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Bird Abundance and Diversity Relative to Habitat Features of Laramie Plains Lakes, Wyoming

Abstract

We determined relative abundance and diversity of bird species and habitat features on 13 lakes on the Laramie Plains, a high-elevation intermountain plain in southeastern Wyoming, during summer 1994. A total of 48 species of birds were observed from May to July. Relative abundance of birds observed on individual lakes increased with water surface area and area of hard-stem bulrush (Scirpus acutus) *along the shoreline. Diversity of bird species declined with increasing water surface area and the length of bare ground along the shoreline. Marsh-like habitat was most abundant around the shore of small lakes forming habitat for marsh birds and leading to greater overall species diversity compared to large lakes. Species richness of birds had a curvilinear relationship with water surface area and was greatest among intermediate-sized lakes. A mix of marsh-like habitat and bare ground along the shoreline provided habitat for marsh birds and shorebirds leading to high species richness among intermediate-size lakes. It appears that stabilization of water levels and resulting succession from playas to lakes with more marsh-like features has led to a greater abundance and diversity of birds associated with lakes on the Laramie Plains.*

Key words: Birds, waterfowl, lakes, Great Plains, Wyoming

Introduction

High-elevation intermountain plains are unique in that they provide lake and wetland habitat for birds amid mountainous terrain. A diversity of lakes and wetlands in close proximity to one another can provide habitat for an array of species of migrating and breeding birds. We studied the birds associated with lakes of the Laramie Plains, a high-elevation (2,200 m above mean sea level), intermountain plain between the Laramie Range and Medicine Bow Mountains in southeastern Wyoming. The high elevation results in a short growing season and wide variation in diurnal air temperatures (Knight 1994). The Laramie Plains are on the periphery of the Central Flyway (Linduska 1964) and attract a variety of waterbirds.

The most common natural wetland type in the semi-arid landscape of the Laramie Plains was the playa lake. Playa lakes are shallow, oval depressions with a clay or fine sandy loam hydric soil formed by wind erosion (Mitsch and Gosselink 1993). Typically, sources of water included precipitation (especially runoff from snowfall), surface runoff, and groundwater discharge. As a result, playa lakes have fluctuating water levels and are often dry by late summer. Although most of the Laramie Plains

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lakes originated as playa lakes, irrigation and construction of small dams have raised water levels to stabilize fluctuations and enhance macrophyte growth in many lakes. Consequently, many lakes now have marsh-like shorelines. Thus, the habitat diversity among the lakes has increased over that which occurred naturally. Most research on playa lakes has focused on migratory waterfowl (Stormer et al. 1981) and little is known about use of these lakes by other kinds of birds.

We describe relative abundance and diversity of birds observed on 13 lakes and their associated wetland areas on the Laramie Plains during summer of 1994, and evaluate associations between habitat features and relative abundance, species diversity, and species richness of birds among lakes.

Study Area

Numerous lakes occur on the Laramie Plains in southeastern Wyoming and we chose 13 representative lakes with water surface areas of 5.0 - 308.4 hectares for study. Maximum distance between study lakes was 30 km.

The climate of the Laramie Plains is continental with annual precipitation of 12-25 cm (Ostresh et al. 1990). Average daily temperatures in July range from a high of 27° C to a low of 9° C (Martner 1986). Average annual wind speed is 20.6 km/h with prevailing westerly winds (Martner 1986). On the Laramie Plains, evaporation rates are greater than precipitation rates with a potential evapotranspiration rate of 51 cm annually (Martner 1986). The landscape is primarily rangeland with some areas of irrigated meadows.

Weather and geology contribute to saline water in Laramie Plains lakes. Soils on the Laramie Plains are influenced by weathering of marine cretaceous shales (Knight 1994). The saline soils in this region often contain high concentrations of sodium, gypsum (hydrated calcium sulfate), and other salts. Thus, the combination of high evaporation rates, low precipitation, and saline soils can result in salinities of lentic waters exceeding 30 mS/cm.

We classified the study lakes according to the salinity criteria of Cowardin et al. (1979). Ten lakes were oligosaline (0.8-8.0 mS/cm at 25° C): Alsop, Caldwell, Carroll, Gelatt, George, Hoge, Meeboer, Mortenson Lake A, Mortenson Lake B, and Rush. Dominant submerged aquatic plants in these lakes were chara *(Chara spp.)*, sago pondweed *(Potamogeton pectinatus)*, and water milfoil *(Myriophyllum sp.)*, and the dominant emergent plant was hard-stem bullrush but chair-maker's rush *(S. americanus)* was common. Two lakes were mesosaline (8.1-30.0 mS/cm), Hutton and Twin Buttes. The dominant submerged aquatic vegetation in these two lakes was ditch-grass of the sea *(Ruppia maritima)* with patches of sago pondweed, and there was no emergent vegetation. Bamforth Lake was hypersaline (> 60.0 mS/cm) and was devoid of emergent and submergent vegetation.

