VEGETATIONAL CHANGES IN YOSEMITE VALLEY

National Park Service Occasional Paper Number Five • 1978

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Library of Congress Cataloging in Publication Data

Heady, Harold F.
Vegetational changes in Yosemite Valley.

(Occasional paper—National Park Service ; no. 5)
Bibliography: p.
Supt. of Docs. no. : I 29.14:5
1. Botany—California—Yosemite Valley—Ecology.
2. Man—Influence on nature—California—Yosemite Valley. 3. Yosemite Valley. I. Zinke, Paul J., joint author. II. Title. III. Series: United States. National Park Service. National Park Service occasional paper ; no. 5.
QK149.H46 639'.99'0979447 78-606040

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IN

YOSEMITE VALLEY

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ACKNOWLEDGMENTS

Although individuals made this study possible, the financial support and the personal interest of staff at the U. S. National Park Service in Yosemite Valley and the Regional Office in San Francisco were the keys to the success of the project. Robert P. Gibbens searched the historical records; Earl Alexander and James Crawford did much of the soil survey; and Robert L. Ziegler and James Bartolome sampled the vegetation. This help is acknowledged gratefully.

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Washington, D.C. 20402

Stock Number 024-005-00749-1

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ABSTRACT

Yosemite Valley in California's central Sierra Nevada has been used primarily as a recreational site since its discovery in 1851. Recreational facilities needed to make the valley accessible and to enhance or maintain its beautiful setting have impacted upon the vegetation, animals, and soil in many ways. Crops, planted pastures, haymaking, horses, dairy animals, corrals, a slaughter house, and fencing preceded automobiles and refrigeration. Roads, campgrounds, a garbage dump, a sewage plant, barrow pits, drainage tiles, buildings, walkways, water developments, and utility lines, enhanced the safety, comfort, and pleasure of visitors. Subtle control occurred in populations of tree seedlings in the meadows, weeds, deer, bear, and forest insects. Removal of trees for building sites, firewood, safety, and vista clearing as well as other ecological influences continues today. It is a necessary situation with more than two million visitors per year in Yosemite Valley.

Despite these disturbances, Yosemite Valley has a healthy vegetational cover. Several conclusions were reached after analysis of photographs (some over 100 years old), written materials in park files, age structure of forest stands, botanical composition in relation to soil development, and vegetational measurements over a 10-year period. Forest stands have thickened with the continuous establishment of trees over the last 100 years. Half of the area that was meadow in the late 1800s is now forest. All of the meadows might have disappeared without the intentional and unintentional control of trees. All the soil types in the valley support trees and many sites are excellent for tree growth. Plant succession on a bare area proceeds rapidly from annual broadleaved plants through annual grasses, perennial grasses, and sedges to dominance by a mixed coniferous forest. Introduced plant species altered botanic composition in all stages of grassland succession, but overall meadow views remain essentially unchanged. Young trees must be removed continually from the meadows to maintain the vistas of waterfalls, granite cliffs, and mountain spires. Suggestions for vegetational management are given.

INTRODUCTION

The Charter of the National Park Service requires conservation of park land, vegetation, and animals in essentially "natural conditions" for the enjoyment of people. However, the presence of people causes many changes in park ecosystems. Each park manager must evaluate the origin and condition of the present system. This paper examines the existing vegetation of Yosemite Valley to determine changes that have occurred in the recent past and the extent to which they might continue.

Since 1851, modern man has subjected the vegetation and soil in Yosemite Valley to burning, plowing, seeding of crops and pastures, irrigation, mowing, livestock grazing, clearing of trees and brush, logging, hand pulling of young conifer trees, and competition from introduced plants such as wildflowers, fruit and ornamental trees, exotic weeds, and many annuals. Changed drainage patterns and soil moisture conditions resulted from filling of low areas, fencing, road building, use of drainage tile in one of the meadows, lowering the Merced River bed at the valley outlet, burying utilities, and construction of hotels, stores, gravel pits, a sewage plant, and a slaughter house. Animal influences fluctuated with varying numbers of horses, dairy cattle, and beef cattle; tule elk from 1921 to 1933; and occasional reduction of deer, bear, rodents, and forest insects. The klamath-weed beetle (*Chrysolina quadrigemina*) was introduced into the valley in 1950.

This study of Yosemite Valley began in 1961 to (1) chronicle events that influenced the valley landscape from 1851 to the present (Gibbens and Heady 1964); (2) make a detailed soil survey of the valley (Zinke and Alexander 1963); (3) quantify the meadow vegetation (Ziegler and Heady 1964); (4) measure the forest vegetation (Ziegler and Heady 1965); and (5) collect information on recent vegetational changes. Results of the vegetational studies are presented here with reference to the soil and historical surveys without which vegetational patterns and successional changes would have little meaning.

Information on the impact of visitors aids landscape management. Yosemite particularly is suited to a study of man's influences because of several unique factors. Since Europeans first entered the valley in 1851, enhancement of aesthetic values and recreational use, rather than logging or grazing, has been the central objective (Bunnell 1911). Unpublished records maintained at the park headquarters permitted appraisal of events that caused vegetational change from the beginning of use. Photographs from the top of the canyon walls in 1866 are among the earliest oblique aerial photographs that recorded valley vegetation long before quantitative vegetational measurements were made. The canyon walls circumscribe environment, vegetation, and use of a small area with natural and unusually restrictive boundaries.

In this study we used current data on soil and vegetation; repeat photographs, some taken over 100 years apart; general descriptions, usually without quantifications of any kind; historical documents which often plead issues; and a large measure of deductive assessment to justify our conclusions on man's impact on the vegetation of Yosemite Valley.

THE VALLEY

The Merced River, which flows through Yosemite Valley, drains westward from the central Sierra Nevada in California at approximately latitude 37°45′ N. and longitude 119°35′ W. A Mediterranean-type climate prevails with cool wet winters and hot dry summers. Monthly mean temperature ranges from 1.33°C in January to 21.56°C in July. The mean annual precipitation for a 56-year period was 950 mm (38 inches) of which 30 mm (1.2 inches) fell from June through September. Snow falls every winter but it usually melts rapidly (U. S. Weather Bureau 1961). Elevations above sea level are 1,250 m (4,125 feet) at the upper end of the valley and 1,180 m (3,894 feet) at the lower. The valley is about 11 km (6.6 miles) long and 0.8 km (0.5 miles) wide. The 1,220 m (4,000 feet) contour on the 1961 U. S. Geological Survey map coincides approximately with the foot of the talus slopes and contains over 890 ha in its loop around the valley above Pohono Bridge.

GEOLOGY

Pleistocene glaciers cut Yosemite Valley into its present pattern of cliffs and hanging valleys and

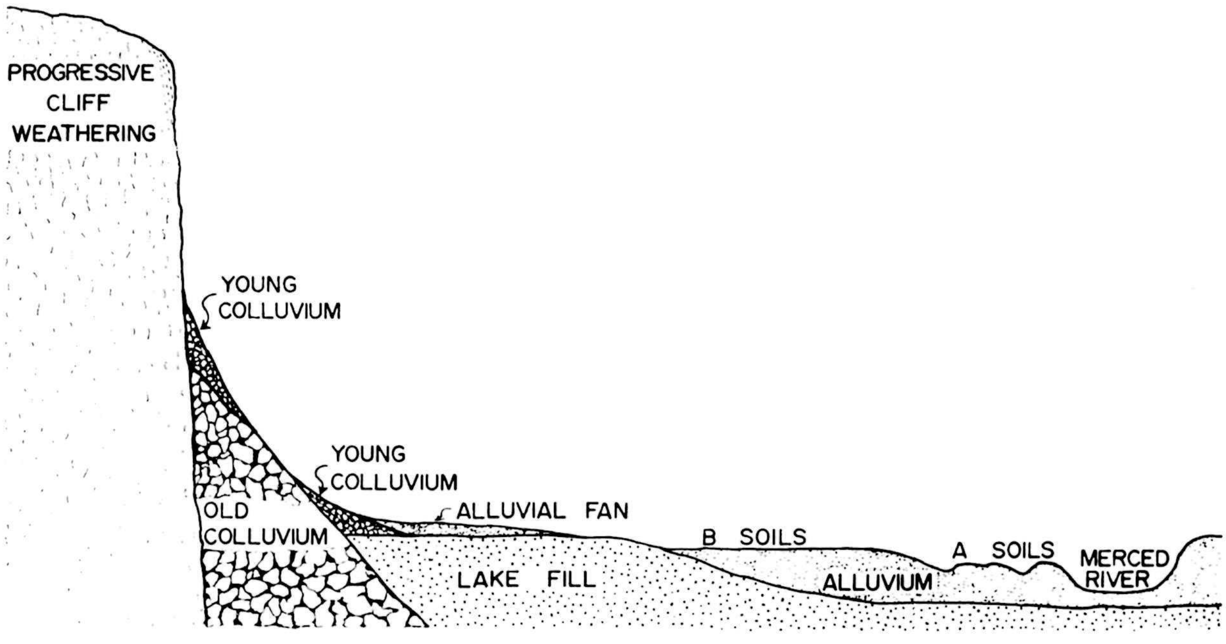

Fig. 1. Cross section of Yosemite Valley showing relationships of several colluvial and alluvial deposits.

quarried away several hundred meters of granite from the valley floor to form ancient Lake Yosemite (Wahrhaftig 1962). At least three glaciers occupied the valley, as indicated by moraines in the vicinity of Bridalveil Falls and by three layers of lake fill which have a total thickness of about 600 m (1,980 feet) (Gutenberg et al. 1956). Ancient Lake Yosemite became completely filled with sediment. Later, the Merced River cut the moraine, reworked the lake fill, and produced the present flood plain about 5 m (16.5 feet) below the older lake terraces. Thus, lake fill has been exposed in a few places (Fig. 1). Most lake deposits are covered with recent colluvial and alluvial materials from the canyon sides. Rocks deposited in the valley are predominantly siliceous igneous intrusive, and the sands principally quartz, alkali feldspars, and biotite.

Frequent winter and spring floods sometimes cover as much as 50% of the valley floor leaving layers of fine sand and silt. Abandoned river channels and low areas gradually are filled. Most efforts to confine the river to its channel and to prevent cutting of banks have failed. Flooding and deposition, as well as a low water table during the dry summer, affect soil development and vegetation. Less marshland occurs now than when the valley was discovered because the Merced River channel has deepened.

METHODS

In a soil survey, the soils of Yosemite Valley were characterized and mapped on 1962 aerial photographs (scale 1/12,000) according to techniques used in the California Soil–Vegetation Survey (Zinke 1962). Profile characteristics served to delineate soils with their classification based on mode of origin and topographic position. Field mapping extended from Artist Creek below Pohono Bridge to Vernal Falls along the Merced River and to Snow Creek in Tenaya Canyon. Vertically, mapping included the talus slopes. Types were mapped to a minimum area of 0.4 ha (1 acre). After field mapping, the information was transferred to the U. S. Geological Survey, Yosemite Valley Quadrangle, scale 1/24,000, 1961 edition base map.

The mapped soil units, 346 in the forest and 48 in meadows, constitute the basic sampling divisions for analyzing the vegetation reported herein. However, the elimination of small soil units and the addition of a few units from widespread soil types resulted in 280 being sampled.

A singular circular vegetational plot 15 m (50 ft) in diameter was located near the middle of each mapped forest type. The investigator tallied woody species in height classes as less than 0.3 m (1 ft), 0.3–1.8 m (1–5 ft), 1.8–6 m (5–20 ft), 6–15 m (20–50 ft) >15 m immature, and >15 m mature. Within each height class, the number of plants per plot was recorded in classes of 1–5, 6–25, 26–100, and >100. Ocular estimates to the nearest 5% characterized total crown cover above 1.4 m (4.5 ft), herbaceous cover below 1.4 m, and litter cover. Herbaceous species were listed for each plot. Frequency of browsing on each woody species was estimated on each plot.

The point system with a frame that held 10 pins was used for sampling the meadows. Groups of 10 points were read on a paced grid for a total of 400 to 800 points within each meadow soil-vegetation type.

