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Floristic and vegetational patterns in a California dredge field

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ABSTRACT. One hundred and nine species of vascular plants were collected from twenty-two stands at six sites in the Snelling, California, dredge field. Five sites were dredged, one per year, in 1910, 1928, 1938, 1941 and 1950, while one site was not dredged. Association analysis of the stand data identified four species groups closely related to dredge spoil topography and moisture availability. In addition, the program ordinated the stand data according to floristic affinities. The ordination showed no age-dependent patterns.

Introduction

The nearly 60 000 acres of dredge fields scattered along the major rivers of the north-eastern part of California's Central Valley are stark testimony to the state's once-flourishing gold-dredging industry. These spoils, left by huge floating bucket-line dredges (Fig. 1), consist of wormlike ridges of unsorted boulders and cobbles and intervening swales with fine-textured soils and standing water (Fig. 2). Whereas the ridges are sparsely vegetated by annual herbs and grasses, the swales are usually forested by *Salix* spp. and *Populus fremontii* (Fig. 3).

Dredged primarily were the shallow (20–80 ft in depth) Quaternary gravels of the modern river terraces and floodplains near the eastern edge of the valley (Lindgren, 1911: 220). Between 1898 and 1968, twelve major dredge fields between Butte Creek and the Merced River were mined (Fig. 4) (Clark, 1970: 19; Wagner, 1970). The total value of gold dredged from some of these fields in the late 1930s and early 1940s was only exceeded in California during the Gold Rush (Clark, 1970: 3).

Except for a few hundred acres levelled for housing or used for aggregate, the dredge fields now serve as little more than poor grazing lands and wildlife habitat. Nevertheless, these man-made landforms offer plant ecologists an opportunity to study vegetation change and plant succession, especially since their evolution and structure are completely different from that of any natural landform and they are fairly similar in structure. Furthermore, each tailing pile can be dated from mining progress maps to the week of its deposition. Summarized here is an investigation of the floristic and vegetational patterns in the Snelling dredge field.

Study area

Snelling is located at 259 ft above mean sea level at the eastern edge of the Central Valley. The climate is hot and dry in summer and cool and humid in winter. Annual precipitation averages 33.2 inches, and most rain falls between November and April (California, 1980). Local vegetation is valley oak woodland (*sensu* Griffin, 1977), grassland (*sensu* Heady, 1977) and riparian forest (*sensu* Conard, MacDonald & Holland, 1977).

The Snelling gold district is primarily a dredging field, although some placer and

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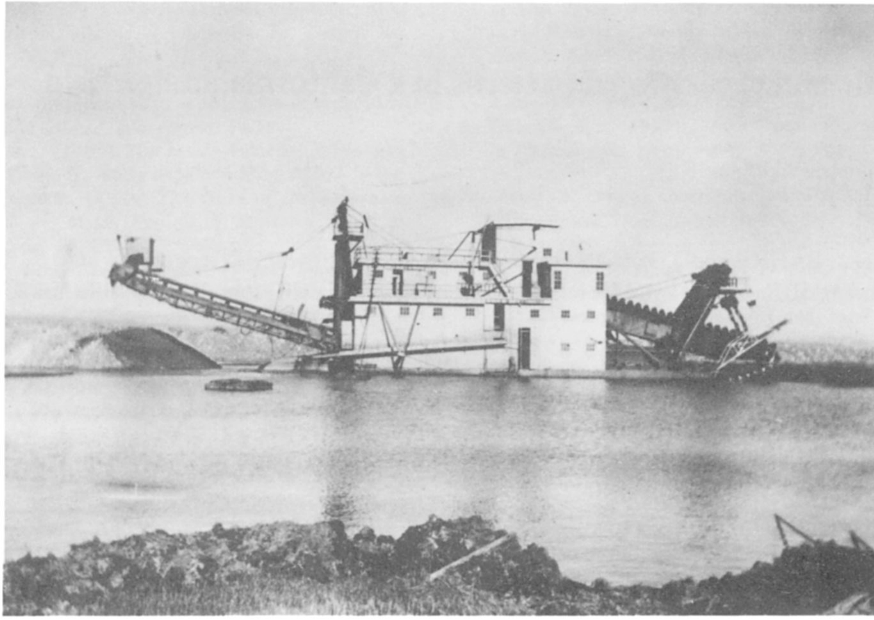