Upland areas around all the lakes were dominated by grasses, such as foxtail barley *(Hordeum jubatum)*, bottlebrush squirrelltail *(Elymus elymoides)*, and inland saltgrass *(Distichlis spicata)*, and sedges *(Carex spp.)*. The outermost edges of the watersheds were marked by shrubland of greasewood *(Sarcobatus vermiculatus)* and big sagebrush *(Artemesia tridentata)*.

Most of the lakes were on public land. Four lakes (Alsop, Gelatt, Meeboer, Twin Buttes) had public access for recreation. Eight lakes were on national wildlife refuges (Bamforth, Carroll, George, Hoge, Hutton, Mortenson Lake A, Mortenson Lake B, Rush) with limited public access. Although the Mortenson lakes were located on a national wildlife refuge, they had restricted access. Caldwell

Lake was on private land. Cattle grazing occurred around the shoreline of all study lakes.

Methods

Surveys of birds were conducted by counting and identifying all birds seen from vantage points around lake perimeters where the entire lake could be observed with a 60 X spotting scope (Uresk and Severson 1988). Surveys were conducted weekly from 9 May to 5 July 1994 between 0630 and 1000 hours. Surveys lasted 15-60 minutes, depending on the size of the lake and bird abundance. Individual lakes were surveyed at different times during the observation interval to minimize potential bias associated with timing of surveys.

Relative abundance was defined as the total number of birds observed over all seven surveys. Diversity was described using the Shannon-Wiener diversity index (Margalef 1958). The index is computed as: $\sum_{i=1}^{s} (p_i)(\log_2 p_i)$ where s is the number of species and p_i is the proportion of the total sample belonging to *i*th species. Species richness was computed as the total number of species observed during the summer survey period.

The lakes were photographed from a fixed-wing aircraft at an altitude of 200 m above the water during July 1994. Photographs were taken with a 35-mm camera using 400 ASA color film. Aerial survey markers were placed at intervals of 100 m on the shoreline to provide a scale of distance on the photos. Water surface area, length of the shoreline, length of bare ground along the shoreline, length of shoreline occupied by hard-stem bulrush, and the area of the lake were features determined from 20 x 30 cm prints that were digitized. Shoreline development (Lind 1985), an index of shoreline sinuosity, was calculated as the length of the lake perimeter divided by two times the square root of the product of the lake surface area and π.

Water samples were collected during the morning of 23 May 1994 along the shoreline of each lake at a depth of 0.5 m. Water quality parameters were measured following standard methods (APHA 1985). Alkalinity and hardness were determined by volumetric titrations and expressed as mg/L $CaCO_3$. Specific conductance was measured with a conductivity bridge in umhos/cm at 25° C and the values were converted to mS/cm. The pH was measured with a meter.

Pearson correlation coefficients and multiple-regression analyses were used to determine relationships between the habitat features and variables describing the birds (relative abundance, Shannon-Wiener diversity index, and species richness). A significance level of $P \leq 0.05$ was used for inclusion of individual variables into regression models. Analyses were performed with STATISTIX 4.0 (Analytical Software 1992).

Results

We observed a total of 48 species of birds, including 16 waterfowl, 28 shorebirds and waders, three passerines, and one raptor (Appendix A). Relative abundance of birds at each lake (239-5,500 total birds observed), Sahnnon-Wiener diversity index (0.56-3.72), and species richness (12-36 species observed) varied among lakes (Table 1). Caldwell Lake had the highest species richness and the second highest relative abundance of birds. Mortenson Lake A had the lowest relative abundance of birds, yet the highest Shannon-Wiener diversity index. Bamforth Lake was excluded from statistical analyses because it had the largest surface area and was the only hypersaline lake (hardness = 341,555 mg/L).

Physical, chemical, and vegetative characteristics varied among lakes

Table 1. *Relative abundance, Shannon-Weiner diversity indices, and species richness of birds on the 13 lakes studied on the Laramie Plains in 1994*

Lake	Relative abundance[a]	Shannon-Weiner diversity index	Species richness
Alsop	602	3.62	31
Bamforth	5,500	0.56	12
Caldwell	4,034	2.86	36
Carroll	763	2.76	24
Gelatt	455	2.90	24
George	278	3.34	21
Hoge	981	3.57	31
Hutton	923	3.23	26
Meeboer	613	3.42	30
Mortensen A	239	3.72	25
Mortensen B	394	2.96	28
Rush	1,338	3.17	32
Twin Buttes	1,542	2.14	25

[a]Total number of birds observed over seven surveys from 9 May to 5 July 1994.

