-central US and an important game bird to the region. Ring-necked pheasants (hereafter, pheasants) use cattail-dominated wetlands during harsh snowy winters for thermal protection and predator avoidance (Trautman 1982). They often use wetlands as foci of their annual home ranges, dispersing only short distances to upland habitats for reproduction and rearing of young. The pheasants remain in the uplands until the following fall, when they move back to residual cattail cover. Previous research has indicated that depletion of large stands of cattail will cause pheasants to abandon their traditional wetland wintering sites (Homan *et al.* 2000). Does this impact use of breeding grounds in adjacent uplands in spring? Excepting the edges of dry wetlands, pheasants will not use cattail cover for nesting (Trautman 1982); apart from this, the question remains about pervasive spatial impacts of cattail management on habitat preferences of nesting pheasants associated either directly with the treated wetland (by formerly overwintering there, for example) or indirectly (by proximity of breeding territories near treated wetlands). For example, the birds may be inclined to avoid upland habitats near treated wetlands solely because of the changes in density of emergent vegetation even though the upland habitat remained in excellent quality. Our research objectives were to (1) identify land-use categories associated with territorial pheasants in south-eastern North Dakota, and (2) assess landscape-level impacts of cattail management on habitat use during the spring reproductive season.

Study area

Our study area was located in the Glaciated Plains Physiographic Region, a component of the Central Lowlands Biogeographic Region (Kantrud *et al.* 1989). The land was most recently shaped by glacial processes approximately 10000 years ago (Murkin *et al.* 2000). The predominant landform was ground moraine, which consisted of flat or gradually mounded terrain with numerous, shallow saucer-shaped depressions (known as 'Prairie Potholes') capable of holding water. Linear arrays of perennial vegetation (shelterbelts) were planted throughout the landscape to prevent wind erosion and furnish thermal protection to residences. Soils were highly permeable sandy loams and loamy sands classified mainly as glacial till. The climate was mid-continental with cold winters and warm summers. Temperatures in the region range from −42 to +45°C, with an average mean temperature of 5.5°C. Thunder showers from April to August constitute 70% of the 48 cm of annual precipitation. Cyclic wet and dry periods cause considerable variation in annual precipitation (Stewart 1975). Average dates of first and last frosts (0°C) were 20 September and 18 May, respectively (North Dakota Department of Agriculture 1991). The vegetation type was northern mixed-grass prairie dominated by western wheatgrass (*Pascopyrum smithii*), big bluestem (*Andropogon gerardii*), and little bluestem (*Schizachyrium scoparium*) (Johnson and Larson 1999). Most of the land has been converted to crop–livestock agriculture. Approximately 60% of the study area was cropped (North Dakota Department of Agriculture 1991). Non-crop lands such as pasture, idle cropland, and other lands (field borders, rights-of-way, state and federal management areas, shelterbelts, and wetlands) comprised the remaining 40% of the study area. Small grains were planted on 58% of the cropped land, compared with lesser amounts of corn (15%), sunflower (12%), and hay (9%). For transportation of grains and supplies, roads and trails grid the study area into 1.6 × 1.6 km sections. The average human population density in south-eastern North Dakota was 14 km^{-2}.

North Dakota has 53 counties, 32 of which have had one or more wetlands treated with glyphosate. In our study area in the south-east (46°28′N, 98°07′W), the four counties of LaMoure, Dickey, Sargent, and Ransom ranked 3rd, 6th, 11th, and 13th, respectively, in the number of hectares of treated wetlands (Homan *et al.* 2001*a*). Moderate to high pheasant densities exist in these counties. At the beginning of the experiment in 1992, road-side count data indicated an average of 42 birds per 160 km, a moderate density for the area (Tripp 1995).

