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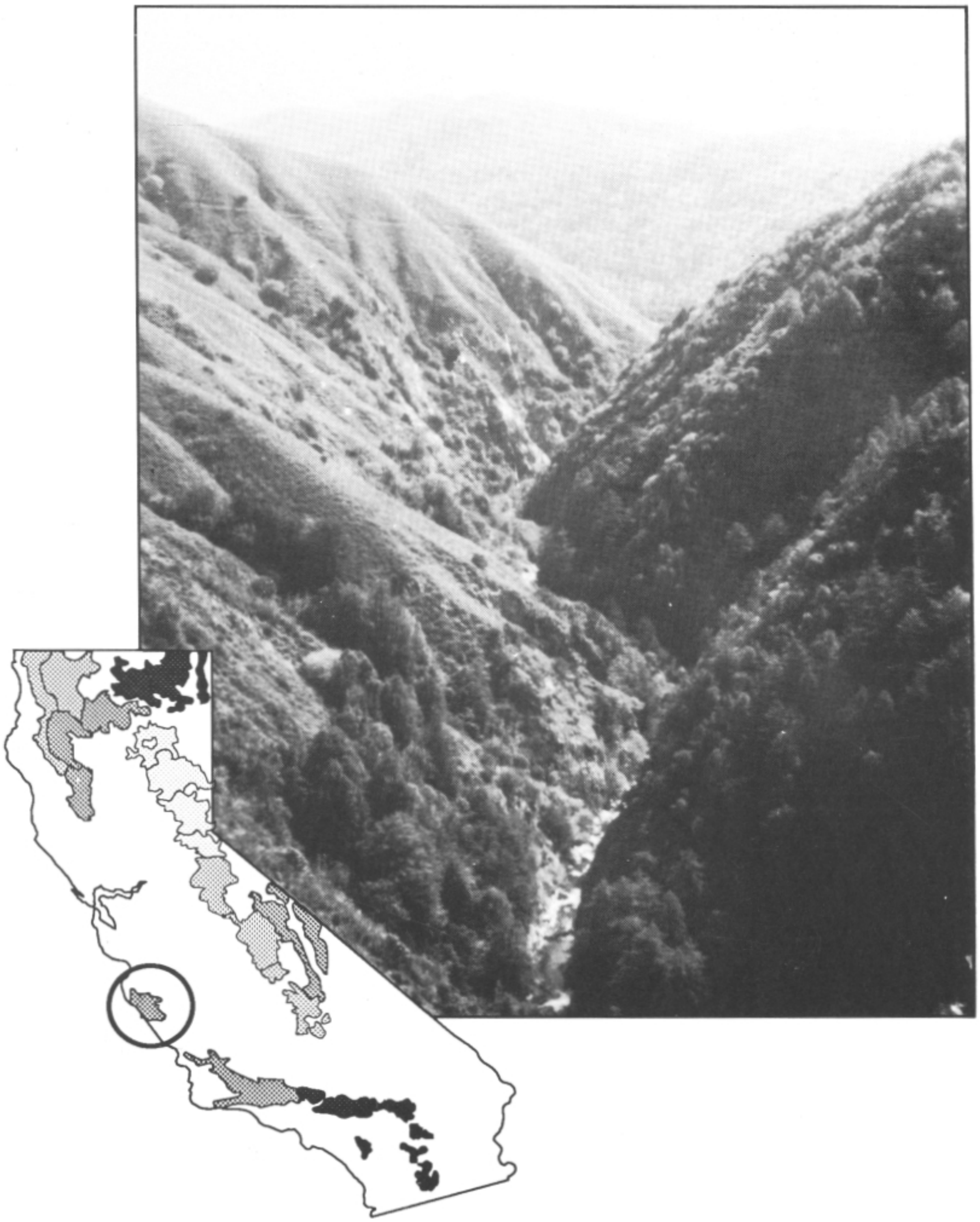
Coast Redwood Ecological Types of Southern Monterey County, California

Mark Borchert Daniel Segotta Michael D. Purser



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An ecological classification system has been developed for the Pacific Southwest Region of the Forest Service. As part of this classification effort, coast redwood (*Sequoia sempervirens*) forests of southern Monterey County in the Los Padres National Forest were classified into six ecological types using vegetation, soils and geomorphology taken from 115, 0.1-acre plots. Four types occur between 100 and 800 ft elevation. The coast redwood/bracken fern-chain fern//streamsides ecological type occupies the narrow flood plains, streambanks and scattered alluvial terraces of large perennial streams. Upslope of this type is the coast redwood/swordfern-western wake robin//Gamboa-Sur ecological type, which covers gentle slopes near ephemeral or perennial streams but is best developed on steep colluvial slopes. Occasional stands of the coast redwood//Gamboa-Sur ecological type are encountered on alluvial-colluvial fans, old stream terraces and lower slope benches. Its upper slope counterpart is the stunted coast redwood/common manroot-common vetch//Gamboa ecological type that occupies steep, ocean-exposed slopes. At elevations above 800 ft there are two types. The rare coast redwood-big leaf maple/California polypody//Gamboa ecological type grows on alluvial terraces of large, open streams. The most xeric and widespread is the coast redwood-tanoak/round-fruited carex-Douglas's iris//Gamboa ecological type which can be found at elevations up to 2650 ft. These ecological types will serve as a framework for gathering productivity and management information for further refinement.

Retrieval Terms: Sequoia sempervirens, coast redwood, ecological type, vegetation classification

Cover: Big Sur River photographed from the Pine Ridge Trail, Monterey Ranger District, Los Padres National Forest.

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INTRODUCTION

Although numerous descriptions of coast redwood (*Sequoia sempervirens,* D. Don, Endl.) forests have been published over the last half-century (Campbell 1946, Jepson 1923, Roy 1966, Shreve 1927, to name a few), it is only within the last 20 years that phytosociological studies have described the compositional variation within this forest type. Most recent classifications have focused on redwood forests in northern California (Becking 1971, Lenihan 1983, Matthews 1986, Muldavin and others 1981). Except for the limited number of plots (26) sampled by Becking (1971), we know of no phytosociological studies of redwood in the southern part of its range.

This report presents an ecological type classification for coast redwoods in the Monterey Ranger District of the Los Padres National Forest *(fig. 1A*). The objectives and rationale for ecological type classification were presented in detail by Allen (1987). Basically, the landscape is partitioned into local ecosystems termed ecological types. As a classification/management unit the ecological type has (a) a unique plant association (Daubenmire 1968), (b) a defined set of site characteristics such as soils, geomorphology, and geology, (c) resource production capabilities, and (d) unique responses and tolerances to management activities.

Designation of a type incorporates all these criteria but, in practice, productivity and management response information often are wanting. Until such information has accummulated in sufficient detail, tentative ecological types are recognized based on biophysical factors alone. The ecological types presented will serve as a framework for gathering productivity and management information for further refinement.

STUDY AREA

Topography

The study area encompasses the rugged coastal slopes of the Santa Lucia Range between Bottchers Gap (36°4'W latitude, 121°48' N longitude) and Salmon Creek (35°45' W latitude, 121°21'N longitude) (*fig. 1A*). The mountains rise abruptly, often precipitously from the coast. Cone Peak, for example, reaches an elevation of 5155 ft within 3.4 mi of the coast—an elevational change of 1516 ft/mi.[1] Equally dramatic elevational gradients are common the length of the study area: south of Cone Peak, Silver Peak ascends at a rate of 1519 ft/mi while to the north Anderson Peak rises 1752 ft/mi and Timber Top 2418 ft/mi (*fig. 1A*). Stream gradients are correspondingly steep. Average length of coastal streams is about 1.3 mi, although some, such as Willow Creek and Devil's Canyon reach 3-3.7 mi. The Little and Big Sur Rivers are exceptionally long, extending inland 10-13 mi (*fig. 1A*).

[1] To convert English measurements to metric, use this table:

To Find	Multiply	By
Centimeters	inches	2.54
Meters	feet	0.3048
Kilometers	miles	1.609
Square meters	square feet	0.0929
Square meters/hectare	square feet/acre	0.0376
Hectares	acres	0.4048
°C	(°F-32)	0.556

Climate

Climate in the study area is characterized by cool, wet winters and warm, dry summers. Three quarters of the precipitation falls between October and the end of February, after which it rapidly declines. June to September are almost completely dry, accounting for less than 2 percent of the total (Talley 1974). Precipitation increases with elevation. The lee side of Cone Peak (5155 ft) receives up to 90 in/yr, much of it snow. In addition to elevation, topography and proximity to maritime air strongly influence the diurnal and seasonal climatic regimes of these coastal canyons. The closely set, precipitous mountain slopes almost continuously shade the canyon bottoms. Of even greater importance, however, is the moderating influence of maritime fog during the hot months of June and July. Although there is disagreement about the causal link between fog and the distribution of redwoods (Marotz and Lahey 1975), fog significantly reduces the evapotranspirational stress of this moisture-sensitive species and also can contribute considerable amounts of moisture to the soil (Azevedo and Morgan 1974, Byers 1952, Cooper 1917, Jacobs and others 1985). Average depth of the fog layer at the University of California Landels-Hill Big Creek Reserve is about 700 ft and ranges to a maximum of 1550 ft (Bickford and Rich 1984). Daytime temperatures below and above the fog layer can differ by as much as 65 °F. Above the fog layer, evaporative stress is ameliorated to some extent by cool, moist, onshore breezes (Talley 1974). Nevertheless, redwoods at these elevations are subject to high summer temperatures (85-95 °F) and, as a consequence, appear to be limited to sites of high moisture availability.

