1-1-1980

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1980. *Transactions of the Nebraska Academy of Sciences,* VIII:77-90.

PLATTE RIVER ISLAND SUCCESSION

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This study was designed to determine successional trends of soils and vegetation on Platte River islands in central Nebraska and to elucidate interactions between them through time.

Twenty study islands from five age-size classes were randomly selected in a 48 km stretch near Kearney, Nebraska. The age of islands was determined by use of aerial photographs. Woody and herbaceous plant species were sampled systematically, and soil cores were analyzed for organic matter and texture at each island. Relative elevation at each sampling plot was determined.

There were 20 islands per linear kilometer in the study area larger than 0.04 ha (0.1 acre). Growth of islands was primarily due to merging of smaller islands and averaged 0.02 ha per year.

Tree stands were dominated by cottonwood and sandbar willow, and herbaceous stands by cocklebur. Stands were most often in a young successional stage regardless of island age. A trend toward more organic matter, finer-textured soils, and higher elevation occurred with older age. Species diversity and percentage of perennial herbaceous species also increased with age.

Flooding and drought seemed to account for the age structure of trees observed and probably for much of the soil structure and island growth.

† † †

INTRODUCTION

The Platte River in Nebraska has undergone considerable change in recent history. The river channel has narrowed and a larger proportion is occupied by vegetated islands. Also, smaller discharges are present now as compared to pre-development (Williams, 1978: Fig. 1). Many investigators have speculated about the role of reduced flows in the Platte on island formation and vegetation establishment. Only sketchy reports exist to substantiate vegetative encroachment due to reduced flows, and little is known about successional patterns on the islands. Studies of vegetative succession and soil development along rivers in Nebraska are few. Rand (1972, Unpublished report to University of Nebraska Water Resources Institute) studied succession on the Republican River, and Kapustka (1972) looked at the role of cottonwoods in early succession on the Platte River in eastern Nebraska. Ruby (1952) investigated forage production on North Platte River islands in Nebraska.

FIGURE 1. Aerial photographs of the Platte River near Kearney, Nebraska, showing change from open channel in 1938 (above) to braided channel interspersed with vegetated islands in 1969 (below). Photos cover about 8 km of river.

The purposes of this study were to:

1. Describe differences in soils and vegetation stands of different aged islands;

2. Determine relationship between soil changes and vegetation changes; and,

3. Determine if and how rapidly an island grows vertically due to soil trapping by vegetation and horizontally due to stabilization of adjacent sand bars.

METHODS

Island Selection and Plot Location

An island within the Platte River may be defined as a vegetated land mass, surrounded by water. Islands sampled were limited to those entirely within the study areas (Fig. 2) and ranged from 0.04 ha to 6 ha (0.1 acre to 15.0 acres). Primary selection of islands was made from false-color infrared film taken on 7 April 1977 (scale 1:36,000). The study areas (Fig. 2) were 16 km apart and 3.2 km wide.

Islands were grouped according to size with size one ranging from 0.04 ha to 2.8 ha (0.1 acre to 7.0 acres); size two included islands larger than 2.8 ha acres and not larger than 6 ha (7.0 acres to 15.0 acres). Island-age classification was as follows: Age one more than 40 years; age two was 21 years to 40 years; age three, 9 years through 20 years; and age four was 1 year through 8 years based upon islands being present for aerial photographs 1938, 1957, 1969, and 1977, respectively.

Acetate overlays showing island size and location were made of each study area from the 1977 infrared film used for island selection. This involved photographing the desired film frame, making black and white prints (scale: 12.7 cm per km), and attaching a cover sheet of acetate. These enlargements will be referred to as the **1977 mosaics**.

Island boundaries, determined from the infrared film using variations in color tones and contrasts, were traced on the acetate overlays. Then each island was assigned a number and grouped according to its size range (*see above*). Sizing the islands was accomplished in three ways: (a) visual inspection of the 1977 mosaics; (b) a calibrated Whipple disc in the infrared viewer (accurate for smaller islands); and (c) planimetry of 1977 mosaics (best for larger islands).

After size and age were determined, islands were assigned identification numbers and divided into groups for random selection. Alternate islands were selected for each category in the event of elimination of an island if field examination showed evidence of recent disturbance.

If the island was found undisturbed, a permanent marker (steel post) was placed at the approximate center of the island. From this point, transects were established at 60 m intervals toward head and tail of the island. Island edges were flagged to correspond to boundaries assumed for April 1977.

Islands smaller than 0.04 ha or larger than 6.00 ha were excluded. Few islands were larger than 6.00 ha. The islands less than 0.04 ha, although numerous (Table I), were too small to sample.