FIG. 1. Yuba Dredge No. 2. This dredge, once owned by Yuba Goldfields, was brought to Snelling from Montana in 1935. Only 75 ft long, it was one of the smallest dredges ever used at Snelling. It was dismantled in 1939 and taken to Chico. The digging ladder is to the right and the stacker to the left.

hydraulic mining was practiced during the Gold Rush. The dredge field, which consists of 7000 acres of spoils paralleling the Merced River between Snelling and Merced Falls, is about 9 miles long and 0.5–1.5 miles wide.

The gold is mostly flour gold derived from the pocket belt of the Mother Lode in Mariposa County, which is traversed by the upper course of the Merced River. It is found in gravel deposits of the modern river that range in depth from 18 to 36 ft. These gravels are loose and generally free of clay and large boulders. Bedrock is slate in the east and volcanic ash in the west. Dredge recoveries varied from 10 to 30 cents worth of gold per cubic yard (Clark, 1970: 121).

Six dredging companies operated in the Snelling district between 1907 and 1951 with ten dredges among them (Aubury, 1910: 211; Logan, 1919: 33; Davis & Carlson, 1952: 225–227; Clark, 1970: 120–121). During that period two hiatuses occurred in the dredging industry. The first took place between 1919 and 1928, when high labour and supply costs depressed the industry, and the second occurred between 1942 and 1946, when the War Production Board closed down gold-dredging operations in the state. The boom years were between 1928 and 1942, when low operating costs, abundant labour, and the valuation of gold upward to $35 an ounce gave added impetus to the industry.

To make clear the ecology and depositional patterns of the dredge spoils, a brief description is presented here of the dredges and their operation. Bucket-line gold dredges, constructed chiefly of steel, were so heavy and cumbersome that they had to be assembled in a dry pit: water from a canal turned into the pit allowed the dredge to float (Aubury, 1905: 19–41; Aubury, 1910: 38–84). Most were operated electrically and were on floodplains and terraces in ponds of their own making that moved with them.

Before being dredged, wooded areas were cleared by bulldozers or by woodcutters who sold the wood. Digging was usually started at the top of the bank, and as the digging ladder moved upward the dredge was swung to the left or right, pivoting about a heavy wood or steel spud (Fig. 1). The spud, fixed into the stern, had its point embedded in the bottom of the pond. The side swing of the ladder was also aided by port and starboard bow lines of

FIG. 2. A section of the dredge field east of Snelling. Note tree-lined swales and sparsely vegetated tailing piles. The oldest spoils do not necessarily have tree-lined swales. In some cases the spoils were stacked so that no swales were left for trees to colonize. (Aerial photograph taken in 1959.)

FIG. 3. Dredge spoil mound tops. Note cobbles and boulders as well as sparse vegetation cover. The trees in the swales are *Salix* spp. and *Populus fremontii*.