Distribution of Coast Redwood

The mountainous terrain is incised into deep, well-shaded canyons, ravines, gulches and inner gorges. On the lower slopes and along stream and river banks, coast redwood forest is the principal vegetation cover. *Figure 1A* shows the distribution of coast redwood in the study area. The best developed redwood forests range in elevation from 100 to 2320 ft, but isolated groves grow near springs, seeps and in sheltered coves up to 3200 ft elevation. Throughout this elevational range, redwoods seldom extend more than 175 ft from the

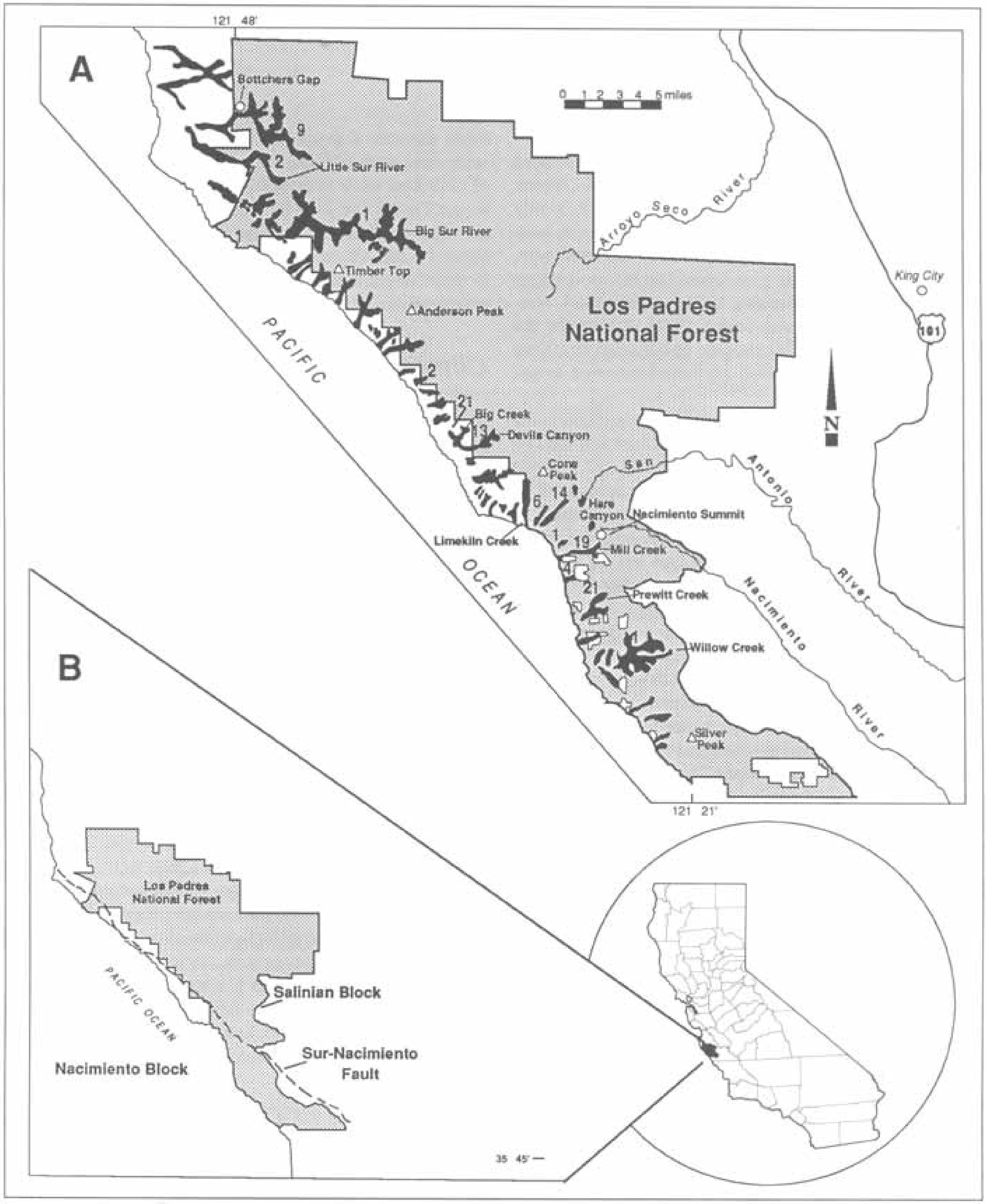

Figure 1—(*A*) The study area was the Monterey Ranger District of the Los Padres National Forest. Shading shows the distribution of coast redwoods (Becking 1971). Numbers next to individual drainages indicate the location and number of study plots used in the analysis. (*B*) Two principal geologic terrains are in the study area (from Wiebe 1970).

main stream channel. In larger drainages, narrow stringers ascend from the stream bottom into side canyons and draws. Here, surface water is usually intermittent, but near-surface ground water is often abundant. On the north slopes of drainages such as Willow Creek, Mill Creek, and the Little and Big Sur Rivers, redwood occasionally intermixes as a subdominant in mixed hardwood forest (Sawyer and others 1977) to elevations of 2000 ft.

The extensive monospecific redwood forests that are common on alluvial flats in the northern part of the species' range are reduced to scattered remnants in this the southernmost extremity of the species distribution. Redwoods usually grow in mixed tree species stands that typically vary in area between 0.1 and 0.5 acres. At upper elevations, individual trees and clumps of redwoods are distributed relatively evenly in a matrix of mixed hardwood forest composed of species such as tanoak (*Lithocarpus densiflorus*), madrone, (*Arbutus menziesii*), canyon oak (*Quercus chrysolepis*), and California bay (*Umbellularia californica*).

The upslope transition from redwood forest to other vegetation types is usually abrupt. Along the immediate coast below 1000 ft elevation, redwood changes to coastal sage scrub or one of three types of chaparral: mixed, California lilac (*Ceanothus thrysiflorus*), or chamise (*Adenostoma fasciculatum*). Above 1000 ft, mixed hardwood forest usually dominates the upper slopes or—less often—annual grassland or coast live oak (*Quercus agrifolia*) forest. Vegetation of the study area and the Santa Lucia Range is described in greater detail by Griffin (1976), Keeler-Wolf and Keeler-Wolf (1977), Shreve (1927), and Talley (1974).

Geology

The northwest trending Sur-Nacimiento fault divides the study area into two distinct terrains. The Salinian block northeast of the fault (*fig. 1B*) is dominated by mid-Cretaceous intrusive and metamorphic rocks, while the Nacimiento block southwest of the fault (*fig. 1B*) is composed of intensely deformed sandstones and shales of the Jurassic to Late Cretaceous Franciscan complex. Common granitic-metamorphic rocks making up the Salinian block are gneiss, schist, granofels, marble, and amphibolite, but these have been extensively intruded by quartz monzonite, quartz diorite and granitic rocks like tonalite and diorite. Granitic-metamorphic basement rock accounts for nearly all of the northern Santa Lucia Range above 3200 ft elevation. The complex geology of this terrain is discussed further by Compton (1966), Reiche (1937), and Wiebe (1970).

The Nacimiento block is dominated by the Franciscan complex. Characteristic rocks of this unit include hard and soft sandstone, siltstone, and shale, with chert and greenstone frequently co-occurring as minor elements. Heavily metamorphosed marine deposits south of Prewitt Creek are extensively intruded by ultrabasic rocks and serpentine, especially in the Willow Creek drainage. Gilbert (1973) discusses in detail the geology of the Franciscan complex in this region.

METHODS

Sampling

Coast redwood stands were sampled in all the larger drainages and in many of the smaller ones in the study area, particularly in the Los Padres National Forest (*fig. 1A*). Supplemental plots were taken in the University of California Landels-Hill Big Creek Reserve, and the Pico Blanco Boy Scout Camp just south of Bottchers Gap. Complete elevational transects were sampled in Mill Creek, Prewitt Creek, Hare Canyon, and the Big Sur River. Sampling in other streams, particularly at higher elevations, was determined by accessibility.

In forests where redwood overstory cover attained at least 50 percent, 162 0.1-acre plots were sampled. A stand was sampled if redwood and associated tree species were relatively evenly distributed over the plot on the same slope and aspect. The majority of plots were circular; however, some along streams and rivers were rectangular with widths that varied between 15 and 40 ft. Nearly all drainages had been logged in the late 1800's, but because trees were harvested for shakes and posts, cutting was scattered and highly selective. As a rule, plots did not contain more than two stumps.

Slope angle, aspect and elevation were recorded for each plot as was landform, slope position, and within-plot vertical and horizontal microrelief. Percent cover of litter, moss, gravel, and rock, and of bare ground also were noted. At three points in the plot, basal area (cross sectional area at breast height in ft^2/acre) was measured by the Bitterlich method using a Spiegel Relaskope. One point was taken at the center of the plot and the others on its perimeter, along the same slope contour as the center point (Talley 1974). Tree height was measured for an average individual in the upper canopy layer.

Percent foliar cover for all plant species was estimated visually for herbaceous, shrub and tree layers. Tree cover was recorded by species for understory seedlings and saplings (≤ 1 in diameter at breast height [d.b.h.]) and overstory trees (>1 in d.b.h.). In addition, understory tree sprouts and seedlings were enumerated by species.

A soil pit was excavated in each plot to a depth of 40 in or bedrock, whichever was encountered first. Thickness of the A horizon was measured and its color, texture, and pH noted. The same data were taken for the subsoil. In addition, percent coarse fragment content was estimated for each layer. Soil drainage, rootability, and lithology were recorded. Available water capacity (AWC) was calculated using soil horizon data.

Data Analysis

Because ecological types are formulated from stands in a relatively stable state (Hall 1970), plots that had burned in the last 40 years were excluded from the analysis, leaving 115 plots (*fig. 1A*). Fire history maps[2] were used to select areas that had not burned in the last 40 years. Analysis followed the sequence presented by Borchert and Hibberd (1984). Using a modified Braun-Blanquet percent cover scale (0-1, 2-5, 6-25,26-50,51-75,76-100), samples were first classified using the two-way indicator species analysis TWINSPAN (Hill 1979a), a polythetic divisive technique. Species with less than three occurrences were deleted from the analysis. Next, samples were ordinated using detrended correspondence analysis DECORANA (Hill 1979b). TWINSPAN groups were examined in the DECORANA ordination space for within-group compositional consistency.

Soils data were not taken for 8 plots, 4 of which were among the plots used in the classification. However, because they were scattered among the ecological types, their absence had little effect on soil descriptions.

RESULTS AND DISCUSSION

Stand Classification

TWINSPAN classified the 115 stands into 14 groups, each composed of at least 2 stands. Some stands were reclassified to other groups, and 7 were eliminated from the analysis as outliers. The remaining 108 stands were ultimately classified into five groups. One of these groups was further divided based on differences in geomorphology. The result was six groups or ecological types.

The first and second axes of the DCA ordination were correlated with elevation ($r=0.63$; $p<0.01$) and slope angle ($r=0.62$; $p<0.01$), respectively (*fig. 2*). Mosaic diagrams for ecological types were constructed by directly ordinating stand samples along these two complex gradients.

Soils

Series— Soils belonging to the Gamboa Series (*table 1*) are the dominant soils in coast redwood forests. These deep, highly productive soils (site index 210 at 100 years; Cook 1978) span a wide range of elevations, but are particularly well represented between 250 and 1500 ft. On slopes greater than 60 percent, Gamboa soils tend to be concentrated on northwest through north-northwest exposures. On slopes less than 60 percent, aspect representation is more variable (*fig. 3A*).

Gamboa soils typically develop on lower and midslope debris slide colluvium; and, less commonly, over streamside alluvial terraces and bedrock. Although it is represented on both major rock units, this soil family has a much higher occurrence on granitic-metamorphic rocks. In addition to the sandstone, schist, and granite parent materials listed by Cook (1978), we encountered this series on marble, gneiss, and quartz.

Soils in the Sur Series (*table 1*) develop on the same parent materials and in the same slope positions as do Gamboa soils; indeed, the two series intermingle extensively enough to form the Gamboa-Sur complex (Cook 1978). Nevertheless, compared with Gamboa soils, Sur soils are only moderately deep and much less productive (site index 130 at 100 years; Cook 1978). They are almost entirely restricted to elevations between 250 and 1250 ft on 60-90 percent slopes. Aspect ranges north-northwest through east-northeast (*fig. 3B*).

The Los Gatos Series (*table 1*) is twice as common on Franciscan as on granitic-metamorphic rocks, which agrees with Cook's (1978) findings. Like Gamboa soils, soils in this series cover the gamut of elevations, but tend to develop on slopes greater than 40 percent that face west-northwest through north-northwest (*fig. 3C*). This series is particularly well represented on lower colluvial slopes.

Although the sample size for the Junipero Series (*table 1*) was small, there are some obvious trends in its distribution (*fig 3D*). It is most prevalent on Franciscan rocks between 750 and 2250 ft elevation. Slope exposures range north through east and slope angle varies between 20-80 percent. Samples of the Plaskett Series (*table 1*) are too variable to indicate a clear distributional pattern.

