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VEGETATION OF THE SALT PLAINS NATIONAL WILDLIFE REFUGE, JET, OKLAHOMA

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VEGETATION OF THE SALT PLAINS NATIONAL

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APPROVED BY

DISSERTATION COMMITTEE

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INTRODUCTION

The vegetation of Oklahoma has been described in a general way by many investigators (Bruner, 1931; Blair and Hubbell, 1938; Carpenter, 1940; Dice, 1943; Duck and Fletcher, 1943, 1945. Kelting and Penfound (1953) called attention to the need for more detailed studies of the vegetation of Oklahoma and several such studies have recently been made (Penfound, 1953; Rice and Penfound, 1959; Taylor, 1961; Buck, 1962, 1964; Crockett, 1962, 1964; Welbourne, 1962; and Galloway, 1963).

The continuing need for further vegetational analyses prompted the present study of Salt Plains National Wildlife Refuge vegetation. Several investigators have given general, qualitative descriptions of plant communities of the refuge (Ortenburger and Bird, 1933; Jenkins, 1949; Penfound, 1953; Williams, 1954), but no detailed studies have been made. The objectives of this work were: (1) to determine the past vegetational history of the refuge; (2) to quantitatively analyze and map the present plant communities; (3) to attempt to determine plant successional trends and changes in vegetation; and (4) to compile a list of plant species for the refuge.

DESCRIPTION OF AREA

History

Salt Plains National Wildlife Refuge is located in Alfalfa County in northwestern Oklahoma (Fig. 1). Present area of the refuge is nearly 33,000 acres.

According to recorded history, the first white men to see the Salt Plains area were those with the George C. Sibley Expedition, consisting of three white men and six Osage Indians, who crossed the Great Salt Plains in the summer of 1811 (Oklahoma Historical Society, 1959). The great expanse of salt, covering nearly 36 square miles, was undoubtedly well known to Indians as a landmark and as a place to obtain needed salt.

On March 26, 1930, the Great Salt Plains National Wildlife Refuge was established by Executive Order No. 5314 and consisted of 19,459 acres (Low, 1941). The name was later changed to Salt Plains National Wildlife Refuge. Upon establishment, the refuge included only the salt plain itself and a small strip of land bordering it. A permanent manager and staff had not been appointed and the refuge boundary was not properly fenced; therefore, protection of wildlife and vegetation was not effectively enforced at that time.

On June 22, 1936, the construction of the Great Salt Plains Dam

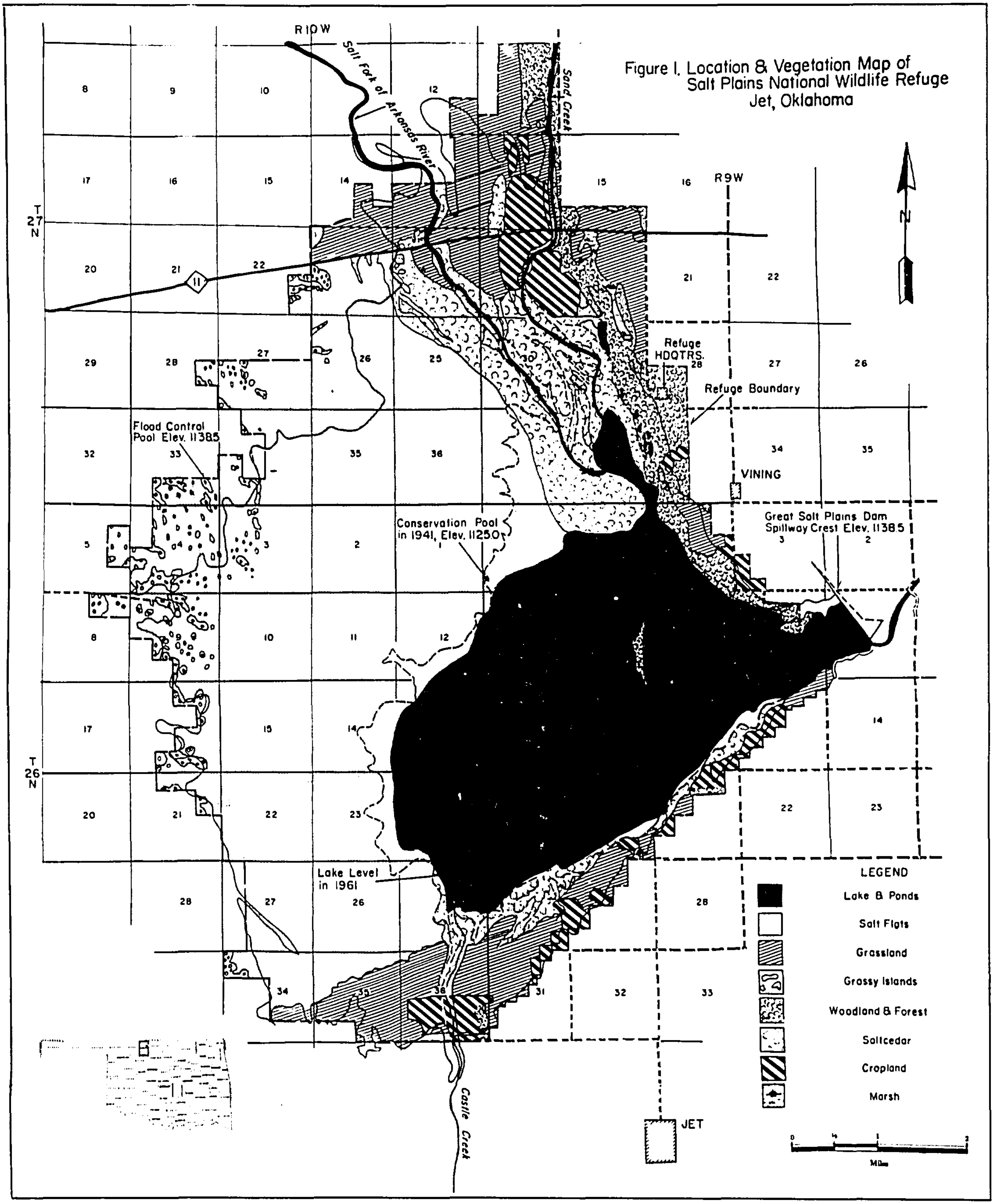

Figure I. Location & Vegetation Map of Salt Plains National Wildlife Refuge Jet, Oklahoma and Reservoir was authorized by the Flood Control Act of 1936. Work was begun on the dam in September, 1938, and the dam was placed in operation on July 2, 1941. Additional acreage was procured by the U. S. Engineers to provide for the lake. Much of this area was later transferred to the control of the U. S. Bureau of Sports Fisheries and Wildlife. The addition increased the area of the refuge to approximately 32,000 acres. Recent purchases of land have brought the total refuge area to its present size.

The refuge operates primarily as a sanctuary and resting place for migrating waterfowl. Management practices are directed toward protecting and feeding these birds, and all wild animals benefit from the protection of waterfowl. Grain and forage crops are maintained to provide food for migrating birds. Certain grasslands are leased to local ranchers and are grazed by cattle during the spring and summer months. Except for those specified grazing units, the vegetation has been essentially undisturbed by domestic animals since 1941, when most of the refuge was fenced and patrolled by the refuge manager and his staff. All areas are protected from burning by a fire-fighting unit operated by the refuge. Controlled burning has been practiced in only one area of the refuge.

Reservoir and Drainage Basin

The Great Salt Plains Reservoir is located on the Salt Fork of the Arkansas River. The dam, which is nearly a mile in length, is located in Section 11, Township 26 North, Range 9 West, Alfalfa County, Oklahoma (Fig. 1). The reservoir is operated by the U. S. Corps of

Engineers primarily as a flood control project, which offers essentially complete flood protection for 50,000 acres in the Salt Fork Valley (U. S. Engineers War Dept., 1947). Nearly all of the lake is administered by the Bureau of Sports Fisheries and Wildlife, U. S. Department of the Interior, as part of the wildlife refuge. Approximately 860 acres of lake and land adjoining the dam and north and south shores are under the control of the Corps of Engineers. The Great Salt Plains State Park occupies a portion of the area southeast of the dam (Bitting, 1963). Most of the eastern portion of the lake is open for use as a recreation area and is heavily used during the summer months by water-sports lovers and fishermen.

The lake, at the conservation pool level (C.P.L.) of 1125.0 feet, covered 10,500 acres with a capacity of 58,000 acre-feet when the lake was first impounded; however, sedimentation has considerably reduced the area covered by water at C.P.L. at the present time (Fig. 1). The flood control pool (F.C.P.) covers 29,000 acres with a volume of 317,000 acre-feet at the F.C.P. level of 1138.5 feet. Thus, a rise in water level of 13.5 feet causes over 18,000 acres to be inundated, leaving only about 4,000 acres of refuge land above water.

Most of the lake is very shallow, the average depth being approximately 5 feet, with a maximum depth of 18 feet near the bluffs on the south side. The entire west side of the lake is less than five feet deep, and it is usually possible to wade several miles into the lake from the western edge. A very shallow slope leads into the lake from the salt plain and a slight rise of water causes a large area of salt plain to be covered. The shallow nature of the lake allows the wind to stir up bottom sediments and keep the lake water murky.

The lake is brackish, but quite variable in content of dissolved salts. Jenkins (1949) reported that the chloride ion content varied from 400 to 2520 parts per million. Fluctuation of the lake with wet and dry periods is extensive, wide expanses of flats being exposed during extended drouths. Large decreases in the lake level result in increased salt concentration which, when associated with water temperatures as high as 85°F, sometimes results in serious fish-kills (Jenkins, 1949).

The principal river flowing into the lake is the Salt Fork of the Arkansas which arises in south-central Kansas and flows in a southeasterly direction to its confluence with the Arkansas River, near Ponca City, Oklahoma, about 50 miles south of the Kansas-Oklahoma border. The river is a typical prairie stream, having a shallow, sand-filled channel, low banks, and a moderately wide valley. The river flow fluctuates seasonally and the river bed is often practically dry for long periods of the year.

The watershed above the reservoir consists of 3,070 square miles. Most of the drainage basin lies within an area of intensive agriculture, so that when heavy rains cause serious flooding above the reservoir, large quantities of silt are carried into the reservoir by the river.

Several smaller streams enter the reservoir from several directions. Sand Creek, a small, relatively clear stream, enters from the north, and Clay Creek flows onto the salt plain from the west. Spring Creek and Castle Creek (Twin Springs Creek) flow into the reservoir from the south.

Geology and Soils

No detailed study of the surface geology of Alfalfa County has been made; however, a number of general descriptions of the refuge area have been published (Clifton, 1926; Gould, 1901, 1911; Gould, Hutchinson, and Nelson, 1908; Oklahoma Geological Survey, 1917; Sheerar, 1932; Snider, 1913, 1917). Theis (1934) reported on the geology of the Great Salt Plains Reservoir basin.

The Salt Plains Refuge lies completely within the Redbed Plains region on an outcrop of the Enid formation of the Permian system. The upper layers consist of red clay, soft shales, and sandstone to a depth of 1200 to 1600 feet. The surface materials are soft and easily weathered, usually resulting in a surface covered with several feet of soil. Tertiary sands (some geologists indicate that they are Quaternary) accumulate along rivers and streams, and extensive areas of large dunes are formed along the north sides of rivers as a result of deposition by the prevailing southerly winds.

The salt plain itself is described by geologists as a saline marsh which was once covered by an ancient lake called Lake Barde (Oklahoma Geological Survey, 1917). This salt plain is the largest of ten such areas in the state. The surface sands of the salt plain are covered with a layer of salt, varying in thickness from one to three millimeters, which causes the entire plain to appear as a dazzling white expanse during dry periods. Rains wash the salt into the lake and the plain appears brown, as sand is then visible. Geologists have disputed the origin of the salt, but it is generally believed that it is derived from underground water moving through extensive salt beds in the Enid member of the underlying Permian Redbed formation. Drainage into the basin keeps the water level just below the sand surface anc water evaporating from the sand leaves its burden of salt on the surface. A hole dug into the plain to a depth of several feet soon fills with brine. Analysis of this brine showed 284,725 parts per million dissolved salts, including 276,437 parts per million of sodium chloride (Engineering Dept., Oklahoma A. & M. College, 1942).

Geologists generally agree that free-flowing springs have never been observed on the salt plain; however, Klepper (1964), a life-long resident of the area, said that he made many trips to such a spring as a young boy to obtain salt for farm animals. He indicated that the salt reached a thickness of an inch or more around the mouth of the extremely saline spring. The spring area which he described is now under the lake, which covers about two-fifths of the original salt plain.

The soils of the drainage basin in Alfalfa County are of the Miles-Vernon type. A description from Soils and Men (U. S. Dept. Agriculture, 1938) presents the following characteristics:

> The surface soils vary in color from red to reddish brown or grayish brown and range in texture from sand to clay. The subsoils are mostly red or reddish brown with light gray or white layers of lime carbonate accumulation in the lower part in most places. This subsoil lime accumulation is typical of the uneven lands, such as the Vernon and Quinlan soils. Miles soils have fairly deep surface soils, usually rather sandy and mellow, over dull-red or reddish-brown crumbly subsoils. Vernon soils have heavy crumbly clay subsoils, and Quinlan very loose, light, sandy subsoils and substrata. Where unprotected, the sandier soils drift in the wind.

Goke, Hollopeter, and Penn (1939) made a detailed description and map of Alfalfa County soils. Of 27 soil types found in the county, 14 are present within the refuge boundary. Nearly all soils listed for the refuge contain a large percentage of sand as indicated in the names of the soil types: (1) Carwile fine sandy loam; (2) Drummond very fine sandy loam; (3) Enterprise-fine sand-dune phase; (4) Nash very fine sandy loam; (5) Riverwash; (6) Broken rough ground, Vernon soil material; (7) Yahola silty clay loam; (8) Yahola fine sandy loam; (9) Vernon fine sandy loam; (10) Reinach silt loam; (11) Reinach very fine sandy loam; (12) Reinach loamy very fine sand; (13) Pratt sandy loam; (14) Pratt loamy fine sand.

More recently, the U. S. Soil Conservation Service (1964) described and mapped 23 soil types on the refuge according to land use capability classes. These descriptions include information on depth of soil, type of substratum, slope, salinity, and potential productivity. These factors will be discussed in relation to the vegetation covering the various soil types.

Climate

General descriptions of the climate of the refuge area are given by Thornthwaite (1933). Blumenstock and Thornthwaite (1941) state that the refuge is in the great subhumid climatic type which is characteristic of areas covered by grassland. Borchert (1950) places most of Alfalfa County in the true prairie climatic type.

The mean annual precipitation at Cherokee, which is three miles west of the refuge, is 27.09 in., and the mean annual temperature is 60.2^{o}F (Cherokee Cooperative Station, 1963) (Table I). Nearly 74 per cent (19.19 in.) of the annual precipitation falls during the period April 1 to September 30. Mean annual precipitation for the ten year period--1954 to 1963--was 29.30 in., with extremes of 18.05 in. in

Table I. Mean precipitation and temperature data

Month	49 Yr. Avg. Mean Precipitation In Inches	49 Yr. Avg. Mean Temp. °F
January	0.81	36.5
February	0.87	40.6
March	1.64	48.3
April	2.87	59.3
May	4.04	68.1
June	4.22	78.9
July	2.57	83.7
August	2.71	83.2
September	2.78	74.5
October	2.21	62.0
November	1.35	47.7
December	0.92	39.1
Avg. Total	27.09	60.2

Data on this page taken from the summary by the U. S. Weather Bureau of the Cherokee Cooperative Station (1963).

1954 to 43.74 in. in 1957. Mean annual snowfall for 38 years has been 9.75 in. Monthly mean temperatures range from 36.5 in January to 83.7°F in July. Extreme temperature range is from -14°F to 114°F. The average length of the growing season is 209 days, the average date of the last killing frost in spring being April 6 and of the first killing frost in the fall, November 1. Winds prevail from the south during all months except December and January, when they are from a northerly direction. February and March have the highest mean wind velocities, which often exceed a 20 mile per hour average for these months. Strong winds of 40 to 50 miles per hour are not unusual during the spring months. Highest recorded evaporation rate at the Great Salt Plains Dam was during July, 1965, when 16.08 in. evaporated from a free water surface. Mean evaporation rates for July and August are 10.51 and 11.29 in., respectively. The area is characterized by periods of drought and excessive rainfall. Extremely heavy rains sometimes fall during the spring and summer as evidenced by a single rainfall of nearly 14 in. west of Cherokee in June of 1963 (Hitch, 1963).

Biotic Affinities and Vegetation

All authorities on the grasslands of North America place the Salt Plains National Wildlife Refuge area in the grassland biome. Many writers place the refuge area in the true prairie or tall grass prairie, although most agree that Alfalfa County is on the western edge of the true prairie and may be ecotonal between it and the mixed prairie to the west. Shelford (1963) states that the western boundary of the tall grass prairie in Oklahoma is the 25 inch isohyet. The refuge, with 27 inches of precipitation, would, therefore, be on the western edge of the tall grass prairie. Carpenter (1940), in an excellent discussion of the grassland biome, also indicates that Alfalfa County is on the western edge of the tall grass prairie and shows the western boundary of Alfalfa County to be the eastern limit of mixed prairie. Weaver and Clements (1938), and more recently, Weaver (1954), and Weaver and Albertson (1956) summarized the voluminous literature on prairie vegetation.

A number of investigators have mapped and described the vegetation of Oklahoma. Bruner (1931), in a study of the vegetation regions of Oklahoma, placed Alfalfa County and the refuge in the mixed prairie (Stipa-Bouteloua)* association with an Andropogon associes in the sandy region on the north edge of the refuge. Dice (1943) placed the refuge area in the "Kansan" Biotic Province which he described as a short-grass prairie with buffalo grass (Buchloe dactyloides) and blue grama (Bouteloua gracilis) as the most important species, but also including the Stipa-Bouteloua association and the Andropogon associes mentioned above. Blair and Hubbell (1938) divided Oklahoma into ten biotic districts and a sandy area. According to them, the most important species in the refuge area are Andropogon scoparius, A. gerardi, A. saccharoides, Agropyron smithii, and several short grasses such as Buchloe dactyloides, Bouteloua gracilis, B. racemosa, and B. hirsuta. They also describe the sandy areas north of the refuge, stating that these areas are covered with tall grasses or shrubs such as Chickasaw plum (Prunus angustifolia)

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*Taxonomic terminology follows Waterfall (1962), except for names quoted in text from other authors. Varietal epithets are omitted from text and all tables except Table XXX. Common names largely follow Anderson (1961).

and stinking sumac (*Rhus aromatica*). Duck and Fletcher (1943) made a map of vegetation cover types for the state in relation to game animal distribution. The same authors (1945) described the areas shown in the map and present one of the best general descriptions, to date, of the vegetation of the Salt Plains Refuge area. They place the refuge in the tall grass prairie with the exception of the dune area to the north, and consider the dominant grasses to be big bluestem (*Andropogon gerardi*), little bluestem (*A. scoparius*), switch grass (*Panicum virgatum*), and silver bluestem (*Andropogon saccharoides*) with the short grasses much less abundant. Harlan (no date) places nearly all of Alfalfa County in Mixed Prairie Grassland with "a mixture of eastern prairie elements such as little bluestem, big bluestem, switchgrass, and Indiangrass together with steppe grass elements such as blue grama, sand dropseed, buffalograss, western wheatgrass, and side-oats grama. Sand bluestem, sand lovegrass, and sand paspalum and similar grasses are also important on sandier sites especially." His description of the grassland areas of the refuge is quite accurate.

It is obvious that the refuge is in the grassland biome; however, edaphic conditions exert an important influence on plant communities. Many areas are highly saline, limiting development to several halophytic species, whereas non-saline areas support a variety of glycophytes. Moisture conditions are more favorable than on the plains areas surrounding the refuge and trees can survive in the better sites. Tall grasses or shrubs dominate non-saline, sandy deposits.

