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A COMPARISON OF RESTORED AND NATURAL WETLANDS AS HABITAT FOR BIRDS IN THE PRAIRIE POTHOLE REGION OF SASKATCHEWAN, CANADA

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ABSTRACT. — To enhance upland and wetland habitat for waterfowl under the North American Waterfowl Management Plan, Ducks Unlimited Canada restored hundreds of wetlands throughout the Prairie Pothole Region in Canada. We surveyed restored wetlands in the Aspen Parkland region of Saskatchewan 3–8 years post restoration to evaluate whether avian species richness and assemblages differed between natural and restored wetlands. We recorded the presence or absence of bird species and local habitat metrics including wetland depth, conductivity, upland vegetation height, and the proportions of the basin covered by vegetation zones (as indicated by characteristic plant species). We quantified the landscape setting of each wetland using GIS, determining the proportion of woodland and wetland within a 500-m radius. We used ordination techniques to evaluate patterns of wetland habitat characteristics and bird community composition. Richness and composition for wetland-dependent bird species were comparable for natural and restored wetlands, however, natural wetlands had higher total species richness and a distinctive overall bird assemblage because of the presence of more woodland species. Environmental differences among individual wetlands included wetland depth, shape, proximity to woodland and roads, but were not consistently related to drainage history. We conclude that restoring seasonal and semi-permanent wetlands in the Aspen Parkland creates avian habitat and should continue to play a role in management.

KEY WORDS. — wetland restoration, birds, Prairie Pothole Region, Saskatchewan, ordination, applied community ecology

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INTRODUCTION

Prior to European settlement, an estimated 8 million ha of wetlands existed in the Prairie Pothole Region (PPR; Leitch, 1989), but drainage of these basins has been widespread and continues today. The physical heterogeneity of this region, characterised by basins of different sizes, depths, and stages of plant succession, provides habitat for a variety of birds (waterfowl, shorebirds, passerines, and raptors) with varying levels of wetland dependence and adaptation (Kantrud et al., 1989; Weller, 1999). The PPR is also the center of agricultural production for North America and development is often accompanied by wetland drainage (Lodge, 1969). Throughout the PPR in Canada, wetland loss is estimated between 40% (Canada/United States Steering Committee, 1986 in Turner et al., 1987) and 70% (Environment Canada, 1986), and more than 90% of the remaining wetlands have been altered by agricultural expansion and urbanisation (Neraasen & Nelson, 1999). Degradation of wetland habitat negatively affects wildlife resulting in a proportionately greater number of wetland-dependent species on lists of species at risk (Gibbs, 2000). Recent work has also shown that restoration may play an important role in ameliorating the impacts of climate change in the PPR (Johnson et al., 2005).

The Aspen Parkland comprises the northern one-third of the PPR, an ecotone between the true prairies, and the boreal forest. The Aspen Parkland is characterised by the presence of aspen (*Populus* spp.) and willow (*Salix* spp.) in wetlands and uplands, interspersed with prairie grasslands

(Walker & Coupland, 1970). In the Aspen Parkland of east-central Saskatchewan, Canada, a farming area focused on grain production and row crops, wetland drainage has been particularly extensive (Sugden & Beyersbergen, 1984; Shutler et al., 2000). In some areas (e.g., Rural Municipalities of Invermay, Buchanan, and Hazel Dell), >80% of quarter sections (64.8-ha plots) have at least one drainage ditch present and the area is considered one of the most impacted of Ducks Unlimited Canada (DUC) management areas in the Prairies (C. Deschamps, pers. comm., MFO Wadena, Saskatchewan, DUC, 2001).

Prior to 1999, to enhance upland and wetland habitat for waterfowl under the North American Waterfowl Management Plan, DUC restored over 900 wetlands throughout the PPR in Canada (Gray et al., 1999). The majority of wetlands had been drained via surface drains, and re-flooding was achieved by simply blocking ditches (Galatowitsch & van der Valk, 1994; Gray et al., 1999). By comparing the habitat and bird species assemblages in restored (i.e., cease to be artificially drained) wetlands with those of natural (i.e., relatively unaltered, reference) wetlands, we objectively evaluated restoration in the Aspen Parkland of east-central Saskatchewan. We employed a classic community ecology approach in an applied setting to assess the effectiveness of a management strategy common on the North American prairies.

(Re)creation of wildlife habitat is often the stated goal of wetland restoration, but several comparative studies in the PPR in the United States, examining avian use of restored wetlands, have produced equivocal results. Delphey & Dinsmore (1993) and Ratti et al. (2001) are the most comparable to the present study in objectives and techniques. While Ratti et al. (2001) found similar species richness in restored and reference wetlands, Delphey & Dinsmore (1993) found bird guilds characteristic of wet meadows and low prairies were lacking in restored wetlands. In the spirit of adaptive management and to encourage the success of future wetland restorations in Canada, we propose that future decisions should be informed by the successes and failures of past restoration efforts.

METHODS

Wetland selection. — In 2000, 80 wetlands (41 restored) were surveyed within 150 km of Foam Lake, Saskatchewan, Canada within the Aspen Parkland Ecoregion of the Prairie Pothole Region (see Fig. 1). Surveyed sites were small (<2 ha), fresh (<500 µS cm^{-1}) to moderately brackish (<5000 µS cm^{-1}), seasonal (III) or semi-permanent wetlands (IV; Stewart & Kantrud, 1971) located on DUC purchased or leased property with surrounding uplands composed of planted wildlife cover or native parkland. Restored wetlands (41) were randomly selected from >150 comparable, restored wetlands in the area. Wetlands were restored using ditch plugs constructed by DUC engineering staff between 1992 and 1997; specific year of restoration and location are documented in Puchniak (2002). The age of study wetlands reflected the peak of restoration activity by DUC. Reference sites (39) were natural or relatively unaltered wetlands selected from approximately 75 wetlands of similar size and permanence located on DUC properties in the area. The extent of agricultural development on the landscape meant that candidate reference sites were limited and randomised selection was not practical.

Because of DUC's management practices, restoration sites were often clustered; surveyed wetland density ranged from 1–5 wetlands per 64.8 ha (quarter section). The mean distance between surveyed wetlands was 551 m ($\pm$ 370 m standard deviation), thus a point count radius of 50 m (see below) ensured that we did not survey the same birds repeatedly.

Bird surveys. — Wetlands were surveyed for all bird species twice during the field season between 21 May – 3 Jun and then again between 18–30 Jun. Surveys were conducted between sunrise (~0500 hours) and 1000 hours in the absence of high winds (>30 km h^{-1}), heavy rain, or fog. Each survey began approximately 100 m from the wetland edge (or from where wetland first became visible) in order to count waterfowl and other birds that commonly take flight upon the investigator's arrival (Bibby et al., 1992).

Following this initial survey, an 8-min point count was conducted from a pre-determined station in the emergent vegetation. All species heard or observed within a 50-m half-radius, including the immediately adjacent upland, were recorded during the 8-min period. The location of a detected bird within the survey area was recorded as open water, wetland vegetation, upland, 'flying within the wetland', or 'flying over the point count area' (>50 m, "fly-over"). Birds that arrived at a wetland during a survey or were observed after the timed survey were recorded as incidental observations. To reduce potential biases, observer and time of survey were alternated between May and June surveys.

