AN ABSTRACT OF THE THESIS OF

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Abstract approved by: William W. Chilcote

During the summers of 1971, 1972, and 1973, a general floristic ecological survey of the naturally-occurring vegetation of the Bear River Migratory Bird Refuge in Utah was carried out. Ten community types were identified and characterized. These included two aquatic communities, the *Potamogeton pectinatus* (Pope) and the *Ruppia maritima*/*Zannichellia palustris* (Ruma/Zapa) communities. There were also three typically emergent communities, the *Scirpus acutus* (Scac), *Typha latifolia* (Tyla), and *Scirpus maritimus paludosus* (Scma) communities. And finally, there were five basically terrestrial communities, the *Distichlis spicata stricta* (Disp), *Distichlis spicata stricta*/*Hordeum jubatum* (Disp/Hoju), *Salicornia europaea rubra* (Saeu), *Agropyron cristatum*/*Atriplex*/*Sacrobatus vermiculatus* (Agcr/At/Save), and *Suaeda depressa*/*Bassia hyssopifolia*/*Lepidium perfoliatum* (Sude/Bahy/Lepe) communities.

The ten communities characterized were interrelated and related to the two apparently overriding environmental factors, soil moisture and soil salinity. The mean soil moisture of the ten communities ranged from wet to dry as follows: Pope, Ruma/Zapa, Scma, Scac, Tyla, Disp, Sude/Bahy/Lepe, Saeu, Disp/Hoju, Agcr/At/Save. When the ten communities were arranged from mean high to low salinity, they fell in the following order: Saeu, Sude/Bahy/Lepe, Ruma/Zapa, Scma, Disp, Pope, Tyla, Disp/Hoju, Scac, Agcr/At/Save.

The total known flora of the Bear River Refuge has increased from 92 species in 1935 to 160 species in 1972. The increase came largely as a result of the introduction of "exotics" from surrounding areas. The three largest families in 1935 were (1) Compositae, (2) Chenopodiaceae, and (3) Gramineae. In 1972 the three largest families were (1) Compositae, (2) Gramineae, and (3) Chenopodiaceae. Based on trends of vegetative development and a continuation of present management practices, coupled with a further amelioration of edaphic conditions, as new silt and a supply of relatively fresh water continue, a further increase in species diversity is predicted.

An Ecological Study of the Vegetation of the Bear River Migratory Bird Refuge, Box Elder County, Utah

by

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AN ECOLOGICAL STUDY OF THE VEGETATION OF THE BEAR RIVER MIGRATORY BIRD REFUGE, BOX ELDER COUNTY, UTAH

I. INTRODUCTION

During the period June 9 - September 12, 1972, an ecological study was made of the naturally-occurring vegetation of the Bear River Migratory Bird Refuge, Box Elder County, Utah, on the delta of the Bear River.

Prior reconnaissance of the refuge during the summers of 1970 and 1971 indicated an interesting pattern of vegetation composed of a complex of community types of low species diversity. A number of readily identifiable mono-or-di-specific community types seemed to form the basis for most of the naturally-occurring marsh/salt marsh - desert/salt desert vegetative complex of the area.

The goals of this study were:

(1) To determine and characterize the community types of the refuge area,

(2) to interrelate the community types identified and to relate these community types with certain overriding environmental factors responsible for zonation, and

(3) to compare the current vegetation of the refuge with that in 1935 in order to characterize the vegetative changes which have occurred, and to aid in predicting future changes.

II. DESCRIPTION OF THE STUDY AREA

Location and Topography

The Bear River Migratory Bird Refuge is located in the southeast corner of Box Elder County in northwestern Utah. It lies in the northern Salt Lake Valley with refuge headquarters at the mouth of the Bear River.

The refuge covers approximately 26,500 hectares, 10,000 hectares of which is under fresh to brackish water ranging from a trace to 1.2 m deep within a series of five main artificial impoundments.

Most of the refuge is exceedingly flat, except where disturbed by man's activities, the shifting of ice sheets during winter, or the blowing of loose, fine soil during the dry summer months. Barren areas outside the main dike system have a gentle slope to the south of less than 0.2 m per km. The elevation of the refuge, therefore, varies very little and may be placed at 1281.7 ± 1.5 m above sea level.

Due to heavy demand on streamflow of the Bear River for agricultural, municipal, and industrial purposes upstream from the refuge, the level of the Great Salt Lake has been artificially reduced to a point about 19 km south of the refuge boundary.[1] Fresh water Willard Bay State

[1]The Great Salt Lake is always represented on maps the way it appeared at its historical highpoint in 1868, although it has since declined substantially and varies from year to year.

Park lies east of the Great Salt Lake just to the south of refuge Unit V. Refuge headquarters are located about 24 km west of Brigham City, Utah, over paved county roads. The main headquarters buildings are at the point where the Bear River loses its identity, being artificially rechannelled at that point into the various refuge impoundments for waterfowl habitat management purposes.

Geological History: Causes of Salinity

Lying as it does at the mouth of the Bear River, the refuge receives suspended sediments and dissolved salts from the entire Bear River drainage area.

The whole area, including the current Great Salt Lake, was once covered by ancient, fresh water Lake Bonneville, which, at its maximum extent, covered about 5,100,000 hectares[2] and stood at a level approximately 300 m higher than the present level of the Great Salt Lake.

When Lake Bonneville rose due to an increase in precipitation, it finally overflowed at Red Rock Pass in Idaho. Overflow, it is believed, took place about 30,000 years ago and erosion rapidly lowered the lake level about 115 m in 25 years, or so, until a hard limestone stratum was reached, and erosion slowed. The lake was then stable for

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[2] By comparison, this is slightly smaller than the combined areas of the states of Maryland, Delaware, Massachusetts, and Rhode Island. The present Great Salt Lake covers approximately 470,000 hectares.

a long period during which evaporation and seepage were the major factors in its decline. At a point some 60 m higher than the present Great Salt Lake level salts began to be precipitated and deposited in the lake sediments. As a result of deposition and isostatic adjustment, valley sediments are relatively uniform in alkalinity and texture to a depth of at least 610 m (Flowers, 1934) and probably exceed 3050 m overall in many areas.

As a result of alkali deposition by the declining Lake Bonneville and recent submergence by the Great Salt Lake during its historical highpoint in 1868, the soils and waters of the refuge area were generally quite saline when the refuge was established in 1928. However, as a result of management activities, the soils and waters within the five artificial impoundments are now generally much less saline, although surrounding areas are still quite brackish. The degree of salinity of all areas varies from year to year and from season to season, depending upon the effects of dilution by fresh water in the fall, winter, and spring, and upon the degree of concentration of salts by evaporation during the hot dry summer months from late May through early September.

History of Development: Management

The Bear River Migratory Bird Refuge Act of April 23, 1928 created the Bear River Refuge to provide a suitable habitat for waterfowl nesting and migration, and to prevent further serious waterfowl losses due to outbreaks of avian botulism.[3] The refuge site has had a long history of concentrated waterfowl use, and, in view of rapidly-diminishing waterfowl habitat areas in other parts of North America, due to cultivation, etc., its future value seems inestimable.

Soon after the refuge was created, a series of five main diked impoundments, each about 2,000 hectares in area, were constructed. Regulation of water levels within these ponded areas or units will be discussed shortly.

More recently, numerous long, low contour furrows have been created. Over a period of several years, a road grader has been used to furrow barren mud flats (playas) inside and outside Units I and IV, inside Unit III, and outside Unit V. These furrows seem to have been effective in promoting vegetative growth where none previously existed, and in facilitating more effective spreading and retention of what little water is available for these barren areas, as illustrated in figure 1. They also seem to have been effective in promoting increased waterfowl nesting and migrational usage on the contoured areas[4] (Black, 1972;

[3]At Lower Klamath Wildlife Refuge in Northern California late summer drainage of water impoundments is practiced in at attempt to prevent serious outbreaks of avian botulism (O'Neill, 1972).

[4]Wein and West (1971) and Branson, et al. (1966) have pointed out that contour furrowing is generally most effective with medium to fine textured soils, typical of playas. Peterson and Branson (1962) give an interesting history of the use of water spreaders going back to the Phoenicians, 3-4,000 years ago.

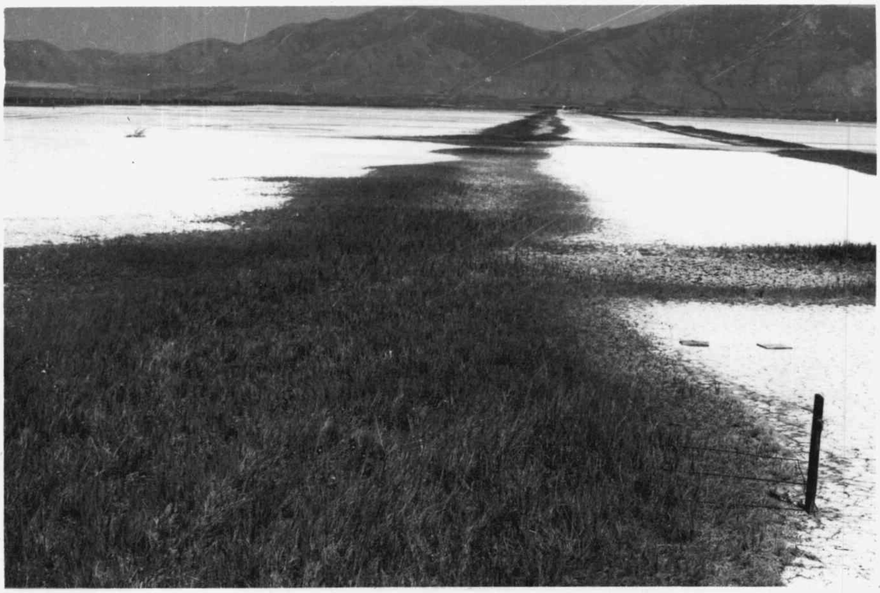

Figure 1. Contour furrows in Unit IV. Growth consists principally of _Salicornia europaea rubra_ and _Distichlis spicata stricta_ with barren, salt-encrusted mud between the furrows.

personal inspection, 1964-1973).

Little active regulation in addition to these activities has in the past, or is currently practiced at the refuge. Other activities affecting refuge vegetation, past and present, include the following:

1. Wheat was at one time cultivated for waterfowl harvest on the dry, elevated barrens at the northwest end of the refuge (the present dump area).
2. Several plant species have been sprayed with various herbicides to eliminate them from the refuge or to control their spread. Included in these spraying efforts have been various species of *Rosa* and *Cirsium* as well as the widespread phraeatophyte, *Tamarix pentandra*.
3. Refuge personnel yearly mow the vegetation along the dikes adjacent to the areas of the refuge opened to hunting. Small areas near the refuge entrance and other limited areas offering hunter access are also mowed occasionally.
4. During the 1930's Russian olive trees, *Elaeagnus angustifolia*, were planted along some secondary dikes. Growth of these trees has been slow, but they have been reproducing themselves in the more favorable areas.

Water Regimes

The water level within the five impounded units is maintained, within certain limits, at approximately 1281.62 m above sea level. Seasonal and yearly fluctuations of river flow (determined largely by yearly rainfall, and winter snowpack in the drainage area, and by agriculture, industry, etc. upstream), precipitation, and evaporation often make difficult the task of water level regulation. The units are usually drained and refilled prior to the waterfowl nesting season.

Water depth within the units tends to increase to the south and away from the points of entry of river water into the units. This increase in depth is due to (1) the general slope of the area toward the south, and (2) the heavier deposition of suspended sediments nearer entry points. It has been estimated that up to 95% of the sediment load is deposited within the units before the water drains from the units. Deposition varies, however, with rates of influx and drainage, and may reach 100% during hot, dry periods, when no outflow is permitted (Anderson, 1969).

Water levels outside the dike system to the south and west of the main impounded areas are not actively regulated, and they fluctuate greatly with changes in season and amounts of excess water spilled from within the main impoundments.

Each summer the vast barren areas outside the dike system dry out leaving a dried, cracked, salt-encrusted surface, for the most part devoid of vegetation. During wet years, such as 1971 and 1972, the extent of these dry areas may be much reduced. During very dry years all five units have been known to dry up in addition to the normally dry external areas. Nevertheless, with few known exceptions (certain dry "islands", particularly in the dump area at the northwest end of the refuge), the water table is seldom more than 0.6 to 1.0 m below the soil surface, even in those areas where the soil surface has dried, cracked, and turned to powder.

Climate

The general climate of the entire Salt Lake Valley system places it in the cold-desert biome, because of its extreme temperatures and low yearly precipitation.

At the Salt Lake City International Airport weather station, one year in four the temperature will exceed either 39°C in summer or -23°C in winter, and yearly precipitation averages only 35.3 cm, including an average of 132 cm of snow in winter (U. S. Dept. of Commerce, 1972).

The Bear River Refuge weather station, located at refuge headquarters, reports similar temperature extremes and an average of 31.8 cm of precipitation per year from 1940 to 1970. Since 1940 temperatures at the refuge have ranged from -32°C to 40°C. Summer high temperatures typically exceed 32°C, while winter lows typically go below 0°C every night. Winter temperatures often remain below freezing for several days in a row. Total yearly precipitation at the refuge has ranged from 19.7 cm in 1952 to 44.2 cm in 1945. Prolonged summer droughts are not uncommon, and winter snowfall is often quite heavy.

Winters at the Bear River Refuge are normally cold and "wet", while summers are typically hot and dry. January is normally the coldest month and July the hottest month at both stations, while April is the wettest and July typically the driest month. For a summary of average monthly temperatures at the Salt Lake City weather station, see figure 2. Average monthly evaporation and precipitation records for the Bear River weather station are summarized in figure 3 (from weather records kept at refuge headquarters).

Potential evapotranspiration is quite high during summer months, especially July and August, due to a combination of high temperatures and low relative humidities (Ungar, 1972; Wein and West, 1972). Figure 3 also illustrates the rather large summer water deficit of the refuge area, based on evaporation and precipitation records kept by the refuge. Frequent strong, warm, dry southern winds (termed HATU's by the U. S. Weather Bureau) have a

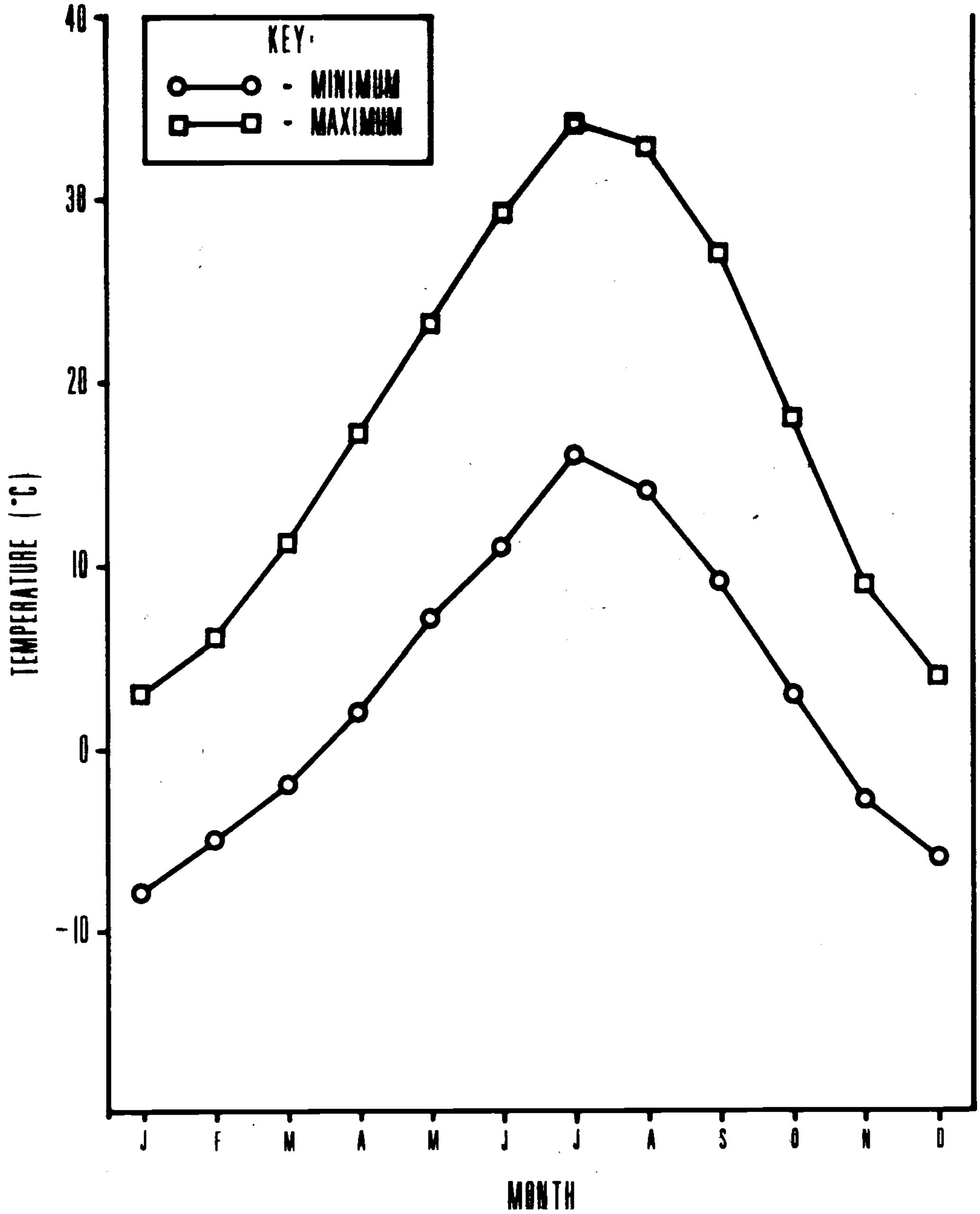

Figure 2. Average monthly minimum and maximum temperatures at the Salt Lake City International Airport weather reporting station.

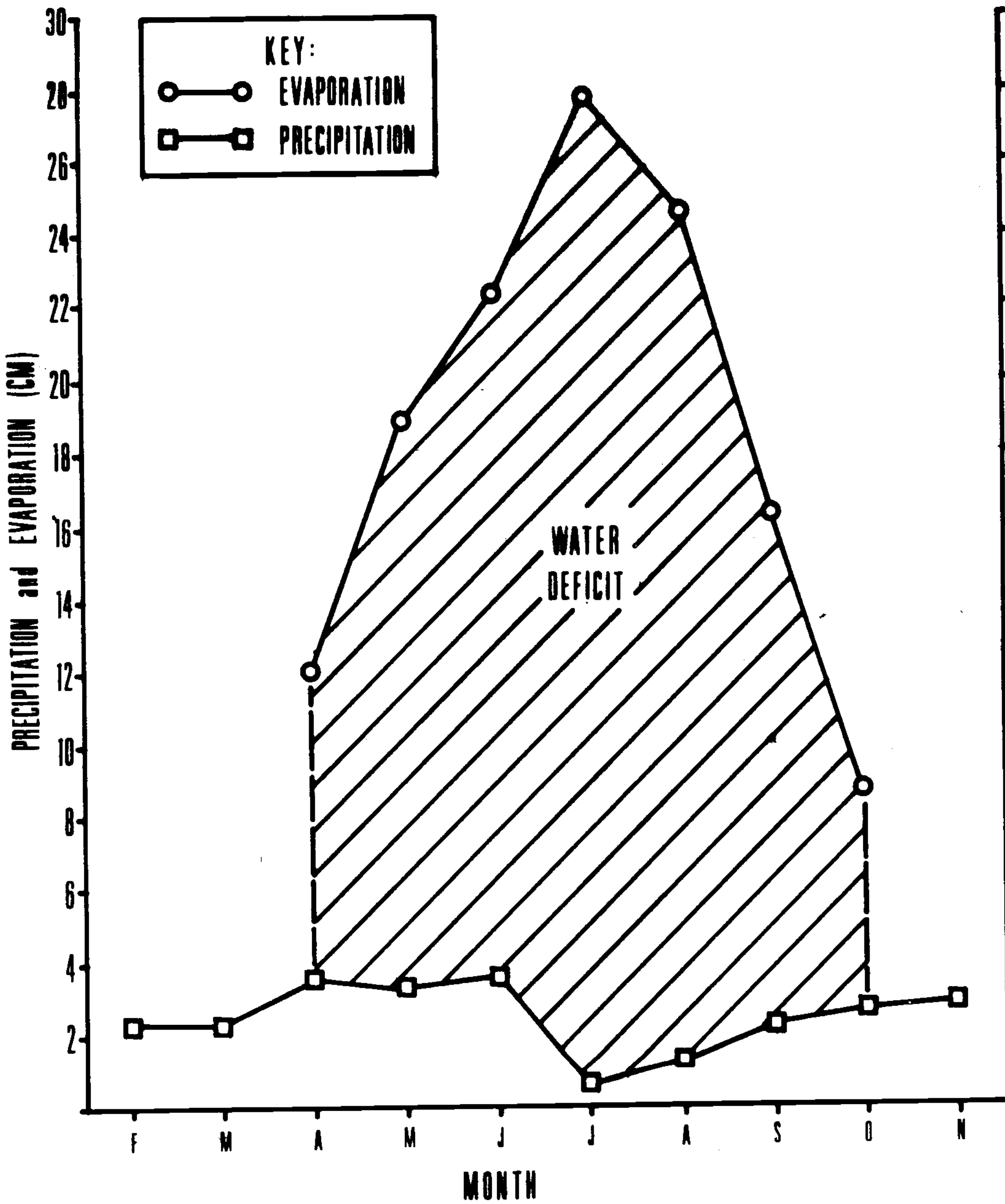

Figure 3. Average monthly precipitation and open pan evaporation for the Bear River Migratory Bird Refuge weather reporting station, showing monthly water deficit.

pronounced drying effect; however, they are often accompanied by some ameliorating precipitation.

