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Interspecific Differences in Habitat Use of Shorebirds and Waterfowl Foraging in Managed Wetlands of California's San Joaquin Valley

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Abstract.—A common wetland management objective is to provide habitat for a diverse assemblage of species, which requires data on interspecific differences in habitat use. Consequently, we studied habitat use by ten waterbird taxa (four dabbling ducks and six shorebirds) foraging in managed, seasonal wetlands in the northern San Joaquin Valley, California during late winter and early spring of 1994 and 1995. A MANOVA analysis detected strong interspecific differences in habitat use, with water depth explaining 86% of differences among taxa in a discriminant function analysis. ANOVA identified four groups based on similarities in use of water depth: 1) small shorebirds (<5 cm); 2) large shorebirds (5-11 cm); 3) teal (10-15 cm); and large dabbling ducks (>20 cm). Among these groups, variation in water depth at foraging locations increased with size, suggesting that water depth constrained foraging by shorebirds and teal more than larger waterfowl. In California's Central Valley, where large numbers of shorebirds and waterfowl winter, our findings suggest that managers can provide habitat for shorebirds and waterfowl by reducing the average depth to which habitats are flooded, especially during winter when deep-water habitat is abundant. Within a wetland complex or an individual wetland, this prescription will yield greatest diversity of water depth, and, hence, bird use in wetlands characterized by variable bottom topography. Received 21 December 1999, accepted 17 February 2000.

Key words.—California, dabbling ducks, moist-soil management, shorebirds, water depth, waterfowl, wetlands. Waterbirds 23(2): 196-203, 2000

Interspecific differences in habitat use are characteristic of all bird communities (Wiens 1989). Of the many habitat features potentially contributing to differences in habitat use among waterbirds (e.g., Anseriformes, Charadriiformes), the most notable is water depth. Interspecific patterns of habitat use by waterfowl and shorebirds (Dubow 1988; Colwell and Oring 1988; Weber and Haig 1996; Colwell and Taft 2000) are mostly related to water depth, and these patterns correlate with species' morphologies (Baker 1979; Pöysä 1983). Larger species (those with longer necks, bills, and legs) feed in deeper habitats than smaller taxa.

From a conservation perspective, the value of understanding interspecific differences in habitat use lies in enhanced management for diverse species assemblages. This is especially true in wetland habitats, which have been destroyed at alarming rates over the past two centuries. In the conterminous United States, approximately 53% of original wetland area has been lost; California has lost nearly 91% of wetland acreage (Dahl 1990). As a result, remaining wetlands are intensively managed, especially in the Central

Valley. The largest remaining block (ca. 47,000 ha) of freshwater wetland habitat in the Central Valley lies within the Grasslands Ecological Area (hereafter The Grasslands) of the northern San Joaquin Valley, where wetland management practices have been used traditionally to produce plant communities and habitat to benefit waterfowl. The Grasslands has long been recognized for its importance to waterfowl (Gilmer 1982) and, more recently, shorebirds (Hunter *et al.* 1991; Shuford *et al.* 1993, 1994). Although the need for data on interspecific differences in habitat use is critical to effective management, no study has examined simultaneously habitat use for waterfowl and shorebirds. The purpose of this paper is to compare habitat use among four waterfowl and six shorebird taxa using managed seasonal wetlands in The Grasslands, and to discuss management implications.

STUDY AREA

We studied waterbirds on nine privately-owned seasonal wetlands (duck hunting clubs; Table 1) in the West Grasslands (37,000 ha), Merced Co., California. Historically, the San Joaquin River and small streams of

Table 1. Character and early sp

| Wetland |
|---------------|
| Deer Park |
| East Gustine |
| Hollister C21 |
| Hollister F10 |
| Salinas |
| Britto |
| Redfern |
| Santa Cruz |
| Sillbow |

