Wetland use by non-breeding ducks in coastal Texas, U.S.A.

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Wetland use by nonbreeding ducks in coastal Texas in the areas between Galveston Bay and the Rio Grande were studied, September 1991 to March 1993, to determine the most important wetland types based on density. Twenty-five species of ducks were observed using wetlands on a stratified (based on dominant land use) random sample of 64.75 ha (one-quarter section) plots. Ranks of density for all ducks, as a group, were highest in lacustrine littoral emergent nonpersistent wetlands. Anatini density ranks were greatest in wetlands with scrub-shrub vegetation, but individual species' ranks varied. Dendrocygnini and Aythyini density ranks were highest in lacustrine littoral wetlands, particularly those with aquatic-bed vegetation. Ducks depend on a wide array of wetland types (including 48 of 82 available subclasses), and management should provide complexes of wetlands. Management should concentrate on protecting, enhancing, and/or creating 15 of 1,201 wetland types occurring in the coastal plains of Texas that were prioritized for management actions. These wetlands were predominantly aquatic-bed, scrub-shrub, and unconsolidated substrate types.

Key Words: *Anas* spp., *Aythya* spp., coastal Texas, dabbling ducks, *Dendrocygnini,* diving ducks, Ruddy Duck, wetland use.

The Texas Gulf Coast marshes and associated rice prairie lands are the most important wintering grounds for waterfowl in the Central Flyway and one of the most important wintering areas for waterfowl in North America, harbouring ≥45% of the ducks and 90% of the geese wintering in the Central Flyway (Bellrose 1980:52; Adair *et al.* 1996; Anderson & DuBowy1996; Anderson *et al.* 1998; Gabrey *et al.* 1999). The lower and middle Texas Coast winters 40-50% of Gadwalls *Anas strepera*, 40-80% of Green-winged Teal *A. carolinensis*, 40-60% of Northern Pintails *A. acuta*, and 50-65% of Northern Shovelers *A. clypeata* in the Central Flyway each year (Texas Mid-coast Initiative Team 1990). American Wigeon *A. americana*, Mottled Duck *A. fulvigula*, Redhead *Aythya americana*, Lesser Scaup *A. affinis*, Ruddy Duck *Oxyura jamaicensis*, Black-bellied Whistling-duck *Dendrocygna autumnalis*, and Fulvous Whistling-duck *D. bicolor* also are common (Anderson *et al.* 1998). An estimated 3.5 million ducks were in the lower and middle coastal plains of Texas in January 1993 (Anderson *et al.* 1998). The area is also important to migrating waterfowl, including an average of more than 500,000 Blue-winged Teal *A. discors* in September (Anderson *et al.* 1998).

An estimated 350,000 ha of wetlands were present in the coastal zone from Galveston Bay south to the Rio Grande in January 1993 (Muehl *et al.* 1994). Texas has lost >52% of its pre-settlement wetland area (Dahl 1990). In the Chenier Plain of Texas, 42,000 ha of wetlands were destroyed between the mid 1960s and 1990 (Tacha *et al.* 1993). Palustrine emergent and palustrine forested wetlands have declined the most (Moulton *et al.* 1997). Wetlands along the Texas Coast face continued destruction from human activities and natural deterioration (Stutzenbaker & Weller 1989; Tacha *et al.* 1993; Moulton *et al.* 1997).

Little data exists on waterfowl use of various wetland types in coastal Texas (Hobaugh *et al.* 1989; Stutzenbaker & Weller 1989; Tietje & Teer 1996; Weller *et al.* 1996; Anderson *et al.* 1999). Studies historically have concentrated on factors affecting waterfowl on the breeding grounds; only in recent decades have wintering grounds received attention (Weller 1988; Bolen 2000). Most emphasis on wintering waterfowl studies has been placed on species-specific biology rather than on habitat and related management (Smith *et al.* 1989; Bolen 2000). Characteristics of wetland habitats chosen by wintering and migrating waterfowl need to be addressed (Tietje & Teer 1996; Gordon *et al.* 1998; Anderson & Smith 1999; Anderson *et al.* 1999). Conditions on wintering grounds can influence the survival and recruitment of waterfowl (Heitmeyer & Fredrickson 1981; Kaminski & Gluesing 1987; Bergan & Smith 1993; Dubovsky& Kaminski 1994; Jorde *et al.* 1995). The objective of this study was to prioritize wetland types for management to benefit non-breeding ducks in the coastal plains of Texas.

Study Area

The study area consisted of 24 coastal Texas counties covering 5,504,389 ha and occurred from Galveston Bay south to the Rio Grande (Anderson *et al.* 1996; 1998; 1999). The study area is dominated by coastal marsh and rice fields to the north and sandy plains and coastal prairie to the south (Anderson *et al.* 1998). Palustrine and estuarine wetlands (Cowardin *et al.* 1979) are the most abundant wetland systems in the area (Muehl *et al.* 1994).

Palustrine emergent wetlands were dominated by *Phragmites australis, Scirpus californicus, Spartina spartinae, Typha domingensis, and Zizaniopsis milacea* (Anderson & Tacha 1998). A more complete description of the study area is provided in Anderson *et al.* (1996; 1998; 1999).

Methods

Stratification

The study area was divided into six strata (Rice Prairie, Coastal, Other Crop, Cotton, Range, and Produce) based on major physiographic regions and land use practices (Anderson *et al.* 1996; 1998; 1999). In 1991-92, map co-ordinates were used to randomly select 512, 64.75 ha (one-quarter section) plots in relative proportion to strata size (Rice Prairie 201, Coastal 25, Other Crop 64, Cotton 25, Range 111, and Produce 86) (Anderson *et al.* 1996; 1998; 1999). In 1992-93, the number of plots were increased and reallocated among strata to decrease variance of population estimates (Kish 1965) based on total ducks counted in January 1992 (Anderson *et al.* 1996; 1998). In 1992-93 1,009 plots (Rice Prairie 241, Coastal 273, Other Crop 86, Cotton 136, Range 46 and Produce 227) were allocated among strata (Anderson *et al.* 1999).

After plots were randomly selected within strata, access permission was obtained or the plot was replaced with another randomly selected plot (Anderson *et al.* 1996; 1998). Surveys were not conducted on national wildlife refuges located on large bays or island habitats as these areas were not conducive to ground surveys (Anderson *et al.* 1999). Similar stratified random sample surveys of plots have been conducted in the Dakotas (Stewart & Kantrud 1972; Brewster *et al.* 1976), Oklahoma (Heitmeyer 1980), and Atlantic Flyway states (Heusmann & Sauer 2000).