Several brief descriptions of the refuge vegetation have been made. Ortenburger and Bird (1931) discussed the general ecological relations of plants and animals within the immediate area of the salt plain and listed important plant species in each of several habitats. A similar, brief description for the regions adjacent to the salt plain was given by Jackson and Warfel (1933), who studied the mammals of the area. A brief discussion of the plants and plant communities of the salt plain is also found in an early geological bulletin (Oklahoma Geological Survey, 1917).

Jenkins (1949) listed dominant plants for four altitudinal levels in both the saline and non-saline areas surrounding the Great Salt Plains Reservoir, and Penfound (1953) listed important plants and plant communities in the lake itself and on the surrounding shorelines. Williams (1954) described seven habitat areas, based on vegetation types and physiography, in relation to mammalian ecology of the refuge.

The vegetation of the refuge has been disturbed through man's activities in many places. A number of attempts have been made to control undesirable species and to propagate desirable ones. Spraying and mowing of undesirable marshland plants is a frequent practice and plantings of certain desirable rushes, sedges, grasses, and shrubs have been made in several places, especially around the lake and ponds. One slough-grass pasture is burned periodically to reduce dead material and allow earlier grazing in the spring. A number of partially successful attempts to control shrubs have been made. Certain areas of salt cedar (Tamarix gallica) have been sprayed and mowed with rather uncertain results. Several stands of plum, sumac, and rough-leaved dogwood have been removed with brush mowers. Most of these control measures have been experimental trials. Little permanent control has been achieved because of the restricted nature of control practices.

Several small dams have been erected to form ponds, and streams have been diverted and controlled to maintain water levels in the ponds. Seepage from the ponds increases soil moisture and allows trees to grow in areas which were grassland before the ponds were made. In general, all these various management practices have been followed in the hope of maintaining or increasing desirable habitat areas for the wildlife, and especially for the waterfowl.

METHODS

A preliminary reconnaissance was made in February, 1963, to outline the general areas of the various plant communities. Further reconnaissance and use of aerial photographs during the early weeks of the summer of 1963 allowed more accurate delimitation of community boundaries.

All plant communities which were selected for quantitative analysis were sampled by the point-centered quarter method outlined by Cottam and Curtis (1956). Points were taken along a compass line at intervals of five paces in herbaceous communities and shrublands and of twenty-five paces in forests. Distances were measured with a centimeter rule in shrubby and herbaceous communities and with an optical rangefinder in the forests. The rangefinder allowed forest communities to be sampled with greater efficiency and gave measurements which were accurate to within five per cent of those obtained with a steel tape measure. Diameter of trees at breast height was measured with a steel diameter tape which gave tree diameters directly. Basal area of trees was determined through use of conversion tables. Shrub diameter, four inches above ground level, was measured with a vernier caliper, and basal area was determined for shrub-dominated areas. In all forests, except the one around ponds, specimens larger than 3 in. diameter breast high (D.B.H.) were called trees and those smaller than 3 in. D.B.H. were called saplings, and were not measured. In the woody community surrounding the fresh-water ponds the size limit of trees was reduced to 2 in. D.B.H. because of the small size of many of the trees. Shrubs were not segregated into size classes.

Tabulated data for herbaceous communities include relative frequency, relative density, importance percentage, and number of stems per acre. The additional parameters of relative basal area and basal area per acre are included in tables of composition of forests, and of shrubs in shrub-dominated communities. The importance percentage is the average of two parameters--relative frequency and relative density--in herbaceous communities, and the average of three parameters--relative frequency, relative density, and relative basal area--in woody communities. Data tabulated include not only information on dominants, but also on sub-dominants and important influents so that a more complete representation of each community may be shown. Species of little importance are placed under the "others" category in the tables.

Penfound (1963) and Dix (1961) used a modified point-centered quarter method to sample grasslands. Penfound included the additional parameter of relative weight for grassland species by taking oven-dry weights of specimens included in the sample, whereas Dix used the number of stems or culms per acre to give an indication of actual basal cover and density. The latter system has been followed in this study. Greig-Smith (1964) warns against calculating the number of stems per acre from point-centered quarter data because of the possibility of nonrandomness of certain species; however, data on actual densities are valuable parameters of community structure, and by taking an adequate number of points one may minimize the possibilities for error.

The number of points taken in each sampling area varied from 40, in communities consisting of nearly a pure stand of one species, to 100, in communities with a large number of species. In all cases, more than the minimum number of points were taken if the species-area curve (Cain, 1938) was used as a criterion.

Plant communities were selected on the basis of physiognomy and species composition. Several communities were similar in species composition but obviously differed in density of plants because of edaphic factors and were considered to be separate communities. Plant communities were named after the dominant plant or plants as suggested by Odum (1959). Nearly all communities were distinct upon analysis by the coefficient of community methods outlined by Oosting (1958), except for those several which differed primarily in density as mentioned above.

An attempt was made to determine the acreage of various recent vegetation types. Obvious vegetation types were outlined on aerial photographs taken in 1961, and areas were measured with a Lasico planimeter. It was impossible to delimit small communities or to distinguish shrubland from grassland on the photographs so that measurements of only general types, such as forest or grassland, were possible.

Personal conversations with long-time residents of the refuge area and use of refuge records gave a general idea of past vegetational history of the refuge; however, no quantitative information about past vegetation was available.

Plant collections were made throughout the summers of 1963 and 1964. Specimens were placed in the herbarium at the refuge and in the

Bebb Herbarium, University of Oklahoma. A number of additional plant specimens were placed in the herbarium of the Geology Department, University of Oklahoma.

RESULTS AND DISCUSSION

Past Vegetation

Only meager records of the vegetation history of the refuge were found. Narrative reports made by the refuge managers provided some general information about the refuge during the early years of its existence. Low (1941) gave the earliest description of general vegetation and habitat types. He noted the presence on the refuge of 3,000 acres of plains, grassy knolls, and intermittent pools; 1,000 acres of agricultural land; 5,500 acres of grassland; and 1,500 acres of upland and pools included in the 32,000 acres then comprising the refuge. No mention was made of the presence of salt cedar and trees were apparently then limited to the immediate headquarters area and to a small strip of land along the east side of the refuge. He mentions the presence of one small pond and scattered grassland through the wooded area.

In a later report, Low (1942) gave a more complete description of the refuge vegetation. He stated that from Section 35, Range 10 West, Township 26 North (Fig. 1) to the dam at the southeast side of the lake, the following acreages of vegetation types were present: agricultural fields, 540; salt pan, gullies, and coulees, 440; trees and shrubs, 20; and open pasture land, 1300. Low also noted the presence of salt cedar in Section 35 and stated that none was present anywhere else along the lake shore, but mentions the presence of salt cedar hedges and cottonwood trees around several old homestead lots on the south side of the lake. A farm in Section 16, Range 9 West, Township 26 North, had several thickets of black locust, elm, hackberry, mulberry, cottonwood, and Chinaberry (western soapberry).

Low described most of the northeast side of the refuge as grassland with a few scattered elms and hackberries. The area along Sand Creek, north of Highway No. 11, was described as a second-growth woods which included black locust, catalpa, elm, cottonwood, hackberry, mulberry, willows, honey locust, Osage orange, and green ash trees. He also mentioned the presence of shrubby button-bush, dogwood, plum, and sumac, intermixed with tangles of briar, poison ivy, and grape. He described the entire northwestern portion of the refuge as grassland.

Comparison of the above descriptions and certain early photographs of the refuge with the present-day vegetation indicate that the refuge once contained much less forest, woodland, and shrubland than it presently does. Photographs of certain areas taken in 1942 pictured tall grass prairie with a few scattered trees. Today, the same areas support a dense elm-hackberry woodland with small, scattered patches of grassland, indicating the dynamic response of vegetation to protection from disturbance. Conversations with Foltz (1964) and Corbin (1964), both long-time residents of the immediate refuge area, confirm the previous absence of trees on much of the refuge. Areas which now support dense thickets of shrubs and trees were, according to them, good tall grass pastures forty years ago. Neither of them remembered having seen salt cedar in the refuge area before impoundment of the reservoir.

A number of plantings of desirable plant species have been made. The lake and pond banks were seeded at various times, between 1942 and 1949, with the following plants: Brasenia sp.; Polygonum pennsylvanicum; Potamogeton pectinatus; Ruppia maritima; Sagittaria sp.; Scirpus acutus; S. americanus; S. paludosus; and S. validus. Cynodon dactylon and Distichlis stricta have been sprigged into most of the pond dams and dikes and Eragrostis trichodes and E. curvula were planted in several sandy areas. Wild millet (Setaria sp.) was planted near several ponds and Rosa multiflora was planted on many upland areas to provide food and cover for quail. A number of shelterbelts of mulberry (Morus sp.) and western soapberry (Sapindus drummondii) were planted on the refuge during 1942. Scattered plantings of Lespedeza bicolor, Indigofera pseudotinctoria, and chufa (Cyperus esculentus) were made in 1953 (Van den Akker, 1953).

The problem of weed-trees was recognized early and control measures were instituted. Howard (1948) reported:

> Weed-tree growths were studied to determine the extent of spread and methods of control. Species concerned included cottonwood, willow, and salt cedar (Tamarisk), of which the latter received the greatest attention. It was known that this pest had become established in narrow bands along sections of the lakeshore, stream margins and roadsides. During a plane trip over the refuge it was found to have taken the mud flats on the deltas and flood plains of the several streams entering the lake from the north. Solid stands now exist in sites which cannot be reached in most seasons with machinery. It is planned to attempt control with plane applied 2-4,D (46% Ester). Other small stands may receive tractor applied sprays.

In the continuing fight against salt cedar, Van den Akker (1955) stated:

> Approximately 92 acres and one mile of shoreline, Salt Cedar and other brush were sprayed with herbicide. Two miles of shoreline were mowed. Some of the work was done in channels, while most

> of it was done along the lakeshore. The intrusion of Salt Cedar on the exposed flats was extensive and it was the hope that the seasonal floods would come to drown the stubble. Unfortunately, at this writing the lake is still three feet below normal. The winter brush control program can be described as comparatively unsatisfactory.

Refuge records indicate that no extensive areas of salt cedar were ever sprayed, and at the present time, control measures directed toward salt cedar are limited to occasional spraying of those trees which become established on dikes and dams.

The lake itself, due to turbidity and salinity, has apparently never supported abundant growth of aquatic plants. During 1956, the lake was treated with rotenone to remove rough fish. Following treatment of the lake, Van den Akker (1956) reported:

> (There is an) . . . abundance of sago pondweed on the south and west side of the lake which is growing in from 6 inches to 3 feet of water and from the shoreline out to 200 yards in the lake. Heretofore an unknown factor, kept down by the abundance of carp, this pondweed has made a phenomenal growth this year. . . .

Vegetation on and around the salt plain was described by Ortenburger and Bird (1933), and has apparently changed very little since that time. They stated that Sesuvium sessile Pers., Dondia depressa (Pursh) Britton [=Suaeda depressa (Pursh) Wats.], and Oscillatoria sp. were the only plants present on the salt plain itself. They described the vegetation of the islands on the salt plain as zones of grasses comprising Distichlis spicata (L.) Greene, Sporobolus airoides Muhl., and Andropogon furcatus Muhl. (= A. gerardi Vitman), from the lowest to the highest levels, respectively. They described most of the grasslands around the salt plain as an Andropogon prairie.

Present Vegetation

The present vegetation of the Salt Plains Refuge is obviously different, in many respects, from that present when the refuge was first established. Measurements of aerial photographs taken in 1961 indicate the following acreages in general habitat types: cropland, 1279; grassland and shrubland, 4163; salt cedar, 2641; forest and woodland, 923; ponds, 86; marsh, 155; reservoir at conservation pool level, 9045; and barren salt flats, 14376 (Table II). The most obvious change in areal cover is that made by salt cedar, which was practically absent in 1942. The acreage of the lake has been reduced because of siltation, whereas the area of salt flats has been increased by the same process; however, much of the newly formed alluvial flat is quickly occupied by salt cedar. Grassland and shrubland, as habitat types have decreased in size, because of the increase in forest and woodland. It is almost certain, however, that grassland has been reduced because of invasion by shrubs although the respective areas of grassland and shrubland could not be accurately measured from the photographs and no quantitative data on these two types can be presented. Area of ponds and marsh has been increased since refuge formation because most of the ponds are artificial structures constructed by refuge personnel. At the present time, however, the ponds are slowly being changed to marshland as the stages of the hydrosere proceed toward the climax. Cropland acreages have remained approximately constant since refuge formation.

Twenty-six distinct plant communities were quantitatively analyzed and 7 communities and habitat areas were described qualitatively. The communities described, and the general habitat in which they are

Table II. Acreage of various habitat types in Salt Plains National Wildlife Refuge in 1942 and 1962

Habitat Type	Acreage in 1942	Acreage in 1962
Cropland	1,000	1,279
Grassland and Shrubland	5,500	4,163
Salt cedar	20	2,641
Forest and Woodland	?	923
Ponds	8	86
Marsh	?	155
Reservoir at Conservation Pool Level	10,700	9,045
Salt Flats	11,000*	14,376
Totals	32,000	32,668

*This figure, given by Low (1942), is almost certainly too small.

found, are as follows:

I. Terrestrial Habitats

A. Sandy soils

1. Saline areas

a. Salt Plain communities

(1) Sesuvium verrucosum consocies

(2) Suaeda depressa consocies

b. Grassland communities

(1) Ungrazed islands on the salt plain

(a) Distichlis stricta consocies on margin of plain

(b) Sporobolus airoides consocies on margin of plain

(c) Sporobolus texanus-Distichlis stricta associes

(d) Leptoloma cognatum community on islands

(e) Andropogon hallii consocies on islands

(f) Panicum virgatum community on islands

(2) Grazed pastures southwest of salt plain

(a) Distichlis stricta associes

(b) Sporobolus airoides-Leptoloma cognatum associes

(3) Ungrazed grasslands south of lake

(a) Distichlis stricta consocies

(b) Weedy Distichlis stricta associes

(4) Grazed pastures northwest of salt plain

(a) Andropogon scoparius consocies

(b) Andropogon scoparius-Sporobolus asper-Sorghastrum nutans associes

(c) Andropogon scoparius-Calamovilfa gigantea associes

c. Shrubland community

(1) Tamarix gallica consocies

2. Non-saline areas

a. Grassland communities

(1) Andropogon community near headquarters

(2) Andropogon scoparius-Eragrostis trichodes community near headquarters

(3) Sporobolus-Andropogon associes on sand dunes

b. Shrubland communities

(1) Prunus angustifolia community

(2) Cornus drummondii community

c. Forests

(1) Robinia pseudoacacia forest

(2) Ulmus americana forest near headquarters

(3) Populus-Salix woodland near lake

B. Clay soils

1. Grassland community

a. Andropogon-Artemisia-Bouteloua associes on Redbeds

2. Shrubland

a. Rhus thickets

3. Woodland community

a. Ulmus-Salix-Populus woodland near streams on north side

II. Aquatic and Marsh Habitats

A. Saline areas

1. Pond, lake, and shoreline communities

B. Non-saline areas

1. Fresh-water ponds and pond margins

a. Submerged and floating plant communities

b. Emergent communities

c. Wetland communities

(1) *Populus*-*Salix* woodland near ponds

(2) *Scirpus* marsh community

(3) *Spartina pectinata* consocies

d. Dike and dam communities

III. Cultivated Habitats and Planted Shelterbelts

Salt Plain Communities

The salt plain, covering approximately 14,400 acres, is essentially a barren waste of salt-covered sand. In certain places, however, one may occasionally find small, elevated areas which support an open stand of halophytic plants. The surface materials of the salt plain are primarily alluvial sands called riverwash. The sand is nearly always wet because of the high water table and is highly saline. Portions of the plain near the lake are frequently inundated when the lake level rises, and nearly all of the salt plain is flooded when the reservoir is at the flood control pool level. A layer of tough, gray silty clay is generally present below the sand surface from a depth of 1 to 3 feet. This layer is only several inches thick and is underlaid by more sand and gravel. After rains, pools of water remain in pockets on the plain. Ortenburger and Bird (1933) and Jenkins (1949) reported that a species of *Oscillatoria* grows on the plain after rains, but none was observed during the present study period. Only two sparse communities are commonly found on the salt plain: the *Sesuvium verrucosum* consocies; and the _Suaeda depressa_ consocies.

Sesuvium verrucosum Consocies

Small patches of _Sesuvium verrucosum_ exist in scattered areas of the salt plain. Almost invariably, the plants are found on patches of sand which are slightly elevated above the salt plain, and which are free from the usual incrustation of surface salt. It is not known whether the elevation of sand in areas where _Sesuvium_ is found is due to accumulation of drifting sand around the plants, or whether the plants are able to survive because the small elevations were present originally and rains washed the salt away. Since a few single plants may occasionally be found growing through the salt-incrusted sand surface, the former explanation is most likely the correct interpretation. Ortenburger and Bird (1933) suggest that the salt-free areas may be due to the presence of more clay in such places, which holds water more tenaciously than sand, preventing a rapid loss of water and large accumulation of salt.

The _Sesuvium_ consocies is always pure on the plain itself, no other plants being associated with it. Individuals are separated by several inches, and the largest communities cover only a small area (Fig. 2). During years of normal rainfall the plants flower and produce seed, but during dry seasons they often wither and die and are blown away by the wind. The sand-blasting effect of drifting sand often causes the plants to be worn away in dry years, and an entire area of _Sesuvium_ may be killed. Because of the variable and restricted nature of the _Sesuvium_ consocies, no sampling data are presented for it.

Suaeda depressa Consocies

Around the margins of the salt plain, restricted areas of *Suaeda depressa* are found. The soil and moisture conditions are similar to those found in the *Sesuvium* consocies, but salinity is lower because of a small elevation of the sand above the salt plain proper. The stands of *Suaeda* are quite open in most places, and subjected to the same conditions found in the *Sesuvium* community. Many plants are removed by blowing sands in dry years, but most are able to produce seed in years of normal rainfall. The *Suaeda* consocies is found at the level just above the plain proper, or above the *Sesuvium* community, if it is present (Fig. 3). The Suaeda community is limited to a small band around islands, and around peninsulas extending into the salt plain. Sampling data for the community are not presented.

Grassland Communities on Sandy Soil in Saline Areas

Ungrazed Islands on Salt Plain

Found on the western edge of the salt plain are 388 islands and peninsula arms (Fig. 1). Both the islands and peninsulas are covered with grasslands of various types. Surface soil on the islands and most peninsulas is Enterprise fine sand although several of the larger peninsulas are composed of Reinach loamy very fine sand. Most islands are above the flood level, but some of the smaller ones are covered during periods of very high water. The islands vary in size from only a few feet in diameter to nearly ten acres. Some are separated by only several feet of salt flat, but others are isolated from adjacent islands by several hundred yards. Soils above the plain are not saline, but the

Figure 2. Sesuvium verrucosum consocies on salt plain. Size of vegetated area about 8 by 50 feet.

Figure 3. Suaeda depressa consocies (center of photo) at level above salt plain. Saltgrass and switchgrass at next higher successive levels. Conspicuous shrub is Baccharis salicina. Note cottonwood sapling in background.

margins of both islands and peninsulas are affected by salt. At approximately one foot above the plain the soils contain negligible quantities of salt.

The presence of the islands, surrounded completely by barren salt flats, has long intrigued geologists and biologists. Several investigators have proposed theories about how the islands were formed. Ortenburger and Bird (1933) described island formation as follows:

> We believe that there is no definite advance of vegetation but rather alternate advances and retreats associated with periods of rain and drought. Patches of the Western Sea Purslane (Sesuvium sessile) are found well out on the plain usually in places where the soil contains more clay and hence gives up less water with a correspondingly smaller deposit of salt. This prostrate Sesuvium is high enough to cause drifting sand to accumulate about it and grass seed (Sporobolus airoides) to lodge and germinate. With the increase in vegetation more sand lodges and islands are formed. This is the first grass to come in on a developing island, but it is quickly followed by Andropogon furcatus Muhl. which becomes the dominant plant . . . (and) may increase to sufficient size to be permanent and withstand periods of drought.

