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The phytogeomorphology of the Niobrara region near Meadville, Nebraska.

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THE PHYTOGEOMORPHOLOGY OF THE NIOBRARA REGION NEAR MEADVILLE, NEBRASKA

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by
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THESIS ACCEPTANCE

Acceptance for the faculty of the Graduate College, University of Nebraska, in partial fulfillment of the requirements for the degree Master of Arts, University of Nebraska at Omaha.

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ABSTRACT

One of the most phytogeomorphologically unique areas of Nebraska occurs along the Niobrara River Valley north of the community of Ainsworth. Not only is this an area where Rocky Mountain, Eastern Deciduous and Northern Boreal Forests converge, but it is also an area of relatively recent geomorphic activity. Landslides are known to have occurred here; there is evidence of very recent, active movement as well as older, stabilized landslides.

The purpose of this study was to examine the relationship between plant communities and geomorphic history. Three 100 m long transects were surveyed in each of five study areas, all but two having different geomorphic histories. Mature trees, those with a diameter at breast height (DBH) of greater than two centimeters, were sampled using the point-centered quarter method. Importance values were obtained via computer analysis; correlation coefficients were derived from a statistical analysis of the importance values.

Slopes that have not undergone movement display a specific distribution of mature trees: mesic species, such as green ash and linden, on footslopes, an oak-juniper association on midslopes and Ponderosa pine on ridgetops. This distribution is shifted downward in elevation on those slopes that have experienced recent land slippages. Landslides also alter the topography of the valley, allowing species normally found at one particular elevation to become established at another elevation. For example, pine trees can be found along the stream bank, and cottonwoods on midslopes.

As the landslide area ages, vegetation appears to succeed back to the typical distribution, that is, a community adapted to a particular elevation on an undisturbed slope.

INTRODUCTION

Vegetation is one of the most conspicuous features of a particular landform. The structure and composition of landforms directly influence the vegetation that covers them, and vegetation, in turn, somewhat modifies the landforms on which it grows. For example, the addition of humic acids to soils affects weathering and infiltration of water. Also, erosion and sedimentation are controlled in part by plant cover (Randall, 1978). Since landforms and vegetation are interdependent, it is important to consider aspects of both when conducting an ecological study. Phytogeomorphology, the study of the relationship between plants and the associated landform, is the term used to emphasize the fact that the distribution of plants is directly affected by an area's geomorphology (Viles, 1988). This interdependence is important since phytogeomorphological data can be utilized in land surveying, and in resource management and planning.

Along the Niobrara River Valley, and specifically in the vicinity of the abandoned town of Meadville, Nebraska, there are two indications of slope failure. The first indication is the atypical distribution of mature trees on north-facing slopes that suggest down-slope movement (Figure 1). In addition, color infrared (CIR) aerial photographs show patches of conifers mixed with deciduous trees. This patchiness is often caused by some geomorphic factor, such as a landslide. Direct evidence of slope failure (Figure 2), combined with the patchy vegetative distribution led to

Figure 1. Conifers and deciduous trees.

Figure 2. Landslide scarp

the present study of landslide activity in the Meadville area. The hypothesis of this study is that the distribution of mature trees on unstable slopes will be dissimilar to that found on stable slopes. In order to test the hypothesis, the following objectives were met: 1) the dominant tree species at each sampling site were determined, and 2) the distribution of mature trees on stable slopes was compared to that found on unstable slopes.

STUDY AREA

Location

The Niobrara River originates in the High Plains of Eastern Wyoming and flows east 692 km to its confluence with the Missouri River in Nebraska (Bartlett, 1984). Mean annual discharge ranges from 2.62 cubic feet per second (cfs) at the Nebraska-Wyoming border high in the drainage network, to 1643 cfs at Verdel, Nebraska near its confluence with the Missouri River (USGS, 1978). By the time the Niobrara River reaches Cherry County, Nebraska, it has the capacity to cut deep canyons through the bluffs, many of which are mantled with a wide variety of trees. As the river flows eastward out of the canyons, its channel widens, averaging 50 m near the study area, and the velocity slows until it meets the Missouri River in northeast Nebraska (Figure 3).

The study area is located near the abandoned town of Meadville, Nebraska on the boundary between Brown and Keya Paha counties, latitude 42° 42' 10" N, longitude 99° 50' 40" W (Figure 4). This area lies within the transition zone between the canyon country to the west and the less rugged topography to the east. The smaller parallelogram near the center of the area (Figure 4) depicts the location of an active landslide (Shroder, pers comm). Smaller slide areas, however, can also be found from Valentine, Nebraska eastward to the Missouri River (Hearty, 1978).

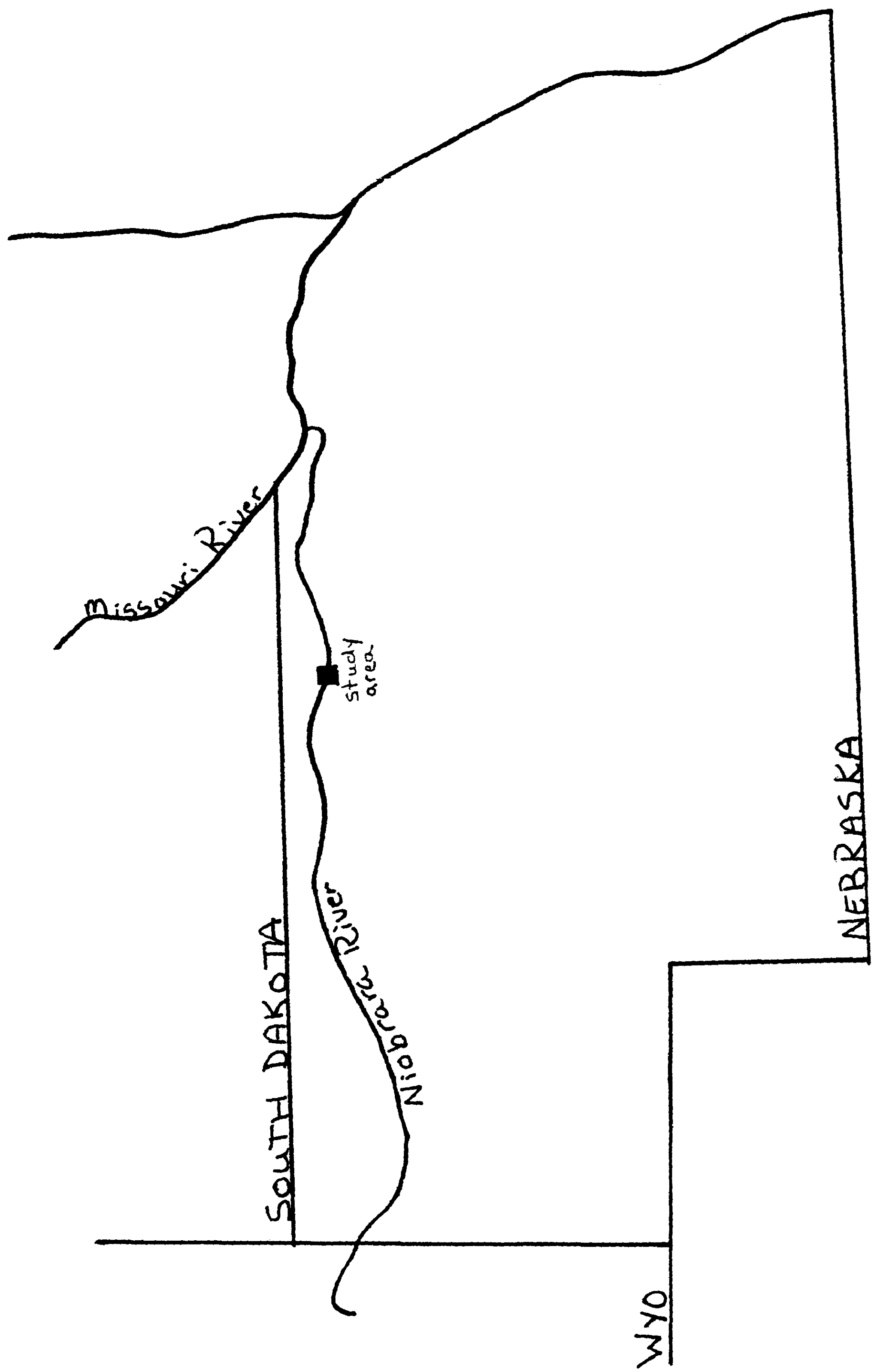


Figure 3. Niobrara River location map.

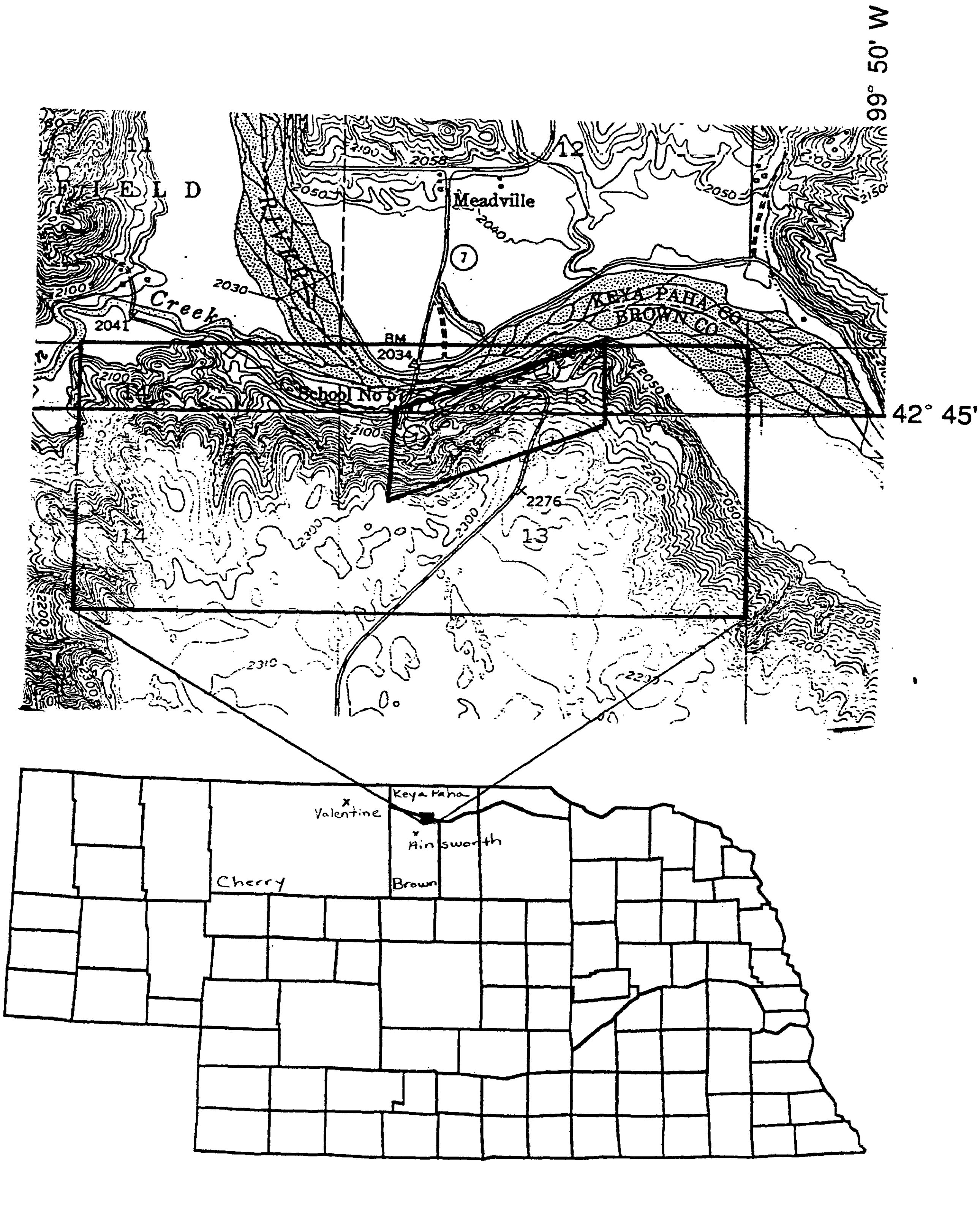


Figure 4. Study area location map.

Vegetation

The Niobrara River Valley is a biogeographically unique area of the Northern Great Plains (Harrison, 1980), containing plant species from the Rocky Mountain, Eastern Deciduous and Northern Boreal forests (Kaul *et al*, 1988). Küchler (1964) describes the upland vegetation of north-central Nebraska as Ponderosa pine forest (*Pinus ponderosa*) mixed with various grass species. Pound and Clements (1900) include American linden (*Tilia americana*), eastern red cedar (*Juniperus virginiana*) and ironwood (*Ostrya virginiana*) in their description of the region's general vegetation.

Floodplains of the area are characterized by riparian forests composed of Eastern Deciduous species; typical species are green ash (*Fraxinus pennsylvanica*), cottonwood (*Populus deltoides*), hackberry (*Celtis occidentalis*) and willows (*Salix, sp.*). At the midslope elevation these species have graded into an oak-cedar association (*Quercus macrocarpa - Juniperus virginiana*). The more xeric ridges are dominated by stands of Ponderosa pine (*Pinus ponderosa*) (Hearty, 1978).

The Niobrara Valley provides a refugium for several species which are at the limits of their ranges. The most unusual of these is the paper birch (*Betula papyifera*), a relic of the Boreal Forest established during the periods of glacial advance and retreat (Kaul *et al*, 1988). The specific habitat for paper birch appears to be on north-facing slopes having sufficient groundwater and shade (Hearty,1978). Groundwater is nearest the surface where the impervious siltstones of the Rosebud Formation are at shallow depths. Water drains through the overlying sands, seeps along the sand-siltstone interface to the surface, creating springs (Harrison, 1980). These particular microhabitats are quite restricted in the study area; therefore, paper birch is not a common species.

The present study examines only north-facing slopes in order to minimize variables. Slopes with a southern aspect receive considerably more insolation which increases soil and air temperature and evapotranspiration rates, and decreases soil moisture (Fraser, 1954). Also, springs are not common on the south-facing slopes which lessens the chance of slope failures occurring.

Climate

The climate of the study area is within Thornthwaite's (1948) dry, subhumid (C1) category. An average 53 cm of precipitation fall annually (Plantz and Zink, 1980), which includes a mean annual snowfall of 95 cm. Annual precipitation totals, however, are highly variable. For example, mean annual precipitation at Valentine, Nebraska, which is 61 km west of the study area, ranged from 73 cm in 1929 to 27 cm in 1974 (Bleed and Flowerday, 1989).

Temperatures reflect the continentality of the region, that is, hot summers and cold winters. The differences between extremes can be dramatic, with daily temperatures dropping to -41° C in winter and reaching +40° C in summer (Lawson *et al*, 1977). The monthly means range from -5.7° C in January to 23.6° C in July with an annual mean of 9.4° C.

Tables 1 and 2 summarize 25 years of climatic data for the area.

Geology

The bedrock geology of the region is dominated by sedimentary units of Cretaceous and Tertiary age. The lowest and, from the point of view of slope instability, the most significant stratum exposed in the valley is the Pierre Shale. Although the Pierre Shale typically is a strong and pliant rock (Lugn, 1935), it becomes unstable when exposed to large amounts of moisture due to its high content of bentonitic and montmorillonitic clays. This may be a primary factor causing the Meadville slope failure, as landslides are a common response to saturated soil conditions (Viles, 1988). The shale is overlain by siltstones of the Rosebud (Brule) Formation (Skinner *et al*, 1972). The uppermost bed is the Valentine Formation, which is Tertiary-aged alluvium composed largely of sand (Figure 5).