Development—Based on the soil development sequence outlined by Marron (1982) for Redwood National Park, the dominant soil series in redwood forests in the study can be characterized as weakly developed. Typical colors in the A horizon are 1OYR, B horizons are weakly developed, and total soil depth to bedrock varies from 24 to 60 in. Except for the Los Gatos Series, there is little accumulation of clay in the profile. Textures are predominantly gravelly sandy loams.

In its broad outline, Marron's (1982) landscape evolution model for Redwood National Park, which was subsequently described in the Coast Ranges (Reneau and others 1985), explains the absence of well-developed soils in southern Monterey County redwoods. As in Redwood National Park, debris avalanche is a dominant hillslope erosion process in the geologically young and geomorphically active Santa Lucia Range. Indeed, the effects of debris avalanches are evident in almost every drainage. Either the entire stand slides into the stream channel leaving a long, narrow scar devoid of vegetation, or upslope material slides through the stand removing understory vegetation, but leaving the trees in place. Marron noted a particularly high frequency of avalanche activity on steep north-facing slopes adjacent to stream channels, the most frequent topographic setting of redwoods in this study.

Following slope failure, usually triggered by high intensity-long duration storms (Reneau and others 1985), the slide scar fills with material that ravels in from the scar edges or enters by sheet wash, upslope landsliding, or tree throw. The scar fills for a few thousand years, but is constantly susceptible to shallow landsliding. Eventually, a pocket of colluvium develops that may remain stable for as long as 17,000

[2] Unpublished maps on file at the Supervisor's Office, Los Padres National Forest, Goleta, California.

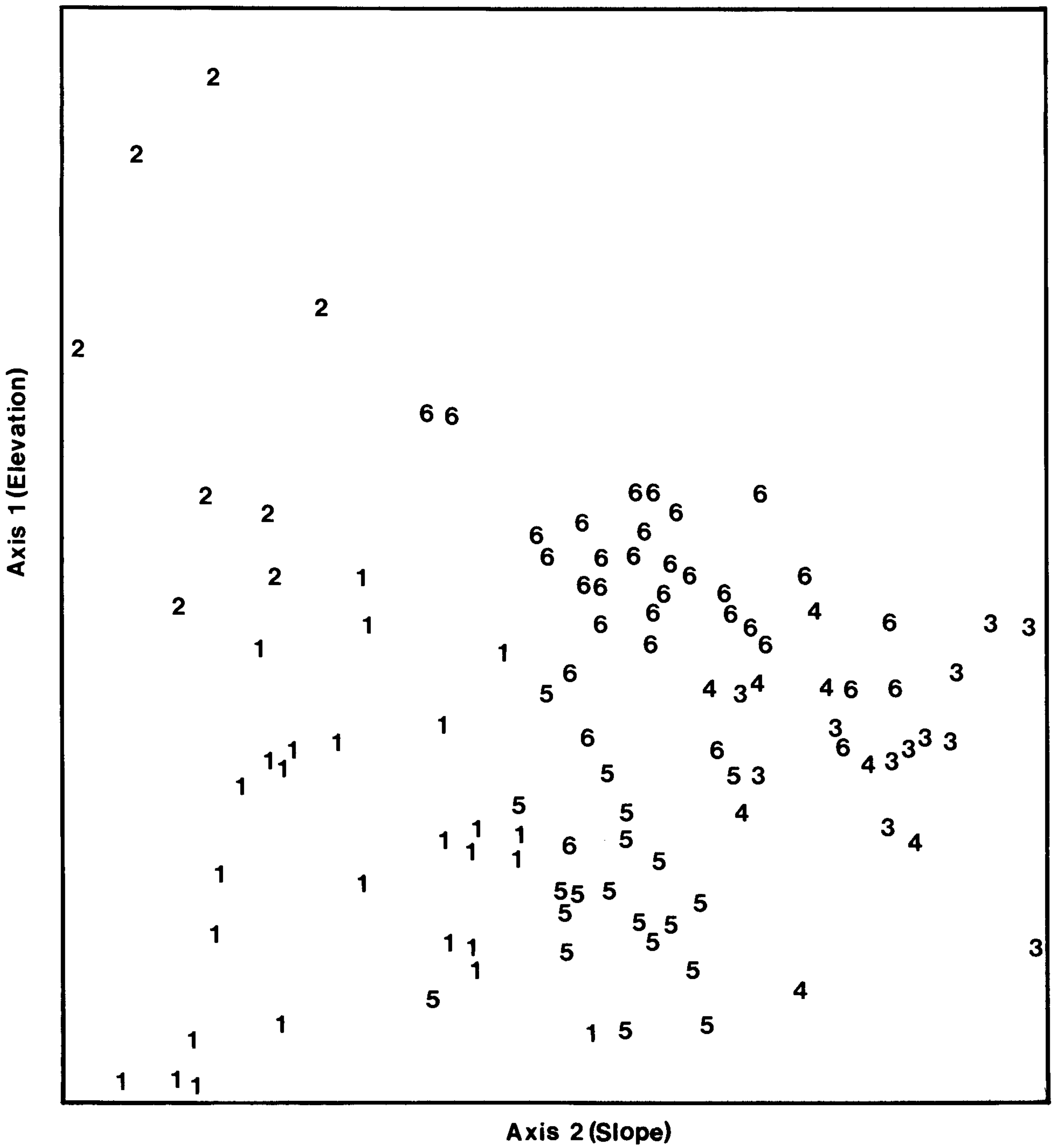

Figure 2—In this detrended correspondence analysis ordination of the 108 plots, ordination axes have been reversed to show the general relationship between slope (X-axis) and elevation (Y-axis). Numbers represent ecological types as follows: 1—Coast Redwood/Western Bracken-Chain Fern//Stream sides, 2—Coast Redwood-Big Leaf Maple/California Polypody//Gamboa, 3—Coast Redwood/Common Manroot-Common Vetch//Gamboa-Sur, 4—Coast Redwood//Gamboa, 5—Coast Redwood/Swordfern-Western Wake Robin//Gamboa-Sur, and 6—Coast Redwood-Tanoak/Round-Fruited Carex-Douglas's Iris//Gamboa.

Table 1—*Mean characteristics of common soil series of the coast redwood forests, California*

Characteristic	Gamboa (43 plots)	Sur (17 plots)	Los Gatos (14 plots)	Junipero (8 plots)	Plaskett (6 plots)
A horizon					
Thickness (in)	15.8	8.3	8.7	9.0	7.3
Course fragment (percent)	31.2	32.3	27.0	14.6	30.3
Texture	gravelly loam; very gravelly loam	gravelly loam	gravelly loam	gravelly loam	very gravelly loam
Color			very dark brown to black		
pH	7.3	7.1	7.2	6.9	7.1
Subsoil					
Coarse fragment (percent)	40.3	42.6	25.0	28.3	50.2
Texture	gravelly loam; very gravelly loam	very gravelly sandy loam	gravelly clay loam	gravelly loam	extremely gravelly sandy loam; extremely cobbley sandy loam
Color	very dark gray; dark very dark gray brown	yellow brown dark	gray brown; dark yellow brown; very dark gray	very dark gray	very dark gray; dark yellow brown
pH	7.2	6.9	7.0	6.8	6.7
Soil drainage	well drained	well drained	mod. well drained; well drained	well drained	somewhat excessively drained
Total soil depth (in)	92 percent> 40 8 percent> 32	78 percent/ 40 22 percent/ 25	75 percent > 40 25 percent> 24	80 percent> 40 20 percent> 32	14-20
Available water capacity (in/40 in of soil)	3.8	2.6	2.5	2.4	1.3
Rootability	no bedrock <40in	no bedrock <40in	no bedrock <40in	no bedrock <40in	hard and fractured

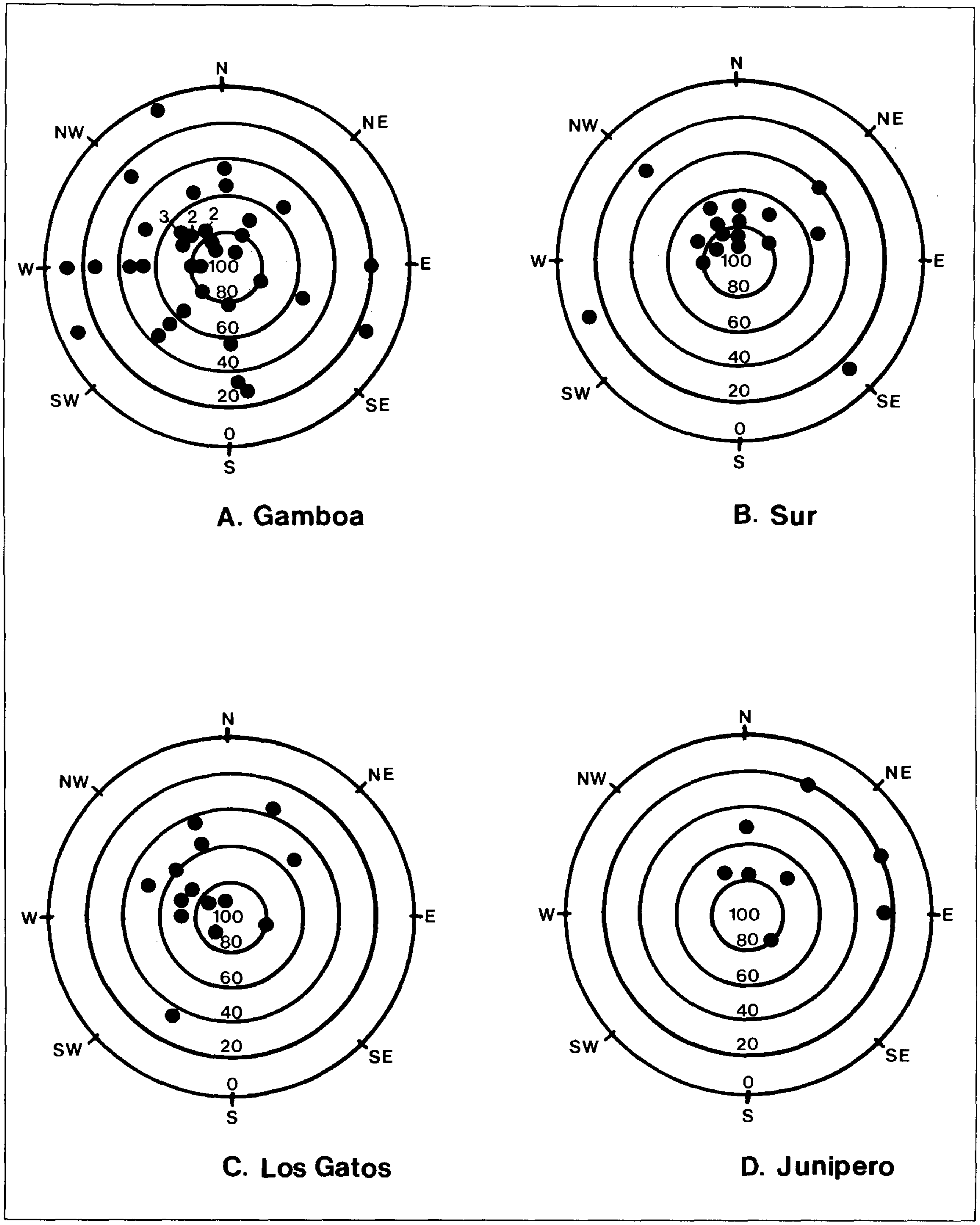

Figure 3—Slope-aspect polar diagrams of the predominant soil series of coast redwood: (*A*) Gamboa, (*B*) Sur, (*C*) Los Gatos and (*D*) Junipero. Each dot represents a plot. Concentric circles represent slope in increments of 20 percent.

years, time enough for weathering and pedogenesis. The pocket does not remain indefinitely, however, because lower slope positions are moist and slope gradients are steep. Soil creep, tree throw and avalanching eventually remove it and the process begins anew. Because slopes of one-half of the 108 plots are steeper than the 30-50 percent slopes investigated by Marron, the period of pocket development probably takes longer, while the period of stability likely is shorter than she observed. Still, the time is long enough for weakly developed subsoils to form.