LANDFORMS, SOILS, AND VEGETATION

All of the soils of Yosemite Valley originated from materials of similar chemical makeup, mineralogical composition, and under similar climatic conditions. None of the soils in Yosemite Valley approach maturity. Topography, stoniness, and age have been the major influences on soil differentiation. Topography was the most important because it controls surface runoff and ground water, accounts for the distribution of stony soils, and causes the separation of alluvial soils of different ages. Topography caused slight climatic differences between the valley floor, the hotter and dryer south-facing slopes, and the cooler north-facing slopes. The resulting landforms, which are shown in schematic profile across the valley (Fig. 1) and mapped (Fig. 2), are used in this paper as the basic units for analysis of soils and vegetation.

The soils were classified in 1962 according to seven landforms. The lowest are near permanent streams and were recently deposited sands with (A) and without (As) profile development. The B soils occurred at slightly higher positions and showed profile development. The outreach of coarse soils extended to alluvial fans (F) and apron deposits (C lower). Upper talus slopes (C upper) and moraines (D) were the other two landforms. Division within each landform into soil series was based on rockiness, color, and internal drainage.

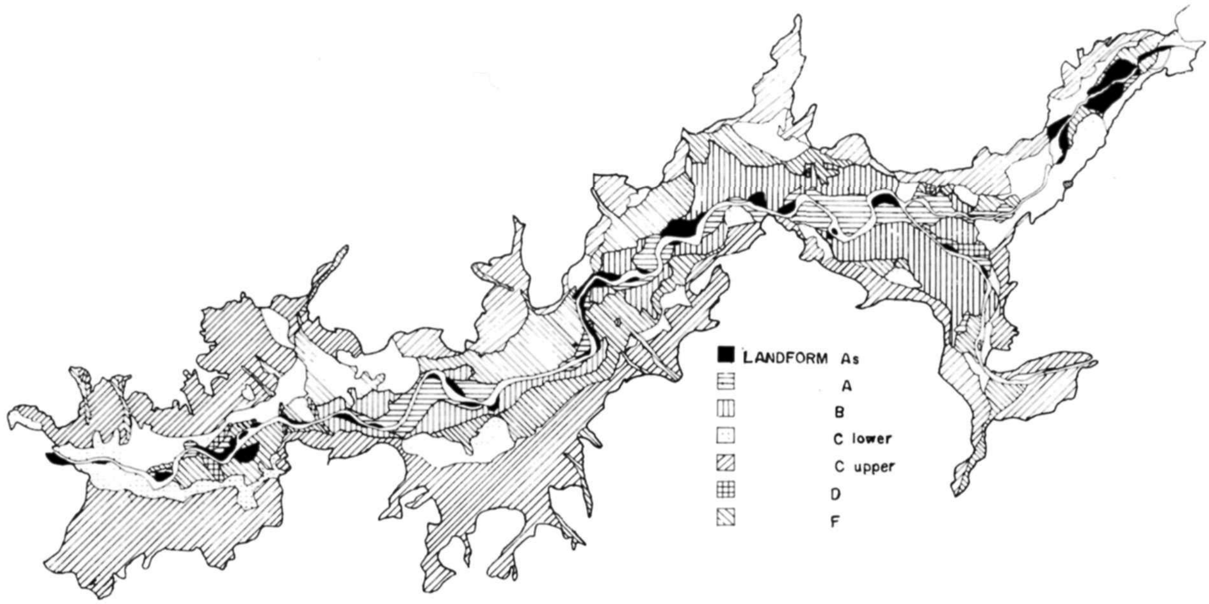

Fig. 2. Landforms in Yosemite Valley. The valley is approximately 11 km × 0.8 km (6.6 × 0.5 miles). Landform As adjoins the Merced River which flows from right to left.

Recent Alluvium Without Profile Development (As)

Landform As (Fig. 2) flooded annually and the soil material consisted of sands and larger components deposited by the Merced River, Tenaya Creek, and small tributary streams. No soil profile had developed. Channels caused by flooding and the presence of oxbows gave the landform an uneven surface. Point-bars in the bends of the Merced River illustrated this most recent alluvium.

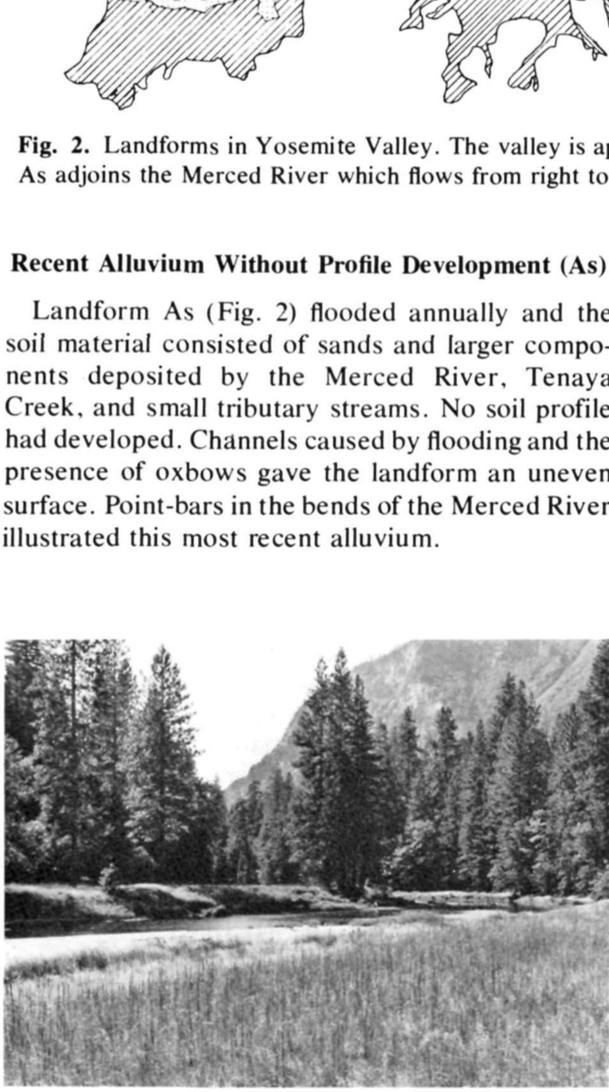

Fig. 3. Grasses and broadleaved plants quickly invade the sandy point-bars of recent alluvial deposits along the Merced River.

Vegetation rapidly becomes established on the youngest alluvial areas (Fig. 3). Tree species common on other landforms dominated, including *Libocedrus decurrens* (incense cedar), *Pinus ponderosa* (ponderosa pine), *Quercus kelloggii* (black oak), *Quercus chrysolepis* (canyon liveoak), *Abies concolor* (white fir), and *Pseudotsuga menziesii* (Douglas fir). Riparian species such as *Populus trichocarpa* (black cottonweed), and *Alnus rhombifolia* (white alder) were abundant locally. The relatively low frequencies and densities of most of the woody species (Fig. 4) suggested open forest. The presence of mature trees of *L. decurrens*, *P. ponderosa*, *Q. kelloggii*, *P. menziesii*, *Acer macrophyllum* (big-leaf maple), *P. trichocarpa*, and *A. rhombifolia*, as well as trees in nearly all of the shorter height classes, implied continuous invasion of plants on new alluvium. The vigor of the trees indicated healthy individuals and fast growth.

Foliage cover in this open forest type was about 41% by trees and 41% by herbaceous species (Table 1), which was the least tree cover and the greatest herbaceous cover of all the forested types. Herbaceous species with the highest frequencies were *Elymus glaucus* (blue wild-rye), *Carex* spp. (sedge), *Pteridium aquilinum* (bracken fern), *Poa pratensis* (Kentucky bluegrass), *Agrostis alba* (redtop), *Artemisia douglasiana* (Douglas mugwort), *Rumex acetosella* (sheep sorrel), *Equisetum arvense* (horsetail), *Galium bolanderi* (bedstraw), *Bromus tec-*

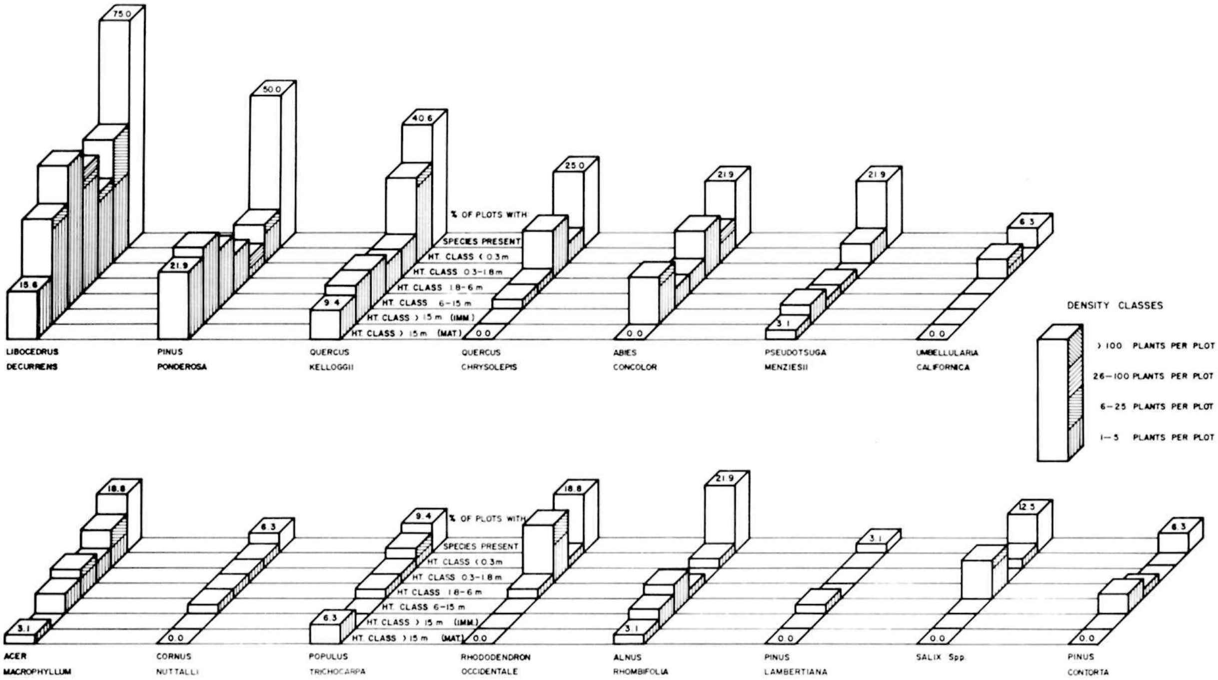

Fig. 4. Frequency, height classes, and density classes of woody plants on landform As, recent alluvium without profile development. Overall frequency is shown in the back bar for each species by the height and as a percentage. The front bars show frequency by height classes. Hatching indicates density within height classes.

torum (cheat grass), *Holcus lanatus* (velvet grass), *Mentha arvensis* (mint), and *Potentilla glandulosa* (cinquefoil) (Table 2). Meadow vegetation on this landform occurred in the Slaughter House, Leidig, Sentinel, and Cook's meadows.

Recent Alluvium with Profile Development (A)

Older alluvial deposits, but those still flooded annually, showed a color profile and were designated landform A (Figs. 1 and 2). These soils had recent

Table 1. *Cover estimates based on plots 15 m in diameter within the forest vegetation of Yosemite Valley.*

		Woody vegetation		Herbaceous vegetation		Litter	
Landform	No. of plots	% Cover	SE	% Cover	SE	% Cover	SE
Alluvium without soil profile (As)	33	41.0	5.33	40.8	5.71	72.4	4.42
Alluvium with soil profile (A)	29	56.9	4.59	37.8	6.81	91.6	2.18
Alluvium seldom flooded (B)	21	54.8	5.30	22.2	6.43	93.3	2.27
Moraine (D)	10	59.0	1.75	2.2	0.63	92.5	3.35
Fans (F)	57	46.0	3.40	10.1	2.35	75.7	4.12
Lower colluvium (C)	63	67.9	2.01	1.9	0.55	89.0	2.50
Upper colluvium C	67	59.0	2.61	3.8	3.80	72.8	3.65
Combined	280	55.7	1.52	13.7	1.50	81.2	1.54

SE = Standard error.