The above explanation, while entirely plausible, may not be responsible for formation of all islands. During floods, the streams entering the plain carry large amounts of driftwood, much of which is left stranded on the plain. Sand which accumulates around the debris often becomes colonized by Sporobolus airoides, which may result in the formation of a stable island. The size of the islands is not static. Moving flood water often removes several feet of soil from around the base of the islands and may remove much vegetation if the entire island is covered with water. Williams (1954) reported that grass cover on an island had been reduced by a flood, and the island later supported many weeds. During dry periods the strong southerly winds frequently cause blowouts on the south side of larger islands which results in a nearly vertical face above the plain on that side. Deposition on the down-wind side indicates that the islands may slowly move across the plain.

Six distinct grass communities are found on the islands and peninsulas: (1) Distichlis stricta consocies on margin of the salt plain; (2) Sporobolus airoides consocies on margin of the plain; (3) Sporobolus texanus-Distichlis stricta associes; (4) Leptoloma cognatum community on the islands; (5) Andropogon hallii consocies on the islands; and (6) Panicum virgatum community on islands and peninsulas.

Distichlis stricta consocies on margin of salt plain

Around the margin of the salt flat, at the next higher level above the Suaeda community, is an open stand of inland saltgrass (Distichlis stricta) (Fig. 4). The saltgrass is dwarfed because of the unfavorable conditions for growth and seldom matures seed, reproduction being carried on primarily by rhizomatous growth. Rhizomes extend out into the salt plain, but the new shoots are usually killed by the first flood.

The width of the saltgrass zone is determined by the degree of slope leading to the upper levels of the islands or peninsulas. Where the slope is very gradual, the zone may be 50 feet or more in width, but where a wave scarp is present above the plain, the saltgrass zone may be only a foot wide. The zone averages about 10 to 30 feet in width around the grazed grasslands but only about 5 feet around the islands. Regardless of its size, the zone of saltgrass is almost invariably present just above the salt plain and is always fairly open and is usually weedy. Saltgrass was found to have an importance percentage of 59.9 (Table III). The only other important species were Russian thistle

(Salsola kali) and Suaeda depressa, which had importance percentages of 17.9 and 17.4, respectively. The three other species encountered in the community had a total importance percentage of only 4.8. Total density was 1,215,000 stems per acre, including 850,000 of saltgrass. An occasional salt cedar shrub was found in this community, and a few stunted individuals of Kochia scoparia, Ambrosia psilostachya, and Chenopodium sp. are also scattered through the saltgrass but are not specifically noted in the table. All plants were deleteriously affected by the high salinity of the Enterprise fine sand which supports the community, and the only species which produced flowers regularly was Suaeda depressa. The factor which controls this community type is obviously soil salinity. Kearney, et. al. (1914) reported that Distichlis was limited around saline lakes in Utah to soils of less than one per cent salinity. Measurements of soil salinity were not made in the present study but it is obvious that salt grass does poorly in extremely saline sites. The Distichlis stricta consocies extends back along the banks of the Salt Fork River where soil conditions allow its growth. Saltgrass does not compete effectively with glycophytic grasses in less saline sites.

Sporobolus airoides consocies on margin of salt plain

Around the salt plain margin, at the next higher level above the saltgrass consocies, is a nearly pure stand of alkali sacaton (Sporobolus airoides) (Fig. 4). The width of the zone of alkali sacaton is again dependent upon the degree of slope from the salt plain and may be several hundred feet wide around certain peninsulas in the grazed pastures, but is generally only 3 to 10 feet wide around the islands. In almost every case, the alkali sacaton consocies is separated from the saltgrass community, at the level below, by a sharp, vertical scarp. This scarp, which is from 6 inches to 2 feet in height, is apparently the result of wave action when the lake is near the flood control pool level.

The alkali sacaton consocies consists of a nearly pure stand of Sporobolus airoides with some scattered western ragweed (Ambrosia psilostachya) and saltgrass. A few individuals of Russian thistle, Chenopodium sp., Aster subulatus, and Suaeda depressa are found in open spaces between the bunches of grass. Sporobolus airoides was the dominant species with an importance percentage of 73.7 (Table IV). Western ragweed and saltgrass had importance percentages of 13.9 and 3.2, respectively, and the five other species included in the sample added 9.2 per cent to the importance percentage. Total density was 479,000 stems per acre, of which 400,000 (82.3 per cent) were Sporobolus airoides.

The sand on which the community is located is Enterprise fine sand, but it contains much less salt than is found in the saltgrass community. Moisture is also less abundant than at lower levels.

The community consists of extremely dense hummocks of grass which are separated from each other by several inches of bare ground. The grass clumps are from 6 to 12 inches in diameter and two feet in height, exclusive of the long inflorescences, and include many dead stems on both the inside and outside. The long, flexuous leaf blades cover the bare areas between clumps and effectively prevent establishment of new plants. A similar growth form for Sporobolus airoides was reported by Flowers (1934) and Vest (1962), who studied communities around saline lakes in Utah. They also found that the alkali sacaton zone was above the saline flats and saltgrass community.

Table III. Composition of Distichlis stricta consocies around margin of salt flats

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Distichlis stricta	49.8	70.1	59.9	850,000
Salsola kali	22.4	13.3	14.9	162,000
Suaeda depressa	22.2	12.5	17.4	152,000
Sporobolus texanus	3.5	3.3	3.4	41,000
Others (2)	2.1	0.8	1.4	10,000
Totals	100.0	100.0	100.0	1,215,000

Table IV. Composition of Sporobolus airoides consocies around margins of islands and peninsulas in salt plain

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Sporobolus airoides	65.1	82.3	73.7	400,000
Ambrosia psilostachya	18.6	9.2	13.9	44,000
Distichlis stricts	4.7	1.7	3.2	8,000
Others (5)	11.6	6.8	9.2	27,000
Totals	100.0	100.0	100.0	479,000

Actual areal cover of the Sporobolus airoides community is rather limited because of the restricted area of habitat suitable for growth of the grass. Small zones extend back from the plain along the various streams where soil conditions permit its growth.

Sporobolus texanus-Distichlis stricta associes

In certain places around the margin of the salt plain the Sporobolus airoides consocies is absent and is replaced with a mixed stand of Texas dropseed (Sporobolus texanus) and saltgrass. This community is generally present only where the typical scarp is absent above the saltgrass consocies and where a gentle slope leads from the saltgrass community to higher levels. Soil conditions are similar to those found in both the saltgrass and alkali sacaton communities, but salinity is apparently lower than in the pure saltgrass community and higher than in the sacaton community. The mixed Texas dropseed-saltgrass community also typically covers the smallest islands which are only several feet in diameter by less than a foot high, which are located along the south side of the plain. Apparently Sporobolus texanus is somewhat more salt tolerant than Sporobolus airoides in the salt plains region.

Total density of the community was relatively high with 2,050,000 stems per acre (Table V). Texas dropseed and saltgrass densities were 1,400,000 and 550,000 stems per acre, respectively, whereas importance percentages for the two were 61.7 and 32.1. Kochia (Kochia scoparia), Russian thistle, and nettleleaf goosefoot (Chenopodium leptophyllum) added 6.2 per cent to the importance percentage.

The community covers little actual area, being limited to the margins of islands and peninsulas in only restricted places.

Leptoloma cognatum community on islands

At the highest level on many of the islands is a weedy community dominated by fall witchgrass (Leptoloma cognatum) growing in Enterprise fine sand which contains very little salt. The community is typically separated from the Sporobolus airoides zone below by a sharp line which marks the upper edge of the slope leading onto the highest island level. Dominant plants are Leptoloma cognatum and Ambrosia psilostachya with importance percentages of 47.2 and 21.4, respectively (Table VI). Chenopodium leptophyllum had an importance percentage of 14.9. Conyza canadensis, Cyperus filiculmis, Distichlis stricta, and four other weedy species added 16.5 to the importance percentage. Total density was low since only 372,600 stems per acre were present and 200,000 stems were of fall witchgrass. Foliage cover was rather dense because of the spreading nature of the witchgrass, but the basal cover was very low. The entire community appeared weedy and open but may be a seral stage leading to the edaphic Andropogon climax. The community type is important on the islands and on several peninsulas because comparatively large areas are covered.

Andropogon hallii consocies on islands

On the highest level of the sandy islands of Enterprise fine sand the edaphic climax is apparently an Andropogon hallii consocies (Fig. 5). Andropogon hallii replaces the weedy Leptoloma cognatum and dominates the upper levels of most of the larger islands. The grass is from 5 to 7 feet tall and forms a dense sod in most areas. Open spaces are present and are generally covered with a weedy, open stand of Leptoloma cognatum and Ambrosia psilostachya. Panicum virgatum is

Table V. Composition of Sporobolus texanus-Distichlis stricta associes on margins of islands and peninsulas

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Sporobolus texanus	55.2	68.1	61.7	1,400,000
Distichlis stricta	37.3	26.9	32.1	550,000
Kochia scoparia	4.5	2.5	3.5	50,000
Others (2)	3.0	2.5	2.7	50,000
Totals	100.0	100.0	100.0	2,050,000

Table VI. Composition of Leptoloma cognatum community on islands in salt plain

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Leptoloma cognatum	41.3	53.1	47.2	200,000
Ambrosia psilostachya	22.7	20.1	21.4	77,000
Chenopodium leptophyllum	16.0	13.8	14.9	51,000
Conyza canadensis	4.0	3.8	3.9	14,000
Cyperus filiculmis	4.0	3.8	3.9	14,000
Distichlis stricta	2.7	1.9	2.3	7,000
Others (4)	9.3	3.5	6.4	9,600
Totals	100.0	100.0	100.0	372,600

present in small quantities, especially where the soil contains more clay. Andropogon hallii had an importance percentage value of 69.3, whereas Ambrosia psilostachya and Leptoloma cognatum had respective values of 14.2 and 10.9 (Table VII). Panicum virgatum added 2.1 per cent to importance percentages, and weedy species such as Conyza canadensis, Chenopodium sp., and Solanum eleagnifolium had an importance percentage of 3.5. Scattered individuals of Baccharis salicina and Cirsium undulatum were occasionally present. Total density was 516,000 stems per acre, of which Andropogon hallii contributed 78.8 per cent (405,000). Ambrosia psilostachya and Leptoloma cognatum comprised 55,000 and 36,000 stems per acre, respectively, and Panicum virgatum added only 6,500.

Panicum virgatum community on islands and peninsulas

On the southwest side of the salt plain several large islands and peninsulas or fingers of land extend onto the plain. The soil of these areas contains more clay than the island soil and is called Reinach loamy very fine sand, which is not saline. Upper levels of these peninsulas and islands support a good stand of switchgrass (Panicum virgatum) which has been protected from grazing for many years (Fig. 3). Switchgrass forms nearly pure stands in many places, but openings are present and are dominated by other grass species. In some places an understory of other plants exists beneath the upper layer of switchgrass. Panicum virgatum was obviously dominant with an importance percentage of 58.1, followed by Poa arida, Cyperus filiculmis, and Distichlis stricta with respective importance percentages of 20.0, 7.2,

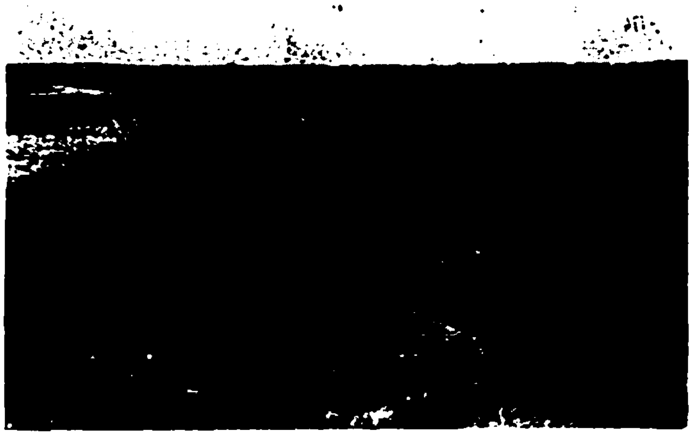

Figure 4. Zonation around margin of salt plain. From left are zones of Sesuvium on salt flat, Distichlis, Sporobolus airoides, and Andropogon scoparius.

Figure 5. Andropogon hallii consocies on top of ungrazed island. Note other islands on salt plain in background.

and 5.7 (Table VIII). A number of other species was present, but only four were included in the sample. Tripsacum dactyloides, Ambrosia psilostachya, Artemisia ludoviciana, and Sporobolus cryptandrus had a total importance percentage of 9.0. Total stem density was 651,000 per acre with switchgrass and plains bluegrass (Poa arida) totaling 392,000 and 132,000 stems per acre, respectively.

Many Baccharis salicina shrubs are present throughout the community and lend an interesting aspect when in fruit. A number of saplings of cottonwood (Populus deltoides), which averaged 8 years old, were found scattered among the grasses, perhaps indicating a further seral change to woodland. The cottonwood saplings will apparently survive on the islands and peninsulas and may bring about striking changes to these areas in future years if they are able to withstand successive years of drouth. No large trees were found within five miles of the area; so seed was undoubtedly carried to the islands and peninsulas by wind, water, or animals. Seed has apparently not yet been produced by the saplings, but seedlings should be able to survive during favorable years once seed is produced.

Grazed Pastures Southwest of Salt Plain

To the southwest of the salt plain, in Section 35, Range 9 West, Township 26 North, is a pasture which is heavily utilized by cattle during the grazing season. The soil is of two types: Reinach loamy very fine sand; and Drummond very fine sandy loam. Both types contain considerable quantities of salt and a number of fingers of salt flat extend back into the pasture, since the relief above the salt plain is

Table VII. Composition of Andropogon hallii consocies on islands in salt plain

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Andropogon hallii	59.7	78.8	69.3	405,000
Ambrosia psilostachya	17.9	10.6	14.2	55,000
Leptoloma cognatum	14.9	6.9	10.9	36,000
Panicum virgatum	3.0	1.3	2.1	6,500
Others (3)	4.5	2.4	3.5	13,500
Totals	100.0	100.0	100.0	516,000

Table VIII. Composition of Panicum virgatum community on islands and peninsulas around salt plain

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Panicum virgatum	54.8	61.3	58.1	392,000
Poa arida	19.4	20.6	20.0	132,000
Cyperus filiculmis	8.1	6.3	7.2	40,000
Distichlis stricta	6.5	5.0	5.7	32,000
Others (4)	11.2	6.8	9.0	45,000
Totals	100.0	100.0	100.0	641,000

only 4 to 5 feet. Each soil type is dominated by a specific grassland community. Reinach soil, which is slightly lower and more saline, supports a weedy stand of Distichlis stricta, whereas the Drummond soil supports an open stand of Sporobolus airoides and Leptoloma cognatum.

Distichlis stricta community in grazed pasture

This weedy community is found at the lower levels of the pasture where soil salinity is highest. The community is fairly open and weedy and is obviously disturbed because of the movement of cattle. The soil is severely compacted due to trampling, and pools of water remain standing after rains even though the soil is sandy. The dominant plants were Distichlis stricta, Ambrosia psilostachya, Aristida oligantha, and Leptoloma cognatum with importance percentages of 34.9, 27.1, 16.7, and 15.5, respectively (Table IX). Other species such as sand dropseed (Sporobolus cryptandrus), alkali sacaton, fern flatsedge (Cyperus filiculmis) and sand paspalum (Paspalum ciliatifolium) added 5.8 per cent to the importance percentage. Scattered individuals of silverscale saltbush (Atriplex argentea) indicated fairly high soil salinity. Total stem density was a relatively high 1,028,000 stems per acre, with saltgrass and western ragweed contributing 379,000 and 270,000 stems, respectively. Plants of the community appeared to be only slightly used by cattle but were trampled as the animals moved through the community in search of more palatable species. Overgrazing has eliminated the palatable species in less saline sites because good stands of sand bluestem and switchgrass are present in adjacent, protected areas of similar soil type.

Sporobolus airoides-Leptoloma cognatum associes

At slightly higher elevations in the grazed pasture, on Drummond very fine sandy loam with a lower salt content, is a weedy associes of alkali sacaton and fall witchgrass. This community is more heavily utilized than the above saltgrass community, and the grasses are usually grazed more intensively. Many weeds are present and much bare ground is exposed throughout the community because heavy trampling has removed many plants. Dominants of the community were Sporobolus airoides and Leptoloma cognatum with importance percentages of 26.3 and 23.9, respectively (Table X). Western ragweed and saltgrass were also important, adding respectively 10.4 and 10.2 to the importance percentage. Sporobolus texanus, Paspalum ciliatifolium, Juncus interior, and five other grasses and weedy forbs had a total importance value of 29.2 per cent. Low basal and aerial cover was obvious as only 433,000 stems per acre were present. Fifty-five per cent of the stems were of alkali sacaton and fall witchgrass, which had densities of 127,000 and 111,000 stems per acre, respectively. The open, weedy nature of the community is caused by over utilization. Similar soil types support fairly good bluestem prairies where protected from grazing.

Ungrazed Grasslands South of Lake

Along the south side of the lake are a number of grasslands which are protected from grazing. Soil type is slightly to moderately saline Drummond very fine sandy loam with a fairly high water table. Before refuge formation, the grasses were moderately grazed by cattle. Since formation of the refuge and lake the areas have been ungrazed but

Table IX. Composition of Distichlis stricta community in grazed pastures on south side of refuge

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Distichlis stricta	32.9	36.9	34.9	379,000
Ambrosia psilostachya	27.9	26.3	27.1	270,000
Aristida oligantha	16.5	16.9	16.7	174,000
Leptoloma cognatum	16.5	14.4	15.5	148,000
Others (4)	6.2	5.5	5.8	57,000
Totals	100.0	100.0	100.0	1,028,000

Table X. Composition of Sporobolus airoides-Leptoloma cognatum associes in grazed pastures on south side of refuge

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Sporobolus airoides	23.2	29.4	26.3	127,000
Leptoloma cognatum	22.2	25.6	23.9	111,000
Ambrosia psilostachya	10.1	10.6	10.4	41,000
Distichlis stricta	11.1	9.4	10.2	46,000
Sporobolus texanus	7.1	6.9	7.0	30,000
Paspalum ciliatifolium	7.1	5.6	6.4	24,000
Juncus interior	7.1	5.0	6.0	22,000
Others (5)	12.1	7.5	9.8	32,000
Totals	100.0	100.0	100.0	433,000

are periodically inundated during floods. Vegetation changes have taken place because of these factors. Two distinct grassland communities are present in these ungrazed areas: a nearly pure stand of Distichlis stricta, and a weedy stand dominated by the same species.

Distichlis stricta consocies south of lake

Extending back from the south lakeshore for a distance of several hundred yards is a closed stand of salt cedar. Just beyond the zone of salt cedar is a dense, nearly pure zone of saltgrass which varies in width from several yards to several hundred feet (Fig. 6). The sandy soil is moderately saline, has a high water table, and is covered by lake water during floods. Distichlis stricta was the only species included in the sample, and had a stem density of 2,200,000 stems per acre, the greatest density of any grassland on the refuge (Table XI). A very few individuals of such species as Ambrosia psilostachya, Solanum eleagnifolium, Rumex crispus, Kochia scoparia, and Glycyrrhiza lepidota were observed in the community, but none was included in the sample. It is thought that periodic inundation prevents the establishment of other species, allowing saltgrass to maintain its complete dominance. Many stems of saltgrass were dead, and the basal cover was relatively low, but this was, nevertheless, the best stand of saltgrass found on the refuge.

Weedy Distichlis stricta community south of lake

Extending back from the above zone of nearly pure Distichlis stricta is a broad band of weedy, open grassland dominated by saltgrass. Many of these areas had been farmed or heavily overgrazed in past years and are slowly undergoing succession to the edaphic climax of saltgrass. The soil is Drummond very fine sandy loam, containing moderate quantities of salt, and is almost never flooded by the lake. The community aspect is one of a weedy, revegetating field, and sampling indicated such a condition. The dominant species was Distichlis stricta with an importance percentage of 54.7 and 122,000 of a total of only 200,000 stems per acre (Table XII). Ambrosia psilostachya was the most important weedy species with an importance percentage of 15.3, whereas Sporobolus airoides and Teucrium canadense added values of 9.5 and 8.0, respectively. Solanum eleagnifolium, Leptoloma cognatum, and seven other species added 12.5 per cent to the importance percentage. The low density was reflected in the many open, bare spaces throughout the community.

