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Abstract. Species composition was monitored in seven permanent exclosures at Mormon Island Crane Meadows, near Grand Island, Nebraska from 1982 to 1987. Crane meadows is a 1,050 ha (2,600 acre) native lowland prairie complex with a corrugated topography of wetland swales and dry sand ridges. Variable precipitation, periodic over-bank flooding, and river stage fluctuations complicate the system's hydrology. In general, springs are wet, but, by late summer, the meadows are usually dry, closely paralleling river flows and precipitation patterns. A sustained high water period in 1983 and 1984 was responsible for major changes in species abundance. Plant responses were consistent with species distributions along the topographic moisture gradient. Species at the lower end of the gradient were subjected to the greatest fluctuation in moisture and responded the most. In wetland swales sedge (*Carex aquatilis* Wahl.), +37%; spikerush [*Eleocharis obtusa* (Willd.) J.A. Schult.], +36%; and American bulrush (*Scirpus americanus* Pers.), +14%; increased significantly during the high water period. At moderate elevations indiangrass [*Sorghastrum nutans* (L.) Nash], +22%; and switchgrass (*Panicum virgatum* L.), +24%; increased, but big bluestem (*Andropogon gerardii* Vitman), -28%; showed a significant decline. All species except switchgrass returned to their former cover when water levels declined. Groundwater levels (mean and maximum) were the most important environmental parameters associated with changes in species cover. Switchgrass, however, did not respond directly to groundwater levels. High water conditions probably promoted the expansion of this species but it was able to sustain itself under much lower subsequent moisture conditions. Big bluestem and switchgrass also increased significantly with prescribed burning.

Key Words. groundwater, plant composition, wetland, prairie, Platte River, Nebraska

INTRODUCTION AND STUDY SITE

This study was conducted at Mormon Island Crane Meadows (MICM) near Grand Island, Nebraska. Mormon Island is a 1,050 ha wet meadow complex, situated between the channels of the Platte River that is owned and managed by the Platte River Whooping Crane Critical Habitat Maintenance Trust. The Trust is a nonprofit conservation organization that protects and maintains habitat for migratory birds in the 128 km reach of the Platte between Lexington and Grand Island, Nebraska. Crane Meadows is the largest contiguous grassland tract remaining on the Platte in this river reach. A few areas on the island have been plowed but the majority is virgin tallgrass prairie dominated by big bluestem (*Andropogon gerardii* Vitman), switchgrass (*Panicum virgatum* L.), and indiangrass [*Sorghastrum nutans* (L.) Nash] (Currier 1982, Nagel and Kolstad 1987). Nomenclature follows the Great Plains Flora Association (1986). Common forbs include Maximillian sunflower (*Helianthus maximillianii* Schrad.), many-flowered aster (*Aster ericoides* L.), ironweed (*Vernonia fasciculata* Michx.), and Canada goldenrod (*Solidago canadensis* L.). Prairie gentian [*Eustoma grandiflorum* (Raf.) Shinners], tall gayfeather (*Liatris pycnostachya* Michx.), sneezeweed (*Helenium autumnale* L.), and blue cardinal flower (*Lobelia siphilitica* L.) are characteristic forbs of the wet meadows. Prairie fringed orchid [*Habenaria leucophaea* (Nutt.) A. Gray], an endangered species candidate, is also present.

The meadows have a corrugated topography of ridges and swales oriented parallel to the river channel. At one time, probably several hundred years ago, the island was part of the active riverbed with the swales representing the former braided river channels and the ridges representing islands of moving sand on the alluvial bed (O'Brien and Currier 1987). Ridgetops are dominated by shortgrass prairie species including little bluestem (*Andropogon scoparius* Michx.), hairy grama (*Bouteloua hirsuta* Lag.), and prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.] (Currier 1982, Nagel and Kolstad 1987). Lowland sites are dominated by sedge meadow species including sedges (*Carex spp.*), American bulrush (*Scirpus americana* Pers.), spikerush [*Eleocharis obtusa* (Willd.) J.A. Schult.], smartweeds (*Polygonum spp.*), and prairie cordgrass (*Spartina pectinata* Link). The dominant grasses, big bluestem, switchgrass, and indiangrass, occur on the intermediate slopes.