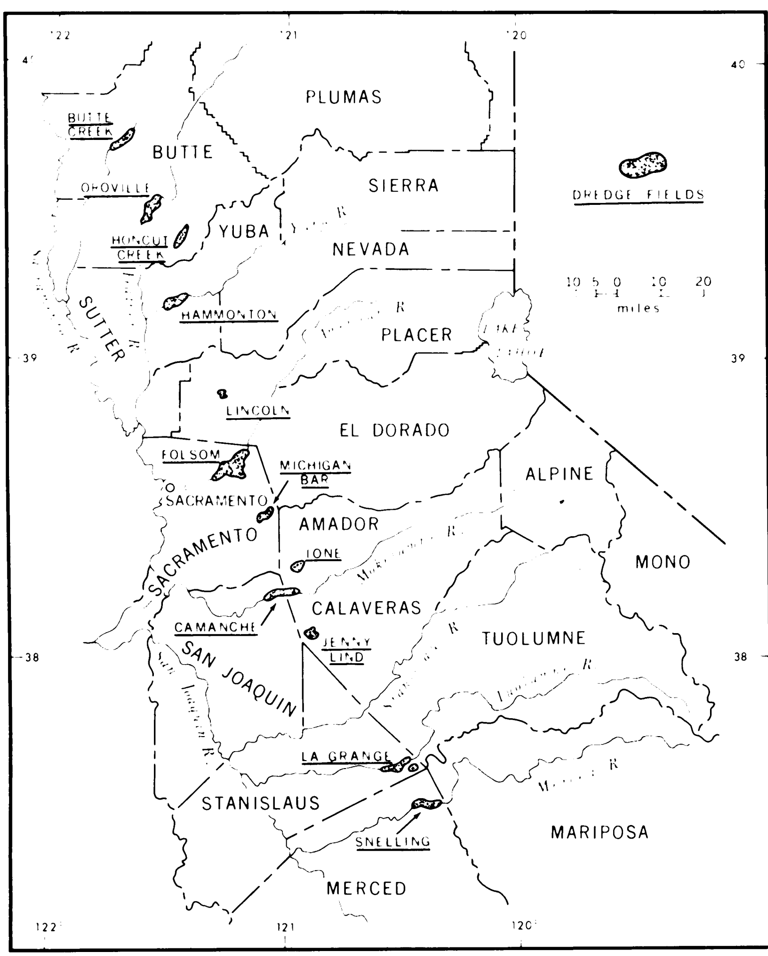

FIG. 4. Map of east-central California showing the major dredge fields from Butte Creek to the Merced River.

heavy steel cable. The digging buckets had capacities varying from 11 ft^3 on the small dredges to 18 ft^3 on the large dredges.

The excavated gravel was dumped from the buckets into a hopper where it was sprayed with water before being passed through a revolving or shaking screen, which separated the coarse gravels and boulders from the fines. The coarse materials were discharged onto a conveyor belt, which stacked them astern in large tailing piles. The fines passed through the perforations of the screen and dropped into riffle sluices or gold-saving tables with quicksilver traps. There the sand and gravel were separated out and dumped astern by tail sluices into the dredge pond, while the free gold readily amalgamated with the quicksilver and collected in the gold boxes.

Although most gold dredges were only capable of digging 25–30 ft below the surface of the dredge pond, some could reach as deep as 50 ft – one at Hammonton could reach nearly 100 ft. The dredges were ordinarily operated 24 h a day. Earth-moving capacity, depending on the size of the dredge, ranged from 200 000 to 340 000 yd^3 per month.

TABLE 1. Age and location of sites and topography of stands in the Snelling dredge field

Site age	Location	Stand no.	Topography
1928	S 1/2 of NE 1/4 of SE 1/4 of Sec. 6, T 5 S., R 15 E.	1	Low swale
		2	High swale
		3	Mound top
		4	High swale
		5	High swale
*	SE 1/4 of NW 1/4 of SE 1/4 of Sec. 5, T 5 S., R 15 E.	6	River terrace top
1950	E 1/2 of SW 1/4 of SW 1/4 of Sec. 6, T 5 S., R 15 E.	7	Mound top
		8	High swale
		9	Mound top
		10	High swale
		11	High swale
1941	NW 1/4 of SW 1/4 of SE 1/4 of Sec. 7, T 5 S., R 14 E.	12	High swale
		13	Mound top
		14	High swale
		15	Low swale
		16	Mound top
1938	NE 1/4 of SW 1/4 of SE 1/4 of Sec. 9, T 5 S., R 14 E.	17	Mound top
		18	High swale
		19	Low swale
1910	W 1/2 of NE 1/4 of NE 1/4 of Sec. 9, T 5 S., R 14 E.	20	Mound top
		21	High swale
		22	Low swale

*Undredged site.