Soils

The soils of the study area belong to the Saltair-Wayment-Arave association. They are classes as poorly-drained and very-poorly-drained very saline silty-clay loams and silt loams, and they lie on old lake plains, low terraces or flood plains (U. S. D. A. Soil Conservation Service, 1968).

Additions and removals by water and wind, and transfers by leaching and inversion due to drying and cracking are major factors in the development of these soils. The churning behavior of the dried, cracked soils, compounded by the rapidity of additions and removals, serves to prevent prominent horizonization.

Based upon these factors and the seasonally-dry climate of the refuge area, the soils should probably be placed in the Vertisol order, suborder Xerert of the comprehensive soil classification scheme (Buckman and Brady, 1969).

III. LITERATURE REVIEW

Introduction

A number of authors have reviewed, discussed, and/or studied various aspects of marsh and desert vegetation. Chapman (1960) summarizes the material relating to salt deserts and maritime salt marshes of the world. More recently, Ungar (1972) reviewed the work relating to inland salt marshes of North America north of Mexico.

This review includes studies of temperate inland marshes, salt marshes, deserts, and salt deserts[5] of North America with special reference to the Salt Lake Valley of northern Utah. Descriptions of vegetative distribution and succession, and factors thought to be causitive to these patterns have been stressed.

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[5] Salt marsh - an area characterized by: (1) a salt-tolerant flora and fauna, (2) periodic (daily or seasonal) inundation by water containing more than 320 ppm of dissolved salts, and (3) a uniformly-textured soil (sand, silt, or clay), often high in organic matter content.

Marsh - an area characterized by: (1) emergent and/or aquatic vegetation, and (2) water containing less than 320 ppm of dissolved salts.

Salt desert - an area characterized by: (1) a salt-and-drought-tolerant flora and fauna, (2) extreme temperatures, (3) low precipitation, and (4) saline or alkali, often poorly drained soil.

Desert - an area characterized by: (1) a drought-tolerant flora and fauna, (2) extreme temperatures, and (3) low precipitation.

The vegetation of desert and salt desert areas is often sparse and shrubby, while the fauna of such areas is typically small, burrowing, and/or nocturnal.

Vegetation: Descriptions, Inland Marshes and Deserts

Numerous workers in other areas have dealt with the topic of marsh and/or desert vegetation, its description, patterns, and trends, especially in relation to salinity and other edaphic factors (Ungar, 1972; also: Billings, 1949; Bolen, 1964; Bradley, 1970; Branson, *et al.*, 1966, 1967, and 1970; Brown, 1971; Busby and Schuster, 1971 and 1973; Chapman, 1960; Evans, 1953; Fautin, 1946; Gates, *et al.*, 1956; Goodman and Caldwell, 1971; Kadlec, 1962; Keith, 1958; Löve and Löve, 1954; Meeks, 1969; Mitchel, *et al.*, 1966; Peterson and Branson, 1962; Rawson and Moore, 1944; Schaffner, 1898; Shantz and Piemeisel, 1924 and 1940; Ungar, 1965; Walker and Coupland, 1968 and 1970; Wein and West, 1971, 1972, and 1973; West and Ibrahim, 1968; and others).

Most workers have reported a number of identical or equivalent plant species in their descriptions of vegetative distribution and succession in marshy and desert areas.

Fresh waters are commonly vegetated by species of *Potamogeton*, particularly *P. pectinatus*. *Ruppia maritima*, *Zanichellia palustris*, and a number of macroscopic algae, including *Chara*, *Cladophora*, and *Ulva*, are more likely to be found in more brackish waters.

Emergents of more shallow waters commonly include species of *Scirpus*, *Typha*, *Eleocharis*, *Phragmites*, and *Spartina*. It has often been noted that the age, successional stage, and general condition of the marsh can be largely determined by the make-up and vigor of the emergents present.

Deserts and salt deserts are typically dominated by shrubby and/or perennial members of three main families, Chenopodiaceae, Compositae, and Gramineae. Highly saline areas are typically first invaded by Salicornia species and by Allenrolfea occidentalis; seepy areas by species of Suaeda and Polygonum and by varieties of Distichlis spicata; drier saline areas by Atriplex species, Salsola iberica, Sarcobatus vermiculatus, and species of Puccinellia and Sporobolus; and dry, non-saline areas by species of Artemesia, Eurotia, Tetradymia, Agropyron, Bromus, Hordeum, and others.

Several older descriptions of the vegetation of or adjacent to the Bear River Refuge are available (Flowers, 1934; Lehmann, 1935; Williams and Marshall, 1937 and 1938). They are particularly valuable for comparison with the present vegetation in the areas described to ascertain long-term vegetative successional trends.

Flowers' (1934) descriptions of vegetative and successional patterns for areas surrounding the Great Salt Lake will be considered in more detail in comparison with the results of the current study. His description of the vegetation of the Willard Spur Area in the Bear River Bay is of particular interest. Since the actual study of this area was done before construction of dikes by the Bear River Migratory Bird Refuge could have had a major effect on the vegetation of the area, and in the absence of any other studies of the original vegetation of the area, Flowers' descriptions of the Willard Spur Area is probably the most complete and reliable record of the vegetation of adjacent areas of the Bear River Refuge at the time of its establishment in 1928.

Relatively deeper water was dominated by *Potamogeton pectinatus*, *Ruppia maritima*, and a form of *Cladophora fraeta*, while *Salicornia rubra* germinated in shallow water up to 5.0 - 7.5 cm deep, and dominated on otherwise bare mud flats. The *Salicornia* was followed by a few scattered *Allenrolfea*, an irregular belt of *Atriplex hastata*, and an irregular zone of *A. truncata* with a slight increase in elevation and decrease in salinity as distance from the bay increased.

Finally, he describes a mixed association of grasses, numerous annuals, and a few shrubby perennials as follows:

Hordeum jubatum L.
H. gussonianum Parl.
Polygonum aviculare L.
Sarcobatus vermiculatus (Hook.) Torr.
Lepidium perfoliatum L.
L. pubicarpum A. Nels.
Sisymbrium altissimum L.
Allocarya nitens Greene
Matricaria suaveolens (Pursh) Buchen.
Grindelia squarrosa (Pursh) Dunal
Helianthus annuus L.

The following were described as occurring in seepage areas:

Puccinellia nuttalliana (Schultes) Hitchc.
Hordeum jubatum L.
Atriplex hastata L.
Spergularia salina Presl.
Ranunculus eremogenes Greene
Halerpestes cymbalaria (Pursh) Greene

A number of Nelson's (1954 and 1955) observations on the reclamation of salt flats at Ogden Bay south of the Willard Spur Area are similar to Flowers' descriptions of the Willard Spur Area.

Lehmann (1935) compiled a species presence list for the Bear River Refuge (Lehmann's list of 92 species is included in Table 7, page 79).

Two papers by Williams and Marshall (1937 and 1938) are of major interest, for they describe quantitatively the early vegetative composition of Bear River Refuge Unit II. They broke down the 2000 hectares of Unit II as follows: 1200 hectares was covered by water 0 - 75 cm deep, supporting, for the most part, a dense growth of _Potamogeton pectinatus_. _P. pusillus_ and _P. filiformis_ were less common. _Zanichellia palustris_, _Ruppia maritima_, and _Chara_ were prominent in shallower, more protected areas. Other common macroscopie algae included _Oscillatoria_, _Cladophora_, and _Oedogonium_. The remaining 800 hectares was either barren or vegetated as follows:

Scirpus paludosus	59%
Distichlis spicata	26%
Typha latifolia and _T. angustifolia_	6%
Scirpus acutus	3%
All others, including the following:	6%
Salicornia rubra	
Phragmites communis (less than 1%)	

Hordeum jubatum
Juncus balticus
Salix exigua
S. amygdaloides
S. lutea
Triglochin maritima
Carex nebraskensis
Eleocharis palustris
Xanthium speciosum
Atriplex hastata
Chenopodium spp.
Asclepias speciosa

Weeds of higher channel banks included (in addition to those listed above):

Ambrosia elatior
Ambrosia biennis
Bassia hyssopifolia
Brassica nigra
Dondia speciosa
Grindelia squarrosa
Helianthus nuttallii
Iva axillaris
Lactuca scariola
Lycopus asper
Medicago lupulina
Melilotus alba
Nepeta cataria
Potentilla anserina
Rosa spaldingii
Senecio hydrophilus
Urtica brewerii

Wingfield and Low (1955) described the vegetation of Knudson's Marsh in their study of waterfowl productivity of that area. Their study area lies 3.2 km west of Brigham City, midway between the county road and Bear River Refuge Unit V. Their description of the vegetation of Knudson's Marsh, summarized below, is in striking contrast to that of Williams and Marshall for Unit II given above:

Scirpus acutus	56.2%
S. olneyi[6]	24.1%
Typha spp.	12.4%
Distichlis stricta	6.5%
Scirpus paludosus	0.8%
Phragmites communis	0.07%

They also describe a strip of Distichlis stricta, Salicornia rubra, and S. utahensis surrounding the marsh, followed by bare alkali flats.

Allen and Smith (1964) mapped the vegetation of the entire Bear River Refuge over a two-year period from April through September, 1963 and 1964. They listed the dominant species present in each area at the time of their visit.

Vegetation: Factors of Distribution and Succession

W. F. Ganong (1903) was perhaps one of the first to recognize the suitability of salt marshes for studies of successional patterns and trends. In referring to the tidal marshes of the Bay of Fundy, he remarked, that

> From a systematic or floristic point of view these marshes are of slight botanical interest. ... the fully reclaimed marsh is but a good hay meadow... Yet from another, namely the ecological point of view, the marsh vegetation is replete with scientific interest, for the marked gradations of physical conditions of soil and water within a limited space ... allow us a rare chance to trace upon a large scale the effects of these important conditions upon the plants, and to

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[6]Scirpus olneyi is an emergent species considered by some to be indicative of stable or mature marshes (Bolen, 1964). The low percentage of S. paludosus, an early invader, would also seem to be indicative of mature marsh conditions.

> draw some conclusions as to the nature of the adaptation of the one to the other ...

His remarks are particularly interesting, for they reflect the general viewpoint held until recently, that marshes are for reclaiming (C. A. Jefferson, personal communication).

Generally, in the absence of well defined climatic variation, most authors have sought to explain the often sharply delimited vegetation zones common to both marsh and desert areas on the basis of edaphic factors, especially soil salinity and water content.

Various workers have reviewed the problem of saline and sodic soils, their origin, nature, distribution, diagnosis, and treatment (Harris, 1920; Magistad, 1945; Kelley, 1951; Chapman, 1960; Szabolcs, 1965; Waisel, 1972). Harris (1920) and others have viewed the problem from an agricultural viewpoint (Kearney, _et al_., 1914; Richards, 1954; Shantz, 1911; Shantz and Piemeisel, 1924 and 1940; Stewart and Keller, 1936; and others).

Kearney, _et al_. (1914), in some of their earlier work with the indicator significance of vegetation of cold desert and salt desert areas of Utah, indicated the feasibility of correlating the distribution of native vegetation with physical and chemical properties of the soil, especially with regard to salinity and alkalinity. Previous work by Shantz (1911) and observations of the sharply delimited vegetation zones indicated the possibility of correlating soil properties with vegetation, since the very abrupt transitions could not be attributed to climatic variation.

A number of workers have published extensive reviews of halophytism -- its definition and scope, as well as its morphological, physiological, and genetic basis (Waisel, 1972; also Ayers, 1952; Barbour, 1970; Barbour and Davis, 1970; Chapman, 1960; Chouduri, 1968; Christiansen and Low, 1970; Fautin, 1946; Goodman and Caldwell, 1971; Ganong, 1903; Hayward and Bernstein, 1958; Kaushik, 1963; McMillan, 1959; Schaffner, 1898; Teeter, 1963 and 1965; Ungar, 1966; Workman and West, 1969; Wiebe and Walter, 1972; and others).

In describing desert halophytes, Branson, et al. (1967) have suggested the term "xerohalophyte" to indicate their tolerance for either or both halic or xeric soils. Others have pointed out that plants growing in moist though highly saline soils may be experiencing a very real "physiological drought."

Results of salt-tolerance studies by Ungar (1966), Barbour (1970), and Barbour and Davis (1970), among others, indicate there may be no such thing as an obligate halophyte in the sense that the plant requires salt to grow normally, although there is some evidence that certain species make optimum growth at low levels of salinity (NaCl) (Gale and Paljakoff-Mayber, 1970), and that growth of some species is even stimulated by relatively high levels of Cl^- (Greenway, 1968). Most greenhouse studies have shown suspected obligate halophytes to make normal, healthy growth under non-saline conditions, in monoculture. However, it may be true that some species are obligate halophytes in the sense that they can only successfully compete with other plant species under saline or alkali conditions (Schimper, 1903; Flowers, 1934).

Barbour (1970) concludes that "ability to reproduce, rather than short-term growth, should be the ultimate criterion of (salt) tolerance." Most other authors of studies of the relative salt tolerances of species at different life stages have noted a definite variability of salt tolerance with age. Germinating seeds and young seedlings are typically the least salt tolerant, while mature specimens often tolerate considerably higher salinities (Kaushik, 1963; Teeter, 1963 and 1965; Macke and Ungar, 1971; Williams and Ungar, 1972). Macke and Ungar (1971) have pointed out that "an important attribute of halophytes is the ability of their seed to withstand long periods at high salinities and then germinate when conditions ameliorate." This property of halophyte seed, also quantified by Teeter (1963), has been termed a high fresh water recovery potential.

Christiansen and Low (1970) give a more detailed discussion of salt-tolerance studies.

The ill effects of saline and sodic soils on vegetation have variously been attributed to increased osmotic pressure of the substrate, poor permeability of the soil to water, lack of oxygen, malnutrition and chlorosis, and the corrosive action or harmful effects of certain ions in too high concentrations (Magistad, 1945). Poor drainage and poor aeration of the soil often lead to the reduction (in the chemical sense) of useful ionic forms to unavailable or toxic forms. The extreme pH values typical of saline and sodic soils (8.0 - 10.0) also play a large part in the malnutrition, chlorosis, and corrosive action of certain ions often observed (Buckman and Brady, 1969).

High salinity and adverse water relations (flooding, poor aeration, drought, etc.) have generally been the main factors used to explain observed vegetative patterns. Long-term changes in these factors have been seen as the explanation for long-term vegetative trends and succession. Bradley (1970) points out that "plant communities arranged along moisture and salinity gradients clearly indicate the importance of water availability and salt content of the soil."

Wherry (1920) believed pH to be a major factor in the distribution of salt marsh communities. West and Ibrahim (1968) measured soil pH and found it to be significantly correlated with vegetative zonation. Other authors, including Nelson (1954), and Branson, et al. (1967 and 1970) have discounted the influence of pH. The pH values observed by Wherry were by far the most variable. It seems possible that pH might be an important factor in vegetative distribution in some cases and not so in others. It is also quite likely that pH itself is not a factor in determining zonation and that its correlation with zonation, when observed, is ancillary to soil salinity to which it is quite often related (Nelson, 1954).

Ahi and Powers (1938) stressed the importance of the combined effects of salinity and temperature, an extreme of either greatly reducing germination and survival of a number of crop plants, while Nieman and Poulsen (1971) have discussed the importance of the interaction of salinity and light.

The seasonal pattern of soil salinity is seen by some as being an overriding factor in determining vegetative distribution patterns (Ayers, 1952; Hayward and Bernstein, 1958), while others have stressed the seasonal pattern of flooding (Kadlec, 1962; Meeks, 1969). These two explanations may often be interrelated. For example, the seasonal pattern of salinity is generally largely controlled by the extent of spring flooding and summer drought. Nelson (1954), Kadlec (1962), and Meeks (1969), while working with areas of only slightly brackish nature, nevertheless pointed out the effect of accelerated succession caused by an early drawdown of impounded waters, or less-than-normal spring flooding, and the subsequent drying effect, even though often associated with an increase in soil salinity.

Flowers (1934) was early to recognize the interrelationship of water table level with percent soil salt content. In general, he found that as the depth to the water table decreased, the salinity of the soil increased. He reasoned that a shallower water table facilitates increased surface evaporation, and that as the water evaporates, its dissolved salt content is left at or near the soil surface, thus increasing the percent salt content of the soil.

Gates, _et al_. (1956) working with the northern desert shrub vegetation of western Utah studied a great number of edaphic factors, but found only five more-or-less-related factors to be significantly correlated with natural vegetation: (1) total soluble salt, (2) saturated extract conductivity, (3) exchangeable sodium, (4) soluble sodium, and (5) one-third atmosphere percentage (the percent water, as (wt. water)/(wt. dry soil), retained at field capacity). Neilson and Shaw (1958) have shown a high correlation between 15 atmosphere moisture percentage (proposed at that time as the percent water retained by the soil at the wilting point) and percent clay content of the soil. Exchangeable sodium and one-third atmosphere percentage are also largely determined by soil clay content, and might also be expected to be found to be correlated with percent clay content (Buckman and Brady, 1969).

Nelson (1954 and 1955) noted the importance of the biotic factor to vegetative distribution patterns. He pointed out that *Typha* spp., *Distichlis spicata stricta*, and *Scirpus acutus* gained dominance in their respective habitat types by crowding and shading out annuals and less vigorous perennials. The effects of grazing by cattle on land plants (not a problem at the Bear River Refuge) and rooting by carp on aquatics were also noted.

Love and West (1972) unsuccessfully tried to relate vegetative distribution to plant moisture stress, rather than soil moisture stress, as had been done previously.

Indicator Significance: Taxonomic Problems

Genetic variation within variable species, such as *Atriplex nuttallii* and *Eurotia lanata*, has, in the past, been a source of confusion to workers seeking to correlate edaphic factors, such as soil salinity, with well defined and delimited vegetative assemblages (Gates, *et al*., 1956). Variation of genetic expression (i.e. phenotypic plasticity) of certain halophytic species, such as *Suaeda depressa* and *Salicornia europaea rubra*, has also been a source of taxonomic consternation (Flowers, 1934; Williams and Ungar, 1972). Recent investigations have demonstrated the existence of several distinct populations or ecological races of *A. nuttalli* and *E. lanata* with varying degrees of salt tolerance (Goodman and Caldwell, 1971; Workman and West, 1969). Such variation of salt tolerance obviously extends the survival potential of the species, but at the same time it somewhat limits their value as indicators of edaphic conditions, in the sense of Kearney, *et al*. (1914). It does, however, explain their presence in several distinctly different vegetative communities.

IV. METHODS

Introduction: Objectives and Plot Establishment

The goals of this study were: (1) to determine and characterize the community types of the refuge area, (2) to interrelate the community types identified and to relate these community types with certain overriding environmental factors responsible for zonation, and (3) to compare the current vegetation of the refuge with that in 1935 in order to characterize the vegetative changes which have occurred, and to aid in predicting future changes.