Table 1. Temperature summary for the years 1951 - 1974 at Springview, Nebraska. (Plantz and Zink, 1980)

				2 years in 10 will have		
MONTH	AVERAGE DAILY MAX °C	AVERAGE DAILY MIN °C	AVERAGE DAILY °C	MAX TEMP GREATER THAN °C	MIN TEMP LESS THAN °C	AVERAGE NO GGD* units
Jan	.3	-12.4	-6.1	17.8	-29.4	11
Feb	3.0	-9.7	-3.3	20.0	-26.7	20
Mar	7..0	-5.8	0.6	26.7	-21.7	104
Apr	15.4	1.3	8.4	31.7	-10.5	243
May	21.8	7.8	14.8	33.9	-3.3	580
June	27.4	13.4	20.4	39.4	4.4	864
July	31.7	16.8	24.2	41.1	8.9	1104
Aug	30.9	15.9	23..4	40.0	7.8	1060
Sept	24.9	9.9	17.4	37.8	-1.7	702
Oct	19.1	4.0	11.6	32.8	-7.2	414
Nov	9.0	-3.7	2.7	25.6	-17.8	80
Dec	2.4	-9.5	-3.6	18.3	-26.1	28
Average	16.1	2.3	9.2			
Extreme				41.7	-30.0	

*A growing degree day (GGD) is a unit of heat available for plant growth.

GGD = [(min + max) / 2] - 4.4 °C

Table 2. Precipitation summary for the years 1951 - 1974 at Springview, Nebraska.
(Plantz and Zink, 1980)

		2 Years in 10 will have			
MONTH	AVERAGE cm	LESS THAN cm	MORE THAN cm	AVERAGE NO DAYS ≤.25 cm	AVERAGE SNOWFALL cm
Jan	.76	.13	1.24	1	9.65
Feb	1.50	.38	2.39	2	17.78
Mar	2.36	.76	3.61	3	20.07
Apr	5.64	3.10	7.70	5	13.72
May	8.36	3.99	11.89	7	.51
June	9.30	5.23	12.57	7	0
July	7.65	2.69	11.58	5	0
Aug	5.08	2.59	7.11	4	0
Sept	4.83	1.14	7.77	4	0
Oct	2.79	1.04	2.29	3	4.57
Nov	1.85	.41	2.97	2	12.70
Dec	1.32	.33	2.06	2	16.00
Total	51.40	40.92	59.87	45	95.00

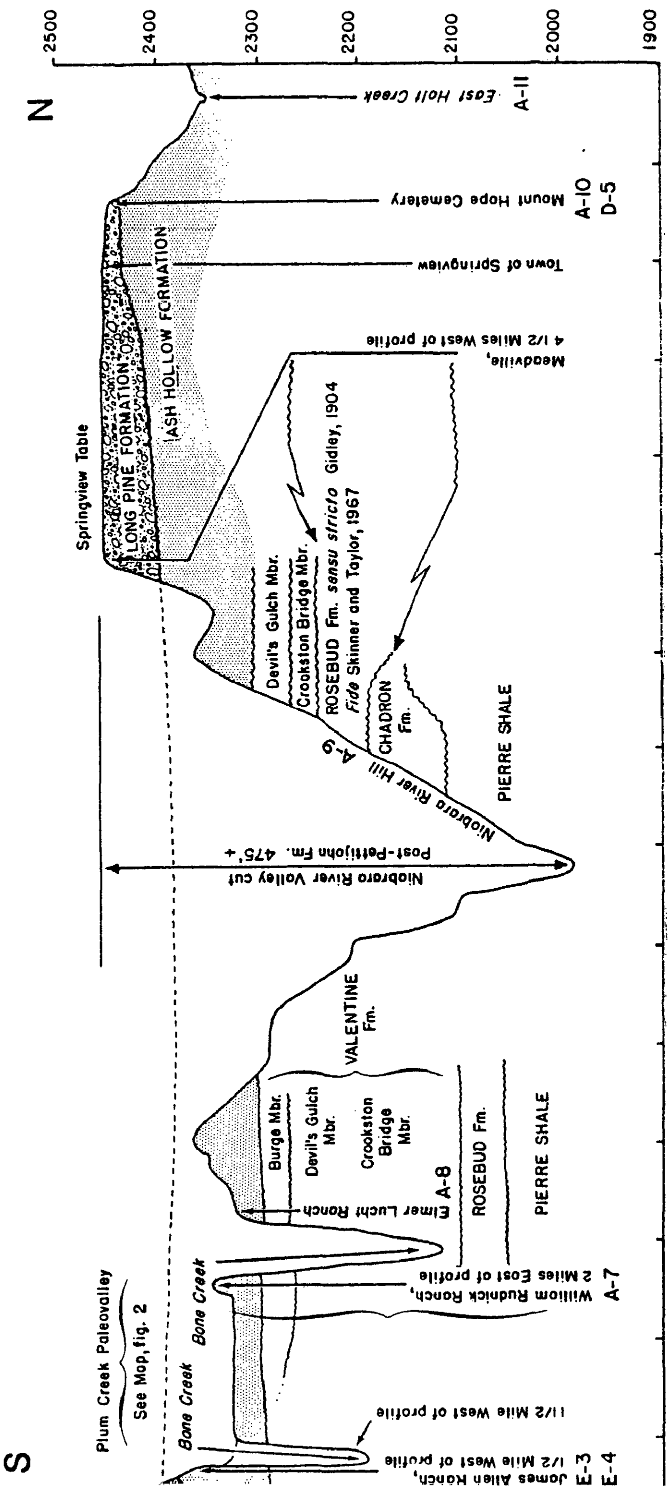


Figure 5. Geologic cross-section of region near study site. (After Skinner *et al*, 1972)

METHODOLOGY

Vegetative sampling was conducted in five landform units within the study area (Figure 6). The identification of discrete sampling units was based on field observation and on color infrared (CIR) photographs. These units were divided into four categories based on geomorphic activity: active landslides (1 and 2 FMT), an inactive landslide (3 FMT), an old, stabilized landslide (4 FMT) and a stable slope (5 FMT). The FMT refers to the location of the transect within the unit: F = foot slope, M = midslope and T= topslope or ridge.

Sampling was conducted along three 100 m transects within each individual landslide unit (Figure 6). Each transect was divided into ten equal parts to provide subsamples (after Hearty, 1978). Transects were placed at upper, middle, and lower elevations, parallel to the contours, in order to identify any vegetative transitions that may occur in relation to topographic location (after Phillips 1959).

Distribution of mature trees along each transect was sampled using the point-centered quarter method recommended by Cottam and Curtis (1956). Mature trees were defined as those with a diameter at breast height (DBH) of greater than two centimeters. This method is widely used in geobotanical studies (Viktorov *et al*, 1964). It involved the selection of sampling points along each transect (Figure 7). The sampling points were emplaced 10 m apart. At each point, a "cross"

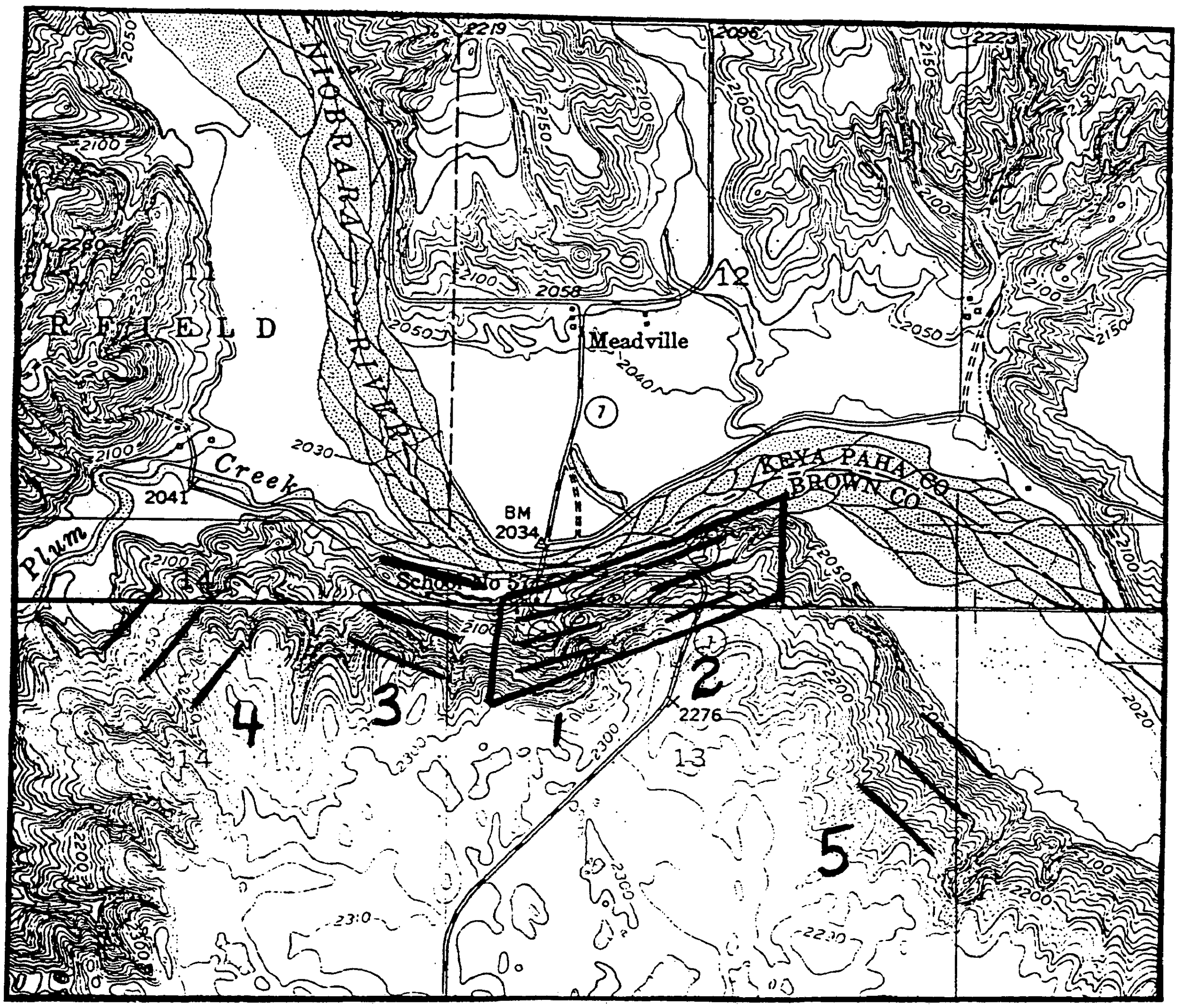


Figure 6. Location of sampling sites within the study area.

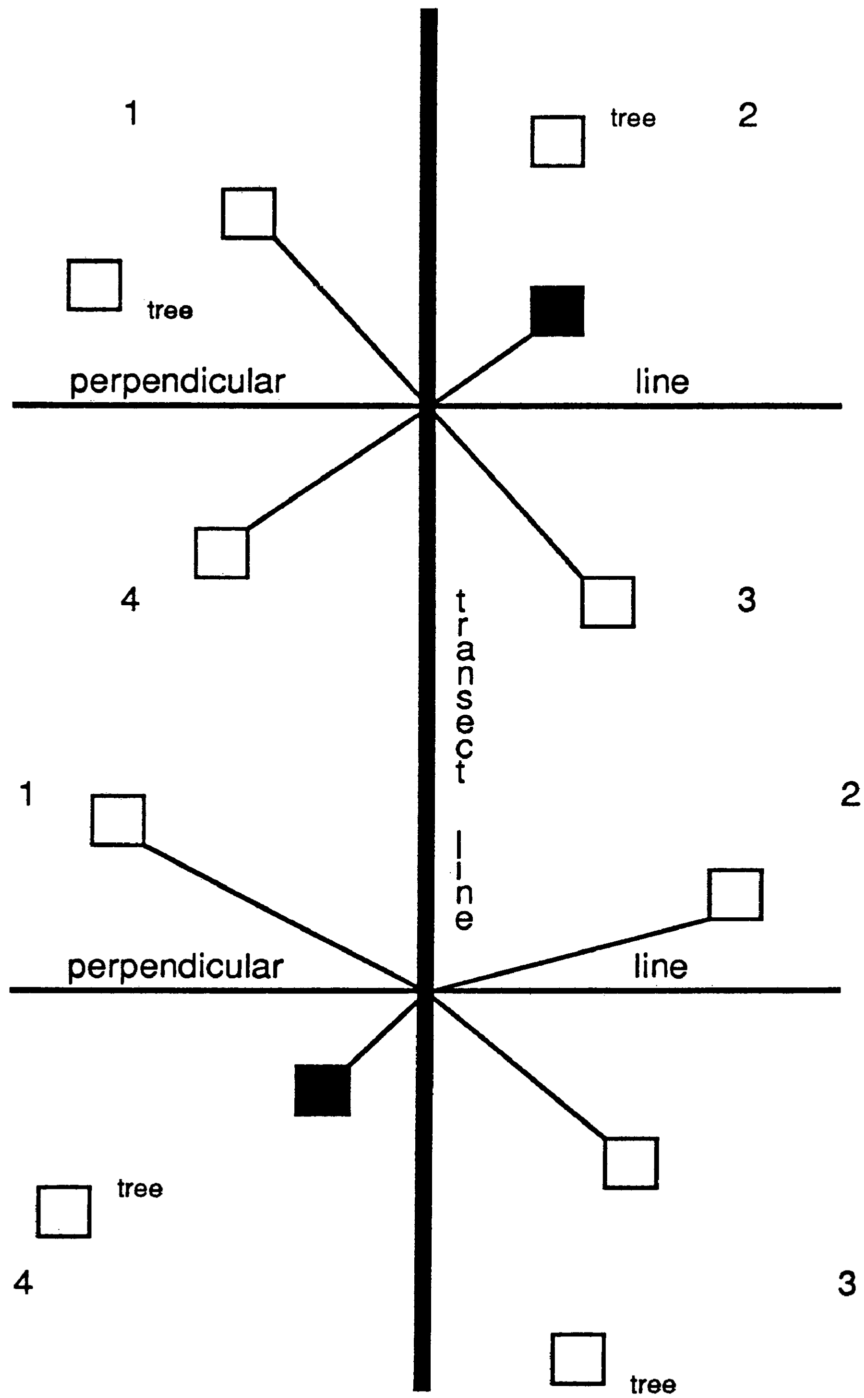


Figure 7. Point centered quarter method of sampling (Cottam and Curtis, 1956). Each perpendicular crossing the transect was measured 10 m apart, dividing the area into a group of quadrats. Within each quadrat, the nearest tree to the transect crossing point was selected for measurement.

divides the surrounding area into four quadrats centered on the sampling point. The closest tree to the center point in each quadrat was identified and recorded. Its DBH and distance from the center point were also recorded. Identification of trees was accomplished using Brockman (1968), Phillips (1978) and Viertel's (1970) vegetation reference manuals. Ten species of mature trees were identified on the study site (Table 3).