Methods

Wetland selection

National Aerial Photography Program photographs (scale 1:40000) were used to identify all large (10 ha) semipermanent wetlands in our 4-county study area (Fig. 1). Wetlands with <70% coverage of cattails or water depths <30 cm were excluded either by aerial inspections or on-site visits (Linz *et al.* 1995). From a pool of 33 wetlands, 8 were randomly selected. The wetlands were chosen according to cattail-management guidelines used by the USDA to reduce blackbird damage. The 8 experimental wetlands ranged in size from 10 to 58 ha and were ≥8 km apart. The General Land Office sections (1.6 × 1.6 km) that contained the wetlands were used as centre sections in 3 × 3-section study blocks (23 km^2). Nine-section blocks centred on core areas of pheasant use have been recommended as adequate-sized management units for pheasants in east-central Wisconsin (Gates 1970), a region both topographically and agriculturally similar to our study area (Dapples 1959; Gates and Hale 1974). None of the wetlands had been treated with glyphosate prior to our experiment.

Herbicide treatment

In late August 1992, 4 of the 8 experimental wetlands were randomly selected for treatment with glyphosate. A fixed-wing aircraft mounted with a 15-m spray boom was used to apply the formulation (2.5 kg glyphosate ha^{-1} mixed in 47 L ha^{-1} aqueous solution with 0.2 L ha^{-1} surfactant [Valent X-77®] and 0.6 L ha^{-1} drift retardant [Chem-trol®]). The treatments were applied in strips running along the wetland's long axis. As per USDA cattail-management guidelines, 70% of the cattails in the block-centred experimental wetlands was treated. A 70% spray coverage requires leaving 6.4-m-wide untreated strips of living cattail between each 15-m-wide treated strip. We sought to induce a treatment effect by additionally spraying 100% of the cattail vegetation in all ancillary wetlands >2 ha in the surrounding eight sections of each treated study block. We used this stringent technique because of the severe consequences that could result from making Type II Errors (i.e. accepting false null hypotheses) during hypothesis testing (Sokal and Rohlf 1981). Glyphosate applied in late August will not reduce cattail density until the following June, when new cattail growth is absent in the treated 15-m strips. Dead cattail stems will weaken and fold over but remain visible above the water surface for ~1 year after treatment (Linz and Hanzel 1997). Treatments can last ≥4 years if water levels remain stable.

Habitat analysis

We used vertical photography to measure habitat composition within the study blocks. Individual sections were aerially photographed at 3000-m altitude with a 24-mm lens and 35-mm Kodak Ektachrome® colour-infrared film. Flights were conducted annually in late August or early September. To identify and quantify habitats, the 35-mm images were digitally converted and processed using a geographic information