A number of different types of plots and transects were used during the study in order to determine and characterize the community types of the refuge.

Before permanent plots could be established, three points had to be decided upon, (1) plot size, (2) sampling intensity, and (3) plot location.

In order to maintain uniformity in plot size and to adequately sample more diverse areas, a three by five meter plot size was decided on. This plot size seemed justified, based on a number of minimum species area curves and prior observations.

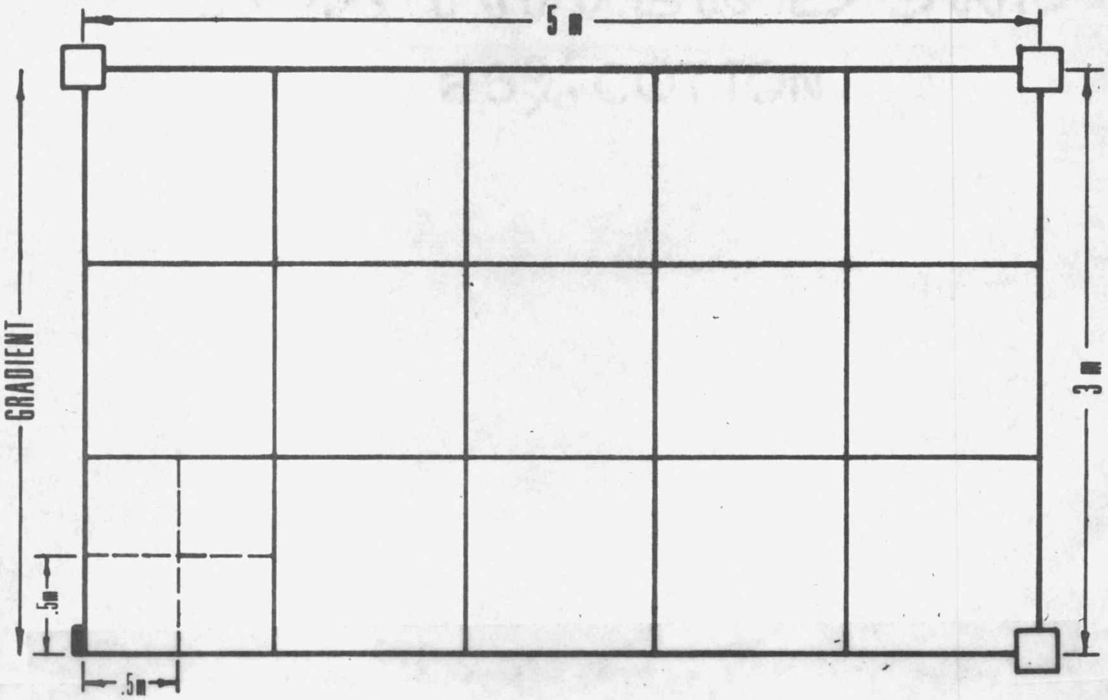
In order to minimize the importance of occasional species within the different community types, the three by five meter macroplots were subdivided into 60 $(\frac{1}{2}m)^2$ microplots for sampling. Macroplots were laid out and marked with three clay tiles and a wooden stake, as illustrated in figure 4. The macroplots were positioned at right angles to vegetative gradients, when observed, since numerous plots were established on rather steep areas of transitional or ecotonal nature, and it was desired to maintain, as far as possible, relatively homogeneous plots.

A total of 69 plots were established to sample suspected vegetative types. Early successional stages were stressed. The basic plan was to include several similar plots of each type from scattered areas of the refuge, both within and outside of the main diked units. Plot locations were subjectively selected to include a representative cross section of observed vegetation types, based upon prior reconnaissance. Although a large number of plots were established in disturbed areas, areas whose vegetation was obviously largely the result of introduced species and/or soils were avoided. Figure 5 shows the relative locations of the 69 plots.

Each plot was photographed at least three times, June, July, and August, in conjunction with vegetative sampling.

Plot Sampling Procedures

Each macroplot was sampled three times during the primary study period, once in June (22-28), once in July (18-21), and once in August (29-31), 1972.



a

b

Figure 4. Macroplot scheme used in the study. a. Plots were laid out at right angles to observed vegetative gradients, when present, as indicated. Each macroplot was subdivided into 60 $(\frac{1}{2}m)^2$ microplots. b. Plot 1 showing how plots were marked for relocation with a wooden stake and three clay tiles.

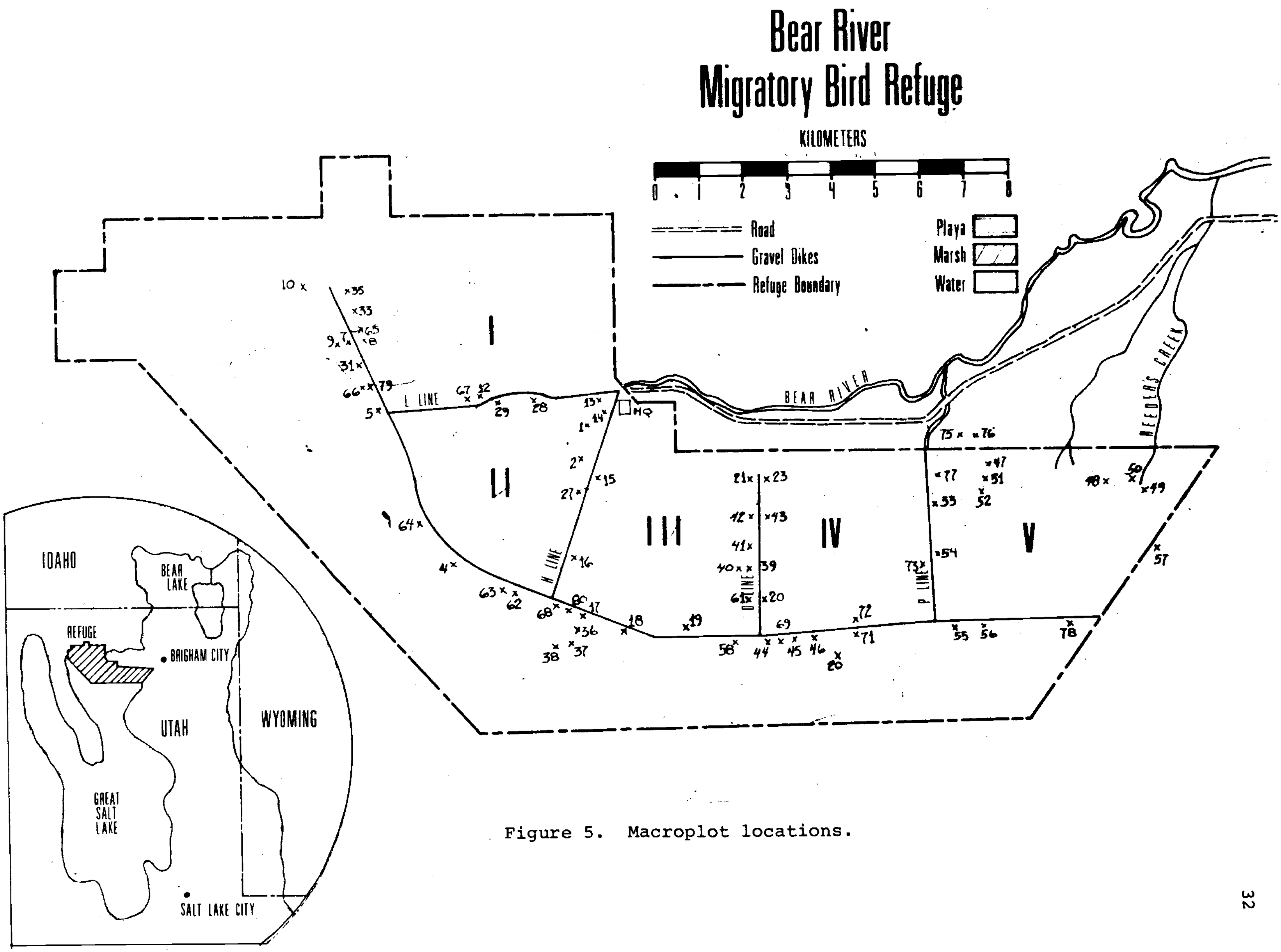


Figure 5. Macroplot locations.

A visual estimate of dominance was made. Each species present within a macroplot was subjectively assigned a dominance value of one to five corresponding to those suggested by Braun-Blanquet (Braun-Blanquet, 1927 in Kershaw, 1964). In addition to assigning dominance values for each species within the macroplot, the presence of species within each microplot ($(\frac{1}{2}m)^2$) was determined using a $(1m)^2$ wire sampling frame subdivided into four $(\frac{1}{2}m)^2$ segments giving frequency values (1-60) for each species occurring in the macroplot.

Soil moisture was categorized on all plots as (1) dry, (2) moist, (3) wet, (4) muddy, or (5) submerged. Water depth was noted for submerged plots. Since plots were randomly numbered by vegetative type, and since it was not practical (within the scope of this study) to obtain a soil sample for each of the 69 macroplots, a soil sample of the top 0.1 m was taken from each plot whose number was a multiple of five. For July only, a complete set of soil core samples of the top 0.3 m were taken. In addition, 0.5 l surface water samples were collected from the 16 plots with standing water present at the time of the regular July sampling. All soil samples were stored as collected in either metal cans or plastic bags. Water samples were stored in 0.5 l polyethylene bottles.

Vegetative Transects

Seven 30 m loop-frequency transects were run on July 11, 1972. They were designed to sample the vegetation along obvious vegetational gradients. Theoretically, as conditions in an area change gradually from those observed at one end of a gradient to those at the other end, succession will proceed roughly in the same way as that observed along the vegetative gradient. Relative locations of these transects are indicated in figure 6.

Each transect was laid out and marked at both ends with a wooden stake. They were then photographed from each end. Every 0.3 m a $(5\ cm)^2$ thin wire loop was placed on the ground along the tape marking the transect. Species occurrence and vigor were recorded. Transect 4 was different in that it was composed of two 15 m segments, 3 m apart, running across an old contour furrow.

Additional Water and Soil Sampling

In order to quantify the variability of water salinity within the five refuge units during the course of the summer, a series of seven sets of 12 samples each were taken at two-week intervals during the main study period. Sampling dates were June 12 and 26, July 10 and 24, August 7 and 21, and September 4, 1972. All samples were collected in 0.5 l polyethylene bottles and stored for

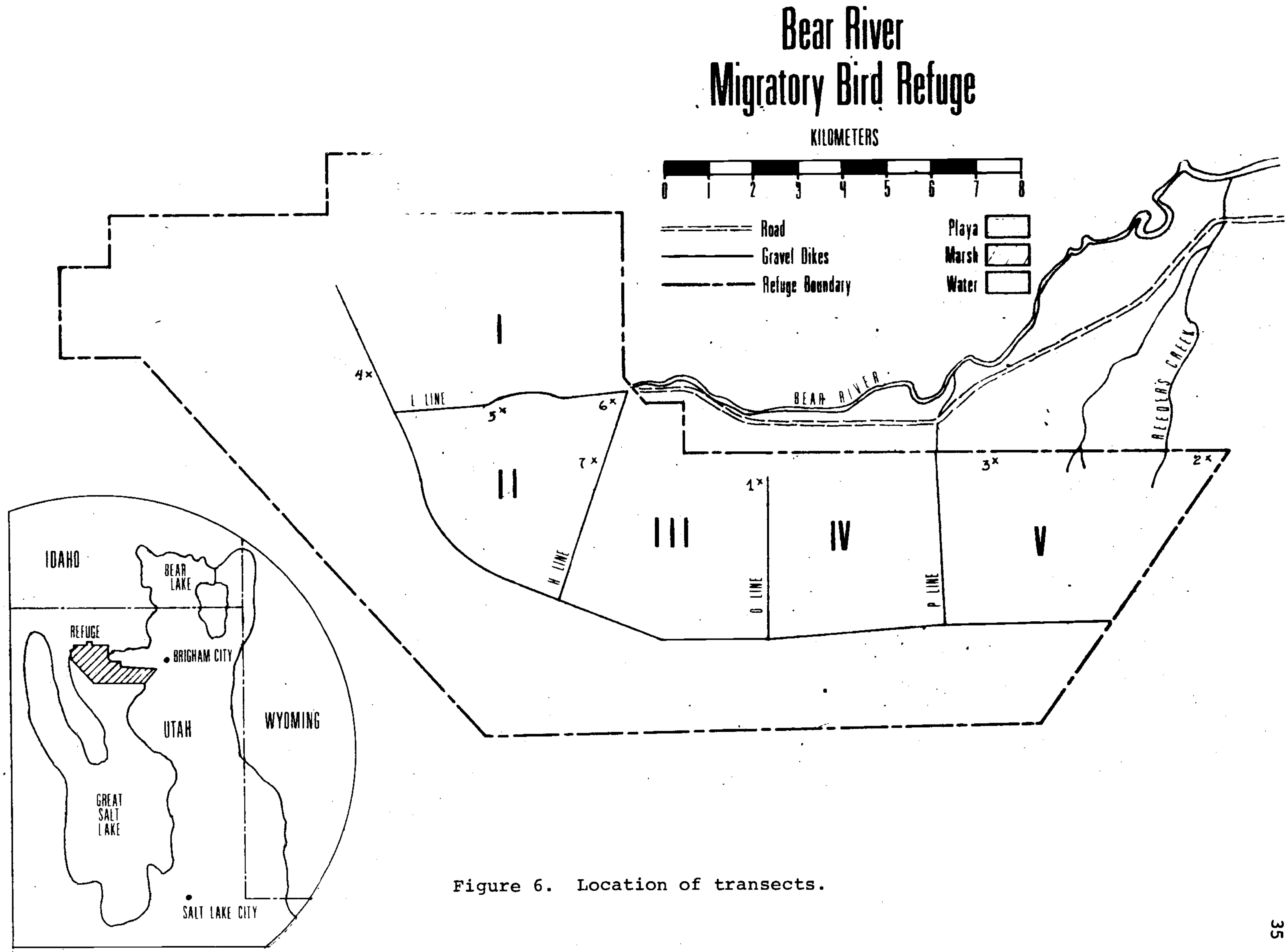


Figure 6. Location of transects.

subsequent laboratory analysis. Most sampling points were at spillboxes. One sample was taken at headquarters, one along the outside of each unit, one between each pair of adjacent units, one at the south end of the H-line, and one at the end of Whistler's Channel. See figure 7 for water sampling locations as related to the approximate locations of refuge spillboxes. As a rule, free flow was permitted between units at the between-unit sampling points throughout the sampling period; however, at each sampling point equal portions were taken from each unit involved. Likewise, at sampling points along the outside dikes, equal portions were collected from inside and outside the spillbox.

On June 11, 1973 several additional soil and water samples were taken. On that date two soil pits were dug, one in the center of plot 1 and the other in a playa near the dump area. The location of these soil pits is indicated in figure 7. The purpose of these soil pits was twofold: (1) to determine the water table depth in playas, and (2) to measure the salinity of the soil in such areas at various depths and of the ground water. Soil samples (500 g minimum) were taken at 0.15 m depth intervals (0.0, 0.15, 0.30, 0.45, and 0.60 m) to the water table in each pit. A 0.5 l water sample was taken from the water that collected at the bottom of each pit. Three additional soil samples were taken along loop-frequency transect 5 and five

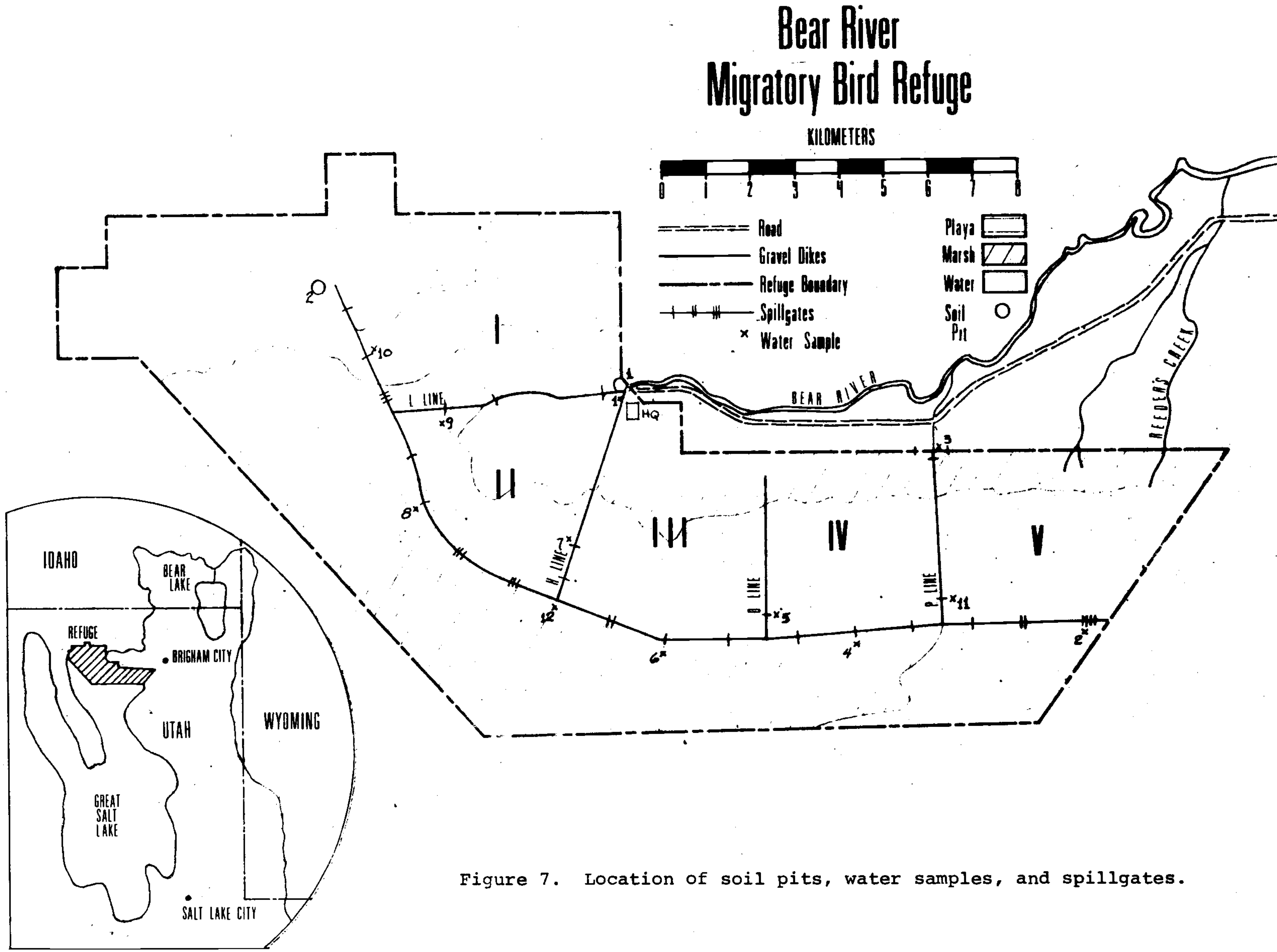


Figure 7. Location of soil pits, water samples, and spillgates.

more samples along loop-frequency transect 6. These samples were taken to verify suspected differences in surface soil salinity associated with the different plant species observed along the transect gradient. The top 0.1 m was sampled to correspond to the approximate maximum rooting depth observed for the earliest colonizer in the area, *Salicornia europaea rubra*.

Soil and Water Analyses

Soil samples were opened in the laboratory and oven dried at 46°C ± 3° until dry, except samples taken June 11, 1973 which were oven dried at 90°C ± 5° for 72 hours.

Bulk densities were determined by a modification of the method of Dawson (1972) for the three sets of 16 samples taken monthly at those plots whose number was a multiple of five.

Following bulk density determinations, all soil samples were pulverized and sieved with a two millimeter sieve. Material not passing the sieve was discarded.

Wet and dry colors of the dried, sieved samples were determined under constant fluorescent lighting by comparison with Munsell soil color charts.

Moisture equivalent was determined for composite surface samples, made by combining June, July, and August samples from a single plot, as an estimate of the percent water (as: weight water/weight dry soil) retained at field capacity (Dawson, 1972).

Textural analysis was performed on 50 g composite soil samples, prepared as for moisture equivalent determination. Organic matter was first removed by oxidation with hot 30% hydrogen peroxide (Bouyoucos, 1927 and 1962; Dawson, 1972).

pH values for 1972 soil samples were determined by testing small dry portions of each with a series of standard indicator dyes (Dawson, 1972).