These data were analyzed to obtain relative density, dominance, and frequency of species. The values, when summed, yielded an importance value for each species at each site (Table 3). The importance value shows the dominance of a certain species within a particular transect. For example, a species with a high importance value is more dominant than a species with a lower value in a transect.

The species, their importance values and elevation locations were ordinated using a simple detrended correspondence analysis (DCA) program designed for community studies. The DCA ordination method is currently the method favored by most ecologists (Pielou, 1984). The output of this analyis is a series of ranked scores or eignevalues. In order to make the within and between elevation relationships more clear, a correlation matrix was derived by comparing each elevation/eigenvalue pair to all others. This was accomplished using the Statview 512+ software program. The resulting correlation coefficients show the degree of correlation within and between site elevations. "Within elevation" refers to comparisons of the same topographic elevation (footslope to footslope [F-F], midslope to midslope [M-M],

Table 3. Importance values for each species along each transect. Numbers indicate sampling sites.
F-Footslope M-Midslope T-Topslope

SITE / SPECIES

	Jv	Fp	Ov	Qm	Pp	Ua	Co	An	Pd	Ta
1F	40	25	62	84	76	14	0	0	0	0
1M	111	11	0	56	88	7	12	7	0	7
1T	99	0	0	9	192	0	0	0	0	0
2F	58	13	44	18	126	0	0	0	0	41
2M	54	28	15	90	0	28	20	9	55	0
2T	125	0	0	0	175	0	0	0	0	0
3F	137	8	23	28	0	0	0	25	0	80
3M	85	7	29	84	95	0	0	0	0	0
3T	51	0	0	0	249	0	0	0	0	0
4F	181	8	54	57	0	0	0	0	0	0
4M	179	0	12	80	0	0	0	0	0	30
4T	148	0	0	51	101	0	0	0	0	0
5F	155	11	25	0	0	0	0	0	64	46
5M	133	0	41	117	0	0	9	0	0	0
5T	47	0	0	47	206	0	0	0	0	0

Jv Eastern Red Cedar
Fp Green Ash
Ov Ironwood
Qm Bur Oak
Pp Ponderosa Pine

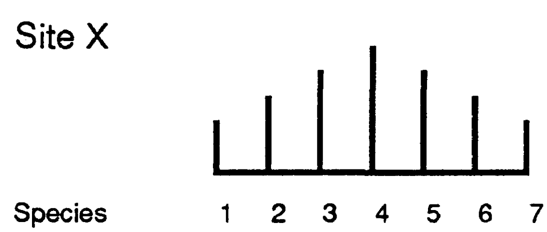
Ua American Elm
Co Hackberry
An Boxelder
Pd Cottonwood
Ta American Linden

Table 4. Correlation matrix derived from species importance values. Numbers indicate site. F-footslope, M-midslope, T-topslope

	1F	1M	1T	2F	2M	2T	3F	3M	3T	4F	4M	4T	5F	5M	5T
1F	1.000														
%	100														
1M	0.909	1.000													
%	83	100													
1T	0.716	0.712	1.000												
%	51	51	100												
2F	0.738	0.495	0.696	1.000											
%	54	25	48	100											
2M	0.755	0.855	0.624	0.676	1.000										
%	57	73	39	46	100										
2T	0.617	0.403	0.667	0.586	0.280	1.000									
%	38	16	44	34	8	100									
3F	0.670	-0.729	-0.571	0.504	0.470	-0.417	1.000								
%	45	53	33	25	22	17	100								
3M	-0.589	-0.019	0.315	0.537	0.556	-0.636	-0.915	1.000							
%	35	.03	10	29	31	40	84	100							
3T	-0.286	0.892	0.705	0.663	0.868	-0.053	-0.827	-0.609	1.000						
%	8	80	50	44	75	2	68	37	100						
4F	-0.960	-0.188	-0.572	-0.453	-0.263	-0.758	0.799	-0.855	-0.690	1.000					
%	92	4	33	21	7	57	64	73	48	100					
4M	0.616	0.770	-0.855	0.272	0.661	-0.818	-0.434	0.013	-0.814	-0.729	1.000				
%	38	59	73	7	44	67	19	.01	66	53	100				
4T	0.584	0.832	0.673	-0.035	0.348	0.132	-0.913	-0.605	0.629	-0.661	-0.831	1.000			
%	34	69	45	.1	12	2	83	37	40	44	69	100			
5F	-0.802	0.857	-0.869	-0.822	-0.523	-0.883	0.666	-0.633	-0.548	0.767	-0.792	-0.968	1.000		
%	64	73	76	68	27	78	44	40	30	59	63	94	100		
5M	0.589	0.731	-0.407	-0.516	-0.712	-0.655	-0.922	0.619	0.500	-0.688	0.855	-0.775	-0.758	1.000	
%	35	53	17	27	51	43	85	38	25	47	78	60	57	100	
5T	0.687	0.707	0.614	0.799	0.882	0.667	-0.825	0.790	0.947	-0.767	-0.743	0.406	-0.526	0.542	1.000
%	47	50	38	64	78	44	68	62	90	59	55	16	28	29	100

topslope to topslope [T-T]); "between elevation" comparisons refer to those of differing elevations (F-M, F-T, M-T). A positive coefficient indicates a direct relationship; a negative coefficient indicates an indirect relationship.

The closer the correlation coefficient is to +1.0 or -1.0, the stronger the correlation; high positive values show that there is a direct relationship between the phenomena being compared, in this case, sampling sites, whereas, a high negative coefficient indicates an inverse relationship. For example, a coefficient of -0.89 indicates that the two sites being compared are dissimilar in an inverse manner, as illustrated below.



Conversely, a coefficient of +0.89 signifies a positive correlation, or a direct relationship. The sites being compared are closely related as to species composition, though not necessarily the absolute numbers of each species, as illustrated below.

Site X

Site Y

Generally, a correlation coefficient of less than -0.5 or greater than +0.5 is considered significant (Gregory, 1963). Values between -0.5 and

+0.5 suggest that there is little, if any, relationship or similarity between the two sites. In the present study, the boundaries were set at -0.6 and +0.6. If the correlation coefficient was less than -0.6 or greater than +0.6, the association was considered significant.

The squared value listed directly below the correlation coefficient (Table 4) indicates the percent of time one can expect the sites to be similar or dissimilar. Again, higher percentages denote closer correlations, either direct or inverse. These values help to explain and support some of the relationships and patterns found in a study such as this.

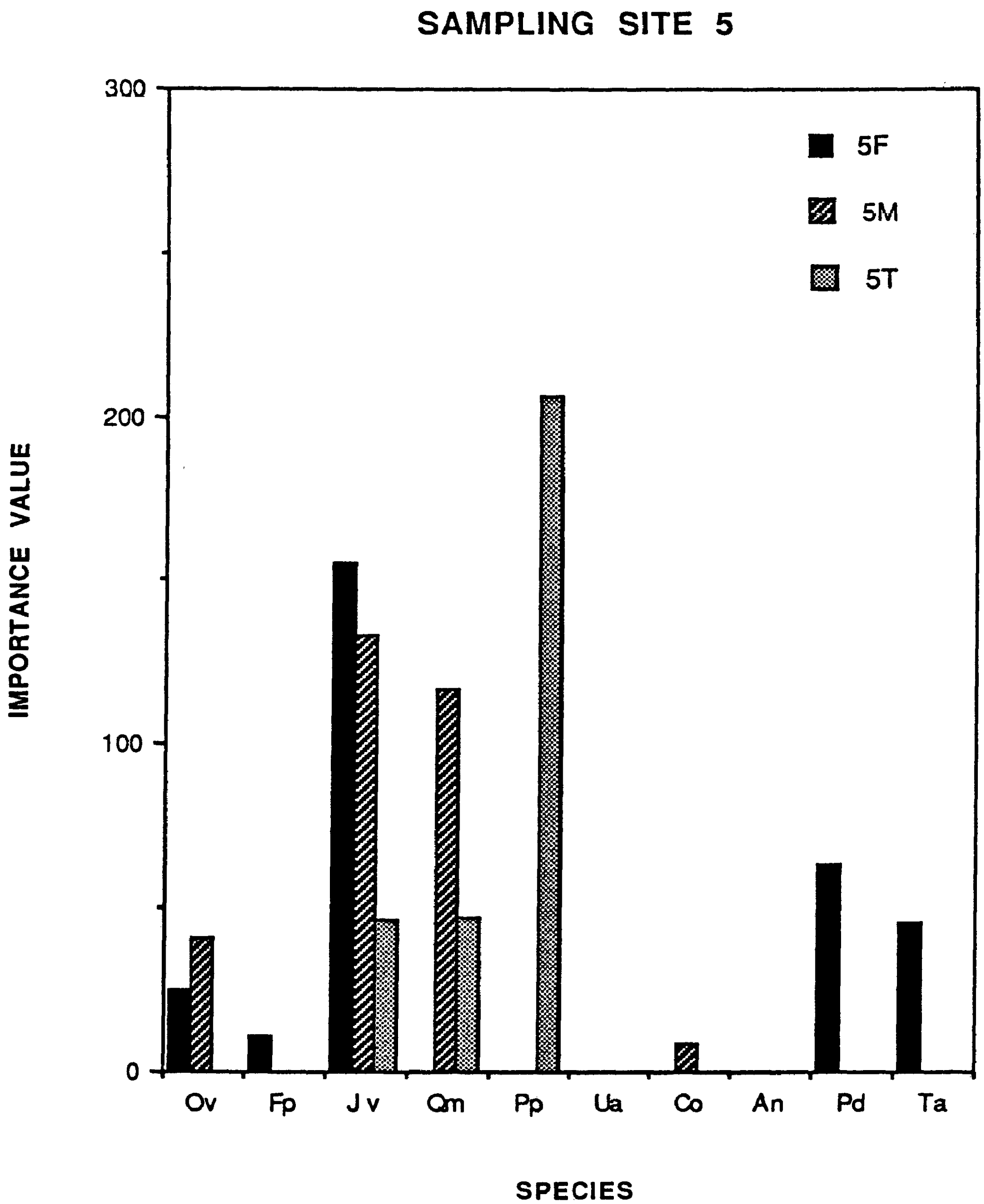
RESULTS

The results from individual transects are presented in Appendix A. Each graph illustrates the species and its importance value sampled along the indicated transect. Table 4 contains correlation coefficients of each transect compared to all others.

Hearty (1978) described typical, undisturbed north-facing slopes along the Niobrara River 25.6 km west of Meadville as being dominated by mesic species, such as green ash and linden near the stream edge, grading into an oak-cedar association on midslopes, with Ponderosa pine dominating the ridges with a few oaks and cedar dispersed intermittently among the pines. Sampling Site 5 most closely approximates this description (Figure 8). Because of apparent vegetative and geomorphic stability, this site is considered undisturbed and stable, representing "typical" topographic and vegetative conditions.

The old, stabilized landslip, Site 4 (Figure 9) is very similar to the stable site (Site 5, Figure 8). The correlation matrix supports this statement (Table 5a). The footslope and midslope areas of the two sites show a positive correlation 59% and 78% of the time, respectively. This means that many of the same species will be found at the same elevation. The coefficient of the ridges, 0.406, shows a positive correlation, though it is too small to be significant.

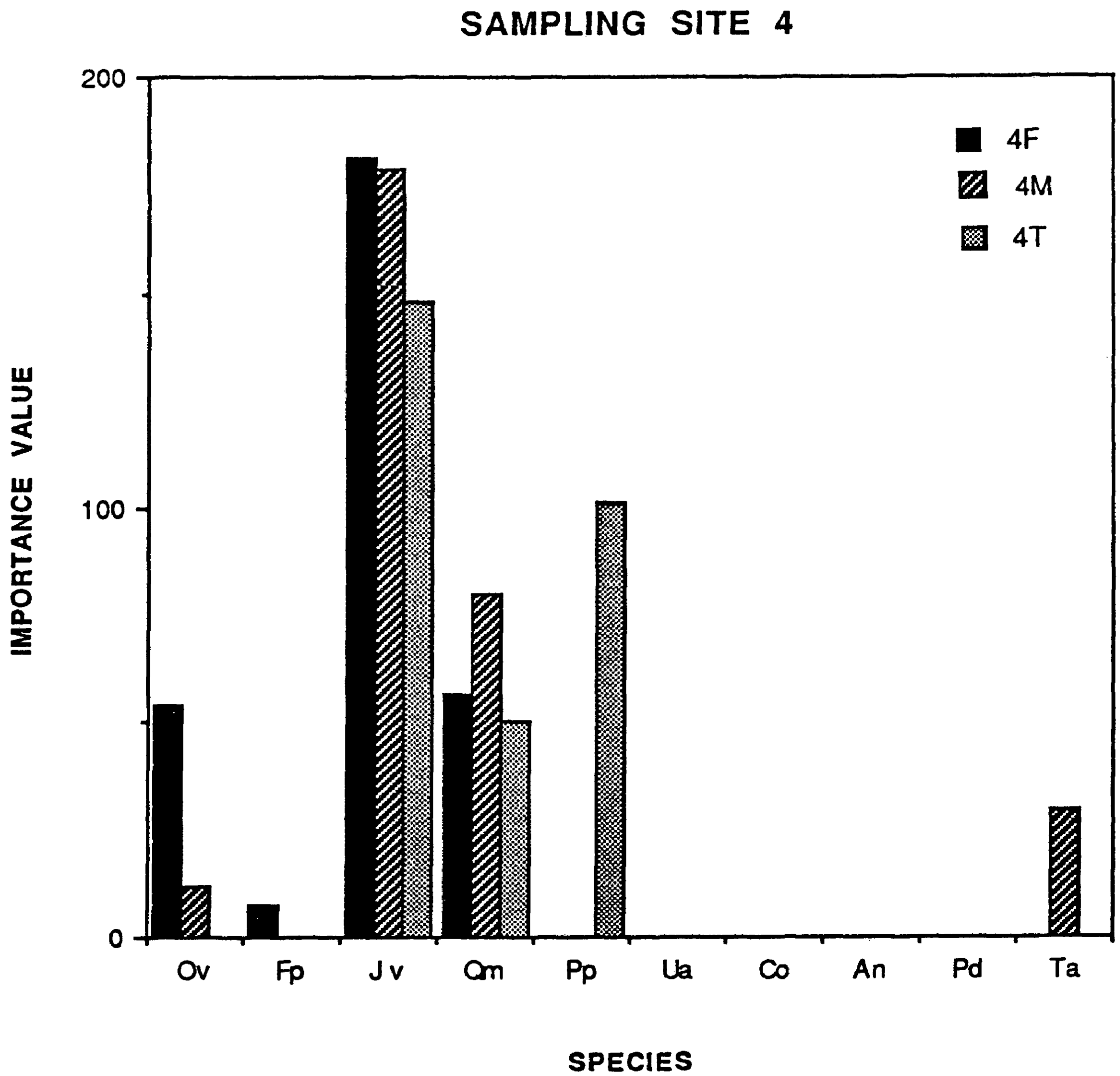
The between-elevation correlation coefficients of Sites 4 and 5 are all negative (Table 5a). This suggests that the vegetation at one



Jv Eastern Red Cedar
Fp Green Ash
Ov Ironwood
Qm Bur Oak
Pp Ponderosa Pine

Ua American Elm
Co Hackberry
An Boxelder
Pd Cottonwood
Ta American Linden

Figure 8. Importance values of species in sampling Site 5. 5F=footslope, 5M=midslope, 5T=topslope



Jv Eastern Red Cedar
Fp Green Ash
Ov Ironwood
Qm Bur Oak
Pp Ponderosa Pine

Ua American Elm
Co Hackberry
An Boxelder
Pd Cottonwood
Ta American Linden

Figure 9. Importance values of species in sampling Site 4. 4F=footslope, 4M=midslope, 4T=topslope

Table 5a. Correlation matrix for Sites 4 and 5.