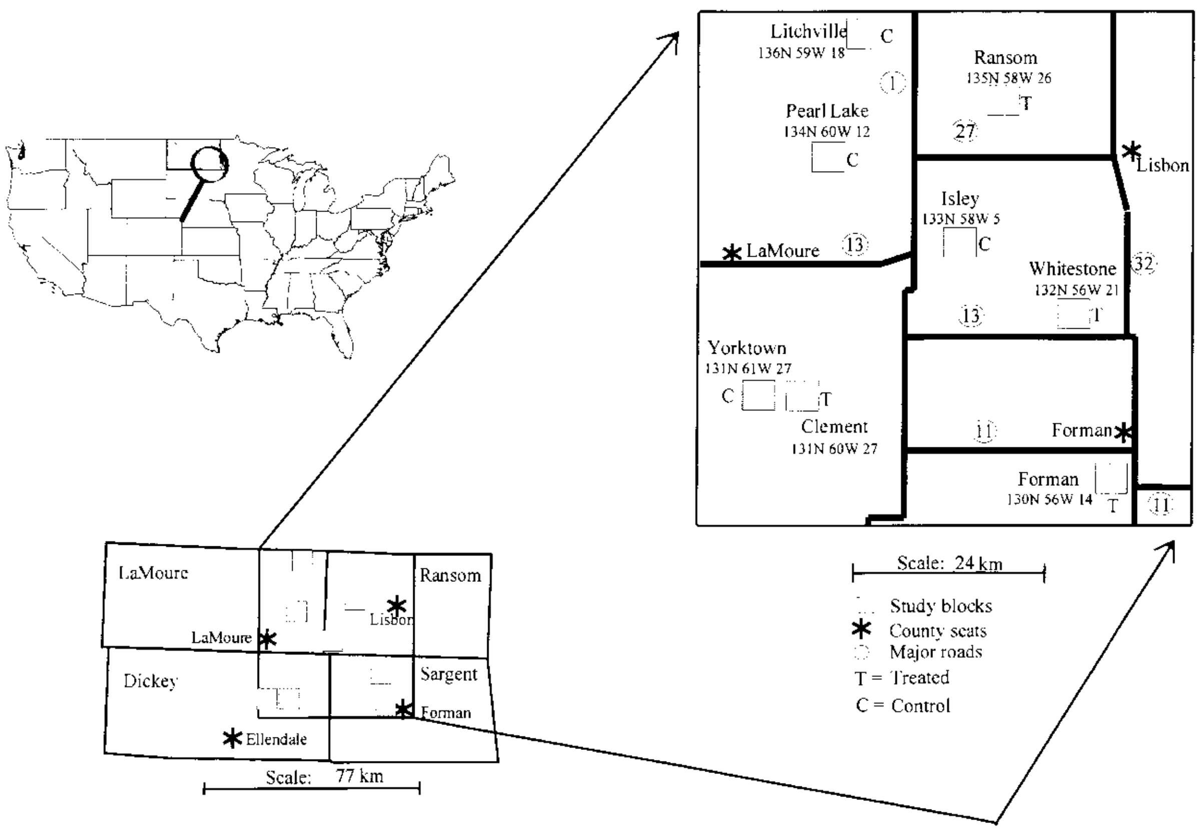

Fig. 1. The study area and experimental sites used for the present study.

system (Map and Image Processing System, MicroImages, Lincoln, Nebraska, USA). Ground truthing was used to determine the different habitats observed in the scanned images. Habitat coverages were quantified using a digital planimeter. The following habitats were categorised for analysis: (1) idle uplands (habitats of dense herbaceous cover), (2) farmstead residences and their associated shelterbelts, (3) agricultural shelterbelts and woodlots, (4) cropland, (5) road and railroad easements, (6) pasture, and (7) three classes of wetlands (Class II, III, and IV). National Wetlands Inventory vector data were imported into the geographic information system and used to categorise the three classes of wetlands and estimate their coverages. The accuracy of the vector data was assessed by overlaying these data on geo-referenced digital images of the study-block sections. The wetlands were classified according to the naming system developed by Stewart and Kantrud (1971). Class II wetlands (temporary wetlands) had surface waters present for only a few days or weeks each spring. Vegetation typical of Class II wetlands was goldenrod (*Solidago* spp.) and crested wheatgrass (*Agropyron cristatum*). Class III wetlands (seasonal wetlands) were capable of holding water in their central portions into early or mid-summer. Class IV wetlands (semipermanent wetlands) maintained surface water in their central portions through spring and summer and frequently throughout the year. Coarse grasses (e.g. *Scolochloa festucacea*) and sedges (e.g. *Carex* spp.) were characteristic vegetation associated with Class III wetlands; whereas emergent species, such as cattail and bulrush (*Scirpus* spp.), occupied the edges and central portions of Class IV wetlands. In our study area, the average density (per km^2) of the three wetland classes was as follows: Class II, 3.6; Class III, 4.2; Class IV, 0.5. Class II and Class III wetlands may be plowed and cropped during dry climatic cycles.