Conductance and glass-electrode pH values were determined for 1:5, soil:distilled water slurries of all soil samples by a technique modified from Nelson (1954) and Bolen (1964). In order to be consistent with the literature, conductance values were recorded as resistance in micromhos per centimeter (μmhos/cm). Conductance values for all water samples and 1:5, soil:distilled water slurries were determined using a YSI Model 33, S-C-T Meter, a portable, battery-operated salinometer manufactured by Simpson Electric Co., Chicago. Glass electrode pH values were determined with a Beckman Zeromatic pH meter.

Plant Collections

A plant collection of all species encountered during the summers of 1970-1972 was made for the refuge area. A complete listing of non-cultivated species is given in table 7. Nomenclature follows Holmgren and Reveal (1966), except as noted in the table. In addition, the following were helpful in plant identification: Arnow, 1971; Barnett, 1964; Hitchcock and Cronquist, 1973; Holmgren, 1958 and 1965; Mason, 1969, Mitchell, 1971; Treshow, *et al*., 1964; and Welsh, *et al*., 1965. A set of voucher specimens is on deposit at Bear River Refuge Headquarters.

V. RESULTS AND DISCUSSION

Introduction

Plot data taken during the month of August and arranged according to Braun-Blanquet sorting methods are given in figure 8. The frequency values for this data are essentially the same as for those taken during June and July (appendix tables I and II). This plot releve (figure 8) suggests ten rather definite community types, a number of these being extremely simple, involving only one or two species.

A more complete description of these ten plant groupings involving their composition and structure follows. Although this ordination is strongly influenced by certain environmental factors measured, the apparent control of these factors upon the groupings found will be presented in a later section, after the presentation of the environmental data.

Community Descriptions

The ten communities identified in the plot releve (figure 8) will be discussed in reverse order, generally from wet to dry.

The two aquatic communities, the *Potamogeton pectinatus* community (Pope) and the *Ruppia maritima*/*Zannichellia*

	Agcr/At/Save	Disp					Disp/Hoju							Sude/Bahy/Lepe															
	10	14	44	48	56	80	62	02	05	06	12	13	61	78	09	69	23	18	58	64	77	65	73	79	04	70	39	63	17
Agcr[1]	60																												
Save	23																												
Atnu	19																												
Brco	18																												
Lase													20																
Atpa								26		14	1						34						1			5	30		12
Hoju							4	19	52		26	42	1											3		6			
Civu									25		6																		
Hean								4	25				9													5			
Disp		60	60	60	60	60	60	60	60	60	60	60	60	60	60	14	53	13	60	17	6	20	12	22		37		15	57
Saeu															58	60	60	52	3	60	48	9	16	2	51	46	1		
Bahy														19						3	10	60	57	26	46	57	59	31	
Sude																10	4	46	10	30	59	40	47	60	43	56		51	52
Lepe	5												9			15						39	40		34	37	46	11	
Scma																													
Pomo												8											1			13			
Tyla																													
Elpl																													
Rucr																													
Lyas																													
Scac																													
Pope																													
Ruma																													
Zapa																													
Posa															36														
Pora																							4						

Figure 8. Ordination of macroplots based on frequency values. [1]A summary of species names and symbols used in figure 8 may be found in appendix table III.

	Saeu						Scma				Tyla						Scac							Ruma/Zapa			Pope	
	43	52	51	07	01[2]	76	46	27	53	38	68	50	66	36	28	55	67	15	71	37	19	49	72	31	40	41	08[3]	16
Hoju							5					1		3														
Civu													6			1												
Hean																10												
Saeu	52	60	60	60	60	50																						
Sude				1																								
Scma							57	60	60	60		1	2															
Atpa									1			3	43	2		49	1	1	54									
Disp	59	57	15	14			60	60	60			16	3	54	55	49			51									
Pomo							56		1					45	14	1		2	20	14								
Tyla											60	60	59	56	60	60	55		2	22								
Elpl												7		45				5		5								
Rucr													16	23				1										
Lyas													19	40					6									
Scac												4		3			53	60	58	60	60	60	49					
Ruma																								30	30	30		
Zapa																								30	30	30		
Pope																											60	10
Epad														1				1										
Trma																		6										
Chal								3																				
Elpr												23																
Racy														53														
Disy																	6											
Chvi																		10										
Asin																		5	4									
Urdi																			25									
Cede																												11

Figure 8. (cont.) [2] Plots 21, 29, 33, 35, 42, 47, 74, and 75 are identical to plot 01.
[3] Plots 20, 45, 54, and 57 are identical to plot 08.

palustris community (Ruma/Zapa), occupy most of the impounded water areas of the Bear River Refuge.

The Potamogeton pectinatus community is by far the more common of the two aquatic communities. It tends to be monospecific, forming dense underwater floating mats of vegetation by June and July, as illustrated in figure 8a. The fruits produced are an important source of waterfowl food, and they often drift up onto the dikes en masse in August and September. Potamogeton pectinatus tends to grow in fresh to slightly brackish water (rooted in the mud bottom) 20 to 75 cm deep. Ceratophyllum demersum and Potamogeton berchtoldii occasionally occur. Ceratophyllum, a species of minimal waterfowl usefulness, appears to be increasing in abundance, perhaps as a result of selective usage by waterfowl (Jack Allen, personal communication, 1971).

The Ruppia maritima/Zannichellia palustris community, illustrated in figure 9, tends to occur in shallower, more brackish water in more sheltered areas than the Potamogeton pectinatus community. This community type is commonly found in waters less than 20 cm deep. Ceratophyllum demersum and Chara sp. are common in similar submerged areas, and Eleocharis parvula occurs in marginally flooded areas where the soil remains soft and wet.

There are three communities which are typically emergent, the Scirpus acutus community (Scac), the Typha

Figure 8a. The <u>Potamogeton</u> <u>pectinatus</u> community (Plot 54, July).

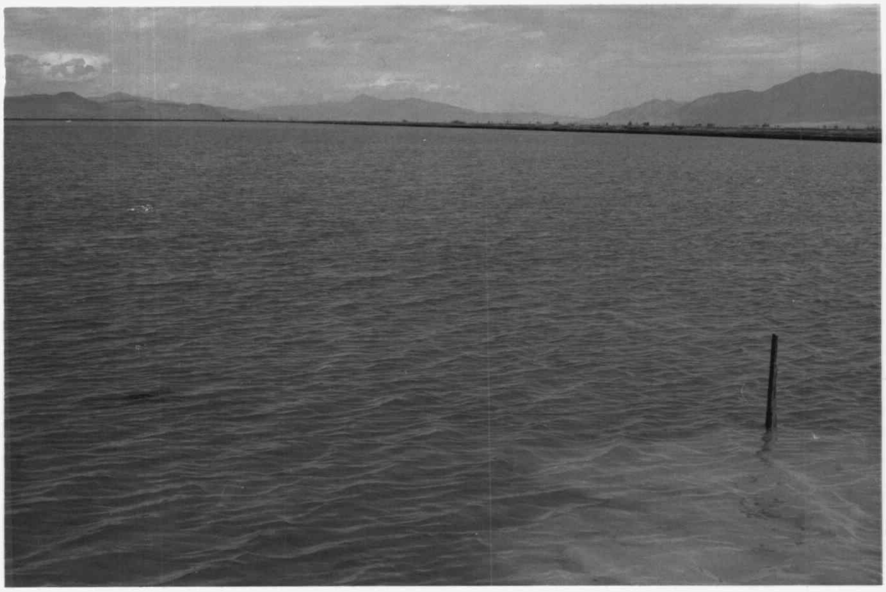


Figure 9. The <u>Ruppia</u> <u>maritima</u>/<u>Zannichellia</u> <u>palustris</u> community (Plot 41, July).

latifolia community (Tyla), and the *Scirpus maritimus paludosus* community (Scma). The *Scirpus acutus* community tends to occur in the freshest, deepest water, while the *Scirpus maritimus paludosus* community tends to occur in the driest, most saline areas, with the *Typha latifolia* community being more or less intermediate. Drier phases of both the *Typha latifolia* and *Scirpus maritimus paludosus* communities are often invaded by *Distichlis spicata stricta* and other grasses. All three communities may be invaded by *Phragmites australis*, but reed is not abundant on the refuge.

A typical *Scirpus acutus* community is illustrated in figure 10. *Scirpus acutus* generally occurs in randomly-scattered clumps which apparently serve to accrete sediments, for the clumps often stand ten cm or more above the rest of the ground surface. Water depths of 15 to 30 cm are common. Associated species include *Polypogon monspeliensis*, *Typha latifolia* (often as a codominant), *Atriplex patula hastata*, and *Eleocharis palustris*, as well as *Distichlis spicata stricta* and *Phragmites australis*. Where the *Scirpus acutus* community forms a border along the inside of the outer gravelled dikes of Units IV and V, *Polygonum lapathifolium* forms a zone in the shallow water just at the edge of the dike.

The *Typha latifolia* community (figure 11) seems to occur in somewhat shallower water and more saline soil

Figure 10. The Scirpus acutus community (Plot 19, July). Note the Polygonum lapathifolium in the shallow water at the right.

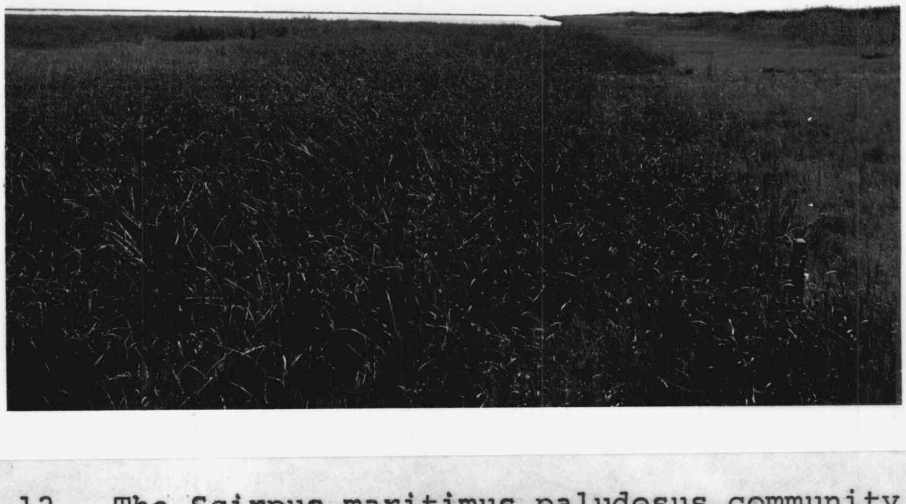
Figure 11. The Typha latifolia community (Plot 68, August).

than the Scirpus acutus community. Typha latifolia was found in wet soils and shallow water up to ten cm deep. Common associated species included Distichlis spicata stricta, Atriplex patula hastata, and Polypogon monspeliensis. Occasional species were Rumex crispus, Eleocharis palustris, E. parvula, Lycopus asper, and Ranunculus cymbalaria saximontanus.

The last emergent community, the Scirpus maritimus paludosus community, is illustrated in figure 12. It is by far the most abundant of the three emergent communities. Scirpus maritimus paludosus, and Distichlis spicata stricta in drier fringe areas, are the only important species. Polypogon monspeliensis, Atriplex patula hastata, Chenopodium album, and Hordeum jubatum are also found occasionally in drier areas. When this type occurs as an emergent community, the water is generally the shallowest (up to ten cm deep) and the most brackish of the three emergent communities.

The remaining five communities are basically terrestrial, although it is not uncommon for the Distichlis spicata stricta, Distichlis spicata stricta/Hordeum jubatum, and Salicornia europaea rubra communities to be flooded in the spring, especially in years of high run-off. The Agropyron cristatum/Atriplex/Sarcobatus vermiculatus and Suaeda depressa/Bassia hyssopifolia/Lepidium perfoliatum communities are seldom, if ever, flooded.

a

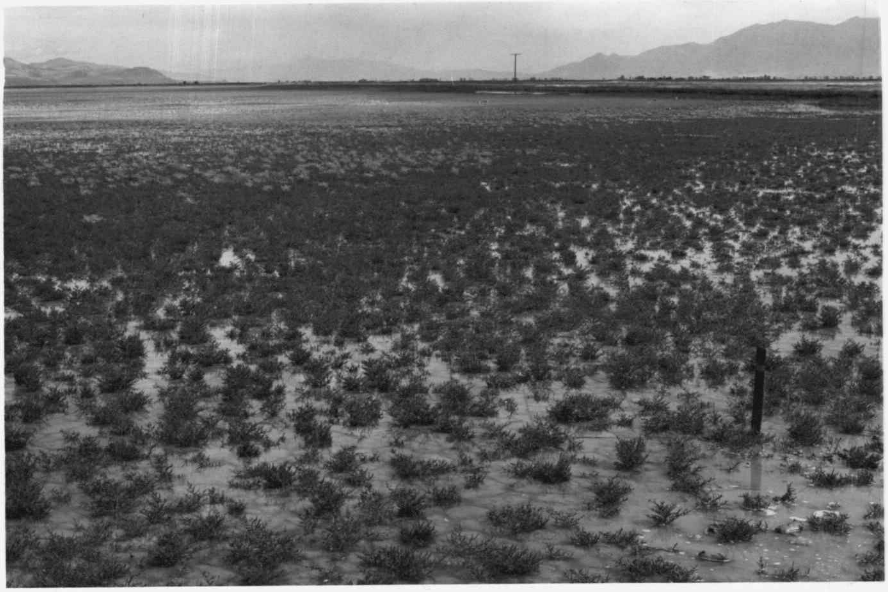


b

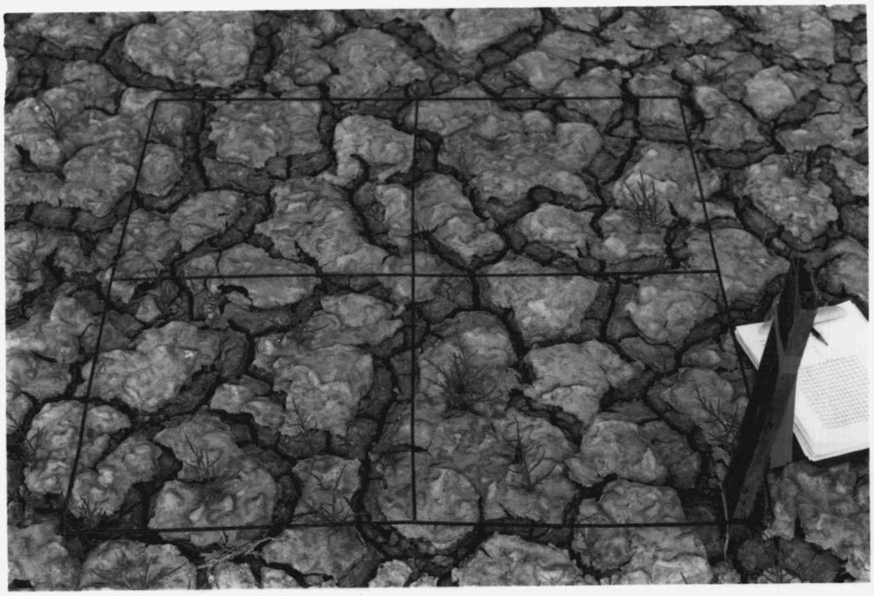
Figure 12. The Scirpus maritimus paludosus community. a. Dry phase; seasonally flooded and baked; vegetation stunted (Plot 38, July). b. Wet phase showing Distichlis spicata stricta encroachment from the right (Plot 53, August).

The _Salicornia europaea rubra_ community (Saeu) is the most salt tolerant vegetation type at the Bear River Refuge. _Salicornia europaea rubra_ is usually the only species present, except where the similar species, _Allenrolfea occidentalis_, accompanies it or where _Distichlis spicata stricta_ invades in less saline areas. Both wet and dry phases of this community are illustrated in figure 13. Note the patterned ground in both phases, indicative of the deep late-summer drying typically experienced by both.

The _Suaeda depressa/Bassia hyssopifolia/Lepidium perfoliatum_ community (Sude/Bahy/Lepe) occurs in seep areas of relatively high soil salinity on the side slopes of dikes. Plots were established at right angles to the often striking vegetative gradient which usually ran up the slope of the dike (i.e. plots were laid out parallel to the dike). Nevertheless, most samples of this community had an obvious vegetative zonation, as can be seen in figure 14. Despite this relative non-homogeneity, the _Suaeda depressa/Bassia hyssopifolia/Lepidium perfoliatum_ community, as a whole, had a very similar species composition. _Suaeda depressa_, _Distichlis spicata stricta_, and _Salicornia europaea rubra_ were each present in over 75% of the plots sampled. _Bassia hyssopifolia_ and _Lepidium perfoliatum_ were prominent in about half the plots and _Atriplex patula hastata_ was also common. Of the three species for which the community is named, _Suaeda_ tended to occur lowest on



a



b

Figure 13. The Salicornia europaea rubra community.
a. Wet phase (Plot 42, July).
b. Dry phase (Plot 7, June).

Figure 14. The Suaeda depressa/Bassia hyssopifolia/Lepidium perfoliatum community (Plot 39, July).

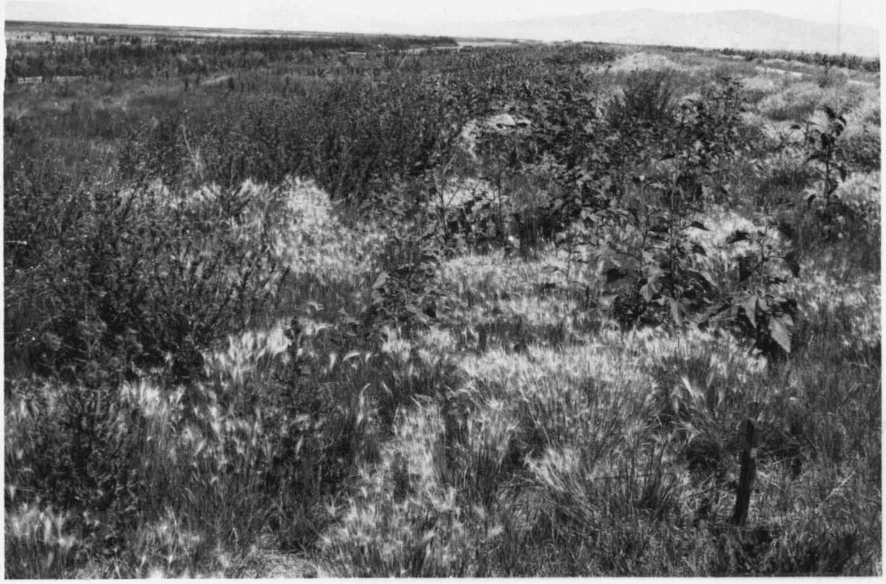


Figure 15. The Distichlis spicata stricta/Hordeum jubatum community (Plot 5, July).

the slope with Bassia intermediate and Lepidium highest up on the dike.

The Distichlis spicata stricta/Hordeum jubatum community (Disp/Hoju) (figure 15) is dominated by Distichlis, but Hordeum is usually prominent also. In addition, Atriplex patula hastata, Helianthus annuus, and Cirsium vulgare are often present. A number of other species, including Lactuca serriola, Lepidium perfoliatum, Polypogon monspeliensis, Bromus sp., Asclepias speciosa, Chenopodium album, Rumex crispus, Amaranthus albus, and Bassia hyssopifolia may be present in various combinations. This is the community characteristic of the ungravelled secondary silt dikes of the refuge.

The Distichlis spicata stricta community (Disp) (figure 16) is quite abundant at the Bear River Refuge. The central portions of several large channel islands in Units I and II are composed almost entirely of this community. This community type is usually monospecific, or nearly so. Cover is dense, as illustrated in figure 16, with only occasional solitary individuals of other species. In June most areas are moist to wet to shallowly flooded with fresh run-off water.

The last community, the Agropyron cristatum/Atriplex/Sarcobatus vermiculatus community (Agcr/At/Save) (figure 17) is the driest community on the refuge. The community occurs only outside the refuge dike system, away from the

Figure 16. The <u>Distichlis spicata stricta</u> community (Plot 48, July).