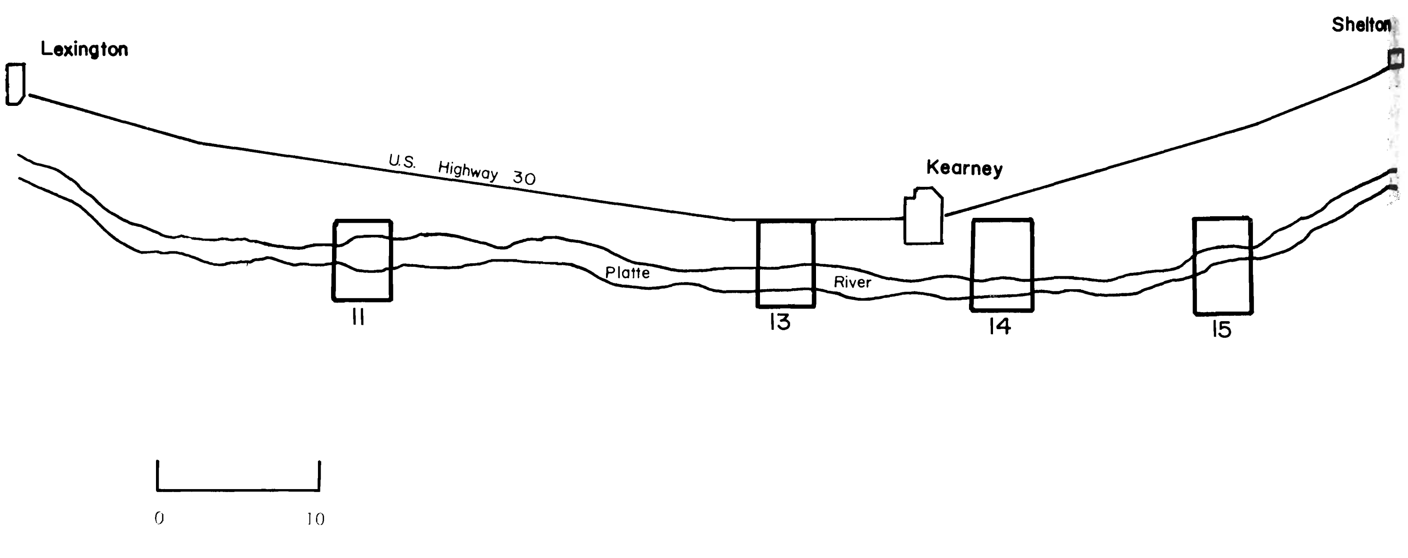

FIGURE 2. Location of study transects.

TABLE I. Distribution of islands by age in 12.8 linear kilometers of Platte River.

Age (Years)	Number of Islands	Percentage of Total	Percentage per Year
> 40	59	23.3	1.55†
21-40	61	24.0	1.26
9-20	52	20.6	1.72
1-8	72	28.5	3.17
Total	244*		

*One hundred seventy-six islands were present which were less than 0.04 ha.

†Assuming a 55-year midpoint for this age class. This midpoint is suggested both by height and size of more than 40-year-old islands. Height and size predicted by annual growth-rates of known-age islands equal actual sizes and heights if a 55-year-old midpoint is assumed.

Islands larger than 2.8 ha were almost all more than 40 yrs old and constituted a fifth class of islands for each transect. Twenty randomly-selected islands from four study areas (Fig. 2) constituted the study islands.

Vegetation Sampling and Analysis

Ten meter-wide belt transects in which woody vegetation was sampled were placed on each study island with centers 60 m apart, and edges sampled every 120 m (every other transect).

At least three quadrats were located on each belt transect: both edges and center of the island. If an island was more than 120 m wide, an additional quadrat was located on the belt transect. At least five quadrats were taken at each island (head, tail, center, and both sides of center). A maximum of 33 quadrats was located on the largest island sampled (5 ha).

Herbaceous vegetation was sampled in 1 m X 1 m quadrats and woody vegetation in the 10 m X 10 m quadrats at each location. Braun-Blanquet cover abundance ratings were given each species of herbaceous vegetation (Mueller-Dombois and Ellenberg, 1974). Importance values were calculated for herbaceous species by island age-size groups using relative frequency plus relative cover abundance values for each species or genus.

At each quadrat where woody vegetation was studied, density, diameter at breast height, and age of each tree or shrub was determined by coring. Basal area and importance value (sum of relative density, relative frequency, and relative basal area) were computed for each species at each quadrat.

An index of maturity for woody vegetation stands was computed for each age-size class of islands. This index was based upon succession sequences of species found by Rand (1972, Unpublished report to University of Nebraska Water Resources Institute) on the Republican River in Nebraska and Wilson (1970) on the Missouri River in South Dakota. Numbers were assigned to stands: sand-bar willow 1, cottonwood 2, peach-leaved willow 3, false indigo 4, dogwood 5, box elder 6, and eastern red cedar dominated stands 7.

Coefficients of similarity (CV = 2c / a + b) between age-size island groups were calculated for both herbaceous and woody vegetation. Shannon-Wiener general-diversity indices, $D = 3.32 (\log_{10} N - 1 / N\Sigma n_i \log_{10} n_i)$ were calculated for vegetation by age-size island groups (Cox, 1976).

Island Elevation

Elevation of each quadrat center was determined with a transit. Only relative elevations were determined, with reference points being the bottom of adjacent channel and lowest point on an island. All elevational measurements were corrected for slope of the river bed over the island's length.

Soil Sampling and Analysis

Soil cores (5 cm diameter X 50 cm deep) were taken at the head, tail, center, and each side of center on each island (total of 20 X 5 = 100 cores).

A quantitative profile-description was made of each core including: (1) depth of saturated water table from soil surface; (2) depth of root penetration; (3) number and thickness of soil horizons; (4) depth from surface to the horizons; (5) width of boundaries separating horizons. Horizons were differentiated based on definite color differences, differences in texture, presence of a new or dead rooting-zone, or percentage of organic matter or clay and silt particles; (6) textural classification; (7) percentage of organic matter; and (8) Munsell color designation.

The separation of sand into particle-size classes required oven-drying for approximately 4 hr at 150 C and mechanically sieving the soil vigorously for 8 to 10 min on a Soiltest Model No. CL-388 sieve shaker. Horizons with particles smaller than 0.05 mm were analyzed for proportion of sand, clay, and silt following the Bouyoucos Hydrometer method (Foth *et al.*, 1976). The Walkley-Black method (Black, 1965) was used for determination of organic carbon.

RESULTS AND DISCUSSION

Island Size, Age Distribution, and Growth

There was an average of 20 islands per linear kilometer larger than 0.04 ha in the 12.8 km study stretch. These islands were about equally distributed in each of the four age-classes, but the age classes were of unequal size.

Islands grew in size due in part to merging of several smaller islands. This confounds the analysis of rate of island formation as the greater percentage formed in recent years may be reduced after 10 or 20 years by merging into larger islands. Growth rate of the islands due to merging as well as marginal accession was linear through time, averaging 0.02 ha per year per island.

Vegetation

Descriptive. Two hundred fifty-two quadrats were sampled from the 20 study islands. Importance values for herbaceous species by age-size class are given in Table II and woody species data are shown in Figure 3. Ninety-three herbaceous and 14 woody species were identified.

Woody species differed in location on the islands. All elms and cedars were in interior quadrats, a majority of dogwood and ash were interior, whereas more than half of the willows and indigo bush were on edges of islands.

Comparison by age-size groupings: *Species Diversity.* Although number of species per quadrat did not differ greatly for herbaceous plots among age-size classes, the proportion of perennial *versus* annual did. The trend from primarily annual species on younger islands to perennial species on older islands is especially apparent when looking at importance values for the two groups (Fig. 4).