	4F	4M	4T
5F	0.767	-0.792	-0.968
%	59	63	94
5M	-0.688	0.885	-0.775
%	47	78	60
5T	-0.767	-0.743	0.406
%	59	55	16

Table 5b. Correlation matrix for Sites 3 and 5.

	3F	3M	3T
5F	0.666	-0.633	-0.548
%	44	40	30
5M	-0.922	0.619	0.500
%	85	38	25
5T	-0.825	0.790	0.947
%	68	62	90

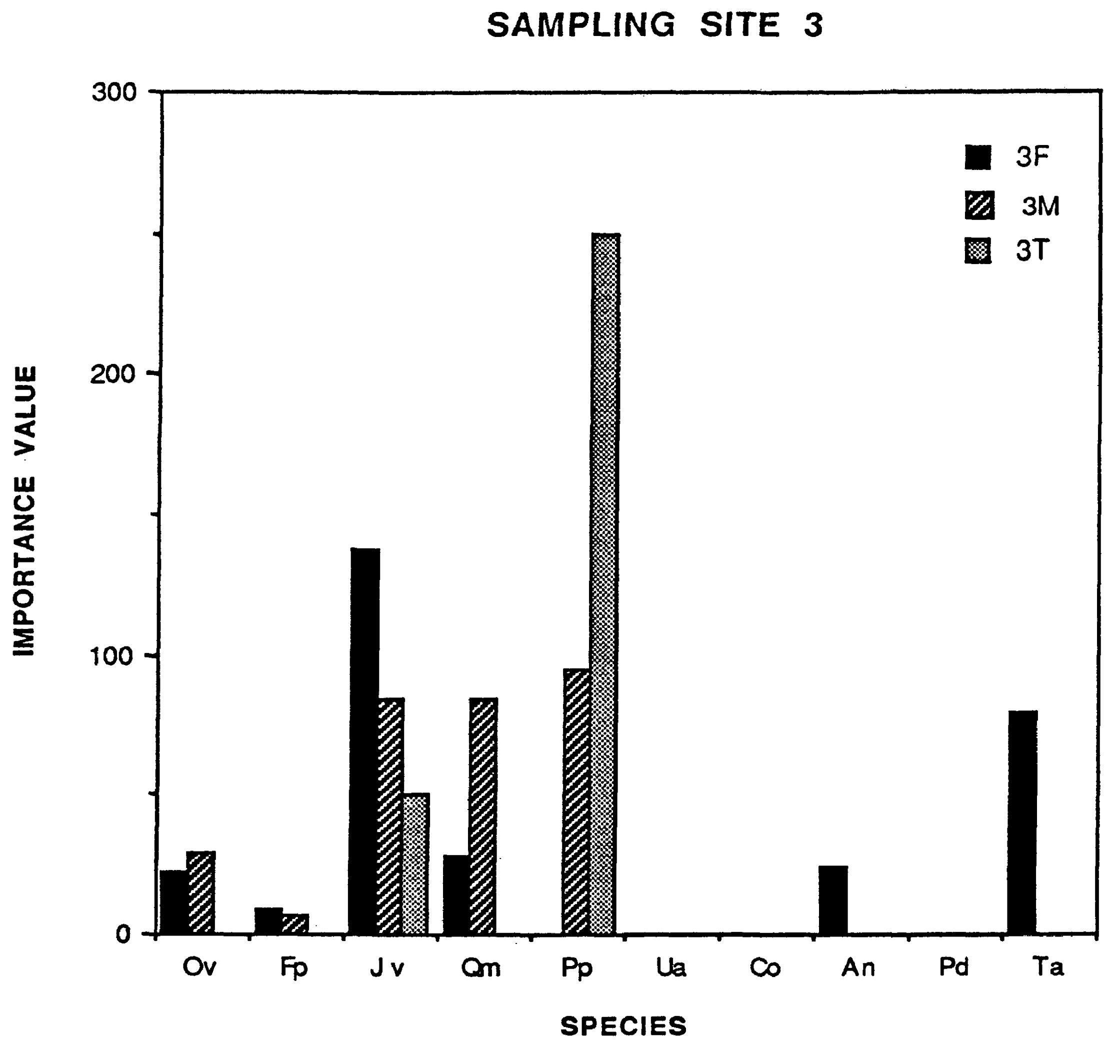
Table 5c. Correlation matrix for Sites 1, 2 and 5.

	5F	5M	5T
1F	-0.802	0.589	0.687
%	64	35	47
1M	0.857	0.731	0.707
%	73	53	50
1T	-0.869	-0.407	0.614
%	76	17	38
2F	-0.822	-0.516	0.799
%	68	27	64
2M	-0.523	-0.712	0.822
%	27	51	78
2T	-0.883	-0.655	0.667
%	78	43	44

elevation will differ from that of another in an inverse manner. This also suggests, but does not prove, that a long-term succession uninterrupted by slope movement has allowed the vegetation to return to near-typical conditions at each elevation. The absence of linden on lower slopes, plus the greater number of red cedar and fewer pines on the upper slopes, probably represents vestiges of past disturbance. There is some evidence that the channel of Plum Creek, a tributary of the Niobrara, flowed close to the base of this slope at one time; hence, bank erosion may have contributed to slope instability. The stream has since changed its course, and the floodplain is well established between the channel and valley wall. Hence, it appears that no movement has occurred for a relatively long period of time.

The presence of mature pines at the midslope location and ridge of Site 3 suggests land slippage. Slope movement would account for the atypical distribution of tree species (Figure 10). The importance values of species other than pine, however, are as would be expected in a typical slope, as represented by the stable site (Site 5). Correlations at the footslope and midslope elevations show a fairly strong positive relationship, 44% and 38%, respectively. (Table 5b). The ridge comparison (5T-3T) shows a very strong correlation. The analysis indicates that these two sites are similar 90% of the time.

This distribution pattern displayed by Site 3 is consistent with that expected of an area of land slippage that has stabilized, but on which vegetation succession towards a relatively stable community is still



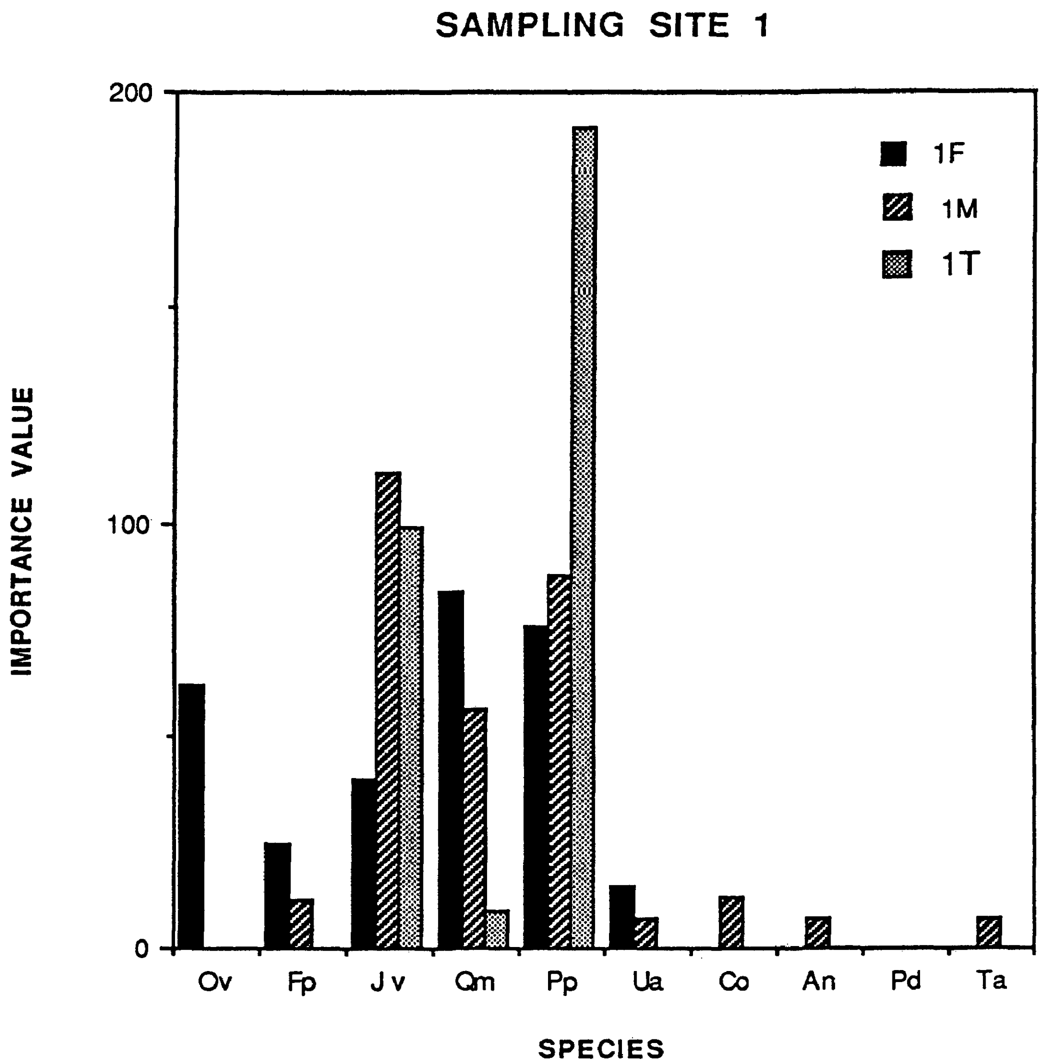
Jv Eastern Red Cedar
Fp Green Ash
Ov Ironwood
Qm Bur Oak
Pp Ponderosa Pine

Ua American Elm
Co Hackberry
An Boxelder
Pd Cottonwood
Ta American Elm

Figure 10. Importance values of species in sampling Site 3. 3F=footslope, 3M=midslope, 3T=topslope

continuing. A pattern such as this represents an intermediate vegetative community within the study area.

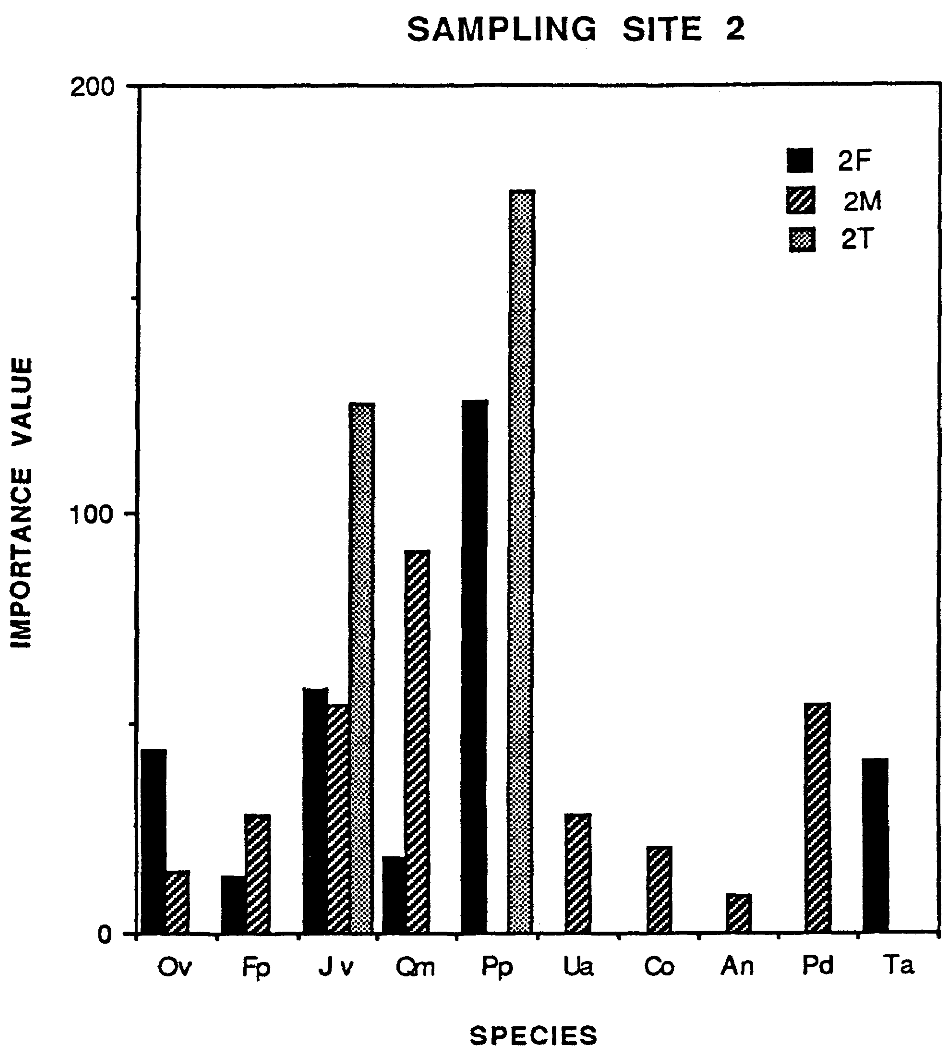
The distribution of pine on the lower slopes, the presence of cottonwood, ash and a variety of other species at midslope, and the high numbers of cedar on the top slope location suggest very recent slippage in Sites 1 and 2 (Figures 11,12). Trees tilted at varying degrees, plus a very hummocky land surface, also point toward recent movement. Both sites display considerable differences in the distribution of mature trees compared to Sites 3, 4 and 5 . The correlation matrix somewhat reveals these differences (e.g. Sites 1 and 5). The results of within-elevation comparisons approach what might be expected. For example, site 1F and site 5F show a strong negative correlation (Table 5c) primarily because of the movement of pines downslope. The communities differ inversely 64% of the time. Site 1M compares favorably with site 5F; they are similar 73% of the time. The data also show that site 1T is very different from site 5F. Sites 1F and 1M are similar to site 5T, again, apparently because of the downslope movement of pines. Site 2 is located within the same geomorphic unit as Site 1, therefore, similar correlation patterns emerge when Sites 2 and 5 are compared.



Jv Eastern Red Cedar
Fp Green Ash
Ov Ironwood
Qm Bur Oak
Pp Ponderosa Pine

Ua American Elm
Co Hackberry
An Boxelder
Pd Cottonwood
Ta American Linden

Figure 11. Importance values of species in sampling Site 1. 1F=footslope, 1M=midslope, 1T=topslope



Jv Eastern Red Cedar
Fp Green Ash
Ov Ironwood
Qm Bur Oak
Pp Ponderosa Pine

Ua American Elm
Co Hackberry
An Boxelder
Pd Cottonwood
Ta American Linden

Figure 12. Importance values of species in sampling Site 2. 2F=footslope, 2M=midslope, 2T=topslope

CONCLUSION

The typical distribution of trees on north-facing slopes of the Niobrara River Valley was found to be characterized by mesic species, such as green ash and American linden along the lower slope, oak-cedar associations at the midslope level, and Ponderosa pine along upper slopes and ridges. Where evidence of land slippage occurs, this distribution is shifted downslope, with the most notable anomaly being the presence of Ponderosa pine at lower elevations. This occurrence of mature pine at lower than normal elevations, in conjunction with geomorphic evidence of unstable slopes, suggest that it is the geologic process that accounts for the atypical distribution of trees and increased spatial heterogeneity.

