Palustrine Wetland Vegetative Dominance Types Along the Central Coast of Texas

James T. Anderson*
Thomas C. Tacha**
Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Campus Box 218, Kingsville, Texas, USA 78363

ABSTRACT

We studied vegetative dominance types in natural and man-made palustrine emergent wetlands in the central coast of Texas during 1991-93. Study design consisted of a stratified random sample of 64.5-ha plots. Fifty-seven dominance types were recorded. Typha *domingensis* was the most abundant dominance type throughout the winter covering over 9,000 ha. Eighty percent of the dominance types were perennials, 93% were native, and 84% were classified as warm-season growth plants. The five most abundant dominance types (i.e., *Typha domingensis, Phragmites australis, Spartina spartinae, Zizaniopsis milacea,* and *Scirpus californicus*) form thick stands of tall, robust emergents that generally make the wetlands unsuitable for wintering waterfowl.

KEYWORDS: Texas Coast, wetland vegetation, palustrine wetlands

Palustrine wetlands are nontidal and tidal wetlands dominated by trees, shrubs, or persistent emergents where ocean-derived salts are <0.5 parts per thousand (ppt) (Cowardin et al., 1979). Palustrine wetlands also include wetlands lacking such vegetation but are <8 ha in area, lack active wave-formed or bedrock shoreline features, are <2 m deep at low water, and have ocean-derived salt levels <0.5 ppt (Cowardin et al., 1979). Palustrine emergent wetlands are wetlands that meet the above definition and are characterized by erect, rooted herbaceous hydrophytes excluding mosses and lichens (Cowardin et al., 1979). Persistent emergent wetlands are dominated by species that generally remain standing until the next growing season (Cowardin et al., 1979). Nonpersistent wetlands are dominated by plants that do not remain standing until the next growing season (Cowardin et al., 1979).

Palustrine emergent wetlands provide important and abundant habitat for waterfowl and other wetland wildlife (Weller and Spatcher, 1965; Murkin et al., 1982; Anderson, 1994; Anderson et al., 1996). Some emergent wetland types produce abundant food resources for waterfowl (Fredrickson and Taylor, 1982; Anderson and Smith, 1998). Wetland vegetation also provides valuable forage for livestock (Catling et al., 1994; Garza et al., 1994).

Accepted 1998. Funding was provided by the Texas Prairie Wetlands Project (part of the North American Waterfowl Management Plan), Texas Parks and Wildlife Department, and the Caesar Kleberg Foundation for Wildlife Conservation. The authors thank the landowners for allowing them access to their properties. *Corresponding author; Current address: West Virginia University, Division of Forestry, Wildlife and Fisheries Program, P.O. Box 6125, Morgantown, West Virginia, USA 26506-6125. **Deceased.

More than 100 species of waterbirds use palustrine emergent wetlands along the coast of Texas (Anderson, 1994; Anderson et al., 1996). Coastal Texas is one of the most important wintering grounds for waterbirds in the United States (Anderson and DuBowy, 1996; Anderson et al., 1998). An estimated 3.5 million ducks and 3.3 million geese winter in the lower and middle coast region of Texas (Anderson et al., 1998). The area also provides important habitat for migrating waterfowl, including >500,000 blue-winged teal (*Anas discors L.*) (Anderson et al., 1998). Over 1.5 million other waterbirds extensively use coastal Texas wetlands during winter (Anderson et al., 1998). The central coast of Texas is especially important, harboring about 90% of wintering ducks; 80% of wintering shorebirds, rails, and waders; 90% of geese; and 60% of gulls, terns, and allies (Tacha et al., 1993; Anderson et al., 1998).

Natural and man-made palustrine emergent wetlands cover over 200,000 ha in coastal Texas (Tacha et al., 1993; Muehl et al., 1994). Despite the abundance of emergent wetlands, no data exist on the abundance of vegetative dominance types occurring in this area. Determining the amount of wetland area covered by each species is vital for describing coastal Texas wetlands.