Table 2. *Percentage frequency of herbaceous species in the understory of forest types according to landform.*

Species	Alluvium without profile	Alluvium with profile	Alluvium seldom flooded	Moraine	Fan	Lower colluvium	Upper colluvium
Broadleaved							
Achillea lanulosa	15.2	6.9	4.8		7.0		1.5
Agastache urticifolia	9.1	10.3	4.8				1.5
Apocynum cannabinum	6.1	3.5	4.8		3.5	3.2	2.9
Aquilegia formosa		13.8			1.8		
Artemisia douglasiana	30.3	6.9	9.5		8.8	3.2	2.9
Artemisia dracunculus	15.2	6.9			5.3		
Artemisia tridentata					1.8		2.9
Asarum hartwegii	6.1	10.3	9.5		17.5	15.8	13.4
Asclepias cordifolia					5.3		
Asclepias speciosa	3.0						
Aster adscendens		3.5					1.5
Boykinia major						4.8	6.0
Brickellia californica						4.8	11.9
Brodiaea lutea		3.5	4.8				
Calyptridium umbellatum					3.5		
Castilleja breweri					3.5		1.5
Chamaebatia foliosa				10.0	7.0	1.6	1.5
Cirsium vulgare	3.0	13.8			3.5		1.5
Conyza canadensis		6.9	4.8				
Erigeron breweri					5.3		
Eriogonum latifolium	6.1		4.8	10.0	7.0	3.2	1.5
Fragaria californica	3.0	6.9				1.6	
Galium bolanderi	24.2	44.8	19.0		21.1	4.8	1.5
Gayophytum diffusum	6.1	3.5	9.5	10.0	5.3		
Gilia capitata		3.5	4.8	10.0	5.3	3.2	
Heracleum lanatum	3.0	3.5			1.8		
Hypericum formosum		6.9					
Hypochoeris glabra					1.8		
Hypochoeris radicata		3.5	4.8		3.5		
Lessingia leptoclada	9.1		4.8		8.8		
Linanthus montanus				10.0			
Lotus oblongifolius	3.0	3.5	4.8	20.0	5.3		2.9
Lupinus albifrons		3.5			1.8	4.8	1.5
Lupinus arbustus		3.5			7.0		4.5
Mentha arvensis	18.2	13.8	4.8		5.3		
Micropus californicus					1.8		
Montia perfoliata	6.1	24.2	4.8		15.8		
Navarretia divaricata					3.5	1.6	1.5
Orobanche fasciculata					1.8		
Penstemon newberryi						9.5	19.4
Phacelia heterophylla	6.1		4.8				7.5
Potentilla glandulosa	18.2	34.5	28.6	10.0	29.8	3.2	7.5
Rudbeckia hirta			4.8				
Rumex acetosella	30.3	13.8	14.3		1.8		
Rumex crispus	9.1						
Senecio vulgaris			4.8			1.6	
Solidago canadensis	9.1	3.5	4.8				
Trillium chloropetalum			4.8				
Vitis californica						1.6	
Grass							
Agrostis alba	30.3	24.2	14.3				

Table 2. *Percentage frequency of herbaceous species in the understory of forest types according to landform (continued).*

Species	Alluvium without profile	Alluvium with profile	Alluvium seldom flooded	Moraine	Fan	Lower colluvium	Upper colluvium
Aira caryophyllea	3.0						
Avena barbata					1.8		
Bromus marginatus	6.1	10.3	14.3		7.0	3.2	1.5
Bromus mollis	6.1						1.5
Bromus rigidus	6.1				1.8		
Bromus rubens					5.3		
Bromus tectorum	21.2		14.3	20.0	17.5	4.8	8.9
Calamagrostis canadensis	15.2	3.5					
Cynosurus echinatus							1.5
Deschampsia elongata	3.0		4.8				
Elymus glaucus	57.6	75.9	52.5		31.6	15.8	11.9
Festuca megalura	9.1	3.5	4.8		12.3	6.4	6.0
Festuca occidentalis	6.1	6.9	4.8		10.5	3.2	4.5
Festuca reflexa						1.6	1.5
Holcus lanatus	18.2	38.0	9.5		3.5		1.5
Melica imperfecta						11.1	13.4
Muhlenbergia filiformis	3.0		4.8				
Panicum pacificum	6.1	6.9	4.8		1.8		
Phleum pratense		3.5					
Poa pratensis	33.3	24.2	19.1		1.8		
Poa scabrella	6.1		28.6	20.0	40.4	34.9	20.9
Sitanion hystrix			4.8	20.0	19.3	3.2	4.5
Stipa columbiana	3.0	3.5	9.5	20.0	15.8	4.8	2.9
Other							
Carex spp.	42.4	58.4	14.3	30.0	10.5		1.5
Juncus balticus	12.1	10.3			22.8	22.2	14.9
Scirpus spp.	6.1	3.5					
Equisetum arvense	27.3	24.2	4.8			1.6	
Athyrium filix-femina					1.8	1.6	2.9
Dryopteris arguta		6.9			1.8	6.4	17.9
Polystichum munitum					3.5		1.5
Pteridium aquilinum	39.4	51.7	66.7	60.0	40.4	11.1	1.5

surface deposits of fresh sand and silt. Judgment was used to designate some A soils because flooding gradually decreases as the distance from the Merced River increases. No distinct modern flood plain terraces occurred in the valley.

Scattered mature trees of *Libocedrus decurrens*, *Pinus ponderosa*, *Quercus kelloggii*, *Populus trichocarpa*, and *Alnus rhombifolia* dominated the forest on landform A (Fig. 5). *L. decurrens*, *P. ponderosa*, and *Q. kelloggii* were the only species in which all size classes occurred. Not only did *L. decurrens* have the highest frequency of any species (87.9%), but it also had the highest frequency in almost all size classes.

Pinus ponderosa showed a relatively higher frequency of trees greater than 15 m (50 ft) tall than those less than 15 m tall. Many individuals in the 1.8- to 6-m (6–20 ft) size class were suppressed, dead, or dying. Trees in the two smaller size classes were not vigorous, especially if they were growing in heavy shade. Dense canopy restricts this species.

Quercus kelloggii had the same total frequency (82.8%) as *Pinus ponderosa*. The high frequency for *Quercus* resulted primarily from the scattered plants in the seedling and mature classes. *Q. kelloggii* had a very low frequency in the intermediate size classes. It formed open stands in or near the meadows (Fig. 6).

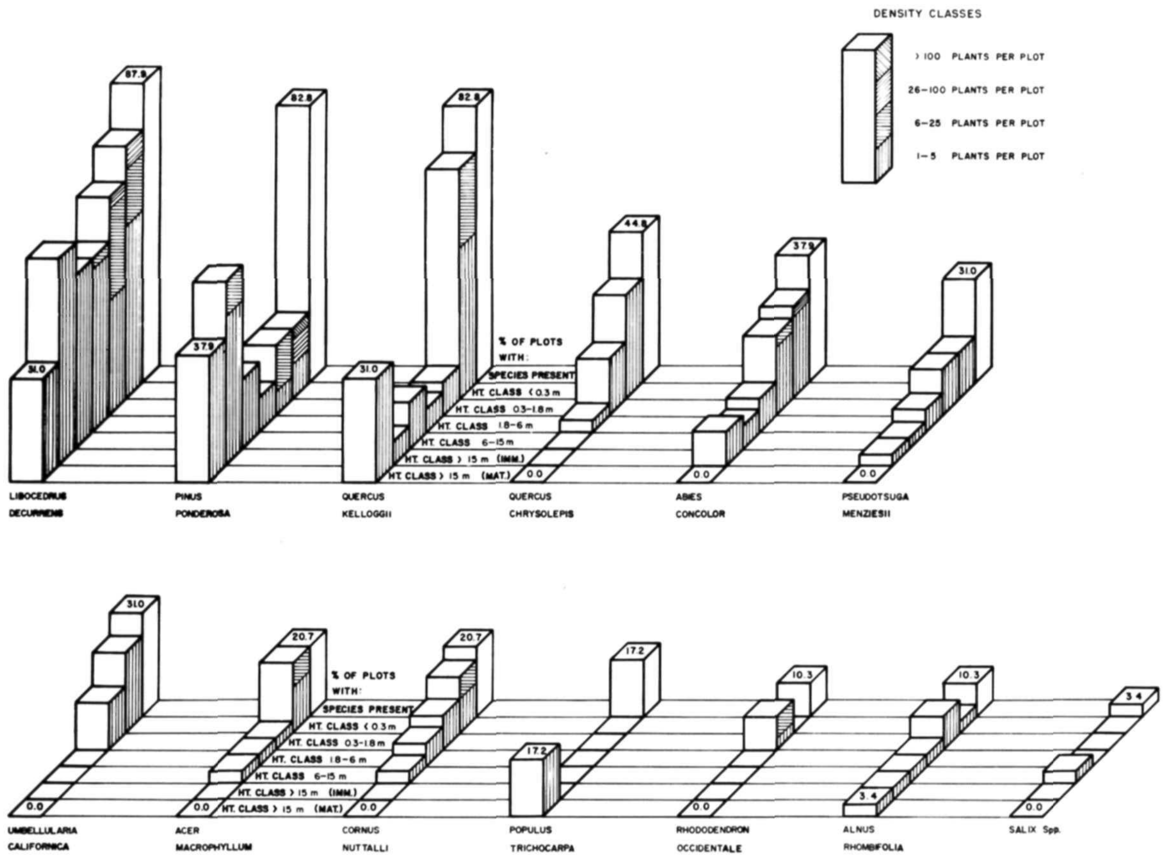

Fig. 5. Frequency, height classes, and density classes of woody plants on landform A, recent alluvium with profile development. Overall frequency is shown in the back bar for each species by the height and as a percentage. The front bars show frequency by height classes. Hatching indicates density within height classes.

Fig. 6. An open stand of mature *Quercus kelloggii* with few weeds or shrubs taller than the grasses. Deer continually browse off the lower branches of the *Quercus* and search for fallen acorns.

On this landform, *Quercus chrysolepis* and *Umbellularia californica* (California bay) appeared as branched shrubs rather than as young, single-stemmed trees, which was the case on the xeric sites in the valley. *Q. chrysolepis* appeared in a growth form greater than 2 m (6.6 feet) tall on only one plot; *U. californica* had not attained 2 m on this landform.

Abies concolor and *Pseudotsuga menziesii* were present on this landform, but mostly in the lower size classes. *P. menziesii* occurred on only one plot and *A. concolor* on three plots with a height greater than 15 m.

The A landform soils had a cover of 57% trees and 38% herbaceous plants (Table 1). The herbaceous species with the highest frequencies in this area were *Elymus glaucus*, *Carex* spp., *Pteridium aquilinum*, *Galium bolanderi*, *Holcus lanatus*, *Potentilla glandulosa*, *Agrostis alba*, *Equisetum ar-*

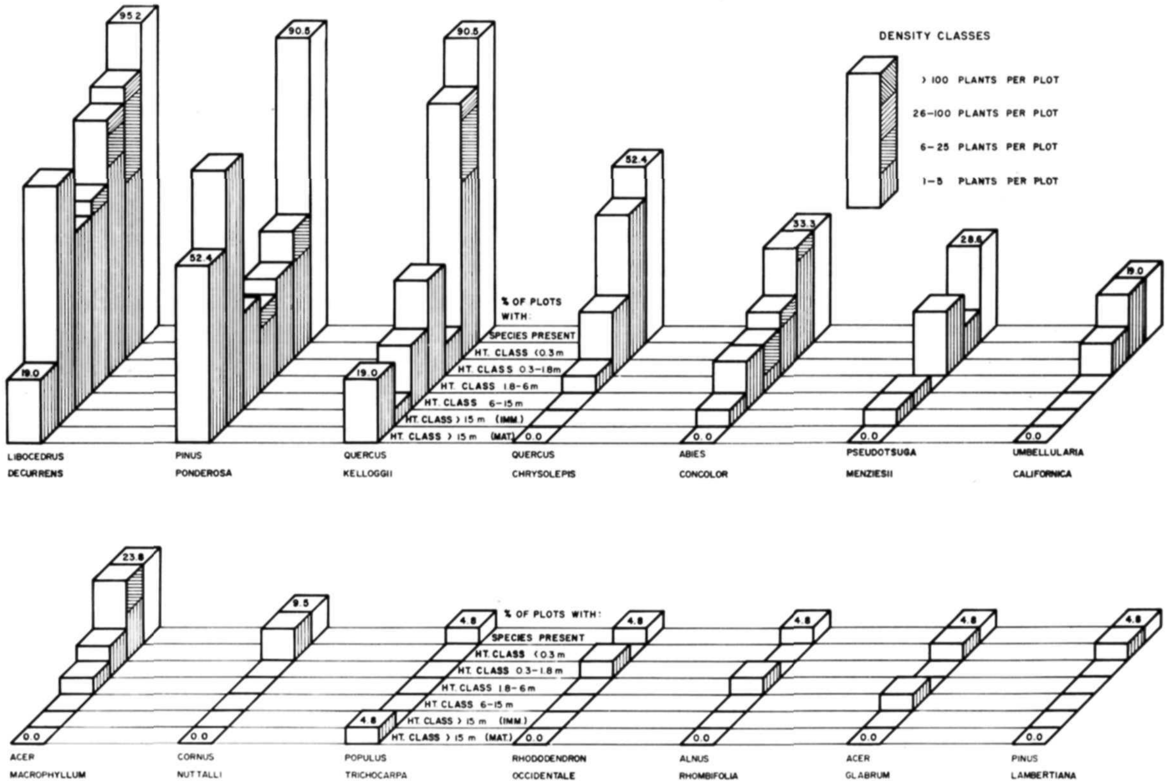

Fig. 7. Frequency, height classes, and density classes of woody plants on landform B, older alluvium with profile development. Overall frequency is shown in the back bar for each species by the height and as a percentage. The front bars show frequency by height classes. Hatching indicates density within height classes.

vense, *Poa pratensis*, and *Montia perfoliata* (miner's lettuce). Landform A supported only grasslands in several of the valley's meadows.

