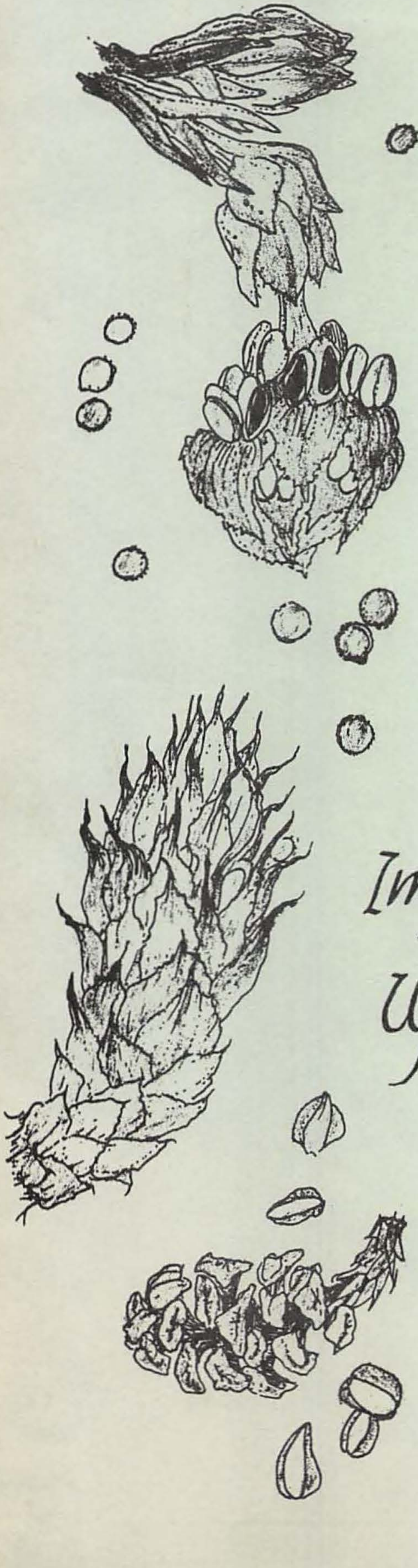

FINAL REPORT
NATIONAL SCIENCE FOUNDATION
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The Ecology of the Coastal Redwood Forest and the Impact of the 1964 Floods Upon Redwood Vegetation

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FINAL REPORT
NATIONAL SCIENCE FOUNDATION GRANT GB # 6310
April 15, 1967 - June 1, 1968

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FINAL REPORT

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OF NORTHERN CALIFORNIA AND THE IMPACT OF THE
1964 FLOOD UPON REDWOOD VEGETATION

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I. INTRODUCTION

This report summarizes the research work conducted under the NSF Research Grant GB # 6310, awarded by the National Science Foundation, Washington, D. C. to the Redwood Research Institute, Inc., P. O. Box 59, Arcata, California on May 15, 1967. This report summarizes the research work until January 1, 1969.

This report summarizes only research findings collected by the NSF Grant GB # 6310. Detailed reports about research methodolgy and previous research findings have been published in the NSF Final Reports of Grant GB # 3468 and GB # 4690. For a more complete review of methods, procedures and objectives one is referred to these reports.

The objectives of the National Science Foundation Grant GB # 6310 are the continuation of current research work:

1. To provide for a computer analysis of phytosociological inventory records of the Redwood Forest Communities.

2. To study the December, 1964 flood impact upon redwood vegetation and to monitor the flood effects with the progression of time. This includes the measurement of temperatures, precipitation and soil moisture trends per month, and the continuous reinventory of redwood regeneration ring plots in the forest environment.

3. To study the riparian vegetation and its effects upon the floods and the ecological significance of riparian vegetation in flood protection.

4. To study the successional plant communities of logged-over areas of the Redwood forest.

II. ADMINISTRATION AND PERSONNEL

THE ADMINISTRATION OF GB # 6310

The administration and fiscal management of the grant funds became the responsibility of the Redwood Research Institute, Inc., P.O. Box 59, Arcata, California, a private non-profit corporation to promote research in the economic, social and ecological aspects of the Redwood Region. The assistance provided by the staff of the Redwood Research Institute, Inc. greatly increased the effectiveness of the research project. The fiscal support provided directly and indirectly by the Redwood Research Institute was much appreciated. The principal investigator further expresses his appreciation for the excellent cooperation and the understanding of the Board of Directors of the Institute and their consistent support of these research efforts.

RESEARCH PERSONNEL FOR GB # 6310

For the summer period of 1967 a research team was organized for the fieldwork. The team consisted of two graduate students: Beverly Elmore and David W. Van Scoyoc, and two undergraduate students Michael R. Gates and Madeline M. Kelly. This team of two girls and two boys received extensive training in phytosociological inventories and the specialized tasks of the monitoring of the Redwood forest environment. The fieldwork was mostly concentrated in the local area of the Humboldt Redwoods State Park, Weott, California. Fieldwork was extended into the Southern range of the Redwood Region of Santa Cruz and Monterey counties. Another major exploration was made of the redwood forest communities of Sonoma and Mendocino counties along the Pacific Coast extending into the Usal and Kings Range area near Shelter Cove, Humboldt County. Additional field travel extended into Jackson State Forest near Fort Bragg, California and the Jedediah Smith Redwood State Park near Crescent City to reinventory previously established redwood regeneration plots.

After the summer work of 1967 the summer personnel could not continue the field and office work. New students had to be trained in the various specialized aspects of the field monitoring. The following graduate students participated on a part-time basis: Beverly Elmore and David W. Van Scoyoc, and the following undergraduate students: Rovan Anderson, Terry A. Benoit, Ronald Gerstenberg, John H. Harris, Ralph R. Johnson, Bruce Van Meter, Roger L. Smith, Daniel L. Stevens III. In the course of 1968, the following undergraduate students continued with the field and office work: Wayne Dodge, William Hay, Dow Jacobszoon, Ronald Jurek, Fred Sutter while in computer work Ralph R. Johnson, Paul Ely and Edith Janzen assisted in the development and execution of the various programs. Beverly Elmore, Sharon Hurst, Avis Toberer and Patricia Hoover were employed on a part-time basis in administrative and secretarial capacities. The excellent cooperation of D. Jack Underwood, Director of the Computer Center of Humboldt State College is hereby acknowledged.

III. THE MEASUREMENT OF THE EFFECTIVE TEMPERATURE BY MEANS OF SUCROSE SOLUTIONS

A. THEORETICAL ASPECTS AND LITERATURE REVIEW

1. Introduction

An aqueous solution of cane sugar or sucrose is subject to hydrolysis or inversion. The reaction proceeds spontaneously and irreversibly. The following equation indicated the progress of this reaction:

$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}} + H_2O \longrightarrow \underset{\substack{\text{d-glucose}\\ \text{or}\\ \text{dextrose}}}{C_6H_{12}O_6} + \underset{\substack{\text{d-fructose}\\ \text{or}\\ \text{levulose}}}{C_6H_{12}O_6}$$

The reaction product is an equimolar mixture of dextrose and levulose, often called invert sugar. The rate of the reaction is dependent upon the pH, which is related to the concentration of H^+ ions, and upon the temperature of the sucrose solution.

Sucrose itself rotates the plane of polarized light to the right, while invert sugar rotates the plane of polarized light to the left. The extent to which the invert sugar solution rotates the plane of polarized light can be determined by the use of a polarimeter or a similar but simpler instrument called a saccharimeter. From polarimetry or saccharimetry data it is possible to calculate the concentrations of the sucrose and the invert sugar in a given mixture at any given time. It is necessary to know the time period during which inversion has occurred, and the rotation angle at the start of the reaction as well as upon total completion of the reaction. The rate of reaction can then be calculated. This reaction rate is dependent upon pH and temperature. If the pH of the solution is known and maintained at a constant value by means of a buffer, and if the initial concentration of the sucrose solution is known, the rate of inversion will be uniquely correlated with the temperature of the solution. When the temperature of the solution is not held constant during the course of the inversion reaction the value of the temperature thus obtained is not the mean temperature of the solution, but rather the "effective" temperature during the time interval the reaction took place.

The inversion rate of a given sucrose solution is a function of the pH and effective temperature of the solution. The function can be determined empirically under controlled conditions. However, the reaction rate constant k is very sensitive to changes in pH. In practice, it will be required to obtain these empirical data each time a new batch of surcrose and buffer solution is prepared because of the impossibility of preparing different batches with exactly the same pH.

2. The Inversion Rate Equation for Hydrolysis of Sucrose

The sucrose hydrolysis proceeds until complete inversion since the reaction is irreversible. The rate constant k is at any given temperature directly proportional to the concentration of the sucrose and to the concentration of (H^+) ions, the pH being a satisfactory approximation of the (H^+) ion concentration. The following differential equation illustrates this proportionality:

$$-\frac{d(A_t)}{dt} = k \cdot (A_t) \cdot (H^+)$$

where (A_t) = sucrose concentration at time t, k = the proportionality or rate constant, and t = time interval during which the inversion progressed. The negative sign follows from the fact that the sucrose concentration decreases as the reaction proceeds with time. Rearrangement yields:

$$k(H^+)\,dt = -\frac{d(A_t)}{(A_t)}$$

Integration over the stated limits yields:

$$k(H^+)\int_{t=0}^{t=t} dt = -\int_{A_0}^{A_t} \frac{d(A_t)}{(A_t)}$$

$$k(H^+)t = -\ln(A_t) + \ln(A_0) = \ln\frac{(A_0)}{(A_t)}$$

where (A_0) = the concentration of sucrose at some arbitrary starting time t = 0, and (A_t) = the concentration at time = t.

3. Measuring Hydrolysis of Sucrose by Polarimeter

Polarimeter readings give rotation angles of the polarized light passing through a given length of sucrose solution. The deflection angle or refraction of the polarized light is measured precisely towards either side from the true vertical plane of light extinction. This is accomplished by precise rotation of the optical elements of the instrument until complete extinction of the polarized light has occurred. The degree of refraction is dependent upon the prevailing concentrations of sucrose and invert sugar, both components having opposing tendencies of plane rotation of the polarized light. For precision, monochromatic light must be used to obtain complete extinction.

Refraction angles are dependent upon the wavelength of the light used and the length of light path through the polarimeter tube. In practice, it is advisable to keep both the light source and the polarimeter tube the same. From the observed refraction angles the relative concentrations of sucrose and invert sugar in solution can be determined by means of the following equation:

$$\ln\frac{(A_0)}{(A_t)} = \ln\frac{a_0 - a_\infty}{a_t - a_\infty}$$

where a_0 = the rotation angle of polarized light at the arbitrary starting time t = 0

a_∞ = the rotation angle of polarized light upon total completion of the inversion reaction

a_t = the rotation angle of polarized light at the observed time t.

Substitution yields:

$$k(H^+)t = \ln \frac{a_0 - a_\infty}{a_t - a_\infty} = 2.30259 \; {}^{10}\log \frac{a_0 - a_\infty}{a_t - a_\infty}$$

Rearrangement of the equation determines the rate constant k as follows:

$$k = \frac{2.30259}{(H^+).\text{time}} \cdot {}^{10}\log \frac{a_0 - a_\infty}{a_t - a_\infty}$$

4. Dependency of the Rate Constant k upon the Temperature

Arrhenius observed the reaction rate constant k is dependent upon the Kelvin temperature of the system as follows:

$$\ln k = a - b/\text{Temp } (^\circ \text{ Kelvin})$$

where a and b are empirically determined constants.

The inversion rate constant k of sucrose solutions under known conditions of pH and temperature have been determined empirically by several investigators. Pallmann (1939, 1940) was one of the first investigators to determine the temperature dependency of k. He found two relationships for k for two temperature regimes at a constant pH of 2.90:

$\log k = -1.220 + 0.0720\ T(^\circ C)$ for the temperature range of $-2^\circ C$ to $+27.3^\circ C$.

$\log k = -.9064 + 0.0597\ T(^\circ C)$ for the temperature range of $+27.3^\circ C$ to $+ 40^\circ C$.

The two equations, each for its own temperature regime are partly due to the use of the ^{10}logarithm base instead of the Naperian logarithm base, and by the expression of the temperature in °Celsius instead of °Kelvin (273.2°K = 0°C). Schmitz and Volkert (1959) found for the pH = 2.90 the following relationship:

$$\log k = 20.1998 - 5{,}856.6 \;.\; 1/T(^\circ K)$$

Berthet (1960) determined the inversion rate constant k dependency upon temperature for two different pH values as follows:

$\log k = 18.99053 - 5{,}854.08 \;.\; 1/T(^\circ K)$ for pH = 1.21

$\log k = 17.28778 - 5{,}854.08 \;.\; 1/T(^\circ K)$ for pH = 2.92

The above differences in the inversion rate constant k values indicate the great sensitivity of k and the need for empirical determination of k for each field trial. In all the above equations the rate constant k was expressed in time units of days. See Table # III-1.

TABLE III-1: COMPARISON OF REGRESSION COEFFICIENTS OF THE REGRESSION OF INVERSION RATE k OVER THE INVERSE OF THE TEMPERATURE FOR A CONSTANT pH OF 2.90-2.92

Modified to log k = a + b / temp (°K)

Investigator	a-value	b-value
Pallmann (1940)*	20.20394	-5,858.97
Schmitz & Volkert (1959)	20.1998	-5,856.6
Berthet (1960)	17.28778	-5,854.08
Becking (1971)	15.72788**	-5,278.11**

* Recomputed from the original data published by Pallmann (1940), Table # 4 & 5, p. 349.

** The a and b values convert to a = 36.215159 and b = 12,153.433 when the equation ln k = a + b • 1/Temp (°K) is used at pH of 2.90.

5. Influence of Temperature upon the Rotation Angle

Schmitz and Volkert (1959) have indicated the need for a temperature correction if the determination of the rotation angle of the sucrose solution occurs at a temperature other than 20°C. Their proposed correction formula is:

$$(a)^t = (a)^{20} + (0.283 + 0.014\ C)\ .\ dT$$

in which:

$(a)^t$ = the rotation angle at t°C.

$(a)^{20}$ = the rotation angle at 20°C.

C = the concentration of the sucrose solution.

dT = the temperature deviation from the 20°C temperature.

Apparently, relatively small deviations in temperature (dT) from the normal 20°C temperature can influence the rotation angle of the sucrose solution, affecting temperature changes of 0.10°C in computed temperature. This temperature correction depends further upon the concentration of the sucrose solution (C). During the hydrolysis concentrations of the sucrose and its byproducts change continuously. However, the concentration of sucrose becomes progressively smaller, and with it this temperature correction. This error is insignificant under normal practice and field testing.

6. Influence of the Sucrose Concentration upon the Rotation Angle

It is postulated that the rotation angle of polarized light is independent of the concentrations of the sucrose solutions and its hydrolysis products. For the sucrose concentrations this is generally true but not for invert sugar concentrations. Here, a strong dependency of rotation angle with the invert sugar concentration has been found by Schmitz and Volkert (1959). The corrected rotation angle can be expressed as:

$$(a)_D^{20} = -\ (19.415 + 0.07065\ C - 0.00054\ C^2).$$

At the start of the hydrolysis the concentration (C) of invert sugar equals zero, and the obtained rotation angle would then be -19.415°. As hydrolysis progresses the concentration (C) of invert sugar increases and the above correction of the obtained rotation angle must be made to eliminate this dependency upon the invert sugar concentration.

The addition of a buffer solution and also a poison will affect the optical rotation of the solution, and again differently in the case of the sucrose solution than the invert sugar solution. Considering the above corrections necessary for temperature deviations from 20°C and for the invert sugar concentration Schmitz and Volkert (1959) concluded that it would be best to determine these relationships empirically. Under their experimental trial conditions using a sucrose concentration of 38.75 gr sucrose/ 100 ml solution with an addition of 1:1 of a solution containing 1500 gr sucrose in 1000 ml of water with a buffer solution (404 ml 0.2 mol sodium citrate solution + 596 ml 0.2 n HCl), relatively large deviations in rotation angles during hydrolysis were observed requiring rotation angle measurements to a high degree of accuracy.

7. Influence of Wave Length upon Polarimeter Readings

The polarimeter readings must be accurate to about 0.05° or less in order to provide data of sufficient quality for field temperature measurements. Most polarimeters have such an accuracy, but measurements have to be replicated for the needed accuracy. The best accuracy is usually obtainable only under reduced light conditions. For routine polarimeter measurements of large batches of sugar vials a darkened room must be used. The accuracy is influenced further by being able to determine the point of light extinction, preferably the point of complete extinction. Many personal factors such as fatigue, visual acuity and distractions determine to a large degree the obtainable accuracy.

Schmitz & Volkert (1959) indicate the importance of the wavelength of the polarized light used for accurate measurement of the rotation angle. The spectral sensitivity of the human eye is not the same for every wavelength. These authors advocate the use of green mercury light of $\lambda = 546.1$ mμ. Under optimal conditions the human eye is able to detect 1 to 2 per cent differences in luminescence for this wavelength, a difference of at least 200 asb. These authors found the yellow sodium light of $\lambda = 589$ mμ yields less precise readings. They accounted for this observed discrepancy by noting that the polarized light of a sodium source is not entirely monochromatic, but it consists of two wavelengths: 589.0 mμ and 589.6 mμ. This double peak reduces the acuity of the human eye in determining the exact extinction angle of the polarimeter. Furthermore, the illumination with green mercury light is greater than with sodium light because of the greater radiant energy of the mercury light source. Also, the human eye has its greatest sensitivity in the spectral range of green light. Differences in rotation angles of sucrose and invert sugar are greater under green light conditions than under yellow light conditions. According to Schmitz & Volkert (1959) the average standard deviation of the rotation angle of the polarized sodium light amounts to $\pm$ 0.015° after 10 replicate measurements while under green light the attainable average standard deviation equals to $\pm$ 0.005° after two or three replicate readings. The use of the blue mercury light of $\lambda = 435.8$ mμ offers no specific advantages. The spectral sensitivity of the human eye is much reduced at this wavelength increasing the deviations in rotation angles. This is primarily due to poor acuity of the exact point of maximum extinction in polarimeter readings by the observer requiring that more than 10 replicate readings be made for each sample to obtain comparable accuracy.

8. Influence of Polarimeter Tube Length upon Rotation Angle

The magnitude of the refraction angle is directly proportional to the path length the polarized light travels through the solution. The rotation angle is doubled when the path length in the polarimeter tube is doubled. Counteracting this is the significant reduction of light intensity through longer tube lengths which influences adversely the acuity of the human eye and thus, the measurement of the rotation angle. The optimal length of the polarimeter tube is about 200 mm requiring at least 250 to 300 cc of solution for rinsing and filling the polarimeter tube. For most practical applications, a 100 mm polarimeter tube may be adequate.

9. Sterilization versus Bacterial Poisoning

In extended field trials it is necessary to prevent the decomposition of sucrose solutions by bacterial activity. Pallmann (1939, 1940) advocated the sterilization of glass vials and the use of sterile solutions. For mass production the two separate stock solutions must be sterilized individually and then cooled before mixing them in order to avoid immediate and complete inversion due to high temperatures. Glass vials are sealed closed by flame. Under normal working conditions, complete sterility of glassware and apparatus is not likely obtainable, and infected sucrose vials must be discarded for temperature measurement.

Kundler (1954) suggested the poisoning of sugar solutions with toluol. Richard (1961) in private correspondence suggested the poisoning by means of a thiomersalate solution. Thiomersalate is an organic mercury poison containing sodium methylmercuri-thiosalicylate: $C_2H_5HgSC_6H_4COONa$. Richard recommends use of 10 grams of thiomersalate in 100 cc of distilled water. After filtration, it is possible that a precipitate will be formed. Some 0.1 cc of a clear supernatant solution of thiomersalate is added to one liter of the sucrose + buffer solution for field use. Richard (1961, personal communication), Berthet (1960) and Damman (1966, personal communication) suggested the use of formaldehyde HCHO as a bacterial poison.

10. Consideration about the Value of Effective Temperature

Sucrose temperature measurements correspond with the socalled "effective" termperature, i.e. the temperature that would continuously prevail during the entire period of field exposure of the vials. This is not an arithmetic or average temperature, but a somewhat higher temperature. Pallmann (1940) and Schmitz & Volkert (1959) called this the "effective" average temperature. Under the same conditions of solution preparation, buffering and instrumentation, relative termperature differences of various field stations can be determined. These temperature measurements would have a greater ecological or biological validity than thermometer readings because "effective" temperature measurement is based upon sucrose hydrolysis. Sucrose hydrolysis is a common biochemical reaction in living organisms, determining many physiological changes within such organisms. This would measure a closer dependency of the living organism with the temperature of its environment. Furthermore, these effective average temperatures integrate all temperature effects over the entire measuring period instead of averaging discontinuous temperature values.

Proper selection of sugar concentration, pH and expected temperature extremes make it possible to adapt this methodology to a wide range of ecological conditions and time spans. There is even a possibility of preparing and calibrating sucrose solutions covering the time span of one full growing season or even several growing seasons. Schmitz & Volkert (1959) have even experimented with "permanent" sucrose vials. The effective temperature of these vials would be determined periodically by bringing these vials into the laboratory under cooled conditions and determining their degree of inversion and returning the same vials again to the field stations. However, the temperature record would have to be interrupted for the length of time the vials were removed from the field.

Temperature measurement by sucrose vials is not limited to measurement of temperature changes in the aerial environment. This methodology is equally well adapted to measurement of temperature changes in the soil environment or under water. The only precaution that must be taken is that the temperature vials are insulated from their support, and that no heat or cold could be conducted to these vials from their mountings.

Measurement errors accumulate because of the many factors involved. Schmitz & Volkert (1959) gave the following summary of error magnitudes:

An error of 0.01 in the pH value will result in a temperature error of 0.15°C.

An error of 2% in the time interval of exposure will result in a temperature error of 0.10°C.

An error in rotation angle measurements of 0.05° will result in a temperature error of 0.05°C.

The greatest source of error is the pH of the solution. Under normal field conditions with the necessary care, effective average temperatures could be obtained within 0.5°C accuracy which would be more than adequate for most ecological purposes.

B. CALIBRATION TRIALS FOR THE REDWOOD ECOLOGY PROJECT

Calibration procedures were initiated prior to field sampling of ecological stations within the redwood forest communities. For this purpose calibrated water baths were used. The water baths were held constant at temperature levels of: 20°C, 35°C and 50°C. Also, five different buffered pH solutions were employed, namely pH = 1.10; 1.30; 1.60; 2.40; 3.10 and 4.10.

The following stock solutions were prepared for these trials:
Sucrose solution:

4,900 gr sucrose (domestic cane sugar was considered to be of adequate purity for ecological purposes)

3,300 ml of distilled H_2O

125 ml of 37% formaldehyde (HCHO)

This mixture was stirred for approximately three hours at room temperature, then filtered under suction, using a coarse filter in a fritted glass funnel. Buffer solutions for the different pH values were prepared as follows:

pH = 1.0 buffer:	475 ml 0.200 N HCl 50 ml 1 N KCl dilute to 1 liter with distilled water.	Actual pH = 1.10
pH =1.21 buffer:	339 ml 0.100 HCl 100 ml 1 N KCl dilute to 500 ml with distilled water.	Actual pH = 1.30
pH = 2.0 buffer:	170 ml 0.200 N HCl 170 ml 1 N KCl dilute to 1 liter with distilled water.	Actual pH = 1.60
pH = 2.4 buffer:	16.00 gr $H_3C_6H_5O_7 \cdot H_2O$ (citric acid) 101 ml 0.100 N NaOH dilute to 1 liter with distilled water.	Actual pH = 2.43
pH = 3.0 buffer:	16.81 gr $H_3C_6H_5O_7 \cdot H_2O$ (citric acid) 4.10 ml 0.100 N NaOH 20 ml 37% formaldehyde (HCHO) dilute to 1 liter with distilled water.	Actual pH = 3.10
pH = 4.0 buffer:	16.81 gr $H_3C_6H_5O_7 \cdot H_2O$ (citric acid) 485 ml o.200 N NaOH 20 ml 37% formaldehyde (HCHO) dilute to 1 liter with distilled water.	Actual pH = 4.10
pH = 5.0 buffer:	16.81 gr $H_3C_6H_5O_7 \cdot H_2O$ (citric acid) 723 ml 0.200 N NaOH 20 ml 37% formaldehyde (HCHO) dilute to 1 liter with distilled water.	Actual pH = 4.80

The buffer solutions and the primary sucrose stock solution can be stored in separate containers for a long time. Only upon mixture of sucrose and buffer solutions will inversion start. Sucrose and buffer solutions are mixed in a ratio of 1 : 1 for field use. Glass vials of 20 - 25 ml were used with plastic stoppers. The filled vials were immediately stored at 0°C until placed in the water bath. Before placement in the water bath, glass vials were brought to ambient temperatures by placing the vials in water for a few minutes. The plastic stoppers were marked numerically for identification. The stopper was sealed with black electric tape to the glass vial. The length of time of submersion in the water bath was noted.

The test vials submerged in the water baths, held at constant temperatures of 20°C, 35°C and 50°C, were measured periodically for their rotation angles by a Model 80 Rudolph Polarimeter. The largest diaphragm opening was used, and the half-shade angle control was set at 2 ½°. The angle of rotation of each sample was determined by approaching the evenly shaded area from both sides and recording the mean values. The polarimeter was first set at 0° with a sample of distilled water at ambient temperature so that no solvent or temperature correction factors had to be used.

Immediately upon the start of the inversion reaction the rotation angle of the solution was determined, yielding the value of the initial rotation angle (= a_o). The value of the rotation angle upon complete inversion (= a_∞) was determined by heating the sucrose + buffer mixture to about 100°C for 3 ½ hours, diluting it back to 50 ml with distilled water, and cooling it to ambient temperature. This value (a_∞) proved to be rather erratic. Thermal decomposition was blamed for this. Another approach was then used, leaving test vials in the water baths until they showed no change in rotation angles. In addition, the final rotation angle (a_∞) was computed by linear regression extrapolation from the different time observations. This latter rotation angle checked out well with the empirically determined final rotation angle without heating the vials. Generally, the first polarimeter readings in the water baths proved to be quite erratic, and the large fluctuations required many replicate readings. In spite of the numerous replicate readings, the obtained a_o-values proved to be not of sufficient accuracy. Therefore, the a_o- values were also obtained by extrapolation and linear regression. Apparently, wide fluctuations occur before the rate k stabilizes itself.

The calibration trials resulted in the empirical determination of inversion rate constants k for different pH values. Computations were performed by utilizing a CDC3150 computer. Source program # 811071 computes the linear regression ln rate k over the inverse of the temperature. Source program # 811072 computes the linear regression of ln rate k over pH. Program # 811073 computes rate k over time (days) under constant temperature.

The regression results are summarized in the following tables: Table III-2, -3, -4, and -5.

The relationship of ln k = a + b . pH is useful to compute the rate k for any given pH. However, the temperature must be held constant. For three water bath temperatures the following regression results were obtained:

TABLE III-2: REGRESSION STATISTICS OF THE LINEAR REGRESSION: ln k = a + b . pH (Program # 811072 - ln-version)

For the constant temperature of	20°C	35°C	50°C
a - value	1.4839854	2.6854671	2.6781051
b - value	-2.3122394	-2.0741578	-1.4104002
standard error of regression ($s_{\hat{y}}$)	0.22619495	0.50070895	0.47725974
standard error of b - value (s_b)	0.060153570	0.067604756	0.011825054
correlation coefficient (r)	0.9848	0.9774	0.9572

Often, it is more convenient to use the common ^{10}log-base rather than the natural (Naperian ^{e}ln-base, especially without computers.) Therefore, the same linear regression has been recomputed from the trial data, using the common logarithmic base:

TABLE III-3: REGRESSION STATISTICS OF THE LINEAR REGRESSION:
$\log k = a + b \cdot pH$
(Program # 811072 - log 10-version)

For the constant temperature of	20°C	35°C	50°C
a - value	0.28227099	0.79384737	0.76616570
b - value	-1.0041928	-0.89842843	-0.60349928
standard error of regression ($s_{\hat{y}}$)	0.098235220	0.21708483	0.20805876
standard error of b - value (s_b)	0.026124363	0.029393338	0.050825469
correlation coefficient (r)	0.9848	0.9778	0.9538

In order to compute the rate k relationship over the temperature, the trial data were used. The linear regression used was: $\ln k = a + b \cdot \text{Temp.}$ with program # 811073. The relationship is valid only under constant pH, and changes for each pH value. The following regression statistics were obtained (for the Naperian logarithmic base):

TABLE III-4: REGRESSION STATISTICS OF THE LINEAR REGRESSION:
$\ln k = a + b \cdot \text{Temp}$
(Program # 811073 - ln-version)

Constant pH-value	a-value	b-value	Standard error of regression ($S_{\hat{y}}$)	Standard error of b-value (s_b)	Correlation coefficient (r)
1.10	20.163489	-6204.6203	0.19631079	0.031940083	0.9672
1.30	30.064465	-9268.7134	0.29792451	0.072529432	0.9288
1.60*	24.104123	-7661.6511	0.60862924	1178.1270	0.8518
2.40	40.254207	-13014.801	0.022557106	59.069894	0.9999
3.10	39.750852	-13286.814	0.047084955	113.19026	0.9996
4.10	39.444428	-13954.933	0.096268555	552.93880	0.9969

* The regression values of pH = 1.60 indicate a significant deviation from the pattern of the statistics of the other pH-values. Inaccuracies in preparation are blamed for this.

From the above data it is possible to compute the required regression parameters for any given pH-value. To accomplish this, linear regressions are computed for the A and B values respectively (Y) (of the equation ln k = A + B . 1/Temp) against the pH-value (X).

For the A-value (Y) against pH (X) or the B-value (Y) against pH (X), the results are listed in Table III-5 (ln-version and log 10-version).

TABLE III-5: REGRESSION STATISTICS SUMMARY

	Naperian log base		Common log 10 base	
	A = a + b . pH	B = a + b . pH	A = a + b . pH	B = a + b . pH
a - value	18.273784	-4881.2512	7.5674887	-2119.9003
b - value	6.1866811	-2507.6490	2.6940304	-1089.0582
$s_{\hat{y}}$	11.336306	3343.6268	4.9354525	1452.1188
s_b	1.7730301	522.95263	0.77191865	227.11547
r	0.81846409	-0.89053830	0.81851967	-0.8905382

The inversion rate k can be transformed into the "effective" temperature with the use of the following formula:

$$\ln k = A + B \cdot 1/\text{Temp} \text{ (ln-version)}$$

$$^{10}\log k = A + B \cdot 1/\text{Temp} \text{ (log 10-version)}$$

in which the A and B values are dependent upon the buffered pH of the sucrose solution, and can be calculated precisely from the data presented in Table III-5.

The choice of the buffered pH-value of the sucrose solution depends also on the expected temperature range to which the sucrose vials are subjected. High temperatures accelerate the inversion. It is desirable for accurate measurement of the inversion that the inversion has progressed only for about 60 to 80% of the completion during the time interval of temperature measurement. A convenient calculation would be to compute the socalled half-life of the sucrose solution. The half-life period of time is the time period required to reduce the original concentration of the sucrose solution by 50%. The formula used is: $t_{\frac{1}{2}} = \frac{1}{k} \cdot \ln 2 = \frac{0.69315}{k}$

in which: $t_{\frac{1}{2}}$ = half-life in time units corresponding to those of k.

k = inversion rate expressed in specific time units, usually days.

ln 2 = 0.69315

In this formula, rate k is dependent upon the buffered pH of the sucrose solution.

With the use of Table III-3 and Table III-5 the appropriate pH value can be chosen to cover 60 to 80 % of complete inversion within the desired time interval of temperature measurement. For the current ecological research work it was found that the pH - values of 2.40 (summer) and of 2.90 (winter) are quite suitable. "Effective" temperatures can be computed by the following equations:

$$\ln k = A + B \cdot 1/\text{Temp } (^\circ K)$$

For pH = 2.90 buffered solution:

$$\ln k = 36.215159 - 12{,}513.433 \; 1/\text{Temp } (^\circ K)$$

or $$^{10}\log = 15.72788 - 5{,}278.11 \; 1/\text{Temp } (^\circ K)$$

For pH = 2.40 buffered solution:

$$\ln k = 33.121818 - 10{,}899.609 \; 1/\text{Temp } (^\circ K)$$

or $$^{10}\log k = 14.0331616 - 4{,}733.6398555 \; 1/\text{Temp } (^\circ K)$$

For pH = 3.20 buffered solution:

$$\ln k = 38.071163 - 12{,}905.728 \; 1/\text{Temp } (^\circ K)$$

or $$^{10}\log k = 16.1883860 - 5604.8863884 \; 1/\text{Temp } (^\circ K)$$

The pH-buffer values influence greatly the inversion rate k and directly its conversion into "effective" temperature. Therefore, it is very important to measure exactly the final pH-value upon buffering. For approximately ± 0.1 pH-unit change the "effective" temperature will be affected by $\pm 0.3^\circ F$ change.

From the harvested sucrose vials the rotation angle of the remnant sucrose is determined by a polarimeter and from it rate k and temperature (°F) by the formulas:

$$\text{rate } k = \frac{1}{\text{time}} \ln . \frac{a_o - a}{a_t - a}$$

$$\ln k = A + B \cdot 1/\text{Temp } (^\circ F)$$

or its log 10-base variant utilizing Program # 811070.

For the field trials the following pH-buffer solutions were used:

53 ml 0.20 N HCl
250 ml 0.10 N KCl
Dilute to 1 liter with distilled water.
Add 10 ml of 37% formaldehyde as a disinfectant.

The calculated pH-value is 2.00 and the measured pH value is 2.09.

1 ml 12 N HCl
39 ml distilled water
149.1 gr pure KCl
Dilute to 2 liters with distilled water.
Add 10 ml of 37% formaldehyde as a disinfectant.

The calculated pH-value is 2.23.

The buffer solutions were added to the sucrose solution in a ratio of 1:1.

The valuable advise and help of Dr. Thomas J. Clark and Dr. Roger H. Weiss, Department of Chemistry, Humboldt State College, in the planning of the calibration trials is acknowledged.

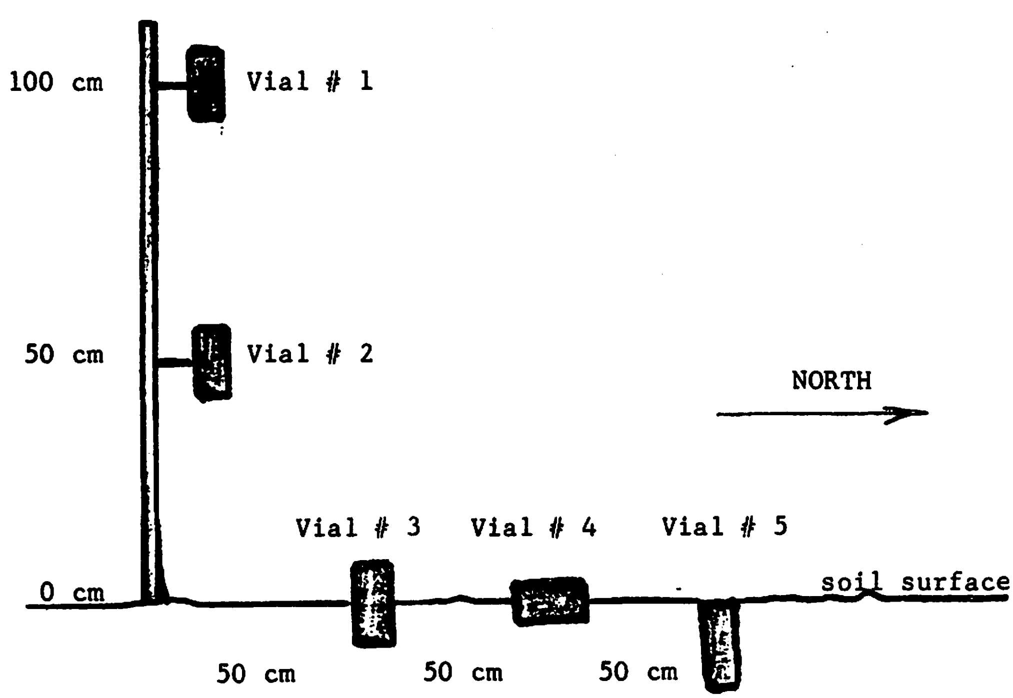
C. TEMPERATURE PATTERNS IN THE REDWOOD FORESTS, HUMBOLDT REDWOODS STATE PARK, WEOTT, CALIFORNIA

FIELD LOCATION:

The measurement of ecological parameters was undertaken along eight transect line: HB01 to HB08 as described in previous reports (GB 3468, GB 4690). At definite intervals cluster plots were established along these transect lines. The results of seedling surveys, redwood plantings, seed and litter fall have already been reported (Becking, 1967, 1968).

Temperature was one of the variables measured within these cluster plots. Two temperature stakes were established, one stake in the area of the densest canopy cover, and the other stake in the area with the least canopy cover. Temperature measurement was done at five different points for each stake (see Fig. III-1). Two sucrose vials were extablished on the north side of the temperature stake, one vial (vial # 1) exactly 100 cm above the soil surface, the other vial (vial # 2) exactly at 50 cm above the soil surface. The vials were taped to plastic electric wire. The plastic coating of the wire insulates the vials against heat conductivity along the wire from the post. These two vials (position 1 and 2 respectively) were to measure air temperature.

Figure: III - 1 TEMPERATURE STAKE DIAGRAM
VIAL POSITIONS



A third vial was located exactly 50 cm north from the temperature stake and placed half into the soil and half into the air. The fourth vial, exactly 50 cm north from vial # 3, was placed flat on the ground. Vial # 5, 50 cm north from vial # 4, was placed vertically completely below the surface soil and in good contact with the soil. All these vials were exchanged with fresh vials on a monthly basis and analyzed for their "effective" temperatures. Thus, a continuous temperature record was obtained.

Temperature measurements were made according to the dates listed in Table III-6. Subsequently, the various temperature stakes were classified according to their ecological position in the transect gradient and their degree of canopy cover. The ecological coding and listing of the temperature stakes is listed in Table III-7.

TEMPERATURE RESULTS:

Occasionally, the sucrose hydrolysis did not proceed normally and aberrant readings were obtained. Often, bacterial growth was visible. Obviously, observations from such vials had to be eliminated from the analysis. Therefore, it is essential to place numerous vials in the field to cope with this loss and to obtain a more reliable average. The chemical experience of the research assistants was limited. This has lead, unfortunately, to the loss of observations for a few months. The errors can only be discovered at the termination of the field exposure time interval. Therefore, it can never be retrieved. There was quite a variation among the empirical values of each batch of buffered sucrose solutions. Such discrepancies tend to develop when mass production is needed and when there is a frequent change of research personnel over the years. Nevertheless, very useful data were developed to illustrate temperature patterns over the years of 1966 to 1968. The average "effective" temperatures are listed in Appendix II. The seasonal and annual temperature patterns are listed in Table III-8.

These temperatures were compared to weather stations closest to the research area. The only available stations were: Scotia and Richardson Grove. Although these stations are quite distant from the research area, their general position along the Eel River would make comparisons valuable. The average temperatures are tabulated in Table III-9.