Description and classification of vegetation provides baseline information for ecological studies concerning wildlife and vegetation management (Meyer, 1985). Baseline information on vegetation abundance provides valuable data on the current status of wetlands and for monitoring the effects of future wetland management actions or continued wetland destruction (Dahl, 1990). The purpose of this study was to document the area of palustrine emergent wetlands dominated by vegetative types in coastal Texas and discuss vegetation as it relates to waterfowl management on the Texas coast.

MATERIALS AND METHODS

The study area includes 16 Texas counties from Corpus Christi to Galveston Bay (Anderson et al., 1996), totaling 3.6 million ha. Climate is subtropical humid with warm summers (Larkin and Bomar, 1983). Average precipitation ranges from 133 cm in the north to 87 cm in the south (National Fibers Information Center, 1987).

The study area is located primarily in the Gulf Prairie and Marsh Ecological Areas of Texas (McMahan et al., 1984). Native climax vegetation is largely tall-grass prairie, with some *Quercus stellata* Wang. savannah on upland areas (Gould, 1969). Climax vegetation in the prairie is dominated by tall bunchgrasses such as *Andropogon gerardi, Schizachyrium scoparium, Sorghastrum nutans* (L.) Nash, *Tripsacum dactyloides* (L.) L., and *Panicum* spp. L.

Soil associations are mainly Lake Charles-Edna-Bernard, Moreland-Pledger-Norwood, Victoria-Orelia-Clareville, and Harris-Veston-Galveston (Westfall, 1975). These associations generally are characterized by soils that are somewhat poorly drained, and have a surface layer of fine sandy loam above several layers of clay and sandy clay to a depth of 2 m.

The study area was divided into three strata based on physiographic regions and land practices: coastal, rice prairie, and other crop (Anderson et al., 1996; 1998). Descriptions of strata can be found in Anderson et al. (1996).

Sample selection and allocation for each strata are described in Anderson (1994) and follow Muehl et al. (1994). In 1991-92, we used map coordinates to randomly select 290 64.5-ha plots, hereafter referred to as plots, within strata. After plots were selected, trespass permission was obtained or the plot was replaced with another random plot. The coastal stratum was allocated 25 plots, rice prairie 201 plots, and other crop 64 plots. Data from 1991-92 were used in 1992-93 to reallocate and increase plots among strata according to (Kish, 1965) based on variance estimates for total waterfowl populations and wetland area (Muehl, 1994). We randomly selected 600 plots in the study area the second year; 273 in the coast, 241 in the rice prairie, and 86 in the other crop strata. All surveys for wetlands and their dominance types occurred during surveys in September, November, January, and March of both years. All plots were visited once per survey period.

The dominant vegetative type (species or co-dominants) in each wetland classified as palustrine emergent was determined by walking each wetland and determining ocularly the most frequently occurring species following the methods of Cowardin et al. (1979). A dominant plant species was the predominant species occurring in a wetland (Cain and de Oliveira Castro, 1959:29). Wetland size was determined by measuring wetland length and width and using the formula provided by Millar (1973).

Plants were identified using Godfrey and Wooten (1979; 1981) and Correll and Johnston (1979). Hatch et al. (1990) was used as the taxonomic authority. Plants were classified as to origin (native or introduced), longevity (annual or perennial), and season of growth (warm or cool season) according to Hatch et al. (1990).

Seasonal estimates of area occupied by dominance types in palustrine emergent wetlands were calculated following Muehl et al. (1994). Mean area of each dominance type within sample plots in each stratum were multiplied by the area of each stratum, and the totals were added to give study area estimates. Standard errors associated with estimates of area dominated by vegetative types were calculated following procedures for weighted pooled stratified random samples (Kish, 1965).

RESULTS

Data from the first year (1991-92) were used to reallocate plots for the second year (1992-93) and therefore are not presented. A total of 57 species was recorded as dominance types on the palustrine emergent wetlands surveyed during 1992-93. Thirty-three genera were recorded, including six species of *Eleocharis.* An additional nine combinations of co-dominants were observed.