Species diversity increased from younger to older islands for both herbaceous and woody species (Table III). The div- sity values are averages for all quadrats taken on all islands of an age-size class.

Coefficient of Similarity. Coefficients of similarity (Fig. 5) were greatest between island classes most nearly alike by age; however, the oldest, large islands were greatly dissimilar only to the youngest, small islands (CS = 36%, Fig. 5). Coe- cients along the rim in Figure 5 should be much larger th those along the spokes if plant succession is occurring. though somewhat larger ($\bar{X}$ = 66% for rim values *vs.* 5 for spoke values), the difference is so small that signific plant succession had not occurred as age and size of isl increased.

Age Structure. This apparent lack of significant pl succession as islands age is also shown in Figure 6, where structure of trees is shown by age of quadrat (as determi from aerial photographs). Seedling trees less than 15 cm t which were abundant, were not used in preparation of Fig 6 or 7. The ages of all trees in the 100 m^2 woody quadr were determined. One- to five-year-old trees predominated all age quadrats, although older islands did have a broa range of tree-age distribution. Young islands (less than 9 y contained almost uniform-aged stands with 77% of tr there being less than three years old. Most areas of the isla were apparently suitable for seed germination and seedl growth. Cottonwood and willow made up the majority of tr on the islands and both species preferred low organic mat and bare sand for germination (Kapustka, 1972; Rand, 19 unpublished report to University of Nebraska Water sources Institute). Frequent flooding (Fig. 8) continua deposits sand over developing surface organic layers, th providing continually suitable surface conditions for seedl development. Mortality of the seedlings and young tr must be very high for several years judging from age tributions in Figures 6 and 7. Flooding probably accou for much of the mortality, especially along the island ed and on those portions of islands at low elevation, where established tree stands were present to reduce the erod force of floodwater.

Several years (Fig. 6) show reduced density, indicat either poorer germination or increased mortality when co pared to other years. Many of these "bad" years for t establishment can be explained by flood or drought (Fig. Flooding can erode sand or break off stems especially wh coupled with ice flows. Relatively-small numbers of 6, 9, a 11 to 15-year-old trees may be explained by mortality cau from floods in 1973, 1971, and 1965, respectively. The re tively-small number of 21 to 25-year-old trees may be plained by drought mortality due to lack of flows during the summers of 1952–1957. As many as 130 days of no flow were reported in 1953 at Grand Island.

TABLE II. Importance values of plant genera by age-size class.*

NAME			IMPORTANCE VALUE			
		Size:	0.04 ha - 2.8 ha			2.8 ha - 6.0 ha
Generic	Common	Age: 1-8	9-20	21-40	>40	>40
Agalinus	––			12	4	
Ambrosia	Ragweed	7	6	19	14	15
Apocynum	Dogbane				4	3
Bidens	Beggarticks		16	16	18	12
Bromus	Brome			4	4	6
Carex	Sedge				13	3
Chenopodium	Goosefoot		5	4		
Cyperus	Nutgrass	30	9	11	5	5
Echinochloa	Barnyardgrass		3	2		
Eleocharis	Spike-rush		33	16	13	12
Equisetum	Horsetail				3	8
Eragrostis	Lovegrass	23	5	2	8	3
Erigeron	Fleabane			5	5	3
Frageria	Strawberry			2		3
Galium	Bedstraw			3	3	5
Hordeum	Barley	3	5			6
Juncus	Rush	22	40	14	10	6
Koeleria	Junegrass	12	4	2	10	4
Lepidium	Pepperweed		4	3	3	3
Lycopus	Bugleweed		2			3
Medicago	Alfalfa, Medic	3		4	10	9
Mentha	Mint			2	3	
Parthenocissus	Virginia Creeper			2		3
Phalaris	Canarygrass			3		3
Phyla	Fogfruit		3	10	9	16
Plantago	Plantain	3	4	2	3	
Poa	Bluegrass			3		10
Polygonum	Smartweed	14	29	19	10	7
Polypogon	Rabbitsfoot Grass	7	5	2		
Rosa	Rose					9
Rumex	Dock	8	2	3	3	7
Scirpus	Bulrush	8	12	24	16	25
Smilacina	Spikenard				3	2
Solidago	Goldenrod			13	16	19
Spartina	Cordgrass			2	8	11
Toxicodendron	Poison Ivy					9
Typha	Cattail	7				
Vernonia	Ironweed	4		29		
Veronica	Speedwell	18	35		9	3
Vitis	Grape				6	12
Xanthium	Cocklebur	124	70	66	73	37
Other genera		7	8	1	14	18
TOTAL		300	300	300	300	300

*Only genera contributing importance values more than 5 in 2 or more age-size classes were included.

