CHARACTERISTICS OF WETLAND HABITATS
AND WATERFOWL POPULATIONS
IN OKLAHOMA

By

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Bachelor of Science

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Columbia, Missouri

1978

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
December, 1980

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ACKNOWLEDGMENTS

I sincerely thank my major advisor, Dr. Paul A. Vohs, Jr., for the advice, support, and freedom that he provided during this study.

I gratefully thank the many individuals who assisted in this extensive project. I especially acknowledge the landowners who allowed access to their property. C.P. Boydstun, H.W. Browers, R.W. Cannon, P.M. Domanski, W.R. Eddleman, C.E. Endicott, D.H. Latham, C.T. Patterson, R.J. Prokop, and W.J. Willis helped collect data; H.W. Browers, P.M. Domanski, and C.P. Boydstun helped compile and code data for keypunching; and J.A. Bissonette, J.H. Eve, J.M. Gray, H.R. Jarrell, O.E. Maughan, and O.T. Sanders provided logistic support. J.L. Wilhm and students provided the conductivity bridge, J.A. Litvaitis and F.A. Stormer provided information on playa lakes, and L.M. Cowardin provided helpful suggestions on wetland classification. W.D. Warde wrote most of the computer programs and conducted the cluster analyses; D. Holbert wrote the time series analysis computer program; and committee members O.E. Maughan, F. Schitoskey, Jr., and W.D. Warde provided editorial assistance. L.H. Fredrickson and F.L. Knopf reviewed portions of the manuscript and J.M. Gray provided irreplaceable secretarial assistance. L.M. Due and C.R. Criswell conducted or assisted in the aerial censuses of reservoirs, D. Love provided midwinter inventory data, and the staffs of Optima, Salt Plains, Washita, Sequoyah, and Tishomingo national wildlife refuges provided data on production.

This study was supported by Pittman-Robertson Project W-128-R-3: the Oklahoma Cooperative Wildlife Research Unit, U.S. Fish and Wildlife Service, Oklahoma Department of Wildlife Conservation, Wildlife Management Institute, and Oklahoma State University cooperating; and by a National Wildlife Federation grant to the author.

I especially thank my parents for their advice, interest, and support throughout my educational career.

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INTRODUCTION

This thesis is comprised of 3 manuscripts written in formats suitable for submission to national scientific journals and research publications and presented as chapters II, III, and IV. Chapter II, "Environmental Characteristics of Oklahoma Wetlands" was written in a format for publication as ENVIRONMENTAL SERIES NUMBER 4, ARTS AND SCIENCES RESEARCH, OKLAHOMA STATE UNIVERSITY. Appendix A contains information referenced in this manuscript and will be included in the publication. Chapter III, "Numbers, Distribution, and Habitats of Waterfowl Wintering on Oklahoma Wetlands" was written in the JOURNAL OF WILDLIFE MANAGEMENT format. Appendix B was written as an appendix to this manuscript and will be submitted with the manuscript for publication. Chapter IV, "Numbers and Distribution of Waterfowl Breeding on Oklahoma Wetlands" was written in the SOUTHWESTERN NATURALIST format. Appendix C contains information referenced throughout the thesis or otherwise tabulated, and will not be submitted for publication.

CHAPTER II

ENVIRONMENTAL CHARACTERISTICS OF OKLAHOMA WETLANDS

BY

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Environmental Series Number 4
Arts and Sciences Research
Oklahoma State University
Stillwater, Oklahoma
1981

ABSTRACT

The basis for management of a resource is the availability of fundamental data concerning the resource. This study of Oklahoma wetlands, other than large impoundments, was undertaken to evaluate the importance of wetlands in the state to wintering and migrating waterfowl on a quantitative basis from June 1978 to March 1980. Physical, chemical, and biological attributes of wetlands occurring on a stratified two stage random sample of ¼-sections of land area proportional to 25 physiographic strata were evaluated. The initial minimum number of ¼-sections evaluated was 448, but 64 additional ¼-sections were added to total 512 for later surveys. The "Classification of wetlands and deepwater habitats of the United States" provided the major guidance for wetland classification in this study. The 25 physiographic strata were combined to 6 to increase sample sizes for statistical analysis.

The estimated small lacustrine and palustrine wetland basins with water present ranged from 162,426 in Dec-Jan 1978-79, to 222,028 in Jan-Feb 1980. Small lacustrine and palustrine wetlands ranged from 31,927 to 88,963 ha of surface water while streambeds varied from 50,110 to 89,779 ha of surface water. All basins statewide (including reservoirs) varied from 312,436 to 375,604 ha surface water. Seasonal and long term dynamics of wetlands in Oklahoma were apparent. Maximum ha of surface water and wetland basin numbers occurred in summer; the low occurred in early winter.

An initial 60 wetland basin types were combined into 25 wetland groups to facilitate analysis. Palustrine basins comprised from 85-86%,

small lacustrine basins comprised from 7-8%, and rivers comprised from 6-8% of the statewide basins. From 80-83% of the statewide basins (excluding reservoirs) were man-made palustrine, while only 3-5% were natural palustrine. Diversity of wetland types was greatest in province 4 (southcentral) followed by province 2 (eastcentral). Province 6 (western and panhandle) was least variable. Natural wetlands were most common in provinces 4 and 6. Moist soil and emergent plant compositions were significantly different among physiographic provinces and wetland types.

In general, riverine, small lacustrine, and natural wetland basins had significantly higher phenolpthalein alkalinity than did man-made palustrine basins. Wetlands in western provinces had higher phenolpthalein and total alkalinities than did wetlands in eastern provinces. Most wetlands were slightly acidic, especially during fall and winter. Conductivity varied greatly among wetland groups and seasons, but wetlands in western provinces had the highest conductivities (366-388 umhos) and the wetlands in the eastern provinces the lowest (188-297 umhos). Greatest light penetration (46-47 cm) occurred in early winter; the low point (28-40 cm) occurred in summer. Light penetration was inversely related to precipitation.

When data for all seasons were combined, wetland groups were significantly different from each other in all respects. Three-dimensional representations of ecological distributions of palustrine wetland groups indicated that ecological positions were dynamic over seasons. Wetland groups were most distinct during summer and fall and were most clustered during late winter. When data for all seasons were combined, wetlands dominated by submergent and emergent vegetation and natural semipermanently and seasonally flooded mud substrate wetlands were closely clustered. Oil pool, natural scrub/shrub, and impounded and natural forested wetland groups were most distinct.

The estimate for total area of surface water in Oklahoma during this study represented approximately 1% of the total surface area in Oklahoma. Oklahoma's surface water area is dominated by man-made impoundments, and natural wetlands are both rare and unique. Oklahoma wetlands are cyclic on a seasonal and long term basis in relation to precipitation, and the cyclic nature provides dynamic changes in physical, chemical, and biological characteristics. Increased precipitation causes an increase in wetland density and diversity; drought results in loss of shallow water areas, but allows the germination and growth of moist soil and emergent plants. Most natural wetlands in Oklahoma are bottomland floodplain wetlands created and maintained by river overflows and saturated soils. Maintenance of most remaining natural wetlands in their current condition is of high priority to maintain the diversity of the systems and the related biological productivity. Proposals and practices that relate to floodplain development should consider the values of flooding and river overflows in maintaining the natural wetlands.

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INTRODUCTION

Information concerning the physical and biological characteristics of aquatic habitats in Oklahoma is lacking, especially data concerning shallow wetland and riverine systems. Major changes in numbers, distribution, and composition of Oklahoma wetland basins and deep-water habitats have occurred during recent decades due to extensive drainage, land clearing, channelization and ditching (Barclay 1978), siltation (Featherly 1940), inundation by reservoirs, and the construction of numerous farm ponds (Oklahoma Water Resources Board 1976).

The extent and results of these and similar changes in numbers of natural wetland basins and riverine basins, stream lengths, ha of surface water, number of wetland types, and dynamics are difficult to evaluate because of the lack of historical, recent, intensive, and extensive data regarding these habitats. Similar changes in prairie and southcentral U.S. areas have, however, resulted in extensive destruction (e.g. Shaw and Fredine 1956, Holder 1970, Sternitzke and Christopher 1976, Korte and Fredrickson 1977, Barclay 1978, Fredrickson 1979). Baseline data on numbers, distribution, and composition of wetland basins are desired to compare, interpret, and evaluate both current and future proposed changes in Oklahoma's wetlands.

The ecological and economical values provided by wetlands and rivers within Oklahoma are irreplacable./Wetlands are among the most productive biological systems in the world (Westlake 1963, Lieth 1975); they serve as important hydrological recharge areas (Carter et al. 1978), and regulate water flows following high rainfall and flooding. The wetlands modify and slow the rate of impending flow on downstream waterways (Niering 1968)./Wetlands act as sinks or valves to regulate or trap nutrients flowing from surrounding terrestrial and wetland systems (Lee et al. 1975) and, under certain circumstances serve as wastewater treatment sites (Sloey et al. 1978). Wetlands provide vital habitat for many resident and migratory birds, and for mammals, reptiles, fish, and invertebrates. Wetlands are extensively used for livestock watering, water sources for irrigation of crops, for drinking water, for transportation lanes for industry, and for recreation.

This extensive statewide study evaluated the physical, chemical, and vegetational characteristics of Oklahoma wetlands. Because of the diversity of wetland types and the continuum of distinction between dry and wet environments, a single, ecologically sound definition of wetlands was difficult (Cowardin et al. 1979). We included shallow and deep-water habitats, either natural or man-made, but excluded large reservoirs in our study. Palustrine, small lacustrine, and riverine basins that occurred on our sample throughout the state were included, but only those classified as seasonally flooded, semipermanently flooded, intermittently exposed, or permanently flooded. Temporary and sheetwater wetland areas could not be adequately addressed under our study design because of their sporadic appearance on a seasonal and daily basis, the extremely short inundation period, and the difficulty in determining basin areas.

Although a few studies have been conducted on the waterline recession (Harper and Stout 1944), limnology (Brown 1950), turbidity and productivity (Knudson 1970, Epperson 1972), and vegetation (Hefly 1937, Kelting and Penfound 1950, Penfound 1953, Collins and Penfound 1966) of wetlands within Oklahoma; these studies concentrated on a small sample of wetland areas, were conducted on man-made habitats or phenomenon, were of short duration (usually during the growing season), provided little information on classification or ecological description of wetland basins studied, and provided minimal data related to physical dynamics. The specific objectives of this study included determining numbers, distribution, composition, and gross dynamics as related to physical, chemical, and vegetational aspects of Oklahoma wetlands. Intensive collection of data was precluded by the nature and extent of the study.

METHODS, MATERIALS, AND DESCRIPTION OF PHYSIOGRAPHIC PROVINCES

Sampling Scheme

A stratified random sample of ¼-sections (160 acres) of land area distributed proportionately to the area of the 25 physiographic strata (Curtis and Ham 1957) present throughout Oklahoma was used to sample wetland habitats. A similar sampling scheme was used to sample wetlands and waterfowl populations in North Dakota (Stewart and Kantrud 1972a:770-773), and South Dakota (Brewster et al. 1976, Ruwaldt et al. 1979). Intersections of range and township lines were numbered and 2-stage cluster sampling was used to randomly select cluster centers, where 1 ¼-section was randomly drawn from each of the 9 mi^2 quadrants surrounding the center. Therefore all ¼-sections within Oklahoma theoretically had an equal chance of being selected.

Initially, 492 ¼-sections were drawn. Denial of permission for access and errors in field work made 33-44 of the ¼-sections unusable from June 1978-April 1979. Sixty-four new ¼-sections were randomly selected in April 1979 to replace the ¼-sections where permission for access was refused, and to slightly enlarge the total sample. An average of 43.1% of the 492 old, and 45.3% of the 64 new ¼-sections had wetland basins with water present. Wetland composition and distribution within seasonal dynamic constraints also remained similar after the 64 new ¼-sections were added. The statewide sample appeared adequate, and no differential bias was introduced by the addition of the 64 additional ¼-sections.

To facilitate data analyses and interpretation, the original 25 physiographic strata were combined into 6 physiographic provinces (Fig. 1) based on wetland, physiographic, and climatic similarities. These 6 physiographic provinces were used in all subsequent data analyses.

Field and Laboratory Work

All wetland habitats on the ¼-sections were visited once during summer 1978 (26 Jun-18 Aug 1978, hereafter referred to as SM78), early winter 1978-79 (18 Dec 1978-20 Jan 1979, hereafter WI), late winter 1978-79 (29 Jan-23 Feb 1979, hereafter WII), spring 1979 (12 Mar-2 Apr 1979, hereafter SP79), summer 1979 (30 Apr-8 Jun 1979, hereafter SM79), fall 1979 (31 Oct-7 Nov 1979, hereafter F79), early winter 1979-80 (17 Dec 1979-5 Jan 1980, hereafter WIII), late winter 1979-80 (15 Jan-18 Feb 1980, hereafter WIV), and spring 1980 (3 Mar-22 Mar 1980, hereafter SP80).

At each visit, cover maps of wetland basins with water present were drawn for basin configuration, surface water configuration, and emergent vegetation/open water interspersion on acetate overlays of aerial photographs. The % of the basin area covered by surface water and the %

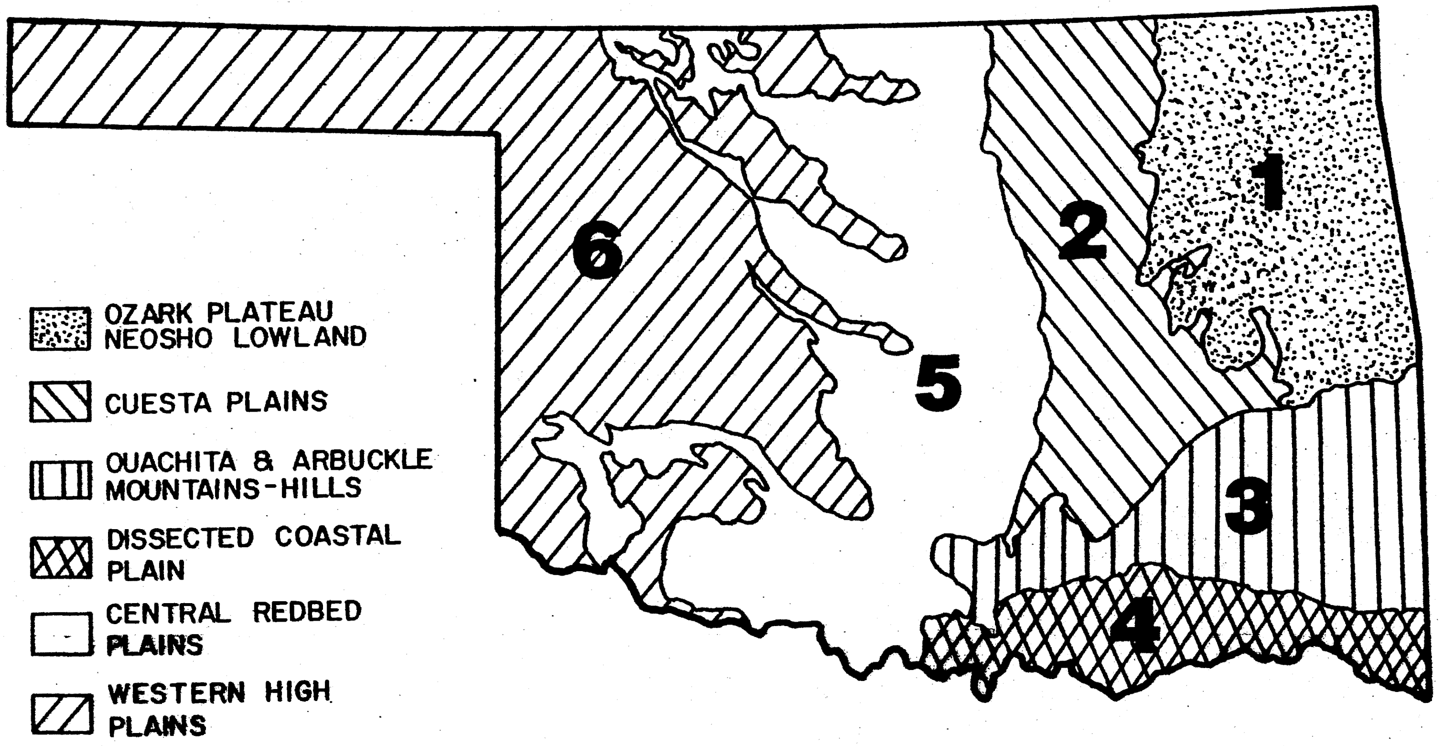

Fig. 1. Physiographic provinces of Oklahoma that served as a basis for analysis of wetland dynamics and characteristics, 1978-80.

of the surface water area not overgrown with emergent vegetation were visually estimated. Streams were mapped from the entering to exiting points on the ¼-sections, and the total number of wetland basins with water present on the ¼-sections was recorded.

The 4 most dominant moist soil and emergent plant species were determined visually, and the average height category in meters of each species was measured. Most wetland basins had less than 4 moist soil and emergent species present, therefore 0-4 species were potentially recorded as present. Groups of hardwood tree species often occurred together at wetland basins (Hefley 1937, Ware and Penfound 1949, Kelting and Penfound 1950, Rice 1965) and were recorded as "various trees". The species in this group included any combination of American elm (*Ulmus americana*), pecan (*Carya illinoensis*), green ash (*Fraxinus pennsylvanica*), sugarberry (*Celtis laevigata*), hackberry (*Celtus occidentalis*), black walnut (*Juglans nigra*), cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), post oak (*Quercus stellata*), blackjack oak (*Quercus marilandica*), pin oak (*Quercus palustris*), and bur oak (*Quercus macrocarpa*). Only genera were recorded for many species in Cyperacea (e.g. *Carex*) because of the close similarities among species and indistinguishable features during winter and spring.

The presence of submergent species was visually determined from the shore or during wading. Conglomerations of algae (usually *Cladophora*) was frequently observed in shallow water and when algae was observed in littoral areas, the category "littoral epipelic algae" was recorded as present.

A surface sample of water was taken from 2-4 areas within each wetland basin and combined. In most cases the combined samples were analyzed either immediately at the wetland or at the end of the day. Both short range (0.2-0.4 intervals) and long range (1.0 intervals) pH paper were used to quantify pH. Alkalinity was determined by titrating 100 ml of the sample to phenolpthalein and methyl purple endpoints using 0.02N H_2SO_4. A few water samples were held 3-4 days before alkalinity could be determined, but control water samples analyzed immediately and after 5-10 days showed little change (i.e. less than 5 ppm). One hundred two ml of the combined water sample were stored for 1-3 weeks and analyzed for conductivity using a conductivity bridge. Light penetration was determined at each visit using a secchi disk.

Where feasible, wetland basins were waded during SM78 to determine depth contours and the % of the surface water area less than 1 m deep. During subsequent visits, the % of surface water area less than 1 m deep was estimated using the known depth contours and present water levels of each wetland basin. The % of the surface water area of each wetland basin that was covered by ice was recorded during winter and spring.

Land use surrounding and on the shorelines of the wetland basins was recorded at each visit using 1 or more of 8 categories (human habitation or building within 0.64 km, cropland, grazing, hayland and ungrazed pasture, idle, game management, forestland, and other). If wetlands were man-made, landowners or tenants were asked to provide the age of the pond in years. Conflicting information relating to pond age was obtained, and the data were unusable.

The wetland basin area (ha), the surface water area (ha), the surface water area not overgrown with emergent vegetation (ha), and stream length on ¼-sections were measured with a Numonics 1224 digitizer from cover maps drawn in the field. A shoreline development index (Lind 1974) was calculated for each wetland. The distance (km) of each wetland basin to the nearest large reservoir (greater than 445.3 ha) and the distance (m) to the nearest permanent stream were measured from aerial photographs and county maps.

Data were placed on computer cards and analyzed using programs of the Statistical Analysis Systems (SAS) (Barr et al. 1972, 1976, 1979). Most data on physical, chemical, and vegetational attributes of wetland habitats were analyzed and presented primarily in regard to the 6 physiographic provinces (Fig. 1). However, data analyzed in relation to individual wetland types were presented within specific tables of this report.

Description of Physiographic Provinces

Province 1 (Fig. 1) (Ozark Plateau and Neosho Lowland) contained 2,453,846 ha and included the Boston Mountains, Ozark Plateau, Claremore Cuesta Plains, Neosho Lowland, and Arkansas Hill and Valley Belt physiographic strata of Curtis and Ham (1957). Province 2 (Cuesta Plains) contained 2,526,286 ha and included the Eastern Standstone Cuesta Plains and Northern Limestone Cuesta Plains. Province 3 (Ouachita and Arbuckle Mountains-Hills) contained 1,876,153 ha and included Beavers Bend Hills, Ridge and Valley Belt, and Hogback Frontal Belt of the Ouachita Mountains; and the Ardmore Basin. Province 4 (Dissected Coastal Plain) contained 1,151,770 ha. Province 5 (Central Redbed Plains) contained 4,431,414 ha. Province 6 (Western and High Plains) contained 5,670,110 ha and included the Granite

Mountain Region and Limestone Hills of the Wichita Mountain Province, the Western Sandstone Hills, Cimarron Gypsum Hills, Weatherford Gypsum Hills, Mangum Gypsum Hills, Western Sand Dune Belts, High Plains, and the Western Redbed Plains. Other climatic, vegetational, landscape, drainage, and soils descriptions of the various areas of Oklahoma were presented by Bruner (1931).

CLIMATIC CONDITIONS DURING THE STUDY

Climatic conditions including the amount of solar radiation, temperature, precipitation, relative humidity, and cyclic regularity directly influence the basic hydrological regime of wetland basins (Gosselink and Turner 1978). Attributes of the hydrologic regime including source, velocity, renewal rate, and timing influence chemical and physical properties of wetlands, cause specific biotic response, and determine the overall structure and function of wetland ecosystems (Harris et al. 1977, Gosselink and Turner 1978). Prairie and southwestern areas of the United States, including Oklahoma, are often subject to drought, long hot summers, high winds, and high evapotranspiration rates. These factors influence water levels, limnology, and plant communities of wetlands (Harper and Stout 1947, Weller and Spatcher 1965, Sublette and Sublette 1967, van der Valk and Davis 1978).

All weather data were obtained from the U.S. Dept. of Commerce (1941-80) for the 9 weather reporting sections (i.e. west, central, and east sections of north, central, and south Oklahoma). All sections had similar temperature and precipitation patterns during this study, and central Oklahoma is graphically presented (Figs. 2 and 3) as

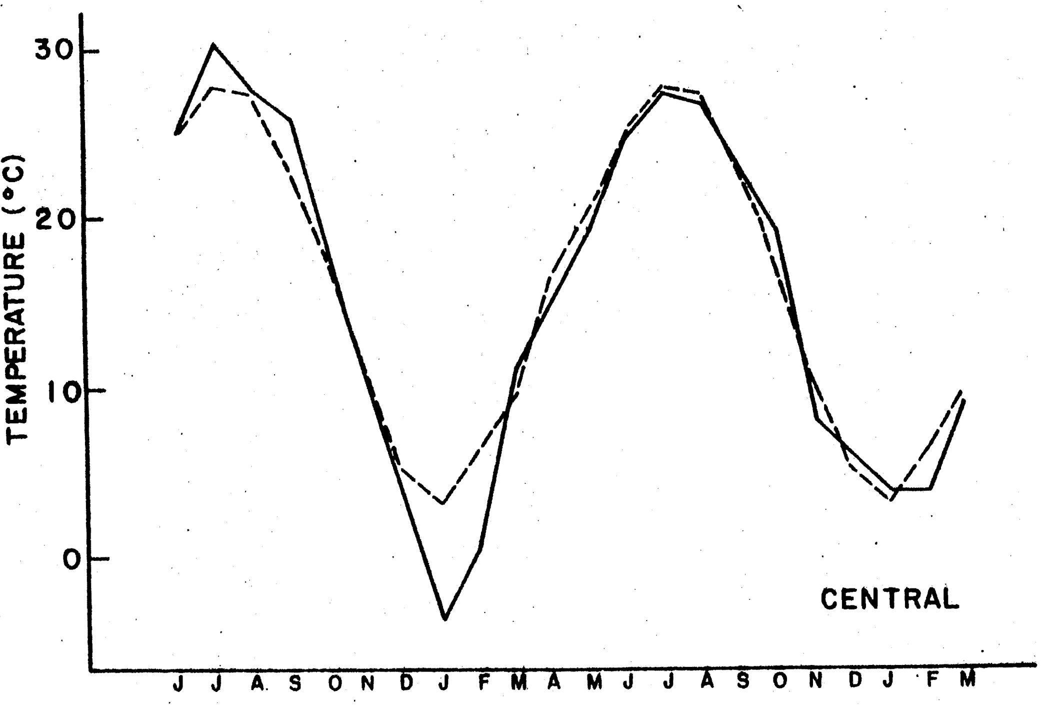

Fig. 2. 1891-1979 mean (dashed line) and Jun 1978-Mar 1980 observed (solid line) monthly temperatures for central Oklahoma.

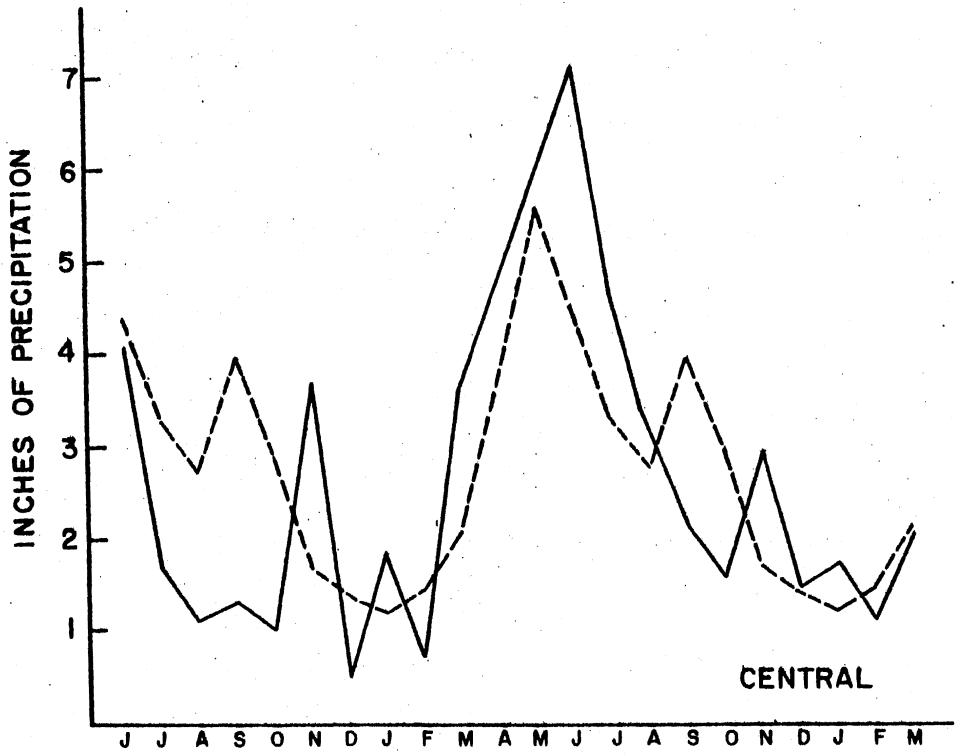

Fig. 3. 1891-1979 mean (dashed line) and Jun 1978-Mar 1980 observed monthly precipitation for central Oklahoma.

representative of all sections. Mean monthly temperatures for all sections were close to normal during the study with the exception of June-August 1978 and December-January 1978-79 (Fig. 2). Summers are normally long and hot and winters short and relatively mild in Oklahoma. However, Summer 1978 was hotter than normal and winter 1978-79 (Dec-Jan) was the 2nd coldest on record since 1891.

Seasonal cycles of precipitation are normally present for all Oklahoma sections and were present during this study (Fig. 3). The annual precipitation cycle is bimodal (maximum precipitation during late spring and secondarily during early fall) in all areas of the state except the panhandle, where no secondary fall peak occurs. Monthly precipitation in all sections (Fig. 3) was well below normal during summer 1978 and above normal during summer 1979. In general, winter precipitation was slightly higher in 1979-80 than 1978-79.

Long term as well as annual cycles of precipitation and drought are common for many areas of the prairie and central U.S. (Weller and Spatcher 1965, Harris et al. 1977), and often occur in 10-20 year cycles. Long term precipitation cycles seem to occur in most Oklahoma sections also (Fig. 4). The long term precipitation pattern in the panhandle (Fig. 4a) is representative of most of province 6; the precipitation pattern of the northeast (Fig. 4b) is representative of province 1; the precipitation pattern of the central (Fig. 4c) is representative of provinces 2, 4, and 5; and the precipitation pattern of the southeast (Fig. 4d) is representative of province 3. A time series analyses using the Fisher's kappa test (probability tables from Fuller 1976:284) and the Bartlett's Kolmogorov-Smirnov test (probability tables from Beyer 1968:426) were conducted to determine

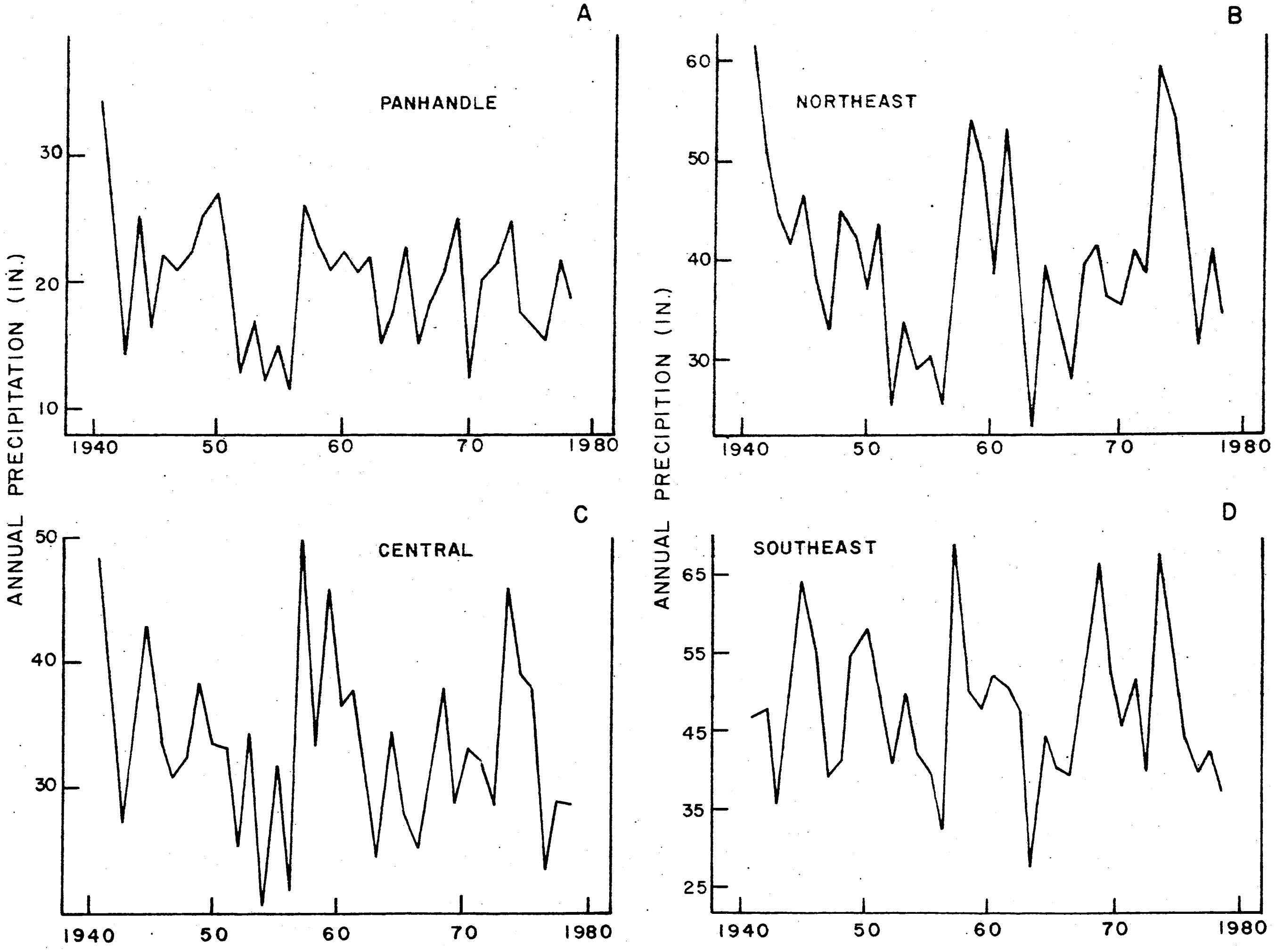

Fig. 4. Annual precipitation (inches) for a) panhandle, b) northeast, c) central, and d) southeast Oklahoma 1941-79.

predominant cycle trends in annual precipitation for all 9 sections of Oklahoma. Approximately 2-year and 12-19-year cycles were most prominent, but none were significant ($\underline{P}>0.05$). Year to year fluctuations appeared to override the long term cycles in significance tests, but visual observations revealed regular peaks and lows in annual amounts of precipitation. Peaks of annual precipitation appeared to occur every 12-18 years in NC, C, SC, NE, EC, and SW Oklahoma from 1941-79. For example, annual precipitation highs for central Oklahoma occurred in 1941, 1957, and 1973 (Fig. 4c). Annual precipitation also appeared to fluctuate regularly in SE and WC Oklahoma, but fluctuations were wider and patterns less obvious. Regular fluctuations in precipitation were difficult to analyze for the panhandle sections.

This study occurred 5-7 years after the recent precipitation peak of about 1973. Precipitation during 1978 seemed at the low trough of the long term cycle, and greater precipitation during 1979 may indicate the beginning of the wet portion of the cycle.

A deficit occurs in the annual water budget for most of Oklahoma. Annual evaporation from lakes is from 2-3 times the average annual precipitation in western and central Oklahoma and from 0.9-1.5 times the average annual precipitation in eastern Oklahoma (Oklahoma Water Resources Board 1976). Together, evapotranspiration and percolation amount to approximately 85% of the statewide average annual rainfall. Average annual runoff ranges from 0.51 cm in the panhandle to 50.8 cm in the southeast.

RESULTS

Physical Attributes of Wetlands

Numbers and densities. The number of large reservoirs (>445.3 ha) present in Oklahoma was known (Oklahoma Water Resources Board 1976). The number of palustrine and small lacustrine (<445.3 ha) wetland basins and streambed km with water present was estimated from the number of wetland basins present on random ¼-sections to a statewide and province level (Table 1). All estimates were derived from the 6 physiographic provinces rather than from the original 25 physiographic strata. Similar estimates of wetland basins and of breeding waterfowl have been made in North Dakota (Stewart and Kantrud 1972) and South Dakota (Brewster et al. 1976, Ruwaldt et al. 1979).

Forty-six reservoirs were present in Oklahoma. Most occurred in provinces 1 and 6; province 4 had comparatively few. The estimated small lacustrine and palustrine wetland basins with water present ranged from 162,426 in WI to 222,028 in WIV (Table 1). The number of wetland basins with water present changed significantly over survey seasons in all provinces; the greatest fluctuation occurred in provinces 1, 2, 5, and 6.

Two dynamic trends in the number of wetland basins with water present occurred during this study. First, within an annual time frame, a seasonal cycle was evident. In all provinces, the highest numbers occurred during summer, then decreased during fall to a low during early winter. Numbers increased during late winter and continued to increase in spring, presumably to the following summer peak. Second, a gradual increase in numbers of wetland basins occurred from the 1st

Table 1. Number of reservoirs greater than 445.2 ha; and the estimated number of permanently, semipermanently, and seasonally flooded palustrine, small lacustrine, and streambed km basins (95% confidence intervals in parentheses) with water present in Oklahoma during 1978-80.

		Season								
	Province	SM78	WI	WII	SP79	SM79	F79	WIII	WIV	SP80
Large reservoirs	1	10	10	10	10	10	10	10	10	10
	2	8	8	8	8	8	8	8	8	8
	3	6	6	6	6	6	6	6	6	6
	4	2	2	2	2	2	2	2	2	2
	5	11	11	11	11	11	11	11	11	11
	6	9	9	9	9	9	9	9	9	9
Total		46	46	46	46	46	46	46	46	46
Palustrine and small lacustrine	1	18271	18271	17225	18948	29918	29307	31415	32412	32911
	2	40434	41852	42498	43195	54621	51818	54257	54866	52428
	3	13467	15507	15507	15916	16998	14686	14085	15877	15083
	4	23019	24065	26951	28029	26412	26412	28569	28569	28569
	5	58660	56324	57339	59727	73485	70665	73488	76293	74049
	6	11299	6407	7062	8613	15762	15179	13427	14011	12260
Total		165150± (29852)	162426± (30569)	166582± (31173)	174428± (25886)	217196± (32365)	208067± (33576)	215241± (33045)	222028± (33766)	215300± (33717)
Streambed	1	3241	3234	3293	3234	2927	2415	2927	2927	2927
	2	889	1371	1347	1905	2257	1667	2293	2293	2293
	3	635	862	862	1313	1243	1086	1230	1285	1214
	4	2040	2410	2483	2483	2483	2483	3035	3035	3035
	5	1755	2303	4018	5481	6386	5260	6386	6386	6386
	6	0	0	0	144	211	328	211	211	211
Total		8560± (8199)	10180± (8484)	12003± (9101)	14560± (10737)	15507± (9235)	13239± (9655)	16082± (9103)	16137± (9207)	16066± (9106)

survey (SM78) to the last (SP80). Using linear regression analyses, 5 of the 6 provinces had significant increases in the number of wetland basins with water present over the study period (Fig. 5a). A gradual increase was also noted in province 3, but seasonal fluctuations were greater than the overall increase.

The dynamics of wetland basins appear related to seasonal (Fig. 3) and long term (Fig. 4) dynamics of precipitation. The number of wetland basins with water present during a survey period was directly related to the amount of precipitation during that survey period in provinces 3 and 6 (Fig. 5b). Because the number of wetland basins present during a given survey might be related to the number of basins with water present that occurred during the previous survey (i.e. serial correlation), a multiple regression analyses using the independent variables of precipitation during the survey and the number of basins present the previous survey was conducted (Table 2). Results indicated that the number of wetland basins present in provinces 1, 2, 4, 5, and 6 was directly dependent on both the precipitation during the survey and the number of basins present during the previous survey (Table 2). However, wetland basins in province 3, in contrast to other provinces, followed more of a seasonal cycle based on the precipitation occurring during the survey, and were independent of the number of basins with water present during the previous survey. The magnitude of fluctuation in basin numbers in province 3 was low (13,467-16,998) in comparison with other provinces.

The dynamics of km's of streambed with water present followed the same trend as palustrine and small lacustrine basin numbers; a gradual increase in streambed km's flooded occurred as the study progressed

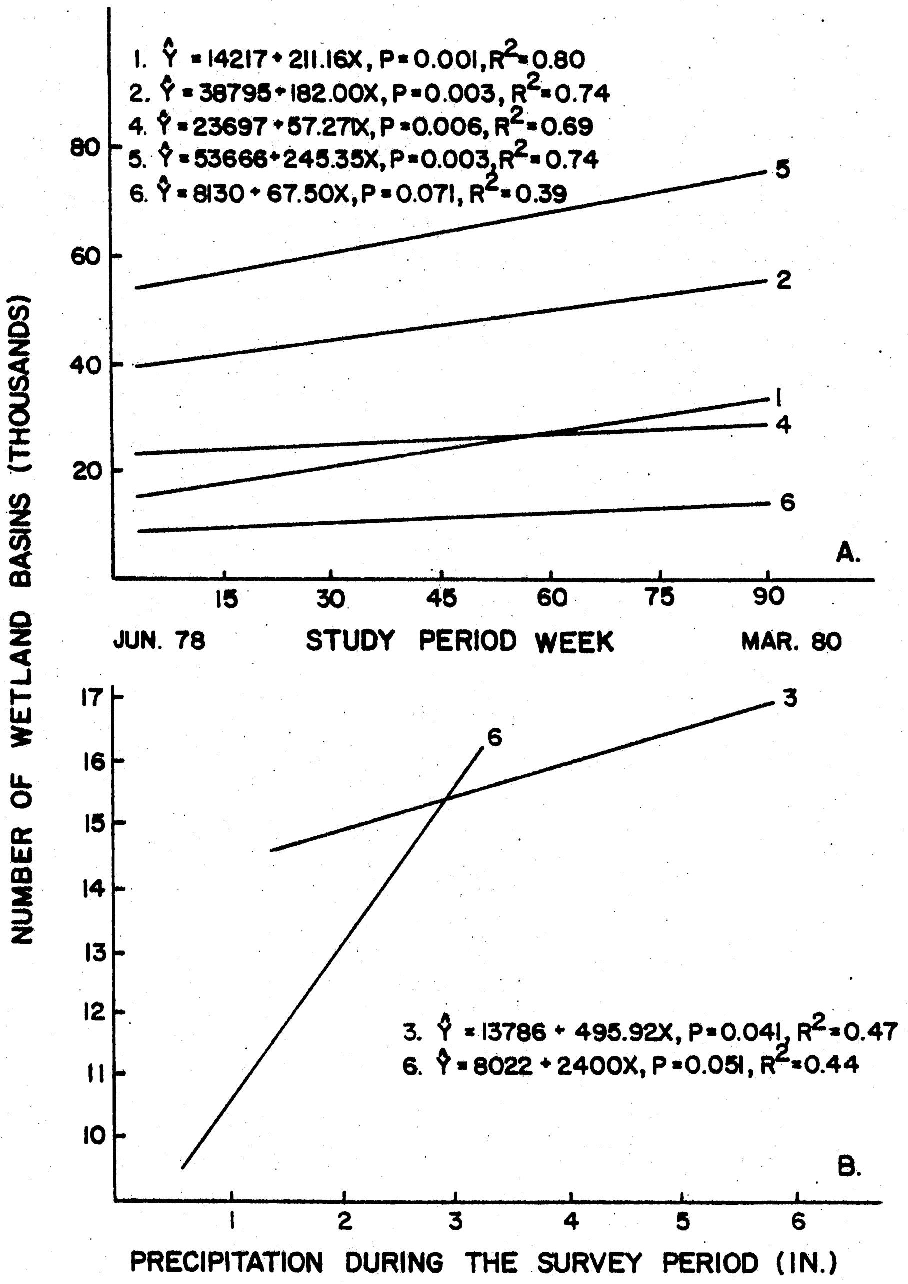

Fig. 5. Relationship between the estimated number of wetland basins with water present in the physiographic provinces (1-6) in Oklahoma and a) the survey period week, and b) the inches of precipitation during the survey period.

Table 2. Significant results of multiple regression analyses of the number of wetland basins with water present on precipitation amounts during survey periods (PCP) and the estimated number of wetland basins with water present during the previous survey (NPS).

Dependent variable	Partial F-test OSL's	Predicted equation	Equation OSL	R^2
# of basins with water present in Province 1	PCP = 0.0765 NPS = 0.0030	Y= -3837 + 2640(PCP) + 0.985(NPS)	0.0093	0.85
Province 2	PCP = 0.2083 NSP = 0.0222	Y= 8455 + 2058(PCP) + 0.757(NPS)	0.0538	0.69
Province 4	PCP = 0.3603 NPS = 0.0420	Y= 12139 - 427(PCP) + 0.6045(NPS)	0.0995	0.61
Province 5	PCP = 0.0300 NPS = 0.0029	Y= 2086 + 4140(PCP) + 0.883(NPS)	0.0072	0.87
Province 6	PCP = 0.0366 NPS = 0.0136	Y= 3960 + 1832(PCP) + 0.473(NPS)	0.0092	0.85

(Table 1). Seasonal cycles of spring and summer peaks in streambed km's were apparent in some provinces.

The ha of surface water present in reservoir, palustrine and small lacustrine, and streambed basins were estimated similarily to wetland basin numbers from the surface water ha's present on random ¼-sections to state and province levels (Table 3). The estimated ha of surface water ranged from 210,543-222,932 in large reservoirs, from 31,927-88,963 ha in small lacustrine and palustrine wetlands, from 50,110-89,779 ha in streambeds, and from 312,436-375,604 ha in all basins statewide. Reservoirs had an estimated 66-80%, small lacustrine and palustrine 15-25%, and streambeds 25-40% of the statewide total ha of surface water respectively.

Hectares of surface water showed both seasonal and long term dynamics (Table 3). The maximum ha of surface water occurred in summer, decreased during fall to a low in early winter, then increased from late winter to summer. This pattern was similar to the seasonal cycle of wetland basin numbers. The seasonal fluctuations of the ha of surface water in palustrine and small lacustrine wetlands were most pronounced in provinces 1, 3, 4, and 6. For example, the ha of surface water in province 4 increased from 6,578 in WI to 26,165 in SM79.

The ha of surface water in provinces 3, 4, and 6 were directly related to the precipitation occurring during the survey period (Fig. 6a) and independent of the ha of surface water present during the previous survey. However, the ha of surface water in provinces 1, 2, and 5 increased over the study period (Fig. 6b) and were related to both the precipitation during the survey period, and to the ha of surface water present during the previous survey (Table 4).

Table 3. Estimated ha of surface water present in Oklahoma reservoirs greater than 445.3 ha; and permanently, semipermanently, and seasonally flooded palustrine, small lacustrine, and streambed wetlands (95% confidence intervals in parentheses) during 1978-80.

		Season								
	Province	SM78	WI	WII	SP79	SM79	F79	WIII	WIV	SP80
Large Reservoirs [a]	1	70991	67007	67007	68818	71716	70267	71716	71716	71716
	2	62578	60887	60887	60887	66299	62578	64269	64269	65961
	3	12305	11277	11526	11838	11993	10592	11875	11838	12149
	4	40362	39327	39327	39741	40362	38292	38292	39292	39327
	5	14746	14746	14746	14746	15565	15155	15155	15237	15729
	6	17751	17524	17050	17997	17760	16861	16340	17618	17050
Total		218733	210768	210543	214027	223695	213745	217647	218970	221932
Palustrine and small lacustrine	1	3279	2170	2155	3832	8819	7135	8418	8944	9143
	2	8827	5278	5863	9184	13454	10742	12392	12716	12805
	3	2766	2101	2103	5252	6488	2806	2916	3250	3404
	4	6296	6578	8574	22462	26165	12110	9075	10670	24034
	5	19466	13794	14398	16191	27287	23403	22392	24338	26170
	6	4386	2006	2275	3211	6750	4220	3774	5434	5465
Total		45020±	31927±	35368±	60132±	88963±	60416±	58967±	65352±	81021±
		(15093)	(14531)	(14630)	(24264)	(30900)	(13641)	(9819)	(12106)	(23264)
Streambed	1	24439	24440	26467	27346	27132	17508	20260	19665	22174
	2	19593	25705	23079	30828	17552	6975	6048	11864	22895
	3	1838	1824	1828	3090	2451	2186	3242	2670	3203
	4	5932	9803	10078	15840	8219	6983	8554	10738	8347
	5	13783	7969	10041	12661	12484	10940	11396	14387	13736
	6	0	0	0	14	508	156	610	643	610
Total		65585±	69741±	71493±	89779±	62946±	44748±	50110±	59967±	70965±
		(56451)	(93089)	(82445)	(90917)	(58230)	(46603)	(43060)	(70535)	(50957)
State total		329338	312436	317404	363938	375604	318909	326724	344289	373918

[a] Estimated for each season by multiplying the % of the basin area covered with water observed on 19 random ¼-section sample plots on reservoirs, by the known conservation pool water acreage of the 46 reservoirs greater than 445.3 ha (Oklahoma Water Resources Board 1976).

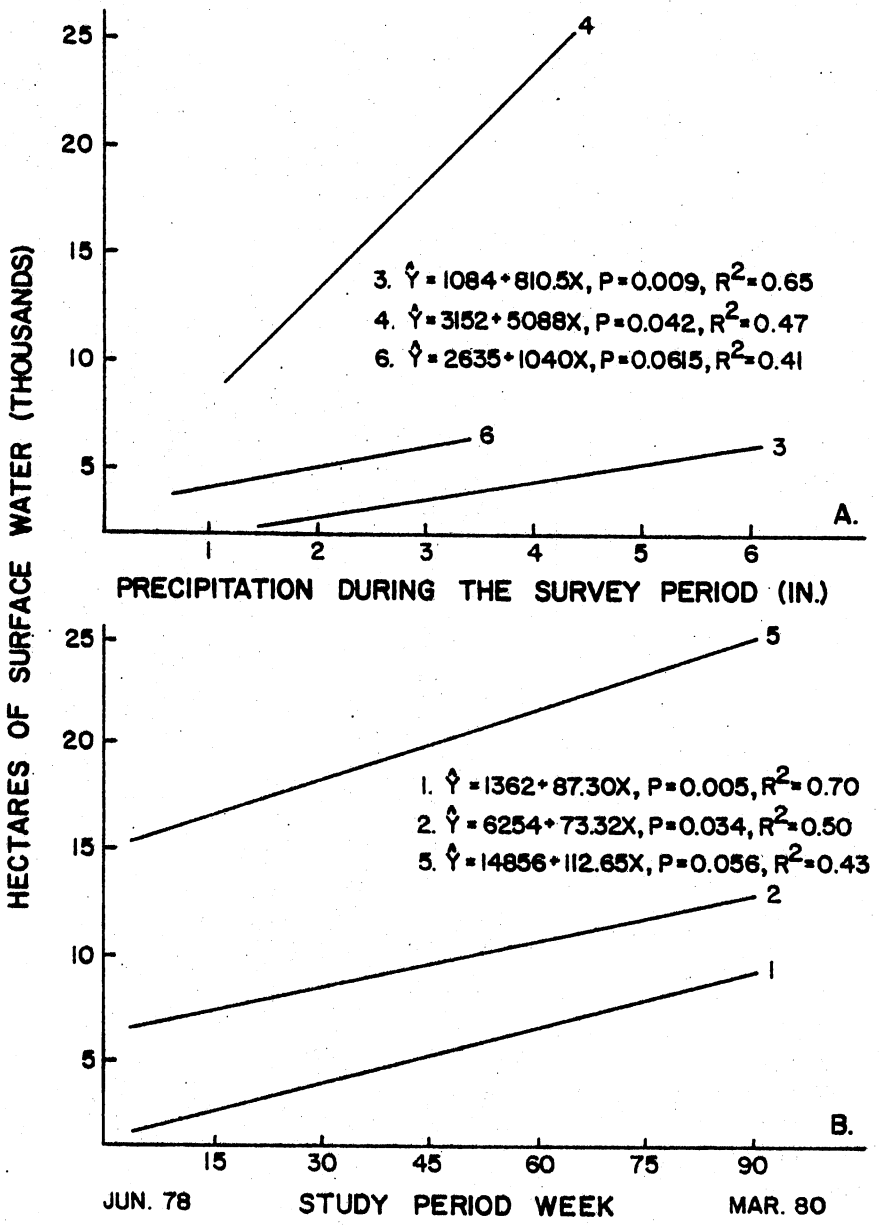

Fig. 6. Relationships between the estimated hectares of surface water present in the physiographic provinces (1-6) in Oklahoma and a) the survey period week, and b) the inches of precipitation during the survey period.

Table 4. Significant results of multiple regression analyses of the hectares of surface water on precipitation amounts during survey periods (PCP) and the estimated hectares of surface water present during the previous survey (HAPS).

Dependent variable	Partial F-test OSL's	Predicted Equation	Equation OSL	R^2
Ha of surface water in Province 1	PCP = 0.1915 HAPS = 0.0163	$Y = -961 + 1062(PCP) + 0.870(HAPS)$	0.0398	0.73
Province 3	PCP = 0.0270 HAPS = 0.6002	$Y = 1123 + 952(PCP) - 0.157(HAPS)$	0.0589	0.68
Province 5	PCP = 0.0304 HAPS = 0.0300	$Y = -1124 + 3773(PCP) + 0.758(HAPS)$	0.0338	0.74

The densities (N/km^2 and ha of surface water/km^2) of palustrine and small lacustrine wetland basins with water present and of streambed km were variable among provinces and reflected the seasonal and long term dynamics (Table 5). Province 4 had the highest densities of small lacustrine and palustrine wetland basins and ha of surface water; especially during late winter, spring, and summer. Provinces 2 and 5 also had high densities, provinces 1 and 3 had intermediate densities, and province 6 had low densities. The highest density of streambed km with water present also occurred in province 4. The density of ha of surface water was highest, alternately, in provinces 1 and 4.

Composition of wetland systems. The percentage of small lacustrine, palustrine, and riverine basins with water present on the random ¼-sections was determined for all 9 surveys in relation to system type, and the composition of palustrine basins in relation to origin and water permanence. Palustrine basins comprised most (85.2-86.3%) of the basins during all seasons (Table 6). Small lacustrine basins comprised 6.8-7.5% and riverine comprised 6.2-7.9% of the basins. The number of wetland types present was significantly (chi-square test ($\underline{X}^2$), $P<0.05$) different among provinces in all seasons. Provinces 3 and 6 had relatively more lacustrine basins, provinces 1 and 4 more riverine basins, and provinces 2 and 5 more palustrine basins.

All small lacustrine basins present on ¼-sections were man-made, but a small portion of palustrine basins were natural (Table 6). From 80.0-83.4% of the statewide basins (excluding reservoirs) were man-made palustrine, while only 2.8-5.3% of the statewide basins were natural palustrine. Provinces 4 and 6 had 2-3 times as many natural wetlands as other provinces. The numbers of these natural palustrine basins

Table 5. Estimated numbers and surface water ha of permanently, semipermanently, and seasonally flooded palustrine and small lacustrine wetlands per km^2 and km's and surface water ha of streambed per km^2 present in Oklahoma during 1978-80 (95% confidence intervals in parentheses).

		Season																	
	Province	SM78		WI		WII		SP79		SM79		F79		WIII		WIV		SP80	
		N/km^2	ha/km^2	N/km^2	ha/km^2	N/km^2	ha/km^2	N/km^2	ha/km^2	N/km^2	ha/km^2	N/km^2	ha/km^2	N/km^2	ha/km^2	N/km^2	ha/km^2	N/km^2	ha/km^2
Palustrine and small lacustrine	1	7.45	1.34	7.45	0.88	7.02	0.88	7.72	1.56	12.19	3.59	11.94	2.91	12.80	3.43	13.21	3.64	13.41	3.73
	2	16.01	3.49	16.47	2.09	16.82	2.32	17.10	3.64	21.62	5.33	20.51	4.25	21.48	4.91	21.72	5.03	20.75	5.07
	3	7.18	1.47	8.27	1.12	8.27	1.12	8.48	2.80	9.06	3.46	7.83	1.50	7.51	1.55	8.46	1.73	8.04	1.81
	4	19.99	5.47	20.89	5.71	23.40	7.44	24.34	19.50	22.93	22.72	22.93	10.51	24.80	7.88	24.80	9.26	24.80	20.87
	5	13.24	4.39	12.71	3.11	12.94	3.25	13.48	3.65	16.58	6.16	15.95	5.28	16.58	5.05	17.22	5.49	16.71	5.91
	6	1.99	0.77	1.13	0.35	1.25	0.40	1.52	0.57	2.78	1.19	2.68	0.74	2.37	0.67	2.47	0.96	2.16	0.96
	State total	9.12± (1.65)	2.49± (0.83)	8.97± (1.69)	1.76± (0.80)	9.20± (1.72)	1.95± (0.81)	9.63± (1.43)	3.32± (1.34)	11.99± (1.79)	4.91± (1.71)	11.49± (1.85)	3.34± (0.75)	11.89± (1.82)	3.26± (0.54)	12.26± (1.86)	3.61± (0.67)	11.89± (1.86)	4.47± (1.28)
Streambed	1	1.32	9.96	1.32	9.96	1.34	10.79	1.32	11.14	1.19	11.06	0.98	7.13	1.19	8.26	1.19	8.01	1.19	9.04
	2	0.35	7.76	0.54	10.18	0.53	9.14	0.75	12.20	0.89	6.95	0.66	2.76	0.91	2.39	0.91	4.70	0.91	9.06
	3	0.34	0.98	0.46	0.97	0.46	0.97	0.70	1.65	0.66	1.31	0.58	1.17	0.66	1.73	0.68	1.42	0.65	1.71
	4	1.77	5.15	2.09	8.51	2.16	8.75	2.16	13.75	2.16	7.14	2.16	6.06	2.64	7.43	2.64	9.32	2.64	7.25
	5	0.40	3.11	0.52	1.80	0.91	2.27	1.24	2.86	1.44	2.82	1.19	2.47	1.44	2.57	1.44	3.25	1.44	3.10
	6	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.002	0.04	0.09	0.06	0.03	0.04	0.11	0.04	0.11	0.04	0.11
	State total	0.47± (0.45)	3.62± (3.12)	0.56± (0.47)	3.85± (5.14)	0.66± (0.50)	3.95± _4.55)	0.80± (0.59)	4.96± (5.02)	0.86± (0.51)	3.48± (3.22)	0.73± (0.53)	2.47± (2.57)	0.89± (0.50)	2.77± (2.38)	0.89± (0.51)	3.31± (3.89)	0.89± (0.50)	3.92± (2.81

Table 6. Percentage of permanently, semipermanently, and seasonally flooded palustrine, small lacustrine, and riverine basins with water present on ¼-section plots in Oklahoma (# of basins in parentheses) during 1978-80 relative to system type, origin, and degree of water permanence.