In order to solicit the calls of more secretive bird species (Virginia rail, *Rallus limicola*; yellow rail, *Coturnicops noveboracensis*), call-response surveys were conducted following the point count (Gibbs & Melvin, 1993; B. Dale,

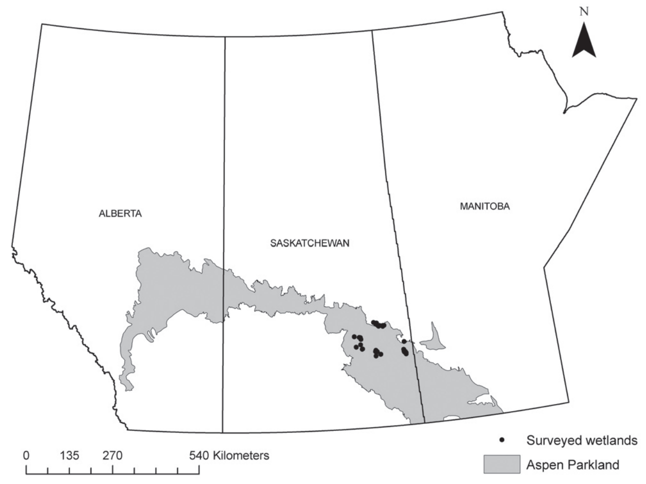

Fig. 1. Location of 41 restored and 39 natural wetlands surveyed in the Aspen Parkland Ecoregion of the Prairie Pothole Region, within 150 km of Foam Lake, Saskatchewan, Canada, 2000.

Canadian Wildlife Service, pers. comm., 1999). No birds were ever detected using this technique.

Habitat characteristics. — At the time of each bird survey, parameters were collected to describe local wetland habitat (Table 1). All wetlands were classified according to Stewart & Kantrud (1971). The proportion of the wetland with plant cover, or, inversely, the amount of open water habitat, was estimated visually. We documented the proportion of the basin covered by the following zones (as indicated by characteristic plant species) based on visual estimates: low prairie, wet meadow, shallow emergent marsh, deep emergent marsh (Stewart & Kantrud, 1971). We estimated the height of surrounding vegetation approximately 20 m from the wetland edge in each cardinal direction to characterise the structure of immediately adjacent upland habitat.

The landscape setting of each wetland was quantified by digitising post-restoration air photos (1:30 000) obtained from DUC. Using Arcview 3.2 (ESRI software, 1992), major habitat types were quantified in the area surrounding each surveyed wetland (the proportion within a 500-m radius). Habitat types were: i) woodland (woody species [*Populus* spp., *Salix* spp., conifers] with a vertical height >3 m), wetland (natural and restored basins of all sizes and classes), cropland (tilled and planted land, fallow fields), and upland (planted cover, native or naturalised grasslands, pastures). The distance (m) to the next nearest patch of woodland (>2 ha), wetland (of any size) and roadway were also recorded. Area (m^2) and perimeter (m) for each surveyed wetland were obtained from the digitised air photos. The extent of the basin was defined by the transition from low prairie vegetation to planted cover. Using the metrics of area and perimeter, an index of wetland shape incorporating shoreline development was calculated (McGarigal & Marks, 1994).

Analyses*: *Habitat characteristics. — Prior to analyses of the relationship of habitat characteristics and species data, we investigated potential differences in the local and landscape features between restored and natural wetlands (Table 1). Habitat characteristics were compared between restored and natural wetlands using t-tests (Zar, 1999).

Using Pearson correlation, MNDEEP, LOGPERIM, ARCUPL (see Table 1 for abbreviations) were eliminated from further analyses due to collinearity. Differences in the wetland environments were further characterised by conducting an unconstrained ordination, Principal Components Analysis (PCA; ter Braak & Smilauer, 1998). After performing PCA, confidence ellipses centered on means for each wetland type (Systat 9.0, SPSS Inc., 1998) were used to assess the position of the majority of restored and natural wetlands on the resulting ordination. The major axes and orientation of these ellipses (based on p=0.683) were determined by the standard deviation and covariance for wetland types, respectively. In order to test the similarity of habitat in restored versus natural wetlands, we compared scores from the first 3 PCA axes using Multi-Response Permutation Procedure (MRPP) with Euclidean distance measures (Zimmerman et al., 1985). MRPP is a non-parametric technique used to test the null hypothesis of no difference between a priori identified groups, and is analogous to Discriminate Analysis.

Analyses: Species richness and diversity. — Species occurrence data were used in all analyses. Presence included bird species documented (observed or heard) at a wetland during the initial survey or the point count; "fly-overs" and incidental observations were excluded. Species richness (S), or the total number of species observed during timed surveys (both dates combined), was calculated for each wetland and compared between wetland types (restored and natural) using t-tests. Bird species diversity was calculated for each wetland using Shannon's diversity index (H) and its equitability measure (E_h), and values from restored and natural wetlands were compared using t-tests.

Analyses: Species composition. — Correspondence Analysis (CA, PCOrd 4.0, McCune & Mefford, 1999) was used to summarise and assess visually patterns in bird species composition (presence/absence) in restored and natural wetlands. Rare species observed on <5% of all wetlands (<4 sites) were excluded from CA (Gauch, 1982). Confidence ellipses were used to highlight the position on the ordination of the majority of restored and natural wetlands. As described above for PCA, CA axis scores were used in MRPP to assess differences in species composition between restored and natural wetlands. Exploration of the relationship between bird species composition and wetland environment was conducted by calculating Pearson correlation coefficients between CA axis scores and habitat characteristics (Zar, 1999). Further exploration of assemblage composition patterns was conducted using additional CAs for wetland-dependent species (17) and upland species (13) separately. Wetland-dependent birds are identified in Table 2. Due to the absence of wetland-dependent species in 5 wetlands (4 restored), analysis of wetland-dependent species was restricted to 75 wetlands (37 restored). All wetlands (80) were included in analyses of upland species. Confidence ellipses on ordinations and MRPP analysis on CA axis scores were used to elucidate differences in composition in restored and natural wetlands for each group of species. The relationship between wetland-dependent and upland bird species and the environment were conducted by calculating Pearson correlation coefficients between CA axes scores and habitat characteristics (Zar, 1999).

RESULTS

Habitat characteristics. — Of the 80 wetlands (41 restored) surveyed, the majority (71 wetlands, 37 of restored wetlands) were Class IV (semi-permanent) wetlands (Stewart & Kantrud, 1971). Nine wetlands (5 restored) were Class III (seasonal) wetlands. Restored and natural wetlands were of comparable area (LOGAREA), conductivity (LOGCOND) and vegetative cover (Table 1, MNBASIN, MNDEEP, MNSHAL, MNWET, MNLOW). However, the overall environment of restored and natural wetlands differed significantly (MRPP, T=–3.92, p=0.005). Although there was substantial overlap between the wetland types in the

Table 1. Local and landscape features of 41 restored and 39 natural wetlands near Foam Lake, Saskatchewan sampled in May–Jun. Variables marked with [i] were included in PCA analyses. Variables were individually compared between restored and natural wetlands using t-tests. Significant tests are highlighted by * ($p<0.05$) or + ($p<0.10$). Variables marked with x are based on means. Landscape habitat types are defined in the text. n/a indicates that no transformation for ordination was required.