Any redistribution of trees can be expected to become less evident as the slope failure stabilizes and as, with time, ecological succession eliminates some species and allows others to become established. Site 3, for example, represents conditions where slope movement has not occurred for many years. The midslope location at this site still contains some species that are atypically situated. Green ash, for example, may occur as a remnant population from the time when conditions were more suitable. Additionally, Ponderosa pine occurs at this elevation, and is probably a relic of prior slippage. On the other hand, the number of oak, eastern red cedar and even ironwood suggest that these species may be increasing on the midslope elevation.

Sites 1 and 2 are located on an active slope failure. Hence, vegetation is least stable on these sites. The slippage apparently has been slow since mature Ponderosa pine and other large trees at lower slope elevations have not been killed in the process. Additional evidence for such downward movement can be seen in the varied orientation of tilted trees throughout Sites 1 and 2 (Smulling, pers comm). Slippage also has distorted the midslopes; infiltration of moisture at these locations is more likely to occur. This allows mesic species, characteristically found at the base of the slope, to become established at higher elevations. A fairly large pond has formed at the middle elevation, which may affect species distribution (Figure 13). Some trees have even been transported so far downslope that, in combination with stream bank erosion, they have nearly fallen into the river (Figure 14).

The terrain of Site 4 appears to have been stable longer than that of Site 3, thus the distribution of mature trees more closely resembles that of Site 5, the undisturbed site. This suggests that enough time has passed in order for the tree communities to succeed back to that which is characteristic of each topographic location.

In addition to vegetative effects, the slope movement alters the micro-topography from being a fairly smooth, uniform slope face to a more hummocky surface. As the surface becomes irregular, more moisture accumulates on and infiltrates into the soil. This makes the environment more conducive for the establishment of species not normally found at a particular elevation. The presence of cottonwood at mid-slope of Site 2 represents one such species.

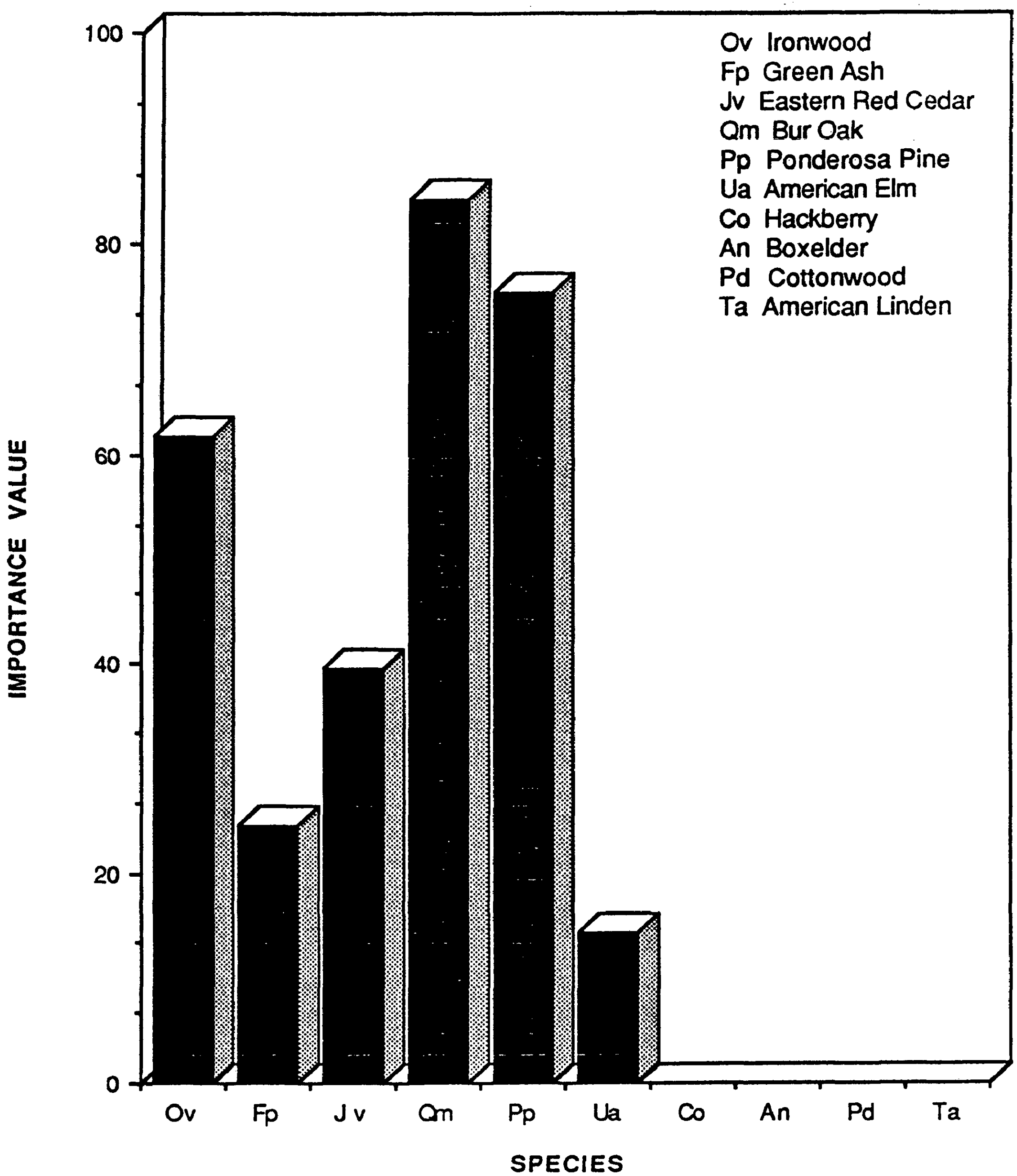
Figure 13. Pond located at midslope.

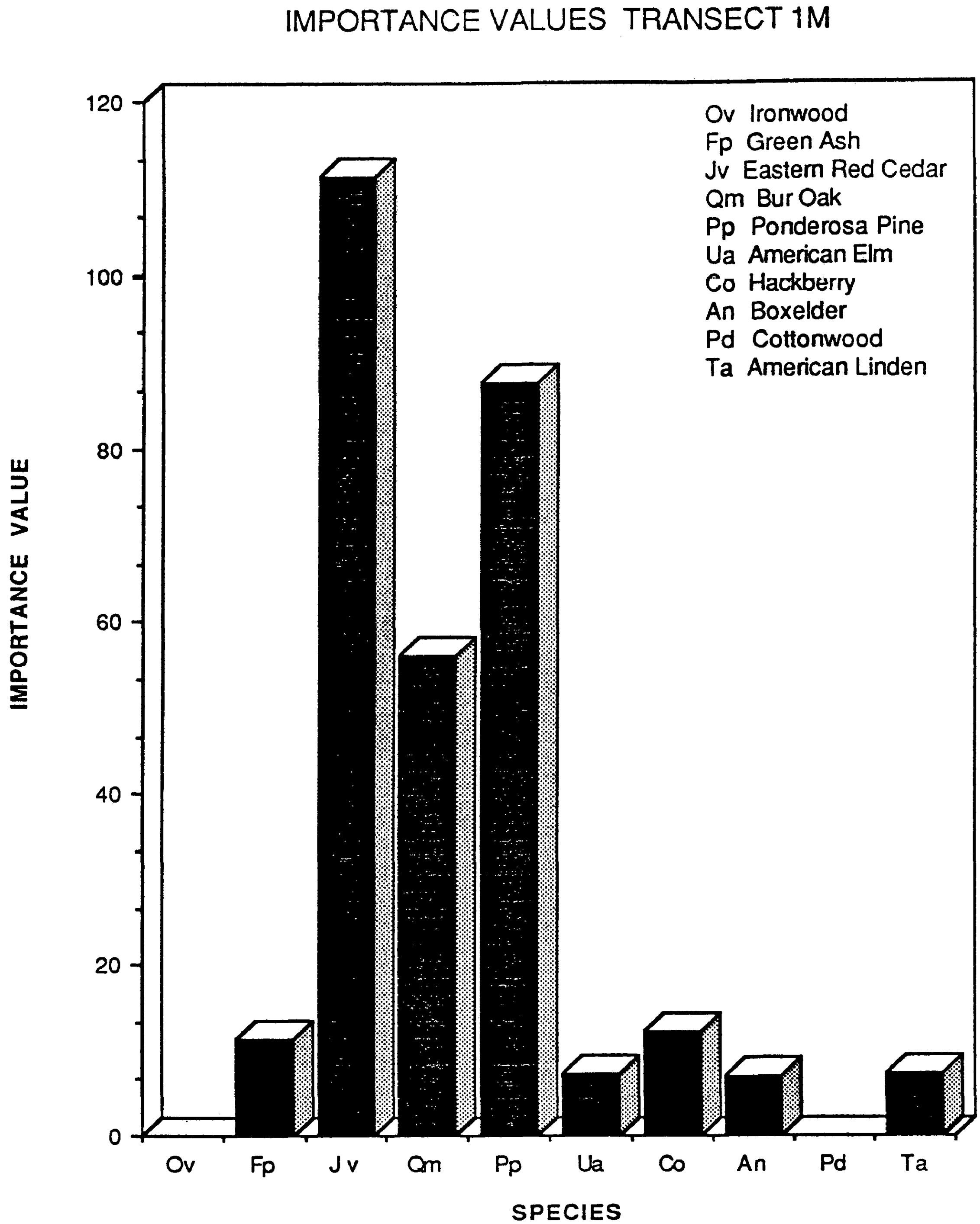
Figure 14. Ponderosa pine trees at edge of Niobrara River.

The general conclusion of this study is that vegetative communities evaluated at Meadville, Nebraska are distributed in a fashion consistent with the hypothesis: stable sites contain communities different from unstable sites at the same topographic location. The difference in composition appears to result from a combination of: 1) downslope movement of mature trees, and 2) the establishment of atypical species on sites where topographic and edaphic conditions have been altered. Once stabilized, tree communities appear to succeed back toward a more typical composition.