Ecological Type Descriptions

Because species composition and cover are variable within an ecological type, it is unlikely that every sample will match all the characteristics of one type. Stands, for example, that are transitional between two types will have attributes of both. The key in the *appendix* will correctly assign most stands to an ecological type; nevertheless, the final choice should be based on the additional information contained in the following type descriptions and the accompanying tables. Also, because the key is based on samples taken within the study area, its utility in other parts of the species' range are not known.

The presence of a species in the name of an ecological type does not indicate that the species occurs only in that type, or even that it is present in all its stands. Instead, a species is included in a name if it has a high constancy or cover in one type relative to the others. For example, common vetch (*Vicia angustifolia*) was encountered in only 50 percent of the sample plots of the coast redwood/common manroot-common vetch//Gamboa-Sur ecological type. Nevertheless, it is used in the name because its constancy in this type is high relative to the others (*table 2*). In addition to plant species indicators, the ecological type name includes a significant physical factor, such as landform or soil series, that also characterizes the type.

Table 2—Constancy and cover for major species of the coast redwood ecological types in southern Monterey County, California[1,2]

Cover Type and Species	SESE2/PTAQL-WOFP[3] (27 plots)	SESE2/POMU1-TROV[4] (20 plots)	SESE2[5] (8 plots)	SESE2/MAFA-VIAN[6] (12 plots)	SESE2-ACMA/POCA1[7] (8 plots)	SESE-LIDE2/CAGL1-IRDO[8] (33 plots)
Overstory trees						
Acer macrophyllum	33/2	—	—	—	88/22	18/+
Alnus rhombifolia	22/2	—	—	—	13/+	—
Lithocarpus densiflorus	56/8	70/14	—	8/+	88/5	94/20
Platanus racemosa	4/+	—	25/3	—	13/+	—
Pseudotsuga menziesii	22/+	5/+	—	—	—	—
Sequoia sempervirens	100/76	100/85	100/83	100/98	100/67	100/78
Umbellularia californica	56/3	65/7	50/+	66/+	38/2	52/3
Understory trees						
Acer macrophyllum	11/+	—	—	—	50/+	6/+
Alnus rhombifolia	15/+	—	—	—	—	—
Lithocarpus densiflorus	74/3	80/5	50/2	33/+	100/3	100/26
Pseudotsuga menziesii	7/+	—	—	8/+	—	—
Quercus wislizenii	11/+	5/+	12/+	8/+	50/+	27/+
Salix lasiolepis	7/+	—	—	—	13/+	—
Sequoia sempervirens	100/2	100/3	88/12	100/6	100/2	100/4
Umbellularia californica	78/3	80/+	50/+	66/+	100/2	82/+

(Continued)

Table 2—*Constancy and cover for major species of the coast redwood ecological types in southern Monterey County, California*[1,2]*—continued*

Cover Type and Species	SESE2/PTAQL-WOFI[3] (27 plots)	SESE2/POMU1-TROV[4] (20 plots)	SESE2[5] (8 plots)	SESE2/MAFA-VIAN[6] (12 plots)	SESE2-ACMA/POCA1[7] (8 plots)	SESE-LIDE2/CAGL1-IRDO[8] (33 plots)
Shrubs						
Corylus cornuta	19/+	20/+	—	—	13/+	—
Lonicera hispidula	67/+	60/+	38/+	50/+	75/+	18/+
Rhamnus californica	26/+	15/+	12/+	33/+	50/+	3/+
Ribes menziesii	15/+	10/+	—	16/+	25/+	3/+
Ribes sanguineum	—	20/+	—	33/+	13/+	—
Rosa gymnocarpa	22/+	30/+	—	8/+	25/+	15/+
Rubus parviflorus	59/+	40/+	12/+	8/+	50/+	3/+
Rubus vitifolius	85/2	55/+	62/+	42/+	63/+	9/+
Toxicodendron diversilobum	63/2	45/2	50/+	92/+	100/4	61/+
Vaccinium ovatum	30/2	55/3	—	16/+	—	—
Herbs and grasses						
Adiantum capillus-veneris	—	—	—	—	25/+	3/+
Adiantum pedatum	22/+	—	—	—	25/+	—
Aquilegia formosa	11/+	—	—	—	13/+	—
Aralia californica	33/+	—	—	—	19/+	4/2
Boykinia elata	41/+	—	—	—	50/+	—
Calochortus albus	4/+	—	—	—	63/+	12/+
Carex bolanderi	19/+	—	—	—	—	—
Carex globosa	37/+	15/+	—	—	38/+	67/+
Clintonia andrewsiana	—	45/+	—	8/+	—	—
Cynoglossum grande	19/+	5/+	—	—	13/+	6/+
Dentaria californica	37/+	60/+	—	66/+	88/+	12/+
Disporum hookeri	63/+	70/+	—	33/+	50/+	30/+
Dryopteris arguta	63/+	100/2	50/+	100/1	88/+	79/+
Equisetum telmateia	19/+	—	—	—	13/+	—
Festuca rubra	7/+	—	—	—	13/+	—
Fragaria vesca	—	—	—	—	38/+	—
Galium aparine	—	—	—	—	38/+	—
Galium californicum	15/+	10/+	—	42/+	85/+	15/+
Hieracium albiflorum	—	—	—	16/+	25/+	—
Hierclöe occidentalis	37/+	45/+	—	16/+	38/+	24/+
Iris douglasiana	33/+	30/+	—	33/+	75/+	67/+

(Continued)

Table 2—*Constancy and cover for major species of the coast redwood ecological types in southern Monterey County, California*[1,2] *—continued*

Cover Type and Species	SESE2/PTAQL-WOFI[3] (27 plots)	SESE2/POMU1-TROV[4] (20 plots)	SESE2[5] (8 plots)	SESE2/MAFA-VIAN[6] (12 plots)	SESE2-ACMA/POCA1[7] (8 plots)	SESE-LIDE2/CAGL1-IRDO[8] (33 plots)
Herbs and grasses, continued						
Lilium pardalinum	15/+	—	—	—	—	—
Madia madioides	7/+	—	—	—	63/+	—
Marah fabaceus	4/+	—	8/+	58/+	—	12/+
Mimulus cardinalis	15/+	—	—	—	—	—
Osmorhiza chilensis	19/+	5/+	—	8/+	63/+	3/+
Oxalis oregana	96/43	90/36	38/2	—	38/18	12/+
Petasites frigidus	15/+	—	—	—	—	—
Polygala californica	11/+	15/+	12/+	—	13/+	3/+
Polypodium californicum	74/+	30/+	—	—	100/4	18/+
Polystichum dudleyi	67/+	10/+	—	—	87/+	33/+
Polystichum munitum	81/4	90/19	75/4	92/18	38/+	73/+
Pteridium aquilinum	52/+	35/+	38/+	16/+	13/+	18/+
Satereja chamissonis	4/+	5/+	—	—	—	9/+
Sanicula crassicaulis	7/+	5/+	—	—	38/+	—
Smilacina racemosa	89/+	90/+	50/+	92/+	88/+	61/+
Stachys bullata	22/+	10/+	—	25/+	75/+	12/+
Stachys mexicana	19/+	5/+	—	16/+	25/+	12/+
Trientalis borealis	67/+	65/+	50/+	16/+	100/6	52/+
Trillium ovatum	52/+	80/+	25/+	42/+	38/+	6/+
Vicia angustifolia	7/+	20/+	12/+	50/+	—	3/+
Viola sempervirens	7/+	5/+	12/+	—	—	—
Woodwardia fimbriata	48/+	—	12/+	—	25/+	12/+

[1]The following species were found in the plots but occurred less than three times: trees—*Abies bracteata, Quercus agrifolia, Quercus chrysolepis,* and *Quercus wislizenii;* shrubs—*Mahonia nervosa, Gaultheria shallon, Myrica californica, Osmaronia cerasiformis,* and *Symphorocarpus mollis;* herbs and grasses—*Disporum smithii, Lithophragma heterophyllum, Melica imperfecta, Pedicularis dudleyi, Scrophularia californica,* and *Vancouveria planipetala.*

[2]Constancy (percent of plots in which a species occurred) is given first followed by cover (average percent cover of a species in an ecological type). The "+" symbol indicates that the average cover is less than 1 percent. The "—" indicates the species did not occur in the type.

[3] Coast Redwood/Western Bracken-Chain Fem//Streamsides Type.

[4] Coast Redwood/Swordfern-Western Wake Robin//Gamboa-Sur Type.

[5] Coast Redwood//Gamboa-Sur Type.

[6] Coast Redwood/Common Manroot-Common Vetch//Gamboa-Sur Type.

[7] Coast Redwood-Bigleaf Maple/California Polypody//Gamboa Type.

[8] Coast Redwood-Tanoak/Round Fruited Carex-Douglas's Iris Gamboa Type.

Figure 4——(*A*) Coast redwood/western bracken-chain fern// streamsides ecological type. The signpost is marked in 1-foot segments.

Coast Redwood/Western Bracken-Chain Fern//Streamsides (Sequoia sempervirens/Pteridium aquilinum-Woodwardia fimbriata//Streamsides) SESE2/PTAQL-WOFI//Streamsides

Environmental Setting—The low elevation coast redwood/western bracken-chain fern//streamsides ecological type (*figs. 4, 5A, 5B*) occupies the narrow floodplains and widely scattered alluvial terraces of Willow Creek, Big Creek, Devil's Canyon, Hare Canyon, and the Little Sur and Big Sur Rivers (*fig. 1A*). Typically, it grows within 50 ft of perennial streams, usually as a discontinuous ribbon of vegetation less than 6 ft wide along the water's edge. Upslope of the stream, this type changes to the coast redwood/swordfern-western wake robin type. Rarely, small stands, some up to 200 ft from the stream, occupy the steep (50-90 percent)(*fig. 5A*) slopes of old landslides or their scars. These isolated stands probably grow where permanent moisture is near the surface since hillslope seeps and springs are widely distributed in redwood forests of the study area.

