The influence of wetland age on bird and aquatic macroinvertebrate use of restored Iowa wetlands

by

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GENERAL INTRODUCTION

Restoration of damaged, lost, and fragmented natural ecosystems is a goal of many public and private conservation organizations, and has become an increasing part of natural resource management. Restoration of wetland habitats has received considerable interest due in part to the dramatic loss of wetland habitat (Dahl 1990), regional decline of waterfowl populations, financial incentives for private landowners to restore former wetland basins (Wetlands Reserve Programs, Conservation Reserve Program), and heightened public awareness of wetland functions and values. More than 10,000 drained basins in the Prairie Pothole region of the United States have been restored to wetland conditions since 1985 through the efforts of federal, state, and private programs. Since 1986, 2,675 acres of wetland have been restored in Iowa (Gladfelter 1990). Restored wetlands are expected to accomplish several functions, including increasing waterfowl populations and sustaining biodiversity. However, few attempts have been made to evaluate the development and success of restored wetlands (National Research Council Committee on Restoration of Aquatic Ecosystems 1992).

My objectives were to (1) determine which bird species and macroinvertebrate taxa are using restored Iowa wetlands within 4 years of restoration; and (2) determine the effect of wetland age on colonization by birds, vegetation, and macroinvertebrates.

Explanation of Thesis Format

This thesis consists of two papers, each intended for publication in a separate scientific journal. The first paper compares bird and vegetation colonization of restored wetlands 1- to 4- years post restoration; the second compares the aquatic macroinvertebrates communities among various aged restored wetlands. A general summary and references cited in the general introduction and general summary are included after the two papers. Kristin VanRees-Siewert helped design the study, conducted the field work, and is the principal author of the papers. Dr. James J. Dinsmore conceived the study idea, assisted in its completion by advising and securing funding for Kristin VanRees-Siewert, and edited these papers.

PAPER I. THE INFLUENCE OF WETLAND AGE ON BIRD USE OF RESTORED IOWA WETLANDS

ABSTRACT

I compared bird species richness, breeding bird species, and re-vegetation of restored Iowa wetlands ranging in age from 1 to 4 years post-restoration. I counted birds present within 3 fixed-radius circular plots on 16 restored wetlands in 1991, and 24 in 1992. A total of 42 bird species were detected in restored wetlands, 15 of which were breeding species. The mean number of breeding bird species and the density of yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) increased with wetland age and percent emergent vegetation cover. Species richness, waterfowl species richness, number of breeding waterfowl species, and density of red-winged blackbirds (*Agelaius phoeniceus*) did not differ between wetland ages. Several special concern species nested in restored wetlands, including the Virginia rail (*Rallus limicola*), sora (*Porzana carolina*), and American bittern (*Botaurus lentiginosus*). Most 1-year old wetlands were largely devoid of vegetation, but percent cover of robust and weak stemmed emergent vegetation increased with wetland age. Wet-meadow zones were absent in all restored wetlands.

Restored wetlands are initially providing habitat for migrating and breeding waterfowl, and a variety of other nongame species. The reestablishment of vegetation and increased use of older restored wetlands by breeding species indicate that they are becoming diverse and productive systems, and fulfilling some of their promise as habitat for wetland species. However, it is uncertain how closely restored wetlands will come to resemble and function as natural wetlands.

INTRODUCTION

The wetland ecosystems of the United States have been dramatically reduced in area and increasingly fragmented since the time of settlement. The conterminous United States has lost 53% of its natural wetlands since 1780, and nearly 90% of the wetlands in the southern Prairie Pothole region have been drained (Dahl 1990). About 50% of North America's waterfowl and more than 30 nongame bird species nest on the wetlands of the Prairie Pothole region (Batt et al. 1989). In addition, more than 100 other bird species rely on these wetlands for part of their life cycle. Regional declines of breeding populations of waterfowl and other bird species indicate that populations of many of these wetland species have been affected by this wetland loss (U.S. Fish Wildl. Serv. 1987, Batt et al. 1989).

Iowa has lost more than 3.5 million acres (89%) of its wetlands, primarily because of changes in land use and agricultural drainage (Bishop 1981, Dahl 1990). As a result, several Iowa marsh birds have been extirpated, and populations of others have declined (Weller 1979, Dinsmore 1981). In response, private and public programs have been initiated to preserve the remaining wetlands and restore wetland conditions to drained basins. The federal government has used section 404 of the Clean Water Act to mitigate restoration of wetland losses caused by draining, dredging, and filling (Rouvalis 1988, National Research Council 1991). Other programs, such as the Conservation Reserve Program and the Wetland Reserve Program, provide opportunities for voluntary wetland restoration by landowners. Although restored wetlands have been shown to support a variety of flora and fauna within a year of reflooding (Hemesath 1991, Sewell and Higgins 1991), species richness and abundance of some bird species are lower on restored Iowa wetlands than on similar natural wetlands, and wet-meadow and low-prairie vegetation zones are missing in restored basins (Delphey 1991, Galatowitsch 1993). It is not clear whether restored wetlands are unable to support the bird and plant species found in natural wetlands, or whether they have not had enough time to recolonize.

The objectives of this study were to (1) determine which bird species are using restored Iowa wetlands within 4 years of restoration; and (2) determine the effect of wetland age on bird use and vegetation development.

METHODS

Study Area

Study sites were located in Clay, Dickinson, Emmet, Kossuth, and Palo Alto counties in Northwestern and North-central Iowa (Table A-1). I studied 16 seasonal or semipermanent restored wetlands in 1991 and 24 in 1992. The wetlands ranged in age from 1 to 4 years post-restoration and from 0.4 to 5.9 ha (Table 1). All wetlands met the following criteria: (1) basin completely drained prior to restoration (not enhancements or wetland creations); (2) formerly tile drained; and (3) row cropped prior to restoration (Table 2).

Avian Community Composition

Three census stations were established in each wetland. The initial station was placed along a random compass bearing, and from that point, the other 2 stations were evenly spaced around the wetland. The stations were positioned in the middle of the emergent vegetation zone, or at the water's edge if no emergent zone was present. Birds were censused on each wetland 5 times yearly between May and July in 1991 and 1992 to determine bird use and breeding species. Since detectability of many bird species peaks in the early morning and declines thereafter (Skirvin 1981), counts were made between sunrise and 0900. Counts were not made during periods of rain or high winds (Robbins 1981). Waterfowl pair counts were made before the basin was entered (Dzubin 1969). All birds seen or heard during a 6-minute counting period within 20m-radius plots were recorded (Edwards et al. 1981). Midway through the counting period, I played tape recordings of sora (*Porzana carolina*), Virginia rail (*Rallus limicola*), least bittern (*Ixobrychus exilis*), and American bittern (*Botaurus lentiginosus*) calls to elicit responses from those secretive species (Marion et al. 1981, Gibbs and Melvin 1993). The tape included 30 seconds of continuous calls of each species.

Table 1. Area and age of restored Iowa wetlands studied in 1991 and 1992. Age refers to number of years since the basin was flooded. A 1-year-old wetland in 1991 was flooded in 1990

	Age				Mean	Range
Year	1	2	3	4	size (ha)	(ha)
1991	6	4	6	NA	2.3	0.7-4.9
1992	6	6	6	6	2.2	0.4-5.9

Table 2. Land history information of study sites

Year	Age	ID#[1]	Size (ha)	Duration of drainage (years)	Crop history[2] 60s	70s	80s
1991	1	13	0.8	30+		r	r
		14	1.4	70+	r/f	r/f	r/f
		15	0.8	60+	r	r	r/f
		16	1.8	50+	r	r	r
		17	0.7	50+	r	r	r
		18	0.9	50+	p	r	r
1991	2	7	4.6	20+		r	r
		8	4.9	65+	r	r	r
		9	1.7	60+	r	r	r/f
		10	4.5	60+	r	r	r
1991	3	1	2.5	40+		r	r/f
		2	2.2	40+		r	r/f
		3	2.7	50+		r	r
		4	3.3	60+	r	r	r/f
		5	2.5	50+	r	r	r
		6	1.8	50+	r	r	r
1992	1	19	0.8	20+		r	r/f
		20	0.8	60+	r	r	r/f
		21	5.8	50+	r	r	r
		22	2.1	60+		r	r
		23	1.3	60+		r	r
		24	0.4	40+	r	r	r
1992	2	13	0.8	30+		r	r
		14	2.5	70+	r/f	r/f	r/f
		15	0.5	60+	r	r	r/f
		16	1.3	50+	r	r	r
		17	0.4	50+	r	r	r
		18	0.8	50+	p	r	r
1992	3	7	4.6	20+		r	r
		8	5.9	65+	r	r	r
		9	1.9	60+	r	r	r/f
		10	4.8	60+	r	r	r
		11	1.9	40+	r	r	r
		12	0.9	50+	r	r/h	f
1992	4	1	2.9	40+		r	r/f
		2	2.8	40+		r	r/f
		3	1.0	50+		r	r
		4	2.9	60+	r	r	r/f
		5	2.7	50+	r	r	r
		6	2.3	50+	r	r	r

[1] See Table A-1.
[2] r=row crop, f=fallow, p=pasture, h=hayfield.

Birds seen or heard outside the counting interval or radius were noted, and included on a species list.

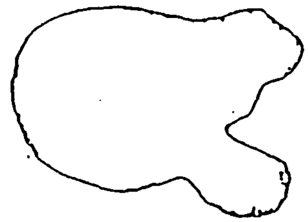
Wetlands were searched for nests weekly in 1991, and bi-weekly in 1992. I searched the emergent zone and 30m of the surrounding upland by foot in a zig-zag manner, scanning the vegetation for nests and flushing birds. Species for which an active nest was found, brood was seen, or that were present 3 of the 5 visits were regarded as breeding.

Vegetation

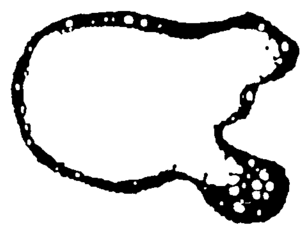
The vegetation community of each wetland was assessed in mid July using the releve method (Mueller-Dombois and Ellenberg 1974, Galatowitsch 1993). For each species the zonation, dispersion, and percent cover were visually estimated. Zonation classes included buffer (low prairie), mudflat, wet meadow, emergent, and open water. Dispersion classes included 1) large pure stands; 2) small colonies; 3) small patches; 4) clumps or dense groups; 5) solitary. Cover of the zone and of the basin was estimated using cover classes: 1) <1%; 2) 1-5%; 3) 6-29%; 4) 30-50%; 5) 51-75%; 6) >75%. A detailed cover map was drawn for each basin, and the total percent emergent cover was visually estimated. Basins were classified according to pattern (spatial relation of emergent vegetation cover to open water) (Fig 1). Vouchered specimens are in the Iowa State University Herbarium.

Basin Information

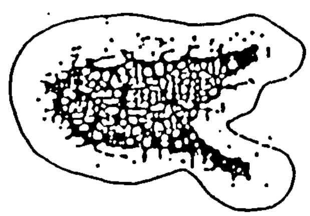
Aerial photographs of all wetland sites were taken each year (early June) and feature mapped using map and imaging processing systems (MIPS) to measure wetland area. Information on the history of each basin was obtained from landowner surveys and the Iowa Department of Natural Resources.



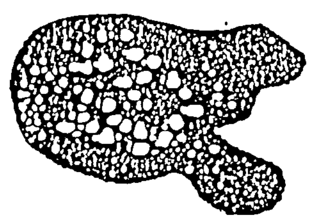
Pattern 1. Largely devoid of emergent vegetation; open water >95% of basin or marginal band of vegetation <2m in width.



Pattern 2. Centrally located areas of open water surrounded by a peripheral band of emergent vegetation >2 m in width.



Pattern 3. Centrally located areas of dense emergent vegetation surrounded by a peripheral band of open water.



Pattern 4. Dense stands of emergent vegetation with open water covering <5% of the wetland area.

Fig. 1. Vegetation patterns in restored wetlands. White areas indicate open water; shaded areas indicate emergent vegetation

Analysis

I compared the dependent variables [number of breeding species, number of breeding waterfowl species, species richness, waterfowl species richness, and density of red-winged (*Agelaius phoeniceus*) and yellow-headed blackbirds (*Xanthocephalus xanthocephalus*)] among wetlands of various ages using general linear models (GLM). All test assumptions, however, were not met. The assumption of normality was met, but independence was not achieved as wetlands used in the first year of study were also used in the second year. Thus differences between ages were blurred due to the increased interaction among variables. My analysis is conservative, as differences reported as significant are great enough to overcome this increased interaction. As a result, the GLM conclusions are valid, but cannot be used for predictions. I used regression analysis to examine the relationship of predictor variables (wetland age, size, pattern of vegetation, and percent emergent vegetation cover) to the dependent measures. Multiple regression models were tested for multicollinearity (correlation among predictor variables) using variance inflation factors (VIF's)(Neter et al. 1990). "Dummy variables" replaced the categorical variables of pattern in multiple regression analysis. Stepwise regression analysis was used to select a model that contained only those predictor variables that were significantly related to the dependent variable. Categorical variable comparisons were analyzed using chi-square and Spearman's rank-order correlation. A significance level of $p \leq 0.05$ was used in all statistical tests.

RESULTS

Bird Use of Restored Wetlands

A total of 42 species were detected on restored wetlands, 33% of which were waterfowl (Tables 3, A-2, and A-3). Red-winged blackbird (RWBB) and blue-winged teal (*Anas discors*) were present on all of the wetlands in both years. Yellow-headed blackbird (YHBB) and American coot (*Fulica americana*) were found in >80% of the wetlands. A total of 15 species were found nesting (Tables 3, A-4, and A-5); the most common nesting species were blue-winged teal and red-winged blackbirds which nested in >90% of the wetlands.

Total Species Richness

I found no significant difference in the overall mean species richness between years or wetland ages (Tables 4 and 5). I found a significant relationship between percent cover of emergent vegetation and species richness in 1991 but not in 1992 (Table 6, Fig. 2). Species richness differed significantly with vegetation cover pattern (Table 4). A multiple regression model containing all predictor variables accounted for 72% of the variation in the bird species richness in 1991 and 52% in 1992 (Table 7). Stepwise multiple regression analysis showed that 1 predictor variable (% emergent vegetation cover) was the best predictor of species richness in 1991, and 2 variables (wetland size and vegetation cover pattern 2) were in 1992 (Table 8).