Nearly 150 species of migratory birds, about one-half of those found in the Platte River valley, use the wet meadows for nesting, feeding, and other activities (Currier *et al*. 1985). These include the endangered whooping crane, bald eagle, and least tern, the threatened piping plover, one-half million sandhill cranes, 7 to 9 million ducks and geese, and many grassland nesting species including the upland sandpiper and bobolink.

This study was initiated to provide baseline data on the interrelationships between hydrology and plants in wet meadows. The surface and ground water hydrology of the meadows is complex and not well understood. In general, major fluctuations in river discharge are reflected in groundwater levels beneath the meadows (Hurr 1983). In the spring and early summer, snow melt in the Rocky Mountains feeds the river, providing high discharge and a corresponding rise in groundwater. River flows and groundwater levels are usually low by July, and surface water has usually drained or evaporated from the meadows. Local precipitation, snow melt, and surface freezing and thawing also contribute to changes in meadow hydrology. In the spring, when surface soils are usually wet and groundwater levels high, precipitation often pools in sloughs and swales on the meadows. By summer, surface water has usually drained or evaporated, except immediately after major rainfall events.

Prescribed burning, rotation grazing, and haying are used in the management of the wet meadows at MICM to promote warm-season native prairie species and to reduce encroachment by tree and shrub species. The affects of burning inside exclosures were also examined in the study.

METHODS

Long-term vegetation composition and cover changes were monitored in this study in relation to wet meadow hydrology and grassland management. Data were sampled in six permanent, 1 m 2 plots located inside seven permanently fenced grassland areas in which cattle and haying were excluded. Each exclosure was oriented perpendicular to the ridge and swale topography. Sample plots were selected to represent a number of elevations including at least one ridge and one swale.

In late July to early August of 1982 through 1987, species composition and percent cover of each species were recorded by cover class (less than 1%, 1-5%, 6-15%, 26-50%, 51-75%, 76-100%) in the permanent plots. River discharge was monitored using records from the United States Geological Survey gauging station located near the Highway 34 bridge over the Platte River, about 13 km downstream of the study site. Groundwater levels were monitored monthly in several wells at the site by lowering a weighted tape from the top of the well casing to the water level. More frequent groundwater measurements were taken during some periods. From 1982 to 1984, Trust staff measured groundwater levels. In 1985, 1986, and 1987, well measurements were conducted by the Bureau of Reclamation. Groundwater levels were recorded at absolute elevations above sea level but for ease of analysis were converted to centimeters above elevation 578.0 m. Total monthly precipitation and average monthly temperature data were obtained from the National Weather Service for the Grand Island Station. Prescribed burns were conducted throughout the study. The percentage of permanent sample plots burned was monitored each year.

Mean cover values for each species were calculated by year (1982-1987), as were May-August values of a number of environmental parameters. The May-August period was chosen since it represented the major portion of the growing season when moisture conditions had the greatest direct influence on wet meadow plants. The environmental parameters included river discharge (total, maximum, and minimum), groundwater elevation (maximum, mean, and minimum), precipitation (total and deviation from normal), temperature (mean and deviation from normal), and whether or not an area had been recently burned. Species cover values were analyzed according to four moisture classes (wet, medium-wet, medium-dry, dry) based on elevation. The total elevational gradient of 1.8 m from swale to ridge top was divided into four equal classes representing 0.45 m. Mean cover values were compared statistically ($P < 0.05$) by year with oneway analysis of variance (ONEWAY procedure) (Norusis 1986). Tukey's test ($P < 0.05$) was used to determine which means were within the same range. When significant differences were determined, stepwise multiple regression ($P < 0.05$) was used to investigate relationships between mean cover (dependent variable) and the measured environmental parameters (independent variables).

RESULTS

During the study, precipitation and ground water elevation followed cyclical patterns with relatively low levels during fall and