		Season								
Category	Province	SM78 (322)	WI (313)	WII (322)	SP79 (340)	SM79 (454)	F79 (431)	WIII (441)	WIV (458)	SP80 (448)
System Type [a,b]										
Lacustrine	1	5.9	5.9	6.2	5.7	11.0	11.6	10.5	11.5	11.4
	2	7.5	7.2	6.9	6.8	5.1	6.4	4.2	3.1	3.2
	3	13.6	10.9	10.6	10.2	11.3	11.4	7.7	10.4	10.9
	4	5.9	5.7	5.3	5.1	5.4	5.4	4.9	4.9	4.9
	5	2.8	4.0	3.9	3.8	2.8	2.9	2.8	2.7	2.8
	6	25.0	36.4	33.3	25.5	25.8	25.8	29.6	28.6	32.0
State total		7.5	7.4	7.1	6.8	7.5	7.9	6.8	7.0	7.1
Riverine	1	14.7	14.7	15.6	14.3	9.6	7.2	9.2	9.0	8.9
	2	4.5	4.4	4.2	5.4	5.1	4.3	6.2	6.2	6.4
	3	4.6	4.4	6.4	8.2	7.6	6.8	5.1	8.3	6.5
	4	9.8	9.4	8.8	8.5	8.9	8.9	9.8	9.8	9.8
	5	4.7	5.0	6.9	7.6	7.7	6.6	7.8	7.5	7.6
	6	0.0	0.0	0.0	5.9	3.2	6.4	3.7	3.6	4.0
State total		6.2	6.4	7.1	7.9	7.3	6.5	7.5	7.6	7.6
Palustrine	1	79.4	79.4	78.1	80.0	79.4	81.2	80.3	79.5	79.8
	2	85.1	85.4	88.9	87.8	89.8	89.4	89.6	90.7	90.3
	3	81.8	84.8	83.0	81.6	81.1	81.8	87.2	81.2	82.6
	4	84.3	84.9	86.0	86.4	85.7	85.7	85.2	85.2	85.2
	5	92.4	91.0	89.2	88.7	89.5	90.5	89.4	89.7	89.6
	6	75.0	63.6	66.7	70.6	71.0	67.7	66.7	67.9	64.0
State total		86.3	86.2	85.7	85.3	85.2	85.6	85.7	85.4	85.3
Palustrine Origin [a,b]										
Man-made	1	76.5	76.5	75.0	74.3	76.7	72.3	76.4	75.7	76.0
	2	85.1	85.5	86.1	83.8	85.7	86.2	85.5	86.5	86.0
	3	81.8	82.6	80.8	79.6	79.2	81.8	87.2	79.1	80.5
	4	78.4	81.2	78.9	76.2	78.6	78.6	75.4	75.4	75.4
	5	89.5	90.0	86.2	85.9	85.3	86.9	85.9	86.3	85.5
	6	60.0	54.5	58.4	53.0	61.3	58.0	59.3	60.8	56.0
State total		82.6	83.4	81.9	80.0	80.8	81.7	81.2	80.8	80.4
Natural	1	2.9	2.9	3.1	5.7	2.7	2.9	3.9	3.8	3.8
	2	3.0	2.9	2.8	4.0	4.1	3.2	4.1	4.2	4.3
	3	0.0	2.2	2.2	2.0	1.9	0.0	0.0	2.1	2.1
	4	5.9	3.7	7.1	10.2	7.1	7.1	9.8	9.8	9.8
	5	2.9	2.0	2.9	2.8	4.2	3.6	3.5	3.4	4.1
	6	15.0	9.1	8.3	17.6	9.6	9.7	7.4	7.1	8.0
State total		3.7	2.8	3.8	5.3	4.4	3.9	4.5	4.6	4.9
Palustrine Water Permanence [a,b]										
Permanent	1	79.4	79.4	78.1	77.1	75.3	78.3	72.4	71.8	72.2
	2	88.1	85.5	86.1	83.8	82.6	87.3	83.3	82.4	83.9
	3	75.0	76.1	74.5	73.4	73.6	81.8	87.2	77.1	80.5
	4	76.5	73.6	66.7	64.4	67.9	67.9	62.3	62.3	62.3
	5	83.9	87.0	26.3	81.2	76.9	81.7	76.7	76.0	76.4
	6	40.0	54.5	58.4	41.2	42.0	38.7	40.8	39.3	44.0
State total		79.1	80.8	78.6	75.3	74.0	77.5	74.1	72.8	73.9

Table 6. continued.

		Season								
Category	Province	SM78	WI	WII	SP79	SM79	F79	WIII	WIV	SP80
Semipermanent										
	1	0.0	0.0	0.0	0.0	2.7	1.5	5.3	5.1	5.1
	2	0.0	2.9	2.8	2.7	5.1	1.1	3.1	5.2	4.3
	3	6.8	8.7	8.5	8.2	7.5	0.0	0.0	4.1	2.1
	4	7.8	11.3	17.5	16.9	16.1	17.8	18.1	18.1	18.1
	5	7.6	3.0	4.9	6.6	10.5	6.6	10.5	11.7	11.1
	6	25.0	9.1	8.3	17.6	22.6	22.5	22.2	25.0	16.0
State total		6.2	5.1	6.9	7.7	9.2	6.5	8.8	10.1	9.0
Seasonal	1	0.0	0.0	0.0	2.9	1.3	1.5	2.6	2.5	2.6
	2	0.0	0.0	0.0	1.3	2.1	1.1	3.1	3.1	2.2
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	1.7	5.1	1.8	0.0	4.9	4.9	4.9
	5	0.9	1.0	0.0	1.0	2.1	2.2	2.1	2.1	2.1
	6	10.0	0.0	0.0	11.8	6.5	6.4	3.7	3.6	4.0
State total		0.9	0.3	0.3	2.4	2.0	1.6	2.7	2.6	2.5

[a] Wetland composition was significantly different, P 0.05 over seasons.

[b] Wetland composition was significantly different, P 0.05 over provinces.

changed in relation to seasonal precipitation and followed the previously discussed cycle.

Most palustrine basins were permanently flooded, but significant ($\underline{X}^2$-test, $\underline{P}<0.05$) differences occurred among provinces and seasons. Provinces 4 and 6 had significantly more semipermanently and seasonally flooded basins than other provinces. Most of the semipermanently and seasonally flooded basins in provinces 4 and 6 were natural. Seasonally flooded basins were the most dynamic (e.g. they comprised 0.0-5.1% of the basins in province 4 and 0.0-11.8% of the basins in province 6).

The composition of ha of surface water present in small lacustrine, palustrine, and riverine basins that occurred on ¼-sections was significantly ($\underline{X}^2$-test, $\underline{P}<0.05$) different over seasons and among provinces (Table 7). Provinces 3, 5, and 6 had proportionately more ha of surface water present in lacustrine basins; provinces 1, 2, and 4 had more riverine surface water, and province 4 had more palustrine surface water.

Most of the palustrine ha of surface water were in man-made basins with the exception of province 4. Province 4 had 11.0-54.6% of its surface water area in natural palustrine basins.

When data from Table 7 were multiplied by the estimated statewide ha of surface water (Table 3) by season, an estimated 23,006-31,141 ha of surface water were in small lacustrine basins, 38,385-77,204 ha were in riverine, 17,894-63,650 ha were in palustrine, 15,657-45,269 ha were in palustrine man-made, 2,237-18,381 ha were in natural palustrine, 16,572-45,421 ha were in permanently flooded palustrine, 1,220-17,621 ha were in semipermanently flooded palustrine, and less

Table 7. Percentage of ha of surface water in permanently, seasonally, and semipermanently flooded small lacustrine, palustrine, and riverine basins in Oklahoma with water present on ¼-sections (# of basins in parentheses) relative to system type, origin, and degree of water permanence during 1978-80.

		Season								
Category	Province	SM78 (322)	WI (313)	WII (322)	SP79 (340)	SM79 (454)	F79 (431)	WIII (441)	WIV (458)	SP80 (448)
System Type ^{b,c}										
Lacustrine	1	0.0	0.0	0.0	0.0	6.4	7.6	6.1	7.2	6.6
	2	7.1	19.7	20.5	16.5	18.7	29.3	19.3	12.6	16.0
	3	45.7	46.1	46.0	36.6	36.7	39.8	34.6	37.1	34.1
	4	9.6	11.0	11.6	6.4	5.8	7.9	10.6	9.3	6.8
	5	36.9	39.9	36.6	31.8	23.3	23.1	19.5	18.9	21.2
	6	71.6	95.0	93.0	87.5	67.8	79.0	78.2	75.8	75.5
State total		20.8	27.8	27.0	20.7	20.5	25.6	21.9	19.8	19.9
Riverine	1	89.1	91.8	92.5	87.7	71.2	71.0	70.6	68.7	70.8
	2	59.3	68.7	65.5	66.5	48.1	29.9	49.3	65.2	55.9
	3	22.5	27.3	27.2	36.9	26.8	28.4	36.1	30.8	34.2
	4	50.1	59.8	54.0	41.4	23.9	36.6	48.5	50.2	25.8
	5	11.5	32.4	36.7	39.8	29.4	29.6	31.5	34.8	32.3
	6	0.0	0.0	0.0	0.1	0.4	1.2	4.5	4.2	4.0
State total		46.4	54.7	53.8	51.5	37.5	36.5	44.3	48.9	41.6
Palustrine	1	10.9	8.2	7.5	12.3	22.5	21.4	23.2	24.1	22.6
	2	33.6	11.6	14.0	17.1	33.2	40.8	31.4	22.2	28.1
	3	31.8	26.6	26.6	26.5	36.5	31.8	29.3	32.1	31.7
	4	40.4	29.2	34.4	52.2	70.3	55.5	40.9	40.6	67.4
	5	51.6	27.7	26.7	28.4	47.2	47.3	49.0	46.3	46.5
	6	28.4	5.0	7.0	12.4	29.1	19.9	17.3	20.0	20.5
State total		32.7	17.6	19.2	27.8	41.9	38.0	33.8	31.3	38.5
Palustrine Origin ^{b,c}										
Man-made	1	10.1	6.9	6.2	10.6	21.1	20.2	21.8	22.5	21.0
	2	32.6	11.5	13.9	16.8	32.3	40.4	30.0	21.6	27.4
	3	31.8	25.4	25.3	24.1	35.3	31.8	29.3	30.8	30.4
	4	19.8	18.2	18.4	13.4	15.7	20.1	23.8	21.2	16.3
	5	50.3	27.6	26.2	26.7	45.7	45.7	47.4	45.0	45.2
	6	27.0	4.8	6.8	12.2	28.7	19.3	17.0	19.4	20.1
State total		28.4	15.4	16.0	16.9	29.8	31.8	30.8	27.8	27.9
Natural	1	0.8	1.3	1.3	1.7	1.4	0.8	1.4	1.6	1.6
	2	1.0	0.1	0.1	0.3	0.9	0.4	1.4	0.6	0.7
	3	0.0	1.2	1.3	2.4	1.2	0.0	0.0	1.3	1.3
	4	20.6	11.0	16.0	38.8	54.6	35.4	17.1	19.4	51.1
	5	1.3	0.1	0.5	1.7	1.5	1.6	1.6	1.3	1.3
	6	1.4	0.2	0.2	0.2	0.4	0.6	0.3	0.6	0.4
State total		4.3	2.2	3.2	10.9	12.1	6.2	3.0	3.5	10.6
Palustrine Water Permanence ^{b,c}										
Permanent	1	10.9	8.2	7.5	11.8	21.4	21.3	21.9	22.7	21.2
	2	33.6	11.3	13.9	16.9	32.4	40.7	31.0	21.7	27.7
	3	31.8	26.2	25.5	23.8	34.9	31.8	29.3	30.8	30.4
	4	25.9	22.8	22.0	14.9	18.9	24.8	29.0	24.5	19.2
	5	49.8	27.4	25.8	26.3	44.3	45.1	45.7	43.3	43.3
	6	24.3	4.8	6.8	10.6	25.1	13.7	11.8	13.6	15.0
State total		29.6	16.3	16.8	17.3	29.9	32.0	30.6	27.5	27.7

Table 7. continued.

		Season								
Category	Province	SM78	WI	WII	SP79	SM79	F79	WIII	WIV	SP80
Semi-permanent										
	1	0.0	0.0	0.0	0.0	1.0	0.1	1.2	1.2	1.1
	2	0.0	0.3	0.1	0.2	0.6	Tr	0.2	0.3	0.2
	3	0.0	0.4	1.1	2.6	1.6	0.0	0.0	1.3	1.3
	4	14.5	6.4	12.3	35.4	50.2	30.7	11.5	15.6	47.9
	5	1.5	0.2	0.9	2.0	2.4	1.8	2.8	2.6	2.8
	6	3.1	0.2	0.2	1.8	3.6	5.8	5.3	5.8	5.2
	State total	3.0	1.2	2.4	9.9	11.6	5.8	2.9	3.6	10.5
Seasonal	1	0.0	0.0	0.0	0.5	0.1	Tr	0.1	0.2	0.4
	2	0.0	0.0	0.0	0.0	0.2	0.1	0.3	0.2	0.2
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.1	1.9	1.2	0.0	0.4	0.5	0.3
	5	0.2	0.1	0.0	0.1	0.5	0.5	0.5	0.4	0.3
	6	1.1	0.0	0.0	0.0	0.4	0.4	0.1	0.5	0.2
	State total	0.1	Tr	Tr	0.6	0.5	0.2	0.3	0.3	0.3

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[a] The estimated hectares of surface water statewide in small lacustrine, riverine, and palustrine wetlands are SM78: 110,605, WI: 128,668, WII: 106,861, SP79: 149,911, SM79: 151,909, F79: 105,164, WIII: 109,077, WIV: 125,319, and SP80: 151,986. All state total percentages in this table can be multiplied by these state projections to give statewide estimates of the surface water hectares present in each of the category types.

[b] Wetland composition was significantly different, P 0.0001 over seasons.

[c] Wetland composition was significantly different, P 0.0001 over provinces within seasons.

than 110-900 ha were in seasonally flooded palustrine basins. From 6.4-50.2% of the ha of surface water present in palustrine basins in province 4 were semipermanently flooded. Palustrine basins in other provinces were mostly permanently flooded.

Composition of classification types. All wetland basins with water present on ¼-sections were individually classified at each visit using the Cowardin et al. (1979) classification system. We used this system to classify the individual wetland basins (as used in plates 19-56, p66-103 in Cowardin et al. 1979) and not just zones or regions within a wetland basin. Sixty wetland basin classification types were observed on the ¼-sections; 1-16 were riverine, 17-24 were small lacustrine, and 25-60 were palustrine (Table 8). These classification types were not the only types present in Oklahoma, but represented those found on the ¼-sections. Because of the adequacy of our sampling scheme, we suggest that classification types present in Oklahoma but not occurring on the ¼-sections are present in relatively small numbers (i.e. less than 300 basins).

The correctness of classification was tested by classifying all wetland basins at each visit and comparing with previous survey classifications. Approximately 86% of the wetland basins were classified correctly after 1 visit (SM78), but it took 7 visits to classify 100% of the wetland basins correctly. Visits to wetland basins during each season, especially the growing season, may be essential to correctly classify basins.

Riverine systems, especially those with mud channels (wetland types 2 and 4, e.g. the Neosho River) and impounded, mud substrate, palustrine systems (wetland type 25, e.g. permanently flooded farm pond)

Table 8. Classification of wetland types (Cowardin et al. 1979) and wetland groupings observed on random ¼-section plots in Oklahoma.

Wetland group	Wetland type	Classification
	Riverine	
1	1.	Riverine-lower perennial-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral
	2.	Riverine-lower perennial-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-artificial
	3.	Riverine-lower perennial-unconsolidated bottom-mud-permanently flooded-fresh-alkaline-mineral
2	4.	Riverine-lower perennial-unconsolidated bottom-mud-semipermanently flooded-fresh-circumneutral-mineral diked
	5.	Riverine-lower perennial-unconsolidated bottom-mud-semipermanently flooded-oligosaline-circumneutral-mineral
	6.	Riverine-lower perennial-unconsolidated bottom-mud semipermanently flooded-fresh-circumneutral-mineral
	7.	Riverine-lower perennial-unconsolidated bottom-cobble gravel-semipermanently flooded-fresh-circumneutral-mineral
	8.	Riverine-lower perennial-unconsolidated shore-cobble gravel-seasonally flooded-fresh-circumneutral-mineral
	9.	Riverine-lower perennial-unconsolidated shore-mud-seasonally flooded-fresh-circumneutral-mineral
	10.	Riverine-lower perennial-unconsolidated shore-sand-seasonally flooded-fresh-circumneutral-mineral

Table 8. continued.

Wetland group	Wetland type	Classification
	Riverine	
3	11.	Riverine-lower perennial-unconsolidated bottom/unconsolidated shore-sand-permanently flooded/seasonally flooded-fresh-circumneutral-mineral
	12.	Riverine-lower perennial-unconsolidated bottom/unconsolidated shore-sand-permanently flooded/seasonally flooded-oligosaline-circumneutral-mineral
	13.	Riverine-lower perennial-unconsolidated bottom/unconsolidated shore-sand-permanently flooded/seasonally flooded-oligosaline-alkaline-mineral
4	14.	Riverine-lower perennial-unconsolidated bottom/unconsolidated shore-mud/sand-permanently flooded/seasonally flooded-fresh-circumneutral-mineral
	15.	Riverine-lower perennial-unconsolidated bottom/unconsolidated shore-mud/sand-permanently flooded/seasonally flooded-oligosaline-circumneutral-mineral
5	16.	Riverine-upper perennial-rock bottom-rubble-permanently flooded-fresh-circumneutral-mineral
	Lacustrine	
6	17.	Lacustrine-littoral/limnetic-unconsolidated bottom-mud-intermittently exposed/permanently flooded-fresh-circumneutral-mineral-impounded
	18.	Lacustrine-litoral/limnetic-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-impounded
	19.	Lacustrine-littoral/limnetic-unconsolidated bottom-mud-semipermanently flooded/permanently flooded-fresh-circumneutral-mineral-impounded-partly drained
	20.	Lacustrine-littoral/limnetic-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-impounded-(sewage)

Table 8. continued.

Wetland group	Wetland type	Classification
6	21.	Lacustrine-littoral/limnetic-aquatic bed/unconsolidated bottom-rooted vascular/mud-permanently flooded-fresh-circumneutral-mineral-impounded
7	22.	Lacustrine-littoral/limnetic-rock bottom-bedrock-permanently flooded-fresh-circumneutral-mineral-impounded
	23.	Lacustrine-littoral/limnetic-rock bottom/unconsolidated bottom-bedrock/mud-permanently flooded-fresh-circumneutral-mineral-impounded
8	24.	Lacustrine-littoral-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-impounded
	Palustrine	
11	25.	Palustrine-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-impounded
	26.	Palustrine-unconsolidated bottom-mud-permanently flooded-fresh-alkaline-mineral-impounded
	27.	Palustrine-unconsolidated bottom-mud-permanently flooded-oligosaline-circumneutral-mineral-impounded
12	28.	Palustrine-unconsolidated bottom-mud-permanently flooded-oligosaline-circumneutral-mineral-impounded-artificial
	29.	Palustrine-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-excavated-(refinery)
13	30.	Palustrine-unconsolidated bottom-mud-semipermanently flooded-fresh-circumneutral-mineral-impounded
	31.	Paluatrine-unconsolidated shore-mud-seasonally flooded-fresh-circumneutral-mineral-impounded
	32.	Palustrine-unconsolidated shore-mud-seasonally flooded-fresh-alkaline-mineral-impounded
14	33.	Palustrine-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-excavated

Table 8. continued.

Wetland group	Wetland type	Classification
14	34.	Palustrine-unconsolidated bottom-mud-semipermanently flooded-fresh-circumneutral-mineral-excavated
15	35.	Palustrine-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral
	36.	Palustrine-unconsolidated bottom-mud-semipermanently flooded-fresh-circumneutral-mineral
16	37.	Palustrine-unconsolidated shore-mud-seasonally flooded-fresh-circumneutral-mineral
	38.	Palustrine-unconsolidated shore-vegetated-seasonally flooded-fresh-circumneutral-mineral
17	39.	Palustrine-aquatic bed-algal-permanently flooded-fresh-circumneutral-mineral-impounded
	40.	Palustrine-aquatic bed algal-permanently flooded-fresh-circumneutral-mineral-impounded-(sewage)
18	41.	Palustrine-aquatic bed-rooted vascular-permanently flooded-fresh-circumneutral-mineral-impounded
	42.	Palustrine-aquatic bed-rooted vascular-permanently flooded-fresh-circumneutral-mineral-impounded
19	43.	Palustrine-emergent wetland-nonpersistent-permanently flooded-fresh-circumneutral-mineral-impounded
	44.	Palustrine-emergent wetland-nonpersistent-semipermanently flooded-fresh-circumneutral-mineral-impounded
	45.	Palustrine-emergent wetland-nonpersistent-permanently flooded-fresh-circumneutral-mineral
20	46.	Palustrine-emergent wetland-nonpersistent-semipermanently flooded-fresh-circummetutral-mineral
21	47.	Palustrine-emergent wetland-persistent-permanently flooded-fresh-circumneutral-mineral-impounded
	48.	Palustrine-emergent wetland-persistent-permanently flooded-oligosaline-alkaline-mineral-impounded

Table 8. continued.

Wetland group	Wetland type	Classification
22	49.	Palustrine-emergent wetland-persistent-semipermanently flooded-fresh-circumneutral-mineral-impounded
	50.	Palustrine-emergent wetland-persistent-seasonally flooded-fresh-circumneutral-mineral-impounded
23	51.	Palustrine-emergent wetland-persistent-semipermanently flooded-fresh-alkaline-mineral-farmed
	52.	Palustrine-emergent wetland-persistent-semipermanently flooded-fresh-circumneutral-mineral
	53.	Palustrine-emergent wetland-persistent-seasonally flooded-fresh-circumneutral-mineral
24	54.	Palustrine-scrub/shrub-broad leaved deciduous-permanently flooded-fresh-circumneutral-mineral-impounded
	55.	Palustrine-scrub/shrub-dead-permanently flooded-fresh-circumneutral-mineral-impounded
25	56.	Palustrine-scrub/shrub-dead-permanently flooded-fresh-circumneutral-mineral
	57.	Palustrine-scrub/shrub-dead-semipermanently flooded-fresh-circumneutral-mineral
26	58.	Palustrine-forested wetland-broad leaved deciduous-permanently flooded-fresh-circumneutral-mineral-impounded
	59.	Palustrine-forested wetland-broad leaved deciduous-semipermanently flooded-fresh-circumneutral-mineral-impounded
27	60.	Palustrine-forested wetland-broad leaved deciduous-seasonally flooded-fresh-circumneutral-mineral

dominated the composition of ha of surface water in province 1 during all seasons (Table 9a). Riverine wetland types 2 and 7 and palustrine type 47 were the most dynamic.

Riverine systems with mud and sand bars present (wetland types 11 and 12, e.g. Cimarron River), small lacustrine systems with mud substrates and submergent vegetation present (wetland type 21), and impounded mud substrate ponds (wetland type 25) were the most abundant in province 2 (Table 9b). Farm ponds dominated by submergent and algal vegetation (wetland types 41 and 39) became more abundant during summer and fall.

Small lacustrine systems with mud substrates (wetland type 18), riverine systems with sand and mud bars (wetland types 15 and 16, e.g. Canadian River), and permanently flooded farm ponds were most abundant in province 3 (Table 9c). Riverine systems with mud and cobble-gravel substrates became more abundant after SP79, and farm ponds with algal or submergent plants (wetland types 39 and 41) were common. Palustrine systems with dead scrub/shrub vegetation (wetland type 55) made up a greater proportion of the ha of surface water in spring and summer when increased runoff expanded their area.

Riverine systems with mud channels (wetland type 1, e.g. Blue River), and mud and sand bars (wetland type 13, e.g. Red River); small lacustrine irrigation lakes (wetland type 19); permanently flooded farm ponds; and natural scrub/shrub sloughs and oxbows (wetland types 56 and 57) comprised the majority of the ha of surface water in province 4 (Table 9d). The sloughs and oxbows were especially dynamic, and they filled or expanded beginning in late winter with rainfall, snow runoff, and river overflows.

Table 9a. Percentage composition of the ha of surface water in permanently, semipermanently, and seasonally flooded small lacustrine, palustrine, and riverine basins present on ¼-sections in Oklahoma in province 1 during 1978-80 (# of basins in parentheses) as classified using Cowardin et al. (1979) classification types.

	Season								
Wetland Type from Table 6	**SM78 (34)**	**WI (34)**	**WII (32)**	**SP79 (35)**	**SM79 (73)**	**F79 (69)**	**WIII (76)**	**WIV (78)**	**SP80 (79)**
1	4.6	5.0	6.7	5.9	7.9	4.0	10.6	11.2	11.0
2	46.0	50.3	47.1	44.2	40.8	46.1	41.2	37.0	39.8
3									
4	17.3	18.8	19.9	16.3	15.3	18.2	14.6	14.7	14.9
5									
6									
7	5.0	2.1	4.2	5.3	5.5	2.7	4.1	5.5	1.6
8					0.2		0.1	0.3	0.4
9									
10									
11								0.4	0.4
12									
13									
14									
15									
16									
17									
18									
19									
20	6.2	5.6	4.5	6.0	6.4	7.6	6.1	6.8	6.2
21									
22									
23									
24									
25	14.4	13.6	13.1	16.0	15.8	15.6	16.0	16.5	15.3
26									
27									
28									
29									
30							0.1	0.1	0.1
31									
32									
33					0.3	0.5	0.6	0.7	
34					0.1	0.1	0.1	0.1	0.1
35	0.8	1.3	1.3	1.1	1.3	1.2	1.3	1.4	1.3
36									
37					0.1	Tr^b	Tr	0.1	0.7
38				0.5			0.1	0.1	0.3
39	2.7	1.2	1.1	2.0	2.0	2.1	2.1	1.8	1.8
40									
41	0.8	0.4	0.4	0.6	0.7		0.6	0.8	0.7
42									
43									
44					0.9		1.0	1.0	0.9
45					0.2	0.3	0.2	0.2	0.2
46									
47	3.4	1.6	1.5	2.0	1.2	1.1	1.1	1.2	1.0
48									
49									
50									
51									
52									
53									
54									
55									
56									
57									
58			0.1						
59									
60									

Table 9a. continued.

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[a] Percentages in this table multiplied by the projected hectares of surface water in province 1 (SM78: 27,718; WI: 26,610; WII: 28,622; SP79: 31,178; SM79: 35,951; F79: 24,643; WIII: 28,678; WIV: 28,609; SP80: 31,317) equals the estimated surface water hectares of individual wetland types in province 1.

[b] Tr = less than 0.005%

Table 9b. Percentage composition of the ha of surface water in permanently, semipermanently, and seasonally flooded small lacustrine, palustrine, and riverine basins present on ¼-sections in Oklahoma in province 2 during 1978-80 (# of basins in parentheses) as classified using Cowardin et al. (1979) classification types.

	Season								
Wetland Type from Table 6	SM78 (67)	WI (69)	WII (72)	SP79 (74)	SM79 (98)	F79 (94)	WIII (96)	WIV (97)	SP80 (93)
1	0.8	0.7	0.6	0.4	0.5	0.6	0.5	0.4	0.6
2									
3									
4									
5									
6									
7									
8				0.3	0.4	0.2	32.5	21.2	27.8
9					0.4		0.3	0.2	0.8
10									
11	12.6	52.7	47.1	38.8	26.1	10.4	6.8	32.2	5.8
12	45.8	15.3	17.8	27.0	20.7	18.8	9.3	10.4	21.0
13									
14									
15									
16									
17	1.6	0.4	0.4	0.3	0.7	0.9	0.6		
18	1.0	0.3	0.3	0.2	0.5	0.8	0.6	0.4	0.4
19									
20									
21	1.0	17.2	17.9	13.7	15.0	24.0	15.7	10.6	13.4
22									
23	3.5	1.8	1.9	2.2	2.4	3.6	2.4	1.6	2.1
24									
25	22.2	8.6	11.0	13.2	23.7	31.0	23.2	16.1	20.6
26									
27									
28	0.3	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
29									
30		Tr[b]	Tr	0.1	0.2	0.1	0.1	0.1	0.1
31									
32									
33									
34									
35	1.0	0.1	0.1	0.3	0.6	0.2	0.3	0.3	0.4
36									
37					0.1	0.1	0.1	0.1	0.1
38					0.1		Tr	Tr	0.1
39	3.1	0.6	0.7	0.6	2.4	2.9	2.6	1.8	2.3
40									
41	4.4	1.5	1.6	1.8	4.2	4.5	3.4	2.4	3.0
42					0.3			0.1	0.1
43	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
44									
45									
46									
47	0.4	0.2	0.2	0.2	0.1	0.9	0.7	0.4	0.6
48									
49		0.2	0.1	0.1	0.2		0.1	0.1	0.1
50							0.2	0.1	
51									
52									
53									
54									
55	1.0	0.2	0.2	0.5	0.5	0.8	0.6	0.4	0.5
56						0.1	0.1	0.1	0.2
57									
58									
59									
60									

Table 9b. continued

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[a] Percentages in this table when multiplied by the projected hectares of surface water in province 2 (SM78: 28,420; WI: 30,983; WII: 28,942; SP79: 40,012; SM79: 31,006; F79: 17,717; WIII: 18,440; WIV: 24,580; SP80: 35,700) equals the estimated hectares of surface water of individual wetland types in province 2.

[b] Tr = less than 0.005%

Table 9c. Percentage composition of the ha of surface water in permanently, semipermanently, and seasonally flooded small lacustrine, palustrine, and riverine basins present on ¼-sections in Oklahoma in province 3 during 1978-80 (# of basins in parentheses) as classified using cowardin et al. (1979) classification types.

	Season								
Wetland Type from Table 6	SM78 (44)	WI (46)	WII (47)	SP79 (49)	SM79 (53)	F79 (44)	WIII (39)	WIV (48)	SP80 (46)
1									
2									
3									
4									
5									
6		0.4	0.4	0.2	0.3		0.3	0.1	
7									
8				16.5	7.2	12.2	13.7	10.9	14.4
9									
10									
11									
12									
13									
14			0.5	0.4	0.5			0.2	
15	15.3	19.0	20.2	11.2	11.4	7.9	14.7	12.3	12.2
16	7.2	8.3	6.7	8.8	7.6	8.3	7.7	7.5	7.6
17									
18	45.7	46.1	46.0	36.6	35.1	38.2	33.2	35.7	32.8
19									
20									
21									
22									
23									
24									
25	19.2	18.0	18.0	16.6	23.0	22.0	20.7	21.7	21.4
26									
27									
28									
29									
30		0.2	0.2	0.2	0.4			Tr[b]	
31									
32									
33									
34									
35									
36									
37									
38									
39	2.3	1.5	1.5	1.6	2.7	2.2	2.3	2.2	2.2
40									
41	2.5	3.1	3.1	2.8	3.5	3.4	3.3	3.3	3.1
42									
43	0.9	0.1	0.1	0.4	1.7	0.6	0.6	0.5	0.5
44									
45									
46									
47	0.9	0.8	0.8	0.6	0.8	0.8	0.4	0.6	0.7
48									
49									
50									
51									
52		1.2	1.2	2.4	1.2			1.3	1.3
53									
54									
55	6.0	1.2	1.2	1.8	3.0	2.8	1.8	2.4	2.3
56									
57									
58									
59									
60									

Table 9c. continued.

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[a] Percentages in this table when multiplied by the projected hectares of surface water in province 3 (SM78: 4,604; WI: 3,925; WII: 3,931; SP79: 8,342; SM79: 8,939; F79: 4,992; WIII: 6,158; WIV: 5,920; SP80: 6,607) equals the estimated hectares of surface water of individual wetland types in province 3.

[b] Tr = less than 0.005%

Table 9d. Percentage composition of the ha of surface water in permanently, semipermanently, and seasonally flooded small lacustrine, palustrine, and riverine basins present on ¼-sections in Oklahoma in province 4 during 1978-80 (# of basins in parentheses) as classified using Cowardin et al. (1979) classification types.

	Season								
Wetland Type from Table 6	**SM78 (51)**	**WI (53)**	**WII (57)**	**SP79 (59)**	**SM79 (56)**	**F79 (56)**	**WIII (61)**	**WIV (61)**	**SP80 (61)**
1	19.2	12.2	11.0	7.2	8.2	14.5	14.2	12.7	8.8
2									
3		3.2	2.7	1.4	1.1	2.4	2.3	2.2	1.5
4									
5									
6									
7									
8									
9							Tr[b]	Tr	Tr
10									
11									
12									
13	30.9	45.0	40.4	32.8	14.6	19.7	32.0	35.2	15.5
14									
15									
16									
17									
18									
19	9.6	11.1	11.6	6.4	5.8	7.9	10.6	9.3	6.8
20									
21									
22									
23									
24									
25	7.1	5.5	7.5	5.5	6.4	8.7	9.0	7.5	6.2
26									
27									
28									
29									
30	0.3	0.4	0.8	0.6	0.6	0.8	1.8	0.9	0.7
31									
32							Tr	Tr	Tr
33									
34									
35									
36									
37									
38				0.1			0.1	0.1	0.1
39	1.5	1.4	1.2	0.9	1.4	1.5	1.6	1.6	1.1
40									
41	2.7	2.8	2.4	1.9	2.6	3.2	3.7	3.4	2.5
42		0.3	0.1	0.3	0.2	0.3	0.1	0.4	0.4
43	2.0	2.1	1.9	1.0	1.2	1.8	2.0	1.6	1.2
44		0.3	0.2	0.2	0.1	0.4	0.5	0.4	0.3
45									
46						2.4	7.1	8.0	7.0
47	0.8	3.5	0.2	0.1	0.1	0.1	0.1	0.1	0.1
48									
49			0.1	0.1	Tr	Tr		0.1	0.1
50									
51	2.0		2.7	4.4	1.9	1.1	1.2	2.0	1.6
52									
53			0.1	0.2			0.2	0.4	0.2
54									
55	5.5	4.3	3.7	3.4	3.7	4.2	5.1	5.1	3.9
56	6.4	5.6	5.1	2.8	4.0	6.2	7.5	5.2	4.3
57	12.2		8.1	29.8	47.5	25.7	0.1	3.8	37.8
58									
59									
60				1.6	1.2				

Table 9d. continued.

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[a] Percentages in this table when multiplied by the projected hectares of surface water in province 4 (SM78: 12,228; WI: 16,381; WII: 18,652; SP79: 38,302; SM79: 34,384; F79: 19,093; WIII: 17,629; WIV: 21,408; SP80: 32,381) equals the estimated hectares of surface water of individual wetland types in province 4.

[b] Tr = less than 0.005%

Riverine systems with mud substrates (wetland type 5, e.g. Chickaskia River) and with mud and sand bars (wetland type 11, e.g. Cimarron River); small lacustrine deep ponds (wetland type 18), shallow flood control structures (wetland type 24), and permanently flooded farm ponds held most of the ha of surface water in province 5 (Table 9e).

Small lacustrine systems such as flood control structures, deep farm ponds, and feedlot sewage lagoons (wetland types 17, 18, 20, and 22); permanently flooded farm ponds (wetland type 25); and ponds dominated with submergent plants (wetland type 41) were most prevalent in province 6 (Table 9f). These deeper and more permanent systems were more common in western Oklahoma because shallower wetlands dry out rapidly, silt in quickly, and receive little or no surface water runoff. Inundation of shallow wetlands in province 6 was sporadic and of short duration.

The statewide percentage of ha of surface water was dominated by riverine wetland types 1, 2, 11, and 12; by lacustrine types 18 and 24; and by palustrine types 25 and 57 during spring and summer. Permanently flooded mud substrate farm ponds (wetland type 25) held the greatest percentage of the ha of surface water in most areas of Oklahoma.

Province 4 had the greatest diversity of wetland types (0.02 types/km^2) followed by province 2 (0.0095 types/km^2), province 1 (0.0078 types/km^2), province 3 (0.0075 types/km^2), province 5 (0.0070 types/km^2) and province 6 (0.0025 types/km^2).

Physical variables. The 60 wetland classification types were condensed into 25 broader wetland groups to facilitate further data analyses. These groups combined ecologically similar wetland types and closely related wetland types to increase sample sizes. Groups 1-5 were

Table 9e. Percentage composition of the ha of surface water in permanently, semipermanently, and seasonally flooded small lacustrine, palustrine, and riverine basins present on ¼-sections in Oklahoma in province 5 during 1978-80 (# of basins in parentheses) as classified using Cowardin et al. (1979) classification types.

	Season								
Wetland Type from Table 6	SM78 (106)	WI (100)	WII (102)	SP79 (106)	SM79 (143)	F79 (137)	WIII (142)	WIV (146)	SP80 (144)
1					1.5	1.1	1.1	2.1	1.4
2	4.2	4.2	4.0	3.5	2.2	2.7	2.6	2.4	2.4
3									
4	2.1	3.9	2.6	3.1	2.1	2.0	0.7	1.9	1.9
5			8.2	14.0	4.9	9.3	10.4	11.3	12.8
6									
7									
8									
9					0.9	2.1	2.1	1.3	1.6
10					0.6		0.3	0.9	1.2
11	0.4	19.4	17.7	15.4	14.6	9.8	12.2	12.8	8.3
12	3.7	3.8	3.1	3.0	2.0	2.3	1.3	1.5	2.3
13									
14									
15	1.0	1.1	1.1	0.8	0.6	0.6	0.8	0.6	0.3
16									
17									
18	13.4	17.7	16.2	14.1	10.6	11.9	11.2	9.5	10.6
19									
20									
21									
22									
23									
24	23.7	2.5	20.4	17.7	12.7	11.3	8.3	9.2	10.6
25	30.8	16.6	19.1	19.0	32.0	32.1	33.1	31.0	31.3
26	0.5	0.3	0.3	0.1	0.2				
27	0.2			0.2	0.2	0.2	0.1	0.3	0.2
28									
29	3.8	3.8			1.9	2.3	2.2	2.1	2.1
30	0.6	0.1	0.2	0.9	1.0	0.7	1.2	1.1	1.2
31	0.2	0.1		0.1	0.3	0.2	0.2	0.2	0.2
32									
33	0.3	0.5	0.9	1.1	0.8	0.8	0.9	0.9	1.0
34	0.3	0.1	0.6	0.6	0.6	0.6	0.8	0.7	0.7
35	0.7	0.1	0.4	1.1	0.8	0.9	0.9	0.8	0.8
36	0.6		0.1	0.6	0.4	0.4	0.4	0.4	0.4
37									
38									
39	1.0	0.4	0.4	0.2	0.7	0.7	0.7	0.7	0.7
40									
41	1.3	0.9	0.9	0.9	1.0	1.0	1.0	0.8	1.0
42									
43									
44									
45									
46									
47	0.9	0.6	0.6	0.4	0.6	0.4	0.6	0.6	0.4
48	0.7	0.4	0.4	0.3	0.3	0.3	Tr[b]	0.1	
49	0.1				0.1	0.1	0.1	0.1	0.1
50									
51									
52									
53									
54	1.6	0.5	0.8	0.8	1.0	0.7	0.6	0.8	0.8
55	3.6	2.1	1.6	1.4	1.6	2.0	2.1	1.8	1.8
56									
57									
58	4.7	1.0	0.9	0.8	3.4	3.5	3.6	3.3	3.2
59					0.3		0.3	0.3	0.5
60					0.3	0.2	0.3	0.2	0.1

Table 9e. continued.

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[a] Percentages in this table when multiplied by the projected hectares of surface water in province 5 (SM78: 33,249; WI: 21,763; WII: 24,439; SP79: 28,852; SM79: 39,771; F79: 34,343; WIII: 33,788; WIV: 38,725; SP80: 39,906) equals the estimated hectares of surface water of individual wetland types in province 5.

[b] Tr = less than 0.005%

Table 9f. Percentage composition of the ha of surface water in permanently, semipermanently, and seasonally flooded small lacustrine, paulstrine, and riverine basins present on ¼-sections in Oklahoma in province 6 during 1978-80 (# of basins in parentheses) as classified using Cowardin et al. (1979) classification types.

	Season								
Wetland Type from Table 6	SM78 (20)	WI (11)	WII (12)	SP79 (17)	SM79 (31)	F79 (31)	WIII (27)	WIV (28)	SP80 (25)
1						1.0	4.5	4.2	4.0
2									
3									
4									
5									
6									
7									
8									
9				0.4		0.2			
10									
11									
12									
13									
14									
15									
16									
17	8.9	0.4	0.4	0.4	2.2	5.3	3.5	4.2	4.1
18	47.3	84.8	83.0	77.8	55.9	67.8	67.8	60.2	60.3
19									
20	10.5	6.7	6.5	6.4	4.7	0.4	3.4	6.1	
21									
22	4.8	3.0	3.0	2.8	5.0	5.5	3.5	5.2	6.1
23									
24									
25	20.9	3.9	5.3	8.0	20.0	10.9	9.2	10.3	11.3
26									
27									
28									
29									
30	2.7			1.7	2.9	4.7	4.3	5.0	4.3
31									
32									
33									
34					0.7	0.9	0.8	0.8	0.8
35									
36									
37					0.4	0.4	0.2	0.5	0.3
38	1.1								
39					0.4	0.7	0.7	0.8	0.7
40		0.4	0.4		0.3	0.4	0.3	0.3	0.3
41	3.4	0.4	1.1	2.2	4.3	1.6	1.6	2.3	2.6
42									
43									
44									
45									
46									
47									
48									
49									
50									
51									
52	0.3	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.2
53									
54									
55									
56									
57									
58									
59									
60									

Table 9f. continued.

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[a] Percentages in this table when multiplied by the projected hectares of surface water in province 6 (SM78: 4,386; WI: 2,006; WII: 2,275; SP79: 3,225; SM79: 7,258; F79: 4,376; WIII: 4,384; WIV: 6,077; SP80: 6,075) equals the estimated hectares of surface water in individual wetland types in province 6.

Table 9g. Percentage composition of the ha of surface water in permanently, semipermanently, and seasonally flooded small lacustrine, palustrine, and riverine basins present on ¼-sections throughout Oklahoma during 1978-80 (# of basins in parentheses) as classified using Cowardin et al. (1979) classification types.

	Season								
Wetland Type from Table 6	SM78 (322)	WI (313)	WII (322)	SP79 (340)	SM79 (454)	F79 (431)	WIII (441)	WIV (458)	SP80 (448)
1	4.6	3.1	3.1	2.8	4.0	3.6	4.9	4.7	4.6
2	15.1	12.8	12.4	9.7	8.5	10.5	9.8	7.5	8.4
3			0.4	0.4	0.5	0.4	0.3	0.3	0.3
4	5.8	5.0	4.9	4.0	3.5	4.4	3.4	3.2	3.4
5			1.8	2.6	1.2	2.7	2.6	2.7	3.1
6		Tr[b]	Tr	Tr	Tr		Tr	Tr	Tr
7	1.9	1.0	1.5	1.2	1.1	0.6	0.9	1.0	1.0
8				1.3	0.7	1.0	8.5	7.0	7.1
9				Tr	0.3	0.6	0.6	0.4	0.5
10					0.1		0.1	0.2	0.3
11	2.3	17.9	15.4	12.2	8.6	4.4	4.6	12.2	3.2
12	9.0	4.8	5.0	7.1	4.5	3.8	2.4	3.3	5.1
13	5.3	7.0	6.8	8.4	3.0	3.0	4.1	4.6	2.9
14			Tr	Tr	Tr			Tr	
15	1.8	1.8	1.8	1.0	1.0	0.8	1.4	1.0	1.0
16	0.7	0.7	0.5	0.6	0.6	0.7	0.7	0.4	0.6
17	0.9	0.1	0.1	0.1	0.3	0.7	0.4	0.4	0.4
18	11.0	15.4	14.8	11.1	10.4	13.6	11.9	10.1	10.0
19	1.6	1.7	1.9	1.7	1.2	1.2	1.3	1.2	1.3
20	0.7	0.6	0.6	0.5	1.7	1.6	1.7	1.8	1.7
21	0.2	4.6	4.4	3.3	2.9	4.0	3.5	3.0	2.9
22	0.3		0.3	0.2	0.4	0.6	0.3	0.4	0.4
23	0.6	0.5	0.5	0.5	0.5	0.6	0.5	0.4	0.5
24	5.5	4.5	4.4	3.3	3.2	3.4	2.2	2.4	2.6
25	16.8	9.1	10.5	10.8	20.1	21.8	20.8	18.6	18.7
26	0.1	0.1	0.1	Tr	Tr				
27	0.1			Tr	Tr	0.1	Tr	0.1	0.1
28	0.1	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
29	0.9	0.8			0.5	0.7	0.5	0.5	0.5
30	0.4	0.1	0.2	0.5	0.7	0.8	1.0	0.9	0.8
31	0.1	Tr		Tr	0.1	0.1	0.1	0.1	0.1
32							Tr	Tr	Tr
33	0.1	0.1	0.2	0.2	0.2	0.4	0.4	Tr	0.4
34	0.1	Tr	0.1	0.1	0.2	0.3	0.3	0.2	0.2
35	0.6	0.3	0.4	0.5	0.6	0.5	0.6	0.6	0.5
36	0.1		Tr	0.1	0.1	0.1	0.1	0.1	0.1
37					0.1	0.1	Tr	0.1	0.1
38	0.1			0.1	Tr		Tr	0.1	0.1
39	2.1	0.8	0.8	0.9	1.6	1.6	1.7	1.4	1.5
40		Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
41	2.2	1.4	1.4	1.6	2.4	2.1	2.1	1.9	1.9
42		Tr	0.1	0.1	0.1	0.1	Tr	0.1	0.1
43	0.4	0.4	0.3	0.3	0.4	0.3	0.3	0.3	0.3
44		Tr	Tr	0.1	0.2	0.1	0.3	0.2	0.2
45					Tr	0.1	0.1	Tr	0.1
46						0.4	0.9	1.0	1.3
47	1.0	0.8	0.6	0.5	0.6	0.6	0.6	0.6	0.5
48	0.2	0.1	0.1	0.1	0.1	0.1	Tr	Tr	
49	Tr	0.1	Tr	Tr	Tr	Tr	Tr	Tr	0.1
50							Tr	Tr	
51		0.9	0.4	1.1	0.4	0.2	0.2	0.3	0.3
52	Tr	0.1	0.1	0.2	0.1	Tr	Tr	0.1	0.1
53			Tr	0.1			Tr	0.1	Tr
54		0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
55			1.3	1.1	1.4	1.5	1.6	1.4	1.4
56	1.1	0.9	0.8	0.7	0.9	1.0	1.0	0.1	0.8
57	2.1		1.4	7.7	9.7	3.9	0.1	0.5	7.2
58		0.2	0.2	0.2	0.8	1.0	0.9	0.8	0.8
59					0.1		0.1	0.1	0.1
60				0.4	0.3	0.1	0.1	0.1	Tr

Table 9g. continued.

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[a] Percentages in this table when multiplied by the projected hectares of surface water statewide (SM78: 110,605; WI: 128,668; WII: 106,861; SP79: 149,911; SM79: 151,909; F79: 105,164; WIII: 109,077; WIV: 125,319; SP80: 151,986) equals the estimated hectares of surface water of individual wetland types statewide.

[b] Tr = less than 0.005%

riverine systems, 6-8 were lacustrine systems, and 11-27 were palustrine systems (Table 8).

The shoreline development index (SDI) (Lind 1974) was significantly (AOV-test, $\underline{P}<0.0001$) different among wetland groups in all seasons (Table 10). Small lacustrine groups 6 and 7 and palustrine groups 15, 23, and 25 had consistently higher SDI's than other wetland groups. Although most wetland groups had little change in SDI over seasons, some wetland groups changed greatly, and the total average SDI of all wetland groups combined was significantly (AOV-test, $\underline{P}<0.05$) different over seasons (Table 10). Seasons that had higher precipitation and water levels (i.e. SM78, SP79, SP80, WIV, and SM79) were directly related to the highest SDI's. SDI was directly related to precipitation during survey periods in province 4, but negatively related in provinces 1 and 3 (Fig. 7a). As wetland basins enlarged during late winter, spring, and summer in province 4, greater shoreline indentation occurred due to increasing shoreline length. However, greater precipitation and runoff in provinces 1 and 3 filled more small, less indentated, wetland basins causing the average SDI's in the province to decrease rather than increase.

The average SDI of all wetlands combined was significantly (AOV-test, $\underline{P}<0.0001$) different among provinces (Table 11). Province 6 had the highest SDI and provinces 1 and 2 the lowest. This same pattern occurred when individual wetland groups were analyzed over all seasons (Appendix A-1).

The % of the surface water area less than 1 m deep was significantly (AOV-test, $\underline{P}<0.0001$) different among wetland groups and seasons (Table 12). Small lacustrine, refinery and oil well pools

Table 10. Mean shoreline development index of wetland basins with water present on random ¼-section sample plots in relation to wetland group and season (sample size of total wetland basins in parentheses).

Wetland group	SM78[a]	WI[a]	WII[a]	SP79[a]	SM79[a]	F79[a]	WIII[a]	WIV[a]	SP80[a]
6	1.61	1.70	1.69	1.70	1.44	1.45	1.46	1.57	1.58
7	2.12	1.90	1.90	1.98	1.88	1.74	1.70	1.78	1.77
8	1.53	1.36	1.36	1.36	1.36	1.19	1.22	1.00	1.06
11	1.25	1.20	1.20	1.24	1.22	1.19	1.23	1.21	1.24
12	1.43	1.43	1.00	1.13	1.43	1.95	1.65	1.58	1.70
13	1.21	1.05	1.02	1.16	1.12	1.27	1.13	1.15	1.19
14	1.08	1.17	1.25	1.16	1.00	1.06	1.06	1.23	1.06
15	2.05	1.11	1.24	1.39	1.42	1.48	1.20	1.43	1.63
16	1.50		1.27	1.26	1.39	1.50	1.08	1.28	1.26
17	1.19	1.16	1.16	1.27	1.23	1.13	1.19	1.17	1.20
18	1.26	1.22	1.22	1.24	1.17	1.14	1.21	1.19	1.21
19	1.33	1.24	1.24	1.43	1.13	1.30	1.32	1.34	1.22
20						1.27	1.19	1.15	1.15
21	1.30	1.20	1.24	1.23	1.30	1.21	1.28	1.38	1.26
22	1.38	1.38	1.06	1.11	1.20	1.06	1.16	1.11	1.10
23		2.06	1.88	1.96	2.07	1.00	1.03	1.56	1.86
24	1.70	1.50	1.58	1.62	1.62	1.70	1.66	1.56	1.67
25	1.81	1.86	2.02	2.18	2.07	1.46	1.38	2.77	1.60
26	1.78	1.39	1.33	1.39	1.46	1.67	1.43	1.42	1.60
27				2.24	1.65	1.00	1.43	1.11	1.57
Total	1.31 (273)	1.24 (272)	1.24 (277)	1.29 (290)	1.25 (402)	1.23 (369)	1.24 (389)	1.25 (400)	1.27 (396)

Duncan's multiple range test, $\alpha = 0.05$, AOV-test, $\underline{P} = 0.0172$
(Total over seasons)

SM78 SP79 SP80 WIV SM79 WII WIII WI F79

Season means with the same underline are not significantly different.

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[a] Mean shoreline development index is different ($P < 0.0001$) among wetland groups within a season.

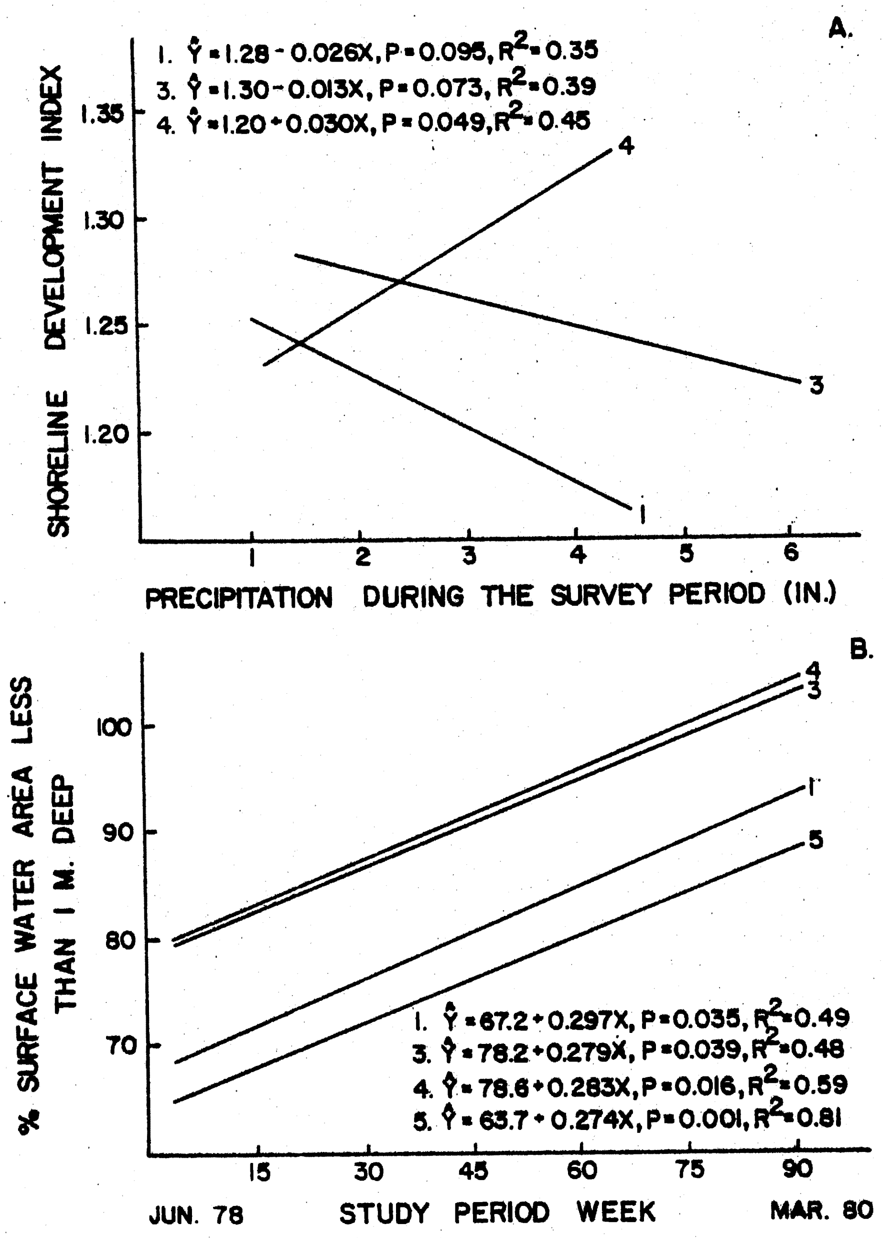

Fig. 7. Relationships between a) the average shoreline development index of wetland basins with water present and the inches of precipitation during the survey period, and b) the average % of the surface water area less than 1 m deep in wetland basins with water present and the survey period week.