^aBR = Baltic 1
(*Typha latifolia*),
^bTiming of we

the Coast Range spring. More recent and removes water Laubhan 1995). A sites because the management practice timothy (*Heliochloa* 1996). In The Grasslands in September March and early swamp timothy s about 4-6 weeks I seed production. flooded to depths have large areas c dered by emergen and Colwell and T details on the study

Bird Observations

We collected ha 1994 and 21 Janua (Altmann 1974) in

Table 2. Common a Joaquin Valley, Calif

| Common name |
|---------------------|
| Least Sandpiper |
| Western Sandpiper |
| Dunlin |
| Dowitcher |
| Black-necked Stilt |
| American Avocet |
| American Green-wing |
| Northern Shoveler |
| Northern Pintail |
| Gadwall |

Table 1. Characteristics of nine wetlands in The Grasslands where waterbird habitat use was studied during late winter and early spring of 1994 and 1995.

| Wetland | Size (ha) | Topography | Soil type | Vegetation ^a | Drawdown ^b |
|---------------|-----------|------------|------------|-------------------------|-----------------------|
| Deer Park | 35 | Variable | Sandy Loam | BR/HSB | Early April |
| East Gustine | 96 | Variable | Clay | BR/HSB | Mid April |
| Hollister C24 | 39 | Variable | Sandy Loam | BR/HSB | Late March |
| Hollister F16 | 28 | Variable | Sandy Loam | BR | Mid March |
| Salinas | 91 | Variable | Clay | HSB/IB | Early April |
| Bittro | 88 | Level | Clay | BR/HSB | Late March |
| Reflem | 30 | Variable | Loam | BLC/BR | Late March |
| Santa Cruz | 64 | Level | Clay | IB/BLC | Mid March |
| Sillbow | 50 | Level | Clay Loam | BR/BLC | Early April |

^aBR = Baltic rush (*Juncus balticus*), HSB = Hard-stemmed bulrush (*Scirpus acutus*), BLC = broad-leaved cattail (*Typha latifolia*), IB = iodine bush (*Allenrolfea occidentalis*).
^bTiming of wetland drawdown to produce swamp timothy.

The Coast Range flooded this area each winter and spring. More recently, a well-developed system delivers and removes water from the wetlands (Fredrickson and Laubhan 1995). We selected the nine wetlands as study sites because they represented the prevalent wetland management practice in The Grasslands, that of swamp timothy (*Heliochloa schoenoides*) production (Williams 1996). In The Grasslands, managers usually flood wetlands in September and October, drain them in late March and early April to stimulate germination of swamp timothy seed (Connelly 1979), and irrigate about 4-6 weeks later to maximize plant growth and seed production. During winter, when wetlands are flooded to depths of 5-50 cm, swamp timothy wetlands have large areas of open water interspersed and bordered by emergent vegetation. See Safran *et al.* (1997) and Colwell and Tait (2000) for a map and additional details on the study area.

METHODS

Bird Observations
 We collected habitat data from 24 February-25 April 1994 and 21 January-23 April 1995 by focal sampling (Altmann 1974) individuals of the six most abundant species. Although specific differences in habitat use were observed, we found no significant differences in habitat characteristics between single and triple quadrat approaches for six variables (t-test, $N = 166$ for each variable, $P \geq 0.44-0.94$). Consequently, results for waterfowl are based on: 1) observations recorded at distances <200 m, and 2) samples from three quadrats.

Table 2. Common and scientific names of eleven waterbird species studied in The Grasslands of the northern San Joaquin Valley, California during late winter and early spring of 1994 and 1995.