Waterfowl Species Richness

I found no significant difference in the mean number of waterfowl species between years or wetland ages (Tables 4 and 8). No significant relationship was found between waterfowl species richness and percent emergent vegetation cover in either year (Table 6, Fig 3). The number of waterfowl species varied significantly with vegetation cover pattern (Tables 4

Table 3. Bird species richness and nesting species found on restored Iowa wetlands, 1991 and 1992

	Species Richness	Nesting Species
Waterfowl	14	4
Bittern/Herons	7	2
Grebes/Coot	2	2
Rails	2	2
Shorebirds	10	0
Terns	2	0
Songbirds	5	5
Total	42	15

Table 4. Results of analysis (ANOVA) comparing bird species richness, waterfowl richness, number of breeding bird species, number of breeding waterfowl species, red-winged blackbird density, and yellow-headed density with year, age, and vegetation cover pattern

Dependent variable (d.f.)	Year (1)	Age (3)	cover pattern (3)
Species richness	n.s.	n.s.	p=0.0002
Waterfowl richness	n.s.	n.s.	p=0.03
Breeding bird species richness	n.s.	p=0.005	p=0.0001
Breeding waterfowl species richness	n.s.	n.s.	n.s.
Red-winged blackbird density	p=0.0001	n.s.	n.s.
Yellow-headed blackbird density	n.s.	p=0.013	p=0.0001

n.s.=no significant difference, p=0.05 level.

Table 5. Average number of species found on four age categories of restored Iowa wetlands, 1991 and 1992

Wetland age	Species richness	# waterfowl species	Total # of breeding species	# of breeding waterfowl species
1	10.0	4.4	4.3	2.1
2	11.3	5.0	5.5	2.2
3	13.2	5.0	6.8	2.6
4	13.0	3.8	7.2	2.2

Table 6. Results of regression analysis between % emergent vegetation cover and species richness, waterfowl richness, number of breeding bird species, number of breeding waterfowl species, red-winged blackbird density, and yellow-headed blackbird density

Dependent variable	% cover emergent vegetation[1] 1991	1992
Species richness	r^2=0.35 p=0.02	r^2=0.09 n.s.
Waterfowl richness	r^2=0.01 n.s.	r^2=0.08 n.s.
Breeding bird species richness	r^2=0.37 p=0.01	r^2=0.33 p=0.003
Breeding waterfowl species richness	r^2=0.07 n.s.	r^2=0.12 n.s.
Red-winged blackbird density	r^2=0.02 n.s.	r^2=0.01 n.s.
Yellow-headed blackbird density	r^2=0.33 p=0.02	r^2=0.47 p=0.0002

[1]df=4.

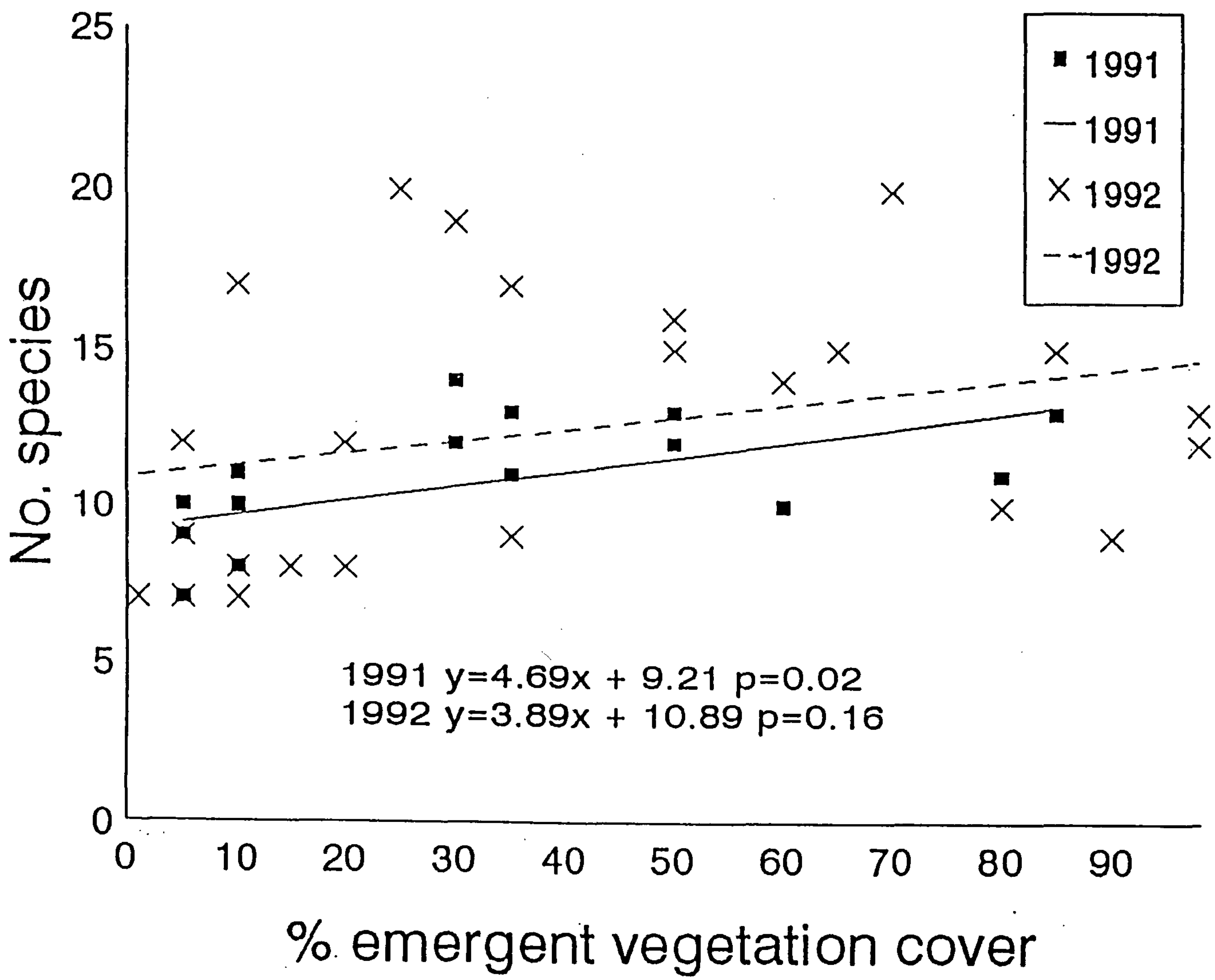


Fig. 2. Linear regression of bird species richness and percent emergent vegetation cover on restored Iowa wetlands in 1991 and 1992

Table 7. Multiple regression of species richness, breeding bird species richness, and bird density with wetland age, wetland size, percent emergent vegetation cover, and vegetation cover pattern on restored Iowa wetlands, 1991 and 1992

Dependent variable	Wetland age	Wetland size	Wetland cover	Veg. cover pattern 2	Veg. cover pattern 3	Veg. cover pattern 4	% Varianc explained
Species richness							
1991	n.s.	n.s.	n.s.	+	n.s.	n.s.	72
1992	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	52
Waterfowl species richness							
1991	-	+	n.s.	n.s.	n.s.	n.s.	62
1992	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	35
Breeding bird species richness							
1991	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	59
1992	+	n.s.	-	+	+	+	75
Breeding waterfowl species richness							
1991	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	46
1992	n.s.	-	n.s.	n.s.	n.s.	n.s.	61
RWBB[1] density							
1991	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	39
1992	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	36
YHBB[2] density							
1991	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	45
1992	+	n.s.	n.s.	n.s.	n.s.	n.s.	76

+ positive slope. n.s. = not significant at $p<0.05$. - negative slope.
[1]Red-winged blackbird. [2]Yellow-headed blackbird.

Table 8. Stepwise regression of species richness, breeding species, and density with wetland age, wetland size, percent emergent vegetation cover, and pattern

Dependent variable	Wetland age	Wetland size	Wetland cover	Veg. cover pattern 2	Veg. cover pattern 3	Veg. cover pattern 4	% Variance explained
Species richness							
1991	...	...	+	...	...	...	34
1992	...	+	...	+	...	...	47
Waterfowl richness							
1991	-	+	...	...	...	...	42
1992	...	+	-	...	...	...	31
Breeding bird species richness							
1991	+	...	...	...	...	+	58
1992	+	...	-	+	+	+	75
Breeding waterfowl species richness							
1991	...	...	...	...	...	x	19
1992	+	...	-	...	+	...	48
RWBB density							
1991	...	...	...	...	...	-	25
1992	...	...	...	+	...	...	32
YHBB density							
1991	...	...	+	...	...	...	33
1992	+	...	...	...	+	+	69

+=positive slope. x=used in model, but not significant.
-=negative slope. ...=not used in model.

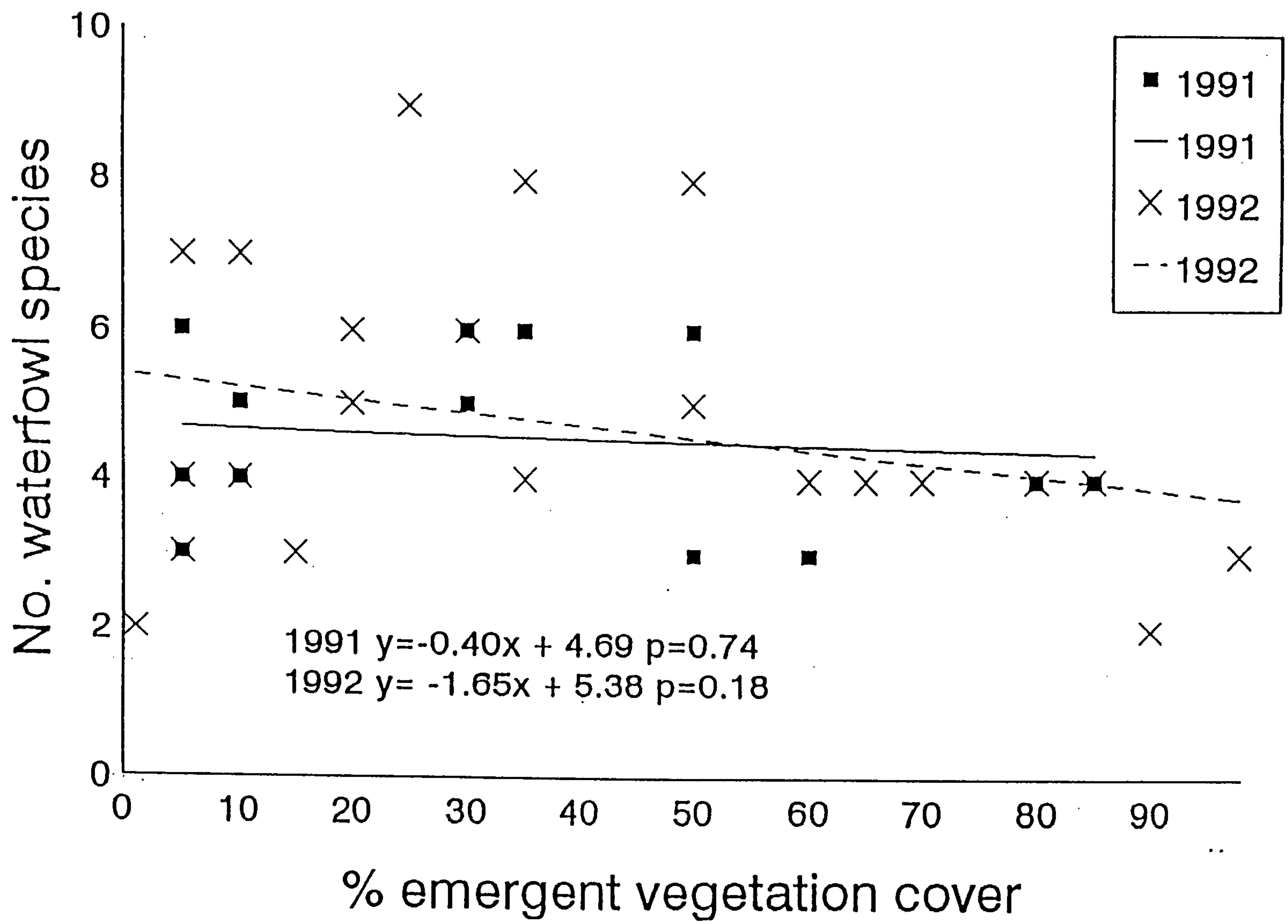


Fig. 3. Linear regression of waterfowl species richness and percent emergent vegetation cover on restored Iowa wetlands, 1991 and 1992

and 9). A multiple regression model containing all predictor variables accounted for 62% of the variation in the number of waterfowl species in 1991 and 35% in 1992 (Table 7). Stepwise regression showed that waterfowl species richness was positively related to wetland size in both years (Table 8).

Breeding Bird Species Richness

I found no significant difference in the mean number of breeding bird species between 1991 and 1992 (Table 4). The mean number of breeding bird species increased with wetland age and varied with vegetation cover pattern (Tables 4, 5, 8, 9). I found a significant relationship between the number of breeding bird species and percent cover of emergent vegetation in both years (Table 6, Fig. 4). A multiple regression model containing all predictor variables accounted for 59% of the variation in the number of breeding bird species in 1991; however, none of the predictor variables were significant (Table 6). In 1992, 75% of the variation was accounted for by the model, and all variables except wetland size were significant. The stepwise regression model containing all significant predictor variables was a 2-variable model 1991, and a 5-variable model in 1992 (Table 8). Wetland age and vegetation cover pattern 4 were positively related to the number of breeding bird species in both years.