Table 11. Ordering of province (1-6) means of shoreline development index and the % of the surface water area less than 1 m deep measured over all wetland basins with water present on random ¼-section sample plots 1978-80 using a Duncan's multiple range test, $\alpha=0.05$. Province means with the same underline are not significantly different.

Variable	Shoreline development index						% surface water area 1m deep					
AOV-test	$P<0.0001$						$P<0.0001$					
Province	6	3	4	5	1	2	4	3	5	6	1	2
Ordering	——						——	——				
		——	——	——					——	——	——	
					——	——				——	——	——
Means	1.4	1.3	1.3	1.3	1.2	1.2	88	87	78	78	77	75

Table 12. Mean % of surface water area less than 1 m deep of wetland basins with surface water present on ¼-section sample plots in relation to wetland group and season (sample size of total wetland basins in parentheses).

Wetland group	SM78[a]	WI[a]	WII[a]	SP79[a]	SM79[a]	F79[a]	WIII[a]	WIV[a]	SP80[a]
1[c]	43.9	57.0	58.3	50.0	82.2	91.1	90.0	86.5	82.5
2	70.0	38.3	100.0	87.2	90.0	84.5	85.6	84.7	84.7
3	100.0	83.3	56.7	36.0	54.0	54.0	88.0	66.0	88.0
4	75.0	100.0	93.3	81.7	93.3	92.5	92.5	95.0	92.5
5	100.0	95.0	95.0	40.0	90.0	90.0	90.0	90.0	90.0
6[c]	16.1	36.2	34.9	31.5	34.3	47.3	47.3	53.3	52.7
7	7.5	5.0	5.0	5.0	46.0	46.0	46.0	46.0	46.0
8	85.0			75.0	75.0	93.3	95.0	95.0	95.0
11[b]	54.8	80.9	88.1	79.0	82.0	82.9	87.1	84.0	88.6
12	50.0	20.0		20.0	20.0	20.0	20.0	20.0	20.0
13[b]	91.4	100.0	100.0	100.0	100.0	98.8	99.2	99.3	99.1
14[b]	63.3		83.3	93.3	100.0	98.5	98.6	95.3	98.6
15	86.2	85.0	100.0	68.8	90.0	90.0	90.0	90.0	90.0
16	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0
17[c]	71.7	91.7	96.8	92.9	88.1	91.0	91.7	91.0	91.7
18[b]	60.0	72.0	89.7	74.6	92.5	85.2	89.8	86.6	90.9
19[b]	61.0	100.0	100.0	92.0	99.0	98.8	98.8	98.8	98.9
20						100.0	100.0	100.0	100.0
21[b]	67.9	86.7	90.0	92.1	95.0	98.4	95.0	95.4	95.0
22	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
23	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
24	40.5	69.4	63.8	50.5	60.9	65.9	65.9	65.9	38.6
25[c]	90.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
26	10.0		50.0	40.0	60.0	40.0	60.0	60.0	60.0
27				100.0	100.0	100.0	100.0	100.0	100.0
Total	57.6 (316)	78.1 (246)	84.2 (217)	76.2 (341)	80.6 (451)	81.5 (426)	85.1 (443)	83.4 (457)	86.5 (446)

Duncan's multiple range test, $\alpha = 0.05$, AOV-test, $\underline{P} < 0.0001$
(Total over seasons)

SP80	WIII	WII	WIV	F79	SM79	WI	SP79	SM78
———	———	———	———					
	———	———	———	———				
		———	———	———	———	———		
					———	———	———	
								———

Season means with the same underline are not significantly different.

---

[a] Mean % of surface water area less than 1m is different ($\underline{P} < 0.0001$) among wetland groups within a season.

[b,c] Mean % of surface water area less than 1m is different ($^{b}\underline{P} < 0.01$, $^{c}\underline{P} < 0.05$) among seasons withina wetland group.

(wetland group 12), and ponds with scrub/shrub (group 24) or flooded trees (group 26) had the smallest % of the surface water area less than 1 m deep. Semipermanently and seasonally flooded wetland basins were usually less than 1 m in depth. The % of the surface water area less than 1 m deep increased throughout the study in provinces 1, 3, 4, and 5 (Fig. 7b). The gradual increase in shallow water area, as precipitation and water levels increased, indicated that flooding and fluctuations in wetland dynamics were primarily shallow water phenomenon in Oklahoma. Almost all wetland groups had the least amount of surface water area less than 1 m deep during SM78 (Table 12). Because of low precipitation and high temperatures in SM78, many shallow wetlands dried leaving only the deeper, more permanent basins with water present.

Provinces 3 and 4 had the greatest % of surface water area less than 1 m deep, while provinces 1, 2, 5, and 6 had less shallow water (Table 11). Most wetland groups followed this trend (Appendix A-2), but riverine groups were much shallower in western Oklahoma.

Ice cover. The average % ice cover was different (AOV-tests, $\underline{P}<0.10$) among wetland groups in 1978-79 (WI and WII) (Table 13) and in 1979-80 (WII and WIV) (Table 14). Water behind flood control impoundments and in shallow farm ponds was frozen to a greater extent than other wetlands in both WI and WII. In contrast, riverine groups and some wetlands dominated by emergent vegetation had the least ice cover. Shallow, semipermanently and seasonally flooded farm ponds froze to a greater extent than other groups during WIII and WIV. Deeper ponds and riverine groups had little ice cover present. The average % ice cover of wetland groups increased from early to late winter in both 1978-79 and 1979-80. Most wetlands had significantly ($\underline{P}<0.05$) greater amounts of ice cover

Table 13. Mean percentage ice cover on wetland groups present in Oklahoma during early and late winter 1978-79.

WI [a]			WII [b]		
Wetland group (from Table 8)	Mean % ice cover	Sample size	Wetland group (from Table 8)	Mean % ice cover	Sample size
8	100.0	1	8	100.0	1
26	100.0	2	26	66.7	3
25	98.0	2	25	100.0	3
4	67.0	2	4	0.0	3
23	63.3	3	23	50.0	4
13	60.0	10	13	41.5	12
17	59.6	24	17	80.4	24
6	56.2	12	6	58.8	12
7	50.5	2	7	50.0	2
19	48.6	5	19	40.0	5
24	45.5	11	24	63.0	10
21	42.9	15	21	92.9	14
11	38.8	158	11	66.0	163
2	36.0	5	2	49.0	7
18	31.9	26	18	80.8	26
3	20.0	5	3	39.0	5
1	13.6	7	1	41.4	7
5	0.0	1	5	10.0	1
12	0.0	4	12	100.0	1
14	0.0	3	14	100.0	3
15	0.0	4	15	100.0	4
22	0.0	1	22	0.0	2
			16	100.0	1

[a] The mean % ice cover was significantly different among wetland groups, AOV-test, $\underline{P}=0.0566$.

[b] The mean % ice ocver was significantly different among wetland groups AOV-test, $\underline{P}=0.0146$.

Table 14. Mean percentage ice cover on wetland groups present in Oklahoma during early and late winter 1979-80.

WIII[a]			WIV[b]		
Wetland group (from Table 8)	Mean % ice cover	Sample size	Wetland group (from Table 8)	Mean % ice cover	Sample size
15	59.0	5	15	21.0	5
14	49.5	14	14	11.3	15
7	33.3	3	7	0.0	3
22	33.3	3	22	40.0	4
23	32.0	3	23	100.0	4
2	30.6	16	2	10.2	16
11	21.9	222	11	24.0	226
18	21.2	28	18	35.5	31
16	20.0	7	16	25.0	8
17	12.7	26	17	24.0	26
13	11.5	26	13	55.9	28
1	10.0	10	1	16.0	10
6	8.0	15	6	10.7	15
21	7.7	13	21	47.1	14
19	5.4	8	19	55.0	8
3	0.0	5	3	8.2	5
4	0.0	2	4	0.0	3
5	0.0	1	5	0.0	1
8	0.0	2	8	10.0	2
12	0.0	4	12	0.0	4
20	0.0	1	20	9.0	1
24	0.0	11	24	1.7	11
25	0.0	3	25	76.3	3
26	0.0	3	26	0.0	3
27	0.0	1	27	0.0	1

---

[a] The mean % ice cover was different among wetland groups, AOV-test, P=0.1002.

[b] The mean % ice cover was significantly different among wetland groups, AOV-test, P=0.0001.

in 1978-79 than in 1979-80.

Vegetational Attributes of Wetlands

Most basins had less than 4 moist soil and emergent species present. Moist soil species were all species occurring from the shoreline to the edge of the basin where upland vegetation began, and emergents were erect species with stems in the water (Fig. 8). Rising water levels often flooded moist soil species making them emergents, and declining water levels often exposed formerly flooded emergents, making them moist soil species. Therefore, many species were transitory between moist soil and emergent zones (Fig. 8).

Distribution. Fifteen moist soil genera, species, or groups had sufficient sample sizes to allow evaluation of species associations with wetland groups (Table 15). Associations were determined using chi-square ($\underline{X}^2$) analysis to test the null hypothesis, Ho: no difference in moist soil plant species composition among wetland groups and among wetland water permanence regimes. The null hypothesis was rejected among wetland groups ($\underline{X}^2$=2730.6, $\underline{P}$<0.0001), and among water regimes ($\underline{X}^2$=65.5,$\underline{P}$=0.0002). All plant species had both positive and negative associations with different wetland groups, indicating varied responses to morphometric, chemical, and biotic characteristics at wetland basins. Few unique composition patterns were present among moist soil plant species groups, but ecologically similar wetland groups seemed to have similar associations.

Riverine systems in general were characterized by the presence of salt cedar (*Tamarix gallica*), sand bar willow (*Salix interior*), and tree species; and the absence of some mudflat (*Polygonum* sp. and *Ludwigia*

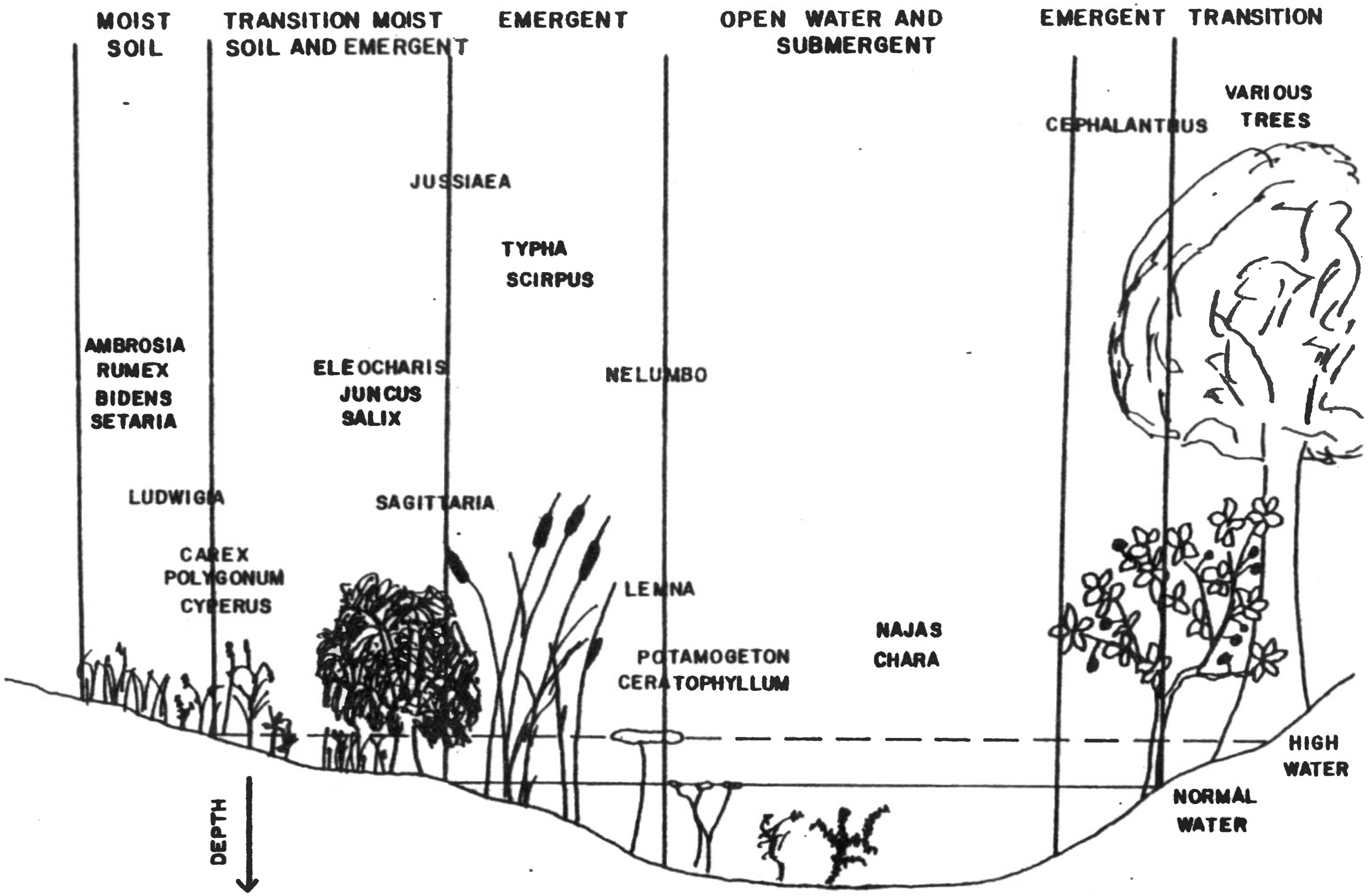

Fig. 8. Wetland profile of vegetation zones in Oklahoma.

Table 15. Positive (+) and negative (-) associations between moist soil plant species (sample size in parentheses) and wetland groups and wetland water permanence at wetland basins with water present on ¼-section plots during 1978-80.

	Ambrosia sp. (153)	*Carex sp.* (121)	*Cephalanthus occidentalis* (160)	*Cyperus sp.* (201)	*Eleocharis sp.* (1069)	*Juncus sp.* (407)	*Jussiaea decurrens* (73)	*Ludwigia sp.* (85)	*Polygonum sp.* (567)	*Salix interior* (55)	*Salix nigra* (967)	*Scirpus sp.* (83)	*Tamarix gallica* (52)	*Typha latifolia* (243)	Various trees (320)
Wetland group															
1					—[a]	-		-		+		-	+	-	++
2	++				—	—	-	-	-				+	-	++
3	-		-		—	-			-	++			++		++
4					-	-			-				++		++
5					-										++
6			++	+	—					-				+	-
7			++	+	-	-			-	+				+	
8				+					+		-				-
11		+	-		++	+		+					—	-	—
12	+								+						
13	+		-	-		-			+	-	+	-		-	
14	+		-		+		+				-				
15									-				++	-	+
16			-		+	+	+				-	+	-	-	-
17	-		—		+						+			+	—
18			-		+								-	+	-
19			-	-	+	+	++		++		—				-
20			+	+	-				+						
21			-	-		+					-		-	++	—
22	+					+			-					++	-
23			++												
24		-	++			-	-					-			+
25	-		++	++							+			-	+
26	+				-				-						++
27					-						+				+
Water permanence															
permanent															
semi-perm.	+		+							-			+		+
seasonal				-			++							-	

[a] - and + are ≥2 and <10 units of the $\underline{X}^2$ total and — and ++ are ≥10 units of the $\underline{X}^2$ total.

sp.) and sedge species. Small lacustrine areas had positive associations with buttonbush (Cephalanthus occidentalis), Cyperus sp., and cattail (Typha latifolia), and negative associations with tree species other than Salix nigra. Ponds dominated by submergent and emergent vegetation had positive associations with cattail and water primrose (Jussiaea decurrens). Small, semipermanently and seasonally flooded natural prairie wetlands (wetland groups 15 and 16) had positive associations with mudflat species and negative associations with trees. In contrast, scrub/shrub and forested sloughs and oxbows were dominated by buttonbush, various trees, and Cyperus sp., and were negatively associated with Eleocharis sp. Moist soil species were not good indicators of water permanence (Table 15). A few associations were present, but no trends were apparent.

Emergent plant species associations were determined using X^2 analysis to test the null hypothesis, Ho: no difference in emergent plant species composition among wetland groups and among wetland water permanence regimes. The composition among groups was different (X^2= 1528.5,$P<0.0001$), but the composition among water regimes was not (see Table 16).

Emergent plant species had many associations with wetland groups that were similar to moist soil species associations (Table 16). Ecologically similar wetland groups had similar associations but few unique associations occurred. Rivers had positive associations with Ambrosia sp. and willows. Small lacustrine wetlands had positive associations with buttonbush, Cyperus sp., and cattail. Man-made, mud substrate, farm ponds had few emergent species present and consequently had few associations. However, Eleocharis sp. and Polygonum sp. were

Table 16. Positive (+) and negative (-) associations between emergent plant species (sample size in parentheses) and wetland groups and wetland water permanence at wetland basins with water present on ¼-section plots during 1978-80.

Wetland group	*Ambrosia sp.* (73)	*Carex sp.* (56)	*Cephalanthus occidentalis* (62)	*Cyperus sp.* (23)	*Eleocharis sp.* (438)	*Juncus sp.* (232)	*Jussiaea decurrens* (93)	*Ludwigia sp.* (41)	*Nelumbo lutea* (17)	*Polygonum sp.* (173)	*Salix interior* (18)	*Salix nigra* (236)	*Scirpus sp.* (45)	*Tamarix gallica* (8)	*Typha latifolia* (216)	Various trees (40)
1					-[a]							++			-	++
2	++		+													++
3											++			++		
4																
5									++							++
6	-						+						+		+	
7			++	+											++	
8				+						+		-			+	
11	+				+				-					-	--	-
12																
13					-					+		+			-	
14					+		++					-				
15													+	++	-	+
16							+						+	++	-	
17					-			++				-			+	-
18			-		+			-	++							-
19	+		-				+		+	++		-				
20				++												
21		+	-		+	+			+			--			++	-
22						+				-		-			++	
23			++			+										
24			+			-					+	++				
25			++	++											-	+
26					-							+				++
27	++											+				++

Water permanence

Permanent
Semi-perm Not Significant, X^2=42.005, P=0.110
Seasonal

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[a] - and + are ≥2 and <10 units of the X^2 total and -- and ++ are ≥10 units of the X^2 total.

positively associated with some groups. Wetlands dominated by submergent and emergent vegetation had positive associations with most emergent species with the exception of buttonbush and trees. The greatest diversity and number of emergent species also occurred at these wetlands. Prairie, natural palustrine, basins had positive associations with *Scirpus* sp. and salt cedar. Sloughs and oxbows were characterized by the presence of trees, buttonbush, and *Cyperus* sp. Emergent plant species occurred at Oklahoma wetlands almost randomly in relation to water permanence (Table 16).

Submergent plant species associations were determined by X^2 tests, Ho: no difference in the occurrence of *Ceratophyllum demersum*, *Chara vulgaris*, *lemna minor*, *Najas guadalupensis*, *potamogeton* sp., and littoral epipelic algae among wetland groups and among wetland water permanence regimes. All X^2-tests had $P<0.0001$ except *Ceratophyllum demersum* ($X^2=7.1, P=0.0285$) and *lemna minor* ($X^2=0.419$, $P=0.811$) among wetland water regimes.

Submergent plant species and littoral epipelic algae seemed more specific in requirements for existance at Oklahoma wetlands (Table 17). Most submergent species had either a distinct positive or negative association for almost all wetland groups. Submergent species were usually positively associated with small lacustrine wetlands and palustrine wetlands dominated by submergent and emergent vegetation, but were negatively associated with mud substrate farm ponds and natural prairie wetlands and rivers. Exceptions were the positive association of *Ceratophyllum demersum* with some mud and sand bar rivers and the positive association of *Lemna minor* with slower flowing mud channel rivers. Natural sloughs and oxbows were positively associated

Table 17. Positive (+) and negative (-) associations between submergent plant species (sample size in parentheses) and wetland groups and wetland water permanence at wetland basins with water present on ¼-section plots during 1978-80.

	Ceratophyllum demersum (34)	*Chara vulgaris* (237)	*Lemna minor* (47)	*Najas guadalupensis* (375)	*Potamogeton sp.* (180)	Littoral epipelic algae (280)
Wetland group						
1	- [a]	--	++	--	--	-
2	-	--		--	--	
3		--	-	--	-	
4	++	-			-	-
5		-		-		-
6	++			-		
7	++			++	++	
8	++	++		++	++	+
11	--	--	--	--		+
12		-		-	-	
13	-	--	-	--	--	--
14		--	-	--	--	-
15			-	--	-	-
16			-	--	-	--
17	++	++		++		
18	++	++	++	++	++	++
19				++		-
20			++			
21		++	+	++	++	
22		+		++	++	+
23		-		--	-	-
24	-	+	-		--	
25			++	++		-
26		-		-	-	
27		-	++	-		-
Water permanence						
Permanent		+	NS	+	+	+
Semi-perm	-	--		--	--	--
Seasonal	-	-		--	-	--

[a] - and + are >2 and <10 units and -- and ++ are ≥10 units of the $\underline{X}^2$ total.

with *Lemna minor* and *Najas guadalupensis* but were negatively associated with *Chara vulgaris*, *Potamogeton* sp., and algae. All submergents except *Lemna minor* were positively associated with permanently flooded and negatively associated with semipermanently and seasonally flooded wetlands (Table 17).

Composition of moist soil plants was significantly (X^2-test, $P<0.0001$) different among physiographic provinces (Table 18). Wetlands in province 1 were positively associated with *Carex* sp., *Jussiaea decurrens*, *Polygonum* sp., and hardwood trees, but negatively associated with most other species. Wetlands in province 2 were positively associated with sedges and *Salix interior*, but negatively associated with woody species and cattail. Wetlands in provinces 3 and 4 had positive associations with woody species and cattails, and negative associations with weeds and *Ludwigia* sp. *Eleocharis* sp. was common in province 4, and *Juncus* sp. and *Polygonum* sp. were common in province 3. Weeds and willows were positively associated, and sedges negatively associated, with wetlands in province 5. Wetlands in province 6 had positive associations with *Polygonum* sp., *Salix nigra*, and salt cedar, and negative associations with sedges.

Composition of emergent plant species varied among provinces (Table 19). Submergent species also showed significant (X^2-tests, $P<0.0001$) differences in their occurrence over physiographic provinces (Table 20). Most submergents were positively associated with wetlands in provinces 2, 3, and 4, and most were negatively associated with wetlands in provinces 1, 5, and 6. Exceptions were positive associations of algae with wetlands in province 1, and *Lemna minor* with wetlands in province 6, and negative associations of *Ceratophyllum demersum* with

Table 18. Positive (+) and negative (-) associations between moist soil plant species (sample size in parentheses) and physiographic provinces at wetland basins with water present on random ¼-section sample plots during 1978-80.[a]

Physiographic province	*Ambrosia* sp. (153)	*Carex* sp. (122)	*Cephalanthus occidentalis* (160)	*Cyperus* sp. (201)	*Eleocharis* sp. (1070)	*Juncus* sp. (407)	*Jussiaea decurrens* (73)	*Ludwigia* sp. (85)	*Polygonum* sp. (568)	*Salix interior* (55)	*Salix nigra* (970)	*Scirpus* sp. (83)	*Tamarix gallica* (52)	*Typha latifolia* (243)	Various trees (339)
1	-	++	-				++	-	++	-	-		-	-	+
2		+	-		+	++	+			+	--	+		-	--
3	-		+			+	-	-	+	-				+	+
4	--		+		+	-		-	-	-	+		-	+	+
5	++	--			-	--	--	++		+	++		+		
6		-			-	-	-		++		++		+		

[a] Associations determined by $\underline{X}^2$-tests; Ho: No difference in moist soil plant species composition among physiographic provinces. $\underline{X}^2$=514.333, $\underline{P}$<0.0001. - and + are ≥2 and <10 units of $\underline{X}^2$ total and -- and ++ are ≥10 units of the $\underline{X}^2$ total.

Table 19. Positive (+) and negative (-) associations between emergent plant species (sample size in parentheses) and physiographic provinces at wetland basins with water present on random ¼-section sample plots during 1978-80.[a]

Physiographic province	*Ambrosia* sp. (73)	*Carex* sp. (56)	*Cephalanthus occidentalis* (63)	*Cyperus* sp. (23)	*Eleocharis* sp. (438)	*Juncus* sp. (232)	*Jussiaea decurrens* (93)	*Ludwigia* sp. (41)	*Nelumbo lutea* (17)	*Polygonum* sp. (174)	*Salix interior* (18)	*Salix nigra* (236)	*Scirpus* sp. (45)	*Tamarix gallica* (8)	*Typha latifolia* (216)	Various trees (43)
1					+		++			+	-	-	-		--	+
2		+	-			++	+	+	-			-		-	-	-
3			++			++	-		++	-	-	--	-			
4		-	+	+	-	-	+	-				-			++	
5	+				-	--	--		-	-	++	++		++	+	
6				+	-	-	-			++		++				

[a] Associations determined by X^2-tests; Ho: No difference in emergent plant species composition among physiographic provinces. $X^2=467.114$, $P<0.0001$. - and + are ≥2 and <10 units of X^2 total and -- and ++ are ≥10 units of the X^2 total.

Table 20. Positive (+) and negative (-) associations between submetgent plant species (sample size in parentheses) and physiographic provinces at wetland basins with water present on random ¼-section sample plots during 1978-80.[a]

Physiographic province	Ceratophyllum demersum (34)	Chara vulgaris (237)	Lemna minor (47)	Najas guadalupensis (375)	Potamogeton sp. (180)	Littoral epipelic algae (280)
1	--	--		--	-	++
2	--	+	+	++	++	++
3	++		+	++	++	-
4	+	++	+	++		--
5	-		--	--	-	
6	-	-	+	--	--	--

[a] Associations determined by $\underline{X}^2$-tests; Ho: No difference in the occurrance of Ceratophyllum demersum, Chara vulgaris, Lemna minor, Najas guadalupensis, Potamogeton sp., and epipelic littoral algae among physiographic provinces. All $\underline{X}^2$-tests had $\underline{P}<0.0001$. - and + are ≥ 2 and <10 units of $\underline{X}^2$ total and -- and ++ are ≥ 10 units of the $\underline{X}^2$ total.

wetlands in province 2 and algae with wetlands in provinces 3 and 4.

Ecological relationships among plant species. Ecological relationships among species with moist soil and emergent groups were determined with cluster analyses using the 36 variables measured at wetland basins where individual plant species were present. A distance matrix using the important variables in the 1st 3 primcipal components of the SM79 data was calculated and analyzed with the dendrograph program of McCammon and Wenniger (1970). The dendrograph depicted the relationships among the plant species in a hierarchial manner in 2 dimensions (figs. 9 and 10).

Arbitrarily using 0.4 as a dividing line, 4 distinct groups of moist soil plant species were apparent (Fig. 9). Group 1 species (i.e. *Ambrosia* sp., *Cyperus* sp., *Echinocloa crusgalli*, *Eleocharis* sp., Graminae sp., *Heteranthera limosa*, *Juncus* sp., *Jussiaea decurrens*, *Polygonum* sp., *Rumex crispus*, *sagittaria* sp., *Salix nigra*, *Scirpus* sp. and *Setaria* sp.) seemed to have similar ecological requirements and often occurred at wetland basins together in various combinations. Hardwood trees and *Sparganium* sp. (group 2) were closely related to each other but distinct from other groups. Group 2 species were more closely related to group 1 than to groups 3 and 4. Both *Typha latifolia* (group 3) and *Cephalanthus occidentalis* (group 4) apparently had distinct ecological requirements at wetland basins and were widely separated from other species. *Typha latifolia* was more closely related to groups 1 and 2 than was *Cephalanthus occidentalis*.

Emergent plant species seemed to have more distinct ecological requirements at Oklahoma wetlands (Fig. 10). Arbitrarily using 0.9 and 0.3 as dividing lines, 2 major groups (A and B) and 7 sub-groups (1-5

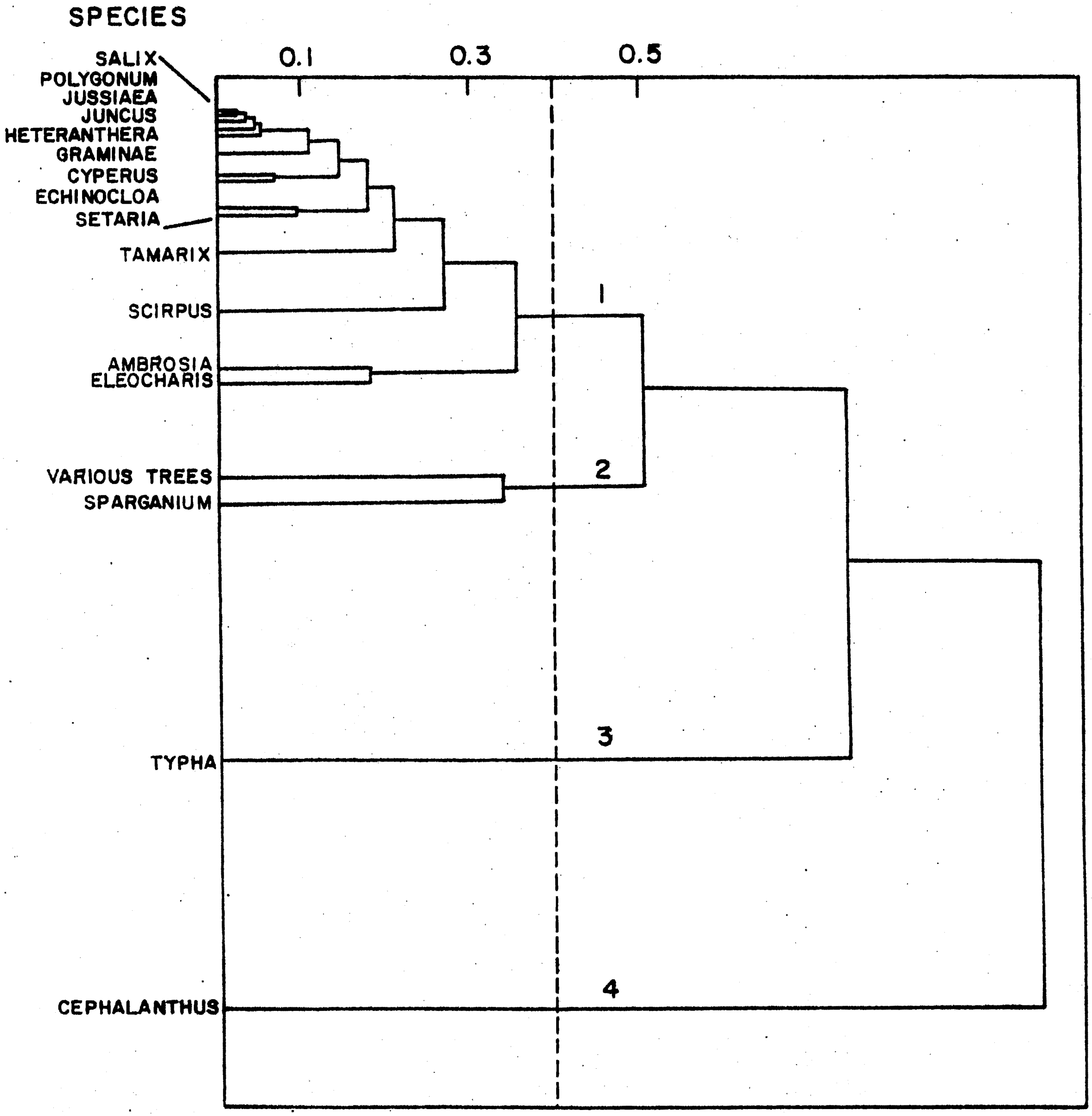

Fig. 9. Dendrograph of the cluster analysis of moist soil plant species present at wetland basins with water present during SM79. See text for interpretation.

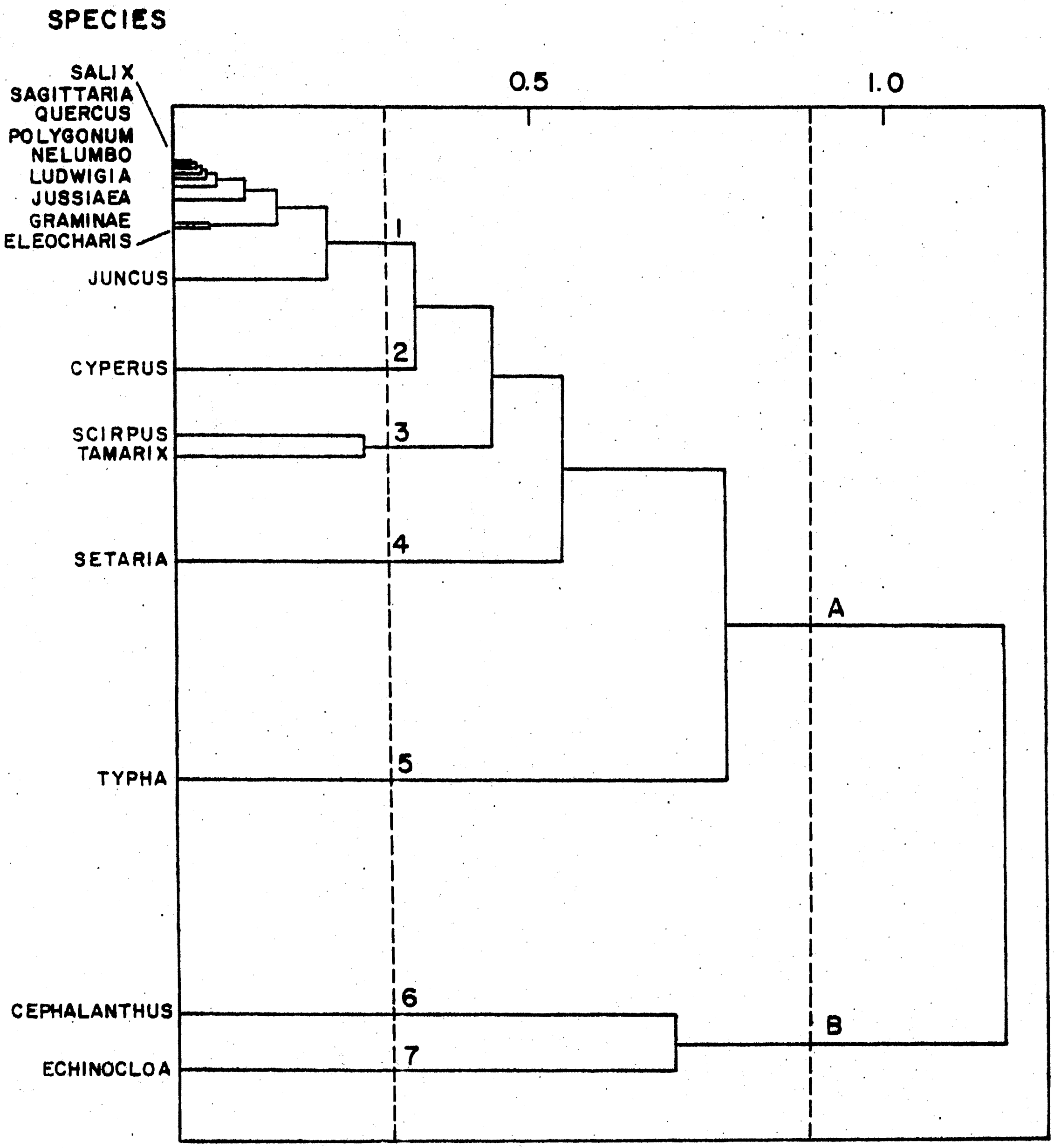

Fig. 10. Dendrograph of the cluster analysis of emergent plant species present at wetland basins with water present during SM79. See text for interpretation.

under group A and 6-7 under group B) were present. Group 1 (i.e. *Eleocharis* sp., Graminae sp. *Jussiaea decurrens*, *Ludwigia* sp., *Nelumbo* sp., *Polygonum* sp., *Quercus* sp., *Sagittaria* sp., *Salix nigra*, and *Juncus* sp.) contained the most species, and these species apparently had the most similar ecological requirements as emergents. None of these species were true emergents, but occurred most often as moist soil plants and became emergents only after flooding during higher water levels. Group 2 contained only *Cyperus* sp. and was closely related to group 1. *Scirpus americanus* and *Tamarix gallica* comprised group 3. Group 4 contained only *Setaria* sp. The distinctness of group 4 may be due to small sample size rather than to real ecological differences. *Typha latifolia* (group 5) seemed relatively distinct, as it did in moist soil relationships. Groups 6 (*Cephalanthus occidentalis*) and 7 (*Echinocloa crusgalli*) were more closely related to each other than to groups 1-5, yet each was distinct. *Cephalanthus occidentalis* and *Echinocloa crusgalli* both occurred more often in sloughs and oxbows, in contrast to groups 1-4 (they occurred more often at farm ponds) and to group 5 (it occurred at both farm ponds and natural wetlands).

Relationships between the occurrence of submergent plant species and the occurrence of individual moist soil and emergent plant species at wetland basins were determined using correlation analysis. All moist soil species except Graminae sp. and *Quercus* sp. had either positive or no correlations with individual submergents (Table 21). Weed species were not correlated, either positively or negatively, with submergents, with the exception of the negative correlation between grasses and *Chara vulgaris*. In contrast, most sedges, typical emergents, and mudflat

Table 21. Significant (*P*<0.01) simple correlation coefficients (either positive or negative) for moist soil plant species with submergent plant species present at wetland basins with water present 1978-80.

Moist soil species	Sample size	SBCT	SBCH	SBL	SBN	SBP
Weed						
Ambrosia sp.	125		-.12			
Graminae sp.	1141					
Rumex sp.	16					
Compositae sp.	86					
Xanthium pennsylvanicam	125					
Sedge						
Carex sp.	110		.08	.15		.09
Eleocharis sp.	1015		.09	.04	.23	.12
Juncus sp.	374		.04	.08	.10	.16
Eleocharis quadrangulata	24				.06	
Cyperus sp.	154		.13			.10
Mudflat						
Echinocloa crusgalli	209	.06			.05	
Polygonum sp.	490			.05	.07	.06
Sagittaria sp.	20			.10		.11
Emergent						
Jussiaea decurrens	70				.05	
Nelumbo lutea	6	.08		.07	.09	
Scirpus sp.	71			.06	.05	.11
Scirpus americanus	24		.13	.09		.04
Typha latifolia	214		.09		.16	.10
Woody						
Cephalanthus occidentalis	108			.08		
Populus deltoids	30					
Quercus sp.	55		-.04		.04	
Salix interior	33		.08			
Salix nigra	805		.07		.07	
Tamarix gallica	19		.06			
Various trees						

species were positively correlated with most submergent species. Willows and salt cedar were correlated with *Chara vulgaris* and *Najas guadalupensis*, and buttonbush with *Lemna minor*, but hardwoods had no correlations.

Emergent plant species had either positive or no correlation with submergents, with the exception of Graminae sp. with *Chara vulgaris* (Table 22). Sedges, typical emergents, and mudflat species had positive correlations with submergents other than *Chara vulgaris*. Only cattail was correlated with *Chara vulgaris*. Buttonbush was positively correlated with *Lemna minor*, but other woody and weed species were not correlated with submergents.

Seasonal and long term dynamics. Although no measurements of the relative density of individual plant species at wetland basins were taken during this study, the % of the wetland basins that had individual plant species (moist soil, emergent, and submergent) present provided some information on seasonal and long term abundance.

Eight common moist soil species (only those with large sample sizes were analyzed) had a general seasonal pattern of high occurrence at basins during summer and fall, and then a gradual decline through winter and spring (Fig. 11). The seasonal pattern of occurrence was related to the germination and growth of species during summer; followed by decay, senesence, consumption, and removal from the wetland basin during winter and spring. However, the occurrence of *Juncus* sp. and some *Polygonum* species began to increase in spring. Cattail remained standing through winter and spring and was relatively constant in occurrence at basins throughout the study. *Jussiaea decurrens*, *Carex* sp., *Juncus* sp., and *Eleocharis* sp. occurred at a higher % of the

Table 22. Significant ($\underline{P}<0.01$) simple correlation coefficients (either positive or negative) for emergent plant species with submergent plant species present at wetland basins with water present 1978-80.

Emergent species	Sample size	SBCT	SBCH	SBL	SBN	SBP
Weed						
Ambrosia sp.	66					
Graminae sp.	309		-.05			
Compositae sp.	16					
Xanthium pennsylvanicum	17					
Sedge						
Carex sp.	52			.10	.04	.14
Eleocharis sp.	420				.11	
Juncus sp.	220				.07	.12
Eleocharis quadrangulata	23				.06	
Cyperus sp.	21					.05
Mudflat						
Echinocloa crusgalli	44	.05				
Polygonum sp.	155					.08
Ludwigia sp.	41					.06
Sagittaria sp.	28			.05		.07
Emergent						
Jussiaea decurrena	87				.06	
Nelumbo lutea	10	.06			.12	
Nymphae sp.	16	.19			.10	
Scirpus sp.	41			.06		.06
Typha latifolia	189	.05	.06		.16	.12
Woody						
Cephalanthus occidentalis	49			.06		
Populus deltoides	17					
Quercus sp.	11					
Salix interior	17					
Salix nigra	206					
Various trees	23					

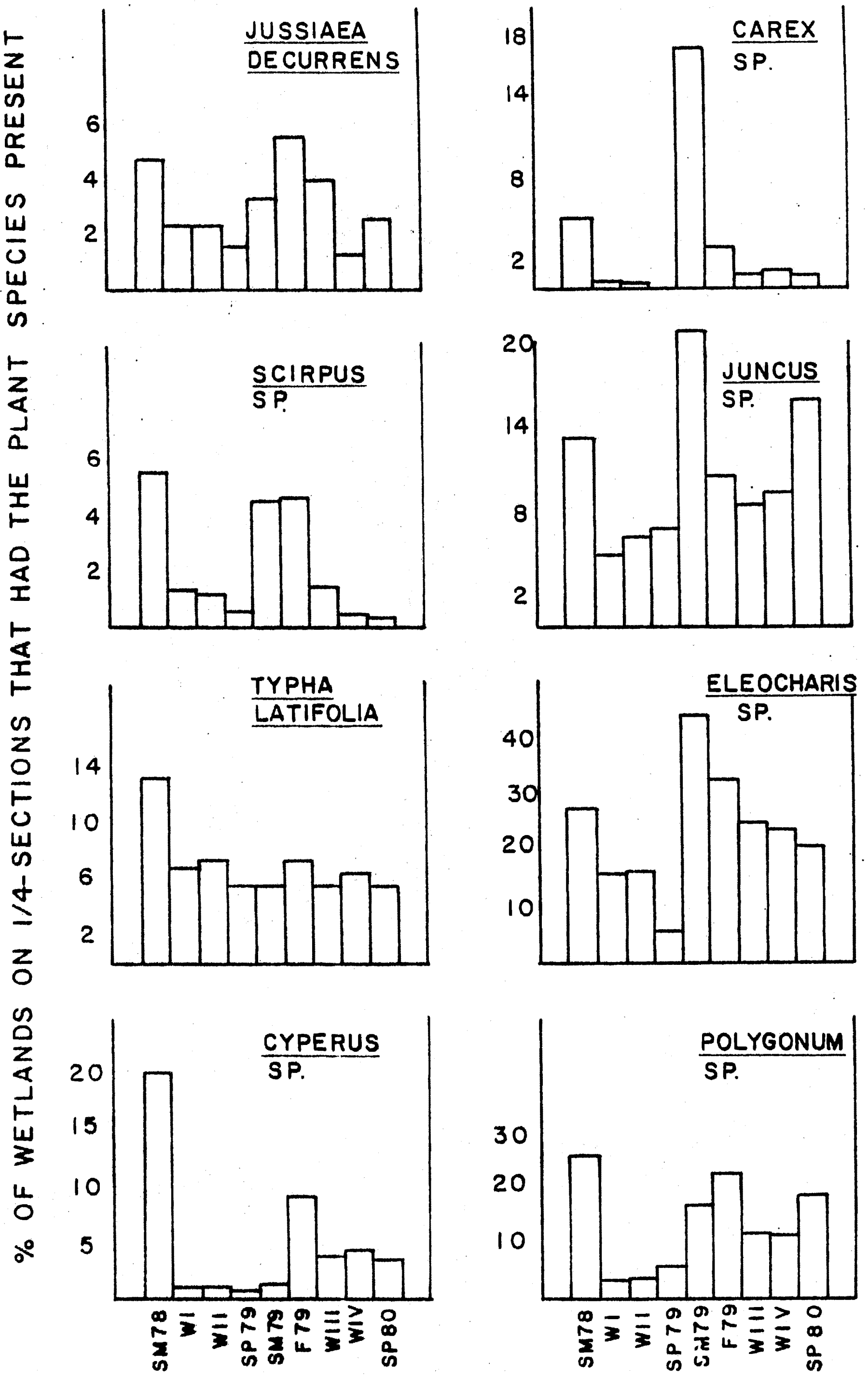

Fig. 11. Seasonal occurrence of moist soil plant species at small lacustrine, riverine, and palustrine wetland basins with water present in Oklahoma.

wetland basins with water present in 1979 than in 1978.

The presence of *Scirpus* sp. as an emergent at wetland basins had a seasonal trend of high occurrence during summer, followed by a gradual decline through spring. Other emergents were erratic in occurrence or showed gradual increases in occurrence from SM78 to SP80 (Fig. 12). Inundation of sedges and mudflat species by higher water levels probably caused some of this increase during later seasons of the study, but *Jussiaea decurrens*, cattail, and other species may have responded by germination and growth following the exposure of mud flats during the low water periods (e.g. Weller 1975).

With the exception of *Ceratophyllum demersum*, submergent species had strong seasonal trends in occurrence (Fig. 13). No fall survey was made in 1978 so interpretation is somewhat incomplete, but *Potamogeton* sp., *Chara vulgaris*, and *Najas guadalupensis* apparently had fall peak occurrences. *Lemna minor* peaked in summer. No data were obtained on the occurrence of littoral epipelic algae during SM78, WI, WII, or SM79; but occurrences were much higher in spring than during fall and winter.

Long term response of vegetation to improved water conditions occurred during this study and was superimposed upon annual seasonal vegetation dynamics. Regression analyses were used to test relationships between vegetation characteristics and the phenology and amounts of precipitation falling during the surveys. Significant regressions should not be interpreted to continually increase or decrease with time and precipitation, but instead only represent responses and changes occurring during the apparent upswing portion of the long term water cycle. The number of moist soil plant species present at wetland basins increased throughout the study in provinces

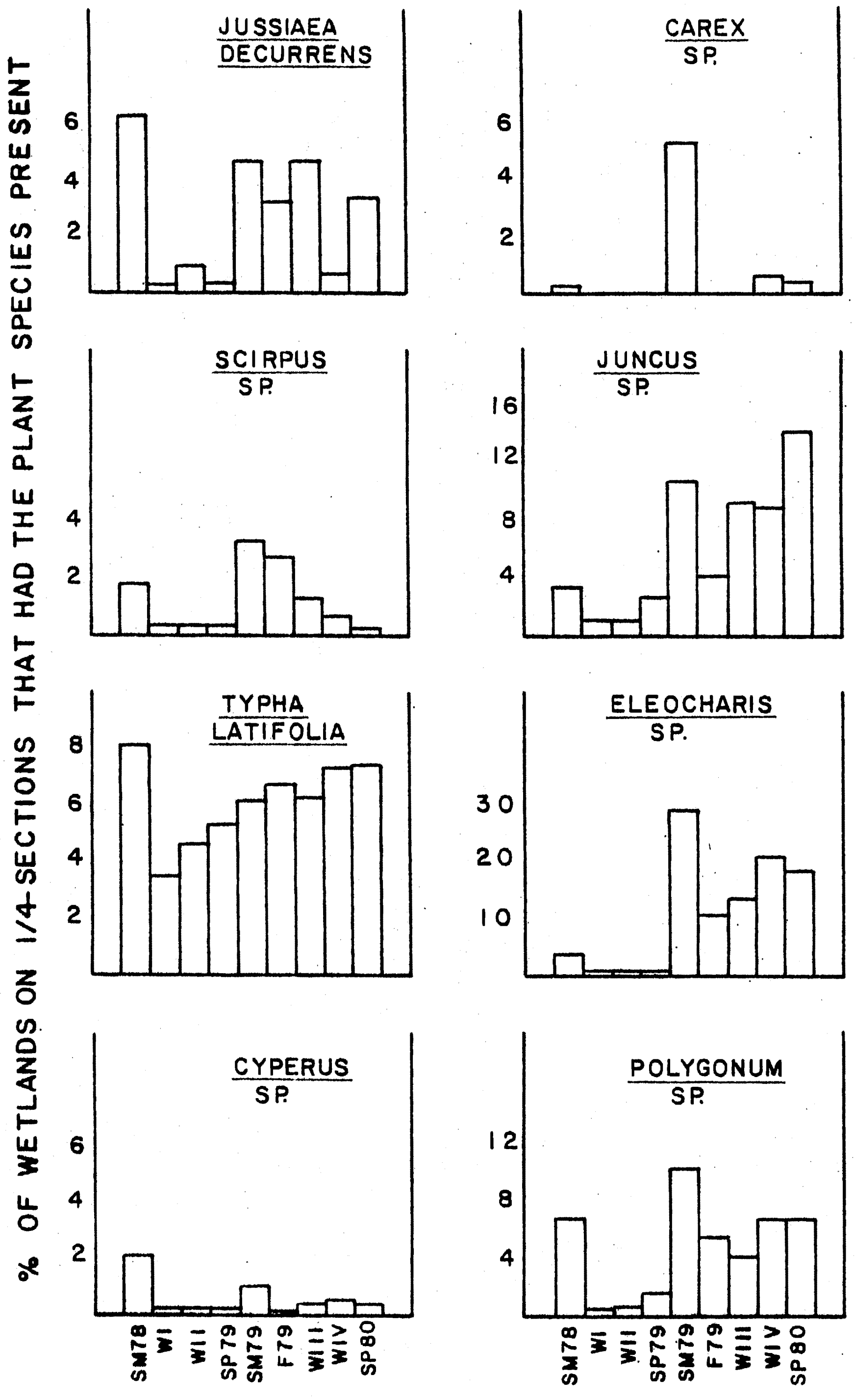

Fig. 12. Seasonal occurrence of emergent plant species at small lacustrine, riverine, and palustrine wetland basins with water present in Oklahoma.

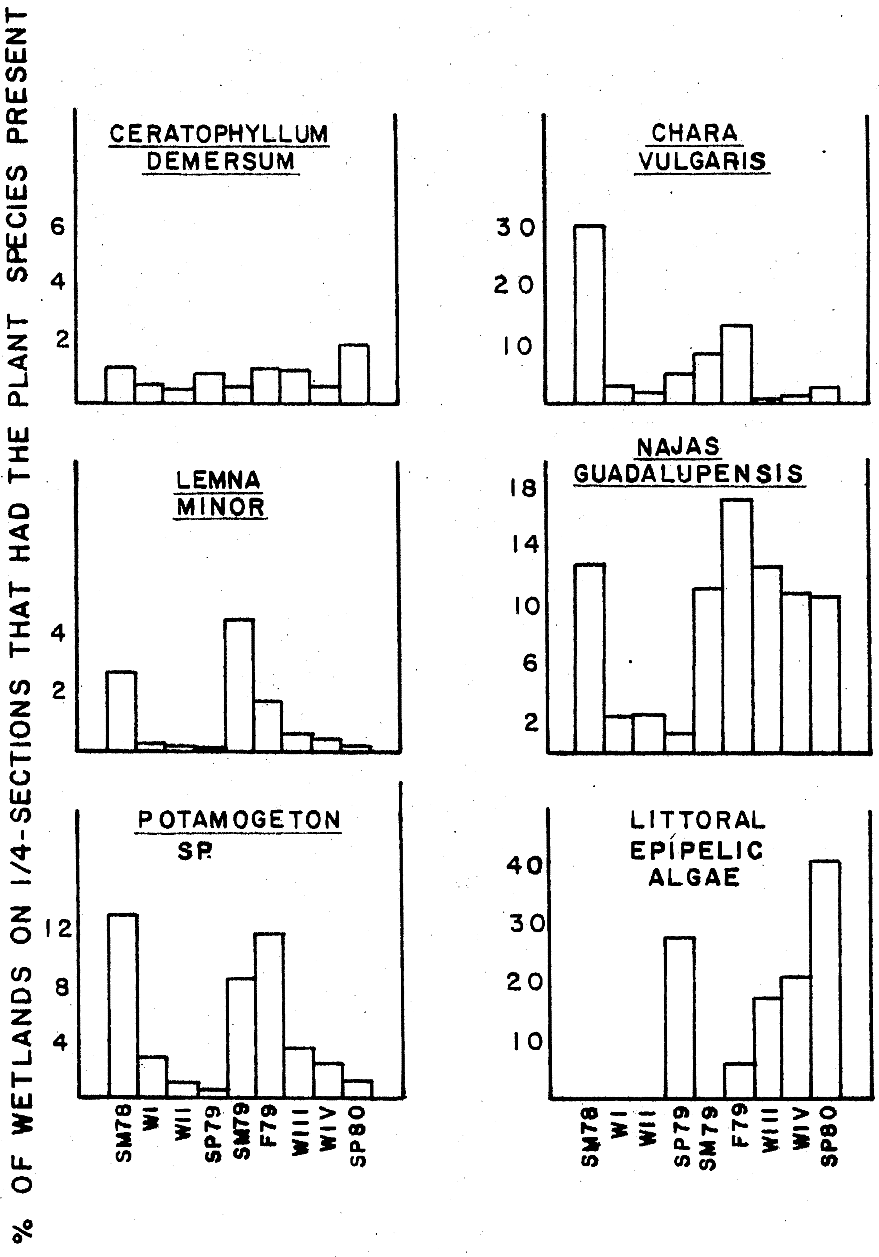

Fig. 13. Seasonal occurrence of submergent plant species at small lacustrine, riverine, and palustrine wetland basins with water present in Oklahoma.

3, 4, and 5 (Fig. 14a); and the average height (MSAVHT) of moist soil plants at wetland basins increased in province 3 during the study (Fig. 14b). The increased MSAVHT at wetland basins was probably due to more scrub/shrub and forested wetlands becoming inundated during higher water levels. The % of surface water area not overgrown with emergent vegetation declined in province 3 throughout the study (Fig. 15a) and was negatively related to precipitation in province 4 (Fig. 15b). Also, the number of emergent plant species present at wetland basins was positively related to the study period week in provinces 1 and 3 (Fig. 16a), and precipitation during the survey period in provinces 5 and 6 (Fig. 16b). The average height (EVAVHT) of emergent plants at wetland basins increased during the study in provinces 2 and 5 (Rig. 17a) and increased with precipitation amounts in province 3 (Fig. 17b).