Older Alluvium with Profile Development (B)

Landform B (Figs. 1 and 2), which was composed of the oldest alluvium, flooded only occasionally. Color and organic profiles separated these soils from those on the recent alluvium. Lake fill materials occurred at shallow depths below the older alluvium, outcropped in small scattered locations, and were exposed in the banks of numerous tributary streams. No textural B horizon existed in this soil. Landform B occurred extensively in the valley.

The alluvial soils showed a varied drainage pattern from excessively well-drained sands at point bar locations and along stream banks to closed depressions that remained wet continuously. However, most of the alluvial soils were well drained and occurred on flat, little-channeled flood plains. Imperfectly and poorly drained soils were very dark grayish-brown and occupied abandoned river channels; a few of which had nearly pure organic matter in the bottoms of the depressions.

Fig. 8. Dense forest developing on alluvium forms a mixture of tree species of many ages. Closed forest canopies restrict views of the cliffs and waterfalls.

Landform B supported *Libocedrus decurrens* (95.2% frequency), *Pinus ponderosa*, and *Quercus kelloggii*, which occurred in all size classes (Figs. 7, 8). The only mature trees on this landform were individuals of *Libocedrus decurrens*, *P. ponderosa*, *Q. kelloggii*, and *Populus trichocarpa*. Landform B showed greater dominance of the upland tree species, fewer of the riverine species, and more seedlings of *Pinus lambertiana* and *Acer glabrum* (mountain maple) than landform A.

The B landform had a mean tree canopy cover of 55% and herbaceous cover of 22%, which was a much thinner herbaceous stand than on landform A (Table 1). This suggests that forests on landform B were replacing meadows. The herbaceous species with the highest frequencies were *Pteridium aquilinum*, *Elymus glaucus*, *Poa scabrella*, *Potentilla glandulosa*, and *Galium bolanderi*. In comparison with landform A, xeric species had increased; for example, *Pteridium* had replaced *Elymus* as the most frequent, *P. scabrella* was more frequent than *Poa pratensis*, and *Carex* spp. were of low frequency. All of the meadows in the valley had areas in the B landform.

Moraines (D)

Terminal moraines occurred near the mouth of Yosemite Valley and lateral moraines were present between Tenaya Creek and the Merced River (Fig. 2). These moraines are late Wisconsin in age and were formed during the third period of glaciation in Yosemite Valley (Matthes 1930). Soils on the moraines have a high stone content. This landform occupies the smallest area of any in the valley.

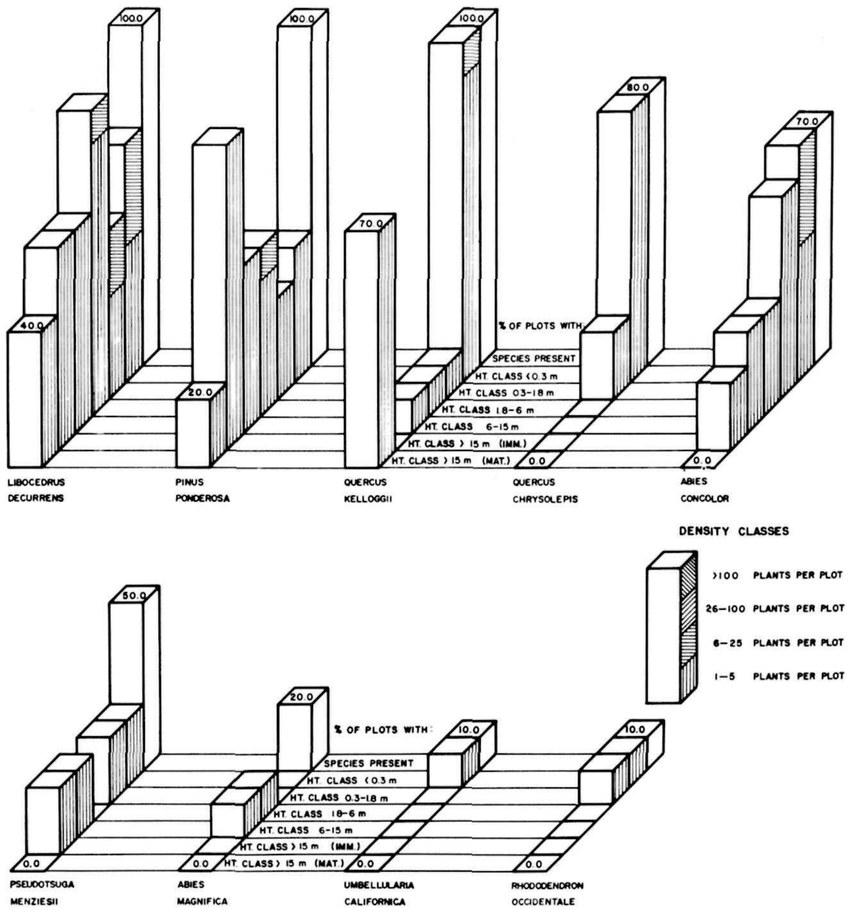

Fig. 9. Frequency, height classes, and density classes of woody plants on landform D, moraines. Overall frequency is shown in the back bar for each species by the height and as a percentage. The front bars show frequency by height classes. Hatching indicates density within height classes.

Libocedrus decurrens, *Pinus ponderosa*, and *Quercus kelloggii* dominated the vegetation, but *Quercus chrysolepis* and *Abies concolor* had relatively high frequencies in the lower height classes (Fig. 9). *L. decurrens* and *P. ponderosa* were present in all size classes on this landform, and with *Q. kelloggii* were the only species with mature trees. Just as on all landforms below the colluvium, *Q. chrysolepis* and *Umbellularia californica* occurred as shrubs less than 2 m tall. *Abies magnifica* (red fir), usually located at higher elevations, existed on two plots on this landform and nowhere else in the valley.

The mean tree cover was 59% and the mean herbaceous cover 2.2% (Table 1). The only herbaceous species with high frequencies were *Carex* spp. and *Pteridium aquilinum* (Table 2). Landform D is the only one in the valley on which *Elymus glaucus* did not appear in abundance. Few species characterized this morainal vegetation.

Alluvial Fans (F)

Alluvial fan and apron deposits occurred along tributary streams, covering the lowest recent colluvium and extending into the valley upon lake fill (Figs. 1 and 2). They were recognized by their topographic form and position. Soil materials were similar in color but rock fragments were generally smaller than those in the colluvial deposits. Fan materials had been transported by water for too short a distance to wear the rocks round. Stratification of particle size classes seldom occurred. Fans constituted the second largest landform in the valley.

As on most of the other landforms, *Libocedrus decurrens*, *Pinus ponderosa*, and *Quercus kelloggii* dominated the vegetation (Fig. 10). *Quercus chrysolepis* and *Abies concolor* also had relatively high frequencies. These species plus *Pseudotsuga menziesii* and *Acer macrophyllum* were present on this landform in all size classes, including mature trees. *L. decurrens* and *A. concolor* were the major understory trees, as indicated by high frequencies in the intermediate size classes. Many seedlings of *Q. kelloggii* fail to establish or to reach heights greater than 30 cm.

Mean canopy cover was 46% for trees and 10% for herbaceous plants (Table 1). The diverse understory vegetation contained 52 of the 81 recorded species in the forest sampling. Those with the highest frequencies were *Poa scabrella* (pine bluegrass), *Pteridium aquilinum*, *Elymus glaucus*, *Potentilla glandulosa*, *Juncus balticus* (Baltic rush), *Galium*

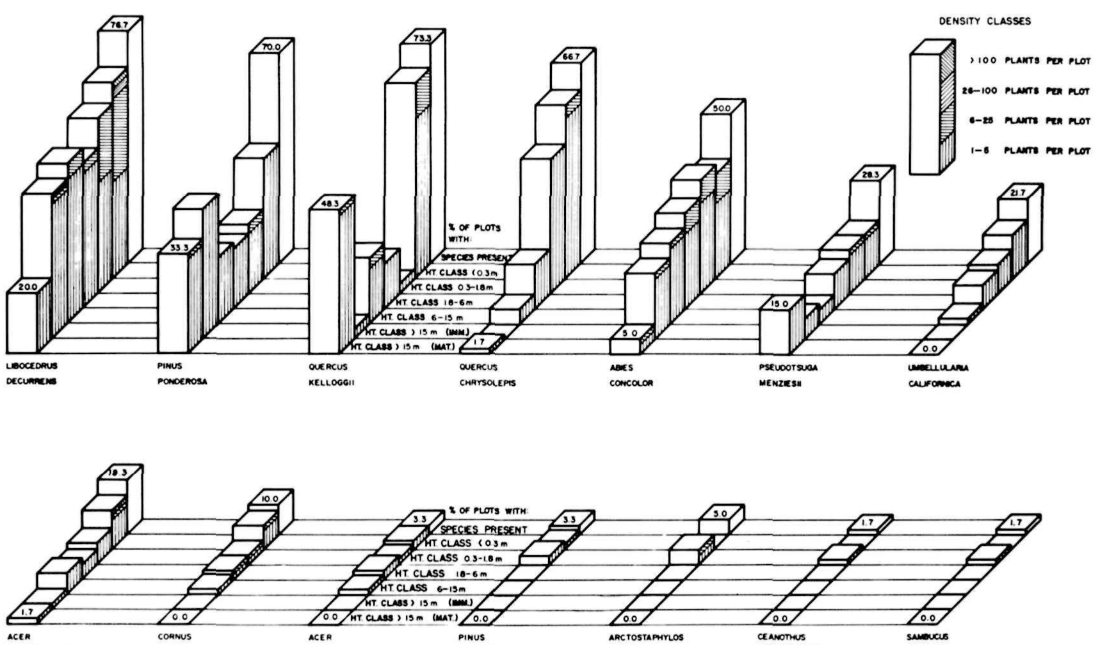

Fig. 10. Frequency, height classes, and density classes of woody plants on landform F, alluvial fans. Overall frequency is shown in the back bar for each species by height and as a percentage. The front bars show frequency by height classes. Hatching indicates density within height classes.

bolanderi, *Sitanion hystrix* (squirreltail), *Bromus tectorum*, and *Asarum hartwegii* (wild-ginger) (Table 2). Bridalveil Meadow was the only meadow on an alluvial fan.

Colluvial Landforms (C)

Colluvial deposits, also called talus, fringed almost the entire valley (Fig. 2). Stones and boulders with diameters greater than 25 cm (10 inches) covered angular-shaped cobble and gravel-sized rock fragments. Material greater than 4 cm (1.5 inches) in diameter exceeded the finer particles in volume. Small remnants of glacial till of Wisconsin age which were scattered over the colluvial slopes did not appear to have extensive influence on these soils. This landform was the most extensive in the valley.

As the alluvial soils, the profile development was correlated with color change. The common sequence of color development of the soils on the colluvial slopes seemed to be the light gray of fresh minerals in the upper colluvium below the rocky cliffs, yellowish brown in the middle of long steep slopes on old colluvium, and grayish-colored soil on gentle foot slopes. This sequence showed where recent torrents had dissected talus slopes.