Crowing call census

Each study block had 24 counting stations located midway on General Land Office section lines (Fig. 2). The stations were assigned to one of three strata. The first stratum had four stations that surrounded the centre section containing the experimental wetland; the second stratum consisted of eight stations on unshared interior lines of the eight sections surrounding the centre section; and the third stratum consisted of 12 stations on mid-section lines bordering the study block. From each stratum, 50% of the sites were randomly selected. The first stratum censused and the first station within that stratum were randomly selected. Visiting order of the remaining 11 stations was arranged to complete the census in ~1 hr. The stations and routes that were selected in 1992 remained the same throughout the 4-year experiment. We reversed routes on alternate replications to nullify any temporal bias in counts. Because of the extensive 1.6 × 1.6-km road grid, most of the counting stations were located either on roads or trails. Stations not on roads or trails were reached on foot. Each census began 40 min before sunrise. After a 2-min quiet period at the station, the observer would face the interior of the study block and count crowing calls undisturbed for 2 min (Kimball 1949). Two blocks were done per day using one observer in each block. All counts were conducted in winds ≤19 km h^{-1}, temperatures >0°C, and no precipitation. Counts were done throughout May and repeated on each block at least four times (about once a week). If repeated visits are made to counting stations, crowing counts provide a good index of pheasant abundance (Gates 1966; David *et al.* 2000).

Statistical analysis

Four replications were made in 1992, 1994 and 1995; five in 1993. Each replication consisted of eight block means representing the average number of calls per counting station per block. The number of crowing calls per block was totaled and divided by 12 to reduce variation among counting stations within blocks. The block means were square-root transformed to approximate normality (Sokal and Rohlf 1981). One-way ANOVAs indicated that there were no within-year differences among

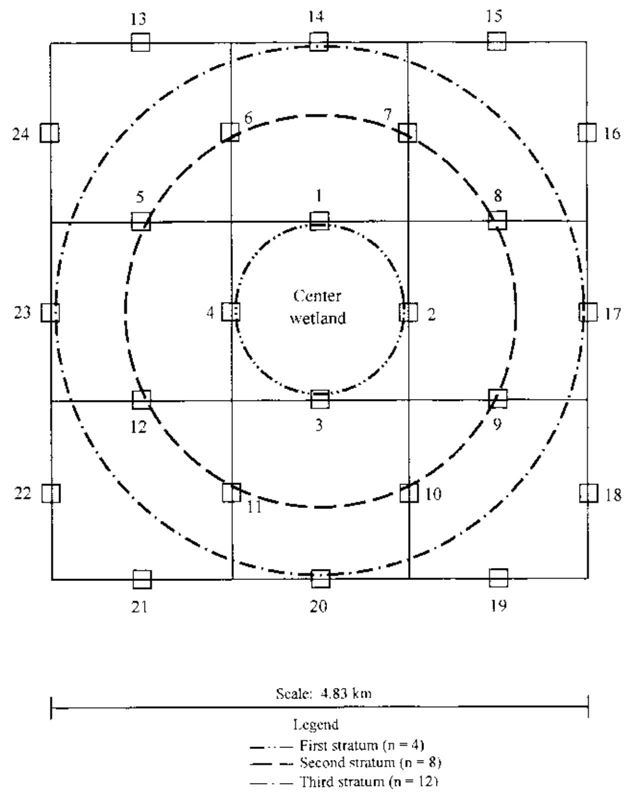

Fig. 2. The locations of listening stations used for counting crowing calls of territorial male ring-necked pheasants in south-eastern North Dakota during 1992–95. The stations were allocated to three strata depending on their distance from the centre wetland in a 3 × 3 block of General Land Office sections (23 km^2).

replications ($P = 0.84$–0.99) or between observers ($P = 0.25$–0.79), and these factors were pooled. The counts conducted in May 1992 and 1993 were pre-treatment counts because the glyphosate had either not been applied (1992) or had not taken effect (1993).

Differences in the proportions of habitat coverages between treated and control blocks were compared with 1-way ANOVAs. Simple correlations between the dependent variable (mean crowing calls per block) and habitat proportions in the blocks were tested with Spearman's correlation coefficients. The crowing calls from the treated blocks counted during the post-treatment period were removed from the correlation analyses to avoid confounding the interpretation of the correlations with a treatment effect from glyphosate. We used 2-factor repeated-measures ANOVAs (repeating on blocks) to assess impacts of glyphosate treatment on the mean number of calls between treated and control blocks for pooled pre-treatment (1992 and 1993) and post-treatment (1994 and 1995) periods (Cody and Smith 1991). Statistical tests were performed with PC-SAS (SAS Institute 1988). Statistical significance was accepted at $\alpha = 0.05$.