TABLE III-6: TEMPERATURE MEASUREMENTS
OF THE ECOLOGICAL STATIONS BY DATE OF MEASUREMENT,
pH OF SUCROSE SOLUTION AND OTHER EMPIRICAL DATA, HB01 - HB08 LINES,
HUMBOLDT REDWOODS STATE PARK, WEOTT, CALIFORNIA

Year/ Month	Date IN - Date OUT	Solution pH	Empirical a_o	Empirical a[illegible]
1966				
Apr.	4/16/66 - 5/12/66	2.40	60.552	-16.260
June	6/ 6/66 - 6/27/66	2.00	59.068	-16.260
July				
Aug.	7/10/66 - 8/22/66	2.40	59.068	-16.260
Sept.	8/22/66 - 10/ 9/66	2.40	58.457	-16.260
Oct.	10/ 9/66 - 10/30/66	2.00	58.457	-16.260
Nov.	10/30/66 - 12/ 2/66	2.00	57.000	-16.260
Dec.	Spoiled by bacterial growth.			
1967				
Jan.	Spoiled by bacterial growth.			
Feb.	2/ 2/67 - 3/ 7/67	2.40	58.500	-16.260
Mar.	3/ 7/67 - 4/ 8/67	2.00	58.457	-16.260
Apr.	4/ 8/67 - 5/ 6/67	2.00	62.626	-16.260
May	5/ 6/67 - 6/ 5/67	2.00	31.313	- 5.900
June	6/ 5/67 - 7/ 7/67	2.00	31.167	- 5.900
July	No vials were placed in the field.			
Aug.	7/31/67 - 8/29/67	2.90	31.167	- 5.900
Sept.	8/29/67 - 10/ 1/67	2.90	24.450	- 5.900
Oct.	10/ 1/67 - 11/ 5/67	2.90	24.450	- 5.907
Nov.	11/ 5/67 - 12/10/67	2.90	24.450	- 5.907
Dec.	12/10/67 - 1/ 5/67	2.40	23.450	- 5.900
1968				
Jan.	1/ 5/68 - 2/ 4/68	2.40	24.40	- 6.13
Feb.	2/ 4/68 - 3/ 2/68	2.40	23.40	- 6.19
Mar.	3/ 2/68 - 3/31/68	2.40	24.50	- 6.18
Apr.	3/31/68 - 4/28/68	2.90	24.50	- 6.18
May	4/28/68 - 5/25/68	2.90	24.53	- 6.18
June	5/25/68 - 7/ 1/68	2.90	24.55	- 6.18
July	7/ 1/68 - 8/ 2/68	2.80	36.080	- 5.907
Aug.	8/ 2/68 - 9/14/68	2.80	36.080	- 5.907
Sept.	9/14/68 - 10/ 5/68	2.90	24.45	- 5.907
Oct.	10/ 5/68 - 11/ 4/68	2.40	36.08	- 5.907

Termination of field work.

TABLE III-7: LISTING OF TEMPERATURE STAKES
ACCORDING TO THEIR ECOLOGICAL CLASSIFICATION, HB01 - HB08 LINES,
HUMBOLDT REDWOODS STATE PARK, WEOTT, CALIFORNIA

HB line #	Temperature Stake #	Ecological Position*	Crown Cover %**
01	11	70	50
	12	70	70
	13	70	50
	14	70	70
	15	55	70
	16	55	50
02	21	55	50
	22	55	70
	23	70	70
	24	70	50
	25	70	70
	26	70	50
03	31	70	50
	32	70	50
	33	80	70
	34	80	50
	35	55	70
	36	55	50

HB lines #	Temperature Stake #	Ecological Position*	Crown Cover %**
04	41	90	90
	42	90	50
	43	70	50
	44	70	70
	45	80	70
	46	80	50
	48	40	90
	49	40	70
05	51	90	90
	52	90	50
	53	90	90
	54	90	50
	55	70	70
	56	70	50
	57	70	70
	58	70	70
06	61	70	70
	62	70	50

TABLE III-7, CONTINUED

HB lines #	Temperature Stake #	Ecological Position*	Crown Cover %**	HB lines #	Temperature Stake #	Ecological Position*	Crown Cover %**
06	63	70	70	07	73	70	50
	64	70	50		74	70	70
	65	56	70		75	70	70
	66	56	50		76	70	50
07	71	40	70	08	81	70	70
	72	40	50		82	70	50

* Ecological codes:

	Code
Alluvial flats	
flooded in 1964, 1966, 1968 and 1970	90
flooded in 1964 only	70
not flooded in 1964	80
Lower slopes	
redwood - oxalis type (R-OX)	55
redwood - swordfern type (R-SF)	56
Middle slopes	40

** Crown cover codes:

		Code
Crown cover	100 - 80%	90
Crown cover	80 - 60%	70
Crown cover	60 - 40%	50
Crown cover	40 - 20%	30
Crown cover	20 - 0	10

TABLE III-8: AVERAGE SEASONAL AND ANNUAL EFFECTIVE TEMPERATURES, HB01 - HB08 LINES, HUMBOLDT REDWOODS STATE PARK, WEOTT, CALIFORNIA

	Ecological Codes** / Season**	4050	4070	4090	5550	5570	5650	5670	7050	7070	8050	8070	9050	9070
	VIAL # 1 AIR TEMPERATURE AT 100 cm LEVEL:													
1966	Spring	56.0	56.2	*	55.8+1.0	55.0	57.7	*	56.4+0.2	56.7+0.3	56.5+1.4	56.5+1.0	62.1+2.9	62.5+2.1
	Summer	67.7+1.8	67.9+2.4	*	73.0+2.3	71.8+2.1	69.4+2.3	69.6+3.0	70.2+0.8	70.1+0.8	71.8+3.0	71.8+2.9	75.6+2.9	74.4+1.9
	Fall	58.2+5.4	59.5+4.2	*	58.0+4.5	60.5+2.8	65.9+4.6	59.4+5.3	59.3+1.4	59.0+1.2	59.5+4.2	58.7+3.6	62.1+3.3	62.9+3.9
	Winter	53.6	51.1	*	52.4+1.6	46.3+1.1	54.8	52.8	51.2+0.6	50.6+0.5	51.1+1.1	52.6+0.6	51.0+0.2	51.6+1.1
	Annual Ave.	61.0+8.0	61.7+2.8	*	64.6+3.0	63.6+2.3	65.7+2.7	63.5+3.9	62.5+1.0	62.2+0.9	63.1+2.9	62.7+2.8	65.7+2.5	66.4+2.4
1967	Spring	58.6+1.3	58.3+1.4	*	59.6+1.3	59.0+1.3	58.7+2.7	60.0+1.3	59.3+0.5	58.9+0.5	60.8+1.7	59.7+0.8	62.3+2.0	59.7+2.3
	Summer	60.7	68.9+7.5	*	71.7+3.9	72.4+4.7	79.0	66.8+9.8	70.0+1.7	71.2+1.5	68.7+7.6	69.9+6.4	71.6+5.9	76.0+3.9
	Fall	61.8+3.8	61.7+2.7	*	62.4+2.6	63.3+2.4	64.2+3.3	61.7+3.2	62.0+1.1	63.1+0.8	60.8+2.1	67.1+3.4	67.1+1.7	62.7+2.6
	Winter	49.4+2.2	42.6+1.0	*	43.9+1.8	46.7+2.1	44.9+0.3	47.3+1.5	44.2+1.0	43.9+0.6	42.9+2.9	39.6+1.4	42.2+1.8	41.5+1.8
	Annual Ave.	59.4+1.7	61.0+2.4	*	61.4+1.7	61.9+1.9	62.8+3.0	61.4+2.7	61.5+0.8	62.0+0.7	61.5+2.2	63.6+2.2	65.3+2.0	63.7+2.1
1968	Spring	58.8+8.4	55.1+5.1	58.9+6.8	57.6+3.5	56.5+3.5	57.2+8.0	59.1+2.4	55.9+1.7	56.2+1.3	55.3+5.3	56.6+4.0	58.4+4.0	57.9+3.3
	Summer	73.6+0.8	76.8+2.0	75.1+1.6	76.3+1.6	76.4+1.4	74.3+1.6	75.2+1.9	74.2+0.6	75.6+0.5	75.0+1.9	78.1+1.1	75.9+1.2	75.8+2.8
	Fall	65.7	60.7+3.8	64.5+8.5	63.2+2.6	64.8+2.5	64.0+5.7	64.0+8.7	64.1+1.2	62.9+0.9	63.5+2.4	66.3+2.7	66.4+1.2	67.4+1.6
	Discontinued Ave.	61.1+3.9	59.1+3.5	66.4+3.9	58.2+2.6	59.5+2.6	61.0+4.1	62.1+3.5	58.3+1.3	59.0+0.9	57.9+3.4	59.6+3.4	60.2+2.6	59.3+2.6

* no record

\+ plus or minus

TABLE III-8, CONTINUED

	Season** \ Ecological Codes**	4050	4070	4090	5550	5570	5650	5670	7050	7070	8050	8070	9050	9070
	VIAL # 2 AIR TEMPERATURE AT 50 cm LEVEL:													
1966	Spring	57.2	56.5	*	55.8+0.8	54.7	*	57.5	56.4+0.3	56.2+0.3	57.0+1.5	58.3	62.3+5.8	61.5+3.4
	Summer	67.5+1.7	67.7+2.2	*	73.0+2.4	71.1+2.4	70.0+2.7	69.1+2.6	70.2+0.9	70.0+0.8	71.3+2.9	71.7+2.9	75.7+3.5	73.3+2.3
	Fall	58.5+5.2	58.2+6.8	*	58.4+3.4	59.1+3.1	58.9+5.0	59.0+5.3	58.9+1.3	58.9+1.2	58.7+3.9	56.7+4.0	58.9+3.6	61.4+3.9
	Winter	52.2	51.2	*	52.6	58.3+0.5	53.3	53.7	53.5+0.8	50.6+0.4	51.9+0.3	53.6+4.2	53.1+2.5	50.8+1.2
	Annual Ave.	61.3+3.1	61.6+3.4	*	63.1+2.5	62.8+2.5	63.3+4.0	62.1+3.3	62.3+1.0	62.1+0.9	62.6+2.8	62.9+3.2	65.1+3.1	64.9+2.5
1967	Spring	58.4+1.5	58.0+1.5	*	58.5+1.3	59.0+1.2	60.4+2.9	61.3+3.7	58.8+0.4	59.0+0.5	59.5+1.1	58.7+0.7	59.1+0.9	61.2+2.3
	Summer	67.4+7.9	68.6+8.9	*	77.0+4.6	74.1+5.0	71.3+7.7	67.3+7.2	70.8+2.0	70.3+1.4	67.9+7.1	69.9+6.8	79.2+4.1	74.5+3.7
	Fall	64.9+3.2	61.4+2.1	*	64.3+1.8	65.0+2.5	59.6+4.2	64.5+0.8	62.0+1.2	62.5+0.8	66.1+2.9	63.2+2.8	63.9+3.4	65.1+2.5
	Winter	39.2+4.1	44.8+3.0	*	47.5+1.7	45.6+2.6	33.8+2.1	44.8+1.7	44.5+1.2	42.8+0.7	44.4+2.7	44.8+1.4	40.4+2.4	39.6+2.6
	Annual Ave.	61.5+2.6	60.7+2.5	*	63.8+1.9	64.1+1.8	61.8+2.8	63.0+2.2	62.0+0.8	61.7+0.6	62.1+2.1	62.3+2.2	63.7+2.3	64.7+2.1
1968	Spring	53.3+1.5	56.3+4.3	54.5+7.7	54.0+3.5	51.0+8.3	58.2+4.2	58.7+6.4	56.2+1.8	55.1+1.3	57.2+4.6	52.5+4.1	56.6+4.0	56.6+3.2
	Summer	71.9+1.0	76.4+1.6	74.3+1.8	76.8+2.0	76.0+1.9	73.6+1.1	76.5+2.7	74.7+0.7	74.8+0.4	77.2+1.8	75.6+1.6	75.5+1.0	75.1+1.8
	Fall	59.7+6.2	61.9+3.8	58.2+3.7	63.9+2.0	62.9+2.9	60.2+3.1	65.6+8.5	62.1+1.5	63.2+0.8	63.7+1.5	64.1+1.5	66.9+0.9	64.6+1.6
	Discontinued Ave.	56.3+3.8	59.2+3.6	58.6+4.8	59.4+2.6	57.4+3.7	58.4+4.8	61.0+4.3	58.3+1.3	58.2+0.9	61.1+3.1	59.2+3.0	59.1+2.8	57.4+2.7

* nor record
\+ plus or minus

TABLE III-8, CONTINUED

Year	Season** \ Ecological Codes**	4050	4070	4090	5550	5570	5650	5670	7050	7070	8050	8070	9050	9070
	VIAL # 3 SOIL/AIR TEMPERATURE AT SOIL SURFACE:													
1966	Spring	54.3	56.0	*	53.7+2.5	51.8+0.4	56.2	*	54.2+0.5	54.0+0.4	54.1+1.5	53.2+1.0	55.7	62.3+2.7
	Summer	62.8+1.7	62.2+1.5	*	66.8+2.0	65.9+2.2	64.1+2.1	63.3+2.2	64.9+0.8	64.0+0.7	63.6+2.4	63.5+2.6	68.5+3.7	68.9+5.3
	Fall	57.6+4.2	54.9+6.4	*	57.9+4.3	57.4+2.4	57.5+4.2	57.1+4.9	58.3+1.3	57.6+1.1	56.8+3.0	57.5+2.7	62.0+4.0	59.2+3.3
	Winter	54.5	52.5	*	52.1+1.1	52.8+2.0	53.7	52.9	51.9+0.8	50.0+0.3	53.1+1.4	57.5	49.6+1.1	52.5+1.0
	Annual Ave.	58.8+2.4	58.0+2.7	*	61.3+2.3	59.5+1.9	59.5+2.5	59.6+3.1	59.7+0.8	59.2+0.7	58.6+1.9	58.8+1.9	63.1+2.9	62.4+2.2
1967	Spring	56.3+2.0	57.6+0.2	*	58.2+1.2	57.9+0.7	59.0+1.2	56.0+1.3	58.0+0.6	57.4+0.3	56.9+1.1	58.7+0.7	62.6+2.0	60.3+1.8
	Summer	67.5+11.1	66.4+10.6	*	68.9+4.4	72.7+6.1	68.2+12.7	67.0+8.7	68.2+2.1	67.9+1.6	68.3+5.9	70.6+5.8	71.5+3.4	67.0+4.6
	Fall	61.3+2.3	58.9+2.4	*	61.8+1.5	59.8+2.6	62.0+3.8	59.9+2.8	61.1+0.9	60.4+0.8	63.3+0.8	65.3+1.5	64.6+2.3	61.1+2.5
	Winter	50.0+2.7	47.0+2.1	*	42.7+2.4	47.0+2.0	49.1+2.5	39.5+4.2	44.4+0.9	43.6+0.8	41.1+2.9	37.7+2.8	41.2+2.3	45.6+1.8
	Annual Ave.	60.2+2.6	59.7+2.7	*	60.8+1.4	60.8+2.1	61.4+2.4	59.4+2.4	60.3+0.7	59.9+0.6	61.0+1.9	63.3+1.6	63.8+1.8	61.0+1.6
1968	Spring	59.5+8.2	56.9+4.3	55.7+6.1	60.8+4.0	58.4+3.9	60.1+4.6	56.5+2.4	58.6+1.6	58.2+1.2	55.3+5.0	57.2+4.3	56.4+4.5	57.1+3.4
	Summer	74.3+1.4	73.7+1.3	75.9+1.6	75.5+1.4	76.4+1.9	72.5+2.0	73.9+1.5	74.9+0.6	75.4+0.4	74.2+1.0	76.0+1.5	77.3+1.2	76.0+3.2
	Fall	60.9+4.0	50.8+8.5	70.7	64.2+1.6	57.8+4.0	63.0+3.1	65.9+9.1	64.0+1.3	63.5+0.8	63.7+1.5	64.1+1.5	66.9+0.9	68.2+1.1
	Discontinued Ave.	59.8+4.1	56.3+3.5	66.5+4.5	59.8+3.0	59.4+2.7	62.2+3.1	58.3+4.5	59.4+1.3	59.5+0.9	57.1+3.4	58.2+3.4	58.1+2.9	61.1+2.3

* no record
\+ plus or minus

TABLE III-8, CONTINUED

Year	Season** / Ecological Codes**	4050	4070	4090	5550	5570	5650	5670	7050	7070	8050	8070	9050	9070
	VIAL # 4 SOIL SURFACE TEMPERATURE:													
1966	Spring	54.5	55.0	*	51.9	51.5	*	*	54.2+0.7	54.0+0.5	54.0+0.2	54.0+0.3	66.2	67.3+4.0
1966	Summer	62.5+1.7	61.9+1.9	*	66.3+2.0	63.5+2.1	63.3+2.0	63.1+2.3	64.4+0.8	63.5+0.7	62.6+2.3	62.2+2.0	67.6+3.0	68.7+4.6
1966	Fall	57.4+4.5	57.4+4.3	*	56.0+3.6	55.4+3.5	57.1+4.6	58.4+3.4	57.7+1.2	57.8+1.0	58.2+2.7	56.6+3.8	57.6+4.0	59.0+4.3
1966	Winter	52.4	*	*	53.7+1.0	54.1+2.4	51.9	52.6	51.5+0.4	49.7+0.7	52.3+0.4	*	51.7+1.7	51.3+1.1
1966	Annual Ave.	58.6+2.4	58.5+2.3	*	60.1+2.4	58.0+2.4	59.5+3.0	60.3+2.3	59.9+0.8	59.2+0.7	58.9+1.7	58.2+2.0	61.1+3.0	63.2+2.7
1967	Spring	57.4+0.5	56.7+2.2	*	58.3+1.0	57.6+0.8	56.3+0.7	57.6+2.4	57.8+0.5	58.0+0.5	58.5+1.2	56.4+0.8	58.3+2.1	61.6+2.2
1967	Summer	68.0+9.0	65.5+9.7	*	81.4	73.6+8.2	67.9+8.7	68.2+8.7	69.6+2.5	70.2+1.8	68.3+5.7	71.9+5.0	74.3+6.7	68.5+3.8
1967	Fall	62.0+2.5	63.3+1.4	*	62.6+2.6	59.8+3.4	55.7+4.6	61.5+1.3	63.0+1.1	62.4+0.7	70.8+5.8	54.2+11.3	65.7+1.3	62.2+2.1
1967	Winter	47.5+1.1	46.5+3.1	*	47.5+2.1	43.2+1.3	42.5	48.1+2.2	46.7+1.0	44.2+0.8	45.4+3.6	43.0+4.2	41.3+2.8	40.1+1.7
1967	Annual Ave.	60.6+2.6	61.4+2.5	*	60.5+1.8	60.5+2.3	58.2+2.7	60.7+2.4	60.6+0.8	60.7+0.7	63.2+2.5	61.6+4.1	61.4+1.9	62.5+1.6
1968	Spring	58.1+3.0	55.0+5.6	54.3+5.9	58.7+4.6	58.5+2.7	58.1+1.2	56.3+6.5	57.7+1.5	57.8+1.2	53.3+4.7	57.7+3.7	62.1+3.7	54.2+3.0
1968	Summer	75.1+3.1	77.0+2.1	77.8+0.2	76.6+2.6	76.8+3.8	75.1+1.6	75.8+1.7	75.3+0.8	75.7+0.5	74.8+1.2	77.0+2.0	75.6+1.2	76.9+4.5
1968	Fall	60.0+4.5	63.1+4.1	59.2+3.6	61.8+2.1	60.9+2.5	60.7+2.8	65.8+7.5	63.2+1.4	64.1+0.7	61.5+2.4	64.4+1.4	63.1+1.6	66.3+1.4
1968	Discontinued Ave.	61.3+3.7	59.4+3.8	62.4+4.7	59.8+2.8	56.0+3.2	62.6+3.7	61.1+3.9	58.6+1.2	60.2+0.9	57.8+3.2	60.3+3.3	59.7+2.9	58.8+3.0

* no record
\+ plus or minus

TABLE III-8, CONTINUED

Season** / Ecological Codes**	4050	4070	4090	5550	5570	5650	5670	7050	7070	8050	8070	9050	9070
VIAL # 5 TEMPERATURE OF THE TOPSOIL:													
Spring	54.4	55.6	*	54.6+1.6	52.5+0.7	55.4	55.3	54.3+0.5	53.9+0.4	54.7	53.0+1.5	59.8+5.0	61.1+2.9
Summer	62.0+1.6	61.0+1.6	*	64.5+1.9	64.1+1.9	62.2+1.8	62.2+2.1	63.8+0.8	63.0+0.7	61.9+2.2	60.4+2.4	67.1+2.5	73.9+4.4
Fall	59.3+3.9	57.2+4.3	*	57.2+3.3	57.0+2.9	59.7+7.1	57.8+4.5	58.2+1.2	57.5+1.0	58.4+2.7	55.9+3.4	60.4+3.4	59.9+2.9
Winter	52.6	52.6	*	51.8+1.1	50.0	52.9	51.4	51.6+0.6	50.2+0.7	51.6	51.7+0.9	49.8+0.9	53.0+2.0
Annual Ave.	59.4+2.1	58.2+2.1	*	59.3+2.1	58.8+1.9	59.8+2.6	58.9+2.4	59.5+0.8	58.8+0.7	59.2+1.8	56.7+2.0	61.9+2.3	64.8+2.6
Spring	56.8+1.0	55.8+2.0	*	57.1+0.9	58.9+1.3	57.3+0.9	56.2+1.1	57.0+0.4	56.9+0.4	58.6+0.9	56.6+0.7	58.5+1.5	60.7+1.7
Summer	67.3+11.2	68.4+12.3	*	68.5+4.2	69.8+6.1	59.5	66.8+11.2	68.5+2.3	67.1+1.7	65.8+8.4	69.2+6.5	66.9+4.3	68.9+4.2
Fall	60.1+3.5	60.7+2.5	*	60.1+1.8	60.8+3.2	62.8+1.6	62.1+2.5	62.4+0.5	60.3+0.7	60.2+2.4	62.4+2.1	65.7+2.4	63.3+2.1
Winter	49.8+4.4	43.9+4.1	*	47.1+2.2	45.3+2.7	47.1+0.4	37.1+3.3	45.6+1.0	43.3+0.8	42.2+3.0	43.4+2.4	41.7+2.2	40.6+3.1
Annual Ave.	59.8+2.7	59.9+2.9	*	59.9+1.5	61.2+1.9	59.1+1.4	60.0+2.7	60.5+0.7	59.5+0.6	60.5+2.2	61.3+2.3	61.4+1.7	62.5+1.5
Spring	51.4+3.0	54.1+3.6	54.0+7.3	57.9+2.7	62.0+4.3	62.4+5.7	56.4+3.9	57.7+1.5	57.0+1.1	55.9+3.1	59.8+3.1	60.0+3.1	56.7+4.6
Summer	75.1+4.0	73.6+1.8	75.1+1.6	76.3+1.6	76.4+1.4	74.3+1.6	75.2+1.9	74.8+0.6	74.8+0.5	77.0+2.5	75.6+1.6	76.6+1.5	75.1+2.8
Fall	63.0+4.9	60.0+2.3	62.4+8.4	63.2+1.4	58.8+1.3	63.4+2.5	58.5+1.2	62.0+1.3	62.4+0.9	67.9+1.3	63.7+1.1	67.0+1.4	66.1+1.2
Discontinued Ave.	55.4+4.5	59.1+3.0	64.0+4.5	60.1+2.8	60.1+2.8	61.9+3.7	58.6+4.6	58.7+1.2	59.0+0.9	58.9+3.4	60.4+2.9	60.9+2.6	59.4+2.8

* no record + plus or minus

** Ecological Codes: site code 40 = middle slope; 55 = lower slope (R-OX type); 56 = lower slope (R-SF type); 70 = alluvial flats flooded in 1964; 80 = alluvial flats not flooded in 1964; 90 = alluvial flats flooded in 1964, 1966 and 1969.
canopy cover code 90 = 100 to 80% cover; 70 = 80 to 60% cover; 50 = 60 to 40% cover.
Example: code 4050 = 40 (site code) and 50 (cover code).

TABLE III-9: THE AVERAGE MONTHLY AND ANNUAL
AIR TEMPERATURES OF SCOTIA AND RICHARDSON GROVE, CALIFORNIA

	Year	Average Annual	Jan.	Feb.	March	April	May
Scotia, Calif.	1966	53.8	46.5	46.3	49.1	52.7	53.5
	1967	53.7	47.2	48.0	47.0	46.2	55.2
	1968	54.5	45.8	54.0	51.7	50.6	54.7
Richardson Grove	1966	--	43.6	44.4	49.2	57.4	60.7
	1967	56.8	44.0	47.7	47.2	46.0	60.7
	1968	56.9	42.6	51.9	51.4	54.8	58.1

	Year	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Scotia, Calif.	1966	58.4	59.4	60.2	62.1	55.8	53.0	48.9
	1967	57.7	60.6	62.2	62.7	58.4	55.1	43.6
	1968	59.5	60.6	62.3	61.0	56.1	52.5	44.6
Richardson Grove	1966	65.2	68.4	71.8	67.0	--	49.9	45.8
	1967	66.2	71.9	75.1	70.5	58.8	52.5	40.5
	1968	66.3	72.1	68.4	67.2	57.5	50.2	41.9

CONCLUSIONS AND SUMMARY

1. There exists excellent correspondence between the "effective" temperatures and the average temperatures as measured by the U. S. Weather Bureau at weather stations within the same general area. The winter temperatures are very close indeed. The summer and early fall temperatures are consistently higher than the U. S. Weather Bureau data. Apparently, the "effective" temperatures register some 10 to 15°F higher for time intervals above 65°F. This temperature difference is consistent for the years of observations (1966-1968).

2. The average air temperatures at the 100 cm level do not differ much from winter to summer. The maximum difference is less than 20°F among the seasons. This confirms the hypothesis that even as far inland as the Bull Creek flats, redwood growth is characterized by a distinct maritime climatic influence with only minor seasonal temperature fluctuations. This indicates a predominant invasion of marine air currents some 60 to 80 miles up the Eel River valley.

3. Crown canopy cover percentage influences the air temperatures at the 100 cm level and the 50 cm level. On slope positions (codes 40 and 55) the summer and fall air temperatures are increased by a few degrees by change of canopy cover from 50% to 70%, while at the same stations the winter and spring air temperatures are just slightly lower. For the alluvial flats (codes 70, 80 and 90) and the R-SF slopes (code 56) the summer temperatures at the 100 cm level are only slightly higher while, generally, the air temperatures in the other seasons are reduced by the increase in canopy cover. The air temperatures at the 50 cm level are generally the same or only slightly lowered by the canopy increase.

4. The highest air temperatures in the spring season are observed on the frequently flooded alluvial flats (9070 and 9050), or on the R-SF slopes (5670 and 5650). The highest air temperatures of the spring season are between 2 to 4°F lower than the average annual temperature. The lowest air temperatures in the spring season are found on the R-OX slopes (5570 and 5550), or on the middle slopes (4070 and 4050). The lowest air temperature is some 3 to 8°F below the average annual temperature. Air temperature extremes for the spring season range from 3 to 7.5°F (see Table III-10).

The colder temperatures on the R-OX slopes and middle slopes indicate the influx of cold air through the draws from the higher ridges downhill, while the ridges on the slope (R-SF--5670 and 5650) are not affected.

The frequently flooded alluvial flats (9070 and 9050) and the ridges (R-SF--5670 and 5650) receive more solar radiation in the spring season than the other sites. Higher air temperatures can affect seed germination favorably early in the growing season, but can create problems with soil moisture availability to the developing redwood seedling later in the growing season also.

5. The highest air temperatures during the summer season were found on the frequently flooded alluvial flats (9070 and 9050) and on the lower slopes (R-OX--5550). The lowest air temperatures of the summer season were observed on the middle slopes (4070 and 4050) and the R-SF slopes (5670 and 5650), suggesting again cold air flow downhill from the higher ridges. In general, summer air temperatures are about 6 to 16°F above the average annual temperature.

6. During the fall season the highest air temperatures were observed most often on the frequently flooded alluvial flats (9070 and 9050), on the non-flooded flats (8070 and 8050) and on the R-SF slopes (5670 and 5650). During the fall the lowest air temperatures are found on the middle slopes (4070 and 4050) or on the non-flooded alluvial flats (8070 and 8050). Fall temperatures indicate a transition to the winter conditions.

7. During the winter season the highest air temperatures are found on all slope positions (4050, 5570, 5550, 5670 and 5650), while the coldest air temperatures were found on the frequently flooded alluvial flats mostly. This indicates again cold air flow. Winter temperatures are generally about 10 to 24°F below the average annual temperature.

8. Air temperatures at the 50 cm level showed greater temperature fluctuations than at the 100 cm level.

9. Soil temperatures measured on the average 3 to 5°F lower than the corresponding air temperatures. The same seasonal temperature patterns prevailed as in the air temperature measurements. Little difference in temperatures were noted among the different vial positions. (See Table III-10.)

10. "Effective" temperature measurements integrate temperatures over a given duration of time. The determination of integrated temperatures provides for a better ecological interpretation of temperature effects upon living organisms in their natural environment.

TABLE III-10: RELATIVE AIR TEMPERATURE CHANGES DURING THE SEASONS FOR DIFFERENT ECOLOGICAL SITES, HUMBOLDT REDWOODS STATE PARK, HB01 - HB08 LINES, WEOTT, CALIFORNIA

Season Temp.	1966 Site*	1966 Diff.** Annual	1967 Site*	1967 Diff.** Annual	1968 Site*	1968 Diff.** Annual
VIAL # 1 AIR TEMPERATURE AT 100 cm LEVEL:						
Spring high:	9070/9050	- 3.9	9050/8050	- 3.0	5670/4090	- 3.0
low:	5570/5550	- 8.6	4070/4050	- 2.7	4070/8050	- 4.0
extreme:	62.5-55.0=	7.5	62.3-58.3=	4.0	59.1-55.1=	4.0
Summer high:	9050/9070	+ 9.9	5650/9070	+16.2	8070/4070	+18.5
low:	4050/4070	+ 6.7	4050/5670	+ 1.3	4050/7050	+12.5
extreme:	75.6-67.7=	7.9	79.0-60.7=	18.3	78.1-73.6=	4.5
Fall high:	5650/9070	+ 0.2	8070/9050	+ 3.5	9070/9050	+ 8.1
low:	5550/4050	- 6.6	8050/4070 & 5670	- 0.7	4070/7070	+ 1.6
extreme:	65.9-58.0=	7.9	67.1-60.8=	6.3	67.4-60.7=	6.7
Winter high:	5650/4050	-10.9	4050/5670	-10.0		
low:	5570/9050	-17.3	8070/9070	-24.0	----------	----------
extreme:	54.8-46.3=	8.5	49.4-39.6=	9.8		
VIAL # 2 AIR TEMPERATURE AT 50 cm LEVEL:						
Spring high:	9050/9070	- 2.8	5670/9070	- 1.7	5670/5650	- 2.3
low:	5570/5550	- 8.1	4070/4050	- 2.7	5570/8070	- 6.4
extreme:	62.3-54.7=	7.6	61.3-58.0=	3.3	58.7-51.0=	7.7
Summer high:	9050/9070	+10.6	9050/5550	+15.5	8050/5550	+16.1
low:	4050/4070	+ 6.2	5650/4050	+ 9.5	4050/5650	+15.6
extreme:	75.7-67.5=	8.2	79.2-67.3=	11.9	77.2-71.9=	5.3
Fall high:	9070/5570	- 3.5	8050/9070	+ 4.0	9050/5670	+ 7.8
low:	8070/4070	- 6.2	5650/4070	- 2.2	4090/4050	- 0.4
extreme:	61.4-56.7=	4.7	66.1-59.6=	6.5	66.9-58.2=	8.7
Winter high:	5570/5670	- 4.5	5550/5570	-16.3		
low:	7070/9070	-11.5	5650/4050	-28.0	----------	----------
extreme:	58.3-50.6=	7.7	47.5-33.8=	13.7		

TABLE III-10, CONTINUED

	1966		1967		1968	
VIAL # 3 AIR/SOIL TEMPERATURE:						
Spring high:	9070/5650	- 0.1	9050/9070	- 1.2	5550/5650	+ 1.0
low:	5570/8070	- 7.7	5670/4050	- 3.4	8050/4090	- 1.8
extreme:	62.3-51.8=	10.5	62.6-56.0=	6.6	60.8-55.3=	5.5
Summer high:	9070/9050	+ 6.5	5570/9050	+11.9	9050/5570	+19.2
low:	4070/4050	+ 4.2	4070/5670 & 9070	+ 6.7	5650/4070	+10.3
extreme:	68.9-62.2=	6.7	72.7-66.4=	6.3	77.3-72.5=	4.8
Fall high:	9050/9070	- 1.1	8070/9050	+ 2.0	4090/9070	+ 4.2
low:	4070/8050	- 3.9	4070/5570	- 0.8	4070/5570	- 5.5
extreme:	62.0-54.9=	7.1	65.3-58.9=	6.4	70.7-50.8=	19.9
Winter high:	8070/4050	- 1.3	4050/5650	-10.2		
low:	9050/7070	-13.5	8070/5670	-25.6	------------------	
extreme:	57.5-49.6=	7.9	50.0-37.7=	12.3		
VIAL # 4 SOIL SURFACE TEMPERATURE:						
Spring high:	9070/9050	+ 4.1	9070/8050	- 0.9	9050/5550	+ 2.4
low:	5570/5550	- 6.5	5650/8070	- 1.9	8050/9070	- 4.5
extreme:	67.3-51.5=	15.8	61.6-56.3=	5.3	62.1-53.3=	8.8
Summer high:	9070/9050	+ 5.5	5550/9050	+20.9	4090/4070 & 8070	+15.4
low:	4070/8070	+ 3.4	4070/5650	+ 4.1	8050/4050 & 5650	+17.0
extreme:	68.7-61.9=	6.8	81.4-65.5=	15.9	77.8-74.8=	3.0
Fall high:	9070/5670	- 4.2	8050/9050	+ 7.6	9070/5670	+ 7.5
low:	5570/5550	- 2.6	8070/5650	- 7.4	4090/4050	- 3.2
extreme:	59.0-55.4=	3.6	70.8-54.2=	16.6	66.3-59.2=	7.1
Winter high:	5570/5550	- 3.9	5670/4050 & 5550	-12.6		
low:	7070/9070	- 9.5	9070/9050	-22.4	------------------	
extreme:	54.1-49.7=	4.4	48.1-40.1=	8.0		

TABLE III-10, CONTINUED

	1966		1967		1968	
VIAL # 5 TEMPERATURE OF THE TOP SOIL:						
Spring high:	9070/9050	- 3.7	9070/5570	- 1.8	5650/5570	+ 0.5
low:	5570/8070	- 6.3	4070/5670	- 4.1	4050/4090	- 4.0
extreme:	61.1-52.5=	8.6	60.7-55.8=	4.9	62.4-51.4=	11.0
Summer high:	9070/9050	+ 9.1	5570/8070	+ 8.6	8050/9050	+18.1
low:	8070/4070	+ 3.7	5650/8050	+ 0.4	4070/5650	+14.5
extreme:	73.9-60.4=	13.5	69.8-59.5=	10.3	77.0-73.6=	3.4
Fall high:	9050/9070	- 1.5	9050/9070	+ 4.3	8050/9050	+ 9.0
low:	8070/5570	- 0.8	4050/5550	+ 0.3	5670/5570	- 0.1
extreme:	60.4-55.9=	4.5	65.7-60.1=	5.6	67.9-58.5=	9.4
Winter high:	9070/5650	-11.8	4050/5550 & 5650	-10.0		
low:	9050/5570	-12.1	5670/9070	-22.9	------------------	
extreme:	53.0-49.8=	3.2	49.8-37.1=	12.7		

* site denotes the ecological sites by code. The two sites with the highest and the two with the lowest temperatures are listed.

** Diff. Annual denotes the difference or deviation from the average annual temperatures for the given sites.

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IV. SEED GERMINATION, SEED AND CONE VARIATIONS OF REDWOOD

INTRODUCTION

Redwood produces annually large cone crops and plenty of seeds. Yet, there is a noticeable lack of natural regeneration of redwood upon the removal of the virgin stands. Most restocking of cutover areas seems to originate from sprout growth rather than from seedlings. These facts indicate the difficulties of establishing redwood by means of natural regeneration. Partly, the failure of natural regeneration has been blamed upon ecological factors such as: exposure, microclimatic factors and the absence of a suitable seed bed. Partly, the problem has been attributed to poor redwood seed germination.

Studies have been undertaken to determine the germination capacity of redwood seeds. Metcalf (1924) reported low germination rates varying from 4 to 33% with delayed germination sometimes up to 60 days from trials in the forest nursery at Scotia, California. Muelder & Hansen (1961) noted lack of cone crops in certain parts of the redwood region and defective embryos in redwood seed. Infections of the germinating embryos were attributed to an unknown pathogen, but they failed to isolate this pathogen. Berryman & Stark (1962) and Stark & Adams (1963) perfected the X-ray technique to determine the soundness of seeds. By using a 10 kilovolts X-ray unit and 20 seconds of exposure, they were able to procure suitable photonegatives of seeds to test their soundness without destroying the viability of the seed. Muelder & Hansen (1963) utilized the X-ray technique for their redwood seed studies. They reported that soundness of redwood seeds varied significantly with seed size. Seeds passing 12, 10 and 8 mesh screens were respectively 2, 8 and 15 per cent sound. Seeds from seven sources were analyzed by the X-ray technique, and the following distribution of seed categories was found: empty or tannin filled seeds, 58 to 97%; seeds with embryos damaged by fungi, 0 to 11%; and sound seeds, 1 to 32%. However, no seed weights were given. Roy (1964) attributed poor redwood germination to defective seed in his review. Boe (1968) attributed low germination rates to the high percentage of empty seed. If seed germination is determined as a percentage of sound seed, germination ranged from 75% to 94% with an average of 85%. Under his test conditions germination started within 5 to 8 days, with peak germination occurring in 7 to 12 days. No trends were observed among the various months in germination percentages. However, Boe's sample sizes in his tests ranged from 13 to 47 sound redwood seeds per dish (Boe, 1968). No seed weights were given, nor the condition of the seeds prior to testing.

Seed weights and germination percentages reported elsewhere in the forestry literature are listed in Table IV-1.

TABLE IV-1: SUMMARY OF REDWOOD SEED WEIGHT AND GERMINATION PERCENTAGES FROM A LITERATURE REVIEW

Author	Seed Weight (gr/100 seeds)	Germination Percentage	Peak of Germination
Fort Bragg (Davis 1930)	*	19 - 39%	14-21 days
Scotia (Wirt, 1926)	0.254-0.409	10 - 46%	30-35 days
Lott (1923)		1 - 20% ave.: 15%	*
Metcalf (1924)			
Humboldt	0.349	11 - 19.5%	up to 60 days
Mendocino	0.372	4 - 5%	
Marin, Sonoma, & Contra Costa	0.355	10 - 33%	
Santa Cruz	0.259	15%	
Merriam (1928)	*	*	14-21 days
Siggins, H. W. (1933)	0.740 (good seed)	*	*
Fritz (1950)	*	20 - 40%	*
Zinke (1960)	0.109-0.494 ave.: 0.252	*	*
Cameron (1960)	0.320-0.660 (1000 seeds)	6 - 22%	5-40 days
Muelder & Hansen (1963)	*	1 - 40% ave.: 15%	*
Boe (1968)	*	75 - 94% (sound seed)	7-12 days

* no record
Note: 1 lb. = 373.242 grams.

Numerous redwood seed germination trials have been undertaken by the author over the past nine years. The experiments can be classified into several categories. For convenience, the following categories are distinguished:

1. The effects of hydrogen peroxide upon redwood seed germination.
2. Preliminary investigations into the germination of redwood pollen.
3. Pollination studies of redwood.
4. Irradiation of redwood seeds.
5. Studies of seed viability by X-ray photography.
6. Effects of ovendrying upon redwood seed germination.
7. Effects of storage upon redwood seed viability.
8. Seasonal variation in redwood seed weight and germination.

Most of these studies have been undertaken by interested students during the past nine years and prior to the NSF sponsored research. Others have been stimulated by the NSF research to explore specific phases of redwood germination.

1. The Effects of Hydrogen Peroxide:

Delayed redwood germination has been reported by Metcalf (1924) up to 60 days. It was therefore, believed that seed dormancy may play a role in the reported low germination rates of redwood. Ching (1958), Shearer (1960), Dhillon (1961), and Trappe (1961) all reported the use of hydrogen peroxide (H_2O_2) to break the dormancy in Douglas fir and conifer seed. Presumably, hydrogen peroxide removes by oxidation the protective coating of the seed. Upon such treatment water can be more readily imbibed by the seed coat, thereby triggering rapid germination. Also, hydrogen peroxide can sterilize seed coats (Trappe, 1961), a very important fact in view of the reported pathogen damage by Muelder & Hansen (1963). To test this, redwood seeds were subjected to treatment of hydrogen peroxide in various concentrations.