Individual dredge piles usually differ in slope and elevation. Fines may or may not be found on tailing surfaces. Whereas some dredge piles are in neat rows, most are rather haphazard. These differences in spoil topography reflect the dredging depths, the particular ways in which the tailing stackers were operated, and whether overburden was sent directly to the stacker without being sorted.

Method

Five study sites in the Snelling dredge field were selected and dated by using large-scale topographic maps and aerial photographs, mining progress maps, interviews with residents of Snelling and Merced Falls, and records in the Merced County Recorder's Office (Table 1). These sites were dredged, one per year, in 1910, 1928, 1938, 1941 and 1950. One additional site, which was not dredged, was selected as a control. The only recent disturbance of the vegetation near any of the sites has been caused by cattle.

Stands on the mound tops, high swales, and low swales at each of the dredged sites were subjectively selected to conduct a complete floristic inventory. Such an inventory was needed to detect floristic distinctions between sites of different age. Random and systematic sampling techniques were impractical and highly sensitive to artefacts of sample location because of the sharp gradients and irregular depositional patterns of the spoils. The stands, which varied in size and shape, were inventoried using the Braun-Blanquet relevé method (Mueller-Dombois & Ellenberg, 1974). High swales were inventoried *in toto*, while mound tops and low swales were inventoried along belt transects whose lengths were determined to include all species in a particular habitat. Edge effects were minimized by placing the stands no closer than 300 ft from the edges of the spoils. The sampling method was designed to eliminate minimum area problems arising from the use of discrete sample sizes, to represent the total flora, and to establish within-stand homogeneity while maximizing the possibility of between stand differences.

The stand data were analysed using the association analysis program of Čĕska & Roemer (1971). This program, which identifies associational relationships between species using pre-established phyto-sociological criteria, was selected because it operates on presence/absence data and has proven useful for organizing stand data from a variety of communities (Holland, 1978; Conard *et al.*, 1977; Atwater *et al.*, 1979). The program arranges species into groups of co-occurrence and ordinates stands according to floristic similarities. The stand data were sorted according to the program's five different 'inside–outside' rules. Of these, the 50%-inside–20%-outside rule was chosen because it included the highest percentage of the entire flora and consequently accounted for more variations than the other rules. According to the 50%-inside–20%-outside rule, a species belongs to a floristic group if it occurs in 50% of the stands in its group and does not occur in more than 20% of the stands outside of its group. A stand belongs to a floristic group when it contains 50% of the species in the group. Field work was carried out between March and May 1980, during the peak bloom of the annual flora.

Results and Discussion

One hundred and nine species of vascular plants were collected from twenty-two stands at six sites in the Snelling dredge field (Tables 1 and 2). The association analysis program organized the stand data into four floristic groups (Table 3). Only thirty-six of the 109 species were sufficiently well associated to be included in these groups. From left to right in the table, the stands range from dry mound tops with sparse annual grass and herbaceous cover, to high dry swales dominated by thickets of *Salix* spp., to low mesic swales that have forests of *Salix* spp. and *Populus fremontii* surrounding shallow ponds. However, the four high swale stands at the far right do not fit within the topographic-moisture gradient of the rest of the ordination or within any single floristic group. This fact, plus their affinities to Groups 1, 2 and 4, are due to small-scale habitat variations. Also, Stand 2, a high swale covered by grass, fell within the xeric mound tops, whereas Stand 10, another high swale, contains two species groups.

The nesting of the species groups according to moisture availability and topography is readily apparent from the table. Group 1, comprised primarily of introduced annual species (Tables 3 and 4), corresponds floristically and physiognomically to the 'California annual type' described by Heady (1956, 1958, 1977). It grows exclusively on mound tops and averages 15–25% cover. That Group 1 is similar to Heady's climax annual grassland shows that his model is inaccurate, because it depends on the development of organic mulch. Here this grassland type has developed on largely unweathered parent material and completely lacks a litter layer.