Grazed Pastures Northwest of Salt Plain

Most of the pastures to the northwest of the salt plain are in various grazing units and are moderately grazed during the growing season. Soils of these grasslands, which lie on each side of Highway No. 11, are of two types: Enterprise fine sand; and Drummond very fine sandy loam, both of which are free from salt in this area. The edaphic climax on both soil types is an Andropogon associes which covers the fingers of land extending out into the northwestern portion of the salt plain, and the grasslands to the north of the plain. Near the margin of the plain the same communities which encircle the islands are present: the Sesuvium consocies; the Suaeda consocies; the Distichlis consocies; and the Sporobolus airoides consocies at each higher successive level, leading to the Andropogon scoparius community at the next higher level.

Table XI. Composition of Distichlis stricta consocies near lake shore in ungrazed areas

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Distichlis stricta	100.0	100.0	100.0	2,200,000
Others (0)	0.0	0.0	0.0	0
Totals	100.0	100.0	100.0	2,200,000

Table XII. Composition of weedy Distichlis stricta community on ungrazed areas south of lake

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Distichlis stricta	48.7	60.6	54.7	122,000
Ambrosia psilostachya	16.2	14.4	15.3	29,000
Sporobolus airoides	9.7	9.4	9.5	19,000
Teucrium canadense	9.7	6.3	8.0	12,500
Solanum eleagnifolium	4.1	2.5	3.3	5,000
Leptoloma cognatum	2.7	1.3	2.0	2,500
Others (7)	8.9	5.5	7.2	10,000
Totals	100.0	100.0	100.0	200,000

Two other communities are present in these grazed grasslands: a mixed Andropogon scoparius-Sporobolus asper-Sorghastrum nutans associes in moist areas, and an Andropogon scoparius-Calamovilfa gigantea community at the very highest levels of unstable sand.

Andropogon scoparius community in grazed pastures

At the next higher level above the Sporobolus airoides consocies is a little bluestem (Andropogon scoparius) community, growing on sandy soil which is presumably salt free (Fig. 4). The two communities are generally separated from each other by a slight scarp and an obvious change in soil salinity which causes a sharp boundary in vegetation types. The moderately grazed little bluestem community is quite open with much bare ground between the dense bunches of grass, which are approximately one foot in diameter. Many weedy species are found in the open areas in addition to young grass shoots, which are soon eaten by cattle. Only the outer edges of the little bluestem clumps are utilized by cattle, and dead culms from previous years' growth are not eaten at all. Andropogon scoparius was clearly dominant with an importance percentage of 54.1 (Table XIII). No other species had an importance percentage greater than 10 per cent. Switchgrass, side-oats grama (Bouteloua curtipendula), Indiangrass (Sorghastrum nutans), fall witch-grass, western ragweed, sand dropseed, and tumble lovegrass (Eragrostis sessilispica) were present in small quantities, adding 30.7 per cent to the importance percentage. The 12 other species included in the sample had a combined importance percentage of 15.3. Of a total stem density of 1,181,000 stems per acre, 770,000 (65.0 per cent) were little blue-stem. An occasional, small Chickasaw plum shrub was seen in sandier areas, but plum was not generally important. Small patches of blue

Table XIII. Composition of Andropogon scoparius community on grazed pastures near Highway No. 11

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Andropogon scoparius	43.2	65.0	54.1	770,000
Panicum virgatum	7.4	5.5	6.5	65,000
Bouteloua curtipendula	6.3	5.5	5.9	65,000
Sorghastrum nutans	6.3	3.5	4.9	41,000
Leptoloma cognatum	5.3	3.0	4.1	34,000
Ambrosia psilostachya	5.3	2.5	3.9	30,000
Sporobolus cryptandrus	3.2	3.0	3.1	35,000
Eragrostis sessilispica	3.2	1.5	2.3	18,000
Others (12)	19.8	10.5	15.3	122,000
Totals	100.0	100.0	100.0	1,181,000

grama and buffalograss were present where the soil was heavier, but such areas were of limited extent. If moderate grazing of the little bluestem community is continued, the vegetation will probably undergo little change. Protection from grazing would most likely result in a successional change to sand bluestem or switchgrass.

Andropogon scoparius-Sporobolus asper-Sorghastrum nutans associes

In several places in the grazed bluestem pasture a community of little bluestem, tall dropseed (*Sporobolus asper*), and Indiangrass was noted. The community was present only where soil moisture was especially abundant throughout the growing season and where salinity was low. Typically, the community was found just above the *Sporobolus airoides* consocies where the typical scarp was absent, as around the mouths of broad, shallow swales which run through the area. Composition of the community approaches that of a typical southern true prairie except for the absence of big bluestem. The predominant plants and their importance percentages were little bluestem (25.4), tall dropseed (21.5), Indiangrass (18.0), and switchgrass (11.4) (Table XIV). Other important species were western ragweed, alkali sacaton and gummy lovegrass (*Eragrostis curtipedicillata*). The presence of Illinois bundleflower (*Desmanthus illinoensis*) and American bulrush (*Scirpus americanus*) reflected the moist conditions.

The community was more heavily utilized by cattle than any other area in the refuge. Because of the heavy cover of palatable species, the heavy use was not surprising. Total density was 1,157,000 stems per acre. The four dominants included more than 75 per cent of the number. Actual area covered by this community is relatively small, but it is important because of its high carrying capacity.

Andropogon scoparius-Calamovilfa gigantea associes

At the highest levels of the sandy, grazed pastures, is an open, weedy grassland dominated by little bluestem and big sandreed (Calamovilfa gigantea). Soil in this community consists of nearly pure sand which is subject to wind erosion, with occasional blowouts. The community was not sampled because of its very restricted nature. Some common plants, besides the dominants, were Eriogonum annuum, Heterotheca latifolia, Haplopappus divaricatus, Gutierrezia dracunculoides, Cenchrus pauciflorus, and Paspalum ciliatifolium.

In summarizing the distribution of all herbaceous communities found in saline areas, it is obvious that several factors control plant distribution and community dynamics. Soil salinity, moisture, and texture; nature and history of disturbance; competitive ability of species; and availability of propagules all exert an influence. Soil salinity is undoubtedly the most important factor limiting plant distribution, and results in distinct zonation of plants from strict halophytes, to facultative halophytes and, finally to glycophytes as salinity conditions decrease around a saline site. Hay (1890) and Ungar (1961, 1963, 1964) reported zones of halophytes and glycophytes around salt marshes in sandy areas of Kansas which are nearly identical in species and composition to those present in the Salt Plains Refuge. They noted the importance of soil salinity in relation to plant distribution. Chapman (1940) also mentions the relation of salinity to halophyte community distribution, and Tansley (1941) suggested recognition of salt-marsh vegetation as a climax type.

Table XIV. Composition of _Andropogon_ _scoparius_-_Sporobolus_ _asper_-_Sorghastrum_ _nutans_ community in grazed pastures near Highway No. 11

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Andropogon scoparius	23.9	26.9	25.4	311,000
Sporobolus asper	21.1	21.9	21.5	253,000
Sorghastrum nutans	16.5	19.4	18.0	224,000
Panicum virgatum	12.8	10.0	11.4	116,000
Ambrosia psilostachya	7.3	5.0	6.1	58,000
Sporobolus airoides	6.4	7.5	7.0	87,000
Eragrostis curtipedicillata	2.8	2.5	2.6	29,000
Others (8)	9.2	6.8	8.0	99,000
Totals	100.0	100.0	100.0	1,157,000

Halophytes do not effectively compete with glycophytes in slightly saline or non-saline habitats and are replaced by the latter. The glycophytes present depend upon the availability of viable dissiminules and upon the nature of disturbance to which they are subjected following original ecesis, so that certain species may not be found in sites where they are capable of growing. Thus, palatable grasses are destroyed in overgrazed pastures, and the nature of the original climax is changed. Introduction of a new species with greater competitive ability--salt cedar--had undoubtedly changed the distribution of the saltgrass community type within the Salt Plains Refuge.

Shrubland Community on Sandy, Saline Soil

Tamarix gallica consocies

As mentioned earlier, salt cedar has made a relatively recent appearance in the Salt Plains Refuge area and now assumes an important position in the overall vegetation picture. Absent from the refuge area forty years ago and present in only one isolated spot in 1942, salt cedar now occupies over 2600 acres of the refuge (Table II).

Salt cedar was probably introduced into this country between 300 and 400 years ago by Spanish settlers (Hefley, 1937), and has since become a major problem around reservoirs, canals, and rivers in the Southwest. Fletcher and Elmendorf (1955) state that many thousands of acre-feet of valuable water are lost each year from reservoirs and rivers in the western United States because of transpiration from salt cedar. The plant grows especially well in areas where the water table is relatively high because it can extend its roots down into the capillary fringe (Marks, 1950). Saline habitats which support few other trees and shrubs are especially suited for invasion by salt cedar because it grows well in such sites and produces seeds which readily germinate under saline conditions (Hulett and Tomanek, 1961). Merkel and Hopkins (1957) studied the life history of salt cedar and found that mature plants may produce a million seeds every two years. Young plants may produce seed their first year if conditions are optimal, and the fluffy seed may be carried long distances by the wind, assuring migration of the species.

The spread of salt cedar from the southern United States is not well documented, but a number of papers describe its presence in recent years. Lowry (1957) reported that salt cedar was absent at McMillan Reservoir along the Pecos River in Texas during 1913, but by 1939, over 13,000 acres were covered. Hefley (1937) and Ware and Penfound (1949) found salt cedar an important species on the Canadian River floodplain in central Oklahoma. Hopkins and Tomanek (1957) reported that salt cedar was the most abundant species around Cedar Bluffs Reservoir in west-central Kansas. One of the most important means of dispersal of the plant has been man himself. Numerous hedges and windbreaks of salt cedar were planted in the central United States during past years.

The salt cedar consocies at the Salt Plains Refuge is present along all of the southern reservoir shoreline, except for the eastern portion where a sharp, vertical scarp rises from the lake. Much of the area along Castle Creek and around ponds in the southwestern portion of the refuge is covered with a dense stand, but no salt cedar is found on the salt plain west of the lake since this portion is frequently inundated. The various branches of the Salt Fork River north of Highway No. 11 support salt cedar along their banks, and an open stand covers a large saline lowland north of the highway (Fig. 1). The largest area of the shrub is found on the alluvial flats which extend from the highway south to the lake. Sand Creek Bay, west of headquarters, and Sand Creek, south of the highway, are bordered by a dense stand of scrubby salt cedar.

The soil on which salt cedar is found is primarily an undifferentiated loamy sand alluvium which covers the original riverwash substratum. Salts are concentrated on the surface of the soil in most salt cedar areas, but the plant also grows in non-saline alluvium if the water table is near the surface.

On the south and southwest side of the lake, salt cedar grows along the shoreline in a band about 30 to 50 feet wide. Soil moisture controls the width of the band and is correlated with the degree of slope from the lake. In situations where there is a gentle slope from the lake the zone of salt cedar may be several hundred yards wide. Herbaceous species are limited in the understory stratum; the most important is saltgrass, but small numbers of alkali sacaton, _Rumex_ sp., kochia, and other weeds are present (Fig. 6). On the alluvial flats north of the lake, a closed community of salt cedar is generally present. A number of branches of the Salt Fork River traverse the delta of alluvial material deposited on the north side of the lake and salt cedar forms dense, almost impenetrable stands along the banks of these streams. Between the streams the stand thins but remains practically closed and few herbaceous species are able to exist. The shrubs are quite variable in height but average 8 to 10 feet in most places. Along the streams many shrubs are larger, but a dense stand of young plants grows below the older ones and these are spindly, being only several feet tall because of severe competition. Large numbers of young plants die during the dry summer months.

Along the streams, where salt cedar has the greatest density, no herbaceous stratum exists. Light levels are very low beneath the shrubs and conditions for growth are very poor. In the more open areas between streams the understory is composed of silverscale saltbush (*Atriplex argentea*), kochia, and saltgrass. Where conditions are favorable the first two species grow to a large size, but in more saline sites they are very small and are usually replaced by saltgrass in the most saline areas. In general, the herb stratum is not well developed but is quite variable because of soil conditions. Nearly all of the salt cedar habitat is covered by water during floods, and many areas of completely barren soil exist throughout the community. Near the lake, all of the lower portions of the area are covered by water for extended periods and no plants grow there, even during dry years. Many such bare areas, some of 10 acres or more, are scattered through the salt cedar community. Large floods carry enormous quantities of silt onto the north-shore delta, and many plants are covered by it. Certain areas of salt cedar were killed because of siltation following a large flood in 1963. Millions of salt cedar seedlings were present in these areas in the spring of 1964, but few of them survived the summer. Hopkins and Tomanek (1957) found that fewer than 30 per cent of seedlings survived the first growing season in Kansas and suggested that less than one per cent of the seedlings reach maturity.

Tamarix gallica was the only important woody species in the consocies with an importance percentage of 99.7, and 99.3 per cent of a total of 8525 stems per acre (Table XV). A few cottonwood (Populus deltoides) saplings were found on salt-free soils. Cottonwood survived only on the highest levels of alluvium where salts are not concentrated. Cottonwood may be able to invade the community more effectively in future years when the alluvial loam covers the salt-bearing sands to a greater depth. Total stem density of the herb stratum was only 90,100 stems per acre. Atriplex argentea, Kochia scoparia, and Distichlis stricta were the most important herbaceous species with importance percentages of 38.0, 32.9, and 12.2, respectively. Suaeda depressa and five weedy species added 16.9 per cent to the importance percentage.

Salt cedar presently occupies most of the habitats which are suitable for its growth, and spread of this pest to other areas will probably not take place unless some factor causes an increase in saline habitats. As the lake fills with silt from the northwest side, added acreage of salt cedar can be expected to occupy the land. This should be the only place of significant increase of salt cedar in the future.

Grasslands on Sandy Soil in Non-saline Areas

Two remaining habitats of sandy soil support three grassland communities. Neither area is salt affected and both are covered by grasslands which are undergoing successional change. Near the headquarters area are two distinct grassland communities which are relicts of the prairie which existed before refuge formation. Both grasslands

Table XV. Composition of shrub and herb strata of Tamarix gallica consocies

Species	Rel.[a] Freq.	Rel.[b] Dens.	Rel.[c] B.A.	Imp.[d] %	Bsl.[e] Area	Number per Acre
			Shrub Stratum			
Tamarix gallica	99.6	99.8	99.3	99.7	29.4	8,500
Populus deltoides	0.4	0.2	0.7	0.3	0.2	25
Others (0)	-	-	-	-	-	-
Totals	100.0	100.0	100.0	100.0	29.6	8,525
			Herb Stratum			
Atriplex argentea	36.2	39.7	-	38.0	-	34,000
Kochia scoparia	31.3	34.5	-	32.9	-	30,000
Distichlis stricta	11.7	12.6	-	12.2	-	11,000
Suaeda depressa	4.6	3.9	-	4.3	-	3,600
Others (5)	16.2	9.3	-	12.6	-	11,500
Totals	100.0	100.0		100.0		90,100

[a]Relative frequency
[b]Relative density
[c]Relative basal area
[d]Importance percentage
[e]Basal area, ft^2 per acre

are presently of limited extent, surrounded by forest and woodland, and characterized by many dense stands of shrubs. South of the headquarters there is an Andropogon associes; to the northwest there is an Andropogon scoparius-Eragrostis trichodes community; and on the sand dunes on the northern end of the refuge there is a Sporobolus-Andropogon community.

Andropogon Associes in Headquarters Area

To the south of the headquarters there are a number of scattered grasslands dominated by bluestems. The grasslands are weedy and restricted in area because of invasion by woody species. The substratum is composed of dune phase Enterprise fine sand which has a fairly high water table because of its proximity to the lake. Dominants were found to be Andropogon hallii and A. scoparius with importance percentages of 37.1 and 19.3, respectively (Table XVI). Four weedy species including Conyza canadensis, western ragweed, Commelina erecta, and Artemisia ludoviciana had importance percentages of between 5 and 9. Twelve other species added 15.8 per cent to the importance percentage. Total density was 540,000 stems per acre, 63.2 per cent of which were sand bluestem and little bluestem. Protection from disturbance has allowed Chickasaw plum, interior willow (Salix interior) and smooth sumac (Rhus glabra) to invade the community, and grassland is being reduced as the shrubs increase their area. An adjacent pasture is grazed and occasionally mowed so that good grassland has been maintained. Refuge personnel have used brush mowers to remove some shrubs from the refuge community, but the expense of clearing was too great to justify continued control measures. In the future, the grassland will probably be completely replaced by shrubland, and further succession may result in an elm-hackberry woodland or forest since saplings of these trees are already present.

Andropogon scoparius-Eragrostis trichodes Community Near Headquarters

There is a strip of grassland which occupies Drummond very fine sandy loam lying between the woody areas bordering Sand Creek Bay on the west and the forests around the headquarters area to the east. Moisture conditions may be less favorable than in the areas dominated by the sand bluestem-little bluestem associes, and the former species is of little importance (Fig. 7). The grassland is quite weedy, with sand lovegrass (Eragrostis trichodes) being an important species. Sampling indicated that dominants were little bluestem and sand lovegrass with respective importance percentages of 34.3 and 21.6 per cent (Table XVII). Torrey nightshade (Solanum torreyi) and western ragweed added 12.3 and 6.8 per cent, respectively, to the importance percentage, indicating the weedy nature of the stand. Fourteen other grasses and weedy forbs contributed 25.0 per cent to the importance percentage. Density was only 432,000 stems per acre, with the two dominants making up 61.9 per cent of the total. Many shrubby stands are present throughout the grassland and are spreading into it. Chickasaw plum, which is rapidly increasing its area, is most important. Interior willow forms dense stands where soil moisture is more abundant. It is, in turn, being invaded by cottonwood. Further protection from disturbance will almost certainly result in the replacement of this grassland by woodland in future years. A number of small trees of American elm, hackberry, and chittamwood are

Table XVI. Composition of weedy Andropogon associes on sandy soil near headquarters area

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Andropogon hallii	31.9	42.3	37.1	228,000
Andropogon scoparius	17.7	20.9	19.3	113,000
Conyza canadensis	9.8	7.7	8.7	42,000
Ambrosia psilostachya	9.8	6.4	8.1	34,000
Commelina erecta	7.1	4.6	5.8	25,000
Artemisia ludoviciana	5.3	5.0	5.2	27,000
Others (12)	18.4	13.1	15.8	71,000
Totals	100.0	100.0	100.0	540,000

Table XVII. Composition of weedy Andropogon scoparius-Eragrostis trichodes community on sandy soil near headquarters

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Andropogon scoparius	28.1	40.6	34.3	176,000
Eragrostis trichodes	22.0	21.3	21.6	92,000
Solanum torreyi	14.6	10.0	12.3	43,000
Ambrosia psilostachya	7.3	6.3	6.8	27,000
Paspalum ciliatifolium	4.9	3.8	4.3	16,000
Panicum virgatum	3.7	4.4	4.1	19,000
Others (12)	19.4	13.6	16.6	59,000
Totals	100.0	100.0	100.0	432,000

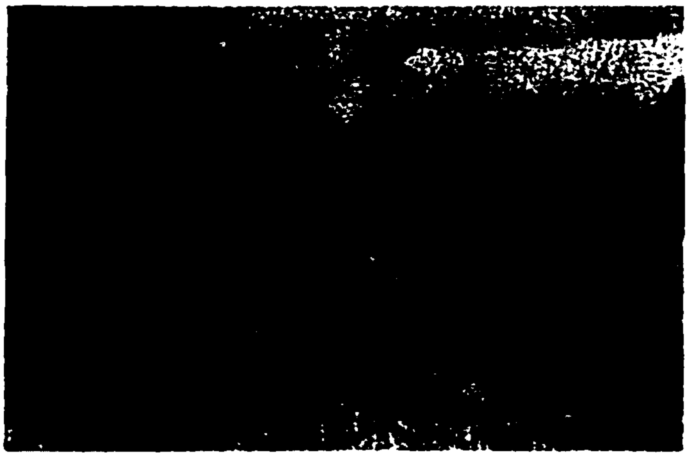

Figure 6. Distichlis stricta consocies in foreground and margin of Tamarix consocies behind. South of lake on southwestern portion of refuge.