Results

Treated and control blocks were similar in habitat composition (all $P \geq 0.17$), with cropland habitat dominating the blocks (Table 1). Idle uplands and Class IV wetlands (2 habitats often used by pheasants) comprised 10% and 5% of the block area, respectively. Mean calls per block were directly correlated to block proportions of idle upland habitat

Table 1. Habitat coverages (ha) in treated and control study blocks (23-km^2) used for testing the effects of glyphosate on the spring distribution of territorial male ring-necked pheasants in south-eastern North Dakota during 1992–95

Habitat	Treated (n = 4)[A]			Control (n = 4)			F[B]	P	1–β[C]
	Mean	s.d.	%	Mean	s.d.	%			
Wetland Class II[D]	44	42.2	2	33	14.6	1	0.24	0.639	0.166
Wetland Class III[D]	112	15.3	5	144	37.2	6	2.46	0.168	0.999
Wetland Class IV[D]	110	81.7	5	121	23.8	5	0.07	0.802	0.771
Idle land[E]	179	198.3	8	300	229.4	13	0.64	0.454	0.071
Cropland	1635	389.1	70	1492	341.3	66	0.31	0.596	1.000
Pasture	146	172.2	6	146	94.9	6	0.00	0.998	0.181
Shelterbelt	34	28.4	1	32	16.1	1	0.01	0.934	0.440
Farmstead	43	10.2	2	30	12.7	1	2.35	0.176	0.994
Easement[F]	28	12.9	1	33	10.0	1	0.43	0.534	0.971

[A]All wetlands that were >2 ha with ≥70% cattail coverage received glyphosate treatments at 70% coverage in August 1992.
[B]One-factor ANOVAs were used to compare hectares of habitat type between treated and control blocks.
[C]Power of the ANOVA to detect a difference at α = 0.05 of a hypothesised value 100% larger than the obtained mean estimate.
[D]Wetland classification system of Stewart and Kantrud (1971).
[E]Uplands are defined as grassy habitats with residual cover (e.g. Conservation Reserve Program lands, uncultivated buffer areas found adjacent to wetlands, etc.).
[F]Road and railroad transportation easements.

Table 2. Spearman's correlation coefficients for the proportions of habitat per study block and mean crowing counts of ring-necked pheasants in south-eastern North Dakota 1992–95

Habitat	r_s	P
Wetland Class II[A]	–0.14	0.521
Wetland Class III[A]	0.43	0.038
Wetland Class IV[A]	0.27	0.201
Idle land[B]	0.44	0.032
Cropland	0.51	0.011
Pasture	0.32	0.121
Shelterbelt	0.22	0.311
Farmstead	0.07	0.738
Easement[C]	–0.09	0.689

[A]Wetland classification system of Stewart and Kantrud (1971).
[B]Grassy habitats with residual cover (e.g. Conservation Reserve Program lands, uncultivated buffer areas found adjacent to wetlands).
[C]Road and railroad transportation easements.

and inversely correlated to proportions of Class III wetlands and cropland habitat (Table 2).

We applied glyphosate to 295 of 440 ha (67%) of available Class IV wetlands in the four treated blocks. The 145 ha of untreated Class IV wetlands were either dry or lacked sufficient cattail coverage at the time of application in August 1992. No differences were observed in number of calls between treated and control blocks during the pre-treatment period (P = 0.90), with an average of ~5 calls per station (Table 3). The number of calls declined between 1992 and 1993 (P = 0.04) after pooling treated and control blocks.