Group 2, made up entirely of native tree species, occupies the bottoms of nearly every

TABLE 2. Vascular plants of the Snelling dredge field. NP = native perennial, NA = native annual, IP = introduced perennial, and IA = introduced annual. The numbers (1–22) indicate the stands in which the species were collected. Nomenclature follows Munz & Keck (1959).

Alismataceae
Alisma sp. (NP–1)
Amaryllidaceae
Brodiaea californica (NP–20)
B. hyacinthina (NP–6, 22)
B. multiflora (NP–20)
Aspidiaceae
Dryopteris arguta (NP–8)
Betulaceae
Alnus rhombifolia (NP–15, 22)
Boraginaceae
Amsinckia sp. (NA–2, 17)
Caprifoliaceae
Cephalanthus occidentalis (NP–22)
Sambucus mexicana (NP–22)
Caryophyllaceae
Silene sp. (NA–10)
Compositae
Achyrachaena mollis (NA–20)
Ambrosia trifida (IA–22)
Anaphalis margaritacea (NP–8)
Artemisia californica (NP–3, 7)
Brickellia californica (NP–22)
Centaurea melitensis (IA–5, 17)
Erigeron sp. (NA–22)
Holocarpha sp. (NA–6)
Hypochoeris glabra (IA–2, 3, 5, 7, 9, 10, 17, 20)
Lactuca sp. (IA–5, 21)
Senecio vulgaris (IA–3)
Taraxacum officinale (IA–13)

Table 2 (Continued)

Cruciferae
- *Brassica* sp. (IA–7, 13, 18)
- *Rorippa nasturtium-aquaticum* (IP–22)
- *Thysanocarpus curvipes* (NA–17)

Cyperaceae
- *Cyperus alternifolius* (IP–1)
- *Eleocharis macrostachya* (NP–1, 5)

Fagaceae
- *Quercus lobata* (NP–2, 10, 12, 14, 15, 21, 22)
- *Q. wislizenii* (NP–22)

Geraniaceae
- *Erodium botrys* (IA–3, 6, 17, 20)
- *Geranium pilosum* (IP–1, 2, 5, 17)

Gramineae
- *Avena barbata* (IA–3, 5, 7, 9, 13, 16, 17, 20)
- *A. fatua* (IA–6)
- *Briza minor* (IA–5)
- *Bromus diandrus* (IA–2, 6, 9, 10, 13, 17, 20, 22)
- *B. mollis* (IA–2, 5, 6, 7, 8, 9, 10, 13, 16, 17, 20)
- *B. rubens* (IA–2, 3, 6, 7, 17, 20, 22)
- *Cynodon dactylon* (IP–1)
- *Hordeum geniculatum* (IA–1, 5)
- *H. leporinum* (IA–11)
- *Polypogon maritimus* (IA–19)
- *Stipa pulchra* (NP–6)
- *Vulpia megalura* (NA–3, 6, 7, 8, 10, 13, 17, 20)
- *V. myuros* (IA–6, 7, 9, 10, 13, 16, 17, 20)
- *V. octoflora* (NA–3)

Hippocastanaceae
- *Aesculus californica* (NP–22)

Juglandaceae
- *Juglans hindsii* (NP–22)

Juncaceae
- *Juncus balticus* (NP–1, 18)
- *J. effusus* (NP–15, 22)

Labiatae
- *Marrubium vulgare* (IP–11, 15)

Leguminosae
- *Lotus humistratus* (NA–2)
- *L. purshianus* (NA–3, 7, 10, 11, 16, 17, 20)
- *L. strigosus* (NA–17)
- *Lupinus densiflorus* var. *palustris* (NA–9, 13, 17, 20)
- *Medicago arabica* (IA–5, 11)
- *M. hispida* (IA–2, 11)
- *Melilotus albus* (IA–2)
- *M. indicus* (IA–5, 8, 22)
- *Trifolium amplectens* (NA–20)
- *T. ciliolatum* (NA–3)
- *T. gracilentum* (NA–10)
- *T. hirtum* (IA–13, 19)
- *T. microcepalum* (NA–6)
- *T.* sp. (NA–8)
- *Vicia benghalensis* (IA–3, 5, 7, 8, 9, 10, 11, 14, 17, 22)
- *V. sativa* (IA–5)