The occurrences of specific moist soil and submergent plant species (only species with large sample sizes were analyzed) at wetland basins during the growing seasons (SM78, SP79, SM79, F79, SP80) were analyzed against time using linear regression. The frequency of occurrence of <u>Jussiaea</u> <u>decurrens</u> in province 3 (Fig. 18a) and <u>Typha</u> <u>latifolia</u> in province 1 (Fig. 18b) declined as moist soil species during the study, while the frequency of occurrence of hardwood trees in province 3 increased (Fig. 19) in relation to increasing surface area of water. The occurrence of <u>Chara</u> <u>vulgaris</u> as a submergent decreased in province 5 (Fig. 20) during the study.

The occurrences of emergent plant species at wetland basins were analyzed over time for all 9 surveys using linear regressions. Even though growth of emergents did not occur during winter, there was

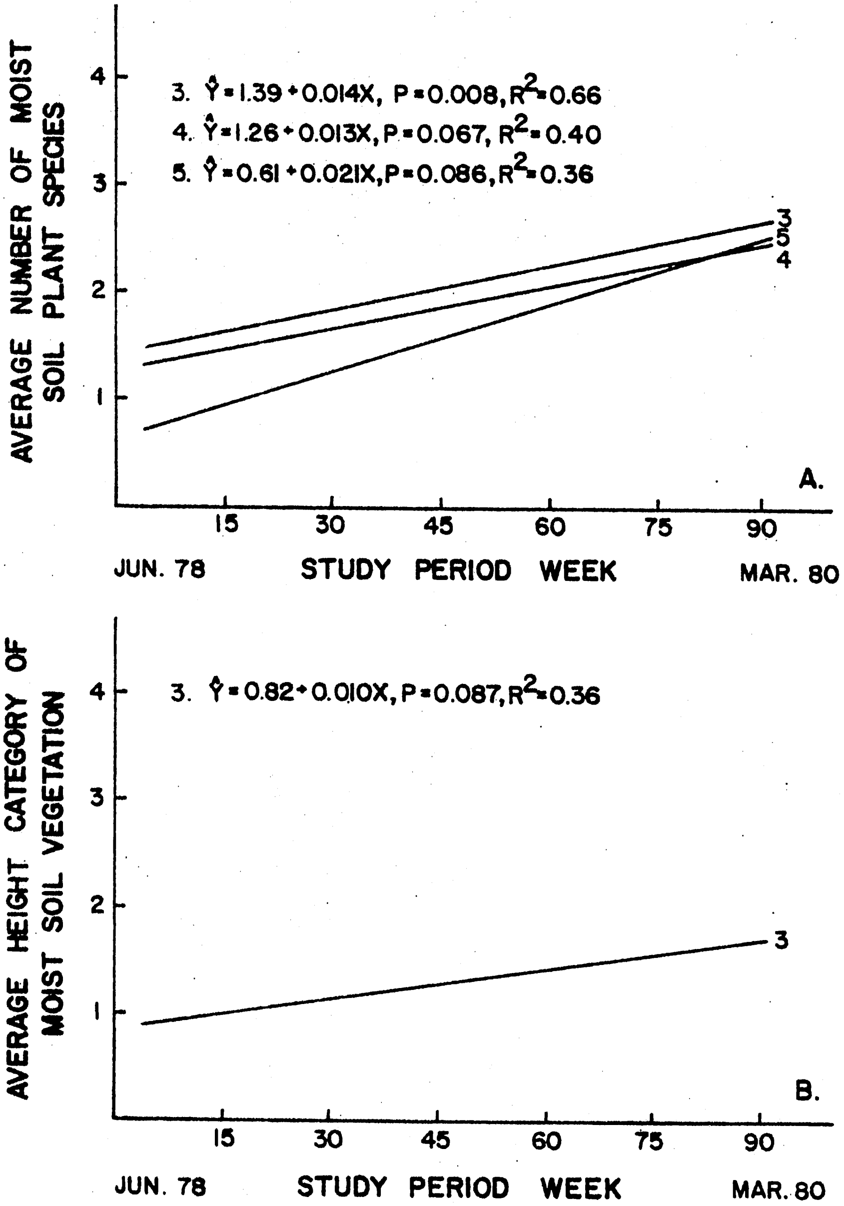

Fig. 14. Relationships between a) the average number of moist soil plant species observed at wetland basins with water present and the survey period week, and b) the average height category of moist soil vegetation observed at wetland basins with water present and the survey period week.

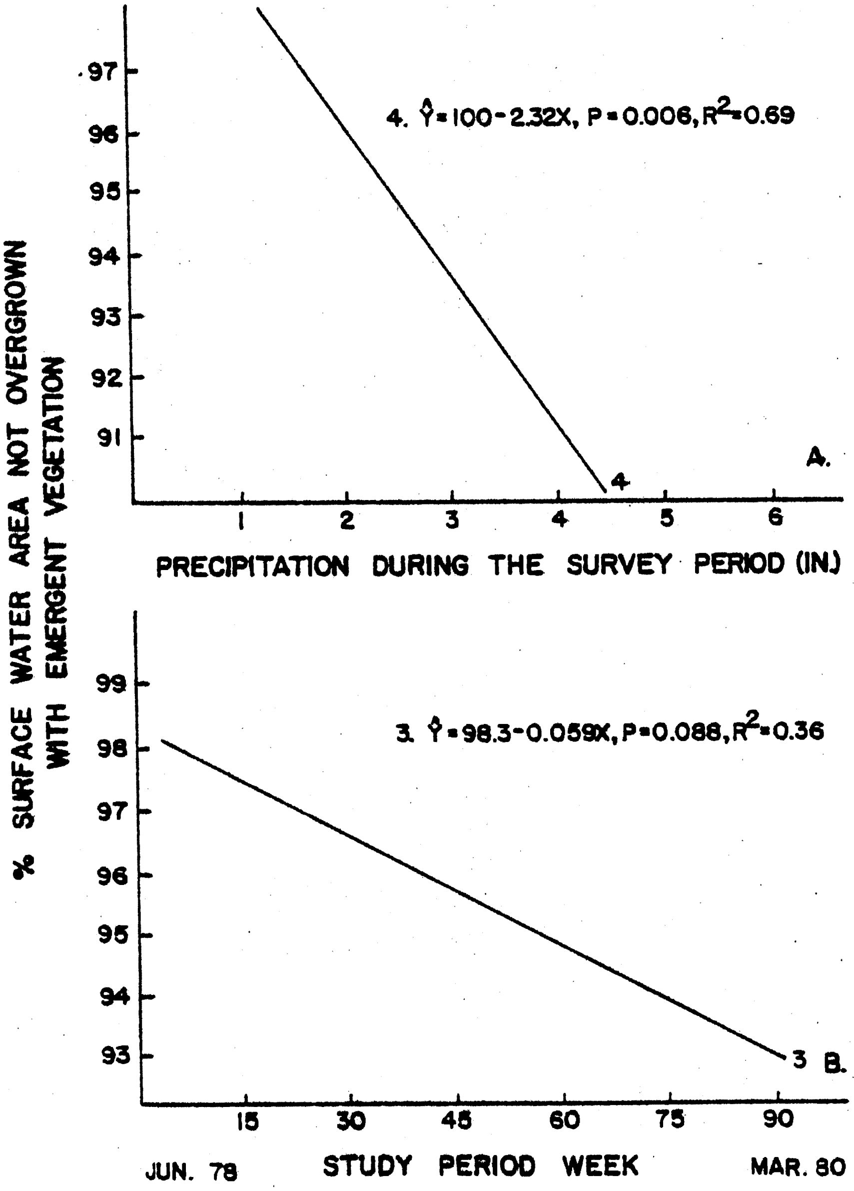

Fig. 15. Relationships between the average % of the surface water area of wetland basins with water present that is not overgrown with emergent vegetation in the physiographic provinces (1-6) of Oklahoma and a) the inches of precipitation during the survey period, and b) the survey period week.

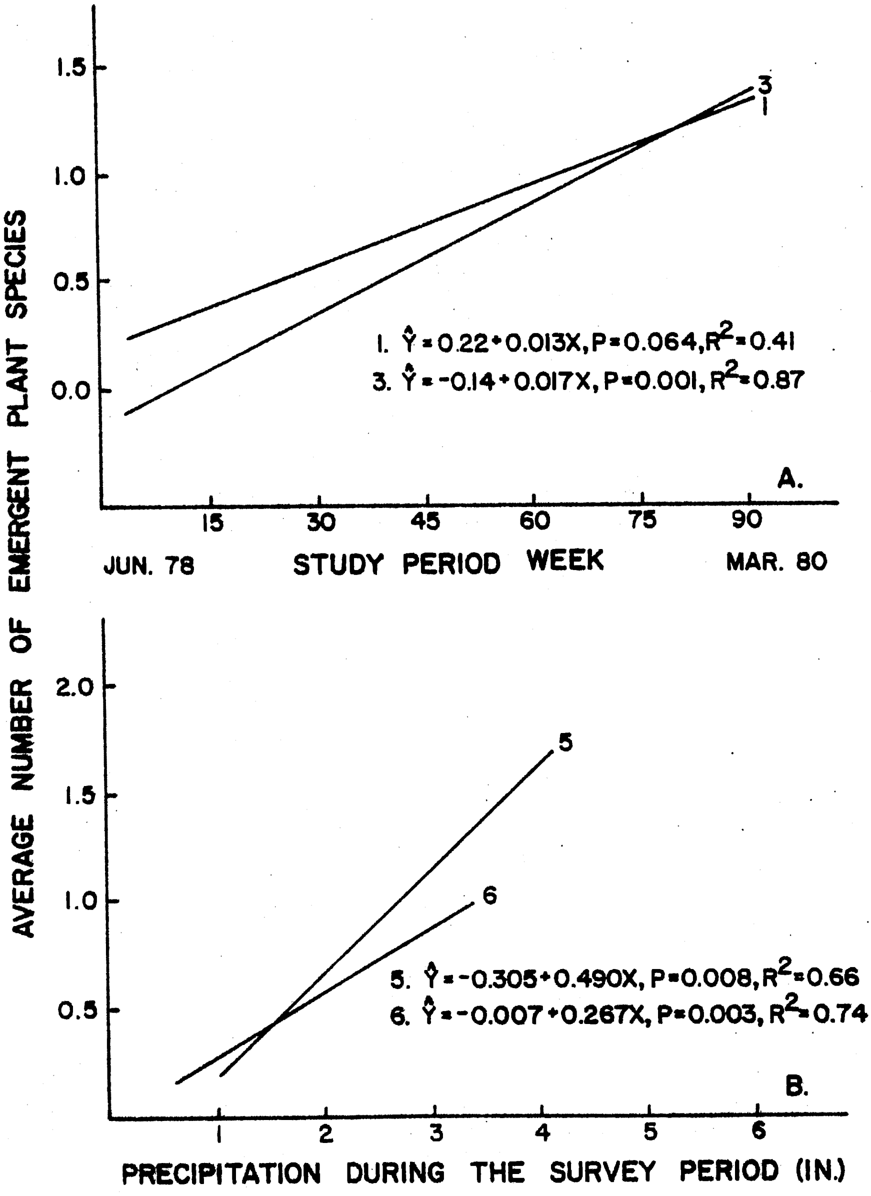

Fig. 16. Relationships between the average number of emergent plant species observed at wetland basins with water present in the physiographic provinces (1-6) in Oklahoma and a) the survey period week, and b) the inches of precipitation during the survey period.

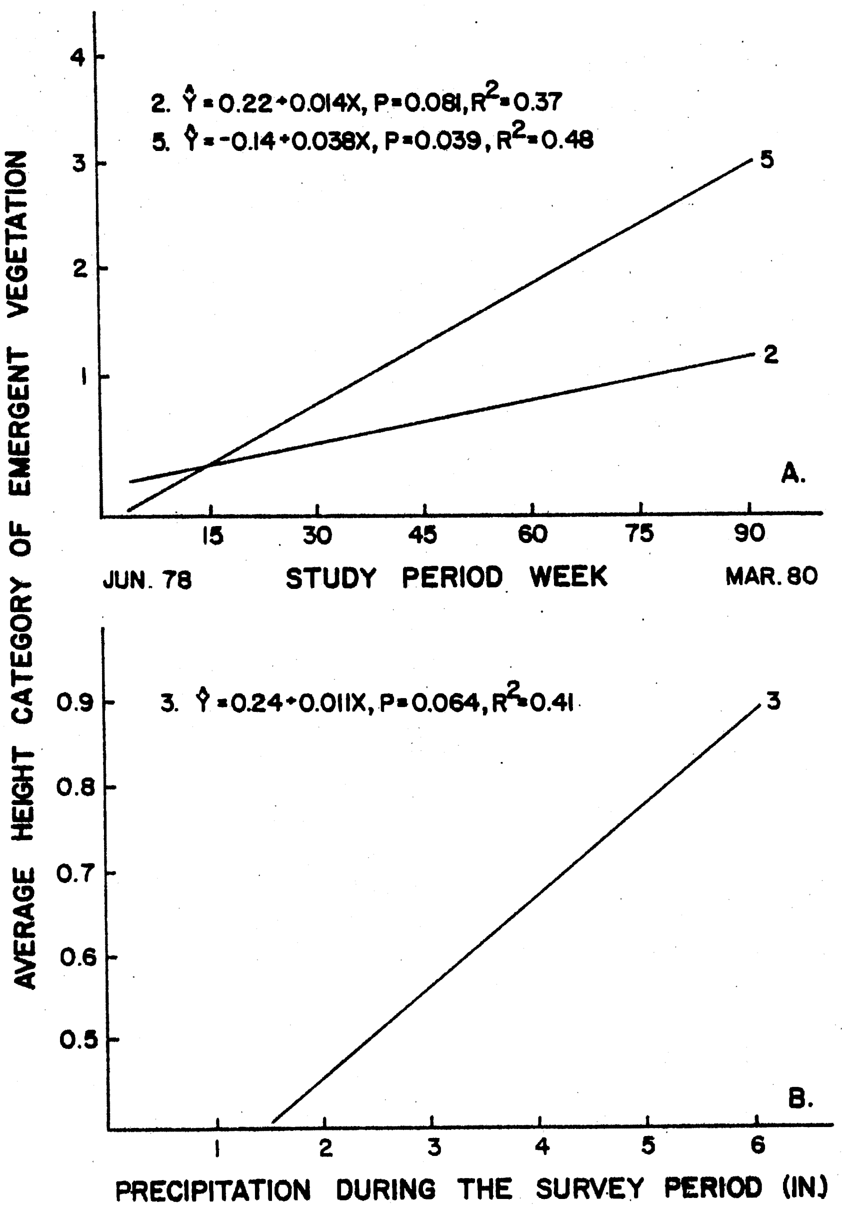

Fig. 17. Relationships between the average height category of emergent vegetation at wetland basins with water present in the physiographic provinces (1-6) of Oklahoma and a) the survey period week, and b) the inches of precipitation during the survey periods.

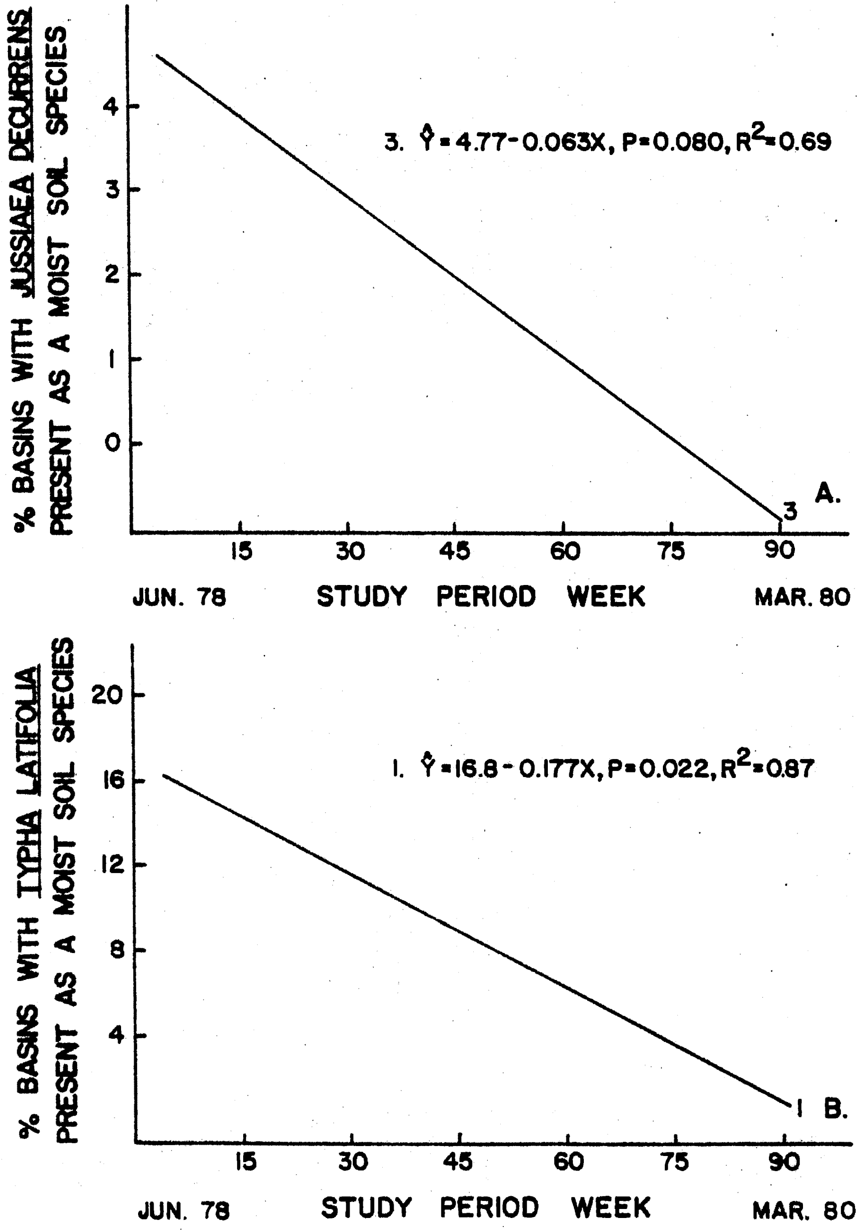

Fig. 18. Relationships between the % of wetland basins with water present in the physiographic provinces (1-6) of Oklahoma that had a) Typha latifolia, and b) Jussiaea decurrens present as moist soil species and the survey period week.

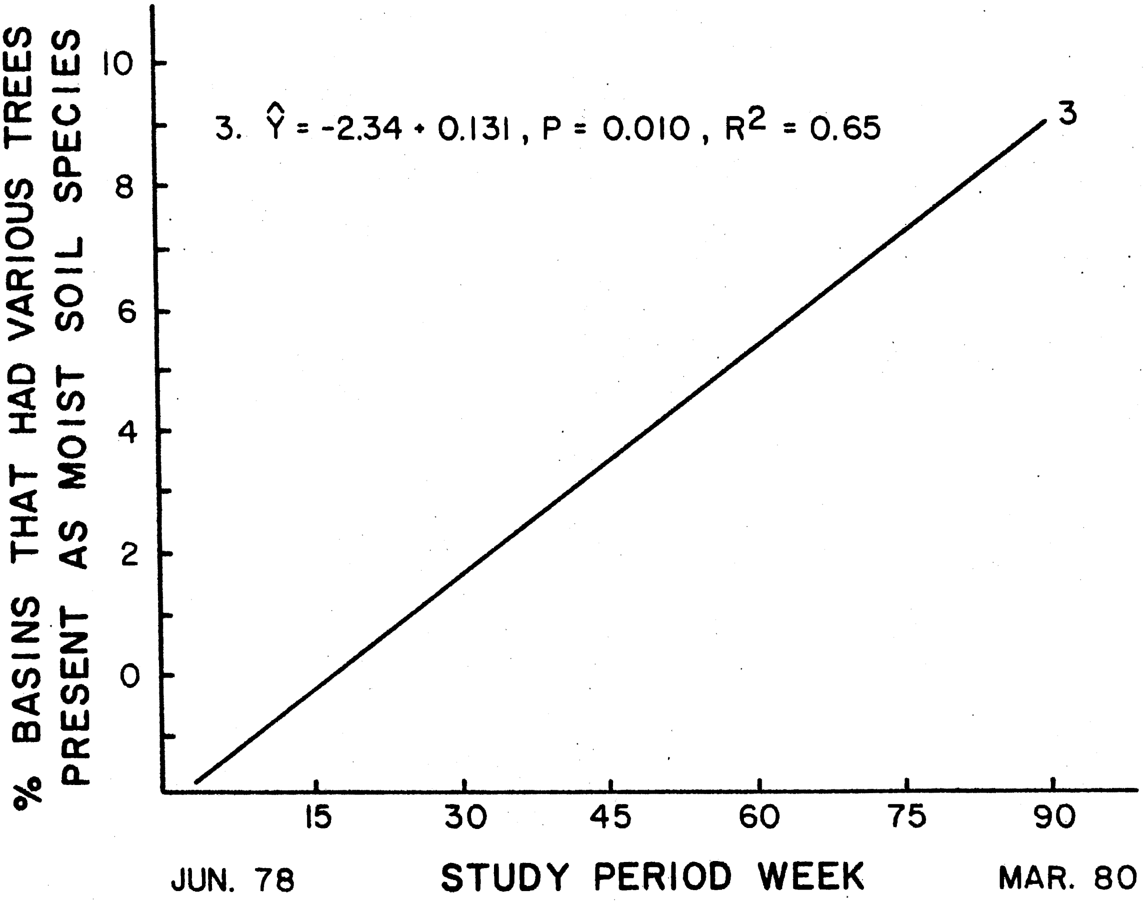

Fig. 19. Relationship between the % of wetland basins with water present in the physiographic provinces (1-6) of Oklahoma that had various trees present as moist soil species and the survey period week.

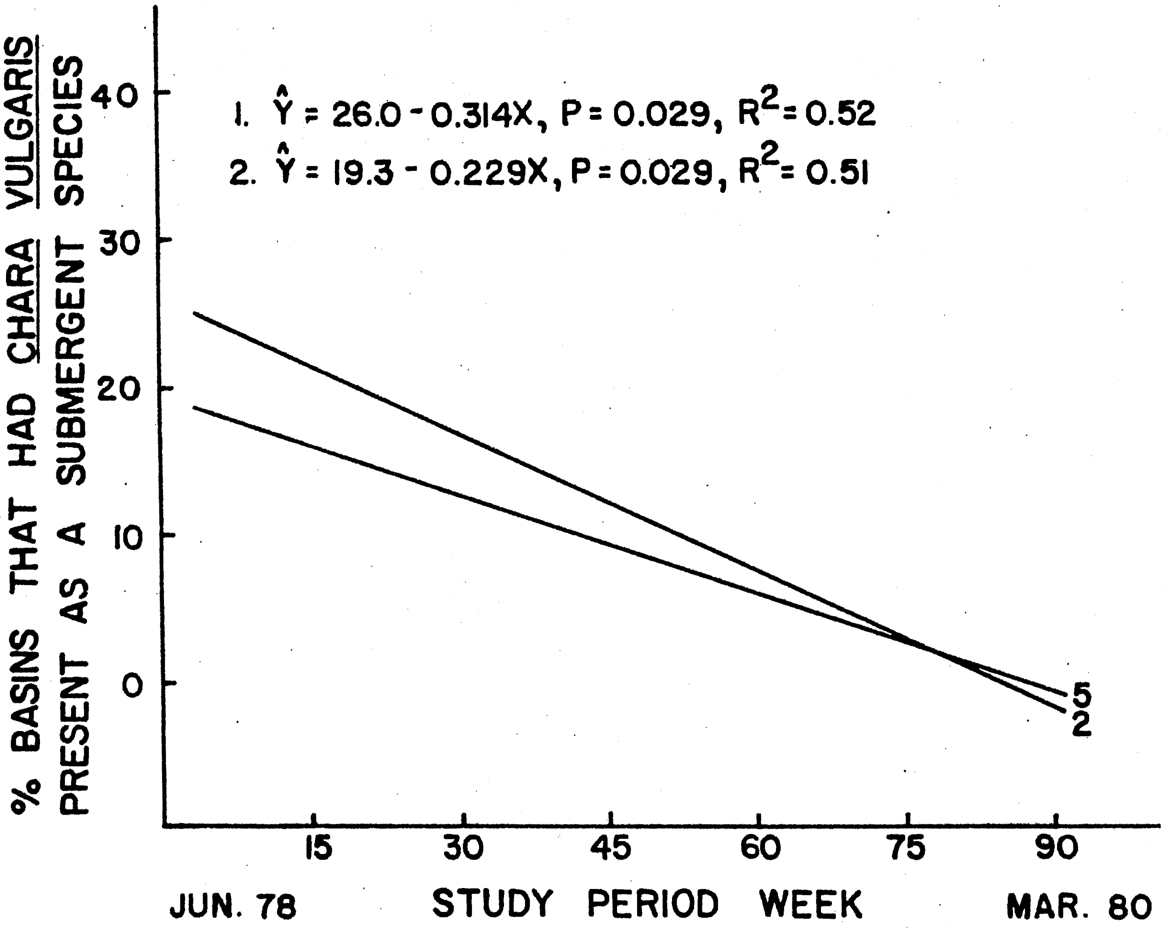

Fig. 20. Relationships between the % of wetland basins with water present in the physiographic provinces (1-6) of Oklahoma that had Chara vulgaris present as a submergent species and the survey period week.

evidence of initial germination during late winter-early spring by certain species. Most emergents remained standing during winter and their presence influenced many ecological characteristics of wetland basins. Because emergents persisted, analyzing emergents over all 9 seasons appeared useful as an expression of wetland dynamics. *Carex* sp. in province 3 (Fig. 21a), *Eleocharis* sp. in provinces 1, 2, and 3 (Fig. 21b) and *Juncus* sp. in provinces 2, 3, and 4 (Fig. 22a) all increased as emergents throughout the study, while the occurrence of cattail in province 1 (Fig. 22b) decreased.

Water Chemistry of Wetlands

Water samples were obtained at each wetland basin once during each survey period. This single analysis per season should be considered an instantaneous sample of the interacting factors of the chemical and physical nature of the watershed and basin, the water supply and loss, and the biological and chemical system within the water itself (Moyle 1956). Only surface samples were taken and associated biases should be considered, especially during summer stratification periods, even in very shallow wetlands (e.g. Wallen 1950, Eriksen 1966). Water samples were taken during different periods of the day, but the variables measured during this study (i.e. phenolpthalein and total alkalinity, pH, and conductivity) changed little during the diel period (Wetzel 1975). Data presented on water chemistry should be considered only as fluctuations around seasonal means, but the data provide general trends in relation to region, wetland composition type, and time.

Phenolpthalein alkalinity (PHEN_ALK) was not common in any wetland group or season during this study (Table 23). In general,

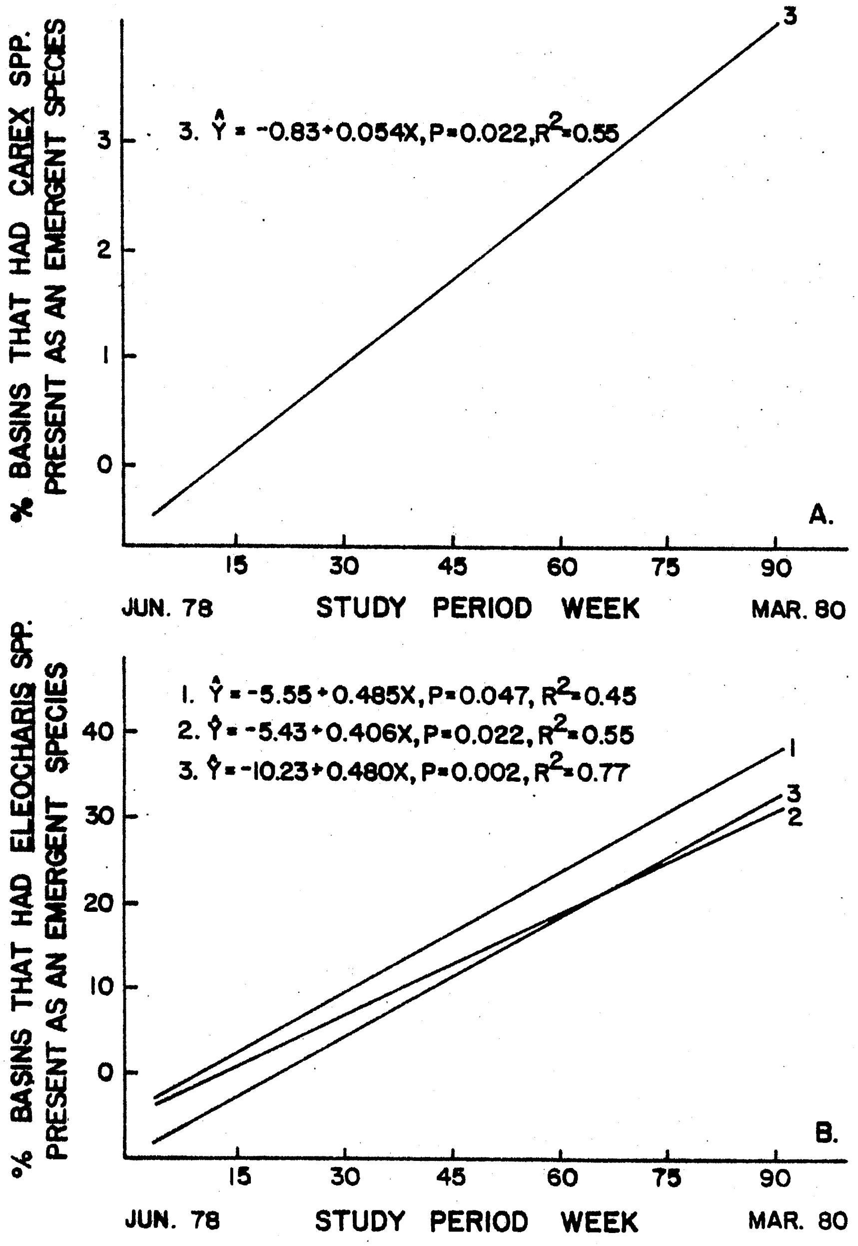

Fig. 21. Relationships between the % of wetland basins with water present in the physiographic provinces (1-6) of Oklahoma that had a) *Carex* sp. and b) *Eleocharis* sp. present as emergent species and the survey period week.

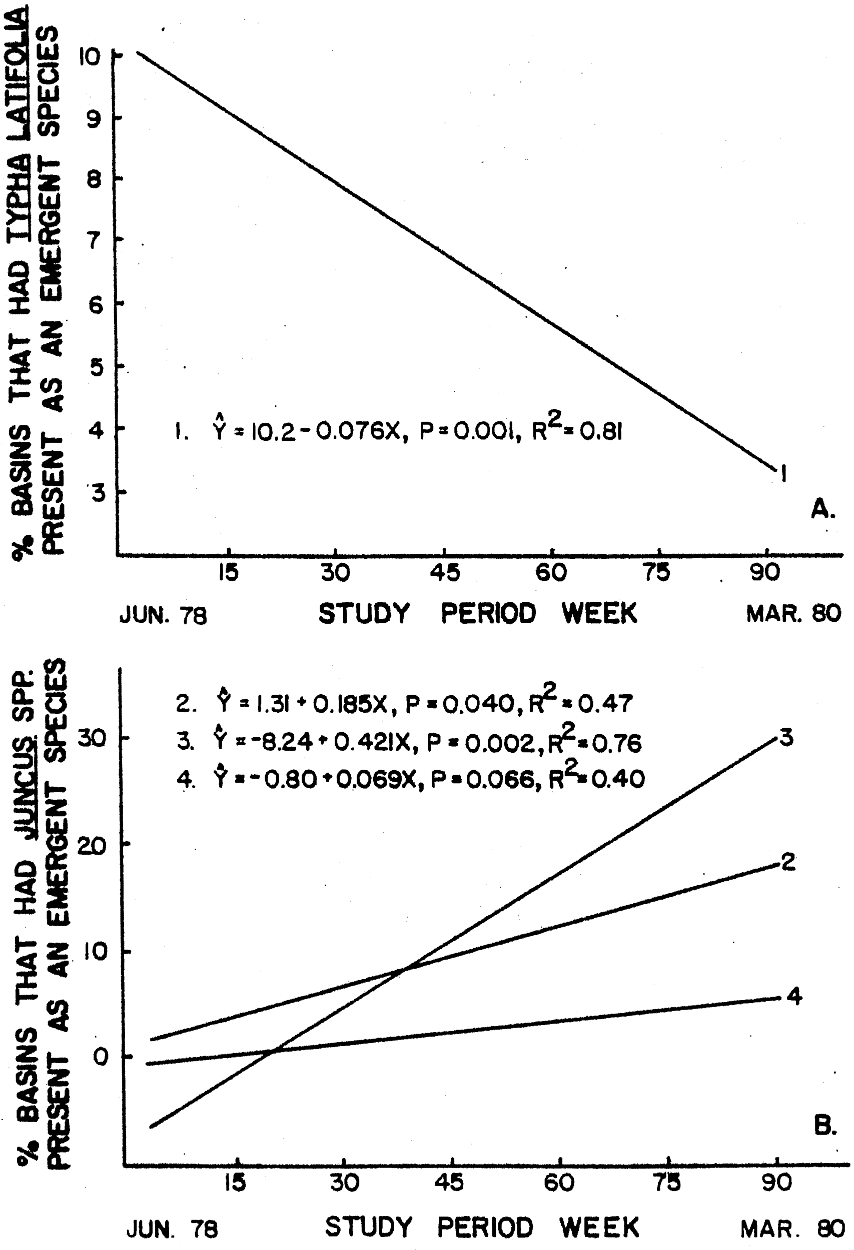

Fig. 22. Relationships between the % of wetland basins with water present in the physiographic provinces (1-6) of Oklahoma that had a) *Juncus* sp. and b) *Typha latifolia* present as emergent species and the survey period week.

Table 23. Mean phenolpthalein alkalinity (ppm) of wetland basins with surface water present on ¼-section plots in relation to wetland group and season (sample size of total basins in parentheses).

Wetland group	SM78^b	WI^c	WII^b	SP79	SM79	F79	WIII^a	WIV	SP80
1^f	8.00	5.43	0.0	0.29	6.20	0.0	0.0	0.0	0.0
2^d	19.33	3.00	0.0	4.45	2.21	1.61	0.80	0.0	0.25
3^f	36.00	4.33	0.0	2.80	11.20	1.20	1.00	0.0	0.0
4^e	13.50	0.0	6.00	13.00	0.0	0.0	3.00	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	3.67	1.12	3.50	4.46	5.60	0.0	1.20	1.57	0.0
7	4.00	3.00	0.0	2.00	2.67	0.0	0.0	0.0	0.0
8	23.00			0.0	0.0	0.0	0.0	0.0	0.0
11^e	7.21	2.37	2.62	2.24	2.02	1.08	0.15	0.63	1.00
12	0.0	0.0		0.0	0.0		0.0	0.0	0.0
13^e	11.42	0.0	0.0	3.23	2.83	3.31	1.96	0.31	1.95
14^d	12.33	25.67		0.0	1.08	3.33	0.0	0.60	0.85
15	9.75	1.00		4.50	2.00	0.0	0.0	0.0	0.0
16^e	22.67			1.33	2.00	2.20	0.0	2.57	0.0
17^d	11.92		3.17	2.08	5.14	2.65	0.67	1.88	3.32
18^d	10.10	1.21	2.80	2.57	0.84	3.42	0.92	0.76	1.14
19^f	6.00	2.50	0.0	0.0	0.0	2.38	0.0	0.0	0.0
20						0.0	0.0	0.0	0.0
21^e	2.14	8.90	0.0	2.00	0.71	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	10.00	6.00	32.00	3.50	1.67	16.50	15.00	0.0	0.0
24	5.09	0.0	1.75	0.0	2.82	2.20	0.0	0.91	0.36
25	2.33	6.50		0.0	0.0	6.00	0.0	0.0	4.33
26	6.00		0.0	0.0	12.33	0.0	0.0	0.0	0.0
27				10.00	5.00	0.0	0.0	0.0	0.0
Total	8.10 (313)	2.94 (208)	2.32 (102)	2.41 (341)	2.42 (451)	1.53 (418)	0.50 (401)	0.64 (424)	0.95 (430)

Duncan's multiple range test, $\alpha = 0.05$, AOV-test, $P < 0.0001$
(Total over seasons)

SM78	WI	SM79	SP79	WII	F79	SP80	WIV	WIII
———								
	———	———	———	———				
		———	———	———	———			
				———	———	———		
					———	———	———	
						———	———	———

Season means with the same underline are not significantly different.

---

a,b,c Mean phenolpthalein alkalinity is different ($^aP < 0.0001$, $^bP < 0.01$, $^cP < 0.05$) among wetland groups within a season.

d,e,f Mean phenolpthalein alkalinity is different ($^dP < 0.0001$, $^eP < 0.01$, $^fP < 0.05$) among seasons within a wetland group.

riverine, small lacustrine, and natural wetland basins had significantly higher PHEN_ALK values than did man-made, palustrine basins. PHEN_ALK declined during the study in all wetland groups and in all provinces (Table 23, Fig. 23a). Wetlands in western provinces (Table 24) had higher PHEN_ALK values than did wetlands in eastern provinces (Appendix A-3).

The highest total alkalinity (TOT_ALK) values occurred in rivers and natural wetlands (Table 25). An exception was the low TOT_ALK values in upper perennial, cobble-gravel streambeds (wetland group 5). Seasonal trends varied among wetland groups. The TOT_ALK of riverine and natural mud substrate wetlands decreased during summer and spring but increased during fall and winter. The TOT_ALK declined throughout the study in provinces 1 and 6 (Fig. 23b), but TOT_ALK generally decreased from west to east among the provinces (Table 24). This trend was also evident within individual wetland groups (Appendix A-4).

Average pH of wetland basins varied among wetland groups and among seasons (Table 26). As with alkalinity, rivers and natural wetlands had higher pH's than other wetlands, with the exception of the upper perennial, cobble-gravel streambeds. Most wetlands were slightly acidic, especially during fall and winter. Average pH was most basic during summer (Table 26) and became more acidic throughout the study in provinces 1, 2, 3, and 4 (Fig. 24a). Average pH was higher in wetlands in southern and western provinces (4, 5, and 6) than in wetlands in the northest. This was especially noticable in rivers and natural wetlands (Appendix A-5).

Conductivity was variable among wetland groups and seasons

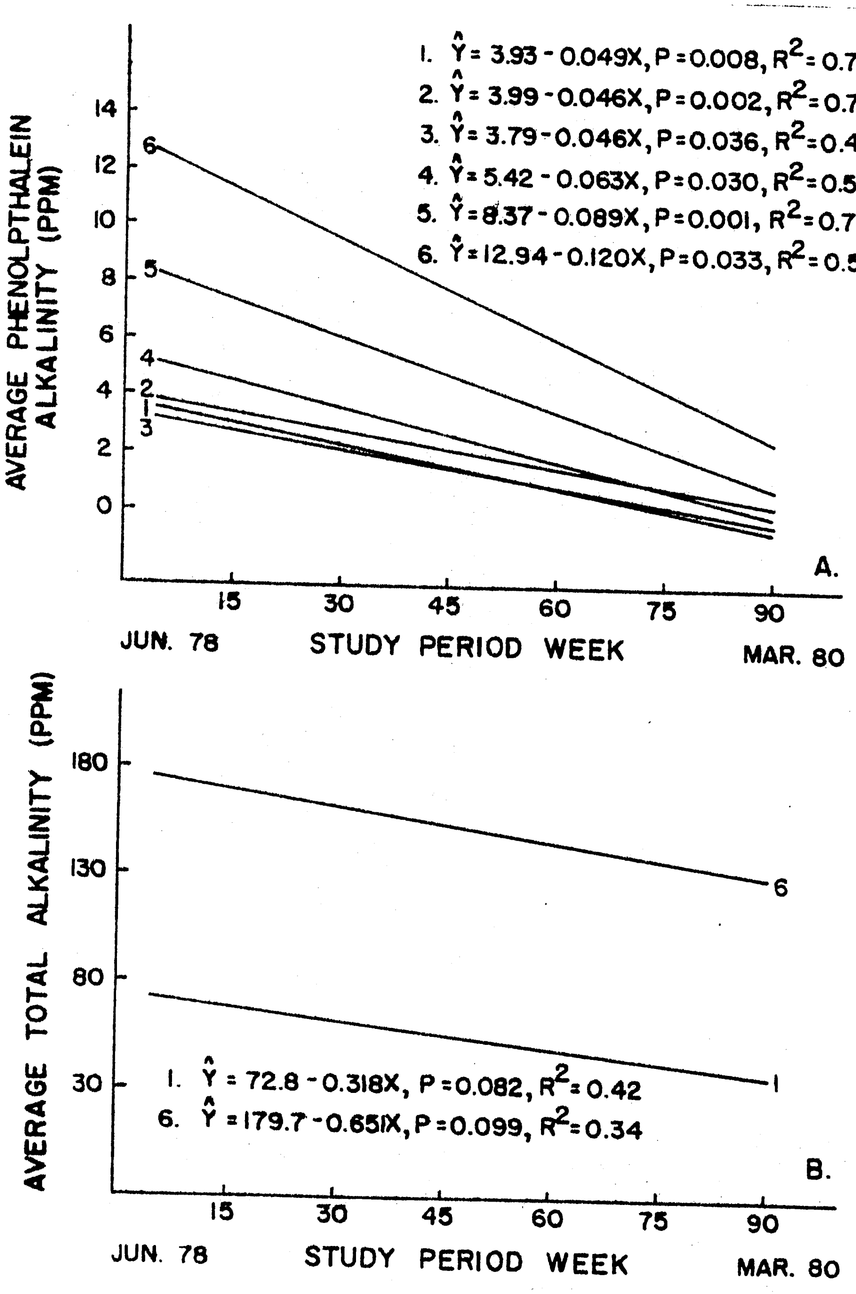

Fig. 23. Relationships between a) the average phenolpthalein alkalinity, and b) the average total alkalinity of wetland basins with water present in the physiographic provinces (1-6) of Oklahoma and the survey period week.

Table 24. Ordering of province (1-6) means of chemical and light penetration variables measured over all wetland basins with water present on random ¼-section sample plots 1978-80 using a Duncan's multiple range test, α=0.05. Province means with the same underline are not significantly different.

Variable	Total alkalinity (ppm)						Phenolpthalein alkalinity (ppm)					
AOV-test	$\underline{P}<0.0001$						$\underline{P}<0.0001$					
Province	6	5	4	2	3	1	6	5	4	3	2	1
Ordering	———						———	———				
		———							———	———	———	
			———							———	———	———
				———								
					———	———						
					———	———						
Means	150	117	88	73	63	60	4.3	3.4	1.9	1.4	1.4	0.9

Variable	Conductivity (umhos)						pH					
OAV-test	$\underline{P}<0.0001$						$\underline{P}<0.0001$					
Province	6	5	4	2	1	4	4	6	5	3	2	1
Ordering	———	———					———	———				
			———	———				———	———			
					———	———				———		
											———	
												———
Means	388	366	297	267	224	188	6.4	6.4	6.3	6.0	5.9	5.7

Variable	Light penetration (secchi disk cm)					
AOV-test	$\underline{P}<0.0001$					
Province	4	3	1	2	6	5
Ordering	———	———				
			———	———		
					———	———
Means	47	46	41	40	31	28

Table 25. Mean total alkalinity (ppm) of wetlands with surface water present on ¼-section plots in relation to wetland group and season (sample size of total basins in parentheses)

Wetland group	SM78[a]	WI[b]	WII[a]	SP79[b]	SM79[a]	F79[a]	WIII[a]	WIV[a]	SP80[a]
1	115.1	147.3	186.5	121.9	175.2	186.6	203.3	160.4	179.9
2	162.0	106.0	177.3	147.3	143.6	150.2	152.7	118.1	142.8
3	157.5	195.3	251.0	149.6	161.4	158.0	189.4	180.6	188.6
4[d]	197.5	312.5	280.0	211.3	190.7	213.0	236.5	214.0	261.5
5	20.0	10.0	10.0	19.0	10.0	12.0	11.0	14.0	17.0
6	105.3	97.5	233.2	170.9	123.1	115.2	91.7	99.7	116.2
7[e]	59.5	129.0	80.0	300.0	78.0	107.0	67.3	70.7	87.7
8	85.0			185.0	135.0	110.0	116.5	118.5	120.0
11[c]	80.2	92.3	91.1	122.1	79.6	86.4	76.1	67.7	78.6
12	12.0	17.0		14.0	11.0		8.0	10.0	17.0
13	87.1	34.2	51.2	96.4	85.2	81.9	72.9	63.3	85.4
14[c]	132.7	280.3		82.3	64.5	107.7	46.0	55.1	78.9
15	100.5	86.0		92.8	83.0	119.5	30.0	71.2	76.2
16[d]	270.0			73.0	87.0	122.6	68.7	68.0	103.1
17	78.4	62.1	143.2	90.6	84.7	84.3	79.9	83.2	80.4
18[d]	58.1	95.7	65.4	105.0	60.7	69.8	55.2	62.4	65.3
19[e]	45.2	101.2	51.3	77.6	61.4	30.5	42.9	36.9	46.6
20						176.0	170.0	159.0	175.0
21	81.9	75.4	114.0	95.9	85.3	69.2	91.4	53.4	65.4
22	44.0	100.0	40.0	37.5	51.7	24.0	30.0	51.0	47.0
23	197.0	218.0	85.0	147.0	202.3	168.0	155.0	135.0	168.3
24	67.4	92.4	108.5	138.7	79.0	90.4	97.2	95.4	111.2
25	161.7	104.5		128.0	166.3	135.0	163.0	116.0	165.7
26	68.0		42.0	153.5	94.0	93.5	89.7	97.7	168.3
27				210.0	230.5	88.0	67.0	96.0	112.0
Total	85.1 (313)	95.6 (207)	105.8 (102)	117.1 (341)	87.5 (451)	91.7 (418)	84.3 (401)	76.4 (423)	88.6 (429)

Duncan's multiple range test, $\alpha = 0.05$, AOV-test, $\underline{P} < 0.0001$
(Total over seasons)

SP79	WII	WI	F79	SP80	SM79	SM78	WIII	WIV
———	———							
	———	———	———					
		———	———	———	———	———	———	
						———	———	———

Season means with the same underline are not significantly different.

[a,b] Mean total alkalinity is different ($^{a}\underline{P} < 0.0001$, $^{b}\underline{P} < 0.01$) among wetland groups within a season.

[c,d,e] Mean total alkalinity is different ($^{c}\underline{P} < 0.0001$, $^{d}\underline{P} < 0.01$, $^{e}\underline{P} < 0.05$) among seasons within a wetland group.

Table 26. Mean pH of wetland basins with surface water present on ¼-section plots in relation to wetland group and season (sample size of total basins in parentheses).

Wetland group	SM78^{c}	WI^{c}	WII^{a}	SP79^{b}	SM79^{a}	F79^{b}	WIII^{b}	WIV^{a}	SP80^{a}
1	6.99	6.67	6.90	6.66	6.76	6.78	6.60	6.75	7.05
2	7.10	6.10	6.60	6.78	6.60	6.15	6.27	5.97	6.66
3	7.10	6.20	6.90	6.40	6.84	6.68	7.10	6.70	7.20
4	7.05	6.90	7.20	7.13	7.20	7.20	7.25	7.00	7.50
5	6.00	6.00	6.00	6.00	6.60	4.50	4.50	6.00	5.00
6^{e}	6.49	5.91	5.95	6.45	6.56	6.11	5.68	5.70	5.90
7	6.20	6.40	6.00	6.60	6.47	6.30	6.33	6.00	6.00
8	6.90			6.80	7.10	6.63	7.00	7.00	7.00
11^{d}	6.51	6.03	6.34	6.37	6.32	5.89	5.69	5.51	5.96
12	5.00	6.00		6.00	6.00	5.00	4.50	5.00	5.00
13^{e}	6.62	5.83	6.15	6.49	6.45	6.28	5.87	5.48	5.95
14^{d}	6.40	6.67		6.73	6.33	5.88	5.27	5.10	6.04
15^{e}	6.47	6.10		6.55	6.40	5.58	4.83	5.20	6.20
16^{e}	7.00			6.50	6.51	5.84	4.83	5.36	5.88
17^{e}	6.67	6.11	6.60	6.48	6.75	6.20	6.17	5.83	6.34
18^{d}	6.51	6.07	6.36	6.38	6.32	5.80	5.73	5.44	5.77
19^{d}	6.48	6.40	6.13	6.16	6.32	5.12	5.12	5.29	5.31
20						7.50	7.50	7.00	7.00
21^{e}	6.40	6.13	7.00	6.36	6.39	5.59	5.71	5.50	5.64
22^{f}	6.40	6.00	6.40	6.10	6.20	5.00	5.00	5.67	5.67
23	7.10	6.80	8.00	6.90	7.07	6.75	6.33	6.33	6.67
24	6.58	6.00	6.10	6.30	6.53	6.40	6.36	5.86	6.59
25	6.80	6.60		6.80	7.13	7.00	6.83	6.33	7.50
26	6.40		6.00	6.60	6.27	6.55	5.67	6.00	6.33
27				7.20	7.00	6.50	6.00	6.50	6.00
Total	6.56 (298)	6.11 (200)	6.40 (102)	6.43 (341)	6.43 (451)	5.97 (426)	5.80 (404)	5.61 (426)	6.07 (432)

Duncan's multiple range test, $\alpha = 0.05$, AOV-test, $P < 0.0001$
(Total over seasons)

SM78	SP79	SM79	WII	WI	SP80	F79	WIII	WIV
───								
	───	───	───					
				───	───			
					───	───		
							───	
								───

Season means with the same underline are not significantly different.

---

a,b,c Mean pH is different ($^{a}P < 0.0001$, $^{b}P < 0.01$, $^{c}P < 0.05$) among wetland groups within a season.

d,e,f Mean pH is different ($^{d}P < 0.0001$, $^{e}P < 0.01$, $^{f}P < 0.05$) among seasons within a wetland group.

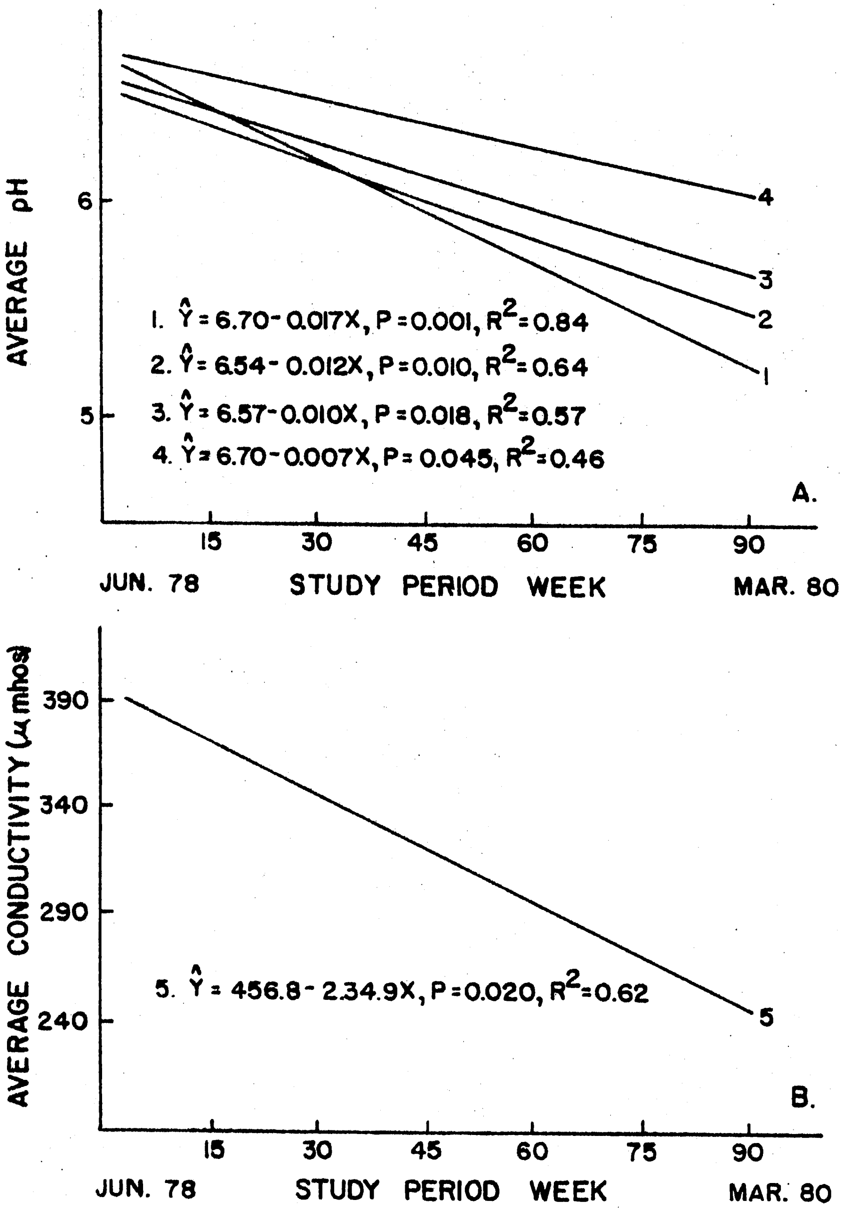

Fig. 24. Relationships between a) the average pH, and b) the average conductivity of wetland basins with water present in the physiographic provinces (1-6) of Oklahoma and the survey period week.

(Table 27). Oil well and refinery pools (wetland group 12) had high (1500-3500 umhos) conductivity. Rivers; other than the upper perennial, cobble-gravel streambeds also had high values (500-1500). Conductivity was highest in wetland groups during spring. The average conductivity of wetlands declined during the study in province 5 (Fig. 24b). As with other water chemistry variables, wetlands in western provinces had the highest conductivity, and those in eastern provinces had the lowest (Table 26, Appendix A-6).

Upper perennial cobble-gravel rivers, small lacustrine wetlands, and wetlands dominated by submergent and emergent vegetation allowed the greatest light penetration (Table 28). Wetlands with mud substrates and little vegetation were especially turbid. A strong seasonal pattern of light penetration was present in almost all wetland groups (Table 28). Greatest light penetration occurred in early winter, penetration gradually declined during late winter and spring to a low during summer, and then increased in fall to the early winter maxima. Light penetration during the survey period was inversely related to precipitation (Fig. 25), and was greatest in wetlands in southern and eastern provinces and lowest in wetlands of western provinces (Table 24, Appendix A-7).

Correlations Among Physical, Chemical, and Vegetational Variables

Significant ($\underline{P}<0.01$) correlations between all physical, chemical, and vegetation variables measured at palustrine wetland basins with water present (Table 29) were determined for each season and for all seasons combined. The correlations by season and for all seasons combined were almost identical, therefore only the combined data are

Table 27. Mean conductivity (umhos) of wetland basins with water present on ¼-section plots in relation to wetland group and season (sample size of total basins in parentheses).