Observations

Plots were surveyed once during each two-week survey period (late September, late November, early January, and late March 1991-92 and 1992-93) to count ducks and classify wetlands (Anderson *et al.* 1996; 1998). Counts were conducted throughout the day, but were not conducted on plots where waterfowl hunting was known to have occurred during that day (Anderson *et al.* 1999). Counts took from 10 to 60 minutes per quarter-section to complete. All ducks were counted by species and wetland type where they occurred.

Wetland Classification

All wetlands and deep-water habitats on plots were classified according to Cowardin *et al.* (1979). System, subsystem, class, and subclass were recorded for each wetland and subsequently referred to as wetland subclasses.

Seven modifiers (i.e. wetland alteration, water regime, salinity, soil type, size, presence or absence of aquatic-bed vegetation, and vegetation pattern) also were determined for each wetland. Wetland alterations were placed into one of three categories: farmed, man-made, or natural. Wetlands were considered man-made if there was evidence of excavation, impoundments, or dikes. Water regimes were classified as permanent, seasonal, or temporary. Eight water regimes of Cowardin *et al.* (1979) were included in the permanently flooded category: subtidal, irregularly exposed, regularly flooded, permanently flooded, intermittently exposed, semi-permanently flooded, permanently flooded-tidal, and semi-permanently flooded-tidal. Three water regimes were included in the seasonally flooded category: seasonally flooded, artificially flooded, and seasonally flooded-tidal. Five water regimes were included in the temporarily flooded category: irregularly flooded, saturated, temporarily flooded, intermittently flooded, and temporarily flooded-tidal. Salinity was measured at six points equally spaced along a transect bisecting the wetland using a battery-operated salinity-temperature meter; the average of the six salinity readings was used in analyses. Salinity was then categorized in six levels (Cowardin *et al.* 1979).

Soil type (mineral or organic) was determined in the field based on rubbed fibre content (Soil Conservation Service 1975; Cowardin *et al.* 1979; Muehl *et al.* 1994). Wetland size was determined following techniques of Millar (1973), and placed into one of three categories: <0.5, ≥0.5 but <5, and ≥5 ha. Wetland size was recorded during each count period as the area of a wetland covered by water. Aquatic-bed vegetation (algae, rooted vascular, and floating vascular species) was recorded as present or absent. Distribution pattern of emergent, scrub-shrub, or forested vegetation was recorded for each wetland as cover type 1-4 following Stewart & Kantrud (1971).

Data analyses

Habitat use was analysed for each abundant (≥ 1,000 observations) duck species or taxonomic group. Data were combined across initiative areas, count periods, and years for analyses (Anderson *et al.* 1996; 1998). Data for all ducks analysed by count periods and initiative area suggested little difference from the combined data, and therefore only overall data are presented (Anderson 1994). Observations of the same wetland basin in successive count periods and years were considered independent because wetlands were so dynamic (i.e. dried or flooded; Muehl *et al.* 1994), count periods were two months apart (Anderson *et al.* 1996), and the number of birds on wetlands varied (Anderson *et al.* 1996; 1998; 1999). Wetlands served as the experimental unit. For data from a count period to be included in a habitat analysis for a species or group, ≥10% of all observations of that species or group in that count year must have occurred during that count period. This was done to avoid periods when there were not enough birds of a given species present to detect them even in the most preferred habitats (Anderson *et al.* 1996). Only wetland types that a species or group occurred on, and wetland types that were adequately sampled (n≥3), were used for that species or group analysis.

Density was calculated for each species or group on each wetland as number of birds/ha of water. All wetlands where a species or group occurred were included in analyses. All density observations were rank-transformed, because (based on visual inspection) data were not normally distributed (Conover & Iman 1981; Potvin & Roff 1993). Density ranks were dependent variables in one-way analyses of variance; the independent variables were wetland types (Anderson 1994; Anderson *et al.* 1996). All analyses were performed using SAS (SAS Institute Inc. 1990) and ∞=0.10 (Anderson *et al.* 1999). Data were not back-transformed because overall density did not always correspond to density ranks (Anderson *et al.* 1996). The top 15 wetland types (based on density ranks) for each taxonomic group are presented in tables due to space constraints. Complete lists of wetland types used by species and groups of ducks are found in Anderson (1994).

Results

Twenty-five species of ducks were observed using wetlands in the study area, but only 12 were abundant enough for analyses (**Table 1**). Eighty-two subclasses of wetlands occurred on the study area, including 25 estuarine, 20 riverine, 16 lacustrine, and 21 palustrine. Wetland abundance data are in Muehl (1994) and Muehl *et al.* (1994).

Total Ducks

Ducks used 48 wetland types that represented 98.4% of the available wetland habitat in the study area. Density ranks were highest in permanently flooded estuarine and lacustrine littoral wetlands, especially lacustrine littoral emergent non-persistent wetlands that were natural and that had fresh water and open water interspersed with emergent vegetation (**Table 2**).

Dendrocygnini

Two species of Whistling-ducks used 27 wetland types that represented 47.0% of the available wetland habitat in the study area. Density ranks were highest in natural fresh water wetlands, especially wetlands that were lacustrine littoral, permanently flooded, and that had aquatic-bed vegetation and emergent vegetation interspersed with open water (**Table 3**). Black-bellied Whistling-ducks used 29 wetland types that represented 42.4% of the available wetland habitat in the study area. Density ranks were highest in permanently flooded aquatic-bed wetlands with mineral soils, especially palustrine aquatic-bed algal wetlands that were mesosaline or fresh and had open water interspersed with emergent vegetation (**Table 3**).

Fulvous Whistling-ducks used 11 wetland types that represented 47.2% of the available wetland habitat in the study area. Density ranks were highest in natural, permanently flooded, freshwater aquatic-bed wetlands, especially palustrine aquatic-bed rooted vascular wetlands (**Table 3**).

Anatini

Ten species of dabbling ducks used 47 wetland types that represented 91.5% of the available wetland habitat in the study area. Density ranks were highest in palustrine scrub-shrub wetland types dominated by dead or needle-leaved shrubs and lacustrine littoral emergent non-persistent wetlands (**Table 4**). American Wigeon used 28 wetland types that represented 46.5% of the available wetland habitat in the study area. Density ranks were highest in natural, permanently flooded estuarine wetlands, especially wetlands that were subtidal, polyhaline, ≥5 ha in size, and that had mud substrates and aquatic-bed vegetation (**Table 4**).