Liliaceae
- *Calochortus luteus* (NP–6)
- *Chlorogalum grandiflorum* (NP–20, 21)

Lythraceae
- *Lythrum californicum* (NA–1, 2, 5, 8)

Marsileaceae
- *Marsilea vestita* (NA–1)

Moraceae
- *Ficus carica* (IP–4, 7, 9, 15)
- *Morus rubra* (IP–21)

Oleaceae
- *Fraxinus latifolia* (NP–22)

Onagraceae
- *Epilobium paniculatum* var. *laevicaule* (NA–3, 16)

Oxalidaceae
- *Oxalis pilosa* (NP–19, 22)

Papaveraceae
- *Eschscholzia californica* (NA–20)
- *E. lobbii* (NA–6)

Plantaginaceae
- *Plantago lanceolata* (IP–10, 15)

Polygonaceae
- *Chorizanthe membranacea* (NA–20)
- *Polygonum* sp. (NA–18)
- *Rumex conglomeratus* (IP–5, 22)
- *R. crispus* (IP–1, 9)

Pontederiaceae
- *Eichhornia crassipes* (IA–3, 19)

Portulacaceae
- *Montia perfoliata* (NA–21, 22)

Pteridaceae
- *Pellaea brachyptera* (NP–3)
- *Pityrogramma triangularis* (NP–3, 7, 22)

Rhamnaceae
- *Rhamnus purshiana* (NP–8, 22)

Rosaceae
- *Adenostoma fasciculatum* (NP–20)
- *Rubus procerus* (IP–15, 19, 22)

Rubiaceae
- *Galium asperrimum* (NP–3, 8)
- *G. parisiense* (IA–2, 16, 20)

Salicaceae
- *Populus fremontii* (NP–1, 8, 10, 11, 14, 15, 18, 22)
- *Salix gooddingii* (NP–1, 5, 8, 12, 14, 15, 19)
- *S. hindsiana* (NP–1, 4, 10, 14, 15, 18, 19, 21, 22)
- *S. laevigata* (NP–8, 11)
- *S. lasiandra* (NP–2, 10, 12, 14, 15, 18, 19, 22)

Salviniaceae
- *Azolla* sp. (NA–15)

Scrophulariaceae
- *Mimulus nasutus* (NA–22)
- *Orthocarpus attenuatus* (NA–7, 10)
- *O. erianthus* (NA–3)

Selaginellaceae
- *Selaginella douglasii* (NP–20)

Solanaceae
- *Solanum nodiflorum* (IA–21)

Typhaceae
- *Typha angustifolia* (NP–15)
- *T. latifolia* (NP–15, 19)

Umbelliferae
- *Caucalis microcarpa* (NA–20, 22)
- *Conium maculatum* (IA–21)
- *Torilis nodosa* (IA–2)

Urticaceae
- *Urtica holosericea* (NP–15, 21)

Vitaceae
- *Vitis californica* (NP–15, 22)

TABLE 3. Stand ordination and species groups on the Snelling dredge field summarized in a species-by-stand matrix using the association analysis program of Čěska & Roemer (1971). Cover values are: R = single individual, + = < 1%, 1 = 1–5%, 2 = 6–25%, 3 = 26–50%, 4 = 51–75%, and 5 = 76–100% (Mueller-Dombois & Ellenberg, 1974).