| Common name | Latin name | Species code | Number of birds sampled |
|----------------------------|--------------------------------------------|--------------|-------------------------|
| Last Sandpiper | <i>Calidris minutilla</i> | LESA | 44 |
| Western Sandpiper | <i>C. mauri</i> | WESA | 44 |
| Dunlin | <i>C. alpina</i> | DUNL | 47 |
| Dowitcher | <i>Limnodromus griseus, L. scolopaceus</i> | DOWI | 47 |
| Black-necked Stilt | <i>Limnodromus mexicanus</i> | BNST | 44 |
| American Avocet | <i>Recurvirostra americana</i> | AMAV | 48 |
| American Green-winged Teal | <i>Anas crecca carolinensis</i> | AGWT | 42 |
| Northern Shoveler | <i>A. clypeata</i> | NOSH | 51 |
| Northern Pintail | <i>A. acuta</i> | NOPI | 38 |
| Cadwall | <i>A. strepera</i> | GADW | 44 |

embrace of species, at use by ten water- r the northern San ysis detected strong taxa in a discrimi- rta: 1) small shore- depth constrained e large numbers of deep-water habitat test diversity of wa- and 21 December 1999, wetland, wetlands, (2): 196-203, 2000

ng block (ca. and habitat in the Grasslands) Valley, where es have been plant commu- waterfowl. The gnized for its ter 1982) and, Hunter *et al.* (74). Although specific differ- ill to effective unined simul- aterfowl and its paper is to our waterfowl managed sea- fs, and to dis-

Table 3. Habitat variables measured at locations of ten waterbird taxa foraging in wetlands of the northern San Joaquin Valley, California during late winter and early spring 1994 and 1995.

| Variable | Definition |
|--------------------------------------------|-----------------------------------------------------------------------------------------------------|
| Percentage surface cover | Percentage of m ² quadrat with cover types above or on the water or substrate surface |
| Submergent vegetation | Presence of aquatic vegetation beneath water's surface in random subplots |
| Water depth | Average depth (cm) from 10 random subplots |
| Vegetation height | Average height (cm) of vegetation in 10 random subplots |
| Maximum vegetation height | Average height (cm) of the tallest vegetation in 10 random subplots |
| Distance to emergent vegetation | Distance (m) from plot center to nearest emergent vegetation >10 cm tall |
| Distance to continuous emergent vegetation | Distance (m) from plot center to nearest emergent vegetation >10 cm and exceeding 1 m linear extent |
| Distance to aquatic-terrestrial interface | Distance (m) from plot center to water's edge |

At each bird location, we sampled habitat using a m² frame subdivided by string into 25 subplots. In each subplot, we estimated percentage surface cover type for vegetation (Table 4) by determining the number of times a cover type (open water, unvegetated mudflat, emergent vegetation, vegetative detritus, floating vegetation) occurred in the corners of each subplot (four observations in each of 25 subplots). Hence, each bird location yielded a single estimate for each cover type. For waterfowl, we calculated percentage cover by averaging values from the three sampling quadrats. We determined presence of submerged vegetation by removing and identifying all vegetation found in randomly selected subplots (five for shorebirds; nine for waterfowl). We recorded all species of emergent and submergent vegetation occurring in the quadrat. We estimated water depth as the average of observations taken with a cm-marked sampling rod placed vertically in the center of ten randomly chosen subplots. We estimated vegetation height as the above-water height (cm) of vegetation nearest the sampling rod. We calculated maximum vegetation height (cm) by measuring the tallest vegetation in each of the ten random subplots. Consequently, each observation of a foraging bird produced an average value for water depth, vegetation height, and maximum vegetation height based on ten (shorebird) or thirty (waterfowl) random subplots. We also estimated several variables based on estimated distances (0-1 m, 1-5 m, 5-10 m, 10-20 m, 20-50 m, 50-100 m, and >100 m) between a bird's location and major habitat boundaries (Table 3).

Data Summary and Analysis

We characterized each species' habitat use as the average value from the total number of focal bird observations (sample sizes given in Table 2). We converted discrete (distance) variables to median values (e.g., 0-1 m = 0.5 m) prior to analyses. Next, we used multivariate analysis of variance (MANOVA, Stevens 1992) to examine interspecific differences using most continuous variables and the three discrete variables. We did not include maximum vegetation height and percentage mudflat in final analyses because these variables correlated highly ($r > 0.90$) with vegetation height and percent open water, respectively. Also, we excluded