ENVIRONMENTAL VARIABLE			Abbreviation	UNIT OF MEASURE	NATURAL WETLANDS		RESTORED WETLANDS			Transformation for ordination
					Mean	Range	Mean	Range		
LOCAL:										
Wetland area		i	LOGAREA	m^2	2383.3	(202.5–8100.0)	2815.2	(405.0–12150.0)		$\log_{10}$
Wetland perimeter			LOGPERIM	m	188.0	(56.3–547.2)	232.8	(72.4–917.3)		$\log_{10}$
Shape index		i	SHAPE	—	1.2	(1.0–1.8)	1.3	(1.0–2.4)	*	n/a
Maximum wetland depth	x	i	MNDPTH	cm	45.5	(11.0–90.0)	35.2	(2.0–71.5)	*	n/a
Conductivity	x	i	LOGCOND	$\mu S\ cm^{-1}$	893.9	(220.0–2300.0)	736.7	(150.0–2575.0)		$\log_{10}$
Proportion of vegetative cover on basin	x	i	MNBASIN	%	66.4	(5.0–95.0)	69.4	(12.5–97.5)		n/a
Proportion of deep marsh vegetation	x		MNDEEP	%	46.6	(0–82.5)	45.5	(7.5–85.0)		n/a
Proportion of shallow marsh vegetation	x	i	MNSHAL	%	28.9	(5.0–77.5)	26.3	(0–55.0)		n/a
Proportion of wet meadow vegetation	x	i	MNWET	%	18.5	(5.0–32.5)	17.0	(2.5–35.0)		n/a
Proportion of low prairie vegetation	x	i	MNLOW	%	10.5	(2.5–25.0)	11.1	(0–35.0)		n/a
Upland vegetation height	x	i	LOGUPHT	cm	44.7	(17.5–125.0)	39.0	(10.7–73.8)		$\log_{10}$
LANDSCAPE:										
Proportion of habitat type within 500 m of surveyed wetland										
Cropland		i	ARCROP	%	26.5	(2.6–50.6)	30.7	(3.3–77.2)		arcsin
Wetland		i	ARCTLWET	%	13.1	(0.8–24.1)	10.0	(3.1–17.8)		arcsin
Upland			ARCUPL	%	49.0	(23.6–85.8)	47.8	(7.0–75.3)		arcsin
Woodland		i	ARCWDL	%	9.5	(1.1–29.1)	6.6	(0.1–32.9)	+	arcsin
Next nearest habitat patch										
Woodland		i	LOGWOOD	m	102.8	(13.0–344.0)	228.3	(0–790.0)	*	$\log_{10}$
Road		i	LOGROAD	m	450.1	(57.0–1399.0)	357.7	(44.0–883.0)	*	$\log_{10}$
Wetland		i	LOGWETL	m	50.8	(13.9–163.0)	76.5	(262.5–16.0)		$\log_{10}$

PCA ordination (Fig. 2), natural wetlands had lower scores on axis 1 and higher scores on axis 2. Scores of restored wetlands were more variable than scores of natural wetlands. Cumulatively, the first 3 PCA axes explained 38.15% of the environmental variation among wetlands (Table 2). Scores on the first axis were positively correlated with local vegetation patterns (MNLOW, MNWET) and negatively correlated with MNDPTH and LOGCOND (Table 3). Scores on the second axis were positively correlated with the proportion of the surrounding area in woodland (ARCWDL) and negatively correlated with the proportion of the surrounding area in wetland habitat (ARCTLWET) and wetland area (LOGAREA). Scores on the third axis (not shown) were also positively correlated with ARCWDL and negatively correlated with the proportion of cropland (ARCRP) and distance to nearest woodland (NNWOOD). Individual habitat characteristics indicated that natural wetlands were deeper ($t=2.98$, d.f.=78, $p=0.004$), had less complex shorelines ($t=-2.15$, $p=0.04$), were closer to woodland patches ($t=-3.24$, $p=0.002$), and further from roads ($t=1.99$, $p=0.05$). There was a trend towards a greater proportion of woodland in the landscape (within 500 m, ARCWDL) surrounding natural wetlands ($t= 1.78$, $p=0.08$).

Species richness and diversity. — A total of 52 bird species were documented, 29 of these are dependent on wetlands for part of their life cycle (Table 2, DUC, unpublished data). Seven species were restricted to restored and 11 to natural wetlands; all of these species were rare, observed in <4 wetlands.

The number of species per wetland (S) differed significantly between restored and natural wetlands with a mean of 9.7 (± 3.0 standard deviation, 5–16) for natural wetlands and 8.1 (± 2.6, 3–15) for restored wetlands ($t=2.61$, d.f.=78, $p=0.01$). Species diversity (H) was also greater in natural wetlands ($H_{natural}=2.0 \pm 0.31$, $H_{restored}=1.8 \pm 0.33$; $t=2.46$, $p=0.02$). The relative equitability across species was comparable between wetland types ($E_{h\ natural}=0.91 \pm 0.04$, $E_{h\ restored}=0.90 \pm 0.04$; $t=0.02$, $p=0.98$).

Species composition. — A CA of bird assemblages based on 30 species illustrated differences in species composition in restored and natural wetlands (Fig. 3a,b). Although there was overlap at the center of the graph, the majority of natural wetlands had negative scores on both axes, whereas the majority of restored wetlands had negative scores on axis 1 and positive scores on axis 2. Scores on the first axis were correlated with variables associated with woodland in the landscape (positively with ARCWDL, negatively with LGWOOD) and wetland area (LOGAREA, Table 4). Scores on the second axis were correlated positively with vegetation characteristics (MNLOW, MNWET, MNBASIN) and displayed a strong negative relationship with wetland depth (MNDPTH). Scores on the third axis were correlated with wetland depth and conductivity (LOGCOND).