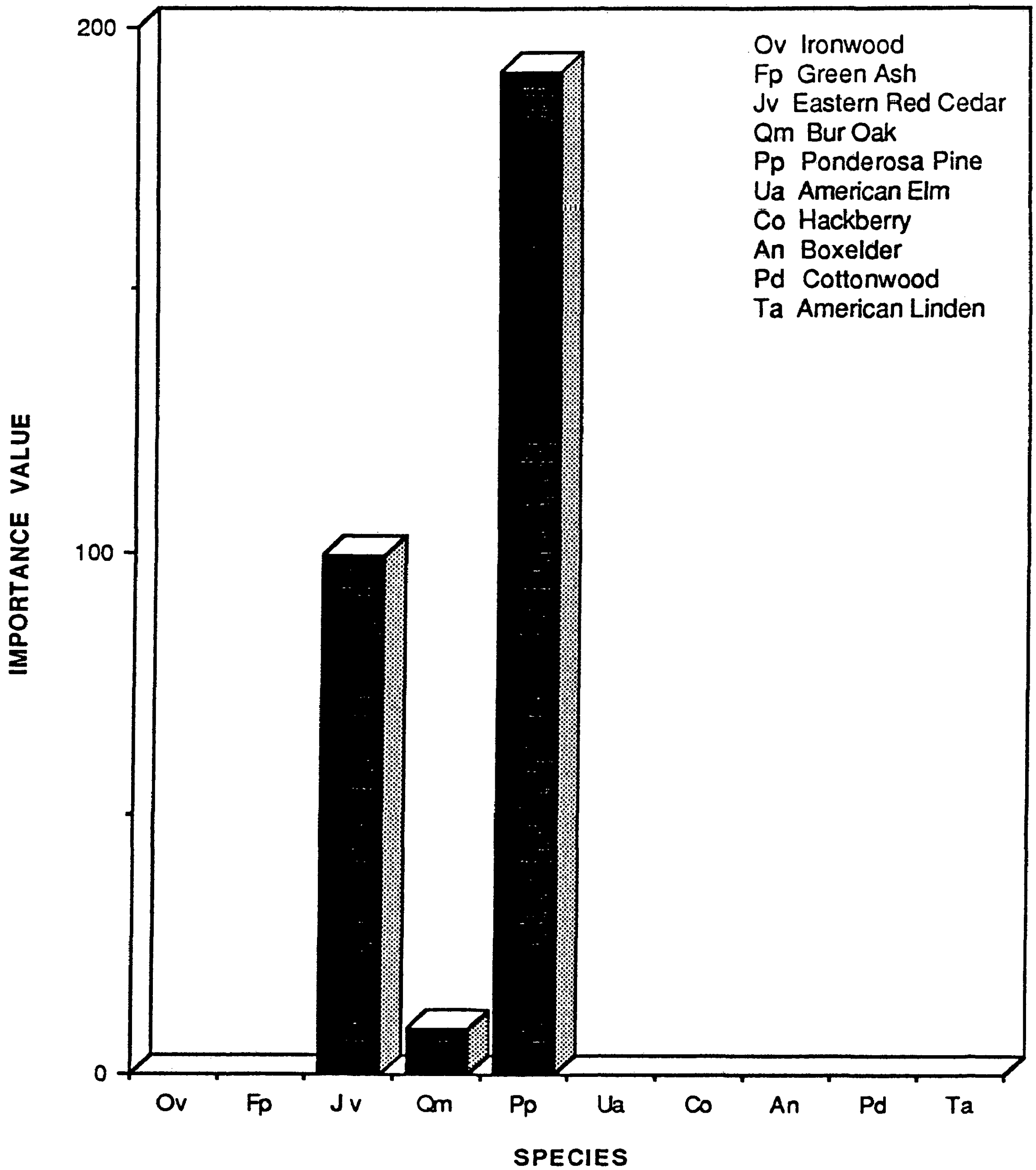
APPENDIX A

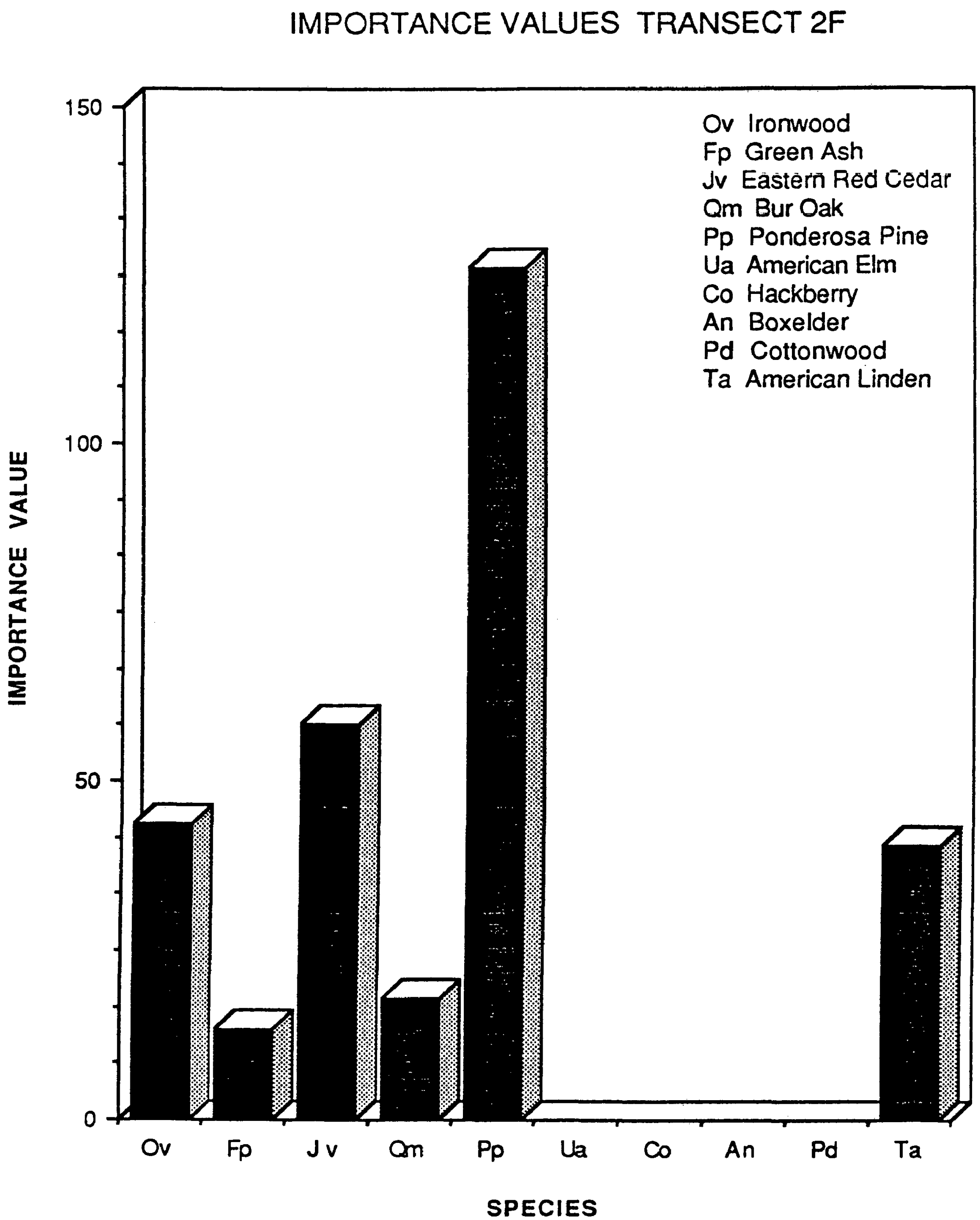
IMPORTANCE VALUES TRANSECT 1F




IMPORTANCE VALUES TRANSECT 1M
Ov Ironwood
Fp Green Ash
Jv Eastern Red Cedar
Qm Bur Oak
Pp Ponderosa Pine
Ua American Elm
Co Hackberry
An Boxelder
Pd Cottonwood
Ta American Linden
IMPORTANCE VALUE
0
20
40
60
80
100
120
Ov
Fp
Jv
Qm
Pp
Ua
Co
An
Pd
Ta
SPECIES

IMPORTANCE VALUES TRANSECT 1T

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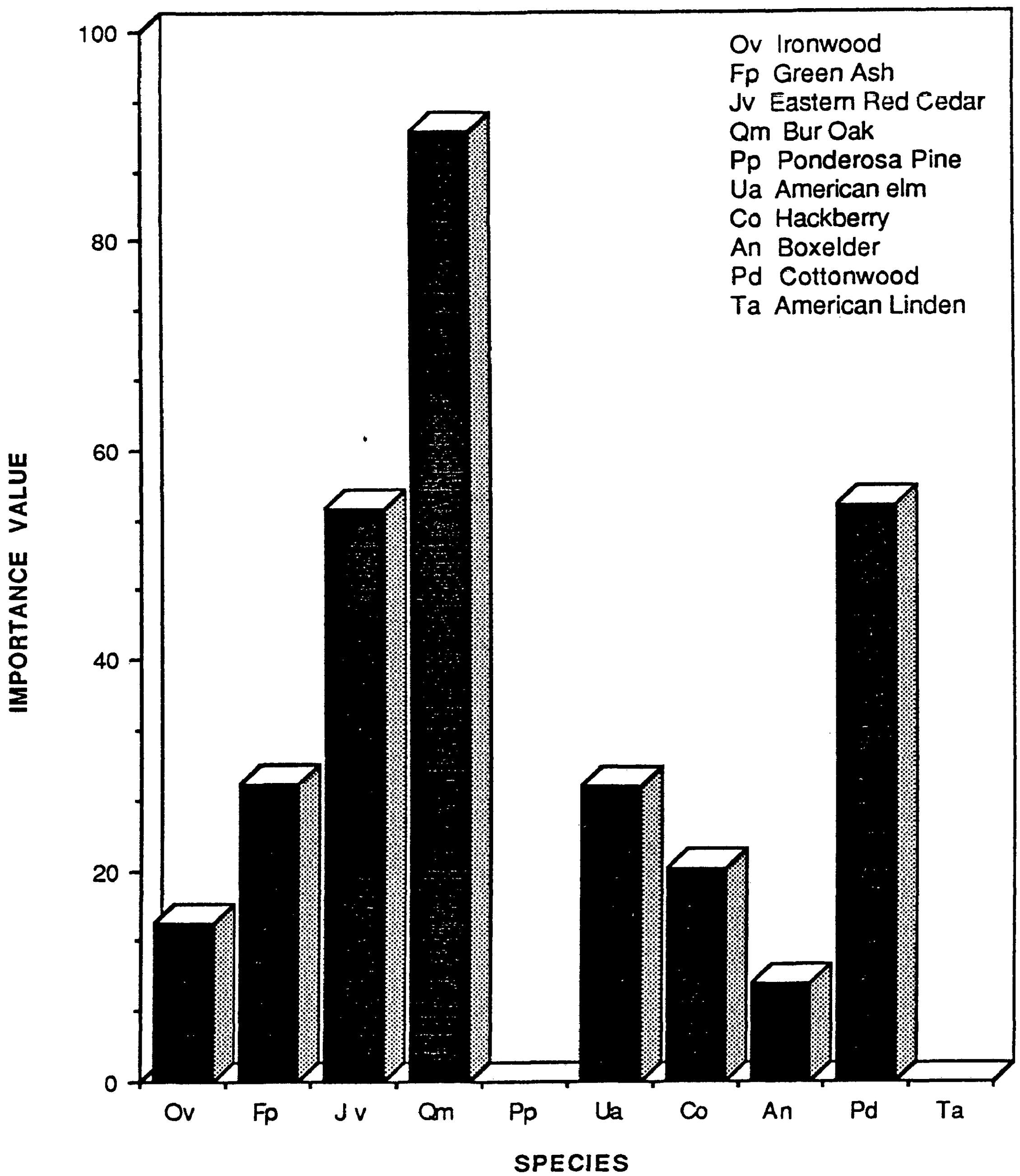
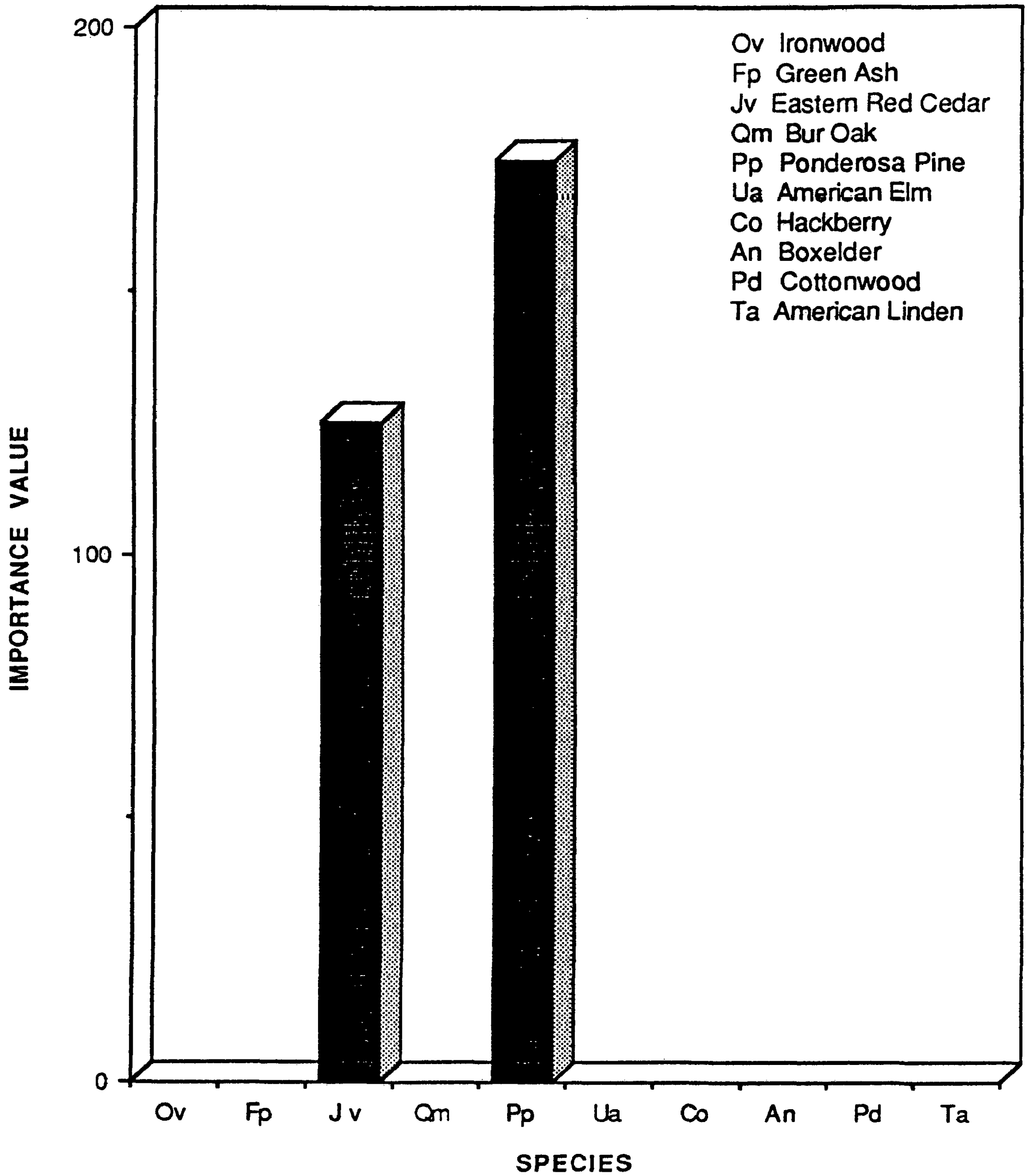
Ov Ironwood
Fp Green Ash
Jv Eastern Red Cedar
Qm Bur Oak
Pp Ponderosa Pine
Ua American Elm
Co Hackberry
An Boxelder
Pd Cottonwood
Ta American Linden
IMPORTANCE VALUE
150
100
50
0
Ov
Fp
J v
Qm
Pp
Ua
Co
An
Pd
Ta
SPECIES