Typha dominigensis was generally the most abundant species during the four survey periods (Table 1). *Spartina spartinae* was the most abundant species ever recorded covering 12,251 ha in March. Other abundant dominance types included *Erianthus giganteus, Paspalidium geminatum, Phragmites australis, Spartina spartinae, Zizaniopsis milacea, Eleocharis quadrangulata,* and *Scirpus californicus.*

Nine species (16% of total number of species) are classified as annuals: *Leptochloa fascicularis, Polypogon monspeliensis, Cyperus odoratus, Eleocharis obtusa, E. parvula, Fimbristylis autumnalis, Polygonum pennsylvanicum, Sesbania macrocarpa,* and *Ammannia coccinea.* Two species (4%) *Polygonum hydropiper* and *P. hydropiperoides* are considered to be either annuals or perennials. The other 46 species (80%) are perennials. Area dominated by annuals totaled 2,006 ha in September, 971 ha in November, 619 ha in January, and 1,138 ha in March. Area dominated by perennials totaled 24,746 ha in September, 29,760 ha in November, 34,757 ha in January, and 54,360 ha in March.

Fifty-three species (93%) are native to the study area. Four species (7%) are not native to the area: *Polypogon monspeliensis, Sorghum halepense, Rumex crispus,* and *Alternanthera philoxeroides.* Area dominated by introduced species totaled 2,418 ha in September, 683 ha in November, 545 ha in January, and 391 ha in March. Area dominat-

Table 1. Total estimated area (ha) and standard errors (SE)[†] of palustrine emergent wetland vegetation in the Texas midcoast region during September and November 1992 and January and March 1993 wetland surveys.

Species	September		November		January		March	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Typha angustifolia L.	0	0	0	0	81	64	0	0
Typha domingensis Pers.	9,186	4,948	10,369	4,885	10,847	5,197	12,192	5,152
Typha latifolia L.	93	85	0	0	12	9	15	12
Sagittaria latifolia Willd.	0	0	0	0	0	0	2	2
Sagittaria longiloba Engelm.	57	57	0	0	0	0	41	25
Sagittaria platyphylla (Engelm.) J. G. Smith	286	286	0	0	0	0	1,050	1,050
Andropogon gerardii Vitman	0	0	170	170	0	0	0	0
Andropogon glomeratus (Walt.) B.S.P.	0	0	0	0	275	196	277	198
Distichlis spicata (L.) Greene	0	0	32	32	39	33	561	513
Erianthus giganteus (Walt.) F. T. Hubbard	0	0	1,752	1,752	1,752	1,752	2,858	2,858
Leersia oryzoides (L.) Sw.	15	15	3	3	3	3	0	0
Leptochloa fascicularis (Lam.) Gray	201	185	528	367	187	153	66	66
Panicum virgatum L.	0	0	86	49	1	1	662	524
Paspalidium geminatum (Forssk.) Stapf	28	28	652	414	2,534	1,341	4,105	2,843
Paspalum distichum L.	1,078	1,078	0	0	0	0	0	0

Table 1. Continued.

Species	September		November		January		March	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Paspalum lividum Trin.	123	123	54	38	36	36	0	0
Paspalum vaginatum Sw.	0	0	0	0	288	288	0	0
Phragmites australis (Cav.) Trin.	1,328	979	1,160	1,136	1,548	1,179	2,293	1,323
Polypogon monspeliensis (L.) Desf.	1,752	1,752	0	0	0	0	0	0
Schizachyrium scoparium (Michx.) Nash	0	0	91	69	0	0	0	0
Sorghum halepense (L.) Pers.	0	0	1	1	9	6	0	0
Spartina spartinae (Trin.) Merr.	0	0	2,499	1,897	2,932	1,898	12,251	7,143
Zizaniopsis milacea (Michx.) Doell and Aschers	8,433	5,433	8,433	5,433	6,953	5,236	8,433	5,433
Carex brittoniana Bailey	1,051	896	166	166	169	169	0	0
Carex longii Mack.	0	0	0	0	0	0	33	33
Carex muhlenbergii Schkuhr.	0	0	0	0	0	0	56	37
Cladium jamaicense Crantz.	0	0	47	38	1,613	1,482	0	0
Cyperus acuminatus Torr. and Hook.	0	0	0	0	0	0	174	174
Cyperus odoratus L.	50	44	19	19	19	19	0	0
Eleocharis acicularis (L.) Roem. and Schult.	0	0	0	0	2	2	0	0

Table 1. Continued.