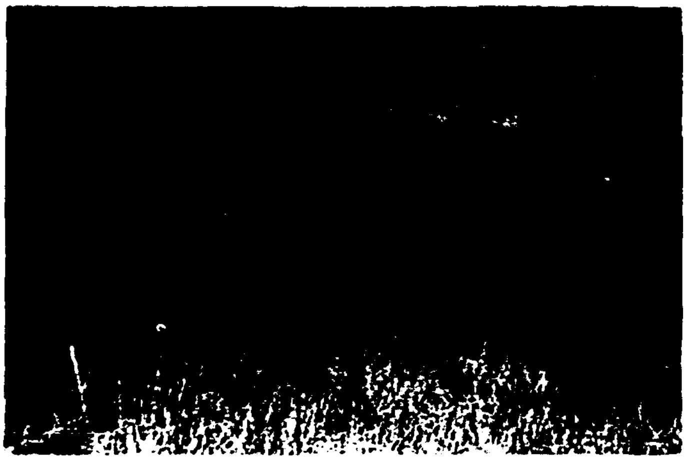

Figure 7. Andropogon scoparius-Eragrostis trichodes grassland near headquarters. Note Chickasaw plum shrubs and cottonwood trees in background.

already present throughout the grassland, indicating the final result of the present successional trend.

The seasonal aspects of the grassland are striking. In early summer the numerous yellow flowers of Oenothera heterophylla completely dominate the aspect. Later, the white flowers of Aphanostephus skirrhobasis and the blue ones of Erigeron bellidiastrum are most obvious. The late summer violet and yellow colors of ironweed and goldenrod complete the showy aspect of the grassland during the growing season.

Sporobolus-Andropogon Associes on Sand Dunes

The sand dunes on the northern end of the refuge consist primarily of Enterprise fine sand, but areas of Drummond very fine sandy loam are also present. The dunes, which were formed from wind-transported sand and gravel which was carried by the Salt Fork River, form rolling hills which are from 40 to 100 feet above the salt plain to the south.

Vegetation of the dunes is grassland. A Sporobolus-Andropogon prairie is present on the one dune area within the refuge boundary, and dominates both types of sand (Fig. 8). The grassland was formerly grazed but has been protected for the past five years. The community is weedy and open, including a large number of species. Sand dropseed and sand bluestem were the most important species with importance percentages of 15.5 and 10.4, respectively (Table XVIII). Little bluestem and sand lovegrass contributed respective values of 7.3 and 7.2 to the importance percentage. Other species, in decreasing order of importance, included Juncus marginatus, Paspalum ciliatifolium, Conyza canadensis, Indigofera miniata, Eriogonum annum, Tradescantia occidentalis, and

Heterotheca latifolia. Twenty-four other species were included in the sample, but each contributed only slightly more than one per cent to the importance percentage. Total density was a relatively low 539,000 stems per acre. Penfound (1963) showed that a southern Oklahoma prairie contained 4,154,215 stems per acre, which is greater density than any of the refuge grasslands.

It is difficult to predict successional changes in the protected duneland prairie. Little bluestem and sand dropseed now dominate the upper levels of the dunes, but the community is open, with many weedy species and stands of Chickasaw plum. Cactus (Opuntia macrorhiza) is abundant. The lowland areas between dunes support sand bluestem and tall weeds. In grazed pastures on dunes adjacent to the refuge, little bluestem is more important, but sand bluestem is virtually absent. It seems probable that species of Andropogon will continue to dominate the refuge prairie under future protection and will probably become more important than they presently are; however, one area of the dunes now supports a dense woodland of black locust (Robinia pseudoacacia). The habitat seems to be especially suited for black locust as many stands are replacing grassland throughout the refuge area.

Shrubland Communities on Sandy, Non-saline Soil

Shrubs are important in many of the sandy soils, especially in the protected grasslands. Shrub communities, which are increasing in area by replacing grassland, appear to be successional stages of the sere leading to woodland or forest in many habitats within the refuge. The most important areas of shrubland are those around the headquarters

Table XVIII. Composition of Sporobolus-Andropogon community on sand dunes on north portion of refuge

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Sporobolus cryptandrus	14.8	16.3	15.5	88,000
Andropogon hallii	8.1	12.0	10.4	65,000
Andropogon scoparius	6.7	8.0	7.3	43,000
Eragrostis trichodes	6.7	7.7	7.2	41,000
Juncus marginatus	6.2	6.7	6.4	36,000
Paspalum ciliatifolium	6.2	5.0	5.6	27,000
Conyza canadensis	4.8	4.3	4.5	23,000
Indigofera miniata	4.3	3.0	3.6	16,000
Eriogonum annuum	3.8	3.0	3.4	16,000
Tradescantia occidentalis	3.8	3.0	3.4	16,000
Heterotheca latifolia	3.4	3.0	3.2	16,000
Others (24)	31.2	28.0	29.5	152,000
Totals	100.0	100.0	100.0	539,000

area and on the sandy areas to the north. The two most important types of shrubland are those formed by Chickasaw plum and rough-leaved dogwood.

Prunus angustifolia Community

Chickasaw plum dominates many areas within grasslands around the headquarters area and in the sand hills on the northern portion of the refuge. The community is restricted to sandy soils within the refuge. Typically, the stands of plum are small, measuring from 10 to 200 feet in diameter. Older plants in the center of the stands average 7 feet in height, but young plants on the margins of the stand are generally less than one foot tall. Plum has a distinct competitive advantage over the grasses which it invades because of its ability to produce large numbers of root sprouts which are nourished until they can dominate the grasses. Protection from fire and grazing allows the shrubs to increase their acreage each year. Herbaceous species are able to exist under the plum shrubs but are reduced in size and number.

Prunus angustifolia was the only woody species encountered in the sampling area and had a density of 3700 stems per acre. Most of the stems were less than an inch in diameter, but the total basal area (measured four inches above the soil surface) was 17.4 ft^2 per acre (Table XIX). Sand lovegrass and sand bluestem were the most important herbs under the plum stratum with importance percentages of 33.5 and 13.3, respectively. Other species, including *Indigofera miniata*, *Cenchrus pauciflorus*, *Commelina erecta*, *Oenothera heterophylla*, and *Psoralea digitata*, contributed 26.5 per cent to the importance percentage. The remaining 26.7 per cent was distributed among the 19 other species encountered in the community.

Small areas of plum have been removed by three successive years of mowing and have not returned after four years; however, the areas treated were only a small fraction of the total area dominated by plum.

Cornus drummondii Community

Around the margins of elm forests in the headquarters area are dense, nearly impenetrable stands of shrubland dominated by rough-leaved dogwood. The community is limited to sandy soils with abundant moisture and appears to be a successional stage in the sere from grassland to forest. A number of species of shrubs and vines is present, along with many seedlings and saplings of trees which dominate the elm forest. The young trees may indicate the final result of the present successional trend. The dominant species was *Cornus drummondii* with an importance percentage of 45.3 (Table XX). Other influents and their importance percentages were *Rhus glabra* (18.0), *Populus deltoides* (8.6), and *Ulmus americana* (6.3). Interior willow, poison ivy (*Rhus radicans*), Chickasaw plum, and grape (*Vitis* spp.) added 18.3 per cent to importance values, whereas four other woody species were present in small numbers. Total density was 4,534 stems per acre, 43.6 per cent of which were dogwood. Dogwood contributed 53.1 per cent to the total basal area of 22.6 ft^2 per acre. The herb stratum was sparse and open, consisting of only 190,000 stems per acre. Little bluestem, sand dropseed, and sandbur (*Cenchrus pauciflorus*) were the most important herbs with respective importance percentages of 35.2, 22.7, and 12.1.

Table XIX. Composition of shrub and herb strata of Prunus angustifolia community

Species	Relative Frequency	Relative Density	Importance Percentage	Bsl.[a] Area	Number per Acre
			Shrub Stratum		
Prunus angustifolia	100.0	100.0	100.0	17.4	3,700
Others (0)	-	-	-	-	-
Totals	100.0	100.0	100.0	17.4	3,700
			Herb Stratum		
Eragrostis trichodes	27.5	39.4	33.5	-	85,000
Andropogon hallii	12.2	14.4	13.3	-	31,000
Indigofera miniata	7.6	7.2	7.4	-	15,000
Cenchrus pauciflorus	8.4	6.1	7.3	-	13,000
Commelina erecta	5.3	3.9	4.6	-	8,000
Oenothera heterophylla	4.6	3.3	3.9	-	7,000
Psoralea digitata	3.8	2.8	3.3	-	6,000
Others (19)	30.6	22.9	26.7	-	50,000
Totals	100.0	100.0	100.0		215,000

[a]Basal area, ft^2 per acre

Table XX. Composition of shrub and herb strata of *Cornus drummondii* thickets near headquarters

Species	Rel.[a] Freq.	Rel.[b] Dens.	Rel.[c] B.A.	Imp.[d] %	Bsl.[e] Area	Number per Acre
			Shrub Stratum			
Cornus drummondii	39.3	43.6	53.1	45.3	12.0	2,200
Rhus glabra	20.2	21.2	12.6	18.0	2.8	650
Populus deltoides	8.7	6.3	10.8	8.6	2.4	510
Ulmus americana	7.3	6.1	5.5	6.3	1.2	275
Salix interior	6.4	5.2	5.2	5.6	1.2	260
Rhus radicans	6.3	5.0	4.0	5.1	1.0	200
Prunus angustifolia	5.9	4.1	3.3	4.4	0.7	165
Vitis spp.	4.6	2.9	2.1	3.2	0.5	104
Others (4)	1.3	5.6	3.4	3.5	0.8	170
Totals	100.0	100.0	100.0	100.0	22.6	4,534
			Herb Stratum			
Andropogon scoparius	32.3	38.1	-	35.2	-	66,000
Eragrostis trichodes	19.7	25.6	-	22.7	-	44,000
Cenchrus pauciflorus	14.2	10.1	-	12.1	-	23,000
Paspalum ciliatifolium	9.5	8.3	-	8.9	-	17,000
Euphorbia spp.	3.6	2.6	-	3.1	-	6,000
Others (8)	20.7	15.3	-	18.0	-	34,000
Totals	100.0	100.0		100.0		190,000

[a]Relative frequency
[b]Relative density
[c]Relative basal area
[d]Importance percentage
[e]Basal area, ft^2 per acre

This community is almost certainly expanding its area at the expense of grassland where conditions are favorable. The early grassland invaders--Chickasaw plum and smooth sumac--are replaced by dogwood, which, in turn, is replaced by elm forest as the habitat becomes modified for the survival of trees during the progression of the sere. If the area continues to be protected from fire and disturbance, the shrub community can be expected to expand until all suitable habitat is occupied. Thus, grasslands in the immediate headquarters area will probably soon be gone.

Forest and Woodlands on Sandy, Non-saline Soil

Three forests and woodlands exist on sandy soils within the refuge. The forests are of two types: elm forest, and black locust forest. A cottonwood-willow woodland is present along the lake shore and several streams. The term woodland, as used herein, pertains to an open stand of rather small trees, with a good herbaceous understory. Trees are smaller and more widely spaced than in forests, but the community is more open than shrubland or thicket. The term is meant to indicate the intermediate position of woodland between shrubland (or thicket) and forest.

Robinia pseudoacacia Forest

A number of stands of black locust are present on the refuge. Most of these have developed along fence rows where the trees were originally planted to protect the sandy soil from wind erosion. Black locust has spread from fence lines to adjacent grasslands and now occupies considerable acreage within the refuge, and is increasing its coverage each year. In former years much locust was periodically cut for fence posts. Each stump then produced from 3 to 10 stump sprouts, which are now from 2 to 4 inches in diameter.

A typical stand of locust on the eastern refuge boundary was sampled during May, 1964 (Fig. 9). The stand is located on Pratt loamy fine sand, the typical substratum of locust in the refuge area. When walking through a stand, one sinks into the soft surface soil to a depth of 2 to 3 inches, which indicates the nature of the surface layers.

Locust is rather severely parasitized each spring by locust sawfly (Pteronidia trilineata) larvae, which completely defoliate most trees during the spring. It is a remarkable sight to see leafless locusts in full flower. When walking through the forest one is constantly pelted by the unceasing rain of larval excrement. Sawfly parasitism has apparently killed approximately 30 per cent of the locusts in the sampled forest. Trees which have survived produce more leaves after the larvae have gone, and appear normal during the summer.

Between the locust forest and the elm forest to the west is a small strip of relict grassland which is being replaced by both types of woody community. The elm forest is expanding from the west and the locust forest from the east, and the grassland is being "squeezed" between them. That locust is replacing the grassland area was strikingly demonstrated. On the western edge of the forest, young locust trees have moved into a stand of Chickasaw plum which was formerly within the grassland. The locusts are about five years old and 20 to 30 feet tall, and beneath them are the dead but undecomposed remains of a plum shrub

Figure 8. Sporobolus-Andropogon community on sand dunes in northern portion of refuge. Little bluestem dominates the hilltop aspect.

Figure 9. Margin of Robinia pseudoacacia forest. Small grassland in foreground is being replaced by black locust.

stand. Each plum shrub remains in place, but each can be readily lifted from the soil because the root systems have deteriorated. This interesting stand might be called a "plum grave yard".

Dominant of the locust forest was Robinia pseudoacacia with an importance percentage of 97.4 (Table XXI). The average of 228 locust trees per acre had a mean basal area of 27.6 ft^2. The only other trees in the forest were netleaf hackberry (Celtis reticulata) and white mulberry (Morus alba), which were present in insignificant numbers. The shrub stratum included 10 species of shrubs and saplings. Black locust was most important with an importance percentage of 51.0, while netleaf hackberry and Virginia creeper (Parthenocissus quinquefolia) added 10.9 and 9.5 per cent, respectively. Over half (647) of the total number of shrubs and saplings per acre (1163) were black locust. Other shrubs and saplings were of little importance, but the presence of American elm and chittamwood (Bumelia lanuginosa) saplings suggest that the locust forest may be replaced by elm forest in the future.

The herb stratum was sparse and open. Conyza canadensis and Chenopodium album were the most important weeds, but a number of grasses, including Elymus virginicus, E. canadensis, and Eragrostis trichodes, were present in appreciable quantities.

The future status of black locust is difficult to predict. The broad band of locust forest along the eastern refuge boundary is located in a habitat which is suitable for growth of elm and hackberry. Future successional changes may result in replacement of locust by an elm forest, but this is not certain. The locust stands which are presently invading grasslands are certain to increase in size and will continue to

Table XXI. Composition of tree, shrub, and herb strata of Robinia pseudoacacia forest

Species	Rel.[a] Freq.	Rel.[b] Dens.	Rel.[c] B.A.	Imp.[d] %	Bsl.[e] Area	Number per Acre
				Trees		
Robinia pseudoacacia	95.2	98.3	98.2	97.4	27.6	228.0
Celtis reticulata	2.4	0.6	1.3	1.4	0.4	1.5
Morus alba	2.4	0.6	0.5	1.2	0.1	1.5
Others (0)	-	-	-	-	-	-
Totals	100.0	100.0	100.0	100.0	28.1	231.0
			Shrubs and Saplings			
Robinia pseudoacacia	46.4	55.6	-	51.0	-	647
Celtis reticulata	11.9	10.0	-	10.9	-	163
Parthenocissus quinquefolia	9.5	9.4	-	9.5	-	109
Ulmus americana	7.1	6.3	-	6.7	-	73
Bumelia lanuginosa	7.1	3.8	-	5.2	-	44
Smilax bona-nox	6.0	4.4	-	5.2	-	51
Cornus drummondii	6.0	3.8	-	4.9	-	44
Others (3)	6.0	6.7	-	6.3	-	32
Totals	100.0	100.0		100.0		1,163
				Herbs		
Conyza canadensis	14.5	18.8	-	16.7	-	4,700
Elymus virginicus	10.8	16.9	-	13.9	-	2,800

Table XXI. Continued

Species	Rel.[a] Freq.	Rel.[b] Dens.	Rel.[c] B.A.	Imp.[d] %	Bsl.[e] Area	Number per Acre
			Herbs--Continued			
Chenopodium album	12.1	14.4	-	13.2	-	3,600
Viola kitaibeliana	10.1	11.3	-	10.7	-	4,200
Elymus canadensis	10.8	10.0	-	10.4	-	2,500
Eragrostis trichodes	8.4	5.0	-	6.7	-	1,300
Pyrrhopappus geiseri	4.8	4.4	-	4.6	-	1,100
Panicum oligosanthes	4.8	3.1	-	3.9	-	780
Others (15)	23.7	16.1	-	19.9	-	4,050
Totals	100.0	100.0		100.0		25,030

[a]Relative frequency
[b]Relative density
[c]Relative basal area
[d]Importance percentage
[e]Basal area, ft^2 per acre

replace grasslands unless the climate changes, or unless man attempts to control them. Many stands of locust surrounding the refuge have been sprayed with 2,4-D or 2,4,5-T by landowners. Two successive years of herbicidal treatment have resulted in a nearly complete kill of locust in such areas.

Ulmus americana Forest near Headquarters

Surrounding the immediate headquarters area and extending to the south is a good elm forest located on Pratt loamy fine sand, Enterprise fine sand, and Yahola fine sandy loam (Fig. 10). Moisture conditions are nearly identical in the three substratum types, and no differences in forest composition, which might be related to soil types, could be detected. Generally, the elm forest is located at a slightly lower level than the black locust forest, and moisture conditions may be somewhat more favorable under the former. The forest is surrounded on all sides by shrubland communities which are spreading into grassland, and forest soon occupies the shrubland and increases in area.

Much of the area which is now occupied by elm forest was almost certainly a forest before refuge formation because many of the trees are large and appear to be old. No increment borings were made, but one elm tree 51 inches D.B.H. was found. This tree was certainly more than 50 years old. The number of large elm, hackberry, and chittamwood trees indicates a mature forest; however, the margins of the original forest have been extended and contain smaller and younger trees.

The dominant tree was <u>Ulmus americana</u> with an importance percentage of 58.1 (Table XXII). Common hackberry (<u>Celtis occidentalis</u>) and

Table XXII. Composition of tree and shrub strata of Ulmus americana forest south of headquarters area

Species	Rel.[a] Freq.	Rel.[b] Dens.	Rel.[c] B.A.	Imp.[d] %	Bsl.[e] Area	Number per Acre
			Trees			
Ulmus americana	43.5	60.6	70.2	58.1	66.1	86.9
Celtis occidentalis	23.5	18.1	6.9	16.2	6.5	26.0
Bumelia lanuginosa	15.3	11.3	10.3	12.3	9.8	16.1
Morus alba	11.8	6.9	4.3	7.7	4.0	9.9
Populus deltoides	1.2	0.6	8.1	3.3	7.6	1.7
Others (2)	4.7	2.5	0.2	2.4	0.2	3.2
Totals	100.0	100.0	100.0	100.0	94.2	143.8
			Shrubs and Saplings			
Parthenocissus quinquefolia	44.6	60.6	-	62.5	-	55,000
Celastrus scandens	12.2	6.9	-	9.6	-	6,200
Cornus drummondii	8.1	6.9	-	7.5	-	6,200
Menispermum canadense	6.8	6.3	-	6.6	-	5,700
Ulmus americana	8.1	4.4	-	6.3	-	4,000
Smilax bona-nox	6.8	5.6	-	6.2	-	5,100
Symphoricarpos orbiculatus	4.1	2.5	-	3.3	-	2,300
Bumelia lanuginosa	4.1	1.9	-	3.0	-	1,700
Others (3)	5.2	4.9	-	5.0	-	3,500
Totals	100.0	100.0		100.0		90,700

[a]Relative frequency
[b]Relative density
[c]Relative basal area
[d]Importance percentage
[e]Basal area, ft^2 per acre

chittamwood were next in importance with respective values of 16.2 and 12.3. A number of white mulberry and large cottonwood trees were scattered through the forest but were of little importance. Total mean density was 143.8 trees per acre and mean basal area was 94.2 ft^2 per acre. The latter figure is relatively high, approaching the maximum basal area of 115.0 ft^2 per acre found in the best eastern Oklahoma upland forest stand studied by Rice and Penfound (1959). American elm made up 60.6 per cent of the total basal area. Cottonwood, with fewer than 2 trees per acre, contributed 7.6 per cent of the total basal area. This indicates the large size of this species. Many cottonwood trees were larger than 4 feet D.B.H.