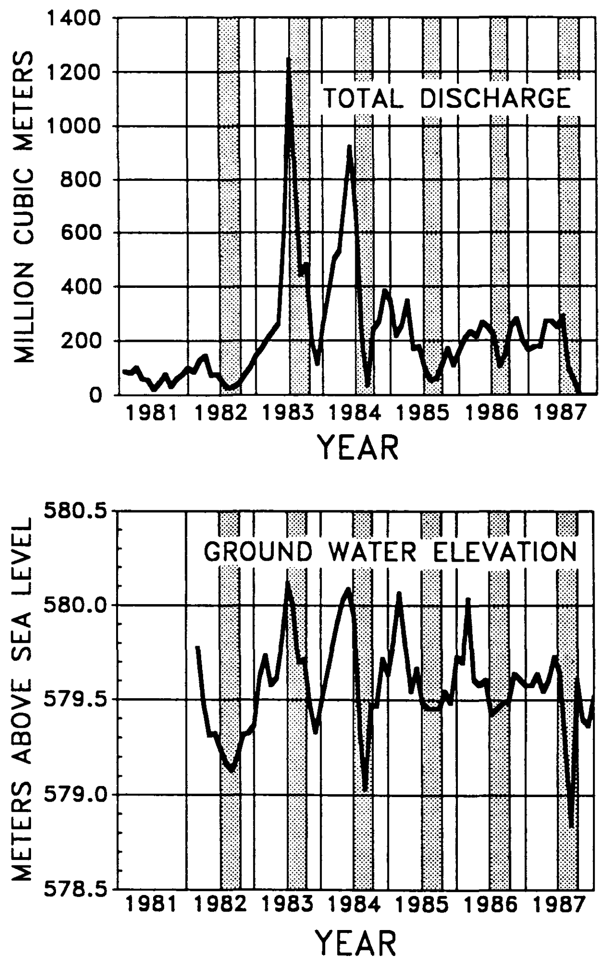

FIG. 1. Monthly river discharge and groundwater elevation during the study. Shaded areas indicate the May-August growing season.

Table 1. Summary of environmental parameters during the growing seasons from 1982 through 1987.

Parameters	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*
Discharge:						
Total (million m^3)	182	3109	1834	395	732	696
Mean (m^3/sec)	17	295	174	38	69	66
Maximum (m^3/sec)	67	666	425	129	178	185
Minimum (m^3/sec)	2	80	9	8	16	5
Groundwater level (cm above elevation 578.0 m):						
Mean	121	190	160	151	149	136
Maximum	132	211	208	166	160	172
Minimum	113	169	103	145	142	84
Precipitation (mm):						
Total	490	347	342	355	302	367
Deviation from Normal	+119	-8	-13	-1	-53	+11
Temperature (C):						
Mean	21.0	22.5	22.3	21.3	21.9	22.5
Deviation from Normal	-2.5	+3.8	+2.2	-1.9	+0.5	+3.0
Burning (%):						
Wet Moisture	54	54	8	46	0	0
Medium Wet Moisture	82	46	100	73	0	54
Medium Dry Moisture	23	54	54	31	46	46
Dry Moisture	100	100	100	0	0	0

winter and peaks in spring and early summer. Total precipitation was above normal in all years except 1986. Although cyclical, the timing of peak ground water levels differed between years. For instance, in 1983 and 1984, peaks occurred during the May through August growing season, while in 1985 and 1986 the peaks occurred earlier in the spring (February) and probably had little direct influence on plant growth (Figure 1). Groundwater levels in 1983 and 1984 reflected extremely high sustained flows in the Platte in mid-1983 (maximum = 666 m^3/sec) and in mid-1984 (maximum = 425 m^3/sec). Environmental conditions during the May through August growing season generally paralleled annual patterns (Table 1). Ground water and discharge were high in 1983 and 1984, while precipitation was high in 1982 and low in 1986. Temperature was relatively uniform throughout the growing season during the six years of the study.

Species Distribution

During the study, 91 species were recorded in the permanent plots. Individual species were, for the most part, distributed unimodally along a moisture gradient from swale to ridge top (Figure 2). It should be emphasized that these were general distribution patterns, since species abundance and distribution shifted along the gradient in response to environmental conditions. Water smartweed (*Polygonum amphibium* L.) was narrowly distributed in wetland sites, but other wetland species such as water sedge (*Carex aquatilis* Wahl.) and American bulrush were widely distributed. The major prairie grasses, switchgrass, indiangrass, and big bluestem had overlapping distributions in the middle of the moisture gradient, however, switchgrass was associated with wetter sites, indiangrass with intermediate sites, and big bluestem with drier sites. Redtop (*Agrostis stolonifera* L.) and smooth brome (*Bromus inermis* Leyss.), are introduced grasses that appeared along the gradient in direct competition with switchgrass and big bluestem, respectively. Many-flowered aster and common ragweed (*Ambrosia artemisiifolia* L.) were ubiquitous along the gradient. Aster was skewed towards higher elevations, while ragweed had a bimodal distribution with peaks at both high and low elevations, where disturbed sites allowed colonization.