Wetland group	SM78	WI[a]	WII[a]	SP79[a]	SM79[a]	F79[a]	WIII[a]	WIV[a]	SP80[a]
1		489.1	476.2	451.4	538.5	658.7	705.1	693.8	916.0
2		422.5	791.7	819.1	972.1	925.1	553.5	562.6	1057.9
3		801.7	975.0	790.0	695.0	1022.0	753.8	1087.5	1245.0
4		850.0	675.0	683.3	950.0	605.0	560.0	1032.5	1275.0
5		45.0	40.0	55.0	50.0	89.0	54.0	80.0	72.0
6		226.4	260.0	335.4	302.7	333.0	280.7	304.4	319.1
7		240.0	162.0	260.0	186.7	254.5	172.3	180.7	227.3
8				400.0	335.0	466.7	439.0	442.5	260.0
11[d]		219.8	313.2	294.4	199.5	251.1	193.1	214.3	228.7
12		2320.0		1900.0	3000.0			3200.0	3425.0
13		132.8	246.2	316.5	455.9	231.1	189.5	199.6	292.4
14[b]		495.7		333.3	167.8	257.0	191.7	178.9	211.2
15				375.0	311.8	293.8	114.0	257.2	329.6
16				296.7	306.4	313.8	190.8	191.4	261.4
17		151.9	362.0	355.4	296.6	276.6	282.9	271.7	308.9
18[c]		202.5	332.0	308.5	185.0	198.6	157.5	186.9	189.4
19		134.8	273.3	196.0	229.0	166.4	202.9	234.3	182.1
20						350.0	475.0	445.0	452.0
21		282.4		405.7	380.7	217.4	333.9	239.8	353.6
22[c]		159.0	220.0	375.0	153.3	147.0	125.0	153.7	166.0
23		405.0	350.0	365.0	405.0	357.0	280.7	331.7	522.3
24		192.8	360.0	288.0	180.9	360.9	361.4	362.1	404.2
25[b]		261.0		558.3	350.0	376.7	337.3	342.7	358.0
26				245.5	193.3	217.0	282.0	505.0	445.0
27				650.0	510.0	168.0	120.0	102.0	182.0
Total		275.1 (203)	349.2 (96)	346.8 (338)	284.4 (451)	294.7 (417)	246.0 (387)	271.7 (421)	322.5 (430)

Duncan's multiple range test, $\alpha = 0.05$, AOV-test, $P = 0.0172$
(Total over seasons)

WII SP79 SP80 F79 SM79 WI WIV WIII

Season means with the same underline are not significantly different.

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[a] Mean conductivity is different ($P < 0.0001$) among wetland groups within a season.

[b,c,d] Mean conductivity is different ([b]$P < 0.0001$, [c]$P < 0.01$, [d]$P < 0.05$) among seasons within a wetland group.

Table 28. Mean light penetration (secchi disk cm) of wetland basins with surface water present on ¼-section plots in relation to wetland group and season (sample size of total basins in parentheses).

Wetland group	SM78[a]	WI[a]	WII[a]	SP79[a]	SM79[a]	F79[a]	WIII[a]	WIV[a]	SP80[a]
1[c]	33.9	70.7	56.4	29.6	27.7	28.6	68.3	60.9	45.7
2[b]	80.3	53.3	20.0	28.0	35.2	45.6	61.2	54.1	49.9
3	60.0	59.7	37.7	19.4	40.8	34.6	50.2	34.6	44.6
4	30.0	48.5	31.0	47.3	47.3	9.5	8.5	20.5	66.5
5	100.0	101.0[e]	101.0	68.0	101.0	58.0	101.0	101.0	101.0
6	36.6	52.6	32.6	50.7	23.0	32.8	39.7	43.9	33.3
7	101.0	101.0	100.0	101.0	101.0	83.7	101.0	99.3	101.0
8	81.0			68.0	60.0	27.7	101.0	101.0	66.5
11	[illegible]6.5	35.1	29.9	24.6	19.3	25.4	38.1	36.9	28.0
12	32.0	38.0		31.0	46.0	30.0	72.0	101.0	73.0
13	22.1	30.0	26.7	28.6	20.0	28.1	28.9	27.1	24.0
14	6.0	7.7		6.0	25.3	14.5	35.1	32.2	23.2
15	14.5	10.5		30.5	16.4	14.4	20.0	24.0	23.8
16	7.3			27.5	22.1	10.8	55.8	52.7	19.5
17[c]	68.6	66.1	59.5	45.3	56.3	54.8	77.8	79.5	63.8
18[c]	72.7	58.1	57.6	40.6	48.8	39.8	59.6	71.6	50.3
19	68.0	34.8	22.7	22.6	47.3	25.1	46.7	65.9	32.2
20						31.0	48.0	46.0	60.0
21	41.2	45.9		33.4	28.3	40.1	53.3	56.3	48.9
22	100.0	17.0	21.5	30.0	43.7	73.0	77.5	37.0	45.3
23	14.5	30.0	51.0	32.0	25.3	8.5	27.7	33.0	30.5
24[b]	67.4	43.2	54.0	34.9	28.7	63.6	53.7	54.3	49.1
25	26.0	67.5		40.0	24.7	14.3	55.3	58.7	47.3
26	15.0		5.0	11.5	10.3	11.5	41.0	22.0	16.0
27				24.0	29.5	5.0	12.0	11.0	12.0
Total	39.9 (312)	46.2 (209)	40.0 (117)	31.2 (341)	28.5 (451)	31.5 (426)	46.8 (377)	46.0 (402)	36.3 (438)

Duncan's multiple range test, $\alpha = 0.05$, AOV-test, $\underline{P} < 0.0001$
(Total over seasons)

WIII	WI	WIV	WII	SM78	SP80	F79	SP79	SM79
────	────	────	────					
			────	────	────			
						────	────	────

Season means with the same underline are not significantly different.

---

[a] Mean light penetration is different ($\underline{P} < 0.0001$) among wetland groups within a season.

[b,c,d] Mean light penetration is different (${}^{b}\underline{P} < 0.0001$, ${}^{c}\underline{P} < 0.01$, ${}^{d}\underline{P} < 0.05$) among seasons within a wetland group.

[e] Means given as 101.0 refer to light penetration greater than 1m.

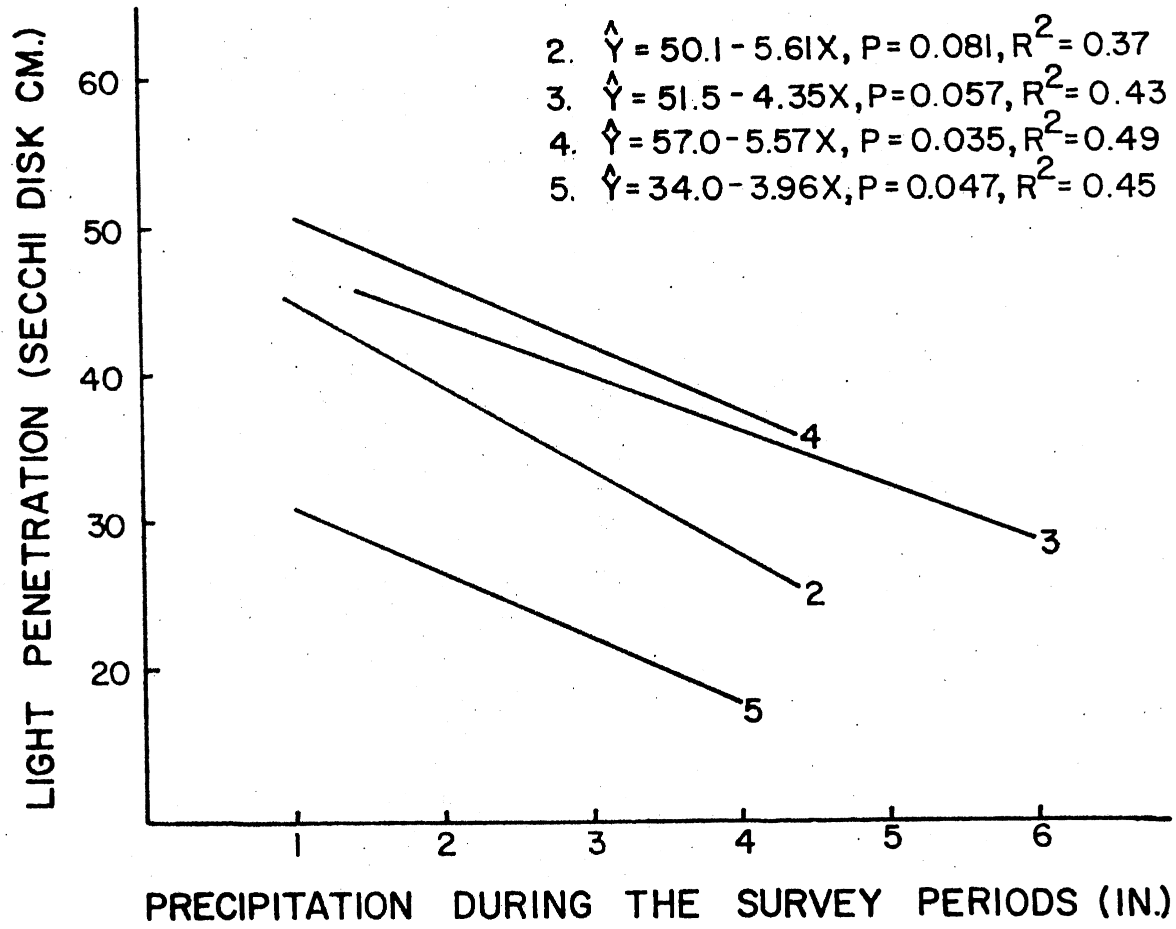


Fig. 25. Relationships between the average light penetration of wetland basins with water present in the physiographic provinces (1-6) of Oklahoma and the inches of precipitation during the survey period.

Table 29. List of physical, chemical, and vegetational variables measured at each wetland basin with water present on random ¼-section sample plots.

Variable	Code
1. Total wetlands on the ¼-section	TOT_WET
2. Surface area (ha) of the wetland basin	POND_HA
3. % of the basin area covered by surface water	PC_SW
4. Surface water area (ha)	SW_HA
5. % of the surface water area not overgrown with emergent vegetation	PC_OP
6. Surface water area (ha) not overgrown with emergent vegetation	OP_HA
7. Shoreline development index	SDI
8. North-South orientation of the wetland basin	01
9. NE-SW orientation of the wetland basin	02
10. East-West orientation of the wetland basin	03
11. NW-SE orientation of the wetland basin	04
12. Distance (km) to the nearest reservoir >445.3 ha	DTI
13. Number of dominant moist soil plant species at a wetland basin	MSCOUNT
14. Average height category of moist soil vegetation	MSAVHT
15. Number of dominant emergent plant species at a wetland basin	EVCOUNT
16. Average height category of emergent vegetation	EVAVHT
17. Presence of *Ceratophyllum demersum*	SBCT
18. Presence of *Chara vulgaris* as a submergent	SBCH
19. Presence of *Lemna minor* as a submergent	SBL
20. Presence of *Najas guadalupensis* as a submergent	SBN

Table 29. continued.

Variable	Code
21. Presence of <u>Potamogeton</u> sp. as a submergent	SBP
22. Phenolpthalein alkalinity (ppm)	PHEN_ALK
23. Total alkalinity (ppm)	TOT_ALK
24. Light penetration (secchi disk cm)	LGT_PEN
25. % of surface water area less than 1m deep	DEPTH
26. Conductivity (umhos)	COND
27. pH	PH
Land use surrounding the wetland	
28. Human habitation	L1
29. Crops-farmland	L2
30. Grazing	L3
31. Hayland and ungrazed pasture	L4
32. Idle	L5
33. Game management	L6
34. Forestland	L7
35. Distance (km) from the nearest permanent stream	DIST_P_S
36. Age of wetland, if man-made	AGE

presented (Table 30).

Many correlations were present among the variables (Tables 30 and 31), but only the more general trends are discussed. 1) The size of wetland basins was directly correlated with the area of surface and open water, % of the basin area covered by water, shoreline development index, number of moist soil and emergent species, and chemical concentrations. 2) The % of the basin area covered by water was negatively correlated with the number of plant species and chemical concentrations. 3) The % of the basin not overgrown with emergent vegetation was negatively correlated with light penetration, shoreline development index, number of moist soil species, and the percentage of the surface water area less than 1 m deep. 4) The number of moist soil and emergent plant species present at wetlands was negatively correlated to chemical concentrations and the height of moist soil and emergent vegetation, but was positively correlated with light penetration. 5) Chemical concentrations were positively correlated with each other but negatively correlated with light penetration and the % of the surface water area less than 1 m deep. 6) Wetlands closer to permanent streams were more numerous, had greater shoreline development indices, had more moist soil and emergent species, and had greater light penetration; but had lower total alkalinity. 7) The presence of grazing at wetland basins was negatively correlated with the ha of surface water and the number and height of moist soil and emergent plants, but was positively correlated with total alkalinity.

Correlations between individual moist soil, emergent, and submergent plant species and physical, chemical, and vegetation variables measured at palustrine wetland basins were evaluated to

Table 30. Significant (P<0.01) simple correlation coefficients among physical, chemical, and vegetational variables measured at wetland basins with water present 1978-80.

	TOT_WET	POND_HA	PC_SW	SW_HA	PC_OP	OP_HA	SDI	O1	O2	O3	O4	DTI	MSCOUNT	MSAVHT	EVCOUNT	EVAVHT	PHEN_ALK	TOT_ALK	LGT_PEN	DEPTH	COND	PH	DIST_P_S
TOT_WET																							
POND_HA	-.09																						
PC_SW	.07	-.10																					
SW_HA	-.06	.75	.05																				
PC_OP				-.06																			
OP_HA	-.07	.75	.06	.98																			
SDI	-.07	.25	.09	.26	-.11	.26																	
O1					-.05		.12																
O2								-.29															
O3		-.06		-.06		-.06	-.11	-.74	-.20														
O4	-.06	.14		.15		.16		-.28	-.08	-.19													
DTI					-.06	-.05		-.11		.09	.05												
MSCOUNT	.06	.08	.24	.10	-.26	.10	.15																
MSAVHT						.05	.16						-.09										
EVCOUNT	.08	.28	.08	-.40	.06	.07							.55										
EVAVHT							.17				.08		-.10	.59	-.11								
PHEN_ALK	-.08											.10	-.10	-.06	-.06								
TOT_ALK	-.15	.11	-.18	.08	.06	.08	.13	.08	.06	-.11		.06	-.24	.08	-.19	.12	.32						
LGT_PEN	.09		.07		-.11				-.07			-.05	.18	-.07	.13	-.14		-.16					
DEPTH			-.21		-.08	-.06	-.12	-.11	.08	.08		.06		-.13		-.10	-.07						
COND			-.11					.11		-.10			-.15		-.14		.23	.36		-.08			
PH	-.15	.11	-.09	.07	.06	.07	.09	.07		-.06			-.20		-.22		.36	.48			.27		
DIST_P_S	-.12						.07					.12	-.05		-.10			.09	-.16				
AGE											.17												

Table 31. Significant (P<0.01) simple correlation coefficients for physical, chemical, and vegetational variables with land use measured at wetland basins with water present 1978-80.[a]

Characteristic (See Table 29)	L1	L2	L3	L4	L5	L6	L7
TOT_WET	.21		-.07			-.07	.09
POND_HA			-.10			.48	.22
PC_SW	.11					-.08	
SW_HA			-.09			.21	.18
PC_OP							
OP_HA			-.08			.23	.20
SDI			-.10			.10	.15
01		.08	-.09				
02			.09				
03							
04	-.06		.07		-.07		
DTI	-.12		-.12		.12	-.10	.10
MSCOUNT	.09		-.11		.17	.09	.09
MSAVHT	-.11		-.10		.07		.11
EVCOUNT			-.10		.13		
EVAVHT	-.10	.11				.11	
PHEN_ALK							
TOT_ALK	-.10		.08		-.11	.13	
LGT_PEN	.10		-.16		.16		
DEPTH							-.10
COND							
PH	-.12				-.12	.11	
L1		-.07					-.10
L2	-.07		-.17				
L3		0.17		-.46	-.59	-.14	-.17
L4			-.46		-.08		
L5			-.59	-.08			.10
L6			-.14				.18
L7	-.10		-.17		.10	.18	
DIST_P_S	-.11	.08		.08	-.08	-.08	-.07
AGE	-.16		.27		-.18		

obtain information on ecological requirements. Almost all moist soil species had positive correlations with the number of moist soil and emergent species; only cocklebur (Xanthium pennsylvanicum) had a negative correlation (Table 32). Weed, sedge, typical emergent, and mudflat species generally occurred at wetlands with more emergent cover, lower chemical concentrations, and greater light penetration. Woody species at basins were positively correlated with greater plant heights, greater surface area, greater shoreline development index, and higher chemical concentrations. Weeds and grasses were common in shallow wetland basins while Cyperus sp., Salix nigra, and salt cedar occurred at deeper basins. Polygonum sp., Juncus sp., and Eleocharis sp. were found closer to streams, but Quercus sp. were present farther from streams.

Wetland basins near buildings had higher occurrences of weeds and mudflat species, but fewer sedges and oaks (Table 33). Grazing at wetlands negatively affected all woody and mud flat species; only cocklebur was encouraged. Wetlands with hayland were positively correlated with Carex sp. and Scirpus sp. while wetlands near idle ground had higher occurrences of weeds, mudflat species, and some trees. Wetlands near game management and forestland were positively correlated with woody species and Polygonum sp. Wetlands in game management areas were also positively correlated with Echinocloa crusgalli and negatively with grasses.

Most emergent species were positively correlated with the number of moist soil and emergent species and the % of the basin covered with water, and were negatively correlated with the % of the surface water area not overgrown with emergents (Table 34). Many species were more

Table 32. Significant $P<0.01$ simple correlation coefficients (either positive or negative) for moist soil plant species with physical, chemical, and vegetational variables measured at wetland basins with water present 1978-80.

Moist soil species	Sample size	TOT_WET	POND_HA	PC_SW	SW_HA	PC_OP	OP_HA	SDI	O1	O2	O3	O4	MSCOUNT	MSAVHT	EVCOUNT	EVAVHT	PHEN_ALK	TOT_ALK	LCT_PEN	DEPTH	COND	PH	DIST_P_S
Weed																							
Ambrosia sp.	125	.08		.06		-.05		-.04		.06			.17		.15				-.05				
Graminae sp.	1141	.11		.24		-.10							.43	-.10	.34		-.14	-.18		.08	-.12	-.28	
Rumex sp.	16												.08		.07								
Compositae sp.	86			.09									.14		.06			-.06			.06	-.13	
Xanthium pennsylvanicum	125			-.13						-.05			.08	-.07	-.07			.05		.07		.06	
Sedge																							
Carex sp.	110			.12		-.08	.05						.20		.13						-.06		
Eleocharis sp.	1015	.05		.17		-.10			-.05				.50	-.19	.34	-.17		-.17	.24	.06	-.13	-.12	-.11
Juncus sp.	374			.16		-.14							.37	-.10	.29	-.11	-.04	-.15			-.10	-.10	-.05
Eleocharis quadrangulata	24																						
Cyperus sp.	154		.17	.05	.14		.15	.08				.05	.24	-.06	.05					-.07		.05	
Mudflat																							
Echinocloa crusgalli	209					-.06		.08					.23	-.10	.08			-.06			-.05		
Polygonum sp.	490		.06	.05	.06	.11	.06	.08					.42	-.10	.21			-.12	.07			-.11	-.10
Sagittaria sp.	20					-.13		-.05					.08		.14								
Emergent																							
Jussiaea decurrens	70	.06				-.08					.05		.10		.07			-.05				-.08	
Nelumbo lutea	6			-.05					-.07														
Scirpus sp.	71	-.05				-.15							.14		.12								
Scirpus americanus	24					-.05				.05			.08		.07		.11					.05	
Typha latifolia	214					-.22			.06			-.04	.22	-.10	.17	-.09		-.07	.13				
Woody																							
Cephalanthus occidentalis	108		.28		.23		.23	.27					.16		.06			.08				.08	
Populus deltoides	30						.05	.05					.09	.17									
Quercus sp.	55	.07							-.05				.05	.20							-.06	.09	.07
Salix interior	33												.06				.06			-.08			
Salix nigra	805							.12					.29	.39	.05	.16			.11				
Tamarix gallica	19											.08	.06		.05		.06				.17		
Various trees	149		.11		.10		.10	.16					.12	.30		.16	-.06			-.05			

Table 33. Significant ($P<0.01$) simple correlation coefficients (either positive or negative) for moist soil plant species with land use measured at wetland basins with water present 1978-80.

Moist soil species	Sample size	L1	L2	L3	L4	L5	L6	L7
Weed								
Ambrosia sp.	125					.06		
Graminae sp.	1141	.11				.09	-.06	
Rumex sp.	16							
Compositae sp.	86	.13						
Zanthium pennsylvanicum	125			.07				
Sedge								
Carex sp.	110	-.06			.06			
Eleocharis sp.	1015	.06						
Juncus sp.	374							
Eleocharis quadrangulata	24							
Cyperus sp.	154			-.11			.31	.12
Mudflat								
Echinocloa crusgalli	209			-.10		.06	.16	
Polygonum sp.	490	.09		-.10		.13	.08	.06
Sagittaria sp.	20							
Emergent								
Jussiaea decurrens	70							
Nelumbo Lutea	6							
Scirpus sp.	71				.08			
Scirpus americanus	24							
Typha latifolia	214							
Woody								
Cephalanthus occidentalis	108			-.07			.06	
Populus deltoides	30			-.05		.10		
Quercus sp.	55	-.08		-.08		.11		.20
Salix interior	33			-.06		.06		
Salix nigra	805			-.07				
Tamarix gallica	19							
Various trees	149			-.07			.06	.18

Table 34. Significant (P<0.01) simple correlation coefficients, either positive or negative, for emergent plant species with physical, chemical, and vegetational variables measured at wetland basins with water present 1978-80.

Emergent species	Sample size	TOT_WET	POND_HA	PC_SW	SW_HA	PC_OP	OP_HA	SDI	O1	O2	O3	O4	MSCOUNT	MSAVHT	EVCOUNT	EVAVHT	PHEN_ALK	TOT_ALK	LGT_PEN	DEPTH	COND	PH	DIST_P_S
Weed																							
Ambrosia sp.	66	.05		.07									.16		.38			-.05			-.05		
Graminae sp.	309	.06		.17		-.16							.23		.51	-.12		-.10			-.09	-.15	
Compositae sp.	16			.06						.05					.10								
Xanthium pennsylvanicum	17														.06								
Sedge																							
Carex sp.	52			.10		-.13							.16		.31			-.05					
Eleocharis sp.	420	.05		.21		-.15			-.05		.05		.36	-.06	.59	-.15	-.05	-.16	.17		-.10	-.18	-.13
Juncus sp.	220			.16		-.18							.27	-.05	.47	-.11		-.15	.07	.05	-.10	-.17	-.07
Eleocharis quadrangulata	23			.05		-.06							.06		.15							-.05	
Cyperus sp.	21	-.06	.11	.05	.15		.14						.10		.13								
Mudflat																							
Echinocloa crusgalli	44			.07		-.13		.07					.12		.31								
Ludwigia sp.	41	.07											.12		.16							-.06	
Polygonum sp.	155	.07		.09	.07	-.16	.06	.06					.19		.37	-.09		-.06				-.08	-.06
Sagittaria sp.	28	.06				-.08		-.06					.06		.15							-.05	
Emergent																							
Jussiaea decurrens	87	.09				-.09							.10		.19			-.10			-.06	.08	-.08
Nymphae sp.	16	-.06		.06		-.14									.11			-.06	.08				
Nelumbo lutea	10	-.05													.06				.06				
Scirpus sp.	41					-.12							.10		.17								.10
Typha latifolia	189					-.29			.05			-.05	.21	-.08	.29	-.10			.15				
Woody																							
Cephalanthus occidentalis	49		.18		.21	-.09	.20						.13		.21								
Populus deltoides	17												.06	.07	.10								
Quercus sp.	11	.09			.06	-.18		.09						.12		.37						-.06	.14
Salix interior	17	.05											.05		.14								-.08
Salix nigra	206			.10	-.07	-.09	.06	.09					.21	.15	.35	.43				-.08			
Various trees	23		.09		.17	-.08	.16	.10						.18	.10	.28							

abundant when more wetlands were near, however, Nymphae sp., Nelumbo lutea, and Cyperus sp. were not. Polygonum sp. and some woody species were positively correlated with larger wetlands and with greater shoreline development indices. Emergent trees were correlated with higher plant heights. Weed, sedge, and mudflat species were negatively correlated with higher chemical concentrations but positively correlated with light penetration. More sedges and Polygonum sp. occurred as emergents near streams, but Scirpus sp. and Quercus sp. did not.

Wetlands near buildings had more emergent grasses, Ludwigia sp. and cattail; and wetlands near cropland had more emergent oaks (Table 35). Cropland was infrequent near wetlands, however, and the correlation with oaks may be due to small sample sizes. Grazing negatively affected Echinocloa crusgalli, cattail, and woody species; but hayland encouraged cattail, oaks, and Scirpus sp. Wetlands with idle land use were positively correlated with compositae sp., some sedges, and trees. More emergent Echinocloa cursgalli, buttonbush, and Cyperus sp. occurred at wetlands in game management areas. Wetlands near forestland were positively correlated with oaks, Cyperus sp., and Ludwigia sp. but were negatively correlated with grasses.

Individual submergent plant species had similar correlations with physical, chemical, and vegetation variables (Table 36). Most species were negatively correlated to the % of the surface water area not overgrown with emergents, plant heights, and grazing. In contrast, submergent plants were positively correlated with the % of the basin covered with water, the number of moist soil and emergent species, light penetration, and to each other. Responses to chemical

Table 35. Significant ($\underline{P}<0.01$) simple correlation coefficients (either positive or negative) for emergent plant species with land use measured at wetland basins with water present 1978-80.

Emergent species	Sample size	L1	L2	L3	L4	L5	L6	L7
Weed								
Ambrosia sp.	66							
Graminae sp.	309	.07				.07		-.07
Compositae sp.	16							
Xanthium pennsylvanicum	17							
Sedge								
Carex sp.	52							
Eleocharis sp.	420					.11		
Juncus sp.	220							
Eleocharis quadrangulata	23					.10		
Cyperus sp.	21						.17	.09
Mudflat								
Echinocloa crusgalli	44			-.06			.11	
Ludwigia sp.	41	.06						.06
Polygonum sp.	155							
Sagittaria sp.	28							
Emergent								
Jussiaea decurrens	87							
Numphae sp.	16					.09		
Nelumbo lutea	10							
Scirpus sp.	41				.07			
Typha latifolia	189	.06		-.06	.08			
Woody								
Cephalanthus occidentalis	49			-.05			.09	
Populus deltoids	17			-.08		.11		
Quercus sp.	11		.11		.07			.14
Salix interior	17			-.10		.16		
Salix nigra	206							
Various trees	23							

Table 36. Simple correlation coefficients for submergent plant species with physical, chemical, and vegetational variables measured at wetland basins with water present 1978-80.

	TOT_WET	POND_HA	PC_SW	SW_HA	PC_OP	OP_HA	SDI	O1	O2	O3	O4	DTI	MSCOUNT	MSAVHT	EVCOUNT	EVAVHT	SBCT	SBCH	SBL	SBN	SBP
SBCT												-.06	.06					.07	.08	.22	.06
SBCH			.06		-.05								.07	-.06			.07		.10	.20	.17
SBL			.05		-.09								.10		.07		.08	.10		.12	.20
SBN					-.09								.22	-.04	.11	-.10	.22	.20	.12		.26
SBP			.05		-.11								.16	-.07	.16	-.08	.06	.17	.20	.26	

	PHEN_ALK	TOT_ALK	LGT_PEN	DEPTH	COND	PH	L1	L2	L3	L4	L5	L6	L7	DIST_P_S	AGE
SBCT	.05		.16												
SBCH	.17		.20	-.09		.14			-.08	.15					
SBL						.06			-.07			.28	.09		
SBN		-.09	.37		-.06				-.08	-.07	.08			-.07	
SBP		-.12	.14		-.08				-.07	.06			.08		

concentrations were varied. *Najas* and *Potamogeton* were negatively correlated with total alkalinity and conductivity while *Chara* and *Lemna*, and *Ceratophyllum* and *Chara* were positively correlated with pH and phenolpthalein alkalinity respectively. *Chara* occurred more often in wetlands near hayland, *Lemna* in wetlands near game management and forestland, *Najas* in wetlands near idle ground, and *Potamogeton* in wetlands near hayland and forestland. *Najas* occurred less often in wetlands near hayland and more often near permanent streams.

Ecological Relationships Among Palustrine Wetland Groups

Ecological relationships were determined only among palustrine wetland groups using multivariate techniques because of the need for large sample sizes. All variables measured at wetland basins (Table 29) were correlated with each other, and correlation coefficients for seasons with 2 surveys (i.e. spring: SP79 and SP80, summer: SM78 and SM79, early winter: WI and WIII, late winter: WII and WIV), for fall (F79), and for all seasons combined were calculated. A principal component analysis was performed for each of these seasons using the correlation coefficients as entries. In all cases, the 1st 3 principal components were comparatively the most important factors (Table 37). The % of the wetland variation explained by the 1st 3 factors ranged from 22.3% when all seasons were combined to 29.1% during late winter (Table 37). Variables related to size and shoreline development index were most important in all of the factor I's (PC-I) except during early winter. Variables related to chemical concentrations, submergent plants and light penetration were usually most important, alternately depending on the seasons, in PC-II's and PC-III's. Land use variables

Table 37. The rotated factor pattern of the 1st 3 principal components by season, showing the most heavily weighted factors (greater than 0.20), either positive or negative, for each of the 34 variables.

	Spring factors			Summer factors			Fall factors			Early winter factors			Late winter factors			Combined seasons factors		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Cumulative %	9.5	18.0	24.5	9.2	17.0	23.7	10.5	18.8	24.9	11.2	21.7	29.0	11.2	22.0	29.1	8.6	16.6	22.3
TOT_WET									0.29									
POND_HA	0.98^{a}			0.98^{a}			0.97^{a}				0.32^{a}		0.76^{a}			0.87^{a}		
PC_SW										0.32^{a}	0.32			-0.22				
SW_HA	0.98^{a}			0.98^{a}			0.97^{a}				0.93^{a}		0.86^{a}			0.95^{a}		
PC_OP								-0.73^{a}				-0.21						
OP_HA	0.98^{a}			0.98^{a}			0.97^{a}				0.94^{a}		0.79^{a}			0.95^{a}		
SDI	0.26^{a}			0.37^{a}		0.26					0.53^{a}		0.69^{a}			0.32^{a}		
01															-0.91^{a}			
02																		
03															0.94^{a}			
04	0.22				-0.22		0.29											
DTI								0.33	0.32^{a}	0.23								
MSCOUNT		-0.31^{a}						0.59^{a}		-0.21	0.23	-0.24	0.25	-0.30				
MSAVHT												0.77^{a}						
EVCOUNT								0.75^{a}		-0.22				-0.21				
EVAVHT							0.25					0.85^{a}						
SBCT			0.26^{a}															0.55^{a}
SBCH			0.67^{a}		0.70^{a}													0.45^{a}
SBL					0.28						0.43^{a}							
SBN			0.41^{a}		0.62^{a}													0.75^{a}
SBP			0.30^{a}		0.48^{a}			0.52^{a}										0.42^{a}
PHEN_ALK		0.64^{a}				0.76^{a}				0.77^{a}				0.60^{a}			0.66^{a}	
TOT_ALK		0.75^{a}			-0.24	0.73^{a}				0.74^{a}				0.76^{a}			0.75^{a}	
LGT_PEN			0.36^{a}		0.71^{a}			0.30										0.62^{a}
DEPTH											-0.22	-0.42^{a}						
COND		0.52^{a}				0.40^{a}				0.70^{a}				0.70^{a}			0.62^{a}	
PH		0.77^{a}				0.75^{a}				0.57^{a}				0.76^{a}			0.71^{a}	
L1								0.24										
L2																		
L3			-0.43^{a}						-0.71^{a}									
L4			0.75^{a}		0.31													
L5									0.82^{a}									
L6							0.72^{a}									0.31		
L7	0.32^{a}								0.40^{a}							0.26		

[a] Variables included in the calculation of B1, B2, and B3.

were most important in PC-III during fall, height and depth variables were important in PC-III during early winter, and orientation variables were important in PC-III during late winter.

For each factor, those variables having a large factor loading after rotation (Table 37) were selected, and a new factor (B1, B2, and B3) was computed for each season as the sum of the selected variables after each had been divided by its standard deviation. These new factors, (i.e. B1, B2, and B3) therefore, represent the PC-I's, PC-II's, and PC-III's for each season; their calculations are shown in Tables 38-43; and they are used for all further multivariate analyses.

Wetland groups had significantly ($\underline{P}<0.0001$) different individual B1, B2, and B3 values (AOV-tests) and combined B1, B2, and B3 values (MANOVA-test) during spring (Table 38). Forested, scrub/shrub, and natural emergent wetlands had the largest basin and surface water areas, and shoreline development index during spring, while farm ponds and refinery and oil well pools were the smallest. Oil pools and natural wetlands had the highest chemical concentrations while man-made emergent and submergent ponds had the lowest. Submergent plant species occurred most often in emergent, submergent, and natural scrub/shrub wetlands but least often in forested wetlands.

Wetland groups were also significantly ($\underline{P}<0.0001$) different from each other during summer (Table 39). Wetland group responses and positions with respect to B1, B2, and B3 were similar to responses and positions during spring, with the exception of the switch in variables making up the B2 and B3 factors. Submergent vegetation and light penetration became more important (altered from B3 to B2) in the separation of wetlands, and chemical concentrations became less

Table 38. Ordering of wetland group means of B1, B2, and B3 during spring 1979 and 1980 using a Duncan's multiple range test, $\alpha=0.05$, and MANOVA-tests. Means with the same underline are not significantly different.

B1=POND_HA/1.702 + SW_HA/1.242 + OP_HA/1.038 + SDI/.306
AVO-test, P<0.0001

Wetland group	25	20	23	26	24	15	27	11	18	21	16	17	13	19	14	22	12
	─																
		─	─														
			─	─	─	─	─										
				─	─	─	─	─	─	─	─	─	─	─	─	─	─
Means	36	13	9	7	7	6	5	5	4	4	4	4	4	4	4	4	4

B2=PHEN_ALK/5.274 + TOT_ALK/69.059 + COND/269.74 + PH/.787 - MSCOUNT/1.388, AOV-test, P=0.0170

Wetland group	12	25	26	23	20	24	17	13	27	14	15	11	16	18	21	19	22
	─	─	─	─	─												
		─	─	─	─	─	─	─	─	─	─	─	─	─	─	─	─
Means	18	11	11	11	10	10	9	9	8	8	8	8	8	7	7	6	6

B3=SBCT/.115 + SBCH/.178 + SBN/.283 + LGT_PEN/25.337 + L4/1.061,
AOV-test, P<0.0001

Wetland group	17	18	25	22	21	12	23	24	15	20	11	16	14	13	19	26	27
	─																
		─	─	─	─	─	─										
			─	─	─	─	─	─	─	─	─	─	─	─	─	─	─
Means	8	6	4	3	3	3	3	3	2	2	2	2	2	1	1	.6	.5

MANOVA-test, Ho: No differnece among wetland groups in the B1, B2, and B3 vector values. P<0.0001

Table 39. Ordering of wetland group means of B1, B2, and B3 during summer 1978 and 1979 using a Duncan's multiple range test, α=0.05, and MANOVA-tests. Means with the same underline are not significantly different.

B1=POND_HA/1.257 + SW_HA/1.218 + OP_HA/1.042 + SDI/.330
AOV-test, P<0.0001

Wetland group	25	23	26	27	24	15	16	11	21	17	18	19	22	13	14	12
	—															
		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Means	33	8	7	6	6	5	4	4	4	4	4	4	4	4	3	3

B2=SBCH/.339 + SBN/.337 + SBP/.314 + LGT_PEN/24.499
AOV-test, P<0.0001

Wetland group	17	18	22	21	19	25	12	11	24	16	14	27	23	13	15	26
	—	—	—													
		—	—	—	—	—	—									
			—	—	—	—	—	—	—	—	—	—	—	—	—	—
Means	4.7	3.9	3.5	3.1	2.8	1.8	1.6	1.2	1.2	1.2	1.1	1.0	.9	.8	.6	.4

B3=PHEN_ALK/9,978 + TOT_ALK/57.155 + COND/360.236 + PH/.471
AOV-test, P<0.0001

Wetland group	12	27	23	25	17	13	26	16	21	15	24	11	14	19	18	22
	—	—	—	—	—	—	—	—	—	—	—					
							—	—	—	—	—	—	—	—	—	—
Means	21	21	20	19	17	17	17	16	16	16	16	16	15	15	15	14

MANOVA-test, Ho: No difference among wetland groups in the B1, B2, and B3 values. P<0.0001 important (altered from B2 to B3) during summer.

Wetland groups had significantly ($\underline{P}<0.0001$) different combined B1, B2, and B3 values (MANOVA-test) and mean individual B1 and B2 values during fall, but did not have significantly ($\underline{P}=0.139$) different B3 values (Table 40). Natural scrub/shrub and emergent wetlands had the largest surface water areas, and farm ponds had the smallest surface water areas. Emergent, natural scrub/shrub, and impounded forested wetlands had the most plant species and the least % of the surface water area not overgrown with emergents, while oil pools had the fewest plant species and the greatest % of the surface water area not overgrown with emergents.

Wetland groups had significantly ($\underline{P}<0.0001$) different combined B1, B2, and B3 values during early winter; but did not have different chemical concentrations (B1) ($\underline{P}=0.152$, Table 41). Forested and impounded scrub/shrub wetlands had taller moist soil and emergent plants and were deeper, while emergent wetlands and dugouts (wetland group 14) had shorter plants and were shallower. Wetland groups were significantly (AOV and MANOVA-tests, $\underline{P}<0.0001$) different during late winter, but their mean B3 values showed no difference when using the Duncan's multiple range test (Table 42). Trends in size and chemical concentration among wetland groups remained similar to earlier seasons.

When data for all seasons were combined, wetland groups were significantly (AOV and MANOVA-tests, $\underline{P}<0.0001$) different from each other in all respects (Table 43). As was the case when seasons were analyzed individually, natural scrub/shrub, forested, and natural emergent wetland basins were the largest in surface area and had more indentated shorelines, while man-made farm ponds and oil pools were

Table 40. Ordering of wetland group means of B1, B2, and B3 during fall of 1979 using a Duncan's multiple range test, α=0.05, and MANOVA-tests. Means with the same underline are not significantly different.

B1=POND_HA/1.624 + SW_HA/.528 + OP_HA/.523 + L6/.541,
AOV-test, $P<0.0001$

Wetland group	25	20	26	23	12	24	15	11	18	27	17	19	13	14	21	16	22
	—																
		—															
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Means	28	17	5	2	2	2	1	1	.8	.7	.7	.6	.6	.5	.5	.4	.2

B2=MSCOUNT/1.401 + EVCOUNT/1.013 + SBP/.315 - PC_OP/10.239,
AOV-test, $P=0.0012$

Wetland group	22	21	26	25	18	15	19	17	11	20	16	13	24	14	27	23	12
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Means	-3	-4	-5	-5	-5	-6	-6	-7	-7	-7	-7	-8	-8	-8	-8	-9	-10

B3=L5/1.507 + L7/1.766 + DTI/17.611 - L3/1.272, $P=0.1390$

MANOVA-test, Ho: Ho difference among wetland groups in the B1, B2, and B3 vector values. $P<0.0001$

Table 41. Ordering of wetland group means of B1, B2, and B3 during early winter 1978-79 and 79-80 using a Duncan's multiple range test, α=0.05, and MANOVA-tests. Means with the same underline are not significantly different.

B1=PHEN_ALK/5.859 + TOT_ALK/69.644 + COND/289.803 + PH/.908 - PC_SW/23.109, AOV-test, P=0.1520

B2=POND_HA/1.255 + PC_SW/23.109 + SW_HA/.265 + OP_HA/.253 + SDI/.289 + SBL/.060, AOV-test, P<0.0001

```
Wetland group
   25   26   23   24   11   19   27   21   17   18   22   14   13   16

   --
        -------
             -------
                  ----------------------------------------------------
Means
   25   17   16   11   10   10   10   10   10    9    9    9    8    6
```

B3=MSAVHT/3.515 + EVAVHT/3.195 - DEPTH/25.504, AOV-test, P=0.0002

```
Wetland group
   27   26   24   11   16   25   13   18   21   17   19   22   23   14

   -------
             ----------------------
                  ----------------------------------------------------
Means
    3    3   -1   -2   -3   -3   -3   -3   -3   -3   -3   -4   -4   -4
```

MANOVA-test, Ho: No differnece among wetland groups in the B1, B2, and B3 vector values. P<0.0001

Table 42. Ordering of wetland group means of B1, B2, and B3 during late winter 1978-79 and 79-80 using a Duncan's multiple range test, α=0.05, and MANOVA-tests. Means with the same underline are not significantly different.

B1=POND_HA/1.703 + SW_HA/.296 + OP_HA/.366 + SDI/.302, AOV-test, P<0.0001

Wetland group	25	20	23	24	15	26	19	11	21	18	17	16	27	14	13	22	12
	—	—															
			—	—	—	—											
					—	—	—	—	—	—	—	—	—	—			
						—	—	—	—	—	—	—	—	—	—	—	—
Means	29	25	11	9	8	7	6	6	6	6	5	5	5	5	4	4	4

B2=PHEN_ALK/3.83 + TOT_ALK/51.400 + COND/259.334 + PH/.785, AOV-test, P=0.002

Wetland group	12	23	25	20	26	24	17	11	16	15	18	21	27	19	13	14	22
	—	—	—	—													
		—	—	—	—	—	—										
			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Means	19	13	13	12	11	11	11	10	10	10	9	9	9	9	9	9	8

B3=03/.474 - 01/.500, AOV-test, P=0.0840

Wetland group	27	14	19	22	20	17	11	16	18	15	26	13	24	25	21	23	12
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Means	2	1	1	.1	0	-.1	-.2	-.3	-.4	-.5	-.6	-.7	-.8	-1	-1	-2	-2

MANOVA-test, Ho: No difference among wetland groups in the B1, B2, and B3 vector values. P<0.0001

Table 43. Ordering of wetland group means of B1, B2, and B3 for all seasons combined 1978-80 using a Duncan's multiple range test, $\alpha=0.05$, and MANOVA-tests. Means with the same underline are not significantly different.

B1=POND_HA/1.514 + SW_HA/.857 + OP_HA/.744 + SDI/.310,
AOV-test, $\underline{P}<0.0001$

Wetland group	25	20	23	26	24	27	15	19	11	21	18	16	17	13	14	22	12
	—																
		—															
			—	—	—	—	—										
						—	—	—	—	—	—	—	—	—	—	—	—
Means	32	13	7	7	7	6	6	5	5	5	4	4	4	4	4	4	3

B2=PHEN_ALK/6.87 + TOT_ALK/62.676 + COND/283.57 + PH/.813,
AOV-test, $\underline{P}<0.0001$

Wetland group	12	23	25	20	27	26	24	17	15	14	13	21	16	11	18	19	22
	—	—	—	—													
		—	—	—	—												
			—	—	—	—											
				—	—	—	—	—	—	—	—	—	—	—	—		
													—	—	—	—	—
Means	15	13	13	13	12	11	11	10	10	10	10	10	10	10	9	9	8

B3=SBCT/.097 + SBCH/.266 + SBN/.326 + SBP/.230 + LGT_PEN/30.185,
AOV-test, $\underline{P}<0.0001$

Wetland group	17	18	22	21	25	29	24	12	11	20	16	14	13	23	15	26	27
	—	—	—														
			—	—	—	—	—	—									
					—	—	—	—	—	—	—	—	—	—			
								—	—	—	—	—	—	—	—	—	—
Means	5	4	3	3	3	2	2	2	2	2	1	1	1	1	1	.6	.6

NANOVA-test, Ho: No difference among wetland groups in the B1, B2, and B3 vector values. $\underline{P}<0.0001$

---

the smallest in area. Oil pools and natural wetlands had the highest chemical concentrations; while mud substrate, emergent, and submergent farm ponds had the lowest concentrations. In general, emergent, submergent, and scrub/shrub wetlands were cleaner and had the most submergents, while forested wetlands were more turbid and had fewer submergents.

A 3-dimensional representation of the ecological distribution of palustrine wetland groups was produced by plotting their mean B1, B2, and B3 scores for each season and for all seasons combined (Fig. 26). The variables included in the B1's, B2's, and B3's that were similar, were plotted on the same axes (i.e. size and SDI on the horizontal, chemical concentration on the vertical, and in most cases, submergent vegetation and light penetration on the height axis) when possible to compare the ecological positions of wetland groups among seasons. However, the variables comprising the B3's were different among seasons, and the differences should be recognized when interpreting the comparisons.

The ecological positions of wetland groups were dynamic over seasons. Wetland groups were most distinct and separated during summer and fall (Fig. 26). They became less separated during early winter and became more grouped during late winter. Separation of wetland groups was again minimally evident during spring. Natural scrub/shrub, oil pool, and natural emergent non-persistent wetland groups were distinct during all seasons. The relative separation and distinction among other wetland groups over seasons appeared to be related to the environmental characteristics of specific groups. Wetlands dominated by submergent and emergent vegetation became

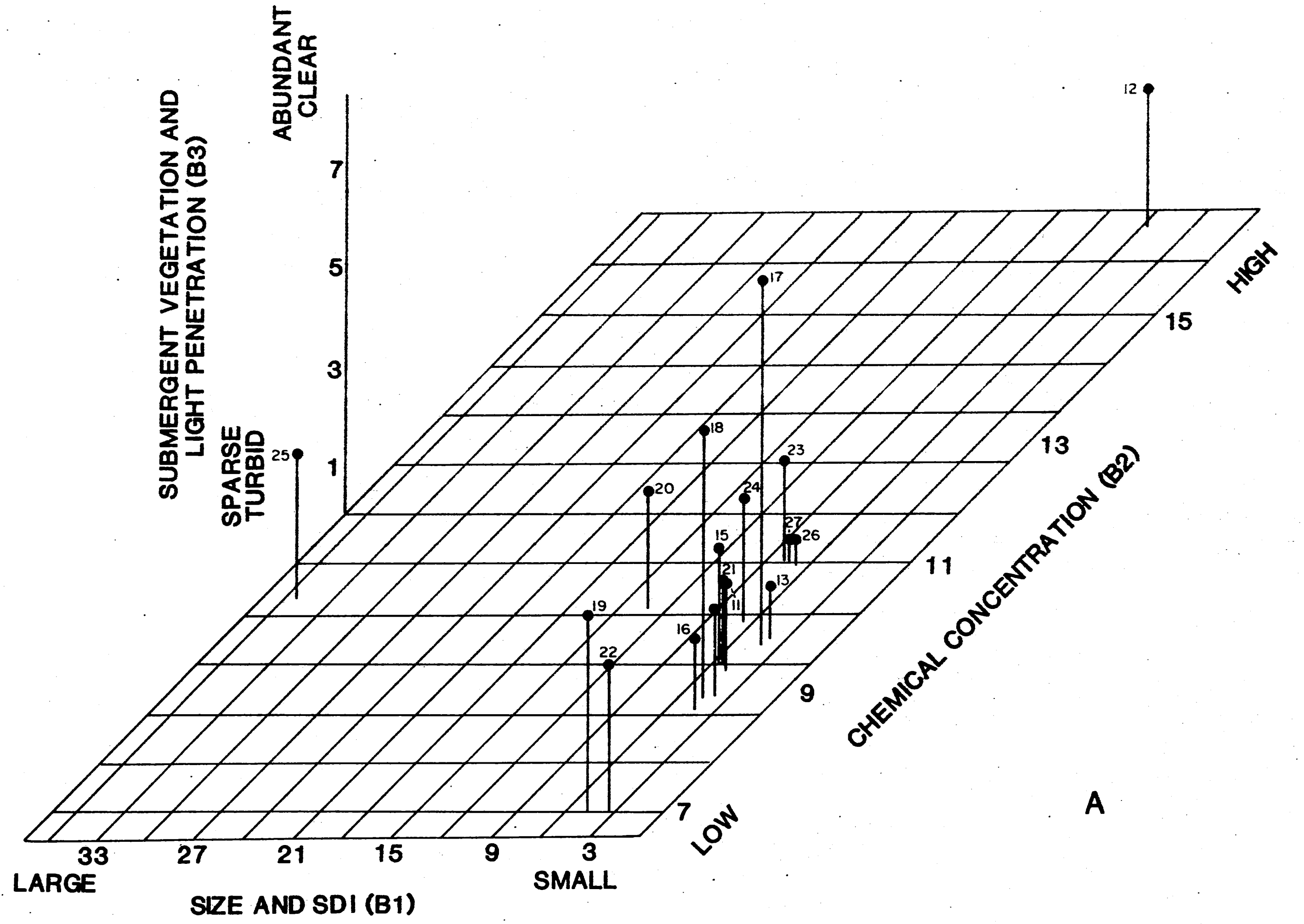
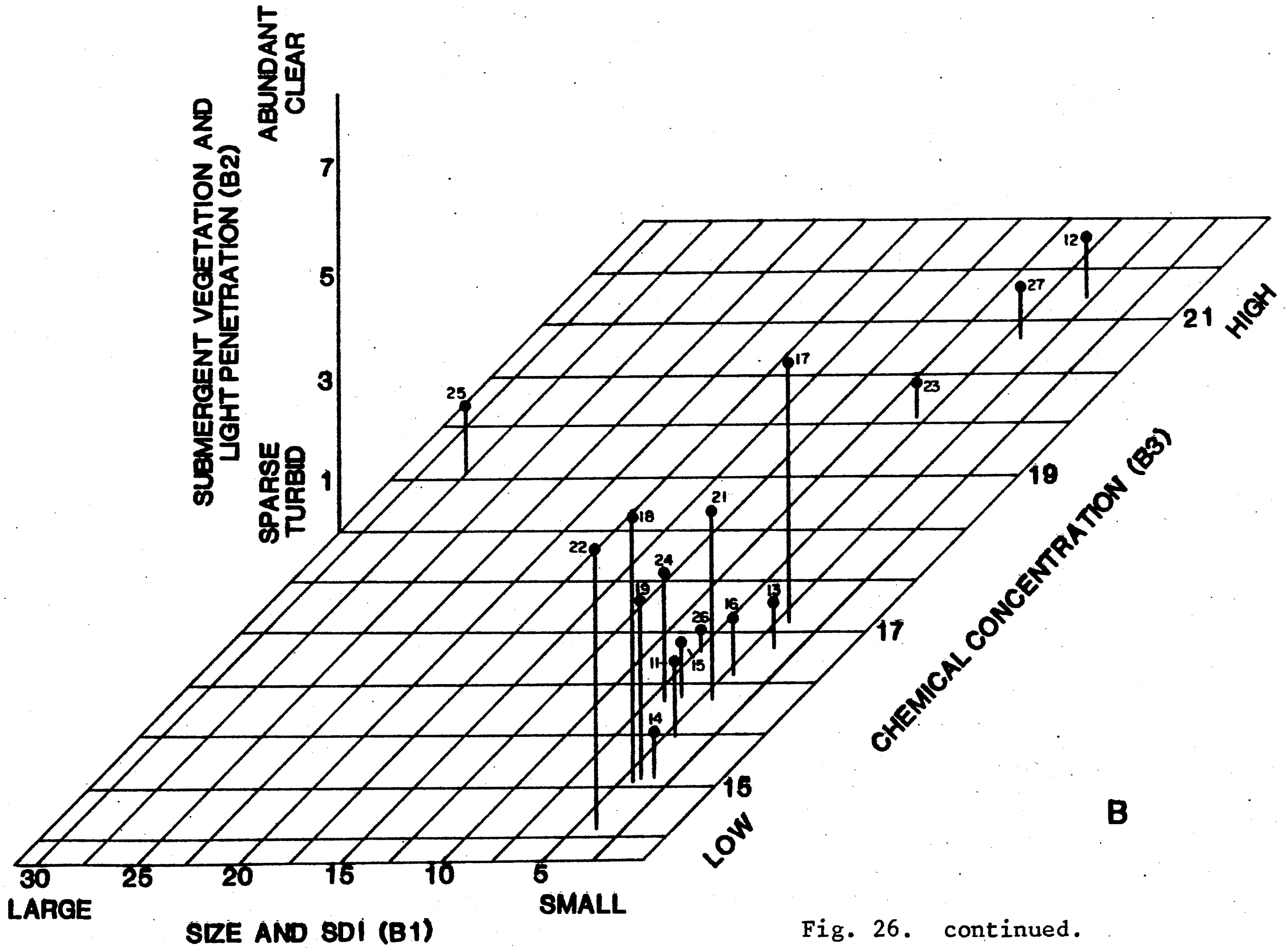


Fig. 26. Projection of 17 palustrine wetland groups present in Oklahoma along the B1, B2, and B3 axes for a) spring, b) summer, c) fall, d) early winter, e) late winter, and f) all seasons combined. See text for interpretation, Table 8 for wetland group description, and Tables 38-43 for calculation of B1, B2, and B3.