Species	September		November		January		March	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Eleocharis austrotexana M. C. Johnst.	59	59	16	16	0	0	95	92
Eleocharis obtusa (Willd.) Schult.	0	0	11	11	43	43	11	11
Eleocharis palustris (L.) Roem. and Schult	142	142	123	123	92	82	1,154	647
Eleocharis parvula (Roem. and Schult) Link	0	0	42	33	120	78	899	541
Eleocharis quadrangulata (Michx.) Roem and Schult.	525	360	1,481	503	1,833	666	1,776	659
Fimbristylis autumnalis (L.) Roem. and Schult.	0	0	0	0	0	0	15	15
Rhynchospora corniculata (Lam.) Gray	0	0	10	10	0	0	0	0
Scirpus americanus Pers.	3	3	0	0	0	0	4	4
Scirpus californicus (C. A. Meyer) Steud.	176	165	379	308	1,215	1,172	1,953	1,297
Scirpus pungens Vahl	0	0	3	3	24	21	6	6
Scirpus robustus Pursh	0	0	28	23	0	0	2	2
Scirpus tabernaemontani Gmelin	295	277	363	288	680	591	905	410
Juncus effusus L.	0	0	143	91	463	307	1,940	1,112
Juncus roemerianus Scheele	0	0	55	48	197	117	277	198
Polygonum hydropiper L.	0	0	5	5	0	0	0	0
Polygonum hydropiperoides Michx.	67	66	344	342	105	71	41	41

Table 1. Continued.

Species	September		November		January		March	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Polygonum pensylvanicum L.	0	0	179	90	92	49	0	0
Polygonum ramosissimum Michx.	37	29	0	0	0	0	0	0
Rumex crispus L.	0	0	11	11	0	0	0	0
Rumex spiralis Small	0	0	0	0	0	0	174	174
Alternanthera philoxeroides (Mart.) Griseb.	666	480	671	483	536	375	391	316
Sesbania macrocarpa Muhl.	3	3	88	63	32	29	28	28
Ammannia coccinea Rottb.	0	0	104	94	126	126	119	119
Ludwigia peploides Kunth.	20	20	0	0	5	5	53	32
Aster tenuifolius L.	0	0	447	447	0	0	0	0
Leucosyris spinosa (Benth.) Greene	1,051	896	166	166	169	169	0	0
Mikania scandens (L.) Willd.	7	7	0	0	0	0	0	0
Typha domingensis-Scirpus californicus	0	0	0	0	224	224	0	0
Eleocharis quadrangulata-Scirpus californicus	0	0	0	0	92	92	0	0
Distichlis spicata-Scirpus californicus	0	0	0	0	12	12	0	0

Table 1. Continued.

Species	September		November		January		March	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Setaria magna Griseb.-*Typha latifolia*	0	0	11	11	11	11	0	0
Alternanthera philoxeroides-*Paspalidium geminatum*	0	0	0	0	11	11	0	0
Ammannia coccinea-*Paspalum distichum*	0	0	242	231	0	0	0	0
Hymenocallis caroliniana (L.) Herb.-*Eleocharis quadrangulata*	0	0	0	0	0	0	530	530
Sorghum halepense-*Rumex spiralis*	0	0	0	0	0	0	2	2
Juncus roemarianus-*Leersia oryzoides*	0	0	0	0	0	0	1	1

† SE was derived from variance estimates following procedures for weighted pooled stratified random samples from Kish (1965).

ed by native species totaled 24,334 ha in September, 30,301 ha in November, 34,831 ha in January, and 55,105 ha in March.