Goggin & Simmons (1962) selected three seed sources from the Freshwater School Forest. Care was taken to collect unopened squirrel-cut green cones from individual trees. The cones were then dried at room temperature to open them and the seeds were subsequently oven-dried at 100°F for 24 hours, and its seed weight was determined. Four concentrations of hydrogen peroxide were tested: 3%, 10%, 20%, 30% and a control without H_2O_2 treatment. Five replications of each treatment were made, each replication containing at least a minimum of 100 seeds randomly selected from the entire seed lot. Each seed batch was placed in a petri dish containing a bottom of sterilized sand. The petri dish itself was also sterilized in an autoclave. The seeds were spread out on a piece of filter paper on top of the sand layer and thoroughly moistened with distilled water. The petri dishes were placed in a germination box which kept temperatures at a constant level of 75°F by heating coils. Germination was observed for 30 days under 100% relative humidity. Checks for germination were made every day throughout the 30-day germination period. Fungus growth in the petri dishes was checked by adding a 10% formaldehyde solution as a disinfectant. Seeds that germinated were periodically removed from the petri dish. Germination was determined as the percentage of the germinated seeds in terms of the total number of seeds.

The germination started after the first week and was completed within 18 days. The results are tabulated in Table IV-2.

TABLE IV-2: AVERAGE GERMINATION AND SEED WEIGHT OF HYDROGEN PEROXIDE TREATED REDWOOD SEEDS

Source*	Seed Weight (gr/100 seeds)	Control	Hydrogen Peroxide Concentration 3%	10%	20%	30%
			(percentage of germination)			
I	0.289	11	8	11	9	6
II	0.274	9	11	5	9	24
III	0.253	27	27	19	8	7

* Source I: Code 18--HSC School Forest, Freshwater, Calif. Nov. 14, 1961.
Source II: Code 19--HSC School Forest, Freshwater, Calif. Nov. 7, 1961.
Source III: Code 17--Simpson Timber Company, Korbel, Calif. Oct. 25, 1961.

The results indicated that, by using the Tukey test, the control and the 10% H_2O_2 treatments differed significantly from all the other treatments in seed source I. The greatest increase in germination for this seed source was in the lower H_2O_2 concentrations. For seed source II, the 30% concentration differed significantly from all the other treatments in source II. In this ource the highest H_2O_2 concentration had the greatest germination! In seed source III, the control, the 3%, and the 10% treatments differed significantly from the 20% and the 30% concentrations by the Tukey test. The lower H_2O_2 concentrations gave the highest germination.

An analysis of variance test was made to determine the significance of variation among the seed sources, H_2O_2 treatment levels and replications. The results of the analysis of variance are listed in the following tabulation:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio
Treatments (5)	4	544	136.00	5.397**
Sources (3)	2	933	466.50	18.512**
Replications (5)	4	206.93	51.73	2.053
Interactions				
Treatment x source	8	2475	309.38	12.277**
Treatment x replication	16	162.07	10.13	0.402
Source x replication	8	138.47	17.31	0.687
Treatm x source x replic	32	806.53	25.20	--------
Total (75)	74	5266		

** Significant at the 0.01 probability level.

This indicates that there are significant differences at the 0.01 probability level among treatments, seed sources and the interaction of treatment with seed source. Although the data are limited and the number of seed sources used include only sources of the Freshwater School Forest and Korbel areas, the above results indicate in general that hydrogen peroxide has a negative effect upon redwood seed germination. It should be further noted that no distinction was made between sound and cull seeds, but that fresh seeds were used.

2. Preliminary Investigations Into the Germination of Redwood Pollen:

Redwood flowers during the months of December and January, coinciding with the time period of the heaviest precipitation. Observations during 1966, 1968, 1969 and 1971 indicated that shedding of pollen occurs during warm and sunny days in the middle of the rainy season. When a light wind is blowing, light yellow dust clouds of pollen could be seen drifting down the tree crowns. Pollen is shed repeatedly under favorable weather conditions. Presumably, the pollen sacks close their pores during the rains, or the pollen becomes moist and somewhat sticky, preventing pollen loss during the rains. Upon drying by the heat of the sun, pollen shedding can start within hours following rain. It has been further observed that shedding of pollen coincided often with the time of shedding of seeds from the ripe cones. Often during light winds, a shower of seeds could be seen falling down from the tree tops. Cone scales will close during the rain, preventing seed drop. Seed drop repeats itself regularly during the sunny intervals within the rainy season.

Only a negligible amount of research has been conducted on pollen germination of redwood in the past. Experiments were undertaken to germinate redwood pollen under laboratory conditions and to determine the fertility of redwood pollen. Low pollen fertility could cause low viability of the seeds. Genetically, redwood is a polyploid species with a chromosome number of 66 which makes it a hexaploid with 6 sets of 11 chromosomes per cell (Stebbins, 1948; Darlington & Wylie, 1955). Polyploids are sometimes known to have low pollen fertility.

Initially, pollen grains were germinated on filter papers moistened with distilled water. Upon incubation for 120 hours at a temperature ranging from 20° to 30°C no pollen germination was observed. Apparently, all pollen grains ruptured their exine layer letting its content protrude through the crack, but no pollen tube growth was observed. This indicates that upon prolonged contact with water redwood pollen would burst without germination taking place. Low fertility of pollen may be attributed to pollen becoming too wet from rain prior to its proper germination.

Many substrates have been used for germination of pollen. Orr-Ewing (1959) used a two-per cent solution of Bacto-agar in petri dishes. Germination on filter paper or paraffin were suggested by Linder & Schwarzenbach (1959). Ching & Ching (1959) found that potassium salts of gibberellic acid at 10, 100 and 1,000 ppm caused significantly more pollen tube growth (1.5 times) than those grains not treated with gibberellin. Kaurov & Vakula (1961) also used gibberellic acid in a series of tests on pollen of 29 tree species and found that low concentrations (0.01 to 0.005 per cent) were favorable to the germinating capacity of some of the tree species. Pollen under the activity of gibberellic acid was marked by an earlier beginning of germination. Gershoy & Gabriel (1961) showed that sugar (type not stated) concentrations of 0.40 to 0.45 molar were optimal for germination of sugar maple pollen. Boron seems to be important to some species (Gershoy & Gabriel, 1961; Kaurov & Vakula, 1961). Chandler (1958), using pollen of Angiosperms, found that pollen tube growth is sensitive to temperature, moisture, sugar concentrations, pH, growth substances, and trace elements. The correct medium will produce pollen tubes within a few hours. Temperature seems to affect pollen tube growth with the higher temperatures (42°C) being generally more limiting than lower temperatures (16°C).

Only Shaw (1896) and Lawson (1904) have made detailed studies on the gametophytes of Sequoia sempervirens and described the full sequence of germination of redwood pollen: "At the time the pollen is shed there are two nuclei in each grain. One is centrally situated and is about two times the size of the other. The smaller nucleus is almost always found near the wall of the pollen grain. At this time, there appears to be a membrane between the two nuclei. The larger nucleus is the socalled tube-nucleus and the smaller one is the generative cell. The first indication of the start of germination of the pollen grain is the splitting of the hard, thick exine wall, leaving a thin, delicate membrane underneath. The pollen tube now pushes out over the apex of the nucellus, and one or two of the tubes may grow down between the nucellus and the integument.

"About the time the pollen tube penetrates the wall of the nucellus, the generative nucleus, having increased to about the size of the tube-nucleus, divides. There are now three nuclei in the tube, one large one and two smaller ones. The large one (situated near the tip) is the tube-nucleus and the other two smaller nuclei are the socalled stalk and body-nuclei. The larger of the latter two (=body-nucleus) appears to be preparing for further activity. During further development of the pollen-tube, the three nuclei remain in close proximity to each other. While these changes are occurring the size of the tube-nucleus remains the same while that of the stalk-nucleus increases slightly. The body-nucleus increases to at least three to four times the size of the stalk-nucleus.

During its development, the body-nucleus surrounds itself with a dense zone of granular cytoplasm which increases in thickness to approximately one half the diameter of the nucleus. It is now shut off from the rest of the cytoplasm in the tube by a distinct membrane and the tube now contains one large cell and two free nuclei."

Shaw (1896) stated that the pollen-tube quite often was observed to branch, one branch growing downward and the other branch taking any direction between the sporangium and the integument or even penetrating the epidermis of the sporangium. The above sequence of events of pollen germination was well illustrated by Lawson (1904).

According to Erdtman (1957) and Preston (1961), redwood pollen grains are monoporate and obovoid in shape. They measure 35 microns long, including the tenuitas or beak of 4 microns. The tenuitas is distal and covered with sparse pila. The pila average 0.5 microns in length. The exine wall is composed of an outer layer (the sexine) and an inner layer (the nexine). The exine is very resistant and is also sparsely covered with pila.

Bemis (1965) utilized pollen from nine different trees located in Prairie Creek State Park, Humboldt State College campus, the Freshwater School Forest, Humboldt Redwood State Park and the North Fork of the Big Sur River. Because redwood pollen tends to burst rather than germinate in watery solutions, Bemis (1965) used Bacto-agar substrates for pollen germination. Temperature effects were studied by germinating pollen grains in incubators at 10°C, 20°C, and 30°C for 71 hours. It was determined that the range between 20°C and 37°C would be optimum for redwood pollen germination. The greatest germination percentage was 64.8 at 20°C for the socalled "spruce-type" redwood. Biochemical effects upon pollen germination were tested by introducing a water extract of ground female conelets into the Bacto-agar plates. The extract was prepared utilizing all available young female conelets of all three phenotypes of redwood ("Taxus," "Spruce," and "Pine") (Becking, 1964). The petri dishes were incubated at a fluctuating temperature of 21.6°C to 25.5°C for 7 days. Periodically, pollen counts were made to record the germination progress. At the end of 7 days the germination percentage was determined. A pollen grain was considered germinated if the pollen tube length equaled or exceeded the widest portion of the ungerminated pollen grain. The field of the microscope was chosen at random. The total number of pollen grains and the number of germinated grains were counted. Ten replications of each petri dish were used to compute the average percentages. The results are listed in Table IV-3.

TABLE IV-3: REDWOOD POLLEN GERMINATION PERCENTAGES
OF NINE REDWOOD TREES (BEMIS)

	Substrate no extract		Substrate with hormonal extract	
	Per cent Germination	ave.		ave.
Spruce	0.26-0.00-0.26	0.17	0.12-0.00-0.00	0.04
Taxus	0.12-0.10-0.56	0.26	0.35-0.00-0.17	0.17
Pine	0.02-0.00-0.03	0.02	0.00-0.00-0.00	0.00

The analysis of variance did not indicate any significant differences in variance among sources, treatments, and replications.

The results indicated that introduction of the female conelet extract reduced the average germination by about 50%. The limited number of samples makes it difficult to draw any statistically valid conclusions. Other confounding factors not incorporated into the experiment include the degree of maturity of the pollen itself and the selective effect of hormonal extracts from the separate phenotypes. The above results may indicate that there is some difference in pollen germination among the phenotypes, and thereby segregating the phenotypes by pollination differences. It is indicated that no hormonal extract from the female conelets is needed to stimulate germination.

The same sequence of germination was observed by Bemis. By the end of the first day, 88% of the pollen grains had split off the exine layer. During the next 24-hour period the thin membrane enclosing the nucleus started to develop the pollen tube growth. During the next two days the germinating pollen tube pierced the thin membrane which enclosed the developing pollen tube. By the end of the fifth day the pollen tubes were fully developed. Many grains germinated and produced a second branch of the germinating tube. Often, the pierced membrane separated entirely from the developing pollen tubes and floated free from the grain. This usually occurred during the third and fourth day of germination. Some pollen grains that failed to germinate showed the membrane protruding from the pore of the tenuitas of the grain.

Difficulties in seed fertility may be attributed to the unique embryology of redwood. Buchholz (1939) and Looby & Doyle (1937) studied most recently its embryology and noted many unique developments. They listed as unique seed characteristics: 1. Archegonia develop laterally and continue to be more numerous towards the micropylar end of the seed. 2. Several gametophytes are present in the early stages of embryo development. All but one are aborted when the gametophyte becomes fully developed. 3. Pollen tubes develop laterally. All these unique characteristics are due to the polypolid nature of the reproductive cells in Sequoia sempervirens.

Looby & Doyle (1937) added that sterility of redwood seeds may be caused by: 1. pollen tends to ripen late in winter and in the cold and wet weather it never properly matures, or when mature it spreads badly, and 2. the shape and arrangement of cone scales and the presence of tannin granules obscuring the nicropyles, all prohibit pollination. Mirov & Baker (1942) estimated that there are about 60 archegonia per redwood seed, while in Pinus there are only two to three archegonia per seed. Many of these archegonia will become abortive.

3. Pollination Studies of Redwood:

Little information is available about the relationship of flowering habit and seed viability of redwood. Female conelets begin to appear in the first weeks of October. They are placed always terminal on branchlets bearing scale-like needles. Thus, they are convined to the tree top and the tips of the upper branches usually. The female strobili are initially erect when they are receptive for pollen in December and January. Fertilized conelets begin to droop in February and April. Cones gradually develop into size and are mature the following October.

Pollination, evidently, takes place in the middle of the rainy season, reducing the chance of the pollen grains to be carried by wind to the receptive female conelets. In comparison to other conifers such as Douglas fir (Pseudotsuga menziesii), Sitka spruce (Picea sitchensis), and Grand fir (Abies grandis), redwood is a sparse pollen producer. It would be safe to say that these conifers as wind pollinators produce abundant pollen in excess of 1,000 times more than redwood.

Staminate strobili are oblong and obtuse, about 6 to 10 mm long and 5 mm wide. They are terminal, and occur more often on lateral branches bearing normal needles. Male strobili are more abundant in the lower tree crown. The emission of pollen is usually empleted by the end of January, but this depends upon the weather conditions. Pollen shedding takes place only during warm and sunny periods in the rainy season with a light wind. The male strobili soon shrivel up in February and begin to drop out of the tree by May and June. Pollen germination studies (Bemis, 1965) have already been reported above.

The experiment is undertaken to see if poor pollination is correlated with poor seed viability by carrying artificial pollination of redwood conelets.

After an extensive reconnaissance in September 1963, Belletto (1964) selected several trees of about 40 to 50 years of age on the Humboldt State College campus for artificial pollination. These trees were selected for their past abundant, annual seed crops as well as accessibility by a hydraulic lift truck. The trees were observed weekly until the staminate flowers were emitting most of their pollen. Pollen of ripe staminate strobili was extracted and stored at -12°C for several days until used in the experiment. On January 29, 1964 a hydraulic lift truck was supplied by the Pacific Telephone Company, Eureka, California. Pollen was applied by a hand sprayer containing a mixture of distilled water and pollen. The size of the sprayer nozzle was predetermined by previous tests and a hole diameter of 0.04 inch seemed to be most advantageous.

Separate clusters of ripe female strobili were selected randomly in the lower portion of the tree crown. Ten clusters were intensively hand-sprayed with the pollen/distilled water mixture while ten other clusters were used as a control. After application the conelets were covered with perforated one-quart size plastic freezer bags tied firmly to the branch. Cone development was observed monthly. Female conelets developed favorably up to May 1, 1964.

On November 12, 1964 the female conelets treated January 29, 1964 were harvested by lift truck. Due to strong winds in August, 1964 many of the plastic bags were blown off the branches. Only 12 of the original 40 plastic bags were recovered. The cones were removed from their branchlets and information as to cone size, and fungal growth were recorded (Table IV-4). The plastic bags of the Men's Gym Tree were placed on the north side of the tree crown while those of the Baptist Church Tree were placed on the south side of the tree crown.

TABLE IV-4: CONE AND SEED GERMINATION OF THE ARTIFICIAL POLLINATION EXPERIMENT, HUMBOLDT STATE COLLEGE CAMPUS, ARCATA, CALIFORNIA

Treatment	# Cones Harvested	Length x Width (mm)	Cone Maturity	Total germination after 19 days
CODE 33	BAPTIST CHURCH TREE:			
# 21-O*	9	18 x 15	5 cones well-developed, 4 cones juvenile, no fungal growth, cones not opening	0.5%** (200 seeds)
# 22-O	6	14 x 11	3 cones well-developed, beginning to open, 3 juvenile cones, no fungal growth	1.0% (100 seeds)
# 23-O	8	19 x 15	8 cones well-developed, beginning to open, no fungal growth	0.5% (200 seeds)
# 40-O	5	18 x 15	5 cones well-developed, beginning to open, no fungal growth	0.0% (100 seeds)
# 26-P*	10	19 x 15	8 cones well-developed, beginning to open, 2 juvenile cones, no fungal growth	1.5% (200 seeds)

TABLE IV-4, CONTINUED

Treatment	# Cones Harvested	Length x Width (mm)	Cone Maturity	Total Germination after 19 days
# 29-P	13	16 x 14	9 cones well-developed, beginning to open, 4 juvenile cones, no fungal growth	3.0% (200 seeds)
Average:	8.5	17.3 x 13.9	Ave.: O-treatment Ave.: P-treatment	0.5% 2.8%
CODE 34 MEN'S GYM TREE:				
# 13-O	17	23 x 21	17 cones well-developed, beginning to open, no fungal growth	1.0% (100 seeds)
# 14-O	20	22 x 20	20 cones well-developed, beginning to open, fungal growth	0.0% (100 seeds)
# 18-O	27	24 x 20	27 cones well-developed, beginning to open, fungal growth	0.0% (200 seeds)
# 5-P	20	24 x 22	20 cones well-developed, beginning to open, fungal growth	3.0% (200 seeds)
# 17-P	19	20 x 19	19 cones well-developed, beginning to open, fungal growth	11.0% (100 seeds)
# 20-P	14	25 x 20	14 cones well-developed, rather green, seeds forced out between scales, no fungal growth	6.0% (200 seeds)
Average:	19.5	23.0 x 20.3	Ave.: O-treatment Ave.: P-treatment	0.3% 6.7%

* O: no hand-pollination
P: hand-pollination

** only mature cones were used for germination tests.

Considerable fungal growth was discovered within the plastic bags. Fungal growth was probably caused by the high relative humidity within the bags. Only conelets not infected visually by fungus and only fully developed cones beginning to open their scales were selected for germination tests. Standard germination test procedures were undertaken with the collected seeds. Seeds were treated with a 3 per cent chlorox solution as a fungal disinfectant. The average temperature of the germinator was 23.1°C, ranging from 24°C to 22°C.

No fungal growth developed during the germination tests. The first seed began to germinate on the seventh day and almost all the seeds did germinate by the tenth day. The germination test was concluded after 30 days. The total germination was very low for the total experiment ranging from 0% to maximum 11%. From the limited data in Table IV-3, it appears that on the average hand-pollinated seeds have a greater germination rate than non-pollinated seeds. However, natural seeds from both sources had also a reasonable germination rate (Table IV-5). The above results were termed inconclusive.

TABLE IV-5: GERMINATION TESTS OF HAND-POLLINATED CONELETS HUMBOLDT STATE COLLEGE CAMPUS, ARCATA, CALIFORNIA

	Baptist Church Tree HSC Campus			Men's Gym Tree HSC Campus		
	Average Germination Percentage					
	After 10 days	After 19 days	After 30 days	After 10 days	After 19 days	After 30 days
Artificial pollination of Jan. 29, 1964 & harvested Nov. 12, 1964	2.5 %	3.5 % (200 seeds)	4.5%	6.7%	6.7% (500 seeds)	6.7%
Non-pollinated cones bagged Jan. 29, 1964 & harvested Nov. 12, 1964	0.75%	0.75% (600 seeds)	0.9%	0.3%	0.3% (400 seeds)	0.3%
Natural seed collected Nov. 16, 1963	--	-- (200 seeds)	4.0%	--	-- (200 seeds)	0.0%
Natural seed collected Jan. 29, 1964	--	-- (200 seeds)	0.0%	--	-- (150 seeds)	2.5%

A second experiment of artificial pollination was carried out to study the possible effects of increased seed germination. In the 1964 experiment the additional effects of cross-pollination were taken into account. Autoplastic pollination was executed by artificial hand-pollination, utilizing the pollen of different trees of the same species. Homoplastic pollination was done utilizing the pollen of the same parent tree and may also be termed self-pollination. Two sources for autoplastic pollination were utilized: the pollen of each of the two parent trees and from trees of the Freshwater Forest area. Fresh pollen was collected on December 17, 1964 and stored at -12°C until used for the experiment. On January 22, 1965 the hand-pollination was carried out utilizing three different kinds of pollen plus a control.

On November 7, 1965 the conelets of the experiment were harvested and 23 plastic bags were recovered from the 40 bags initially placed on the two trees. The germination results again indicated that no conclusive results can be drawn from the data (Table IV-6). Apparently, there are numerous other variables involved in seed germination. Only an experiment on a much larger scale involving several parent trees could establish meaningful results. In addition, at the time of these tests little was known about redwood germination in general. With the improved knowledge the experiment should be undertaken again in a better manner. Seed germination should be followed up to nine weeks and only fresh seeds should be used. Conelets should be bagged prior to becoming receptive and plastic bags should be removed in March or April when the female conelets start to droop on their terminal branchlets after having lost all fertility to pollen. The other problem is to harvest a sufficient quantity of seed to obtain statistically valid results for germination testing.

TABLE IV-6: CONE AND SEED GERMINATION OF THE CROSS-POLLINATION EXPERIMENT HUMBOLDT STATE COLLEGE, ARCATA, CALIFORNIA

		# Seeds per cone	Seed wt. g/100 seeds	Weight/ Cone	# Scales/ Cone	Total Germination
CODE 33 BAPTIST CHURCH TREE, HSC CAMPUS:						
Nov. 16, 1963	XPB(2)	213.0	0.137	0.210	17.7	0
	XPG(5)	200.4	0.188	no data		0
	XPS(5)	226.6	0.156	0.258	19.3	0
	X O(3)	305.6	0.296	no data		0
CODE 34 MEN'S GYM TREE, HSC CAMPUS:						
Nov. 16, 1963	XPB(1)	80.0	0.458	0.740	23	0
	XPG(2)	149.0	0.352	0.419	19.6	0
	XPS(3)	256.3	0.269	no data		0
	X O(2)	100.0	0.316	0.594	25	0

4. Irradiation of Redwood Seeds:

Redwood seed, freshly collected November 1, 1963 from a tree in the Freshwater School Forest (Code 29), was extracted from the unopened cones and prepared for shipment to be irradiated with a gamma source. The average seed weight of the source was determined as 0.250 g/100 seeds with a $s_{\bar{x}} = + 0.0157$ g. The redwood seeds were ovendried for extraction from the cones for 48 hours at 100°F temperature. On November 18, 1963 the seeds were sent to the Biological Research Center, General Electric Company, Hanford, Washington. Samples of 100 seeds each were subjected to various gamma radiation dose rates indicated as follows:

Sample #	Dose Rate	Time of Exposure (minutes)
1	Control	0.0
2	50 r	0.2
3	100 r	0.4
4	500 r	2.0
5	1000 r	4.0
6	1500 r	6.0
7	2000 r	8.0

The dose rate was calibrated using a Victoreen Ionization Meter, and using 100 r and 250 r calibrated chambers for the irradiation experiment. The seeds were placed 12 inches from the head of the X-ray machine with a calibrated dose rate of 250 r/min.

The irradiated seeds were subsequently germinated in petri dishes under standardized temperature and relative humidity conditions for 30 days. No germination, even of the control, was observed which left the experiment inconclusive. The normal germination rate of the redwood seed source determined previously was 0.12 to 0.33%. Possibly, conditions during shipment of the seeds had negatively affected the germination. Unfortunately, the 30-day observation period may have been too short; the observed peak germination in later germination trials of this source occurred in the sixth to eighth week interval.

5. Studies of Seed Viability by X-ray Radiography:

The application of radiography to live seeds has been advocated by Berryman & Stark (1962), Hansen & Muelder (1963) and Gius (1961). The X-ray negative helps in identifying the soundness of the seeds as well as the presence of parasites within the seed.

For the current experiment six different seed sources in Humboldt County were selected for radiography. Six cones were randomly chosen from each source; cone ovendry weight and number of seeds extracted per cone were noted. The seeds were further ocularly screened into two size classes: Class A of seeds 5 x 5 mm in size or larger; and Class B of seeds 4 x 4 mm in size or smaller. Passing seeds through mesh screens did not give satisfactory results. The seeds were mounted by means of scotch tape in rows on stiff drawing paper and sent to the University of California at Berkeley for radiography. Exposures of 8 x 10-inch Kodak Industrial

Type AA film were made with a Picker 5-35 kv portable unit at 11 kv, 10 ma for 25 seconds at a distance of 50 cm from the source head. Satisfactory contrast was obtained at a very low dose rate so that the redwood seeds were practically unharmed. Muller-Olsen et al (1956) stated that in their studies of seeds the small dosages of 12 kv, 25 ma at 25 cm from the source was found to be absolutely harmless. An even lower dosage was used in this study. Hansen & Muelder (1963) using the same X-ray unit on the Berkeley campus reported no abnormal behavior from this kind of radiography.

Exposures varied generally depending upon the density of the seeds and the mounting paper from 10 to 12 seconds using 10 to 13 kv and 10 milleamperes. Seeds on the photo-negative were stratified into three categories: 1.) sound seed with a well-developed and dense embryo occupying over 80% of the seed; 2.) seeds with a deformed or defective embryo. The embryo does not occupy 80% or more of the seed, or is deformed, or is less dense. Often embryos occupied only less than 50 % of the seed. 3.) Empty seeds, usually tannin-filled. Seed counts were executed for each seed class and category. The results are tabulated in Table IV-7.

Some 100 seeds of each class and category were selected for germination. They were germinated in four replicate lots of 25 seeds each. Germination started on March 25, 1964 and was terminated on May 4, 1964 after some six weeks. Unfortunately, none of the seeds germinated. Initially, this was attributed to some defective procedure. Later, it was concluded that redwood seeds stored from November, 1963 to March, 1964 most likely would have lost all their germinative capacity. The experiment should be repeated with fresher seeds. The normal germination percentage of the sources varies from 0% to 4% on the average. Most likely, an insufficient number of seeds have been tested.

It is therefore, unfortunate that no comparative germination percentages could be established among the classes and categories. Boe (1968) reported 75% to 94% germination rates for sound seed, while Muelder & Hansen (1963) reported 100% germination of their best seeds. The current tests indicate no germination at all, even of sound seed. No seed weights were reported by Boe (1968) or by Muelder & Hansen (1963). Muelder & Hansen did not observe loss of seed viability from improper storage. No seed weights were determined in our experiment because of great difficulties in separating the seeds from the scotch tape.

Our results indicate that there are significant differences among the various seed sources, while the variation within each source was only minor as compared with the variance among sources (see Table IV-7). Some seed sources have 80% to 93% of their seeds in the 5 x 5 mm class, while others have only 24% in the same class. The smaller seed class of 4 x 4 mm have a preponderance of empty seeds. Muelder & Hansen (1963) analyzed their seed sources from Mendocino County according to soundness also. Their results are compared with our six Humboldt County sources in Table IV-8. It is evident that similar trends were observed. It is interesting to note the high percentage of empty or tannin-filled seeds (82%) of the Mendocino sources. However, there is a greater amount of defective seeds in Humboldt County. Muelder & Hansen (1963) indicated that loss of viability is caused by an unknown pathogen attacking and destroying the developing embryo. Both in Mendocino and Humboldt Counties only 13% to 20% of all the seeds were considered to be sound.

TABLE IV-7: SEED VIABILITY FROM X-RAY ANALYSIS OF SIX REDWOOD SEED SOURCES

	Cone Ovendry Weight (g)	Total Seeds per cone (#)	Large Seeds 5 x 5 mm (1) full	(2) defective	(3) empty	Total	Small Seeds 4 x 4 mm (1) full	(2) defective	(3) empty	Total
			Percentage of Total							
	CODE 31: FRESHWATER FOREST E $\frac{1}{16}$ $\frac{28}{33}$ NOVEMBER 1, 1963									
	1.091	160	0.331	0.443	0.125	0.900	0.013	0.063	0.019	0.094
	0.803	127	0.346	0.472	0.094	0.913	0.008	0.047	0.031	0.087
	0.650	119	0.227	0.353	0.101	0.697	0.067	0.134	0.101	0.303
	0.875	142	0.289	0.282	0.204	0.782	0.007	0.119	0.092	0.218
	0.842	164	0.256	0.280	0.098	0.634	0.055	0.159	0.152	0.366
	0.802	142	0.246	0.331	0.310	0.880	0.007	0.007	0.113	0.127
Ave:	0.844	142	0.283	0.360	0.155	0.801	0.026	0.088	0.085	0.199
	CODE 30: FRESHWATER FOREST E $\frac{1}{16}$ $\frac{28}{33}$ November 1, 1963									
	0.998	143	0.175	0.615	0.154	0.944	0.000	0.014	0.042	0.056
	0.852	105	0.282	0.225	0.408	0.915	0.000	0.028	0.056	0.085
	1.203	127	0.145	0.201	0.614	0.960	0.000	0.024	0.016	0.040
	1.100	125	0.081	0.163	0.715	0.959	0.000	0.000	0.041	0.041
	0.844	129	0.147	0.279	0.434	0.860	0.000	0.023	0.116	0.139
	0.938	115	0.174	0.270	0.513	0.957	0.000	0.009	0.034	0.043
Ave:	0.989	125	0.167	0.292	0.473	0.933	0.000	0.016	0.051	0.067
	CODE 33: HSC CAMPUS BAPTIST CHURCH TREE, NOVEMBER 16, 1963									
	0.279	83	0.024	0.096	0.048	0.169	0.024	0.036	0.771	0.831
	0.352	87	0.000	0.069	0.287	0.356	0.000	0.069	0.575	0.644
	0.281	69	0.087	0.058	0.058	0.203	0.145	0.058	0.565	0.797
	0.345	75	0.000	0.147	0.120	0.267	0.040	0.293	0.400	0.733
	0.388	67	0.134	0.060	0.119	0.313	0.045	0.045	0.597	0.687
	0.416	67	0.030	0.090	0.030	0.149	0.030	0.134	0.687	0.851
Ave:	0.344	75	0.046	0.087	0.110	0.243	0.047	0.106	0.599	0.757
	CODE 34: HSC CAMPUS MEN'S GYM TREE, NOVEMBER 16, 1963									
	0.880	108	0.315	0.333	0.352	1.000	0.000	0.000	0.000	0.000
	0.963	115	0.252	0.304	0.365	0.922	0.009	0.009	0.061	0.078
	0.687	101	0.089	0.317	0.337	0.743	0.000	0.069	0.188	0.257
	0.797	101	0.168	0.436	0.356	0.960	0.020	0.010	0.010	0.040
	0.674	101	0.228	0.396	0.356	0.980	0.000	0.010	0.010	0.020
	0.714	93	0.344	0.376	0.215	0.935	0.043	0.011	0.011	0.065
Ave:	0.785	103	0.233	0.360	0.330	0.923	0.012	0.018	0.047	0.077

TABLE IV-7; CONTINUED

PRAIRIE CREEK STATE PARK, ORICK, NOVEMBER 17, 1963

	0.524	80	0.138	0.225	0.050	0.413	0.025	0.038	0.525	0.587
	0.531	93	0.140	0.344	0.108	0.591	0.000	0.075	0.333	0.409
	0.645	124	0.185	0.355	0.105	0.645	0.032	0.105	0.218	0.355
	0.550	108	0.167	0.241	0.074	0.481	0.028	0.120	0.361	0.509
	0.349	81	0.000	0.259	0.037	0.296	0.074	0.148	0.481	0.704
	0.430	79	0.127	0.114	0.076	0.316	0.089	0.253	0.342	0.684
Ave:	0.505	94	0.126	0.256	0.075	0.457	0.041	0.123	0.377	0.541

PRAIRIE CREEK STATE PARK, ORICK, NOVEMBER 17, 1963

	0.476	111	0.099	0.108	0.261	0.468	0.018	0.045	0.468	0.532
	0.800	144	0.229	0.333	0.215	0.778	0.028	0.028	0.167	0.222
	0.427	103	0.117	0.126	0.107	0.350	0.019	0.019	0.612	0.650
	0.474	88	0.170	0.159	0.136	0.466	0.100	0.034	0.500	0.534
	0.585	89	0.337	0.292	0.067	0.697	0.000	0.034	0.270	0.303
	0.608	121	0.107	0.438	0.207	0.769	0.025	0.025	0.182	0.231
Ave:	0.562	109	0.177	0.243	0.166	0.588	0.015	0.031	0.367	0.412

TABLE IV-8: COMPARATIVE SOUNDNESS OF SEEDS BY RADIOGRAPHY FROM MENDOCINO AND HUMBOLDT COUNTIES, CALIFORNIA

Source Location	Fully Sound	Infected or Defective Embryos	Empty or Tannin-filled Seeds
		Percentage	
MENDOCINO COUNTY			
South Fork, Noyo River (1961)	0.19	0.11	0.70
Horsetail Ridge (1961)	0.10	0.03	0.87
Jackson State Forest	0.32	0.10	0.58
Pudding Creek (1959)	0.10	0.03	0.87
Pudding Creek (1960)	0.01	0.00	0.99
Ukiah (1959)	0.19	0.03	0.78
Ukiah (1960)	0.02	0.03	0.95
Average	0.133	0.047	0.820
HUMBOLDT COUNTY			
Code 31 Freshwater Forest (1963)	0.31	0.45	0.24
Code 30 Freshwater Forest (1963)	0.17	0.31	0.52
Code 33 HSC Campus (1963)	0.09	0.20	0.71
Code 34 HSC Campus (1963)	0.24	0.38	0.38
* Prairie Creek State Park (1963)	0.17	0.38	0.45
* Prairie Creek State Park (1963)	0.19	0.27	0.54
Average	0.195	0.332	0.473

6. Effects of Ovendrying Upon Redwood Seed Germination:

Seed germination tests were run on seeds collected monthly in litter traps in the virgin redwood forests of Humboldt Redwoods State Park, Weott, California. The seed traps were located at different sites related to their ecological effects and past flooding history. Seasonal weight changes in the collected redwood seeds were noted, and significant weight differences among the selected sites had been noted previously (Becking, 1968).

Initially, seed collected in the seed traps were ovendried before determining their weight per 100 seeds. However, starting with January, 1969 seeds collected in seed traps were divided into two equal lots, one lot being germinated as fresh seeds without ovendrying and heating, and the other lot with ovendrying for 48 hours at 100°F. Separate records were kept of the differences in germination. Germination was observed for a period of six weeks.

In January, 1969, fresh seed weights were determined but they proved to be very erratic. Some of the fresh weights were very close to the ovendry weights, indicating that the seeds had dried out very well in the field while adjacent seed traps had moister seeds. There were no consistent patterns in weight. Determination of seed freshly extracted from ripe cones showed a weight loss of 158% moisture of the ovendry weight basis. However, such fresh weights can be determined rarely from field collections. Therefore, no fresh weights were determined later. Only ovendry seed weights were measured for the lots that were ovendried. The results of tests run for the four consecutive seasons of 1969 are listed in Table IV-9.

Considerable variation exists among the different seasons and different sites with few consistent patterns emerging from the data. On the alluvial flats ovendry seed has a better germination percentage than fresh seed in comparable paired tests. Practically all germination occurred in the winter (Nov-Dec-Jan) season and the spring (Feb-Mar-Apr) season. No germination was observed during the summer (May-June-July) and fall (Aug-Sep-Oct) seasons. There were only two exceptions to this. The ovendry weight decrease per 100 seeds is consistent among all alluvial flats. On the lower slopes in the one instance that germination occurred there was a significant better germination percentage among the fresh seeds than among the ovendry seeds. The same trend is accentuated on the middle slope positions. Seed weight per 100 seeds on lower and middle slopes followed a similar weight reduction from the winter to the fall season, but its reduction was less than for the alluvial flats.

The Woody Plant Seed Manual*(1948) indicated improved germination of some seed lots after stratification for 60 days at cold temperatures (41°F). Otherwise, heat seems to be a favorable pretreatment of redwood seeds prior to germination. Fritz (1950) and others have indicated that heat and moisture are essential for germination with too much moisture resulting into fungal attack of the seeds. Gius (1961) noted that ripe cones subjected to higher temperatures (terminal cones) had a higher proportion of tannin-filled seeds or empty seeds. Presumably, high temperatures affect developing seeds and embryos negatively based upon this evidence. Siggins (1933)

* U. S. Forest Service

TABLE IV-9: SEASONAL VARIATION OF SEED GERMINATION AND SEED WEIGHT OF REDWOOD, COLLECTED IN LITTER TRAPS, HB01 - HB08, HUMBOLDT REDWOODS STATE PARK, WEOTT, CALIFORNIA**

Season	Fresh Seed Germination Rate at 6 wks. %	Ovendry Seed Seed Weight gr/100 seeds	Ovendry Seed Germination Rate at 6 wks. %
FLATS FLOODED 1964, 1966, 1968			
Winter 1969	0.00	0.312	0.02
Spring 1969	0.01	0.294	0.30
Summer 1969	no data	no data	
Fall 1969	0.00	0.175	0.00
FLATS FLOODED 1964			
Winter 1969	0.02	0.444	0.04
Spring 1969	0.04	0.293	0.00
Summer 1969	0.01	0.215	0.00
Fall 1969	no data	0.209	0.00
FLATS NOT FLOODED			
Winter 1969	0.00	no data	
Spring 1969	0.00	no data	
Summer 1969	0.00	no data	
Fall 1969	no data	0.188	0.00
LOWER SLOPES			
Winter 1969	0.00	0.286	0.00
Spring 1969	0.45	0.327	0.14
Summer 1969	0.00	0.217	0.00
Fall 1969	no data	0.218	0.00
MIDDLE SLOPES			
Winter 1969	1.07	0.267	1.09
Spring 1969	25.00	0.221	0.00
Summer 1969	0.33	no data	
Fall 1969	no data	0.195	0.16

** Data pertain only to those seed trap collections which were split into two lots of equal number of seeds, one lot germinated with fresh seed, the other lot after ovendrying the seed.

noted that not all the cones on the same tree ripened at the same time. Cones subjected to higher temperatures reached maturity at a faster rate. These two heat or temperature effects play a role upon seed formation and ultimately, of course, upon total germination.

The results of our experiments cannot be termed conclusive because of the great inherent variability of redwood germination. There is strong evidence that genetic and ecological differences as well as seasonal differences affect germination, which makes it difficult to assess the importance of ovendrying or heat. However, currently there are no indications that ovendrying would affect redwood seed germination negatively. On the contrary, there is limited evidence that among the sources tested ovendrying may even improve germination.

7. Effects of Storage Upon Redwood Seed Germination:

There are conflicting reports of the effects of seed storage upon the viability of redwood seed. The Woody Plant Seed Manual (1948) reports that redwood seeds kept in a sealed bottle at 26° to 30°F lost about half of its viability at the end of one year, and deteriorated rapidly upon removal from cold storage. Another test showed fair viability at the end of 10 years of cold storage. Fritz (1950) claimed practically no loss in viability due to storage within one year.

Litter trap data of seed germination (Becking, 1968) indicated a decided decrease in germination percentage from the winter to the fall season. In other words, the freshest and heaviest seeds showed consistently the greatest germination. Many field observations were made to substantiate this. During the winter and spring rains, particularly after a week of higher temperatures, many sprouting redwood seeds could be observed among the litter and on rotten logs within the virgin redwood forest. As a general rule, there seems to be no dormancy or delay in germination once conditions of temperature and moisture are adequate for germination. This can be further exemplified by finding often dropped redwood cones on the forest floor with sprouting seeds still in their scales. This was also noted by Linhart & Libby (1965).

Seed sources stored for one to three years in sealed plastic bags under normal room temperatures lost all their germination potential in extensive trials involving some 26 sources. The cause of this decline in germination cannot be fully explained. It would require detailed physiological studies of seed biochemistry of redwood seed. It is, however, fair to say that under normal field conditions redwood seeds would have lost all their germination potential within one growing season.

8. Seasonal Variation in Redwood Seed Weight and Germination:

Becking (1968) reported a consistent and marked seasonal decline in seed weight for seeds collected by litter traps in the Humboldt Redwoods State Park, Weott, California area. Litter trap collections have extended almost over a 4-year period. The data of seed weight and germination rates are summarized in Table IV-10.