Breeding Waterfowl Species Richness

I found no significant difference in the mean number of breeding waterfowl species between year or wetland age (Tables 4, 5, 8, 9). No significant relationship was found in either year between number of species and percent cover of emergent vegetation or cover pattern (Tables 4 and 6, Fig. 5). A multiple regression model containing all predictor variables accounted for 46% of the variation in species in 1991, and 61% in 1992 (Table 7). In 1991 no stepwise regression model

Table 9. Effect of vegetation cover pattern on bird species richness and density in restored Iowa wetlands. Results of Tukeys Studentized Range Test. Data from 1991 and 1992 combined. Different letters within a column indicate a significant difference at $p<0.05$

Veg. Cover Pattern	Species Richness $p=0.0002$	Waterfowl Richness $p=0.03$	Breeding Bird Species Richness $p=0.0001$	Breeding Waterfowl Sp. Richness $p=0.89$	RWBB[1] Density $p=0.22$	YHBB[2] Density $p=0.0001$
1	9.4 B	4.6 AB	4.4 C	2.3 A	1.5 A	0.3 B
2	15.3 A	5.9 A	5.9 BC	2.4 A	2.0 A	1.3 B
3	13.0 AB	4.6 AB	7.2 AB	2.3 A	1.6 A	4.4 A
4	12.4 AB	3.2 B	8.2 A	2.0 A	0.5 A	6.0 A

[1]Red-winged blackbird.
[2]Yellow-headed blackbird.

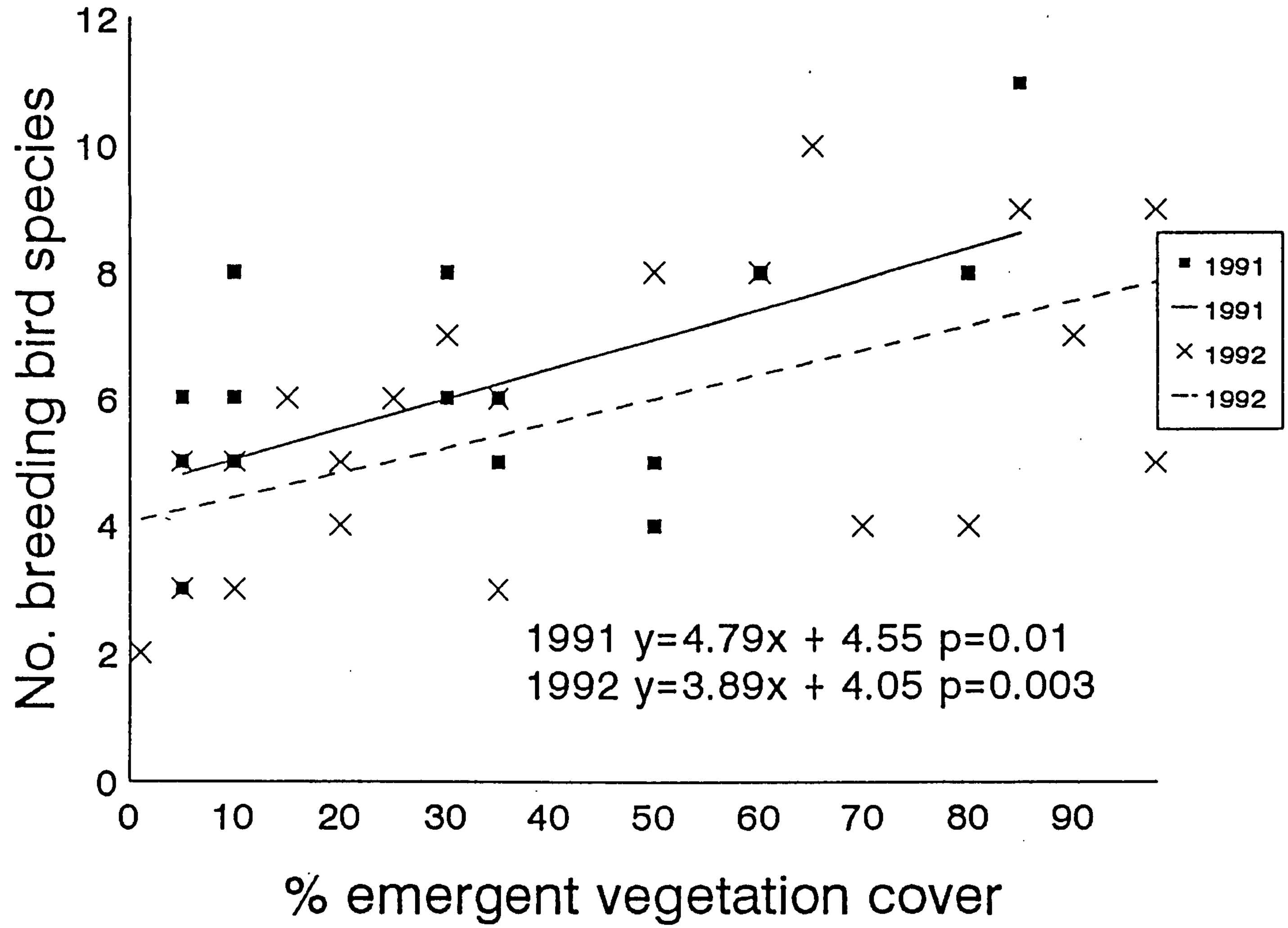


Fig. 4. Linear regression of breeding bird species richness and percent emergent vegetation cover on restored Iowa wetlands, 1991 and 1992

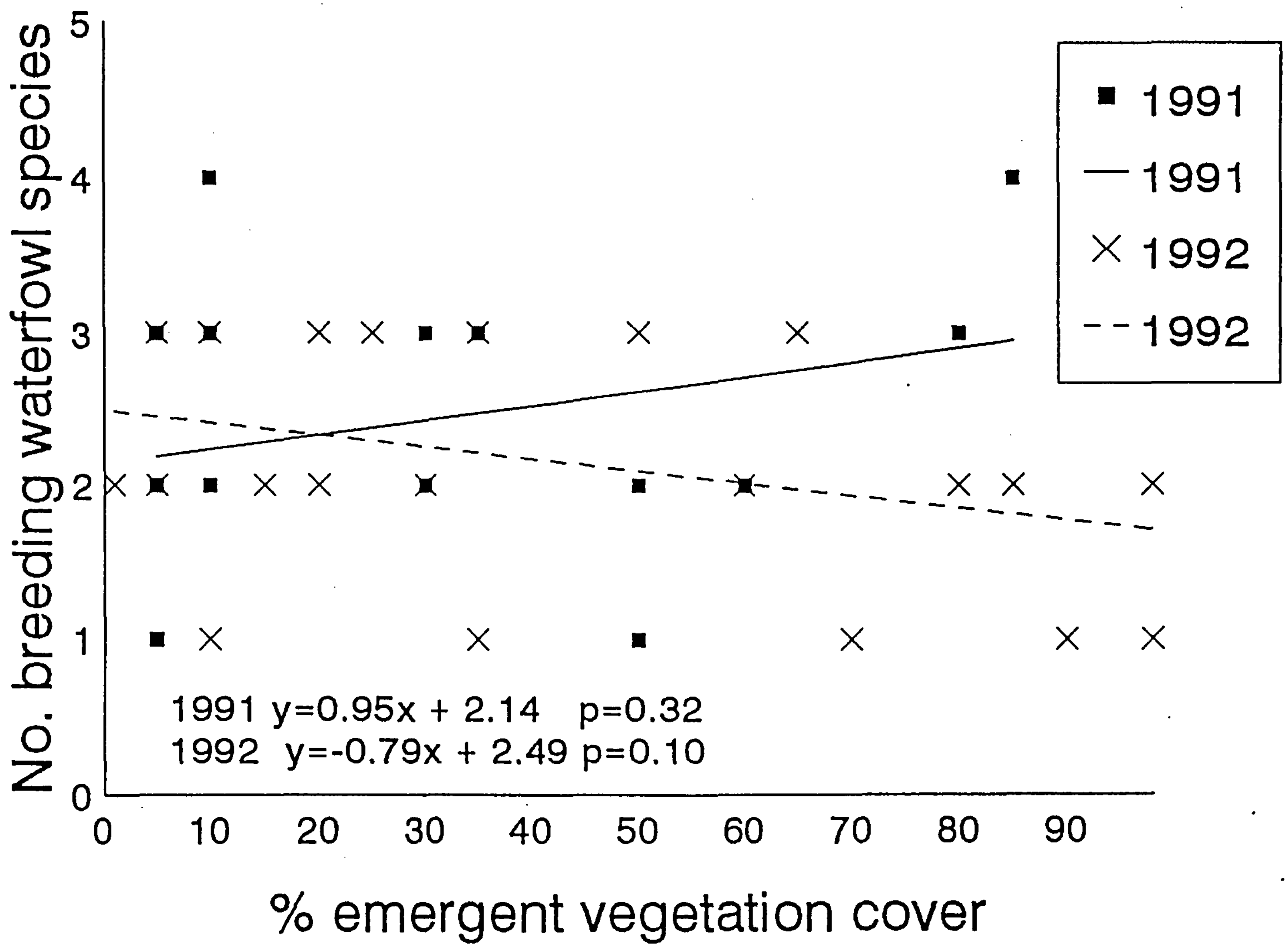


Fig. 5. Linear regression of breeding waterfowl species richness and percent emergent vegetation cover on restored Iowa wetlands, 1991 and 1992

contained all significant predictor variables. The stepwise regression model in 1992 contained 3 significant predictor variables (% cover, cover pattern 3, and age)(Table 8).

Blackbird Densities

The two most common species on restored wetlands were red-winged and yellow-headed blackbirds. The relationships between their densities and year, wetland age, and vegetation cover are examined below. The density of all individuals (male and female) within the plot was recorded, and the analysis was run using the 2 weeks of peak density.

Density of Red-winged blackbirds

The density of RWBB in 1991 was significantly greater than in 1992 (Tables 4, 10). RWBB density did not differ in either year between age categories (Tables 4, 10). No significant relationship was found in either year between RWBB density and percent cover of emergent vegetation or vegetation cover pattern (Tables 4, 5, 9 Fig. 6). A multiple regression model containing all predictor variables accounted for 39% of the variation in density in 1991, and 36% in 1992 (Table 7). The stepwise regression model containing all significant predictor variables was a 1-variable model in both years (Table 8). In 1991, RWBB density was negatively associated with vegetation pattern 4, while in 1992 it was positively associated with vegetation pattern 2.

Density of Yellow-headed blackbirds

I found no significant difference in the density of YHBB between 1991 and 1992 (Tables 4, 10). YHBB density increased significantly with wetland age (Tables 4, 10). I found a significant relationship between YHBB density and percent cover of emergent vegetation in both years (Table 6, Fig. 7). YHBB density also varied with vegetation cover pattern (Tables

Table 10. Density (#/ha) of red-winged and yellow-headed blackbirds on restored Iowa wetlands 1991 and 1992

		Wetland Age			
Species	Year	1	2	3	4
Red-winged blackbird	1991	21.7	21.7	22.5	-
Red-winged blackbird	1992	3.3	8.3	7.5	3.3
Yellow-headed blackbird	1991	5.8	5.0	25.8	-
Yellow-headed blackbird	1992	10.0	10.8	20.0	45.0

[1] Sample size for wetland age 2 in 1991 n=4, all others n=6.

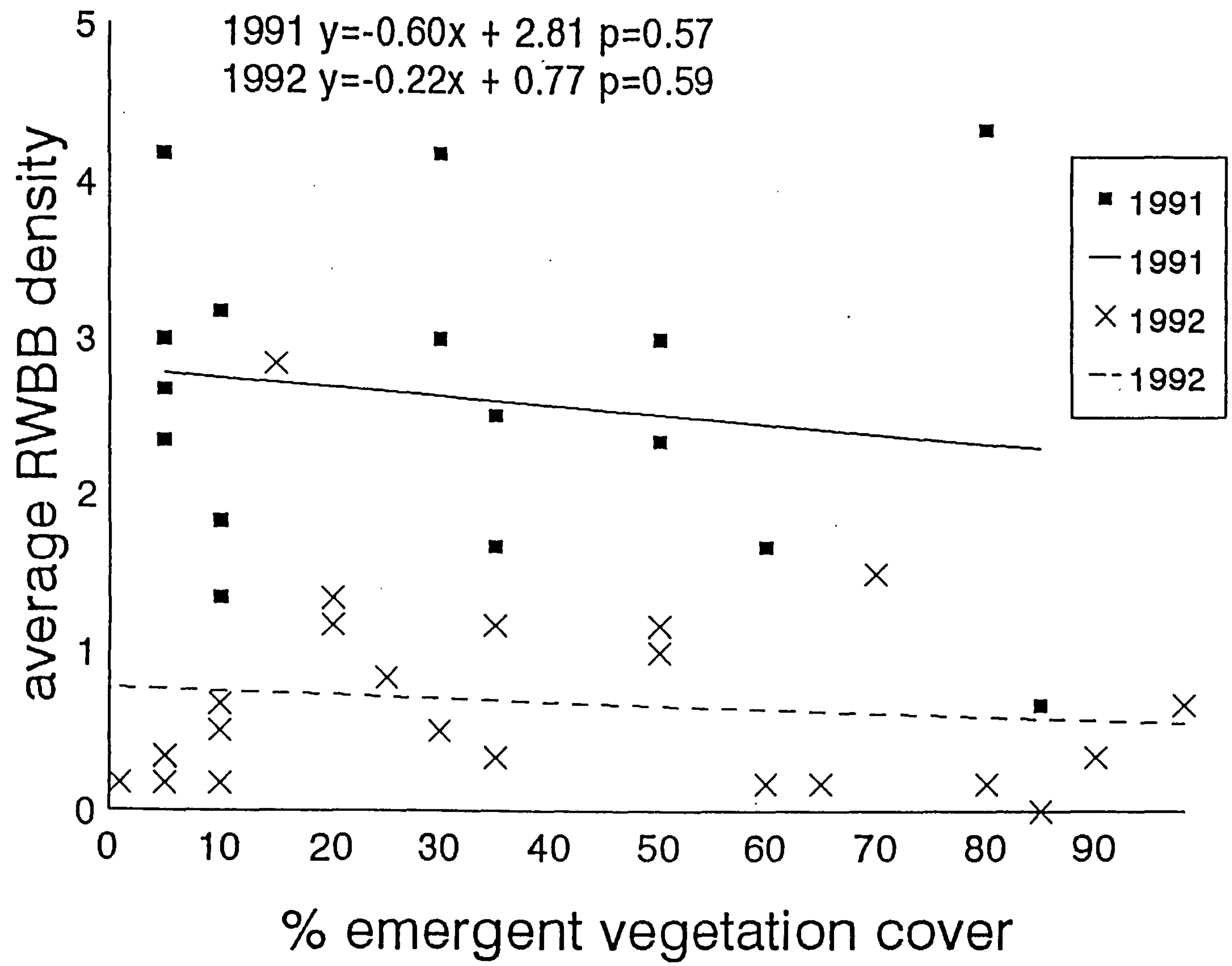


Fig. 6. Linear regression of red-winged blackbird density and percent emergent vegetation cover on restored Iowa wetlands, 1991 and 1992