Blue-winged Teal used 36 wetland types that represented 86.9% of the available wetland habitat in the study area. Density ranks were highest in wetlands with open water interspersed with shrubs or emergent vegetation (**Table 4**), especially palustrine scrub-shrub needle-leaved evergreen wetlands that were man-made, had low salinity, and were ≥5 ha in size. Gadwalls used 29 wetland types that represented 72.1% of the available wetland habitat in the study area. Density ranks were highest in permanently flooded

Table 1. Number of individuals, number of flocks, and number of wetland types that species and groups of ducks occurred on in 64.75 ha (one-quarter section) study plots, in the coastal plains of Texas during September and November 1991 and 1992, and January and March 1992 and 1993.

Species	No. birds	No. flocks	No. wetland types
Dendrocygnini[a]	4,575	124	34
Black-bellied Whistling-duck	3,538	101	29
Fulvous Whistling-duck	1,037	33	11
Anatini[b]	159,207	823	47
American Wigeon	22,902	137	28
Blue-winged Teal	23,838	302	36
Gadwall	5,509	143	29
Green-winged Teal	49,207	200	39
Mottled Duck	6,295	504	40
Northern Pintail	39,149	164	35
Northern Shoveler	9,373	244	37
Aythyini[c]	9,883	146	36
Lesser Scaup	1,539	75	28
Redhead	7,407	42	20
Ruddy Duck	4,401	70	25
Total Ducks[d]	178,958	975	48

[a] Dendrocygnini include Black-bellied and Fulvous Whistling-ducks.

[b] Anatini include seven Dabbling Ducks in table, American Black Duck *Anas rubripes*, Mallard *A. platyrhynchos*, and Cinnamon Teal *A. cyanoptera*.

[c] Aythyini include Canvasback *Aythya valisineria*, Redhead, Ring-necked Duck *A. collaris*, and Lesser Scaup.

[d] Total ducks include all of the above, plus Wood Duck *Aix sponsa*, White-winged Scoter *Melanitta fusca*, Bufflehead *Bucephala albeola*, Common Goldeneye *B. clangula*, Hooded Merganser *Lophodytes cucullatus*, Common Merganser *Mergus merganser*, Red-breasted Merganser *M. serrator*, and Masked Ducks *Oxyura dominica*.

estuarine and lacustrine wetlands that were ≥5 ha in size (**Table 4**). Density ranks were especially high in estuarine intertidal unconsolidated shore organic wetlands that had low salinity.

Green-winged Teal used 39 wetland types that represented 80.9% of the available wetland habitat in the study area. Density ranks were highest in permanently or seasonally flooded lacustrine and palustrine wetlands, especially lacustrine littoral unconsolidated shore organic wetlands that were farmed, and seasonally flooded with fresh water (**Table 4**).

Mottled Ducks used 40 wetland types that represented 73.3% of the available wetland habitat in the study area. Density ranks were highest in natural or man-made wetlands with ≥30% vegetation, especially palustrine scrub-shrub dead wetlands that

Table 2. The most important wetland types[a] based on density (no./ha) ranks[b] for all ducks in the coastal plains of Texas during 1991-92 and 1992-93.

Wetland Type	Rank
L2EM2, permanently or seasonally flooded, fresh water, ≥5 ha, open water interspersed with emergent vegetation.	1
E1UB1, natural, permanently flooded, poly- or mesohaline, mineral soil, ≥5 ha, aquatic-bed vegetation present, ≥95% open water.	2
L2AB3, man-made or natural, permanently flooded, fresh water, mineral soil, ≥5 ha	3
E2AB3, man-made or natural, permanently flooded	4
E2US4, man-made or natural	5
PSS4, man-made, oligosaline or fresh, mineral soil, ≥0.5 ha, open water interspersed with scrub-shrub vegetation	6
E2AB1, man-made or natural, oligohaline	7
L2AB4, man-made or natural, permanently flooded, oligosaline or fresh, mineral soil, ≥5 ha	8
E2AB3, man-made or natural, permanently flooded, oligohaline, ≥95% open water	9
L1RB2, man-made, permanently flooded, fresh water, mineral soil, ≥5 ha, ≥95% open water	10
E1UB4, man-made or natural, permanently flooded, fresh water, mineral soil, ≥5 ha, ≥95%, open water	11
E2US3, permanently or temporarily flooded, oligohaline, ≥95% open water	12
E1UB2, natural, permanently flooded, mineral soil, ≥0.5 ha, ≥95% open water	13
PAB3, man-made or natural, permanently or seasonally flooded, mineral soil	14
L2UB3, man-made, permanently flooded, mineral soil, ≥95% open water	15

[a] Only the top 15 wetland types (based on density ranks) used by ducks are included in the table; see Anderson (1994) for complete listings. Wetland types are modified from Cowardin *et al.* (1979). See **Appendix 1** for wetland codes.

[b] Density ranks ($F_{27,1,426}$=16.39, P<0.001) varied among wetland types used by ducks.

[c] Proportion feeding ranks ($F_{23,1,371}$=14.80, P<0.001) varied among wetland types used by ducks.

Table 3. The most important wetland types based on density (no./ha) ranks for Whistling-ducks, in the coastal plains of Texas during 1991-92 and 1992-93.