Colluvial landforms were divided into a lower (<30% slope) and an upper landform (>30% slope) due to differences in vegetation (Figs. 11 and 12). Lower colluvial vegetation was dominated by *Quercus kelloggii*, *Quercus chrysolepis*, *Libocedrus decurrens*, and *Pinus ponderosa*. The upper colluvium supported abundant *Q. chrysolepis* and a small number of the other three species (Fig. 13). These species plus *Abies concolor* and *Pseudotsuga menziesii* were present in all size classes. Landform C supported higher frequencies of *Umbellularia californica* and *P. menziesii*, as well as the *Q. chrysolepis*, than did the valley floor.

The mean herbaceous cover on the two colluvial landforms was the lowest at 1.9% and 3.8%, and tree canopy was thicker than on other landforms (Table 1). Herbaceous species with the highest frequencies were *Poa scabrella*, *Juncus balticus*, *Elymus glaucus*, *Asarum hartwegii*, *Penstemon newberryi* (beardtongue), *Dryopteris arguta* (wood fern), and *Melica imperfecta* (onion-grass) (Table 2).

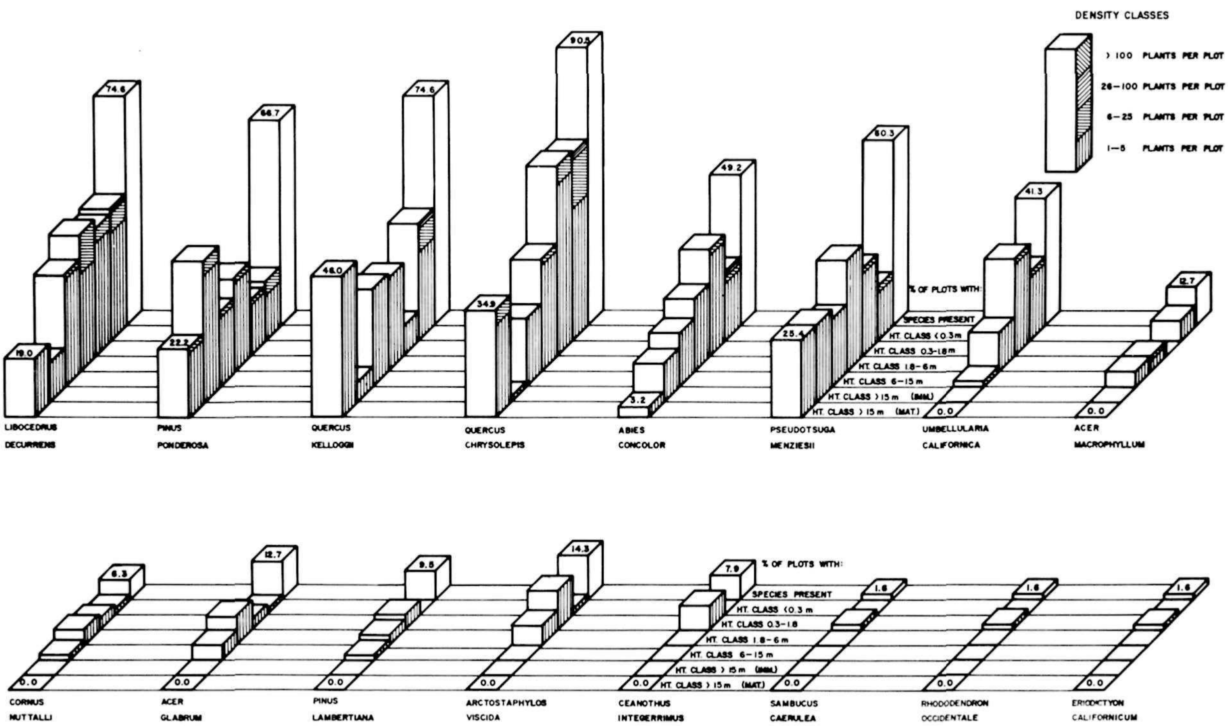

Fig. 11. Frequency, height classes, and density classes of woody plants on landform C, lower talus slopes. Overall frequency is shown in the back bar for each species by the height and as a percentage. The front bars show frequency by height classes. Hatching indicates density within height classes.

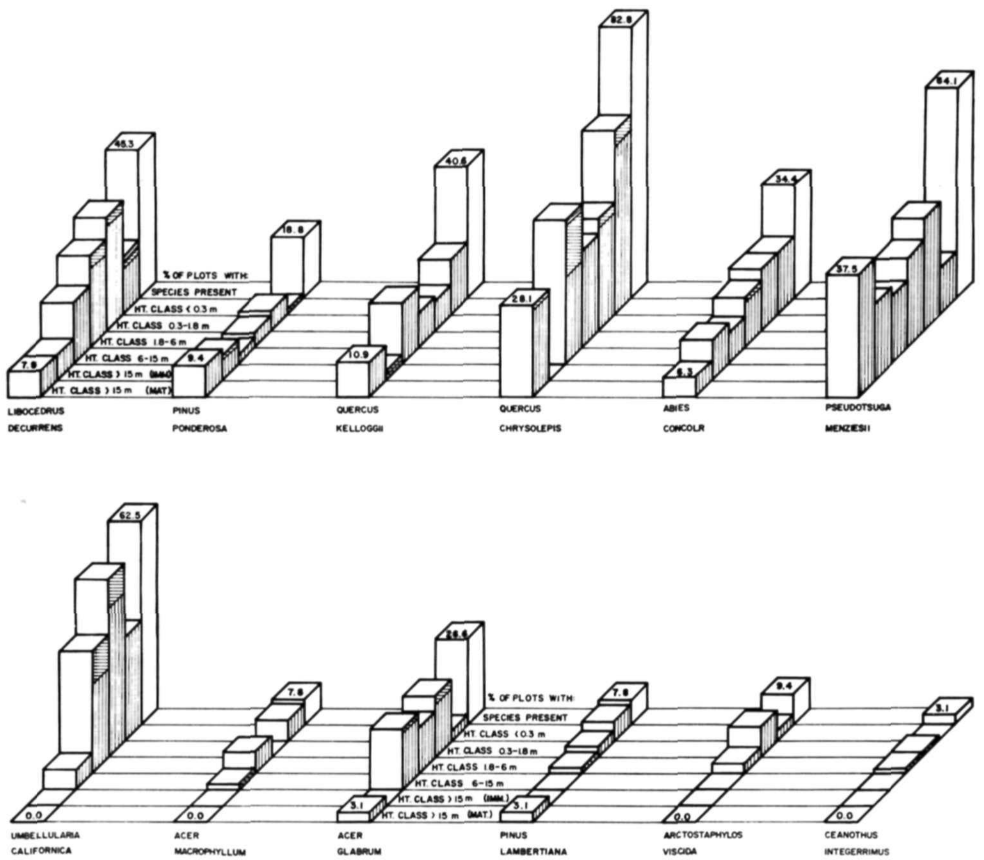

Fig. 12. Frequency, height classes, and density classes of woody plants on landform C, upper talus slopes. Overall frequency is shown in the back bar for each species by the height and as a percentage. The front bars show frequency by height classes. Hatching indicates density within height classes.

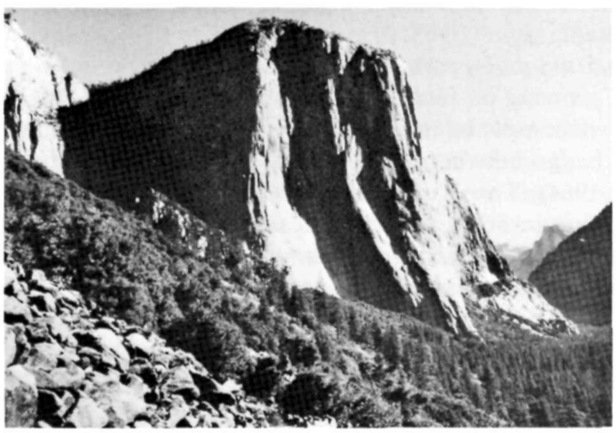

Fig. 13. *Quercus chrysolepis* dominates the vegetation on upper talus slopes. The cliff in the background is El Capitan.

EVALUATION OF VEGETATIONAL CHANGES

Previous sections describe the soils and vegetation samples from Yosemite Valley in quantitative terms. The following sections examine vegetational descriptions more broadly, assess vegetational changes, and discuss the implications this intensely used recreational site has for management.

Forest Vegetation

Seven species of trees characterized the forests in Yosemite Valley: *Libocedrus decurrens*, *Quercus kelloggii*, *Pinus ponderosa*, *Quercus chrysolepis*, *Pseudotsuga menziesii*, *Abies concolor*, and *Umbellularia californica*. These grew on all the landforms from the sandy soil without profile development near the Merced River to the top of the talus slopes. *L. decurrens*, *Q. kelloggii*, *P. ponderosa*, and *A. concolor* tended to dominate the valley floor in the size of plants and the number of plants per unit of area. *Quercus chrysolepis*, *U. californica*, and *P. menziesii* dominated on the upper talus slopes. *L. decurrens* and *P. ponderosa* dominated on the recent alluvium. *Populus trichocarpa*, *Alnus rhombifolia*, and *Salix* (willow) were restricted to the soils of the valley floor, usually near water or on the banks of former rivers. *Pinus lambertiana*, *Acer glabrum*, *Arctostaphylos viscida* (whiteleaf manzanita), *Ceanothus intergerrimus* (deer brush), and *Sambucus caerulea* (elderberry) occurred only on the fans and talus. Two species, *Pinus contorta* (lodgepole pine) on recent alluvium near the Merced River and *Abies magnifica* on moraine, appeared essentially out of their normal range. They may have become established from seed that drifted or washed down from the canyon tops 900 m (3,000 feet) or more above the valley.

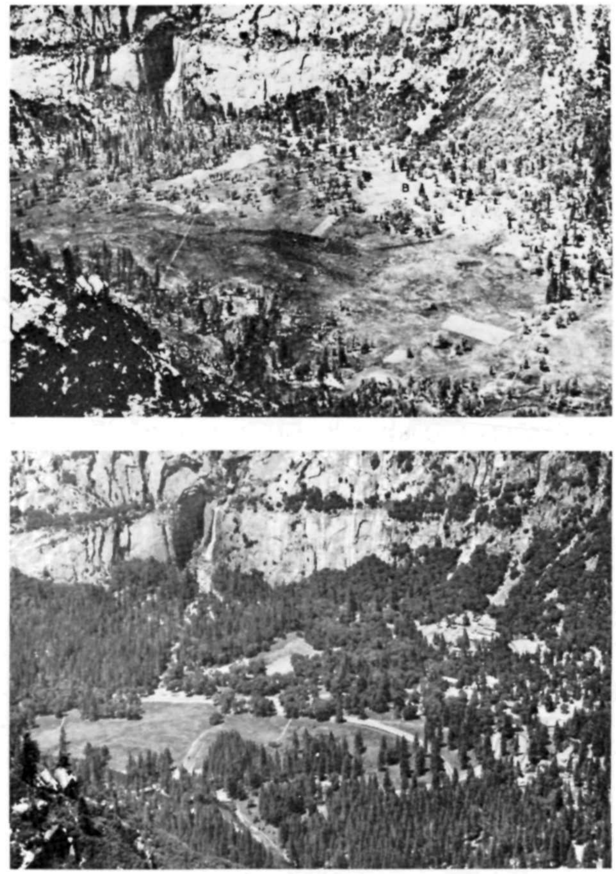

Fig. 14. (*Upper*) Yosemite Valley from Glacier Point in 1866 (photographed by C. E. Watkins) shows a wet meadow at *A* near photograph center and open forest on alluvial fan materials at *B*. (*Lower*) A 1973 photo of the same area (by J. Bartolome) shows less meadow, greatly increased forest cover, and buildings in the location of *B*.

Crown cover by woody plants amounted to approximately 55% of the area and varied from 41 to 68% by landform. The densest forest occurred on the talus and the thinnest on recent alluvium near the Merced River. Herbaceous cover under forest canopies was highest (41%) on the fine alluvial sands and least on the moraines, fans, and talus. Although forest litter tended to be least near the river and on the upper talus, in these areas litter covered more than 70% of the soil surface. Except in areas heavily trampled by people, no accelerated erosion was found. Litter and live vegetation covered the soil sufficiently to prevent erosion.