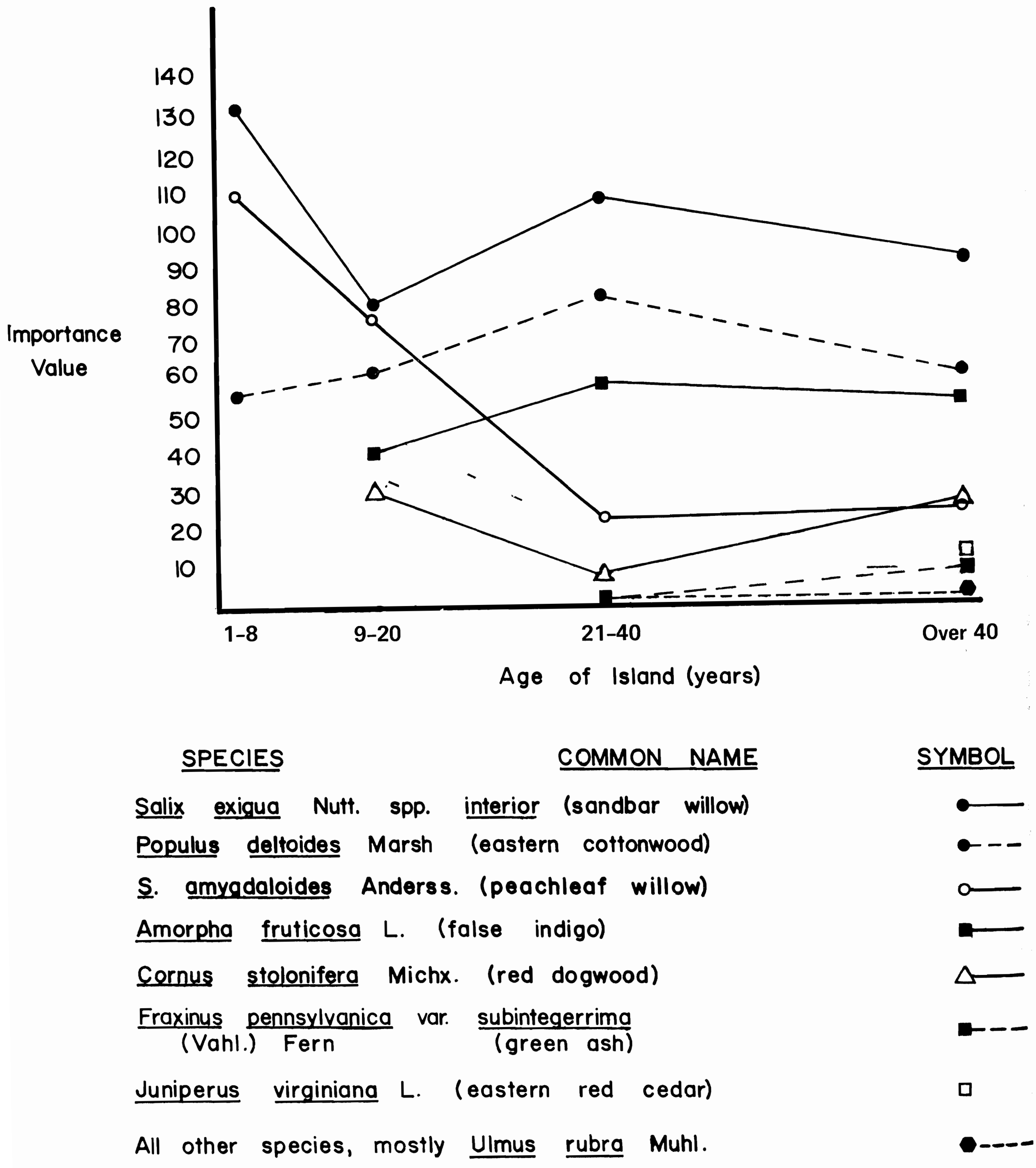

FIGURE 3. Importance values of woody species found on islands grouped by age.

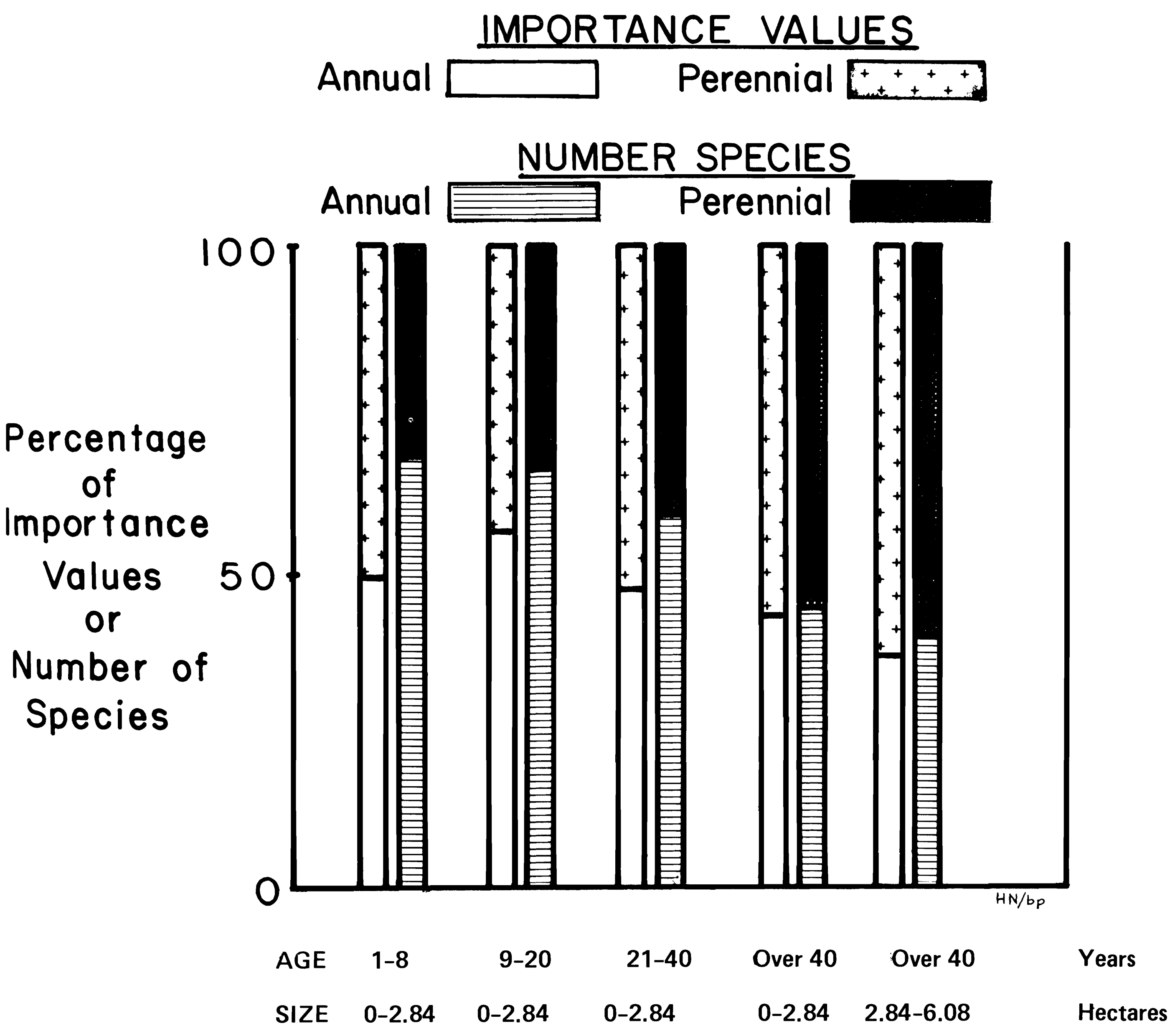

FIGURE 4. Annual *versus* perennial herbaceous-vegetation compared by age-size class.