percentage floating vegetation because it occurred in <15% of observations for each species. Following MANOVA, we used one-way ANOVA to examine interspecific differences in individual habitat variables (Stevens 1992). When we detected significant differences we used Tukey's pair-wise comparison test to assess interspecific differences (Day and Quinn 1989). To evaluate the relative importance of variables in distinguishing habitat use among species, we used step-wise discriminant function analysis (Stevens 1992). We examined the importance of each variable included in the discriminant function by comparing the contribution of each to the Wilk's Lambda test value of the discriminant function. We examined interspecific differences in occurrence (presence/absence) of aquatic submergent vegetation, using chi-square contingency analysis followed by pair-wise chi-square tests (Zar 1984). Lastly, we compared relationships among species with regard to pairs of habitat variables (e.g., water depth and distance to aquatic-terrestrial interface), using Spearman rank correlation.

RESULTS

We detected strong interspecific differences in habitat use (MANOVA, $F = 14.4$, $P < 0.000001$); species differed for each variable we measured (Table 4). Step-wise discriminant function analysis (Table 5) identified six variables that explained 84.6% of the variation in habitat use among species. Water depth was the most important variable distinguishing among species, accounting for 86% of the Wilks' lambda value.

Species differed significantly in water depth at foraging locations, and pair-wise comparisons identified four groups of species (Table 4). Moreover, a ranking of species based on water depth correlated highly ($r_s = 0.99$, $P < 0.01$) with distance to the aquatic-

Table 4. Average (\pm SE) values for habitat variables measured at foraging locations of ten waterbird taxa using managed wetlands in the northern San Joaquin Valley, California from Jan.-April of 1994 and 1995. Sample sizes and acronyms are listed in Table 2. Results of one-way ANOVA examining interspecific differences in habitat use are presented below each variable. For each variable, species with similar ($P > 0.05$, Tukey's pair-wise comparison test) values share alphabetic codes.

| Habitat variable | Waterbird species | | | | | | | | | |
|-----------------------------------------------------|---------------------|------------------------|------------------------|---------------------------|------------------------|---------------------------|---------------------------|------------------------|---------------------|------------------------|
| | LESA | WESA | DUNL | DOWI | BNST | AMAV | AGWT | NOSH | NOPI | GADW |
| Water depth (cm) F = 142.0, P < 0.000001 | 1.0 \pm 0.1 a | 1.3 \pm 0.2 a | 3.2 \pm 0.2 a | 6.5 \pm 0.3 b | 8.4 \pm 0.6 b | 9.5 \pm 0.8 b | 13.0 \pm 0.8 c | 22.1 \pm 1.2 d | 22.5 \pm 1.3 d | 25.1 \pm 1.0 d |
| Vegetation height (cm) F = 15.7, P < 0.000001 | 2.2 \pm 0.3 a | 0.6 \pm 0.1 b, c | 0.6 \pm 0.2 b, c | 0.4 \pm 0.2 b, c | 0.9 \pm 0.2 c | 0.3 \pm 0.1 b, c | 0.4 \pm 0.1 b, c | 0.2 \pm 0.1 b | 0.2 \pm 0.1 b | 0.1 \pm 0.1 b |
| % Open water F = 26.3, P < 0.000001 | 59.9 \pm 5.5 a | 66.2 \pm 6.4 a | 93.6 \pm 2.7 b | 97.2 \pm 1.1 b | 94.4 \pm 2.0 b | 99.3 \pm 0.3 b | 97.7 \pm 0.7 b | 99.5 \pm 0.2 b | 99.4 \pm 0.4 b | 99.8 \pm 0.1 b |
| % Emergent vegetation F = 14.8, P < 0.000001 | 10.3 \pm 1.6 a | 1.5 \pm 0.8 b, c | 2.0 \pm 0.5 b, c | 1.8 \pm 0.7 b, c | 4.5 \pm 1.3 c | 0.7 \pm 0.3 b | 1.8 \pm 0.6 b, c | 0.5 \pm 0.2 b | 0.5 \pm 0.3 b | 0.2 \pm 0.1 b |
| % Vegetative detritus F = 5.2, P = 0.000001 | 3.0 \pm 0.9 a | 2.1 \pm 1.0 a | 0.0 \pm 0.0 b | 0.0 \pm 0.0 b | 0.7 \pm 0.7 b | 0.0 \pm 0.0 b | 0.1 \pm 0.1 b | 0.0 \pm 0.0 b | 0.0 \pm 0.0 b | 0.0 \pm 0.0 b |
| Distance emergent veg. F = 8.7, P < 0.000001 | 1.5 \pm 0.3 a | 6.5 \pm 0.9 a, b | 3.9 \pm 0.5 a | 3.8 \pm 0.8 a | 3.5 \pm 0.5 a | 8.9 \pm 2.1 a, b | 10.0 \pm 2.6 a, b | 13.9 \pm 3.0 b, c | 22.1 \pm 4.4 c | 13.7 \pm 2.3 b, c |
| Dist. cont. emerg. Veg. F = 4.6, P = 0.000009 | 12.9 \pm 1.8 a | 30.1 \pm 4.1 b, c | 31.0 \pm 4.0 b, c | 27.0 \pm 3.6 a, b, c | 16.1 \pm 2.5 a, b | 23.8 \pm 3.2 a, b, c | 25.6 \pm 3.6 a, b, c | 35.0 \pm 3.7 c | 36.9 \pm 4.7 c | 29.9 \pm 4.1 c |
| Dist. aqua-terr interface F = 30.7, P < 0.000001 | 1.6 \pm 0.3 a | 2.0 \pm 0.9 a | 8.5 \pm 1.3 a, b | 16.4 \pm 2.2 a, b | 16.1 \pm 2.4 a, b | 20.0 \pm 3.1 b, c | 33.0 \pm 4.4 c, d | 46.0 \pm 4.4 d, e | 50.2 \pm 5.4 e | 48.1 \pm 5.2 d, e |