Forty-eight species (84%) are classified as warm-season growth plants. Nine species (16%) are classified as cool-season growth plants: *Polypogon monspeliensis, Carex brittoniana, C. longii, C. muhlenbergii, Cladium jamaicense, Eleocharis austrotexana, E. obtusa, E. parvula,* and *Rumex spiralis.* Area dominated by warm-season growth species totaled 23,890 ha in September, 30,702 ha in November, 33,442 ha in January, and 53,698 ha in March. Area dominated by cool-season species totaled 2,862 ha in September, 282 ha in November, 1,945 ha in January, and 1,268 ha in March.

DISCUSSION

The importance of wetland vegetation to waterfowl depends on several biotic and abiotic factors. Dominant plant species or community composition (White and James, 1978), seed and nutlet production (Fredrickson and Taylor, 1982; Haukos and Smith, 1993), tuber, bulb, and rhizome availability (Alisauskas et al., 1988), nutritional value of foods (Haukos and Smith, 1995; Anderson and Smith, 1998), taxa and abundance of invertebrates (Krapu, 1974), and spatial pattern of vegetation (Weller and Spatcher, 1965; Anderson, 1994) all affect use of palustrine emergent wetlands by waterfowl. Use of vegetated wetlands is also influenced by water depth, hunting pressure, juxtaposition to other wetlands, and surrounding landuse (Jorde and Owen, 1988). Our data are valuable because they address the amount of habitat available as it relates to some of these other factors affecting use by wildlife.

Our data suggests that *Typha domingensis, Phragmites australis, Spartina spartinae, Zizaniopsis milacea,* and *Scirpus californicus* are the 5 most abundant species. These species are all tall, robust, perennial plants that form dense stands and are generally invasive (Beule, 1979). Wetlands dominated by *Typha* spp., *Phragmites australis,* and other plant species that form thick stands often provide poor quality habitat for waterfowl by excluding more valuable vegetation (Beule, 1979; Smith and Kadlec, 1986). These wetland types do not provide the favored aspects of wetlands sought by waterfowl (Anderson, 1994), but no previous estimates of their extent in coastal Texas are available.

No quantitative data exist on palustrine emergent vegetation in coastal Texas, although Stutzenbaker and Weller (1989) list *Typha* spp., *Scirpus* spp., *Cyperaceae, Juncaceae, Echinodorus* spp. and *Rhynchospora* spp. as dominating palustrine and estuarine emergent wetlands. Our study suggests similar findings, but provides unbiased estimates of the amount of area covered by various plant species. Our study supports previous findings that most plant species that occur in wetlands are perennials (van der Valk, 1981).

Our data suggests that if the goal of palustrine wetland management along the Texas coast is for diversity, dominance types rather than nonpersistent emergents should be emphasized, because nonpersistent emergent vegetation is rare in comparison to persistent emergent vegetation. Nonpersistent vegetation in general provides palatable forage and abundant seeds for waterfowl (Haukos and Smith, 1993).

The amount of area dominated by vegetative types in this study should be considered minimum estimates for the area as we did not include estuarine and lacustrine wetland systems (Cowardin et al., 1979), wetlands that did not flood during the study period, and upland areas. Our estimates do, however, provide unbiased estimates of the extent of coverage of vegetation in palustrine emergent wetlands that are potentially accessible to waterfowl. Our data show that most palustrine wetlands are dominated by only one plant species, indicating that many wetlands need to be conserved in order to increase or maintain vegetative diversity.

Relatively high standard errors were associated with the estimates for vegetative dominance types. Standard errors could have been reduced if sample sizes were increased or if plots were reallocated based on palustrine emergent wetlands. One of the main purposes for this study was to estimate waterfowl populations and overall wetland abundance. Therefore, plots were reallocated among strata to reduce variance estimates for total waterfowl (Anderson et al., 1998). Lower standard errors for vegetative dominance types could have been achieved, without increasing sample size, if all plots contained palustrine emergent wetlands.