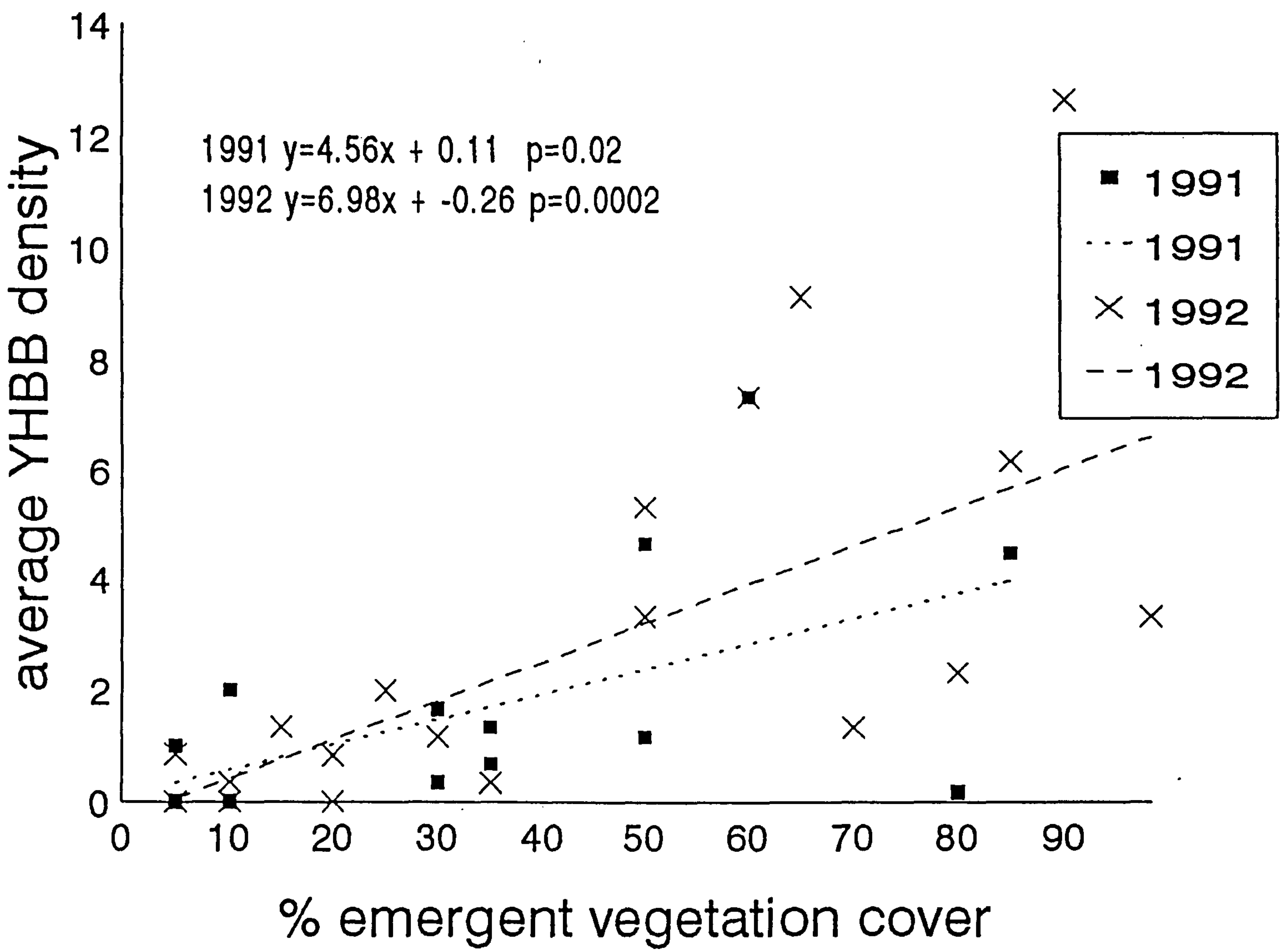


Fig. 7. Linear regression of yellow-headed blackbird density and percent emergent vegetation cover on restored Iowa wetlands, 1991 and 1992

4, 9). A multiple regression model containing all predictor variables accounted for 45% of the variation in 1991, and 76% in 1992 (Table 7). The stepwise regression model containing all significant predictor variables was a 1-variable model 1991, and a 3-variable model in 1992 (Table 8). There was a positive relationship between YHBB density and percent emergent cover in 1991. Vegetation patterns 3 and 4, and wetland age showed a positive relationship with YHBB density in 1992 (Tables 9,10).

Species of Special Concern

Several species which were not found in previous studies of restored wetlands in Iowa (Delphey 1991, Hemesath 1991) or which were identified by the U.S. Fish and Wildlife Service as species of special interest were found on the restored wetlands I studied. These include the sora, Virginia rail, American bittern, least bittern, and black tern (*Chlidonias niger*). None of these species nested in restored wetlands in 1991. Three of these species (sora, Virginia rail, and American bittern) nested there in 1992. The Virginia rail nested on 3 restored wetlands; 2 of which were 4 years old, and 1 which was 2 years old. The American bittern nested on 2 restored wetlands; 1 each of 2- and 4-year wetlands. The sora nested on a single 2-year-old restored wetland. The sora, Virginia rail, and black tern were present in all restored wetland age classes (Fig. 8). The black tern foraged at about a third of wetlands of all ages, while the occurrence of the sora and Virginia rail increased with wetland age. The American bittern was not present in 1-year-old wetlands, but used 2- to 4-year-old basins. The least bittern was only present in a single 4-year-old restored wetland.

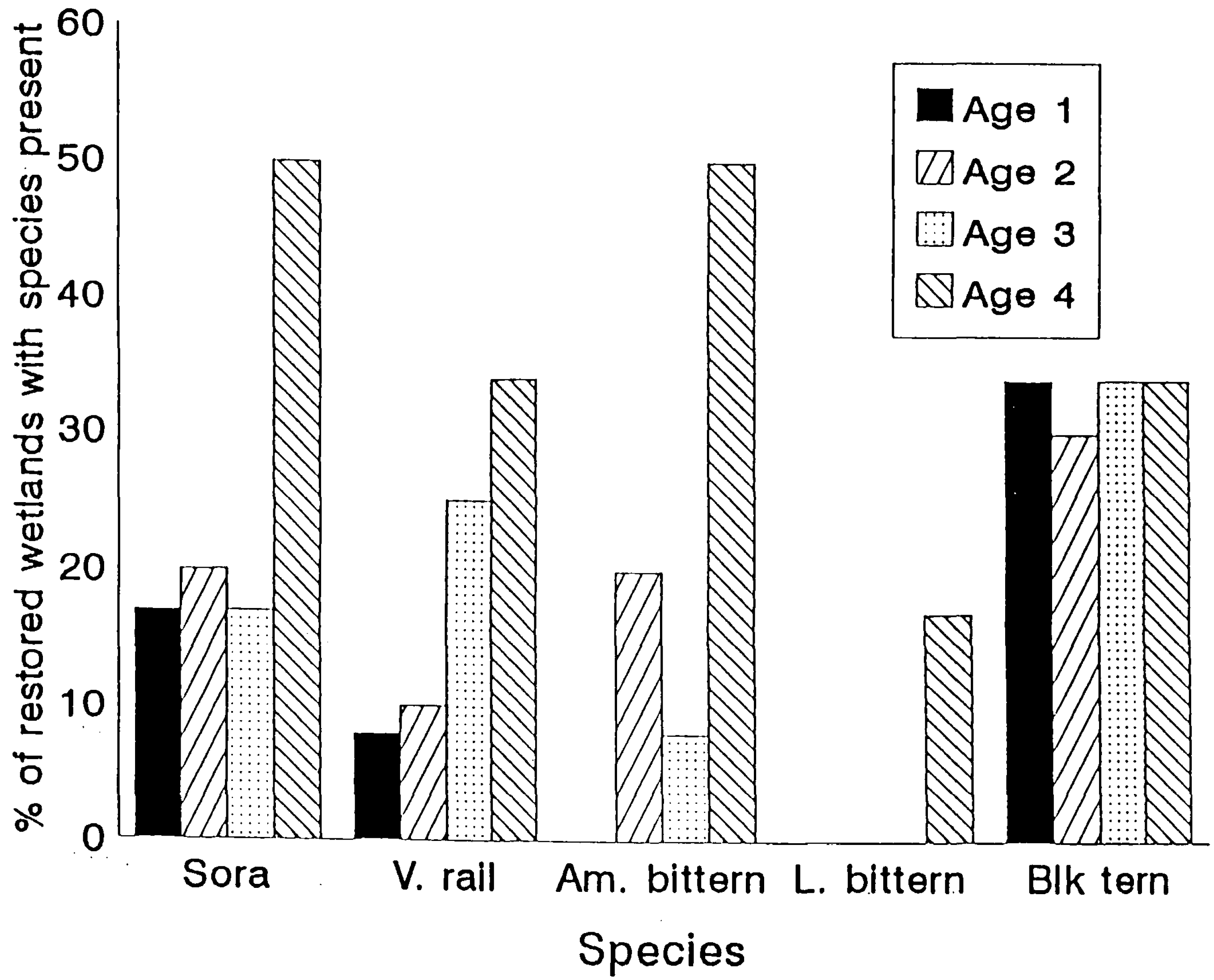


Fig. 8. Use of restored Iowa wetlands by species of special concern in 1991 and 1992

Vegetation

So far as is known, no artificial planting or seed establishment has occurred in the restored wetlands I studied. All basins were re-vegetated naturally, based on the original seed bank and natural mechanisms of seed dispersal. Restored wetlands supported a variety of plant species, but lacked wet meadow zones (Table A-6). The percent cover of emergent vegetation increased significantly with wetland age ($p=0.03$, Table 11). Vegetation cover pattern also differed with wetland age (Table 12). Most 1- and 2-year-old wetlands were largely devoid of emergent vegetation (pattern 1), while half of the 4-year-old wetlands were >95% vegetated (pattern 4). Many 3-year wetlands were vegetated in the center (pattern 3). This is likely a result of the 1989 drought, as emergent vegetation became established in the center of the wetlands during the drawdown period, and remained after reflooding (Sue Galatowitsch, Iowa State University, pers. comm.).

The type of vegetation found in restored wetlands differed somewhat with age. Percent cover of robust emergent and floating vegetation increased significantly between wetland ages (Table 13). Cover of weak stemmed emergent vegetation and algae did not differ significantly between wetland ages (Table 13). Seventy-three percent of all wetlands contained submerged vegetation, and no significant difference was found between wetland ages (Table 12).

Table 11. Comparison of emergent vegetation cover among 4 age classes of restored Iowa wetlands; results of Tukeys Studentized Tange Test

Wetland Age	n	avg. % cover emergent veg[1]	Standard Deviation
1	12	20 A	0.26
2	10	31 AB	0.25
3	12	46 AB	0.27
4	6	63 B	0.36

[1]Averages with the same letter are not significantly different at the p=0.05 level.

Table 12. Relationship of wetland age and vegetation cover pattern in restored Iowa wetlands. Values are percentages of wetlands in each cover category

Wetland	Pattern				
Age	1	2	3	4	n
1	75	8	17	0	12
2	50	30	10	10	10
3	25	25	42	8	12
4	17	17	17	50	6

Table 13. Correlation and chi-square analysis between vegetation categories and restored wetland age in 1991 and 1992

Vegetation type	Spearman correlation	X^2	p	df
Floating leaved[1]	+ r=0.23 n.s.	12.61	0.05	6
Weak stemmed[2] emergents		11.29	0.08	6
Robust emergents[3]	+ r=0.41 p=0.01	26.23	0.04	15
Algae		14.27	0.28	12
Submergent[4]		1.88	0.60	3

[1]Does not include *Lemna*.

[2]Includes emergent vegetation which I found too weak to provide adequate nesting support for birds with elevated nests. Includes *Polygonum*, *Phalaris*, *Cyperus*, *Sagittaria*, and *Alisma* spp..

[3]Includes *Typha*, *Scirpus*, and *Sparganium* spp..

[4]Includes *Potamogeton*, *Myriophyllum*, *Ceratophyllum*, and *Utricularia* spp..

n.s.=not significant at the $p<0.05$ level.

DISCUSSION

Bird Use

The results of this study indicate that a variety of bird species rapidly colonize restored Iowa wetlands. A total of 42 bird species were found on restored wetlands during the breeding season, 14 of which were waterfowl. This total is similar to the 13 waterfowl species found on restored wetlands in South Dakota and Minnesota (Sewell and Higgins 1991).

Overall, I found 15 species breeding on restored wetlands with an overall average of 5.8 breeding species per wetland (1991=6.1, 1992=5.6). This is fewer than the average number found in two other studies of similar-sized natural wetlands in this region (6.6 and 6.6 species, Brown 1985; 7.3 and 8.6 species, Delphey 1991). However, it is more than the number of breeding species found in 1- to 3- year old restored wetlands (3.6 and 5.4 species, Delphey 1991). Although the number of breeding species I found on restored wetlands was less than on similar-sized natural wetlands (Brown 1985, Delphey 1991), the number I found in older restored wetlands (3- and 4-years old) more closely resembles the numbers found in natural wetlands (Brown 1985, Delphey 1991)(Table 5).

Red-winged blackbird and blue-winged teal were the most ubiquitous species in this study, and each nested at >90% of all wetlands in both years (Tables A-4 and A-5). Delphey (1991) also found red-winged blackbird and blue-winged teal among the most common nesters at restored wetlands, both nesting in ≥ 70% of restored wetlands.