TABLE III. Shannon-Wiener species diversity by island age-size class.

	Size:	0.04 ha to 2.8 ha				2.8 ha to 6.0 ha
Plant-type	Age (years):	1-8	9-20	21-40	>40	>40
Herbaceous		3.38	4.11	4.71	4.89	5.85
Woody		1.62	2.49	2.12	2.23	2.90

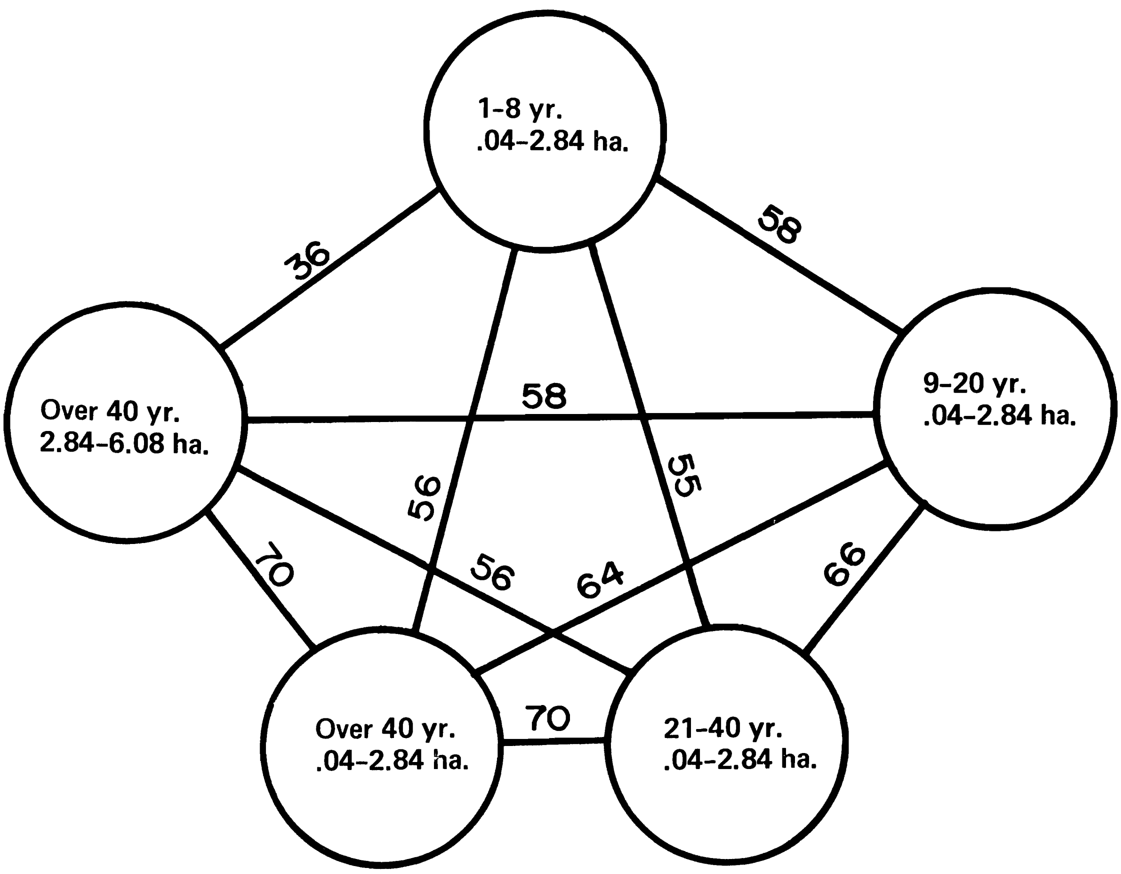

FIGURE 5. Coefficients of species similarity between islands of different age-size classes. Coefficients are averages of herbaceous (based upon cover-abundance ratings) and woody (based upon basal area). Four islands occur in each age-size class.