	Rank		
Wetland Type[a]	Black-bellied Whistling-duck[b]	Fulvous Whistling-duck[c]	Total Dendrocygnini[d]
L2UB3, man-made or natural, permanently flooded, fresh water, mineral soil, ≥5 ha, aquatic-bed vegetation present, open water interspersed with emergent vegetation.	3	0	1
L2AB4, natural, permanently flooded, fresh water, mineral soil, ≥5 ha, open water interspersed with emergent vegetation	10	2	2
PEM2, man-made, permanently flooded, fresh water, mineral soil, ≤0.5 ha, aquatic-bed vegetation present, open water interspersed with emergent vegetation or exterior rings of emergent vegetation	6	0	3
PSS5, permanently flooded, fresh water, mineral soil, ≥0.5 and <5 ha, open water interspersed with scrub-shrub vegetation	7	0	4
PAB4, man-made, permanently flooded, fresh water, organic soil, <5 ha, exterior rings of vegetation or ≥95% open water	8	0	5
L2UB1, man-made, permanently flooded, fresh water, mineral soil, ≥5 ha, open water interspersed with emergent vegetation	4	0	6
E2US2, natural, permanently flooded, polyhaline, ≥5 ha, aquatic-bed vegetation present, ≥95% open water	9	0	7
E1UB1, natural, permanently flooded, polyhaline, ≥5 ha, aquatic-bed vegetation present, ≥95% open water	11	0	8
PUS4, natural, seasonally flooded, fresh water, ≥0.5 and <5 ha, ≥95% open water	12	0	9
L2AB3, man-made, permanently flooded, fresh water, mineral soil, ≥5 ha, ≥95% open water	13	0	10
PAB1, permanently flooded, mesosaline or fresh water, mineral soil, <5 ha, open water interspersed with emergent vegetation or ≥95% open water	1	0	11
PUS5, man-made, temporarily flooded, fresh water, <5 ha, aquatic-bed vegetation present	0	3	12
L2UB3, man-made, permanently flooded, fresh water, mineral soil, ≥5 ha, ≥95% open water	15	9	13
PAB3, permanently flooded, open water interspersed with emergent vegetation or ≥95% open water	20	1	14
E2US4, permanently flooded, meso- or oligohaline, ≥0.5 ha	16	0	15

[a] Only the top 15 wetland types (based on density ranks) used by Whistling-ducks are included in the table; see Anderson (1994) for complete listings. Wetland types are modified from Cowardin *et al.* (1979). See Appendix 1 for wetland codes.
[b] Density ranks ($F_{28,2059} = 6.89$, $P<0.001$) varied among wetland types used by Black-bellied Whistling-ducks.
[c] Density ranks ($F_{10,663} = 4.00$, $P<0.001$) varied among wetland types used by Fulvous Whistling-ducks
[d] Density ranks ($F_{26,2359} = 5.29$, $P<0.001$) varied among wetland types used by Whistling-ducks

Table 4: the most important wetland types based on density (no./ha) ranks for dabbling ducks in the coastal plains of Texas during 1991-92 and 1992-93.

Wetland Type[a]	Density Rank							
	American Wigeon[b]	Blue-winged Teal[c]	Gadwall[d]	Green-winged Teal[e]	Mottled Duck[f]	Northern Pintail[g]	Northern Shoveler[h]	Total Anatini[i]
PSS5, natural, permanently flooded, fresh water, mineral soil, <5 ha, open water interspersed with shrub vegetation	0	0	0	8	1	12	3	1
PSS4, man-made, mineral soil, ≥5 ha, open water interpsersed with shrub vegetation	0	1	0	0	7	0	10	2
L2EM2, natural, permanently or seasonally flooded, fresh water, ≥5 ha, open water interspersed with vegetation	10	2	4	0	4	0	0	3
E1UB1, natural, permanently flooded, polyhaline, mineral soil, ≥5 ha, aquatic-bed vegetation present, ≥95% open water	1	11	0	0	0	2	2	4
E2AB1, natural, meso- or oligohaline, ≥5 ha	7	13	9	24	2	7	4	5
E2AB3, natural, permanently flooded	3	7	5	7	3	8	0	6
L2AB3, permanently flooded, fresh water, mineral soil, ≥5 ha	14	8	2	14	8	19	6	7
E2US4, ≥5 ha	8	4	1	6	6	6	9	8
E1AB1, natural, permanently flooded, meso- or oligohaline, mineral soil, ≥5 ha, ≥95% open water or exterior rings of vegetation	11	17	0	12	22	9	7	9
E1UB4, permanently flooded, meso- or oligohaline, ≥5 ha, ≥95% open water or exterior rings of vegetation	13	21	3	18	15	0	0	10
E1AB3, permanently flooded	2	19	12	27	0	10	11	11
E2US3, oligohaline, mineral soil, ≥0.5 ha	15	12	11	16	9	23	8	12
E1UB2, natural, permanently flooded, mesohaline, mineral soil, ≥5 ha, ≥95% open water	12	0	0	0	18	17	0	13
R2AB4, man-made, permanently flooded, fresh water, <5 ha	4	0	6	5	16	0	12	14
PUS4, fresh water, organic soil	0	26	16	23	5	35	24	15

a Only the top 15 wetland types (based on density ranks) used by dabbling ducks are included in this table; see Anderson (1994) for complete listings. Wetland types are modified from Cowardin *et al.* (1979). See **Appendix I** for wetland codes. **b** Density ranks ($F_{27,1717}$ = 12.77, P<0.001) varied among wetland types used by American Wigeon. **c** Density ranks ($F_{35,3528}$ = 9.52, P<0.001) varied among wetland types used by Blue-winged Teal. **d** Density ranks ($F_{28,2672}$ = 8.77, P<0.001) varied among wetland types used by Gadwall. **e** Density ranks ($F_{38,2871}$ = 12.94, P<0.001) varied among wetland types used by Green-winged Teal. **f** Density ranks ($F_{39,5228}$ = 19.94, P<0.001) varied among wetland types used by Mottled Ducks. **g** Density ranks ($F_{34,1773}$ = 15.48, P<0.001) varied among wetland types used by Northern Pintail. **h** Density ranks ($F_{36,3117}$ = 7.61, P<0.001) varied among wetland types used by Northern Shoveler. **i** Density Ranks ($F_{46,5250}$ = 22.55, P<0.001) varied among wetland types used by dabbling ducks.

were natural, permanently flooded with fresh water, and had mineral soil and shrubs interspersed with open water (**Table 4**).

Northern Pintails used 35 wetland types that represented 55.8% of the available wetland habitat in the study area. Density ranks were highest in large lacustrine and estuarine wetlands, especially lacustrine littoral wetlands that were farmed or man-made, seasonally flooded with fresh water, and had organic soil and ≥95% open water (**Table 4**).

Northern Shovelers used 37 wetland types that represented 81.2% of the available wetland habitat in the study area. Density ranks were highest in lacustrine littoral unconsolidated shore organic wetlands that were seasonally flooded and man-made or farmed. Density ranks also were high in estuarine subtidal unconsolidated bottom cobble-gravel and aquatic-bed algal wetlands (**Table 3**).

