Wetlands
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ARTICLE

Tropical Storm Driven Hydrologic Regimes Support *Spartina spartinae* Dominated Prairies in Texas

David J. Cooper · Joel I. Wagner

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Abstract We measured daily precipitation, duration of ponding and soil redox potential for 2 years in three coastal prairie sites near the mouth of the Rio Grande in south Texas. The area historically was dominated by gulf cordgrass, *Spartina spartinae*. Much of the area was plowed for agriculture and *Spartina* has not recolonized disturbed sites. Regulation of the Rio Grande has eliminated flooding and disconnected the study area from the river. The goal of this project was to use continuous measures of water levels and soil redox potential to determine whether the study areas have a wetland hydrologic regime. Anoxic soils formed and persisted for at least 2 weeks only following hurricanes or large tropical storms that produced at least 15 cm of precipitation over 1–3 days and created ponding. Over the past century storms of this magnitude occurred only 1 out of 4 years. This study determined that the study sites do not support wetland hydrologic regimes due to river regulation, however reestablishment of the dominant wet prairie species is possible through planting.

Keywords *Spartina spartinae* · *Borrichia frutescens* · Redox potential · Tropical storm · Ponding · Texas

Introduction

Expansive marshes have been identified on maps of the Texas coastal plain in the vicinity of the Rio Grande for more than 150 years (Clover 1937). Historically the Rio Grande flooded regularly, producing a wide delta and coastal plain near Brownsville, Texas that supported large marsh and prairie ecosystems with numerous distributaries and oxbows (locally termed resacas). One of the main prairie vegetation types in brackish or saline sites in this region was dominated by *Spartina spartinae* (Trin.) Merr. ex Hitchc. (gulf cordgrass) (Johnston 1955). In the first battle of the Mexican-American War (1846–1848), fought in the vicinity of the Palo Alto Resaca just north of Brownsville, Ulysses S. Grant noted in his war diary that the grass (*S. spartinae*) "was tall, reaching the shoulders of the men, very stiff, and each stock pointed at the tip, and hard, almost as sharp as a darning needle" (Sanchez 1985). A 1934 land cover classification map based on historic aerial photography (Ramsey et al. 2004) showed that *S. spartinae* (hereafter called *Spartina*) was the dominant cover for most of the battlefield area. The battlefield site is now protected and managed within Palo Alto Battlefield National Historical Park (PAAL), a unit of the U.S. National Park System.

Today this historic vegetation type exists only in small patches in the area of PAAL due in part to 20th century plowing and farming. However, extensive modifications of the flow and structure of the Rio Grande by dams, dikes and water diversions limit the river's connectivity with its historic floodplain (Jahrsdoerfer and Leslie 1988). Resacas are no longer filled by floodwater, and many former wetland complexes are wetted only by precipitation (Judd and Lonard 2002). Because of the hydrologic disconnection of these wetlands from the Rio Grande, it is uncertain whether the area supports wetland hydrologic processes that could facilitate the reestablishment of *Spartina*-dominated communities in former agricultural fields.

Spartina dominates intermittently flooded saline coastal prairies in south Texas, often to the exclusion of other species (Oefinger and Scifres 1977; Scifres et al. 1980; Smiens et al. 1991; Judd and Lonard 2002). Both *Spartina* and *Borrichia*

D. J. Cooper (✉)
Department of Forest and Rangeland Stewardship and Graduate Degree Program in Ecology, Colorado State University, Fort Collins, CO 80523, USA
e-mail: david.cooper@colostate.edu

J. I. Wagner
Water Resources Division, National Park Service, P.O. Box 25287, Denver, CO 80225, USA

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frutescens (L.) DC. (bushy seaside tansy), a dominant plant in resacas and in many disturbed coastal prairie sites, are listed as obligate wetland plants in Texas (Lichvar and Kartesz 2009). However, species like *Spartina* can persist in saline environments that do not support wetland hydrologic regimes (Shiflet 1963).

The goal of this research was to determine whether coastal prairies on the former Rio Grande floodplain in the vicinity of Brownsville, Texas have a hydrologic regime that supports flooding and anoxic soil conditions for long enough duration in most years to facilitate the restoration of the coastal prairie ecosystems.