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Table 5. Results of discriminant function analysis^a examining the contribution of habitat variables to explaining interspecific differences in habitat use. Sample sizes are listed in Table 2.

| Habitat variable | F | P | % Wilk's Lambda Value |
|-----------------------------------------|--------|-----------|-----------------------|
| Water depth | 141.03 | <0.000001 | 86.0 |
| % Open water | 16.27 | <0.000001 | 7.5 |
| % Emergent vegetation | 8.02 | <0.000001 | 3.2 |
| Distance aquatic-terrestrial edge | 4.06 | 0.00005 | 1.5 |
| Distance continuous emergent vegetation | 3.65 | 0.0002 | 1.2 |
| Distance emergent vegetation | 1.96 | 0.04 | 0.6 |

^aWilk's Lambda = 0.1359; eigenvalue = 3.3156; percent variation explained = 84.6; $P < 0.0001$.

terrestrial edge, indicating that shallow-water taxa occurred nearer the edge, compared with species that fed in deeper habitats. Small calidridine sandpipers used habitats averaging 1-3 (range of 95% confidence intervals: 0.8-3.6) cm depth within 10 m of the water's edge; dowitchers, Black-necked Stilt and American Avocet fed at depths of 6-10 (CI: 5.9-11.1) cm at 15-20 m from the edge. Of the four dabbling ducks, American Green-winged Teal used shallower (13 cm; CI: 11.4-14.6) habitats nearer (~33 m) the edge compared with Northern Shoveler, Northern Pintail, and Gadwall, which foraged at depths of 22-25 (CI: 19.8-27.1) cm, more than 45 m from the edge. The range of depths used by foraging birds correlated with average depth ($r_s = 0.96$, $P < 0.01$), indicating that larger ducks were more flexible in their use of habitats compared to smaller shorebird taxa.