Aythyini

Four species of diving ducks used 36 wetland types that represented 42.4% of the available wetland habitat in the study area. Density ranks were highest in permanently flooded lacustrine littoral wetlands with aquatic-bed vegetation, mineral soil, and fresh water, especially natural unconsolidated bottom mud wetlands with emergent vegetation interspersed with open water (**Table 5**). Lesser Scaup used 28 wetland types that represented 35.6% of the available wetland habitat in the study area. Density ranks were highest in large permanently flooded wetlands with unconsolidated substrates, especially palustrine unconsolidated bottom mud wetlands that were man-made or natural, and oligosaline (**Table 5**). Density ranks also were high in lacustrine littoral unconsolidated bottom mud wetland types with fresh water. Redheads used 20 wetland types that represented 26.0% of the available wetland habitat in the study area. Density and proportion feeding ranks were highest in estuarine subtidal unconsolidated bottom cobble-gravel wetlands that were natural, polyhaline, ≥5 ha in size, and had aquatic-bed vegetation (**Table 5**).

Oxyurini

Ruddy Ducks used 25 wetland types that represented 26.0% of the available wetland habitat in the study area. Density ranks were highest in estuarine wetlands with unconsolidated substrates (**Table 6**).

Discussion

Total Ducks

Management for all ducks must consider the 48 wetland types they occupied, because ducks used wetlands representing almost all available wetland area. However, providing lacustrine littoral wetlands with abundant seed-producing vegetation should be a management priority. These were large moist-soil managed areas and unmanaged areas dominated by annual plants. Moist-soil managed wetlands provide abundant seeds and invertebrates that attract waterfowl and other waterbirds (Fredrickson & Taylor 1982; Haukos & Smith 1993; Anderson & Smith 1998; 1999; Gray *et al.* 1999).

In general, farmed wetland types were not heavily used by ducks as a group but they were important to specific species. Indeed, flooded rice stubble and shallow goose roost ponds were important in this study and others (Miller 1987; Hobaugh *et al.* 1989; Cox & Afton 1997; Miller &

Newton 1999). Natural wetlands appeared to be of most value to ducks. However, non-breeding ducks in coastal Texas were more abundant in freshwater man-made impoundments (Weller *et al.* 1996) than adjacent natural estuarine wetlands (Weller 1994). This may be caused by differences in wetland type rather than wetland alteration category, as fresh water wetlands are valuable in coastal areas (Briggs & Everett 1983; Adair *et al.* 1996; Tietje & Teer 1996). Indeed, Northern Shovelers feeding in fresh water wetlands are in better condition than those feeding in saline wetlands (Tietje & Teer 1996). Invertebrate abundance and avian use in some manmade wetlands are similar to densities found in natural wetlands (Ashley *et al.* 2000). Heitmeyer (1980) found that most ducks preferred natural over man-made wetlands in Oklahoma.

This study generally found larger wetlands to be used more than smaller wetlands, but all were of value. Density ranks of ducks were generally highest in wetlands ≥5 ha in size. Small wetlands are important to some waterbirds (Briggs & Everett 1983; Anderson *et al.* 1996) and other wetland-dependent wildlife (Gibbs 1993). Larger wetlands generally provide greater habitat diversity, increased protection from predators and humans, and more food resources than smaller wetlands (Nudds & Ankney 1982; Anderson *et al.* 1996). More small (≤5 ha) than large (≥5 ha) wetlands were present in the study area, but the majority of the total wetland area was comprised of large wetlands (Muehl *et al.* 1994).

Mineral soils were associated with wetlands most used by ducks. The majority of farmed wetlands had organic soils; by avoiding some types of farmed wetlands, ducks also avoided organic soil (Anderson 1994). Mineral soils in wetlands indicate efficient internal nutrient cycling and potentially high productivity (Haukos & Smith 1996). Organic soils can be a result of high litter fall and may harbour large invertebrate populations that are essential foods for ducks (Kaminski & Prince 1981; Watt & Golladay 1999). However, many of these wetlands were only flooded for several days to a few weeks (temporarily flooded), and this may have prevented invertebrates from reaching high densities (Murkin *et al.* 1982; Batzer *et al.* 1993; Anderson & Smith 2000). Additionally, farmed wetlands may have lower invertebrate densities due to pesticide use on crops (Eisler 1985; Wildhaber & Schmitt 1998). Waterfowl densities in Arkansas and Mississippi were greater on wetlands dominated by moist-soil plants than on flooded agricultural fields (Twedt & Nelms 1999).

As in our study, Heitmeyer (1980) found that many species of ducks preferred wetlands with aquatic-bed vegetation. However, not all species had high densities in aquatic-bed wetland types. Many used other wetland types that had some aquatic-bed vegetation present. Preference for wetlands with aquatic-bed vegetation may be related to use of plants as food (Mitchell *et al.* 1994; Gordon *et al.* 1998), consumption of invertebrates on plants (Olson *et al.* 1995), or provision of cover (White & James 1978; Thompson & Baldassarre 1988; Anderson *et al.* 1996). Ducks generally preferred permanently flooded wetland types. This may be related to aquatic-bed vegetation, as many submergent plant species grow best in stable or permanently flooded wetland areas (Prevost 1987; Davis & Short 1997).

Wetlands with exterior rings of emergent vegetation or open water interspersed with emergent vegetation had higher densities than those with ≥95%

Table 5. The most important wetland types based on density (no./ha) ranks for diving ducks in the coastal plains of Texas during 1991-92 and 1992-93.

Wetland Type[a]	Density Rank: Lesser Scaup[b]	Density Rank: Redhead[c]	Density Rank: Total Aythyini[d]
L2UB3, man-made or natural, permanently flooded, fresh water, mineral soil, ≥5 ha, open water interspersed with vegetation or ≥95% open water	2	14	1
L2AB4, permanently flooded, fresh water, mineral soil, ≥5 ha, open water interspersed with emergent vegetation	7	0	2
E1UB2, natural, permanently flooded, mesohaline, mineral soil, ≥5 ha, ≥95% open water	0	4	3
PEM1, permenantly flooded, fresh water, aquatic-bed vegetation present, open water interspersed with emergent vegetation or exterior rings of emergent vegetation	14	15	4
PUB3, permanently flooded, mineral soil, ≥5 ha, exterior rings of vegetation or ≥95% open water	1	8	5
E1UB1, natural, permanently flooded, polyhaline, mineral soil, ≥5 ha, aquatic-bed vegetation present, ≥95% open water	0	1	6
L2AB3, permanently flooded, fresh water, mineral soil, ≥5 ha, open water interspersed with emergent vegetation or ≥95% open water	8	10	7
PAB3, permanently flooded, oligosaline or fresh, mineral soil, ≥0.5 ha	9	16	8
PUB4, man-made, permanently flooded, oligosaline or fresh, ≥5 ha, aquatic-bed vegetation absent, exterior rings of vegetation or ≥95% open water	10	0	9
E2AB1, natural, permanently flooded, ≥0.5 ha, ≥95% open water	6	0	10
E1UB4, natural, permanently flooded, mesohaline, ≥5 ha, aquatic-bed vegetation absent, exterior rings of vegetation of ≥95% open water	0	0	11
E1UB3, permanently flooded, polyhaline, mineral soil, ≥5 ha, ≥95% open water	24	7	12
PUB2, man-made, permanently flooded, fresh water, mineral soil, ≥0.5 ha, and <5 ha, aquatic-bed vegetation absent, exterior rings of emergent vegetation or ≥95% open water	11	0	13
E1AB3, permanently flooded, ≥5 ha, ≥95% open water	23	2	14
L2RB2, man-made, permanently flooded, fresh water, ≥5 ha, aquatic-bed vegetation present, ≥95% open water	12	0	15