Wetland size has been suggested as being important in determining which species nest on various wetlands. Brown and Dinsmore (1986) indicated that pied-billed grebe (*Podilymbus podiceps*) and ruddy duck (*Oxyura jamaicensis*) were area-dependent species, and American coots were possibly area-dependent. I found all three of these species nesting on restored wetlands, and two of them nesting on small wetlands

(<2 ha). Pied-billed grebes were found nesting on 25% of the wetlands in 1991 and 29% in 1992. They nested on 2 of the 8 wetlands <2 ha (25%) in 1991, and 2 of the 13 <2 ha (15%) in 1992. Ruddy ducks were not found nesting on any of the wetlands in 1991, but nested on 1 wetland in 1992. That wetland, however, was 2.7 ha, suggesting that Ruddy ducks require somewhat larger wetlands for breeding. American coots were found nesting on 81% of the wetlands in 1991, and 38% in 1992. They nested on 5 of the 8 wetlands which were <2 ha in 1991 (63%), and 3 of the 13 wetlands <2 ha in 1992 (23%). For all three of these species, the percentage of small restored wetlands on which they nested is similar to that found on similar sized natural wetlands (Brown and Dinsmore 1986). This suggests that restored wetlands are providing habitat for these species.

Effect of Wetland Age on Bird Use

The number of breeding bird species on restored wetlands and abundance of yellow-headed blackbirds increased with wetland age, while species richness, waterfowl richness, number of breeding waterfowl species, and red-winged blackbird density did not differ with age (Table 4). Since the amount and complexity of vegetative cover increased with age (Table 11), the increase in number of breeding bird species was expected. The lack of change in waterfowl richness or number of breeding waterfowl species was not surprising as waterfowl tend to use areas as soon as water is available. Apparently restored wetlands provide suitable habitat for waterfowl as soon as they are flooded. Restored wetlands are also rapidly recolonized by invertebrates (see section II, Sewell and Higgins 1991, Delphey 1991). Most waterfowl species nest on the uplands surrounding a wetland, so the quantity and quality of upland vegetation and presence of an invertebrate food source may be more important to waterfowl use than vegetative development in the wetland itself.

The lack of significant changes in species richness and red-winged blackbird abundance was somewhat surprising. Hemesath (1991) also found that species richness did not change with restored wetland age. It appears that many of the species which initially used restored wetlands (waterfowl and sandpipers) did not use older restored wetlands (Tables A-2 and A-3). This may be due in part to the availability of mudflats and open water in 1- and 2- year old wetlands. Other species (bitterns, Sora, Pied-billed grebe, Marsh Wren, Black-Crowned Night Heron) were present at more of the older wetlands (3- and 4- years old), probably in response to the increased emergent vegetation. So although species richness did not differ with wetland age, the structure of bird communities did change somewhat with wetland age. Perhaps other factors such as wetland isolation, competition, wetland size, and lack of wet meadow vegetation affect the species richness of restored wetlands.

Red-winged blackbirds use a diversity of nesting habitats, but prefer wetland habitats (Clark and Wearherhead 1987); so their early appearance in restored wetlands was expected. However, red-winged blackbirds require robust vegetation to support their nests, so I expected red-winged blackbird abundance to increase as the amount of robust vegetation increased. The failure of red-winged blackbird abundance to increase with wetland age may be due to competition from other bird species. The increase in vegetation cover with wetland age may increase competition from yellow-headed blackbirds and Marsh Wrens (*Cistothorus palustris*), and reduce the habitat available to red-winged blackbirds in older wetlands (Miller 1968, Picman 1977, 1984). Red-winged blackbirds use edge habitat, and the differences in density between 1991 and 1992 may be a result of availability of edge habitat. The density of red-winged blackbirds was higher in 1991 (a drier year, with more edge habitat available) than in 1992 (a wetter year in which edge habitat was reduced due to inundation). Although red-winged blackbirds have been shown to have site fidelity (Beletsky and Orians 1991), my results suggest that habitat quality is more important than site fidelity in determining population density.

Special Concern Species

A goal of wetland restoration is to provide habitat for a broad range of species, including species with declining populations. The use of restored wetlands by 5 special concern species indicates that these wetlands are meeting that goal. Although no species of special concern nested in restored wetlands in 1991, the 3 species found nesting in 1992 indicate that restored wetlands have the potential to support populations of these species, and perhaps over time to help reverse their declining numbers. The sora nested in 1 2-year-old wetland (#18) that had 98% emergent vegetation cover. The Virginia rail nested in 3 restored wetlands, 2 of which were 4-years-old (85% and 90% emergent vegetation cover), and 1 2-years-old (#18). The American bittern nested in 2 restored wetlands, 1 which was 4-years-old (65% cover), the other 2-years-old (again #18). Neither the Black Tern nor the Least bittern was found nesting in restored wetlands.

All three of the nesting species used restored wetlands with fairly extensive emergent vegetation cover. Emergent vegetation provides a variety of nesting habitats, protection from adverse weather and predators, and high invertebrate densities. Since the percent cover of emergent vegetation increased significantly with wetland age, the use of restored wetlands by these special concern species is likely to increase in the future. Wetland complexes may attract species of special concern, as the sora, Virginia rail, and American bittern all nested in wetland 18. This 2-year old wetland was in a complex of natural and various age restored wetlands. Special concern species also nested in isolated wetlands, but only those 4- years-old which contained >60 percent emergent vegetation cover. Restoring complexes of wetlands, or placing wetland restorations near existing natural wetlands may accelerate vegetation development and enhance colonization by special concern species.

Vegetation Colonization

One-year-old wetlands were mostly devoid of emergent vegetation, or had sparse stands of *Typha* (Table 12). Submergent vegetation became established rapidly in restored wetlands and was found in 58% of 1-year-old wetlands (Table 13); this was similar to findings in South Dakota and Minnesota (Sewell and Higgins 1991). The abundance of submerged vegetation in newly established restored wetlands may account for the pioneering of these basins by waterfowl, as mallards and blue-winged teal feed on submergent vegetation (e.g. *Potamogeton pectinatus*), and many waterfowl species eat the invertebrates which feed on submergent vegetation (Murkin 1989). Algae is also a food source for invertebrates. Most (83%) of the 1-year-old wetlands contained macroscopic mats of algae. The lack of emergent vegetation in 1-year-old wetlands may have encouraged the rapid colonization of algae (Crumpton 1989).

The diversity and amount of robust emergent vegetation increased with wetland age. Wetlands ranging from 30-50% cover have the greatest diversity and abundance of birds (Weller and Spatcher 1965). The average cover of emergent vegetation reached this range in 2- and 3-year-old restored wetlands. Most 4-year-old wetlands exceeded the 30-50% cover range, and they averaged 63% emergent cover. Some of the shallow 4-year-old wetlands were completely (95-98%)

vegetated. Several factors including deep water, prolonged flooding, and muskrats (*Ondatra zibethicus*), which normally reduce vegetation cover, were absent in these shallow wetlands.

Although vegetation rapidly colonized most wetlands, there were a few exceptions. Two wetlands, 4 and 12, had only 5% emergent cover by age 3 (Table A-1). In 1991, one of these wetlands (#4) had no robust vegetation. It contained only algae, small amounts of water smartweed (*Polygonum amphibium*), and trace amounts of submergent vegetation. In 1992, cover from smartweed and *Typha* had increased and this wetland (now age 4) had 10% emergent cover. Wetland 4 was located <1.6 km from two other wetlands which were both 1 year younger than wetland 4; both had greater emergent vegetation cover (1992: 50% and 20%).

Two other 1-year-old wetlands (#21 and #22) were rapidly colonized by vegetation (percent cover of emergent vegetation was 50 and 80 respectively). Both wetlands had floating and weak-stemmed emergent vegetation. Wetland 21 was one of the largest wetlands studied, while wetland 22 was intermediate in size. Both of these wetlands were located adjacent to natural wetlands. The early development of vegetation is likely a result of seed dispersal from these natural wetlands, and indicates a benefit of restoring wetlands in complexes. The lack of vegetation development at the first two sites, and its rapid development at two others is puzzling, but suggests that re-vegetation is site specific. Factors not examined in this study such as soil quality, hydrology, water chemistry, and surrounding land use probably influence vegetation development.

All restored wetlands I studied lacked a wet-meadow zone. The absence of wet meadow-zones has also been noted in other studies of restored wetlands (Delphey 1991, Galatowitsch 1993). The lack of this zone could affect restored wetland recolonization by bird species, as wet-meadow areas are the preferred nesting habitat of several species, including the swamp sparrow, common yellowthroat, marsh wren, sora, and Virginia rail (Weller and Spatcher 1965, Kantrud and Stewart 1984, Delphey 1991). The establishment of wet-meadow zones in restored wetlands may require initial seeding or transplanting by wetland managers (Galatowitsch 1993), and may be necessary to further increase their use by breeding bird species.

MANAGEMENT CONCLUSIONS

The use of restored wetlands by a variety of waterfowl and other bird species for both nesting and other activities indicates that one objective of restoration is being met. Several waterfowl and special concern species nested in restored wetlands, indicating that they may be influential in reversing the declines of these populations. The number of breeding bird species increased with wetland age, but even basins 4 years after restoration had fewer breeding species than were found in similar sized natural wetlands in previous studies. The increase in breeding bird diversity with age suggests that restored wetlands may continue to become more diverse with time, but raises the question of how closely restored wetlands will come to resemble and function as natural wetlands.

The percent cover of emergent vegetation increased with wetland age, indicating that restored wetlands are progressing towards the vegetative structure of natural wetlands. However, none of the restored wetlands studied contained a wet-meadow zone. Dissimilarity was evident in the re-vegetation of restored wetlands, suggesting that re-vegetation is site specific; restorations on some sites may be unable to develop or support the vegetation communities found in natural wetlands.

Despite these limitations, wetland restoration in the Prairie Pothole region appears to be a successful tool to increase the population of waterfowl and other wetland bird species in this region. The results of this study suggest that several factors may increase the "success" of restored wetlands. Although the goal of restoration should be a self-sustaining system (National Research Council 1992) I suggest that initial management intervention be used to establish wet-meadow zones, as they were absent in all wetlands studied. This study indicated that revegetation of restored wetlands is site specific, and factors not examined in this study such as size, depth, soil quality, hydrology, water chemistry, surrounding land use, and landscape pattern may influence vegetation development. These factors should be considered when selecting restoration sites. Wetland complexes may accelerate recolonization by vegetation and species of special concern, so efforts should be made to restore future wetlands in clusters or close to existing wetlands. Since vegetation, number of breeding bird species, and yellow-headed blackbird density increased with wetland age, efforts should be made to promote conservation easements and other long-term restoration efforts.

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APPENDIX

Table A-1. LANDOWNER AND LOCATION OF STUDY SITES

ID #	Landowner/title	County	Township/Range/Section
* 1	McBreen	Dickinson	T100N R37W S13 SW1/4
* 2	McBreen	Dickinson	T100N R37W S13 SW1/4
* 3	Henry	Emmet	T98N R34W S36 SW1/4
* 4	Love	Emmet	T99N R34W S7 NE1/4
* 5	Appel	Palo Alto	T97N R33W S31 NW1/4
* 6	Thu	Palo Alto	T97N R34W S8 NW1/4
* 7	East Slough	Emmet	T98N R32W S6 NE1/4
* 8	Four Mile WPA	Emmet	T99N R34W S8 SE1/4
* 9	Twelve Mile WPA	Emmet	T98N R34W S22 SW1/4
10	NE Pleasant Lake	Dickinson	T99N R35W S7 NE1/4
*11	Nock	Palo Alto	T97N R32W S28 SW1/4
12	Pelzer	Emmet	T98N R34W S27 SW1/4
13	Center Lake	Dickinson	T99N R36W S7 NW1/4
*14	E. of Ingham High	Emmet	T98N R33W S24 NE1/4
15	Osher	Emmet	T98N R33W S20 SE1/4
*16	Braby	Palo Alto	T97N R34W S12 N1/2
*17	Clay 1	Clay	T97N R35W S26 NE1/4
18	Clay 2	Clay	T97N R35W S26 NE1/4
19	Graff	Dickinson	T99N R37W S34 NE1/4
*20	Westergaard	Dickinson	T99N R36W S9 NE1/4
21	Kossuth	Kossuth	T100N R30W S7 NW1/4
*22	E. of Jemmerson	Dickinson	T100N R36W S32 SE1/4
*23	E. of Jemmerson	Dickinson	T100N R36W S32 SE1/4
24	Clay 3	Clay	T97N R35W S26 NE1/4

*Wetlands sampled for macroinvertebrates.