TABLE IV-10: GERMINATION PERCENTAGE AND SEED WEIGHT OF REDWOOD SEEDS COLLECTED IN LITTER TRAPS, HUMBOLDT REDWOODS STATE PARK, WEOTT, CALIFORNIA

January 26, 1966 to January 5, 1968

Season	Ovendry Seed Weight (gr/100 seeds)	Total %	Ovendry Seeds Germination Percentage At end of week: #1	#2	#3	#6	#9
ALLUVIAL FLATS FLOODED 1964 & 1966, (1968)							
Jan. 26 - Feb. 16, 1966	0.6397	3.69			no data		
Feb. 16 - Apr. 8, 1966	0.4374	0.00	---	---	---	---	---
Apr. 8 - July 11, 1966	0.3304	0.00	---	---	---	---	---
July 11 - Oct. 8, 1966	0.3302	0.00	---	---	---	---	---
Oct. 8 - Dec. 8, 1966	0.3304	0.00	---	---	---	---	---
Dec. 8 - Feb. 2, 1967	0.6390	0.00	---	---	---	---	---
Feb. 2 - Apr. 8, 1967	0.3289	0.00	---	---	---	---	---
Apr. 8 - Sep. 30, 1967	0.3505	0.00	---	---	---	---	---
Sep. 30 - Jan. 5, 1968	0.3508	5.29	0.00	3.80	1.49	0.00	0.00
Jan. 5 - Mar. 26, 1968	0.3303	0.00	---	---	---	---	---
Mar. 26 - July 2, 1968	0.2600	0.00	---	---	---	---	---
July 2 - Nov. 2, 1968	--	1.48	0.00	0.00	1.48	0.00	0.00
Nov. 2 - Jan. 4, 1969	0.3531	0.54	0.00	0.46	0.07	0.01	0.00
Jan. 4 - Apr. 19, 1969	0.5857	3.37	0.87	1.84	0.00	0.66	0.00
Apr. 19 - July 1, 1969	--	0.00	---	---	---	---	---
July 1 - Sep. 28, 1969	0.2158	0.00	---	---	---	---	---
Discontinued							
Average 1966	0.4145	0.74			no data		
Average 1967	0.4173	1.32	0.00	0.95	0.37	0.00	0.00
Average 1968	0.3145	0.51	0.00	0.12	0.39	0.00	0.00
Average 1969	0.4008	1.12	0.29	0.61	0.00	0.22	0.00
FLATS FLOODED 1964 ONLY							
Jan. 26 - Feb 16, 1966	0.7583	8.95			no data		
Feb. 16 - Apr. 8, 1966	0.3285	0.38	0.00	0.00	0.05	0.33	0.00
Apr. 8 - July 11, 1966	0.3123	0.00	---	---	---	---	---
July 11 - Oct. 8, 1966	0.3505	1.01	0.00	0.00	0.32	0.70	0.00
Oct. 8 - Dec. 8, 1966	0.3508	0.95	0.38	0.43	0.08	0.05	0.00
Dec. 8 - Feb. 2, 1967	0.7401	2.63	1.13	0.70	0.03	0.77	0.00
Feb. 2 - Apr. 8, 1967	0.3294	0.06	0.02	0.03	0.01	0.00	0.00
Apr. 8 - Sep. 30, 1967	0.3507	0.02	0.00	0.00	0.02	0.00	0.00
Sep. 30 - Jan. 5, 1968	0.3505	2.24	0.63	1.09	0.37	0.15	0.00

TABLE IV-10, CONTINUED

Season	Seed Weight	Total %	% at end of week: #1	#2	#3	#6	#9
Jan. 5 - Mar. 26, 1968	0.3291	0.12	0.00	0.10	0.00	0.03	0.00
Mar. 26 - July 2, 1968	0.4044	0.00	----	----	----	----	----
July 2 - Nov. 2, 1968	--	0.96	0.00	0.88	0.03	0.05	0.00
Nov. 2 - Jan. 4, 1969	0.2607	0.62	0.13	0.34	0.05	0.12	0.00
Jan. 4 - Apr. 19, 1969	0.2788	0.63	0.36	0.27	0.00	0.00	0.00
Apr. 19 - July 1, 1969	0.3367	0.00	----	----	----	----	----
July 1 - Sep. 28, 1969	0.2269	0.05	0.00	0.00	0.04	0.01	0.00
Discontinued							
Average 1966	0.4201	2.26	0.08	0.09	0.09	0.36	0.00
Average 1967	0.4427	1.24	0.45	0.46	0.11	0.23	0.00
Average 1968	0.3314	0.43	0.03	0.33	0.02	0.00	0.00
Average 1969	0.2808	0.23	0.12	0.09	0.01	0.00	0.00
FLATS NOT FLOODED							
Jan. 26 - Feb. 16, 1966	0.6865	6.00			no data		
Feb. 16 - Apr. 8, 1966	0.3538	1.52	0.00	0.00	0.76	0.76	0.00
Apr. 8 - July 11, 1966	0.3503	0.00	----	----	----	----	----
July 11 - Oct. 8, 1966	0.3506	0.00	----	----	----	----	----
Oct. 8, - Dec. 8, 1966	0.3508	0.00	----	----	----	----	----
Dec. 8 - Feb. 2, 1967	0.7395	0.00	----	----	----	----	----
Feb. 2 - Apr. 8, 1967	0.3333	0.00	----	----	----	----	----
Apr. 8 - Sep. 30, 1967	0.3512	0.00	----	----	----	----	----
Sep. 30 - Jan. 5, 1968	0.3521	0.00	----	----	----	----	----
Jan. 5 - Mar. 26, 1968	--	----	----	----	----	----	----
Mar. 26 - July 2, 1968	--	----	----	----	----	----	----
July 2 - Nov. 2, 1968	--	----	----	----	----	----	----
Nov. 2 - Jan. 4, 1969	--	----	----	----	----	----	----
Jan. 4 - Apr. 19, 1969	--	----	----	----	----	----	----
Apr. 19 - July 1, 1969	--	----	----	----	----	----	----
July 1 - Sep. 28, 1969	0.2800	----	----	----	----	----	----
Discontinued							
Average 1966	0.4184	0.00	----	----	----	----	----
Average 1967	0.4440	0.00	----	----	----	----	----
Average 1968	--	----	----	----	----	----	----
Average 1969	0.2800	0.00	----	----	----	----	----

TABLE IV-10, CONTINUED

Season	Seed Weight	Total %	% at end of week: #1	#2	#3	#6	#9
LOWER SLOPE							
Jan. 26 - Feb. 16, 1966	0.7591	0.00	no data				
Feb. 16 - Apr. 8, 1966	0.2566	0.12	0.00	0.00	0.00	0.12	0.00
Apr. 8 - July 11, 1966	0.3814	0.00	----------				
July 11 - Oct. 8, 1966	0.4136	0.00	----------				
Oct. 8 - Dec. 8, 1966	0.4134	0.27	0.07	0.07	0.00	0.13	0.00
Dec. 8 - Feb. 2, 1967	0.2567	1.36	0.55	0.32	0.01	0.48	0.00
Feb. 2 - Apr. 8, 1967	0.2614	0.26	0.00	0.24	0.02	0.00	0.00
Apr. 8 - Sep. 30, 1967	0.3483	0.07	0.00	0.00	0.00	0.00	0.07
Sep. 30 - Jan. 5, 1968	0.4136	2.23	0.00	0.78	1.28	0.17	0.00
Jan. 5 - Mar. 26, 1968	0.2896	0.05	0.00	0.00	0.00	0.05	0.00
Mar. 26 - July 2, 1968	0.3960	0.00	----------				
July 2 - Nov. 2, 1968	--	1.07	0.00	1.07	0.00	0.00	0.00
Nov. 2 - Jan. 4, 1969	--	0.00	----------				
Jan. 4 - Apr. 19, 1969	0.2853	3.79	1.27	1.65	0.87	0.00	0.00
Apr. 19 - July 1, 1969	0.2175	0.00	----------				
July 1 - Sep. 28, 1969	0.2251	0.05	0.00	0.05	0.00	0.00	0.00
Discontinued							
Average 1966	0.4446	0.08	0.01	0.01	0.00	0.05	0.00
Average 1967	0.3200	0.98	0.14	0.34	0.33	0.16	0.02
Average 1968	0.3428	0.28	0.00	0.27	0.00	0.01	0.00
Average 1969	0.2426	1.28	0.42	0.57	0.29	0.00	0.00
MIDDLE SLOPE							
Jan. 26 - Feb. 16, 1966	0.7968	9.40	no data				
Feb. 16 - Apr. 8, 1966	--	----------					
Apr. 8 - July 11, 1966	0.2825	0.00	----------				
July 11 - Oct. 8, 1966	0.2656	0.00	----------				
Oct. 8 - Dec. 8, 1966	0.2655	1.26	0.00	1.05	0.00	0.21	0.00
Dec. 8 - Feb. 2, 1967	--	3.64	2.58	0.91	0.15	0.00	0.00
Feb. 2 - Apr. 8, 1967	0.2896	0.00	----------				
Apr. 8 - Sep. 30, 1967	0.2655	0.00	----------				
Sep. 30 - Jan. 5, 1968	0.2655	2.43	1.82	0.15	0.46	0.00	0.00
Jan. 5 - Mar. 26, 1968	0.2894	0.99	0.00	0.20	0.59	0.20	0.00
Mar. 26 - July 2, 1968	0.3240	0.00	----------				
July 2 - Nov. 2, 1968	--	----------					
Nov. 2 - Jan. 4, 1969	--	0.96	0.27	0.72	0.00	0.00	0.00

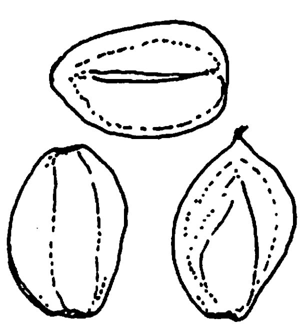
TABLE IV-10, CONTINUED

Season	Seed Weight	Total %	% at end of week: #1	#2	#3	#6	#9
Jan. 4 - Apr. 19, 1969	0.2165	17.84	8.33	9.51	0.00	0.00	0.00
Apr. 19 - July 1, 1969	--	0.33	0.00	0.00	0.00	0.33	0.00
July 1 - Sep. 28, 1969	0.2132	0.34	0.00	0.00	0.00	0.34	0.00
Discontinued							
Average 1966	0.4026	2.13	0.00	0.21	0.00	0.04	0.00
Average 1967	0.2735	1.52	1.10	0.27	0.15	0.00	0.00
Average 1968	0.3067	0.49	0.07	0.23	0.15	0.05	0.00
Average 1969	0.2149	6.17	2.78	3.17	0.00	0.22	0.00

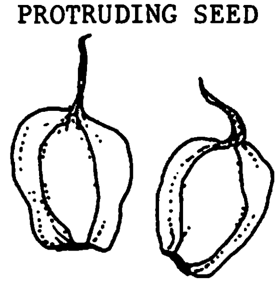
The same consistent trends in weight decline can be observed among the different ecological sites and the seasons. It is obvious that seed production, seed weight and germination capacity of the seeds are functions of tree vigor. Over the past four years the trees on the frequently flooded alluvial flats have declined markedly in vigor (Becking, 1968), and many have even died upon repeated flooding and siltation. Seed production, seed weights and germination rates have also declined in the same relation as tree vigor. It is noteworthy that seed weights on the middle slopes and lower slopes still seem to be superior to those on the adjacent alluvial flats. This supports a previous supposition (Becking, 1967) that the greatest vigor of redwood trees is not on the alluvial flats, but on the adjacent lower slopes.

An interesting observation has been made repeatedly by studying ripening redwood cones. When the green cones have reached their full length by the end of June, the green scales begin to swell and the terminal ends of the scales become thickened. Seeds begin to protrude between the scales and seem to be squeezed out. The seeds are light greenish brown in color when they become exposed. Several seed sources in the Arcata and Scotia area exhibited this phenomenon. Two trees were sampled: the HSC Campus, Baseball Field Tree (code 140) on July 14, 1968, and a redwood tree at Scotia, California (code 141) on June 30, 1968. Exposed seeds were harvested and categorized into normal and deformed seeds. Definitely deformed seeds are smaller and odd in shape. The averages are listed in Table IV-11.

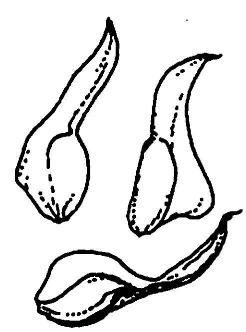
PROTRUDING SEED



Normal Seed



Seed + Mucro



Deformed Seed

TABLE IV-11: PROTRUDING NORMAL AND DEFORMED SEEDS OF IMMATURE REDWOOD CONES, SEED WEIGHT AND GERMINATION

	HSC Baseball Field Arcata, Calif. Code 140	Highway 101 Tree Scotia, Calif. Code 141
	Values Per Cone	
PROTRUDING SEEDS		
Average normal seeds (protruding)	12.6	6.3
Average deformed seeds (protruding)	3.8	1.0
Standard error:		
normal seeds	0.88	0.69
deformed seeds	0.91	0.21
Average # seeds/ cone:	154	83
Germination % after 9 weeks:*	0%	0%
Fresh wt. (g/100 seeds)	0.1972	0.2205
Ovendry wt. (g/100 seeds)	0.1484	0.1652
% moisture of fresh seed	125%	153%

* The protruding seeds were probably immature because none germinated among 200+ seeds.

	HSC Baseball Field Arcata, Calif. Code 140	Highway 101 Tree Scotia, Calif. Code 141
NORMAL MATURE SEEDS		
Germination % after 9 weeks:	0.00 to 1.00%	0%
Ovendry wt. (g/100 seeds)	0.1904	0.1652
Average # seeds/cone	149-154	83
Ovendry wt. of cone	0.788	0.665
Fresh wt. of cone	3.131	no data

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V. SEASONAL LITTER AND SEED FALL HUMBOLDT REDWOODS STATE PARK, WEOTT, CALIFORNIA

January, 1968 - September, 1969

Litter and seed fall records from Janurary, 1966 to January, 1968 already have been reported in the NSF GB # 4690 report (Becking, 1967).

The flats repeatedly flooded in 1964, 1966 and 1968 are generally declining in vigor, and litter fall is reducing as well as seed fall. The production of cones is gradually reducing and seed viability is practically nil.

The flats flooded only in 1964 and only partly in 1968 are showing signs of somewhat declined vigor. Litter and seed fall is lower and probably approaching normal rates. The initial litter and seed production increased substantially following the 1964 floods and are now gradually leveling off. A somewhat greater amount of seeds/m^2 fall in the forests under the 80-60% crown cover calss as compared to the 100-80% crown cover class. Germination of seeds occurred only in the November, 1968 to April, 1969 period and is generally very low, varying from 0.1 to 1.5%. The non-flooded flats are very similar to the flats flooded in 1964.

The lower and middle slopes indicate generally the same litter and seed fall pattern with a reasonable seed germination of 0.9 to 17.8%. Again, the highest germination rates were observed on the middle slopes. The drier middle slopes and the lower slopes (R-SF type) receive more solar radiation (heat), apparently favoring redwood seed germination and reducing the chances of fungal infections. The seasonal data are summarized in Table V-1.

The seasonal trends of changing seed weights is further documented. The heaviest seed falls early in the winter and germinates almost immediately. The best germination is from the heaviest seed while seed fallen during the summer and fall has practically no germinative energy left. This indicates rapid loss of seed viability within one growing season. The data have already been reported in Table IV-10 (page 55) and are summarized in Table V-2.

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TABLE V-1: SEASONAL LITTER COLLECTIONS, HB01 - HB08 LINES
HUMBOLDT REDWOODS STATE PARK, WEOTT, CALIFORNIA
January, 1968 - September, 1969

INVEN DATES	SITE CONDITION / CROWN COVER % / # OBSERVATIONS	FLOODED 1966 & 1964				FLOODED 1964 ONLY		NOT FLOODED	TOE OF SLOPE		LOWER SLOPE		MIDDLE SLOPE
		100-80	80-60	60-40	20-0	100-80	80-60	100-80	100-80	80-60	100-80	80-60	100-80
January 5 - March 26, 1968	Redwood Seeds												
	Total (ungerm.)	112	384	32	0	1216	1648	1120	112	48	1072	1856	136
	# Germinated #/m^2	0	160	0	0	64	96	32	16	0	48	128	16
	# Damaged #/m^2	48	64	0	0	672	416	208	48	0	160	112	144
	Redwood Cones	0	48	0	0	32	32	16	0	0	48	0	16
	Ovendry Weights												
	Litter g/m^2	29.5	9.0	17.0	6.4	84.6	63.6	38.8	35	43.7	66.7	18.5	64.1
	Cones g/m^2	2.2	23	--	--	16.1	15.4	612	--	--	16.6	--	4.9
	Total g/m^2	31.7	32	17	6.4	100.7	79	45	35	43.7	83.3	18.5	69
	Seed Germination												
	Total %	0	0	0	0	0.08	0.16	0	0	0	0.05	0	0.99
	At End 1st week %	0	0	0	0	0	0	0	0	0	0	0	0
	At End 2nd week %	0	0	0	0	0.03	0.16	0	0	0	0	0	0.20
	At End 3rd week %	0	0	0	0	0	0	0	0	0	0	0	0.59
	At End 6th week %	0	0	0	0	0.05	0	0	0	0	0.05	0	0.20
March 26 - July 2, 1968	Redwood Seeds		NO DATA		NO DATA								
	Total (ungerm.)	24		1280		92	888	248	176	464	521	1584	451
	# Germinated #/m^2	0		0		--	--	--	--	--	--	--	--
	# Damaged #/m^2	0		0		--	--	--	--	--	--	--	--
	Redwood Cones	16		16		47	51	24	0	0	41	64	35
	Ovendry Weights												
	Litter g/m^2	313.4		134.1		114.7	123.8	37.5	55	41.1	76.3	216.8	93
	Cones g/m^2	4.5		--		24.3	23.2	2.8	--	--	11.1	42	13
	Total g/m^2	317.9		134.1		139	147	40.3	55	41.1	87.4	258.8	106
	Seed Germination												
	Total %	0		0		0	0	0	0	0	0	0	0
	At End 1st week %	0		0		0	0	0	0	0	0	0	0
	At End 2nd week %	0		0		0	0	0	0	0	0	0	0
	At End 3rd week %	0		0		0	0	0	0	0	0	0	0
	At End 6th week %	0		0		0	0	0	0	0	0	0	0

TABLE V-1, CONTINUED

INVEN DATES	SITE CONDITION / CROWN COVER % / # OBSERVATIONS	FLOODED 1966 & 1964 100-80	FLOODED 1966 & 1964 80-60	FLOODED 1966 & 1964 60-40	FLOODED 1966 & 1964 20-0	FLOODED 1964 ONLY 100-80	FLOODED 1964 ONLY 80-60	NOT FLOODED 100-80	TOE OF SLOPE 100-80	TOE OF SLOPE 80-60	LOWER SLOPE 100-80	LOWER SLOPE 80-60	MIDDLE SLOPE 100-80
July 2 - November 2, 1968	Redwood Seeds												
	Total (ungerm.)	56	368	400	272	802	999	56	32	16	517	1520	533
	# Germinated #/m^2	--	--	--	--	17.6	--	--	--	--	--	16	5
	# Damaged #/m^2	--	16	--	--	56	73	--	--	--	98	192	43
	Redwood Cones	4	32	0	--	51	21	8	--	--	9	48	37
	Ovendry Weights												
	Litter g/m^2	263.9	128.2	144.4	176	290	322.3	228.2	207.5	144.2	196.6	192.1	261.2
	Cones g/m^2	0.3	1.2	--	--	12.4	7.9	0.3	--	--	5.3	17	11.6
	Total g/m^2	264.2	129.4	144.4	176	302.4	330.2	228.5	207.5	144.2	201.9	209.1	272.8
	Seed Germination												
	Total %	0	0	0	5.90	0.45	1.46	0	0	0	3.21	1.05	1.52
	At End 1st week %	0	0	0	0	0	0	0	0	0	0	0	0
	At End 2nd week %	0	0	0	0	0.30	1.46	0	0	0	3.21	1.05	0
	At End 3rd week %	0	0	0	5.90	0.06	0	0	0	0	0	0	1.52
	At End 6th week %	0	0	0	0	0.09	0	0	0	0	0	0	0
November 2, 1968 - January 4, 1969	Redwood Seeds									NO DATA			
	Total (ungerm.)	1624	10288	64	0	1692	1278	24	16		235	496	592
	# Germinated #/m^2	0	32	0	0	4	18	0	0		0	0	3
	# Damaged #/m^2	228	2704	32	16	197	162	0	0		130	144	32
	Redwood Cones	0	0	16	0	48	23	8	0		18	32	288
	Ovendry Weights												
	Litter g/m^2	232.9	33.2	64.3	silted	109.6	60.3	53.2	48		68.1	30.9	78.4
	Cones g/m^2	--	--	1	--	17.6	12.1	3.1	0		3.8	1.5	6.9
	Total g/m^2	232.9	33.2	65.3	--	127.2	72.4	56.3	48		71.9	32.4	85.3
	Seed Germination												
	Total %	1.34	0.20	0	--	1.11	0.13	0	0		0	0	0.96
	At End 1st week %	0	0	0	--	0.25	0	0	0		0	0	0.24
	At End 2nd week %	0.58	0.10	0	--	0.67	0	0	0		0	0	0.72
	At End 3rd week %	0.09	0	0	--	0.09	0	0	0		0	0	0
	At End 6th week %	0.67	0.10	0	--	0.10	0.13	0	0		0	0	0

TABLE V-1, CONTINUED

INVEN DATES	SITE CONDITION / CROWN COVER % / # OBSERVATIONS	FLOODED 1966 & 1964				FLOODED 1964 ONLY		NOT FLOODED	TOE OF SLOPE		LOWER SLOPE		MIDDLE SLOPE
		100-80	80-60	60-40	20-0	100-80	80-60	100-80	100-80	80-60	100-80	80-60	100-80
January 4 - April 19, 1969	Redwood Seeds												
	Total (ungerm.)	1072	3680	144		1754	1415	40	32	32	512	1120	797
	# Germinated #/m^2	72	336	0		30	75	0	0	0	14	12	0
	# Damaged #/m^2	136	1280	0		125	155	0	0	0	25	160	51
	Redwood Cones	8	32	0		41	53	4	16	0	43	16	35
	Ovendry Weights												
	Litter g/m^2	95.3	--	159.8	SILTED	106.3	88.8	66.7	45.0	66.2	67.9	47.4	119.8
	Cones g/m^2	7.4	--	--		20.9	28.7	0.9	3.2	0	23.1	9.3	28.3
	Total g/m^2	102.7	--	159.8		127.2	117.5	67.6	48.2	66.2	91.0	56.7	148.1
	Seed Germination												
	Total %	1.50	5.23	25.00		1.02	0.24	0	0	0	3.72	11.43	17.84
	At End 1st week %	0	1.74	12.50		0.48	0.24	0	0	0	2.22	2.86	8.33
	At End 2nd week %	1.50	2.18	6.25		0.54	0	0	0	0	0.90	5.71	9.51
	At End 3rd week %	0	0	0		0	0	0	0	0	0.60	2.86	0
	At End 6th week %	0	1.31	6.25		0	0	0	0	0	0	0	0
April 19 - July 1, 1969	Redwood Seeds												
	Total (ungerm.)	480	240	0	48	497	590	56	0	48	261		253
	# Germinated #/m^2	0	16	0	0	1	0	0	0	0	0		0
	# Damaged #/m^2	96	48	0	32	79	94	4	0	0	48		45
	Redwood Cones	0	16	0	0	26	41	4	16	16	34		24
	Ovendry Weights												
	Litter g/m^2	114.2	37.6	144.3	58	61.3	96.8	31.3	27.8	50.6	61.0	NO DATA	95.8
	Cones g/m^2	0	7.8	0	0	12.1	18.4	2.5	3.8	4.6	14.2		10.3
	Total g/m^2	114.2	45.4	144.3	58	73.4	115.2	33.8	31.6	55.2	75.2		106.1
	Seed Germination												
	Total %	0	0	0	0	0	0	0	0	0	0		0.33
	At End 1st Week %	0	0	0	0	0	0	0	0	0	0		0
	At End 2nd week %	0	0	0	0	0	0	0	0	0	0		0
	At End 3rd week %	0	0	0	0	0	0	0	0	0	0		0
	At End 6th week %	0	0	0	0	0	0	0	0	0	0		0.33

TABLE V-1, CONTINUED

INVEN DATES	SITE CONDITION CROWN COVER % # OBSERVATIONS	FLOODED 1966 & 1964 100-80	80-60	60-40	20-0	FLOODED 1964 ONLY 100-80	80-60	NOT FLOODED 100-80	TOE OF SLOPE 100-80	80-60	LOWER SLOPE 100-80	80-60	MIDDLE SLOPE 100-80
July 1 - September 28, 1969	Redwood Seeds												
	Total (ungerm.)	779	256	0	160	1250	1193	32	0	48	1829	2032	973
	# Germinated #/m^2	0	0	0	0	0	0	0	0	0	0	0	0
	# Damaged #/m^2	16	48	0	32	100	78	4	0	0	107	128	35
	Redwood Cones	48	96	0	0	19	21	0	16	16	23	80	19
	Ovendry Weights												
	Litter g/m^2	113.9	174.9	311.9	123.3	212.1	226.7	117.1	27.8	50.6	168.3	210.2	170
	Cones g/m^2	0.9	33.5	0	0	8	9	0	3.8	4.6	7.8	40.7	14.5
	Total g/m^2	114.8	208.4	311.9	123.3	220.1	235.7	117.1	31.6	55.2	176.1	250.9	184.5
	Seed Germination												
	Total %	0	0	--	0	.09	0	0	0	0	0.19	0	0.34
	At End 1st Week %	0	0	--	0	0	0	0	0	0	0	0	0
	At End 2nd Week %	0	0	--	0	0	0	0	0	0	0.19	0	0
	At End 3rd Week %	0	0	--	0	0.07	0	0	0	0	0	0	0
	At End 6th Week %	0	0	--	0	0.02	0	0	0	0	0	0	0.34

TABLE V-2: ANNUAL LITTER COLLECTIONS, HB01 - HB08 LINES, HUMBOLDT REDWOODS STATE PARK, WEOTT, CALIFORNIA (Ovendry Weight g/m^2)

Year:	1966	1967	1968	1969
FLATS FLOODED 1964, 1966 & 1968				
Winter*	41.9	226.8	21.8	131.3
Spring	224.3	62.1	226.0	90.5
Summer	320.9	242.6	178.5	189.6
Fall	95.9	280.8	110.5	--
Total	683.1	812.3	536.8	411.4
FLATS FLOODED 1964 ONLY				
Winter	62.4	134.9	89.9	122.4
Spring	579.4	104.1	143.0	94.3
Summer	260.8	191.3	316.3	227.9
Fall	216.5	315.1	99.8	--
Total	1119.1	745.4	649.0	444.6
FLATS NOT FLOODED				
Winter	57.0	104.5	44.9	67.6
Spring	217.2	51.2	40.3	33.8
Summer	161.0	105.6	228.5	117.1
Fall	257.0	277.6	56.3	--
Total	692.3	538.8	370.0	218.5
LOWER SLOPES				
Winter	25.9	73.4	45.1	65.5
Spring	156.9	127.0	110.6	54.0
Summer	258.5	167.1	190.7	128.5
Fall	154.7	218.7	50.8	--
Total	596.0	586.3	397.2	248.0
MIDDLE SLOPES				
Winter	78.4	156.8	69.0	148.1
Spring	378.0	138.1	106.0	106.1
Summer	156.8	174.1	272.8	184.5
Fall	131.2	187.0	85.3	--
Total	744.3	655.9	533.1	438.7

* Winter - Dec., Jan., Feb.
Spring - March, April, May
Summer - June, July, Aug.
Fall - Sept., Oct., Nov.

VI. REDWOOD REFORESTATION IN HUMBOLDT COUNTY, CALIFORNIA DURING 1922-1932

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Redwood reforestation efforts were undertaken during the years of 1922 to 1932 by six redwood lumber companies in Humboldt County, California. The need for redwood reforestation was recognized by many foresters because of the obvious lack of natural regeneration of the logged-over areas. This caused considerable concern for the future of the lumbering operations, and it was then decided to undertake the redwood reforestation efforts.

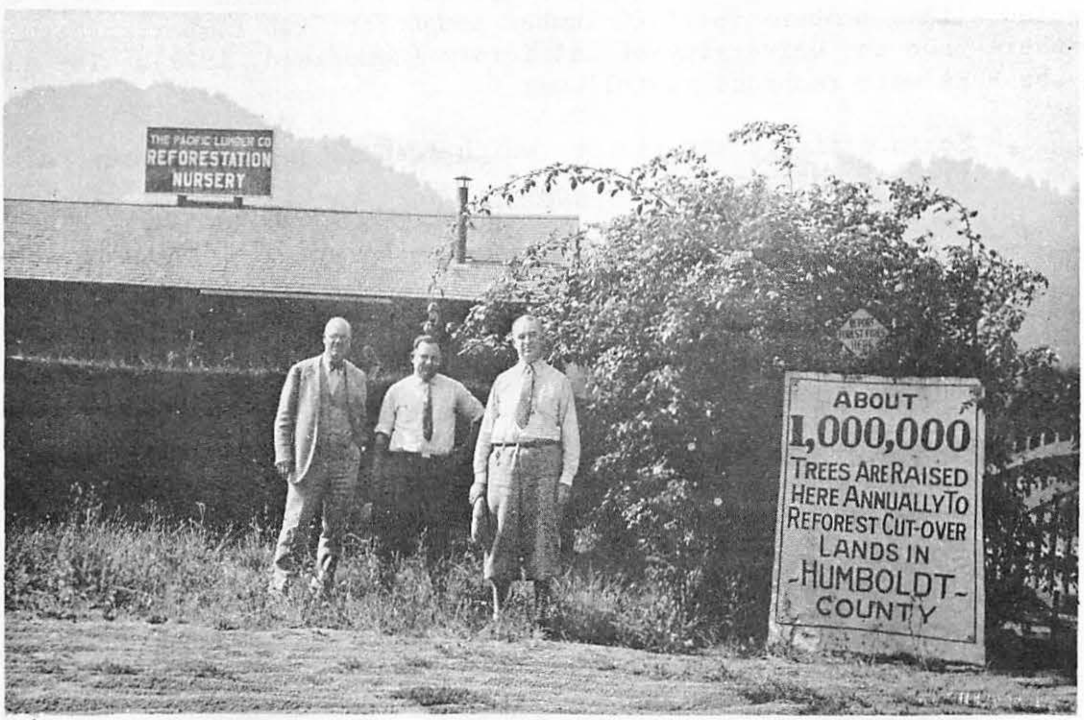

FIG. VL-1: THE FOREST NURSERY AT SCOTIA, CALIFORNIA
In center of the picture is Mr. William H. Wirt, manager of the nursery. Photograph taken in about 1925. (Courtesy of Mrs. Marguerite Wirt, Seattle, Washington.)

* The author wishes to express his gratitude for the valuable first-hand information received from: Mr. Willis G. Corbitt, 707 SW Westwood Dr., Portland, Ore. 97201; Mr. W. R. Schofield, 915 Neilson St., Albany, Calif. 94706; Mr. Hubert L. Person, 140 Camino Encanto, Danville, Calif. 94526; Mr. Lawrence C. Merriam, Save-the-Redwoods-League, 114 Sansone St., San Francisco, Calif. 94104; Mrs. William C. Wirt, 41-5 Brooklyn Ave., NE, Seattle, Wash. 96105; and Mr. Myron Krueger, 1426 Rockledge Lane #6, Walnut Creek, Calif. 94595.

In the 1920's cable logging systems required large clear-cut areas for efficiency and operation. This left the logged areas without any seed trees. Advanced technology in slack-line cable logging with powerful steam donkeys allowed removal of large timber volumes, thus creating large clear-cuts. The main mode of timber transportation was the railroad. Steam donkeys were used to drag the logs by cable directly downhill to landings alongside the railroad track. Much timber was destroyed and serious soil disturbances caused erosion and damage to the site. Logging slash was generally burned prior to cable skidding to clear the ground as much as possible. A second burn was usually made upon conclusion of the logging activity to reduce fire hazards. This repeated burning eliminated any immediate establishment of regeneration upon completion of all logging activities. The absence of seed trees compounded the problem of dissemination of seed over the large clear-cut blocks. Thus, brush fields were created lacking adequate natural regeneration by commercial coniferous species. These understocked areas were first selected for reforestation efforts.

In 1923, the Humboldt Redwood Reforestation Association (HRRA) was created with a membership of 12 lumber companies, two timber investment companies and the University of California (Schofield, 1929). The goals of the HRRA were recorded as follows:

1. To investigate the factors which lead to successful reforestation of cutover lands.

2. To coordinate cooperative work in fire protection and prevention.

3. To enhance natural reproduction in cutover areas or execute otherwise reforestation by planting.

4. To adopt a land classification upon which reforestation should be centered.

5. To seek copperation with state and federal agencies and other organizations.

6. To seek reservation and preservation of a reasonable amount of old-growth timber if preservation of such timber is practical and interferes as little as possible with lumbering operations.

7. To aid in the planning and supervision of redwood reforestation projects of its members.

The HRRA was supported by an assessment of two cents per acre of timber of its membership. In 1923, some 247,420 acres were managed under the above purposes by the HRRA. By 1928 this acreage had grown to 293,794 acres (Schofield, 1929).

The HRRA contracted with the Pacific Lumber Company to create at Scotia a forest nursery for the delivery of redwood planting stock to its membership. Wirt, Haas, Merriam, Schofield, Corbitt and Person have made reports on specific aspects of these reforestation efforts, but much of the information obtained was never summarized for publication. This paper will review the available reports and include many private notes of those foresters engaged in the actual reforestation efforts of the years 1923 to 1932.

In 1922 the Pacific Lumber Company was one of the first companies in Humboldt County to adopt reforestation by planting as its official policy. Mr. David T. Mason, a well-known consulting forester in the Northwest, was instrumental in convincing the officers of the Pacific Lumber Company that it would be to the advantage of the lumber company to secure the future timber supply by reforestation (Corbitt, 1960). For this reason, Myron E. Krueger was transferred in April, 1922, from the Engineering Department in the logging camps to the Forestry Department to start this reforestation effort. Krueger carried out, as his first task, field surveys to determine the extent of areas in need of reforestation. He made plans for future plantings and thinnings of areas which were then well-stocked with natural or sprout regeneration. During the spring of 1922, Krueger and his assistant Robert Downs, began the layout of the forest nursery immediately south of the town of Scotia. A small area was cleared of its large redwood stumps. On May 21, 1923, Willis C. Corbitt was chosen to carry on the forestry work when Robert Downs was transfered to the engineering crew. On May 31, 1923, William H. Wirt, a graduate of the College of Forestry, the University of Washington at Seattle, was hired to assist with the forestry work and nursery operations. Corbitt, as a professional engineer, was put in charge of the engineering surveys to re-establish property lines and section corners. He executed topographic mappings of many logged areas. Wirt was placed in charge of all nursery operations. He supervised the plantings during the late fall and early spring months, the cone collections in the fall, and the experimental plantings in open second-growth stands. Wirt was further charged with the development of an educational program for fire prevention, and he presented many talks to local rural schools. When forest fires did occur, Corbitt was actually put in charge of fighting the fire. This included fires that occurred in the planted or clear-cut areas as well.

THE SCOTIA FOREST NURSERY

The site of Scotia Forest Nursery was chosen by the Pacific Lumber Company between the Redwood Highway and the Northwestern Pacific Railroad track, just south of the lumbering community of Scotia. The chosen area was ideally located for publicity purposes. One of the main purposes of establishing the forest nursery program was improvement of public relations and publicity about reforestation.

The nursery site was originally an alluvial flat of heavy, rich clayey silt soil, practically devoid of humus and with only a very small portion of sand in the soil texture. It was almost purely a fine silt. No rocks or gravel were found. The level terrace was about 5- to 60-feet above the low water level of the South Fork of the Eel River. The site originally had a fairly good drainage, having a gulch on either side of it. Originally, the area produced a very heavy stand of old-growth redwoods of exceptional quality, as demonstrated by the large and fairly uniformly spaced stumps which remained. An average of 25 stumps per acre wer counted, many of them between 8 to 12 feet in diameter. The largest stump measured 18 feet across the top of the cut (Wirt, 1928).

Clearing operations for forest nursery purposes were expensive. First, two powder men wer brought in from the logging camps, and the stumps were blown into pieces by charges of black powder placed in them. Very few roots had to be shot a second time in order to remove the stumps. Subsequently, the shattered stumps and roots were removed by a socalled "chunking out" crew with a small spool donkey. A man and a horse were used to haul the slack-line cable from the donkey engine to the stump pile and back to the donkey. The hauls were short and many setups were needed to clear the area. A pole of 30 to 40 feet length was finally used as a high pole as the hauls became longer. The stump holes were leveled by a man and a team of horses. First, the stump holes were filled by throwing small roots and chunks into the bottom of the hole, and then, by plowing around the hole, throwing the dirt with the plow from the rim into the center of the hole. By repeating this operation the holes were finally filled to a point where a team and a plow could be driven across them. The entire field was then plowed, and cuts and fills were made with a team of horses and a Fresno scraper. Many of the stump holes were 6 to 7 feet deep. The dirt later settled in these large holes, and the surface was lowered by a foot or more by this settling. The area was then finally leveled with a Fordson tractor with a 16-inch plow. In 1923, 5 acres were cleared at an approximate cost of $500 per acre (Wirt, 1928).

After the final clearing and leveling operations, the nursery area was surveyed and sub-divided into blocks bounded with 4-feet wide alleys. Provisions were left for making 12-feet wide roadways through the nursery to divide it inot four parts. The development of a watering system for the nursery was accomplished by extending the Scotia Fire Main into the nursery, thereby supplying sufficient water and good pressure to meet all the needs for fire protection as well as watering of the nursery stock.

An accounting system was set up allowing for expenditures in the following accounts: Supervision, Nursery Planting, Tree Seed, Seedling Production, Transplant Production, Planting Equipment, Planting Trees, Surveying Equipment, Tinning Operations, Removal of Old Products, Forest Protection and Publicity (Wirt, 1928).

TREE SEED COLLECTION

When the nursery was started at Scotia in 1922, no seed was available except what could be purchased. The first lot of 45 lbs. of redwood seed was purchased from the Union Lumber Company at Fort Bragg. This seed was sown Jan. 6, 1923. It was found a little later that no satisfactory germination was obtained, so another lot of 15 lbs. was purchased from the Manning Seed Company. This latter seed gave better germination results. However, this seed also was collected by the Union Lumber Co. and subsequently purchased by the Manning Seed Co. (Wirt, 1928).

In the fall of 1923, it was decided that it would be best to collect cones for their own use. Cones were collected in the logged areas which had turned to a straw-yellow color. Several school boys, equipped with canvas buckets and pack bags, were hired to go into the woods on Saturdays to collect cones from trees which had been chopped down by the choppers. Cone collecting trees were selected by means of a cutting test. Four or six cones were cut with a knife on three or four sides, deep enough to cut through seeds. If as many as 25, or five per cent of the seeds showed up as full white seed, the cones were considered good. The pickers were instructed to collect only from these marked trees. There were no visual appearances to distinguish a good cone tree. As a rule, only about 10 per cent of the trees actually turned out to be trees with cones good enough to pay for the picking. A good cone-producing tree would require two or three days for about two men to clean it. One man can pick from 40 to 70 lbs. of cones in a day, depending on how much travel is necessary to get in and out, and on the weather conditions as well as the size and quantity of cones on the tree. It is advisable to take the cones as soon as possible to prevent them from drying and scattering out the seed. Often, the help of school boys on Saturdays would not be sufficient. So, additional men had to be hired and stationed at the nearest logging camps to collect cones for the nursery.

Through the cooperation of the head choppers and the foremen in the woods, trees with heavy loads of cones could be located more readily. The foreman could advise the pickers where burns were to be executed and the best means of getting into and away from the cone tree. Cones collected from one tree in 1926 amounted to better than 350 lbs., not including all the cones which had been cut by the red squirrel. This was an unusually good tree and such cone production has not been equalled since. Cones collected from along the highway within the state park groves were cut by the red squirrel. The squirrel cuts the cones loose from the branch and drops them to the cuff below where they can easily be recollected.

Redwood cone collecting usually starts in October and lasts until enough cones are collected to give the desired quantity of seeds. This is usually about the first or middle of December. Douglas fir cones were usually collected from trees bordering the prairies which were bushy and low in height (30 to 80 feet high). The pickers climbed those trees, taking three or four sacks, rope and a 12-foot pole with a hook with them in the tree. The pole with the hook is used to draw in the long branches and pick the cones from these branches. As the sack is filled it is securely tied and dropped to the ground. The average picking rate for a man is about four sacks of 80 lbs. of Douglas fir cones per day, or seven hours. The travel time is usually two hours per day.