Soils—Soils supporting this ecological type are highly variable, but all develop from alluvium or—less frequently—from a mixture of alluvium and colluvium. Stands within 30 ft of the stream are subject to seasonal flooding, or flooding in years of high precipitation. In this zone, five soil families are represented: Camas, Wilshire, Sequim, Fallon and Springdale (*table 3*). As a group, they are deep, gravelly and cobbley, and somewhat excessively drained to well-drained.

At intermediate distances (40-60 ft) from the stream, soils of the Gamboa and Sur Series have developed on old alluvial terraces subject to infrequent flooding, while stands situated on toeslopes 100-200 ft from the stream frequently grow on the Los Gatos Series.

Vegetative Characteristics— Below the dominant redwood overstory of this type is an open subcanopy of tanoak (*Lithocarpus densiflorus*) and California bay (*Umbellularia californica*) with occasional individuals of big leaf maple (*Acer macrophyllum*), western sycamore (*Platanus racemosa*), Douglas-fir (*Pseudotsuga menziesii*) and white alder (*Alnus rhombifolia*) (table 2).

The understory tree and shrub layers, although relatively diverse in species, have a low mean cover (*table 4*). Of the shrubs, California blackberry (*Rubus vitifolius*) attains its highest constancy and cover in this ecological type (*table 2*). The herbaceous layer is well-developed, reflecting the favorable moisture conditions of this streamside habitat. Redwood sorrel (*Oxalis oregana*) dominates the herb layer with a mean cover of 43 percent. High fidelity (but low constancy) species like Bolander's carex (*Carex bolanderi*), tiger lily (*Lilium pardalinum*), elk clover (*Aralia californica*) and western coltsfoot (*Petasites frigidus*) grow exclusively in the wet, rocky zone at the stream's edge. Three ferns characterize the herb layer: chain fern (*Woodwardia fimbriata*), Dudley's shield fern (*Polystichum dudleyi*) and western bracken (*Pteridium aquilinum*). Of these, the chain fern is the best

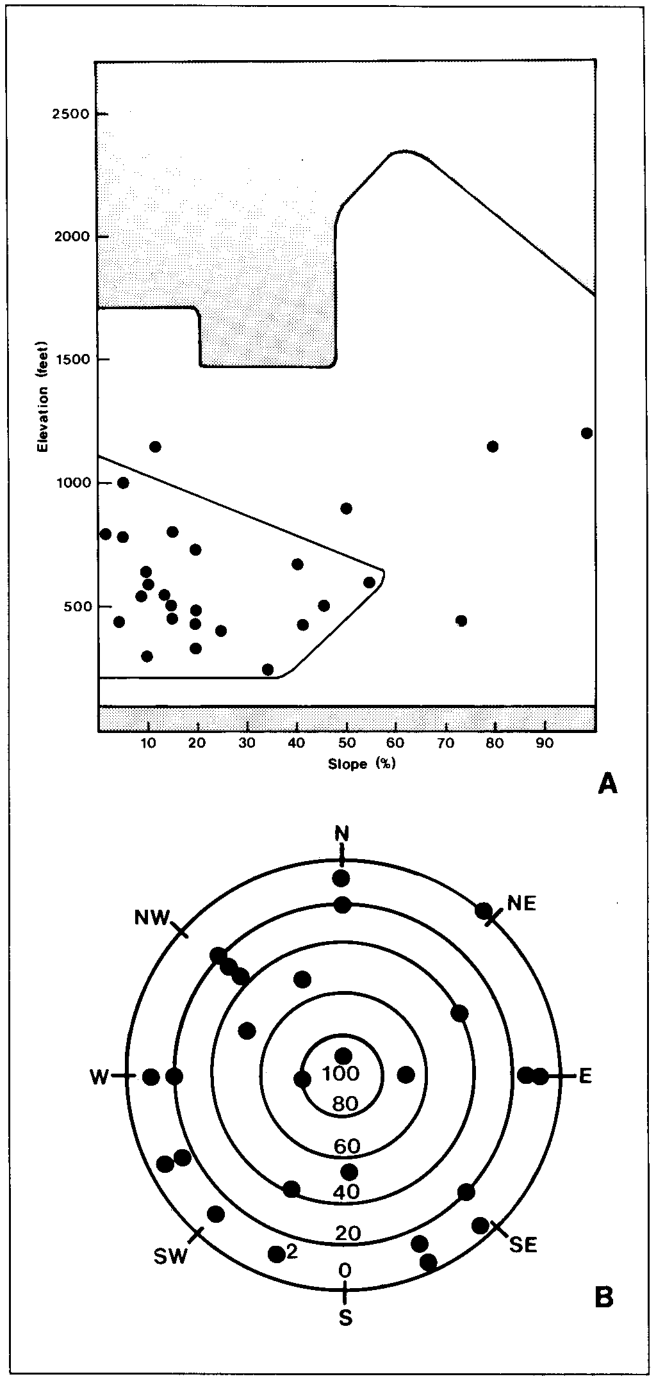

Figure 5—(*A*) Mosaic diagram of the coast redwood/western bracken-chain fern//stream sides ecological type. Solid circles indicate the location of individual plots, while shaded areas are outside the sampling environment. The type occurs most frequently in the environment encompassed by the solid line. (*B*) Slope-aspect polar diagram of the coast redwood/western bracken-chain fern//streamsides ecological type. Each dot represents a plot. Concentric circles represent slope in increments of 20 percent.

Table 3—*Frequency of soils by series, family or great group for the ecological types*

Common soil name and taxonomic class	SESE2/PTAQL-WOFI[1] (25 plots)	SESE2/POMU1-TROV[2] (20 plots)	SESE2[3] (8 plots)	SESE2/MAFA-VIAN[4] (12 plots)	SESE2-ACMA/POCA1[5] (7 plots)	SESE-LIDE2/CAGL1-IRDO[6] (32 plots)	AWC[7]
Atter Family (Sandy-skeletal, mixed, mesic Typic Xerorthents)	—	1	—	—	—	—	2.1
Camas Family (Sandy-skeletal, mixed, mesic Fluventic Haploxerolls)	2	—	—	—	—	—	1.5, 2.5
Central Point Family (Coarse-loamy, mixed, mesic Pachic Haploxerolls)	—	—	—	—	—	1	2.4
Fallon Family (Coarse-loamy, mixed, nonacid, mesic Aquic Xerofluvents)	1	—	—	—	—	—	1.1
Gamboa (Loamy-skeletal, mixed, mesic Pachic Haploxerolls)	2	10	2	7	2	12	2.1-4.7
Gazos (Fine-loamy, mixed, thermic Pachic Haploxerolls)	1	—	—	—	—	1	5.2
Junipero (Coarse-loamy, mixed, mesic Pachic Ultic Haploxerolls)	—	1	—	1	—	3	4.3-5.7
Knutsen Family (Coarse-loamy, mixed, mesic Typic Haploxerolls)	—	—	1	—	—	—	3.5
Los Gatos (Fine-loamy, mixed, mesic Typic Argixerolls)	4	1	—	—	—	4	2.6-5.0
McMullin (Loamy, mixed, mesic, Lithic Ultic Haploxerolls)	—	—	—	1	—	—	5.0
Newberg Family (Coarse-loamy, mixed, mesic Fluventic Haploxerolls)	—	—	1	—	—	—	4.0
Plaskett (Loamy-skeletal, mixed, mesic Lithic Haploxerolls)	2	1	-	-	1	3	0.5-1.7
Sequim Family (Sandy-skeletal, mixed, mesic Entic Haploxerolls)	1	—	—	—	—	—	1.5
Sheridan Family (Coarse-loamy, mixed, thermic Pachic Haploxerolls)	—	—	—	—	—	1	5.6
Springdale Family (Sandy-skeletal, mixed, mesic Typic Xerorthents)	1	—	—	—	1	1	0.9-1.3

(Continued)

Table 3—*Frequency of soils by series, family or great group for the ecological types—continued*

Common soil name and taxonomic class	SESE2/PTAQL-WOFI[1] (25 plots)	SESE2/POMU1-TROV[2] (20 plots)	SESE2[3] (8 plots)	SESE2/MAFA-VIAN[4] (12 plots)	SESE2-ACMA/POCA1[5] (7 plots)	SESE-LIDE2/CAGL1-IRDO[6] (32 plots)	AWC[7]
Sur (Loamy-skeletal, mixed, mesic Entic Haploxerolls)	4	5	2	3	1	3	1.6-3.5
Sur Family (Loamy-skeletal, mixed, mesic Entic Haploxerolls)	—	1	1	—	1	1	1.1, 1.9 4.1
Waterman Family (Sandy-skeletal, mixed, mesic Typic Xerofluvent)	—	—	—	—	1	—	0.1
Wilshire Family (Sandy-skeletal, mixed, mesic Typic Xerofluvents)	2	—	1	—	—	—	1.1, 1.3 2.1
Aquic Xerofluvent	1	—	—	—	—	—	0.5
Fluvent	2	—	—	—	—	1	0.1, 1.4
Xerofluvent	2	—	—	—	—	1	0.5, 2.7

[1]Coast Redwood/Western Bracken-Chain Fern//Streamsides Type.
[2]Coast Redwood/Swordfern-Western Wake Robin//Gamboa-Sur Type.
[3]Coast Redwood//Gamboa-Sur Type.
[4]Coast Redwood/Common Manroot-Common Vetch//Gamboa-Sur Type.
[5]Coast Redwood-Bigleaf Maple/California Polypody//Gamboa Type.
[6]Coast Redwood-Tanoak/Round Fruited Carex-Douglas's Iris//Gamboa Type.
[7]Range of available water capacity in inches per 40 in of soil.

known indicator of permanent moisture, and grows exclusively in the vicinity of streams, springs, seeps, and near-surface groundwater (Becking 1982, Talley 1974, Waring and Major 1964).

Comments— Stands sampled by Becking (1971) on the Big Sur River and classified as "alluvial" fit well into this ecological type, as does the redwood-streamside forest described for the Landels-Hill Big Creek Reserve (Bickford and Rich 1984) and Gamboa Point Properties (Engles and Genetti 1984).

The relatively large plot size used in this study masks much of the small-scale complexity of the understory vegetation in this riparian habitat. More so than other redwood ecological types, this and the riparian coast redwood-big leaf maple/California polypody//Gamboa ecological type described below, are strongly influenced by complex physical factors that vary spatially and temporally such as material deposition, fluctuating water levels, and—less frequently—fire, floods and debris torrents. Such environmental variability can produce a highly heterogeneous assemblage of understory species. In the western Cascade Mountains of Oregon, for example, Campbell and Franklin (1979) described 16 distinct species groups (communities) growing in fragmented microhabitats (such as gravel bars, rock faces, and wet logs) along the margins of streams similar in size to those in the study area.

Coast Redwood/Swordfern-Western Wake Robin//Gamboa-Sur (*Sequoia sempervlrens/Polystlchum munitum-Trillium ovatum//*Gamboa-Sur) SESE2/POMU1-TROY//Gamboa-Sur

Environmental Setting—On mesic, moderate to very steep (50-100 percent) lower slopes between 100 and 850 ft elevation, the coast redwood/swordfern-western wake robin//Gamboa-Sur ecological type dominates (*figs. 6, 7A*). Most stands in this type (75 percent) face north to north-northwest and are located at distances of 50-175 ft from the nearest ephemeral or perennial stream, although stands also may be encountered on gentler (<40 percent) slopes of variable aspect (*fig. 7B*).