Table A-2. SUMMARY OF BIRD SPECIES USING RESTORED IOWA WETLANDS IN 1991

Species	Wetland															
	1	2	3	4	5	6	7	8	9	10	13	14	15	16	17	18
Red-winged Blackbird	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Yellow-headed Blackbird	X	X	X		X	X	X	X	X	X			X		X	X
Blue-winged Teal	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Green-winged Teal												X				
Mallard	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
Gadwall																X
Northern Shoveler	X	X	X	X		X	X	X	X	X	X	X		X	X	X
Wood Duck	X						X								X	
Ruddy Duck	X				X			X		X				X		
Redhead							X	X		X					X	X
Canada Goose		X		X	X	X	X	X	X	X		X	X	X	X	X
American Coot	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pied-billed Grebe		X	X		X	X						X				
Sora		X						X								
Viriginia Rail					X											
American Bittern	X							X								
Great Blue Heron							X									X
Black-Crowned Night Heron						X		X								
Black Tern					X		X			X						X
Lesser Yellowlegs									X							
Semipalmated Plover	X															
Marsh Wren	X		X		X	X	X									
Swamp Sparrow		X	X	X	X	X		X	X	X	X	X				X
Common Yellowthroat	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table A-3. SUMMARY OF BIRD SPECIES AT RESTORED IOWA WETLANDS IN 1992

Species	Wetland 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
RWBB	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
YHBB	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X		X	X	X	X	X
BW Teal	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
GW Teal							X				X	X	X				X		X					X
Mallard	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Gadwall	X							X		X		X		X	X									
N. Shoveler						X			X	X		X		X	X						X	X		X
Wood Duck				X				X		X		X		X		X	X						X	X
Ruddy Duck					X			X		X														
Redhead	X									X	X			X										X
Hooded Merganser								X	X								X		X		X			
Northern Pintail									X					X										
American Wigeon								X						X										
Canada Goose	X	X	X			X	X	X	X	X			X	X				X			X			X
American Coot	X	X	X		X	X		X	X	X	X			X		X		X			X			
PB Grebe	X	X	X	X	X	X	X	X		X	X			X		X					X			
Sora	X	X				X					X							X			X			X
Virginia Rail			X			X	X				X							X				X		
Am. Bittern	X	X			X													X						
Least Bittern					X																			
Great Blue Heron					X		X							X				X			X			X
Green-b.Heron	X																							X
B.C.NighHeron	X					X					X													
Great Egret																					X			
Black Tern	X					X		X	X	X				X									X	X
Foresters Tern	X	X			X																			
Yellowlegs species							X			X			X											
Semipalmated plover									X															
Black-bellied Plover	X																							
Spotted Sandpiper							X																	
Pectoral Sandpiper							X					X		X						X				
Semipalmated Sandpiper							X							X					X					
Least Sandpiper							X							X										
White-rumped Sandpiper							X			X				X										
Solitary Sandpiper																								X
Hudsonian Godwit												X												
Wilson's Phalarope												X												
Marsh Wren	X		X		X		X	X			X													X
Swamp Sparrow	X	X			X	X	X	X	X		X							X			X			X
C.Yellowthroat	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table A-4. SUMMARY OF BREEDING BIRDS FOUND ON RESTORED IOWA WETLANDS IN 1991

Species	Wetland															
	1	2	3	4	5	6	7	8	9	10	13	14	15	16	17	18
Red-winged Blackbird	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Yellow-headed Blackbird	X	X	X		X	X										
Marsh Wren	X		X			X										
American Coot	X	X	X	X	X	X	X	X	X	X	X	X		X		
Blue-winged Teal	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Mallard	X	X	X	X		X	X			X		X		X		
Northern Shoveler	X	X				X	X	X	X	X		X				X
Canada Goose					X		X						X		X	X
Common Yellowthroat	X	X	X	X	X	X	X	X	X			X	X	X	X	X
Pied-billed Grebe		X	X			X						X				
Swamp Sparrow						X		X								

Table A-5. SUMMARY OF BREEDING BIRD SPECIES AT RESTORED IOWA WETLANDS IN 1992

	Wetland																							
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
RWBB	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
YHBB	X	X	X		X	X		X			X			X		X		X			X			
Marsh Wren	X						X				X													
American Coot		X	X		X	X		X		X						X		X			X			
BW teal	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
Mallard	X	X		X	X	X		X	X	X	X	X	X	X	X	X			X	X	X	X	X	
Northern Shoveler												X												
Ruddy Duck					X																			
C.Yellowthroat	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X
PB Grebe		X	X		X	X		X			X										X			
Canada Goose								X	X	X			X	X				X			X			
Swamp Sparrow	X				X	X					X							X						
Virginia Rail			X			X												X						
American Bittern					X													X						
Sora																								

RWBB=Red-winged Blackbird.
YHBB=Yellow-headed Blackbird.
BW teal=Blue-winged Teal.
C.Yellowthroat=Common Yellowthroat.
PB grebe=Pied-billed Grebe.

Table A-6. VEGETATION FOUND IN RESTORED IOWA WETLANDS, 1991 AND 1992

<u>OPEN WATER AND SUBMERGED AQUATICS</u>	
Algae	
Ceratophyllum demersum	Coontail
	Chara
Lemna minor	Duckweed
Lemna trisulca	Star duckweed
Myriophyllum exalbescens	American milfoil
Potamogeton foliosus	Leafy pondweed
Potamogeton illinoensis	Illinois pondweed
Potamogeton nodosus	Longleaf pondweed
Potamogeton pectinatus	Sago pondweed
Potamogeton zosteriformis	Flatstem pondweed
Utricularia vulgaris	Common bladderwort
<u>EMERGENT (ROOTED EMERGENT AQUATIC)</u>	
Alisma	Water plantain
Carex	Sedge
Carex vulpinoidea	Fox Sedge
Cyperus erythrorhizos	Umbrella Sedge
Phalaris arundinacea	Reed canary grass
Polygonum amphibium	Water smartweed
Populus deltoides	Cottonwood (marsh species)
Sagittaria brevirostra	Arrowhead
Sagittaria graminea	
Sagittaria latifolia	Arrowhead
Scirpus atrovirens	Bulrush
Scirpus fluviatilis	Bulrush
Scirpus validus/acutus	"Roundstem" Bulrush
Sparganium eurycarpum	Bur-reed
Spartina pectinata	Prairie cordgrass
Typha	Cat-tail
<u>MUDFLAT (EXPOSED SOIL)</u>	
Eleocharis acicularis	Spikerush
Eleocharis macrostachya	Spikerush
Eleocharis palustris	
Juncus macrostachya	Rush
Juncus tenuis	Path rush
Polygonum amphibium	Water smartweed
<u>BUFFER</u>	
Acer negundo	Box elder
Agropyron	Wheatgrass
Agropyron repens	Quackgrass
Agropyron smithii	Western wheatgrass
Agrostis stolonifera	Redtop
Amaranthus	Pigweed

Ambrosia artemisiifolia	Common ragweed
Ambrosia psilostachya	Western ragweed
Ambrosia trifida	Giant ragweed
Apocynum cannabinum	Prairie dogbane

Table A-6 cont.

Asclepias	Milkweed
Asclepias incarnata	Swamp milkweed
Aster	Wild Aster
Aster puniceus	
Bidens	Beggar-ticks
Bromus	Brome grass
Carex	Sedge
Carex vulpinoidea	
Cirsium	True thistles
Cirsium arvense	Tall thistle
Convolvulus sepium	Bindweed
Conyza canadense	Horseweed
Dactylis glomerata	Orchard grass
Echinocloa crusgalli	Barnyard grass
Elymus canadensis	Canada wild rye
Equisetum fluviatile	Water horsetail
Eupatorium perfoliatum	Boneset
Festuca arundinacea	Tall fescue
Hordeum jubatum	Foxtail barley
Lolium perenne	Ryegrass
Lycopus americanus	American bugleweed
Lysimachia ciliata	Fringed loosestrife
Medicago sativa	Alfalfa
Melilotus alba	White sweet clover
Melilotus officinalis	Yellow sweet clover
Mentha arvensis	Field mint
Panicum virgatum	Switchgrass
Pastinaca sativa	Wild parsnip
Phalaris arundinacea	Reed canary grass
Phleum pratense	
Polygonum pensylvanicum	Pennsylvania smartweed
Populus deltoides	Cottonwood (marsh sp.)
Rorippa palustris	Bog yellow cress
Rosa carolina	Pasture rose
Rumex	Dock
Rumex crispus	Curly dock
Salix nigra	Black willow
Setaria viridus	Green foxtail
Solidago canadensis	Canada goldenrod
Teucrium canadense	American germander
Tragopogon dubius	Goat's beard
Verbena stricta	Hoary vervain
Xanthium strumarium	Cocklebur

PAPER II. THE INFLUENCE OF WETLAND AGE ON AQUATIC MACROINVERTEBRATE USE OF RESTORED IOWA WETLANDS

ABSTRACT

I compared the number of macroinvertebrate taxa, and life-history and functional groups in restored Iowa wetlands ranging from 1- to 4-years post restoration. Macroinvertebrates were sampled using activity traps and benthic corers, and were also collected from the surface of vegetation. I found a total of 60 macroinvertebrate taxa in restored wetlands, comprising 33 families. No significant difference was found in the number of taxa among wetlands of different ages. Representatives of four life-history groups and five functional groups were present in ≥94% of all wetlands. No significant difference was found between number of taxa in any functional or life-history group and wetland age class. Although many invertebrate taxa rapidly colonized restored wetlands, the number of taxa in some orders was fewer than that found previously in natural Iowa wetlands. This suggests that the restored wetlands studied have not yet reached the richness of natural wetlands.

INTRODUCTION

For generations, wetlands have been regarded as impediments to agricultural productivity, road building, and other signs of human progress which have little productive use to society and no economic value to landowners. Consequently, many wetlands have been drained, filled, or plowed without regard to their value to wildlife and the environment (Thorp and Covich 1991). Wetland loss has been accompanied by loss of valuable environmental functions and declines of wildlife populations (National Research Council 1992). Recently, this trend has begun to be reversed, and the functions and values of wetlands are being recognized (Hubbard 1988). One evidence of this change in attitude is the increasing rate of wetland restorations as a part of natural resource management programs. Since 1985, more than 10,000 wetland basins in the prairie pothole region of the United States have been restored to wetland conditions. A major objective of wetland restoration is to provide habitat for breeding waterfowl and other wildlife. Nelson and Kadlec (1984) suggested that the suitability of a wetland as waterfowl habitat may be determined by invertebrate populations. Numerous studies have documented the importance of invertebrates in the feeding ecology of waterfowl and their young (Swanson and Sargeant 1972, Swanson et al. 1974, 1985; Swanson and Meyer 1977, Krapu 1979, Nudds and Bowlby 1984, Murkin and Kadlec 1986, Murkin and Batt 1987, Swanson and Duebbert 1989, Eldridge 1990). Aquatic invertebrates are also important in the diet of many other wetland birds including shorebirds (Hauge 1987, Helmers et al. 1990), Virginia rail (*Rallus limicola*, Horak 1970), American coot (*Fulica americana*; Hill 1990), sora (*Porzana carolina*, Kaufmann 1989), and several species of songbirds including the yellow-headed blackbird (*Xanthocephalus xanthocephalus*; Orians 1966, Voigts 1973a) and red-winged blackbird (*Agelaius phoeniceus*; Mott et al. 1972, Voigts

1973a). Aquatic invertebrates are an important link in the food web of wetlands, as they are both decomposers and a food source for other organisms (Riley and Bookhout 1990). Therefore, re-colonization by aquatic invertebrates is necessary for successful restoration of drained basins.

Recently, several studies of aquatic invertebrates in restored prairie wetlands have concluded that invertebrates rapidly colonize restored wetlands (LaGrange and Dinsmore 1989, Delphey 1991, Hemesath 1991, Sewell and Higgins 1991). A comparison of natural and restored Iowa wetlands indicated some invertebrate taxa are poor colonizers of restored wetlands within 2 years of restoration (Delphey 1991). The objectives of this study were to: 1) compare the number of aquatic macroinvertebrate taxa in wetlands 1- to 4-years post restoration, and 2) compare the number and percent of taxa in life-history and functional groups between wetlands 1- to 4-years post restoration.

STUDY AREA

Study sites were located in Clay, Dickinson, Emmet, Kossuth, and Palo Alto counties in northwestern and north-central Iowa (Table A-1). All wetlands met the following criteria: (1) basin completely drained prior to restoration (not enhancements or wetland creations); (2) formerly tile drained; and (3) row cropped prior to restoration (Table 1). Four wetlands of each of 4 age categories (1-4 years post-restoration) were studied. Age refers to number of years since the basin was flooded. For example, a 1-year-old wetland in 1991 was first flooded in 1990. Five wetlands were sampled in 1991 and 11 in 1992 (Table 2).

Table 1. Land history information of study sites

Wetland age	year	ID#[1]	Size (ha)	Duration of drainage (years)	Crop history[2] 60s	70s	80s
1	1991	14	1.4	70+	r/f	r/f	r/f
	1992	20	0.8	60+	r	r	r/f
	1992	22	2.1	60+		r	r
	1992	23	1.3	60+		r	r
2	1991	7	4.6	20+		r	r
	1991	8	4.9	65+	r	r	r
	1992	16	1.3	50+	r	r	r
	1992	17	0.4	50+	r	r	r
3	1991	3	2.7	50+		r	r
	1991	4	3.3	60+	r	r	r/f
	1992	9	1.9	60+	r	r	r/f
	1992	11	1.9	40+	r	r	r
4	1992	1	2.9	40+		r	r/f
	1992	2	2.8	40+		r	r/f
	1992	5	2.7	50+	r	r	r
	1992	6	2.3	50+	r	r	r

[1] See Paper I, Table A-1.
[2] r=row crop, f=fallow.

Table 2. Age of restored Iowa wetlands studied in 1991 and 1992. Age refers to number of years since the basin was flooded. A 1-year-old wetland in 1991 was flooded in 1990

Year	Wetland age (years)			
	1	2	3	4
1991	1	2	2	NA
1992	3	2	2	4
Total	4	4	4	4

METHODS

Wetlands were sampled twice per season; the first and third weeks of June. Three sampling zones; emergent, submergent, and open water were established in each wetland. The zones were defined as follows: 1) emergent zone-- area supporting emergent vegetation; 2) submergent zone-- area midway between peripheral emergent vegetation and wetland center; 3) open water-- area devoid of emergent vegetation, usually near wetland center. I randomly selected 3 1m x 1m sampling sites within each zone using a grid system (Murkin and Kadlec 1986). A total of 18 stations were established in each wetland (9 per sampling period). I used 3 sampling methods, as differences between various invertebrate life stages necessitates the use of more than one sampling method to adequately sample the various invertebrates (Malley and Reynolds 1979).

I sampled the population of benthic invertebrates with a core sampler (6 cm diameter), as this method is more accurate in soft sediments than other sampling methods (Flannagan 1970, Downing 1984). One core was taken from each sampling site per sample period. Core samples were taken to a depth of 5 cm, as most benthic animals are aggregated in the upper 2-10 cm of sediment, and deeper samples underestimate populations (Hamilton 1971, Downing 1984).

Activity traps made of plastic soda bottles similar to those described by Riley and Bookout (1990) were used to sample nektonic (free-swimming) invertebrates. Activity traps were anchored to marked stakes in each sampling site, and collected after a 24-hour period.

Macroinvertebrates attached to the vegetation surface were collected from the 3 dominant plant species within each marsh. Five plants of each species were cut at the soil-water interface, bagged, and returned to the laboratory where the invertebrates were removed.