Study Area

This study was conducted at Palo Alto Battlefield National Historical Park near Brownsville, Texas (Fig. 1). The highly saline Lomalta clay is the predominant soil series (Williams et al. 1977) of the park's core battlefield area. Many areas disturbed by farming at Palo Alto Battlefield are now dominated by *Borrichia frutescens* and little or no recolonization of *Spartina* has occurred in the historically farmed prairies (Margo 2006).

Methods

Hydrology and Climate

Due to the clay soil, we installed several types of ground water monitoring wells, and staff gauges. Wells installed more than 3 m deep encountered ground water with electrical conductance exceeding 35,000 uS in many areas, which we interpreted to be intruded ocean water. Wells within 1–2 m of the surface never contained water, suggesting that a shallow water table did not exist. Water ponded on the ground surface following rain events. Therefore we installed staff gauges each instrumented with an In-Situ Level Troll 300 to record the timing and duration of ponding. Instrument readings were corrected for barometric pressure using an In-Situ BaroTroll. Daily precipitation totals and long term temperature data are from the Brownsville, Texas airport weather

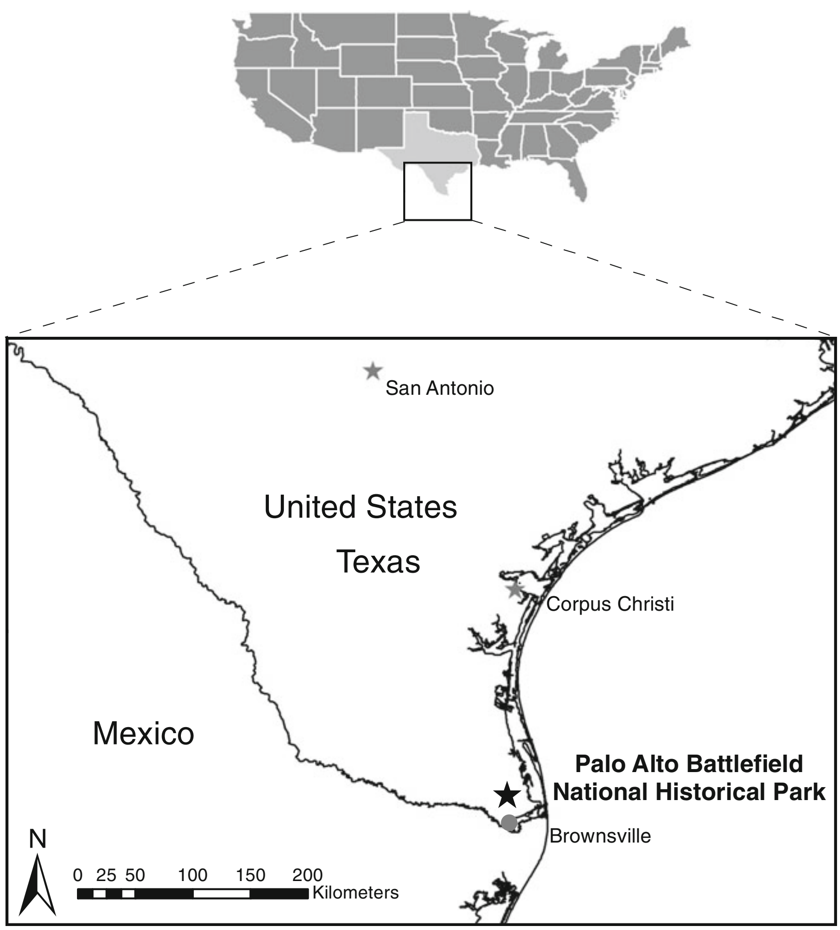

Fig. 1 Location of Palo Alto Battlefield National Historical Park near Brownsville, Texas

station that extends back to 1901 and includes 87 years with complete data.

Soil Chemistry

Samples from the upper 20 cm of root zone were collected from *Spartina* and *Borrichia* dominated stands. We used standard analytical procedures recommended by the American Public Health Association (APHA 2005) for analysis: Ca and Mg using direct nitrous oxide- acetylene flame method (APHA 3111-D), Na and K using flame photometric method (APHA 3500-K-B), HCO3 using titration (APHA 2320-B), SO4 using turbidimetric method (APHA 4500-SO4 E).