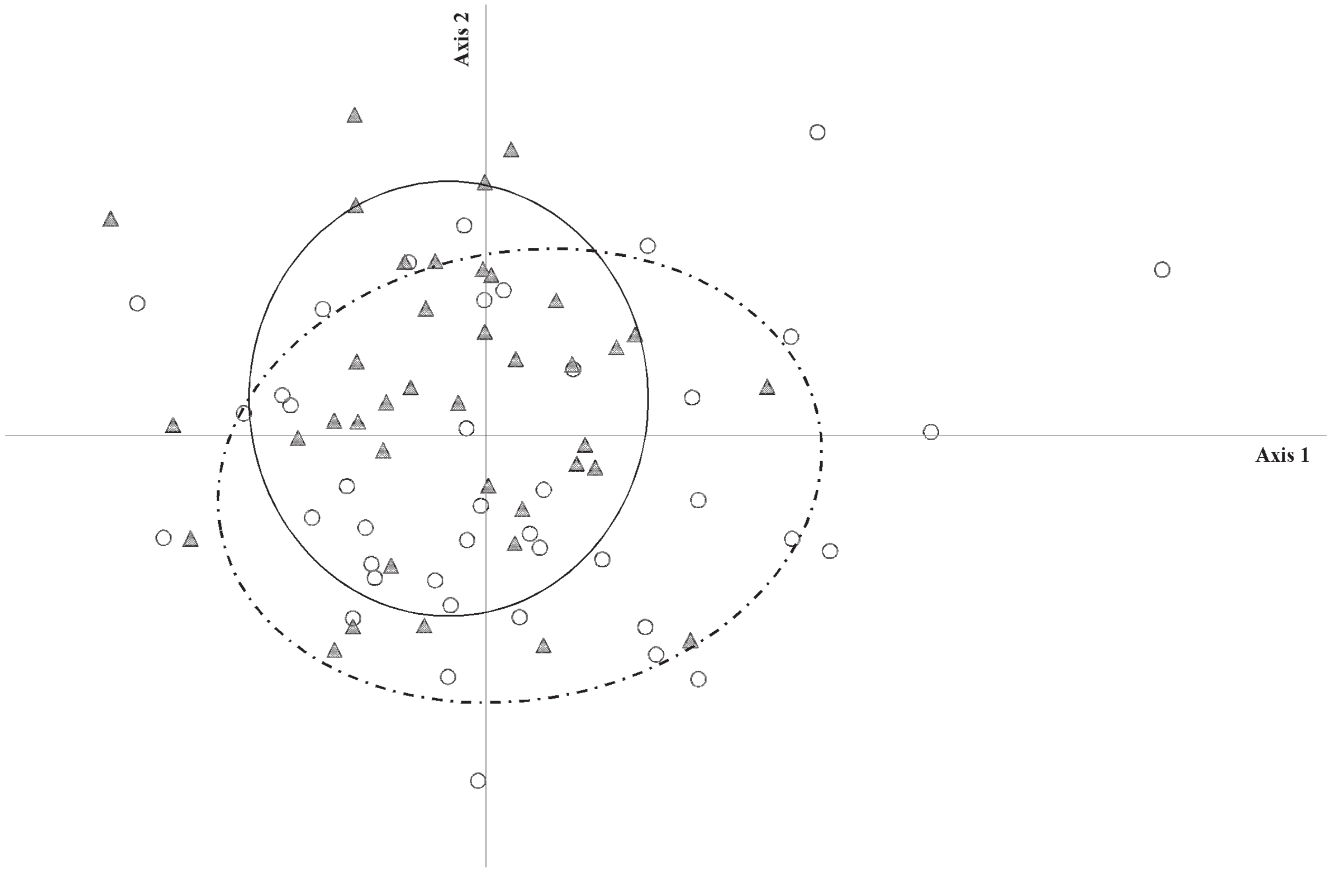

Fig. 2. Association of 80 Saskatchewan PPR wetlands (41 restored) based on Principal Components Analysis (PCA) of 15 local and landscape habitat characteristics. Confidence ellipses represent the position of the majority of restored and natural wetlands.

Table 2. Fifty-two avian species documented in restored (41) and natural (39) wetlands in the Prairie Parkland near Foam Lake, Saskatchewan, Canada. [*]indicates wetland dependent species as defined by Ducks Unlimited Canada (unpublished data). [r]indicates species considered rare (observed <4 wetlands total) that were not included in community analyses. Code represents abbreviation used in figures.

CODE			Common name	Genus species	Documented presence in: Natural wetlands (39)	Restored wetlands (41)
ALFL	r	*	Alder flycatcher	*Empidonax alnorum*	0	1
AMBI		*	American bittern	*Botaurus lentiginosus*	1	3
AMCO		*	American coot	*Fulica americana*	14	4
AMCR	r		American crow	*Corvus brachyrhynchos*	0	1
AMGO			American goldfinch	*Carduelis tristas*	3	1
AMRE	r		American redstart	*Setophaga ruticilla*	0	1
AMRO			American robin	*Turdus migratorius*	3	2
AMWI	r	*	American wigeon	*Anas americana*	1	0
BASW	r	*	Barn swallow	*Hirundo rustica*	0	2
BCCH	r		Black-capped chickadee	*Poecile atricapillus*	0	1
BHCO			Brown-headed cowbird	*Molothrus ater*	4	3
BLTE		*	Black tern	*Childonias niger*	4	2
BOBO			Bobolink	*Dolichonynx oryzivorus*	21	21
BWTE		*	Blue-winged teal	*Anas discors*	24	16
CANV	r	*	Canvasback	*Aythya valisineria*	1	0
CCSP			Clay-colored sparrow	*Spizella pallida*	39	40
CORA	r		Common raven	*Corvus corvax*	1	0
COSN		*	Common snipe	*Gallinago gallinago*	5	3
COYE		*	Common yellowthroat	*Geothlypis trichas*	9	12
EAKI			Eastern kingbird	*Tyrannus tyrannus*	7	1
GADW		*	Gadwall	*Anas strepera*	14	10
GRCA	r		Gray catbird	*Dumetella carolinensis*	0	1
GWTE		*	Green-winged teal	*Anas crecca*	6	1
HOGR	r	*	Horned grebe	*Podiceps auritius*	2	0
KILL		*	Killdeer	*Charadrius vociferous*	2	3
LEFL	r		Least flycatcher	*Empidonax minimus*	2	1
LESA	r	*	Least sandpiper	*Calidris minutilla*	1	0
LESC		*	Lesser scaup	*Aythya affinis*	10	4
LESP			Leconte's sparrow	*Ammodramus leconteii*	27	29
MALL		*	Mallard	*Anas platyrhynchos*	15	14
MAWR		*	Marsh wren	*Cistothorus palustris*	3	4
MODO	r		Mourning dove	*Zenaida macroura*	0	1
NOFL	r		Northern flicker	*Colaptes auratus*	1	0
NOHA	r	*	Northern harrier	*Circus cyaneus*	1	2
NSHO		*	Northern shoveler	*Anas clypeata*	11	12
PBGR	r	*	Pied-billed grebe	*Podilymbus podiceps*	3	0
REDH	r	*	Redhead	*Aythya americana*	2	0
RTHA	r		Red-tailed hawk	*Buteo jamaicensis*	1	2
RTHU	r		Ruby-throated hummingbird	*Archilochus colubris*	1	0
RUDU		*	Ruddy duck	*Oxyura jamaicensis*	4	1
RWBL		*	Red-winged blackbird	*Agelaius phoenicus*	32	33
SASP			Savannah sparrow	*Passerculus sandwichensis*	32	40
SEWR		*	Sedge wren	*Cistothorus platensis*	14	12
SORA		*	Sora	*Porzana carolina*	13	9
SOSP			Song sparrow	*Melospiza melodia*	17	8
STSP			Nelson's sharp-tailed sparrow	*Ammodramus nelsoni*	4	12
SWSP	r	*	Swamp sparrow	*Melospiza georgiana*	1	0
VESP			Vesper sparrow	*Pooecetes gramineus*	5	3
WEME			Western meadowlark	*Sturnella neglecta*	1	4
WIPH	r	*	Wilson's phalarope	*Phalaropus tricolor*	2	1
YEWA			Yellow warbler	*Dendroica petechia*	15	11
YHBL	r	*	Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	1	20