Eleven species of vines, shrubs, and saplings were encountered beneath the forest stratum. Virginia creeper dominated the shrub stratum with an importance percentage of 52.5, and 60.6 per cent of the total of 90,700 stems per acre. In decreasing order of importance, *Celastrus scandens*, *Cornus drummondii*, *Menispermum canadense*, *Ulmus americana*, *Smilax bona-nox*, *Symphoricarpos orbiculatus*, *Bumelia lanuginosa*, and three woody vines completed the species encountered in the shrub stratum. Herbaceous species were so widely scattered and so few in number that they were not included in the sampling data. *Bidens bipinnata* was the most important herb.

At the present time, the elm forest is increasing in acreage, and further increases can be expected if the area is protected from fire and disturbance.

Populus-*Salix* Woodland near Lake

Along the northeastern shore of the reservoir is a woodland dominated by cottonwood and black willow (*Salix nigra*) (Fig. 11). The soil which supports the community is Pratt loamy fine sand with a high water table. The entire area is covered by water when the lake is at the flood control pool level, and small quantities of salt remain when the water recedes. The community is open and consists of a tree stratum and an herb stratum, dominated by grasses. Woody species have come into prominence only since the reservoir was formed. A row of large cottonwood trees was originally present along the lake shoreline, but these have been killed and cut down because erosion of the shoreline removed the soil from around them. The lake shoreline is slowly moving towards the northeast as waves formed by southerly winds remove the shoreline soil. Willow and cottonwood trees are constantly being killed as their roots are uncovered by wave action (Fig. 11).

The woodland was dominated by cottonwood and black willow, which had importance percentages of 46.1 and 33.7, respectively (Table XXIII). Scattered salt cedar and black locust trees were encountered. The former added 11.8 per cent to the importance percentage. Cottonwood comprised one-half, and willow one-fourth of the total basal area of 18.2 ft^2 per acre. The herb stratum was dominated by grasses such as switchgrass, little bluestem, and sand bluestem. The first two species included over half of the total of 500,000 stems per acre. Grass species have maintained themselves well beneath the woody species and will probably remain important influents in the community. The cottonwood-willow woodland now occupies most habitats suitable for its growth and should undergo little

Figure 10. Ulmus americana forest near Headquarters. Note the dense shrub stratum below the trees.

Figure 11. Populus-Salix woodland on northeastern shore of Salt Plains Reservoir. Note trees which have been washed out by waves.

Table XXIII. Composition of tree and herb strata of Populus-Salix woodland near lake on northeast shore

Species	Rel.[a] Freq.	Rel.[b] Dens.	Rel.[c] B.A.	Imp.[d] %	Bsl.[e] Area	Number per Acre
			Trees			
Populus deltoides	43.2	42.4	52.7	46.1	9.6	110
Salix nigra	38.7	36.6	25.8	33.7	4.7	95
Tamarix gallica	9.6	13.7	12.1	11.8	2.2	36
Others (3)	8.5	7.3	9.4	8.4	1.7	19
Totals	100.0	100.0	100.0	100.0	18.2	260
			Herbs			
Panicum virgatum	31.2	34.3	-	32.8	-	172,000
Andropogon scoparius	26.5	29.2	-	27.9	-	146,000
Andropogon hallii	12.1	8.2	-	10.1	-	41,000
Eragrostis trichodes	7.3	6.1	-	6.7	-	30,000
Artemisia ludoviciana	6.2	6.0	-	6.1	-	30,000
Others (15)	16.7	16.2	-	16.4	-	81,000
Totals	100.0	100.0		100.0		500,000

[a]Relative frequency
[b]Relative density
[c]Relative basal area
[d]Importance percentage
[e]Basal area, ft^2 per acre

change in future years.

Plant Communities on Clay Soils

The only soils on the refuge containing appreciable quantities of clay are those forming the surface layers of the Red Bed escarpment on the southeastern portion of the refuge, south of the lake, and those along Sand Creek.

In most places, the Red Beds rise vertically from the lake to a height of 20 to 30 feet, and a steep slope leads from the top of the scarp to the upper levels of the Red Beds, which are 100 to 150 feet above the lake itself. The soil is placed in the general category--Rough Broken Land, Vernon soil material--and is easily eroded. Many steep-walled gullies lead from the highest levels to the lake. Between the gullies are rolling uplands which slope toward the lake. Three plant communities were found on the Red Beds: an Andropogon-Artemisia-Bouteloua associes; Rhus shrublands; and ravine woodlands (Fig. 12). Only the first is quantitatively described.

Along Sand Creek, on the northern end of the refuge, the soils are fairly heavy Yahola silty clay loam. This is an alluvial soil carried into the riverbottom by Sand Creek. An Ulmus-Salix-Populus woodland occupies this soil along the creek.

Andropogon-Artemisia-Bouteloua Associes on Red Beds

On the rolling upland, between ravines which cross the Red Beds, is a grassland community. Soils are fairly sandy and loose but contain appreciable quantities of clay. The upland hills slope rather sharply toward the lake and are subject to severe water erosion.

The grassland has been protected from grazing since refuge formation. It appears weedy in most places and is variable because of soil conditions. Tall grasses occupy sandier sites, and short grasses dominate areas of heavy clay. A number of stands of stinking sumac (Rhus aromatica) are present in scattered patches through the grassland, and the areas of grass are separated by wooded ravines.

Sampling of the grassland indicated that four species were of nearly equal importance. Big bluestem (Andropogon gerardi), Louisiana sagewort (Artemisia ludoviciana), little bluestem, and side-oats grama (Bouteloua curtipendula) had respective importance percentages of 25.2, 23.0, 22.1, and 18.4 (Table XXIV). Blue grama was important on heavier soils, but such habitats were limited. As the uplands approach the lake, they generally end abruptly at the vertical scarp; however, in some places a steep slope extends nearly to the shoreline. In such areas the vegetation is very open, consisting of scattered clumps of grasses and many species of weeds and forbs. A greater number of species was found on the eroded Red Beds than on any other area of the refuge.

Rhus Shrublands on Red Beds

Small, dense stands of Rhus aromatica are present through the grasslands. Most of the stands are only several feet in diameter so that the total acreage of shrub is small. The upper banks of ravines are often covered with open stands of stinking sumac, which are apparently preventing more serious erosion on such sites. At the upper end of nearly every ravine leading to the lake is a dense stand of smooth sumac (Rhus

Table XXIV. Composition of Andropogon-Artemisia-Bouteloua associes on Red Beds south of lake

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Andropogon gerardi	24.1	26.3	25.2	220,000
Artemisia ludoviciana	22.9	23.1	23.0	194,000
Andropogon scoparius	20.5	23.8	22.1	199,000
Bouteloua curtipendula	19.3	17.5	18.4	147,000
Bouteloua gracilis	6.0	5.0	5.5	42,000
Others (5)	7.2	4.3	5.8	35,000
Totals	100.0	100.0	100.0	837,000

glabra), which slows the rate of erosion back into the upper levels of the rolling plain. Because of the variable and restricted nature of the Rhus thickets, none was sampled.

Ravine Woodlands on Red Beds

The numerous ravines which dissect the Red Beds on the south lake shore support an interesting vegetation. At the mouth of each ravine, at the lake shoreline, is a small stand of salt cedar. Away from the lake, one encounters successive zones of black willow, cottonwood, American elm-western soapberry (Sapindus drummondii) and finally, a smooth sumac thicket at the head of the ravine. In some ravines, the cottonwood-willow zones are indistinct as species are intermixed, but rather distinct zones, correlated with available soil moisture, are generally present. The bottom of most ravines supports a stand of weeds or aquatics, depending upon moisture conditions in the ravine. Giant ragweed (Ambrosia trifida) is most common, but many sedges, spikerushes, and rushes are also present. The ravines were not sampled because of their restricted and variable nature.

Ulmus-Salix-Populus Woodland near Sand Creek

Along Sand Creek, from north of Highway No. 11 to the northern refuge boundary is a heterogenous woodland. The soil is rather heavy silty clay loam with a moderately high water table. Seasonal flooding of Sand Creek results in inundation of most of the riverbottom, and the consequent siltation prevents stabilization of the non-wooded lowland by any vegetation type. The understory appears very weedy, and sampling data indicate that weeds are quite important.

The woodland is dominated by American elm, black willow, and slippery elm (Ulmus rubra), which had importance percentages of 35.0, 29.1, and 18.5, respectively (Table XXV). Cottonwood and netleaf hackberry were present in most areas and were locally dominant. Black willow was generally found nearest the creek, but all species were present on the creek bank, and no distinct communities dominated by a single species were delimited. The average of 139 trees per acre had a mean basal area of 10.7 ft^2. The four most important trees comprised 96.2 per cent of the basal area and 94.8 per cent of the total density.

The herb stratum was very weedy and open. American germander (Teucrium canadense), bermudagrass (Cynodon dactylon), and ironweed (Vernonia baldwinii) were the most important herbaceous species, comprising 66.0 per cent of the total importance percentage. Little bluestem

Table XXV. Composition of tree and herb strata of Ulmus-Salix-Populus woodland near Sand Creek

Species	Rel.[a] Freq.	Rel.[b] Dens.	Rel.[c] B.A.	Imp.[d] %	Bsl.[e] Area	Number per Acre
				Trees		
Ulmus americana	29.8	35.3	39.9	35.0	4.3	49
Salix nigra	27.6	31.6	28.1	29.1	3.0	44
Ulmus rubra	18.4	19.2	17.8	18.5	1.9	27
Populus deltoides	9.3	8.7	10.4	9.5	1.1	12
Celtis reticulata	6.5	3.1	1.9	3.9	0.2	4
Others (3)	8.4	2.1	1.9	4.1	0.2	3
Totals	100.0	100.0	100.0	100.0	10.7	139
				Herbs		
Teucrium canadense	25.1	30.4	-	27.8	-	109,000
Cynodon dactylon	19.6	25.7	-	22.6	-	94,000
Vernonia baldwinii	14.3	16.8	-	15.6	-	60,000
Andropogon scoparius	11.2	9.6	-	10.4	-	35,000
Solidago spp.	8.9	8.1	-	8.5	-	29,000
Panicum virgatum	7.1	5.7	-	6.4	-	21,000
Others (14)	13.8	3.7	-	8.7	-	13,000
Totals	100.0	100.0		100.0		361,000

[a]Relative frequency
[b]Relative density
[c]Relative basal area
[d]Importance percentage
[e]Basal area, ft^2 per acre

and switchgrass were the only prairie grasses present and were of little importance. Of a total of 361,000 stems per acre, 88.6 per cent were weedy species.

This woodland is the most perplexing community on the refuge. Composition is not what one would expect for a bottomland forest and the relative unimportance of grasses is confusing. No obvious reasons for the nature of the community were found, but it seems probable that flooding and siltation are responsible for the present conditions and will continue to prevent stabilization of the community.

Aquatic and Marsh Habitats

Pond, Lake and Shoreline Communities (Salt Affected)

The lake itself is brackish and generally muddy so that few plants are able to survive in the water. Around the mouths of the several streams, patches of sago pondweed (*Potamogeton pectinatus*) and longleaf pondweed (*P. nodosus*) were seen. Occasional individuals of *Chara* sp., *Najas guadalupensis*, and *Ceratophyllum demersum* were seen in stagnant, clear pools in the Salt Fork River but were not observed in the lake. As a whole, the lake is a very poor habitat for aquatic vegetation.

The lake shoreline supports a number of plants but is also a rather poor habitat area. Extreme fluctuation of water causes the shoreline to be flooded during certain periods of the year, but the same area may be completely dry a month later. No plants can be found on the western shoreline where the lake and salt plain merge, and salinity of the shoreline soil limits growth of most plants around the remainder of the lake. Along the north shore and around Sand Creek Bay, there are scattered patches of cattail (Typha latifolia and T. domingensis). Soil salinity limits cattail distribution to small areas, except where fresh water enters the lake. McMillan (1959) reported that cattail grows in saline sites in Nebraska but will tolerate only low concentrations of salt. Small, dense clumps of American and softstem bulrush (Scirpus americanus and S. validus) are present along the north shoreline, but the plants are obviously not growing well. In certain areas alkali bulrush (Scirpus paludosus) forms dense stands, but many plants are killed during periods of drouth when the lake is low. Alkali bulrush tolerates saline conditions well and is commonly found in seeps and sloughs which lead into the lake.

During the summer of 1964, the lake was very low and Sand Creek Bay was completely dry. A broad expanse of shoreline was exposed and supported a number of weeds and grasses. Barnyard grass (Echinochloa crusgalli), bearded sprangletop (Diplachne fasicularis), prairie cupgrass (Eriochloa contracta), common purslane (Portulaca oleracea), and heliotrope (Heliotropium curassavicum) were the most common species invading the mudflats. Most of them grew well and produced seed during the summer. Late fall rains caused a rise in the lake, which again covered the plants. Prairie cordgrass (Spartina pectinata) forms open stands along part of the northern lake shore but is limited both by salinity and water fluctuation. Along certain areas of the northern lake shore, salt cedar grows to near the water's edge. Many shrubs are killed when the lake level is high because salt cedar can withstand only brief periods of inundation. A large number of dead salt cedar shrubs is present along the north shore. In general, the lake and shoreline must be considered as poor habitats. Few plants are able to survive in either habitat, and extreme variation of environmental conditions prevents development of any stable plant communities.

Several ponds are present along the southwestern lake shore. Dams were erected by the refuge personnel to catch water from several ravines which drain the low-lying, alkaline lowlands on the southwestern portion of the refuge. Salinity is higher than in the lake, but the water generally remains clear, supporting the development of several plant communities. Most ponds support a good growth of sago pondweed, which is heavily utilized by waterfowl during the autumn months. Alkali bulrush forms dense stands around the pond margins, and American bulrush is present where salinity is lowest. Stands of cattail are present around the larger ponds, but the plants are small and seldom produce flowers. When the ponds recede during the summer, bands of salt cedar seedlings can be found on the shoreline. Millions of seedlings are present, but few survive inundation when the pond level again rises. Nearly all dams support dense stands of salt cedar. Indigobush amorpha (*Amorpha fruticosa*) is present on the salt-free portions of several dams.

Fresh-water Ponds and Pond Margins

A number of man-made ponds are present along the eastern side of the refuge. These ponds were constructed to provide resting and feeding areas for waterfowl. Water flows into the series of ponds from a controlled diversion canal on Sand Creek, and from a small, spring-fed creek called Powell Creek, which joins the diversion canal to form a single stream. Flowing from the north, the streams enters a low, swampy area called Big Marsh, just south of Highway No. 11. Continuing to the south it enters a series of small ponds and finally flows into the large Wilson Pond. From Wilson Pond the stream enters and fills the following ponds: Mink Run Pond; School Marsh Pond (which also receives water from another spring-fed stream); a series of small, unnamed ponds; Intermediate Pond, northwest of headquarters; and the Display Pond in the headquarters yard. The stream then flows into Headquarters Pond, southwest of headquarters; Upper Dog Pond; Lower Dog Pond; and enters Sand Creek Bay about a mile south of headquarters. A controlled gate and an overflow pipe allow water to flow south from Mink Run Pond through a marsh to Puterbaugh and Eagle Roost ponds, which are separated from Sand Creek Bay by a low, man-made dike. Two small ponds near Sand Creek Bay are fed by overflow from Eagle Roost Pond.

The larger ponds fluctuate seasonally, depending upon the flow of water in Sand Creek but always contain water. Many of the small ponds are dry during much of the summer or, at best, undergo a great amount of fluctuation each season. All ponds contain clear, fresh water except Puterbaugh, Eagle Roost, and Lower Dog ponds. These three contain large numbers of carp which keep the bottom sediments suspended, making the water muddy. Lower Dog Pond and Eagle Roost Pond are directly connected with Sand Creek Bay and are filled by back-flow from the lake during floods. The water is, therefore, slightly brackish.

Three types of communities are found in the ponds and along the streams: a submerged and floating plant community; emergent communities; and wetland communities (Fig. 13).

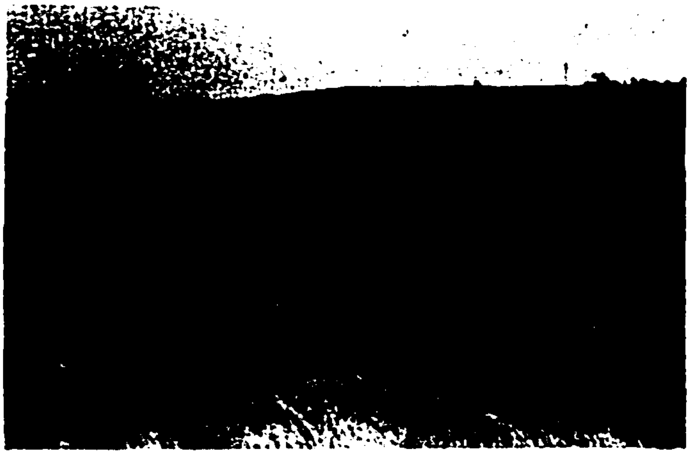

Figure 12. Communities on Red Beds south of lake. Great Salt Plains Dam in left background. Note grassland with scattered shrubs on upper levels, and the wooded ravines.

Figure 13. Margin of typical fresh-water pond. Note floating, emergent, and wetland zones. American lotus in foreground.

Submerged and floating plant communities

All clear-water ponds contain fairly well developed aggregations of submerged and floating plants. Since most of these ponds are relatively shallow, light levels are sufficient for aquatic plant growth at all depths. In the deepest, central portion of most ponds the predominant plant is sago pondweed (*Potamogeton pectinatus*), which floats near the surface. This species is valuable to the refuge program because the fruits are especially good duck food, and many plantings of sago pondweed have been made. In many ponds, sago pondweed is the only important submerged or floating aquatic; however, nearly all ponds support small quantities of such species as *Ceratophyllum demersum*, *Najas guadalupensis*, *Chara* sp., and many green and blue-green algae.

In all ponds the most important floating-leaf aquatic is American lotus (*Nelumbo lutea*), which extends from near the shoreline out into the pond. The plant occurs only where water is less than 3 feet deep, but several shallow ponds are completely covered by it. Refuge personnel wage a continual battle against lotus in an attempt to control its spread. Upper Dog Pond was completely covered by lotus in 1963 and was sprayed with 2,4-D during July. The plant is very susceptible to this herbicide, and all leaves appeared to be dead two days after treatment. Yearly spraying is practiced on many ponds, however, because numerous seeds are present on the pond beds, and these propagate the plant each spring. Other floating and floating-leaf aquatic plants include duckweed (*Lemna minor*) and longleaf pondweed (*Potamogeton nodosus*), but these plants are only rarely seen and are of little importance in refuge ponds.

Emergent plant communities

All pond margins support stands of emergent aquatics. The most important emergent plants are cattails (Typha latifolia and T. domingensis). Cattail dominates pond margins from the one foot water level back to the shoreline. Extremely dense stands of cattail are present on alluvial soils which have been deposited into the upper pond levels. Where the soil is less frequently covered by water, American bulrush, softstem bulrush, and spikesedge form a mixed community. Around certain pond and stream margins, dense zones of spikesedge (Eleocharis spp.) are found. Mixed stands of sedges (Carex spp.), Torrey rush (Juncus torreyi), and lippia (Lippia lanceolata) are usually present above the Eleocharis zone.

Several attempts have been made to control cattail. Certain stands were sprayed with 2,4-D during 1963, but only a moderate kill was achieved. Treatment with more effective herbicides is to be practiced in the future, according to refuge officials. Stands of cattail around small ponds are sometimes mowed in the autumn, but this practice only increases the available water surface, so that the ponds will be more appealing to ducks, and has little permanent effect on cattail.