Figure 17. The <u>Agropyron cristatum</u>/<u>Atriplex</u>/<u>Sarcobatus vermiculatus</u> community (Plot 10, June).

effects of seasonal flooding, mainly at the dump area in the northwest corner of the refuge. *Agropyron cristatum*, *Atriplex nuttallii*, *Sarcobatus vermiculatus*, and *Bromus commutatus* were prominent in the single sample plot. *Atriplex confertifolia*, *Lepidium perfoliatum*, *Bassia hyssopifolia*, *Sitanion hystrix*, and *Allium acuminatum* are also common species in the community as a whole, as well as perennial *Suaeda* spp. The soil is very dry, even in June, and the salinity appears to be very low.

Vegetative Transects

The loop-frequency transect vegetative data are summarized in figure 18. These transects were designed to sample observable gradients of the type shown in figure 19, from bare mud to dry dikes.

Typical results showed bare mud giving way to *Salicornia europaea rubra*, which blended into *Distichlis spicata stricta*, then a mixture of *Hordeum jubatum*, *Atriplex patula hastata*, and *Suaeda depressa* with *Distichlis*, and finally a more diverse mixture of *Lactuca serriola*, *Poa sandbergii*, *Polypogon monspeliensis*, etc., usually with *Distichlis*.

Soil salinity data for transects 5 and 6 are presented in table 1. The gradients studied may be typified as wet, saline to dry, non-saline. There appeared to be a slight increase in elevation above bare mud with decreased

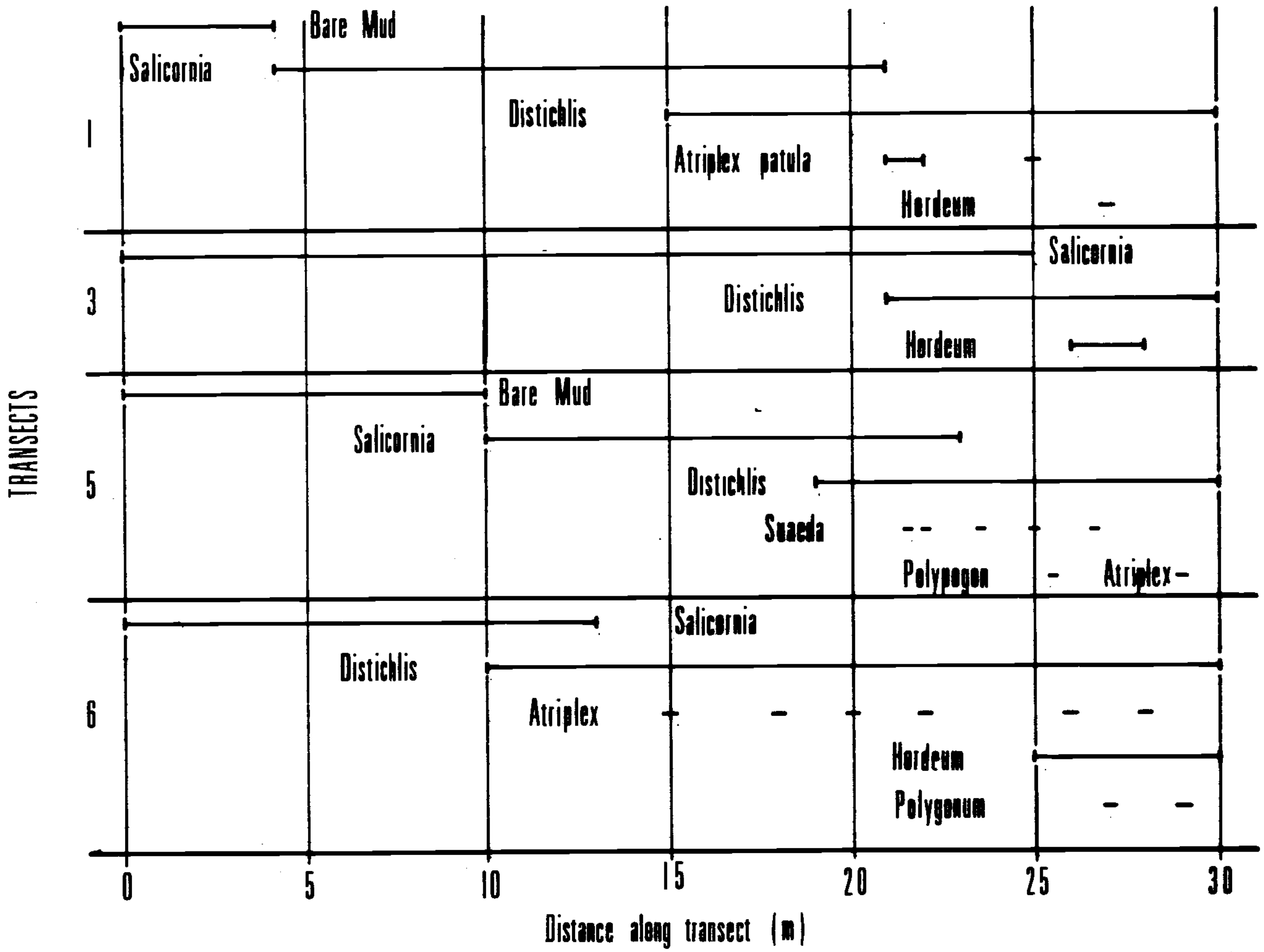


Figure 18. Loop-frequency transects.

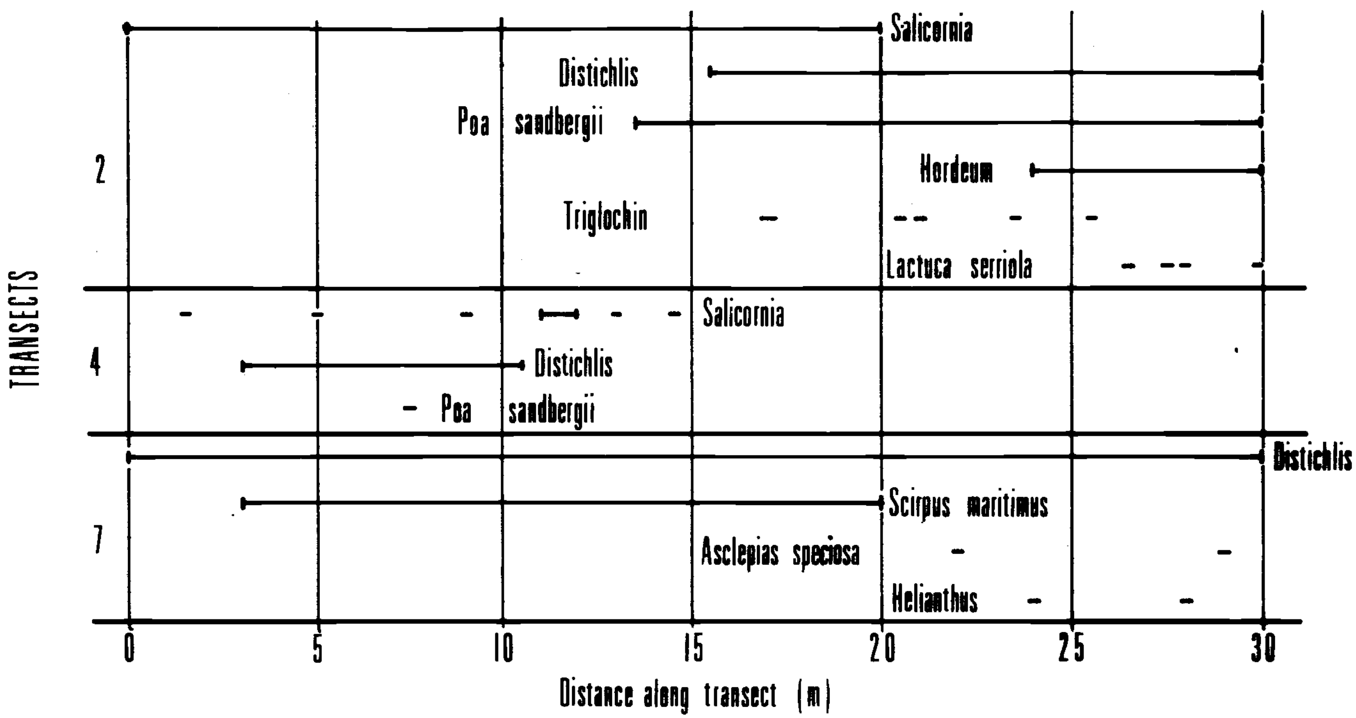


Figure 18 (continued). Loop-frequency transects.

Figure 19. Distinct vegetative zonation at loop-frequency transect 6.

Table 1. Conductance and percent salt of June 1973 loop-frequency transect soil samples.

Sample Location (Vegetation)	Conductance[1] (μmhos)	% Salt[2]
Transect 5:		
Bare mud	15200	4.6
Salicornia europaea rubra	16200	4.9
Distichlis spicata stricta with small *Salicornia*	13000	3.9
Distichlis, *Suaeda depressa*, and *Atriplex patula hastata*	12400	3.7
Transect 6:		
Bare mud	11200	3.4
Salicornia	8100	2.4
Distichlis with small *Salicornia*	6400	1.9
Distichlis and scattered *Atriplex*	2630	0.8
Distichlis, *Hordeum jubatum*, *Atriplex*, and *Polygonum* sp.	2530	0.8

[1] 1:5, soil:distilled water slurries.

[2] % salt = 0.3 x the conductivity in mmhos for a 1:5, soil:distilled water slurry (Nelson, 1954).

salinity, drier soil conditions, and increased species diversity, although this factor was not quantified.

The vegetative results varied only slightly from site to site. For the most part, variation involved only the rate of change of the vegetation and the substitution of similar species where diversity increased at the dry end of the transect. In general, floristic diversity increased with distance from bare mud, as soil salinity and moisture decreased. Also, the early colonizer, *Salicornia europaea rubra*, tended to become less vigorous at either end of its range of occurrence.

The transects related four of the communities already described, the *Salicornia europaea rubra*, *Distichlis spicata stricta*, and *Distichlis spicata stricta/Hordeum jubatum* or the *Scirpus maritimus paludosus*, *Distichlis spicata stricta*, and *Distichlis spicata stricta/Hordeum jubatum communities*. From the environmental data presented, these communities seem to be related in terms of decreasing soil moisture and/or salinity.

Ordination of Communities with Respect to Soil Moisture and Soil Salinity

A subjective assessment of the water regime of the 69 macroplots is given in table 2.

As shown in table 2, there tended to be a drying trend of most macroplots as the summer progressed, as would be expected. June soil moisture values, therefore, are

Table 2. Macroplot soil moisture values.[1]

Plot	June	July	Aug.	Plot	June	July	Aug.	Plot	June	July	Aug.
1	3	2	3	31	5	4	5	56	5	2	1
2	2	2	1	33	3	2	2	57	5	5	5
4	3	1	1	35	2	1	1.5	58	2	2	2
5	2	2	1.5	36	4	3	3	61	2	2	1
6	2	2	2	37	3	3.5	4	62	2	2	2
7	2	1	2	38	4	2	1	63	4	2	2
8	5	5	5	39	2	2	1	64	3	2	3
9	2	1	2	40	5	5	5	65	2	1	1
10	1	1	1	41	5	5	5	66	3.5	4	4
12	3	2	2	42	2	5	2	67	5	5	5
13	3	3	2	43	4	3	3	68	5	4	4
14	3	2	1	44	3	2	3	69	4	2	3
15	4	4.5	4	45	5	5	5	70	2	2	1
16	5	5	5	46	4	2	4	71	5	3	3
17	3	3	3	47	2	2	1	72	5	5	5
18	3	3	3	48	2	2	2	73	2	2	1
19	5	5	5	49	4	5	3.5	74	3	2	3
20	5	5	5	50	5	4	3.5	75	3	1	1
21	4	3	3	51	2	2	1	76	3	1	1
23	3	2	2	52	2	2	1	77	3	2	1
27	5	4	4	53	5	3	3.5	78	2	2	2
28	4	4	3.5	54	5	5	5	79	3	2	2
29	3	2	1	55	4	3	2	80	2	2	1

[1]Values were subjectively assigned as follows:

1 = dry
2 = moist
3 = wet
4 = muddy
5 = submerged

probably most representative of the preferred soil moisture condition for each community, especially if average June values are used to minimize extreme, and perhaps unusual, values.

When the ten communities are plotted according to their June soil moisture ranges, as in figure 20, there is a considerable overlap of ranges. The mean June soil moisture of the communities ranged from wet to dry as follows: Potamogeton pectinatus, Ruppia maritima/Zannichellia palustris, Scirpus maritimus paludosus, Scirpus acutus, Typha latifolia, Distichlis spicata stricta, Suaeda depressa/Bassia hyssopifolia/Lepidium perfoliatum, Salicornia europaea rubra, Distichlis spicata stricta/Hordeum jubatum, and Agropyron cristatum/Atriplex/Sarcobatus vermiculatus communities.

The Agropyron cristatum/Atriplex/Sarcobatus vermiculatus community is clearly the driest. The Potamogeton pectinatus community appears to be found in the deepest water, followed by the Ruppia maritima/Zannichellia palustris community. The Scirpus acutus, Typha latifolia, and Scirpus maritimus paludosus communities range from wet to submerged and cannot be distinguished on this basis. Similarly, the Distichlis spicata stricta/Hordeum jubatum, Distichlis spicata stricta, Salicornia europaea rubra, and Suaeda depressa/Bassia hyssopifolia/Lepidium perfoliatum

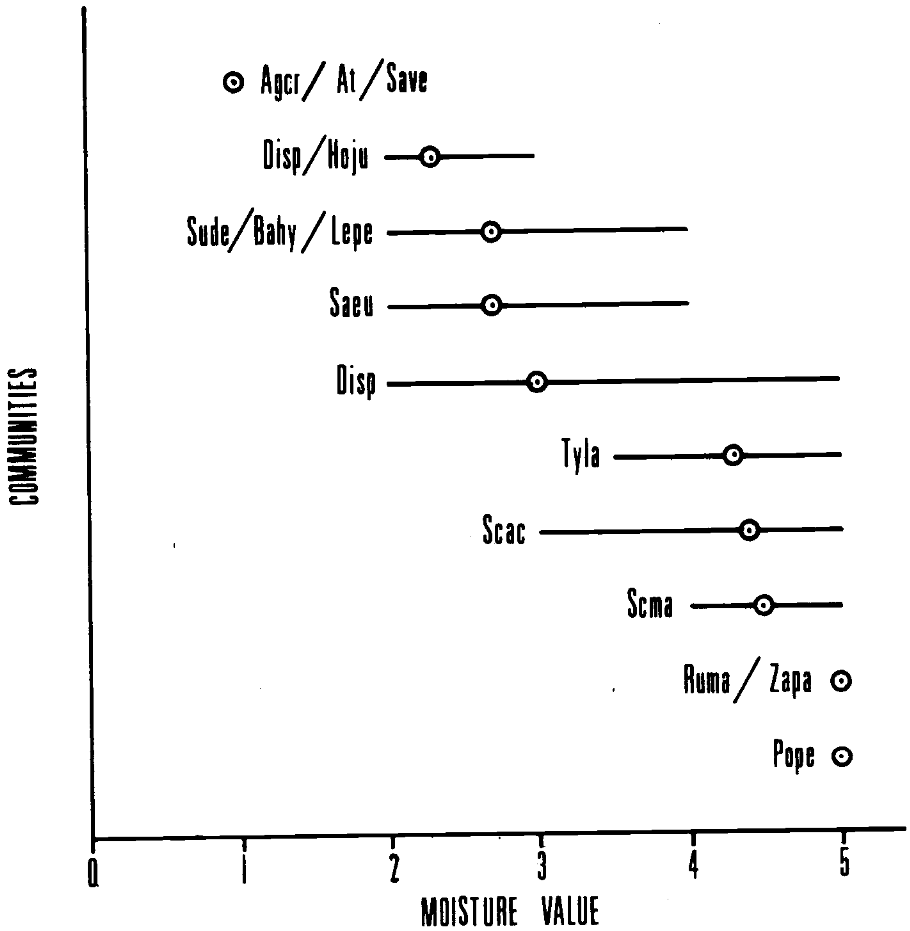


Figure 20. Ordination of communities by June soil moisture ranges (circles represent mean values).

communities range widely from moist to submerged, and could not be distinguished on the basis of June soil moisture alone.

Salinity values (as conductance values for 1:5, soil: distilled water slurries) of the July 0.3 m soil core samples (table 3) ranged from 340 to 17,400 µmhos. These salinity values are probably the most representative of the soil salinity typical for each community, as the top 0.3 m appeared to approximate the major rooting zone of most of the species sampled.

If the ten communities are ordinated, as in figure 21, by top 0.3 m soil salinity, there is again considerable overlap of community ranges. When the ten communities were arranged from mean high to low salinity, they fell in the following order: Salicornia europaea rubra, Suaeda depressa/ Bassia hyssopifolia/Lepidium perfoliatum, Ruppia maritima/ Zannichellia palustris, Scirpus maritimus paludosus, Distichlis spicata stricta, Potamogeton pectinatus, Typha latifolia, Distichlis spicata stricta/Hordeum jubatum, Scirpus acutus, and Agropyron cristatum/Atriplex/Sarcobatus vermiculatus communities.

The Salicornia europaea rubra community is clearly the most salt tolerant. The Ruppia maritima/Zannichellia palustris community is the more salt tolerant of the two aquatic communities, occurring in shallower, more brackish water than the Potamogeton pectinatus community. The

Table 3. Conductance and percent salt of July 0.3 m soil cores.

Plot	Conductance[1] (μmhos)	% Salt[2]	Plot	Conductance (μmhos)	% Salt
1	5100	1.5	45	830	0.2
2	2000	0.6	46	4570	1.4
4	13500	4.0	47	3870	1.2
5	780	0.2	48	1280	0.4
6	2210	0.7	49	1250	0.4
7	5050	1.5	50	1260	0.4
8	1990	0.6	51	3730	1.1
9	5700	1.7	52	1730	0.5
10	340	0.1	53	800	0.2
12	410	0.1	54	4710	1.4
13	870	0.3	55	770	0.2
14	3580	1.1	56	1170	0.4
15	400	0.1	57	1560	0.5
16	880	0.3	58	2300	0.7
17	4170	1.3	61	1430	0.4
18	9100	2.7	62	2080	0.6
19	370	0.1	63	4610	1.4
20	1650	0.5	64	10300	3.1
21	10600	3.2	65	6700	2.0
23	6300	1.9	66	5500	1.6
27	2060	0.6	67	340	0.1
28	540	0.2	68	880	0.3
29	7300	2.2	69	5800	1.7
31	6200	1.9	70	4550	1.4
33	17400	5.2	71	1190	0.4
35	11100	3.3	72	700	0.2
36	530	0.2	73	7700	2.3
37	720	0.2	74	8000	2.4
38	2070	0.6	75	4700	1.4
39	4000	1.2	76	6300	1.9
40	3510	1.1	77	4990	1.5
41	3410	1.0	78	1090	0.3
42	7900	2.4	79	890	0.3
43	6800	2.0	80	2230	0.7
44	2850	0.9			

[1] 1:5, soil:distilled water slurries.

[2] % salt = 0.3 x the conductivity in mmhos for a 1:5, soil: distilled water slurry (Nelson, 1954).