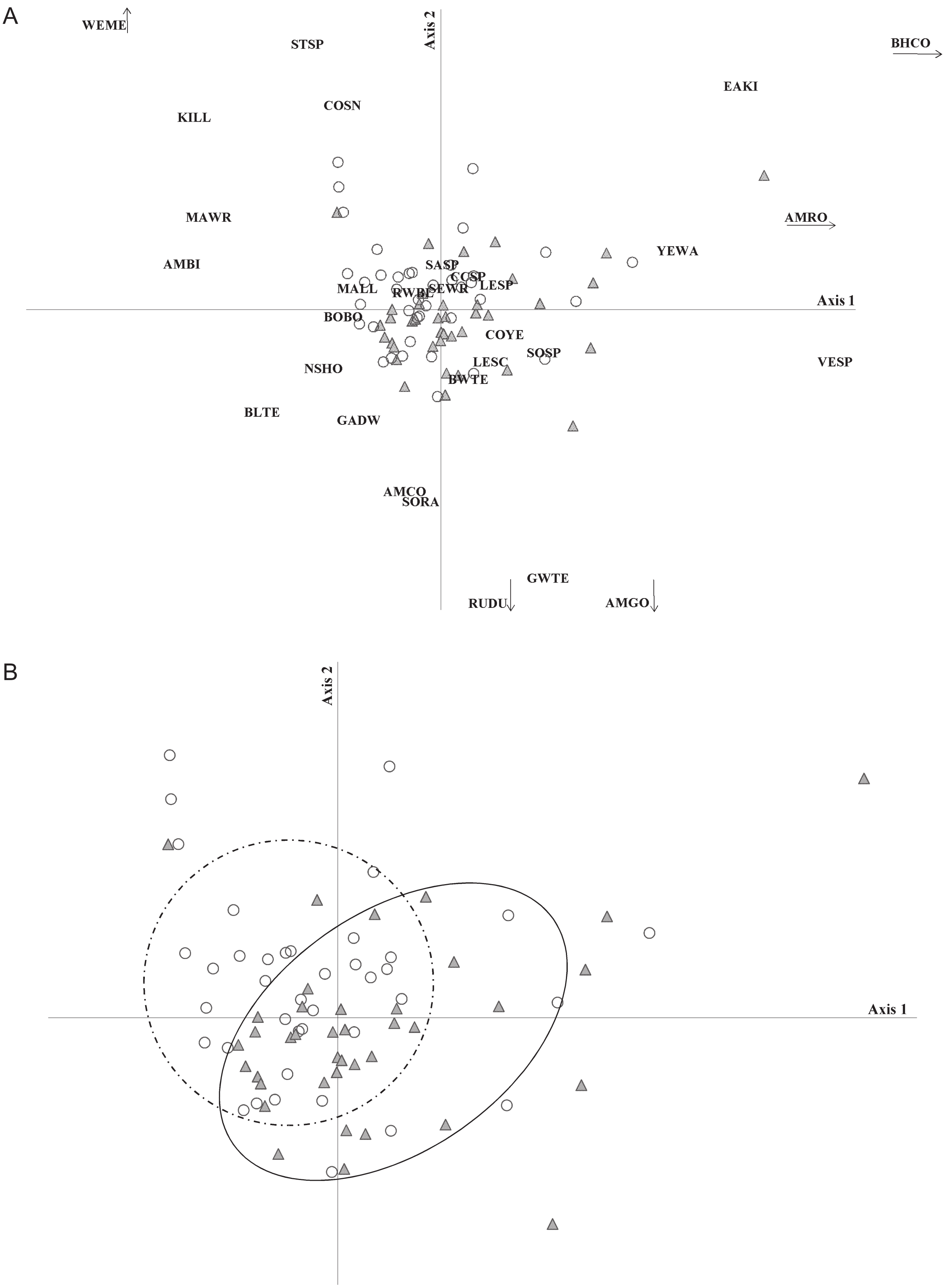

Fig. 3. A) Correspondence Analysis (CA) ordination of bird assemblages (30 bird species, abbreviations in Table 2) from 80 Saskatchewan wetlands (41 restored). Arrows indicate the position of species that would otherwise be outside the graph. B) Correspondence Analysis (CA) ordination of 80 Saskatchewan wetlands (41 restored) based on the presence or absence of 30 bird species. Confidence ellipses enclose the majority of restored and natural wetlands.

Table 3. Results of PCA for 15 habitat characteristics in 80 wetlands (41 restored) in Saskatchewan and correlations between the habitat characteristics and scores from the first 3 axes of the PCA. *indicates significance at $p<0.05$; **indicates $p<0.01$.

	AX1		AX2		AX3	
Eigenvalue	2.23		1.84		1.65	
%variance	14.89		12.27		10.99	
Cummulative %variance	14.89		27.16		38.15	
Habitat characteristics						
MNLOW	0.78	**	0.10		0.02	
MNWET	0.58	**	–0.15		0.35	**
MNSHAL	0.43	**	0.24	*	0.15	
MNDPTH	–0.50	**	0.29	**	–0.08	
LOGCOND	–0.63	**	–0.21		–0.27	**
LOGUPHT	0.30	**	–0.03		–0.01	
MNBASIN	0.10		–0.38	**	0.34	**
ARCCRP	0.16		–0.13		–0.52	**
ARCTLWET	–0.15		–0.60	**	0.38	**
ARCWDL	–0.22	*	0.60	**	0.58	**
LOGAREA	–0.02		–0.62	**	0.22	
SHAPE	0.00		–0.37	**	0.24	*
NNWOOD	0.19		–0.42	**	–0.46	**
NNROAD	–0.28	**	–0.09		0.50	**
NNWETL	0.33	**	–0.02		–0.02	

Table 4. Results of Correspondence Analysis (CA) applied to 80 wetlands (41 restored) with 30 bird species in the PPR of Saskatchewan and Pearson correlations (r) for 15 habitat characteristics with axes. Abbreviations for habitat characteristics can be found in Table 1. *indicates significance at $p<0.05$; **indicates $p<0.01$.

	AX1		AX2		AX3		Total inertia
Eigenvalue	0.2528		0.216		0.1787		2.4028
Cummulative %variance of species data	0.11		0.20		0.27		
Habitat characteristics:							
MNLOW	–0.06		0.27	**	–0.08		
MNWET	0.09		0.33	**	–0.01		
MNSHAL	0.10		0.10		–0.28	**	
MNDPTH	0.01		–0.42	**	0.31	**	
LOGCOND	–0.16		–0.13		0.31	**	
LOGUPHT	–0.10		–0.11		0.01		
MNBASIN	0.08		0.25	*	–0.19		
ARCCRP	–0.16		0.07		0.03		
ARCTLWET	–0.15		0.18		–0.01		
ARCWDL	0.34	**	–0.21		–0.25	*	
LOGAREA	–0.25	*	0.20		–0.14		
SHAPE	0.08		0.07		–0.04		
LGWOOD	–0.46	**	0.01		0.08		
LGROAD	–0.21		–0.04		–0.01		
LGNNWT	–0.14		0.22	*	–0.12		