A dense stand of such plants as Juncus spp., Cyperus spp., Fimbristylis vahlii, Fuirena simplex, Rorippa spp., and Echinodorus spp. may be found on beds of ponds which go dry during the summer. These plants generally remain until September, when the ponds are again filled.

Wetland communities

Around ponds and along most streams there are several wetland communities. Water seldom covers the soil of such communities, but the water level is just below the soil surface. The most important wetland communities in the refuge are: the Salix-Populus woodland near ponds and streams; the Big Marsh Scirpus community; and Spartina pectinata wetland consocies.

Salix-Populus woodland near ponds and streams.—Above the emergent aquatic community around ponds and along streams is a woodland dominated by black willow and cottonwood. Buttonbush (Cephalanthus occidentalis) is important along the shorelines, where it grows in wet soil and in water less than a foot deep. A zone of black willow extends back from near the waterline and becomes mixed with cottonwood at a distance of about 30 to 50 feet from the water's edge. Scattered salt cedar and elm trees are found around certain ponds.

Dominants of the community were Salix nigra and Populus deltoides with respective importance percentages of 54.5 and 29.8 (Table XXVI). With the exception of Cephalanthus occidentalis, all other species were relatively unimportant. The large number of small trees required that a change be made in sampling procedures. The size limit for trees was reduced from 3 inches to 2 inches, D.B.H. so that a more complete sample of important trees could be included. Total density was 612 trees per acre, of which 55.2 per cent were willow. Total basal area was 32.4 ft^2 per acre and willow and cottonwood comprised 97.6 per cent of the total. The herb stratum was quite variable and has been influenced by man. The most important herbaceous species was bermudagrass (Cynodon dactylon), which has spread from dikes, where it was originally planted, to many favorable habitats. American bulrush and knotgrass (Paspalum distichum) were the only other important herbs in the understory.

Table XXVI. Composition of tree and herb strata of *Salix-Populus* woodlands near fresh-water ponds

Species	Rel.[a] Freq.	Rel.[b] Dens.	Rel.[c] B.A.	Imp.[d] %	Bsl.[e] Area	Number per Acre
			Trees			
Salix nigra	51.7	55.2	56.7	54.5	18.3	337
Populus deltoides	23.9	24.6	40.9	29.8	13.2	151
Cephalanthus occidentalis	14.6	10.3	1.3	8.7	0.4	63
Tamarix gallica	5.3	4.1	0.5	3.4	0.2	25
Others (3)	4.5	5.8	0.6	3.6	0.3	36
Totals	100.0	100.0	100.0	100.0	32.4	612
			Herbs			
Cynodon dactylon	35.9	40.2	-	38.0	-	38,000
Scirpus americanus	23.2	29.3	-	26.3	-	27,000
Paspalum distichum	16.4	15.0	-	15.7	-	14,000
Scirpus validus	4.6	3.3	-	4.0	-	3,000
Others (19)	19.9	12.2	-	16.0	-	10,000
Totals	100.0	100.0		100.0		92,000

[a]Relative frequency
[b]Relative density
[c]Relative basal area
[d]Importance percentage
[e]Basal area, ft^2 per acre

Willow and cottonwood now occupy most habitats suitable for their growth and will probably undergo little future expansion of area. One possible area--the Big Marsh--may, however, be invaded by this woodland type as the habitat becomes modified.

Scirpus marsh community.--The Big Marsh, adjacent to Highway No. 11, is a low, wet marshland dominated by rushes (Scirpus spp.). The central portion of the marsh contains standing water during the spring and fall but is practically dry during much of the summer. Similar marsh habitats are found above Puterbaugh and Headquarters ponds.

The dominants of the marsh were found to be Scirpus americanus and S. validus with respective importance percentages of 42.4 and 32.0 (Table XXVII). Several species of spikesedge (Eleocharis) formed a second stratum below the larger rushes, and Juncus torreyi was fairly common. Hibiscus (Hibiscus lasiocarpos) was found throughout the community. Margins of the marsh habitats support scattered indigobush amorpha and buttonbush shrubs. Black willow and cottonwood saplings were occasionally present. As the hydrosere progresses towards climax, these woody species may assume greater importance and may dominate present marshland areas at some future date.

Spartina pectinata consocies.--On the north end of the refuge there is a lowland, slightly saline pasture extending north from the eastern branch of the Salt Fork River. The water table is so slightly below the surface of the sandy loam soil that water remains standing on the surface throughout the spring months. The entire area is dominated by prairie cordgrass (Spartina pectinata) which is 6 to 7 feet tall (Fig. 14). The prairie is included within one of the grazing units and

Figure 14. Spartina pectinata grassland on northern end of refuge.

is grazed by cattle during the spring and summer. However, the rancher who holds the present lease has made little use of the grass for the past several seasons. Cattle placed in the pasture were afflicted often, according to him, with a fungous foot-rot which was caused by the wet soil conditions. Early spring burning of the grassland has been practiced for a number of years. More efficient use of the area results from the early removal of the heavy layer of old grass.

The dominant plant of the grassland was *Spartina pectinata*, which had an important percentage of 57.8 (Table XXVIII). *Scirpus americanus* and *Eleocharis* spp. contributed 19.0 and 16.6 per cent, respectively, to the importance percentage, but the latter species were actually of little importance because the individual plants were small and etiolated, being completely overshadowed by the large cordgrass. Small patches of saltgrass were found scattered through the community but added little to the total composition.

The cordgrass pasture can be expected to undergo little change if spring burning is continued. If protected from disturbance, the area might eventually become an elm woodland. Elm dominates an adjacent area of the same soil type.

Dike and Dam Communities

The several artificial dikes and dams around the fresh-water ponds support plant communities which are the result of disturbance or management. A brief description is included only because the plant aggregations are so different from natural communities.

Most dikes and dams were sprigged with bermudagrass soon after construction to prevent erosion. On most structures the grass maintains

Table XXVII. Composition of Scirpus community in marshland areas

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Scirpus americanus	38.6	46.2	42.4	390,000
Scirpus validus	34.2	29.7	32.0	250,000
Eleocharis spp.	10.2	12.6	11.4	106,000
Juncus torreyi	6.9	4.9	5.9	41,000
Others (12)	10.1	6.6	8.3	57,000
Totals	100.0	100.0	100.0	840,000

Table XXVIII. Composition of Spartina pectinata grassland on northern end of refuge

Species	Relative Frequency	Relative Density	Importance Percentage	Number per Acre
Spartina pectinata	50.0	65.6	57.8	485,000
Scirpus americanus	23.0	15.0	19.0	111,000
Eleocharis spp.	18.9	14.4	16.6	106,000
Distichlis stricta	5.4	3.8	4.6	28,000
Others (2)	2.7	1.2	2.0	10,000
Totals	100.0	100.0	100.0	740,000

complete dominance and forms a dense sod. However, several dikes have undergone successional changes and no longer support bermudagrass. Some dikes have been invaded with dense stands of salt cedar and indigobush amorpha, which have shaded out desirable grasses. Dense stands of weedy species such as johnsongrass (Sorghum halepense), kochia (Kochia scoparia), and giant ragweed (Ambrosia trifida) now dominate these dikes. Other dikes and dams support black willow and cottonwood, but the understory of bermudagrass remains present under these trees. One dike supports a good stand of green ash (Fraxinus pennsylvanica), along with a few scattered honey locust (Gleditsia triacanthos) trees. It will be interesting to see future vegetation changes on these artificial structures.

Cultivated Habitats and Planted Shelterbelts

Approximately 1200 acres of land are farmed by the refuge personnel. Most farming practices are directed toward the production of waterfowl food. Most of the cultivated fields are sandy and subject to wind erosion, which causes cultivation practices to be modified. Nearly all land is strip-cropped in an east-west direction to reduce erosive effects of the southerly winds. Weeds are allowed to grow on the land during the spring to prevent erosion. The dense growth of weeds uses much of the available soil moisture. The loss of soil moisture often results in a reduced crop yield, but the reduction of yield may be justified since the practices now followed do prevent serious wind erosion. Nearly all cultivation is done with oneway disc plows which bury practically all plant parts. The use of sweep-type implements might allow earlier farming of weedy fields, which would preserve moisture and, at the same time, leave sufficient plant remains on the soil surface to prevent wind erosion.

The primary crops on the refuge are wheat, rye, cowpeas and grain sorghums. Wheat and rye are planted in late summer to provide food for geese and ducks which arrive in the fall. Geese, especially, love green wheat and rye, and browse certain fields on the refuge and adjoining farms throughout much of the winter. Fields may be stripped of nearly every blade of wheat when heavily utilized by geese. Grain sorghums are more heavily utilized by ducks, and little grain remains present in the sorghum fields by springtime. Cowpeas are utilized by both ducks and geese. During especially productive years some grain is harvested during the summer and stored for distribution to waterfowl the following winter. Such productive years have been of rather infrequent occurrence on the refuge, and additional grain is generally obtained from other sources.

Several planted windbreaks and shelterbelts are present on the refuge. Black locust has been mentioned earlier. Cottonwood was commonly planted in the area before refuge formation, but the remaining trees are very old and are dying out. Western soapberry (*Sapindus drummondii*) was planted in several places, and dense stands occupy restricted areas around the headquarters. A few stands of juniper (*Juniperus virginiana*), and Siberian elm (*Ulmus pumila*) exist around old homesteads. Catalpa (*Catalpa speciosa*), walnut (*Juglans nigra*), and green ash (*Fraxinus pennsylvanica*) have escaped from early plantings south of headquarters but are not common.

The best windbreaks on the refuge are found on the south side of the lake. Several long rows of western soapberry, Siberian elm, and green ash are found there.

Relation of Plant Communities to Habitat Conditions

The distribution of plants in both saline and non-saline habitats is controlled by soil moisture, topography, and disturbance. It is almost certain, however, that soil salinity is the single most important factor limiting plant distribution within the refuge.

Of the total of 26 communities which were studied quantitatively, 10 were limited to saline soils and 16 to non-saline soils (Table XXIX). Nine of the saline communities were dominated by herbaceous species, and 7 of these were grasslands. The most versatile species in saline habitats was saltgrass, which was dominant in 4 communities and codominant in one. Three species (*Sesuvium verrucosum*, *Suaeda depressa*, and *Sporobolus texanus*) were each limited to a single community.

Table XXIX. Relation of plant communities to soil type

Soil Type	Type and Number of Communities				Total Number
	Forb	Grass	Shrub	Forest	
Saline Sand	2	7	1	0	10
Non-saline Sand	0	9	2	3	14
Clay	0	1	0	1	2
Total Number	2	17	3	4	26

In non-saline habitats, 14 of the 16 communities sampled were located on sandy soil. Nine of the sand communities were grasslands. The most versatile non-saline species was little bluestem, which was the dominant of one community and the codominant of 6 others. Sand bluestem was dominant in one, and codominant in 2 other communities.

Seven woody communities were sampled. Six were located on sandy soil and only one on clay. Non-saline sand supported 5 of the 7 woody communities. Four forests and woodlands were sampled. Soil moisture was most important in determining forest distribution.

Flora of the Salt Plains Refuge

An attempt was made to collect as many plant species as possible during the summers of 1963 and 1964, so that a preliminary list of species and a small herbarium might be readily available at the refuge headquarters. No effort was made to determine the nature of other collections from the refuge, so that the list contains only names of these species collected during the study period. The list of plant taxa is in no way intended to represent a complete collection of all species located within the refuge boundary, since many species were not obtained.

A total of 312 taxa, included in 76 plant families, were collected. Specimens of nearly all the taxa may be found in the refuge herbarium or in the Bebb Herbarium, located at the University of Oklahoma. Scientific nomenclature of the plants included in the list follows Waterfall (1962), except where noted. Common names were taken from Anderson (1961). The list of species appears in Table XXX.

Table XXX. Species list for the Salt Plains National Wildlife Refuge

Family and Scientific Name	Common Name
ACERACEAE	
Acer saccharinum L.	silver maple
AIZOACEAE	
Mollugo verticillata L.	carpetweed
Sesuvium verrucosum Raf.	sea purslane
ALISMATACEAE	
Alisma plantago-aquatica L., var. parviflorum (Pursh) Torr.	waterplantain
Echinodorus berteroi (Spreng.) Fassett, var. berteroi	burhead
Sagittaria latifolia Willd., var. latifolia, forma latifolia	common arrowhead
AMARANTHACEAE	
Froelichia floridana (Nutt.) Moq.	field snakecotton
Amaranthus retroflexus L.	rough pigweed
Amaranthus tamarascinus Nutt.	waterhemp
ANACARDIACEAE	
Rhus aromatica Ait., var. serotina (Greene) Rehd.	aromatic sumac
Rhus glabra L.	smooth sumac
Rhus radicans L., var. rydbergii (Small) Rehd.	poisonivy
APOCYNACEAE	
Apocynum cannabinum L., var. hypericifolium Gray	hemp dogbane
ASCLEPIADACEAE	
Asclepias arenaria Torr.	sand milkweed
Asclepias quadrifolia Jacq.	milkweed
Asclepias speciosa Torr.	showy milkweek
Asclepias tuberosa L.	butterfly milkweed
Asclepias verticillata L.	whorled milkweed
BIGNONIACEAE	
Campsis radicans (L.) Seem.	common trumpetcreeper
Catalpa speciosa Warder	catalpa
BORAGINACEAE	
Cryptantha minima Rydb.	cryptantha
Heliotropium curassavicum L.	heliotrope
Lithospermum carolinense (Walt.) MacM.	Carolina gromwell

Table XXX. Continued

Family and Scientific Name	Common Name
Lithospermum incisum Lehm.	gromwell
CACTACEAE	
Opuntia macrorhiza Engelm.	bigroot pricklypear
CAMPANULACEAE	
Specularia holzingeri (McVaugh.) Fern.	venuslookingglass
CAPPARIDACEAE	
Cleomella angustifolia Torr.	cleomella
CAPRIFOLIACEAE	
Sambucus canadensis L., var. canadensis	American elderberry
Symphoricarpos orbiculatus Moench	buckbrush
CARYOPHYLLACEAE	
Silene antirrhina L., forma antirrhina	sleepy silene
CELASTRACEAE	
Celastrus scandens L.	American bittersweet
CHARACEAE	
Chara keukensis (Allen) Robinson*	chara
CHENOPODIACEAE	
Atriplex argentea Nutt.	silverscale saltbush
Chenopodium ambrosioides L., var. ambrosioides	wormseed goosefoot
Chenopodium hybridum L., var. gigantospermum (Allen) (Roleau)	mapleleaf goosefoot
Chenopodium leptophyllum Nutt.	slimleaf goosefoot
Cycloloma atriplicifolium (Spreng.) Coult.	tumble ringweed
Kochia scoparia (L.) Schrad.	kochia
Monolepis nuttalliana (R. & S.) Greene	nuttall monolepis
Salsola kali L., var. tenuifolia Tausch	russianthistle
Suaeda depressa (Pursh) Wats.	pursh seepweed

*Identified according to keys in Ophel (1952).

Table XXX. Continued

Family and Scientific Name	Common Name
COMMELINACEAE	
Commelina erecta L., var. erecta, forma intercursa Fern.	erect dayflower
Tradescantia occidentalis (Britt.) Smyth	prairie spiderwort
COMPOSITAE	
Achillea lanulosa Nutt., forma lanulosa	western yarrow
Ambrosia psilostachya DC., var. coronopifolia (T. & G.) Farw.	western ragweed
Ambrosia trifida L., var. texana Scheele	giant ragweed
Aphanostephus skirrhobasis Trel.	aphanostephus
Artemisia ludoviciana Nutt., var. ludoviciana	Louisiana sagewort
Aster subulatus Michx., var. ligulatus Shinners	aster
Baccharis salicina T. & G.	willow baccharis
Bidens bipinnata L.	spanishneedles
Chrysopsis villosa (Pursh) Nutt., var. canescens Gray	goldaster
Cirsium altissium (L.) Spreng.	tall thistle
Cirsium undulatum (Nutt.) Spreng.	wavyleaf thistle
Conyza canadensis (L.) Cronq., var. glabrata (Gray) Cronq.	horseweed
Coreopsis tinctoria Nutt., forma tinctoria	plains coreopsis
Erigeron bellidiastrum Nutt.	fleabane
Erigeron tenuis T. & G.	fleabane
Gaillardia pulchella Foug.	rosering gaillardia
Gutierrezia dracunculoides (DC.) Blake	broomweed
Gutierrezia sarothrae (Pursh) Britton & Rusby	broom snakeweed
Haplopappus ciliatus (Nutt.) DC.	goldenweed
Haplopappus divaricatus (Nutt.) Gray, var. hookerianus (T. & G.)	slender goldenweed
Haplopappus spinulosus (Pursh) DC.	ironplant
Helianthus annuus L.	common sunflower
Helianthus maximiliani Schrad.	maximilian sunflower
Helianthus petiolaris Nutt.	prairie sunflower
Heterotheca latifolia L.	camphorweed
Liatris punctata Hook., var. nebraskensis Geiser	dotted gayfeather
Pluchea purpurascens (SW.) DC.	marsh fleabane
Pyrrhopappus geiseri Shinners	falsedandelion

Table XXX. Continued

Family and Scientific Name	Common Name
Ratibida columnifera (Nutt.) W. & S., forma columnifera	upright prairieconeflower
Rudbeckia hirta L., var. pulcherrima (DC.) Fern.	blackeyedsusan
Senecio riddellii T. & G.	riddell groundsel
Solidago canadensis L., var. gilvocanescens Rydb.	Canada goldenrod
Solidago canadensis L., var. scabra (Muhl.) T. & G.	Canada goldenrod
Solidago missouriensis Nutt., var. fasciculata Holz.	Missouri goldenrod
Thelesperma megapotamicum (Spreng.) Kuntze	greenthread
Verbesina encelioides (Cav.) B. & H.	golden crownbeard
Vernonia baldwinii Torr., var. interior (Small) Schub.	inland ironweed
Xanthium strumarium L.	cocklebur
CONVOLVULACEAE	
Convolvulus arvensis L.	field bindweed
Convolvulus incanus Vahl.	gray bindweed
Cuscuta pentagona Engelm.	field dodder
Evolvolus nuttallianus R. & S.	nuttall evolvulus
Ipomea leptophylla Torr.	bush morningglory
CORNACEAE	
Cornus drummondii Meyer	roughleaf dogwood
CRUCIFERAE	
Descurainia pinnata (Walt.) Britt.	tansy mustard
Lepidium densiflorum Schrad.	peppergrass
Lepidium oblongum Small	pepperweed
Lesquerella auriculata (Engelm. & Gray) Wats.	bladderpod
Rorippa islandica (Oeder) Borbas, var. fernaldiana Butte. & Abbe.	watercress
CUCURBITACEAE	
Cucurbita foetidissima HBK.	buffalogourd
Cyclanthera dissecta (T. & G.) Arn.	cyclanthera
Melothria pendula L.	- - -
CYPERACEAE	
Carex blanda Dewey	sedge
Carex brevior Mack.	sedge
Carex lasiocarpa Ehrh., var. latifolia (Boeck.) Gl.	sedge