Two additional variables, percent open water and percent emergent vegetation, contributed 7.5% and 3.2% to the discriminant function. With the exception of Least and Western sandpipers, species primarily foraged in flooded, unvegetated (>90% open water; <5% emergent vegetation) habitats. Although distances to edge and emergent vegetation differed significantly among taxa, these variables contributed relatively little to discriminating among species (Table 5). The presence of submerged vegetation varied significantly (49-81%) among species' foraging sites ($\chi^2 = 18.5$, $df = 9$, $P = 0.03$). Pair-wise comparisons indicated: Gadwall fed in locations with 81% coverage by submerged vegetation, which was not significantly different ($P > 0.05$) from values for Northern Pintail (69%), Dunlin (68%), and Western Sand-

piper (66%); remaining species fed at locations with 49-61% submerged vegetation.

DISCUSSION

We found water depth to be the most important variable distinguishing interspecific patterns of habitat use by ten species of waterbirds, a finding reported by others studying waterfowl (Taylor 1977; White and James 1978; DuBowy 1988) and shorebirds (Baker 1979; Weber and Haig 1996; Safran *et al.* 1997). Moreover, our estimates of water depth at foraging locations of dabbling ducks and shorebirds are similar to those reported elsewhere, despite different methods. Most studies estimated depth by observing individuals remotely and judging depth based on prior knowledge of wetlands or with a depth gauge. For example, Weber and Haig (1996) estimated water depths for 14 shorebird taxa using coastal impoundments in South Carolina by scan sampling plots and tallying the number of individuals of a species; for each scan, they estimated water depth using a single depth gauge (marked at ≥ 5 cm intervals) on each plot. This depth-gauge method produced very similar estimates of average depth (avocet ~8.5 cm; dowitcher ~5.0 cm; Dunlin ~3.0 cm; Western Sandpiper ~2.0 cm; Least Sandpiper ~1.0 cm) for five species we studied. DuBowy (1988) used prior knowledge of wetland depth to estimate water depth at foraging locations of seven dabbling duck species, four of which (American Green-winged Teal, Northern Shoveler, Northern Pintail, and Gadwall) were included in the present study (one of DuBowy's study sites was The

Grasslands). Average here are similar to DuBowy (1988): teal of observations at deep (38-46% at 10-20 cm) and northern pintail (27-44% at 20-30 cm) est habitats (78-90%

For waterfowl depth at foraging sites morphologies; birds to forage in habitats to them (Pöysä 198 bodied, long-necked deeper water than 1983); among shore are correlated with lengths (Baker 1979 cal pattern also exist munity we studied. water depth delineate in size: small sand teal, and large dab ings corroborate th ous authors for bot 1977; DuBowy 198 Baker 1979; Weber

An important fe ferences in habitat water depth increa cies. Data provide (1996) also reveal depths used by la which waded in deep range of depths us cates that large-bo shorebirds were ab range of depths th: versely, the short leg birds constrained t shallow water zone: During this study, se habitats that were s er, Western Sandpi lin) than at randor Isola 1998), indica habitats. The gre depths shown by v partly because duck riety of foraging ma

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Grasslands). Average water depths reported here are similar to those presented by DuBowy (1988): teal used shallowest (>50% of observations at depths estimated to be <10 cm) habitats, followed by northern shoveler (38-46% at 10-20 cm; 25-33% at 20-30 cm) and northern pintail (42-45% at 10-20 cm; 27-44% at 20-30 cm); gadwall used the deepest habitats (78-90% of observations >20 cm).

For waterfowl and shorebirds, water-depth at foraging sites varies with species' morphologies; birds are constrained by size to forage in habitats where food is available to them (Pöysä 1983). For example, large-bodied, long-necked waterfowl forage in deeper water than small species (Pöysä 1983); among shorebirds, foraging depths are correlated with culmen and tarsus lengths (Baker 1979). This eco-morphological pattern also existed in the waterbird community we studied. Pair-wise comparisons of water depth delineated four groups varying in size: small sandpipers, large shorebirds, teal, and large dabbling ducks. These findings corroborate those reported by numerous authors for both waterfowl (e.g., Taylor 1977; DuBowy 1988) and shorebirds (e.g., Baker 1979; Weber and Haig 1996).