Plant dominance types are formed in response to water depth, salinity, water turbidity, frequency and duration of flooding, and other chemical and physical parameters (Mitsch and Gosselink, 1986). To decrease the area occupied by Typha spp. and other thick stands of robust emergents a proactive approach of cutting and flooding (Beule, 1979) should be pursued to create more favorable habitats for waterfowl. The goal of palustrine emergent wetland management for waterfowl in coastal Texas should aim for open water interspersed with persistent emergent vegetation and more nonpersistent emergent wetlands.

Coastal Texas has suffered substantial losses of wetlands and degradations of others. Area of wetlands in the upper coast have declined by 16% (>47,000 ha) from the mid 1960's to 1990 (Tacha et al., 1993). Estuarine subtidal unconsolidated bottom wetlands increased 69% and palustrine unconsolidated bottom wetlands increased 754%, indicating substantial losses of vegetated wetlands (Tacha et al., 1993). About 70% of palustrine wetlands in coastal Texas are natural (Tacha et al., 1993; Muehl et al., 1994). We found <10% of the wetland area to be dominated by introduced species. An additional large expanse of area is occupied by thick stands of vegetation that make the wetlands inaccessible to waterfowl. Area dominated by introduced species, wetland losses, and wetland modification combined show that little of the original wetland area is in pristine condition.

Identification of the extent of wetland vegetation types is an important step to improve the decision making process regarding palustrine wetland management for waterfowl in this region. Future research should involve identification of the important emergent vegetative types for waterfowl and other waterbirds in the central coast region of Texas.

REFERENCES

Alisauskas, R. T., C. D. Ankney, and E. E. Klaas. 1988. Winter diets and nutrition of midcontinental lesser snow geese. J. Wildl. Manage. 52:403-414.

Anderson, J. T. 1994. Wetland use and selection by waterfowl wintering in coastal Texas. M.S. Thesis. Texas A&M Univ.-Kingsville, Kingsville.

Anderson, J. T., and P. J. DuBowy. 1996. The importance of coastal Texas wetlands for wintering and migrating waterbirds. Wetland J. 8:10-13.

Anderson, J.T., T. C. Tacha, G. T. Muehl, and D. Lobpries. 1996. Wetland use by waterbirds that winter in coastal Texas. Nat. Biol. Serv., Inf. Tech. Rep. 8., Lafayette, LA.

Anderson, J. T., G. T. Muehl, and T. C. Tacha. 1998. Distribution and abundance of waterbirds in coastal Texas. Bird Pop. 4:1-15.

Anderson, J. T., and L. M. Smith. 1998. Protein and energy production in playas: implications for migratory bird management. Wetlands 18:(437-446).

Beule, J. D. 1979. Control and management of cattails in southeastern Wisconsin wetlands. Wisc. Dep. Nat. Resour. Tech. Bull. 112, Madison.

Cain, S. A., and G. M. de Oliveira Castro. 1959. Manual of vegetation analysis. Harper and Brothers, New York.

Catling, P. M., A. R. McElroy, and K. W. Spicer. 1994. Potential forage value of some eastern Canadian sedges (Cyperaceae: *Carex*). J. Range Manage. 47:226-230.

Correll, D. S., and M. C. Johnston. 1979. Manual of the vascular plants of Texas, Second ed., Univ. Texas, Dallas.

Cowardin, L. M., V. Carter, F. C Golet, and E. T. Laroe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildl. Serv., Office of Biol. Serv., Washington, DC, FWS/OBS-79/31.

Dahl, T. 1990. Wetland losses in the United States-1780's to 1980's. U.S. Fish and Wildl. Serv., Office of Biol. Serv., Washington, DC.

Fredrickson, L. H., and T. S. Taylor. 1982. Management of seasonally flooded impoundments for wildlife. U.S. Fish and Wildl. Serv. Resour. Publ. 148, Washington, DC.

Garza, A. Jr., T. McLendon, and D. L. Drawe. 1994. Herbage yield, protein content, and carbohydrate reserves in gulf cordgrass (*Spartina spartinae*). J. Range Manage. 47:16- 21.

Godfrey, R. K., and J. W. Wooten. 1979. Aquatic and wetland plants of Southeastern United States. Univ. Georgia Press, Athens.