Seed collected in 1925 for filling foreign orders had to be disinfected as a preventive measure against the spread of hoof-and-mouth disease which had been prevalent in the southern part of California. This requirement was placed upon the seed export by the New Zealand government. The disinfectant used was an aqueous mercury bichloride solution of 1 to 1,000 parts of water. The treatment consisted of placing small quantities of this seed in the solution and stirring them until all the seeds were thoroughly wet.

The seed was then spread out on a warm concrete floor to dry. Steel containers for the seed were sterilized with steam before the seed was packed for shipment. No other disinfectant had been used on redwood seeds (Wirt, 1928).

Upon inspection of the Douglas fir seed in 1927, it was noticed that many small worms were in the seed. It was decided to use the fumes of carbon bisulphate (CS_2) to kill the larvae and disinfect the seed. A pan of carbon bisulphate liquid was set on top of an open barrell of seed. The heavy fumes would then penetrate the seed, displacing the air. After several hours of this treatment, the barrel was then tipped upside down, a screen being used to keep the seed from pouring out, to let the fumes drain out. The barrel was left in this position for several days. No live worms could be found in the seeds since the fumigation. Only Douglas fir was treated satisfactorily by CS_2. Fumigation affected the redwood seeds germination adversely (Wirt, 1928).

Redwood cones were generally spread out about one layer deep in trays which were placed in boiler rooms of the saw mill. Temperature ranged here from 75° to 110°F. After the cones were sufficiently dry, they were put through a shaker which loosened the seed from the cones. In 1926, a dry kiln with automatic heat control, temperature and humidity recording instruments was used to dry the seed. Its capacity was 75 to 80 trays at each drying. A tray would hold about 7 lbs. of wet cones, and 24 to 36 hours of drying time were needed to dry out seeds. The temperature never exceeded 120°F for even an instant and in most cases it was below 110°F (Wirt, 1928).

The amounts of seed collected annually and the dates of sowing are listed in Table VI-1.

TABLE VI-1: SEED COLLECTIONS AND DATE OF SOWING, SCOTIA NURSERY, THE PACIFIC LUMBER COMPANY
(Data by Merriam, 1928)

	1923	1924	1925	1926	1927
Amounts of seeds (lbs.)					
Redwood	192	314.5	314	1,088[a]	1,241[a]
Douglas fir	--	--	46	--	115
Date of Sowing	Jan. 6-Apr. 30	Jan. 29-May 26	Mar. 25-May 1	Mar. 13-Apr. 29	Apr. 21-May 4
Amount of redwood seed sown per 4 x 12 feet seedbed (ounce weight)	*	4 to 10.5	1.3 to 4.3	2.5 to 3.0	2.3 to 3.2 (new crop) 5.2 (holdover)

TABLE VI-1, CONTINUED

	1923	1924	1925	1926	1927
Density of redwood seedlings sown (#/sq. ft.)					
# sowed for	100	70	50	50	*
# obtained	*	11 to 216	--	about 50	*
# thinned out to	*	50	50	50	*
Total amount of seed sown (lbs.)					
Redwood	*	60	203	130 1/8	174
Douglas fir	--	*	12 ½	6 1/8	22 ½
Sitka spruce	--	2 3/4	5 ½	4 3/4	8
Port Orford cedar	--	--	4	5 ½	7
Total	*	62 3/4	225	146 ½	211 ½

* information missing

[a] Part of these collections were used to fill foreign orders.

The prevailing price for the selling of redwood seed gathered by the nursery had been $4.00 per lb. for a single pound; $3.75 per lb. for 1- to 10-lb. lots; and $3.50 per lb. in larger amounts (Merriam, 1928).

SEEDBED PREPARATION AND TREATMENT

When the seed was sown, the seed was covered with a layer of dry sand. Usually, screened river sand was used and, in one instance, beach sand was used. Sand was transported to the nursery by railroad to the sand storage shed and by tractor or truck to the nursery. Seed was sown in April & May.

It is important that germination be stimulated by the right moisture content of the soil. Inadequate moisture at the time of germination means death to the redwood seedlings. Too much moisture means development of the "damping-off" disease. Weed growth seemingly has no effect upon the redwood seedling growth in the seedbed. Sometimes, growth rate increases after weeds have been removed. The seedbeds should be kept moist by plowing, harrowing, and leveling, and also by mixing the right amount of sand and humus into the soil. The seedbeds are rolled prior to sowing. Sowing is done by hand-broadcasting and requires experience to get a good, even distribution of the seed, especially when the wind is blowing. Since 1925, a seed sowing machine was developed at Scotia which cut the average time down to about 27 minutes per block. The advantages were saving of time and a more uniform application of the seed irrespective of the wind velocity. The sown seed was rolled in by a ground roller attached to the same machine. The rate of sowing was determined experimentally. In sowing redwood, more seed is always used than would be needed to obtain the required density of stock. Thinning operations in the seedlings were kept to a minimum because they were expensive. Generally, it consisted of pulling out smaller and poorer stock first. Usually, the stocking was reduced to 40 to 50 plants per square foot. Weeding was done with small hand tools. The best instruments were the knives made from band-saw steel. It could be shaped and sharpened to fit the wish of the operator; a wooden handle was put on the steel blade to make a good grip of the tool possible. The steel blade was usually 4 to 5 inches long with a bend of 30° to 45°. The entire nursery was weeded four to six times each year. This usually took three to four weeks to cover the seedbeds each time. Weeding was done most frequently during the first part of the season. Watering was necessary to sustain good growth. The average rate of application was about ten gallons per minute per sprinkler per hundred square feet. Sprinklers were allowed to run for 7 to 10 minutes. This is the equivalent of about 1.6 inches of water per square foot. Trees were watered before root pruning. At that time, the sprinklers were allowed to run for 30 to 45 minutes in order to thoroughly saturate the soil to a depth of four to six inches. After root pruning, water was again applied in the fastest possible manner to offset transpiration losses.

In 1923, burlap was used to cover the seedbeds. This prevented the drifting of sands by the wind and helped retain the moisture and heat. Burlap was usually laid immediately after the seed was covered with sand and allowed to remain until about a quarter of the seed had germinated. The burlap was wetted with a sulphuric acid solution to disinfect the seeds. After that, it was practically worthless for another year's service. So, the burlap had to be replaced each year. A very close observation showed, however, that very little difference existed in the percentage of germination among the various beds covered with burlap or without burlap. Some beds used a moss covering, under which the redwood seed germinated very nicely. But when the moss was removed, many of the young seedlings were pulled out or broken off. With the expansion of the nursery in 1925 it was impossible to get enough burlap or moss to cover the entire area. As a substitute, tarred and paraffined paper was used which was inconvenient to handle and did not work out as well. After 1926, however, no burlap or paper was used on all the redwood beds. With care and attention the moisture content of the seedbed could be kept at the right level and very good success in germination could be obtained (Wirt, 1928; Merriam, 1928).

In order to combat the "damping-off" disease, a dilute solution of sulphuric acid was used as a preventative for the first two or three years of nursery practice. The application used was 8 ounces of commercial sulphuric acid to three gallons of water for each 48 square feet of seedbed. The solution was usually applied immediately after the seed had been covered with sand and burlap. It is estimated that from one-third to one-half of the solution was used in wetting the burlap. But sufficient quantities of the solution penetrated the sand under the burlap to wet the seed sufficiently and to moisten the soil beneath it. This was considered to be of value to kill any fungal spores that might have been present. Varying concentrations of sulphuric acid were tested. But in checking the germination results of treated and untreated beds, it was hard to say with certainty if the treatment had been very effective.

Because of this, the application of sulphuric acid was therefore discontinued after 1924. Other "damping-off" preventatives and weed killers were used. In 1924, Bordeaux mixtures were used to check the "damping-off" disease. Concentrations varied from one pint to 48 square feet to two or more pints per 48 square feet. However, the redwood seedlings showed no relief from the "damping-off" infestation on account of this treatment (Wirt, 1928).

Observations on the treatment of mercury bichloride in a 1 : 1,000 solution had an unfavorable effect upon seed germination; the treated seed had to be sown twice as thick as the untreated seed, indicating that the germination was about half what it should have been. Seedling growth rate was also reduced, the average height of the treated seedling being about two inches shorter than the untreated seedling at the conclusion of one growing season. However, these results were still considered inconclusive. Other chemical treatments in various concentrations, such as $FeSO_4$ and $ZnSO_4$ were applied as weed killers. The effectiveness of these chemicals was doubtful. No permanent decrease of weeds could be noted. Some of the more concentrated solutions of $ZnSO_4$ and $FeSO_4$ caused the leaves of the weeds to wilt and dry up, but no weeds were really killed. In 1927, further experiments with zinc sulphate indicated that the concentration of 9 : 1 seemed to be the most effective. In general, the higher the concentration of the chemical the greater its efficiency as a weed killer (Wirt, 1928; Merriam, 1928).

Height growth of the seedlings can be materially increased by shading, keeping the soil cooler and more moist. Shades and frames were placed on the seedbed at the time of seed germination and were taken off a week or so prior to root pruning. The shades used were of an over-all size of 4 by 8 feet and made from redwood lath (Wirt, 1928).

Weeding was best done after watering when the soil surface was soft and the weeds could be removed more easily. It also was noted that the weeds which had grown on the shaded beds were more difficult to pull out effectively and had a greater tendency to break off because of their slenderness. Some 36 different weeds had been identified by Professor W. L. Jepson of the University of California from weed collections made in 1925 by W. H. Wirt and Oscar Ricter. The following species were identified: *Equisetum arvense*, *Polypogon monspeliensis*, *Panicum capillare*, *Echinochloa crus-galli*, *Polygonum aviculare*, *Rumex salicifolius* var: *montigenitus*, *Rumex obtusifolius*, *Rumex pulcher*, *Chenopodium botrys*, *Chenopodium album*, *Mollugo verticillata*, *Cerastium vulgatum*, *Stellaria media*, *Spergula arvensis*, *Ranunculus californicus*, *Sisymbrium officinale*, *Brassica campestris*, *Capsella bursa-pastoris*, *Geranium molle*, *Erodium cicutarium*, *Euphorbia* sp., *Stachys* sp., *Datura stramonium*, *Solanum nigrum*, *Scrophularia californica*, *Plantago lanceolata*, *Galium* sp., *Sonchus oleraceus*, *Helenium puberulum*, *Chrysanthemum leucanthemum*, *Achillea millefolium*, *Anthemis cotula*, *Senecio* sp., *Senecio vulgaris*, *Gnaphalium* sp., *Centaurea metitensis*. The great variety of weeds in the nursery was attributed to use of sand from the river bar and from the beach (Wirt, 1928).

Nursery production and operational costs for the Scotia Nursery are summarized in Table VI-2 and VI-3.

TABLE VI-2: NURSERY PRODUCTION OF THE SCOTIA NURSERY, THE PACIFIC LUMBER COMPANY**

	1923	1924	1925	1926	1927	1928	1929	1930
Redwood	40,898	672,261	678,938	1,756,918	--	--	--	--
Douglas fir	14	8	227,200	230,310	--	--	--	--
Sitka spruce	1	59,474	160,941	178,611	--	--	--	--
Port Orford cedar	1	54,948	10,950	121,226	--	--	--	--
Other Species	462	3,880	4,969	4,653	--	--	--	--
Total	41,356	790,571	1,082,998	2,291,718	807,540	1,500,000	--	--
	41,960*	677,250*	971,950*	2,244,750*	1,122,100*	1,025,280*	269,800*	465,000*
Percent Seelings	96 %	100 %	95 %	98 %	--	--	--	--
Percent Transplants	4 %	0 %	5 %	2 %	--	--	--	--
Percent Redwood	98.8 %	84.8 %	62.6 %	76.6 %	--	--	--	--
Redwood Selling Price $1/1000	$30.00**	14.10**	9.65**	7.40**	--	--	--	--

** Data from Merriam, 1928 & Schofield, 1929.

* Data from H. L. Person, 1937.

TABLE VI-3: NURSERY OPERATIONAL COSTS OF THE SCOTIA NURSERY, THE PACIFIC LUMBER COMPANY*

	$ per 1,000 Trees Produced 1925	1926
I. Seed Beds		
Seed	$ 0.139	$ 0.129
Sowing of Seed	0.584	0.440
Care of Seed Beds	1.240	0.885
Lifting, Bundling, Sorting	0.528	0.415
Packing	0.112	0.177
Miscellaneous	0.798	0.528
Total	$ 3.401	$ 2.574
II. Transplant Beds		
Transplanting	$ 6.83	$ 3.65
Care of Transplants	5.67	6.02
Lifting Transplants	0.709	1.79
Bundling	0.232	1.57
Shipping	---	0.33
Total	$13.441	$13.36
III. Supervision	$ 2.42	$ 0.50
Nursery:		
Nursery Plant	2.38	1.94
Tractor Operations, Repairs		0.125
Nursery Operation		1.43
Forest Publicity		0.066
TOTAL COSTS		
1-0 Seedlings (I plus III)	$ 8.20 (8.78)**	$ 6.63 (6.74)**
1-1 Transplants (II plus III)	18.24	17.42

* Data according to Merriam, 1928 (**) & Schofield, 1929 (*). According to Merriam, 1928, costs per 1,000 redwood seedlings was $135.76 in 1923, and $14.10 in 1924.

PLANTING STOCK GRADING AND SHIPMENT

Several size grading systems for redwood seedlings were used after the seedlings were carefully lifted. In 1923, redwood seedlings were graded into 12-inch height classes, and later into 6-inch classes starting with the 3- to 9-inch height class. In 1924, the redwood planting stock was similarly graded by their root development. Grading was further modified by eliminating some of the height grading categories and concentrating more upon the root development grading.

Three to four men were used in grading redwood stock at the sorting table while one man lifted the trees from the seedbed. Trees were tied in bundles of 50 and later grouped in lots of 1,000 trees each and heeled-in until the time for shipment. Later, the grading was done directly in the nursery from the piles of trees lifted on top of the seedbed. For protection and shelter, a portable framework on wheels with a canvas cover was devised. A crew of four or five men would work under this cover while sorting trees. Trees were sorted and tied in bundles and stored in powder boxes which contained enough water to keep them damp. Gradually, the grading system deemphasized height classification and substituted root system grading as the more important criteria. Seedling stock whose roots were seriously damaged in lifting were discarded as culls as well as some of the other seedlings which had scanty root development. Planting stock with thick, fibrous and long root systems were considered ideal. Stock with short and fairly-even thick roots were not used for planting, but were held as extra good culls and used later in transplanting operations. Stock with small tops or both small tops and roots were culled (Wirt, 1928).

Normally, stock which had been bundled was heeled-in. Occasional checks were made to see what changes had taken place. After about three weeks, it was noted that the small roots had changed from a brown color to black, smelling like decayed or rotten roots. Closer examinations showed that the bark of the roots would strip off easily and leave discolored woody roots. At first only the tip of the roots showed signs of this decay, but later the whole root was affected. A mildew developed on the surface of the roots where they were closely tied together. This mold did not appear to be a damping-off mold, although some damping-off was found in the bundles. No evidence of heating was found among the good stock. However, planting stock left heeled-in for several months showed signs of decay of leaves and small branchlets and bark decay on the stem, indicating heat or sweating damage from decay. In some instances, discoloration of the roots was caused by too much water in the root trench. On several occasions, the water was discolored to blackish-brown with a mal odor. Observations of long time storage effects of heeled-in stock were made in planting stock starting with the spring and allowing the stock to remain heeled-in during the entire summer. Initially, the heeled-in stock stayed green for a period from two to three months. The stock was watered occasionally, but no further care was given. The first decay signs were noted in plants in the center of the bunches and rows. Later observations showed more trees were beginning to die. During the summer, a few of the trees started to grow. An occasional watering seemed to be all they needed to carry them along. The rest just dried up while remaining heeled-in. The growing ones had developed a few long roots and went deep into the soil. The lateral roots that the planting stock had when they were heeled-in were detected in the same number, but each lateral root had grown in diameter and length. No survival count was made of the total number of heeled-in stock after one summer, but it was estimated that not more than one per cent lived through the summer and the following winter. It seemed, therefore, advisable to lift stock in such a quantity that it would not be kept heeled-in for longer than a week or two, expecially when the soil drainage is poor and the soil hard (Wirt, 1928).

In 1923, it was found that some moss for packing could be picked off maple trees growing in the Freshwater track. A few grain sacks of this moss were collected during this summer when it was found that these trees were to be cut down for a clearing. It was enough moss to take care of the seedling supply of 1923. In 1924, moss was picked in the same track and twenty-four sacks were collected with a good surplus to start 1925. In 1925, another opportunity to get moss presented itself. A couple of boys were hired to collect moss from fallen maple trees before they were to be burned. Eighty-two sacks were collected in that year in the course of three or four days. In 1926, about 93 more sacks were collected, giving a supply for about a year or so. However, the needs for moss were increasing and negotiations were opened with the Union Lumber Company to supply bails of sphagnum moss that was sacked from the swamps near their operations in Fort Bragg. In 1926, about one-half ton of peat moss was purchased from this company. In 1927, another ton of peat moss was purchased from a moss and seed collector in the Coos Bay area in Oregon. It was dried, bailed and shipped by boat to Eureka and then via stagecoach to Scotia. Peat moss was to be used as packing material for shipment of live seedlings (Wirt, 1928).

A packing frame was used to make bails of the bundled redwood seedlings before shipment into the woods or to other companies. Signode strapping was used to tie the bundles and the bails were sealed with ordinary lightweight butcher paper or burlap strips. Laths were used as stiffeners and guards for the smaller orders of planting stock that were packed to be sent by parcel post. Wet moss was used in two-inch layers between bundles. The bundles were stacked in opposite ways in such a manner that the roots pointed towards the center of the bundle with the foliage sticking out on either end. For shipment over longer distances more moss was used in the center than normally. Shipments to Honolulu, Hawaii, were packed in an open-ended crate to give the tops of the trees more protection (Wirt, 1928).

TRANSPLANT OPERATIONS

When transplant trees were to be lifted, special care was to be used to get as much of the root system as possible. In the case of redwood, the tops were cut back to 6- to 8-inch stem height. The stock lifted for transplanting purposes was usually bundled 25 a bunch because of their larger size. Usually, the entire root system and tops were left on the stock, but root pruning could also be done on the transplant stock. Transplanting within the nursery was done during the wet winter and early spring months. Because of the rainy weather it was almost impossible to get a tractor and a plow on the ground during these wet months. Thus, the transplant beds had to be prepared by hand. Soil was spaded and completely turned over and loosened to a depth of 8 to 10 inches. It was then leveled by hand raking and sometimes was rolled. Different methods of transplanting seedlings have been used. The planting stock was usually set in rows. A spade or shovel was used when the species to be transplanted had a branching or bushy root system. It was often necessary to use a spade or shovel first to make a trench or dig a small hole to plant the stock in. A board with notches was used to make V-shaped trenches in the bed. The trees were then planted in these trenches, and the trenches filled by hand and trampled and smoothened. Transplant stock required a good deal of moisture until they adjusted to the new conditions of growth. Weeding in transplant beds was done with specially made hoes and tools. Weeding was not as frequently done in the transplant beds as it was in the seedbeds. About three weedings separated by two to three months each were all that were necessary to keep the beds clean enough for good tree growth (Wirt, 1928; Merriam, 1928).

For planting in cutover areas a mattock was used and the seedlings were carried in a planting bag. Each man in the planting crew was given enough trees each morning and noon to last until he could stock up again. The planting crew ordinarily consisted of 10 to 15 men planting about 500 trees per acre or more than 20 times the average number of old-growth trees. Normally, the planting crew lined up with a spacing of about 8 feet apart in a line and a spacing of 8 feet was generally maintained in planting trees. Prefered for planting were shade depressions and protection from logs and chunks, and any place where the soil surface and the ground cover would assist in retaining moisture and furnish protection for the trees. For planting of larger trees shovels were used, although this method was slower. A good amount of tamping was done on the soil in order to secure the direct contact of the roots with dirt. Usually the sod and all vegetation was cleared from the planting site in a radius of a foot or more from the tree. The most common method was to drive the blade of the planting tool into the soil in its entire length in order to make a V-shaped hole. This would permit the tree to be pushed in as deep as possible and then carefully lifted until it was inserted into the soil just a little deeper than in the nursery. By wiggling the roots were freed and by tamping with the back of the tool or with the heel of the boot a very tight soil contact was made. The tree could not be readily pulled up. On the average, a planter could plant 70 trees per hour, including travel time, or about 80 trees per hour of actual planting time. Each man would plant from 500 to 800 trees per day depending upon the topography of the planting site. Rains occurred generally quite frequently during the planting season, so the planted stock did not lack moisture and was ready to grow in their new location with the first warm days of the spring (Wirt, 1928).

ABANDONMENT OF THE SCOTIA NURSERY PROJECT

When the depression came in 1929 it was necessary for the Pacific Lumber Company to curtail all expenses, and the forestry program was one of the first to suffer from the economic recession. On May 20, 1929, Mr. W. H. Wirt was given full charge of the forest nursery work and other field work while Willis C. Corbitt was assigned to the selective logging study being started by David T. Mason under the field supervision of his representative, Lawrence C. Merriam and his assistants. This and a number of other projects were undertaken by Corbitt until he was granted a six-month leave of absence by the Pacific Lumber Comapny to accept the appointment as Project Superintendent of the Civilian Conservation Camp at Dyerville, California. On July 9, 1934 Corbitt left the Pacific Lumber Company to accept promotion to Forest Technician with the California Division of Forestry in Sacramento, California. Mr. W. H. Wirt continued with the forestry work until all the trees in the nursery had been disposed of and the fire season had passed in 1931. Wirt was then employed on some research work on composition boards and other projects until he left Scotia May 12, 1932 to accept employment with the California State Park Department at Richardson's Grove. Wirt later joined the National Park Service (Wirt, 1968). Employment records of the Pacific Lumber Company show that Corbitt terminated his employment with the Pacific Lumber Company on February 12, 1935 and Wirt on May 25, 1932.

With the departure of these two men the entire reforestation and nursery program of the Pacific Lumber Company came to an end and it has never been revived since. After the tree planting program was discontinued the policy of the Pacific Lumber Company changed in the depression years and the ranch department was allowed to burn the logged-off lands with the hopes of providing grazing areas for cattle and income to the company. As a result, some if not all of the plantations were damaged by fire and cattle grazing if not completely destroyed. Even some of the areas well stocked with natural seedlings and stump sprouts were slashed and burned, especially around the west end of the Larabee Creek valley (Corbitt, 1960, 1968).

SURVIVAL COUNTS OF EXPERIMENTAL PLANTATIONS

Mr. M. C. Merrill performed survival counts on several of the Pacific Lumber Company plantations from 1924 to 1927 for the Redwood Reforestation Association. Plantations were approximately located in the areas indicated in Figure VI-2 on page 84 (Person, 1937). Survival counts were made along check rows within the planted areas. The number of trees found alive among the total number of check trees constituted the survival. Survival estimates do not include trees dying between the planting date and the establishment of the check rows. Generally, only a very minor portion of the planted area was thus checked. The counts listed in Table VI-4 were made by M. C. Merrill of the Redwood Reforestation Association and covered company plantings from 1924 to the 1926-27 season. From the data it is evident that there is good survival of most plantings within one or two growing seasons after the initial planting, even for redwood. Redwood survival was poorest on pasture land and exposed sites. Unfortunately, no survival counts were made beyond the first two growing seasons. South exposures particularly were poor in survival. Person (1937) estimated the survival of the redwood plantings in 1931 at about 30%. Upon field inspections in 1969 to 1970 none of the plantings could be discovered in the field with certainty. It would be impossible now to determine which of the redwoods present originated from the plantings or from natural regeneration. In general, most of the planted areas seemed to be understocked and brushy.

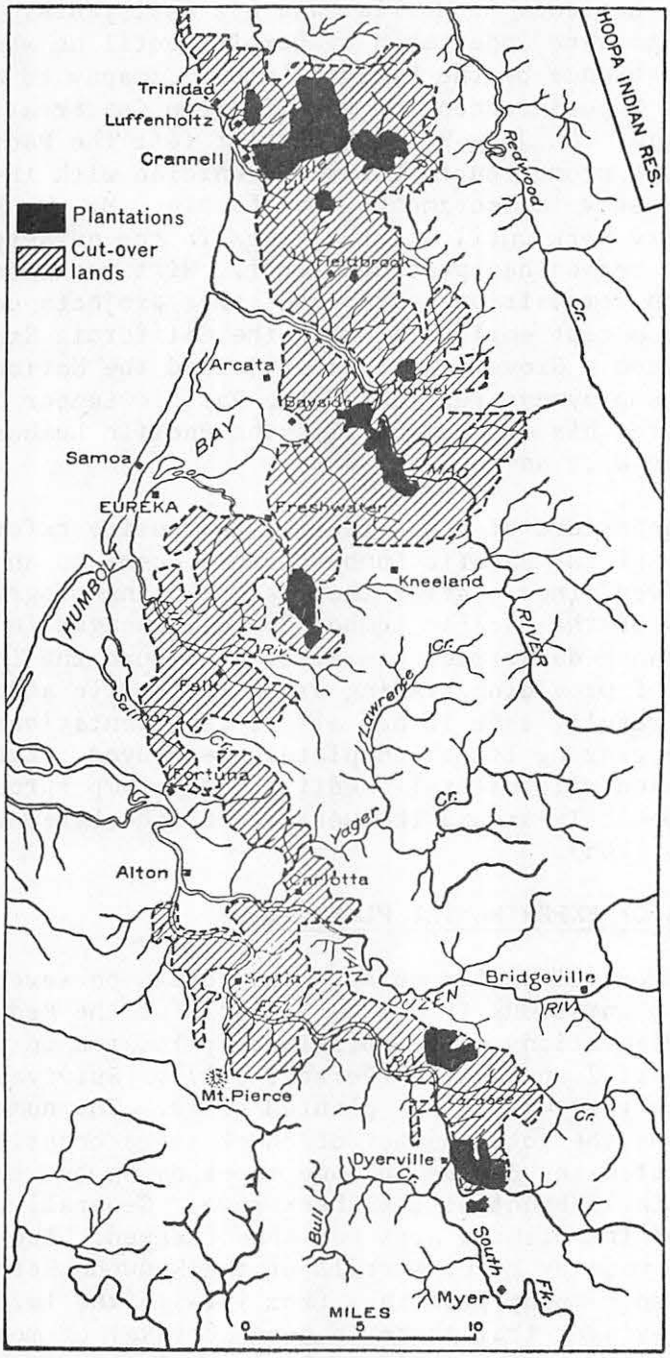

FIG. VI-2: Planted Areas and Redwood Cutover Lands of Humboldt County, California.

TABLE VI-4: SURVIVAL COUNTS MADE IN THE FIELD PLANTATIONS OF THE PACIFIC LUMBER CO.

Plantation	Date of Planting	Age of Trees	Species	Slope	Remarks	Date of Counting	# of Trees	Percent Living
Freshwater	1924	1-0	Redwood	Flat	Old Camp Site	Aug. 1926	100	67
*Freshwater	1924	1-0	Redwood	East	Clay R.R. Bank	Oct. 1926	42	95
Freshwater	1924	1-0	P.O. Cedar	East	Clay R.R. Bank	Oct. 1926	33	96.9
*Freshwater	1924	1-0	Redwood	West	Clay Landing	Oct. 1926	83	96.4
Freshwater	1924	2-0	S. Spruce	West	Clay Landing	Oct. 1926	24	83
Bridge Creek	1925	1-0	Redwood	West	Clay Slide	July 1926	82	37.8
					Took out trees	Oct. 1926	82	2.4
Bridge Creek	1925	1-0	Redwood	East	Weeds, shaded	July 1926	118	88.9
					Woodcutters destroyed trees	Oct. 1926	118	62.7
Collen	1926-27	1-0	Redwood	South	Packed soil,	May 1927	111	96.3
					weeds, exposed	Oct. 1927	111	12.6
Collen	1926-27	1-0	P.O. Cedar	North	Weeds, shaded	May 1927	102	97.1
						Oct. 1927	102	89
Chris Creek	1926-27	1-0	Douglas fir	South	Flat, grassy	May 1927	28	60.7
					pastured land	Oct. 1927	28	28.6
Chris Creek	1926-27	1-0	Redwood	South	Flat, grassy	May 1927	104	86.5
					pastured land	Oct. 1927	104	19.2
Patmore Inc.	1926-27	1-0	P.O. Cedar	SE	Clay, gravel	May 1927	95	95.8
					Exposed	Oct. 1927	95	41

TABLE VI-4, CONTINUED

Plantation	Date of Planting	Age of Trees	Species	Slope	Remarks	Date of Counting	# of Trees	Percent Living
Patmore Inc.	1926-27	1-0	P.O. Cedar	NW	Clay, steep slope, washed	May 1927 Oct. 1927	97 97	93.8 92.8
Patmore Inc.	1926-27	1-0	Redwood	SE	Clay, gravel Exposed	May 1927 Oct. 1927	94 94	88.3 4.3
Patmore Inc.	1926-27	1-0	Redwood	NW	Clay, steep slope, washed	May 1927 Oct. 1927	98 98	91.9 66.4

* Count made by M. C. Merrill, Redwood Reforestation Association.

In 1925, William H. Wirt started experimental plantings and a kind of an arboretum adjacent to the forest nursery in Scotia. In these areas redwoods and other exotic tree species were planted to test their suitability for reforestation. In Tables VI-5 and VI-6 survival counts of the planted tree species were reported by Wirt. It is interesting to note that redwood seedling survival was 20 to 40% while redwood cuttings survived much better. Unfortunately, both experimental areas have now been destroyed by the relocation of the freeway, Highway 101 around Scotia, and the storage area for air drying (Corbitt, 1968). It is also very difficult to determine which redwoods were planted or grew from natural regeneration in these locations. It appears that whatever area was left of these two experimental areas that there is little survival if any at all of the planted stock. Most of the exotic tree species have vanished (Corbitt, 1968).

TABLE VI-5: SURVIVAL COUNTS OF TREES PLANTED (1925-1928) IN WIRT'S EXPERIMENTAL GROVE, SCOTIA, CALIFORNIA (Data from W. H. Wirt, February 6, 1928)

	North Side Creek		South Side Creek		Percentage Survival	
Year of Planting:	1925	1926	1925	1926	1925	1926
	(# trees)		(# trees)		(% survival)	
Redwood <u>Sequoia</u> <u>sempervirens</u>						
seedlings	57	86	80	70	19.6	39.0
cuttings	15	31	--	26	50.0	57.0
cuttings (highway fence)	--	28	--	--	----	----
Douglas fir <u>Pseudotsuga</u> <u>menziesii</u>	52	124	57	71	26.7	48.8
Port Orford Cedar <u>Chamaecyparis</u> <u>lawsoniana</u>	63	143	46	150	27.3	73.2
Western Red Cedar <u>Thuja</u> <u>plicata</u>	35	--	20	--	27.5	----
Incense Cedar <u>Libocedrus</u> <u>decurrens</u>	--	68	--	23	----	91.0
Western Yellow Pine <u>Pinus</u> <u>ponderosa</u>	55	6	75	8	41.3	23.0
Pepperwood <u>Umbellularia</u> <u>californica</u>	--	---	23	--	28.4	----
Sitka Spruce <u>Picea</u> <u>sitchensis</u>	4	8	4	30	1.9	19.0
Nutmeg <u>Torreya</u> <u>californica</u>	1	--	1	--	50.0	----
Monterey Cypress <u>Cupressus</u> <u>macrocarpa</u>	1	1	1	2	50.0	100.0

The Experimental Grove, immediately east of Scotia, was destroyed by the relocation of the freeway, Highway 101.

TABLE VI-6: SURVIVAL COUNTS OF TREES PLANTED (1925-1928)
IN WIRT'S ARBORETUM # 1, SCOTIA, CALIFORNIA
(Data from W. H. Wirt, February 6, 1928 Survey)

Year of Planting:	1922 (# trees)	1923	1924	1925	Percentage Survival Feb. 6, 1928: 1922 (% survival)	1923	1924	1925
Tennessee Red Cedar *Juniperus occidentalis*	--	133	--	--	--	63.4	--	--
Oriental Cedar *Thuja orientalis*	--	13	--	--	--	76.5	--	--
Western Yellow Pine *Pinus ponderosa*	--	10	35	--	--	13.5	71.5	--
Bishop Pine *Pinus muricata*	--	26	--	--	--	89.6	--	--
White Fir *Abies grandis*	--	18	4	--	--	18.0	16.0	--
Sequoia gigantea	--	3	--	--	--	4.0	--	--
Nutmeg *Torreya californica*	--	2	--	--	--	4.0	--	--
Redwood *Sequoia sempervirens*	30	70	59	73	17.5	63.0	79.8	66.8

The Arboretum # 1, immediately east of Scotia, was destroyed by the relocation of the freeway, Highway 101.

During the years of 1923 to 1931 some 14,338 acres have been reforested in Humboldt County and planted, for the predominant part, into redwood. The distribution among the private forest owners is illustrated in Table VI-7 (Person, 1937). From this, it is indicated that The Pacific Lumber Company has made the greatest reforestation effort as far as acreage is concerned, and also planted at twice the density per acre as compared with the other companies. Upon field inspection of the planting sites of these different companies most areas have regenerated naturally also, but still appear to be understocked at the present. Several of these areas have now been logged over for export of their second growth timber to Japan. Therefore, it is difficult to determine the actual success of these plantings.

In summary, the redwood reforestation efforts in Humboldt County have indicated only limited success in planting redwoods. No further redwood plantings on a large commercial scale of cutover forest lands have been attempted since.

TABLE VI-7: ACREAGE PLANTED AND PLANTING COSTS
OF CUTOVER LANDS IN HUMBOLDT COUNTY, 1923-1931
(Data According to Person, 1937)

Company Ownership	Area Planted (acres	Trees Planted (#)	Ave # Trees Per Acre (#)	Cost Per Acre ($)	Cost Per 1,000 Trees ($)
Pacific	15,814	3,493,990	601	8.30	13.80
Little River Redwood	3,299	1,285,010	390	5.90	15.10
Hammond	2,825	1,120,600	397	7.29	18.40
Northern Redwood	2,000	763,000	382	7.52	19.70
Dolbeer-Carson	400	150,000	375	9.89	26.40
Total or Average	14,338	6,812,600	475	7.48	15.80

Planting Stock by Age Classes and Species (in 1,000 trees, 1923-1927)

Company Ownership	Redwood 1-0	Redwood 1-1	Redwood 2-0	Douglas fir 2-0	Douglas fir 1-0	Douglas fir 1-1	Douglas fir 2-1	Port Orford Cedar 1-0 2-0	Port Orford Cedar 1-1 2-1	Sitka Spruce 2-0 3-0	Sitka Spruce 2-1
Pacific	1,314	15	0	125	64	13	0	56	3	28	0
Little River Redwood	537	6	0	42	29	0	0	39	4	159	7
Hammond	800	24	0	25	99	0	0	47	3	116	11
Northern Redwood	243	2	0	8	25	0	0	14	0	24	0
Dolbeer-Carson	50	0	0	0	0	0	0	0	0	0	0
Total	2,944	47	0	200	217	13	0	156	10	327	18

Subtotals by Tree Species in 1,000 Trees

	Redwood	Douglas fir	P. O. Cedar	Sitka Spruce
Pacific	1,329	202	59	28
Little River Redwood	543	124	43	166
Hammond	824	71	50	127
Northern Redwood	245	33	14	24
Dolbeer-Carson	50	0	0	0
Total	2,991	430	166	345

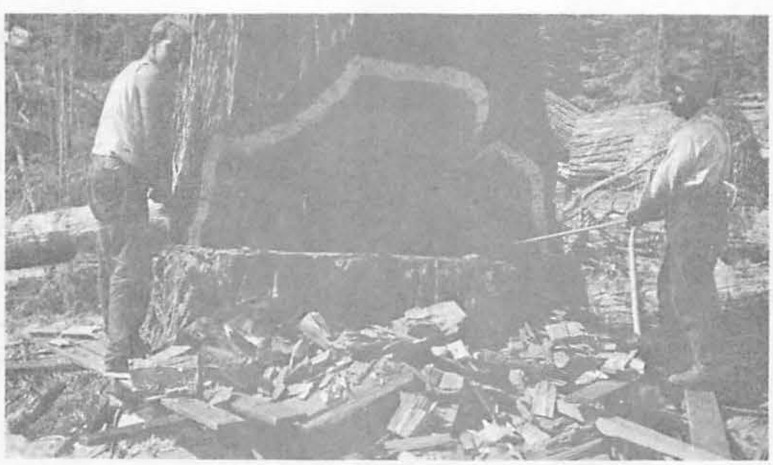

FIG. VI-3: Early timber felling operations in the Freshwater area, The Pacific Lumber Company. Photos: Willis G. Corbitt, around 1922.

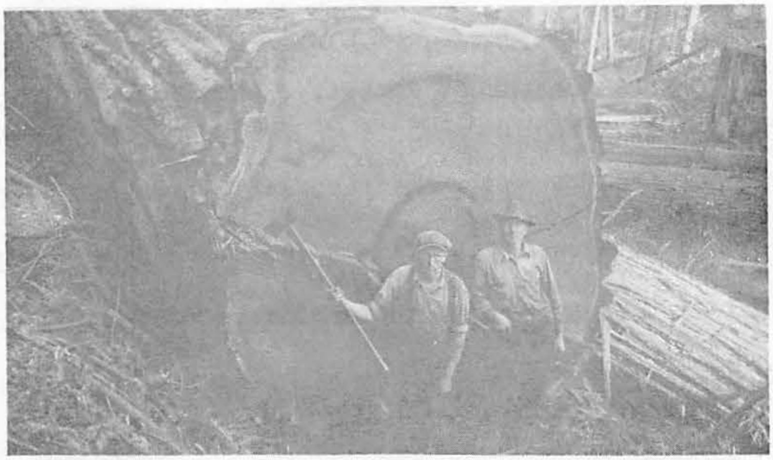

FIG. VI-3, CONTINUED

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VII. THE COMMERCIAL PLANTING EXPERIENCE OF COASTAL REDWOODS IN MENDOCINO COUNTY, CALIFORNIA DURING 1922-1932

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and

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INTRODUCTION

Between 1922 and 1932 commercial redwood plantings were undertaken by private lumber companies in northern California. This project received an unusual amount of publicity both because of the size and the character of this undertaking, and because of the increasing public interest in the Redwood Region and in redwood conservation. Partial results of this project have already been published by Person (1937), Schofield (1929) and others. However, much of the original reports and experiences remained unpublished. Our interest in publishing additional information was spurred by the growing public demand for a forest conservation policy that would insure the continued productivity of the redwood forest lands and the promise of a permanently established redwood industry. Large acreages of cutover redwood lands are in need of reforestation by commercial species. Plantings would be necessary to restore the natural productivity of such lands. This paper describes commercial planting experiments that were carried out in Mendocino County, California between 1922 to 1932. Information on the planting project was obtained from former company foresters, from Lawrence Merriam of the Save-the-Redwood-League, and from those who had direct supervision of these planting projects. An analysis will be made of differences in survival of redwood, Douglas fir and other species used in these commercial plantings. Experiences with nursery practices and planting costs that remained unpublished will also be included in this report.

The devastating influence of cable logging methods, particularly the slack-line method upon the site has left large acreages of inadequately stocked lands in need of reforestation and rehabilitation. The need for a large scale planting program was recognized following World War I (Anon., 1922). In 1922, the Redwood Fire and Protective Association of Mendocino County was organized by the five local large timber operators: Union Lumber Company; Mendocino Lumber Company; Glen Blair Lumber Company; Caspar Lumber Company; and Albion Lumber Company. One of the main purposes in forming this association was to rehabilitate the newly logged sites and the old cutover areas as soon as possible.

THE FORT BRAGG FOREST NURSERY

In 1921, the Union Lumber Company was contracted to supply the needed planting stock for this rehabilitation project from its forest nursery south of Fort Bragg. The first field plantings were begun in the winter of 1923-24 in Mendocino County. Thus, the Union Lumber Company was the first lumber company in the Redwood Region to engage in redwood reforestation. The Fort Bragg nursery started in 1921 with a 4-acre area, expanded in 1925 to 8 acres and then again to 9 acres in 1927. It was closed down in 1932; the last planting was in the fall of 1931. During its total operation this nursery supplied an estimated 6 million seedlings for reforestation projects on private lands. Another smaller forest nursery of 1/3 acre was started by the Caspar Lumber Company in 1923 in Caspar, California, and abandoned in 1927. At the peak of its production in 1925 the Caspar nursery produced 62,700 seedlings. The total production of this nursery during its operations was probably less than 200,000 seedlings (Wirt, 1928). (See Table VII-1.)