An important feature of interspecific differences in habitat use was that variation in water depth increased with the size of species. Data provided by Weber and Haig (1996) also reveal an increase in range of depths used by larger shorebird species, which waded in deeper habitats. The greater range of depths used by larger species indicates that large-bodied dabbling ducks and shorebirds were able to feed over a greater range of depths than small shorebirds; conversely, the short legs and tarsi of small shorebirds constrained them to use mudflats or shallow water zones along the wetland edge. During this study, several shorebird taxa used habitats that were shallower (Least Sandpiper, Western Sandpiper, dowitchers, and Dunlin) than at random sites (Safran *et al.* 1997; Isola 1998), indicating selection for shallow habitats. The greater variation in water depths shown by waterfowl probably arose partly because ducks swim and use a wider variety of foraging maneuvers (e.g., tipping-up,

head-under, surface dabbling; Isola, unpubl. data) compared with shorebirds. Interestingly, teal, the smallest waterfowl species, foraged in water that was shallower than random locations (Isola 1998), suggesting that habitat use by small dabbling ducks may also be constrained by water depth.

Management Implications

In The Grasslands, managers have traditionally manipulated wetlands for waterfowl. These practices often involved maintaining deep-water (>25 cm) habitats during winter and early spring, followed by drawdowns to stimulate germination of moist-soil plants (Williams 1996; Isola 1998). In part, this pattern arose from a limited water supply, necessitating deep flooding of wetlands as an insurance against unpredictable and short water supplies later in the year. With passage of the Central Valley Project Improvement Act in 1992, managers now have a predictable water supply, resulting in greater ability to maintain wetlands at shallower depths with a constant flow of water. Changes in water supply provide the opportunity to manage wetlands for a greater diversity of species, while maintaining approaches that benefit waterfowl.

Interspecific differences in use of habitats varying in depth (Table 4), selection of shallow habitats by shorebirds and teal (Safran *et al.* 1997; Isola 1998), and morphological constraints on use of shallow habitats by shorebirds (Baker 1979) and teal (DuBowy 1988) indicate that traditional management practices can be altered to benefit shorebirds and waterfowl. The following suggestions apply to landscape and/or wetland-level management. In either case, management requires region-specific knowledge of seasonal variation in waterbird abundance (Davis and Smith 1998), so that manipulations are timed to coincide with the greatest needs of different waterbird groups.

During late winter (January/mid-March), a time when The Grasslands supports large numbers of waterfowl (Gilmer *et al.* 1982) and shorebirds (Shuford *et al.* 1993, 1994), deep-water conditions prevail across the

landscape and shallow habitats are scarce. We propose that managers provide increased amounts of shallow-water habitat by conducting: 1) partial drawdowns of some wetlands, and 2) slow drawdowns (>2 weeks) to prolong availability of shallow habitats and food, especially for shorebirds and teal. These late-winter drawdowns would benefit wintering populations (~60,000) of shorebirds (Shuford *et al.* 1993, 1994) and (~300,000) American Green-winged Teal, both of which use shallow habitats. Late winter drawdowns also could increase plant diversity by promoting various winter-germinating plants.

In early spring (mid-March through April), when shorebird abundance increases with migration (Shuford *et al.* 1993, 1994) and wetland managers traditionally conduct drawdowns of moist-soil wetlands, we believe that managers could increase the availability of shallow-water habitats (and food availability) by conducting slow drawdowns (approximately two weeks). Currently, most wetlands in The Grasslands are drawn down in late-March/early April to germinate swamp timothy. Hence, this prescription is not at odds with traditional wetland management aimed at waterfowl.

Finally, during both winter and spring, we propose that wetlands be managed at average water depths of 15-20 cm (Williams 1996). In wetlands with variable bottom topography this prescription would provide the range of habitats necessary to attract shorebirds, dabbling ducks, and most diving waterbirds. Nevertheless, it is essential to maintain some wetlands with deep-water habitats for diving waterbirds.

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