Temporal Changes in Species Cover

Of the 91 species sampled in the study, six were chosen for detailed analysis because they showed statistically significant ($P < 0.05$, one-way ANOVA) responses from year to year (Table 2). These species included water sedge, spikerush, and American bulrush, which are characteristic of lowland sites, and indiangrass, big bluestem, and switchgrass, which dominate intermediate slopes. Species responses were similar for each of the four moisture classes (Figure 3). Sedge (+37%) and bulrush (+14%) increased substantially between 1982 and 1984, when discharge and groundwater levels also increased. Spikerush (+36%) and indiangrass (+22%) also responded positively to this wet period but they peaked early in 1983. At medium wet sites, however, sedge and spikerush continued to increase until 1985, even though groundwater and discharge levels had already declined substantially (Table 1). Following the peak cover values in 1983, 1984, and 1985;

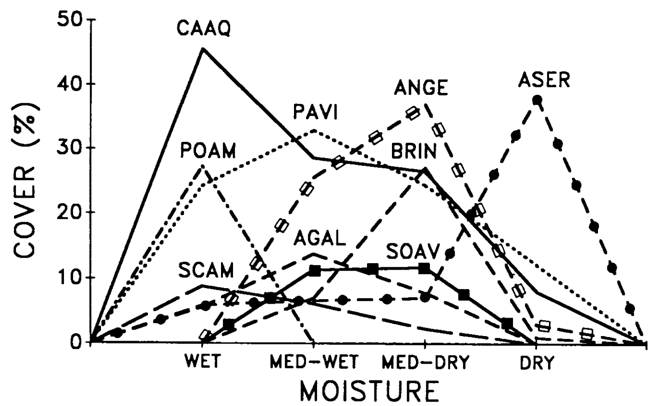

FIG. 2. Distribution of major species along the topographic (moisture) gradient. Wet represents the bottom of the swales while dry represents ridge tops. (CAAQ = water sedge, SCAM = American bulrush, POAM = water smartweed, PAVI = switchgrass, SOAV = indiangrass, ANGE = big bluestem, AGAL = redtop, BRIN = smooth brome, ASER = many-flowered aster).

Table 2. Statistically significant (P < 0.05, one-way ANOVA) responses of major species during the 1982-1987 period (+ = significant increase, - = significant decline). The year of peak increase or decline is provided for the overall population and for each moisture class. NS = not significant.

Species	*Overall*	*Wet*	*Moisture Class Medium wet*	*Medium dry*	*Dry*
Water sedge	(+) 1984	(+) 1984	(+) 1985	NS	NS
Spikerush	(+) 1983	(+) 1983	(+) 1985	(+) 1983	NS
American bulrush	(+) 1984	(+) 1984	(+) 1984	NS	NS
Indiangrass	(+) 1983	NS	(+) 1983	(+) 1983	NS
Big bluestem	(-) 1984	NS	(-) 1984	NS	NS
Switchgrass	(+) 1985	NS	(+) 1985	(+) 1984	NS

Table 3. Stepwise multiple regression equations associated with mean cover of major species during the 1982-1987 period[1]. Environmental parameters were measured during the growing season (May-August).

Water sedge	y = (27.86)(MEANGW)-(0.45)(MINQD)-18.9	$R^2 = 0.18$
Spikerush	y = (13.15)(MEANGW)-10.41	$R^2 = 0.28$
American bulrush	y = (5.57)(MAXGW)-(0.09)(MINQD)-6.39	$R^2 = 0.24$
Indiangrass	y = (7.18)(MAXGW)-8.25	$R^2 = 0.29$
Big bluestem	y = (14.68)(BURN)-(7.25)(MAXGW)+46.65	$R^2 = 0.11$
Switchgrass	y = (-0.17)(TOTPC)+(8.70)(BURN)+84.33	$R^2 = 0.20$

[1]MEANGW = mean groundwater elevation, MINQD = minimum river discharge, MAXGW = maximum groundwater elevation, BURN = percentage of plots burned, TOTPC = total precipitation.

sedge, bulrush, spikerush, and indiangrass all declined to near their former levels. Big bluestem (-28%) responded negatively to the high water period, declined until 1984, and then began to recover to its former level. Switchgrass (+ 24%) increased substantially between 1982 and 1985, during the high water period, but unlike the other species, it was able to maintain its increased cover after water levels declined.