Soil Redox Potential

Soil oxidation-reduction potential provides a direct measurement of the oxidation state of soils. We built three automated redox potential measuring systems and installed them in an intact *Spartina* stand, a former *Spartina* stand that is now an abandoned agricultural field dominated by *Borrichia frutescens*, and a mixed *Spartina-Borrichia* stand. Each station was powered by a solar panel with battery, and operated by a Campbell CR1000 data logger. Platinum tipped electrodes were built at Colorado State University using pure platinum wire fused to copper rods (Faulkner et al. 1989). Each platinum electrode was paired in the field with a Beckman Calomel reference electrode, and eight pairs of electrodes were installed at 10–20 cm depth at each site. The voltage difference between the platinum and reference electrodes was measured hourly by the logger and stored on the data logger (Rabenhorst et al. 2009). We corrected for the reference electrode by adding 244 mV to the measured value, and for soil pH. Redox values are commonly divided into four categories: oxidized (> +350 mV), moderately reduced soils (+100 to +350 mV), reduced (−100 to +100 mV), and highly reduced (−300 to −100 mV) (Batzer and Sharitz 2006). We consider sites to be oxic if their redox potential was≥+350 mV, and reducing if their redox potential was<+350 mV.

Results

History of Rio Grande Flow

Falcon Dam, located approximately 80 km above McAllen, Texas on the Rio Grande was constructed from 1950 to 1954, and substantially influenced annual peak flows (Fig. 2). From 1955 to 1977 annual peak flow at the State of Texas's Brownsville gauge averaged less than ½ of the peak flow from 1935 to 1951. While most post Falcon Dam flows of the Rio Grande have been low, flows have exceeded 2,400 m^3/s several times, with Hurricane Beulah in 1967 exceeding 5,800 m^3/s at the State of Texas's Rio Grande City gauge (Fig. 3). To control potential flooding two additional dams were built downstream from Falcon Dam to capture and divert flows into canals that bypass the cities of McAllen and Brownsville, Texas and Matamoros, Mexico and the large agricultural region of the lower Rio Grande. Anzalduas Dam can divert up to 2,970 m^3/s of flow from the Rio Grande into the Banker channel and into the Arroyo Colorado and North Floodway to the Gulf of Mexico. The Retamal Dam can divert an equal flow through Mexico's interior floodway system also to the Gulf of Mexico. Both dams are located near McAllen, Texas.

The dams, diversions, and dikes disconnect the Rio Grande from its former floodplain. Coastal prairies now pond and resacas fill with water only after large local or regional rain events.

Climate, Precipitation, Water Levels, Site Redox Potential, and Soil Chemistry

Mean minimum daily temperature exceeds 10 °C for every month, and temperatures below 0 °C occur on average twice annually. Thus, the study area has a 12-month growing season. Mean annual precipitation at the Brownsville airport is 69.8 cm, and September is the month with the highest mean total with 15.0 cm (NOAA, National Climate Data Center, Global Historical Climatology Network-Daily Station USW00012919, Brownsville Int. Airport, Brownsville, TX), indicating the importance of late summer storms to the annual total. During our study period March 2010 through April 2012, Hurricane Alex made landfall in the area on 30 June 2010, followed by Tropical Depression Two on 8 July 2010 (Fig. 4). Tropical Storm Hermine produced significant rain on 6 September 2010, followed by another storm on 19 September 2010. Other rainy periods occurred in late June 2011, and early February 2012.

Extensive ponding on our study sites occurred only during and following Hurricane Alex and Tropical Storm Hermine (Fig. 4). Each storm produced precipitation totals exceeding 15 cm. For the 87 years with complete data in the Brownsville record 26 % of years had at least one 3-day period with greater than 15 cm of precipitation. Thus, storm driven events create ponding in about 1 of 4 years.

Soil redox potentials in June 2010 at the three study sites were all>+350 mV (Fig. 4). Rainfall generated by Hurricane Alex on June 30 produced local ponding and the redox potential at all three sites dropped sharply. The *Borrichia* and the mixed *Spartina-Borrichia* sites remained anoxic for 22 and 13 days respectively, while at the *Spartina* site anoxic conditions persisted through early August. Tropical Storm Hermine and the rain event that followed produced local ponding again, and redox potentials dropped to 240, 215 and 193 mV at the *Spartina-Borrichia, Borrichia* and *Spartina* sites. For the remainder of the measurement period the *Borrichia* and mixed