Height classes of woody plants indicate the timing of forest regeneration. Because height classes only approximate age, no claim is made for definite years of seedling establishment. However, it is reasonable to assume that a tree species is reproducing itself if individuals are present in a height range from less than 30 cm (12 inches) to tall, mature trees. Immature conifers have pointed tops. Rounded tops indicate maturity. Evaluation of maturity in broadleaved species was most subjective, as indicated by size and vigor. The objectives of national park administrators at the time of field sampling prevented extensive increment borings and cutting of woody plants to determine age.

The earliest sources used in this study indicated that the forest has expanded and thickened in Yosemite Valley during the last 100 years. Paired photographs taken 107 years apart show this vividly (Fig. 14). A study of annual rings of *Pinus ponderosa*, *Libocedrus decurrens*, and *Abies concolor* growing on former meadow areas indicates that invasion of the meadows and thickening of the forest began between 1860 and 1870 (Gibbens and Heady 1964). Those researchers also found that the invasion was continuous because trees of many ages less than 100 years were found. Ernst (1943, 1949) recorded the invasion of trees into meadows, and the commissioners' report (1882) also recognized tree invasion. There appeared to be scattered trees of two earlier age groups, one established about 1800 and the other about 1700 (Reynolds 1959). Decimation of Indian populations by disease coincided roughly with the two oldest age classes of trees. Frequent burning by Indians probably prevented tree regeneration during intermediate times.

Individual plants of *Libocedrus decurrens*, *Quercus kelloggii*, and *Pinus ponderosa* occurred in all height classes on all landforms in Yosemite Valley. These species reproduced in all areas and continue to dominate the forest. Mature individuals of *Quercus chrysolepis*, *Pseudotsuga menziesii*, and *Abies concolor* were limited to the fans and talus. Shorter and presumably younger trees occurred in abundance on the alluvial soils of the valley floor, which suggests that they are increasing rapidly along with *L. decurrens* in former meadows or open forests. Much of the increase in forest area and density was attributed to the last four species mentioned above. Although short and shrubby on the alluvial soils, *Umbellularia californica* and *Quercus chrysolepis* may become dominant trees on the valley floor.

The number of plants of each tree species declined in succeedingly taller height classes. Exceptions indicated periods of establishment and changes in the relative dominance of the species. *Pinus ponderosa* under 15 m (50 ft) in height were less numerous than those over 15 m and immature trees over 15 m were more numerous than mature ones. *P. ponderosa* appeared to be diminishing in importance in the valley forests. Abundance of seedlings and mature *Quercus kelloggii* with fewer trees of intermediate sizes suggests that the rate of establishment has been erratic; however, it too could be decreasing relative to other trees, but enough survive to maintain the species. The scarcity of mature *Abies concolor* and abundance of immature sizes indicated that this species is rapidly becoming more important, especially on the alluvial soils. *Pseudotsuga*, *Umbellularia*, and *Quercus chrysolepis* also were becoming more important on the valley floor but their frequency was generally low. *Pinus contorta* and *Abies magnifica*, rarely present in the 1.8- to 6-m (6–20 ft) height class, probably became established only through a peculiar chain of events several decades ago.

Forest vegetation in the valley at the time of discovery consisted of widespread trees of which *Quercus kelloggii* and *Pinus ponderosa* were the most numerous individuals. The openness of forest and dominance by the two species probably resulted from periodic fires and the efforts of Indians to maintain orchards of *Quercus* for acorns. Both these factors have been greatly reduced for over 100 years. Although man's activities have influenced the valley's vegetation in many ways, the reduction of fire has permitted tree species to invade the meadows and alter species relationships in terms of dominance and density. Stand structures show that *Libocedrus decurrens*, *Abies concolor*, *Pseudotsuga menziesii*, and *Quercus chrysolepis* are present in all size classes. If no catastrophe or managerial impact causes their demise, the forest stands in the valley will become dominated increasingly by these species in the coming decades. The data collected in this study suggest that these four species will not replace *Q. kelloggii* and *P. ponderosa* but will combine with them to form a mixed, dense conifer–oak forest.

Forest Understory Vegetation

Understory herbaceous vegetation in Yosemite Valley exhibited relationships to landforms (Table 2). Some 81 herbaceous species were recorded in the understory vegetation. The most widespread and common species were *Pteridium aquilinum*, *Elymus glaucus*, *Potentilla glandulosa*, and *Galium bolanderi*. Widespread species with low frequency included *Stipa columbiana* (needlegrass), *Bromus marginatus* (mountain brome), *Bromus tectorum*, *Apocynum cannabinum* (Indian hemp), *Artemisia douglasiana*, and *Asarum hartwegii*.

Understory herbaceous cover on the flood plain soils was 20–40%, which is somewhat higher than expected under coniferous forest. This was caused by occasional deposition of silt which had a fertilizer effect, tree crown cover which tended to be less than in the forests on the valley sides, and small, irregular forest stands which permitted side lighting. The herbaceous vegetation in these conditions resembled the meadows, whose dominants were *Agrostis alba*, *Holcus lanatus*, *Poa pratensis*, *Carex* spp., *Mentha arvensis*, and *Rumex acetosella*. On the fans and talus slopes, *Poa scabrella*, *Melica imperfecta*, *Festuca occidentalis* (western fescue), *Juncus balticus*, *Dryopteris arguta*, *Asarum hartwegii*, and *Penstemon newberryi* characterized the thin understory cover.

Deer Browsing

Although wild animals, especially deer, are a great asset to the recreational resources in Yosemite Valley, overbrowsing by deer has been an intermittent problem for several decades. At times subtle live trapping and removal programs have kept their numbers in check. The meadows show little influence from deer grazing although the animals are commonly seen in the grasslands. Browsing is their principal impact on the valley vegetation because it influences the rate of increase and spread of woody species into the grasslands as well as regeneration of woody species within the forest (Fig. 15). Severely hedged young trees and shrubs occur at the

Fig. 15. Heavily browsed *Abies concolor* with young unbrowsed *Libocedrus decurrens* and *Pinus ponderosa* in the background. Browsed young trees were numerous along the edges of the meadow.

meadow edges. The presence or absence of browsing on the different species was recorded on plots 15 m in diameter.

The kinds and relative availability of plants are two of the factors that influenced selectivity of foods by grazing animals. In Table 3 columns labeled A under each landform give the percentage of plots that contained the species in the height classes 0–0.3 m and 0.3–1.8 m. This is a measure of availability. Columns labeled B give the percentage of those plots where the species showed evidence of browsing. The order of the species (Table 3) gives their decreasing importance on the basis of frequency. Two of the dominant species (*Libocedrus decurrens* and *Pinus ponderosa*) were seldom browsed. *Quercus kelloggii* and *Quercus chrysolepis* were browsed on all landforms, but probably at greater intensities than the frequency data indicate because of their high palatability. Browsing of oaks kills seedlings, leads to the development of browse lines, and reduces the volume of acorns. Deer selected *Abies concolor* and *Pseudotsuga menziesii* more than the other conifers. These two species, the two *Quercus* species, and *Umbellularia californica* were the major browse plants in Yosemite Valley because of their widespread distribution. Other palatable species that deer selected but that did not occur widely included *Populus trichocarpa*, *Alnus rhombifolia*, *Salix*, and *Ceanothus intergerrimus*.

Of the tree species only *Abies concolor* showed severe and widespread evidence of browsing by deer; however the full range of size classes on all

Table 3. *Availability of browse* (A) *expressed as a percentage of plots with plants less than 1.8 m tall on each landform and percentage of those plots which showed browsing* (B).

	Alluvium without profile		Alluvium with profile		Alluvium seldom flooded		Fans		Colluvium	
Species	A	B	A	B	A	B	A	B	A	B
Libocedrus decurrens	46.9		72.4		85.7	5.6	71.0		41.4	
Quercus kelloggii	40.6	23.1	72.4	14.3	76.2	12.5	67.7	9.5	29.3	19.5
Pinus ponderosa	15.6		27.6		42.9		43.5	11.1	16.4	
Quercus chrysolepis	21.9	14.3	41.4	25.0	47.6	10.0	67.7	33.3	67.9	25.3
Pseudotsuga menziesii	6.3		24.1	57.1	23.8	60.0	19.4	33.3	35.0	26.5
Abies concolor	21.9	85.7	31.0	100.0	33.3	100.0	48.4	80.0	31.4	77.3
Umbellularia californica	6.3		31.0	55.6	19.0	50.0	21.0	15.4	44.3	24.2
Acer macrophyllum	15.6	20.0	20.7		23.8	20.0	19.4		5.7	
Cornus nuttallii	3.1		17.2	60.0	9.5	50.0	11.3		1.4	
Rhododendron occidentale	18.8	16.7	10.3		4.8	10.0			0.7	
Populus trichocarpa	9.4	66.7								
Alnus rhombifolia	3.1	100.0								
Salix spp.	18.8	83.3								
Pinus lambertiana					4.8		4.8		5.7	
Acer glabrum					4.8		3.2		12.1	5.9
Arctostaphylos viscida							4.8	33.3	10.7	6.7
Ceanothus integerrimus							1.6	100.0	5.0	85.7
Sambucus caerulea							1.6		0.7	
Eriodictyon californicum							1.6		0.7	

landforms indicated increasing importance of *Abies*. While deer undoubtedly affected regeneration and spread of the tree species differentially, little conspicuous evidence existed that the recent level of deer populations had affected unduly the woody vegetation. With the possible exception of *Ceanothus integerrimus*, the range of size classes from seedlings to plants beyond the reach of deer was unbroken for all woody species. Young *Quercus kelloggii* were present throughout the forest types and *Quercus chrysolepis* had spread from the fans and talus onto alluvial sites.

Meadow Vegetation

Most meadows in Yosemite Valley border the Merced River. The principal soils developed from alluvial sands which originated from parent materials with the same mineralogical composition. Similar climate occurred throughout the valley without any apparent relationship to vegetational type. Slopes of the meadows were less than 3%. None of the meadow soils approached maturity. They varied in texture from loam to sand <2 mm (0.08 inches) in diameter, in structure from single-grain to weak medium-blocky, and in consistency from loose to

Table 4. *Average percentage species composition of meadow vegetation arranged from wet sites on the left to dry sites on the right.*

	Bottom of depressions	Closed depressions	Poorly drained	Imperfectly drained	Moderately well drained	Well drained	Excessive drainage
No. of areas	4	7	3	7	2	10	4
Total sample points	1,600	3,000	1,400	3,300	1,100	4,700	1,800
Carex spp.	80.2	75.0	70.2	41.8	23.4	16.8	16.0
Poa pratensis	12.9	12.9	17.1	25.8	45.8	42.2	21.8
Elymus spp.	3.6	5.0	2.7	20.2	5.3	21.0	46.9
Agrostis alba	0.5	2.8	7.5	4.8	13.3	5.3	0.3
Bromus marginatus					1.9		
Bromus rigidus						0.6	
Bromus tectorum				0.3		3.3	3.7
Calamagrostis canadensis		1.0			1.2	0.5	
Deschampsia danthanoides						0.1	
Festuca californica					1.2		
Festuca megalura						0.5	
Festuca reflexa						0.2	0.3
Juncus effusus		1.0	0.2		1.7		
Muhlenbergia filiformis				0.2		2.7	2.5
Panicum occidentale				0.6			
Scirpus acutus	1.8			0.3			
Achillea lanulosa	0.3			0.7	1.1	0.2	
Apocynum cannabinum				0.5		0.1	
Artemisia douglasiana		0.5		0.2		0.8	
Asclepias cordifolia	0.3	0.4		0.3	0.5	0.9	
Euphorbia sp.						0.1	
Equisetum laevigatum		1.0	0.8				
Fragaria californica			0.1			0.1	
Galium aparine					1.0		
Iris missouriensis			1.1	0.3	1.0	0.2	
Lessingia leptoclada				1.4		1.8	3.9
Lotus oblongifolius				1.5		1.7	4.3
Pteridium aquilinum				0.7	2.1	0.8	0.3
Rudbeckia hirta		0.4					
Rumex acetosella					0.5		
Solidago canadensis	0.4		0.3	0.4			

slightly hard when dry. Acidity averaged about pH 6 with variation from pH 5 to 7 except for the litter layers which often were more acid than pH 5. Soils with developed profiles of color and organic matter did not have a textural B horizon and recent alluvium existed without profile development. None of these variations in soil characteristics seems sufficient to cause the observed differences in botanical composition of the vegetation.