All samples were washed through a U.S. standard no. 35 sieve (0.5 mm mesh) and preserved in 70% ethanol. I identified most invertebrates to family using keys in McCafferty (1981), Merritt and Cummings (1984), and Pennak (1989). A few were identified to order or genus. Invertebrates were grouped into four life-history groups following Wiggins et al. (1980): 1) Overwintering residents-- capable of passive dispersal only; 2) Overwintering spring recruits; require water to lay eggs in the spring; 3) Overwintering summer recruits-- oviposition independent of water; lay eggs in moist mud of drying wetlands during summer; 4) Non-wintering spring migrants-- can't withstand drying and freezing so overwinter in permanent bodies of water (Table A-1). Invertebrates were also grouped into five functional groups following Merrit and Cummings (1984): 1) parasite 2) collector 3) shredder 4) scraper 5) predator (Table A-1).

Analysis

Statistical analyses were run using totals based on the most specific level of identification (usually family, see Table A-2). I compared the total number of taxa and number of taxa in various classes and orders between years using an ANOVA. Crustaceans were the only group to show a significant difference between years, so I combined the data of both years in all analyses.

I used an ANOVA and Tukeys studentized range test to compare the number of taxa among various age restored wetlands, and the frequencies of occurrence of life-history and functional groups. Due to the small sample size and lack of assurance of normality, I confirmed the significant results with the Kruskal-Wallis non-parametric test (Zar 1984). The non-parametric test was not used initially because it is based on the relative ranks of values and does not necessarily incorporate the magnitudes of differences between groups.

Sorenson's index of similarity (Odum 1971) was used to compare my results with previous studies. A significance level of $p<0.05$ was used in all statistical tests.

RESULTS

I found a total of 60 macroinvertebrate taxa, comprising 33 families in restored Iowa wetlands (Table A-2). Several families were present in all wetlands, including Physidae (pouch snail), Planorbidae (orb snail), Notonectidae (back swimmer), Corixidae (water boatman), Hydrophilidae (water scavenger beetle), Dytiscidae (predaceous diving beetle), and Chironomidae (midge). Other common taxa included Lymnaeidae (pond snails), Hirudinea (leeches), Odonata (dragonflies and damselflies), Talitridae (scuds), Ephemeroptera (mayflies), and water scavenger beetles.

I found no significant difference between the number of all insect, crustacean, odonate, coleopteran, hydrophilid, dytiscid, or total number of invertebrate taxa and wetland age class (Table 3). The number of hemipteran taxa in 1-year-old wetlands was significantly less than the number in 2- and 4-year old wetlands with both ANOVA ($p=0.02$) and the Kruskal-Wallis tests ($p<0.002$).

Representatives of all four life-history groups were present in all restored wetlands. No significant difference was found between the number or percentage of taxa in any life-history group and wetland age class (Table 4). Thus all 4 age categories of wetlands had similar representatives of the four life history groups. Four of the functional groups (collector, scraper, shredder, and predator) were present in all, and the parasite group in 94% of the restored wetlands. No significant difference was found between the number or percentage of taxa in any functional group and wetland age (Table 5). Again, all 4 age categories had similar composition with regard to these 5 functional groups.

Comparison of my data with previous studies of Iowa wetland invertebrates suggests that the number of Mollusca, Ephemeroptera, and Odonata taxa in restored and natural wetlands is similar (Table A-3)(Voigts 1973b, LaGrange and Dinsmore 1989, Delphey 1991, Hemesath 1991). I found fewer

Table 3. Average number of taxa in four age categories of restored wetlands, 1991 and 1992

Taxa	Wetland Age 1 n=4	2 n=4	3 n=4	4 n=4
All Crustacea	1.8	1.8	1.5	2.5
All Insecta	18.3	21.3	21.0	22.3
Odonata	1.8	3.5	2.8	3.0
Hemiptera[1]	2.3	3.5	2.8	3.5
All Coleoptera	11.0	9.3	10.5	10.0
Hydrophilidae	4.0	2.5	2.8	2.8
Dytiscidae	5.8	5.3	6.0	5.5
Total taxa	24.0	28.5	27.5	31.0

[1]The number of hemipteran taxa in wetland age 1 is significantly different from ages 2 and 4 (Tukeys studentized range test).

Table 4. Average number and percentage of taxa by life-history group in four age categories of restored wetlands, 1991 and 1992

	Wetland Age			
Life-history group	1	2	3	4
Passive dispersers	5.0 19.0%	6.5 21.7%	6.0 20.4%	8.25 25.6%
Spring recruits	3.8 15.3%	5.0 16.7%	4.8 16.2%	5.0 15.5%
Summer recruits	2.3 8.9%	3.3 11.5%	3.5 11.7%	3.5 10.9%
Nonwintering spring migrants	14.5 56.9%	15.0 50.2%	15.3 51.7%	15.5 48.0%

n=4 for all wetland ages.

Table 5. Average number and percentage of taxa by functional group in four age categories of restored wetlands, 1991 and 1992

	Wetland Age			
Functional group	1	2	3	4
Parasite	1.5 3.7%	1.8 4.8%	1.5 4.1%	2.0 4.9%
Collector	9.5 30.0%	8.8 23.8%	9.0 25.0%	10.8 26.2%
Shredder	2.0 6.4%	3.0 8.6%	3.0 8.1%	3.8 9.2%
Scraper	4.0 12.5%	4.5 12.3%	5.0 13.9%	5.5 13.4%
Predator	15.0 47.4%	18.0 50.5%	17.5 49.0%	19.0 46.3%

n=4 for all wetland ages.

crustacean, hemipteran, coleopteran, and dipteran taxa than previous studies of natural Iowa wetlands (Voigts 1973b, Delphey 1991). Overall, my results were most similar to those of Hemesath (1991)(Table 6).

Table 6. Results of Sorenson's test of similarity between VanRees-Siewert and previous studies of invertebrates in Iowa wetlands

Study	Wetland type	Sorenson's index
Voigts (1973)	Natural	0.71
Delphey (1991)	Natural	0.66
Delphey (1991)	Restored	0.68
Hemesath (1991)	Restored	0.77

DISCUSSION

The results of this study suggest that invertebrates colonize restored wetlands rapidly, and that diverse invertebrate communities are present even in the first year after restoration. All life-history and functional groups were present in the restored wetlands studied, and the number and percent of taxa in these groups did not differ significantly among wetland ages. Apparently restored wetlands provide adequate habitat for invertebrates of all life-history and functional groups soon after reflooding.

The total number of invertebrate taxa did not differ with restored wetland age, nor did the number of taxa in most groups of invertebrates. The only group to differ significantly with wetland age was the order Hemiptera; the number of hemipteran taxa in 1-year-old wetlands was significantly less than the number in 2- and 4- year old wetlands. All wetlands had the hemipteran families of Notonectidae, Belostomatidae, and Corixidae. One-year-old wetlands had fewer Belostomatidae (giant water bug) genera, and lacked Hydrometridae (marsh treader) and Gerridae (water strider) which were present in older wetlands. Gerridae and Hydrometridae inhabit areas associated with emergent vegetation, and prefer areas with minimal wave action (Merrit and Cummins 1984, Thorp and Covich 1991). The prevalence of open water and lack of emergent vegetation in 1-year-old restored wetlands (see paper I) may account for the absence of these two taxa in the younger wetlands.

Many invertebrate taxa known to be important in the feeding ecology of breeding, juvenile, and postbreeding waterfowl were present in restored wetlands. Swanson et al. (1979) found midge larvae (Chironomidae), caddisfly larvae (Trichoptera), dragonflies (Odonata), damselflies (Odonata), predaceous diving beetles (Dytiscidae), water boatmen (Corixidae), and mosquito larvae (Culicidae) to be the most commonly consumed aquatic insects by laying dabbling ducks on prairie wetlands in North Dakota. Snails are an important component of the diets of egg-laying blue-winged teal and northern shoveler, and crustaceans are a dominant food item in diets of gadwalls and northern shoveler (Swanson and Duebbert 1989). Crustacea, Gastropoda, and Insecta have all been identified as important foods of juvenile ducklings during the early stages of development (Sugden 1973, Swanson and Meyer 1973, Swanson 1985). Post-breeding ducks consume Cladocera, midges, snails, mayflies, scuds, and plants (Bergman 1973, DuBowy 1985, Swanson and Duebbert 1989). Of the invertebrates commonly consumed by waterfowl, only mosquitos and caddisflies were not found at a high proportion of the restored wetlands I studied. Mosquitos use only the very shallow edge habitats of wetlands (Wayne Rowley, Iowa State University, pers comm.); since my activity traps required 10 cm of water for submergence, mosquito populations probably were not adequately sampled. The absence of caddisfly larva is puzzling; however other studies of Iowa wetlands (natural and restored) have found few or no caddisfly species (Voigts 1973b, LaGrange and Dinsmore 1989, Delphey 1991, Hemesath 1991). Results of this study suggest restored wetlands contain most of the invertebrate community necessary to meet the nutritional requirements of waterfowl.

Invertebrates also constitute a major part of the diets of non-waterfowl wetland birds. Larval dipterans, especially chironomids, and larval coleopterans are important components of the diets of migrating shorebirds on prairie wetlands (Eldridge 1987, Hauge 1987, Helmers et al. 1990). These taxa were frequently found in restored wetlands of all age categories (Table A-2). Odonata, Coleoptera, and Diptera are important components of yellow-headed blackbird, Virginia rail, and sora diets (Orians 1966, Horak 1970, Voigts 1973a). These taxa were found in all of the restored wetlands I sampled.

Although a variety of invertebrate taxa were found in restored wetlands, I found fewer crustacean, hemipteran, coleopteran, and dipteran taxa than were found in previous studies of natural Iowa wetlands (Voigts 1973b, Delphey 1991). Delphey (1991) found crayfish (order Dacapoda), clam shrimp (order Conchostraca), seed shrimp, and isopods to be poor colonizers of restored wetlands, due to their poor dispersal abilities. Many of the peracarids (Amphipoda, Iospoda, and Mysidae) also lack adaptations for dispersal (Thorp and Covich 1991). Some of these "poor colonizers" (crayfish, seed shrimp, isopods) were not found in the restored wetlands I studied, although other passive dispersers [snails, leeches, clam shrimp, scuds, and springtails (order collembola)] were present. These missing taxa may need more time or require stocking to become established in restored wetlands. The few dipteran taxa is puzzling. I found fewer taxa than Hemesath (1991), but more than LaGrange and Dinsmore (1989). Activity traps may have undersampled the dipteran taxa, as water mites (Hydracarnia) (Mundie 1957) and predaceous diving beetles (Dytiscidae) may have preyed upon dipteran larvae within the traps. Previous studies of Iowa wetlands have used sweep nets, and avoided this problem. Although I found fewer coleopteran and hemipteran taxa than were found in previous studies of natural Iowa wetlands (e.g., Voigts 1973b, Delphey 1991), I found more than previous studies of restored Iowa wetlands, with one exception (hemipteran taxa equal to the number of taxa found by LaGrange and Dinsmore 1989). The use of three sampling methods in this study (activity traps, benthic cores, and vegetation clippings) may have more adequately sampled these invertebrates than the single sweep net method used in other studies of restored wetlands (Delphey 1991, Hemesath 1991). Even so, natural Iowa wetlands probably have more coleopteran and hemipteran taxa than restored wetlands (Delphey 1991, Voigts 1973b).

The predominance of selected invertebrate taxa in restored wetlands is puzzling. Within the order Hemiptera, two families, Notonectidae and Corixidae, were present in all restored wetlands studied. Other families were present in all age categories, but in a much smaller percentage of all wetlands. Likewise, within the family Hydrophilidae, two genera, *Tropisternus* and *Berosus,* were present in all restored wetlands, while other genera were found less often. I am uncertain if these genera are better adapted to restored wetlands, are good pioneers, or have activity patterns which increase their capture rate.

CONCLUSIONS

Restored Iowa wetlands were rapidly colonized by a wide variety of aquatic macroinvertebrates, even the first year after restoration. The variety of macroinvertebrate taxa found in restored Iowa wetlands indicates that restored wetlands provide habitat adequate to support a diverse invertebrate community and provide a food source for numerous birds. This is not surprising as many invertebrates have good dispersal capabilities, are widely distributed, and have physiological adjustments for widely fluctuating water conditions (Swanson and Duebbert 1989).

Although many invertebrate taxa were found in restored wetlands, some invertebrate orders were more poorly represented in restored wetlands than in natural Iowa wetlands (Voigts 1973a, Delphey 1991). The variety of invertebrates available to some species of birds in restored wetlands therefore may be reduced compared to natural wetlands. However, the invertebrate communities in restored wetlands seem to be developing adequately through natural recolonization, and stocking of passive dispersers seems unnecessary.

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APPENDIX

Table A-1. GUILD CLASSIFICATIONS ASSIGNED TO INVERTEBRATES FOUND IN RESTORED IOWA WETLANDS, 1991 AND 1992. CLASSIFICATION FOLLOWS WIGGINS ET AL. (1980) AND MERRIT AND CUMMINGS (1984)

Taxon	Life history stage				Functional group[1]				
	D-1	D-2	D-3	D-4	F-3	F-2	F-3	F-4	F5
MOLLUSCA									
Class Gastropoda									
Order Basommatophera									
Family Physidae	X								X
Family Planorbidae	X							X	
Family Lymnaeidae	X							X	
Order Mesogastropoda									
Family Valvatidae	X							X	
Class Bivalvia									
Order Pelecypoda									
Family Sphaeriidae	X					X			
NEMATODA	X					X	X	X	X
ANNELIDA									
Class Hirudinea	X				X				X
ARTHROPODA									
Class Arachnoidea									
Suborder Trombidiformes									
"Hydracarnia"				X	X				X
Class Crustacea									
Order Conchostraca	X					X			

Table A-1 cont.