Soils—Soils of one-half of the stands sampled in this type were in the Gamboa Series and another one-third in the Sur Series (*table 3*). The remainder were represented by the Plaskett, Junipero, Los Gatos Series and Atter family (*table 3*). Although soils of the five stands on gentle to moderate slopes (25-40 percent) formed on alluvium or a mixture of alluvium and colluvium, mixed colluvium on steep debris slides was by far the most important substratum of the predominant series.

Figure 6—Coast redwood/swordfern-western wake robin//Gamboa-Sur ecological type. The signpost is marked in 1-foot segments.

Vegetative Characteristics—The subcanopy tree layer of this type is comparatively well developed (*table 4*). Indeed, California bay (*Umbellularia californica*) attains its highest cover here (*table 2*). In the understory tree and shrub layer, California huckleberry (*Vaccinium ovatum*) has a high relative constancy (55 percent) but low cover. California huckleberry in northern California (Lenihan 1983; Waring and Major 1964) and Santa Cruz County (Greenlee 1983) thrives in a wide variety of forest vegetation types, but prefers the more xeric types. In southern Monterey County, in contrast, it is restricted to low-elevation mesic and moist environments (Keeler-Wolf and Keeler-Wolf 1977).

The herbaceous layer of this type is well developed (*table 4*). Swordfern (*Polystichum munitum*) and redwood sorrel (*Oxalis oregana*) dominate (mean cover 55 percent). Western wake robin (*Trillium ovatum*) attains its highest constancy (80 percent) in this ecological type. Other characteristic species are California wood fern (*Dryopteris arguta*) and fairy bells (*Disporum hookeri*). Red clintonia (*Clintonia andrewsiana*) is almost entirely restricted to this ecological type.

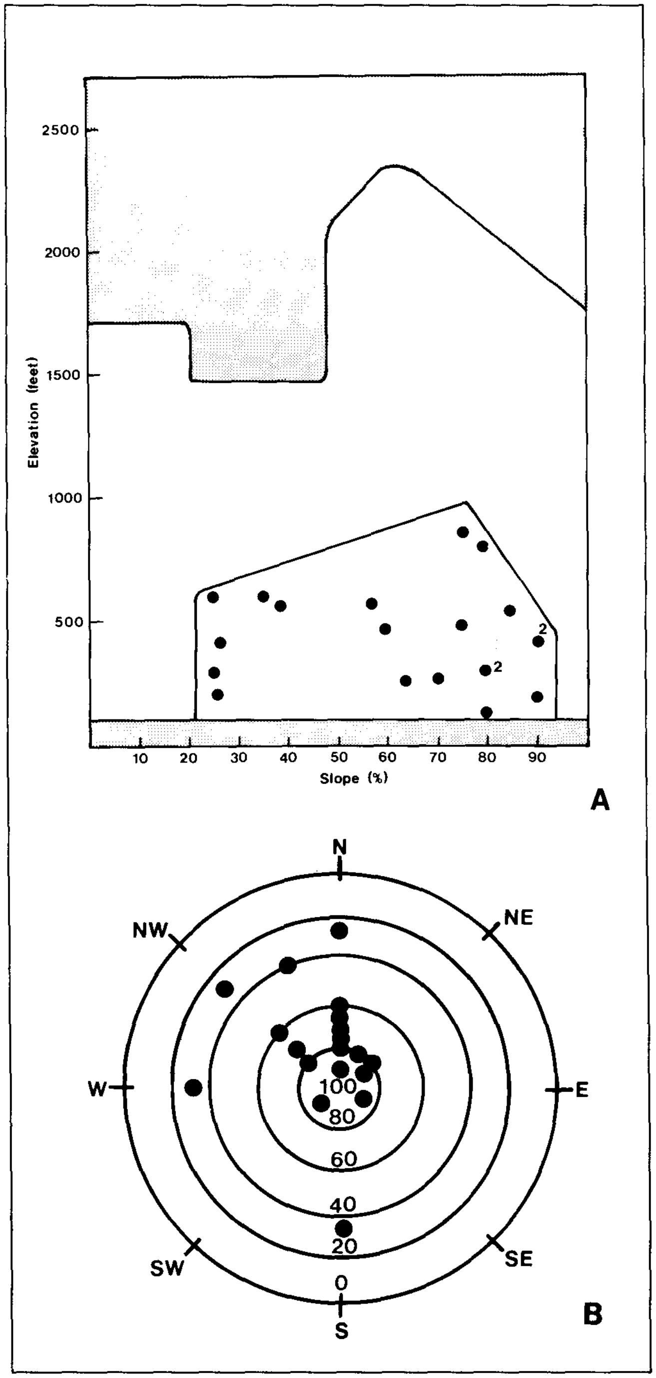

Figure 7—(*A*) Mosaic diagram of the coast redwood/swordfern-western wake robin//Gamboa-Sur ecological type. Solid circles indicate the location of individual plots, while shaded areas are outside the sampling environment. The type occurs most frequently in the environment encompassed by the solid line. (*B*) Slope-aspect polar diagram of the coast redwood/swordfern-western wake robin//Gamboa-Sur ecological type. Each dot represents a plot. Concentric circles represent slope in increments of 20 percent.

Table 4—*Mean stand structure, topographic and soil characteristics of the ecological types of southern Monterey County, California*

Characteristic	SESE2/PTAQL-WOFI[1]	SESE2/POMU1-TROV[2]	SESE2[3]	SESE2/MAFA-VIAN[4]	SESE2-ACMA/POCA1[5]	SESE-LIDE2/CAGL1-IRDO[6]
Total basal area (ft^2/acre)	509	639	700	552	341	560
Redwood tree height (ft)	153	134	140	62	163	190
Overstory tree cover (percent)	93	107	99	98	98	107
Shrub cover (percent)	7	7	1	4	10	0.8
Herb and grass cover (percent)	55	63	7	23	39	6
Understory tree cover (percent)	7	8	14	7	5	13
Understory tree density (no./acre)	650	1135	690	1225	565	1125
Mean species richness	20	16	9	13	26	11
Linear distance to stream (ft)	40	181	130	333	26	148
Slope position	streamside	lower	lower	upper	streamside	middle, lower
A horizon thickness (in)	5.3	12.6	8.8	13.0	7.0	11.0
A horizon coarse fragment (percent)	27	35	20	26	35	25
Subsoil coarse fragment (percent)	44	43	37	37	45	38
Available water capacity (in/40 in)	2.9	3.1	2.9	3.9	1.5	3.5

[1]Coast Redwood/Western Bracken-Chain Fern//Streamsides Type.
[2]Coast Redwood/Swordfern-Western Wake Robin//Gamboa-Sur Type.
[3]Coast Redwood//Gamboa-Sur Type.
[4]Coast Redwood/Common Manroot-Common Vetch//Gamboa-Sur Type.
[5]Coast Redwood-Bigleaf Maple/California Polypody//Gamboa Type.
[6]Coast Redwood-Tanoak/Round Fruited Carex-Douglas's Iris//Gamboa Type.

Coast Redwood//Gamboa-Sur
(*Sequoia sempervirens*//Gamboa-Sur)
SESE2//Gamboa-Sur

Environmental Setting—The coast redwood//Gamboa-Sur ecological type (*fig. 8*) occupies the low elevation, gently sloping (5-35 percent) (*figs. 9A, 9B*) alluvial-colluvial fans, old stream terraces, and lower-slope benches of larger drainages such as Mill Creek, Prewitt Creek, Big Creek, and the North Fork of the Little Sur River (*fig. 1A*). This type has a highly fragmented distribution in the study area. Individual stands seldom exceed 0.25 acre in area. High basal areas (>700 ft^2) are common, as are trees with a large average d.b.h. (35-60 in).

Soils—Soils of this type are highly variable (*table 3*). In addition to the Gamboa and Sur Series, soils of the Knutsen, Newberg, and Wilshire families also are represented.

Vegetative Characteristics—The high basal area, dense canopy cover, and attendant deep litter layer (average 3.25 in) on the forest floor in this type produce sparse understory herb and shrub layers (*table 4*) lacking in distinctive species. In fact, the only distinguishing feature of the understory is the relatively high density and coverage of redwood sprouts (*tables 2, 4*).

Comments—Slope position and landform likely contribute to the development and maintenance of this type. Situated on the lower portion of the slope, these stands receive both nutrients and runoff from the rapidly draining, steep upper slopes. In fact, a continuous source of underground water may be a prerequisite to the formation of this type. Furthermore, the relatively stable landforms where this type grows appear less prone to landslides that characterize the upper slopes, or—in the nearstream zone—to infrequent debris torrents and channel scouring (Jackson 1977).

Figure 8—Coast redwood//Gamboa-Sur ecological type. The signpost is marked in 1-foot segments.

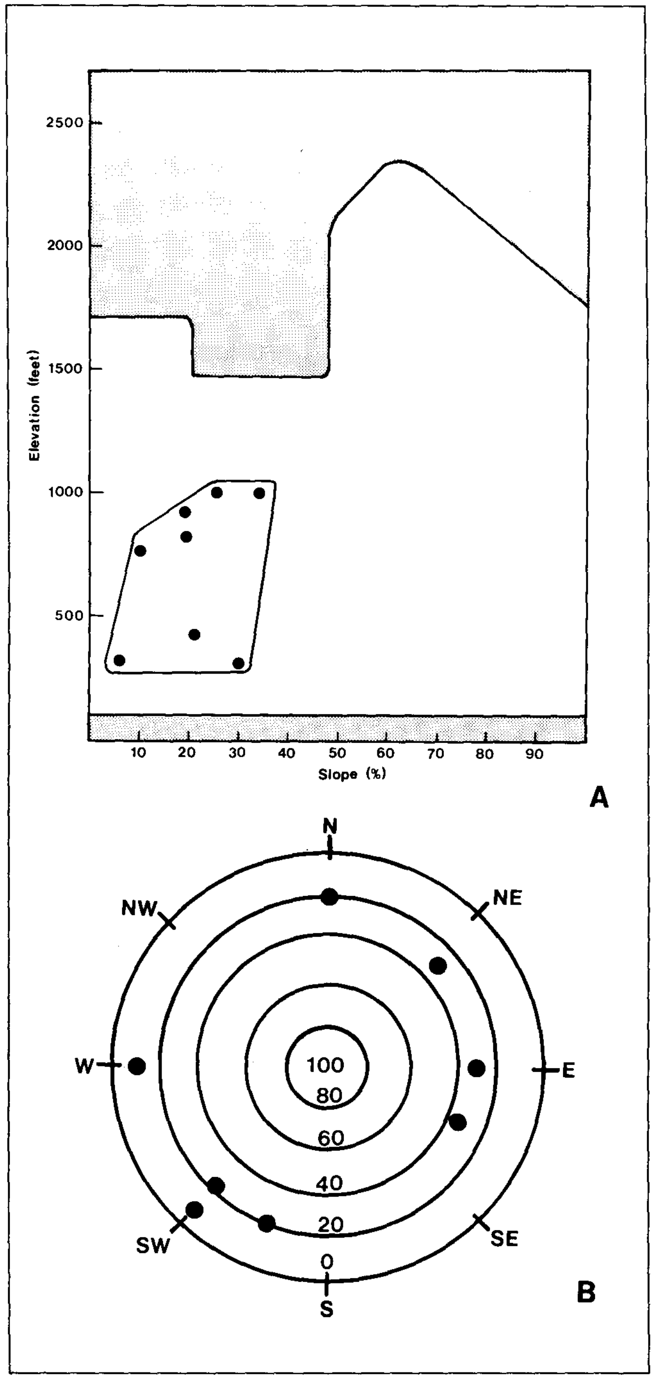

Figure 9— (*A*) Mosaic diagram of the coast redwood//Gamboa-Sur ecological type. Solid circles indicate the location of individual plots, while shaded areas are outside the sampling environment. The type occurs most frequently in the environment encompassed by the solid line. (*B*) Slope-aspect polar diagram of the coast redwood//Gamboa-Sur ecological type. Each dot represents a plot. Concentric circles represent slope in increments of 20 percent.