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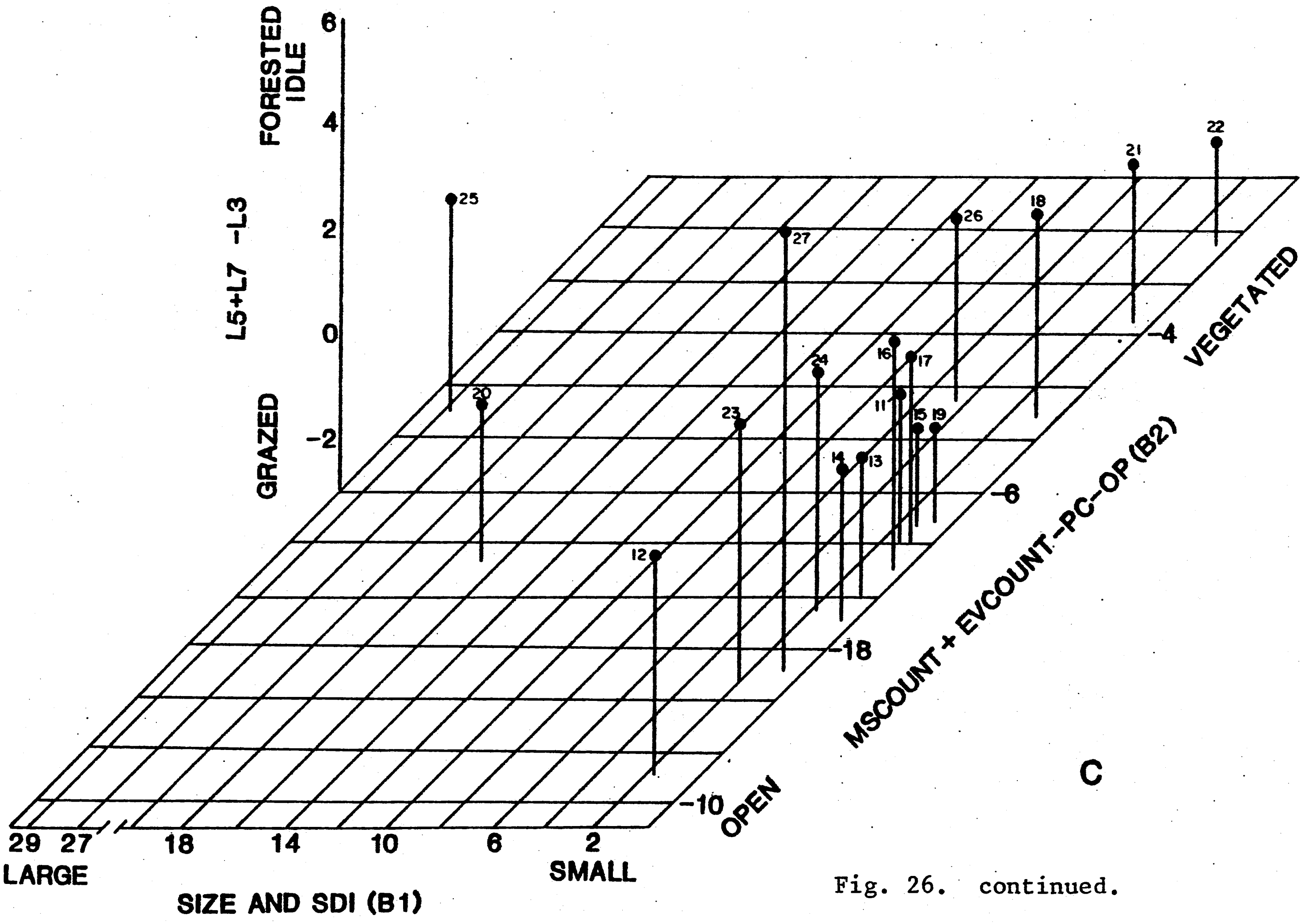

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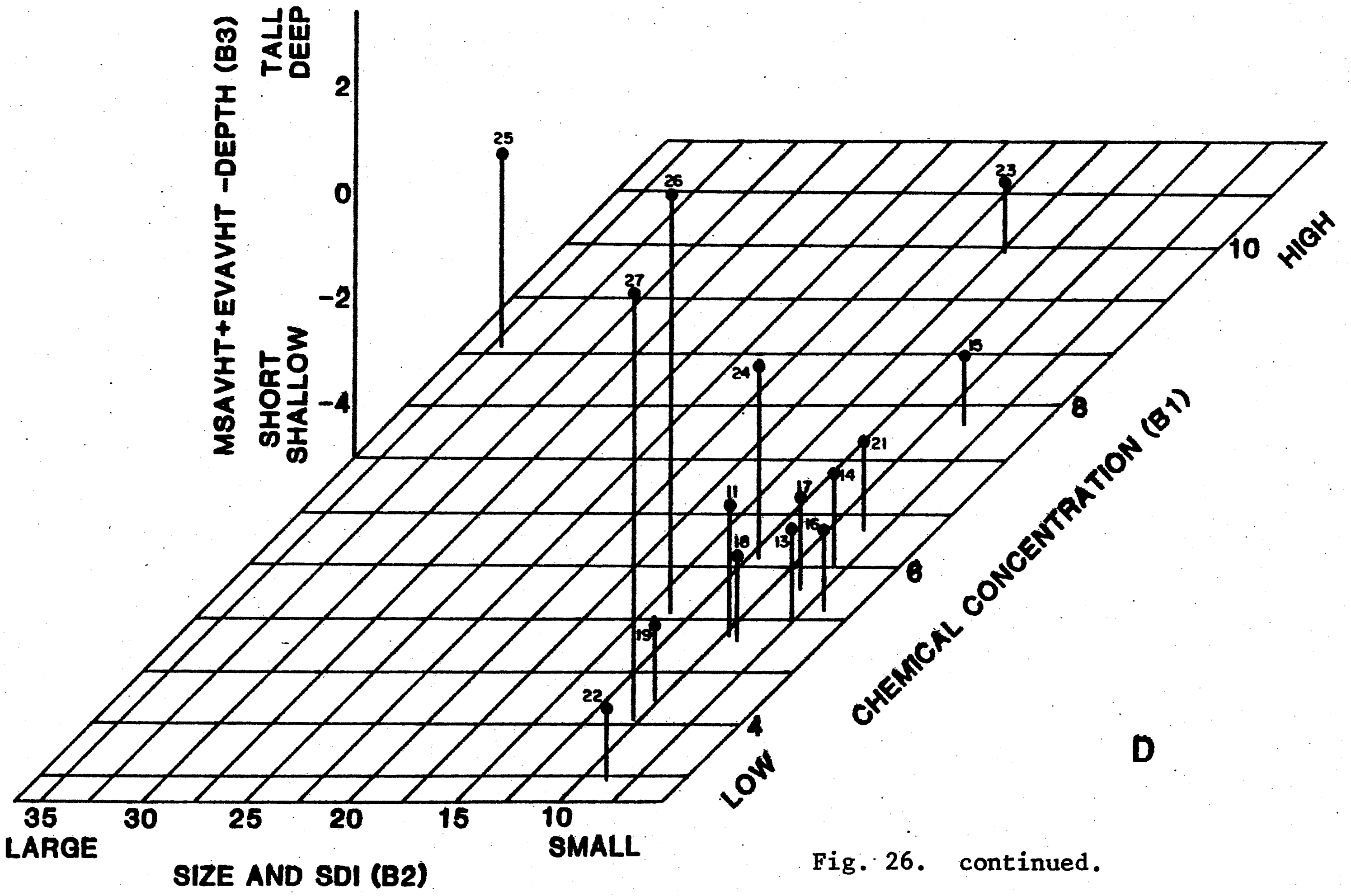

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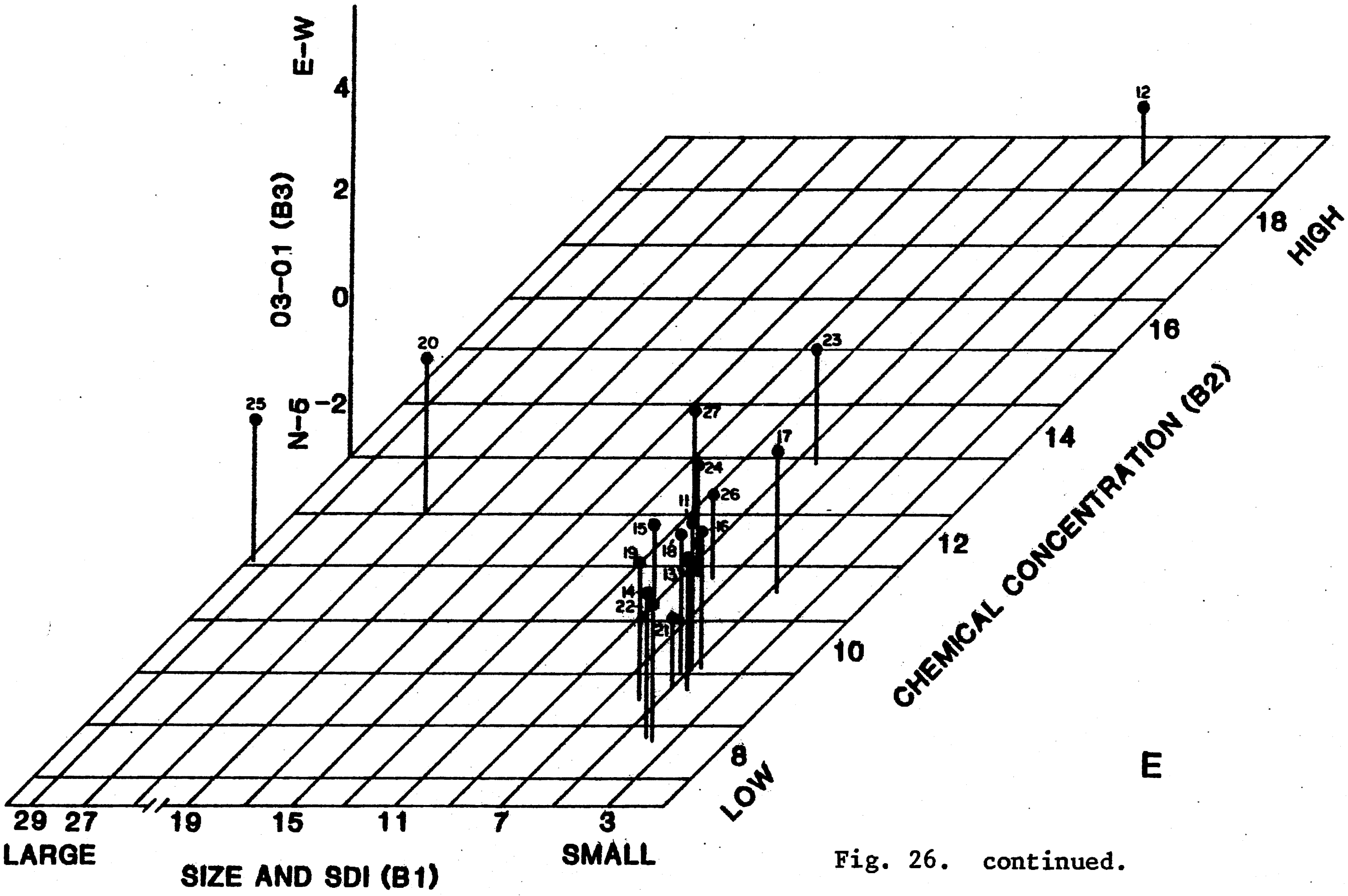

Fig. 26. continued.

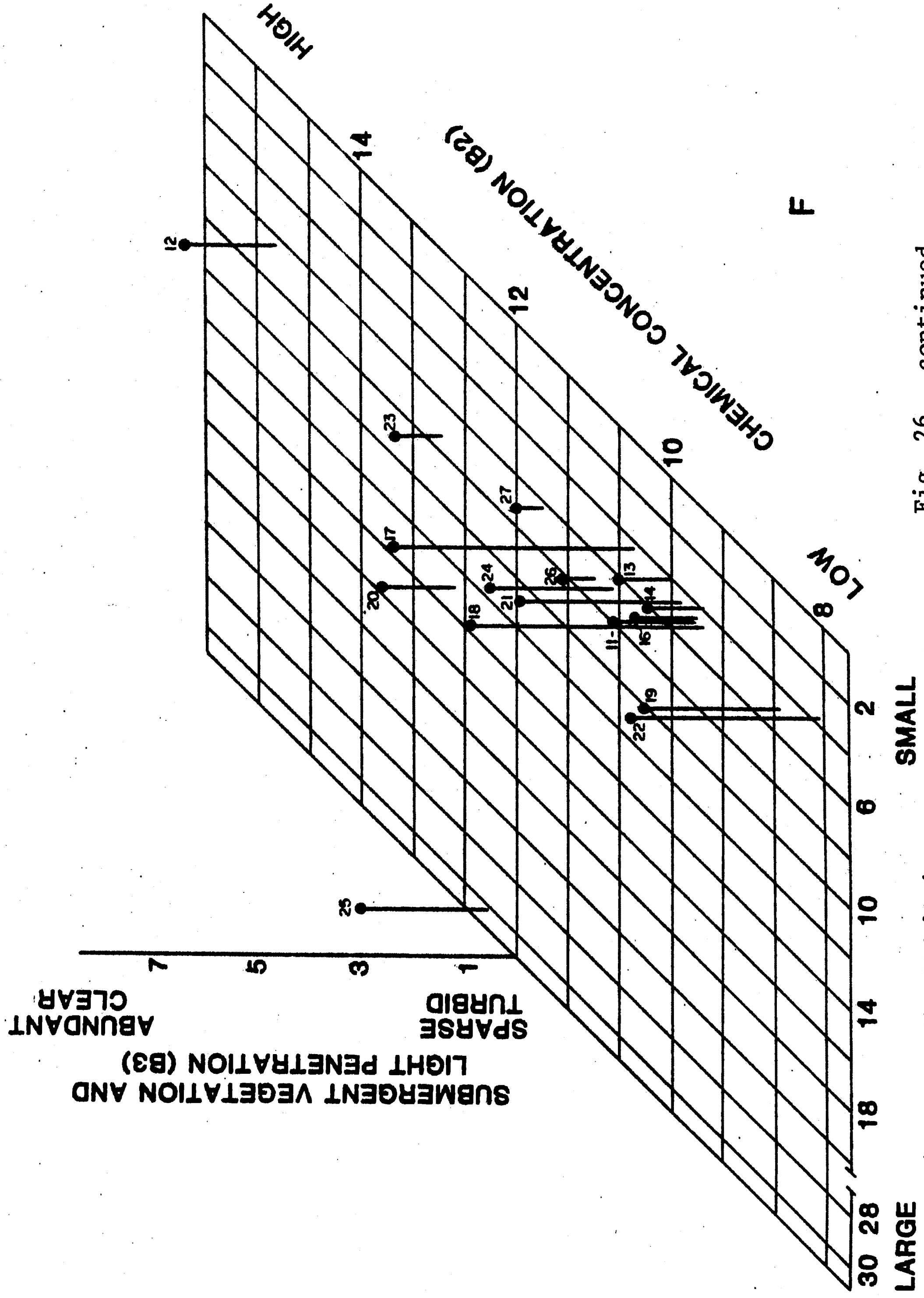

Fig. 26. continued.

separated and distinct from other wetland groups during spring-fall, and then became less distinct during winter. But scrub/shrub, forested, and natural wetlands became more ecologically separated during winter. Mud substrate wetlands (groups 11, 13-16) were usually closely grouped in all seasons with the exception of permanently flooded natural wetlands (group 15) during early winter. Therefore, no individual environmental characteristic that we measured seemed responsible for ecological separation, but instead, the seasonal characteristics of different wetland groups determined the relative seasonal and total distinctiveness.

The average B1, B2, and B3 values of wetland groups were used in a cluster analysis to determine which palustrine wetland groups were most closely related. A dendrograph (McCammon and Wenniger 1970) was constructed for each season (Figs. 27-31) and for all seasons combined (Fig. 32).

Wetland groups that were dominated by emergent and submergent vegetation (groups 17-23) were closely related in their ecological characteristics during all seasons (Figs. 27-31). Some mud substrate wetlands were also closely related to vegetated wetland basins. But semipermanently and seasonally flooded natural wetlands (group 15) became more distinct during spring and fall; permanently flooded farm ponds (group 11) became more distinct during spring and early winter; and impounded semipermanently and seasonally flooded wetlands (group 13) became more distinct during summer. Oil pools were distinct during all seasons except summer. Natural scrub/shrub wetlands were separated from other groups during spring, summer, and early winter, but impounded scrub/shrub wetlands usually remained more closely

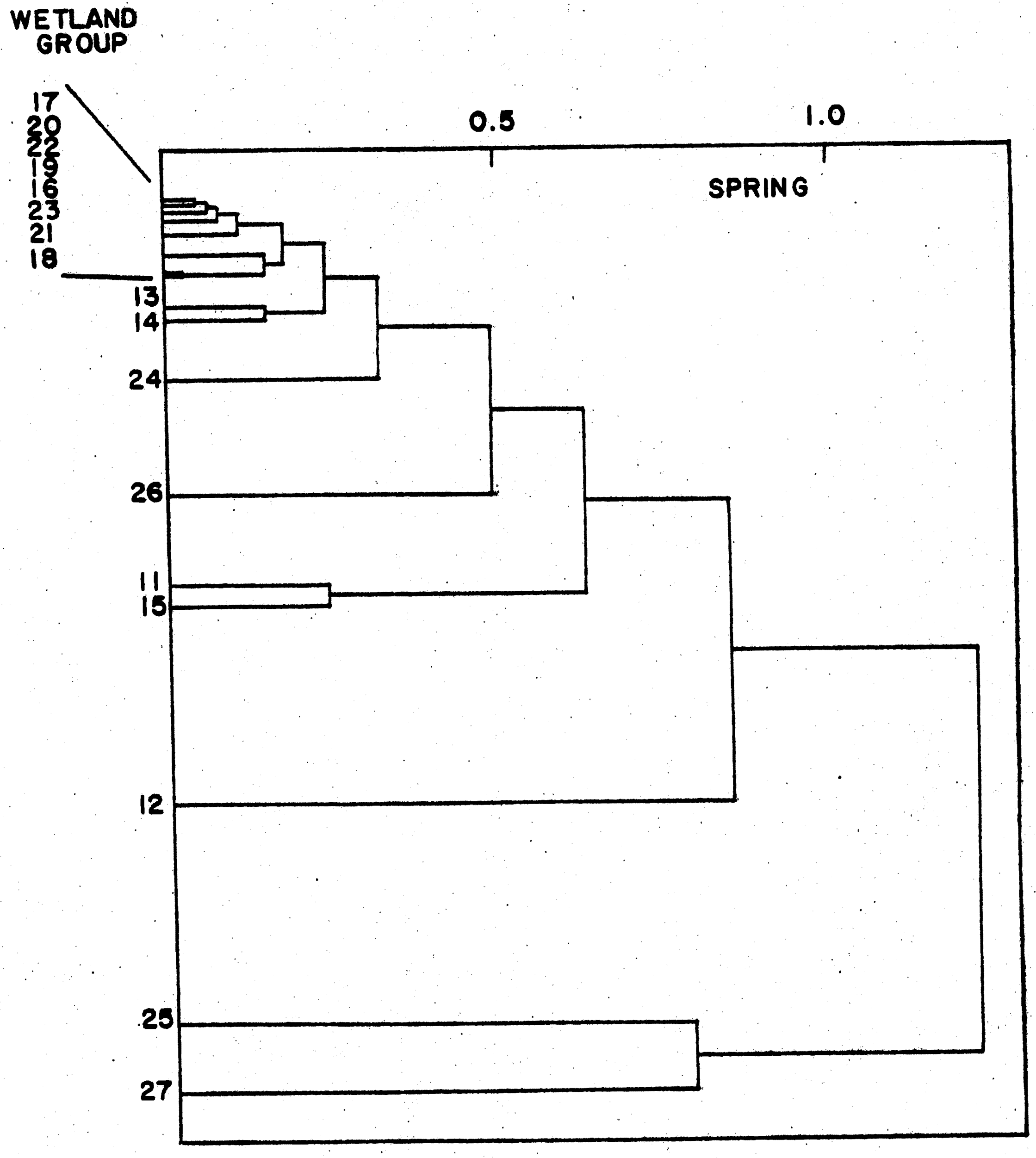

Fig. 27. Dendrograph of the cluster analysis of the ecological relationships of wetland groups present in Oklahoma during spring. See text for interpretation.

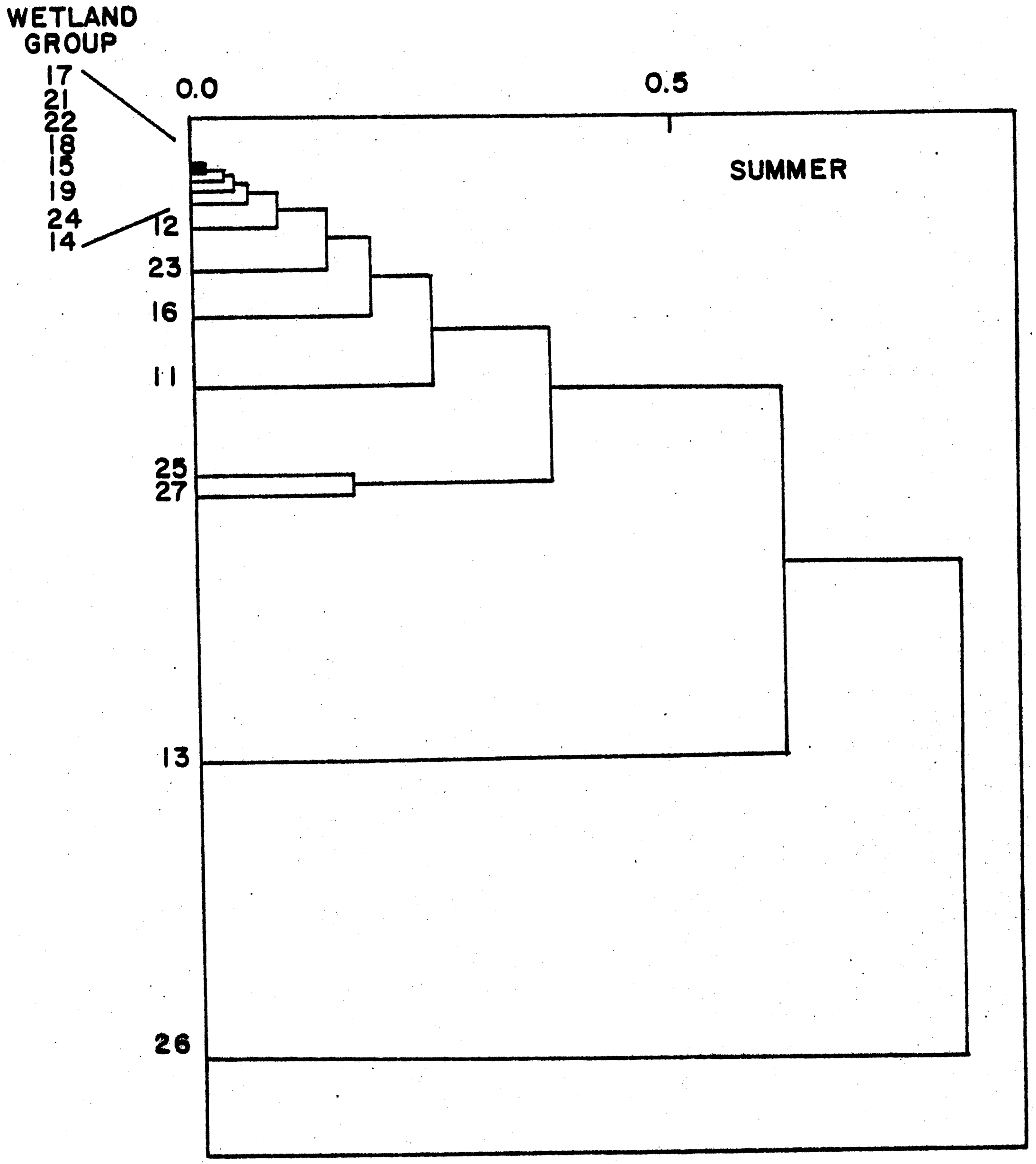

Fig. 28. Dendrograph of the cluster analysis of the ecological relationships of wetland groups present in Oklahoma during summer. See text for interpretation.

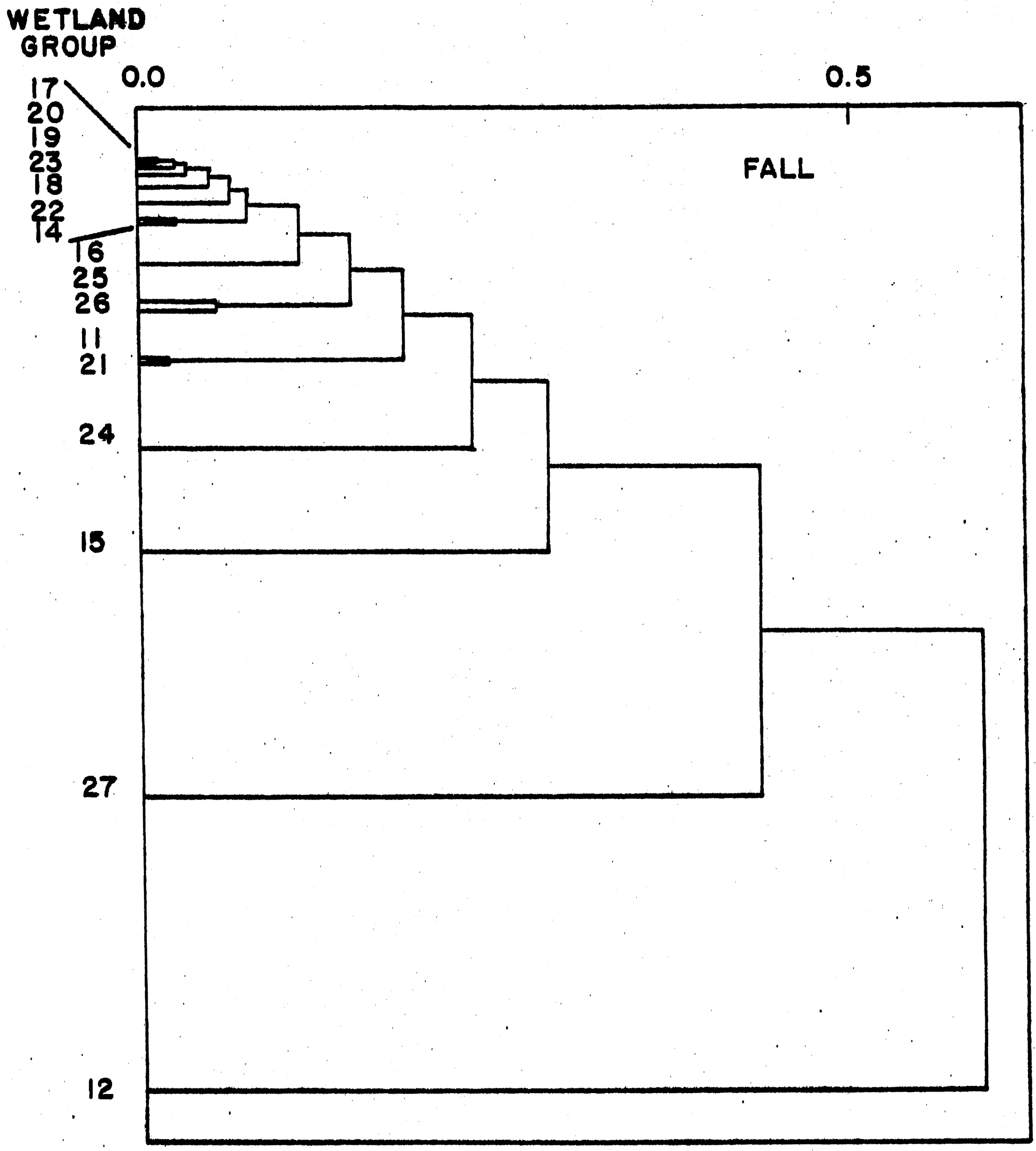

Fig. 29. Dendrograph of the cluster analysis of the ecological relationships of wetland groups present in Oklahoma during fall. See text for interpretation.

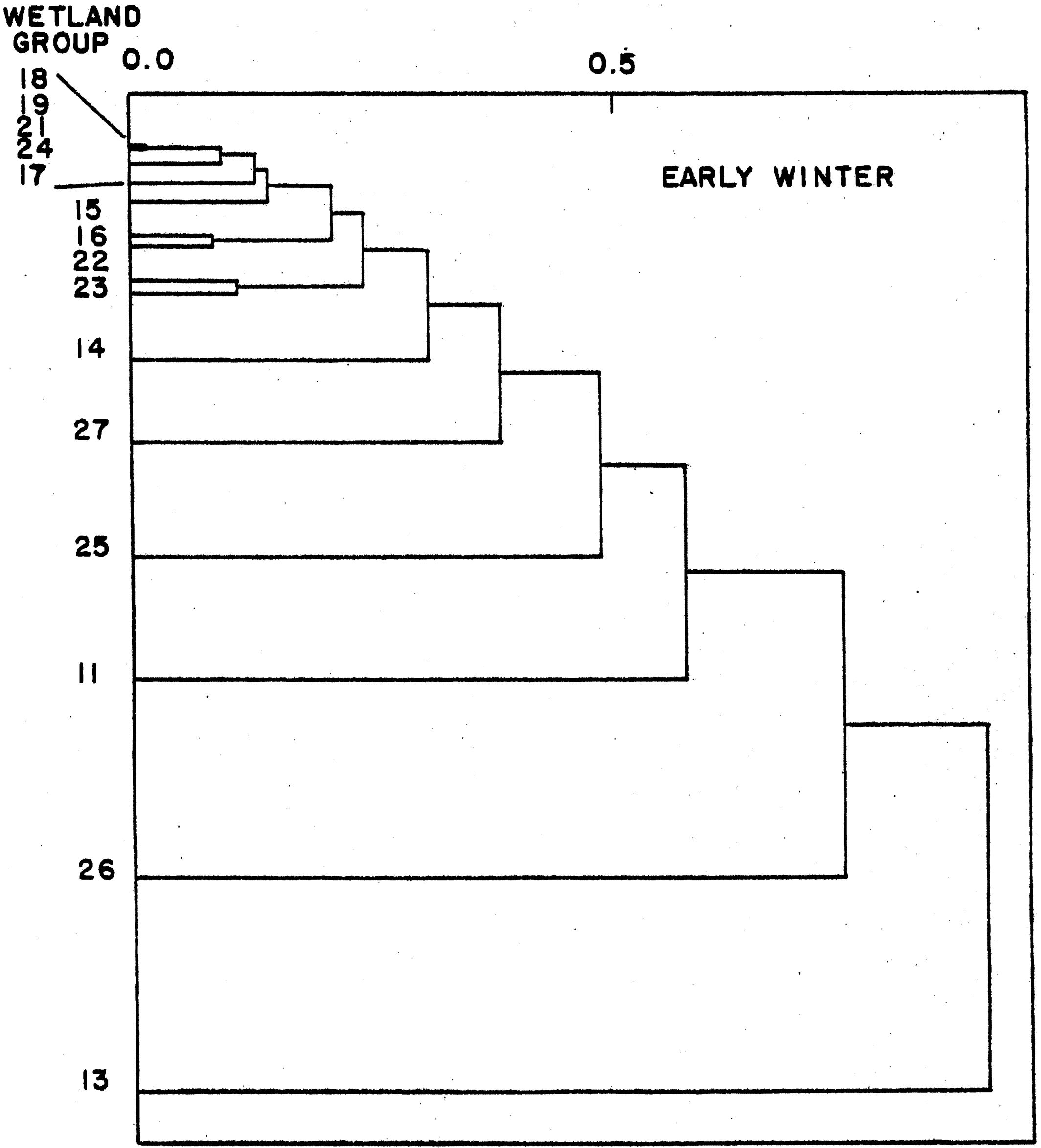

Fig. 30. Dendrograph of the cluster analysis of the ecological relationships of wetland groups present in Oklahoma during early winter. See text for interpretation.

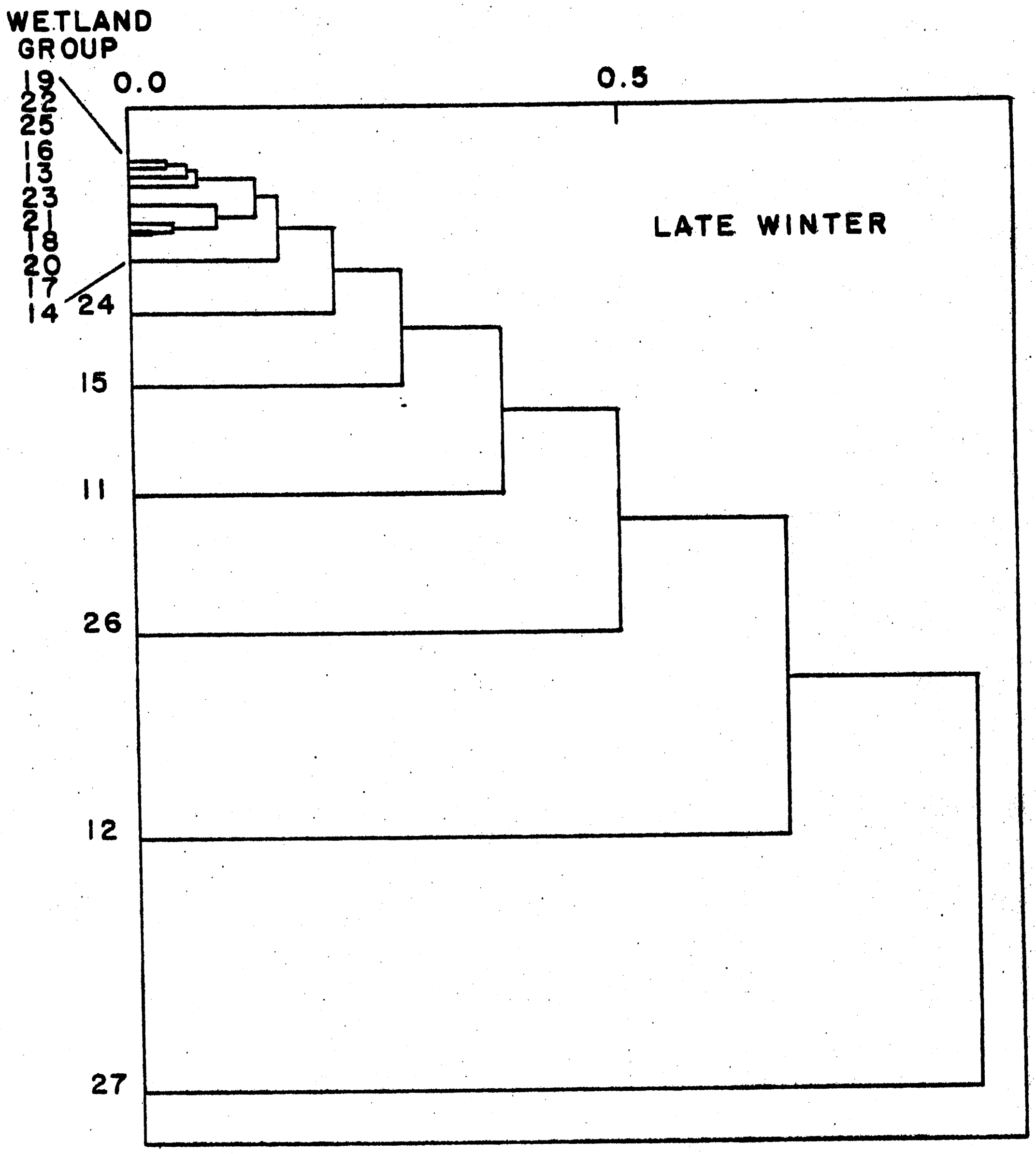

Fig. 31. Dendrograph of the cluster analysis of the ecological relationships of wetland groups present in Oklahoma during late winter. See text for interpretation.

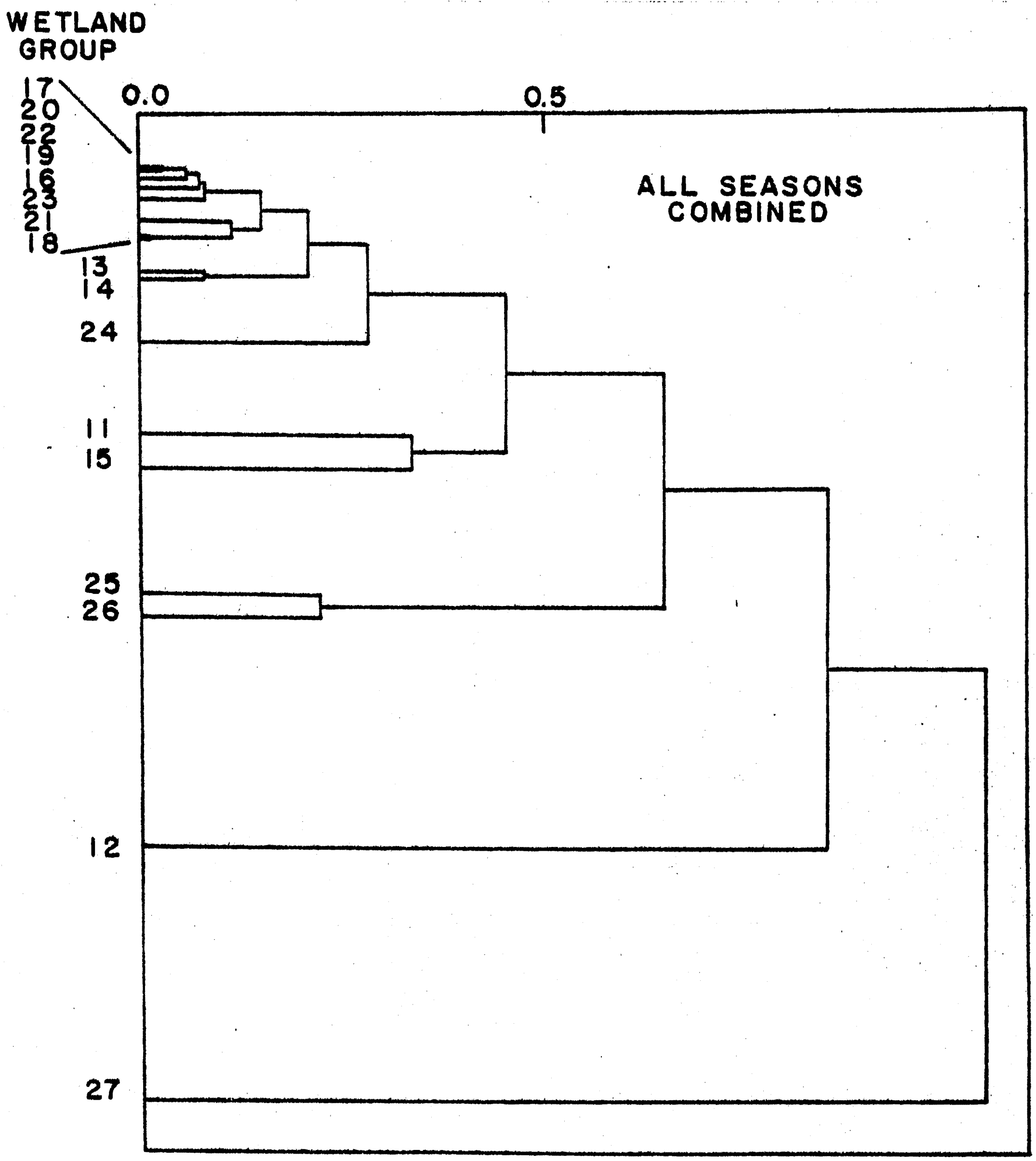

Fig. 32. Dendrograph of the cluster analysis of the ecological relationships of wetland groups present in Oklahoma during 1979-80 (all seasons combined). See text for interpretation.

related to other impounded wetland groups. Natural forested wetlands were unique in all seasons, while impounded forested wetlands became distinct only in summer, early winter, and late winter.

When data from all seasons were combined, wetlands dominated by submergent and emergent vegetation and natural semipermanently and seasonally flooded mud substrate wetlands were closely clustered (Fig. 32). Wetland groups 13 and 14 were closely related to each other and also to the wetlands that were dominated by emergent and submergent vegetation. Impounded scrub/shrub wetlands and impounded and natural permanently flooded mud substrate wetlands were intermediately related to the preceding wetland groups. Oil pool, natural scrub/shrub, and impounded and natural forested wetland groups were most distinct.

DISCUSSION

Physical

Few estimates, either past or present, of the numbers and ha of surface water present in Oklahoma have been made. The Oklahoma Water Resources Board (1976) did estimate that approximately 190,000 farm ponds less than 10 acres, 2,500 lakes greater than 10 acres, and 575,000 acres of surface water in large reservoirs were present in Oklahoma during the early 1970's. But we could find no estimates for natural wetlands or rivers. Our maximum estimate of 222,028 small lacustrine and palustrine basins during WIV, approximated the Oklahoma Water Resources Board estimate for farm ponds and small lakes. The differences were probably due to the inclusion of natural wetlands in our estimates, the different estimation techniques used, new pond construction, and the time difference of the estimates (early 1970's vs. 1978-80).

The total surface water area in Oklahoma (maximum of 375,604 ha) during our study represents approximately 1% of the total land area. Comparable data show 7.3% in Florida, 6.9% in Louisiana, 4.8% in Minnesota, 3.3% in New York, 2.1% in Michigan, and 1.4% in Texas (Penfound 1953). Oklahoma's surface water area is dominated by man-made impoundments in contrast to the natural wetland of other states.

Wetlands are dynamic ecosystems. The changes in water levels of wetland basins that occur from flooding and drying are well known for prairie regions in the northcentral U.S. and southern Canada (Weller and Spatcher 1965, Hartland-Rowe 1966, Kerekes and Nursall 1966, Eisenlohr and Sloan 1968, Walker and Coupland 1968, van der Valk and Bliss 1971, Millar 1973). Although less documented, wetland systems in the southern prairie (Jewell 1927, Harper and Stout 1944, Penfound 1953, Jantzen 1960, Collins and Penfound 1966, Black 1976), southwestern (Sublette and Sublette 1967, Reeves 1964, Bolen et al. 1979), northestern (Lippert and Jameson 1964), forested northcentral (Dineen 1953), and southern (Brown 1943, Moore 1970, Barstow 1971, Conner and Day 1976, Fredrickson 1979, Mitsch et al. 1979) areas of the United States are also dynamic.

Few long term data were available for comparison, but the wetland complex within Oklahoma appears as dynamic as the well known northern prairie and coastal wetlands (Table 44). Because our study was conducted during only 2 years, we used the maximum seasonal differences as indicators of potential low and high water conditions. Therefore the

Table 44. Comparison of wetland numbers and surface water area during low and high water level conditions for Oklahoma provinces, Green Bay, Wisconsin coastal marshes; and Canadian prairie provinces.

Area	Low	High	% Change
Numbers (this study Oklahoma)			
Province 1	17225	32911	91.1
2	40434	54866	35.7
3	13467	16998	26.2
4	23019	28569	24.1
5	56324	76293	35.4
6	6407	15762	146.0
Hectares (this study Oklahoma)			
Province 1	2155	9143	324.3
2	5278	12805	142.6
3	2101	6488	208.8
4	6296	26165	315.6
5	13794	26170	89.7
6	2006	6750	236.5
Green Bay marshes (mi^2 1945-75) (Harris et al. 1977)	5.89	17.08	190.0
Canadian prairie provinces (1955-79, strata 25-40, U.S. Fish and Wildl. Serv. unpublished files)			
May ponds (thousands)	1635.7	7303.6	346.5
July ponds (thousands)	562.0	3351.8	496.3

relative % change may overestimate or underestimate annual differences. Inclusion of sheetwater and temporary wetlands would have increased the relative dynamics of Oklahoma wetlands.

The different hydrological conditions were major determinants of wetland characteristics in Oklahoma, and water levels were directly related to precipitation (through its influences on throughfall, runoff, groundwater supplies, and soil saturation). Wetland basin numbers in province 3 and the ha of surface water in provinces 3, 4, and 6 were directly related to amount of seasonal precipitation; while wetland numbers in provinces 1, 2, 4, 5, and 6 and the ha of surface water in provinces 1, 2, and 5 were serially correlated with seasonal precipitation and water conditions of the previous seasons and years. The R^2 values of linear regressions between water levels and precipitation were significant but did not explain all of the observed variation due to differences among wetlands and provinces in evapotranspiration rates, soil texture, topography and basin area, land use, and our non-instantaneous survey periods.

We suggest that a cyclic, seasonal, wetland system; superimposed upon a cyclic, long term, wetland system; and driven by precipitation, is operating within Oklahoma (Fig. 33). A seasonal cycle of low water levels and precipitation during early winter and highest water levels and precipitation during late spring and summer was present in all provinces of Oklahoma during our study. Long term cycles of wetland water levels can be confirmed only by long term studies. However, the apparent regular fluctuations of annual precipitation in many Oklahoma areas (Fig. 4) and the gradual increase in water levels throughout this study provide corroborative evidence. Long term water

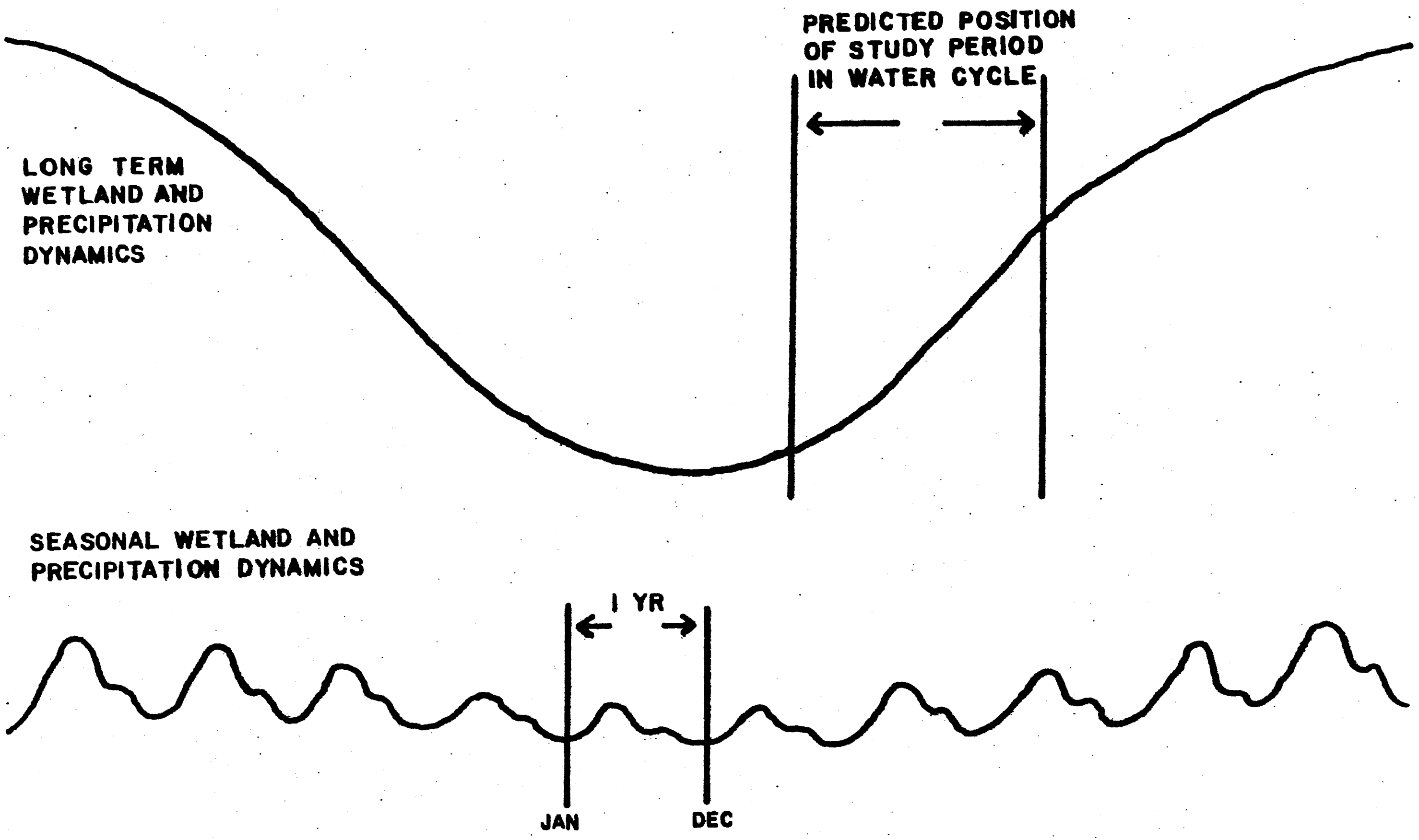

Fig. 33. Model of seasonal and long term wetland and precipitation dynamics in Oklahoma.

and vegetative cycles related to precipitation are present in other prairie wetland ecosystems (Weller and Spatcher 1965, Weller and Fredrickson 1974, van der Valk and Davis 1978) and in Green Bay coastal marshes (Harris et al. 1977). This long term dynamic system probably occurs in other wetland systems (Livingston and Loucks 1979) and tends to stabilize wetlands through an ecological system of nutrient replenishment, detritus decomposition, substrate oxidation, and restored vegetative germination, growth, and seed bank replenishment (Weller and Spatcher 1965, van der Valk and Davis 1978). Successional influences are restricted by this phenomenon and lend long term stability to the wetland systems.

Long term cycles seem less obvious and seasonal dynamics more obvious in southeastern and southcentral Oklahoma. The wetland complex in these areas is dominated by more natural bottomland and river overflow wetlands, and long term stability may be retained more through a seasonal phenomenon of flooding and drying and associated nutrient and vegetative fluxes (Klopatek 1978, Mitsch et al. 1979).

Seasonal and long term dynamics in hydrological conditions caused changes in the composition of wetland types with water present during any given time. Overall, the wetland complex was dominated by impounded, permanently flooded mud substrate basins, especially farm ponds. Although water was almost always present in these basins, extreme fluctuations in surface water area were caused by gradual recession of the water lines during summer to early winter (Harper and Stout 1944). However, the dynamic nature of wetlands largely results from the seasonal flooding and drying of semipermanently and seasonaly flooded palustrine basins, especially natural wetlands. Riverine systems are also dynamic.

Most wetland basins in western and central Oklahoma were enclosed and had few outlets. They became flooded by spring and summer rainfall. In contrast, most natural wetlands in eastern and southern Oklahoma were bottomland systems that were flooded by river overflows during late winter and spring (U.S. Dept. of Commerce 1971) or by runoff during saturated soil conditions. Groundwater recharge in Oklahoma also occur during late winter and early spring (Morton 1980). The high diversity and density of wetland basin types in southern Oklahoma (especially province 4) during late winter, spring, and summer were a result of the associated hydrologic regime.

Both long term and seasonal wetland dynamics were shallow water phenomena in Oklahoma. More shallow wetlands became flooded as water conditions improved, causing an increase in both wetland density and diversity. The rate of water loss within a wetland basin is directly correlated with the length of shoreline per unit area (Millar 1971). Therefore smaller, shallower wetlands with high shorelines/unit area dry more quickly than larger, deeper wetlands. Shallow wetlands also had larger littoral areas, supported emergent macrophytes and high evapotranspiration. The composition of wetland basins that remained flooded during dry, low water periods, was less diverse and contained less shallow water (e.g. in province 6). This wetland composition also influenced the rate of freezing during winter and affected chemical, vegetation, and animal responses.

Vegetation

The occurrence of individual moist soil, emergent, and submergent plant species at individual wetland basins was a result of complex interactions among the basin water regime, wetland composition type, water chemistry, land use, and geographical location. Land use especially affected moist soil, emergent, and submergent plant species composition. Grazing was most detrimental and reduced the occurrence of all plant species except Xanthium pennsylvanicum, either by direct consumption, or indirectly by decreasing the light penetration of wetlands. Idle land use seemed to filter runoff more effectively, allowing increased light penetration and better growth of many plant species. Most sedge, mudflat, and emergent plant species were negatively influenced by high chemical concentrations. However, tree and scrub species were positively correlated with chemical concentrations. However, this relationship may have been caused by their higher occurrence at natural wetland basins rather than to direct influences of water chemistry. Bottomland wetlands contained more moist soil, emergent, and submergent plant species, perhaps as a result of higher soil fertility, greater light penetration, greater wetland diversity, and/or increased shoreline development indices of bottomland wetlands.

In general, moist soil and emergent plant species were not reliable indicators of environmental conditions or geographical locations. Submergents, however, were indicators of more permanently flooded water regimes. No apparent correlation occurred between wetland plant species and soil types (Collins and Penfound 1966). Most wetland basins in Oklahoma were man-made and heavily grazed, and these factors may have been responsible for the lack of predictable responses by plants.

A continuum of species composition from west to east in Oklahoma seemed apparent. *Tamarix gallica* and *Scirpus americana* were more common at wetland basins in western Oklahoma, while woody species were more common in eastern Oklahoma. Prairie wetlands were dominated by weed, sedge, and mudflat species while submergents were not common. Natural wetlands in southern Oklahoma had many tree and shrub species present with an understory of *Cyperus* sp., *Eleocharis* sp., and *Echinocloa crusgalli*. Few submergent or floating species other than *Lemna minor* were present in these wetlands, probably because of the shading effect of the woody vegetation.

Many mudflat, sedge, and weed species present at wetland basins had similar ecological requirements. These species were most common at enclosed wetland basins where summer shoreline recession exposed mud flats and allowed germination (e.g. van der Valk and Davis 1978, Staniforth and Cavers 1979). The typical plant zonation in these wetlands from open water to the edge of the basin (i.e. *Potamogeton* sp. and *Jussiaea decurrens* ---> *Eleocharis* sp., *Polygonum* sp., and *Juncus* sp. ---> Compositae sp. and *Ambrosia* sp. ---> *Salix nigra*) was similar to that found in Muskogee County farm ponds (Little 1938). In contrast, species that occurred at wetlands with more complex water regimes (sloughs, oxbows, and rivers) had more distinct ecological requirements. True emergent species had more specializations due to the anaerobic environment of their roots and rhizomes (Scultrope 1969, Klopatek 1978), and were more distinct than transitory species that became flooded only during high water levels.

The seasonal occurrence of moist soil, emergent, and submergent species was related to the hydrological regimes of the wetland basin where they occurred, within constraints of the growing season. For example, mudflat species such as Polygonum sp. and Cyperus sp. only germinate during lower water conditions that expose mud flats (Salisbury 1970, van der Valk and Davis 1978) and their peak occurrence was during fall. More water tolerant species however, such as Juncus sp., began growth in late winter-early spring. All submergents had definite seasonal growth patterns, and most peaked during fall. Littoral, epipelic algae began growth during winter and seemed to peak during spring or early summer. This common phenomenon among macroalgae may be related to differential use of nutrients by submergent plants and algae, and might be stimulated by gradual increases in light and water levels (Wetzel 1975).

Because the germination, growth, senesence, and death of wetland plant species were governed by the wetland basin water regime (Moyle 1945, Dineen 1953, Jantzen 1960, Walker and Coupland 1968, Linde 1969, Meeks 1969, Stewart and Kantrud 1972b, Weller 1975, and others), both seasonal and long term water dynamics greatly influenced wetland vegetation dynamics (Kadlec 1962, Harris and Marshall 1963, Weller and Spatcher 1965, Millar 1973, Weller and Fredrickson 1974, van der Valk and Davis 1978). These wetland dynamics influenced vegetation in Oklahoma also, either directly or through changes in wetland composition. Increased precipitation and improved water conditions resulted in a greater diversity of moist soil and emergent plant species present at wetland basins and had a net effect of increasing the emergent vegetation/open water interspersion (Fig. 34). The increased diversity of plant species following drought and subsequent reflooding was similar to the vegetative response of other exposed prairie and southern

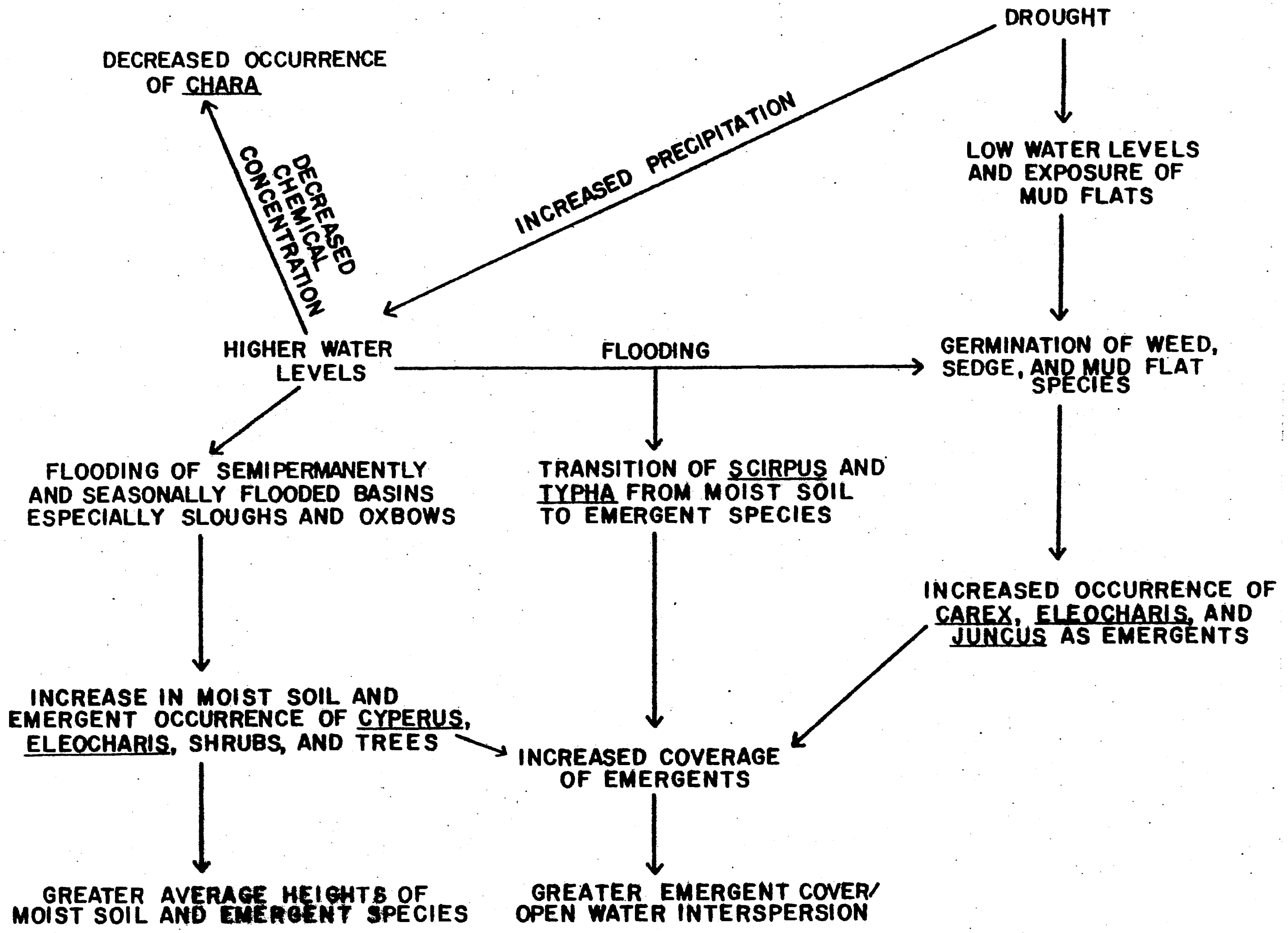

Fig. 34. General relationships between drought and increasing precipitation and plant species occurrence at wetland basins in Oklahoma.

wetlands (Hall et al. 1946, McGregor 1948, van der Valk and Davis 1978).