TABLE VII-1: PRODUCTION OF NURSERY STOCK IN MENDOCINO COUNTY
(Data from L. C. Merriam, 1928)

Year		Total # Seedlings (#)	Redwood	Douglas fir	Sitka Spruce	Port Orford Cedar	Other Species*
			(% species distribution)				
	Fort Bragg Nursery						
1923	Total	300,000	66.0	28.0	1.3	2.7	2.0
	Seedling Stock	118,000	84.7	--	3.4	6.8	5.1
	Transplant Stock	182,000	53.8	46.2	--	--	--
1924	Total	814,000	72.8	10.8	11.7	4.5	0.1
	Seedling Stock	485,000	79.0	4.3	11.1	5.4	0.2
	Transplant Stock	329,000	63.8	20.4	12.5	3.3	--
1925	Total	1,268,400	90.4	7.4	1.1	0.6	0.5
	Seedling Stock	895,400	87.7	10.1	1.5	--	--
	Transplant Stock	372,500	97.2	0.9	--	1.9	--
1926	Total	1,528,900	88.6	5.9	3.0	1.8	0.6
	Seedling Stock	1,081,500	85.8	6.4	4.3	2.6	0.9
	Transplant Stock	447,400	95.2	4.8	--	--	--

No Data for 1927 to 1932

TABLE VII-1, CONTINUED

Year		Total # Seedlings	Redwood	Douglas Fir	Sitka Spruce	Port Orford Cedar	Other Species*
	Caspar Nursery						
1924	Total	19,300	92.5	--	--	--	7.5
	Seedling Stock	19,300	--	--	--	--	--
	Transplant Stock	--	--	--	--	--	--
1925	Total	62,758	83.7	10.9	--	--	5.4
	Seedling Stock	56,308	81.8	12.2	--	--	6.0
	Transplant Stock	6,450	100.0	--	--	--	--
1926	Total	36,875	90.3	--	9.7	--	--
	Seedling Stock	30,800	100.0	--	--	--	--
	Transplant Stock	6,075	41.2	--	58.8	--	--

No Data for 1927 to 1932

* The other species include: lowland white fir (Abies grandis); nutmeg (Torreya californica); sugar pine (Pinus lambertiana); Monterey pine (Pinus radiata); Monterey cypress (Cuprssus macrocarpa); western red cedar (Thuja plicata); Port Orford cedar (Chamaecyparis lawsoniana); and sitka spruce (Picea sitchensis).

THE FOREST NURSERY PRACTICES AT FORT BRAGG

The Fort Bragg nursery was located half a mile south of Fort Bragg on a level piece of land which used to produce rye. The soil was a sandy loam of sedimentary origin. The site was chosen because of its central location and its accessibility. The area was affected by prevailing northwestern winds which, particularly in the spring, sometimes caused severe dessication of the nursery stock. The winters on the coast were mild; but during the five winters of this operation some frost damage occurred during two winters by frost heaving of the soil causing damage to the small germinating seedlings. The main germination of the redwood seeds was completed within three weeks under favorable climatic conditions. Delayed germination in Port Orford cedar as long as six to twelve months after sowing had been noted, probably caused by the fact that this species was planted considerably further south than its natural range.

Redwood seed was collected in logged areas from felled trees. Within the forest squirrel-cut cones were prefered. Every tree that appeared to have an abundance of cones was tested before any cone collecting. The test involved slicing a number of cones to expose the seed. Unless the cutting exposed an average of 10 to 12 good seeds per cone the tree was rejected. Redwood seeds were purchased locally at $3.50 to $4.00 per pound. Seed germination averaged between 19 to 39 per cent. The cone collecting season generally lasted from October to December. It was possible to collect some 75 to 80 pounds of redwood cones in a day at a cost of approximately $0.10 to $0.15 per pound. The green cones were brought to the nursery and dried in a kiln for 24 hours at 85° to 90°F, after which the cones opened. The drier had a capacity of 250 to 400 pounds of cones every 24 hours. The seed was separated from the cones in a tumbler. A large quantity of seed from the Fort Bragg nursery was exported to New Zealand in 1926 in sealed five gallon cans.

Seedbeds of the size of 4 x 12 square feet were generally constructed by plowing, harrowing and smoothening with a rake. Four beds were established end to end in rows, and 46 seedbeds two feet apart were laid out as a tier of beds. The nursery consisted of three tiers separated by 6-foot lanes. Side boards of 1- to 2-inch thickness were placed along the sides of each bed and the bed was leveled with a planer board. Seeds were sown by hand, initially in the amount of 12 to 14 ounces per 4 x 12 feet seedbed and later reduced to 6 ounces per seedbed (see table VII-2). No fertilizers were used.

TABLE VII-2: SEED COLLECTIONS AND DATE OF SOWING, FORT BRAGG NURSERY, UNION LUMBER COMPANY
(Data by Merriam, 1928)

	1923	1924	1925	1926	1927
Date of Sowing	*	Nov. to March	Jan. to Mar. 19	Nov. 18 to Mar, 10	Nov. 9 to Apr. 15
Amount of Redwood Seed Sown/4 x 12 ft. Seedbed (ounce weight)	7 *	12 to 14 *	8 to 10 (12 **)	6 to 8 (8 **)	6 for 1926 crop 10 to 12 for 1925 crop (6 **)
Total Amount of Seed Sown (lbs)					
Redwood	22.5	44.5	240 (12**)	407 (192**)	377 (12**)
Douglas fir	6 7/8	7	22 (2**)	10.5	-- (1**)
Port Orford cedar	1	7	-- --	3 1/8	8 (1**)
Sitka spruce	1 7/8	2 5/8	4.5 (1**)	3.5	-- (1**)
Nutmeg	----	23	-- (335**)	20	--
White fir	----	--	3 --	--	--
Laurel	----	--	-- (110**)	--	--
Total	32.5	26 1/8	280 ½ (460**)	443 (12**)	385 (15**)

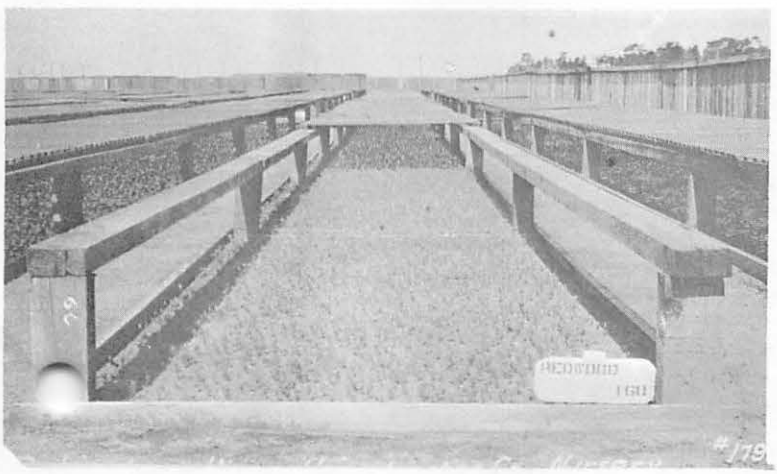
* Information missing

(**) Data for the Caspar Nursery, Caspar, California.

FIG. VII-1: Mr. Virgil B. Davis at the nursery site in Fort Bragg, California about 1925.

ENTRANCE TO FOREST NURSERY
FORT BRAGG 1922

REDWOOD SEEDLINGS WITHOUT
LATH SHADING, June 9 1925



REDWOOD SEEDLINGS GROWN
UNDER LATH SHADING

PREPARING SEEDBEDS BY COVERING
BED WITH COARSE RIVER SAND AND
SOWING REDWOOD SEEDS, 1922

The seed was wetted down with a sulfuric acid solution (9 ounces sulfuric acid per 9 gallons of water) per 4 x 12 square feet bed. Subsequently, a cover of 1/8- to 1/4-inch coarse beach sand was applied with a planer board to cover the seeds. Shade frames of 4 x 6 square feet were used, using a 1/2-inch wide, 1/4-inch thick lath to cover the beds on sunny days. The shade frames cost $0.48 to $0.55 a piece. The sulfuric acid was used to reduce the damping-off losses. Experiments were undertaken to use Uspulin and Semesan solutions (hydroxy-mercurichlorophenol sulfate 30%) sprayed on the foliage against Botrytis, but the results were unsatisfactory. By removing shade frames and by cutting down on the watering, the disease could be controlled in most cases. Sometimes the losses in damping-off were considerable.

Watering was started at Fort Bragg when the seedbeds began to dry out, while at the Caspar nursery the beds were watered generally three times a week for one hour. Chemical weed control with zinc sulfate was used to reduce the weeding in the seedbeds, but this proved to be unsuccessful, and most weeding had to be done by hand (Davis, 1930; Merriam, 1928).

White grubs, the larvae of the June beetle gave the nursery considerable trouble in the third and fourth year of operations. Several fungal diseases occurred and were grouped as "damping-off." Fungus and mildew were a consistent problem. Attack of mildew on the tender foliage was combatted by removal of the shade frames and reduction of sprinkling. One or two fungicides were tried with little success (Davis, 1930).

Roots were mechanically pruned late in the fall at a 4 1/2-inch depth on foggy days to promote a short and branched root system. The beds were immediately soaked with water to fill the cracks made by the root pruner. The lifting and selection of the planting stock was done by hand a few weeks later. Seedling bundles were made containing 1,000 to 3,000 seedlings with their roots wrapped in damp Sphagnum moss. The bundles were reinforced with wooden sticks or cleats and stout cords. Dry Sphagnum moss was obtained locally at the cost of $0.025 to $0.03 per pound as packing material.

TRANSPLANTING OPERATIONS

Transplanting was done by contract at a cost of $0.70 per 1,000 seedlings. An experienced planter could transplant between 8,000 to 9,000 seedlings a day. The total production cost per 1,000 seedlings (Merriam, 1928), including supervision and overhead was $7.65 in 1923; $6.84 in 1924; $6.75 in 1925; and $6.96 in 1926. The Union Lumber Company sold this nursery stock to the other contracting companies at the following prices: $7.00 per 1,000 seedlings of redwood 1-0* stock; $7.50 per 1,000 seedlings of Douglas fir 2-0* stock; and $10.00 per 1,000 seedlings for redwood 1-1* stock and Port Orford Cedar 2-0 (Davis, 1930).

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* Planting stock is denoted by symbols such as "1-0" or "1-1", the first digit referring to the number of years that the seedling remained in its original seedbed and the second digit to the number of years in the transplant bed. For example, "1-1" denotes stock left 1 year in the seedbed, then transplanted, and left 1 year in the transplant bed, the seedling thus being 2 years of age.

The Fort Bragg nursery produced redwood 1-0 seedlings of an average minimum height of 3 inches with a good lateral root system. The Caspar nursery produced a redwood 1-0 stock of 4 to 10 inches in height with roots pruned to 8 inches. The following tables indicate production costs of seedling and transplant stock (Table VII-3) and nursery utilization (Table VII-4).

TABLE VII-3: THE AVERAGE NURSERY COST FOR PRODUCING SEEDLING AND TRANSPLANT STOCK PER THOUSAND SEEDLINGS

<u>Seedling Stock</u>	
Seeds	$ 0.52 - 0.60
Sowing of Seeds	0.37 - 0.66
Care of Seedbeds	0.99 - 1.59
Lifting, Bundling, Sorting	0.77 - 1.23
Packing	0.13 - 0.15
Total Cost Seedling Stock 1-0	2.80 - 3.88
<u>Transplant Stock</u>	
Lifting, Bundling, Sorting for Transportation	$ 0.88 - 1.17
Ground Preparation	0.08 - 0.09
Transplanting	0.98 - 1.29
Care of Transplant Beds	1.51 - 2.36
Lifting, Bundling	1.23 - 1.47
Total Cost of Transplants	2.12 - 2.65

These costs do not include any depreciation of equipment or supervision. The current wage scale was $0.30 to $0.40 per hour for nersery labor and for an assistant forester in charge: $175 per month (Davis, 1930).

TABLE VII-4: UTILIZATION OF NURSERY AREAS
(Data From L. C. Merriam, June, 1928)

	1921-22	1922-23	1923-24	1924-25	1925-26	1926-27
Total Nursery Area (acres)						
Fort Bragg	*	4	4	8	8	8 - 9
Caspar	*	*	0.33	0.33	0.33	0.33
Area in Use in Raising Trees (acres)						
Fort Bragg	0	0.16	1	3	4	5
Caspar	*	*	0.16	0.16	0.16	0.16
Area Under Vetch or Other Soil Crop (acres)						
Fort Bragg	0	0	0	1	3	3
Caspar	*	*	0.16	0	0	0
Number of Seedbeds (Equivalent of 4 x 12 sq. ft. beds)						
Fort Bragg	96	128	470	880	1,004	1,200
Caspar	*	*	--	24	43	31.5
Area in Seedbeds (square feet)						
Fort Bragg	4,608	6,144	22,080	42,240	48,192	57,600
Caspar	*	*	0	1,132	2,064	1,512
Number of Transplant Beds (Equivalent of 4 x 12 sq. ft. beds)						
Fort Bragg	0	222	471	570	720	522
Caspar	*	*	0	0	10.5	10.5
Area in Transplant Beds (square feet)						
Fort Bragg	0	10,686	22,608	27,360	34,560	25,056
Caspar	*	*	0	0	504	504

* Information missing.

BUILDINGS AND EQUIPMENT

The Fort Bragg nursery had two buildings. The main building was 8 x 32 feet and used for an office and tool house. The seed extraction plant was also located in it. The drying plant was equipped with an electric heating unit and a blower to dry cones in about 24 hours. Its capacity was about 250 to 400 pounds of cones every 24 hours.

The second building was 16 x 64 feet and used largely as a packing room. It housed all the equipment necessary to store moss, shred it for packing, and to pack and bundle the trees as well as sorting tables and some tool storage.

The nursery was bounded on three sides by a woven wire fence, and on the front by a white picket fence.

The nursery received its water supply out of a pipeline running past the nursery. The pump was a centrifugal type operated by a 5 hp induction motor. Its capacity was 75 gallons per minute. The main lead from the pump was 2 1/2-inch black pipe and 400 feet long. The laterals were spaced 100 feet apart. North of the main there was 1 1/4-inch galvanized iron pipe; south of the main there was 1 1/2-inch galvanized iron pipe. On the laterals 2-foot stand pipes were spaced 24 teet apart with a 3/4-inch galvanized iron pipe with the standard crane garden valves (Davis, 1930).

There is no information available of the Caspar nursery.

THE EXPERIMENTAL PLANTINGS IN THE TEN-MILE RIVER AREA

During the winter of 1924-1925 experimental plantings were conducted in Section 3 T19N R17W to determine the survival of redwood, Douglas fir, Port Orford cedar and Sitka spruce in relation to planting on north and south facing slopes to the date of planting and to the severity of root pruning. Survival counts were made from seedlings which were individually staked with a redwood lath at the time of planting. The site selected was a narrow valley with relatively steep slopes in the lower drainage of Ten-Mile River, some ten miles north of Fort Bragg. This narrow valley made it possible to run rows north and south across the drainage from ridge top to ridge top. The elevation of the ridge tops was approximately 800 feet above sea level, while the valley bottom was at approximately 100 feet elevation. The experimental area was situated approximately five miles inland from the Pacific Ocean and under the influence of the typical maritime climate.

The area had been logged approximately five years prior to the experimental planting. Although there was considerable regrowth of redwood stump sprouts and other herbaceous vegetation, very little brush species had yet invaded the site. One-year old as well as two-year old redwood seedling stock was used in the field plantings. All planting steps were performed by a single man, each man completing the entire operation of digging the holes with a mattock and planting the tree. The trees were planted eight feet apart in rows, the rows being eight feet apart also. Some 200 to 300 trees were planted in each row. Two men were used who could be depended upon to follow instructions and work without constant supervision. A record was kept of the rows planted by each man.

The planting was favored because of an unusual high precipitation during the months of April and May of 1925 following the winter planting. The total rainfall for the winter season (October, 1924 to April, 1925) averaged 48 inches; it was 12 inches above normal but fairly well distributed over the entire winter season. These very favorable weather conditions from the standpoint of precipitation have undoubtedly influenced the result of this experimental planting. The factors used in determining the significant influences upon the planted stock were species, aspect, planter, date of planting, and the root pruning length of the planted seedlings. Redwood, Douglas fir, Port Orford cedar and Sitka spruce were used for the commercial plantings. The plantings were executed on December 15 to 19, 1924; January 12 to 16, 1925; and February 6 to 14, 1925. Roots were pruned to the lengths of four, six and eight inches. The survival counts were made in the early summer of 1926 (see Table VII-5).

TABLE VII-5: SURVIVAL PERCENTAGE OF THE EXPERIMENTAL PLANTINGS, TEN-MILE RIVER AREA, FORT BRAGG, CALIFORNIA (Data from Virgil B. Davis, 1930)

		Planter #1		Planter #2	
	Slope Aspect:	North	South	North	South
Date	Root Length (inches)	Percentage Survival (%)			
REDWOOD 1-1 STOCK					
Dec. 5-6, 1924	8	89	57	91	64
Jan. 7-8, 1925	8	83	60	90	63
Jan. 8-9, 1925	6	83	60	*	*
Jan. 9-10, 1925	6	80	78	*	*
Feb. 2, 1925	8	90	74	94	72
Feb. 4-5, 1925	8	87	60	*	*
Feb. 5-6, 1925	8	90	64	*	*
March 3, 1925	8	(88)	(62)**	81	44
REDWOOD 1-0 STOCK					
Dec. 15-16, 1924	8	74	65	*	*
Dec. 17-18, 1924	6	69	54	*	*
Dec. 17-19, 1924	4	73	53	*	*
Jan. 12-13, 1925	8	78	62	*	*
Jan. 14-15, 1925	6	71	28	*	*
Jan. 15-16, 1925	4	76	50	*	*

TABLE VII-5, CONTINUED

Date	Root Length (inches)	Planter #1 North	Planter #1 South	Planter #2 North	Planter #2 South
		Percentage Survival (%)			
Feb. 6-9, 1925	8	77	44	*	*
Feb. 10-14, 1925	6	79	33	*	*
Feb. 10-14, 1925	4	71	34	*	*
March 4, 1925	8	(83)	(46)**	89	64
DOUGLAS FIR 1-1 STOCK					
Jan. 8-9, 1925	8	*	*	56	73
Jan. 9-10, 1925	6	*	*	61	78
Jan. 12-13, 1925	6	*	*	64	61
PORT ORFORD CEDAR 1-1 STOCK					
Dec. 15-16, 1924	8	*	*	93	85
Dec. 17-18, 1924	8	*	*	91	79
SITKA SPRUCE 2-1 STOCK					
Jan. 14-15, 1925	8	*	*	78	48
Jan. 15-16, 1925	8	*	*	80	49
Feb. 5-6, 1925	8	*	*	80	44
Feb. 6-9, 1925	8	*	*	72	44

* None planted by planter.

** Actually, another planter than planter #1 was used. For the remainder of the data the same planters #1 and # 2 were involved in the entire experimental plantings.

Plantings were undertaken in rows running across the valley from north to south facing slopes. Generally, the same planter planted the entire row. The average survival on the north slope was 74 per cent and on the south slope was 47 per cent. Because of the nature of the data and the deficiencies in the experimental design not all of it could be analyzed statistically. The analysis of variance for the redwood 1-0 stock indicates that for the same planter #1 only the slope aspect had a significant influence upon the average survival (Table VII-6). No significant differences were observed due to planting date or root length pruning. Nevertheless, the influences of these two factors could be critical since their significance may have been obscured by the unusually favorable weather conditions following the winter planting. Unfortunately, the experiment was not repeated in other years with more normal weather conditions.

TABLE VII-6: ANALYSIS OF VARIANCE
FOR THE REDWOOD 1-0 STOCK PLANTED BY PLANTER #1
(Davis, 1930)

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	z-ratio
Aspect (2)	1	3,364	3,364.0	46.79**
Planting Date (3)	2	209	104.5	1.45
Root Length (3)	2	374	187.0	2.60
Error	7	863	71.9	--
Total (12)	11	4,810		

Redwood 1-1 planting stock was analyzed for influences between the two different planters, the slope aspect, and the planting date with a uniform root pruning length of eight inches. The analysis of variance (Table VII-7) indicates that the slope aspect was again the most significant factor while no significant differences were observed among the two planters used, the planting date nor their interactions.

TABLE VII-7: ANALYSIS OF VARIANCE FOR THE REDWOOD 1-1 STOCK
AT THE UNIFORM 8-INCH ROOT LENGTH
(Davis, 1930)

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	z-ratio
Planters (2)	1	2	2.00	0.154
Planting Dates (4)	3	268	89.33	6.871
Aspects (2)	1	2,947	2,947.00	226.68**
Interaction Planter x Date	3	230	76.67	5.897
Interaction Planter x Aspect	1	1	1.00	0.0769
Interaction Date x Aspect	3	47	15.67	1.205
Interaction Planter x Date x Aspect	3	39	13.00	--
Total	15	3,534		

The average survival on the north slope was 90 per cent and on the south was 64 per cent. The average survival for planter #1 was 74.3 per cent and for planter # 2 was 74.9 per cent.

The unusual amount of precipitation during the following spring season of 1925 may have obscured many important facts of severe root pruning and of the influence of planting date in this experiment. Such influences could only be properly assessed with repeated observations in other years under more typical weather conditions, and with an improved statistical design of the experiment.

COMMERCIAL PLANTING PRACTICES AND PLANTING COSTS

According to preliminary results, the Union Lumber Company believed that trees set out after March 1 had less chance to survive than trees planted during the previous months. Therefore, winter planting was advocated. Root growth in redwood seedlings begins in early February. Seedlings planted late in the spring are believed to have insufficient root development to survive the summer droughts. Generally, no planting could be started before November 15 because usually the growing season had not been terminated by that time. Sufficient rain is needed to soak the soil thoroughly for successful field plantings. The only climatic danger for planting during the winter period would be frost which might injure the plants directly or indirectly by heaving of frozen soil around the roots or freezing of the foliage. Frozen foliage often turns into a reddish brown.

The planters were mostly company employees, unemployed in winter, or on light duty because of physical problems. Field crews of 8 to 12 planters operated under one foreman. The crews usually worked up and down the slope at right angles to the contours, but in some cases planting was done parallel to the contours. The most common method was to loosen the soil with a mattock and dig a socalled slit-hole in which the tree was planted. The spacing varied from 6 x 6 to 12 x 12 feet, resulting in a total stand of approximately 680 trees per acre. Since no planting was done within eight feet of redwood stumps that produce large clumps of sprouts, the actual number of trees averaged more nearly 500 trees per acre. In some plantings pieces of slash were placed on the south side of the newly planted seedlings to protect the young plants against excessive temperatures and evaporation losses. Mostly sufficient protection developed quickly within the planting sites from herbaceous vegetation. In Table VII-8 the acreages reforested by planting stock of various species by lumber companies are listed.

In general, the planting operations were well supervised and well handled. In Table VII-9 the average planting costs were computed for a few lumber companies based upon costs for the years 1924-1927 (Person, 1937).

TABLE VII-8: ACREAGE PLANTED BY SPECIES AND BY LUMBER COMPANY DURING THE 1923 - 1927 PERIOD (Person, 1937)

Company Ownership	Acreage Planted (acres)	Trees Planted (#)	Ave. # Trees Per Acre Planted	Cost Per Acre ($)	Cost Per 1,000 Trees ($)
Union	5,150	2,551,000	495	11.01	22.20
Mendocino	1,666	797,000	478	10.20	21.30
Glen Blair	100	47,000	470	10.20	21.70
Caspar	3,325	1,587,970	478	10.43	21.80
Albion	1,844	920,000	499	9.35	18.70
Total or Average	12,085	12,715,570	488	10.48	21.50

Planting Stock by Age Classes and Species

Company Ownership	Redwood			Douglas Fir				Port Orford Cedar		Sitka Spruce	
	1-0	1-1	2-0	2-0	1-1	1-1	2-1	1-0 2-0	1-1 2-1	2-0 3-0	2-1
Union	714	301	44	66	36	119	24	55	17	86	68
Mendocino	347	207	0	40	0	23	0	0	1	0	1
Glen Blair	37	10	0	0	0	0	0	0	0	0	0
Caspar	586	264	0	3	0	0	0	5	0	9	3
Albion	486	365	0	46	0	0	0	0	0	0	0
	2,170	1,147	44	155	36	142	24	60	18	95	72

Subtotals by Tree Species in 1,000 Trees

Company	Redwood	Douglas Fir	P.O. Cedar	Sitka Spruce
Union	1,059	245	72	154
Mendocino	554	63	1	1
Glen Blair	47	0	0	0
Caspar	850	3	5	12
Albion	851	46	0	0
Total	3,361	357	78	167

TABLE VII-9: COMPUTED PLANTING COSTS INCLUDING THE COST OF STOCK FOR FIVE MAJOR LUMBER COMPANIES IN MENDOCINO COUNTY, CALIFORNIA

Lumber Company	Total Cost Per Acre	Total Cost Per 1,000 Trees
Union	$ 11.01	$ 22.20
Mendocino	10.20	21.20
Glen Blair	10.20	21.70
Caspar	10.43	21.80
Albion	9.35	18.17
Average	$ 10.48	$ 21.50

The total reforestation costs of redwood plantings, considering all expenditures, amounted to about $0.055 per Mbf of lumber produced, an expenditure which is by no means a burden to these companies, with an average sale price of $25 to $27 per Mbf stumpage (Davis, 1930). Fritz (1969) indicates, however, stumpage prices of $2.00 to $4.00 per Mbf.

Many of the companies had made insufficient check surveys to assess the survival accurately. Most programs did not continue long enough and no checks were made anymore after 1931. Therefore, only estimated survival figures could be presented. Person (1937) inspected many of the planted areas between 1931 and 1932. His findings were generally consistently lower than the companies' estimates of survival. His conclusions have been summarized in Table VII-10.

TABLE VII-10: SURVIVAL ESTIMATES OF COMMERCIAL REDWOOD PLANTINGS IN MENDOCINO COUNTY, CALIFORNIA

Lumber Company	Company Estimates on Staked Check Trees	Adjusted Survival Estimate Person (1937)
Union	33	30
Mendocino	55	45
Glen Blair	77	60
Albion	50	45
Caspar	66	60
Weighted Average	--	36

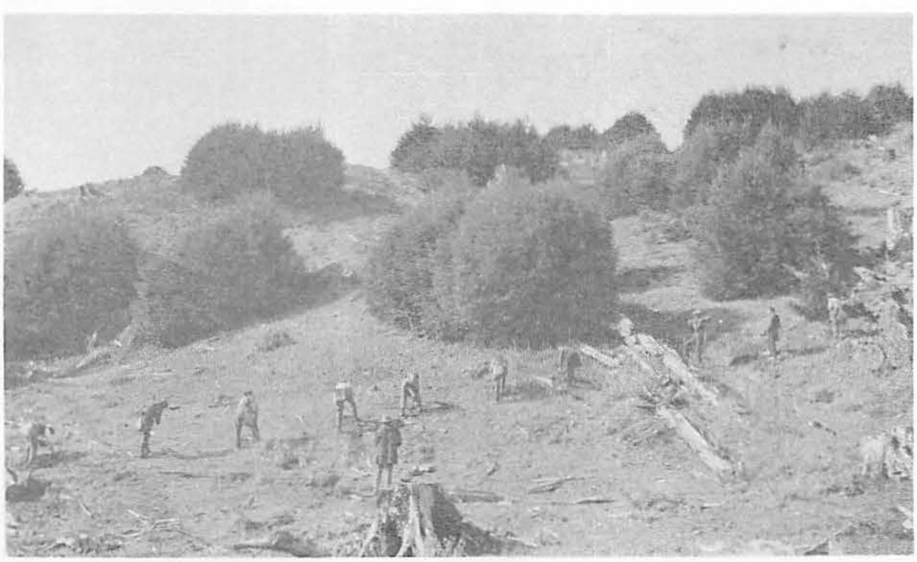
LUMBER CAMP ON THE SOUTH FORK OF
TEN MILE RIVER, UNION LUMBER COM-
PANY, FORT BRAGG, CALIF. 1922

ALLUVIAL FLAT WITH 70-YEAR OLD REDWOOD
STAND ALONG BIG RIVER, FORT BRAGG.
About 1920 (Courtesy Wonacott's Studio)
Note the silt markings on trees from flood.

CUTOVER LANDS POORLY STOCKED WITH REDWOOD SPROUT CLUMPS, TEN MILE RIVER AREA. 1920

HIGH CLIMBER JUST BELOW THE CROWN OF THE DOUGLAS FIR TREE READY TO TOP THIS TREE FOR A SPAR TREE IN HIGH LEAD LOGGING, FORT BRAGG, June 1925

CARL GERHARDY (with hat) AND FLOYD COONEY ON REFORESTING CUTOVER LANDS NEAR FORT BRAGG. June 1925



UNION LUMBER COMPANY PLANTING CREW IN THE CUTOVER AREA OF THE SOUTH FORK OF TEN MILE RIVER NEAR CAMP #1. FOREMAN IN THE FOREGROUND IS GUERDON ELLIS. About 1924.

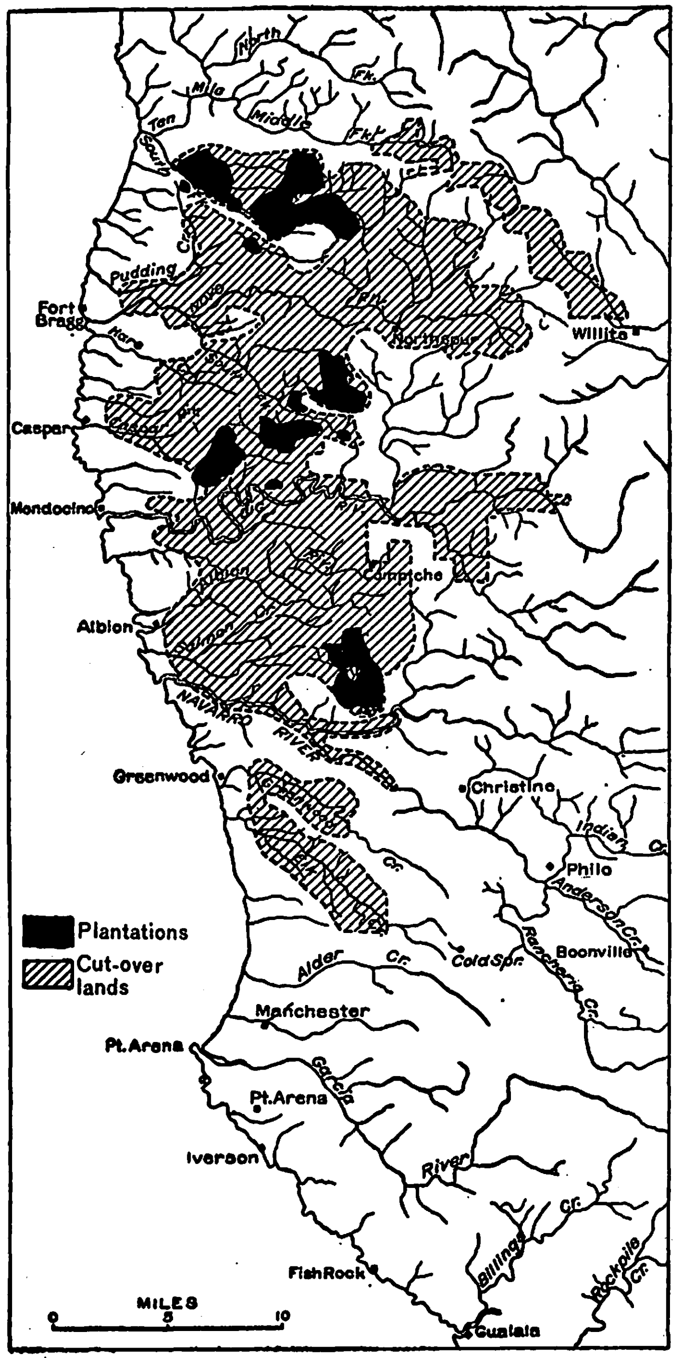
The length of time between logging and planting was found to be directly related to the survival of the plantation. Planting within one year after logging resulted in 55 per cent survival after the first growing season, more than twice the survival obtained in plantings after a lapse of two or more years since logging. The latter survival ranged from 16 to 28 per cent for areas planted two to six years since logging. Another important cause of failure in plantations was rodent damage by wood rats. It was observed that the wood rat damage significantly increased between 1930 and 1932 as the cutover lands provided more favorable vegetative growth and cover causing an increase in rodent populations. The marked superiority of the survival of the 1-1 redwood planting stock (53.9 %) over the 1-0 redwood planting stock (33.3 %) should be noted. More remarkable is the slow height growth of the planted stock. After some six years, height growth of redwood and other species averaged only about 35 inches as compared to their average height of seven inches after the first year of plantings (Person, 1937). Interesting also is the survival of a redwood plantation of the Albion Lumber Company which was destroyed by the Comptche fire in September, 1931. Person (1937) counted in May, 1932, an average survival of 27 per cent of which seven per cent survived with undamaged top; two per cent of the redwoods were top-killed but did not resprout while 18 per cent of those that were top-killed resprouted from the burl. Burls form just below the ground level on all redwood trees over five years of age. Similar survival observations were made within the burned redwood plantation of the Caspar Lumber Company that was planted in 1924-25 and burned in September, 1920 (Person, 1937).

TERMINATION OF PLANTING PROJECTS

The virutal collapse of this redwood ref)restation project in 1932 was caused mainly by the economic depression. In 1931, the California Forest and Range Experiment Station, Berkeley, California, of the United States Forest Service, started with formal forest research programs in the Redwood Region, mostly utilizing private lands. One of its first priorities was an evaluation of these commercial plantings before much of the information would be lost (Person, 1937). All of the company foresters engaged in this planting project were forced to leave the local area to seek employment elsewhere. No complete scientific records of survival and costs had been maintained by the different companies and only occassional rows of check trees were staked in the field to estimate the survival. Therefore, it was necessary to revisit most of the redwood plantings in Mendocino County during 1931-32. A summary of observed survival rates was published by Person in 1937.

CURRENT STATUS OF THE PLANTINGS

During the depression years and thereafter there were no maintenance or weeding operations within these plantations. Plantations that were sufficiently open or damaged by ground fires developed grassy and herbaceous growth in their openings. Cattle drifted in for the better forage on cutover lands. Grazing further severely damaged these plantations.



VII-3: Planted areas and redwood cutover lands of Mendocino County.

From the commercial viewpoint these plantations have resulted in failure to reforest the sites for commercial timber production. Everywhere shrubs and hardwood sprout growth had encroached after five to six years and this dense vegetation resulted in severe competition and suppression of the planted redwood stock. Even upon careful inspection of the planted areas it is now impossible to determine with certainty which trees or sprout clumps have resulted from the original plantings.

SUMMARY AND CONCLUSIONS

The experience and failure of these commercial plantings have indicated that:

1. It is difficult to reforest large cutover areas with redwood 1-0 stock, even under most favorable weather conditions.

2. Redwood 1-1 stock has proven to be superior in their initial five to six year survival as compared to 1-0 stock in the Mendocino plantings.

3. Winter planting is recommended. No planting of redwood stock should be executed after March in Mendocino County.

4. South aspects or dry site are most difficult to reforest with redwood, presumably because of drought, high summer temperatures and excessive evaporation losses.

5. Rodent damage and particularly cattle grazing result in severe damage or complete failure of plantations. Cattle grazing is highly incompatible to reforestation efforts. Cattle does not eat the redwood plantings but trampling destroys the small trees.

6. Repeated silvicultural measures or treatments may be needed to overcome competition from brush and hardwoods and prevent suppression of the slow growing redwood planted stock.

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VIII. THE NORTHERN RANGE OF THE REDWOOD FOREST IN OREGON

The northern limit of the distribution of the redwood forest in Oregon has been known for a number of years, but no ecological studies have been made explaining its distribution. Sudworth (1908) was one of the first to record accurately the range of redwood in Oregon. Sudworth notes that redwood growth is limited to southern Curry County: "Two groves aggregating some 2,000 acres on the northwestern side of the Chetco River, 6 and 12 miles from its mouth, a third grove, farther south on the Winchuck River, only a few miles from sea and fairly near the California line." Guthrie (1925) reported essentially the same distribution. Eliot (1948) reported the same distribution, but specified that the third grove lays about 10 miles up the Winchuck River.

Personal visits were made to the Oregon redwoods in 1965, 1966 and 1967. A limited amount of ecological and inventory data was collected. All the available information from other sources was compiled and field-checked where possible. The following is an account of the current knowledge about the distribution of redwood in southern Oregon.

INFORMATION OBTAINED FROM U. S. FOREST SERVICE

From the Siskiyou National Forest Headquarters the following information was received (Philbrick, 1964):

"Redwood grows in southern Curry County as widely scattered individuals pretty much throughout the Winchuck drainage. It also occurs in mixed groves on some of the smaller creeks emptying into the Chetco River. It is not possible to make a thorough survey of all the redwoods in the Chetco Ranger District. Such a survey would be a major project that would occupy a two-man crew for at least a full season. The (Chetco) District Ranger and his men are quite familiar with areas where redwood can be found.

"The attached map shows locations of groves which we believe might be of sufficient interest to justify special designation. None of these areas are threatened by programmed logging sales.

"The southernmost grove (1), located on Bear Creek in Section 14, T 41 S R 12 W Willamette Meridian, contains the largest trees. The major specimens measure 9 to 15 feet in diameter. There are numerous cases where three to four such trees have grown together at the base, resulting in tremendous stump diameters. This area shows evidence of some strange disease or affliction which is killing large numbers of trees in the 6- to 30-inch diameter classes. The bark peels off from the tree at the cambium. There is no visible sign of the causative agent. The disease is not new, for most of the big trees show spiked tops and massive scars down their trunks, indicating damage many years ago from the same agent.

"The evidence of disease affects the desirability of the grove for special designation. This grove is difficult of access and will undoubtedly remain so for a number of years. It is suggested to designate this grove as a natural area.

"The second and third groves (2 & 3) to be considered are in the Wheeler Creek drainage in Sections 15, 16 and 21, T 40 S R 12 W. The major trees here are somewhat smaller than those in the Bear Creek tract, but they are very fine specimens of mixed redwood on dry ridge tops sites. No evidence was noted of the disease found in the Bear Creek tract. These groves are on a good road and are readily accessible to the public. We believe that these groves should be designated as unusual interest (botanical) areas.

"The fourth area (4) considered was the most northerly grove found. It is located in Section 28, T 39 S R 12 W. This is a small group of redwood mixed with equal-sized Douglas fir. Probably not over five acres contain redwood. These are 6 to 8 feet in diameter and quite tall and well-formed. This grove is on a good road and lays between two clearcut areas. It is to be classed as an unusual interest (botanical) area.

"The fifth area (5) to be considered is the Redwood Park tract in Sections 12 and 13, T 40 S R 13 W. This is the tract which has been considered for transfer to state ownership. In view of current pressure for the Forest Service to designate and preserve certain specimen areas of redwood, this tract is recommended to be retained by the Forest Service and designated as an unusual interest (botanical) area. It could be very easily developed with a self-guiding nature trail.

"The redwood comprising the Kerr Exchange selected lands (6) is of much lower quality than the Bear Creek tract. On the selected lands of Section 7, T 40 S R 12 W, the 24- to 48-inch DBH class (inclusive) account for 89.59 per cent of the trees; the 50- to 62-inch DBH class (inclusive) account for 6.85 percent of the trees; and the larger classes over 62 inches account for only 3.56 per cent of the trees. The 36 per cent cruise picked up only 25 trees over 6 feet in diameter on the entire 526.67 acres of selected lands. These selected lands lay in an island of National Forest ownership surrounded by private property which is used mostly for ranching purposes. The repeated burning of these private lands in an effort to maintain grazing conditions poses a constant fire threat. The Forest Service lands are in Section 17 and 18, adjacent to the selected lands, and are mostly cutover or over-grown brush fields. The offered lands in the Kerr Exchange will provide protection to these redwoods. It is therefore recommended that the exchange be consumated."