Coast Redwood/Common Manroot-Common Vetch//Gamboa-Sur (*Sequoia sempervirens/Marah fabaceus-Vicia angustifolia*//Gamboa-Sur) SESE2/MAFA-VIAN//Gamboa-Sur

Environmental Setting—The most conspicuous, widespread, but patchily distributed pure redwood forest is the coast redwood/common manroot-common vetch//Gamboa-Sur ecological type (*fig. 10*). It occupies the near-ocean (<0.5 mi), steep, upper slopes of the coastal entrances to large and small drainages. Nearly all stands face northeast through northwest; north-northwest is the most common exposure (*figs. 11A, 11B*).

Soils—Gamboa and Sur soils dominate this type, representing 58 percent and 25 percent of the stands, respectively *(table 3*). Soils of the Junipero and McMullin Series were also encountered.

Vegetative Characteristics—Because this ecological type is exposed to salt-spray bearing onshore winds, trees are stunted (mean height 62 ft) (Becking 1971, Shreve 1927), although in sheltered coves they sometimes reach heights of 100 ft. These forests are exceptionally dense (average of 615 stems/acre) (*fig. 10*). D.b.h. of most stems ranges between 8 and 20 in; individuals larger than 35 in d.b.h. are rare. Understory layers are poorly developed; only redwood seedlings and sprouts, and swordfern (*Polystichum munitum*) provide any measurable cover (*table 2*). The fact that a considerable number of understory species persist in this dense forest is largely due to its high slope position and low tree canopy height, factors which allow much light penetration to the forest floor.

Comments—Becking (1971) calculated site indices in this type that ranged from 65 to 100 (at 100 years), which is far different from the potential site index of 215 (at 100 years) for Gamboa soils (Cook 1978). This disparity underscores the dramatic effect of salt spray on forest height. At an extreme, redwoods on the bluffs above Pfeiffer Beach form a spreading mat equal in height to adjacent coastal sage scrub (3 ft). Depending on the orientation of each drainage, the effects of aerosol spray on tree height can be observed well inland. In Prewitt Creek, for example, tree height increases with the distance of the stand from the coast (Y= 52 ft + 54 ft X mi inland from the coast) ($r=0.87$, $p<.01$). A similar relationship was noted for Big Creek ($r=0.81$, $p<0.01$) and, to a lesser extent, in Mill Creek ($r=0.66$, $p<0.05$). However, canyon entrances that turn abruptly just inland, thereby greatly diminishing salt spray penetration, show no height trends as—for example—in Hare Canyon ($r=0.26$, $p<0.10$) or Devil's Canyon ($r=0.27$. $n<0.10$).

Figure 10—Coast redwood/common manroot-common vetch//Gamboa-Sur ecological type. The signpost is marked in 1-foot segments.

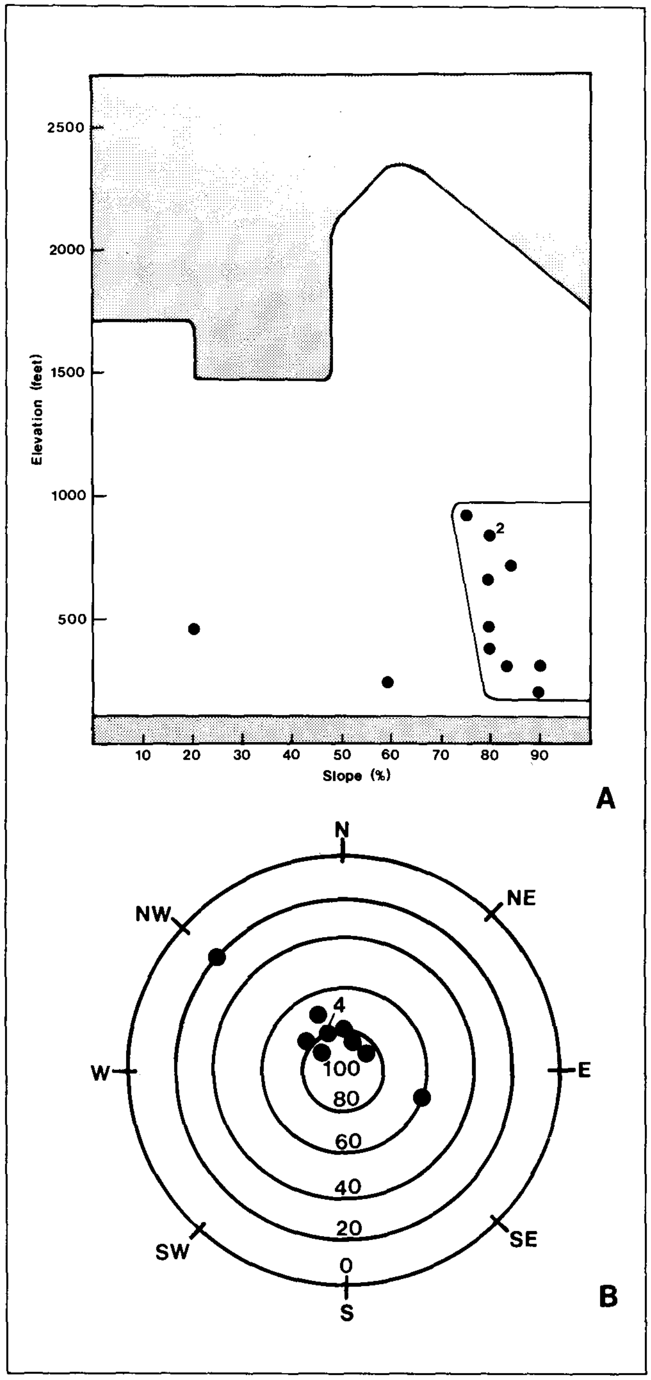

Figure 11— (*A*) Mosaic diagram of the coast redwood/common manroot-common vetch//Gamboa-Sur ecological type. Solid circles indicate the location of individual plots, while shaded areas are outside the sampling environment. The type occurs most frequently in the environment encompassed by the solid line. (*B*) Slope-aspect diagram of the coast redwood/common manroot-common vetch// Gamboa-Sur ecological type. Each dot represents a plot. Concentric circles represent slope in increments of 20 percent.

Coast Redwood-Big Leaf Maple/California Polypody//Gamboa (*Sequoia sempervirens-Acer macrophyllum/ Polypodium californicum*//Gamboa) SESE2-ACMA/POCA1 //Gamboa

Environmental Setting—Gently sloping to level nearstream alluvial terraces at higher elevations support the coast redwood-big leaf maple/California polypody//Gamboa ecological type (*figs. 12, 13A, 13B*). This type is rare, being best developed in large openings along particularly rocky and boulder-filled streams like Hare Canyon, Devil's Canyon and Big Creek (*fig. 1A*).

Soils—Two stands of this type grow in Gamboa soils and one each on the Sur and Plaskett Series. The remaining five stands grow on soils of the Springdale, Waterman, and Sur families (*table 3*), which often are encountered in the nearstream (<30 ft) zone.

Vegetative Characteristics—This ecological type is distinguished from the others by its high mean species richness (*table 4*), which—to a large extent—reflects the considerable variety of microhabitats afforded by these rocky alluvial fans and terraces. Species preferring a combination of moderate shade, and wet or moist rocky substrates like big leaf maple (*Acer macrophyllum*), elk clover (*Aralia californica*), brook foam (*Boykinia elata*), California polypody (*Polypodium californicum*), Dudley's shield fern (*Polystichum dudleyi*), and starflower (*Trientalis borealis*) flourish on these sites. At the same time, herbaceous species closely aligned with the drier upland mixed hardwood forest like California hedge-nettle (*Stachys bullata*), wood cicely (*Osmorhiza chilensis*), woodland madia (*Madia madioides*), California bedstraw (*Galium californicum*), and white globe lily (*Calochortus albus*) grow in xeric microsites among the rocks where permanent moisture is probably available only to deeper rooting species. Significantly, redwood sorrel (*Oxalis oregana*) is absent in most stands (62 percent) of this type. This moisture-sensitive herb dominates lower moist and mesic slopes in the summer fog belt below 1000 ft; thus, its absence or overall reduced cover in this type underscores the generally drier conditions of this riparian habitat.

Comments—This ecological type occurs where streams are large enough to create openings in the forest overstory. In general, a floristically and physiognomically distinct redwood riparian habitat is absent at elevations above 1800 ft. Here streams become increasingly steep, deeply dissected, and heavily shaded, with few terraces or floodplains. In this setting, big leaf maple (*Acer macrophyllum*), elk clover (*Aralia californica*), or chain fern (*Woodwardia fimbriata*) appear sporadically, but mostly as scattered individuals in small openings.

Figure 12—Coast redwood-big leaf maple/California polypody//Gamboa ecological type. The signpost is marked in 1-foot segments.