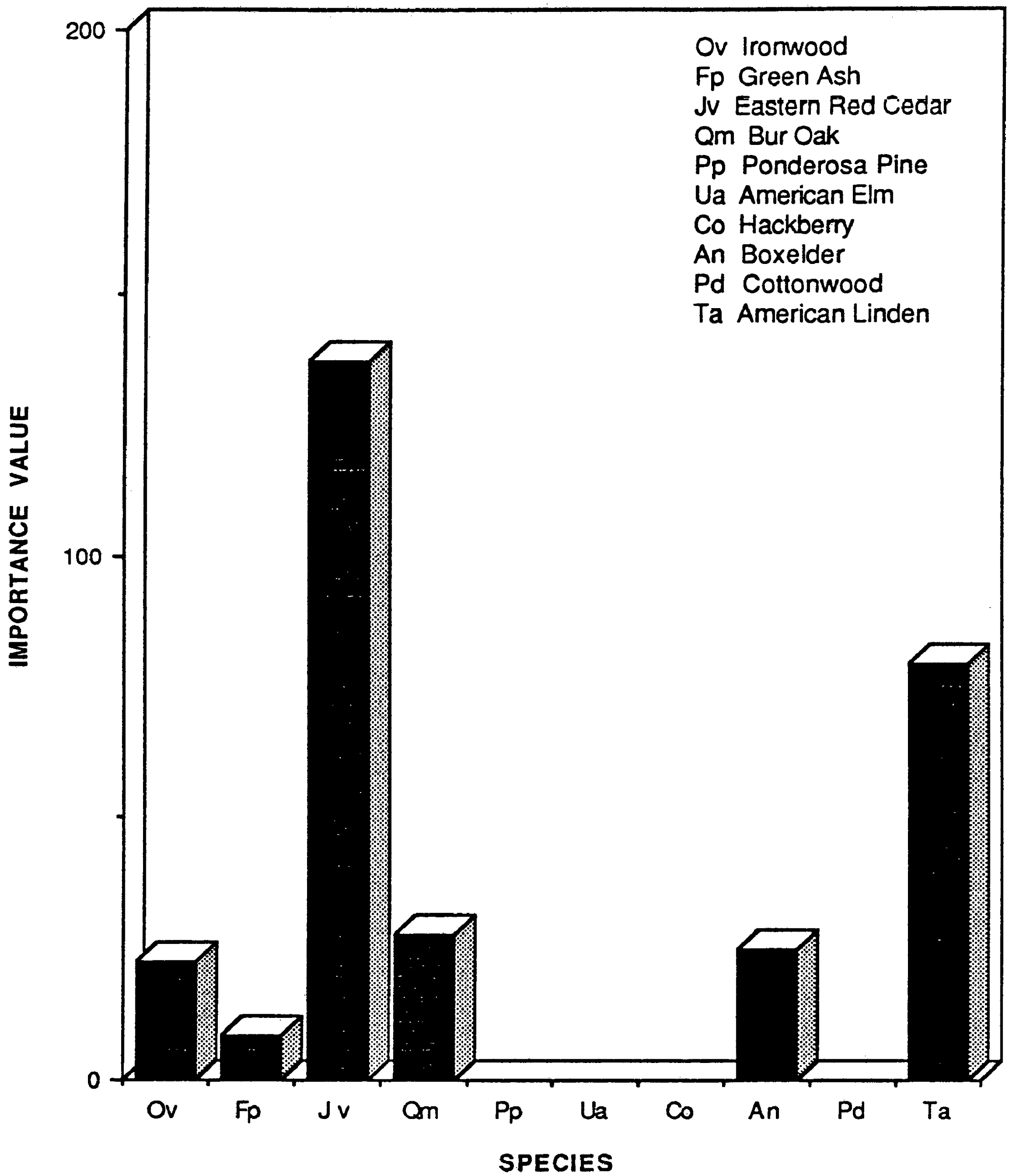
IMPORTANCE VALUES TRANSECT 2M

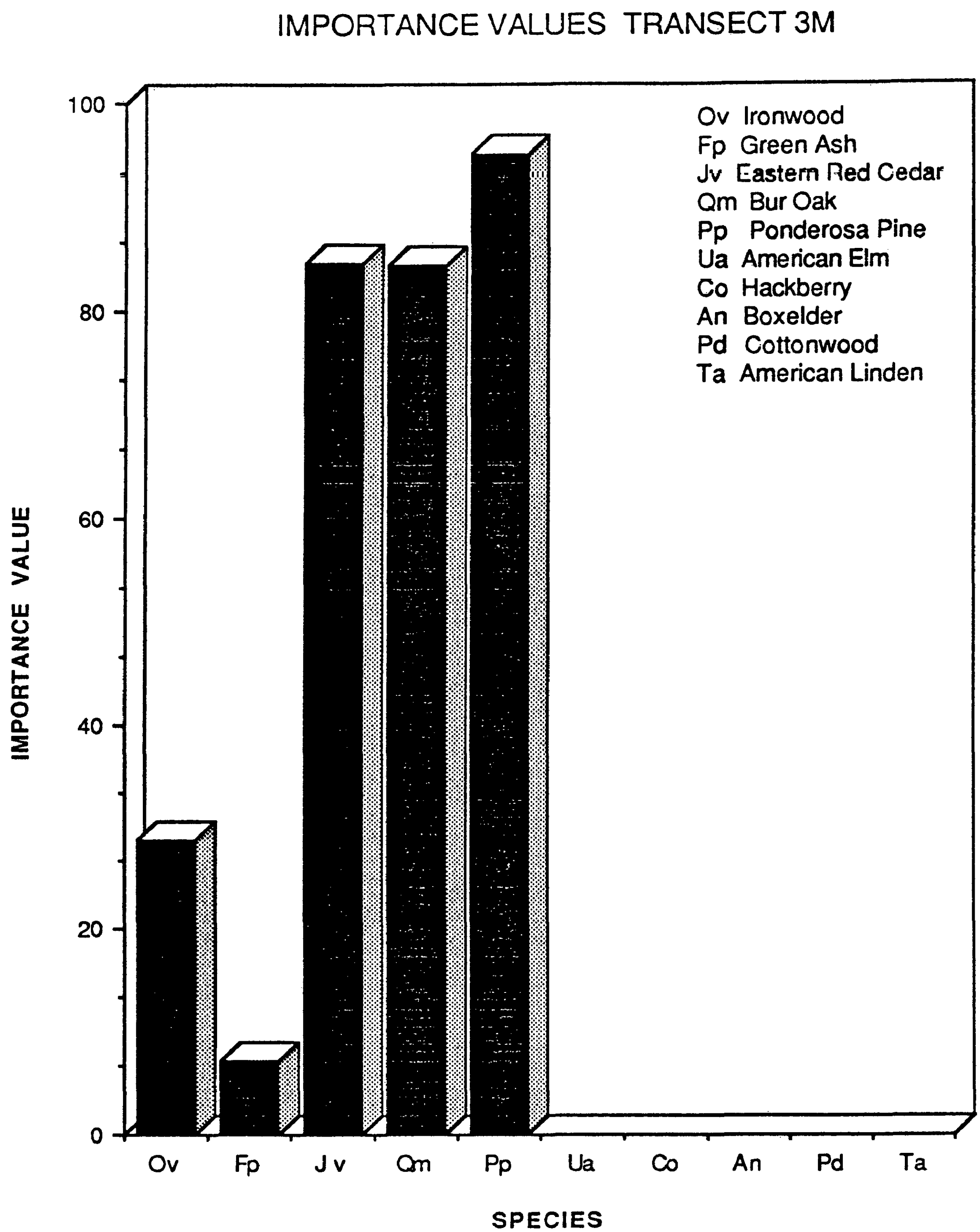


IMPORTANCE VALUES TRANSECT 2T

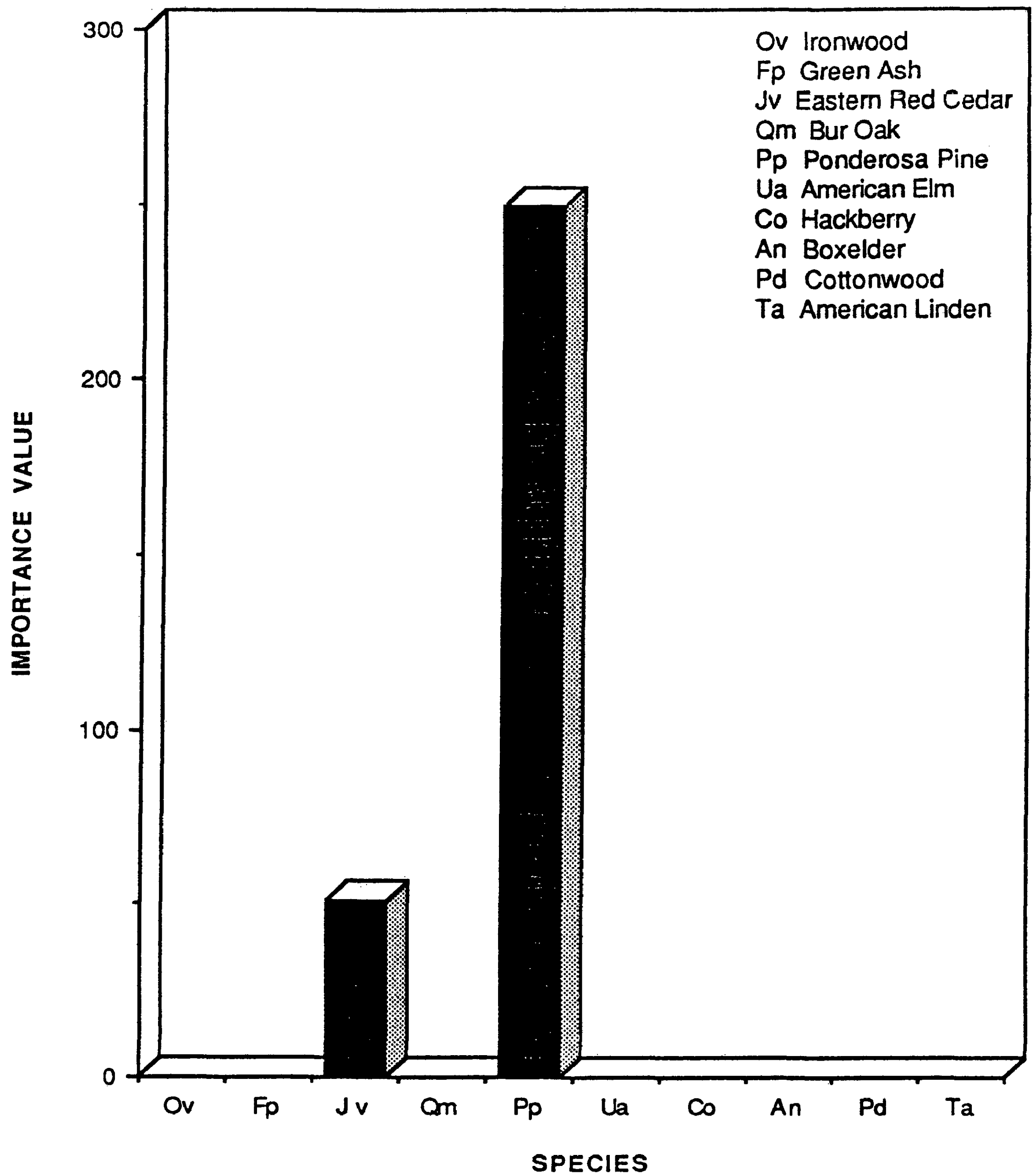


IMPORTANCE VALUES TRANSECT 3F




IMPORTANCE VALUES TRANSECT 3M
IMPORTANCE VALUE
0
20
40
60
80
100
Ov Ironwood
Fp Green Ash
Jv Eastern Red Cedar
Qm Bur Oak
Pp Ponderosa Pine
Ua American Elm
Co Hackberry
An Boxelder
Pd Cottonwood
Ta American Linden
Ov
Fp
J v
Qm
Pp
Ua
Co
An
Pd
Ta
SPECIES

IMPORTANCE VALUES TRANSECT 3T



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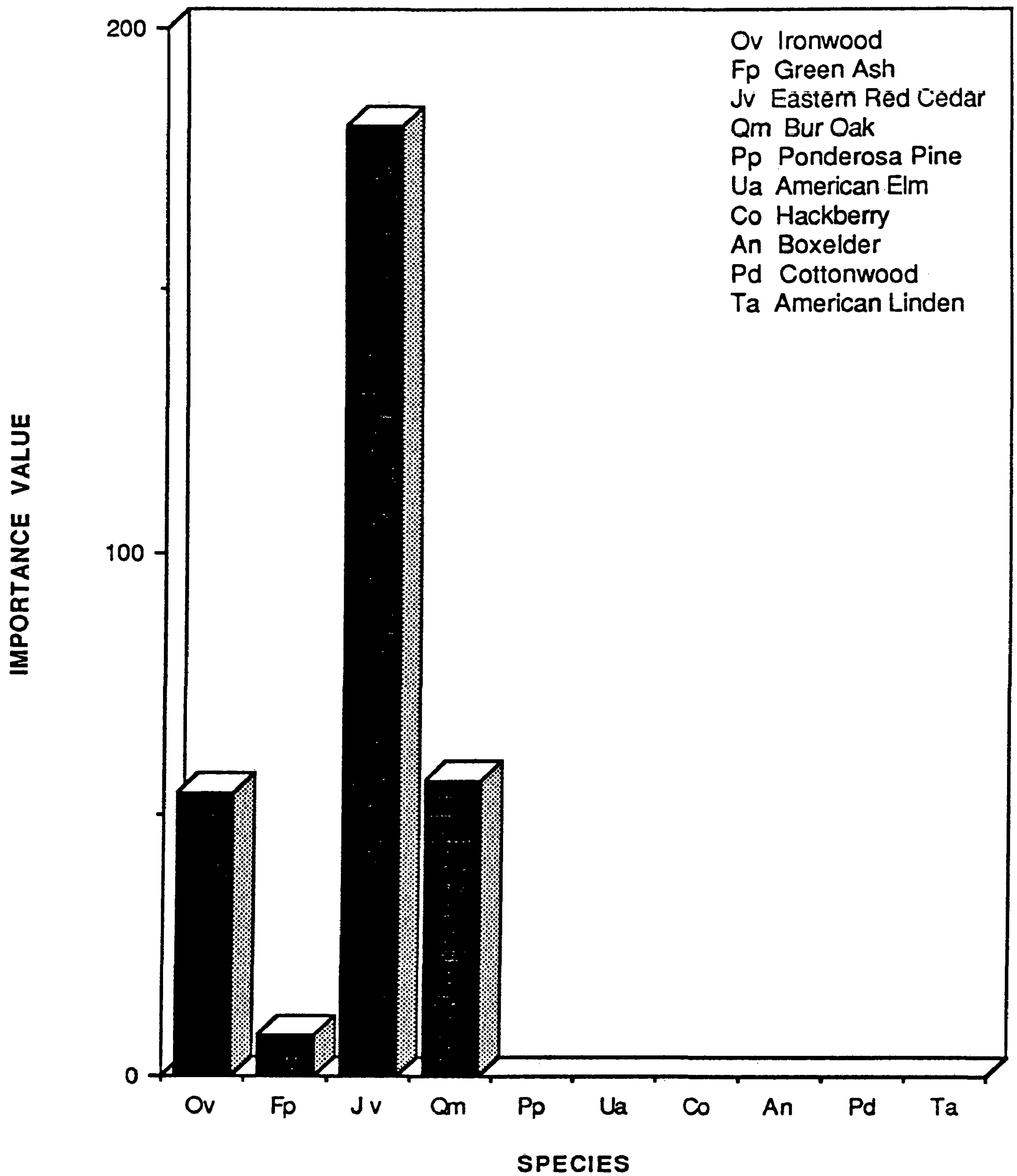
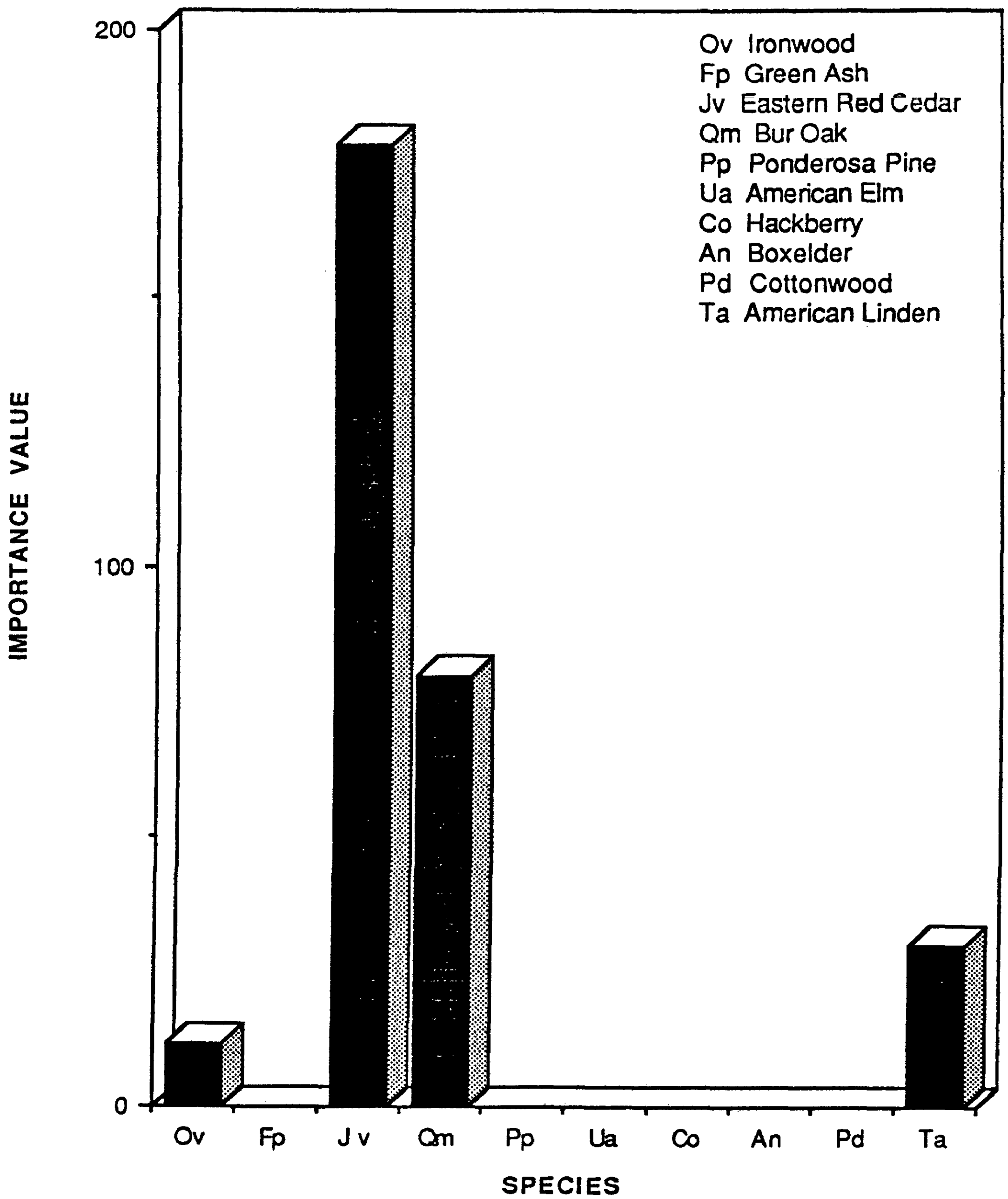
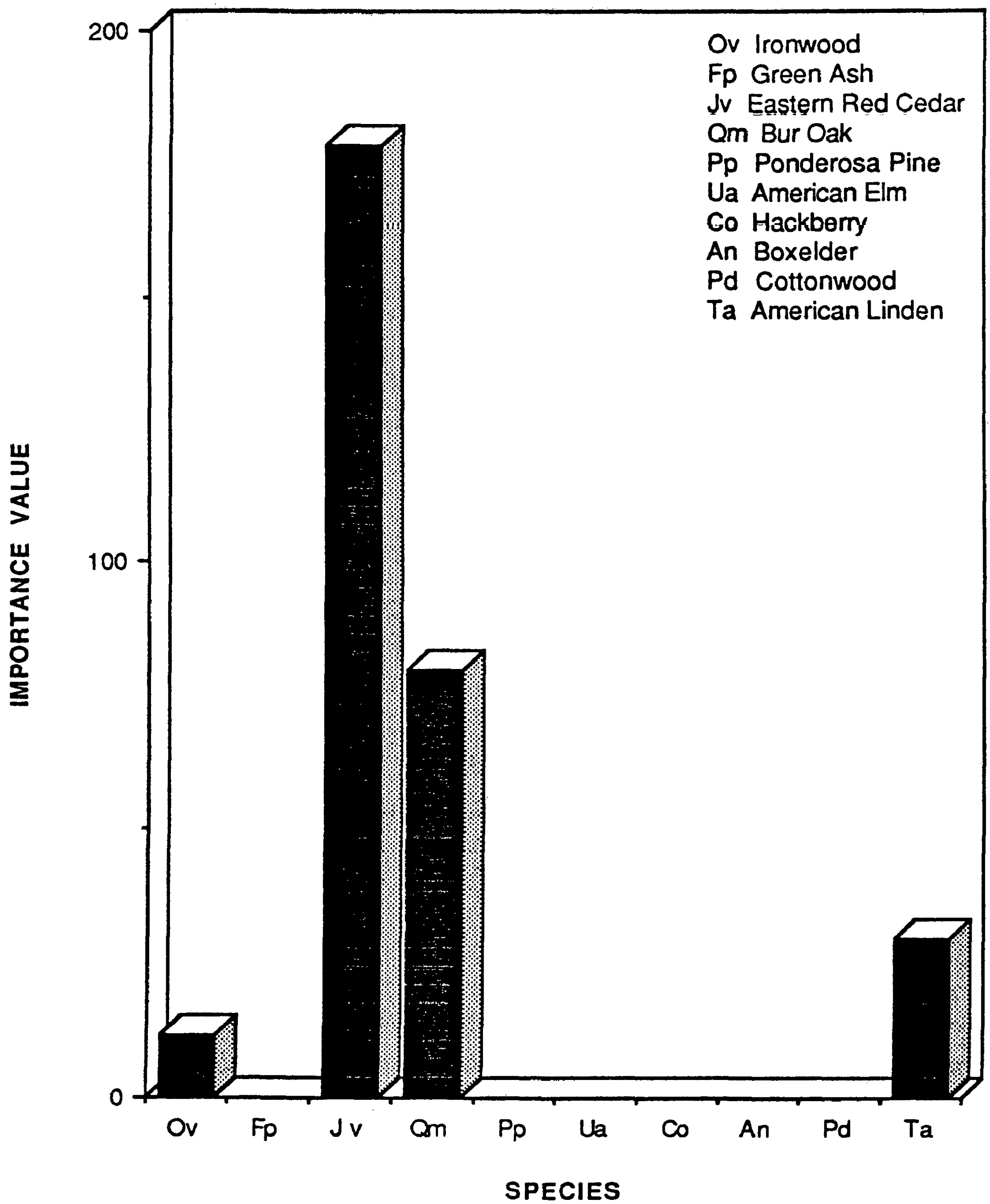