Drainage or water table levels appeared to be the main cause of different vegetational types within the meadows (Table 4). Where the water table was closer than 75 cm (30 inches) to the soil surface, or perhaps as deep as 1.5 m (5 ft) in the dry season, the top soil horizons were high in organic matter, dark gray to dark grayish-brown in color, and some were slightly gleyed. These soils were usually in closed depressions or seeps and their shape often indicated abandoned river channels. Some contained shallow water throughout the year.

Vegetation on the imperfectly drained soils, poorly drained soils, and wet depressions was dominated by *Carex barbarae*, *C. vesicaria*, *C. feta*, and *C. kelloggii*. Of 21 locations sampled, percentage composition on a foliage cover basis of all the *Carex* spp. varied from 40.3 to 86.3%. Other dominants were *Poa pratensis, Elymus triticoides* (beardless wild-rye), and *Agrostis alba* (Fig. 16). Occasional patches of *Scirpus acutus* (common tule), *Calamagrostis canadensis* (bluejoint redgrass), *Typha latifolia* (cattail), and *Salix* spp. were scattered on poorly drained areas. The grasses mentioned above occupied the edges of the wettest soils with *Alnus rhombifolia, Libocedrus decurrens*, and seedlings of *Pinus ponderosa* and *Quercus kelloggii* nearby.

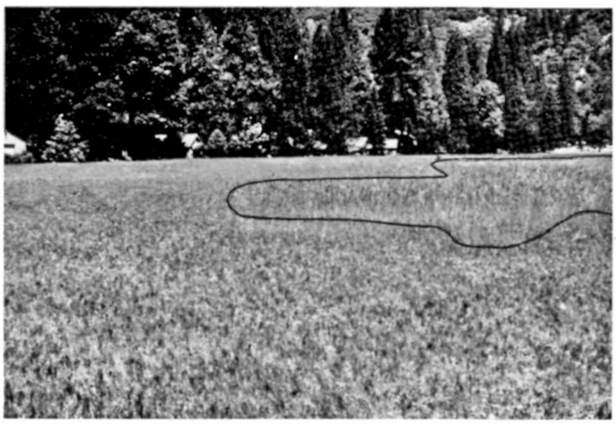

Fig. 16. Perennial grasses invading annual grasses is shown within the marked area.

The moderately well- and well-drained soils, most extensive in the meadows, generally had a smooth, gently sloping surface with few channels. Some were flooded every year but others only rarely or not at all. These soils were grayish-brown, gray, or pale brown in color, loamy very fine sand to fine sandy loam in texture, moderately subangular, blocky in consistency, and slightly hard when dry. *Poa pratensis, Elymus triticoides, Agrostis alba*, and *Carex* spp. dominated the vegetation. Fourteen of the 16 sites samples had between 14 and 24% *Carex* spp.

Poa pratensis, clearly as abundant in the meadows of Yosemite Valley as the group of Carex species, tended to be scarce in the wet sites, especially those with standing water, and abundant on the moderate and well-drained soils. It appeared quickly on newly deposited alluvium, in the mixture of many annual species.

Elymus triticoides occurred in large patches frequently adjacent to areas of poor drainage and on recent, but more than year-old, alluvium that had good drainage. *Poa pratensis* and *Carex* spp. grew with it. Sites that were moderately well-drained and seldom flooded usually had *Elymus glaucus* (Fig. 17). The two *Elymus* spp. were difficult to distinguish by vegetative means in the field.

Annual species such as *Bromus tectorum, Lessingia leptoclada* (sierra lessingia), *Lotus oblongifolius* (narrow-leaved lotus), and others dominated on excessively well-drained new alluvium, especially following disturbance (Fig. 18). In most such areas perennials invaded quickly. Abundance of annual grasses suggested a low stage in plant succession rather than permanent vegetation.

Vegetation on several soil types did not follow the *Carex–Poa–Elymus* gradient according to decreasing soil moisture. One soil with high organic matter classed as "bottom of depression" (Table 5, Area 1) contained vegetation dominated by *Apocynum cannabinum* with only 9% *Carex* spp. This area dried excessively in late summer. A ditch and a road recently had altered drainage in areas 2 and 3. Trees shaded areas 4 and 5. Areas 6–9 showed evidence of recent soil disturbance. Botanical composition in the meadows responded to outside influences as well as to the drainage pattern.

In 1962 the garbage dump was leveled, compacted by bulldozer, and covered with 10 cm of manure and 5–15 cm (2–6 inches) of alluvium. *Cynodon dactylon* (Bermuda grass) appeared in 1963 as did typical first-year herbs such as *Chenopodium album* (lamb's quarters), *Amaranthus graecizans* (amaranth), *Lotus* sp. (lotus), *Brassica* spp. (mustard), *Lepidium*

Fig. 17. *Pinus ponderosa* invading perennial grassland.

Fig. 18. Perennial grasses invading annual grass in a former wet oxbow.

densiflorum (pepper grass), and *Rumex crispus* (curly dock). Seeds of these species probably came from hay used in the stables. *Cynodon* did not persist into the second year and other perennial grasses had not invaded by 1968. Seedlings of *Quercus kelloggii* did not persist. In 1968, *Bromus tectorum* was 28% of the vegetative composition. In 1973 the five most common species were *L. densiflorum, Chenopodium botrys* (Jerusalem-oak), *B. tectorum, Sisymbrium altissimum* (tumble-mustard), and *Polygonum aviculare* (knotweed), a vegetation much as it was 10 years earlier in 1963. Use of the area for parking and as a staging location for a rock climb slowed plant succession.

Table 5. *Percentage species composition of meadow areas in the soil survey that had uncommon vegetational combinations.*

	Bottom of depression	Poorly drained	Imperfectly drained			Moderately well drained	Well drained	Excessively drained	
Area No.	1	2	3	4	5	6	7	8	9
Total sample points	400	400	800	600	600	400	400	400	400
Carex spp.	9.0	8.8	16.4	9.2	5.2	4.4			
Poa pratensis	20.4	68.0	64.2	28.2	30.2	58.4	1.3	38.3	4.8
Elymus spp.			6.7		16.4				
Agrostis alba		5.2	10.3	6.2		4.8			
Bromus inermis		1.2				2.4			
Bromus tectorum		14.0				26.0	60.4		17.3
Dactylis glomerata		1.2							
Festuca reflexa									28.4
Juncus effusus								2.5	
Phleum pratense		1.2							
Apocynum cannabinum	70.6								
Artemisia douglasiana			1.2						
Asclepias cordifolia			1.2	2.4				2.2	
Fragaria californica								2.2	
Galium aparine								8.6	
Lessingia leptoclada						4.0	20.1		4.8
Lotus oblongifolius							18.2		40.6
Pteridium aquilinum				54.0	48.2			46.2	
Rumex acetosella									4.1

In the second year after removal of the Old Village Store and restoration of the site, *Sisymbrium altissimum*, annual grasses, and many of the same annual herb species mentioned above were present in the vegetation (Gibbens and Heady 1964). Perennial grasses (*Elymus* spp., *Poa pratensis*, and *Agrostis alba*) composed 35% of the cover and *Festuca rubra* (red fescue), which was seeded, made up 31%. Five years later in 1968 the three resident perennial grasses had increased to 77% of the cover and *F. rubra* had decreased to 5.5%. In 1973, 67% was *Elymus* spp., 13% *Carex* spp., 5% *P. pratensis*, and 1% *F. rubra*. Thus, except for the wet sites, plant succession following disturbance (cut and fill sites, new alluvial sand deposits, etc.) began with annual herbs, had an annual grass and herb stage, and proceeded to perennial grasses and *Carex* spp. Seeded grasses did not persist in abundance.

Botanical composition of the meadows has changed since the valley became a recreational site. Whitney (1868) described the meadows as chiefly sedges and coarse grasses. Sedges remain important and presumably are the same species. The three principal grasses listed by Whitney, *Calamagrostis canadensis, Phragmites communis* (reed), and *Glyceria nervata* (manna grass), have been replaced. We found the first to be widely distributed but scattered, the second absent, and the third rare. *Poa pratensis, Elymus* spp., and *Agrostis alba*, which probably came to the valley as seed in hay, now cover the meadows. These introduced species are better adapted to the meadow conditions in Yosemite Valley and have permanently replaced the original meadow climax species, just as in other wet meadows throughout the Sierra Nevada.

Numerous other hay and pasture species, introduced both intentionally and unintentionally, have not become dominant elements in the vegetation, although they are present in Lamon Meadow near the stable. Most disturbed areas, such as abandoned roads, about 100 ha (250 acres) of formerly cultivated land, and the former racetrack in Leidig Meadow, are not detectable to the casual observer. Vegetation in Yosemite Valley has a remarkably strong recuperative ability. The meadows are healthy and pleasing to the eye, although quite different from those of 100 years ago. Perhaps they are even better suited to public use than the original meadows.

MAINTAINING MEADOWS

Plants of *Cirsium vulgare* (bull thistle) and *Hypericum perforatum* (Klamath weed) have been controlled chemically and by hand for the last 25 years; however, these were not new effects (Gibbens and Heady 1964). Civilian Conservation Corps workers in the 1930s removed weeds and young trees from the meadows, and a sizable area of the valley floor was cleared of underbrush in the 1890s. Man has maintained the meadows, probably by burning previous to 1850, and by cultivation, grazing, tree pulling, and camping between 1850 and 1916. The National Park Service has removed young trees from meadows by cutting, pulling, and, since 1970, by prescribed fire. Although Whitney (1868) recorded 300 ha (750 acres) of meadows in 1866, only 135 ha (340 acres) could be found on aerial photographs taken in 1960.

As noted earlier, the three most common trees were present on the meadow soils in dense stands of all ages. A complete tree canopy occupied a wet site in the Black Springs area and tree seedlings grew at the edges of poorly drained depressions. The present acreage of meadows would have been smaller or perhaps nonexistent without intentional and unintentional removal of young trees. To preserve the meadows in Yosemite Valley, they must be kept free of trees.

In addition to the influences of man, natural causes contributed to changes in meadow vegetation. Deposits from the annual spring floods, which occasionally were large, served to build the land surface and to fill abandoned river channels. Concurrently, erosion began to deepen the channel in the Merced River. In 1879 the channel was deepened by blasting the terminal moraine near Bridalveil Falls. Debris has been removed periodically from the channel to reduce flooding. Although the extent of these influences has not been substantiated, the meadows of today probably are drier than those of 100 years ago which results in more grass, more trees, and fewer of the *Carex* species than in Whitney's time.

Left alone, plant succession in Yosemite Valley would continue toward an undesirably thick canopy of forest trees (Fig. 19). Maintenance of vistas, from a grassy foreground to spectacular waterfalls and cliffs, requires forest openings with meadow vegetation (Fig. 20). However, manipulation to maintain meadows must be subtle to avoid impairment of natural processes and beauty. So much alteration of the meadows has occurred that they can no longer be restored to their primitive state. Therefore, the objective must be to maintain a natural appearance compatible with public enjoyment of Yosemite Valley as a unique mixture of forest and grassland with

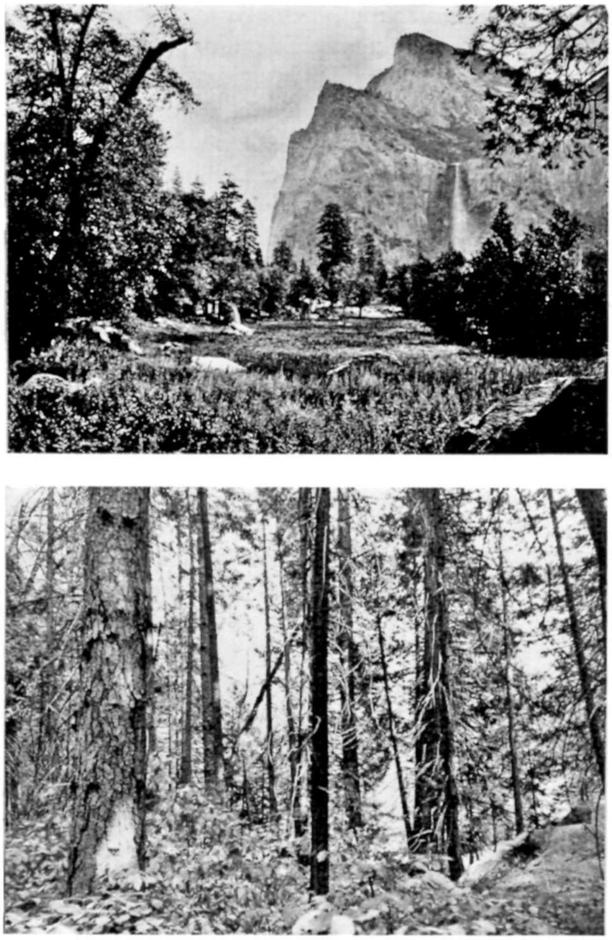

Fig. 19. (*Upper*) The Black Springs area with Bridalveil Falls in the background, photographed by C. E. Watkins in 1866. (*Lower*) The same view, photographed by H. F. Heady in 1961, as indicated by the rock in the lower right-hand corner of both photos. Reduced meadow area has restricted views of striking cliffs and waterfalls.