Communications from the Chetco Ranger District (Taylor, 1965; Kahre, 1968) added the following information to the distribution of the redwoods:

"The elevation range appears to be from sea level to approximately 1,800 feet. The appearance is that the trees grow from the valley up to the ridge tops with no certain preference for either site. Its distribution is rather discontinuous. Several drainages are entirely skipped, while other drainages contain isolated stands of redwood." (Taylor, 1965).

"It is true that there are serpentine rock out-croppings on Mt. Emily, but they are well up on the mountain. I do not conclude that soil is the reason for redwood not occurring in Big Emily Creek." (Kahre, 1968). Soils derived from serpentine rock have a very distinctive vegetation. They can be discerned from a distance because of the presence of open pine forests. No redwood seems to grow on serpentine soils.

The absence of redwood is "due to differences in microclimate which may or may not be caused by the high elevation of Mt. Emily and the ridge to the East. Big Emily Creek lies on the lee side of this high ridge system and may be partly sheltered from weather coming from the southwest." (Kahre, 1968).

The redwood distribution is probably most closely associated with the distribution of the fog. "The Winchuck and Wheeler Creek drainages are usually the first ones to have fog move into them from the ocean. Also, fog moves a long way up the Chetco River drainage. The overall climate is uniform (hence the lily bulb industry). Redwoods seem to grow from creek bottoms to ridges and, now and then, skip entire drainages. Fog may be a critical factor for redwood growth." (Taylor, 1965).

In most of the stands in Oregon, no old redwood stumps have been noted. This has aroused interest from both the Forest Service and Dr. Becking (1965). "Indications are that fires had been present in the area, but most date from the coming of white man during the latter half of the 1800's and up to as late as 1938. It is rather doubtful that fires would burn up old stumps completely, especially in redwood stands. [Redwood stumps are very resistant to decay and fire.] They certainly do not in Douglas fir stands. The fact that we have very few nature-caused fires and the vast occurrance of Douglas fir old-growth stands indicate to me that most of the fire history of the area was probably man-caused and primarily by the white man. Old fire records tend to substantiate this also." (Kahre, 1968).

"Perhaps, redwood has not been in this area much more than 300 years. Most of our old-growth Douglas fir appears to be around 300 years old also. But there are indications that Douglas fir has been around longer. Perhaps there was a major destruction of the forest in this area about that time in history." (Kahre, 1968).

"The first lumbering operations we have record of were by the California and Oregon Lumber Company, which had a mill in Brookings and a railroad. Lumber was shipped out by water from a wharf at the mouth of the Chetco River. The mill apparently closed in 1926. This company and its lumbering operation accounted for some of the names around the country and in town. In Brookings there is a Railroad Street with no railroad, Wharf Street, etc. Some of the original offices and buildings of the lumber company are still in use. Most of the lumbering activity of this company was in the Jack Creek drainage, and as near as can be determined, it was generally not very successful. A fire in their operations in Jack Creek forced the mill to closure. I don't think that there were large amounts of redwoods growing on the alluvial flats of the Chetco River to cut. Redwood was cut in the vicinity of the Redwood Park on the Chetco River in the days when spring boards were used. Some redwood trees were cut on private land on or near the alluvial flats in the vicinity of the mouth of the South Fork of the Chetco River. But this was in recent years. These stumps have sprouted. There is one redwood tree now on the river bank in the Redwood Park." (Kahre, 1968).

From the available information it appears that the distribution of the redwood in Curry County is very limited, and that currently there is no sound ecological explanation for its present distribution.

ECOLOGICAL AND MENSURATIONAL STUDIES BY THE NSF RESEARCH TEAM

During the visits of 1965-67, ecological and mensurational data were obtained from all the locations in which redwood was known to occur in Curry County, Oregon. It was noted that most of the trees were of rather low height and appeared to be very young in age (about 300 years), as compared with the old-growth stands of Del Norte County. No redwood stumps were found here, and no extremely large redwoods. The distribution and the redwoods will be discussed by the different areas separately. The mensurational information is compiled in Table VIII-1 and Table VIII-2. For the location of the areas one is referred to the map (Figure VIII-1).

TABLE VIII-1: STAND INVENTORY DATA
OF REDWOOD STANDS IN OREGON

Basal Area (Sq. Ft./Acre)

	Total	Redwood	Douglas fir	Tan Oak
WHEELER CREEK				
Plot 660816	520	300	220	--
660817	627	510	78	39
LITTLE REDWOOD CREEK				
Plot 650739	420	0	420	20
650738	400	80	240	80

TABLE VIII-2: SITE INDEX OF DOMINANT SAMPLE TREES

Redwood Stands in Oregon

Species	Crown Class	D.B.H. Inches	Height Feet	D.B.H. Age Years	Site Index*
WHEELER CREEK					
Plot 660816					
Douglas fir	C	14.4	107	73	123
Redwood	D	24.8	104	278	48
Plot 660817					
Douglas fir	D	14.1	104	69	124
Redwood	D	21.7	96	106	90
LITTLE REDWOOD CREEK					
Plot 650739					
Douglas fir	D	38.1	167	156	147
Plot 650738					
Redwood	D	59.7	130	187+	?
Redwood	I	7.4	37	36	100

* Site index information was obtained for Douglas fir from Bull. 201: "Yield of Douglas Fir in the Pacific Northwest" (1949), and Bull. 796: "Empirical Yield Tables for Young-Growth Redwood."

Area No. 1: Bear Creek Drainage, T 41 S, R 12 W; Sect. 14 Willamette Meridian:

This area is approximately 10 miles up the Winchuck River and redwood becomes a normal component of the mixed conifer stands around the Winchuck campground, particularly in the lower valley bottom. The purest redwood stand is beyond the private ranch of Mr. Donnely. When the area was visited in 1965 and 1966, no permission could be obtained from the Donnelys to cross their land and to examine the redwood groves and stands in the Bear Creek drainage beyond their property line. There appears to be more or less pure redwood stands within the river valley itself, becoming more and more mixed as the redwood extends up the slope. The largest distribution of redwood occurs along Bear Ridge, which is continuous with the block of redwood from Del Norte County, coming up the Rowdy Creek drainage. Observations along the Winchuck Road indicate good redwood stands on top of the ridges towards the south into Del Norte County. There was no redwood noted on Elk Mountain towards the north, nor on any of the other ridges north of the Winchuck River except the solitary occurrance of a few redwoods.

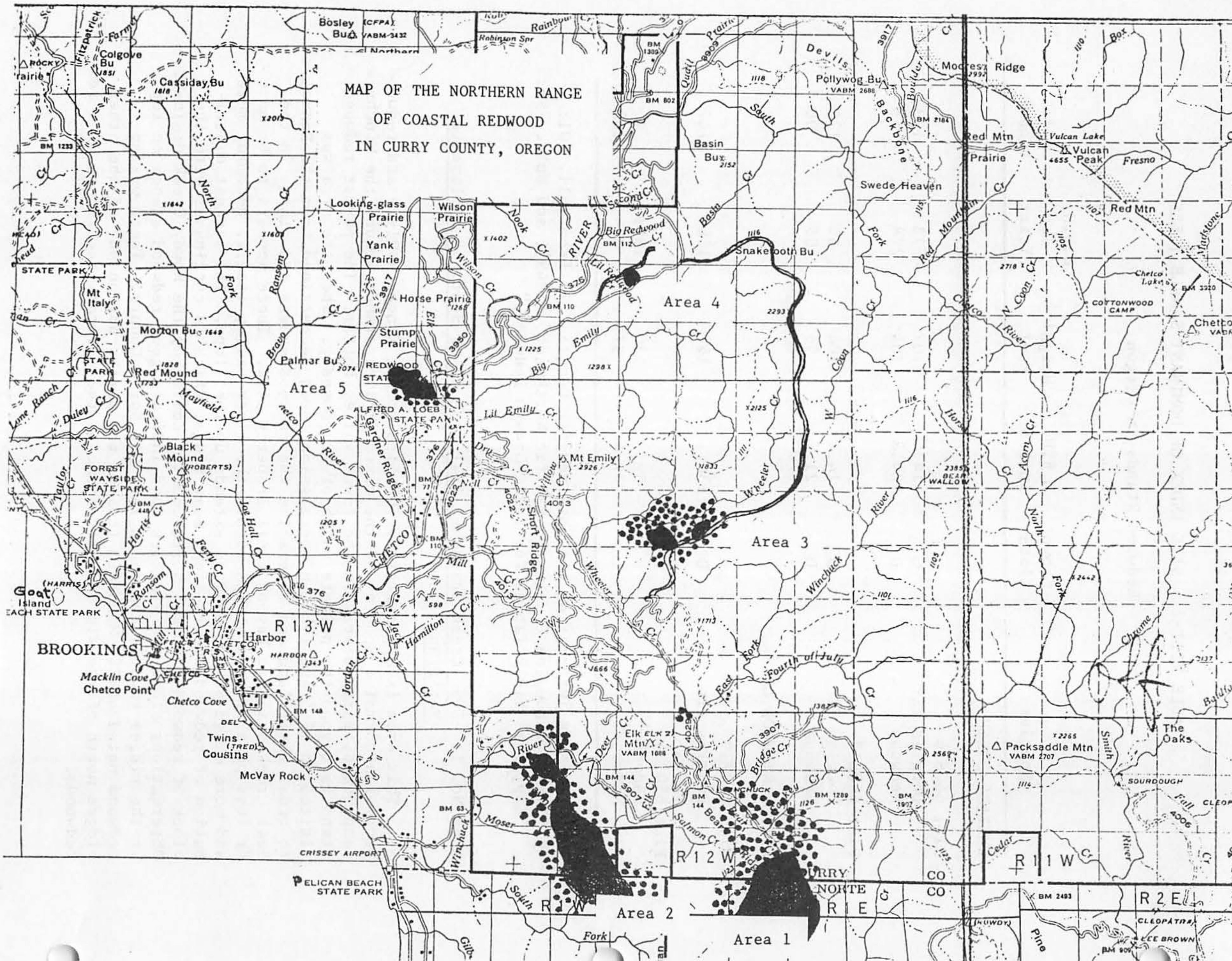
MAP OF THE NORTHERN RANGE
OF COASTAL REDWOOD
IN CURRY COUNTY, OREGON
Area 1
Area 2
Area 3
Area 4
Area 5
BROOKINGS
Harbor
Macklin Cove
Chetco Point
Chetco Cove
Twins
Cousins
McVay Rock
Goat Island
PELICAN BEACH STATE PARK
CRISSEY AIRPORT
FOREST WAYSIDE STATE PARK
ALFRED A. LOEB STATE PARK
REDWOOD STATE
Mt Emily
Snakeooth Bu
Big Redwood
Swede Heaven
Red Mtn
Vulcan Peak
Vulcan Lake
Pollywog Bu
Basin Bu
Moores Ridge
Packsaddle Mtn
The Oaks
Looking-glass Prairie
Wilson Prairie
Yank Prairie
Horse Prairie
Stump Prairie
Palmar Bu
Red Mound
Black Mound
Morton Bu
Mt Italy
Cassiday Bu
Colgove Bu
Bosley Bu
R 1 3 W
R 1 2 W
R 1 1 W
R 1 W
R 1 E
R 2 E
CURRY
DEL NORTE
CO
CO

FIG. VIII-1

Because of lack of access no inspection could be made of the diseased redwood trees in this area reported by Taylor (1965).

Area No. 2: Peavine Ridge, T 41 S, R 12 W; Sect. 6,7,8,16,17 and 18 W. M.:

The Peavine Ridge area is approximately five miles up the Winchuck River. Partly, the redwood stands are on private property (Kerr Exchange) and some are on U. S. Forest Service lands. From observations of the road across the river the tallest redwoods occur right on the Peavine Ridge, particularly in Sections 6, 7, 8, 16, 17, and 18. Access to this area is very difficult because of the river and the private farm lands. No road system has been developed up the Peavine Ridge. This seems to be the area of the oldest redwood trees with typical old-growth appearances of spike tops and very mature trees.

The area has not been visited, but the redwood stands merge along the ridge with the redwood forests of the Rowdy Creek drainage.

Area No. 3: Wheeler Creek Drainage, T 40 S, R 12 W; Sect. 15, 16 and 21, W. M.:

The purest redwood stand occurs on the ridge top on the east-facing slope towards Wheeler Creek, while the remainder of the scattered trees occurs on the southwesterly slope. Redwood is particularly rich in the stand mixtures in the gullies. The stand inventory data are recorded in Table VIII-2.

Two vegetation plots have been made here: plot 660816 and 660817. The predominant vegetation of the tree overstory is Douglas fir, with a good mixture of redwood on the ridge tops with tan oak (*Lithocarpus densiflorus*) and a scattering of chinquapin (*Castanopsis chrysophylla*). The shrub understory is very dense and chiefly composed of *Vaccinium ovatum*, *Rhododendron macrophyllum* and *Lithocarpus densiflorus*. The dense herb understory is chiefly composed of *Vaccinium ovatum*, *Rhododendron* and the usual associates of the redwood forest of the Redwood-Swordfern-Alliance. It is interesting to note that a few site indicators of extremely poor site quality extend into this redwood forest. These are *Xerophyllum tenax*, *Hemitomes congesta*, *Pyrole picta* and *Polygala californica*. The site index for the Wheeler Creek plots for Douglas fir is around 123 to 124, while the redwood site index is far below 100. This means that the redwood site index is beyond the extreme low site index limit of the Site Index Table (Lindquist & Palley, 1963). The heaviest redwood tree found in this area is approximately 278 years of age at the D.B.H. level, or roughly about 285 to 290 years of total age.

A summary of the plot record is included in Table VIII-2. The area is easily accessable by the newly built forest road and is classified as an unusual (botanical) area.

Hector & Wasson (1970) noted numerous fire scars and goosepens, especially on the larger trees. Regeneration was mainly by sprouts and there was a lack of redwood seedlings in the area.

Area No. 4: Redwood Creek Drainage, T 39 S, R 12 W; Sect. 28 and 29, W. M.:

This constitutes the most northerly redwood grove known. This is a small group of redwood mixed with a group of equal-sized Douglas fir, and predominantly the stand cover is a Douglas fir type. The area is again situated on the ridgetop and the saddle overlooking the Chetco River. The elevation ranges from approximately 800 feet to about 1,200 feet. Two vegetation plots have been made in this area with the general vegetation being approximately the same as has been reported for the Wheeler Creek Drainage. However, the absence of the low site indicators is notable, and the site index for the Douglas fir is 147, while the redwood site index approaches the extreme low limit of 100. The area is characterized by some fairly large-sized trees which grow in small drainages mixed with the old-growth Douglas fir forest. Some trees are up to 6 to 8 feet in diameter, and quite tall and well-formed. The mensurational data of the stand are reported in Table VIII-1. It is interesting to note that no redwoods have been observed right along the Chetco River, but that the redwood seem to be limited to the middle and upper slopes of the terrain. Redwoods were only observed within the drainage of the Little Redwood Creek, while the big Redwood Creek Drainage had been clear-cut and no redwoods have been spotted from the cut stumps. The moist-site indicators for this forest type include: the presence of hemlock, *Rubus vitifolius*, and the absence of *Xerophyllum tenax*, and the other low site indicators mentioned under the Wheeler Creek plots (see Table VIII-3).

Hector & Wasson (1970) measured redwood trees of D.B.H.'s ranging from 59 to 105 inches. Many seedlings up to 30 feet in height were observed on an old logging road in an opening about 40 feet away from the nearest redwood trees. Douglas fir measured about 83.6 inches at D.B.H. maximum. Ring counts of two downed Douglas fir trees indicated that at 40 years their diameters were 21.6 and 20.4 inches respectively; at 80 years 32.4 and 30.0 inches; and at 220 years 40.8 and 38.4 inches.

TABLE VIII-3: SYNTHESIS TABLE
OF REDWOOD VEGETATION PLOTS, CURRY COUNTY, OREGON

	660816	660817	650738	650739	650740
Tree Height (m)	30	--	80	60	30
Cover %	85	--	80	80	50
Pseudotsuga menz.	33⊛	55⊛	44⊛	44⊛	--
Tsuga heteroph.	--	--	+1	--	--
Lithocarpus dens.	22⊛	21	+1	+1⊛	--
Sequoia semperv.	33⊛	32⊛	11	--	--
Arbutus menz.	12	--	--	--	--

TABLE VIII-3, CONTINUED

	660816	660817	650738	650739	650740
Fraxinus oregana	--	--	--	--	33
Umbellularia calif.	--	--	+1	--	44
Acer macroph.	--	--	--	--	+1
Shrub Height (m)	+6	+6	1-6	1-6	1-6
Cover %	90	80	100	60	40
Pseudotsuga menz.	--	--	--	11	--
Lithocarpus dens.	22	21	43	43	+1
Vacc. parvifol.	+2	--	--	--	--
Tsuga heteroph.	--	--	--	+1	--
Sequoia semperv.	22	+1	+1	--	--
Vacc. ovatum	44⊗	44⊗	54⊗	54	--
Rhododendra macroph.	22⊗	32⊗	12⊗	--	--
Castanopsis chrysoph.	12	+1	--	--	--
Umbellul. calif.	--	--	--	--	32
Acer macroph.	--	--	--	--	+1
Fraximus oregana	--	--	--	--	11
Rubus spectab.	--	--	--	--	11
Sambucus callic.	--	--	--	--	11
Rhamnus pursh.	--	--	--	--	11
Corylus calif.	--	--	--	--	11
Rubus vitifol.	--	--	--	--	21
Herb Height (m)	1	1	1	1	1
Cover %	80	50	80	50	40
Polystichium munit.	+2	+1	12	+1	12⊗
Gaultheria shallon.	12	+1	--	22	--
Vacc. ovatum	44⊗	32	32	32	--
Trientalis latifol.	--	--	+1	--	--
Viola sempervir.	+2	21	--	+1	--
Dentaria tenella	--	--	--	--	+1
Mahonia nervosa	+1⊗	+2	12	--	--
Rhododendr. macroph.	12	11	22	+1	--
Lithocarpus dens.	12	+2	+1	+1K	+1
Pseudotsuga menz.	+1	11	+1	+1	--
Lilium columb.	+1	--	--	--	--
Chimaphila umbell.	--	--	--	+1	--
Pyrola picta	--	+1	--	12⊗	--
Chimaphila menz.	--	--	--	--	--
Hypopites hypopites	--	--	--	--	+1⊗
Goodyera oblongifol.	+1	22	--	--	--
Corallorhiza macul.	+1	--	--	--	--

TABLE VIII-3, CONTINUED

	660816	660817	650738	650739	650740
Xerophyllum tenax	+2	+1	--	12	--
Polygala calif.	+1	21	--	--	--
Castanopsis chrysoph.	+1	--	--	--	--
Hemitomes congesta	--	+1	--	--	--
Vacc. parvifol.	+2	+1	+1	--	--
Rubus vitifolia	--	--	+1	+1	21
Oxalis oregana	--	--	--	--	12⊛
Asarum caundat.	--	--	--	--	11
Stachys emerson.	--	--	--	--	+1
Athyr. filixfem.	--	--	--	--	+1
Adenocaulon bicol.	--	--	--	--	11⊛
Umbellularia calif.	--	--	--	--	11
Osmaronia cerasif.	--	--	--	--	+1
Salix lasiandra	--	--	--	--	+1
Symphoricarp. alba	--	--	--	--	+1
Equiset. telmateia	--	--	--	--	+1
Euonymus occid.	--	--	--	--	+1
Urtica dioica	--	--	--	--	+1
Petasites speciosa	--	--	--	--	+1
Hydrophyll. tenuips	--	--	--	--	22
Erechtites prenan.	+1	--	--	--	--
Disporum hookeri	+1	+1	--	--	--
Sequoia sempervir.	12	--	--	--	--
Smilacina racemos.	+1	+1	--	--	--
Pterid. aquilin.	+1	+1	--	+1	--
Iris chrysoph.	+1	--	--	--	--
<u>Moss soil</u> %	5	0	60	90	1
Eurhynch oregana	13	--	42	55	--
Eurhynch stokesii	--	--	--	--	+2
<u>Logs</u> cover %	15	--	80	100	70
Pseudoisothec stolon.	+2	--	43	22	44
Eurhynch. oregan.	+2	--	33	22	+1
Hypnum circinale	13	--	43⊛	--	--
Cladonia fimbr.	+2	--	11	12	--
Scapania boland.	--		+2	+2	--
Dicran. scoparium	--	--	+2	--	--
Dicran. fuscesc.	+2⊛	--	--	--	--

TABLE VIII-3, CONTINUED

	660816	660817	650738	650739	650740
Lepidozia reptans	--	--	12	--	--
Aulacomn. androgyn.	+2	--	--	--	--
Cladonia furcat.	+2	--	--	--	--
Frullania calif.	+2	--	--	--	--
Sphaerophorus globos	+2	--	+1	--	--
Dioranoweisia cirrhata	--	--	12⊕	--	--
Scapania umbrosa	--	--	--	--	+1
Metzgeria conjugata	--	--	--	--	+1
Mnium punctat.	--	--	+2⊕	--	+2
Porothamn. bigelov.	--	--	--	--	+2

Plot 650738: July 14, 1965; Chetco River, Oregon, Little Redwood Creek, middle slope, little spur ridge in river gorge, slope WNW 25°; T 39 S, R 12 W, Section 29, NE 1/4 NE 1/4, 820 feet elevation.

Plot 650739: July 14, 1965; Chetco River, Oregon, ridge top in saddle at junction of roads, flat topography; T 39 S, R 12 W, Section 29 SW 1/4 SW 1/4, 1,220 feet elevation.

Plot 650740: July 14, 1965; Chetco River, Oregon, alluvial flat recently silted below Loeb State Park, flat topography; T 40 S, R 13 W, Section 13 SW 1/4 SE 1/4, 80 feet elevation.

Plot 660816: August 17, 1966; Wheeler Creek, Oregon, upper slope, slope E 15°; T 40 S, R 12 W, Section 16 SE 1/4 SE 1/4, 1,760 feet elevation.

Plot 660817: August 17, 1966; Wheeler Creek, Oregon, ridge top, flat topography; T 40 S, R 12 W, Section 16 SE 1/4 SE 1/4, 1,770 feet elevation.

Area No. 5: <u>Redwood State Park, T 40 S, R 13 W; Sect. 12 and 13, W. M.:</u>

This area is located some 8 or 10 miles up the Chetco River, and is preserved partly within the Oregon State Park system as the Redwood State Park. Redwoods occur on both sides of the river, but primarily on the westerly side slopes of the Chetco River valley. Two of the largest trees are located within the socalled "Boy Scout area," close to the top of the ridge, just outside the Redwood Park. Several redwood trees were measured for D.B.H. in the Redwood Park. Redwood D.B.H.'s were recorded at 135.0-inch, 79.5-inch, and 62.6-inch, while a Douglas fir measured 64.6 inches. The largest known redwood tree in Oregon at the Boy Scout camp measured in August, 1964 at the D.B.H. level 155.5 inches in diameter, and at ground level 192.9 inches in diameter. Its height was 222 feet due to a broken top (Hector & Wasson, 1970; McCain, 1971).

There is further evidence that the alluvial flats of the Chetco River did support some redwood forests because a single tree has been observed on the alluvial flat within this area. Generally, the stand has been heavily mixed with Douglas fir, but no vegetation records have been obtained.

SOIL PROFILE INFORMATION

The soil information is tabulated in Table VIII-4. Generally, the soils are of a rich red-brown to yellow-brown, sandy loam texture. They appear to be all derived from marine deposits, similar to most of the soils in Del Norte County, which support redwood growth. The alluvial flats occupied by a maple forest, exhibit the typical gray silt loam soil characteristic of most alluvial flats in Del Norte and Humboldt Counties. Such alluvial flats can support redwood groves.

A map of the redwood distribution is presented in Figure VIII-1 on page 122.

TABLE VIII-4: SOIL PROFILE DATA
OF REDWOOD SITES, CURRY COUNTY, OREGON

Plot 650738: Middle slope, July 14, 1965 -- Little Redwood Creek

Layers:	L F	A_1	B_{21}	B_{22}	B_{23}	B_3
Depth (cm)	3 2	9	18	34	94	172
Texture		rocky loam	sandy loam	clay loam	clay loam	rocky loam
Consistence		friable	friable	friable	--	--
Rocks		50 %	10 %	65 %	60 %	70 %
Gley		none	30 %	50 %	60 %	40 %
Charcoal		--	--	1 %	--	--
Color (dry)		10YR7.5/3	10YR5.6/3	10YR6/4	10YR7/4	7.5YR6/6
Color (wet)		10YR5/3	10YR5/3	7.5YR4/4	7.5YR5/4	7.5YR5/6
pH		4.9	4.9	4.9	5.0	5.2

Plot 650739: Upper slope, July 14, 1965 -- Chetco River

Layers:	L F H	A_1	B_{21}	B_{22}	B_{3g}
Depth (cm)	7 4 3	1	30	40	72
Texture		silty loam	sandy loam	clay loam	sandy loam
Consistence		friable	--	compacted	compacted
Rocks		--	20 %	70 %	70 %
Gley		none	30 %	20 %	40 %
Charcoal		--	faint 10%	--	--

TABLE VIII-4, CONTINUED

	L F H	A_1	B_{21}	B_{22}	B_{3g}
Color (dry)		2.5Y5/2	10YR5/2	10YR6/4	10YR7/4
Color (wet)		2.5Y3/2	10YR2/2	10YR3/4	7.5YR6/6
pH		4.1	4.1	4.9	5.3

Plot 650740: Alluvial flat, July 14, 1965 -- Chetco River

Layers:	no L,F	A_1	B_{11}	B_{12}	B_2
Depth (cm)		16	26	85	120
Texture		loamy silt	clayey silt loam	clayey silt loam	clay loam
Consistence		loose	--	--	compacted
Rocks		none	none	none	none
Gley		none	none	faint 30%	30 %
Color (dry)		5Y5/1	5Y5/1	5Y5/2	5Y6/1
Color (wet)		5Y3/2	5Y3/2	5Y3/2	5Y3/1
pH		6.4	5.4	5.4	5.6

Plot 660816: Upper slope, August 17, 1966 -- Wheeler Creek

Layers:	L F H	A_1	B_{21}	B_{22}	B_3
Depth (cm)	6 4 2	34	63	73	75+
Texture		clay loam	clay loam	clay loam	schist loam
Consistence		friable	--	compacted	compacted
Rocks		10 %	10 %	20 %	60 % (gravel)
Gley		20 %	30 %	60 %	50 %
Color (dry)	2.5YR2/0	10YR5/2	10YR4/4	10YR7/3	10YR5/6
Color (wet)	2.5YR2/0	10YR3/1	10YR3/4	10YR5/4	10YR5/6
pH	5.7	5.7	5.7	5.4	5.6

Plot 660817: Ridge top, August 17, 1966 -- Wheeler Creek

Layers:	L F H	A_1	B_{21}	B_{22}	B_3
Depth (cm)	2 6 3	4	36	65	73
Texture		loam	clay loam	clay loam	clay loam
Consistence		friable	compacted	compacted	compacted
Rocks		none	none	none	none
Gley		none	none	10 %	30 %
Charcoal		--	1 %	1 %	--
Color (dry)	2.5YR3/2	10YR3/2	10YR5/3	10YR7/2	10YR7/4
Color (wet)	2.4YR2/0	10YR2/2	10YR3/3	10YR5/3	10YR5/6
pH	5.7	5.9	5.7	5.9	6.0

SUMMARY

From the above data it appears that the northern limit of the redwood forest in southern Curry County is determined by a combination of soil and climatic factors. The presence of a large body of serpentine rock formation (Diller, 1914; Butler & Mitchell, 1916; Treasher, 1943) just north of Brookings to the coast may well have prevented the spread of redwoods across this serpentine belt into Rogue River. No redwood has been observed to occur on serpentine rock formations or on soil derived from serpentine rock. Neither does redwood seem to thrive well on alluvial flats and sediments which have been primarily developed from such serpentine materials.

Another important factor limiting the redwood distribution further upwards towards the north may have been the microclimate. Only within the direct influence of the oceanic winds with its summer fog and with the ameliorating temperatures during the winter can redwood persist. Although redwood may withstand snow and frost to a limited extent, a long frost and snow period will definitely limit the growth of the redwood forest. Snow falls regularly above 1,300 to 1,500 feet elevation in December and January more inland. Snow cover is between 1 to 2 feet deep preventing travel along the ridges (Taylor, 1971). This tends to limit redwood to elevations below 1,500 feet. There is no information of snow fall on the ridges where redwood grows. On account of low temperatures redwood seems to limit its natural occurrence at the northern extreme of its range to the warmer ridge tops, saddles and upper slopes, which are directly influenced by the oceanic weather and receive much solar radiation.

Many of the redwood forests seem to be of relatively young age, and real old, decadent, virgin timber stands are absent. This may be the result of past severe fire damage which would have eliminated most of the old-growth trees and replaced those with young growth trees. Another possibility is that due to forest fires, redwood has only recently invaded those areas. In general, redwood is less competitive here than further south in Del Norte County. Douglas fir tends to replace it with tan oak being most prevalent. As a consequence, redwood occupies upper slope positions of poor quality in terms of commercial timber value. Hellmers (1963) found in his studies that low soil temperatures were limiting redwood seedling growth. It may be that the valley soils are too cold for redwood survival.

Because of these ecological limitations it is very unlikely that redwood will or can spread further northward unless it is introduced by man elsewhere.

Taylor (1971) reports that the area of the Winchuck Campground was an old plantation of the 1930's. There are, however, no further records available about this redwood plantation.

A REDWOOD PLANTATION OF GRAYS HARBOR COUNTY, OLYMPIC PENINSULA, WASHINGTON

During August, 1965 Robert J. Bates, forester of the Rayonier, Incorporated at Hoquiam, Washington, came across several redwood trees which apparently were planted in this area about 35 years ago and had survived up to now. The area is in Section 2, T 21 N, R 10 W. The redwood trees seem to be putting on pretty good growth for their age, but no cones were produced last year on any of these trees. There were no cones on the ground from any of the previous years.

The foliage is of a very deep green and lush color. The crown shape is characteristic of a fairly good site for redwood. The overall climate is very mild, varying between 30° to 70°F. Rainfall is about 75 inches with a little fog in the winter months. Several trees have branches twisted at the base, about one-third the distance from the bottom to the top as a result of last year's heavy snow fall. One small tree had the top knocked out and is forming a characteristic mature or over-mature type snag top as a result of an early freeze two years ago (Bates, 1965).

The measurements of the redwood trees were performed on October 21, 1965, and are incorporated in Table VIII-5. It is note worthy that all trees have some form of top damage due to freeze or snow break, and that good form of the tree has been reduced by this damage. The lower form class of 66 may be due to the wide spacing of the trees. However, the form class 66 is not unusual for redwood trees of Del Norte or Humboldt Counties. None of these trees showed any signs of excessive butt flair or of taper. The foliage seems to be lush dark green and the limbs extend to the ground. The trees are now pruned to 6-feet height.

Bates reported in October, 1965 that several Sequoia gigantea trees have been located within the same area. One tree of Sequoia gigantea is about one and a half miles west of the site of the redwood trees and is about 30 feet high, with a D.B.H. of 29 inches. The second Sequoia gigantea tree is up in an area called Railroad Camp, and is located in Section 36 of T 20 N, R 10 W, and is about 100 feet high with a D.B.H. of 72 inches. All giant Sequoia trees look to be in real fine shape. It appears that the Sequoia gigantea is better suited to grow in the Hoquiam area than the Sequoia sempervirens, and has produced superior growth.

It is postulated that the trees were planted some 35 years ago by Mr. W. C. Dillaway, Jr. of the old Polson Logging Company. The Polson Logging Company is now owned by Rayonier, Incorporated, and Mr. Dillaway is reported to be retired and living in Olympia at the present time. Mr. Dillaway was the logging superintendent of the Polson Logging Company at the time of the redwood plantings and may have some information as to the source of these redwood trees and others in the area, where the trees came from and what other information there may be available as to its plantings. The following information is available about the seeding operations of the Polson Logging Company during the years of 1926 to 1941.

TABLE VIII-5: TREE MEASUREMENTS OF REDWOOD TREES PLANTED IN GRAYS HARBOR COUNTY, WASHINGTON IN ABOUT 1930 (Bates, 1965)

Cruise Date: October 21, 1965

Tree #	D.B.H. (inch)	Height (feet)	Age at D.B.H. Level*	Height Growth (ft) 1965-1955	1955-1945	
1a	19.5	52	29	4.70	4.10	top forked rotted sprout on side
2	15.1	27	31	2.25	3.10	forked at 1 ft. from ground
3	16.3	41	29	?	?	(bear damage)
4	16.0	30	29	2.60	4.10	grown together at base
5	9.7	35	29	2.10	1.40	
6	9.5	35	29	2.50	1.65	
7	11.2	38	29	2.20	1.80	forked top
8	16.0	30	30	3.00	2.50	spike top fork is live
9	16.0	36	30	2.40	2.70	forked top
10	12.5	36	30	?	?	forked top
11a	29.2	57	30+	4.80	4.10	good form
12	19.0	?	29	3.50	4.00	spike top fork live

* For total age, add some six years to D.B.H. age.

a Form class determined is 66. Form class is only taken on trees large enough to have one 32-foot merchantable log in their bole. Form class was determined by actual measurement in the tree of the top diameter inside bark at the first 16-foot log from D.B.H.

Direct seeding was begun by the Polson Logging Company in 1926. Clyde Martin and Ben Cooksey, acting principally as fire wardens or fire patrolmen were kept on the company payroll the year around with the understanding that, among other things, they were to gather and plant seed during the off-season. Seed was gathered in August and September on days when fire hazard was not extreme, and planted during October and November of each year. The first area seeded is in Sections 3, 4 and 9 of T 20 N, R 10 W, H. M., and in Section 35, T 21 N, R 10 W. W.M. This is shown in the accompanying map. Areas on this map are approximations as maps made at the time of the planting have been lost. However, their approximate boundaries were designated by Mr. Cooksey. Dates are also approximate but should be correct within one year, or at the most, two years. This area is roughly 640 acres in extent and was seeded during the seasons of 1926, 1927, 1928 and 1929, beginning at the southern end in 1926 and working northward. Douglas fir seed was used exclusively in this area. Density of seeding, as near as can be determined was about 1 pound to 8 acres in all the major areas. Fire, as indicated on the map, burnt over the southern tip of this area in 1941.

The second area seeded was in Sections 33 and 34, T 21 N, R 10 W, W. M. This area was seeded in 1930 and 1931 exclusively with Douglas fir and was about 180 acres in extent.

The third area seeded is in Sections 1, 2 and 3 of T 21 N, R 10 W, H. M. The part east of the highway was sown with a mixture of one-half hemlock and one-half Douglas fir seed. The part west of the highway was sown with Douglas fir on the higher grounds, and with cedar on the flats or wherever the stumps indicated that cedar had grown before. This area was sown beginning in 1932, working from east to west through the seasons of 1933, 1934, 1935, and 1936, and is about 1,120 acres in extent.

In the west half of the northeast quarter of Section 2 within this area a plot of 5 acres in a row was staked out as a sample plot. This plot parallels the road on the west side and lays just south of the national forest boundary. The sowing was done about 1930. Numbering the acres from north to south, # 1 was sown with one-half pound of Douglas fir seed; # 2 with one-half pound of hemlock seed; # 3 with one-half pound of spruce seed; # 4 with one-half pound of western red cedar seed; and # 5 with one-half pound of Port Orford seed.

In the seasons of 1937 through 1940 about 640 acres (not shown on the map) were sown in Sections 4, 5, 8 and 9 of T 21 N, R 10 W, W. M. This area was entirely destroyed by fire.

In 1940 about 2 acres in the southeast quarter of Section 1 of T 21 N, R 10 W, H. M. was sown with Port Orford cedar seed which were gathered from trees growing in area # 5 of the sample plot in Section 2. This area had been cleared and leveled as a site for a CCC camp. Growth in the area at the time of seeding was grass. Density of seeding here was 1 pound per acre.

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IX. THE DISTRIBUTION OF THE COASTAL REDWOOD IN MONTEREY COUNTY, CALIFORNIA

The distribution of the coastal redwood in its southern extreme range in Monterey County has received little ecological study. The southern area studied ranges from T 17 S to T 24 S and R 1 E to R 6 E. It extends along the Pacific coast south of Carmel and is accessible by Highway 1.

Redwood occurs scattered on the westerly slopes of the Santa Lucia Mountain range. Sudworth (1908) gave the first detailed account of its distribution. He writes: "The redwood ceases for a few miles around Monterey Bay, but in Santa Lucia Mountains (Monterey County) occurs in canyons chiefly on the seaward side of the range at altitudes from sea-level to 3,000 feet (the largest trees growing in Little Sur basin near Pico Blanco), extending south to Salmon Creek canyon (12 miles south of Puenta Gorda, latitude 35° 50'), the southern limit." Fowells (1965) and others have reported the same location of redwood as the southern extremity of its range. No detailed ecological studies have been made of its scattered distribution in Monterey County. The U. S. Forest Service, Los Padres National Forest (Campbell, 1967) has prepared a detailed distribution map of the coastal redwood. During 1965, 1966 and 1967 personal field trips were made into the Santa Lucia Mountains to verify the redwood distribution. Ecological data and vegetation information were collected in typical redwood stands.

The scattered distribution of redwood makes it practical to divide the area into seven smaller geographic areas or drainages. These areas will be discussed individually with the information collected.

The general geology and climate of the Santa Lucia Mountains has been studied by Trask (1926), Taliaferro (1944), Bowen (1958), and Jennings & Strand (1958). The northern part of this mountain range consists of mesozoic granite and quartz-diorite intrusions into a large paleozoic rock mass surrounding it. The stratigraphy and faulting of the granite intrusions is in the northwest to southeast direction. The higher parts of the southern portion of the Santa Lucia Mountains consists of Cretaceous marine deposits surrounded by Pre-Cretaceous or paleozoic rock formations. They become increasingly metamorphized by volcanic activity south of Plaskett Creek where numerous local serpentine or ultrabasic intrusions occur. Along the coast line itself, there are narrow pleistocene marine terraces south of Carmel and Point Sur. Mesozoic sedimentary rocks of the Franciscan group surface in the Big Sur Valley and a little southwards along the coastline and again in the coastal area north and just south of Lucia. South of Salmon Creek, many tertiary volcanic intrusions occur mixed with ultrbasic (serpentine) intrusions.

The general climate of the redwood belt is definitely of pronounced maritime influence with only minor temperature fluctuations the year around. Close to the ocean and at low elevation, the summers are very cool and foggy while the winters are mild with the major precipitation occurring during the winter season. The few reporting weather stations are all situated in areas outside the redwood belt except for Big Sur. The available information on temperature and rainfall patterns has been categorized by area and are summarized in Table IX-1.

TABLE IX-1: CLIMATIC COMPARISON OF REDWOOD GROVES IN MONTEREY COUNTY, CALIFORNIA

Area #:	1**	2	3	4	5**	6	7
CLIMATE							
Ave. Annual Temp. °F	57.6	*	*	*	58.6	*	*
January	50.1				53.4		
February	56.4				56.3		
March	53.9				55.8		
April	54.9				56.0		
May	56.6				56.9		
June	61.7				61.7		
July	62.3				64.1		
August	64.1				62.6		
September	64.8				62.9		
October	60.6				63.0		
November	55.0				58.6		
December	47.9				51.9		
Precipitation Annual	14.19	*	*	40.85	20.53	15.92	*
Monthly: January	3.13			8.63	3.93	3.56	
February	0.81			8.02	3.31	3.05	
March	2.80			5.86	3.04	3.74	
April	0.30			3.25	1.08	1.40	
May	0.50			1.09	0.38	0.29	
June	0.11			0.28	0.00	0.00	
July	0.02			0.00	0.00	0.00	
August	0.04			0.03	0.23	0.18	
September	0.00			0.39	0.00	0.25	
October	0.33			1.78	1.28	0.21	
November	1.89			3.42	2.17	1.27	
December	3.88			8.10	5.10	1.97	

* No data available.

** Weather stations included in Area # 1 are Carmel Valley (425 feet elevation) and Clemente Dam (600 feet elevation); in Area # 4 Big Sur State Park (235 feet elevation); in Area # 5 Point Piedras Blancas (59 feet elevation) and Roosevelt Ranch (1,100 feet elevation); and in Area # 6 Lucia, Willow Springs (355 feet elevation).