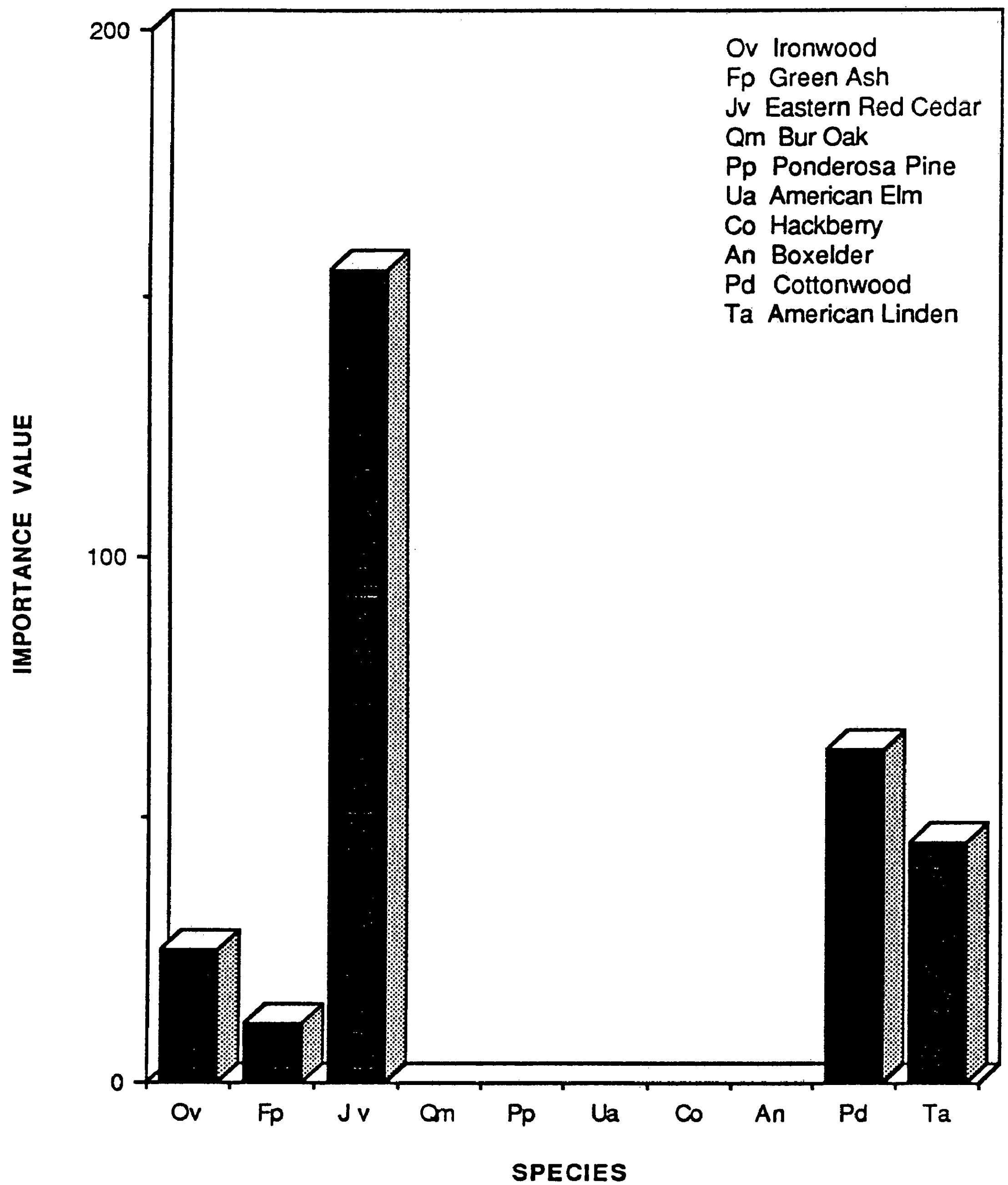
IMPORTANCE VALUE TRANSECT 4M



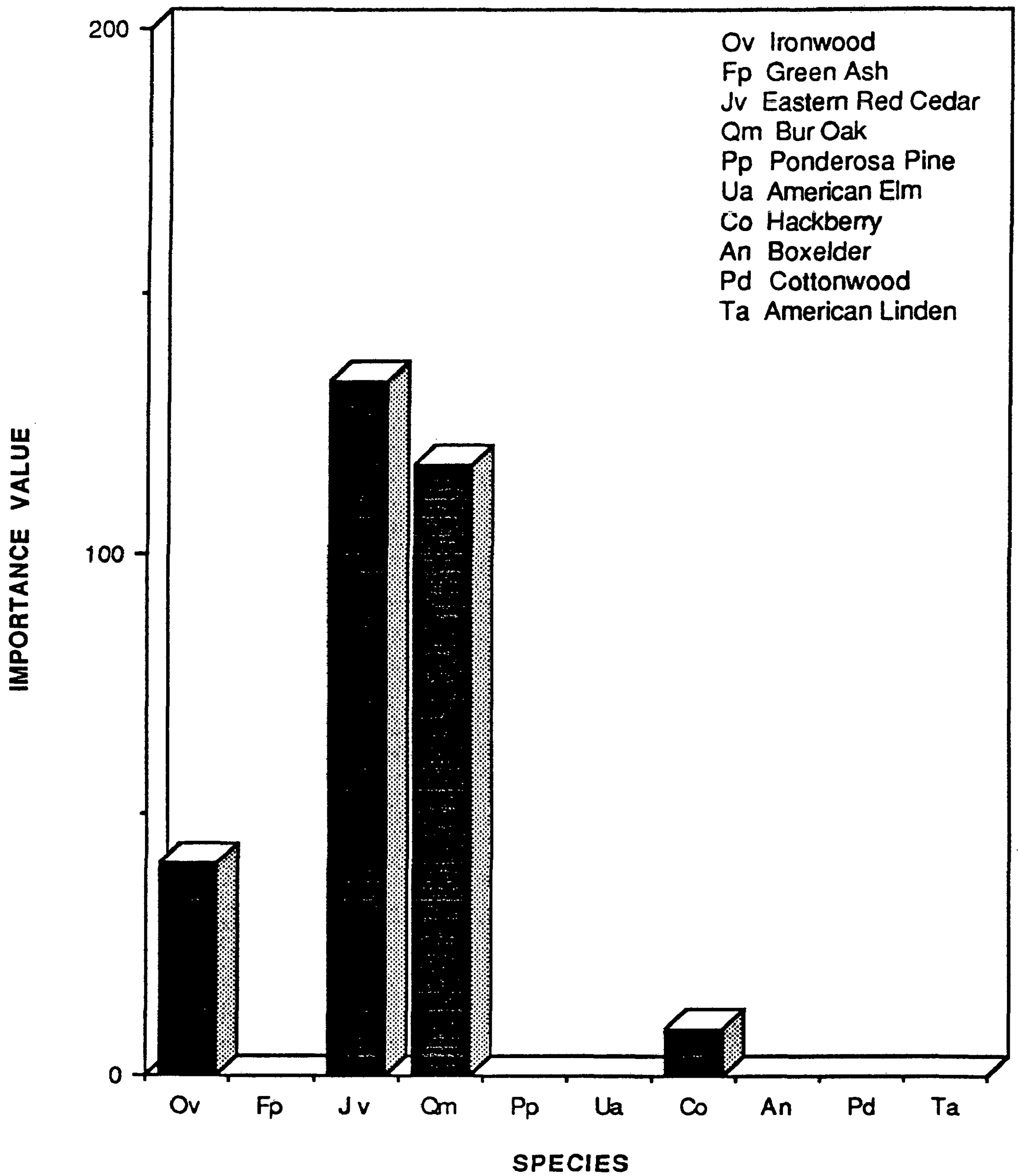
IMPORTANCE VALUES TRANSECT 4T



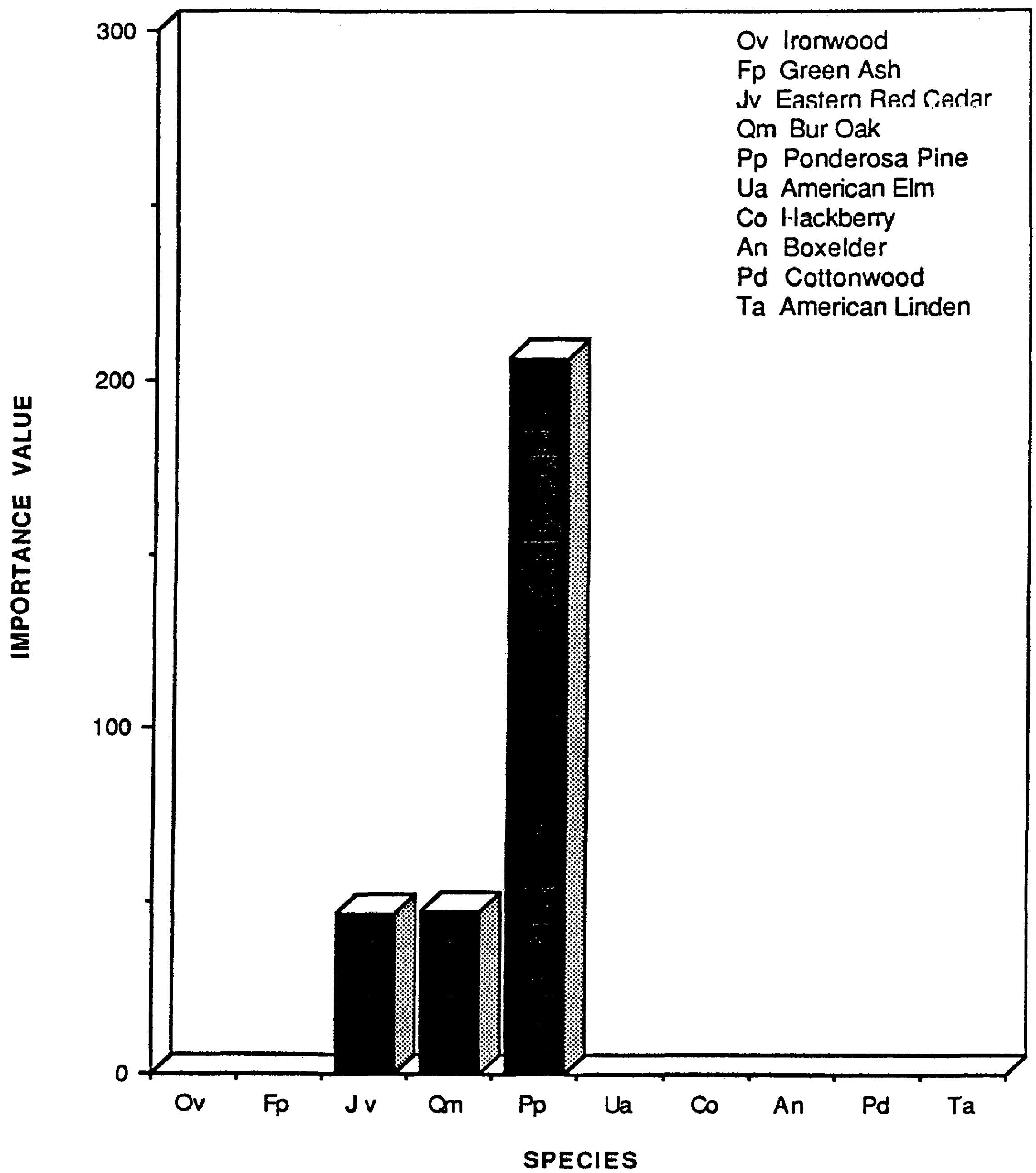
IMPORTANCE VALUES TRANSECT 5F



IMPORTANCE VALUE TRANSECT 5M



IMPORTANCE VALUES TRANSECT 5T



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