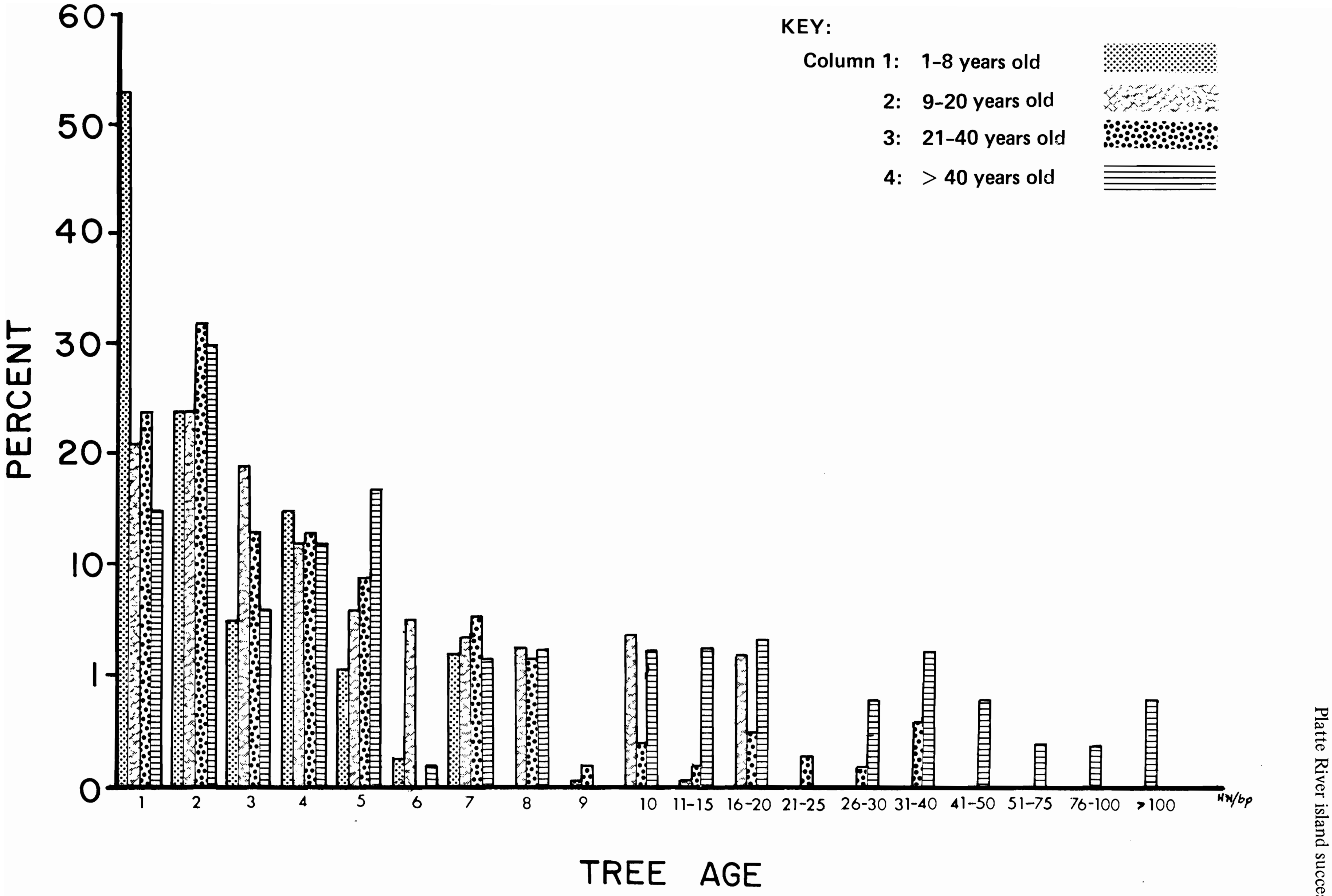

FIGURE 6. Tree age structure using only center quadrats

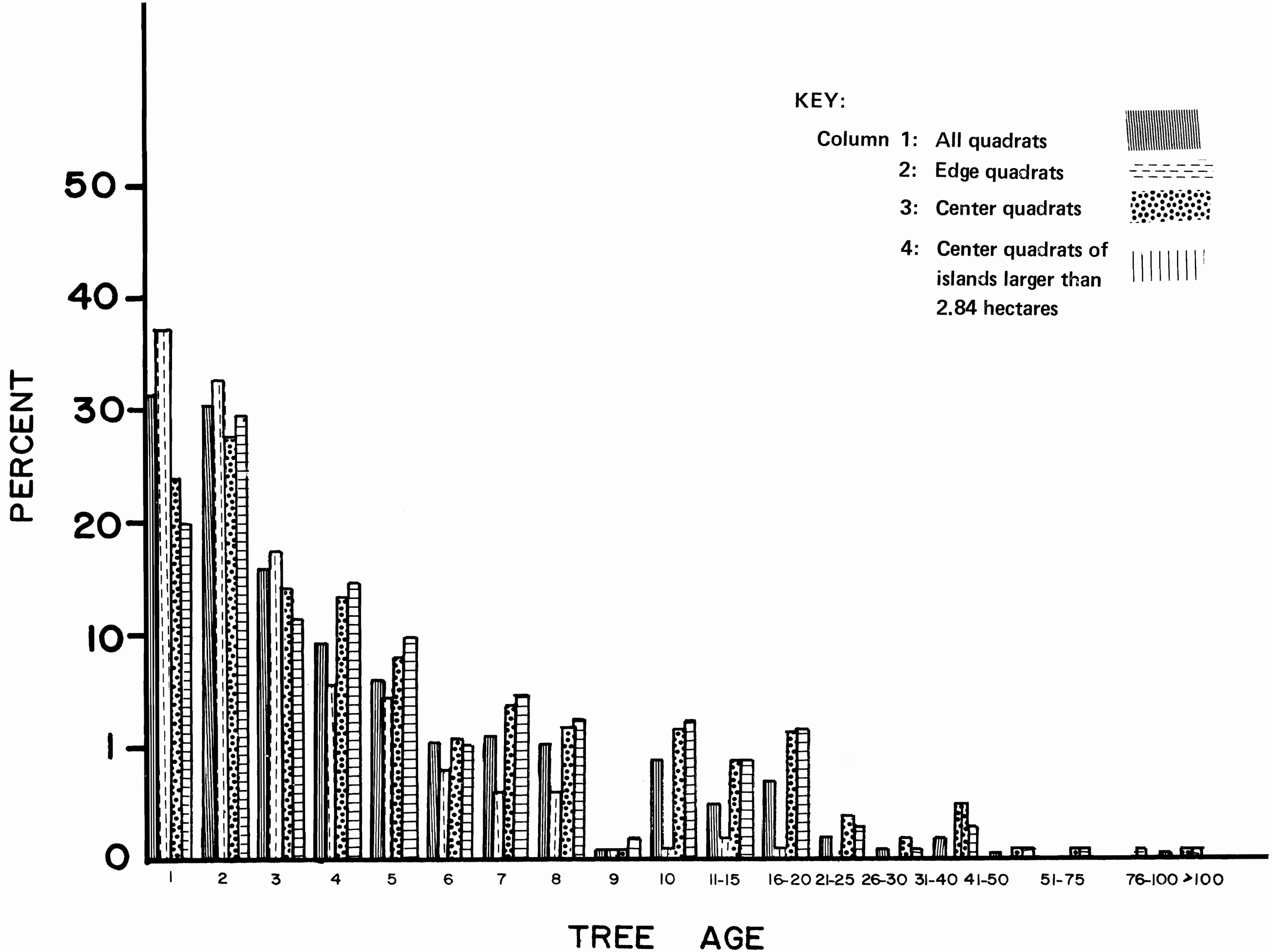

FIGURE 7. Tree age structure for Platte River islands.