Vegetation dynamics are cyclic in northern U.S. prairie marshes (Weller and Spatcher 1965, Weller and Fredrickson 1974, van der Valk and Davis 1978). Only long term studies will determine if these cyclic dynamics occur in Oklahoma. However, the vegetation responses that occurred during this study were similar to the dry marsh and regenerating marsh conditions demonstrated by van der Valk and Davis (1978).

Water Chemistry

Water chemistry values of wetlands during this study were generally within the ranges cited for other Oklahoma and southwestern farm ponds (Brown 1950, Knudson 1970, Epperson 1972, Repress et al. 1972, Black 1976), playas (Sublette and Sublette 1967), oxbows (Reece 1979), and rivers (Oklahoma State Dept. of Health 1977, Wilhm et al. 1979). Almost all of the alkalinity in the wetland basins was due to HCO_3 (Lind 1974), and little CO_3 occurred, except in natural wetlands, rivers, and wetlands dominated by emergent and submergent vegetation. Chemical and organic input from livestock was common in farm ponds and may have had an effect on this relationship. The higher CO_3 values of all wetlands during summer was probably caused by increased photosynthetic processes (Knudson 1970, Wetzel 1975). Natural and vegetated wetlands had higher CO_3 values than other wetland types.

The decline of both phenopthalein and total alkalinity concentrations throughout this study was probably related to long term water dynamics. Increased water levels and volume dilute chemical concentrations (Tucker 1958, Kerekes and Nursall 1966, Rozkowska and Rozkowski 1969, Knudson 1970, Epperson 1972, Repress et al. 1972, Wetzel 1975). Conductivity and pH also declined throughout the study, and chemical concentrations were negatively correlated with the % of the basin area covered by surface water.

The pH of natural wetlands and rivers became more acidic during fall and winter, and was probably caused by the decomposition of allochtonous organic material, especially autumn shed leaves, deposited in wetlands and rivers after the growing season (Kaushik and Hynes 1968, 1971, Moore 1970, Cummins 1974, Boling et al. 1975, Davis and van der Valk 1978, Mitsch et al. 1979).

The higher conductivity of western Oklahoma wetlands and rivers was probably caused by the rapid drying of enclosed basins. Drainage systems often flush salt deposits from shallow depressions and sheet water areas and cause higher concentrations in rivers that flow from west to east in Oklahoma.

Increased silt and debris in runoff during periods of high seasonal precipitation seemed to reduce the light penetration in Oklahoma wetlands (see also Irwin and Stevenson 1951, Epperson 1972). Wetlands with submergent and emergent vegetation had greater light penetrations. Increased light penetration probably allows greater growth of submergents and the vegetation may reduce wind action and increase precipitation of suspended clay colloids (Moyle 1956, Robel 1961, Edwards 1969, Epperson 1972, Wetzel 1975, Anderson 1978).

Many authors have equated high chemical concentrations, especially alkalinity, with higher biological productivity (e.g. Orians 1966, Russell-Hunter 1970, Patterson 1976, White and James 1978). The interpretation of higher productivity at higher chemical concentration may not be entirely correct for Oklahoma waters, especially between individual wetland basins of a particular composition type. The increased alkalinity and accumulation of CO_2 in the trophogenic zone from decomposition is theoretically proportional to the production of organic matter in the trophogenic zone that is transported to the hypolimnion (Wetzel 1975). This concept, however, is complicated by several other sources of organic matter (such as allochtonous inputs) that are not from the trophogenic zone and by losses from the system that are not represented in CO_2 changes in the tropholytic zone (Wetzel 1975). Allochtonous inputs and system losses are common in rivers, sloughs, oxbows, flood control structures, and farm ponds with small capacities and low spillways. The differential chemical concentrations within a wetland type in Oklahoma appeared to be more related to fluctuating water levels and dilution rates than to productivity.

The concept of higher productivity at higher chemical concentrations may have more validity for Oklahoma when analyzed across wetland types. If this is true, then rivers, natural wetlands, and wetlands that are dominated by submergent and emergent vegetation are more productive than mud substrate palustrine and small lacustrine wetland basins in Oklahoma.

Chemical concentrations can directly influence distribution of wetland plant species (Moyle 1945, 1956, Wood 1952, Ellis 1955, Walker and Coupland 1968, McLay 1976, Anderson 1978, and others); but excluding some emergent and moist soil species adapted to high salinity (Stewart and Kantrud 1972b), only the occurrence of Chara vulgaris was positively correlated with high chemical concentrations in our study. The greatest abundance and distribution of aquatic plants occurred in mid-range (90-150 ppm) alkalinities in Minnesota (Moyle 1945). Principal component analyses indicated negative relationships between chemical concentrations and emergent vegetation in south Texas oxbows (White and James 1978). Growth of duckweeds were best at slightly acidic to neutral pH's (McLay 1976). The number of moist soil, emergent, and submergent plant species present at wetland basins was negatively correlated with alkalinity, conductivity, and pH values during this study. Therefore, we postulate that increases in total dissolved solids, alkalinity, and pH within specific Oklahoma wetland types increases vegetative productivity to a certain point (species specific), and then further increases inhibit organoproduction (see Kerekes and Nursall 1966). The availability of essential nutrients, and solubility of toxic elements, and/or sensitivity of root or epidermal cells could be limiting factors ot either low or high chemical concentrations (Scultrope 1969, McLay 1976).

Structure and Ecological Relationships of Palustrine Wetland Groups

Wetland groups present in Oklahoma were significantly different from each other in their ecological relationships based on environmental variables measured during this study. The most important variables separating wetland groups were basin morphometry, water chemistry, and vegetation. The difference in the relative importance of these variables among seasons indicated that individual wetland groups were not ecologically static but have internal flutuations throughout the annual cycle.

We see the most potential for interpreting wetland responses through examination of organic carbon and detritus characteristics of wetland groups. The metabolism of detrital organic matter within wetland basins resulted in a complex carbon cycle that dominates both the structure and function of aquatic ecosystems (Wetzel 1975). The relative contributions of organic inputs and outputs within a wetland basin depends on the extent of littoral, pelagic, and allochtonous production; the soluble pool proportions of dissolved organic carbon and particulate organic carbon; the water source; the vegetation and size of the drainage basin; and the degree of openess of closedness of the system (Eisenlohr and Sloan 1968, Kaushik and Hynes 1971, Rich et al. 1971, Cummins 1974, Boling et al. 1975, Howard-Williams and Lenton 1975, Wetzel 1975). The hydrology of individual wetland basins determines the associated attributes (Gosselink and Turner 1978).

In general, running water habitats in the temperate zone are dependent for their major energy supply upon reduced carbon compounds produced in the watershed (Minshall 1967, 1968, Vannote 1970, Kaushik and Hynes 1971, Cummins 1974, Boling et al. 1975). These systems, especially low order streams are therefore heterotrophic (i.e. respiration by the community exceeds photosynthesis in the ecosystem) (Boling et al. 1975, Marzolf 1978). The allochtonous organic matter input of these systems is largely autumn shed leaves (Moore 1970, Kaushik and Hynes 1971, Conner and Day 1976, Mitsch et al. 1979). In Oklahoma, most riverine systems and natural bottomland wetlands have few submergents or littoral macrophytes; but large areas of the moist soil and watershed regions are dominated by hardwood trees and woody shrubs. These systems are hydrologically open (e.g. Klopatek 1978) and are annually recharged by runoff, seepage, and river overflows beginning in late winter. We hypothesize that decomposition and heterotrophic activity is high during late winter and early spring as leaves and detritus become flooded (see Kaushik and Hynes 1971). The flushing of these systems by flooding during spring and early summer seem to function as a nutrient deposition and recharge period, especially for phosphorus (Mitsch et al. 1979). The flooding also maintains specific vegetation species composition through the differential germination and survival of woody species (Johnson and Bell 1976, Teskey and Hinckley 1977, 1978, Fredrickson 1979), and accelerates the growth of hardwood trees (Broadfoot 1967).

In contrast, most wetland basins in Oklahoma, especially those that are man-made, are relatively closed systems, and often have extensive littoral production of submergent and emergent vegetation. These systems appear more autotrophic in nature. The littoral macrophytes dominate the total primary production and regulate the functioning of the wetland basin (Rich et al. 1971, Howard-Williams and Lenton 1975, Mason and Bryant 1975, Godshalk and Wetzel 1978, Prentki et al. 1978, Weller 1978). These wetlands often go dry during periodic drought cycles, and nutrient availability is then increased by oxidation of detritus and sediments (Weller and Spatcher 1965, Kadlec 1979). The emergent vegetation in these systems acts as a pump to translocate buried nutrients from the sediments to the open water. The translocation increases nutrient conservation (i.e. keeps nutrients from permanent burial), frees available nutrients for submergent, free floating, and seston plankton; and together with the drought phenomenon regulates vegetation and nutrient cycling.

The cluster analyses dendrographs of palustrine wetland groups within Oklahoma (Figs. 32-37) closely clustered all wetlands that were dominated by submergent and emergent vegetation. All of these wetlands were relatively closed systems, and we suggest that they were all autotrophic ecosystems regulated by dynamic water level regimes and the littoral vegetation. In contrast, the more distinct wetland groups were always forested, scrub/shrub, and oil pool wetlands. Oil pools were distinct because of high chemical concentrations. The natural scrub/shrub and forested wetlands were bottomland and open in nature, and we hypothesize that they were largely heterotrophic systems regulated by autumn leaf and detritus deposition and river overflows. Impounded scrub/shrub and forested wetland groups are also likely to be heterotrophic.

If out logic is correct, we suggest that wetland groups intermediate between wetlands dominated by submergent and emergent vegetation and those dominated by bottomland hardwoods and scrubs, or those that fluctuate in their ecological groupings among seasons, are also intermediate or fluctuate between being autotrophic and heterotrophic. These wetlands include many man-made wetlands that receive organic input from livestock and are turbid, but often support large bacteria and phytoplankton populations (Knudson 1970, Epperson 1972).

Because most of the palustrine wetlands in Oklahoma are man-made and are relatively closed systems, wetland groups became more separated during the growing season, (i.e. spring, summer, and fall); and wetlands dominated by submergent and emergent vegetation became most distinct on the 3-dimensional ordinations. As the growing season ends, these wetland groups become less separated. But scrub/shrub and forested wetlands become more separated and distinct during winter. We interpret the separation of scrub/shrub and forested wetlands during winter as an indication of their more heterotrophic nature and accelerated decomposition processes during that time. These wetlands received large allochtonous input from deciduous hardwood trees and scrub leaf litter during fall and winter, and received hydrologic recharge during winter.

The differential relationships among wetlands in their degree of autotrophy or heterotrophy, and the hypotheses that we have presented can only be determined and tested by further intensive and long term research into the aquatic metabolism and the organic carbon and detrital structure of various wetland types. For this research to be most fruitful, we suggest an intensive integrated approach involving studies of the hydrology, nutrient cycling and conservation, and the benthic and detrital community ecology.

We did not attempt to evaluate invertebrate populations. However, information concerning abundance and composition of aquatic invertebrates in relation to wetland composition type and water, chemical, and vegetation dynamics (such as Jewell 1972, Tucker 1958, Hartland-Rowe 1966, Sublette and Sublette 1967, Krull 1969, Moore 1970, Voigts 1976, Driver 1977, Kaster and Jacobi 1978, and Wilhm et al. 1979) is important if the ecology of Oklahoma wetlands is to be completely understood.

Historical and Present Wetland Status

The numbers, distribution, and composition of wetlands within

Oklahoma during historical periods is unknown. Expeditions into Oklahoma in the early 1800's did not record naturalistic information, and later expeditions usually only mentioned flora and fauna aspects. Topographic and plat maps were 1st constructed in the late 1800's, but these were incomplete. Small playa basins were apparently common in western prairie regions (Irving 1835), and the many drainage systems flowing through Oklahoma probably created and maintained extensive bottomland hardwood sloughs and oxbows (see Irving 1835:159). The remnant swamp area in southeastern Oklahoma indicates that bald cypress (Taxodium distichium) and tupelogum (Nyssa aquatica) swamps were common.

The destruction of natural palustrine wetland basins within Oklahoma has probably been extensive. A total of 7,488 ha of high quality, 54,149 ha of moderate quality, and 51,559 ha of low quality wetlands (wetlands were defined as lowlands covered with shallow and sometimes temporary or intermittent water, including shallow ponds and lakes) were estimated for Oklahoma in the early 1950's (Shaw and Fredine 1956). These authors did not specify how many ha were in natural basins; but the indication was that most, if not all, of the high and moderate quality wetlands were natural. A total of 29,138 ha of natural wetland basin area was estimed for Oklahoma during the early 1960's (Sanderson and Bellrose 1969).

The estimates of the early 1950's and 1960's did not consider the long term dynamics of wetlands within Oklahoma, and the period in the long term water cycle at the time of the estimates was unknown. However, our study estimated from 2,237 ha in WI to 18,381 ha of surface water in SM79 was in natural palustrine wetlands during 1978-80. Using our highest figure, there has been a loss of 10,757 ha (or 40%) since the early 1960's, and if all of the high quality and ½ of the moderate quality wetlands estimated by Shaw and Fredine (1956) were natural, then a loss of 16,181 ha (or 41%) has occurred since the early 1950's.

A comparison of 1871 plat and topographic maps with aerial photographs to 1976, indicated that all of the original 726 ha of natural wetland area on the 11,638 ha floodplain area of Wildhorse and Rush creeks in southcentral Oklahoma have been destroyed (Hedrick 1978). Similar destruction seems to have occurred throughout Oklahoma as a result of drainage, channelization, and inundation. Most natural wetlands in Oklahoma are bottomland floodplain wetlands created and maintained by river overflow and saturated soils. Therefore, the construction of large reservoirs and their inundation of over 232,875 ha of bottomland has probably been a major cause of wetland destruction (since the mid-1900's), either directly or indirectly by reducing the flood water and overflows.

Many of the remaining natural wetland basins have been severely altered due to changes in their hydrologic regimes. Soil erosion and siltation have altered elevations and drainages, vegetation species composition, and animal populations (Featherly 1940, Edwards 1969, Reed 1977, Cooper and Knight 1978, Gosselink and Turner 1978, Bellrose et al. 1979). Reduced groundwater levels due to irrigation and channelization have increased periods between inundation, reduced seepage, and altered water chemistry of Oklahoma wetlands, especially playas in western Oklahoma (Carr and Bergman 1976, Havens 1977, Barclay 1978, Morton 1980). Chemical and fertilizer runoff from crop and pasture land have altered water chemistry, plant and animal populations, and eutrophication processes of wetlands (Sanderson and Bellrose 1969, Holder 1970, Wetzel 1975). Many other perturbations such as livestock management, highway and powerline construction, industrial pollution, oil and sludge pollution, and small flood control structures have also degraded natural wetland basins (Barstow 1971, Quigley 1977).

CONCLUSION AND MANAGEMENT RECOMMENDATIONS

Wetland ecosystems within Oklahoma are unique and highly dynamic. Man-made, permanently flooded basins currently dominate the wetland complex, yet the small seasonally and semipermanently flooded natural wetlands that remain are probably of greater ecological value in terms of biological productivity, hydrology, species diversity, and faunal and floral preservation (Gosselink and Turner 1978, Gucinski 1978, Weller 1979, Heitmeyer and Vohs, unpublished ms). Differential hydrological regimes among wetland groups control the structure and function of individual wetland basins. In unaltered natural wetland basins, the plant, animal, nutrient, and water attributes that are present can be considered evolutionarily adaptive responses to given environmental conditions.

Management of wetland ecosystems depends on various socio-economic, political, ecological, and preservation priorities (Weller 1978). With that in mind, we suggest the following management considerations as beneficial and vital to all of these concerns within Oklahoma:

1) An effort to preserve remaining natural wetlands in pristine condition should have high priority. We suggest acquisition and

preservation of these natural wetlands, with special emphasis on bottomland floodplain and playa wetlands. Mitigation is not a feasible biological alternative to continued loss of the remaining natural wetlands in Oklahoma.

2) Management of natural wetlands and construction and management of man-made wetlands should attempt to maintain the natural or near natural hydrological regime, nutrient cycling mechanisms, and plant and animal responses and attempt to emulate the naturally occurring water, chemical, and vegetation dynamics.

3) Further stream channelization, construction of reservoirs and flood control impoundments, drainage of wetlands or saturated soils, and clearing riparian vegetation should be severely restricted and eventually stopped. Irrepairable damage to the biological community has already occurred from these activities, and the increasing impact of similar future activities must be realized. The entire ecological function and balance of water recharge, soil fertility, natural pollution filtration, species diversity, and nutrient cycling depends upon flooding and river overflows, and we must recognize these beneficial aspects in our planning. Floodplain development should properly consider the necessity of continued flooding and usual river overflows. Water regulatory projects, housing developments, and agricultural developments should be appropriately conducted to allow these natural phenomena to occur.

ACKNOWLEDGMENTS

This extensive project required the assistance of many individuals, and we gratefully acknowledge their contributions. We especially acknowledge the landowners for access to private property. C.P. Boydstun, H.W. Browers, R.W. Cannon, P.M. Domanski, W.R. Eddleman, C.E. Endicott, D.H. Latham, C.T. Patterson, R.J. Prokop, and W.J. Willis helped collect data; H.W. Browers, P.M. Domanski, and C.P. Boydstun helped compile and code data for keypunching; and J.A. Bissonette, L.M. Due, J.H. Eve, J.M. Gray, H.R. Jarrell, O.E. Maughan, and O.T. Sanders provided logistic support. J.L. Wilhm and students provided the conductivity bridge, J.A. Litvaitis and F.A. Stormer provided information on playa lakes, and W.D. Warde wrote most of the computer programs and conducted the cluster analyses, D. Holbert wrote the time series analysis computer program, and L.H. Fredrickson, F.L. Knopf, O.E. Maughan, F. Schitoskey, Jr., and W.D. Warde provided editorial assistance. J.M. Gray provided irreplaceable secretarial assistance.

This study was supported by Pittman-Robertson Project W-128-R-3: the Oklahoma Cooperative Wildlife Research Unit, U.S. Fish and Wildlife Service, Oklahoma Department of Wildlife Conservation, Wildlife Management Institute, and Oklahoma State University, cooperating; and by a National Wildlife Federation fellowship to the senior author.

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APPENDIX A

Table A-1. Ordering of province (1-6) means of shoreline development index of wetland basins with water present on random ¼-section sample plots 1978-80 in relation to wetland group using a Duncan's multiple range test, α=0.05. Province means with the same underline are not significantly different.

Wetland group 6, AOV-*P*<0.0001

Province	6	3	5	4	2	1
	———	———	———	———		
		———	———	———	———	
						———
Means	1.7	1.7	1.6	1.6	1.5	1.2

Wetland group 11, AOV-*P*<0.0001

	6	5	3	4	2	1
	———					
		———	———	———		
			———	———		
				———	———	———
	1.3	1.2	1.2	1.2	1.2	1.2

Wetland group 12, AOV-*P*<0.0001

Province	5	2
	———	
		———
Means	1.8	1.0

Wetland group 13, AOV-*P*<0.0001

	6	5	4	1	2	3
	———					
		———	———	———	———	———
	1.4	1.1	1.1	1.0	1.0	1.0

Wetland group 14, AOV-*P*=0.008

Province	5	6	1
	———	———	
		———	———
Means	1.1	1.1	1.0

Wetland group 15, AOV-*P*<0.0001

	1	2	5
	———		
		———	———
	2.2	1.4	1.1

Wetland group 16, AOV-*P*=0.0047

Province	6	1	4	5	2
	———				
		———	———	———	———
Means	1.9	1.2	1.1	1.1	1.0

Wetland group 17, AOV-*P*<0.0001

	1	3	5	2	4	6
	———					
		———				
			———	———		
				———	———	———
	1.5	1.4	1.2	1.1	1.1	1.0

Table A-1. continued.

Wetland group 18, AOV-P<0.0001

Province	6	1	4	2	3	5
	—	—	—	—		
				—	—	
					—	—
Means	1.3	1.3	1.3	1.1	1.1	1.1

Wetland group 19, AOV-P=0.0005

Province	4	3	1	2
	—	—		
		—	—	—
Means	1.4	1.2	1.0	1.0

Wetland group 21, AOV-P=0.0002

Province	1	5	4	2	3
	—	—	—		
		—	—	—	
					—
Means	1.4	1.3	1.3	1.2	1.0

Wetland group 22, AOV-P=0.0008

Province	5	2	4
	—	—	
			—
Means	1.3	1.2	1.0

Wetland group 23, AOV-P=0.0003

Province	3	4	6
	—		
		—	
			—
Means	2.6	1.8	1.0

Wetland group 24, AOV-P=0.0028

Province	3	2	4	5
	—	—		
		—	—	—
Means	2.1	1.8	1.7	1.5

Wetland group 27, AOV-P=0.003

Province	4	5
	—	
		—
Means	2.2	1.2

Table A-2. Ordering of province (1-6) means of the % surface water area <1m deep of wetland basins with water present on random ¼-section sample plots 1978-80 in relation to wetland group using Duncan's multiple fange test α=0.05. Province means with same underline are not significantly different.

Wetland group 1, AOV-$\underline{P}$=0.0571

Province	6	2	1	4	5
	———	———	———	———	
			———	———	———
Means	100	97	75	68	57

Wetland group 2, AOV-$\underline{P}$<0.0001

	3	6	5	4	2	1
	———	———	———	———		
		———	———	———	———	
						———
	100	100	99	96	79	41

Wetland group 3, AOV-$\underline{P}$=0.0019

Province	2	4	5
	———	———	
			———
Means	84	84	43

Wetland group 4, AOV-$\underline{P}$=0.033

	3	5
	———	
		———
	97	82

Wetland group 6, AOV-$\underline{P}$=0.0537

Province	1	4	3	6	2	5
	———	———				
		———	———	———	———	———
Means	67	43	41	37	36	35

Wetland group 7, AOV-$\underline{P}$=0.0045

	6	2
	———	
		———
	50	8

Wetland group 8, AOV-$\underline{P}$=0.0078

Province	3	5
	———	
		———
Means	100	81

Wetland group 11, AOV-$\underline{P}$<0.0001

	4	3	6	1	5	2
	———	———	———			
			———	———		
					———	———
	93	92	90	84	76	75

Table A-2. continued.

Wetland group 14, AOV-P=0.0111

Province	1	6	5
	—	—	
		—	—
Means	100	100	91

Wetland group 15, AOV-P<0.0001

	5	2	1
	—		
		—	
			—
Means	100	90	49

Wetland group 17, AOV-P<0.0001

Province	5	3	6	4	2	1
	—	—	—	—		
			—	—	—	
						—
Means	97	96	94	93	85	71

Wetland group 18, AOV-P<0.0001

	6	3	4	5	2	1
	—	—	—	—		
				—	—	—
Means	100	94	93	79	73	66

Wetland group 24, AOV-P=0.0098

Province	3	4	5	2
	—	—	—	
			—	—
Means	82	79	60	41

Table A-3. Ordering of province (1-6) means of phenolpthalein alkalinity (ppm) of wetland basins with water present on random ¼-section sample plots 1978-80 in relation to wetland group using a Duncan's multiple range test, α=0.05. Province means with the same underline are not significantly different.

Wetland group 7, AOV-P=0.0102

Province	2	6
	———	
		———
Means	2.9	0.0

Wetland group 11, AOV-P<0.0001

	6	5	4	3	2	1
	———					
		———				
			———	———	———	———
	6.5	3.1	1.2	1.1	0.9	0.9

Wetland group 13, AOV-P=0.027

Province	5	3	6	2	4	1
	———	———				
		———	———	———	———	———
Means	5.1	3.2	1.6	0.9	0.8	0.0

Wetland group 18, AOV-P=0.0511

	6	5	2	3	4	1
	———					
		———	———	———	———	———
	9.7	2.7	2.4	2.2	1.9	0.4

Table A-4. Ordering of province (1-6) means to total alkalinity (ppm) of wetland basins with water present on random ¼-section sample plots 1978-80 in relation to wetland group using a Duncan's multiple range test, α=0.05. Province means with the same unverline are not significantly different.

Wetland group 1, AOV-P=0.0003

Province	6	5	4	2	1
	———	———			
			———	———	———
Means	274	207	158	145	131

Wetland group 2, AOV-P< 0.0001

Province	5	4	3	6	1	2
	———					
		———	———	———		
				———	———	———
Means	215	141	121	104	93	45

Wetland group 3, AOV-P=0.0004

Province	5	2	4
	———		
		———	———
Means	214	162	130

Wetland group 6, AOV-P<0.0001

Province	6	5	1	4	3	2
	———					
		———	———			
			———	———	———	———
Means	212	153	105	51	45	40

Wetland group 11, AOV-P<0.0001

Province	6	5	4	2	1	3
	———					
		———				
			———	———		
					———	———
Means	147	109	75	74	57	56

Wetland group 13, AOV-P<0.0001

Province	5	3	6	4	2	1
	———	———	———			
				———	———	———
Means	103	90	87	49	43	21

Wetland group 14, AOV-P<0.0001

Province	5	6	1
	———	———	
		———	———
Means	121	94	40

Wetland group 15, AOV-P=0.0404

Province	5	2	1
	———	———	
		———	———
Means	103	60	58

Table A-4. continued.

Wetland group 16, AOV-P<0.0001

Province	6	5	2	1	4
	———				
		———	———		
			———	———	———
Means	194	112	58	41	40

Wetland group 17, AOV-P<0.0001

	6	5	4	3	2	1
	———	———				
			———	———		
					———	———
	147	129	89	68	59	43

Wetland group 18, AOV-P =0.0012

Province	6	2	4	5	1	3
	———	———				
		———	———	———	———	
				———	———	———
Means	118	81	71	63	59	40

Wetland group 21, AOV-P=0.0022

	5	4	2	3	1
	———	———	———	———	
			———	———	———
	114	99	75	67	30

Wetland group 22, AOV-P=0.0194

Province	2	5	4
	———		
		———	———
Means	65	33	33

Wetland group 24, AOV-P<0.0001

	5	3	4	2
	———	———		
		———	———	
				———
	115	96	72	22

Wetland group 25, AOV-P=0.0008

Province	4	2
	———	
		———
Means	166	104

Wetland group 27, AOV-P=0.0083

	4	5
	———	
		———
	303	86

Table A-5. Ordering of province (1-6) means of th pH of wetland basins with water present on random ¼-section sample plots 1978-80 in relation to wetland group using a Duncan's multiple range α=0.05. Province means with the same underline are not significantly different.

Wetland group 1, AOV-P=0.0004

Province	4	6	5	2	1
	—	—	—		
		—	—	—	
				—	—
Means	7.1	7.0	6.8	6.5	6.4

Wetland group 2, AOV-P<0.0001

Province	5	4	3	6	1	2
	—	—				
		—	—	—		
			—	—	—	
				—	—	—
Means	7.0	6.5	6.3	6.3	5.8	5.5

Wetland group 5, AOV-P=0.0008

Province	5	6	3	1	4	2
	—	—	—			
		—	—	—	—	
			—	—	—	—
Means	6.6	6.3	6.0	5.9	5.9	5.6

Wetland group 7, AOV-P=0.0182

Province	2	6
	—	
		—
Means	6.6	5.8

Wetland group 11, AOV-P<0.0001

Province	6	4	5	3	2	1
	—					
		—	—			
				—	—	
						—
Means	6.6	6.2	6.2	5.9	5.8	5.7

Wetland group 13, AOV-P=0.0002

Province	5	3	6	4	2	1
	—	—	—			
		—	—	—	—	
					—	—
Means	6.4	6.3	6.1	5.9	5.5	4.8

Wetland group 14, AOV-P=0.0108

Province	5	6	1
	—	—	
		—	—
Means	6.1	6.0	5.5

Wetland group 16, AOV-P<0.0001

Province	6	5	4	2	1
	—	—			
		—	—		
			—	—	—
Means	6.8	6.3	5.6	5.5	5.0

Table A-5. continued.

Wetland group 17, AOV-*P*<0.0001

Province	5	4	3	6	1	2
	———	———				
			———	———	———	
				———	———	———
Means	6.8	6.7	6.3	6.2	6.0	5.9

Wetland group 18, AOV-*P*=0.0003

	6	4	5	2	3	1
	———	———	———			
			———	———	———	———
	6.5	6.3	6.0	5.9	5.7	5.6

Wetland group 19, AOV-*P*=0.0208

Province	4	3	2	1
	———	———	———	
		———	———	———
Means	6.0	5.9	5.7	5.3

Wetland group 21, AOV-*P*=0.002

	4	3	5	2	1
	———	———			
		———	———	———	
				———	———
	6.8	6.2	6.1	5.8	5.6

Wetland group 24, AOV-*P*=0.0056

Province	3	5	4	2
	———	———	———	
				———
Means	6.7	6.4	6.2	5.6

Wetland group 25, AOV-*P*=0.003

	4	2
	———	
		———
	7.2	6.4

Wetland group 27, AOV-*P*=0.0042

Province	4	5
	———	
		———
Means	7.4	5.9

Table A-6. Ordering of province (1-6) means of the conductivity (umhos) of wetland basins with water present on random ¼-section sample plots 1978-80 in relation to wetland group using a Duncan's multiple range test α=0.05. Province means with the same underline are not significantly different.

Wetland group 1, AOV-P=0.0337

Province	5	4	6	1	2
	———	———	———		
			———	———	———
Means	845	802	544	423	359

Wetland group 2, AOV-P<0.0001

5	1	2	4	3	6
———					
	———	———	———	———	———
1395	465	450	429	377	244

Wetland group 6, AOV-P<0.0001

Province	1	6	5	2	3	4
	———	———				
			———	———	———	———
Means	514	467	290	173	128	113

Wetland group 7, AOV-P=0.0075

2	6
———	
	———
272	166

Wetland group 8, AOV-P=0.0005

Province	5	3
	———	
		———
Means	553	227

Wetland group 11, AOV-P<0.0001

6	5	2	4	1	3
———					
	———				
		———	———		
			———	———	———
346	273	231	193	192	150

Wetland group 14, AOV-P=0.0027

Province	5	6	1
	———	———	
		———	———
Means	295	197	158

Wetland group 16, AOV-P<0.0001

5	6	2	1	4
———	———			
		———	———	———
442	377	181	132	114

Table A-6. continued.

Wetland group 17, AOV-*P*<0.0001

Province	6	4	5	2	3	1
	—					
		—	—			
			—	—	—	—
Means	913	305	262	215	202	152

Wetland group 18, AOV-*P*=0.0002

Province	1	6	2	4	5	3
	—	—				
		—	—	—		
				—	—	
					—	—
Means	326	304	233	202	164	121

Wetland group 21, AOV-*P*<0.0001

Province	5	4	2	3	1
	—	—			
		—	—	—	—
Means	633	372	209	165	131

Wetland group, AOV-*P*=0.0567

Province	2	4	5
	—	—	
		—	—
Means	228	186	113

Wetland group 23, AOV-*P*=0.0004

Province	3	6	4
	—		
		—	
			—
Means	700	423	239

Wetland group, AOV-*P*=0.0045

Province	4	5	3	2
	—			
		—	—	—
Means	596	282	232	105

Wetland group 25, AOV-*P*=0.0361

Province	4	2
	—	
		—
Means	412	306

Wetland group, AOV-*P*=0.0003

Province	4	5
	—	
		—
Means	775	138

Table A-7. Ordering of province (1-6) means of light penetration (secchi disk cm) of wetland basins with water present on random ¼-section sample plots 1978-80 in relation to wetland group using a Duncan's multiple range test α=0.05. Province means with the same underline are not singificantly different.

Wetland group 1, AOV-P=0.0589

Province	4	6	5	1	2
	—	—	—	—	
		—	—	—	—
Means	58	45	45	41	23

Wetland group 2, AOV-P=0.0405

2	3	4	5	1	6
—	—	—			
	—	—	—	—	—
68	47	46	43	42	8

Wetland group 3, AOV-P=0.0192

Province	4	2	5
	—		
		—	—
Means	67	37	31

Wetland group 4, AOV-P=0.0179

3	5
—	
	—
46	21

Wetland group 6, AOV-P<0.0001

Province	2	3	1	5	6	4
	—					
		—	—			
			—	—	—	—
Means	71	49	37	25	24	13

Wetland group 11, AOV-P<0.0001

4	3	2	1	5	6
—	—	—	—		
				—	
					—
37	34	33	32	22	11

Wetland group 13, AOV-P=0.0067

Province	5	4	3	1	2	6
	—	—	—	—	—	
			—	—	—	—
Means	31	30	26	20	17	10

Wetland group 14, AOV-P<0.0001

1	5	6
—		
	—	—
39	9	6

Wetland group 15, AOV-P=0.0196

Province	1	5	2
	—	—	
		—	—
Means	27	19	13

Wetland group 16, AOV-P=0.0164

1	2	5	4	6
—	—			
	—	—	—	—
59	35	27	19	8

Table A-7. continued.

Wetland group 17, AOV-P=0.0008

Province	6	4	1	3	2	5
	—					
		—	—	—	—	
			—	—	—	—
Means	98	70	63	59	57	51

Wetland group 18, AOV-P<0.0001

Province	3	1	4	5	2	6
	—	—	—			
		—	—	—		
				—	—	—
Means	78	73	64	52	41	26

Wetland group 21, AOV-P<0.0001

Province	4	2	1	3	5
	—	—			
			—	—	—
Means	64	64	40	39	26

Wetland group 22, AOV-P=0.0013

Province	5	2	4
	—		
		—	—
Means	83	33	28

Wetland group 23, AOV-P=0.0015

Province	3	4	6
	—		
		—	—
Means	59	29	14

Wetland group 25, AOV-P=0.0483

Province	2	4
	—	
		—
Means	56	33

Wetland group 27, AOV-P=0.0131

Province	4	5
	—	
		—
Means	37	10

NUMBERS, DISTRIBUTION, AND HABITATS OF WATERFOWL WINTERING ON OKLAHOMA WETLANDS[1]

Wintering Waterfowl in Oklahoma

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Abstract: The numbers, distribution, and habitats of waterfowl present in Oklahoma during early and late winter were studied in 1978-79 and 1979-80. Mallard (*Anas platyrhynchos*), wigeon (*A. americana*), gadwall (*A. strepera*), greenwinged teal (*A. crecca*) common merganser (*Mergus merganser*), lesser snow goose (*Anser caerulescens*), and Canada goose (*Branta canadensis*) were the most common species. Thirty-one percent, 52%, 26%, and 34% of dabbling ducks wintered on smaller wetlands during early and late winter 1978-79 and 1979-80 respectively. Natural wetlands were selected by dabbling ducks over man-made impoundments. Large reservoirs constituted the predominent habitat utilized by common mergansers.

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[1] Supported by Pittman-Robertson Project W-128-R-3: the Oklahoma Cooperative Wildlife Research Unit, U.S. Fish and Wildlife Service, Oklahoma Department of Wildlife Conservation, Wildlife Management Institute, and Oklahoma State University, cooperating, and by a National Wildlife Federation grant to the senior author.

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Geese wintered mainly on national wildlife refuges (NWR's) associated with large reservoirs. The numbers of all dabbling duck species decreased on large reservoirs during late winter, and subsequently increased on small (<445 ha) natural wetlands. The smaller wetlands were differentially selected for by paired and hen mallards, primarily as feeding habitats. A greater percentage of dabbling ducks wintered on palustrine wetlands during 1979-80 than during 1978-79, apparently in response to wetland dynamics. Maintenance of natural wetlands and unaltered rivers appears more ecologically beneficial to wintering dabbling ducks and indirectly to hunters than to develop management areas associated with large reservoirs and/or construct additional farm ponds.

J. WILDL. MANAGE. 00(0):000-000

Key words: Central flyway, dabbling ducks, Oklahoma, reservoirs, sex ratios, waterfowl, wetland dynamics, wintering

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Wetland habitats used during the non-breeding portion of the annual cycle for waterfowl populations contribute both maintenance and breeding energies essential to perpetuation of the populations (Lack 1966, Fretwell 1972). The availability, dispersion, and quality of habitats and foods influences waterfowl concentrations, movements, energy budgets, and pairing processes during winter (Fredrickson and Drobney 1979, Paulus 1980); and affects reproductive potential through the overwintering physiological condition (Ryder 1970, Milne 1976, Reed 1976, Ankney 1977). Natural wetland conditions and dynamics in the Mississippi delta during winter may influence subsequent recruitment of mallards more than availability of breeding habitats (Heitmeyer and Fredrickson, unpublished data). Yet knowledge of winter population sizes (Crissey 1957), distribution on wintering grounds (Stewart et al. 1958), specific wetland habitat types used (Weller 1979), winter habitat selection (Hilden 1965), and ecological strategies employed by waterfowl during winter are represented by only a few studies. The rapid decline and destruction of habitats used in winter (e.g. Holder 1970, St. Amant 1972, Fredrickson 1979) accentuates the need for immediate study.

Out purpose is to provide information on the numbers, distribution, composition, and habitats of waterfowl wintering within Oklahoma as related to wetland availability and dynamics.

We thank C.P. Boydstun, H.W. Browers, P.M. Domanski, C.T. Patterson, R.J. Prokop, and W.J. Willis for helping collect and compile data; J.A. Bissonette, J.H. Eve, J.M. Gray, O.E. Maughan, and O.T. Sanders for providing logistical support; and F.L. Knopf, F. Schitoskey, Jr., and W.D. Warde for providing editoral assistance. W.D. Warde provided statistical advice and wrote most of the computer programs, and L.M. Due and C.R. Criswell conducted or assisted in the aerial censuses of reservoirs. We especially acknowledge the landowners who allowed access to their property.

METHODS

Population estimates and distributions of waterfowl present in Oklahoma during early and late winter 1978-79 and 1979-80 were projected by combining data obtained from: 1) a stratified random sample of waterfowl present on palustrine, small lacustrine, and riverine (Cowardin et al. 1979) wetlands on selected ¼-sections (0.65 km^2) (Stewart and Kantrud 1972:770-773, Heitmeyer and Vohs 1981); 2) aerial and ground censuses of waterfowl present on large reservoirs (greater than 445.3 ha); and 3) data from winter inventories of waterfowl present on NWR's. This combination of waterfowl projections from smaller wetlands and from major areas of concentration permitted a more complete statewide estimate (e.g. Rutherford and Hayes 1976).

All wetland basins on the ¼-sections were visited once during early winter 1978-79 (18 Dec 1978-20 Jan 1979, hereafter referred to as WI), late winter 1978-79 (29 Jan-23 Feb 1979, hereafter WII), early winter 1979-80 (17 Dec 1979-5 Jan 1980, hereafter WIII), and late winter 1979-80 (15 Jan-18 Feb 1980, hereafter WIV). Waterfowl on reservoirs were counted on 2-6 Jan 1979, 15-20 Feb 1979, 2-7 Jan 1980, and 2-6 Feb 1980. The mean number of each waterfowl species present on Optima, Salt Plains, and Washita NWR's in western; and on Sequoyah and Tishomingo NWR's in eastern Oklahoma (during 18 Dec 1978-20 Jan 1979, 29 Jan-22 Feb 1979, 17 Dec 1979-11 Jan 1980, and 14 Jan-15 Feb 1980) were recorded.

The sex, reproductive status, and activity of ducks observed on wetlands present on ¼-sections were determined if ducks were observed undisturbed for at least 5 minutes. Some birds flushed immediately and only sex was ascertained. These data were supplemented by observations of waterfowl present on wetlands randomly observed while in route to and from ¼-sections. Additional sex ratios and information on pairing were obtained by observing flocks on 11 eastern and 8 western reservoirs, and on all 5 NWR's. Activity (feeding, loafing and courtship) classification followed Tamisier (1976) and Skead (1977), and courtship was ascertained from observations of courting displays described by Johnsgard (1965) and Lebret (1961). Reproductive status was classified as paired or unpaired. Paired ducks were identified by general association of a hen with a drake (Weller 1965, Soutiere et al. 1972) and expressed as the % of hens observed that were paired. Although the pairing process consists of many temporary bonds (Wiedmann 1956, Weller 1965), any visible association between hen and drake defined a pair.

Thirty-six physical, chemical, and vegetational variables (Heitmeyer and Vohs 1981:Table 29) were measured at each wetland basin with water present on ¼-sections during each visit. All wetland basins were individually classified using the Cowardin et al. (1979) classification systems. We used this system to classify the individual wetland basins (as used in plates 19-56, pp 66-103 in Cowardin et al. 1979) and not just zones or regions within a wetland basin. Sixty palustrine, small lacustrine, and riverine wetland basin classification types were present on ¼-sections during 1978-80 (Heitmeyer and Vohs 1981), but only 27 types (Appendix B-1) had waterfowl present during winter.

All data were analyzed using programs in the Statistical Analysis System (SAS) (Barr et al. 1976, 1979). Unless otherwise noted all probability levels refer to chi-square tests.

CLIMATIC AND WETLAND CONDITIONS DURING THE STUDY

The structure and function of wetland basins within Oklahoma are controlled by the associated hydrologic regimes, as influenced by precipitation, runoff, evapotranspiration rates, and river overflows (Gosselink and Turner 1978, Heitmeyer and Vohs 1981). A deficit occurs in the annual water budget for most of Oklahoma (Oklahoma Water Resources Board 1976), and seasonal and long term precipitation trends provide a dynamic wetland complex, both seasonally and annually.

Our study occurred at the low to increasing portion of the long term water cycle. Wetland numbers, ha of surface water, diversity, and emergent vegetation/open water interspersion increased from 1978 to 1980 (Heitmeyer and Vohs 1981). The annual recharge of wetland basins, through increased precipitation and river overflows, begins between early and late winter. Flooded or expanded basins, especially semipermanent and seasonally flooded natural bottomland sloughs and oxbows, increased during WII and WIV.

The winter (Dec-Feb) of 1978-79 was the 2nd coldest on record since 1891; above normal snowfall occurred (U.S. Department of Commerce 1978-80), and many wetlands were covered with ice. The winter of 1979-80 had near normal temperatures and snowfall, and less ice formed.

RESULTS

Numbers and Distribution

Mallard and common merganser were the most common duck species wintering in Oklahoma during 1978-79 and 1979-80 (Table 1). Wigeon, gadwall, pintail (*A. acuta*), green-winged teal, wood duck (*Aix sponsa*), ring-necked duck (*Aythya collaris*), common goldeneye (*Bucephala clangula*), and hooded merganser (*Mergus cucullatus*) were present in lesser numbers. Small numbers of shoveler (*A. clypeata*) (3-500), redhead (Aythya americana) (0-42), canvasback (Aythya valisneria) (0-102), and coot (Fulica americana) (400-4000) were present (Appendix C-1). Lesser snow goose numbers increased from 12,404 in WI to 17,266 in WII and from 18,683 in WIII to 34,774 in WIV. Canada goose numbers decreased from 75,202 in WI to 68,604 in WII and from 69,747 in WIII to 60,552 in WIV. White-fronted geese (Anser albifrons) and Ross' geese (Anser rossii) wintered in small numbers (600-1400 and 1-15 respectively). Statewide populations of wigeon, gadwall, lesser scaup, and coot decreased from early to late winter in both 1978-79 and 1979-80 (Table 1). In contrast, populations of pintail, green-winged teal, and common merganser increased from early to late winter. Wood duck populations decreased from WI to WII but increased from WIII to WIV. Ring-necked duck, common goldeneye, and hooded merganser populations increased from WI to WII, but decreased from WIII to WIV.

From 50-78% of the mallards wintered in eastern Oklahoma and were most common in provinces 1 and 4 (Table 1). Wigeon wintered mainly in provinces 3, 4, and 5; gadwall and common goldeneye in 1, 3, and 4; pintail and gree-winged teal in 4 and 5; wood ducks and ring-necked ducks in 3 nad 4; and hooded mergansers wintered mainly in provinces 1 and 3. The number of birds of all species/ha of surface water was greatest in provinces 4, 3, and 6 respectively (Appendix C-2). Density (birds/ha of surface water) of waterfowl wintering on large reservoirs was low (mean of 0.504/ha). Thiry-one percent, 52%, 26%, and 34% of dabbling ducks wintered on smaller wetlands during early and late winter 1978-79 and 1979-80 respectively. Common mergansers wintered almost exclusively on large reservoirs while geese wintered primarily on NWR's.

The distribution and habitats of ducks changed between early and late winter during both winters (Table 1). Mallard populations decreased on large reservoirs and subsequently increased on small wetlands in provinces 1 and 4 during late winter. The number of mallards in Oklahoma remained constant between early and late winter, and the increase in numbers on smaller wetlands was almost equal to the decrease on reservoirs, suggesting a direct movement from the reservoirs to the small wetlands. Mallards, wigeons, gadwalls, pintails, Green-winged teal, lesser scaup, Canada geese, and coots moved away from 23 of the 28 reservoirs with waterfowl present during late winter 1978-79 and moved away from 19 of 25 reservoirs with waterfowl present during late winter 1979-80. Mallard populations decreased on eastern NWR's in WIV. No mallards wintered on small wetlands in province 6 during 1978-79, but 19,658 and 2,383 mallards wintered on small wetlands in province 6 during WIII and WIV respectively.

Pairing and Sex Ratios

The sex ratio of mallards was different ($\underline{P}<0.05$) among habitats during WII and WIV (Table 2). A higher percentage of males was present on reservoirs and NWR's, and a higher percentage of hens was present on small wetlands. Correspondingly, a significantly ($\underline{P}<0.05$) higher percentage of the hens present on small wetlands were paired than hens wintering on reservoirs and NWR's. The percentage of hen mallards observed that were paired increased or remained constant from early to late winter on western reservoirs, NWR's, and small wetlands (Table 2). However, the percentage of hens observed that were paired decreased during late winter on eastern reservoirs.

Other species (those with N<10) wintering in Oklahoma had more males or adult males present, with the exception of hooded mergansers in WI and common goldeneyes in WIII and WIV (Table 3). In general, the % of males was higher for species during 1978-79 than during 1979-80.

Habitat Distribution

Dabbling ducks used a variety of wetland types during winter (Table 4). Mallards were most flexible and used 24 of the 27 wetland types used by all species. Species habitat use during any season was not related ($P<0.0001$) to the availability of surface water of a specific wetland type (Table 4). Habitat use was different among species ($P<0.0001$) in both 1978-79 and 1979-80.

Mallards, gadwalls, wigeon, wood ducks, common goldeneyes, and hooded mergansers wintered primarily on riverine habitats during 1978-79 (Table 4). Green-winged teal, ring-necked ducks, and lesser scaup wintered mainly on small lacustrine wetlands, and pintails were found mainly on scrub/shrub and bottomland palustrine wetlands. Movement from 1 habitat type to another occurred from WI to WII for mallards ($P<0.0001$), gadwalls ($P<0.0002$), wigeons ($P<0.0001$), and green-winged teal ($P= 0.0094$). Mallards moved from sand and mud bar rivers and farm ponds in WI to mud channel rivers, irrigation lakes, and bottomland sloughs and oxbows during WII; gadwalls moved from sand and mud bar rivers to mud channel rivers; wigeon moved from rivers to vegetated small lacustrine wetlands; and green-winged teal moved from mud substrate small lacustrine wetlands in WI to vegetated small lacustrine wetlands in WII.

Most species wintered on palustrine wetlands during 1979-80 in contrast to the riverine use in 1978-79. Mallards and green-winged teal wintered mainly on bottomland and scrub/shrub wetlands, wigeons and gadwalls were present on vegetated wetlands, and lesser scaup and common goldeneyes wintered mainly on small lacustrine wetlands during 1979-80.

Habitat shifts were noted between WIII and WIV for mallards ($\underline{P}<0.0001$), wigeon ($\underline{P}=0.0302$), green-winged teal ($\underline{P}<0.0001$), and wood ducks ($\underline{P}=0.0111$). Mallards shifted from mud farm ponds in WIII to bottomland and vegetated wetlands in WIV, wigeons shifted from mud farm ponds to wetlands dominated by submergent and emergent vegetation, green-winged teal shifted from man-made to natural scrub/shrub and bottomland wetlands, and wood ducks shifted from bottomland wetlands to rivers.

Dabbling ducks preferred natural wetlands (both riverine and palustrine) over man-made wetlands (Table 5). Using only species and seasons with larger sample sizes, 36-71% of mallards, 50% of pintails, 100% of gadwalls, 0-72% of green-winged teal, and 100% of wood ducks wintered on natural wetlands on the selected ¼-sections in Oklahoma. Yet, natural wetlands comprised only 12.2-12.5% of the wetland basins and only 36-45% of the ha of surface water present on ¼-sections. The % of wintering mallard populations increased on natural wetlands from early to late winter. Natural bottomland wetlands and rivers were used almost exclusively by mallards in province 4 (95.7%, 34.4%, 94.6%, and 88.2% of 23, 58, 37, and 51 mallards present in province 4 during WI, WII, WIII, and WIV were observed on these wetlands).

Farm ponds and dugouts were especially selected against by wintering waterfowl. Farm ponds comprised over 95% of the palustrine and small lacustrine wetland basins in Oklahoma during winter, but they wintered less than 10% of the statewide duck population. Only farm ponds dominated by submergent and emergent vegetation were commonly used. Waterfowl especially avoided mud substrate farm ponds. Mud substrate ponds comprised approximately 80% and 35% of the statewide basins and ha of surface water during winter, but wintered less than 5% of the state's waterfowl.

Activities

Feeding activity of mallards was positively associated with semipermanently flooded mud channel rivers in WI, with irrigation lakes in WII, with wetlands dominated by algal growth to WIII, and with natural bottomland wetlands in all seasons (Table 6). Loafing activity was associated with sand and mud bar rivers and small lacustrine wetlands, and courtship was associated with small palustrine wetlands and mud channel rivers. Observations of activities for other species were too few for similar analysis.

Habitat Variables

Analysis of the 36 habitat variables between wetlands used and wetlands not used by individual species during a given season did not show significant trends. Variables that were different between used and unused basins were most often simply reflections or characteristics of natural wetlands (Heitmeyer and Vohs 1981) used during a given season rather than habitat selection cues. We, therefore, used multivariate techniques to determine if various combinations or interactions of variables influenced winter habitat selection. All variables were correlated with each other using correlation analysis and correlation coefficients were calculated for each season. A principal component analysis was performed for each season using the correlation coefficients as entries. The percentage of the wetland variation explained by the 1st 3 factors was 33.0% in WI, 32.6% in WII, 24.0% in WIII, and 23.5% in WIV (Appendix C-3). For each of the 1st 3 factors in each season, those variables having a large factor loading after rotation were selected and a new factor (PC-I, PC-II, and PC-III) was computed as the sum of the selected factors after each had been divided by its stnadard deviation (Appendix C-4). These PC-I, PC-II, and PC-III values were then tested individually (*t*-tests) and when combined (multivariate analysis of variance (MANOVA) tests) for differences between wetland basins used and basins not used by individual waterfowl species for each season.

Wetland basins used by mallards during WI, WII, and WIV; by wigeons during WIII; by green-winged teal during WI and WIV; and by common goldeneyes during WIV were consistently larger, had more of the basin covered by surface water, and had a greater shoreline/unit area (Table 7). Wetlands used by green-winged teal during WI had more vegetative coverage in the basin and had less suspended solids. The MANOVA-tests also showed differences in combinations of variables between used and unused wetlands for these species and seasons. Other combination of variables for other species and seasons were not different ($\underline{P}>0.10$) between used and unused basins. Sample sizes were small for many species and further intensive studies are needed during winter to elucidate the affects of individual habitat variables on individual waterfowl species within specific geographical areas of Oklahoma.

DISCUSSION

Oklahoma is at the northern edge of the major wintering areas of most waterfowl species (Bellrose 1976) and it is doubtful that large numbers of any species, other than mallards traditionally wintered within the state. Gadwall, wigeon, lesser scaup, and coot seemed less tolerant of cold temperatures or did not have suitable habitats available, and most had departed from Oklahoma by late winter.

The increase of lesser snow geese during late winter may have been due to southern movement by populations that began the winter farther north. However, we doubt that the increase in pintail and green-winged teal numbers during late winter was caused by an influx of birds from northern states because only small numbers of these species began the winter in Kansas or farther north (Central Flyway Council, unpublished midwinter inventories). Pintail are early spring migrants (Bellrose 1976), and the increase within Oklahoma during late winter may have been prepreparatory to spring migration. Cold temperatures and high winds can increase stress among green-winged teal wintering in the Texas high plains and cause hens to move farther south (Bennett and Bolen 1978). The influx of green-winged teal into Oklahoma was not a sexually differentiated movement, however (sex ratios were constant between early and late winter), and we are unsure of the cause or ecological significance of the movement.

Species of the Mergini are the latest inland fall migrants and winter farther north than most other waterfowl. Large numbers moved into Oklahoma during late winter in 1978-79, but fewer were present in 1979-80. Female and immature Mergini often migrate earlier and winter farther south (Nilsson 1969, 1970, Anderson and Timken 1972). Our data support this concept as more adult males were present during the harsher winter of 1978-79 and more females and immatures were present in 1979-80. Aythyini species have more specialized and concentrated winter habitats due to more rigid behavioral, morphological, and food preference adaptions (Nilsson 1970, 1972, Hilden 1965 , Alexander and Hair 1977). Apparently habitats in Oklahoma were not suitable for Aythyini during 1978-80 with the exception of ring-necked ducks, which used many habitats similar to those used by dabblers. In general, our data, with the exception of green-winged teal, support the statement of Prince (1979:112-113) and the data of Bellrose (1976) that dabbler species with heavier body weight winter farther north.

The geographical distribution of waterfowl wintering in Oklahoma was probably in response to the distribution and availabilities of preferred habitats. The wetland diversity and abundance of natural wetlands was greatest in provinces 4, 1, and 3 respectively (Heitmeyer and Vohs 1981). The greatest densities and diversities of wintering ducks also occurred in these provinces. All species of dabbling ducks preferred natural wetlands over farm ponds. Mallards and wood ducks especially selected for bottomland wetlands and rivers in provinces 1, and 4, and more mallards moved to provinces 1 and 4 in late winter. Gadwall and wigeon selected for wetlands dominated by submergent and emergent vegetation and were most common in provinces 1 and 3, where these vegetated wetlands were most abundant (Heitmeyer and

Vohs 1981). The increased use of reservoirs in western Oklahoma by mallards may have resulted from the absence of natural wetlands in western Oklahoma because of lowered groundwater levels and decreased periods of flooding due to irrigation and drainage (Morton 1980), construction of reservoirs (Heitmeyer and Vohs 1981), and stream channelization (Barclay 1978).