Except for switchgrass, ground water parameters (mean and maximum ground water elevation) were the overriding environmental variables associated with cover changes (Table 3). Although the R^2 values for the regression equations in Table 3 are relatively low (0.11 to 0.29), the equations themselves were highly significant. This indicated that the equations could be used with confidence to identify relationships between cover changes and environmental parameters, but because of high variability (low R^2 values) in the data, the equations are not useful in predicting the exact relationship. Sedge, spikerush, bulrush, and indiangrass were positively related to high groundwater levels. Sedge and bulrush were also negatively related to minimum discharge in the river. Big bluestem was negatively related to high ground water, but positively related to burning. The decline of big bluestem from 1982 to 1984 was directly related to high ground water, but its subsequent recovery was promoted by both declining water levels and burning. Big bluestem was also negatively affected by overbank flooding in 1983 which inundated a few of the permanent plots. The duration and magnitude of the flooding, however, was not monitored.

Switchgrass cover values were not directly related to groundwater levels, but were positively related to burning and negatively related to precipitation. High ground water in 1983 and 1984 was coincident with the rapid expansion of switchgrass. When groundwater levels declined, however, there was no corresponding decline in cover. It is not immediately clear why switchgrass cover should be negatively related to precipitation.

DISCUSSION

Major changes in species cover occurred in this study following a 1-in-50 year high water period in 1983 and 1984. Unusually high soil moisture conditions were created in the wet meadows at Mormon Island during this period. Although most species responded directly to changes in mean or maximum groundwater levels, they also responded indirectly to river stage because there was a high correlation (0.89 to 0.92) between maximum, mean, and total discharge, and mean and maximum groundwater levels during the May-August growing season.

In contrast, there was little relationship between May-August precipitation and groundwater levels. Summer precipitation was fairly consistent from year to year during the study, and clearly was not the primary factor driving fluctuations in groundwater levels (Table 1). Although precipitation patterns undoubtedly affected plant growth, the high rainfall and low variability during the study probably masked any differences in species cover values.

Annual cycles in precipitation, groundwater elevation, and river discharge are common at MICM although the magnitude and timing of these fluctuations are variable and unpredictable (Figure 1). Because the elevational gradient on the island is very shallow (ranging only 1.8 m from swale to ridge top), as much as 10%-35% of the land surface can be covered by water sometime during the spring as a result of precipitation, high groundwater levels, and snowmelt. During these high moisture periods, 25% to 50% of the surface soils are saturated.

Precipitation alone, however, may have little effect on species cover depending upon the time of year and the rate of percolation and runoff. In early spring, when there is little plant growth, moisture levels may have little influence on cover values. In addition, river stage and groundwater elevation affect surface drainage and percolation, allowing water to pond on the surface of the meadows for extended periods during high water conditions. When such conditions occur during the growing season, species cover values may be significantly affected. This could be the case in this study. Some surface water ponding occurred in several areas in 1983 and 1984 when groundwater levels and river stage were high, but the duration and magnitude of these conditions were not monitored. In any case, changes in species cover were not directly related to precipitation events, but rather to the groundwater levels.

Although some level of minimal soil moisture undoubtedly is necessary to sustain wet meadow species (particularly hydrophytes such as bulrush, spikerush, and water sedge), it is uncertain whether precipitation or groundwater alone can meet this need. Further studies to determine the physiological moisture requirements of wet meadow species and the relative contributions of precipitation and groundwater are needed.

Fluctuating water levels are an important component of nearly all wetlands (Duever 1987). Because environmental conditions such as moisture levels at a site change from year to year, the vegetation is constantly adapting to a unique, new set of biological and physical conditions. Except for switchgrass, the changes observed in this study in response to the high water condition in 1983 and 1984 appear to be temporary and cyclical with species abundance returning to near pre-1983 levels within a few years. Switchgrass, in contrast, maintained its increased cover value even when water levels declined. This species may simply be more resilient to low moisture conditions and may persist for a longer period of time before declining. Between 1985 and 1987 switchgrass declined slightly (Figure 3), suggesting a slow downward trend.

Platte River wet meadows are an uncommon remnant of the once widespread complex of marshes, sloughs, and other wetlands along the river complex. Since the 1840s these wetlands have been systematically ditched, drained, and converted to cropland. The remaining wet meadows are a unique natural resource supporting lowland prairie and wetland plants, a host of vertebrate and invertebrate organisms and many species of migratory birds. Groundwater, river stage, and precipitation patterns are constantly changing, making it difficult to understand the interrelationship between these components and the response of wet meadow flora and fauna to these fluctuations. This study is a first step in outlining the complexities of the system and documenting changes in the abundance of certain wet meadow plants in relation to groundwater and surface water. Additional long-term studies to monitor surface and groundwater fluctuations and the relationships between soil moisture and the distribution and abundance of macroinvertebrates and wet meadow plants are needed before we will understand enough about the system to manage and maintain it.