a Only the top 15 wetland types (based on density ranks) used by diving ducks are included in the table; see Anderson (1994) for complete listings. Wetland types are modified from Cowardin *et al.* (1979). See **Appendix 1** for wetland codes. **b** Density ranks ($F_{27,1426}$ = 16.39, P<0.001) varied among wetland types used by Lessar Scaup. **c** Density ranks ($F_{19,581}$ = 6.06, P<0.001) varied among wetland types used by Redheads. **d** Density ranks ($F_{35,1855}$ = 18.58, P<0.001) varied among wetland types used by diving ducks.

Table 6. The most important wetlands types[a] based on density (no./ha) ranks[b] for Ruddy Ducks in the coastal plains of Texas during 1991-92 and 1992-93.

Wetland Type	Rank
E1UB, natural, permanently flooded, meso- or oligohaline, ≥5 ha, ≥95% open water	1
E2US3, man-made, permanently flooded, meso- or oligohaline, ≥5 ha	2
L1RB2, man-made, permanently flooded, fresh water, mineral soil, ≥5 ha, ≥95% open water	3
PAB3, man-made, permanently flooded, fresh water, mineral soil, ≥0.5 ha, open water interspersed with emergent vegetation	4
L2AB3, man-made, permanently flooded, fresh water, mineral soil, ≥5 ha, ≥95% open water	5
PEM1, man-made or natural, permanently flooded, oligosaline or fresh, mineral soil, ≥95% open water	6
PUS3, man-made, seasonally flooded, ≥0.5 and <5 ha, ≥95% open water	7
PSS4, man-made, seasonally or temporarily flooded, fresh water, mineral soil, open water interspersed with scrub-shrub vegetation	8
PAB1, man-made, permanently flooded, mesosaline, mineral soil, <5 ha, ≥95% open water	9
L2AB4, permanently flooded, fresh water, mineral soil, ≥5 ha, open water interspersed with emergent vegetation or ≥95% open water	10
L2US4, man-made, seasonally flooded, fresh water, ≥5 ha, ≥95% open water or exterior rings of vegetation	11
L1UB3, man-made, permanently flooded, fresh water, <0.5 ha, ≥95% open water	12
E1AB3, natural, permanently flooded, mesohaline, mineral soil, ≥5 ha, ≥95% open water	13
L2UB1, man-made, permanently flooded, fresh water, ≥5 ha, ≥95% open water	14
L2UB3, man-made or natural, permanently flooded, fresh water, ≥95% open water or exterior rings of vegetation	15

[a]. Only the top 15 wetland types (based on density ranks) used by Ruddy Ducks are included in the table; see Anderson (1994) for complete listing. Wetland types are modified from Cowardin *et al.* (1979). See **Appendix 1** for wetland codes.

[b] Density ranks ($F_{24,580}$ = 4.30, P<0.001) varied among wetland types used by Ruddy Ducks.

open water or with <5% open water. Vegetation and open water interspersion are important determinants of dabbling duck use of wetlands on breeding grounds (Kaminski & Prince 1981; Murkin *et al.* 1982). Wetland vegetation pattern on wintering grounds may influence invertebrate populations (Kaminski & Prince 1981; Murkin *et al.* 1992), visual isolation from conspecifics (Kadlec 1962; McKinney1965; Murkin *et al.* 1982), biomass of submerged aquatic vegetation, protection from wind, and cover from predators and hunters.

Dendrocygnini

Freshwater rooted vascular, floating vascular, and algal wetlands appeared to be more valuable to Whistling-ducks than other wetlands. Freshwater man-made reservoirs may have contributed to the northern range expansion of Black-bellied Whistling-ducks in Texas (Bolen *et al.* 1964; Schneider *et al.* 1993). Natural and man-made wetlands generally were most important, but flooded rice fields and some shallow sheet-water areas in ploughed fields also were important as feeding areas. Bolen & Rylander (1983) and Hohman *et al.* (1996) suggested that Black-bellied and, in particular, Fulvous Whistling-ducks depend on rice fields for cover and food. Kramer & Euliss (1986) found cereal grains to be the most important food items of wintering Black-bellied Whistling-ducks in north west Mexico; seeds from several moist-soil plant species also were of value. During the breeding season Black-bellied and Fulvous Whistling-ducks feed primarily on plant foods, but animal matter also is taken (Bolen & Forsyth 1967; Hohman *et al.* 1996). Estuarine wetlands are of minor value for feeding, but do provide some useable habitat. Many wetland types with high density ranks were not used for feeding, suggesting that field feeding may be important (Bolen & Forsyth 1967).

Anatini

The most abundant dabbling duck species in the study area were Northern Pintails, Green-winged Teal, Blue-winged Teal, and American Wigeon. Dabbling ducks used wetland types representing almost all available wetland habitat in the study area. Palustrine scrub-shrub wetlands were extremely important for Blue-winged Teal and Mottled Ducks. These wetlands were dominated by woody vegetation <6m tall. Important scrub-shrub wetland types also had open water interspersed with scrub-shrub vegetation, providing heterogenous habitat. This mixture of open water and clumped vegetation provides numerous benefits as described previously.