(Table 2). The 12 lakes were generally oval in shape as evidenced by the shoreline development index (1.0-1.7). The proportion of bare ground along the shoreline (3-100%), and proportion of shoreline vegetated by hard-stem bulrush (0-97%) were highly variable. The water chemistry parameters of alkalinity (55-517 mg/L), conductivity (0.7-16.6 mS/cm), hardness (292-17,672 mg/L), and pH (7.7-9.1) were variable and highly correlated.

Multiple-regression analysis identified significant relations of relative abundance of birds (total number of birds observed over all surveys), Shannon-Wiener diversity index, and species richness with physical and vegative habitat features, but no significant relations were observed with measures of water chemistry or shoreline development.

Regression analysis indicated that the relative abundance of birds varied with water surface area ($r^2 = 0.36$, $P = 0.040$), the area of hard-stem bulrush ($r^2 = 0.35$, $P = 0.043$), and both water surface area and area of hard-stem bulrush ($R^2 = 0.64$, $P = 0.010$) as independent variables:

$$ABUND = 418.7 + 14.4\ WSA;$$

$$ABUND = 596.7 + 111.9\ ABUL; \text{ and}$$

$$ABUND = 94.9 + 13.1\ WSA + 101.4\ ABUL$$

where, ABUND = total number of birds observed over all surveys, WSA = water surface area (hectares), and ABUL = area of hard-stem bulrush (hectares).

Table 2. *Physical and biological features of the 13 lakes studied on the Laramie Plains in 1994.*

			Bare shoreline		Shoreline of hard-stem bulrush						
Lake	Water surface area (ha)	Shoreline development	Length (m)	%[a]	Length (m)	%[a]	Area (ha)	Alkalinity (mg/L)	Hardness (mg/L)	Conductivity (m S/cm)	pH
Alsop	16.3	1.3	1,869	100	0	0	0.0	373	941	3.8	8.8
Bamforth	308.4	1.7	10,621	100	0	0	0.0	2,800	341,550	73.2	8.3
Caldwell	99.4	1.1	544	55	358	45	16.0	72	327	0.9	9.1
Carroll	15.4	1.1	322	41	0	0	0.0	344	1,104	3.3	9.1
Gelatt	14.4	1.7	62	6	131	47	8.8	96	1,267	2.4	8.3
George	5.7	1.1	108	12	210	69	10.4	77	792	1.8	8.0
Hoge	24.7	1.3	275	12	0	0	0.0	55	3,643	3.0	9.1
Hutton	22.3	1.0	100	6	0	0	0.0	517	17,622	15.8	8.5
Meeboer	91.4	1.7	86	15	75	5	0.8	358	2,128	4.4	8.9
Mortensen A	5.0	1.3	151	65	0	0	0.0	425	624	3.6	8.7
Mortensen B	38.3	1.2	104	4	268	20	1.8	232	292	0.7	8.7
Rush	26.5	1.6	47	3	407	97	6.8	174	742	1.5	7.7
Twin Buttes	134.8	1.5	6,026	100	0	0	0.0	363	17,672	16.6	8.3

[a]Percent of the total length of shoreline.

Regression models indicated that the Shannon-Wiener diversity index varied with water surface area ($r^2 = 0.37$, $P = 0.034$) and length of bare ground along the shoreline ($r^2 = 0.37$, $P = 0.034$):

SW = 3.40 - 0.00639 WSA; and

SW = 3.27 - 0.000159 LBARE

where, SW = Shannon-Wiener diversity index, WSA = water surface area (hectares), and LBARE = length of bare ground along the shoreline (meters). However, water surface area and length of bare ground along the shoreline were found to be positively correlated (r = 0.65, $P = 0.0216$).

A significant ($R^2 = 0.55$, $P = 0.027$) curvilinear relationship was observed between species richness and water surface area:

$$RICH = 21.71 + 0.3303\ WSA - 0.00225\ WSA^2$$

where, RICH = species richness and WSA = water surface area (hectares). The regression model indicated that lakes of intermediate size had higher species richness than small or large lakes.

When regression analysis was applied to individual species, the relative abundances of five species were observed to vary positively with the length of shore bare of vegetation, and the relative abundances of 15 other species were observed to vary positively with the length of shoreline with hard-stem bulrush or the area of hard-stem bulrush (Table 3).