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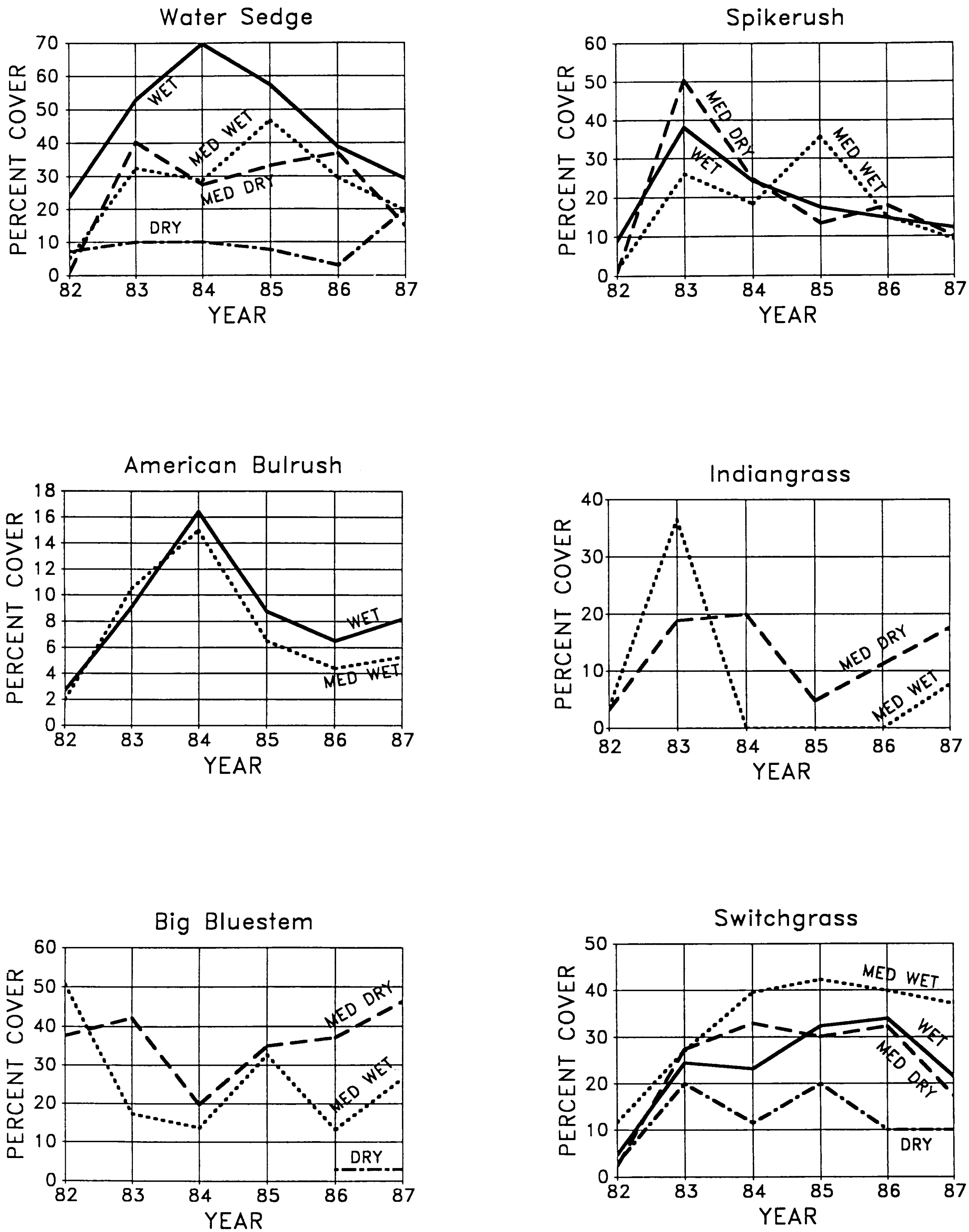

FIG. 3. Changes in percent cover of 6 major species during the study. Curves for each elevation at which a species occurred are shown.

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