Five of the seven species of dabbling ducks used palustrine scrub-shrub dead or needle-leaved evergreen wetlands. Northern Shovelers, Mottled Ducks, and Blue-winged Teal used needle-leaved wetland types. Green-winged Teal, Northern Pintails, Mottled Ducks, and Northern Shovelers used scrub-shrub dead wetlands. Therefore, American Wigeon and Gadwall would not benefit from management aimed at these wetland types. Another study in Texas (Briggs & Everett 1983) and one in New York (Losito & Baldassarre 1995) have shown scrub-shrub wetlands to be important for some non-breeding dabbling ducks. Lacustrine littoral unconsolidated shore organic wetlands were not in the top 15 for dabbling ducks, as a group, but were extremely important to Northern Shoveler, Northern Pintail, and Green-winged Teal (Anderson 1994).

Aythyini

Inland diving ducks were strongly associated with lacustrine littoral wetlands, which are large, relatively shallow (<2m deep), and have an abundance of open water. However, this was not true for Lesser Scaup and Redheads, the two most abundant diving duck species. Common to the most used wetland types were unconsolidated substrates.

Wetlands ≥5 ha in size were most used by diving ducks, smaller wetlands were most used if they were elongated because diving ducks need areas large enough for take off and landing (Todd 1997). Diving ducks preferred wetlands with no emergent vegetation or that had only exterior rings of emergent vegetation; this again may stem from their need for a large take off and landing area. Numerous studies have shown the importance of large lacustrine and estuarine wetlands for diving ducks (Jones & Drobney 1986; Christopher & Hill 1988; Bergan & Smith 1989a; Michot & Nault 1993; Thompson & Drobney 1997).

Oxyurini

Ruddy Ducks were unique from other ducks in that they preferred manmade wetlands that lacked vegetation. Impoundments provided appropriate habitat for feeding and other activities in our study and in South Carolina (Bergan & Smith 1989a, b). Impoundments may be sought because they are large and provide a relatively stable water level (Johnsgard & Carbonell 1996). Estuarine wetlands also were important, but only if they were large and permanently flooded. Farmed wetlands were generally of little value to Ruddy Ducks as they were too shallow and did not provide appropriate foods. Masked Ducks, which along with Ruddy Ducks are classified as Stiff-tailed Ducks, occurred primarily in man-made lacustrine wetlands in the same study area (Anderson & Tacha 1999).

Data use and limitations

Results of this study can assist management throughout the Texas coastal plains and may be beneficial in other coastal areas, also. Precipitation was generally average to above average during this study (National Oceanic and Atmospheric Administration 1991; 1992; 1993); therefore, wetland use and selection by waterfowl might be different during years of varying water conditions. Additionally, this study only addressed diurnal use of wetlands. It is possible that different levels of use or wetland types were used nocturnally (Bergan & Smith 1989a; Anderson & Smith 1999).

Many factors are responsible for the use of wetland habitats by non-breeding waterfowl. The Cowardin *et al.* (1979) wetland and deepwater classification and the additional modifiers used to categorize wetland use represented only a subset of the factors influencing use of wetlands by ducks (Anderson *et al.* 1996; Laubhan & Gammonley 2000). Although this study did not address the issue of why certain habitats were used, it does indicate which habitats are most used based on density. Density is not the only criteria by which wetland quality can be assessed and in some instances may actually not be a good indicator of habitat quality (Van Horne 1983). However, arguments raised by Van Horne (1983) concerning seasonal measurements, site tenacity, and social interactions were generally not valid arguments against the use of density in this study. The temporal and spatial scale of the study and the life-history behaviour of target species during the study period (non-breeding) make density a reliable indicator of use among habitat types. By including all wetlands of a type that occurred in the study area even if a particular wetland of that type was not used by ducks makes the inference valid across the entire study area. The amount of area used in calculating densities of birds has an impact on density comparisons but are unlikely to be a major confounding factor for calculating trend or habitat data (Gaston *et al.* 1999). However, management of all wetland types for all duck species is in most cases impractical. The top 15 wetland types for a group were chosen to be presented in tables to focus the attention of managers to those wetlands with the highest densities. Wetlands of great importance to some species had low rank order in group analyses; this underscores species differences and complexity of managing ducks as a whole. If management of all ducks is a primary goal, then the most used wetland types for each species should be integrated into a comprehensive management plan.

All wetland types used by a species are potentially important to annual cycle needs. By rank ordering wetland types, it is interpreted that certain wetland types are of higher quality for a species or group, and that management of these types may preferentially affect that species. Despite a low ranking, a specific wetland type may contain some critical resource and be important in the overall management of a species. Consequently, management consideration must be given to all wetland types that a species uses. This study was of value by documenting the types of wetlands used by individual species of ducks. The incorporation of density ranks into use of wetlands allows managers to prioritise limited resources for management actions.

Management Implications

Rather than focusing efforts on species-specific management, management of wetland systems for multiple species seems most beneficial. Concentrating on certain wetland types that are of importance to a variety of waterfowl should benefit the most abundant species as well as other species associated with that wetland type.

Fifteen wetland types are recommended for inclusion in any comprehensive management plan involving protection, enhancement, and/or creation of wetlands for non-breeding waterfowl in coastal Texas (**Table 7**). These wetland types are recommended based on at least one species or groups receiving a ranking of one or two for density. Four wetland types had high density ranks by more than three species or groups and should be a priority for management. These include some lacustrine littoral and estuarine subtidal wetlands with aquatic-bed vegetation. Four wetland types had high density ranks by two species or groups and are of secondary priority. These wetlands include some palustrine and lacustrine wetlands dominated by vegetation. Seven wetland types had high density ranks by one species or groups and receive a tertiary priority rating. These were mainly estuarine and palustrine types dominated by different vegetative lifeforms or with unconsolidated substrates. Prioritising 15 wetland types for management is a well defined goal when compared to the 82 subclasses and 1,201 wetland types that occurred in the study area.

Rice field roost ponds and flooded rice stubble provide important habitat and should be developed in areas where these features are currently lacking to maximise their value. Potential areas for rice field roost pond development exist in the southern portion of the Rice Prairie stratum, but have not received much attention. Estuarine aquatic-bed and unconsolidated substrate types are valuable to a wide array of waterfowl species. Management efforts should concentrate in areas where tidal pools or pannes (areas that are favourable for growth of aquatic-bed vegetation) are common. Subtidal and irregularly exposed cobble-gravel and sand substrate wetlands appear particularly valuable. The best estuarine habitats consisted of diverse intertwined complexes of subtidal and intertidal aquatic-bed, unconsolidated bottom, unconsolidated shore, and emergent or scrub-shrub wetlands.