	Xeric mound tops									Semi-xeric high swales				Mesic swales					Misc. swales			
Date of deposition (19– –)	28	28	—*	50	50	41	41	38	10	50	41	41	38	41	38	10	28	28	28	50	50	10
Stand no.	02	03	06	07	09	13	16	17	20	10	12	14	18	15	19	22	01	05	04	08	11	21
Species										Cover values												
Group 1																						
Bromus mollis	+		2	1	1	+	1	1	1	1								+		+		
Bromus diandrus	1		1		+	+		1	1	+						R					1	
Avena barbata		2		1	1	1	1	1	1									1				
Vulpia myuros			1	+	1	1	+	1	1	+												
Lotus purshianus		1		1		1	1	+	1	1											1	
Vulpia megalura		1	2	+		+		1	1	+										+		
Hypochoeris glabra	+	+		+	+			+	R	R								+				
Bromus rubens	1	2	+	1				1	+							R						
Group 2																						
Salix lasiandra	4									3	4	2	3	2	2	2						
Salix hindsiana										3		2	3	2	2	1			3			4
Populus fremontii										3		2	1	1		2	3			3	2	
Quercus lobata	R									R	R	1		1		1						R
Salix gooddingii											3	2		2	2		3	2		1		

Group 3												
Rubus procerus					2	2	2					
Oxalis pilosa						+	+					
Alnus rhombifolia					1		1					
Vitis californica					2		2					
Typha latifolia					2	2						
Juncus effusus					+		+					
Group 4												
Lythrum californicum	R							+	R	R		
Geranium pilosum	+		+					+	R			
Melilotus indicus							R		+	1		
Hordeum geniculatum								+	+			
Rumex crispus							R		R			
Eleocharis macrostachya								1	1			
Centaurea melitensis			+						3			
Juncus balticus				+				+				
Medicago arabica									+		+	
Lactuca sp.									R			+
Rumex conglomeratus		R						R				
Alisma sp.								R				
Marsilea vestita								+				
Briza minor									R			
Cynodon dactylon								R				
Cyperus alternifolius								+				
Vicia sativa									1			

* Undredged grassland site.

TABLE 4. Floristic origin and lifespan, as a per cent of total species in each group

	Native species		Introduced species	
	Annual	Perennial	Annual	Perennial
Group 1	25	0	75	0
Group 2	0	100	0	0
Group 3	0	83	0	17
Group 4	12	18	41	29
Outliers	30	35	25	10

swale having fine-textured soils. It overlaps little with Group 1; only Stand 10 includes both groups. Group 2 species are common pioneers in disturbed riparian habitats in the Central Valley, and, save for *Quercus lobata,* all have wind-dispersed seeds (Munz & Keck, 1959; Thompson, 1961; Conard *et al.,* 1977). Except for two large individuals at the 1910 site, the oaks are seedlings in the shade of willows. Since no parent oaks grow nearby, these oaks most likely germinate from acorns dispersed by animals. Only the bottoms of the swales have soil conditions that are favourable for oak generation and establishment in the dredge field.

Group 3, consisting of woody perennials and emergent aquatics, occupies the edges of forested sites and shares most of the low mesic swales with Group 2 species. Group 3 reflects the greater habitat diversity of the low swales owing to the presence of perennial ponds and a forest canopy. *Vitis californica* and *Rubus procerus* occupy the landward margins, whereas *Typha latifolia* and *Juncus effusus* occupy the pond margins.

Group 4 is made up largely of herbaceous annuals growing in semi-shaded, moist places in the swales containing standing water. The species in this group range from emergent and floating aquatics (*Cyperus alternifolius, Alisma* sp., and *Marsilea vestita*) to plants usually found in open, droughty habitats (*Centaurea melitensis, Briza minor* and *Cynodon dactylon*). Also, Group 4, like Group 3, is associated with a forest canopy.

62% of the species collected in the dredge field are native, while 38% are introduced (Table 5). According to Heady (1977), the percentage of native plants in species lists for individual stands in California's annual grassland varies from 71% at Hastings Reservation (White, 1967) to 20% or less at Hopland (Heady, 1956). Furthermore, Talbot, Biswell & Hormay (1939) found that annuals constituted 94% of the herbaceous cover in California's grassland and that introduced species accounted for 63% of that cover. Our findings indicate that the dredge fields, often considered among the most disturbed habitats in the Central Valley, may have a relatively high number of native species.