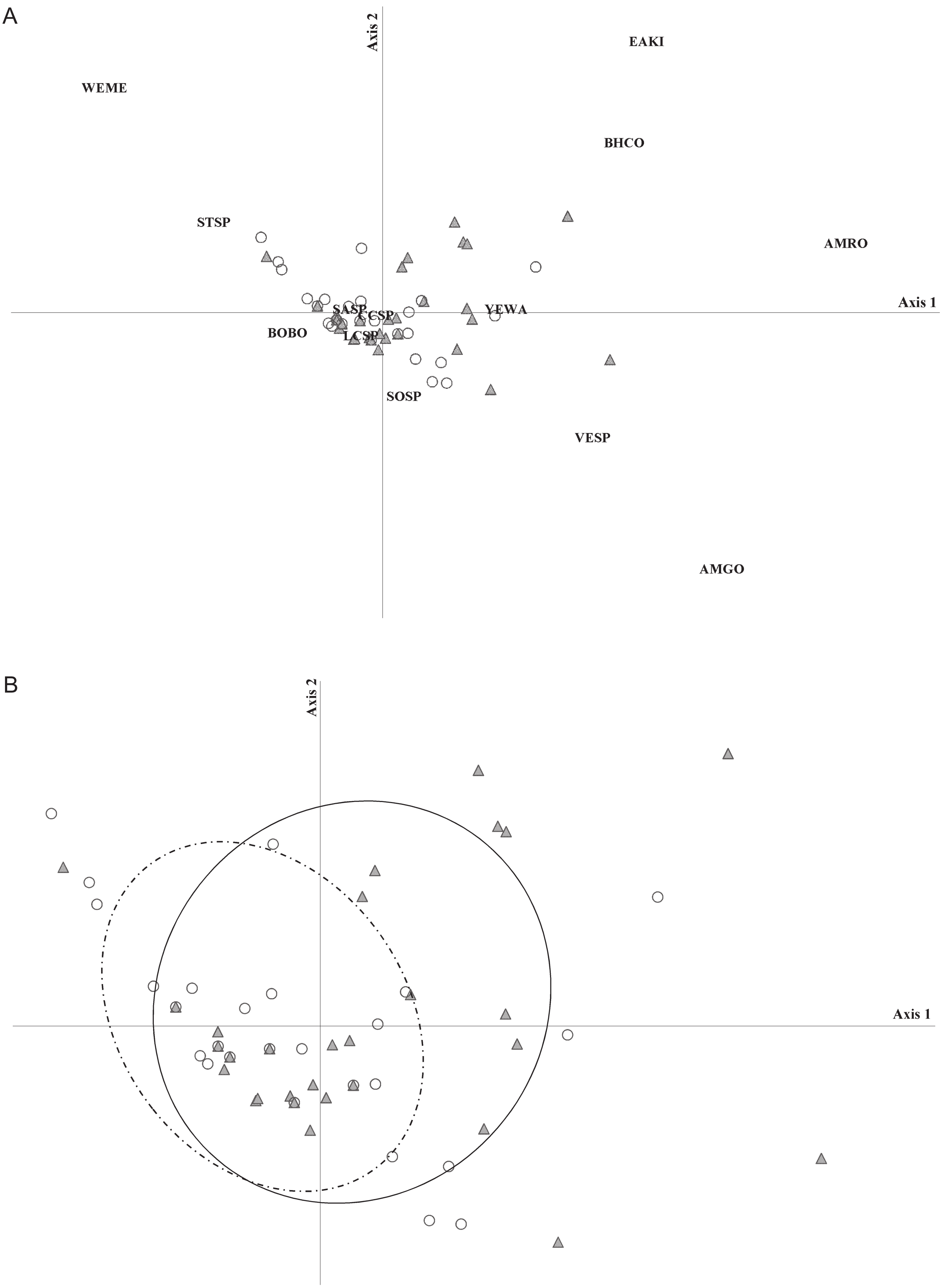

Fig. 4. A) Correspondence Analysis (CA) ordination of 13 upland bird assemblages from 80 Saskatchewan wetlands (41 restored). Bird species codes are given in Table 2. B) Correspondence Analysis (CA) ordination of 80 Saskatchewan wetlands (41 restored) based on the occurrence of 13 upland bird species. Confidence ellipses enclose the majority of restored and natural wetlands.

Assemblages on natural wetlands were characterised by the presence of woodland-associated species (American robin, brown-headed cowbird) and diving birds (ruddy duck, lesser scaup). Assemblages on restored wetlands were characterised by the presence of open-grassland birds (western meadowlark, bobolink) and shorebirds (killdeer, common snipe). Compositional differences between wetland types were confirmed by MRPP analysis of site scores from the first 3 CA axes (T=–4.40, p=0.002).

The species ordination showed that bird species formed two clusters united by common feeding and nesting habitats (Fig. 3a). Dabbling (e.g., mallard) and diving (e.g., ruddy ducks) ducks were found in deeper wetlands of moderate area with some open water areas (decreased MNBASIN). As might be expected, birds that nest in the wet meadow zones (e.g., marsh wren) were found predominantly in wetlands with greater proportions of that vegetation type. Characteristic upland passerines consisted of two groups, either species found near wetlands with greater surrounding woodland habitat (e.g., American robin, song sparrow) or species associated with wetlands distant from woodlands (e.g., bobolink or western meadowlark) typified by open prairie habitat.

Canonical Analysis of 80 wetlands limited to 13 upland bird species continued to display differences in species composition between restored and natural wetlands (Fig. 4a,b). Scores on axis 1 were strongly correlated with surrounding woodland features (ARCWDL, NNWOOD) reflecting differences between restored and natural wetlands (Table 5). Woodland-nesting passerines (e.g., American robin) were characteristic of wetlands with higher scores on axis 1, and prairie or grassland birds (e.g., bobolink, Nelson's sharp-tailed sparrow) were characteristic of wetlands with lower scores on axis 1. Confidence ellipses highlighted differences in restored and natural wetlands, with a greater number of natural wetlands with high scores on axis 1. Difference in upland bird species composition between restored and natural wetlands was supported by MRPP analysis on site scores from the first 3 axes (T=–4.16, p=0.004).

In contrast, species assemblages did not differ between restored and natural wetlands based on CA conducted on presence/absence patterns of 17 wetland-dependent species for 75 wetlands (37 restored) (Fig. 5a). There was substantial overlap in the confidence ellipses for restored and natural wetlands in the CA plot (Fig. 5b), and convergence in species composition between wetland types was supported by MRPP analysis (T=–0.76, p=0.19). Site scores on the first two axes were weakly correlated with wetland depth (MNDPTH) and vegetation characteristics (MNSHAL, MNBASIN), and site scores on the third axis displayed a stronger correlation with MNDPTH (Table 6). The species ordination showed birds distributed in a pattern that weakly reflected feeding location within a wetland. Open water foragers (e.g., American coot) and dabbling ducks (e.g., blue-winged teal) were characteristic of wetlands with lower scores on the first and second axis. Birds that feed in shallow water or mudflats (e.g., killdeer) or drier wetland sites (e.g., sedge wrens) were characteristic of sites with higher scores on the axis 2.