Table XXX. Continued

Family and Scientific Name	Common Name
Carex normalis Mack.	sedge
Cyperus aristatus Rottb.	flatsedge
Cyperus filiculmis Vahl.	fern flatsedge
Cyperus ferruginescens Boeckl.	flatsedge
Cyperus ovularis (Michx.) Torr., var. sphaericus Boeckl.	flatsedge
Cyperus uniflorus Torr. & Hook.	flatsedge
Eleocharis engelmanii Steud.	engelmann spikesedge
Fimbristylis vahlii (Lam.) Link	fimbristylis
Scirpus americanus Pers., var. polyphyllus (Boeckl.) Beettle	American bulrush
Scirpus paludosus A. Nels.	alkali bulrush
Scirpus validus Muhl., var. creber Fern.	softstem bulrush
ELAEAGNACEAE	
Elaeagnus angustifolia L.	russianolive
EQUISETACEAE	
Equisetum laevigatum A. Br.	smooth horsetail
EUPHORBIACEAE	
Croton glandulosus L., var. septentrionalis Muell. Arg.	croton
Croton texensis (Klotzsch) Muell. Arg.	texas croton
Euphorbia dentata Michx., forma dentata	toothed euphorbia
Euphorbia hexagona Nutt.	sixangle euphorbia
Euphorbia marginata Pursh	snow-on-the-mountain
Euphorbia missurica Raf.	Missouri spurge
Stillingia sylvatica L.	stillingia
FUMARIACEAE	
Corydalis curvisiliqua Engelm., var. grandibracteata Fedde	corydalis
GENTIANACEAE	
Eustoma grandiflorum (Raf.) Shinners, forma grandiflorum	prairiegentian
GERANIACEAE	
Geranium carolinianum L.	Carolina gernaium
GRAMINEAE	
Aegilops cylindrica Host., var. rubiginosa Popova	goatgrass

Table XXX. Continued

Family and Scientific Name	Common Name
Agropyron smithii Rydb., var. smithii	western wheatgrass
Andropogon gerardi Vitman. var. gerardi	big bluestem
Andropogon hallii Hack.	sand bluestem
Andropogon saccharoides Sw,	silver bluestem
Andropogon scoparius Michx.	little bluestem
Aristida oligantha Michx.	prairie threeawn
Aristida purpurea Nutt.	purple threeawn
Bouteloua curtipendula (Michx.) Torr.	sideoats grama
Bouteloua gracilis (Willd. ex HBK.) Lag. ex Griffiths	blue grama
Bouteloua hirsuta Lag., var. pectinata (Featherly) Cory	hairy grama
Bromus catharticus Vahl.	rescue brome
Bromus japonicus Thunb.	Japanese brome
Bromus secalinus L.	cheat
Bromus tectorum L.	downy brome
Buchloe dactyloides (Nutt.) Engelm.	buffalograss
Calamovilfa gigantea (Nutt.) Scribn. & Merr.	big sandreed
Cenchrus pauciflorus Benth.	sandbur
Chloris verticillata Nutt.	windmillgrass
Cynodon dactylon (L.) Pers.	bermudagrass
Digitaria sanguinalis (L.) Scop.	crabgrass
Diplachne fascicularis (Lam.) Beauv.	bearded sprangletop
Distichlis stricta (Torr.) Rydb.	inland saltgrass
Echinochloa crusgalli (L.) Beauv.	barnyardgrass
Elymus canadensis L.	Canada wildrye
Eragrostis curtipedicillata Buckl.	gummy lovegrass
Eragrostis curvula (Schrad.) Nees	weeping lovegrass
Eragrostis oxylepis (Torr.) Torr., var. beyrichii (T. G. Sm.) Shinners	red lovegrass
Eragrostis poaeoides Beauv.	little lovegrass
Eragrostis spectabilis (Pursh) Steud.	purple lovegrass
Eragrostis trichodes (Nutt.) Nash, var. pilfera (Scheele) Fern.	sand lovegrass
Eragrostis trichodes (Nutt.) Nash, var. trichodes	sand lovegrass
Eriochloa contracta Hitch.	prairie cupgrass
Festuca octoflora Walt.	sixweeks fescue
Glyceria striata (Lam.) Hitchc.	fowl mannagrass

Table XXX. Continued

Family and Scientific Name	Common Name
Hordeum jubatum L.	foxtail barley
Hordeum pusillum Nutt.	little barley
Leersia oryzoides (L.) Sw.	rice cutgrass
Leptoloma cognatum (Schultes) Chase	fall witchgrass
Panicum anceps Michx.	beaked panicum
Panicum capillare L., var. capillare	common witchgrass
Panicum capillare L., var. occidentale Rydb.	cushion witchgrass
Panicum lanuginosum Ell., var. fasiculatum (Torr.) Fern.	- - - -
Panicum obtusum HBK.	vinemesquite
Panicum oligosanthes Schultes, var. scribnerianum (Nash) Fern.	Scribner panicum
Panicum virgatum L.	switchgrass
Paspalum ciliatifolium Michx.	fringeleaf paspalum
Paspalum distichum L.	knotgrass
Phalaris caroliniana Walt.	Carolina canarygrass
Poa arachnifera Torr.	Texas bluegrass
Poa compressa L.	Canada bluegrass
Schedonnardus paniculatus (Nutt.) Trel.	tumblegrass
Setaria geniculata (Lam.) Beauv.	knotroot bristlegrass
Setaria glauca (L.) Beauv.	- - - -
Setaria italica (L.) Beauv.	foxtail millet
Setaria viridis (L.) Beauv.	green bristlegrass
Sorghum halepense (L.) Pers.	johnsongrass
Spartina pectinata Link, var. suttiei (Garv.) Fern.	prairie cordgrass
Sphenopholis obtusata (Michx.) Scribn., var. obtusata	prairie wedgescale
Sporobolus airoides Torr.	alkali sacaton
Sporobolus asper (Michx.) Kunth, var. asper	tall dropseed
Sporobolus cryptandrus (Torr.) Gray	sand dropseed
Sporobolus texanus Vasey	Texas dropseed
Tridens flavus (L.) Hitch.	purpletop
Tripsacum dactyloides L.	eastern gamagrass
ILLECEBRACEAE	
Paronychia jamesii T. & G.	james nailwort
JUGLANDACEAE	
Juglans nigra L.	black walnut

Table XXX. Continued

Family and Scientific Name	Common Name
JUNCACEAE	
Juncus interior Wieg.	inland rush
Juncus marginatus Rostk.	rush
Juncus torreyi Coville	torrey rush
LABIATAE	
Hedeoma hispida Pursh	rough falsepennyroyal
Monarda citriodora Cerv. ex Lagusca	lemon beebalm
Monarda clinopodioides Gray	basil beebalm
Monarda punctata L., var. occidentalis (Epl.) Palm. & Steyerm.	spotted beebalm
Salvia azurea Lam., var. grandiflora	pitcher sage
Teucrium canadense L., var. canadense	American germander
LEGUMINOSAE	
Amorpha fruticosa L.	indigobush amorpha
Astragalus gracilis Nutt.	loco
Astragalus lotiflorus Hook., var. lotiflorus	milkvetch
Baptisia australis (L.) R. Br., var. minor (Lehm.) Fern.	blue wildindigo
Cassia fasciculata Michx.	showy partridgepea
Dalea aurea Nutt.	silktop dalea
Dalea candida Willd., var. oligophylla (Torr.) Shinners	white prairieclover
Dalea laxiflora Pursh	prairieclover
Dalea villosa (Nutt.) Spreng.	silky prairieclover
Desmanthus illinoensis (Michx.) MacM.	Illinois bundleflower
Desmodium sessilifolium (Torr.) T. & G.	sessile tickclover
Gleditsia triacanthos L.	honeylocust
Glycyrrhiza lepidota (Nutt.) Pursh	American licorice
Indigofera miniata Ortega, var. leptosepala (Nutt.) Turner	western indigo
Melilotus alba Desv.	white sweetclover
Psoralea digitata Nutt.	scurfpea
Psoralea tenuiflora Pursh	slimflower scurfpea
Robinia pseudoacacia L.	black locust
Schrankia uncinata Willd.	catclaw sensitivebriar
Strophostyles leiosperma (T. & G.) Piper	smoothseed wildbean

Table XXX. Continued

Family and Scientific Name	Common Name
Vicia villosa Roth.	hairy vetch
LEMNACEAE	
Lemna minor L.	common duckweed
LENTIBULARIACEAE	
Utricularia vulgaris L.	common bladderwort
LILIACEAE	
Allium perdulce S. V. Fraser	wild onion
Smilax bona-nox L.	greenbriar
Smilax rotundifolia L.	roundleaf greenbriar
Yucca glauca Nutt., var. glauca	small soapweed
LINACEAE	
Linum rigidum Pursh, var. berlandieri (Hook.) T. & G.	stiffstem flax
MALVACEAE	
Callirhoe involucrata (Nutt. ex Torr.) Gray, var. involucrata	purple poppymallow
Hibiscus lasiocarpos Cav.	hibiscus
MENISPERMACEAE	
Cocculus carolinus (L.) DC.	Carolina snailseed
Menispermum canadense L.	common moonseed
MORACEAE	
Morus alba L.	white mulberry
Morus rubra L.	red mulberry
NAJADACEAE	
Najas guadalupensis (Spreng.) Magnus	Southern najad
NYCTAGINACEAE	
Mirabilis exaltata (Standl.) Standl.	four-o'clock
Mirabilis linearis (Pursh) Heimerl., var. linearis	Narrowleaf four-o'clock
NYMPHACEAE	
Nelumbo lutea (Willd.) Pers.	American lotus
OLEACEAE	
Fraxinus pennsylvanica Marsh., var. subintegerrima (Vahl.) Fern.	green ash

Table XXX. Continued

Family and Scientific Name	Common Name
ONAGRACEAE	
Gaura villosa Torr., var. arenicola Munz	hairy gaura
Ludwigia palustris (L.) Ell., var. americana (DC.) Fern. & Grisc.	seedbox
Oenothera heterophylla Spach., var. rhombipetala (Nutt.) Fosberg	evening primrose
Oenothera laciniata Hill, var. laciniata	cutleaf eveningprimrose
Oenothera serrulata Nutt.	serrate leaf eveningprimrose
Stenosiphon linifolius (Nutt.) Britt.	stenosiphon
OROBANCHACEAE	
Orobanche ludoviciana Nutt	Louisiana broomrape
PAPAVERACEAE	
Argemone polyanthemos (Fedde) G. B. Ownb.	pricklepoppy
PASSIFLORACEAE	
Mentzelia stricta (Osterhout) Stevens ex Jeffs. & Little	bractless mentzelia
PHYTOLACCACEAE	
Phytolacca americana L.	common pokeberry
PINACEAE	
Juniperus virginiana L.	juniper
PLANTAGINACEAE	
Plantago purshii R. & S., var. purshii	woolly plantain
Plantago virginica L.	paleseed plantain
POLYGONACEAE	
Eriogonum annuum Nutt.	annual eriogonum
Polygonum bicorne Raf.	smartweed
Polygonum coccineum Muhl.	swamp smartweed
Polygonum lapthifolium L.	curltop smartweed
Rumex altissimus Wood	pale dock
Rumex crispus L.	curled dock
Rumex obtusifolius L.	bitter dock
Rumex verticillatus L.	whorled dock

Table XXX. Continued

Family and Scientific Name	Common Name
PORTULACACEAE	
Portulaca oleracea L.	common purslane
PRIMULACEAE	
Androsace occidentalis Pursh	western rockjasmine
Samolus parviflorus Raf.	samolus
RANUNCULACEAE	
Anemone caroliniana Walt., forma caroliniana	Carolina anemone
Anemone caroliniana Walt., forma violacea Clute	Carolina anemone
Delphinium virescens Nutt.	plains larkspur
Ranunculus abortivus L.	littleleaf buttercup
ROSACEAE	
Prunus angustifolia Marsh.	chickasaw plum
Rosa multiflora Thunb.	multiflora rose
RUBIACEAE	
Cephalanthus occidentalis L., var. occidentalis	common buttonbush
Galium aparine L.	catchweed bedstraw
Galium circaezans Michx.	bedstraw
Hedyotis nigricans (Lam.) Fosb.	narrowleaf bluets
SALICACEAE	
Populus deltoides Marsh.	eastern cottonwood
Salix interior Rowlee, forma interior	interior willow
Salix nigra Marsh.	black willow
SAPINDACEAE	
Cardiospermum halicacabum L.	heartseed
Sapindus drummondii H. & A.	western soapberry
SAPOTACEAE	
Bumelia lanuginosa (Michx.) Pers.	woolybucket bumelia
SAXIFRAGACEAE	
Penthorum sedoides L.	penthorum
SCROPHULARIACEAE	
Buchnera americana L.	American bluehearts
Linaria canadensis (L.) Dumont, var. texana (Scheele) Pennell	toadflax

Table XXX. Continued

Family and Scientific Name	Common Name
SOLANACEAE	
Physalis angulata L., var. pendula (Rydb.) Waterfall	cutleaf groundcherry
Physalis heterophylla Nees, var. heterophylla	clammy groundcherry
Physalis virginiana Mill., var. virginiana	Virginia groundcherry
Physalis viscosa L., var. cinerascens (Dunal) Waterfall	viscid groundcherry
Solanum americanum Mill.	black nightshade
Solanum eleagnifolium Cav., forma eleagnifolium	silverleaf nightshade
Solanum rostratum Dunal.	buffalobur nightshade
Solanum torreyi Gray, forma torreyi	torrey nightshade
SPARGANIACEAE	
Sparganium eurycarpum Engelm.	giant burreed
TAMARICACEAE	
Tamarix gallica L.	tamarisk
TYPHACEAE	
Typha domingensis Pers.	cattail
Typha latifolia L., forma latifolia	common cattail
ULMACEAE	
Celtis occidentalis Pursh	common hackberry
Celtis reticulata Torr.	netleaf hackberry
Ulmus americana L.	American elm
Ulmus rubra Muhl.	slippery elm
Ulmus pumila L.	Siberian elm
UMBELLIFERAE	
Ammoselinum popei T. & G.	sand parsley
Cicuta maculata L.	waterhemlock
Sanicula canadensis L.	Canada sanicle
Spermolepis echinata (Nutt.) Heller	spermolepis
VERBENACEAE	
Lippia lanceolata Michx.	lippia
Verbena bracteata Lag. & Rodr.	bigbract verbena
Verbena hastata L.	blue verbena
Verbena stricta Vent., forma stricta	woolly verbena

Table XXX. Continued

Family and Scientific Name	Common Name
VIOLACEAE	
Viola kitaibeliana R. & S., var. rafinesquii	johnny jumpup
Viola sagittata Ait.	violet
VITACEAE	
Parthenocissus quinquefolia (L.) Planch, forma quinquefolia	Virginia creeper
Vitis riparia Michx.	wild grape
Vitis vulpina L.	wild grape
ZOSTERACEAE	
Potamogeton pectinatus L.	fennelleaf pondweed
Ruppia maritima L., var. longipes Hagstrom	Widgeongrass
ZYGOPHYLLACEAE	
Tribulus terrestris L.	puncturevine

SUMMARY

Salt Plains National Wildlife Refuge, covering nearly 33,000 acres, is located in the water-shed of the Salt Fork River in Alfalfa County, near Jet and Cherokee, Oklahoma. The refuge, established in 1930, is operated by the Bureau of Sports Fisheries and Wildlife of the United States Department of the Interior as a haven for migratory water-fowl. Included within the refuge are a 10,000 acre lake, 14,000 acres of barren salt flats, 5,000 acres of grassland, 1,000 acres of forest, 2,500 acres of shrub, 1,200 acres of farmland, and several ponds and marshes.

The refuge is located within the tall grass prairie of the grassland biome; however, edaphic factors cause the vegetation to be quite variable. Plant communities vary from a sparse, open herbaceous stand on the salt plain to dense upland and bottomland forests.

A study of vegetation and flora of the refuge was made during 1963 and 1964. Twenty-six distinct plant communities were delimited through reconnaissance and the use of aerial photographs and were studied by use of the point-centered quarter method of vegetation analysis. Seventeen grassland communities, 4 forests, 3 shrublands, and 2 herb communities constituted the 26 communities subjected to quantitative analysis. Seven other community and habitat types were located and described qualitatively.

Ten communities were limited to sandy, saline soils. These communities exist on and around the salt plain. Two distinct forb communities are present on the salt plain itself: a Sesuvium verrucosum consocies; and a Suaeda depressa consocies. Seven grassland aggregations on sandy, saline soils include four communities dominated by inland saltgrass (Distichlis stricta), the most ubiquitous and versatile halophyte in the refuge region. The other saline grasslands are dominated by alkali sacaton (Sporobolus airoides), Texas dropseed (Sporobolus texanus), and fall witchgrass (Leptoloma cognatum). Several saline grasslands are grazed by cattle. Others are protected but remain weedy and are undergoing successional changes.

The most important shrubland in the refuge is the salt cedar (Tamarix gallica) consocies which covers more than 2500 acres of lake shore and alluvial flats. This woody pest was not found on the refuge until the Great Salt Plains Reservoir was impounded in 1942.

Non-saline, sandy soils support 14 communities, including 9 grasslands, 3 forests, and 2 shrublands. Seven of the 9 grassland communities are dominated by species of Andropogon. Little bluestem (Andropogon scoparius) is one of the dominants in six of the communities, and sand bluestem (Andropogon hallii) is a dominant in several. Switchgrass (Panicum virgatum) and fall witchgrass each dominate one grassland community. Most of the sandy grasslands are grazed by cattle, but several have been protected from disturbance for more than 20 years and are presently being replaced by woody species. Tertiary sand dunes on the northern end of the refuge support bluestem prairie which is being invaded by shrubs.

Two important shrubland communities exist on sandy, non-saline soil. Chickasaw plum (Prunus angustifolia) forms dense stands throughout most sandy grasslands, and rough-leaved dogwood (Cornus drummondii) exists in many sandy, lowland areas. Both species are rapidly replacing those grasslands which are protected from fire and grazing.

Three forest communities on sandy soil include a bottomland forest and two upland forests. The bottomland forest is dominated by cottonwood (Populus deltoides) and black willow (Salix nigra) and is present around all fresh-water ponds and streams. A typical upland elm forest covers several hundred acres on the eastern portion of the refuge. This mature forest is dominated by American elm (Ulmus americana), but it also contains hackberry (Celtis spp.) and chittamwood (Bumelia lanuginosa). Black locust (Robinia pseudoacacia) forests dominate many sandy soils where moisture is available. Both upland forest communities are increasing in acreage at the expense of grassland. Protection from disturbance has given trees a competitive advantage which allows them to replace the grasses.

Clay soils cover a limited area within the refuge and support only two of the communities which were analyzed. An Andropogon prairie covers the uplands of the Permian Red Beds on the south side of the reservoir. Dominant plants are big bluestem (Andropogon gerardi) and little bluestem. Clay soils along Sand Creek, which enters the refuge from the north, support a mixed elm-cottonwood-willow woodland.

The lake itself is muddy, shallow, and brackish and supports few aquatic plants. The shoreline is virtually barren because of rapid and extensive fluctuation of the water level. Alkali bulrush (Scirpus paludosus) is a characteristic plant of the lake shoreline.

Man-made fresh-water ponds support all the typical hydrosere stages. Cattail and American lotus (Nelumbo lutea) are present in most ponds and are difficult to control. Sago pondweed (Potamogeton pectinatus) is the most important submerged aquatic in fresh-water ponds. Several large marshlands support a luxuriant Scirpus community. Many marshlands show evidence of a slow replacement by bottomland forest. One lowland, marshy area is occupied by a grazed prairie cordgrass (Spartina pectinata) consocies. Controlled burning maintains the community.

Cultivated lands comprise over 1200 acres of the refuge. Important planted crops include wheat and grain sorghums, which serve as food for migrating waterfowl. Most cropland consists of sandy soil which is subject to severe wind erosion.

The vegetation of all protected areas on the refuge is undergoing a rather rapid change. Generally, grasslands are being replaced by shrubland, woodland, and forest under protection from grazing and fire. Future areas of grassland on sandy, protected sites will be very small. Grazed pastures are apparently undergoing little change. Continued disturbance can be expected to maintain grasslands in grazed pastures. Vegetation of the undisturbed, sandy soils of the refuge is definitely postclimax to vegetation on the surrounding plains. The edaphic climax on favorable sites is woodland or forest rather than the tall grass climax indicated by climate alone.

Little change can be expected on the highly saline areas. Soil salinity is the most obvious factor limiting plant distribution on the refuge so that halophytes will continue to occupy, and to be restricted to, saline sites because they are unable to compete with glycophytes in non-saline sites. Most glycophytes are unable to grow on saline soils and will continue to be restricted to non-saline areas.

Plants collected within the refuge comprised 312 taxa distributed among 76 families. It is hoped that this preliminary list of plant species and the collection of preserved specimens, located in the refuge herbarium, may serve in further studies of the refuge flora.

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