Table 3. *Regression equations for signifcant relationship between relative abundance of individual bird species and the length (meters) of bare shoreline (LBARE), length (meters) of shoreline with hard-stem bulrush (LBUL), and area (hectares) of lake with hard-stem bulrush (ABUL). Relative abundance is the total number of a species seen over seven weekly surveys from 9 May to 5 July 1994.*

Species	Equation	r^2	*P*
	Species associated with bare shoreline		
American avocet	6.30 + 0.0223 LBARE	0.92	<0.001
Greater yellowlegs	- 0.09 + 0.0004 LBARE	0.91	<0.001
Spotted sandpiper	0.22 + 0.0008 LBARE	0.79	<0.001
Franklin's gull	- 0.21 + 0.0015 LBARE	0.98	<0.001
California gull	8.61 + 0.1524 LBARE	0.95	<0.001
	Species associated with hard-stem bulrush		
Pied-billed grebe	2.05 + 0.0548 LBUL	0.72	<0.001
	3.88 + 1.2869 ABUL	0.50	0.010
Eared grebe	- 33.85 + 58.3464 ABUL	0.46	0.015
Western grebe	- 0.32 + 0.9375 ABUL	0.43	0.021
Snowy egret	- 0.05 + 0.0011 LBUL	0.35	0.044
Black-crowned night-heron	- 3.36 + 0.1154 LBUL	0.61	0.003
	- 1.40 + 3.2249 ABUL	0.61	0.003
White-faced ibis	- 3.39 + 0.1129 LBUL	0.61	0.003
	- 0.17 + 2.8042 ABUL	0.48	0.013
Green-winged teal	0.16 + 0.2481 ABUL	0.47	0.014
Ruddy duck	4.68 + 0.1323 LBUL	0.41	0.025
	6.08 + 3.9234 ABUL	0.46	0.016
Northern harrier	- 0.12 + 0.1225 ABUL	0.56	0.005
Sora	- 0.06 + 0.1065 ABUL	0.56	0.005
American coot	13.80 + 0.3171 LBUL	0.56	0.005
	20.07 + 8.6124 ABUL	0.52	0.008
Black-necked stilt	- 0.44 + 0.8812 ABUL	0.66	0.001
Forster's tern	- 1.29 + 0.1522 LBUL	0.44	0.020
Black tern	- 0.02 + 0.0236 LBUL	0.38	0.034
Yellow-headed blackbird	24.18 + 1.0061 LBUL	0.74	<0.001
	74.60 + 19.1218 ABUL	0.34	0.048

Discussion

Variation in relative abundance of birds among lakes on the Laramie Plains was related to water surface area of individual waters similar to what has been observed among lakes and wetlands in other areas. In northeast Wyoming, 30 species of migrating birds were identified on 80 man-made wetland ponds and water surface area was the single habitat variable associated with abundance (McKinstry 1993). Relative abundance of birds increases with water surface area of ponds in northern Wyoming (Svingen 1991) and wetlands on the Northern Great Plains (Uresk and Severson 1988). Similarly, relative abundance of birds also increases with water surface area of marshes in Iowa (Brown and Dinsmore 1986).

Our analysis indicated that the relative abundance of birds also was related to the area of hard-stem bulrush. Associated with increases in the area or hard-stem bulrush were increases in marsh-like habitat and the vertical diversity of vegetative habitat used by birds (Wiens 1983). Water level stabilization and resulting succession from playa to more marsh-like habitat among lakes on the Laramie Plains apparently resulted in a more abundant bird community.

Our data suggest a negative relationship between water surface area and species diversity, as well as between the length of bare shoreline and species diversity. However, we also found a significant positive correlation ($r = 0.92$, $P < 0.001$) between water surface area and length of bare shoreline. The functional relationship to species diversity probably occurs through greater habitat diversity (Wiens 1983) as the length of bare shoreline decreases. As with the relative abundance of birds, reduction of bare shoreline and development of more marsh-like habitat apparently resulted in a more diverse bird community among lakes on the Laramie Plains.

Species richness was highest among lakes of intermediate size and lowest among the smallest and largest lakes. This probably was a function of greater habitat diversity among intermediate-size lakes than among small and large lakes. Small lakes tended to have little or no bare shoreline, were ringed with marsh-like vegetation, and a relatively high abundance of marsh birds. Large lakes had predominantly bare shorelines, little marsh-like habitat, and an abundance of shorebirds. Intermediate-size lakes had marsh-like habitat and bare shorelines that provided habitat for marsh and shorebirds.