DISCUSSION

Although restored wetlands in the Aspen Parkland of Saskatchewan were similar in size, conductivity, and vegetative cover to natural wetlands, they did not provide equivalent habitats for birds. PCA, MRPP, and univariate analyses on 80 wetlands (41 restored) showed that restored wetlands were shallower, with less complex shorelines, closer to roads, and further from woodland patches.

Contrary to previous studies (Delphey & Dinsmore, 1993; Galatowitsch & van der Valk, 1996a, 1996b; VanRees-Siewert & Dinsmore, 1996; Aronson & Galatowitsch, 2008) restored wetlands in Saskatchewan did not display a reduction in or absence of wet meadow and low prairie plant guilds. Intensive vegetation sampling in 7 restored and 7 natural wetlands demonstrated that all vegetative zones were present in restored wetlands and plant species composition was comparable to natural wetlands (Puchniak, 2002). Rather, differences in species richness and diversity in restored wetlands appeared related to differences in local and landscape factors not examined by earlier studies. On average, there was a lower diversity ($H_{restored}$=1.8, $H_{natural}$ =2.0) and number of species ($S_{restored}$=8.1, $S_{natural}$=9.7) in restored versus natural wetlands. Delphey & Dinsmore (1993) also found differences in species richness between restored (S=3.6–5.4) and natural (S=7.3–8.6) wetlands in Iowa. Equitability or relative abundance of species was comparable between wetland types in Saskatchewan, reflecting the presence of a core group of ubiquitous species recorded across all wetlands (clay-colored sparrow, LeConte's sparrow, red-winged blackbird, savannah sparrow).

Bird species that were restricted to either restored or natural wetlands were, for the most part, rare species that were observed in a single survey. Three of these species (redhead, pied-billed grebe, horned grebe) were associated with wetlands that were deeper than average (>50 cm) and had greater species richness than other surveyed wetlands (S=10–16). These deeper basins provided the habitat required by species that feed up to 60 cm below the water's surface (i.e., diving ducks, grebes; Galatowitsch & van der Valk, 1994).

Bird composition also differed between restored and natural wetlands, but not because of species nesting in the wet meadow and low prairie zone as reported in previous studies (Delphey & Dinsmore, 1993; Galatowitsch & van der Valk 1994). CA and MRPP analyses on wetland-dependent bird species only (including wet meadow and low prairie species) indicated comparable assemblages in restored and natural wetlands. Rather, compositional differences were related to upland species such as the American goldfinch, brown-headed cowbird, and American robin that occurred on natural wetlands. The presence of these species was correlated with differences in the proportion of surrounding woodland and distance to nearest woodland patch between restored and natural wetlands.

Table 5. Results of Correspondence Analysis (CA) applied to 80 wetlands (41 restored) with 13 upland (not wetland-dependent) bird species in the PPR of Saskatchewan and Pearson correlations (r) for 15 habitat characteristics with axes. Abbreviations for habitat characteristics can be found in Table 1. *indicates significance at p<0.05; **indicates p<0.01.

	AX1		AX2		AX3		Total inertia
Eigenvalue	0.333		0.258		0.226		1.742
Cummulative %variance of species data	0.19		0.34		0.47		
Habitat characteristics:							
MNLOW	–0.13		0.12		0.03		
MNWET	0.08		0.20		0.13		
MNSHAL	0.06		–0.09		–0.02		
LOGCOND	–0.04		0.11		0.04		
LOGUPHT	–0.01		–0.03		–0.29	**	
MNBASIN	0.01		0.08		0.17		
ARCCRP	–0.06		0.13		0.04		
ARCTLWET	–0.27	*	0.09		0.08		
ARCWDL	0.41	**	–0.23	*	0.02		
LOGAREA	–0.25	*	0.17		0.04		
SHAPE	0.09		0.07		–0.01		
LGWOOD	–0.44	**	0.01		0.04		
LGROAD	–0.10		–0.01		0.11		
LGNNWT	–0.09		0.10		0.23	*	

Table 6. Results of Correspondence Analysis (CA) applied to 75 wetlands (37 restored) with 17 wetland-dependent bird species in the PPR of Saskatchewan and Pearson correlations (r) for 15 habitat characteristics with axes. Abbreviations for habitat characteristics can be found in Table 1. *indicates significance at p<0.05; **indicates p<0.01.

	AX1		AX2		AX3		Total inertia
Eigenvalue	0.303		0.269		0.261		2.550
Cummulative % variance of species data	0.12		0.22		0.33		
Habitat characteristics:							
MNLOW	–0.07		0.20		0.02		
MNWET	0.11		0.09		0.18		
MNSHAL	0.23	*	0.23	*	–0.07		
MNDPTH	–0.25	*	–0.23	*	–0.34	**	
LOGCOND	–0.11		0.15		–0.16		
LOGUPHT	0.08		–0.07		–0.08		
MNBASIN	0.27	*	0.06		0.31	**	
ARCCRP	0.04		0.13		0.04		
ARCTLWET	–0.05		0.03		0.23	*	
ARCWDL	0.10		–0.15		–0.11		
LOGAREA	0.05		0.20		0.08		
SHAPE	0.00		0.04		0.12		
LGWOOD	–0.05		0.14		–0.06		
LGROAD	–0.15		0.10		0.01		
LGNNWT	–0.08		–0.12		0.20		