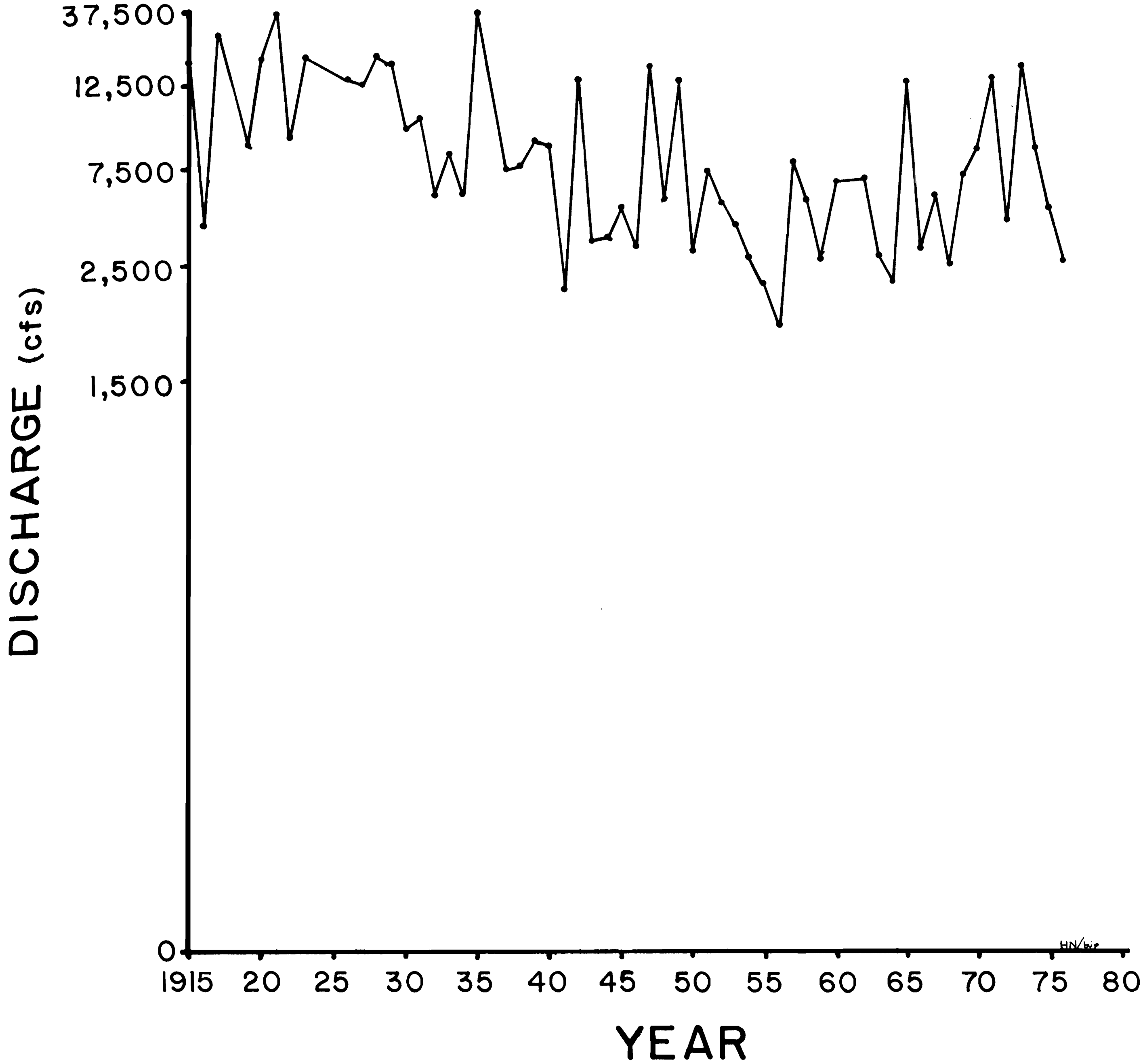

FIGURE 8. Instantaneous maximum discharges for the year at the Overton gauging station. (Data from USGS.)

Flooding, especially when combined with ice, can cut off all young trees on an island. This phenomenon frequently resulted in uniform-aged stands of willows (*e.g.*, 7 yrs) which originated from older (*e.g.*, 28 yrs) buried stems. To assess properly the tree age on the islands, almost all trees would have to be dug up to see if they originated from an older tree. This preponderance of shoot stems arising from older, buried bases was found especially in sand-bar willow, but also occurred in cottonwood (Everitt, 1968) and probably accounts for much of the young-age distribution on older islands.

Regression Analysis. Age of the quadrats, as determined from aerial photographs, was predicted fairly well from data collected for woody species. A multiple correlation coefficient of 0.76 was obtained in predicting island age by using importance values and basal area of the dominant tree species on the islands. The oldest tree of any species in a quadrat accounted for 66% of the variability in quadrat age on transects 11 and 13 (Fig. 2). The oldest cottonwood tree in the quadrat had almost as great predictability, producing an R^2 of 0.58 when regressed against quadrat age-rank. Total basal area of all tree species in a quadrat predicted quadrat age well also (R^2 = 0.58), indicating greater tree growth on older quadrats.

Mature forest stands (with an index over 3.0) should have heavy shade and relatively-high soil organic matter which retard growth and germination of the willows and cottonwoods prevalent in young stands. Eighteen quadrats contained stands with an index of maturity exceeding 3.0. These 18 stands averaged 1.38% organic matter compared to 0.58% for 72 stands with a maturity index of less than 3.0 ($P < 0.001$). All of the 18 mature stands had either high soil organic matter (> 0.6%) or contained trees old enough to produce intense shading (>20 years old).

Herbaceous Plant Succession. Xanthium strumarium dominated the herbaceous vegetation on all age-size classes (Table II). However, the cocklebur was found primarily in a ring around the older islands where the soil was younger and also more disturbed by spring floodwaters. Cocklebur had only about one-half the importance value on large, old islands as on small, old islands. This is probably an artifact due to the systematic sampling because more interior quadrats were taken on larger than smaller islands.

Several genera seemed to characterize older islands (*e.g.*, most perennial grasses, dogbane, sedges, horsetail), whereas several others characterized younger islands (*e.g.*, cattails, annual grasses).

Some plants having extensive rhizomatous root-systems were instrumental in island-margin stabilization and resulted in lateral expansion of the island. An example would be *Scirpus* species, which were primarily found at edges, heads, and tails of islands.