The relationship between the relative abundance of individual species and the amount of bare shoreline or marsh-like habitat further supports an observed relationship between species diversity and species richness. Among the 48 species observed among the Laramie Plains lakes, the relative abundance of five species that are generally described as shorebirds were positively related to the length of bare shoreline, whereas 15 species that are generally associated with marshes were positively related to the shoreline length or area with hard-stem bulrush. While 16 waterfowl species were observed among the lakes, only two were related to habitat features, but waterfowl contributed substantially to species diversity and species richness. The negative relationship between lake size and species diversity probably resulted as a function of a large number of marsh birds associated with high amounts of marsh-like habitat around smaller lakes. Similarly, the high species richness of intermediate-size lakes may have resulted from the mix of marsh-like and bare shoreline habitats allowing both marsh and shorebird species to use these lakes.

No temporal trends in relative abundance of individual bird species on the 12 Laramie Plains lakes were observed from May to July 1994. Breeding bird counts during May and early June have considerd birds counted at that time as summer residents rather than migrants (Brewster et al. 1976, Ruwaldt et al. 1979, McKinstry 1993). Our data suggest that birds observed on the Laramie Plains were summer residents that probably breed there. The only exception was Wilson's phalarope for which we observed the maximum number was observed in early May after which numbers decreased.

The Laramie Plains lakes provide habitat for a diverse array of bird species. The semi-arid Laramie Plains were devoid of surface water except for ephemeral playa lakes, but irrigation and construction of small dams has stabilize water levels and enhance wetland habitat for birds in many of the playa lakes. However, the nature of the soils and high evapotranspiration rates may adversely affect water quality (Dickerson 1993). Management should focus on maintaining a wide array of habitats among playa lakes altered by stabilizing water levels to provide habitat for a diversity of game and nongame birds.

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Appendix A. *Total number of each species of bird observed during all seven surveys on 13 lakes on the Laramie Plains from 9 May to 5 July 1994.*

Common name	Scientific name	Number
Pied-billed grebe	*Podilymbus podiceps*	104
Eared grebe	*Podiceps nigricollis*	2,196
Western grebe	*Aechmophorus occidentalis*	38
American white pelican	*Pelecanus erythrorhynchos*	125
Double-crested cormorant	*Phalacrocorax auritus*	152
Great blue heron	*Ardea herodias*	15
Snowy egret	*Egretta thula*	11
Cattle egret	*Bubulcus ibis*	1
Black-crowned night-heron	*Nycticorax nycticorax*	129
White-faced ibis	*Plegadis chihi*	123
Canada goose	*Branta canadensis*	1,863
Green-winged teal	*Anas crecca*	13
Mallard	*Anas platyrhynchos*	57
Northern pintail	*Anas acuta*	8
Blue-winged teal	*Anas discors*	8
Cinnamon teal	*Anas cyanoptera*	42
Northern shoveler	*Anas clypeata*	46
Gadwal	*Anas strepera*	114
American wigeon	*Anas americana*	183
Canvasback	*Aythya valisneria*	163
Redhead	*Aythya americana*	218
Ring-necked duck	*Aythya collaris*	5
Scaup spp.	*Aythya marila, A. affinis*	513
Bufflehead	*Bucephala albeola*	6
Common merganser	*Mergus merganser*	9
Ruddy duck	*Oxyura jamaicensis*	248
Northern harrier	*Circus cyaneus*	4
Sora	*Porzana carolina*	4
American coot	*Fulica americana*	625
Black-bellied plover	*Pluvialis squatarola*	1
Killdeer	*Charadrius vociferus*	269
Black-necked stilt	*Himantopus mexicanus*	7
American avocet	*Recurvirostra americana*	330
Greater yellowlegs	*Tringa melanoleuca*	2
Lesser yellowlegs	*Tringa flavipes*	1
Solitary sandpiper	*Tringa solitaria*	1
Willet	*Catoptrophorus semipalmatus*	5
Spotted sandpiper	*Actitis macularia*	10
Whimbrel	*Numenius phaeopus*	1
Common snipe	*Gallinago gallinago*	14
Wilson's phalarope	*Phalaropus tricolor*	592
Franklin's gull	*Larus pipixcan*	12
California gull	*Larus californicus*	<7000
Forster's tern	*Sterna forsteri*	205
Black tern	*Chlidonias niger*	34
Red-winged blackbird	*Agelaius phoeniceus*	77
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	1,748
Brewer's blackbird	*Euphagus cyanocephalus*	120