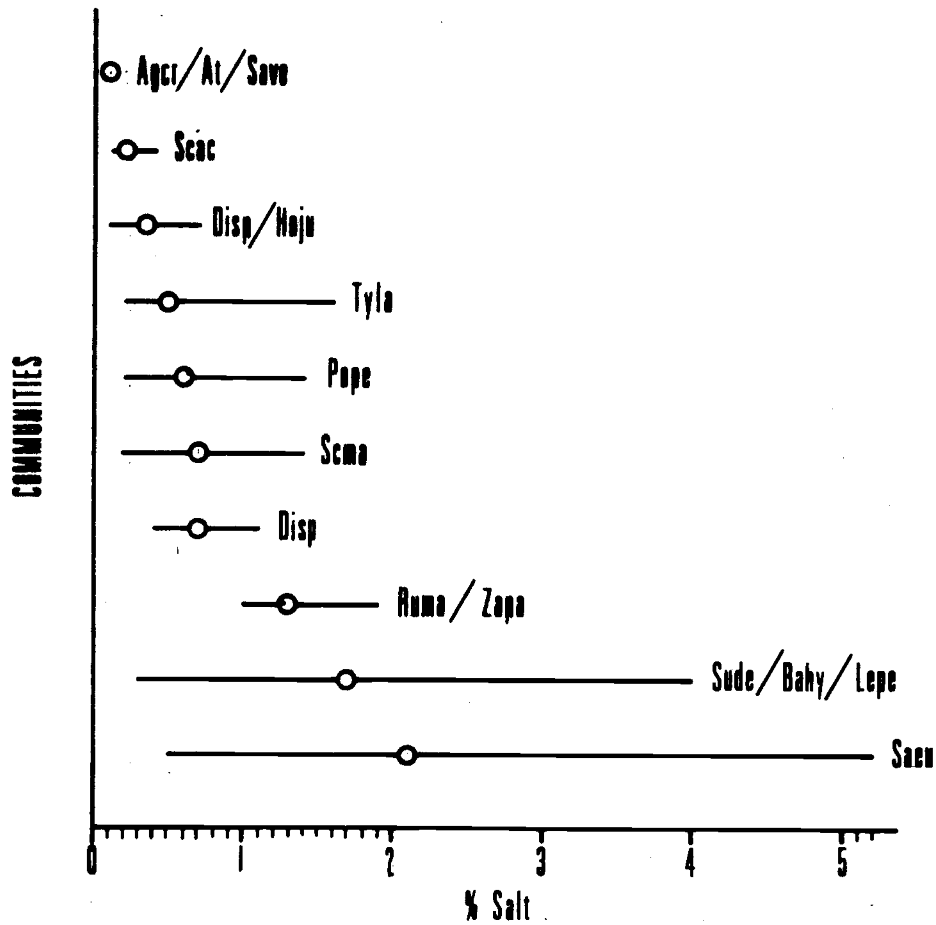


Figure 21. Ordination of communities by July 0.3 m soil core salinity ranges (circles represent mean values).

Agropyron cristatum/Atriplex/Sarcobatus vermiculatus, Distichlis spicata stricta/Hordeum jubatum, Scirpus acutus, and Typha latifolia communities tend to occur in soil with a very low salinity. The Scirpus maritimus paludosus, and Distichlis spicata stricta communities are found in areas of moderately low salinity and the Suaeda depressa/Bassia hyssopifolia/Lepidium perfoliatum community is found in areas of moderately high salinity.

Salinities of the composite 0.1 m surface samples (June, July, and August samples combined)(appendix table IV) varied from 185 to 17,500 μmhos. These values are not easily correlated and have not been used in the description or ordination of communities.

When both June soil moisture values and July 0.3 m soil salinity values are used to graph the 69 sample plots, the ten communities identified can be blocked out as in figure 22 with very little overlap of ranges. The interdigitation required between the Salicornia europaea rubra and Suaeda depressa/Bassia hyssopifolia/Lepidium perfoliatum communities is caused mainly by the ecotonal nature of the latter. The combined zone representing both of these communities could probably better be subdivided into four monospecific bands -- Lepidium perfoliatum, Bassia hyssopifolia, Suaeda depressa, and Salicornia europaea rubra -- with increasing salinity, as suggested by the pattern of vegetation within the plots of the latter community.

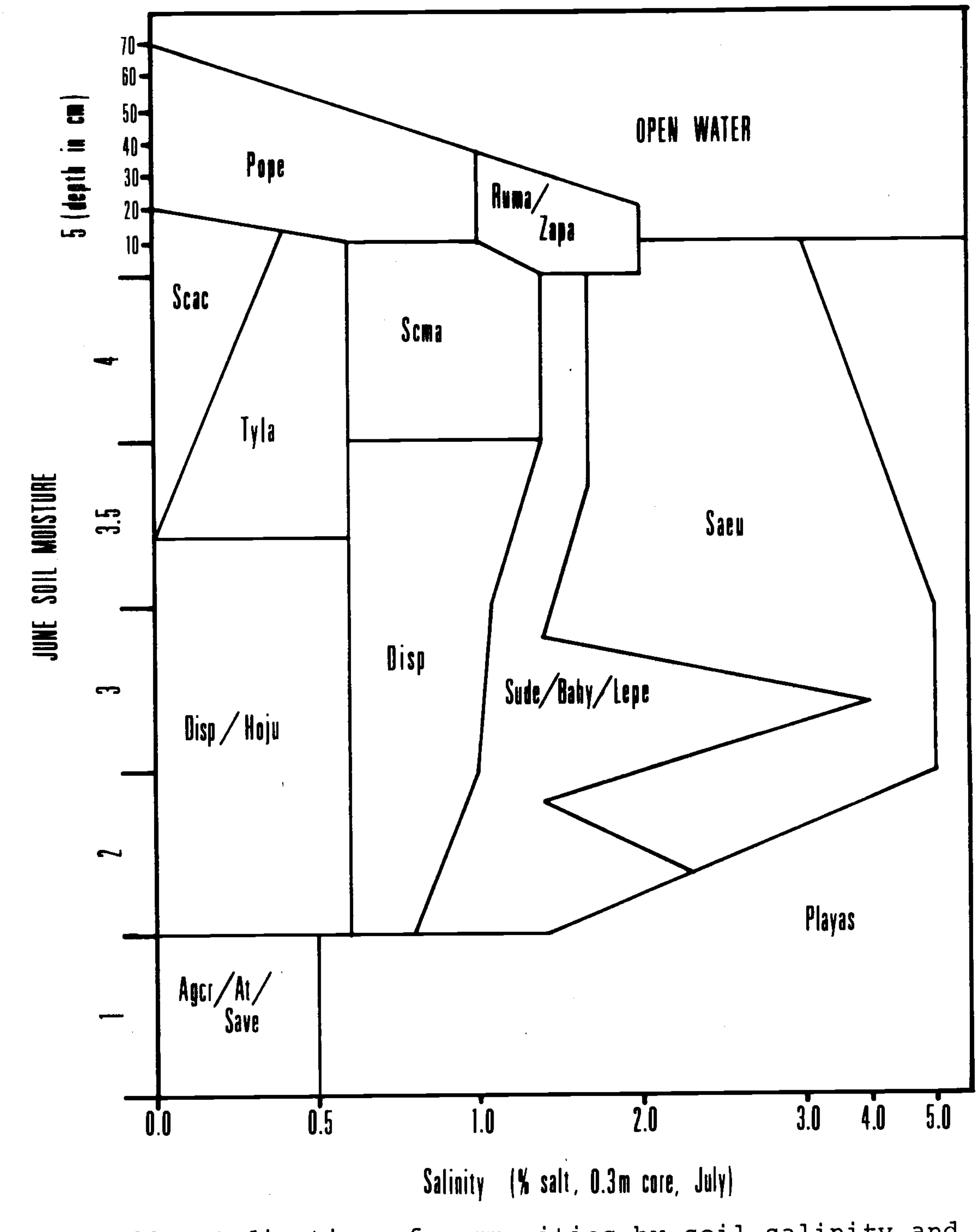


Figure 22. Ordination of communities by soil salinity and soil moisture.

Figure 22 shows the tendency of the aquatic communities, the Potamogeton pectinatus and Ruppia maritima/ Zannichellia palustris communities, to be less saline the deeper the water, with the Potamogeton pectinatus community usually found in deeper, fresher water than the Ruppia maritima/Zannichellia palustris community.

Of the three emergent communities, the Scirpus acutus community appears to be the freshest and wettest with the Scirpus maritimus paludosus community the most salt tolerant and the Typha latifolia community somewhere inbetween.

The Distichlis spicata stricta community seems to be the most intermediate community present. It invades all of the surrounding communities to some extent. Distichlis appears to be quite adaptable; it can tolerate flooding, drying, and high salinity, once established. Since it reproduces vegetatively, it apparently survives under such adverse conditions by bypassing the typically vulnerable seedling stage. The Distichlis spicata stricta/Hordeum jubatum community probably represents a "moderate climax" for the area. Water isn't as limited as it is for the Agropyron cristatum/Atriplex/Sarcobatus vermiculatus community. The latter seems to be representative of the freshest, driest community present, while the Salicornia europaea rubra and Suaeda depressa/Bassia hyssopifolia/ Lepidium perfoliatum communities represent the most salt tolerant and probably the earliest successionally.

Additional Environmental Data

Conductance values, as a measure of salinity, for the seven sets of periodic water samples collected biweekly from various points on the refuge from June through September are summarized in table 4. The data revealed that, in general, water salinity increased from June through August and then declined in September. Conductance values recorded ranged from 460 to 4870 μmhos for the periodic water samples. Rainfall and increases in river flow just prior to some of the sampling dates no doubt modified the results somewhat.

Conductance values for the water samples taken from submerged plots during July vegetative sampling (table 5) ranged from 860 to 7000 μmhos. The plant community in which each plot occurred is also shown in the table.

A plot dominated by *Salicornia europaea rubra* had the highest water salinity reading, 7000 μmhos. It is interesting to note that the *Salicornia europaea rubra* community may occur in shallowly flooded areas, especially earlier in the year. Salinity values for *Typha latifolia* and *Scirpus acutus* dominated plots were only slightly brackish, and the two communities could not be distinguished on this basis. The salinities of *Potamogeton pectinatus* plots were markedly lower than those for *Ruppia maritima*/*Zannichellia palustris* plots. The average salinity for the six *Potamogeton* plots was 1255 μmhos, while the average

Table 4. Salinities, as conductance values in μmhos, for the 12 periodic water sampling locations.

Sampling Locations	Sampling Dates 6/12	6/26	7/10	7/24	8/7	8/21	9/4
1	460	720	840	1190	1120	1090	850
2	630	720	810	900	1230	1300	1510
3	560	640	750	1480	800	940	800
4	530	780	800	1050	1150	1440	990
5	4410	760	1350	2750	2110	3510	4870
6	740	790	820	1110	1040	1760	1030
7	490	670	780	1070	1150	1730	1060
8	530	660	760	720	840	1160	1080
9	670	700	810	940	1370	1590	1670
10	3220	1310	760	1780	1100	1120	1120
11	710	650	750	1070	1240	1470	860
12	910	980	1010	2970	1710	1830	1960

Table 5. Vegetation and water salinity for macroplots submerged in July.

Plot	Community[1]	Conductance (μmhos)
8	Pope	1500
15	Scac	1090
16	Pope	860
19	Scac	1000
20	Pope	990
40	Ruma/Zapa	2970
41	Ruma/Zapa	4090
42	Saeu	7000
45	Pope	1140
49	Scac	1820
54	Pope	1880
57	Pope	840
66	Tyla	1500
67	Scac	1030
71	Scac	1740
72	Scac	990

[1]Community symbols are as given with the community descriptions in the text.

salinity for the two *Ruppia/Zannichellia* plots was almost three times as high, 3530 μmhos.

According to Lunin, *et al*. (1960) and Stewart and Kantrud (1971), the water samples collected ranged from fresh to brackish, the majority being slightly to moderately brackish. None of the readings were as extremely brackish as might well have been the case during a drier summer (Christiansen and Low, 1970; Kaushik, 1963).

Salinities of the ground water samples and the soil samples taken in July 1973 from soil pits in plot 1 and at the dump (table 6) were quite high. The conductance values for the two ground water samples, 12,300 and 12,700 μmhos respectively, are indicative of the extreme salinities to which the deeper roots of woody and other deeprooted species are typically exposed.

Salinities of the soil samples taken at regular depth increments showed an inverted soil salinity profile similar to those reported by Flowers (1934) and by Robinson (1969). Salinity was greatest right at the surface. Values decreased to a depth of about 0.3 m, and then increased again down to the water table. Flowers and Robinson pointed out similar increases in soil salinity with increasing depth and also the surface concentration of salts over a relatively shallow water table in areas with high evaporation rates. The shallowness of the water table, 0.6 m below ground level in both cases, and the high rate of evaporation

Table 6. Salinity of June 1973 soil pit soil and water samples.

Sample		Conductance[1] (μmhos)	% Salt[2]
Soil Samples:			
Plot 1:	surface	8100	2.4
	0.15 m	3390	1.0
	0.30 m	3320	1.0
	0.45 m	5400	1.6
	0.60 m	8000	2.4
Dump:	surface	17500	5.2
	0.30 m	8600	2.6
	0.60 m	9400	2.8
Water Samples:			
Plot 1		12300	---
Dump		12700	---

[1]1:5, soil:distilled water slurries.

[2]% salt = 0.3 x the conductivity in mmhos for a 1:5, soil: distilled water slurry (Nelson, 1954).

experienced by the whole refuge during the summer months may serve to explain the higher surface soil salinities and inverted soil salinity profiles in both playas sampled.

Several additional edaphic characteristics were measured but were not readily correlated with the communities identified at the level used. These include pH, bulk density, moisture equivalent, texture, and color.

Glass electrode pH values for July 1972 0.3 m soil cores and indicator dye values for the same samples are compared in appendix table V. Electrode values, which were determined as 1:5, soil:distilled water slurries, ranged from 8.15 to 9.60, and were, in general, slightly lower than the values determined by the use of standard indicator dyes.

Glass electrode pH values for composite June-July-August 0.1 m surface soil samples (appendix table IV) ranged from 8.00 to 9.60, but tended to be slightly lower than comparable July 0.3 m core electrode values.

Soil bulk densities for composite June-July-August 0.1 m surface soil samples (appendix table VI) ranged from 1.16 to 1.74 g/cm^3.

Moisture equivalent values for composite June-July-August 0.1 m surface soil samples (appendix table VII) ranged from 21% to 56%.

Most of the samples tested had at least 50% silt content. Textures (appendix table VII) reflected this high silt content, ranging from silts to silty-loams to silty-clay-loams.

Colors of the dry soil samples (appendix table VIII) were almost uniformly light gray, while wet colors (Appendix table VIII) ranged from gray through the gray-browns to brown. All these colors are generally indicative of a chemically reduced state.

Indicator Significance

Branson, *et al*. (1970) provide an interesting discussion of the indicator significance of plant communities and species. They point out that habitats may be roughly approximated by the dominant species present, but that a consideration of all species yields a much better characterization. Further, presence of species with wide tolerance limits "may be almost meaningless, but abundance and associated species may give useful approximations of site conditions." And finally, "species with narrow ranges of tolerance to soil-moisture stress conditions should be the most useful indicators of soil-moisture conditions in different habitats." The same should apply to other edaphic characteristics, especially soil salinity and soil moisture, since these are merely factors of soil-moisture stress.

The mere presence of *Distichlis* or *Salicornia* is of little value in defining edaphic conditions, since these two appear to have very great tolerance limits for soil moisture and soil salinity. However, if their abundance, vigor, and associated species are considered, soil conditions can be delimited fairly accurately. *Potamogeton pectinatus*, on the other hand, has probably the narrowest tolerance limits for soil moisture and soil salinity. Likewise, as predicted by Branson, *et al.*, it is a good indicator of both soil moisture and soil salinity conditions. Similarly, *Ruppia* and/or *Zannichellia*, *Typha*, or *Scirpus acutus* are good indicators of soil moisture and soil salinity, where they are the dominant vegetation.

In any event, it should be kept in mind that, as pointed out by Ayers (1952), Kaushik (1963), Hayward and Bernstein (1958), and others, vegetation, especially in harsh environments, tends to be more reflective of the conditions at the time of establishment than of current conditions, due to variation in tolerance of the different life stages of most species.

Vegetative Zonation

As in other studies of similar areas, sharp distinction between adjacent vegetative types was apparent. Climatic variables, such as precipitation, temperature, and insolation were discounted, since the changes in vegetation are obviously too abrupt to be indicative of significant variation of these factors.

Soil pH, and texture, and the depth of the water table are other factors, which are sometimes found to be responsible for vegetative zonation, but which were also discounted in this study. In the range of reaction encountered in the study (8.0 to 9.6), and in the absence of any definable relationship of pH and vegetation, it seems unlikely that pH alone plays a major role in determining vegetative distribution. Any correlation which might be discerned from the data might better be attributed to differences in salinity, because of the slight correlation of soil salinity and pH (Buckman and Brady, 1969; Branson, et al., 1967 and 1970; Nelson, 1954). Soil textures and water table depth were found to be quite uniform refuge-wide.

June soil moisture and 0.3 m soil salinity were the only two factors measured which appeared to be significantly correlated with vegetative zonation. These two factors are probably largely responsible for vegetative zonation, as observed on the Bear River Migratory Bird Refuge.

Some Recent Changes in the Bear River Flora

In 1935 the total known flora of the Bear River Refuge consisted of 92 species (Lehmann, 1935). By 1972 the flora had increased to at least 160 non-cultivated species. Lehmann's list has been combined with the results of the present survey for comparison in table 7. The table lists all the species in alphabetical order by family, genus,

Table 7. A comparison of the flora of the Bear River Migratory Bird Refuge compiled by Lehmann (1935) with that compiled during the present study. Nomenclature follows Holmgren and Reveal (1966), except as noted. Symbols are as used in figure 8. Abundance notations are A = abundant, C = common, U = uncommon, R = rare.

Symbol	Abundance 1935	Abundance 1972	Name
			Aceraceae
		R	*Acer negundo* L.
			Aizoaceae
	C		*Sesuvium verrucosum* Raf.
			Alismaceae
		R	*Sagittaria cuneata* Sheld.
			Amaranthaceae
		U	*Amaranthus albus* L.
		U	*A. retroflexus* L.
			Amaryllidaceae
		U	*Allium acuminatum* Hook.
			Apocynaceae
	U	U	*Apocynum cannabinum* L.[1]
			Asclepiadaceae
Asin		C	*Asclepias incarnata* L.
	C	C	*A. speciosa* Torr.
			Boraginaceae
		U	*Amsinckia retrorsa* Suksd.
		U	*Cynoglossum officinale* L.
			Capparidaceae
	R	R	*Polanisia dodecandra* (L.) DC[2]
			Caryophyllaceae
	C		*Spergularia marina* (L.) Griseb.
			Ceratophyllaceae
Cede		C	*Ceratophyllum demersum* L.
			Characeae
	R	U	*Chara* sp.

[1]= *Apocynum* sp. of Lehmann?
[2]= *Cleome serrulata* of Lehmann?

Table 7 (continued)

Symbol	Abundance 1935	1972	Name
			Chenopodiaceae
	R	U	Allenrolfea occidentalis (S. Wats.) Kuntze
	A	U	Atriplex confertifolia (Torr. & Frem.) S. Wats.
Atnu	C	C	*A. nuttallii S. Wats.
Atpa	A	C	A. patula L. var. hastata (L.) Gray
	A	C	A. rosea L.
Bahy	A	A	Bassia hyssopifolia (Pall.) Kuntze
Chal	A	C	Chenopodium album L.[3]
	C		C. glaucum L. var. salinum (Standl.) Boivin
Saeu	A	A	Salicornia europaea L. ssp. rubra (A. Nels.) Breitung
	C	U	**Salsola iberica Sennen & Pau
Save	C	C	Sarcobatus vermiculatus (Hook.) Torr.
Sude		A	Suaeda depressa (Pursh) S. Wats.
		U	S. fruitcosa (L.) Forsk
	C	U	S. nigra (Raf.) J. F. McBr.
	C	U	S. occidentalis S. Wats.[4]
			Compositae (Asteraceae)
		R	Achillea millefolium L. ssp. lanulosa (Nutt.) Piper
		R	Agoseris glauca (Pursh) Raf.
	C	C	Ambrosia artemisiifolia L.
	R	U	A. psilostachya DC.
	R	R	Arctium minus (Hill) Bernh.
	A	R	Artemesia cana Pursh[5]
	C	C	Aster chilensis Nees var. adscendens (Lindl.) A. Cronq.
	C		A. falcatus Lindl. in Hook.
		R	A. frondosus (Nutt.) Torr. & Gray
		U	A. hesperius A. Gray
		U	Bidens cernua L.
	C	R	B. frondosa L.
Chvi		C	Chrysothamnus viscidiflorus (Hook.) Nutt.
		R	Cichorium intybus L.
	C	U	Cirsium arvense (L.) Scop

*Nomenclature follows Hitchcock, et al., 1955-69.
**Nomenclature follows Beatley, 1973.

[3]= C. sp. of Lehmann?

[4]Identification of Suaeda are difficult. The genus is confused and in need of revision (L.A. Arnow, personal communication).

[5]= A. biennis of Lehmann?