In the first year of post-treatment (1994), crowing calls dropped by approximately 60% in the treated and control blocks. The number of calls stabilised in the treated blocks in 1995 but continued to decline in the control blocks, falling another 59%. At the conclusion of the study, calls per station were nearly equal between treatments, averaging about 1 call per station (Table 3). No treatment effect was detected during the 2-year post-treatment period (P = 0.93). After pooling treated and control blocks, the number of calls were similar in 1994 and 1995 (P = 0.11). Over the 4-year study, crowing calls fell by 94% in the treated blocks and 86% in the control blocks.

Discussion

The positive correlation we found between crowing calls and study block proportions of idle upland habitat is in accord with data collected in Iowa and Kansas showing that pheasant abundance increased with the enrolment of agricultural lands in the Conservation Reserve Program (King and Savidge 1995; Riley 1995). Lands in this federal program have vegetation composition and structure similar to that of our idle upland category. Indeed, most of the idle upland habitat in south-eastern North Dakota has resulted from enrolment in the Conservation Reserve Program (CRP), which takes lands with erosional soils out of agricultural production. The size of CRP lands in our study area was typically 65–259 ha; native grasses (e.g. *Panicum virgatum* and *Andropogon gerardii*) are amongst the more common herbaceous species planted on these tracts. In spring when male pheasants begin leaving their wetland wintering areas for up-

Table 3. Mean crowing calls of ring-necked pheasants recorded during 2-min listening periods in eight 23-km^2 study blocks used to measure the effects of cattail reduction with glyphosate in south-eastern North Dakota

Year	Study blocks					
	Treated (n = 4)[A]		Control (n = 4)		Pooled (n = 8)	
	Mean	s.d.	Mean	s.d.	Mean	s.d.
Pre-treatment[B]						
1992	7.9	7.20	5.0	2.80	6.4	5.29
1993	2.1	2.14	4.3	3.06	3.2	2.54
Mean	5.0	4.09	4.6	0.45	4.8	2.27
Post-treatment[C]						
1994	0.8	0.14	1.7	1.92	1.3	1.34
1995	0.8	0.44	0.7	0.42	0.8	0.51
Mean	0.8	0.05	1.2	0.71	1.0	0.38

[A]All wetlands that were >2 ha with ≥70% cattail coverage received glyphosate treatments at 70% coverage in August 1992.

[B]Repeated measures ANOVAs indicated a difference in mean crowing calls per station between 1992 and 1993 (F = 7.17, d.f. = 1,6, P = 0.037) but not between treated and reference blocks (F = 0.02, d.f. = 1,6, P = 0.898). Additionally, there was no treatment*year interaction (F = 4.38, d.f. = 1,6, P = 0.081).

[C]Repeated measures ANOVAs indicated no difference in mean crowing calls per station between 1994 and 1995 (F = 3.49, d.f. = 1,6, P = 0.111) and no difference between treated and reference blocks (F = 0.01, d.f. = 1,6, P = 0.933). Additionally, there was no treatment*year interaction (F = 1.73, d.f. = 1,6, P = 0.236).

lands, herbaceous cover in CRP lands consists of residual patches of standing grass (usually ≤90 cm tall) interspersed among open areas of flattened vegetation caused by lodging from snows and wind (Homan *et al.* 2001*b*). This spatial configuration is ideal for the 'exploded lek' mating system of ring-necked pheasants (Gill 1990). Of the habitats available to territorial male pheasants in south-eastern North Dakota, idle upland habitat (as characterised by CRP fields) appeared to be the most attractive. The males display and crow in the open areas of the CRP out of sight from one another but relatively close together (often only 50–150 m apart); the fields are therefore capable of holding high densities of birds. The females establish their nests in cover near the leks but away from the main activity centres of the males (Gates and Hale 1974; Dumke and Pils 1979).