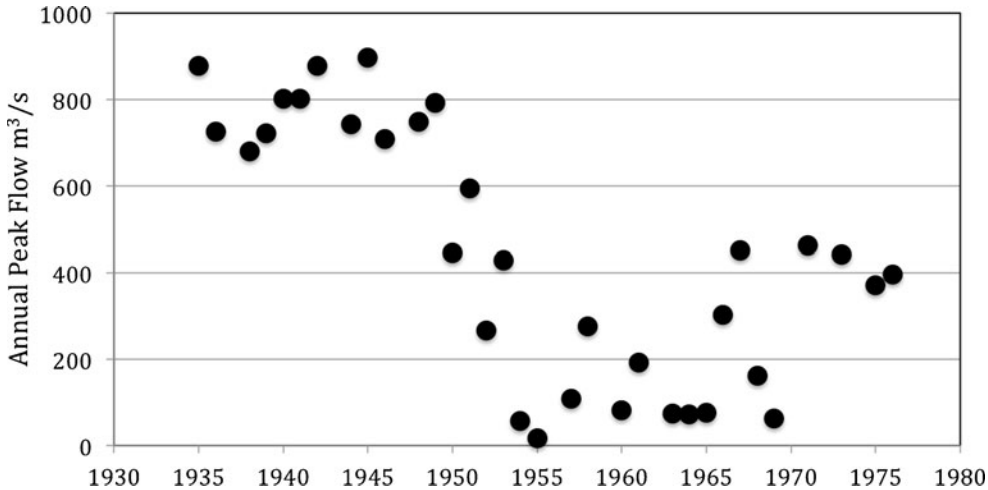

Fig. 2 Annual peak flow for Rio Grande at Brownsville, Texas for years 1935–1977

Spartina-Borrichia sites remained oxic, with noticeable short term drops in redox potential only after rain events in June 2011 and February 2012. The *Spartina* site redox potential remained near +350 mV for much of the study period.

Concentrations of Ca, Mg, Na, K, B, Cl and SO_4 were more than double in *Borrichia* than *Spartina* stands (N=2 for each). For example, Na averaged 1237 vs. 455 mg/L, and Cl 1541 vs. 95 mg/L.

Discussion

Dam regulation and dewatering are the most widespread human alterations of rivers (Dynesius and Nilsson 1994). In most regions dams are built for hydroelectric production, flood control, and/or to store water for human use or irrigation. Along the lower Rio Grande dams, water diversions and floodwater conveyance canals have been built to reduce flood risk for human communities and agricultural land. Large dikes line the river providing further confinement of the river water and protection from floods. The elimination of flooding from hurricanes and tropical storm runoff as well as the storage in upstream reservoirs of snowmelt water from the Rio Grande headwaters, has converted the lower Rio Grande into little more than an irrigation water conveyance channel.

Areas that were hydrologically connected to the Rio Grande during flood events are now wetted solely by precipitation. Ground water in the area investigated is too deep and saline for most plant use. Thus, soil saturation is produced only by precipitation events large enough to create ponding. Wetlands typically are supported by 14 or more consecutive days of flooding or ponding during the growing season at a minimum frequency of 5 years in 10 (U.S. Army Corps of Engineers 2010). We have shown that a hurricane or other significant tropical storm that produces rainfall totals exceeding 15 cm can produce long duration ponding and low redox potentials for 14 or more days at our study site. However, tropical storms producing this quantity of precipitation occur with a frequency of 1 in 4 years. These sites would not meet the hydrologic criteria for wetlands according to the Corps of Engineers. *Spartina* and *Borrichia frutescens* remain dominant on these prairies more than