Taxon	D-1	D-2	D-3	D-4	F-1	F-2	F-3	F-4	F5
Order Cladocera									
Family Daphnia									
Daphnia sp.	X					X			
Order Amphipoda									
Family Talitridae									
Hyalella azteca	X						X		
Class Insecta									
Order Collembola									
Family Poduridae									
Podura aquatica	X					X			
Order Ephemeroptera									
Family Baetidae									
Callibaetis sp.				X		X			
Family Caenidae									
Caenis sp.				X		X		X	
Order Odonata									
Suborder Anisoptera									
Family Aeshnidae									
Anax sp.				X					X
Aeshna sp.				X					X
Family Libellulidae									
Libellula sp.			X						X
Suborder Zygoptera									
Family Coenagrionidae									
Coenagrion sp.			X						X
Amphiagrion sp.			X						X
Family Lestidae									
Lestes sp.			X						X

Table A-1 cont.

Taxon	D-1	D-2	D-3	D-4	F-1	F-2	F-3	F-4	F-5
Order Hemiptera									
Family Notonectidae									
<u>Notonecta</u> sp.				X				X	
Family Corixidae				X					X
Family Belostomatidae									
<u>Belostoma</u> sp.				X					X
<u>Lethocerus</u> sp.				X					X
Family Hydrometridae									
<u>Hydrometra</u> sp.				X					X
Family Gerridae									
<u>Gerris</u> sp.				X					X
<u>Trepobates</u> sp.				X					X
Order Coleoptera									
Family Hydrophilidae									
<u>Tropisternus</u> sp.				X		X			X
<u>Berosus</u> sp.				X		X			X
<u>Neohydrophilus</u> sp.				X		X			X
<u>Hydrochara</u> sp.				X		X			X
<u>Hydrophilus</u> sp.				X		X			X
<u>Hydrochus</u> sp.				X			X		
<u>Enochrus</u>				X		X			X
Unknown				X		X			X
Family Dytiscidae									
<u>Dytiscus</u> sp.				X					X
<u>Acilius</u>				X					X
<u>Ilybius</u> sp.				X					X
<u>Uvarus</u> sp.				X					X
<u>Coptotomus</u> sp.				X					X
<u>Laccophilius</u> sp.				X					X
<u>Rhantus</u> sp.				X					X
<u>Hydaticus</u> sp.				X					X
<u>Copelatus</u> sp.				X					X

Table A-1 cont.

Taxon	D-1	D-2	D-3	D-4	F-1	F-2	F-3	F-4	F-5
Hygrotus sp.				X					X
Graphoderus sp.				X					X
Unknown				X					
Family Curculionidae									
Hyperodes sp.			X				X		
Family Haliplidae									
Peltodytes sp.		X					X		
Haliplus sp.		X					X		
Family Gyrinidae									
Gyrinnus sp.				X					X
Family Chrysomelidae			X				X		
Order Diptera									
Family Chironomidae									
Subfamily Chironominae		X		X		X			X
Subfamily Orthocladiinae		X				X		X	
Subfamily Unknown		X				X			
Family Stratiomyidae									
Caloparyphus sp.		X				X			
Stratiomys sp.		X				X			
Unknown		X				X			
Family Tipulidae			X	X		X	X		
Family Ceratopoganidae		X							X

1 F-1=parasite, F-2=collector, F-3=shredder, F-4=scraper, F-5=predator.

Table A-2. SUMMARY OF MACROINVERTEBRATE TAXA FOUND IN RESTORED IOWA WETLANDS, 1991 AND 1992

	Wetland Age															
	1				2				3				4			
Taxon/Wetland #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
MOLLUSCA																
Class Gastropoda																
Order Basommatophera																
Family Physidae	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Family Planorbidae	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Family Lymnaeidae		X	X		X	X	X	X	X	X	X	X	X	X	X	X
Order Mesogastropoda																
Family Valvatidae							X									
Class Bivalvia																
Order Pelecypoda																
Family Sphaeriidae							X							X		
# mollusc taxa	2	3	3	2	3	3	5	3	3	3	3	3	3	4	3	3
NEMATODA			X					X	X			X	X	X	X	X
ANNELIDA																
Class Hirudinea		X	X		X	X	X	X	X	X	X	X	X	X	X	X
ARTHROPODA																
Class Arachnoidea																
Suborder Trombidiformes																
"Hydracarnia"		X	X	X		X	X	X				X	X	X	X	X
Class Crustacea																
Order Conchostraca		X	X					X		X			X			X

Table A-2 cont.

Taxon/Wetland #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Order Cladocera																
Family Daphnia																
Daphnia sp.		X	X	X		X	X	X	X		X	X	X	X	X	X
Order Amphipoda																
Family Talitridae																
Hyalella azteca			X	X	X	X		X	X			X	X	X	X	X
# Crustacean taxa	0	2	3	2	1	2	1	3	2	1	1	2	3	2	2	3
Class Insecta																
Order Collembola																
Family Poduridae																
Podura aquatica															X	X
Order Ephemeroptera																
Family Baetidae																
Callibaetis sp.	X		X	X		X	X	X	X			X	X	X	X	X
Family Caenidae																
Caenis sp.						X		X	X			X	X			X
Order Odonata																
Suborder Anisoptera																
Family Aeshnidae																
Anax sp.							X			X						
Aeshna sp.					X		X			X			X			
Family Libellulidae																
Libellula sp.		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Suborder Zygoptera																
Family Coenagrionidae																
Coenagrion sp.				X	X	X			X			X	X		X	X
Amphiagrion sp.					X											

Table A-2 cont.

Taxon/Wetland #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Family Lestidae																
Lestes sp.	X	X	X		X	X	X	X		X	X	X	X	X	X	X
# of Odonate taxa	1	2	2	2	5	3	4	2	2	4	2	3	4	2	3	3
Order Hemiptera																
Family Notonectidae																
Notonecta sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Family Corixidae	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Family Belostomatidae																
Belostoma sp.		X			X	X	X			X		X	X			X
Lethocerus sp.							X									
Family Hydrometridae																
Hydrometra sp.						X			X				X		X	X
Family Gerridae																
Gerris sp.								X								
Trepobates sp.														X		
# of Hemipteran taxa	2	3	2	2	3	4	4	3	3	3	2	3	4	3	3	4
Order Coleoptera																
Family Hydrophilidae																
Tropisternus sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Berosus sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Neohydrophilus sp.	X														X	
Hydrochara sp.		X	X							X						
Hydrophilus sp.		X	X	X		X		X			X	X	X			
Hydrochus sp.	X															
Enochrus			X													
Unknown													X			
Family Dytiscidae																
Dytiscus sp.	X	X	X				X	X	X	X		X	X	X	X	X
Acilius sp.			X		X	X	X	X			X	X	X	X	X	X

Table A-2 cont.

Taxon/Wetland #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Ilybius sp.			X							X		X				X
Uvarus sp.	X	X	X				X	X	X	X	X	X	X	X		X
Coptotomus sp.	X	X	X	X	X	X	X	X	X		X	X		X		X
Laccophilius sp.		X	X	X	X	X	X	X	X		X	X	X	X	X	X
Rhantus sp.	X			X			X			X		X		X		
Hydaticus sp.	X	X													X	
Copelatus sp.	X									X						
Hygrotus sp.		X	X	X			X	X						X		
Graphoderus sp.					X					X	X					
Unknown						X					X	X				X
Family Curculionidae																
Hyperodes sp.	X	X			X		X		X	X		X		X	X	
Family Haliplidae																
Peltodytes sp.	X	X	X		X	X		X	X	X	X		X	X	X	X
Haliplus sp.								X								
Family Gyrinidae																
Gyrinnus sp.										X						
Family Chrysomelidae																X
# of Coleopteran taxa	12	12	13	7	8	8	10	11	8	12	10	12	9	11	9	11
Order Diptera																
Family Chironomidae																
Subfamily Chironominae	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Subfamily Orthocladiinae	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Subfamily Unknown				X			X	X		X	X	X		X	X	X
Family Stratiomyidae																
Caloparyphus sp.					X			X	X							
Stratiomys sp.						X	X					X			X	
Unknown	X															X
Family Tipulidae									X	X						
Family Ceratopoganidae								X	X				X			X
# of Dipteran taxa	3	2	2	3	3	3	4	5	5	4	3	4	3	3	4	5

Table A-2 cont.

Taxon/Wetland #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
# of insect taxa	19	19	20	15	19	20	23	23	20	23	17	24	22	20	21	26
Total # of taxa	21	26	29	20	24	27	31	32	28	28	22	32	31	29	29	35

Table A-3. COMPARISON OF INVERTEBRATES FOUND IN NORTHWESTERN AND NORTH-CENTRAL IOWA WETLANDS

Taxon	Voigts Natural	Delphey Natural	Delphey Rest.	VanRees-Siewert Restored	Hemesath Restored	LaGrange Restored
MOLLUSCA	5	4	3	5	4	3
Class Gastropoda						
Order Basommatophera						
Family Physidae	X	X	X	X	X	X
Family Planorbidae	X	X	X	X	X	X
Family Lymnaeidae	X	X	X	X	X	X
Order Mesogastropoda						
Family Valvatidae	X			X		
Class Bivalvia						
Order Pelecypoda	X	X		X	X	
ANNELIDA						
Class Hirudinea	X	X	X	X	X	
ARTHROPODA						
Class Crustacea	7	7	5	3	4	2
Order Conchostraca	X	X	X	X	X	
Order Cladocera	X	X	X	X	X	
Order Amphipoda	X	X	X	X	X	X
Order Decapoda	X	X				X
Order Isopoda	X	X	X		X	
Order Ostracoda	X	X	X			
Order Copepoda	X					
Order Anostraca		X				

Table A-3 cont.

Taxon	Voigts Natural	Delphey Natural	Delphey Rest.	VanRees-Siewert Restored	Hemesath Restored	LaGrange Restored
Class Insecta						
Order Collembola	2	3	1	1	0	0
Family Poduridae	X	X		X		
Family Sminthuridae	X	X				
Family Isotomatidae		X				
Unknown			X			
Order Ephemeroptera	2	3	2	2	2	1
Family Baetidae	X	X	X	X	X	
Family Caenidae	X	X	X	X	X	X
Family Leptophlebiidae		X				
Order Odonata	4	4	4	4	4	*
Family Aeshnidae	X	X	X	X	X	
Family Libellulidae	X	X	X	X	X	
Family Coenagrionidae	X	X	X	X	X	
Family Lestidae	X	X	X	X	X	
Order Hemiptera	9	11	9	5	4	5
Family Notonectidae	X	X	X	X	X	X
Family Corixidae	X	X	X	X	X	X
Family Belostomatidae	X	X	X	X	X	X
Family Hydrometridae	X			X		
Family Gerridae	X	X	X	X		X
Family Pleidae	X	X	X			
Family Nepidae	X					X
Family Veliidae	X				X	
Family Mesoveliidae	X	X				

Table A-3 cont.

Taxon	Voigts Natural	Delphey Natural	Delphey Rest.	VanRees-Siewert Restored	Hemesath Restored	LaGrange Restored
Family Hebridae		X	X			
Family Cicadellidae		X	X			
Family Gelastocoridae		X				
Family Saldidae		X	X			
Family Aphidae		X	X			
Order Coleoptera	12	10	10	6	3	3
Family Hydrophilidae	X	X	X	X	X	
Family Dytiscidae	X	X	X	X	X	X
Family Curculionidae	X	X	X	X		
Family Haliplidae	X	X	X	X	X	X
Family Gyrinidae	X			X		X
Family Chrysomelidae	X	X	X	X		
Family Carabidae	X					
Family Noteridae	X					
Family Staphylidae	X	X	X			
Family Lampyridae	X	X				
Family Helodiae	X	X	X			
Family Coccinellidae	X					
Family Hydroscaphidae			X			
Family Dryopidae			X			
Family Heteroceridae		X				
Family Elmidae		X	X			
Order Diptera	10	10	10	4	6	2
Chironomidae	X	X	X	X	X	X
Family Stratiomyidae	X	X	X	X	X	
Family Tipulidae	X	X	X	X	X	
Family Ceratopoganidae	X	X	X	X		
Family Chaoboridae	X		X		X	

Table A-3 cont.

Taxon	Voigts Natural	Delphey Natural	Delphey Rest.	VanRees-Siewert Restored	Hemesath Restored	LaGrange Restored
Family Culicidae	X	X	X		X	X
Family Tabanidae	X	X	X			
Family Syrphidae	X	X				
Family Sciomyzidae	X	X			X	
Family Ephydridae	X	X	X			
Family Empididae		X	X			
Family Dixidae			X			
Order Lepidoptera	1	1	2	0	0	0
Order Tricoptera	3	0	2	0	1	0

*Only reported to subfamily, but did find both subfamilies present.

GENERAL SUMMARY

Restoration in the truest sense of the word implies returning an ecosystem to a close approximation of its former natural condition. Within four years of restoration, wetlands are providing habitat for a variety of bird and invertebrate species, and are developing increasingly diverse floral and faunal populations. My study supports the results of other studies; restored prairie wetlands recover many of the plant and bird taxa typical of natural prairie wetlands (LaGrange and Dinsmore 1989, Sewell and Higgins 1991, Delphey 1991, Hemesath 1991, Galatowitsch 1993). However, some invertebrates (crayfish) and vegetation zones (wet-meadow) were not present in restored wetlands. I also found revegetation of restored wetlands to be site-specific, showing the importance of site selection, and suggesting directions for further research. Since the vegetation and number of breeding bird species increased with restored wetland age, restoration efforts should be concentrated on long-term restorations such as easements and wetland purchases.

Wetland restorations are an attempt to reverse habitat fragmentation, regional declines of waterfowl and other wetland species, and to maintain biodiversity for future generations. "The acid test of our understanding is not whether we can take ecosystems to bits on pieces of paper, however scientifically, but whether we can put them together in practice and make them work" (Bradshaw 1983). Although wetland restoration is at an early stage of development, the results of this study indicate that restored wetlands show promise towards meeting the goal of maintaining biodiversity. The emphasis of wetland restoration needs to be directed towards large-scale (landscape) perspectives, and long-term goals and objectives need to be identified. Comparisons of restored and natural wetlands are needed to assess the success of restoration efforts, and continued monitoring of restored wetlands is needed to evaluate their development and response to stressful events such as drought, invasion by exotic species, and other perturbations. With such long-term efforts, perhaps the functions and goals of wetland restorations could be met.

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