Management activities should be concentrated throughout the Coastal and Rice Prairie strata, and along the coast in the Cotton, Range, and Produce strata. Complexes of some of the 15 wetland types should be targeted. Complexes provide wetland habitat suitable for a variety of waterfowl and other waterbird (Anderson *et al.* 1996) species. Development of wetlands must be considered in the context of existing

Table 7. Fifteen priority wetland types for management of wintering ducks in coastal Texas. Only wetland types that were ranked number 1 or 2 for density for either species or groups are included.

Priority[a]	Wetland Type[b]
1	E1UB1, natural ≥5 ha, aquatic-bed vegetation present
	L2UB3, fresh water
	L2AB4, permanently flooded, fresh water, mineral soil
	E1AB3
2	L2EM2, natural, fresh water, open water interspersed with emergent vegetation
	L2US4, seasonally flooded, fresh water
	PAB1, permanently flooded
	PSS5, natural, permanently flooded, fresh water, mineral soil
3	PSS1, fresh water
	PAB3
	PSS4, man-made, ≥5 ha
	PUB3
	E2AB1, natural
	E2US4, permanently flooded
	L2AB3, permanently flooded, fresh water

[a] Priority 1 wetland types were important to ≥3 species or groups, priority 2 was important to 2 species or groups, and priority 3 was important to 1 species or group. Priority 1 wetland types should receive highest management priority, followed by priorities 2 and 3 in order. Important wetland types for other waterfowl and waterbirds in the region are found in other publications (Anderson 1994; Anderson *et al.* 1996; 1999; Anderson & Tacha 1999; Anderson *et al.* 2000). See **Appendix 1** for wetland codes.

[b] Only modifiers that were consistently shown to be valuable and were not by definition the only possibility, were included.

wetlands adjacent to development sites. Managers should consider developing a diversity of wetland types that will in turn benefit a large number and diverse array of waterfowl species.

Wetland management should be approached from a landscape perspective. Complexes of various wetland types should be targeted in specific areas that maximizes the spatial distribution and considers the biotic potential of an area. For example, estuarine wetlands should not be a targeted goal in the Rice Prairie stratum but should be targeted in the coastal stratum. Site specific management goals for wetlands need to be incorporated into a context so all wetland types necessary can be provided at the appropriate spatial scale.

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Appendix 1: Codes used for describing wetland subclasses[a] observed on the coastal plains of Texas during September and November 1991 and 1992, and January and March 1992 and 1993.

Wetland Subclass	Code
Estuarine	
Subtidal	
rock bottom bedrock	E1RB1
rock bottom rubble	E1RB2
unconsolidated bottom cobble-gravel	E1UB1
unconsolidated bottom sand	E1UB2
unconsolidated bottom mud	E1UB3
unconsolidated bottom organic	E1UB4
aquatic-bed algal	E1AB1
aquatic-bed rooted vascular	E1AB3
aquatic-bed floating vascular	E1AB4
reef mollusk	E1RF2
Intertidal	
stream-bed cobble-gravel	E2SB1
stream-bed mud	E2SB3
stream-bed organic	E2SB4
rocky shore rubble	E2RS2
unconsolidated shore cobble-gravel	E2US1
unconsolidated shore sand	E2US2
unconsolidated shore mud	E2US3
unconsolidated shore organic	E2US4
aquatic-bed algal	E2AB1
aquatic-bed rooted vascular	E2AB3
emergent persistent	E2EM1
scrub-shrub broad-leaved deciduous	E2SS1
scrub-shrub needle-leaved evergreen	E2SS4
Riverine	
Tidal	
unconsolidated bottom mud	R1UB3
unconsolidated bottom organic	R1UB4
unconsolidated shore mud	R1US3
unconsolidated shore organic	R1US4
Lower Perennial	
unconsolidated bottom cobble-gravel	R2UB1
unconsolidated bottom sand	R2UB2
unconsolidated bottom mud	R2UB3
unconsolidated bottom organic	R2UB4
aquatic-bed algal	R2AB1
aquatic-bed rooted vascular	R2AB3
aquatic-bed floating vascular	R2AB4
unconsolidated shore sand	R2US2
unconsolidated shore mud	R2US3
emergent non-persistent	R2EM2
Upper Perennial	
unconsolidated bottom cobble-gravel	R3UB1
Intermittent	
stream-bed bedrock	R4SB1
stream-bed sand	R4SB4
stream-bed mud	R4SB5

Wetland Subclass	Code
Intermittent (cont'd)	
stream-bed organic	R4SB6
stream-bed vegetated	R4SB7
Lacustrine	
Limnetic	
rock bottom bedrock	L1RB2
unconsolidated bottom mud	L1UB3
Littoral	
rock bottom bedrock	L2RB1
rock bottom rubble	L2RB2
unconsolidated bottom cobble-gravel	L2UB1
unconsolidated bottom sand	L2UB2
unconsolidated bottom mud	L2UB3
unconsolidated bottom organic	L2UB4
aquatic-bed algal	L2AB1
aquatic-bed rooted vascular	L2AB3
aquatic-bed floating vascular	L2AB4
rocky shore rubble	L2RS2
unconsolidated shore mud	L2US3
unconsolidated shore organic	L2US4
unconsolidated shore vegetated	L2US5
emergent non-persistent	L2EM2
Palustrine	
rock bottom bedrock	PRB1
unconsolidated bottom cobble-gravel	PUB1
unconsolidated bottom sand	PUB2
unconsolidated bottom mud	PUB3
unconsolidated bottom organic	PUB4
aquatic-bed algal	PAB1
aquatic-bed rooted vascular	PAB3
aquatic-bed floating vascular	PAB4
unconsolidated shore cobble-gravel	PUS1
unconsolidated shore sand	PUS2
unconsolidated shore mud	PUS3
unconsolidated shore organic	PUS4
unconsolidated shore vegetated	PUS5
emergent persistent	PEM1
emergent non-persistent	PEM2
scrub-shrub broad-leaved deciduous	PSS1
scrub-shrub broad-leaved evergreen	PSS3
scrub-shrub needle-leaved evergreen	PSS4
scrub-shrub dead	PSS5
forested broad-leaved deciduous	PFO1
forested dead	PFO5

[a] Wetland subclasses from Cowardin *et al.* (1979) based on National Wetland Inventory codes.