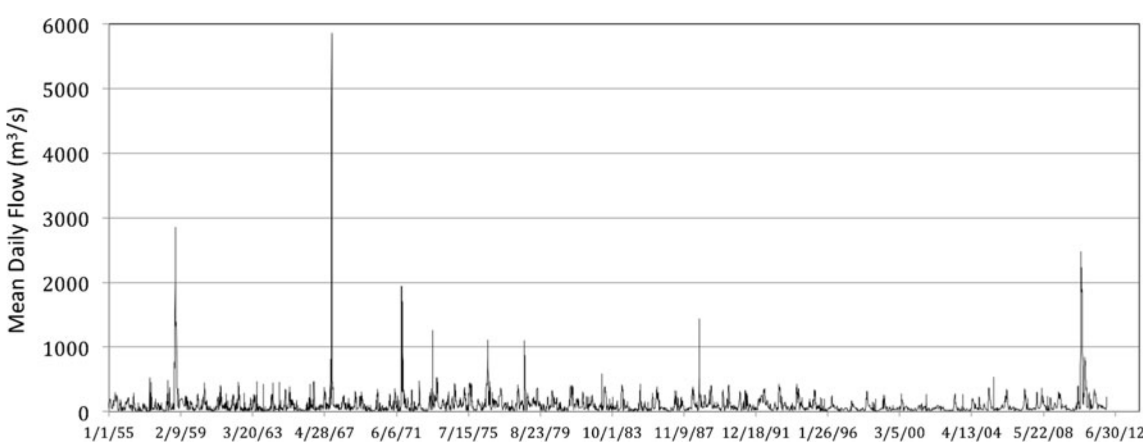

Fig. 3 Mean daily flow for the Rio Grande at Rio Grande City, Texas from 1955 to 2011. Large floods occurred due to Hurricane Beulah in 1967 and Hurricane Alex in 2010

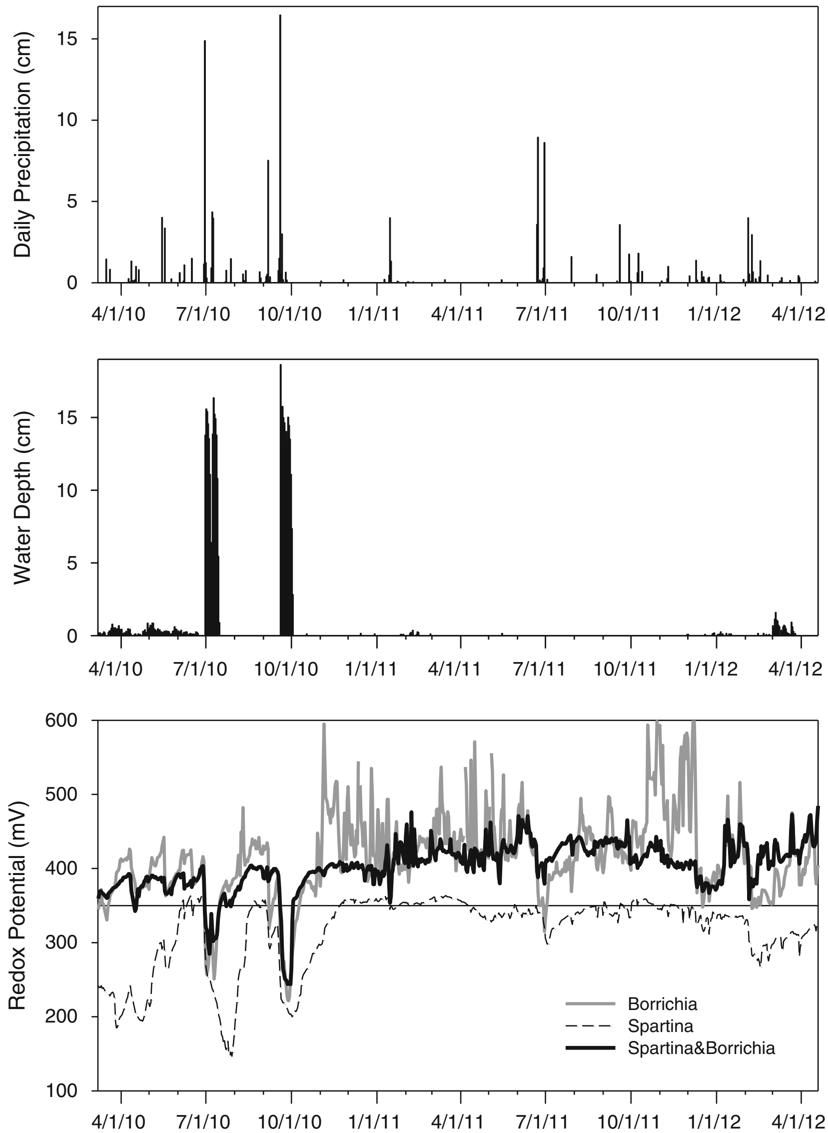

Fig. 4 Top: Daily precipitation totals (cm) for Brownsville for the study period, 6 March 2010 through 24 April 2012. Middle: Daily surface water depth (cm) during the study period for *Borrichia* site. Bottom: Daily redox potential (mV) for the three study sites

50 years following regulation of the Rio Grande and the switch from regular flooding by overbank events to rarely flooded by direct precipitation.