Table 7 (continued)

Symbol	Abundance 1935	1972	Name
			Compositae (Asteraceae) (continued)
		R	C. foliosum (Hook.) DC.
Civu	C	A	C. vulgare (Savi) Tenore
	C	U	Conyza canadensis (L.) Cronq.
		R	Coreopsis cf. atkinsoniana Dougl. in in Lindl.[6]
	C	C	Grindelia squarrosa (Pursh) Dunal
		U	Gutierrezia sarothrae (Pursh) Britt. & Rusby
		R	Haplopappus racemosus (Nutt.) Torr. & Gray
	C		Helenium autumnale L. var. montanum (Nutt.) Fern.
Hean	A	A	Helianthus annuus L.[7]
	C	U	Iva axillaris Pursh
	C	C	I. xanthifolia Nutt.
	C	U	Lactuca pulchella (Pursh) DC.
Lase	A	C	L. serriola L.
		R	Matricaria matricarioides (Less.) Porter
	C		Senecio hydrophilus Nutt.
	A		Solidago occidentalis (Nutt.) Torr. & Gray
	A	C	Sonchus asper (L.) Hill
	C	U	S. oleraceus L.[8]
		R	Taraxacum officinale Weber in Wiggers
		R	Tragopogon dubius Scop. (?)
	C	U	Xanthium strumarium L.[9]
			Convolvulaceae
	R	U	Convolvulus arvensis L.[10]
		R	C. sepium L.
			Cruciferae
	A	C	Brassica nigra (L.) Koch
		R	Capsella bursa-pastoris (L.) Medic.
		R	Cardaria draba (L.) Desv.
		U	Descurainia sophia (L.) Webb
		C	Isatis tinctoria L.

[6]The symbol cf. indicates a tentative identification, often based upon an immature or incomplete specimen.

[7]= H. nuttallii of Lehmann?

[8]= S. sp. of Lehmann?

[9]= X. echinatum of Lehmann? X. pennsylvanicum is a common synonym.

[10]= Cressa truxillensis of Lehmann?

Table 7 (continued)

Symbol	Abundance 1935	1972	Name
			Cruciferae (continued)
Lepe	R	A	*Lepidium perfoliatum* L.
	R		*Nasturtium officinale* R. Br.
		U	*Sisymbrium altissimum* L.
		R	*Thlaspi arvense* L.
			Cyperaceae
	C		*Carex nebraskensis* Dewey
Elpl	C	C	**Eleocharis palustris* (L.) Roem. & Schult.[11]
Elpr	C	U	*E.* cf. *parvula* (Roem. & Schult.) Link[12]
Scac	A	A	*Scirpus acutus* Muhl. ex Bigel.
		U	*S. fluviatilis* (Torr.) A. Gray[13]
Scma	A	A	**S. maritimus* L. var. *paludosus* (A. Nels.) Kuekenth
	R	U	*S. olneyi* A. Gray[14]
			Dipsacaceae
Disy	C	C	*Dipsacus sylvestris* Huds.
			Elaeagnaceae
		U	*Elaeagnus angustifolia* L.
			Euphorbiaceae
		R	*Euphorbia glyptosperma* Engelm.
			Geraniaceae
		U	*Erodium cicutarium* (L.) L'her. ex Ait.
			Gramineae (Poaceae)
Agcr		U	*Agropyron cristatum* (L.) Gaertn.
		C	*A. intermedium* (Host) Beauv.
		U	*A. subsecundum* (Link) A. S. Hitchc.[15]
		R	*Agrostis alba* L.
Brco	C	C	*Bromus commutatus* Schrad.[16]
		U	*B. japonicus* Thunb.
		U	*B. tectorum* L.
		R	*Digitaria sanguinalis* (L.) Scop.

*Nomenclature follows Hitchcock, *et al.*, 1955-69.

[11] *E. macrostachya* Britt. ex Small is a common synonym.

[12] = *E. spicata* of Lehmann?

[13] Could have been present in 1935 and included in *S. maritimus*.

[14] = *S. americanus* of Lehmann?

[15] *A. caninum* (L.) Beauv. is a common synonym.

[16] = *B. sterilis* of Lehmann?

Table 7 (continued)

Symbol	Abundance 1935	1972	Name
			Gramineae (Poaceae) (continued)
Disp	A	A	*Distichlis spicata* (L.) Greene var. *stricta* (Torr.) Beetle
	C	U	*Echinichloa crusgalli* (L.) Beauv.
	C	R	*Elymus glaucus* Buckl.[17]
Hoju	A	A	*Hordeum jubatum* L.
		R	*Muhlenbergia asperifolia* (Nees & Meyen) Parodi
	A	C***	*Phragmites australis* (Cav.) Trin. ex Steudel[18]
		U	*Poa pratensis* L.
Posa		U	*P. sandbergii* Vasey[19]
Pomo	A	C	*Polypogon monspeliensis* (L.) Desf.
		R	*Puccinellia distans* (L.) Parl.
	C	R	**P. nuttalliana* (Schult.) A. S. Hitchc.
		R	*Setaria viridis* (L.) Beauv.
		R	*Sitanion hystrix* (Nutt.) J. G. Smith
	R		*Sorghum halepense* (L.) Pers.
	R	R	*Spartina pectinata* Link[20]
		R	*Triticum aestivum* L.
			Grossulariaceae
		U	*Ribes aureum* Pursh
			Juncaceae
		U	*Juncus balticus* L.
		U	*J. torreyi* Cov.
			Juncaginaceae
Trma	C	C	*Triglochin maritima* L.
			Labiatae (Menthaceae)
Lyas	C	C	*Lycopus asper* Greene
	C	U	*Nepeta cataria* L.
		U	*Scutellaria galericulata* L.
			Leguminosae (Fabaceae)
		R	*Gleditsia triacanthos* L. var. *inermis* Willd.
	C	U	*Medicago lupulina* L.

*Nomenclature follows Hitchcock, *et al.*, 1955-69.
***Nomenclature follows Clayton, 1968.

[17]= *E. canadensis* of Lehmann?

[18]*P. phragmites* of Lehmann is a tautonym. *P. communis* is a very common synonym.

[19]*P. secunda* of American authors is a common synonym.

[20]= *S. gracilis* of Lehmann?

Table 7 (continued)

Symbol	Abundance 1935	Abundance 1972	Name
			Leguminosae (Fabaceae) (continued)
		U	*M. sativa* L.
	C	C	*Melilotus alba* Desr.
		C	*M. officinalis* (L.) Lam.
	C	U	*Trifolium fragiferum* L.[21]
			Lemnaceae
		C	*Lemna minor* L.
			Liliaceae
		U	*Asparagus officinalis* L.
			Loasaceae
		R	*Mentzelia laevicaulis* (Dougl.) Torr. & Gray
			Malvaceae
		R	*Althaea rosea* Cav.
		R	*Hibiscus trionum* L.
	R	R	*Malva neglecta* Wallr.
			Oleaceae
		R	*****Fraxinus pennsylvanica* Marsh
			Onagraceae
Epad	R	C	*Epilobium adenocaulon* Hausskn.
		U	*Gaura parviflora* Dougl. ex Hook.
	R	U	*Oenothera biennis* L.
	R		*O.* sp.[22]
			Plantaginaceae
	C	U	*Plantago major* L.[23]
			Polygonaceae
		U	*Polygonum amphibium* L. var. *stipulaceum* Coleman
		C	*P. aviculare* L.
	C	C	*P. lapathifolium* L.
		C	*P. persicaria* L.
	C		*P. puncatatum* Ell.
Pora	C	C	*P. ramosissimum* Michx.
Rucr	C	C	*Rumex crispus* L.
	C		*R. fueginus* Phil.
	R		*R. hymenosepalus* Torr.
	C	U	*R. salicifolius* Weinm.

****Nomenclature follows Welsh, Treshow, and Moore, 1965.

[21]= *T. hybridum* of Lehmann?

[22]Reported as *Pachylopus eximus* by Lehmann.

[23]= *P. nigra* of Lehmann?

Table 7 (continued)

Symbol	Abundance 1935	1972	Name
			Portulacaceae
		U	Portulaca oleracea L.
			Potamogetonaceae
	R	U	Potamogeton berchtoldii Fieb.[24]
	R		P. filiformis Pers.
	R		P. nodosus Poir.
Pope	A	A	P. pectinatus L.
			Primulaceae
		R	Glaux maritima L.
			Ranunculaceae
Racy		U	Ranunculus cymbalaria Pursh var. saximontanus Fern.
		R	R. sceleratus L.
			Rosaceae
	C	U	Potentilla anserina L.
	C	C	Rosa woodsii Lindl. var. ultramontana (S. Wats) Jeps.[25]
			Rubiaceae
		U	Galium aparine L.
			Ruppiaceae
Ruma	A	A	Ruppia maritima L.
			Salicaceae
		R	Populus alba L. var. bolleana Lauche
		R	P. fremontii S. Wats
	C	U	Salix amygdaloides Anderss.
		R	S. bebbiana Sarg. var. perrostrata (Rydb.) Schneid.
	C	C	S. exigua Nutt.
			Scrophulariaceae
		R	Castilleja exilis A. Nels.
		R	Verbascum thapsus L.
			Solanaceae
		U	Solanum dulcamara L.
			Tamaricaceae
	C	C	Tamarix pentandra Pall.
			Typhaceae
		U	Typha domingensis Pers.

[24] P. pusillus is a common synonym.

[25] = R. nutkana var. hispida of Lehmann?

Table 7 (continued)

Symbol	Abundance 1935	1972	Name
			Typhaceae (continued)
Tyla	A	A	T. latifolia L.[26]
			Ulmaceae
		R	Ulmus pumila L.
			Umbelliferae
		U	Conium maculatum L.
			Urticaceae
Urdi	C	C	Urtica dioica L. ssp. gracilis (Ait.) Seland var. lyallii (Wats.) C. L. Hitchc.
			Verbenaceae
		U	Verbena bracteata Lag. & Rodr.
			Zannichelliaceae
Zapa	?	C	Zannichellia palustris L.[27]
			Zygophyllaceae
		U	Tribulus terrestris L.

[26]Lehmann lists only T. angustifolia. No T. angustifolia was found during the present study. It is improbable that such an exchange as this suggests could have taken place in 37 years. Hybridization on the refuge seems to have created a number of intermediate clones, many of which resemble T. angustifolia vegetatively, and with re-regard to the flower stalk.

[27]An aquatic seems to have been omitted from the copy of Lehmann's list available at Bear River Refuge Headquarters (pp. 54-56 of a document referred to as the Halloran Report). It may well have been Z. palustris.

and species. It indicates which species were present and their abundance in 1935 or 1972 or both. Nomenclature follows Holmgren and Reveal (1966), for the most part.

In 1935 there were 27 families, 68 genera, and 92 species. The 1972 survey revealed 52 families, 118 genera, and 160 species. Between 1935 and 1972, 27 new families, 62 genera, and 94 species were added.

The three largest families represented in 1935 were (1) Compositae, (2) Chenopodiaceae, and (3) Gramineae. In 1972 the largest families were (1) Compositae, (2) Gramineae, and (3) Chenopodiaceae. The Chenopodiaceae had the greatest similarity of the three between 1935 and 1972.

Table 8 summarizes the vegetative changes which have occurred since 1935. Generally speaking, certain weedy species, such as *Lepidium perfoliatum*, and weedy, annual species in general, have apparently increased since 1935. The total number of species has also increased substantially. The latter increase seems to have resulted mainly from refuge management activities, e.g. dike construction and maintenance. However, this increase in diversity may be taken as an indication of an overall maturation of the refuge area, reflective of these and other management practices.

Increase in species has come mainly as a result of the addition of new genera and families since 1935. Of the 27 families present in 1935, 25 were still represented in

Table 8. Comparison of the 1935 Bear River Migratory Bird Refuge flora with that in 1972. Values listed are for numbers of species, unless otherwise designated.

Category	1935	1972	1935/72*	I.S.**
Families	27	52	25	63.0
Genera	68	118	60	64.5
Species	92	160	76	60.5
Woody	9	20	8	55.0
Forbs	65	107	52	60.5
Graminoids	17	32	15	61.0
Macroalgae	1	1	1	100.0
Compositae	22	32	18	66.5
Gramineae	10	23	9	54.5
Chenopodiaceae	13	14	12	89.0
Polygonaceae	7	7	4	57.0
Cyperaceae	6	6	5	83.0
Cruciferae	3	8	2	36.0
Leguminosae	3	6	2	44.5
Species/Genus	1.35	1.35	1.27	
Species/Family	3.41	3.08	3.04	
Genera/Family	2.51	4.41	2.40	

*Many comparisons involve assumed species.

**Index of Similarity: I. S. = (200 x C)/(A + B), where A = the number in 1935, B = the number in 1972, and C = the number present in both 1935 and 1972.

1972, while 27 new families were added. Likewise, 60 of the 68 genera found in 1935 were still represented in 1972, in addition to 58 new genera. The number of species per genus has remained unchanged. The number of species per family has decreased, and the number of genera per family has increased substantially.

If composite 1935/1972 results are compared with either the 1935 or 1972 results alone, the proportions of species per genus, species per family, and genera per family are all reduced. This seems to indicate that when a species is replaced, it may tend to be replaced by a similar species within the same genus.

When both the number of species and abundance of the major plant families of the Bear River Refuge are compared (1935/1972), some interesting trends are apparent. The number of Compositae has increased substantially, but there is no indication that the family has increased in relative importance. The number of Chenopodiaceae has remained almost unchanged, as has the composition of the family. As a result, the family dropped from second to third in total number of species. A number of species seem to have decreased in importance, while the more seral species, Suaeda depressa, seems to have made a sharp increase in abundance. The family as a whole has decreased in relative importance. The grass family has enjoyed the greatest increase in number of species. Several new, weedy grasses have been added, in addition to a few that were introduced intentionally, including the three *Agropyron* species. *Distichlis* appears to have substantially increased in abundance. The weedy mustard family has experienced the greatest relative increase with several new species having been added and *Lepidium perfoliatum* having enjoyed the greatest increase in abundance.

Other better-represented families have shown similar trends. The numbers of rushes and buckwheats (Cyperaceae and Polygonaceae) have remained about the same with a few changes in species composition. The legumes (Leguminosae) have added a few species and a few more have increased in abundance. *Scirpus maritimus paludosus* appears to have substantially decreased in abundance since 1935. This decrease is probably due to encroachment by *Distichlis* in large areas that have become silted in over the last 37 years. The abundance of *Polygonum lapathifolium* has apparently increased in selected areas.

Succession

At the time of its establishment, the Bear River Refuge was basically wetter and more saline than it is today. Therefore, the vegetative changes since that time need to be viewed in terms of a successional pattern based upon changing environmental conditions, in this case, changing edaphic conditions.

In general, the successional relationships suggested in figure 24 probably represent succession from high salinity or abundant water, whether fresh or brackish, to low salinity and desert conditions. This was demonstrated by the transects run along observable and measurable gradients from wet and salty to dry and non-saline. Transects run up out of playas all began with *Salicornia*, then *Distichlis*, then *Distichlis*/*Hordeum*, and finally *Distichlis* plus a variety of annuals. On many of the gravelled dikes *Salicornia* led through the *Suaeda*/*Bassia*/*Lepidium* community up to *Distichlis*. Brackish water was typically invaded by *Ruppia*/*Zannichellia*. *Scirpus maritimus* tended to invade shallow water areas along with *Distichlis* and to lead to the *Distichlis*/*Hordeum* community. Fresh water was typically invaded first by *Potamogeton*. Fresh shallow water, as at the edge of the dikes, was colonized by *Typha* and *Scirpus acutus*. *S. acutus* tended to grow in deeper water. Both types tended to lead up to higher channel banks vegetated by various assortments of plant species, representing a type of moist, artificial "climax" for the area. The *Agropyron*/*Atriplex*/*Sarcobatus* complex seems to represent a dry "climax" for the refuge area.

Flowers (1934) presents the most pertinent summary of successional trends for areas comparable to those at Bear River Refuge. His successional scheme is presented in figure 25. Flowers' nomenclature has been changed to

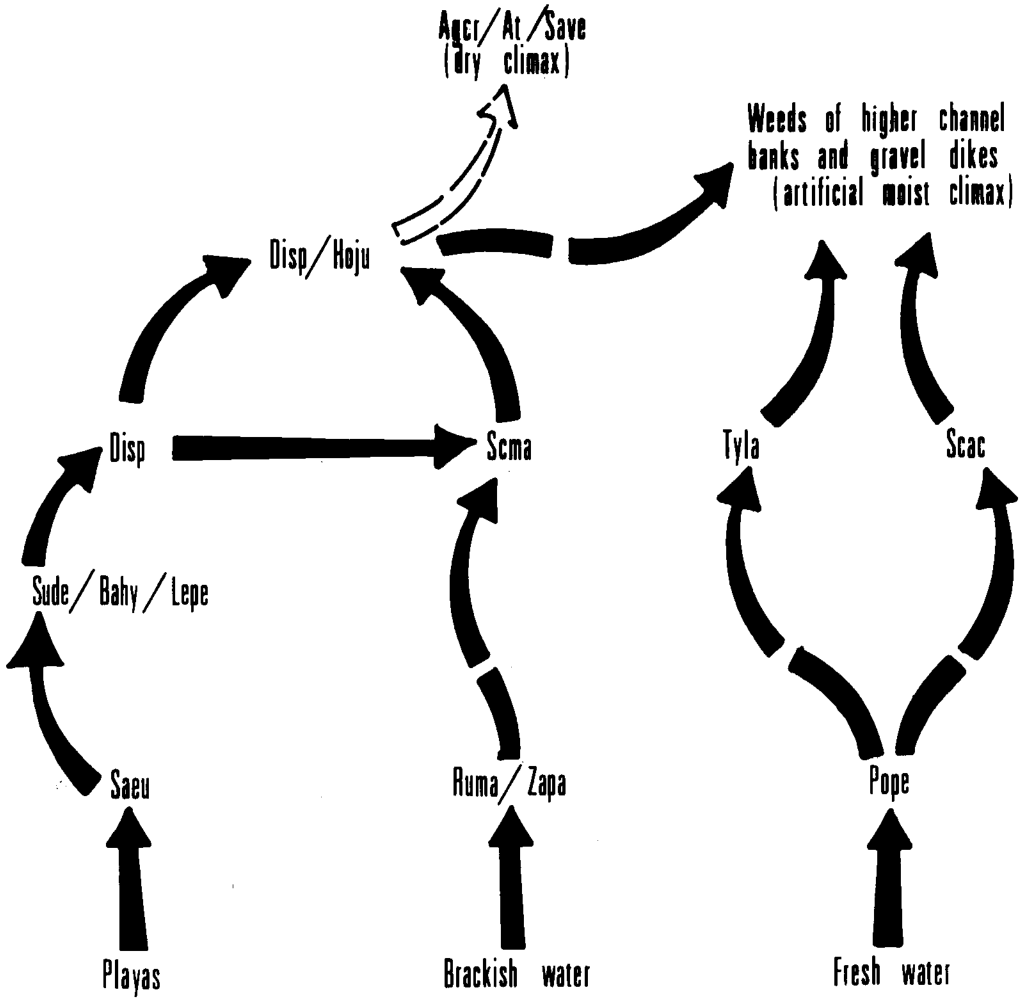


Figure 23. Suggested successional relationships of the ten communities identified.