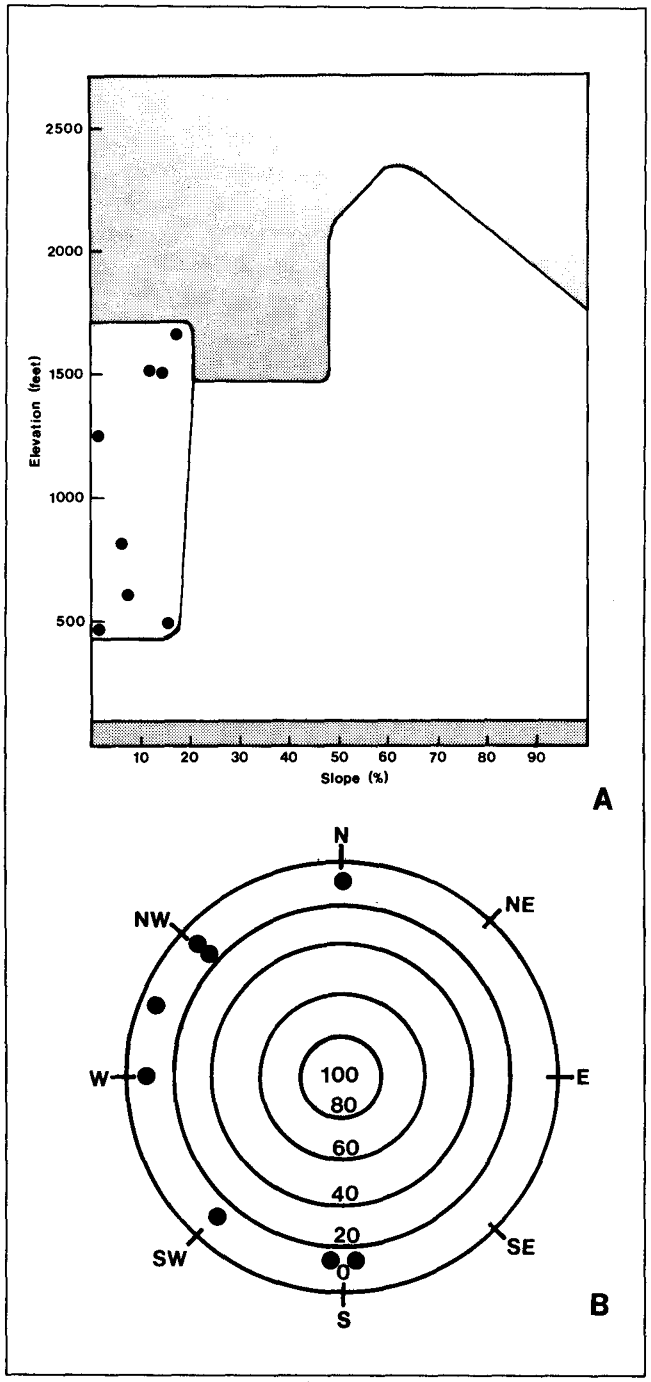

Figure 13— (*A*) Mosaic diagram of the coast redwood-big leaf maple/California polypody//Gamboa ecological type. Solid circles indicate the location of individual plots, while shaded areas are outside the sampling environment. The type occurs most frequently in the environment encompassed by the solid line. (*B*) Slope-aspect diagram of the coast redwood-big leaf maple/California polypody//Gamboa ecological type. Each dot represents a plot. Concentric circles represent slope in increments of 20 percent.

Coast Redwood-Tanoak/Round Fruited Carex-Douglas's Iris//Gamboa (*Sequoia sempervirens-Lithocarpus densiflorus/ Carex globosa-Iris douglasiana*//Gamboa) SESE2-LIDE2/CAGL1-IRDO//Gamboa

Environmental Setting—The most widespread redwood forest in the study area is the coast redwood-tanoak/round-fruited carex-Douglas's iris//Gamboa ecological type (*fig. 14*). It occupies middle and lower convex slopes of the main canyons and smaller draws above 800 ft elevation (*fig. 15A*). On steep (>60 percent) colluvial slopes, stands are abundant on north and northwest facing slopes, while those on slopes less than 60 percent are common on west through south-southeast exposures (*fig. 15B*).

Soils—The Gamboa Series dominates this type (40 percent of the stands). Other series in this type include Sur, Los Gatos, Plaskett, Junipero and a plot each in the Camas, Sheridan, Sur and Springdale families (*table 3*).

Vegetative Characteristics—Tanoak (*Lithocarpus densiflorus*) is the most important tree species after redwood and is especially abundant in the understory (*table 2*). Although tanoak occupies a wide range of redwood types, it attains its highest cover in this relatively xeric habitat. Understory cover is sparse. Round-fruited carex (*Carex globosa*) and Douglas's iris (*Iris douglasiana*) characterize the herbaceous layer.

Comments—Associations comparable to this type in the northern part of the species range are the *Sequoia/Arbutus* association in Humboldt County, California (Lenihan 1983), the depauperate upland *Sequoia sempervirens* forest in Curry County, Oregon (Dyrness and others 1972), and the *Sequoia sempervirens-Pseudotsuga menziesii/Arbutus menziesii* associations (Matthews 1986). All three types occur above the fog layer (1000 ft) on relatively dry sites and have significant cover of hardwood forest tree species in the overstory or understory or both. Despite these similarities, however, the herb and shrub species composition of the SESE2-LIDE2/CAGL1-IRDO//Gamboa type differs completely from its northern counterparts.

Figure 14—Coast redwood-tanoak/round-fruited carex-Douglas's iris//Gamboa ecological type. The signpost is marked in 1-foot segments.

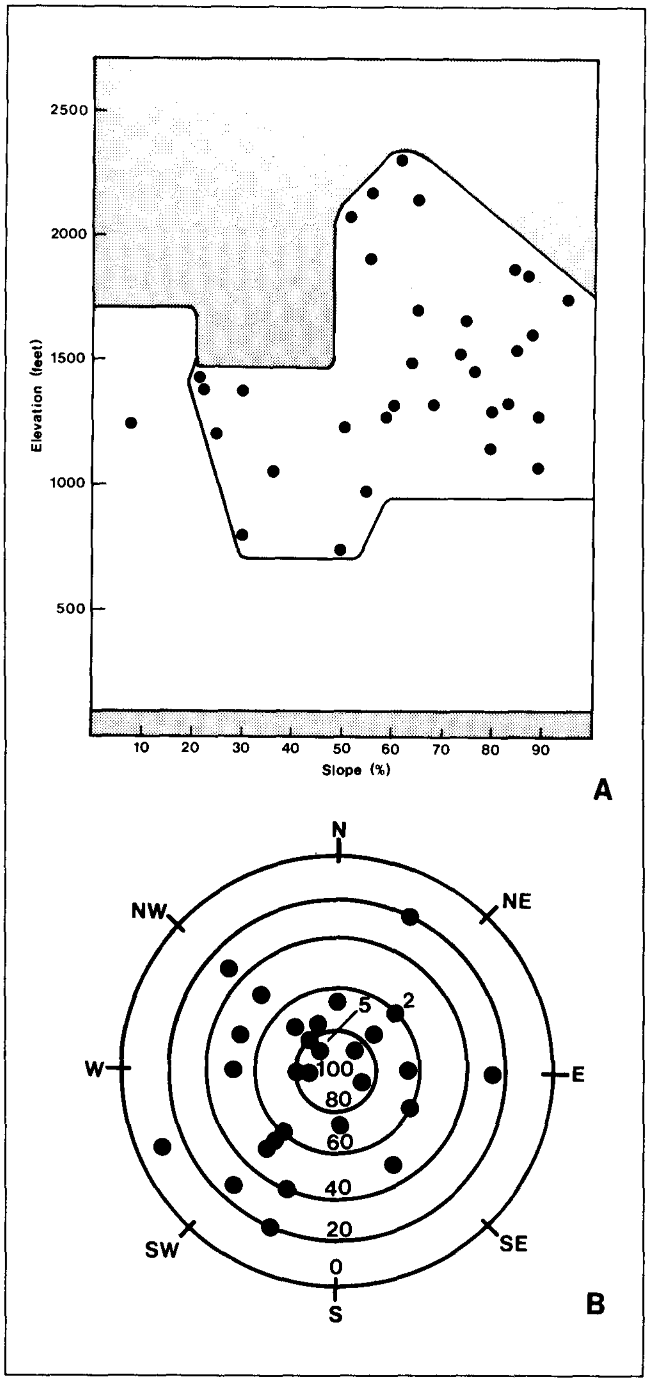

Figure 15—(*A*) Mosaic diagram of the coast redwood-tanoak/round fruited carex-Douglas's iris//Gamboa ecological type. Solid circles indicate the location of individual plots, while shaded areas are outside the sampling environment. The type occurs most frequently in the environment encompassed by the solid line. (*B*) Slope-aspect diagram of the coast redwood-tanoak/round fruited carex-Douglas's iris//Gamboa ecological type. Each dot represents a plot. Concentric circles represent slope in increments of 20 percent.

APPENDIX—KEY TO ECOLOGICAL TYPES

The four steps in using this key are as follows:

- Select an area of about 0.1 acre with uniform slope and aspect. Coast redwood overstory cover should be at least 50 percent. The plot should be representative of a larger area.
- Be able to recognize the diagnostic species used in the key and estimate their foliar cover. Remember, 1 percent foliar cover is equivalent to 44 ft^2.
- Work carefully through the ecological type key to a preliminary identification.
- Read the description of the ecological type to verify your identification. Species codes in the type descriptions are taken from Reed and others (1963).

1 Redwood sorrel (*Oxalis oregana*) has greater than 5 percent cover in the herbaceous understory 2

2 Swordfern (*Polystichum munitum*) has at least 10 percent cover in the herbaceous layer. Chain fern (*Woodwardia fimbriata*) is absent; California polypody (*Polypodium californicum*) and Dudley's shield fern (*Polystichum dudleyi*) are only occasionally present in the herbaceous layer. This type usually occupies slopes greater than 50 percent, 50-175 ft from the nearest perennial or ephemeral stream, although stands also may be found on slopes between 0-40 percent. **Coast redwood/sword fern -western wake robin//Gamboa-Sur ecological type.**

2 Swordfern (*Polystichum munitum*) has less than 10 percent cover in the herbaceous understory. Chain fern (*Woodwardia fimbriata*), Dudley's shield fern (*Polystichum dudleyi*), and western bracken (*Pteridium aquilinum*) are present individually, or in combination, in the understory. This type grows on slopes of less than 20 percent, up to 50 ft from the nearest perennial stream, but usually occupies a narrow zone of less than 6 ft at the water's edge. **Coast redwood/western bracken-chain fern//streamsides ecological type.**

1 Redwood sorrel is absent or has less than 5 percent cover 3

3 Coast redwood is the only overstory tree species 4

4 Occurs on steep (80-100 percent) upper slopes usually near the coast. Trees are dense and stunted (30-80 ft) by salt-spray bearing winds; d.b.h. ranges from 8 to 20 in; individuals with d.b.h. greater than 35 in are rare. Common vetch (*Vicia angustifolia*) and common manroot (*Marah fabaceus*) are often present (50 percent of the plots) in the understory. **Coast redwood/common manroot-common vetch//Gamboa-Sur ecological type.**

4 Occurs on gentle (5-35 percent) lower slopes, old stream terraces or colluvial-alluvial fans. Trees are tall (100-165 ft) and individuals with d.b.h. greater than 35 in are common. **Coast redwood//Gamboa-Sur ecological type.**

3 The overstory contains at least 10 percent cover of individual tree species other than coast redwood 5

5 Overstory has at least 10 percent cover of tanoak (*Lithocarpus densiflorus*); big leaf maple (*Acer macrophyllum*) is occasionally present, but with cover that seldom exceeds 5 percent. Generally it occurs on slopes greater than 50 percent. Milkmaids (*Dentaria californica*), California polypody (*Polypodium californicum*) and Dudley's shield fern (*Polystichum dudleyi*) are rare, or only occasional understory components. Round-fruited carex (*Carex globosa*) and Douglas's iris (*Iris douglasiana*) are usually present, together or individually**. Coast redwood-tanoak/ round-fruited carex-Douglas's iris//Gamboa ecological type.**

5 Overstory has less than 10 percent cover of tanoak (*Lithocarpus densiflorus*), and at least 20 percent cover of big leaf maple (*Acer macrophyllum*). Occurs within 50 ft of the nearest perennial stream on slopes less than 20 percent. Milkmaids (*Dentaria californica*), California polypody (*Polypodium californicum*) and Dudley's shield fern (*Polystichum dudleyi*) are nearly always present in the herbaceous understory. **Coast redwood-big leaf maple/California polypody//Gamboa ecological type.**

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