Remnant *Spartina* stands are dense monocultures with leaves and litter covering the ground. Even when dry, the soil surface is covered by plant matter. In comparison, areas that were plowed for agriculture are dominated by *Borrichia frutescens* and maintain a sparse canopy with low plant cover. We have found no *Spartina* seedlings in *Borrichia* stands. This could be due to the high salt concentration in *Borrichia* stands, or a failure of seed to germinate and seedlings to establish. A pilot project introducing bare rooted *Spartina* plugs as fall plantings had 80 % survival over 2 years and dense stands had formed within 6 years at PAAL (Margo 2006). Thus, the restoration of former agriculture lands to *Spartina* dominated prairie will require the planting of seedlings or transplants. The resulting ecosystems will resemble coastal prairie that occurs throughout the Texas coast, but these ecosystems likely will not be wetlands under current climate and river management conditions.

References

American Public Health Association (2005) Standard methods for the examination of water and wastewater, 21st edn. American Public Health Association, Washington

Batzer DP, Sharitz RR (2006) Ecology of freshwater and estuarine wetlands. University of California Press, Berkeley, 568p

Clover GU (1937) Vegetational survey of the lower Rio Grande Valley, Texas. Madrono 4:41–127

Dynesius M, Nilsson C (1994) Fragmentation and flow regulation of river systems in the northern third of the world. Science 266:753–762

Faulkner SP, Patrick W, Gambrell RP (1989) Field techniques for measuring wetland soil parameters. Soil Sci Soc Am J 53:883–890

Jahrsdoerfer SE, Leslie DM (1988) Tamaulipan brushland of the lower Rio Grande valley of south Texas: description, human impacts and management options. U.S. Department of Interior, Fish and Wildlife Service, Biological Report 88(36), 62p

Johnston MC (1955) Vegetation of the aeolian plain and associated features of southern Texas. Unpublished Ph.D. dissertation, University of Texas, Austin, Texas, 167p

Judd FW, Lonard RI (2002) Species richness and diversity of brackish and salt marshes in the Rio Grande Delta. J Coast Res 18:759–785

Lichvar RW, Kartesz JT (2009) North American Digital Flora: National Wetland Plant List, version 2.4.0 (http://wetland_plants.usace.army.mil). U.S. Army Corps of Engineers, Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH, and BONAP, Chapel Hill, NC

Margo MR (2006) Restoration of resaca wetlands and associated wet prairie habitats at Palo Alto Battlefield National Historic Site. Unpublished Masters Thesis, Texas A&M University, College Station, Texas. 68 p

Oefinger RD, Scifres C (1977) Gulf cordgrass production, utilization and nutritional values following burning. Tex Agric Exp Station Bull 1176:19

Rabenhorst MC, Hively WD, James BR (2009) Measurements of soil redox potential. Soil Sci Soc Am J 73:668–674

Ramsey E, Nelson G, Yan YY (2004) Palo Alto Battlefield National Historic Site landscape classification and historic analysis. USGS-National Wetlands Research Center, Lafayette

Sanchez JP (1985) General Mariano Arista at the Battle of Palo Alto, Texas 1846: military realist or failure? J West 24:8–21

Scifres CJ, McAtee JW, Drawe DL (1980) Botanical, edaphic, and water relationships of gulf cordgrass (*Spartina spartinae*) communities. Southwest Nat 25:397–410

Shiflet TN (1963) Major ecological factors controlling plant communities in Louisiana marshes. J Range Manage 16:231–235

Smiens FE, Diamond D, Hanselka CW (1991) Coastal Prairie. pp. 269–290, in Ecosystems of the World 8A. Natural grasslands: Introduction and Western Hemisphere. R.T. Coupland (ed.). Elsevier, Amsterdam, London, New York, and Tokyo. 469 pp

U.S. Army Corps of Engineers (2010) Regional supplement to the Corps of Engineers Wetland Delineation Manual: Atlantic and Gulf Coastal Plain Region (Version 2.0). ERDC/EL TR-10-20. U.S. Army Engineer Research and Development Center, Vicksburg

Williams D, Thompson CM, Jacobs JL (1977) Soil survey of Cameron County, Texas. U.S. Department of Agriculture, Soil Conservation Service, Texas, 92 p