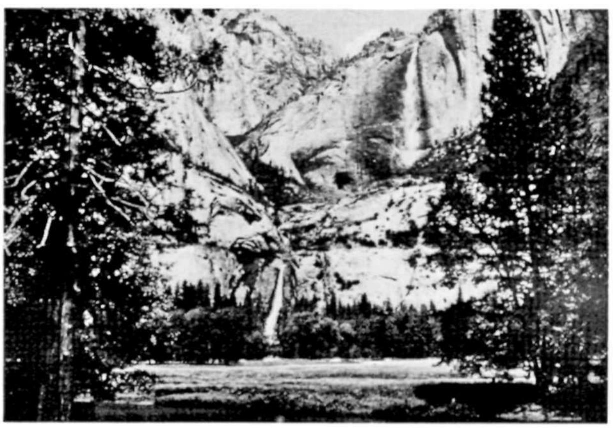

Fig. 20. Vistas such as this one of Yosemite Falls must be maintained by removal of trees.

overpowering views of mountains, granite cliffs, and some of the highest waterfalls in the world.

RECOMMENDATIONS FOR VEGETATIONAL MANAGEMENT

This study and others, coupled with long experience in Yosemite Valley, show that the vegetation must be managed continually to preserve views and safety. The first three of the following suggestions are the most important.

1. Large areas of relatively open forest should be developed and maintained for their beauty and access to visitors. Considerable tree removal and prevention of forest regeneration will be needed. The Indians did this with fire and by pulling young trees. The modern manager should use the same tools selectively. For example, *Pinus ponderosa* and *Quercus kelloggii* may be encouraged in one place, but forests dominated by other species should be developed on different sites. Vegetational management within the forest types is needed to make them safe from catastrophic fire and to decrease the likelihood of property damage and human injury from falling materials. Management should follow development of a vegetational management plan for the valley.

Fig. 21. Fire hazards have become extreme in parts of Yosemite Valley due to the accumulation of fine fuels from ground level into the tree canopy.

2. Large ground accumulations of woody debris and the continuous vertical canopy created by trees of many heights produce an excessive wildfire hazard (Fig. 21). These fuel conditions could cause extensive conflagrations during dry, windy weather.

Understory fuels along roads and in irregular strips through the forest should be reduced by removing dead limbs from large trees, eliminating small overtopped trees, and prescribed burning of the accumulated debris during safe weather conditions. Burning was a natural process in the pristine Yosemite Valley. The ultimate objective should be restoration of open forest conditions by reducing large bodies of fuel in nearly all the forests on and below the lower talus slopes.

3. The meadows must be maintained and preferably enlarged to attain a maximum variety of views of mountains, cliffs, and waterfalls. To achieve this, techniques such as pulling and cutting young trees, cutting large trees, and prescribed burning can be used. Any debris should be spread thinly or burned during periods when fire danger is minimal. Prescribed burning should be used on meadow areas where tree regeneration is abundant. Vistas cut through forests should be wide and irregular to give the appearance of natural openings. The forest should not hide the views and consequently reduce the value of Yosemite Valley as a recreational site.

4. Road maintenance, building, and most other development leave bare soil which should be seeded to grasses such as *Poa pratensis, Festuca rubra, Bromus inermis* (smooth brome), and *Lolium* spp. (rye grass) to attain a quick cover that will reduce erosion. These species spread throughout the valley in the 1800s as a result of forage grown to feed livestock. They have become a part of the natural meadow vegetation and nothing about them gives the appearance of intrusion into the valley, nor can they be removed by any known means. These species should be considered native species. Seed is available at low cost and there is no danger that they will displace the native vegetation beyond that which occurred several decades ago. Flowers might be planted along new roads but they will disappear as the grasses invade. Heavy grassland litter and thick growth generally reduce plants with highly conspicuous flowers. The alternative to seeding is to allow bare soil to revegetate naturally because seeds of the native species are not available. When development or construction leaves bare soil, it should be seeded without waiting for natural plant succession to take place.

5. Paving of additional trails on the meadows and lower talus slopes will reduce erosion and serve as fire lines. Hikers tend to use paved trails, which saves the soil from trampling and erosion.

6. Removal of large weeds, such as thistles, and trees hazardous to visitors should continue on a planned basis open to public view.

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APPENDIX

Scientific and common names of plants in this paper according to Munz, P. A. and D. E. Keck. 1973. A California Flora and Supplement. Univ. Calif. Press, Berkeley. 1681 p. and 224 p. The third column gives growth habit as annual (A), biennial (B), or perennial (P), and column four gives origin as native (N) or introduced (I).

Abies concolor	White fir	P	N
Abies magnifica	Red fir	P	N
Acer glabrum	Mountain maple	P	N
Acer macrophyllum	Big-leaf maple	P	N
Achillea lanulosa	Yarrow	P	N
Agastache urticifolia	Horsemint	P	N
Agrostis alba	Redtop	P	I
Aira caryophyllea	Silver hairgrass	A	I
Alnus rhombifolia	White alder	P	N
Amaranthus graecizans	Amaranth	A	N
Apocynum cannabinum	Indian hemp	P	N
Aquilegia formosa	Columbine	P	N
Arctostaphylos viscida	Whiteleaf manzanita	P	N
Artemisia douglasiana	Douglas mugwort	P	N
Artemisia dracunculus	Sagewort	P	N
Artemisia tridentata	Big sagebrush	P	N
Asarum hartwegii	Wild-ginger	P	N
Asclepias cordifolia	Purple milkweed	P	N
Asclepias speciosa	Green milkweed	P	N
Aster adscendens	Aster	P	N
Athyrium filix-femina	Lady fern	P	N
Avena barbata	Slender wild oat	A	I
Boykinia major	Mountain boykinia	P	N
Brassica spp.	Mustard	A	I
Brickellia californica	Brickellbush	P	N
Brodiaea lutea	Pretty face brodiaea	P	N
Bromus inermis	Smooth brome	P	I
Bromus marginatus	Mountain brome	P	N
Bromus mollis	Soft chess	A	I
Bromus rigidus	Ripgut	A	I
Bromus rubens	Red brome	A	I
Bromus tectorum	Cheat grass	A	I
Calamagrostis canadensis	Bluejoint reedgrass	P	N
Calyptridium umbellatum	Pussy paws	P	N
Carex barbarae	Sedge	P	N
Carex feta	Sedge	P	N
Carex kelloggii	Sedge	P	N
Carex spp.	Sedge	P	N
Carex vesicaria	Sedge	P	N
Castilleja breweri	Paint-brush	P	N
Ceanothus integerrimus	Deer brush	P	N
Chamaebatia foliosa	Mountain misery	P	N
Chenopodium album	Lamb's-quarters	A	I
Chenopodium botrys	Jerusalem-oak	A	I
Cirsium spp.	Thistle	B	I
Cirsium vulgare	Bull thistle	B	I
Conyza canadensis	Horseweed	A	N
Cornus nuttallii	Mountain dogwood	P	N
Cynodon dactylon	Bermuda grass	P	I
Cynosurus echinatus	Dogtail	A	I

Dactylis glomerata	Orchard grass	P	I
Deschampsia danthanoides	Annual hairgrass	A	N
Deschampsia elongata	Slender hairgrass	P	N
Dryopteris arguta	Wood fern	P	N
Elymus glaucus	Blue wild-rye	P	N
Elymus spp.	Wild-rye	P	N
Elymus triticoides	Beardless wild-rye	P	N
Equisetum arvense	Horsetail	P	N
Equisetum laevigatum	Scouring-rush	P	N
Erigeron breweri	Fleabane	P	N
Eriodictyon californicum	Yerba santa	P	N
Eriogonum latifolium	Wild buckwheat	P	N
Euphorbia sp.	Spurge	A	I
Festuca californica	California fescue	P	N
Festuca megalura	Foxtail fescue	A	N
Festuca occidentalis	Western fescue	P	N
Festuca reflexa	Reflexed fescue	A	N
Festuca rubra	Red fescue	P	N
Fragaria californica	Strawberry	P	N
Galium aparine	Annual bedstraw	A	I
Galium bolanderi	Bedstraw	P	N
Gayophytum diffusum	Gayophytum	A	N
Gilia capitata	Gilia	A	N
Glyceria nervata	Manna grass	P	N
Heracleum lanatum	Cowparsnip	P	N
Holcus lanatus	Velvet grass	P	I
Hypericum formosum	St. John's wort	P	N
Hypericum perforatum	Klamath weed	P	I
Hypochoeris glabra	Smooth cat's ear	A	I
Hypochoeris radicata	Cat's ear	P	I
Iris missouriensis	Iris	P	N
Juncus balticus	Baltic rush	P	N
Juncus effusus	Rush	P	N
Lepidium densiflorum	Pepper grass	A	N
Lessingia leptoclada	Sierra lessingia	A	N
Libocedrus decurrens	Incense-cedar	P	N
Linanthus montanus	Mustang-clover	A	N
Lolium spp.	Rye grasses	P-A	I
Lotus oblongifolius	Narrow-leaved lotus	P	N
Lotus sp.	Lotus	A	N
Lupinus albifrons	Bush lupine	P	N
Lupinus arbustus	Lupine	P	N
Melica imperfecta	Onion-grass	P	N
Mentha arvensis	Mint	P	N
Micropus californicus	Slender cottonweed	A	N
Montia perfoliata	Miner's lettuce	A	N
Muhlenbergia filiformis	Pull-up muhly	A	N
Navarretia divaricata	Mountain navarretia	A	N
Orobanche fasciculata	Broom-rape	P	N
Panicum occidentale	Panic-grass	P	N
Panicum pacificum	Panic-grass	P	N
Penstemon newberryi	Beardtongue	P	N
Phacelia heterophylla	Phacelia	B	N
Phleum pratense	Timothy	P	I
Phragmites communis	Reed	P	N
Pinus contorta	Lodgepole pine	P	N
Pinus lambertiana	Sugar pine	P	N
Pinus ponderosa	Ponderosa pine	P	N

Poa pratensis	Kentucky bluegrass	P	I
Poa scabrella	Pine bluegrass	P	N
Polygonum aviculare	Knotweed	A	N
Polystichum munitum	Sword fern	P	N
Populus trichocarpa	Black cottonweed	P	N
Potentilla glandulosa	Cinquefoil	P	N
Pseudotsuga menziesii	Douglas fir	P	N
Pteridium aquilinum	Bracken fern	P	N
Quercus chrysolepis	Canyon liveoak	P	N
Quercus kelloggii	Black oak	P	N
Rhododendron occidentale	Western azalea	P	N
Rudbeckia hirta	Black-eyed susan	B	I
Rumex acetosella	Sheep sorrel	A	I
Rumex crispus	Curly dock	P	I
Salix spp.	Willow	P	N
Sambucus caerulea	Elderberry	P	N
Scirpus acutus	Common tule	P	N
Scirpus spp.	Tule	P	N
Senecio vulgaris	Groundsel	A	I
Sisymbrium altissimum	Tumble-mustard	A	I
Sitanion hystrix	Squirreltail	P	N
Solidago canadensis	Goldenrod	P	N
Stipa columbiana	Needlegrass	P	N
Trillium chloropetalum	Trillium	P	N
Typha latifolia	Cattail	P	N
Umbellularia californica	California bay	P	N
Vitis californica	Grape	P	N

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