Woody Plant Succession. Vines, and low shrubs were found only on old (40 yr) islands (*e.g.*, rose, grape, Virginia creeper, poison ivy; Table II).

The oldest successional stage for woody species was composed of dogwood, red cedar, peachleaf willow, green ash, and slippery elm.

Soil Development

Averages and standard deviations for soil parameters tested are given in Tables IV and V. Island-soil profiles ranged from graded sands similar to bed material to loams with distinct profiles. However, most of the 100 cores analyzed contained numerous ($\bar{X}$ = 3.9, SD = 1.8) thin, textural, or organic horizons with distinct boundaries.

These textural horizons (different grades of sand, or silt and clay) were probably deposited during floods. No significant correlation exists between numer of horizons and age of island. However, island age was correlated with island elevation ($r = +.27, P < .05$) which in turn was positively correlated with textural maturity (*i.e.*, relatively high percent of silt and clay). Lack of correlation between numer of soil horizon and age may be due to much vertical mixing of soil by animals, especially by the ant, *Formica bradleyi*, which was very abundant on many islands.

Layers of organic matter a few centimeters (2 cm–5 cm) thick were perhaps buried organic horizons which developed near the surface from terrestrial plant litter, but they may be due more frequently to algal mats washed up on banks of the island, and then covered by layers of sand during higher flows. The positive correlation ($r = +.66, P < .001$) between organic-matter content and percentage of clay, and absence of significant correlation between either clay or organic matter with age, support this hypothesis. Still pools are where algal populations build up enough to produce the mats, and this is also the only location where suspended clay will settle out of the water column.

TABLE IV. Soils data, based upon 100 soil cores taken from 20 study islands.

Parameter	Unit	Mean	Standard Deviation
Organic matter	%	0.77	0.88
Textural maturity*	–	2.67	1.20
Sand and gravel	%	86.29	22.45
Silt	%	11.25	11.98
Clay	%	2.46	2.75
Soil horizons	No.	3.92	1.81
Herbaceous root-depth	cm	20.26	10.70

*An index where 1 = coarse sand with low water and nutrient holding capacity and 8 = loam texture with relatively high water and nutrient holding-capacity.

TABLE V. Selected soils data by island age.

Parameter	Unit	1-8 yrs		9-20 yrs		21-40 yrs		> 40 yrs	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Clay	%	2.2	2.5	2.3	2.9	3.1	3.4	2.7	2.8
Organic matter	%	0.9	1.1	0.7	0.8	0.5	0.4	0.5	0.2
Soil horizons	No.	3.8	2.0	4.0	1.8	3.7	1.5	2.9	1.2
Surface silt + clay*	%	12.4	11.8	12.0	15.1	11.3	12.6	30.4	21.2
Textural maturity	–	2.8	1.2	2.5	1.3	2.5	1.2	3.4	1.1
Sample size	No.	37		36		12		9	

*Top 5 cm of soil.

Plant roots seemed to concentrate in the organic layers, and a positive correlation ($r = .41$, $P < .001$) existed between maximum depth of root penetration by herbaceous vegetation and number of horizons present. Thus, algal growth may be important in terrestrial plant-growth on young infertile islands by extracting nutrients from nutrient-poor water, then concentrating them in buried horizons where terrestrial plant-roots concentrate and extract nutrients. Wells and Shunk (1931) suggested that low nitrogen-content of sands results in slow seral progress. Cowles (1901) stated that low water-content of sandy soils can be overcome by accumulation of thin layers of humus.

Number of soil horizons was weakly correlated ($r = +.27$, $P < .05$), with island elevation. This relationship should be stronger if the horizons were due to soil-particle trapping by vegetation. Erosion during flooding may have been continually intense enough to erode developing soil, thus preventing greater development of the soil.

Elevation did increase with island age. Islands older than 40 years were 0.76 m ± 0.46 ($\bar{X}$ ± SD) higher than adjacent channel, 21-40-year-old, 0.57 ± 0.66 m taller; 9-20-year-old, 0.43 ± 0.34 m; and 1-8-year-old islands only 0.32 ± 0.31 m above the channel surrounding the islands. Islands were generally very flat, with no large elevation formed even on older islands.

Location of the soil sample on an island was an important factor affecting organic-matter content and soil textural-maturity. Samples taken from island sides had significantly ($P < 0.05$) more organic matter than did tail, head, or center samples (1.06% *vs.* 0.6%, 0.5%, and 0.6% respectively) and sides and center had more mature soil texture. Island sides typically were covered with thick willow stands capable of trapping soil particles and adding surface layers of organic matter due to leaf fall. Island centers were usually older than other locations but were drier during low flows. Wilting of annual herbaceous species was noted in July and August at the center of even moderate-sized islands but not on edges.

Eastern red cedar, the woody species most intolerant to inundation (Teskey and Hinckley, 1977), was found in only 10 quadrats which averaged 0.85 ± 0.54 m elevation, perhaps indicating a preference for islands not inundated for long periods during flood episodes.

Although the soil and woody-species successional trend seems similar to that expected, it is characterized by much variation. Some variation is no doubt due to effects of man not evident at sampling time. Overgrazing, logging, bulldozing, and other past activities would affect patterns greatly.

Succession to mature forests on sandy substrates is a slow process and most islands studied were less than 50 years old. The oldest trees found were about 110 years old, so even the oldest islands have probably not been stabilized for much more than a century. Almost yearly flooding up until 1940 probably removed much of the vegetation periodically. High water episodes since establishment of Lake McConaughy (1940) have apparently been adequate to keep woody stands at an early successional level, but not adequate to remove newly-formed islands completely, as occurred in the past.

ACKNOWLEDGMENTS

Funding for this study was from a National Science Foundation Student Originated Studies grant No. SPI78-03495. The U.S. Fish and Wildlife Service provided a vehicle, driver, equipment, and aerial photographs for project use. Special thanks are due Charles Frith, Northern Prairie Wildlife Research Center, and Gene Miller, Ecological Services Office of U.S. Fish and Wildlife Service, Grand Island, Nebraska, for consulting on survey and photogrammetry techniques, and to Rusty Kologiski, Northern Prairie Wildlife Research Center, for reviewing the manuscript.

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