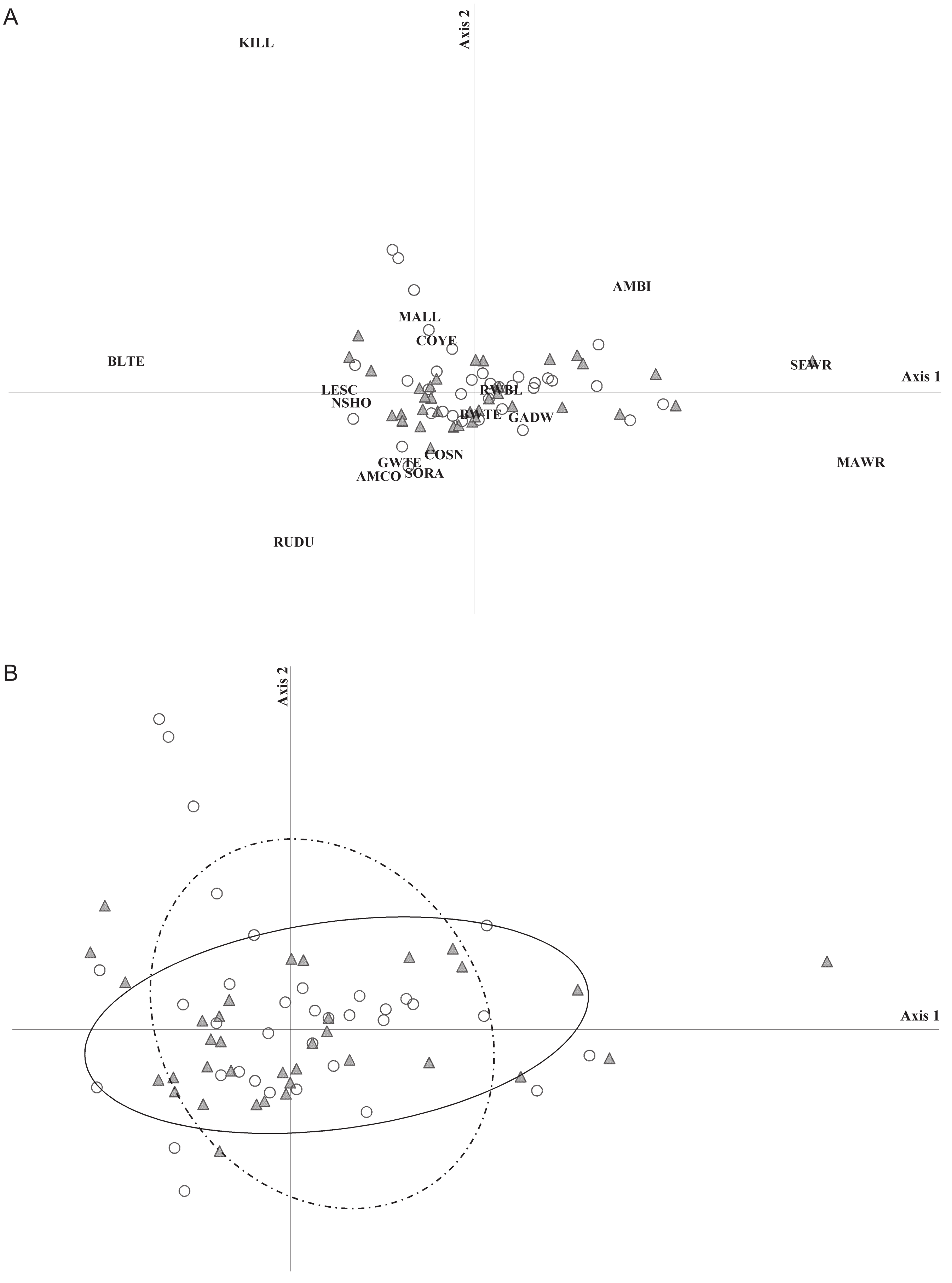

Fig. 5. A) Correspondence Analysis (CA) ordination of 75 Saskatchewan wetlands (37 restored) based on the presence or absence of 17 wetland-dependent bird species. Bird species codes are given in Table 2. B) Correspondence Analysis (CA) ordination of wetland-dependent bird assemblages from 75 Saskatchewan wetlands (37 restored). Confidence ellipses enclose the majority of restored and natural wetlands.

The fundamental goal of the present study was to assess the success of restoration in creating habitat for wetland bird species and we avoided sampling wetlands with conspicuous woodland perimeters. However, the distance between natural wetlands and woodlands was on average less than for restored wetlands (natural=102.8 m, restored=228.3 m), and facilitated the movement of upland bird species from nearby woodlands. Therefore, birds characteristic of forested areas made a greater contribution to species assemblages found at natural wetlands.

Wetlands that were further from woodland patches were also further from roads. While no wetland was particularly close to roads (natural=450.1 m, restored=357.7 m), restored wetlands were on average closer. Proximity to roadways may influence bird assemblage composition as species vary in their affinity for roadside habitat. Some species appear to be more abundant along roads (e.g., savannah sparrow) or trails (Baird's sparrow, *Ammodramus bairdii*; Sutter et al., 2000), and more secretive species may avoid areas with greater human activity (LeConte's sparrow, yellow rail; Ehrlich et al., 1988).

Compositional differences between bird assemblages on restored and natural wetlands also reflected differences in very local habitat features. Bird species composition in an individual wetland, regardless of its history, is influenced by wetland depth and vegetative composition. Deeper wetlands (>50 cm) with open water areas provide foraging habitat for diving ducks (ruddy duck, lesser scaup), and shallower wetlands are characterised by species that nest or feed in shallow marsh vegetation (e.g., wrens, common yellowthroat).

Pothole wetlands are classified based on the presence of characteristic vegetation that reflects the duration of inundation (Stewart & Kantrud, 1971). Increases in wetland depth (Weller, 1999) and resulting changes in wetland permanence (Stewart & Kantrud, 1971) can increase the diversity and availability of wetland habitat for foraging and nesting. The shallow marsh zone, in particular, is often flooded for several weeks in the spring, but basins dry up by late summer or fall in most years (Stewart & Kantrud, 1971). In the study wetlands, a greater proportion of shallow marsh vegetation was characteristic of shallower basins with greater total vegetative basin cover. These basins provide nesting habitat for wetland obligates such as the sora, marsh wren, and American bittern, and greater proportions of shallow marsh vegetation reduces the available habitat for species that nest in cattails (e.g., blackbirds) and on open water (e.g., grebes), and results in a different species composition.

The shallower depth and less complex shorelines typical of restored wetlands could be an artifact of the construction process, or the result of tilling and/or filling of the basin while under agricultural production. Alternately, surviving natural wetlands may have remained unaltered due to their size and depth, thus effective draining and cultivation of their shorelines may have proven more challenging.

A parallel study of avian assemblages on restored wetlands was conducted further west in the Aspen Parkland in Alberta (Puchniak, 2002). As in Saskatchewan, the composition of wetland-dependent bird assemblages in Alberta was comparable in restored and natural wetlands. However, contrary to results for Saskatchewan, the 56 restored and 46 natural wetlands in Alberta shared equivalent physical habitats, overall bird species richness (6.9 species/natural wetland, 6.0 species/restored wetland; (t_{100}=1.24, p=0.22) and overall species composition. The different patterns may reflect divergence in land use between provinces. Saskatchewan has historically been dominated by grain farming, whereas Alberta has less land in crop production and a larger cattle industry (Statistics Canada, 2001). Wetlands are less likely to be drained and stands of trees cleared on lands used for pasture. The result is an Albertan landscape with greater representation of perennial cover (including woodlands) and greater similarities between DU properties with surviving natural wetlands and properties with restorations (J. Thompson, DUC, pers. comm., 2002).

A 2011 evaluation of DUC's wetland restoration program found that, among other factors, variations between ecoregion and surrounding land use can influence the total wetland acreage restored (J. Thompson, DUC, pers. comm., 2011).

Knowledge that restored wetlands in Saskatchewan and Alberta do provide valuable habitat for wetland-dependent birds has bolstered use of the technique by DUC, including a role in wetland mitigation (J. Thompson, DUC, 2011). As restoration and mitigation proceeds, managers need to recognise that the greatest number of bird species will benefit if strategies encompass a range of classes and sizes of wetlands (Fairbairn & Dinsmore, 2001; Naugle et al., 2001) with diverse patterns of hydrology and vegetation (O'Neal et al., 2001). An integrated conservation approach should identify and prioritise wetland sizes and classes that are under-represented in the existing landscape and aim to reduce isolation (distance) between individual wetlands (Gibbs, 2000) as well as incorporate a system of evaluation (La Peyre et al., 2001). Successful recovery of wildlife is also critically linked to successful revegetation which is affected by the length of time that wetlands have been drained and accessibility of still existing seed banks. As such, the current methodology for restoring wetlands in the Aspen Parkland offers a promising means for mitigating wetland loss and should continue to play a regional role in habitat management.

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