In addition to identifying associational groups, the Češka and Roemer program ordinated the stand data according to floristic affinities (Table 3). However, the ordination table shows no age-dependent patterns. In some cases there are closer affinities between stands of the oldest and youngest sites than between stands of the same age.

Seventy-three species were not included in any of the four species groups because they were too frequent (> 66% is the threshold value of the program), non-constant or both (Tables 2 and 4). Although we lack the quantitative data to interpret fully the significance of the rare species, two conclusions are drawn. First, our sampling was adequate because it included so many rare species. Large stands usually include a high proportion of rare species (Preston, 1948). Secondly, rare species are continually being added to the flora for at least 50 years after spoil deposition.

TABLE 5. Species characteristics of the total flora

	Native species		Introduced species	
	Annual	Perennial	Annual	Perennial
Total number	30	38	30	11
Per cent of total flora	27.5	34.9	28.0	10.1
Total number	68		41	
Per cent of total flora	62.4		37.6	

TABLE 6. Per cent of rare species for each age class

	Undredged control	1910	1928	1938	1941	1950
Total number of species	12	56	57	29	41	54
Total number of outliers*	7	31	17	9	13	21
Per cent outliers	58	55	30	31	32	39

*Excluding *Vicia benghalensis.*

Table 6 summarizes the percentage of rare species in proportion to the total flora of the six study sites. *Vicia benghalensis* was excluded because its occurrence exceeded the 66% threshold of the program. The other species had presence values of 18% or less. Note that rare species made up 55% or more of the total species in the undredged and 1910 sites, and only 30–39% of the species in the other sites. This trend has been documented by others. For example, Bazzaz (1975), in his study of old-field succession in Illinois, found that while species diversity increased most rapidly the first 15 years after field abandonment, the species colonization curve maintained a positive slope for at least another 25 years.

Since the youngest spoils are 30 years old, we have probably missed the rapid colonization phase that occurred after spoil deposition. This is supported by White's studies (1966) of abandoned fields at Hastings Reservation: only 18–28 years were needed after initial disturbance for the dominant species of the climax grassland to become re-established.

Changes in species diversity were not quantifiable because the stands were of different sizes. Nevertheless, the 1910 and 1928 sites were floristically richer than the other sites (Table 6). Of particular interest is the presence of *Chlorogalum grandiflorum, Brodiaea californica* and *B. multiflora,* all native perennials at the 1910 site. The occurrence of these perennials and greater species diversity there may not be entirely age-dependent. The site, which is periodically flooded by the Merced River, has some alluvium and is exposed to flood-borne propagules. Furthermore, these perennials were not found at any other dredged site. The undredged grassland site contained most Group 1 species plus three native perennials: *Stipa pulchra, Brodiaea hyacinthina* and *Calochortus luteus.* In general, species diversity is highest in the forests of the mesic swales and lowest in the grasslands of the mound tops.

Conclusions

Only small changes in species composition were found in the dredge spoil sequence investigated at Snelling. The dominant species probably colonized rapidly after spoil deposition. The four floristic groups identified by the Češka & Roemer program (1971) appear to be constant for most sites regardless of age. The groups correlate most closely with dredge spoil topography and moisture availability. In general, the slow weathering of the dredge spoil has not resulted in enough soil development to affect the vegetation. Only in a few swales having moist shallow soils and standing water is the vegetation very diverse or structurally complex. Several immature *Quercus lobata* in the swales and a *Quercus wislizenii* at the 1910 site are the only evidence of direct species replacement in the study sites. The data suggest that species richness increases with successional age and that 50 years or more are required for the accumulation of a well-developed flora. Structural changes will be much slower, correlating with the slow development of soil.

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