Godfrey, R. K., and J. W. Wooten. 1981. Aquatic and wetland plants of Southeastern United States. Univ. Georgia Press, Athens.

Gould, F. W. 1969. Texas plants: a checklist and ecological summary. Texas A&M Univ., College Station.

Hatch, S. L., K. N. Gandhi, and L. E. Brown. 1990. Checklist of the vascular plants of Texas. Texas Agric. Exp. Stn. Publ. MP-1655, College Station.

Haukos, D. A., and L. M. Smith. 1993. Moist-soil management of playa lakes for migrating and wintering ducks. Wildl. Soc. Bull. 21:288-298.

Haukos, D. A., and L. M. Smith. 1995. Chemical composition of seeds from plants in playa wetlands. Wildl. Soc. Bull. 23:514-519.

Jorde, D. G., and R. B. Owen, Jr. 1988. The need for nocturnal activity and energy budgets of waterfowl. p. 169-180. *In:* M. W. Weller (ed) Waterfowl in Winter. Univ. Minn. Press, Minneapolis.

Kish, L. 1965. Survey sampling. John Wiley and Sons, Inc., New York.

Krapu, G. L. 1974. Feeding ecology of pintail hens during reproduction. Auk 91:278-290.

Larkin, T. J., and G. W. Bomar. 1983. Climatic atlas of Texas. Texas Dep. Water Resour., Austin.

McMahan, C. A., R. G. Frye, and K. L. Brown. 1984. The vegetation types of Texas including cropland. Texas Parks and Wildl. Dep. Bull. 7000-120, Austin.

Meyer, M. I. 1985. Classification of native vegetation at the Woodworth Station, North Dakota. Prairie Nat. 17:167-175.

Millar, J. B. 1973. Estimation of area and circumference of small wetlands. J. Wildl. Manage. 37:30-38.

Mitsch, W. J., and J. G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold, New York.

Muehl, G. T. 1994. Distribution and abundance of water birds and wetlands in coastal Texas. M.S. Thesis. Texas A&M Univ.-Kingsville, Kingsville.

Muehl, G. T., T. C. Tacha, and J. T. Anderson. 1994. Distribution and abundance of wetlands in coastal Texas. Texas J. Agric. Nat. Resour. 7:85-106.

Murkin, H. R., R. M. Kaminski, and R. D. Titman. 1982. Responses by dabbling ducks and aquatic invertebrates to experimentally manipulated cattail marsh. Canadian J. Zool. 60:2324-2332.

National Fibers Information Center. 1987. The climates of Texas counties. Univ. Texas, Austin.

Smith, L. M., and J. A. Kadlec. 1986. Habitat management for wildlife in marshes of Great Salt Lake. Trans. North Am. Wildl. Nat. Resour. Conf. 51:222-231.

Stutzenbaker, C. D., and M. W. Weller. 1989. The Texas Coast. p 385-405. *In:* L. M. Smith et al. (eds.) Habitat management for migrating and wintering waterfowl in North America. Texas Tech Univ. Press, Lubbock.

Tacha, T. C., A. M. Holzem, and D. W. Bauer. 1993. Changes in waterfowl and wetland abundance in the Chenier Plain of Texas 1970s-1990s. Texas J. Agric. Nat. Resour. 6:31-40.

van der Valk, A. G. 1981. Succession in wetlands: a Gleasonian approach. Ecology 62:688-696.

Weller, M. W., and C. E. Spatcher. 1965. Role of habitat in the distribution and abundance of marsh birds. Iowa Agric. and Home Econ. Exp. Station Spec. Rep. 43, Ames.

Westfall, D. G. 1975. Rice soils-properties and characteristics. p. 22-30. *In:* J. E. Miller (ed.) Six decades of rice research in Texas, Texas Agric. Exp. Station Res. Mono. 4, College Station.

White, D. H., and D. James. 1978. Differential use of fresh water environments by wintering waterfowl of coastal Texas. Wilson Bull. 90:99-111.