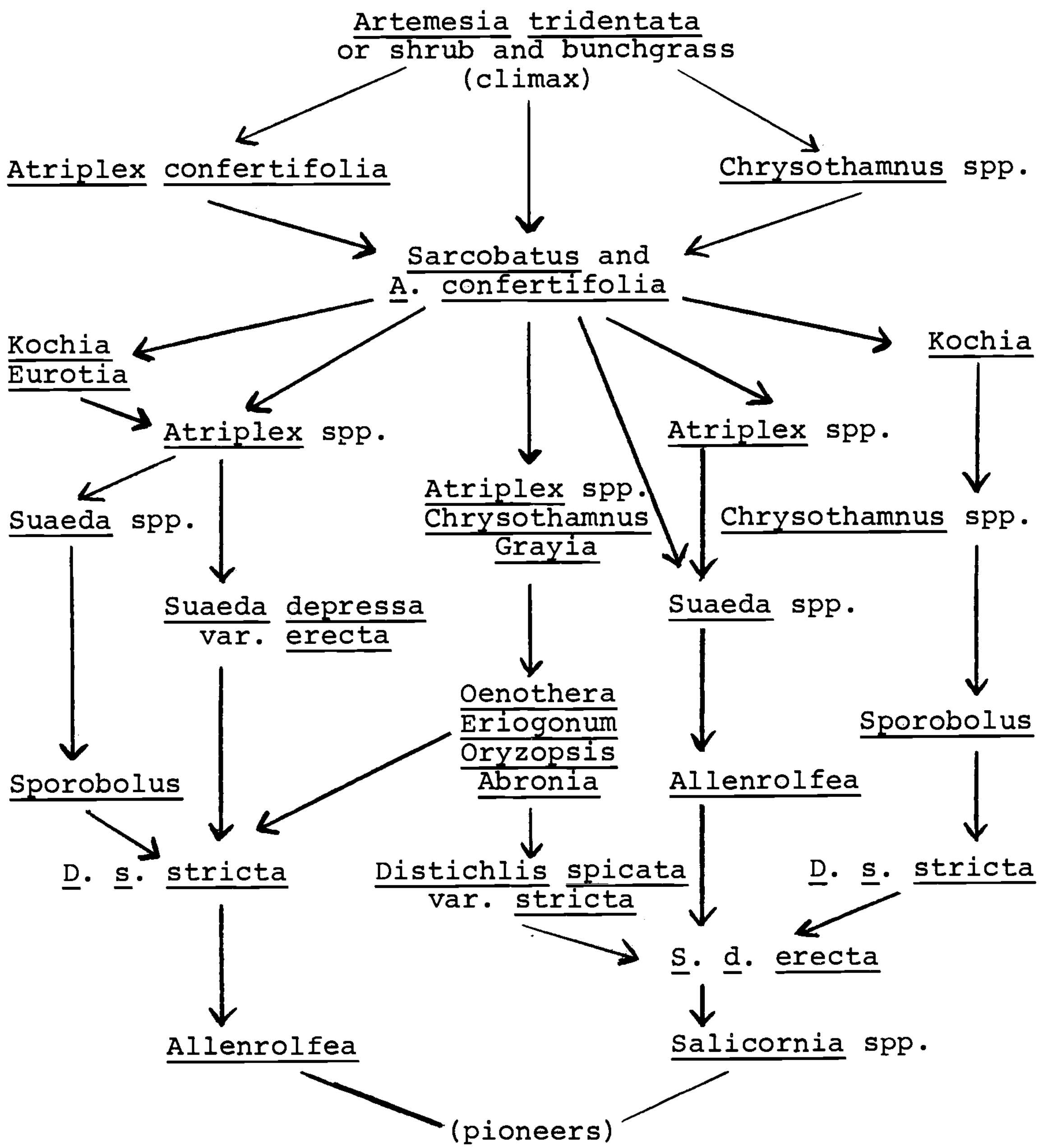


Figure 24. Principal successional trends of the invasion of strands and playas of the Great Salt Lake (after Flowers, 1934).

follow Holmgren and Reveal (1966) for ease of comparison with the summary of successional relationships observed during the present study, presented in figure 24. Flowers' successional summary considers only the invasion of barren playas by native climax vegetation. The present summary relates the invasion of playas to the succession into (or out of) fresh and brackish waters.

For the most part, the present successional summary relates the vegetative communities identified and stresses early stages of succession. Superficially this simplified successional scheme seems quite different from Flowers'. There is, however, a basic agreement about the pioneer nature of Salicornia and Allenrolfea, the importance of Distichlis as a common intermediary, and the climax nature of the shrub/bunchgrass or Agropyron/Atriplex/Sarcobatus vermiculatus complex. A number of the stages indicated by Flowers refer to species not present at Bear River, e.g. Kochia, Eurotia, and Eriogonum. Others are unimportant at the refuge, e.g. Sporobolus. For the most part, the artificial vegetation of gravelled dikes was not characterized during the present study. These areas would include Flowers' Chrysothamnus and Oenothera successional stages.

Future Vegetative Trends

The overall vegetative successional pattern of the Bear River Refuge has been based upon moderation of the environment with regard to soil salinity and soil moisture. There seems to have been a lessening of the importance of the more salt-and-drought-tolerant Chenopodiaceae. Species diversity has generally increased with the introduction of "exotics" from surrounding areas, in large part as a result of refuge activities. A large number of the new species were collected in areas created as a result of dike construction and maintenance (shoulders).

If a prediction of future floristic development were to be made, a continuation of currently observed trends would have to be proposed, in light of present management practices and philosophies. A further increase in overall diversity is expected as more surrounding vegetation becomes introduced and established, concurrent with further amelioration of edaphic conditions. A further decrease in the importance of the Chenopodiaceae may also be expected, as they are reduced by competition with heartier, less salt tolerant species. There will probably be a significant further increase in the importance of the *Distichlis spicata stricta* and *Distichlis spicata stricta*/*Hordeum jubatum* communities in the short term as the refuge silts in and the emergent communities move outward into areas currently occupied by the aquatic communities. Long term succession may lead to a situation where desert shrubs and grasses dominate, as suggested by Flowers (1934).

VI. SUMMARY

During the summers of 1971, 1972, and 1973, a general floristic ecological survey of the naturally-occurring vegetation of the Bear River Migratory Bird Refuge in Utah was carried out. Ten community types were identified and characterized. These included two aquatic communities, the *Potamogeton pectinatus* (Pope) and the *Ruppia maritima*/*Zannichellia palustris* (Ruma/Zapa) communities. There were also three typically emergent communities, the *Scirpus acutus* (Scac), *Typha latifolia* (Tyla), and *Scirpus maritimus paludosus* (Scma) communities. And finally, there were five basically terrestrial communities, the *Distichlis spicata stricta* (Disp), *Distichlis spicata stricta*/*Hordeum jubatum* (Disp/Hoju), *Salicornia europaea rubra* (Saeu), *Agropyron cristatum*/*Atriplex*/*Sarcobatus vermiculatus* (Agcr/At/Save), and *Suaeda depressa*/*Bassia hyssopifolia*/*Lepidium perfoliatum* (Sude/Bahy/Lepe) communities.

The ten communities characterized were interrelated and related to the two apparently overriding environmental factors, soil moisture and soil salinity. The mean soil moisture of the ten communities ranged from wet to dry as follows: Pope, Ruma/Zapa, Scma, Scac, Tyla, Disp, Sude/Bahy/Lepe, Saeu, Disp/Hoju, Agcr/At/Save. When the ten communities were arranged from mean high to low salinity, they fell in the following order: Saeu, Sude/Bahy/Lepe, Ruma/Zapa, Scma, Disp, Pope, Tyla, Disp/Hoju, Scac, Agcr/At/Save.

The total known flora of the Bear River Refuge has increased from 92 species in 1935 to 160 species in 1972. The increase came largely as a result of the introduction of "exotics" from surrounding areas. The three largest families in 1935 were (1) Compositae, (2) Chenopodiaceae, and (3) Gramineae. In 1972 the three largest families were (1) Compositae, (2) Gramineae, and (3) Chenopodiaceae. Based on past trends of vegetative development and a continuation of present management practices, coupled with a further amelioration of edaphic conditions, as new silt and a supply of relatively fresh water continue, a further increase in species diversity is predicted.

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APPENDIX

Table I. Summary of macroplot vegetation frequency data for June.

	10	14[2]	44	80	62	02	05	06	12	13	61	78	09	69	23	18	58	64	77	65	73	79	04	70	39	63	17
Agcr[1]	15																										
Save	8																										
Atnu	11																										
Brco	14																										
Lase							1				13																
Atpa			1			11		3		1	2				12						1			3	13		5
Hoju				1	15	10	15	11	14	14	6											4		3			2
Civu							11		3																		
Hean						2	10				8													3			
Disp		15	15	15	15	15	15	15	15	15	15	15	15	3	14	15	15	3	3	5	6	10		9		5	15
Saeu													15	15	15	14	2	15	15	4	5	6	14	13	1		
Bahy					1						2	7							15	15	15	8	13	15	15	14	
Sude												1		5	1		2	6	15	15	13	15	11	15	10	12	14
Lepe	9										5			7						14	15	5	15	14	15	4	
Pomo										3											2						
Posa												11															
Pora																					2						
Assp							1																				
Amal																						2					

[1]Abbreviations of species names used here are summarized in Appendix table III.

[2]Plots 48 and 56 were the same.

Table I (continued)

	43	52	51	01[3]	46	27	53	38	68	50	66	36	28	55	67	15	71	37	19	49	72	31	40	41	08[4]	57
Hoju					13							13					7	1								1
Hean														5												
Saeu	15	15	15	15																						
Scma					15	15	15	15				2														
Atpa											12			13	4	2	14									
Disp	15	15	5		13	15	13	2	1	5		11	15	14			14	2								5
Pomo					15		1				7	7				8	9	2								2
Tyla									15	15	15	15	15	15	13		2	8								
Elpl												15				3		14								
Rucr									1		11	7						4								2
Lyas											8	8														
Scac												1			15	15	15	15	15	15	13					
Ruma																						15	8	15		
Zapa																							7	15		
Pope																									15	8
Epad												2														
Trma																2										
Chal						1																				
Racy												15														
Disy															3											
Chvi																8										
Asin																14	2									
Urdi																	9									
Rusa												2														
Lemi																1					1					
Lase																	1									
Pola																			3							

[3]Plots 7, 21, 29, 33, 35, 42, 47, 74, 75, and 76 were the same.

[4]Plots 16, 20, 45, and 54 were the same.

Table II. Summary of macroplot vegetation frequency data for July.

	10	14[2]	44	62	02	05	06	12	13	61	78	09	69	23	18	58	64	77	65	73	79	04	70	39	63	17
Agcr[1]	60																									
Save	22																									
Atnu	22																									
Brco	25																									
Lase						1				40																
Atpa			1		15		6	1						23						4			3	28		18
Hoju				31	30	56	25	40	45												8		8			
Civu						30		4																		
Hean					3	19				17													3			
Disp		60	60	60	60	60	60	60	60	60	60	60	16	51	1	60	12	6	16	13	18		35		14	57
Saeu												54	60	60	53	4	60	54	2	16		47	47	2	3	
Bahy											17		6				7	35	60	57	58	44	50	59	49	
Sude											6		19	2	45	11	12	58	35	42	58	25	49		45	51
Lepe	9									16			21						37	45	11	43	37	48	11	
Pomo					1				11														14			
Posa	1											35														
Pora																				6						
Assp					1	1																				
Amal																					5					

[1] Abbreviations of species names used here are summarized in Appendix table III.

[2] Plots 48, 56, and 80 were the same.

Table II (continued)

	43	52	51	01[3]	76	46	27	53	38	68	50	66	36	28	55	67	15	71	37	19	49	72	31[4]	08[5]	16	20	57
Hoju						5							3														
Hean															10												
Saeu	52	60	60	60	55																						
Scma						57	60	60	60																		
Atpa								2			1	41	2	1	49	3	13	54	2								
Disp	59	58	12			60	60	50			19		54	57	49			51	32								18
Pomo						56		1				35	45	20	1		25	20	2								3
Tyla										60	60	60	36	60	60	53		2	19								
Elpl											1		45				5		12								
Rucr												26	23						2								2
Lyas												19	40				11	6	1								
Scac											8		3			42	60	58	60	60	60	52					
Ruma																							30				
Zapa																							30				
Pope																								60	15	40	54
Epad													1				1										
Trma																	6										
Chal							3				2																
Racy													53														
Disy																3											
Chvi																	9										
Asin																	7	4									
Urdi																		25							2		
Lemi																											
Civu												2			1												
Sude		1																									

[3]Plots 7, 21, 29, 33, 35, 42, 47, 74, and 75 were the same.

[4]Plots 40 and 41 were the same.

[5]Plots 45 and 54 were the same.

Table III. Summary of species names and symbols.

Symbol	Species
Agcr	*Agropyron cristatum*
Amal	*Amaranthus albus*
Asin	*Asclepias incarnata*
Assp	*A. speciosa*
Atnu	*Atriplex nuttallii*
Atpa	*A. patula hastata*
Bahy	*Bassia hyssopifolia*
Brco	*Bromus commutatus*
Cede	*Ceratophyllum demersum*
Chal	*Chenopodium album*
Chvi	*Chrysothamnus viscidiflorus*
Civu	*Cirsium vulgare*
Disp	*Distichlis spicata stricta*
Disy	*Dipsacus sylvestris*
Elpl	*Eleocharis palustris*
Elpr	*E. parvula*
Epad	*Epilobium adenocaulon*
Hean	*Helianthus annuus*
Hoju	*Hordeum jubatum*
Lase	*Lactuca serriola*
Lemi	*Lemna minor*
Lepe	*Lepidium perfoliatum*
Lyas	*Lycopus asper*
Pola	*Polygonum lapathifolium*
Pomo	*Polypogon monspeliensis*
Pope	*Potamogeton pectinatus*
Pora	*Polygonum ramosissimum*
Posa	*Poa sandbergii*
Racy	*Ranunculus cymbalaria saximontanus*
Rucr	*Rumex crispus*
Ruma	*Ruppia maritima*
Rusa	*Rumex salicifolius*
Saeu	*Salicornia europaea rubra*
Save	*Sarcobatus vermiculatus*
Scac	*Scirpus acutus*
Scma	*S. maritimus paludosus*
Sude	*Suaeda depressa*
Trma	*Triglochin maritima*
Tyla	*Typha latifolia*
Urdi	*Urtica dioica gracilis lyallii*
Zapa	*Zannichellia palustris*

Table IV. Salinities and glass electrode pH's of the composite 0.1 m surface soil samples.

Plot	Conductance (μmhos)	% Salt	pH
5	275	0.1	8.50
10	185	0.1	8.55
15	655	0.2	8.25
20	1260	0.4	8.70
35	17500	5.3	8.25
40	2385	0.7	8.40
45	395	0.1	8.85
50	1570	0.5	8.55
55	2465	0.7	8.30
65	8335	2.5	8.40
70	13135	3.9	9.05
75	12235	3.7	8.60
80	1505	0.5	9.20

Table V. A comparison of dye-determined and glass electrode pH's for the July 0.3 m core soil samples.

Plot	pH		Plot	pH	
	Dye	Elec.[1]		Dye	Elec.
1	8.6	8.70	45	9.0	9.60
2	8.7	8.90	46	8.7	8.60
4	8.7	8.50	47	9.1	9.35
5	8.6	8.95	48	8.9	8.90
6	8.3	8.75	49	8.7	8.80
7	8.6	8.60	50	8.9	8.80
8	8.3	8.55	51	9.2	9.20
9	8.2	8.50	52	9.4	9.50
10	8.9	9.35	53	8.7	9.10
12	8.3	8.90	54	8.7	8.50
13	8.8	9.35	55	8.7	8.85
14	9.0	9.15	56	9.1	9.45
15	8.4	8.90	57	8.6	8.30
16	8.6	9.15	58	8.9	8.90
17	9.4	9.60	61	8.8	9.15
18	8.7	8.75	62	8.7	9.10
19	8.5	8.55	63	9.0	9.10
20	8.6	8.65	64	8.8	8.90
21	8.8	8.95	65	8.5	8.55
23	8.1	8.50	66	9.3	9.20
27	8.6	8.85	67	8.5	8.50
28	8.6	8.70	68	8.5	8.30
29	8.7	8.90	69	8.7	9.00
31	8.0	8.40	70	9.1	9.20
33	8.2	8.40	71	8.6	8.50
35	8.4	8.45	72	8.7	8.45
36	8.5	8.40	73	8.7	8.80
37	8.4	8.30	74	8.8	8.95
38	8.7	8.80	75	8.8	9.00
39	8.0	8.70	76	8.8	8.95
40	8.3	8.30	77	9.3	9.05
41	8.7	8.80	78	8.6	8.80
42	8.7	8.60	79	8.4	8.15
43	8.2	8.60	80	9.2	9.40
44	8.6	8.80			

[1]For 1:5, soil:distilled water slurries.

Table VI. Bulk densities of composite 0.1 m surface soil samples.

Plot	June	July	August	Average
5	1.17	1.35	----	1.26
10	1.44	1.38	1.49	1.44
15	1.19	1.32	1.16	1.22
20	1.50	1.36	1.50	1.45
35	----	1.60	----	1.60
40	1.45	1.54	1.49	1.49
45	1.47	1.54	1.59	1.53
50	1.37	1.49	1.41	1.42
55	1.25	1.29	1.26	1.27
65	1.40	1.55	----	1.48
70	1.47	1.58	1.50	1.52
75	1.73	1.66	1.46	1.62
80	1.74	1.49	----	1.62

Table VII. Moisture equivalents and textural analyses of composite 0.1 m surface soil samples.

Plot	ME[1]	% Sand	% Silt	% Clay	Textural Class
5	36	18	78	4	Silt-Loam
10	26	24	56	20	Silt-Loam
15	49	16	80	4	Silt
20	35	30	52	18	Silt-Loam
35	33	10	80	10	Silt
40	49	16	82	2	Silt
45	35	26	44	30	Clay-Loam
50	24	24	60	16	Silt-Loam
55	56	12	82	6	Silt
65	34	18	78	4	Silt-Loam
70	25	26	68	6	Silt-Loam
75	21	14	48	38	Silty-Clay-Loam
80	48	32	48	20	Loam

[1]Moisture equivalents are listed as percent water retained at field capacity.

Table VIII. Dry and wet colors of the 0.3 m core soil samples.

Plot	Dry V/C[1]	Dry Color[2]	Wet V/C[3]	Wet Color	Plot	Dry V/C	Dry Color	Wet V/C	Wet Color
1	7/2	LG	5/3	B	45	7/1	LG	5/1	G
2	7/1	LG	5/2	GB	46	7/1	LG	5/1	G
4	7/1	LG	5/1	G	47	7/1	LG	5/1	G
5	7/1	LG	6/2	LBG	48	7/1	LG	5/1	G
6	7/1	LG	6/1	LG	49	7/1	LG	5/2	GB
7	7/1	LG	6/1	LG	50	7/1	LG	5/2	GB
8	6/1	LG	5/1	G	51	7/1	LG	5/1	G
9	6/1	LG	5/1	G	52	7/1	LG	5/1	G
10	7/1	LG	6/2	LBG	53	7/1	LG	5/1	G
12	7/1	LG	5/2	GB	54	7/1	LG	5/1	G
13	6/2	LBG	5/1	G	55	7/1	LG	5/1	G
14	7/1	LG	5/2	GB	56	7/1	LG	5/1	G
15	7/1	LG	5/2	GB	57	7/1	LG	5/1	G
16	7/1	LG	5/1	G	58	7/1	LG	5/2	GB
17	7/1	LG	5/2	GB	61	7/1	LG	5/1	G
18	7/1	LG	5/2	GB	62	7/1	LG	5/2	GB
19	7/1	LG	5/1	G	63	7/1	LG	5/2	GB
20	6/1	LG	5/1	G	64	7/1	LG	5/1	G
21	7/1	LG	5/2	GB	65	7/1	LG	6/2	LBG
23	7/1	LG	5/2	GB	66	7/1	LG	6/2	LBG
27	7/1	LG	5/2	GB	67	7/1	LG	5/2	GB
28	7/1	LG	5/2	GB	68	7/1	LG	5/2	GB
29	7/1	LG	5/1	G	69	7/1	LG	5/2	GB
31	7/1	LG	5/1	G	70	7/1	LG	6/2	LBG
33	7/1	LG	5/2	GB	71	7/1	LG	5/2	GB
35	7/1	LG	6/2	LBG	72	7/1	LG	6/2	LBG
36	7/1	LG	5/2	GB	73	6/1	LG	4/2	DGB
37	7/1	LG	5/2	GB	74	7/1	LG	6/2	LBG
38	7/1	LG	5/1	G	75	7/1	LG	6/1	LG
39	6/1	LG	6/2	LBG	76	7/1	LG	6/1	LG
40	7/1	LG	5/1	G	77	7/1	LG	5/1	G
41	7/1	LG	6/2	LBG	78	7/1	LG	5/2	GB
42	7/1	LG	6/1	LG	79	7/1	LG	5/2	GB
43	7/1	LG	5/1	G	80	7/1	LG	6/2	LBG
44	7/1	LG	5/2	GB					

[1]Value/Chroma

[2]LG = light gray; LBG = light brownish gray; B = brown; G = gray; GB = grayish brown; DGB = dark grayish brown

[3]All colors were determined by comparison with hue page 10YR of the Munsell soil color chart.