Although man-made farm ponds are often used by breeding waterfowl in the northern prairies (Flake 1979), they did not provide valuable wintering habitat in Oklahoma during 1978-80. Farm ponds in Oklahoma are generally built with steep sides to maximize water storage and most do not have the degree of water dynamics or shallow littoral zones that maintain the biological productivity of natural wetlands (Heitmeyer and Vohs 1981). Therefore farm ponds are not ecologically similar to natural wetlands, and the management potential of existing farm ponds to benefit wintering waterfowl appears minimal.

Preserving a variety of natural wetland types may be necessary to support and maintain waterfowl populations and homing traditions within Oklahoma. Natural wetlands comprised only 10-15% of the wetland basins in Oklahoma, but they wintered up to 70% of statewide dabbling duck populations, and almost all of the mallards in province 4. These natural wetlands, especially bottomland wetlands and rivers, were differentially selected for by paired and hen mallards, especially during late winter, and were used primarily as feeding habitats. Paired gadwall wintering in Louisiana also segregate from unpaired birds and may enjoy advantages in resource exploitation and energy acquisition (Paulus 1980).

Preservation of natural wetland diversity may also be essential to support wintering dabbling ducks during different water and climatic conditions both within and between winters. Dabbling ducks are adaptable species and commonly respond to changes in wetland dynamics on prairie breeding grounds (Weller and Spatcher 1965, Weller and Fredrickson 1974, Weller 1975). They appear mobile and adaptable on wintering grounds as well. A combination of low water levels and cold temperatures caused many shallow natural wetlands to dry or freeze during 1978-79, and most ducks used riverine habitats (see also Kinghorn 1949). However, increased precipitation, runoff, and river overflows throughout 1979 flooded and expanded wetland basins, created more shoreline and littoral areas, increased wetland diversity, and improved the emergent vegetation/open water interspersion (Heitmeyer and Vohs 1981). These habitat characteristics were all factors identified in the multivariate analysis as being selected for by dabbling ducks, and consequently dabbling ducks used more palustrine habitats in 1979-80 than in 1978-79.

Most waterfowl shifted to different geographical areas and habitats during midwinter. Movements during late winter were probably the result of interactions between changes in disturbance, physiology and behavior of birds, and habitat quality and availability as winter progressed. Bottomland wetlands are recharged by river overflows and runoff during late winter and begin their seasonal cycle of productivity at this time (Heitmeyer and Vohs 1981). Mallards increasingly utilized these wetlands as winter and spring progressed (this study, Heitmeyer and Vohs unpublished data). Movements away from refuges and reservoirs during midwinter after hunting seasons ended have been noted for many species (Thomas 1976, Owen and Thomas

1979) and occurred during this study. The end of hunting seasons may act as a releaser, allowing birds to move away from reservoirs during midwinter. If this is true then the timing and length of hunting seasons could influence the well being of wintering populations. Out data suggest, at least for mallards, that many paired birds are moving away from reservoirs, leaving a less productive portion of the population (i.e. many drakes and unpaired birds) on reservoirs. It also suggests that pairs may have different physiological and behavioral needs during midwinter.

MANAGEMENT IMPLICATIONS

Midwinter waterfowl inventories in Oklahoma are conducted only on large reservoirs and NWR's. Because of the extensive use of smaller wetland habitats, these counts may underestimate the early winter populations of some species, especially dabblers, by 50-90%. This bias toward underestimation probably occurs throughout the Central Flyway (Reeves et al. 1976) and other areas as well. Although these counts may be useful indicators of population trends if the sources and directions of the bias remain relatively constant between years, differential use of small wetlands in relation to species and wetland dynamics between years must be recognized.

Current waterfowl management efforts in Oklahoma are concentrated on large reservoirs and surrounding lands. Reservoirs have visibly large concentrations during fall and early winter. However, following the close of hunting, reproductively important segments of the population seek other wetland types. These movements from reservoirs to other habitats are presumed to indicate limitations of reservoirs for meeting optimum winter habitat needs. Flooding of thousands of hectares of valuable riverine and natural bottomland wetlands by reservoirs has reduced the magnitude of wetlands available to the birds for late winter use.

Future management efforts for wintering waterfowl in Oklahoma and similar areas in the south-central U.S. should be directed at preserving natural wetlands including playas, sloughs, bottomland hardwoods, and riparian areas. Both the ecological and economic benefits/cost of preserving natural wetlands in Oklahoma are far greater than the potential for management of farm ponds and reservoirs to benefit wintering waterfowl. Natural wetlands are most abundant in province 4 and offer the greatest potential for wetland preservation. However, the recent losses of natural wetlands in other Oklahoma provinces may require accelerated action.

The remaining natural wetlands in Oklahoma are rare, unique, differentially selected for by hen and paired mallards, and provide the diversity necessary to support and maintain wintering populations and homing traditions. These unique wetlands are the very wetlands that are being extensively altered or destroyed because of land clearing, channelization, drainage, and inundation (Holder 1976, Barclay 1978, Fredrickson 1979). Further reduction in the numbers and diversity of these wetlands will result in increased competition for food and space and the eventual loss of a portion of the population that is adapted to wintering in the northernmost portion of the winter range.

Research on the timing of midwinter movements is critically needed to understand winter strategies, habitat preferences, and the influence of hunting pressure on waterfowl populations. Even though hunting mortality may be mainly compensatory to natural mortality of waterfowl populations (Anderson and Burnham 1976), long or improperly timed hunting seasons may adversely affect pairing, resource exploitation, and physiological condition of wintering waterfowl, and therefore influence subsequent recruitment.

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Table 1. Number of waterfowl wintering in Oklahoma during early and late winter 1978-79 and 1979-80 as estimated from palustrine, small lacustrine, and riverine wetlands present on random ¼-section plots (standard error in parentheses), ground counts of national wildlife refuges, and aerial and ground censuses of large reservoirs.

Species and season	¼-sections within provinces							National wildlife refuges		Large reservoirs		Total
	1	2	3	4	5	6	Total	East	West	East	West	
Mallard												
WI	677	9222	9386	15172	14536		48993(16142)	49645	32826	53958	20076	208,498
WII	62014		816	31264	3699		99205(64769)	50333	29228	19635	10784	209,185
WIII	3203	4405		17788	6222	19658	51276(19945)	49300	39667	23107	33942	197,292
WIV	7473	11957		29264	10747	2383	61824(18213)	38665	42920	13432	40350	197,191
Wigeon												
WI			5305				5305(5299)	2725	2598	160		10,788
WII					1233		1233(1232)	1792	3500	100		6,625
WIII						1191	1191(1190)	5680	1609	1215	1150	10,845
WIV			414	2295			2709(2330)	4482	2689			9,880
Gadwall												
WI	8121		1224				9345(8206)	1317	55	700		11,417
WII	1378						1378(1377)	717		156		2,251
WIII	534			1148			1682(1264)	1752	495	950	345	5,224
WIV				574			574(573)	174	542	20	10	1,320
Pintail												
WI								193	62	150		405
WII				3773	4316		8089(5728)	1181	139		25	9,435
WIII								150	483	200		833
WIV					1131		1131(1130)	1938	1739		50	4,858
Green-winged teal												
WI				7847	606		8453(7345)	2307		725		11,485
WII				7007	11098	706	18811(12628)	1512	8	300		20,631
WIII					2262		2262(2260)	2900	343	700	435	6,640
WIV			5381	2869			8250(5498)	1980	200	200		10,630
Wood duck												
WI			6938				6938(6929)	330		250		7,518
WII								292		200		492
WIII					566		566(565)	405		150		1,121
WIV				4590			4590(4035)	350		250		5,190

Table 1. continued.

Species and season	¼-sections within provinces							National wildlife refuges		Large reservoirs		Total
	1	2	3	4	5	6	Total	East	West	East	West	
Ring-necked duck												
WI								421		215	100	736
WII				4312			4312(4308)	117		30		4,459
WIII				574		2383	2957(2449)	110	5			3,072
WIV			414				414(413)	15		25		454
Common goldeneye												
WI			2449	1570			4019(2905)	29	16	264	170	4,498
WII			4489	539			5028(4516)	20	35	590	200	5,873
WIII	6939						6939(6413)	9	13	29		6,990
WIV		629		574			1203(850)		6	291	4	1,504
Common merganser												
WI								450	462	24820	22600	48,332
WII								380	347	58830	1500	61,057
WIII								560	339	490	8735	10,124
WIV					4525		4525(4521)	1231	378	28120	17930	52,184
Hooded merganser												
WI								87	5	10		102
WII			1632				1632(1630)	34				1,666
WIII	3203						3203(2371)	355	11			3,569
WIV			1242				1242(1240)	156				1,398

Table 2. Sex ratios and pairing status of mallards wintering in Oklahoma (Sample size in parentheses) in relation to habitat type.

Season	Eastern reservoirs		Western reservoirs		Eastern national wildlife refuges[a]		¼-section smaller wetlands	
	% male	% paired[b]	% male	% paired	% male	% paired	% male	% paired
WI	63.3 (319)	72.7 (33)	56.8 (81)	63.6 (11)	57.8 (45)		58.8 (102)	95.5 (22)
WII	70.5 (227)	63.0 (27)	61.8 (270)	73.3 (15)	61.3 (1366)		57.4 (101)	95.2 (41)
WIII	57.8 (1665)	69.5 (332)	57.6 (151)	61.6 (73)	58.0 (412)	59.4 (106)	55.8 (68)	93.3 (30)
WIV	69.9 (365)	54.8 (42)	57.1 (1095)	70.0 (190)	69.6 (191)	65.4 (26)	54.4 (125)	98.2 (57)

[a] Sequoyah and Tishomingo NWR's. No data was taken on pairing on NWR's in 1978-79.

[b] Expressed as the percentage of hens observed that were paired.

Table 3. Sex ratios of waterfowl, other than mallards, observed on wetlands in Oklahoma during winter 1978-79 and 1979-80.

	WI		WII		WIII		WIV	
	N	% male	N	% male	N	% male	N	% male
Gadwall	188	61.7			87	58.6	104	58.7
Wigeon	13	61.5			11	54.5	35	62.9
Pintail					27	77.8	34	73.5
Green-winged teal	16	68.7	44	68.2			191	68.1
Wood duck	17	58.8						
Ring-necked duck			10	80.0	66	63.8	31	77.4
Canvasback	40	75.0	40	75.0			100	78.0
Common goldeneye[a]	34	70.6	30	66.7	20	35.0	16	31.1
Common merganser[a]	1678	62.8	679	68.9			96	60.4
Hooded merganser[a]	86	45.3	14	64.3	23	52.2		

[a] Percent adult males to brown birds of the same species, because immatures are indistinguishable from adult females in the field.

Table 4. Percentage composition of dabbling ducks observed on random ¼-sections in relation to wetland type during winter 1978-79 and 1979-80.

Species, season, and (sample size)	Riverine								Small Lacustrine						Palustrine												
															Mud impounded			vegetated impounded					scrub/ shrub		bottomland natural		
	01	02	04	03	11	15	13	06	19	18	20	21	24	23	25	34	35	39	41	47	40	45	54	55	57	56	46
Mallard																											
WI (90)	3.3			17.8	5.6	14.4		11.1		10.0			13.3	7.8	5.6											11.1	
WII (158)	60.1			2.5		1.3	3.2		21.5		1.3		1.9		3.2			1.3							3.8		
WIII (88)	1.1		2.3												25.0			27.3	5.7		1.1	4.6				22.7	10.2
WIV (107)										1.9	3.7	1.9			22.4	1.9		1.9		14.0		3.7			14.9	15.9	15.0
Pintail																											
WII (14)										50.0															50.0		
WIV (2)																								100.0			
Gadwall																											
WI (15)		80.0				20.0																					
WII (2)	100.0																										
WIII (3)																		33.3	66.7								
WIV (1)																			100.0								
Wigeon																											
WI (13)						100.0																					
WII (2)										100.0																	
WIII (2)															100.0												
WIV (5)																		80.0		20.0							
Green-winged teal																											
WI (16)									87.5	6.2																6.2	
WII (32)									40.6	53.1	3.1				3.1												
WIII (4)																							100.0				
WIV (18)																				5.6				66.7		5.6	
Wood duck																											
WI (17)								100.0																			
WIII (1)																							100.0				
WIV (8)	87.5			12.5																							
% available surface water ha in																											
WI[a]	3.1	12.8	5.0	0.0	17.9	1.8	7.0	Tr.[b]	1.7	15.4	0.6	4.6	4.5	0.5	9.1	Tr.	0.1	0.8	1.4	0.8	Tr.	0.0	0.1	0.0	0.0	0.9	0.0
WII	3.1	12.4	4.9	0.4	15.4	1.8	6.8	Tr.	1.9	14.8	0.6	4.4	4.4	0.5	10.5	0.1	0.2	0.8	1.4	0.6	Tr.	0.0	0.2	1.3	1.4	0.8	0.0
WIII	4.9	9.8	3.4	0.3	4.6	1.4	4.1	Tr.	1.3	11.9	1.7	3.5	2.2	0.5	20.8	0.3	0.4	1.7	2.1	0.6	Tr.	0.1	0.2	1.6	0.1	1.0	0.9
WIV	4.7	7.5	3.2	0.3	12.2	1.0	4.6	Tr.	1.2	10.1	1.8	3.0	2.4	0.4	18.6	0.2	Tr.	1.4	1.9	0.6	Tr.	Tr.	0.2	1.4	0.5	0.1	1.0

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[a] The estimated ha of surface water present in Oklahoma was 101,668 in WI, 106,861 in WII, 109,077 in WIII, and 125,319 in WIV.

[b] Tr.= less than 0.1%.

Table 5. Percentage of dabbling ducks observed on random ¼-section plots (only species and seasons with *N*>14) that were present on natural and man-made riverine, palustrine, and small lacustrine wetlands.

Species and season	N	% on natural	% on man-made
Mallard			
WI	90	63.3	36.7
WII	158	70.9	29.1
WIII	88	36.3	63.7
WIV	107	45.8	54.2
Pintail			
WII	14	50.0	50.0
Gadwall			
WI	15	100.0	0.0
Green-winged teal			
WI	16	6.2	93.8
WII	32	0.0	100.0
WIV	18	72.3	27.7
Wood duck			
WI	17	100.0	0.0

Table 6. Positive (+) and negative (-) associations between the feeding (F), loafing (L), and courtship (C) activity of mallards (sample size in parentheses) and wetland types observed on ¼-section plots during winter 1978-79 and 1979-80.

Wetland type	WI			WII			WIII			WIV		
	(41) F	(19) L	(0) C	(45) F	(14) L	(3) C	(24) F	(1) L	(16) C	(95) F	(8) L	(30) C
Riverine												
1					+[a]	++						
52		+										
53					+							
86	+	-										
Lacustrine												
12				+	-							
13										-		
14										-	++	
22					+							
Palustrine												
Mud Impd.												
24							-		+			+
Vegetated Impd.												
36									+			
40												+
70							++					
Bottomland natural												
69	+	-		+			+		-	+		
$\underline{X}^2$ OSL, Ho: no difference in activity among wetland types	P=0.0066			P 0.0001			P 0.0001			P 0.0001		

[a] + and - are greater than 3, and ++ and -- are greater than 10 units of the $\underline{X}^2$ total.

Table 7. Variable combinations from the 1st 3 principal components during winter 1978-79 and 1979-80 that were significant between wetlands used by waterfowl (W) and wetlands not used by waterfowl (W/O) on ¼-section plots

Species and season	PC-I[a] Means W	W/O	PC-II[b] Means W	W/O	PC-III[c] Means W	W/O	MANOVA OSL
Mallard							
WI	12.9***[d]	6.2	15.7	15.3	-11.2	-12.6	P=0.0002
WIII	10.4***	5.5	4.3	3.6	1.5	0.1	P<0.0001
WIV	13.9***	5.6	10.0	9.7	0.0	-0.3	P<0.0001
Wigeon							
WIII	13.7*	5.6	1.9	3.7	0.2	0.2	P=0.0766
Green-winged teal							
WI	31.3***	6.2	16.6	15.2	-4.7**	-12.6	P<0.0001
WIV	21.9***	5.7	11.7	9.7	-0.8	-0.3	P<0.0001
Common Goldeneye							
WIV	30.6***	5.8	11.9	9.7	0.1	-0.3	P<0.0001

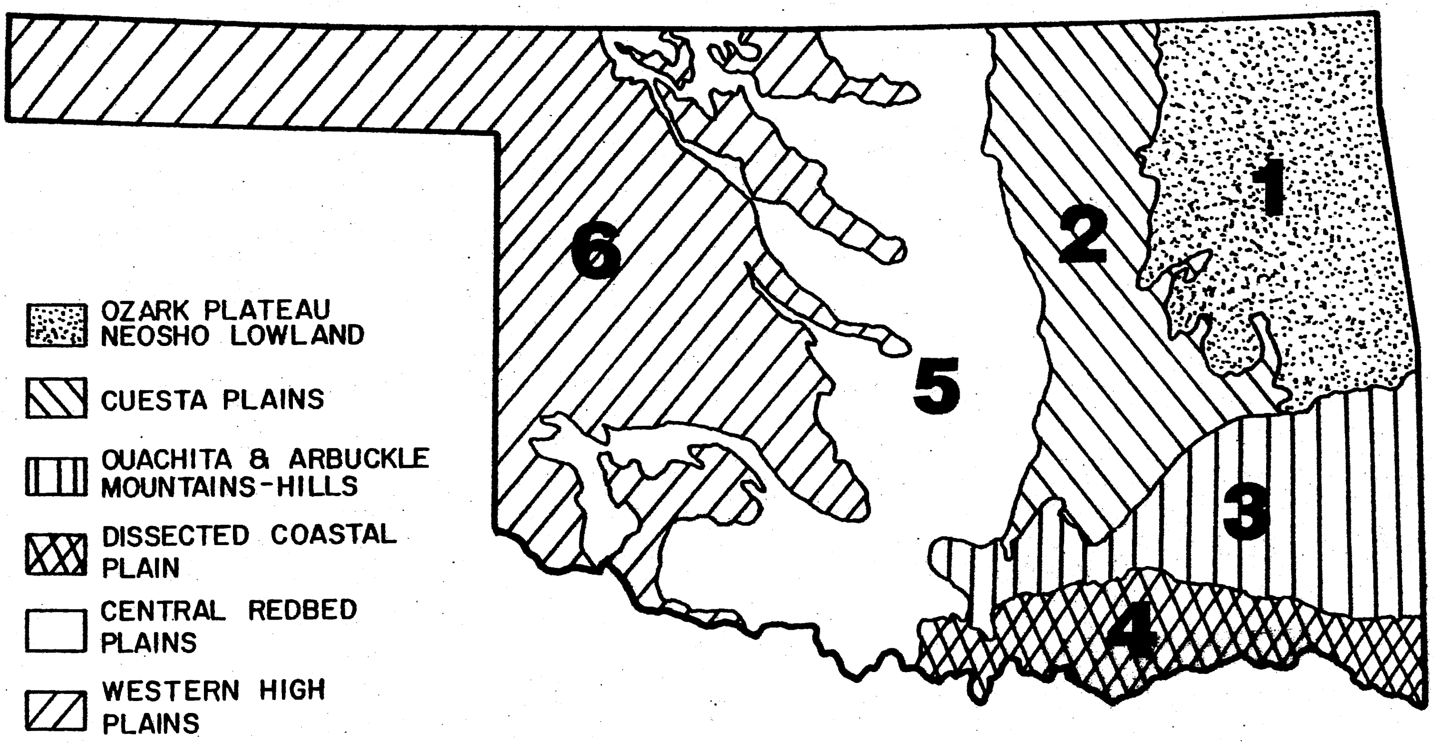
[a] Higher PC-I values for all seasons indicate larger wetlands with more endentated shorelines.

[b] Higher PC-II values for WI, WIII, and WIV indicated higher chemical concentrations and higher PC-II values for WII indicate more emergent and moist soil plant species and more of the surface water area overgrown with emergent vegetation.

[c] Higher PC-III values for WI indicate more plant species, greater light penetration, and more emergent cover. Higher PC-III values in WII indicate higher chemical concerntrations. Higher PC-III values in WIII indicate greater % of idle and forested land use and less grazing near the wetland. Higher PC-III values in WIV indicated more idle land use and less grazing.

[d] *=means are different P<0.05, ** P<0.01, and *** P<0.0001.

LIST OF FIGURES


1
2
3
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OZARK PLATEAU NEOSHO LOWLAND
CUESTA PLAINS
OUACHITA & ARBUCKLE MOUNTAINS-HILLS
DISSECTED COASTAL PLAIN
CENTRAL REDBED PLAINS
WESTERN HIGH PLAINS

APPENDIX B

Table B-1. Wetland classification types (Cowardin et al. 1979) observed on random ¼-section that had waterfowl present during winter.

Wetland type	Classification
	Riverine
01	Riverine-lower perennial-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral
02	Riverine-lower perennial-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-artifical
03	Riverine-lower perennial-unconsolidated bottom-mud-permanently flooded-fresh-alkaline-mineral
04	Riverine-lower perennial-unconsolidated bottom-mud-semipermanently flooded-fresh-circumneutral-mineral-diked
06	Riverine-lower perennial-unconsolidated bottom-mud-semipermanently flooded-fresh-circumneutral-mineral
11	Riverine-lower perennial-unconsolidated bottom/unconsolidated shore-sand-permanently flooded/seasonally flooded-fresh-circumneutral-mineral
13	Riverine-lower perennial-unconsolidated bottom/unconsolidated shore-sand-permanently flooded/seasonally flooded-oligosaline-alkaline-mineral
15	Riverine-lower perennial-unconsolidated bottom/unconsolidated shore-mud/sand-permanently flooded/seasonally flooded-oligosaline-circumneutral-mineral
	Small Lacustrine
18	Lacustrine-littoral/limnetic-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-impounded
19	Lacustrine-littoral/limnetic-unconsolidated bottom-mud-semipermanently flooded/permanently flooded-fresh-circumneutral-mineral-impounded-partly drained
20	Lacustrine-littoral/limnetic-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-impounded-(sewage)

Table B-1. continued

Wetland type	Classification
21	Lacustrine-littoral/limnetic-aquatic bed/unconsolidated bottom-rooted vascular/mud-permanently flooded-fresh-circumneutral-mineral-impounded
23	Lacustrine-littoral/limnetic-rock bottom/unconsolidated bottom-bedrock/mud-permanently flooded-fresh-circumneutral-mineral-impounded
24	Lacustrine-littoral-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-impounded
	Palustrine
25	Palustrine-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-impounded
33	Palustrine-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-excavated
34	Palustrine-unconsolidated bottom-mud-semipermanently flooded-fresh-circumneutral-mineral-excavated
39	Palustrine-aquatic bed-algal-permanently flooded-fresh-circumneutral-mineral-impounded
40	Palustrine-aquatic bed-algal-permanently flooded-fresh-circumneutral-mineral-impounded-(sewage)
41	Palustrine-aquatic bed-rooted vascular-permanently flooded-fresh-circumneutral-mineral-impounded
45	Palustrine-emergent wetland-nonpersistent-permanently flooded-fresh-circumneutral-mineral-excavated
46	Palustrine-emergent wetland-nonpersistent-semipermanently flooded-fresh-circumneutral-mineral
47	Palustrine-emergent wetland-persistent-permanently flooded-fresh-circumneutral-mineral-impounded
54	Palustrine-scrub/shrub-broad leaved deciduous-permanently flooded-fresh-circumneutral-impounded

Table B-1. continued.

Wetland type	Classification
55	Palustrine-scrub/shrub-dead-permanently flooded-fresh-circumneutral-mineral-impounded
56	Palustrine-scrub/shrub-dead-permanently flooded-fresh-circumneutral-mimeral
57	Palustrine-scrub/shrub-dead-semipermanently flooded-fresh-circumneutral-mineral

CHAPTER IV

NUMBERS AND DISTRIBUTION OF WATERFOWL BREEDING ON OKLAHOMA WETLANDS

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ABSTRACT. The numbers and distribution of waterfowl broods present in 1978, and adults present in 1979, were estimated for Oklahoma from birds observed on a stratified random sample of ¼-sections of land area, and counts on national wildlife refuges (NWR's). An estimated 2730 mallards (*Anas platyrhynchos*), 1412 pintails (*A. acuta*), and 7132 wood ducks (*Aix sponsa*) were produced in 1978. In early summer 1979, an estimated 1792 mallards and 7568 wood duck adults were present. Natural playas in western Oklahoma were selected by mallards and pintails; and bottomland wetlands were selected by wood ducks. Mallard production on Salt Plains NWR was directly related to precipitation during summer.

The extent of waterfowl production in the southern great plains is unknown. Small numbers of ducks commonly breed in the Texas high plains (Rhodes 1978, Bolen et al. 1979) and near the Cheyenne Bottoms NWR in central Kansas (Bellrose 1976), but no quantitative data on duck production is available for Oklahoma. The purpose of this report is to

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provide information on the numbers, distribution, and species composition of waterfowl breeding in Oklahoma.

METHODS. Population estimates and distributions of waterfowl broods present during summer 1978, and of breeding pairs present during early summer 1979 were each projected by combining data obtained from 1) a stratified random sample of waterfowl present on (0.65 km^2) (Stewart and Kantrud 1972:770-773, Heitmeyer and Vohs 1981) palustrine, small lacustrine, and riverine (Cowardin et al. 1979) wetlands on selected ¼-sections, and 2) ground counts of Optima, Salt Plains, and Washita NWR's in western; and on Sequoyah and Tishomingo NWR's in eastern Oklahoma.

All wetland habitats on the ¼-sections were visited once during summer 1978 (26 Jun-18 Aug 1978, hereafter referred to as SM78) and early summer 1979 (30 Apr-8 Jun 1979, hereafter SM79). All wetland basins with water present on ¼-sections were individually classified using the Cowardin et al. (1979) classification system. We used this system to classify individual wetland basins (as used in plates 19-56, pp 66-103 in Cowardin et al. 1979) and not just zones or regions within a wetland basin.

Large reservoirs (greater than 445.3 ha) were not censused for breeding waterfowl. Although small numbers of ducks may breed on reservoirs, observations indicated that few young are produced. Human disturbance, fluctuating water levels, and unsuitable habitats on reservoirs are cited as reasons for minimal production.

Information on the number of duck broods produced on Salt Plains NWR was obtained from the 1941-79 annual narrative reports prepared by refuge personnel. These reports constitute the only long term data available on duck production in Oklahoma and provided additional information on habitats and species records.

All data were analyzed using programs in the Statistical Analysis System (SAS) (Barr et al. 1972, 1979).

CLIMATIC AND WETLAND CONDITIONS DURING THE STUDY. A deficit occurs in the annual water budget for most of Oklahoma (Oklahoma Water Resources Board 1976), and seasonal and long term precipitation trends causes the Oklahoma wetland complex to be dynamic, both seasonally and annually (Heitmeyer and Vohs 1981). Highest water levels and greatest ha of surface water area occur during spring and summer.

This study occurred at the low to increasing portion of the long term water cycle; and wetland numbers, ha of surface water, diversity, and emergent vegetation/open water interspersion increased from 1978 to 1979 due to increased precipitation, runoff, and river overflows (Heitmeyer and Vohs 1981). Summer (Apr-Aug) 1978 had slightly higher than normal temperatures, while temperatures were near normal in 1979 (U.S. Department of Commerce 1978-79).

RESULTS. Numbers and Distribution. Mallard, pintail, blue-winged teal (*A. discors*), and wood duck broods were observed on small wetlands on ¼-sections and NWR's during SM78 (Table 1). An estimated 7132 wood ducks were produced in provinces 3 and 4 (Fig. 1), and 2730 mallards and 1412 pintails were produced in provinces 5 and 6. Only 1 blue-winged teal brood (on Salt Plains NWR) was observed.

Adult mallard, blue-winged teal, wood duck, gadwall (*A. strepera*), and coot (*Fulica americana*) were present in Oklahoma during SM79

(Table 1). However, blue-winged teal observed might have been late migrants rather than breeding pairs. Few solitary blue-winged teal pairs were observed (most were still in small flocks of 6-10 birds), and no nests were found. An estimated 1768 mallards were present in provinces 2 and 6, and 6746 wood ducks were present in provinces 3, 4, and 5. Many wood ducks were also present on Tishomingo and Sequoyah NWR's. One gadwall pair was observed on Sequoyah NWR. Coots were observed on small wetlands in provinces 5 and 6, but we were unsure of their breeding status. One pair, 1 group of 3, and 3 single coots were observed, and no coot nests were found during our routine activities associated with wetland visits.

Species Breeding in Oklahoma. Mallards, pintails, gadwalls, blue-winged teal, cinammon teal (*A. cyanoptera*), shovelers (*A. clypeata*), coots and wood ducks have been recorded nesting in small numbers in Oklahoma, and 1 redhead (*Aythya americana*) brood was observed in 1958 on Salt Plains NWR (Sutton 1967). One ruddy duck (*Oxyura jamaicensis*) brood was observed in Oklahoma during 1979 (Shackford 1980). During our review of the Salt Plains NWR narrative reports, we found the following unreported species and brood records: 1 black duck (*A. rubripes*) brood of 6 in 1942, 1 black duck brood of unknown size in 1943, 1 redhead brood of 6 in 1960, and 1 wigeon (*A. americana*) brood of 8 in 1974.

Habitats. Sixty palustrine, small lacustrine, and riverine wetland basin classification types were present on ¼-sections during 1978-80 (Heitmeyer and Vohs 1981). Only 4 types were used by broods, and only 11 types were used by adults during SM78 and SM79 (Table 2). The 2 mallard broods present on the ¼-sections (brood sizes 4 and 6) were observed on a sewage lagoon (wetland type 20) and a seasonally flooded playa lake (wetland type 38). The single pintail brood was observed on a playa lake, 2 wood duck broods (sizes 3 and 6) were found on a flood control lake (wetland type 24), and 1 wood duck brood was observed on a scrub/shrub wetland (wetland type 55).

Wood duck pairs were most common in SM79 (11 of 15 seen) on natural bottomland scrub/shrub and forested wetlands (wetland types 56, 57, and 60) (Table 2). One pair of mallards was observed on a playa, and 1 drake was present on a farm pond dominated by submergent vegetation (wetland type 41). Blue-winged teal were most common on ponds dominated by emergent vegetation (wetland type 43). Four of the 8 coots observed were on small lacustrine wetlands, and 4 were observed on palustrine wetlands. Sample sizes were small, but no species used wetland types in proportion to the availability of the ha of surface water of specific wetland types (chi-square-test, $\underline{P}<0.05$). Breeding ducks especially avoided mud substrate farm ponds (wetland type 25). These ponds comprised 85% of the wetland basins and 30% of the ha of surface water during summer (Heitmeyer and Vohs 1981), but only 2 blue-winged teal, 2 wood ducks, and 3 coots, were observed on these ponds. In contrast, natural playas and bottomland sloughs, oxbows, and lowland hardwoods comprised approximately 4% of the wetland basins and 7% of the ha of surface water, but were selected for by breeding mallards and pintails, and wood ducks respectively.

The estimated number of mallards and blue-winged teal produced on Salt Plains NWR was analyzed in relation to amounts of precipitation received on the refuge during the summer breeding period (Mar-Jun). Data for 19 of the years between 1941-78 were used because the most complete brood counts were made during that period. Only mallards and blue-winged teal commonly nest at Salt Plains NWR (means of 68.5 and 41.1 young produced/yr). Nesting by other species was not evaluated because of small sample sizes. The number of mallards produced on Salt Plains was positively related (P=0.0191) to precipitation amounts during a summer (Fig. 2), but the number of blue-winged teal produced was not (P=0.4403).

DISCUSSION. Waterfowl production was limited in Oklahoma during 1978-79 with the exception of wood ducks. Bellrose (1976) estimated a breeding population of 5000 wood ducks in Oklahoma. Our estimate of 7568 adults present in 1979 was only slightly higher. Wood ducks were only observed on ¼-sections in provinces 3, 4, and 5. However, we did observe 4 pairs away from ¼-sections in provinces 1 and 2, and wood ducks are known to nest in northeastern Oklahoma (Sutton 1967). Based on our sample design, we suggest the number of wood ducks breeding in provinces 1 and 2 must be small (i.e. less than 400). Our failure to observe other waterfowl species nesting on the ¼-sections or within our extensive travel to reach the ¼-sections leads us to believe that they do not occur except in small numbers in restricted areas.

We doubt that large numbers of waterfowl, other than wood ducks, were ever attracted to Oklahoma for nesting, but small numbers of many species were probably present. The number of species breeding and the subsequent production was probably related to wetland conditions and water dynamics (see Weller 1978). More mallards were produced on Salt Plains NWR during improved water conditions caused by increased precipitation. Most dabbling ducks seem to produce more young during good wetland conditions throughout the northern prairie provinces (Crissey 1969, Weller 1979). The low R^2 value (0.283) of the predicted regression equation for mallards was probably partially caused by inconsistency between years in personnel, extent of surveys, and visibilities of ducks on Salt Plains NWR.

Observations of breeding mallards and pintails were largely confined to province 6. Wood ducks were most abundant in provinces 3 and 4. Provinces 3, 4, and 6 have the highest proportions of natural palustrine wetland basins (Heitmeyer and Vohs 1981), and breeding waterfowl seemed to select for these wetlands. The natural wetland types present and used by ducks differed between northwestern and southcentral areas however. Mallards and pintails used shallow playa wetlands that had emergent cover, and wood ducks used natural bottomland wetlands.

Wood ducks are common on rivers during spring and early summer (Bellrose 1976), but we did not observe wood ducks using rivers on ¼-sections during SM78 or SM79. Breeding wood duck pairs may select shallow, dynamic bottomland wetlands to obtain protein from invertebrates necessary for egg production (Drobney and Fredrickson 1979), and broods may concentrate on more heavily vegetated wetlands. Rivers may be used primarily as travel lanes (Hardister et al. 1962, Hepp and Hair 1977) or when natural palustrine wetlands are unavailable.

Although breeding waterfowl commonly use man-made ponds and dugouts in the northern prairies (Flake 1979), man-made ponds were seldom used by breeding waterfowl in Oklahoma during 1978-79. Only 10 of the approximately 400 farm ponds present on ¼-sections were used by broods or pairs, and mud substrate ponds (wetland types 17, 24, 25) were especially under represented in use. Blue-winged teal and coots were most common on man-made ponds during SM79, but they were probably late migrants or nonbreeders rather than breeding pairs. Man-made ponds were not ecologically similar to most natural wetlands (Heitmeyer and Vohs 1981) and were not viable substitutes for natural wetlands used by breeding ducks.

Oklahoma wetlands are dynamic, especially in western and southcentral sections. These natural dynamics seem to maintain wetland stability, productivity, and diversity (Heitmeyer and Vohs 1981). However, reduced groundwater supplies in western Oklahoma (Morton 1980) and drainage, channelization, and construction of reservoirs and flood control impoundments throughout Oklahoma have reduced periods between inundations or have destroyed many natural wetlands. Natural wetlands currently present in Oklahoma are less numerous, less diverse, more widespread, and more susceptible to drying during low precipitation periods than the previous spectrum of wetlands present before human manipulation. A tradition of waterfowl breeding in Oklahoma does not appear to have been established, and waterfowl move to other areas for nesting.

We thank H.W. Browers, P.M. Domanski, and C.E. Endicott for helping collect and compile data; J.A. Bissonette, J.H. Eve, J.M. Gray, O.E. Maughan, and O.T. Sanders for providing logistrical support; F.L. Knopf, F. Schitoskey, Jr., and W.D. warde for providing editorial assistance, and the staffs of Optima, Salt Plains, Washita, Sequoyah, and Tishomingo NWR's for providing production data. W.D. Warde provided statistical advice and wrote most of the computer programs. We especially acknowledge the many landowners who allowed access to their property. This study was supported by Pittman-Robertson Project W-128-R-3: the Okla. Coop. Wildl. Res. Unit, U.S. Fish and Wildl. Serv., Okla. Dept. Wildl. Cons., Wildl. Manage. Inst., and Okla. State Univ. cooperating; and by a National Wildlife Federation grant to the senior author.

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Table 1. Number of waterfowl produced during 1978 (SM78), and the number of waterfowl present during early summer 1979 (SM79) as estimated from palustrine, small lacustrine, and riverine wetlands present on random ¼-section plots (standard error in parentheses) and counts on national wildlife refuges in Oklahoma.

Species and season	¼-sections with provinces							National wildlife refuges	
	1	2	3	4	5	6	Total	East	West
Mallard									
SM78		600			611	2119	2730 (1687)		
SM79						1168	1768 (1764)		24
Pintail									
SM78						1412	1412 (1411)		
SM79									
Blue-winged teal									
SM78									2
SM79			5409		1078	2335	8822 (5748)	10	2
Wood duck									
SM78			1632	5500			7132 (5732)		
SM79			773	4851	1122		6746 (3129)	798	24
Gadwall									
SM78									
SM79								2	
American coot									
SM78									
SM79					561	2919	3480 (1629)	10	

Table 2. Number of mallards (ML), blue-winged teal (BT), pintail (PT), wood duck (WD), and coot (CT) young observed in 1978 and adults observed in 1979 that were present on random ¼-sections in relation to wetland classification types (Cowardin et al. 1979).

Wetland Type	Species and (# adults) 1979	Species and (#young) 1978
Small Lacustrine		
17 Lacustrine-litoral/limnetic-unconsolidated bottom-mud-intermittently exposed/permanently flooded-fresh-circumneutral-mineral-impounded	BT (2) CT (1)	
20 Lacustrine-littoral/limnetic-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-impounded (sewage)	CT (1)	ML (6)
24 Lacustrine-littoral-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-impounded	WD (2) CT (2)	WD (9)
Palustrine		
25 Palustrine-unconsolidated bottom-mud-permanently flooded-fresh-circumneutral-mineral-impounded	BT (2) WD (2) CT (3)	
38 Palustrine-unconsolidated shore-vegetated-seasonally flooded-fresh-circumneutral-mineral-impounded	ML (2)	ML (4) PT (5)
41 Palustrine-aquatic bed-rooted vascular-permanently flooded-fresh-circumneutral-mineral-impounded	ML (1) BT (2)	
43 Palustrine-emergent wetland-nonpersistent permanently flooded-fresh-circumneutral-mineral-impounded	BT (14)	

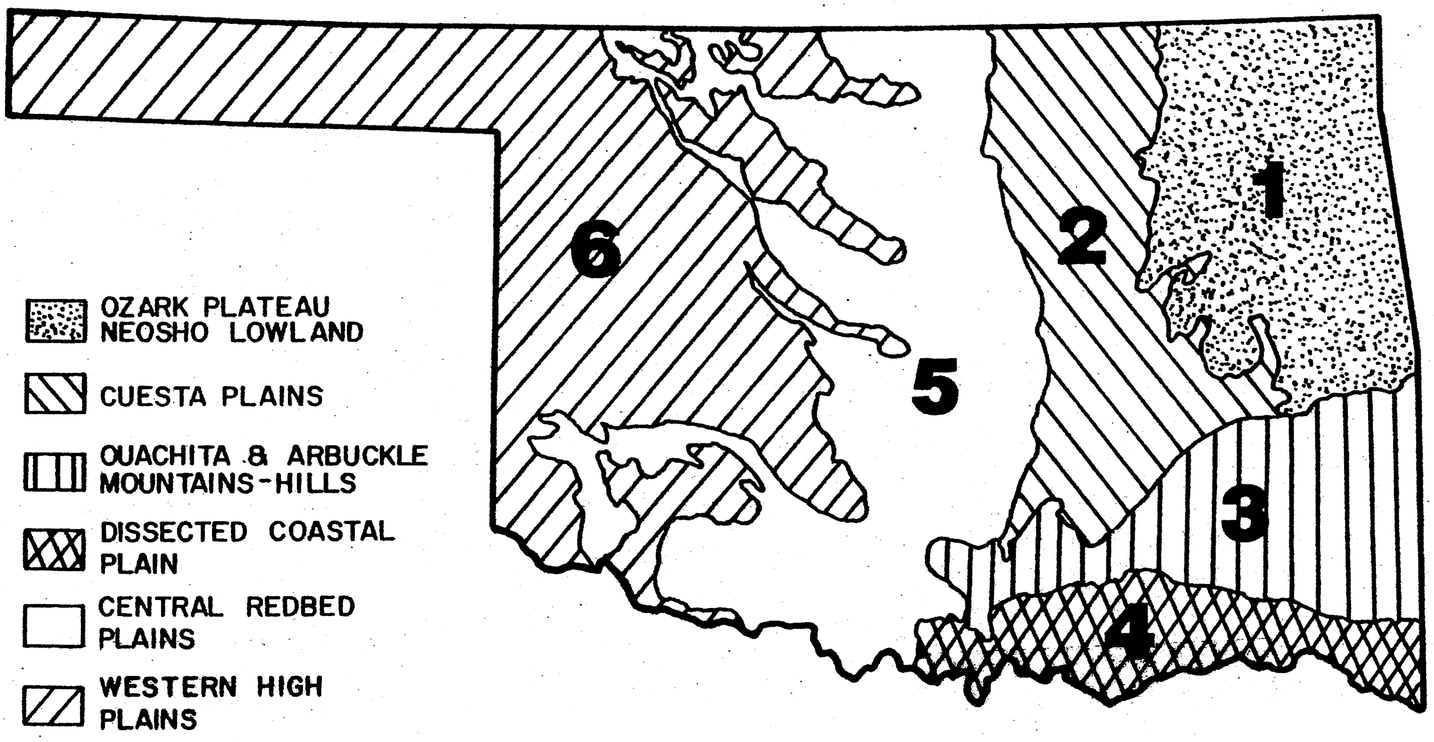
Table 2. continued.

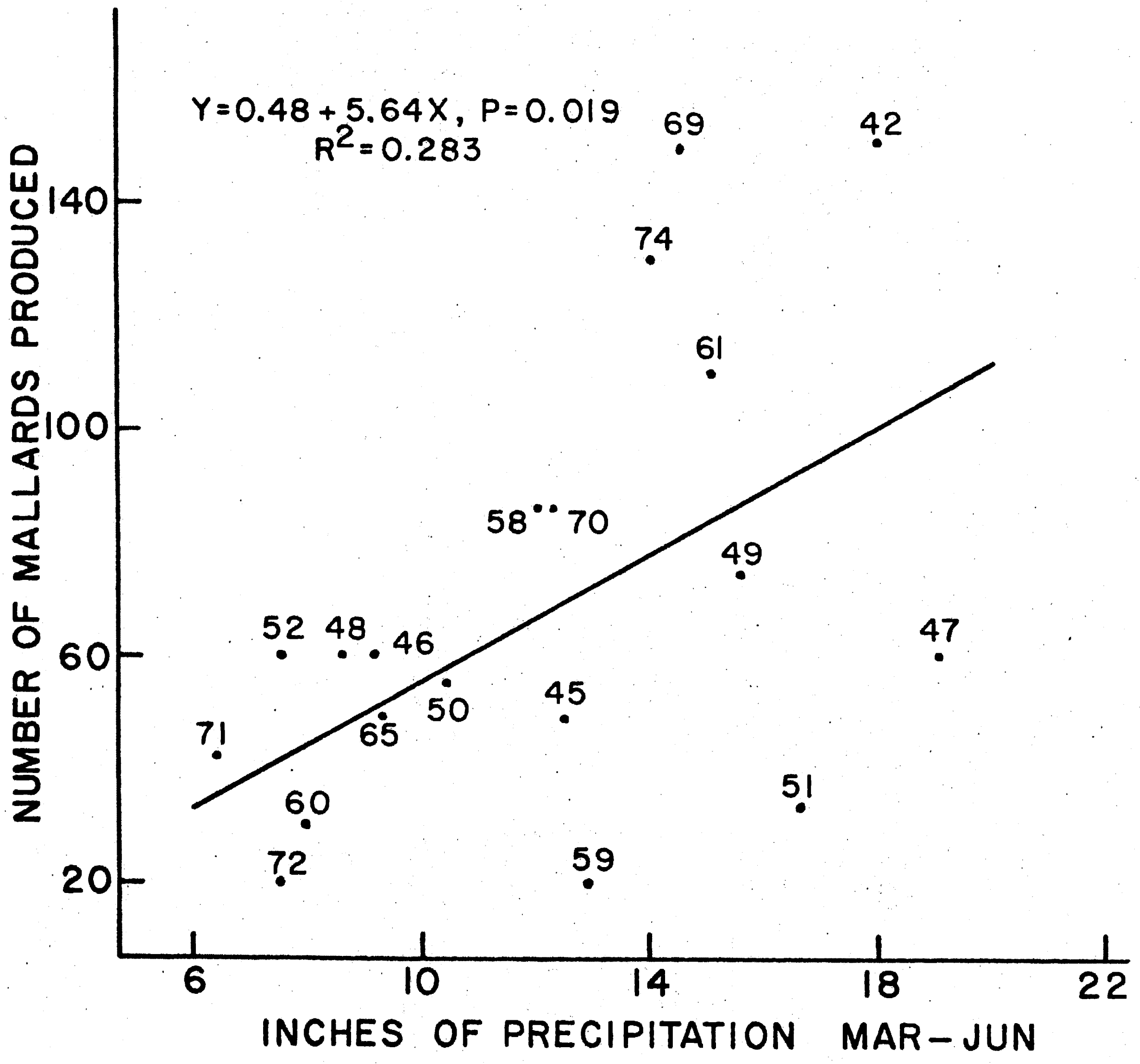
Wetland Type	Species and (# adults) 1979	Species and (# young) 1978
55 Palustrine-scrub/shrub-dead-permanently flooded-fresh-circumneutral-mineral-impounded		WD (4)
56 Palustrine-scrub/shrub-dead-permanently flooded-fresh-circumneutral-mineral	WD (2)	
57 Palustrine-scrub/shrub-dead-semipermanently flooded-fresh-circumneutral-mineral	WD (4)	
58 Palustrine-forested wetland-broad leaved deciduous-permanently flood-fresh-circumneutral-mineral-impounded	CT (1)	
60 Palustrine-forested wetland-broad leaved deciduous-seasonally flooded-fresh-circumneutral-mineral	WD (3)	

Figures

Fig. 1. Physiographic provinces of Oklahoma

Fig. 2. Relationship between the number of mallards produced on Salt Plains National Wildlife Refuge and the inches of precipitation occurring from Mar-Jun of a given year.


1
2
3
4
5
6
OZARK PLATEAU NEOSHO LOWLAND
CUESTA PLAINS
OUACHITA & ARBUCKLE MOUNTAINS-HILLS
DISSECTED COASTAL PLAIN
CENTRAL REDBED PLAINS
WESTERN HIGH PLAINS


Y=0.48+5.64X, P=0.019
R^2=0.283
NUMBER OF MALLARDS PRODUCED
20
60
100
140
6
10
14
18
22
INCHES OF PRECIPITATION MAR-JUN
69
42
74
61
58
70
49
52
48
46
47
50
45
65
71
51
60
72
59

APPENDIX C

Table C-1. Number of waterfowl wintering in Oklahoma in small numbers during early and late winter 1978-79 and 1979-80 as estimated from palustrine, small lacustrine, and riverine wetlands present on random ¼-section plots (standard error in parentheses), ground counts of national wildlife refuges, and aerial and ground censuses of large reservoirs.

Species and season	¼-sections within provinces							National wildlife refuges		Large reservoirs		Total
	1	2	3	4	5	6	Total	East	West	East	West	
Shoveler												
WI								565				565
WII								287				287
WIII								340	20			360
WIV								312	1	15		328
Redhead												
WI								13				13
WII								13				13
WIII									2		40	42
WIV									1			1
Canvasback												
WI								55				55
WII								15				15
WIII												
WIV								100	2			102
Lesser scaup												
WI	678						678(676)	8		100		784
WII												
WIII	534						534(533)	200		106		890
WIV												
Bufflehead												
WI								38	7		50	95
WII								67	7			74
WIII								35	4			39
WIV									4			4

Table C-1. continued.

Species and season	¼-sections within provinces							National wildlife refuges		Large reservoirs		Total
	1	2	3	4	5	6	Total	East	West	East	West	
Lesser snow goose												
WI								12068	36	250	50	12,404
WII								13762	29	3475		17,266
WIII								11395	86	7202		18,683
WIV								25312	62	9400		34,774
Canada goose												
WI								29696	41015	3366	1125	75,202
WII								36721	29218	1665	1000	68,604
WIII								25625	38567	1685	3970	69,747
WIV								18545	35487	1355	5165	60,552
White-fronted goose												
WI								560	88			648
WII								989	462			1,451
WIII								368	235			603
WIV								475	251			726
Ross's goose												
WI									10			10
WII									5			5
WIII									15			15
WIV									9			9
American coot												
WI								1224	2	3175	150	4,551
WII								60		2000	10	2,070
WIII								135	122	750	270	1,277
WIV									150	295		445

Table C-2. Densities (N/ha of surface water) of waterfowl on small winter areas and large reservoirs during winter 1978-79 and 1979-80.

Species and season	¼-section within provinces							Large reservoirs	
	1	2	3	4	5	6	Total	East	West
Mallard									
WI	0.025	0.298	2.391	0.926	0.668		0.482	0.302	0.622
WII	2.167		0.208	1.676	0.151	0.621	0.928	0.110	0.339
WIII	0.112	0.239		1.009	0.184	4.484	0.470	0.124	1.078
WIV	0.261	0.486		1.367	0.278	0.392	0.493	0.072	1.228
Wigeon									
WI			1.352				0.052	0.001	
WII					0.050		0.012	0.001	
WIII						0.196	0.011	0.007	0.037
WIV			0.070	0.107			0.022		
Gadwall									
WI	0.305		0.312				0.092	0.004	
WII	0.048						0.013	0.001	
WIII	0.019			0.065			0.015	0.005	0.011
WIV				0.027			0.005	0.0001	0.0003
Pintail									
WI								0.001	
WI				0.202	0.177		0.076		0.001
WIII								0.001	
WIV					0.029		0.009		0.002
Shoveler									
WI									
WII									
WIII									
WIV								0.0001	

Table C-2. continued.

Species and season	¼-section within provinces							Large reservoirs	
	1	2	3	4	5	6	Total	East	West
Green-winged teal									
WI				0.479	0.028		0.083	0.004	
WII				0.376	0.454	0.310	0.176	0.002	
WIII					0.067		0.021	0.004	0.014
WIV			0.909	0.134			0.066	0.001	
Wood duck									
WI			1.768				0.068	0.001	
WII								0.001	
WIII					0.017		0.005	0.001	
WIV				0.214			0.037	0.001	
Redhead									
WI									
WII									
WIII									0.001
WIV									
Lesser scaup									
WI	0.025						0.007	0.001	
WII									
WIII	0.019						0.005	0.001	0.001
WIV									
Ring-necked duck									
WI								0.001	0.003
WII				0.231			0.040	0.0002	
WIII				0.033		0.544	0.027		
WIV			0.070				0.003	0.0001	

Table C-2. continued.

Species and season	¼-section within provinces							Large reservoirs	
	1	2	3	4	5	6	Total	East	West
Common goldeneye									
WI			0.624	0.096			0.039	0.001	0.005
WII			1.142	0.029			0.047	0.003	0.006
WIII	0.242						0.064	0.0001	
WIV		0.026		0.027			0.010	0.002	0.0001
Common merganser									
WI								0.139	0.700
WII								0.329	0.047
WIII								0.003	0.047
WIV					0.117		0.036	0.150	0.546
Hooded merganser									
WI								0.0001	
WII			0.415				0.015		
WIII	0.112						0.029		
WIV			0.210				0.010		
Lesser snow goose									
WI								0.001	0.002
WII								0.019	
WIII								0.039	
WIV								0.050	
Canada goose									
WI								0.019	0.035
WII								0.009	0.031
WIII								0.010	0.123
WIV								0.007	0.157

Table C-2. continued.

Species and season	¼-section within provinces							Large reservoirs	
	1	2	3	4	5	6	Total	East	West
American coot									
WI								0.018	0.005
WII								0.011	0.0003
WIII								0.004	0.009
WIV								0.002	

Table C-3. The rotated factor pattern of the 1st 3 principal components by survey period, showing the most heavily weighted factors (> 0.20), either positive or negative, for each of the 34 variables.

	WI Factors			WII Factors			WIII Factors			WIV Factors			SP79 Factors			SP80 Factors		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Cumulative %	12.8	23.9	33.0	13.9	23.7	32.6	9.2	17.9	24.0	10.2	17.8	23.5	15.7	27.0	35.8	9.5	17.8	24.6
TOT_WET																		
POND_HA	.92			.83		.21				.77			.97			.99		
PC_SW		-.31	.27			-.31	.38	-.58						-.21				
SW_HA	.96			.95			.89			.54			.97			.98		
PC_OP			-.67		-.84												-.76	
OP_HA	.95			.95			.91			.65			.97			.98		
SDI	.69			.65			.54			.63			.36				.33	
O1																		
O2																		
O3																		
O4													.23					
DTI									.34			.40		.23				
MSCOUNT		-.30	.58	.33	.39									-.22			.67	
MSAVHT			-.24						.24									
EVCOUNT			.81	.23	.80			-.45							.20		.76	
EVAVHT			.32	.46														
SBCT															.98			.70
SBCH									.21									.65
SBL			.22				.53								.98			
SBN													.48		.51			.64
SBP								-.27										.47
PHEN_ALK		.85		.24		.82		.26			.60			.81				
TOT_ALK		.68				.56		.79			.78			.59				
LGT_PEN			.39						.25			.22						.60
DEPTH							-.36											
COND		.69				.67		.62			.63			.48				
PH		.82				.77		.73			.74			.86				
L1																	.23	
L2																	.20	
L3									-.68			-.90						-.27
L4																		.43
L5									.79			.84						
L6							.38			.51								
L7									.47	.78						.29		

Table C-4. Calculations of the PC-I, PC-II, and PC-III values used as representatives of the 1st 3 principal component rotated factors for winter and spring 1978-80.

Season	Calculation
WI	PC-I = POND HA/.388 + SW_HA/.201 + OP_HA/.191 + SDI/.275
	PC-II = PHEN_ALK/9.001 + TOT_ALK/83.620 + COND/426.988 + PH/.458
	PC-III = MSCOUNT/1.139 + EVCOUNT/.405 + LGT_PEN/30.161 - PC_OP/6.59
WII	PC-I = POND_HA/1.884 + SW_HA/.245 + OP_HA/.241 + SDI/.294
	PC-II = MSCOUNT/1.145 + EVCOUNT/.428 - PC_OP/7.998
	PC-III = PHEN_ALK/6.053 + TOT_ALK/58.478 + COND/235.005 + PH/.397
WIII	PC-I = SW_HA/.296 + OP_HA/.282 + SDI/.298 + SBL/.051
	PC-II = TOT_ALK/60.443 + COND/178.314 + PH/1.046 - EVCOUNT/1.161 - PC_SW/22.407
	PC-III = L5/1.372 + L7/1.409 + DTI/17.119 - L3/1.214
WIV	PC-I = POND_HA/1.572 + SW_HA/.322 + OP_HA/.426 + SDI/.307 + L6/.523 + L7/.704
	PC-II = PHEN_ALK/3.128 + TOT_ALK/48.967 + COND/262.096 + PH/.766
	PC-III = L5/1.641 + DTI/16.970 - L3/1.169
SP79	PC-I = POND_HA/1.849 + SW_HA/1.295 + OP_HA/.970 + SDI/.303
	PC-II = PHEN?ALK/5.727 + TOT_ALK/82.258 + COND/255.26 + PH/.381
	PC-III = EVCOUNT/.755 + SBCT/.059 + SBL/.059 + SBN/.143
SP80	PC-I = POND_HA/1.593 + SW_HA/1.205 + OP_HA/1.085 + L7/1.445
	PC-II = MSCOUNT/1.278 + EVCOUNT/1.195 - PC_OP/9.861
	PC-III = SBCT/.143 + SBCH/.160 + SBN/.346 + SBP/.134 + LGT_PEN/27.341

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