The inverse correlation between block proportions of cropland habitat and crowing calls probably reflects the dominance of agricultural land use in south-eastern North Dakota. Alternative uses of land are limited here, and the amount of idle land and cropland become mutually exclusive (i.e. a greater proportion of cropland results in a lesser proportion of idle land). Because most males prefer to establish their territories in idle upland habitat, the negative relationship with cropland likely arose. A negative correlation with cropland is probably only present during the spring season, as the highest densities of pheasants tend to be associated with landscapes having 50–70% of their area in cultivation (Trautman 1982). No significant correlation existed between the number of crowing calls and block proportions of Class IV wetlands. We believe this is caused by seasonal differences in space distribution of pheasants. Pheasants aggregate in flocks during winter but by spring the flocks have split up, with territorial males establishing a fairly uniform distribution in preferred nesting habitats, a distribution based on their roughly similar abilities to defend territories. The change in social behaviour (i.e. aggregated in wetlands in winter to uniform in uplands in spring) probably breaks the positive association between pheasant densities and Class IV wetlands likely to have formed during the winter months.

Multi-year cycles of wet and dry precipitation regimes occur in the region where our experiment was conducted. Beginning in the summer of 1993, a period of above-normal precipitation began, leading to increased water levels in deeper Class IV wetlands. Cattail stands in the deeper basins were reduced because of the rising water levels, which 'drowns' the cattail (Murkin *et al.* 2000). However, the loss of cattail cover in the large Class IV wetlands was counteracted by new cattail growth in the shallower Class IV and Class III wetlands, which had been recharged with water from the increased precipitation. These wetlands had been excluded from herbicide treatment in 1992 because of cattail-management guidelines. The dynamics of cattail growth among the various wetlands probably allowed pheasants to remain in or near the treated study blocks in newly created cattail cover. Apparently, the scale of natural processes affecting cattail growth in the landscape during the change in precipitation regimes was greater than the impact caused by glyphosate. We speculated *a priori* that pheasants, being sedentary species, would abandon the treated blocks and not return to breeding territories near treated wetlands. We believed this for the following reasons: first, the average home range of pheasants in agriculturally dominated landscapes is 125 ha (*see* Homan 1998), with most males dispersing ≤1 km to their breeding territories. This behavior should lead to an inverse relationship between spring dispersal distance and rate-of-return to breeding territories, as observed in Wisconsin (Gates and Hale 1974; Dumke and Pils 1979). Any significantly long movement away from the treated blocks would have necessarily required an extraordinarily long spring dispersal to return. Second, because idle upland cover was plentiful throughout our study area, it seemed unlikely that displaced birds would have avoided quality upland habitat within newly established home ranges.

If new cattail growth provided enough cover for the pheasants to remain in the treated blocks, the applications of herbicide could still have had an effect on the number of crowing calls. This may have come about, for example, from territorial males innately avoiding upland sites near treated wetlands. This type of effect could occur if movements from uplands to wetlands were necessary to fulfill some nutritional or behavioural requirement during the breeding season. Such movements back to the wetlands seem improbable because by late spring most wetlands are thawed and have become unsuitable for use. The requirements of cover and food are probably satisfied solely within the upland habitats, and the birds will not return to wetlands until late fall or winter, and only then when forced to leave because of deterioration of upland cover caused by accumulation of snows (Gates and Hale 1974; Dumke and Pils 1979; Homan *et al.* 2000). We conclude that, under the climatic conditions encountered during our study, use of upland habitats by territorial males was independent of cattail density in treated wetlands and that no pervasive landscape effects from treatment were present. Additional supporting evidence is lent by the continued decline in crowing calls in our control blocks in the second post-treatment year (1995), suggesting that other environmental factors were negatively impacting the number of calls.

Consecutive severe winters of 1992–93 and 1993–94 decimated the pheasant population in south-eastern North Dakota, which in turn led to the overall decline in calls among all study blocks (Homan *et al.* 2000). Our research was conducted when the pheasant population was in steep decline and when wetland vegetation conditions were rapidly changing because of changes in precipitation regimes. Because glyphosate treatments are somewhat persistent (>4 years under stable water levels), they have the potential to be cumulative during stable climatic periods or dry periods. Concomitantly, pheasant populations typically rebound during dry periods, which could lead to increased competition for breeding territories. We recommend that another experiment on cattail management be conducted when water levels are more stable and when pheasant densities have increased.

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