Area No. 1: San Clemente Creek, Carmel Valley:

Redwoods grow here on the eastern side of the coastal range but within the Carmel River drainage. The climate is influenced by the marine air invasions through the Carmel Valley and is, therefore, still maritime in its aspects. Redwood occurs some 15 to 17 miles inland in the Carmel Valley at elevations ranging from 1,200 to 1,500 feet. Two small redwood areas have been noted on the map (see Fig. IX-1). This area has not been visited during the current explorations but from reports it is very similar to the redwood stands of the Palo Colorado River drainage.

Area No. 2: Palo Colorado River Drainage:

Redwoods occur only on the northern slopes of the river valley between 2 to 6 miles inland at elevations ranging from 150 to 2,200 feet. Included in Area # 2 are the redwood stands some 3 to 6 miles up the Bixby Creek valley, just adjacent to the Palo Colorado River. This area supports dense young-growth of redwoods and no old-growth trees have been spotted. The trees are mostly stunted when growing on slopes directly exposed to ocean winds. The site index ratings for redwood range from dry upper slopes of site index 65 to medium or mesic sites with site index ratings of 134 to 168. For the site index determination Bulletin 796 (Lindquist & Palley, 1963) was used. For site index values below 100 the site index trends were extrapolated by the alinement chart technique, and the alinement chart was subsequently used to determine the site index ratings beyond the range of the data of Bulletin 796. The alinement chart used is reproduced as Figure IX-2.

The local redwood stands are very dense and have high mortality due to their density. No redwood reproduction was noted on account of the dense canopy. A heavy mixture of red alder (Alnus rubra) is usually associated with the redwoods. Mensurational information is summarized in Table IX-2 and Table IX-3.

TABLE IX-2: STAND INVENTORY DATA OF REDWOOD STANDS IN MONTEREY COUNTY, CALIFORNIA

Basal Area (Sq. Ft./Acre)

	Total	Redwood Sequoia semperv.	Tan Oak Lithocarpus densiflorus	Madrone Arbutus menziesii	Pinus coulteri	Umbellularia Acer macr.
Area # 7: Naciamento Summit						
Plot 670716	397	218	105	57	17	
670717	566	392	235	39	--	
Area # 6: Redwood Gulch						
Plot 670718	353	353	--	--	--	
670719	560	560	--	--	--	
670720	220	220	--	--	--	

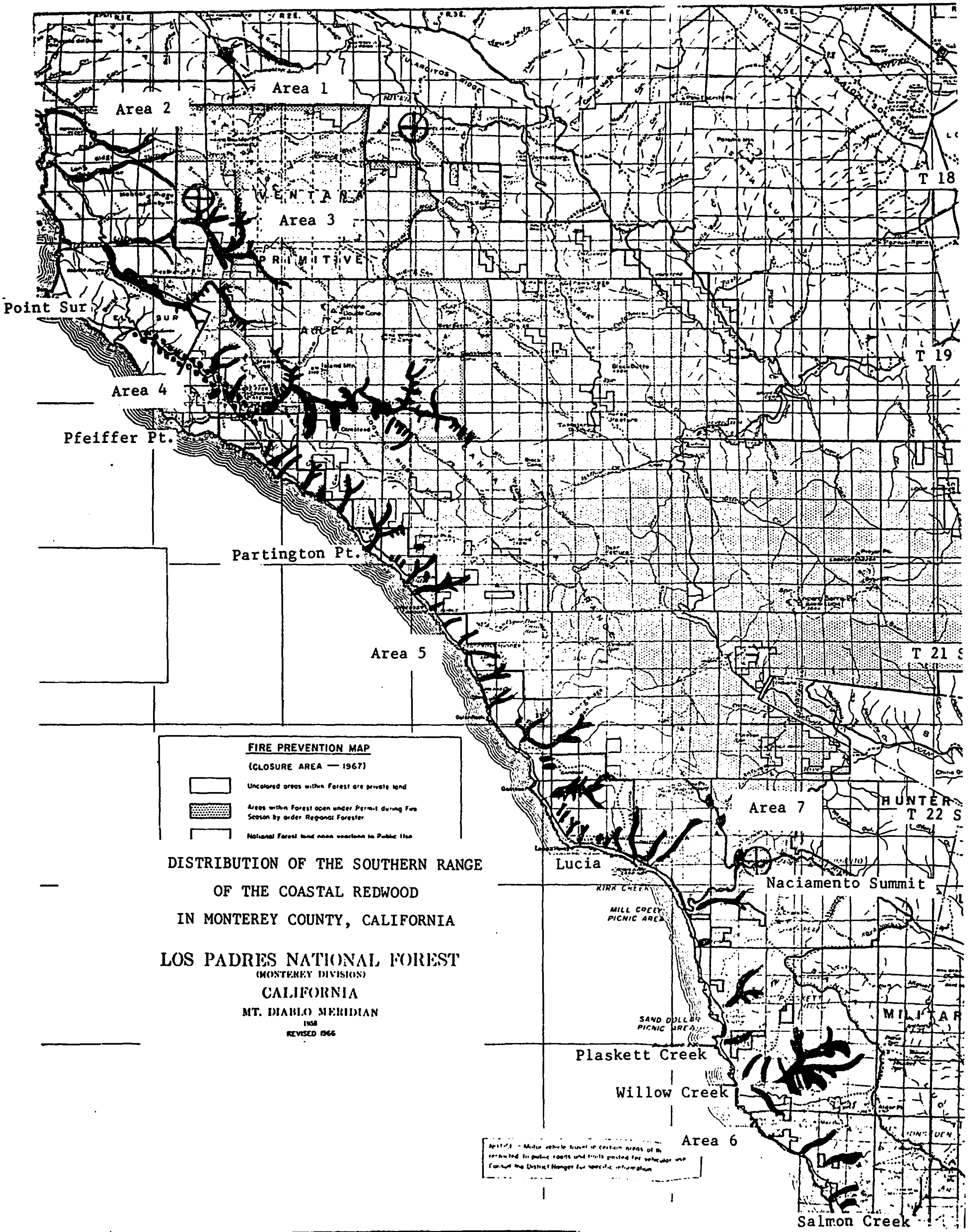
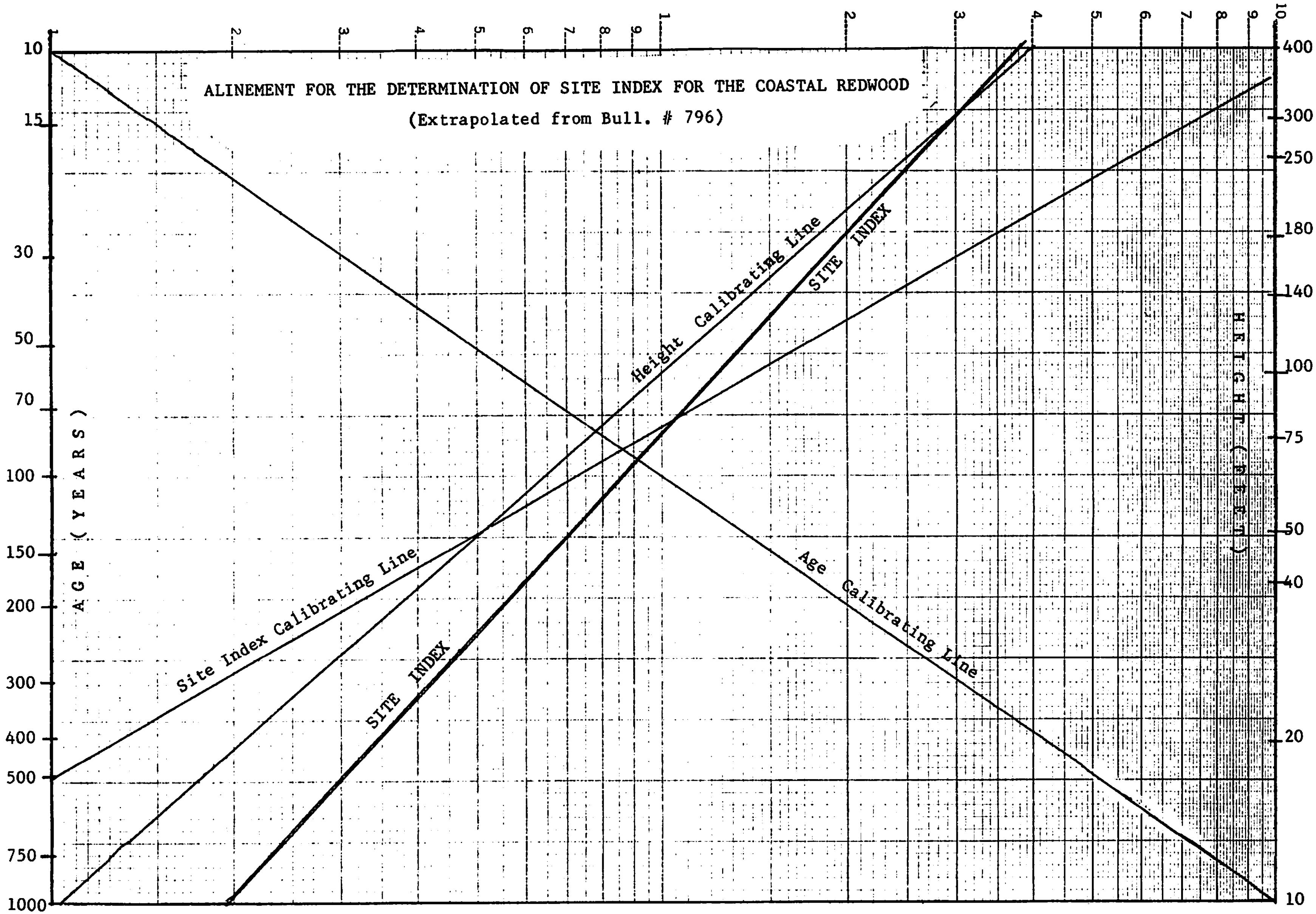

Area 1
Area 2
Area 3
VENTANA
PRIMITIVE
AREA
Point Sur
Area 4
Pfeiffer Pt.
Partington Pt.
Area 5
T 18
T 19
T 21 S
Area 7
HUNTER
T 22 S
Lucia
Naciamento Summit
KIRK CREEK
MILL CREEK PICNIC AREA
SAND DOLLAR PICNIC AREA
Plaskett Creek
Willow Creek
Area 6
Salmon Creek
FIRE PREVENTION MAP
(CLOSURE AREA — 1967)
Uncolored areas within Forest are private land
Areas within Forest open under Permit during Fire Season by order Regional Forester
DISTRIBUTION OF THE SOUTHERN RANGE
OF THE COASTAL REDWOOD
IN MONTEREY COUNTY, CALIFORNIA
LOS PADRES NATIONAL FOREST
(MONTEREY DIVISION)
CALIFORNIA
MT. DIABLO MERIDIAN
1958
REVISED 1966

FIG. IX-1



ALINEMENT FOR THE DETERMINATION OF SITE INDEX FOR THE COASTAL REDWOOD
(Extrapolated from Bull. # 796)
AGE (YEARS)
HEIGHT (FEET)
Height Calibrating Line
SITE INDEX
Site Index Calibrating Line
Age Calibrating Line
10
15
30
50
70
100
150
200
300
400
500
750
1000
400
300
250
180
140
100
75
50
40
20
10

FIG. IX-2

	Total	Redwood	Tan Oak	Madrone	Pinus	Umbellul.
670721	420	420	--	--	--	
670722	566	566	--	--	--	
670723	245	245	--	--	--	
Area # 5: Coastal Canyons, Lucia						
Plot 670724	400	380	20	--	--	
650912	680	680	--	--	--	
650914	640	640	--	--	--	
650915	640	640	--	--	--	
Area # 4: Big Sur Valley						
Plot 650901	600	600	--	--	--	
650902	320	240	--	--	--	80
650903	560	360	200	--	--	
650904	680	680	--	--	--	
650905	840	840	--	--	--	
650906	760	720	40	--	--	
650907	440	400	40	--	--	
650908	260	220	--	--	--	40
650911	720	720	--	--	--	
Area # 2: Palo Colorado, Bixby Creek						
Plot 650917	340	40	---300---		--	--
650916	560	560	--	--	--	--

TABLE IX-3: SITE INDEX AND TREE MEASUREMENTS
OF REDWOOD IN REDWOOD STANDS
IN MONTEREY COUNTY, CALIFORNIA

	Crown Class	D.B.H. (inches)	Height (feet)	Age (Years)	Site Index
Area # 7: Naciamento Summit					
Plot 670716	C	16.0	71	36	141
	C	16.0	71	38	137
670717	D	20.5	87	89	95
	I	7.5	38	30	(106)**
	I	9.2	60	42	(114)**
Area # 6: Redwood Gulch					
Plot 670718	D	24.2	82	77	100
	S	2.1	11.8	5***	(110)**
670719	D	21.5	110	113	90*
	I	3.2	19	30	(67)*
670720	S	5.6	21	25	(77)*

	Crown Class	D.B.H. (inches)	Height (feet)	D.B.H. Age (years)	Site Index
Area # 5: Coastal Canyons, Lucia					
Plot 670722	D	9.4	46	31	116
	D	13.0	52	22	150
670724	D	18.0	70	37	137
	D	77.0	190	?	?
	D	13.5	76	29	163
650911	D	17.9	117	79	134
650914	D	9.6	38	71	65
Area # 4: B_g Sur Valley					
Plot 650902	D	31.6	96	53	143
650903	D	31.5	96	132	94
650905	D	19.7	112	65	146
	I	2.7	22	13+9	107
650906	D	32.0	126	127	107
	D	5.0	28	13+9	97
650907	D	61.4	222	?	?
	I	21.3	114	129	95
	D	26.3	128	79	145
650908	D	18.2	87	90	95
Area # 2: Palo Colorado, Bixby Creek					
Plot 650916	D	31.1	135	68	168
650917	D	16.3	91	55	135

* Site index values were obtained from Bulletin 796, "Empirical Yield Tables of Young-Growth Redwood" (1963) and by extrapolation (beyond the data range) using the alinement chart technique.

** Site index values were determined for trees other than dominant or codominant trees.

*** Total age of this tree was 19 years, requiring 14 years to reach the D.B.H. level.

Data on soil profiles is summerized in Table IX-4.

Area No. 3: <u>Little Sur Valley:</u>

Redwood occurs here between 3 to 10 miles inland occupying elevations from 150 to 2,200 feet, and also occurs chiefly on northern slopes. Sudworth (1908) reported the oldest stands in this drainage and redwood extends indeed far inland in this drainage. This area has, however, not been visited by Dr. Becking.

TABLE IX-4: SOIL PROFILE DATA OF REDWOOD STANDS IN MONTEREY COUNTY, CALIFORNIA

Area # 7: Naciamento Summit

Plot 670716: Cone Peak Road, July 14, 1967, upper slope

	L F H	A_{11}	A_{12}	B_{21}	B_{22}	B_{23}
Depth (cm)	4 0 0	--	--	24	87	--
Texture		--	--	sand	sand	--
Consistency		--	--	friable	friable	--
Rocks		--	--	--	--	--
Gley		--	--	--	--	--
Charcoal		--	--	--	--	--
Color (dry)		--	--	--	10YR6/3	--
Color (wet)		--	--	--	10YR4/4	--
pH		--	--	--	5.6	--

Plot 670717: Cone Peak Road, July 14, 1967, upper slope

	L F H	A_{11}	A_{12}	B_{21}	B_{22}	B_{23}
Depth (cm)	4 1 0	52	--	100	--	--
Texture		loam	--	loam	--	--
Consistency		friable	--	*	--	--
Rocks		20 %	--	60 %	--	--
Gley		10 %	--	30% orange	--	--
Charcoal		1 %	--	1 %	--	--
Color (dry)		10YR4/2	--	10YR5/2	--	--
Color (wet)		5YR3/2	--	7.5YR3/2	--	--
pH		6.45	--	6.45	--	--

Area # 6: Redwood Gulch

Plot 670719: Redwood Gulch, July 14, 1967, lower slope

	L F H	A_{11}	A_{12}	B_{21}	B_{22}	B_{23}
Depth (cm)	5 1 0	25	--	35	90	--
Texture		loam	--	loam	loam	--
Consistency		friable	--	slightly compact	compact	--
Rocks		--	--	70 %	70 %	--
Gley		--	--	1 %	5 % orange	--
Charcoal		--	--	--	--	--
Color (dry)		5YR3/1	--	5YR3/1	10YR3/2	--
Color (wet)		5YR2/2	--	5YR2/2	5YR2/2	--
pH		6.5	--	6.2	6.3	--

TABLE IX-4, CONTINUED

	L F H	A_{11}	A_{12}	B_{21}	B_{22}	B_{23}
Area # 5: Coasta Canyons--Lucia						
Plot 670722: Wild Cattle Creek, July 14, 1967, lower slope						
Depth (cm)	7 3 0	1	200	--	--	--
Texture		loam	loam	--	--	--
Consistency		very loose	very loose	--	--	--
Rocks		--	60 %	--	--	--
Gley		--	--	--	--	--
Charcoal		--	--	--	--	--
Color (dry)		10YR3/1	10YR2/1	--	--	--
Color (wet)		10YR2/1	10YR2/1	--	--	--
pH		7.0	6.7	--	--	--
Area # 4: Big Sur						
Plot 650906: Big Sur, September 3, 1965, upper slope						
Depth (cm)	7 3 --	11	55	93	120	--
Texture		loam	loam	loam	loam	--
Consistency		friable	friable	*	more compact	--
Rocks		20 %	50 %	50 %	40 %	--
Gley		--	--	50 %	70 %	--
Charcoal		--	--	--	--	--
Color (dry)		10YR4/1	10YR5/1	10YR4/2	2.5YR5/2	--
Color (wet)		10YR2/1	10YR2/1	10YR2/2	10YR3/2	--
pH		6.9	6.9	6.4	6.5	--
Plot 650911: Post Creek, September 5, 1965, lower slope/ridge						
Depth (cm)	12 3 --	4	--	28	73	110
Texture		loam	--	loam	silt loam	silt loam
Consistency		friable	--	*	compact	compact
Rocks		--	--	--	--	--
Gley		--	--	--	10 % faint	30 % red
Color (dry)		10YR5/2	--	10YR6/2	10YR6/3	10YR7/3
Color (wet)		10YR3/3	--	10YR3/3	10YR4/3	10YR5/4
pH		6.2	--	5.3	5.5	5.6

TABLE IX-4, CONTINUED

	L F H	A_{11}	A_{12}	B_{21}	B_{22}	B_{23}
Area # 2: Palo Colorado--Bixby Creek						
Plot 650914: Bixby Creek, September 5, 1965, lower slope/ridge						
Depth (cm)	21 12 6	25	60	73	--	
Texture		fine loam	loam	loam	bed rock	
Consistency		friable	*	*	limestone	
Rocks		60 %	80 %	80 %	--	
Gley		--	--	--	--	
Color (dry)	10YR5/2	10YR4/1	10YR4/2	10YR6/4		
Color (wet)	10YR2/2	10YR2/1	10YR2/2	10YR4/4		
pH	6.2	6.3	6.4	6.8		

* normal condition
-- absent, missing

Area No. 4: Big Sur Valley:

Pfeiffer Redwood State Park and the adjoining redwood groves undoubtedly comprise one of the most extensive and purest redwood groves in the southern range of the redwood belt. The Big Sur Valley has most of the largest trees and the purest stands of redwoods. However, their height reaches barely over 200 feet. Most of the redwoods occur between 6 to 20 miles inland and extend into the Ventana Primitive Area, penetrating into the interior of the Santa Lucia Mountains. Elevations range from 100 to 500 feet in the wider Big Sur Valley, but up the Ventana Creek and its tributaries redwood grows up to 750 feet elevation. The best redwood stands are to be found on alluvial flats in the wider parts of the Big Sur Valley. In the canyons deeper inland redwood is limited to northern exposures. Site index ranges from 97 to 146 depending upon slope position and moisture supply. The oldest redwood trees have been found in the Big Sur Valley. Tree diameters up to some 8 feet can be found, but height growth is generally stunted and reaches only a measured 220 feet maximum.

Muelder & Hansen (1961) reported on the cone production of redwood trees in the Pfeiffer Redwoods State Park. Trees here apparently produce abundant annual cone crops. No information on seed weight or quantity was presented.

Area No. 5: Coastal Ravines, Lucia:

In this area the Santa Lucia Mountains come directly to the Pacific shoreline. The short and steep canyons or ravines created by erosion are directly open to ocean winds. Redwood does not occur directly at the seashore level itself. Apparently, redwood is very sensitive to salt spray.

Redwoods begin to occur at the 150 feet elevation level immediately behind the first bluffs in positions sheltered from salt spray. Height growth here is very stunted and measurement of site index is meaningless under such conditions. Within sheltered coves, redwood site quality is good (site index 163). Particularly, in the Partington Creek area, sizeable redwoods can be found measuring up to 6 to 8 feet in diameter; but height growth is again limited by the ocean winds to about 190 feet. Soils are very unstable and rocky with many metamorphic rock fragments. Redwood seems to thrive best in colluvial soils with adequate moisture seepage through the soil in sheltered positions on the lower slopes of the canyons.

The most important canyons are: Torre Canyon (redwood range: 150 to 2,000 feet); Partington Creek (150 to 2,000 feet); McWay Canyon (150 to 1,250 feet); Anderson Canyon (150 to 2,000 feet); Devils Canyon (250 to 1,500 feet); Vincent Creek (250 to 2,000 feet); and Hare Canyon (250 to 2,000 feet).

Area No. 6: Redwood Gulch--Salmon Creek:

Redwood reaches its southern limit here in a few scattered, isolated groves, varying from one-fourth to 6 miles inland along the ravines. Ravines are not as steep and short as in the Lucia stretch, but the topography is characterized by unstable soils and an increasing amount of volcanic, metamorphic and ultrabasic rock outcroppings. Undoubtedly, the greatest distribution of redwood is in the Willow Creek drainage where redwood occupies an elevation range of 400 to 2,000 feet, chiefly on north exposures. Other drainages with redwood growth are: Wild Cattle Creek (200 to 800 feet redwood elevational range); Prewitt Creek (200 to 800 feet); Plaskett Creek (400 to 800 feet); Willow Creek (400 to 2,000 feet); Alder Creek (400 to 800 feet); Villa Creek (400 to 800 feet); Redwood Gulch (400 to 1,000 feet); and a drainage just north of Salmon Creek (400 to 800 feet). The Willow Creek drainage was not visited, but ecological studies have been made in the Wild Cattle Creek, Redwood Gulch and the Salmon Creek areas. Generally, the site quality for redwood is extremely low, varying from site index 77 to 110 at best.

The redwood stands are surprisingly pure with many young trees in the openings and a dense shrub understory of *Vaccinium ovatum*. The adjacent slopes and south exposures are dominated by chaparral. Most redwoods are severely stunted in their height growth because of the ocean winds. The extreme low site quality of redwood may be attributed to the increasing presence of serpentine rock outcroppings in these drainages.

Muelder & Hansen (1961) have reported on cone production of redwood stands in Prewitt Creek and Redwood Gulch. Individual trees in the creek bed of Prewitt Creek produced practically no cones at all, while trees on adjacent slopes outside the creek bed were loaded with cones. Good cone crops were noted in Redwood Gulch.

Area No. 7: Naciamento Summit:

Three small, completely isolated redwood stands occur on top of the Santa Lucia Range in the vicinity of Naciamento Summit. The stands are all located on the eastern side of the range but very near the crest. Two areas are in the San Antonio River drainage while the third and largest area is in the Naciamento River drainage at Redwood Springs. The airline distance to the Pacific Coast is only 2 to 3 miles across the Santa Lucia Mountains crest. The elevation ranges from 2,000 to 2,600 feet. All stands are situated in protected gullies and are close to springs or creeks. Coulter pine (*Pinus coulteri*), madrone (*Arbutus menziesii*) and tan oak (*Lithocarpus densiflorus*) are the predominant stand components while redwood occupies only a minor position in the tree canopy. Redwood seems to occur as isolated individual trees among the pine stand. Redwood site quality is extremely low (site index 95 to 141), but not as low as in the Redwood Gulch - Salmon Creek area.

VEGETATION ANALYSES OF REDWOOD STANDS IN MONTEREY COUNTY, CALIFORNIA

Some 26 vegetation plots and some additional soil profiles have been collected in the redwood stands of Monterey County. The standard methodology of the Zurich-Montpellier School (Braun-Blanquet, 1926; Becking, 1957) has been used to obtain the vegetation records and analyze them. Sample plot size was 10 x 10 m^2, and every effort was made to include only homogeneous vegetation. Soil and site index information supplemented the vegetation records.

All sampled forest communities with the exception of the Naciamento Summit stands belong to the Redwood - Tan Oak Alliance (*Sequoieto-Lithocarpion*) of the Tan Oak - Oak Order (*Lithocarpeto - Quercetalia*). This information is based upon studies of the vegetation of the entire redwood belt. The Order- and Alliance Character Species of both the Alliance and the Order cannot be definitely determined pending further studies of plant communities outside the redwood belt. Tentatively, the following plant species may serve as Differentiating Species:

OC*	Arbutus menziesii	AC*	Claopodium whippleanum
OC	Dentaria tenella californica	AC	Festuca occidentalis
OC	Dryopteris arguta	AC	Fissidens limbatus
OC	Galium californicum	AC	Galium californicum
OC	Isothecium cristatum	AC	Hieracium albiflorum
OC	Isothecium spiculiferum	AC	Hierochloe occidentalis
OC	Lithocarpus densiflorus	AC	Polygala californica
OC	Lonicera hispidula	AC	Pseudoisothecium stoloniferum
OC	Quercus agrifolia	AC	Sequoia sempervirens
OC	Quercus chrysolepis	AC	Umbellularia californica
OC	Quercus wislezenii	AC	Vaccinium ovatum
OC	Rhus diversiloba		

* OC denotes Order Character Species; AC denotes Alliance Character Species.

The Order Character Species of the Swordfern - Douglas fir Order (*Polysticheto - Pseudotsugetalia*) (Becking, 1954, 1956) are not well represented and occur only in the moister and more favorable sites. This species group includes:

Galium triflorum	Trientalis latifolia
Polystichum munitum	Trillium ovatum
Rosa gymnocarpa	Vaccinium parvifolium
Rubus vitifolius	Viola sempervirens

In Monterey County, only *Polystichum munitum* and *Rubus vitifolius* occur with the greatest constancy. It appears, therefore, that all the accompanying species of the Douglas fir forest communities reached their southern limit in Monterey County, and here they are limited to favorable sites close to the Pacific Coast.

Redwood forest communities are limited in their inland distribution in direct proportion to the maritime climatic influences and soil moisture conditions. Redwood needs plenty of soil moisture, particularly during the long and dry summer. This limits redwoods to steep canyons and draws where there is adequate soil moisture seepage during the summer and to northern exposures to limit moisture losses. Many canyons are open to ocean fogs and marine air invasion. All major redwood stands occur on exposures varying from NW to NE; none occur on south exposures. The elevation limit of redwood is approximately 3,000 feet. Except for a few small stands redwood occurs only on the west flank of the Santa Lucia Mountains.

Based upon the present available information the redwood forest communities in Monterey County can be grouped into the following associations within the Redwood - Tan Oak Alliance:

1. The Redwood - Tan Oak - Coulter Pine Association:
(*Sequoieto - Lithocarpetum coulteretosum*)

Only three vegetation plots have been collected with one plot being most typical. Tentatively, the following differentiating species can be used in Monterey County:

Arctostaphylos menziesii	Photinia arbutifolia
Calochortus sp.	Pinus coulteri
Cladonia cf. pyxidata	Rhamnus californicus
Eriodyction crassifolius	Rhancomitrium cf. varium
Grimmia trichophylla	

The association occupies upper slopes and ridge tops between 2,000 to 3,000 feet elevation, and constitutes the altitudinal limit as well as the interior limit of the redwood forsts. It occurs on soils derived from sandstone and shales.

It may be better to distinguish this forest community as an association of the Coulter pine forest with an admixture of redwoods locally. The same forest community has been observed in Santa Cruz county. (See Vegetation Plots # 670717, 670716 and 650917.)

2. The Redwood - Tan Oak - Sorrel Association (Sequoieto - Lithocarpetum oxalidetosum)

The association occupies lower slopes and is limited to NW-NE slopes in Monterey County, or on alluvial flats. Its elevation range is from 150 to 2,000 feet. Its soils are primarily colluvial and sometimes alluvial with adequate soil moisture supplies during the dry summer. Differentiating species useful for Monterey County are:

Acer macrophyllum
Adiantum pedatum
Aralia californica
Asarum candatum
Athyrium filix-femina
Chrysoplenium oppositifolium
Dendroalsia abietina
Dicranum strictum
Disporum hookeri
Disporum smithii
Echinocystis oregona
Equisetum telmateia
Eurhynchium stokesii
Festuca subulata
Galium aparine
Icmadophila ericetosum
Osmaronia cerasiformis
Oxalis oregana
Polypodium glycyrhiza
Polypodium scouleri
Polystichum californicum
Porothamnium bigelovii
Rhamnus purshiana
Rubus parviflorus
Rubus spectabilis
Smilacina racemosa
Stachys emersonii
Thalictrum occidentale
Woodwardia fimbriata

Often Rubus vitifolius and Polystichum munitum are among the dominant herbs, together with Oxalis oregana, particularly on the best sites in coves.

There are two major differences among the site index ratings of the association. Redwood stands occupying the windward side of canyons with slopes facing towards West and Northwest generally support stunted redwood growth because of the exposure to ocean winds. Height growth then becomes less characteristic of the site quality potential, and its values range from site index 65 to 100. Adjacent North and Northeast slopes have site index values ranging from 130 to 160. There are no significant differences among the floristic composition of the vegetation nor in the soil profiles. Thus, the fact that height growth of redwood is adversely affected by direct ocean winds makes the distinction of site index differences unmeaningful in terms of the site potential for trees and vegetation other than redwood. Red alder (Alnus rubra) suffers also from wind in its height growth.

The steep topography and the limited areas available to favorable redwood growth makes it impractical to distinguish moister and drier variations in this association. Certain of the above differentiating species are more optimal in moister sites than others; some may indicate colluvial soils, others alluvial soils. The available material does not warrant presently such distinctions. Furthermore, the steep gradients in these canyons and the rocky substrates make alluvial sorting very difficult and no siltation effects have been observed. Redwood site quality is further reduced by increase in elevation. Many of the above differentiating species do not occur at the upper limit of the redwood occurence. The main transition seems to occur around 700 feet elevation but sufficient material has not been obtained to warrant such separations.

For a more complete analysis one is referred to the synthesis table (Table IX-5).

ECOLOGICAL LIMITATIONS OF REDWOOD FOREST COMMUNITIES

The current distribution of redwood forests in Monterey County can be explained best by the dependency of redwood upon available soil moisture storage. The need for soil moisture is well established by the presence of redwoods in canyons, on alluvial flats, in river valleys and on northerly exposures. Redwood further depends upon the maritime climatic influences. It is adversely affected by salt spray and salt carrying ocean winds. Yet, it depends upon the marine air invasion in the form of fog to supplement its moisture requirements. However, these above postulates still do not explain fully the current distribution pattern of the redwood forests.

The best stands occur in the Big Sur Valley. It should be noted that geologically, the rock formations of the Big Sur Valley are sedimentary rocks of the Franciscan group. Becking (1967) already noted the preference of redwoods for the Franciscan formation in the main redwood belt. Moreover, there is a very small Franciscan outcropping in the Redwood Gulch area which is now dominated by redwood growth. Ultrabasic rock formations may explain the absence of redwoods south of Salmon Creek and in some drainages in the Lucia area. South of the Salmon Creek area tertiary volcanic rocks and highly metomorphized serpentine-like rock materials occur frequently. Thus, serpentine may also be one of the limiting factors in its southern range as it could be one in the limits of its northern range. In order to investigate this, water quality measurements of surface waters by the Department of Water Resources (1969) were consulted. It is very fortunate that in 1969, the Department of Water Resources sampled practically every creek along Highway 1 between Salmon Creek and Monterey. The results of the mineral constituents have been averaged by the areas distinguished in relation with redwood growth and are summarized in Table IX-6.

It is evident from the data presented that in particular, concentrations of magnesium and calcium in the surface waters increase at the expense of potassium. As a consequence, Total Dissolved Solids (TDS), Total Hardness (TH) and Noncarbonate Hardness (NCH) increase from Area # 1 to Area # 6. This supports the hypothesis of the negative growth influence of ultrabasic rock materials upon redwoods. Such rocks are high in magnesium and calcium content. Thus, redwood growth at its southerly extreme range is not only limited by climatic and soil moisture factors but, in addition, by geological factors--in particular the presence of serpentine.

TABLE IX-5: SYNTHESIS TABLE OF REDWOOD FOREST COMMUNITIES, MONTEREY COUNTY, CALIFORNIA

	High Elevation							Low Elevation					
	Naciamento Summit			Big Sur		N.S.	B.S.	Redwood Gulch West			Redwood Gulch North		
Area # :	7			4		7	4	6			6		
	670717	670716	650917	650907	650911	650916	650908	670718	670719	670721	670720	670723	670722
Township South	22	22	18	19	19	18	20	24	24	22	24	23	22
Range East	5	4	1	2	2	1	2	5	5	4	5	4	4
Section	7	1	14	34	34	14	3	23	23	36	23	1	36
Slope	up	up	m	lo	lo	m	lo	m	lo	lo	m	m	lo
Aspect	N	N	W	NNE	NNE	W	N	NW	NW	W	N	N	N
Slope Degree	31	20	25	28	28	15	25	22	35	35	45	40	60
Elevation	2950	2850	1960	1600	1650	2100	2500	450	650	600	775	210	100
Total BA/Acre	566	397	340	440	720	560	260	353	560	420	220	245	566
BA/Acre Redwood	392	218	40	400	720	560	220	353	560	420	220	245	566
Site Index Redwood	105	140	135	140	134	168	95	100	90		77		130

	Low Elevation												
	Coastal Canyons				Big Sur Canyons						Big Sur Alluvial		
Area # :	5				4						4		
	650910	650909	650915	650914	650903	650906	650905	650912	650913	650901	670724	650904	650902
Township South	22	22	18	18	19	19	19	18	18	19	20	19	19
Range East	4	4	1	1	3	3	3	1	1	1	3	2	1
Section	15	15	18	18	30	30	30	18	18	24	24	30	24
Slope	lo	lo	up	lo	lo	up	lo	m	lo	lo	al	al	al
Aspect	W	W	NW	NW	N	N	E	NE	NE	N	O	O	O
Slope Degree	15	15	30	25	40	35	10	25	33	10	0	0	0
Elevation	475	450	680	700	825	750	675	700	675	425	200	750	410
Total BA/Acre			640	640	560	760	840	680		600	400	680	320
BA/Acre Redwood			640	640	360	720	840	680		600	380	680	240
Site Index Redwood				65	94		146				163		139

TABLE IX-5: CONTINUED

Area #	High Elevation: Naciamento Summit 7			High Elevation: Big Sur 4		High Elevation: N.S. 7	High Elevation: B.S. 4	Redwood Gulch: West 6			Redwood Gulch: North 6			Low Elevation: Coastal Canyons 5				Low Elevation: Big Sur Canyons 4						Low Elevation: Big Sur Alluvial 4		
Plot #	670717	670716	650917	650907	650911	650916	650908	670718	670719	670721	670720	670723	670722	650910	650909	650915	650914	650903	650906	650905	650912	650913	650901	670724	650904	650902
TREE LAYER																										
Height (m)	30	20	25	80	25	50	60	40	45	50	50	20	25	30	25	15	12	60	40	60	40	40	80	70	60	60
Cover (%)	70	70	90	70	100	80	60	60	85	90	80	100	100	90	100	70	100	80	90	90	80	80	80	80	90	80
Sequoia sempervirens	32⊛	+2	11⊛	44⊛	45	54	43⊛	31⊛	52	54	43⊛	53	53	55⊛	55⊛	45⊛	55⊛	44⊛	55⊛	54⊛	55⊛	55⊛	54⊛	43	54⊛	44⊛
Lithocarpus densifl.	22	11																32⊛	12	21			11	11	12	
Arbutus menziesii	33	42	32																							
Pinus coulteri		21																								
Quercus chrysolepis		12																								
Quercus		12																								
Umbellularia calif.				22			12	31	+1	12	22			12	12			21⊛	22⊛	11⊛			21⊛	11	+1	32
Acer macrophyllum				32			32							22										12		12
Platanus occidental.																										21
SHRUB LAYER																										
Height (m)	1-6	1-6	1-6	1-6	1-6	1-6	1-6	1-6	1-6	1-6	1-6	1-6		1-6	1-6	1-6	1-6	1-6	1-6	1-6	1-6	1-6	1-6	1-6	1-6	1-6
Cover (%)	30	30	20	40	20	10	50	30	35	50	40	1		10	10	80	0	40	50	30	30	100	10	20	50	30
Lithocarpus densifl.	32	12	22		12	+1	33									+2		22	12	22				+2	22	12
Sequoia sempervirens	+1		+1	33	22	12	22		32	32	32	12	12	12	12	21		22	34	32	32		12	22	32	32

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TABLE IX-5, CONTINUED

Area #	Naciamento Summit 7			Big Sur 4		N.S.B.S. 7	N.S.B.S. 4	Redwood Gulch West 6			Redwood Gulch North 6			Coastal Canyons 5				Big Sur Canyons 4						Big Sur Alluvial 4		
Plot #	670717	670716	650917	650907	650911	650916	650908	670718	670719	670721	670720	670723	670722	650910	650909	650915	650914	650903	650906	650905	650912	650913	650901	670724	650904	650902
Umbellularia calif.		12		12			11	21							+1			22	12	+1			+1	11	12	
Vaccinium ovatum											+2	+2	+2	12	+2	32						+2				
Arctostaphylos menz.		12																								
Arbutus menziesii	22																									
Photinia arbutifolia		+2⊗																								
Quercus chrysolepis		12																								
Quercus wislezenii		22																								
Rhamnus californica		12⊗																								
Rhus diversiloba		+2⊗																								
Holodiscus discolor								+1⊗	+1		12⊗					+2*										
Lonicera hispidula	+2																									
Rosa gymnocarpa				+2																						
Rubus parviflorus								11⊗		12⊗	22			+2										+2		
Salix sp.								11																		
Acer macrophyllum				32			32⊗							22										12		12
Ribes ?divaricata									+1																	
Ribes sanguineus											12					32⊗					12⊗					
Rhamnus purshiana				+2																						
Sambucus callicarpa															+1											
Aralia californica				+1		+1⊗								+1⊗								55⊗				+2
Platanus occidental.																22⊗										

TABLE IX-5, CONTINUED

Area #	Naciamento Summit 7			Big Sur 4		N.S. 7	B.S. 4	Redwood Gulch West 6			Redwood Gulch North 6			Coastal Canyons 5				Big Sur Canyons 4						Big Sur Alluvial 4		
Plot #	670717	670716	650917	650907	650911	650916	650908	670718	670719	670721	670720	670723	670722	650910	650909	650915	650914	650903	650906	650905	650912	650913	650901	670724	650904	650902
HERB LAYER																										
Height (m)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cover (%)	5	10	10	80	10	20	5	90	70	80	100	20	30	80	100	70	5	20	30	70	90	100	20	80	30	30
Galium triflorum			+2⊛													+1⊛					+2⊛	+2⊛				+2⊛
Polystichum munitum	+1K	+1		+2	11	+1	+1	31⊛	33⊛	22⊛	55⊛	21⊛	+2	22	12	+2	21	+2	32	12	21	22		12		
Rosa gymnocarpa			+1			+1																				
Rubus vitifolius								11	+1	12	+1	21	22	21	+1	32	+1					12		+1	+1	11
Trientalis latifolia	+1			32										12	+1		11							+1	+1	11
Trillium ovatum						+1								+1	+1		11				+1		+1			
Vaccinium parvifol.											+2															
Viola sempervirens									+1															+1		
Sequoia semperv. S	+2			+1	22	+2	12	+1	+2	+2		+2	+2		+2		+2	+1	22	12	12		12	+2	22	12
Sequoia semperv. K				+1		+2	+1		+1		+1			+1	+1				+1	+1	+1			+1		
Lithocarpus densifl.	+2	+2	12		+2	+1	21											12	+2				+1	+2	+2	12
Lithocarpus densi. K			+1		+1	+1												+1	+1		+1		+1			
Galium californicum	+2	+2							+2		12					+2	22									
Lonicera hispidula	+1	+1	11					+1	+1		+1								+2							+1
Dryopteris arguta	+1			+2	+2				22⊛	+2	11	+1	11	+2		+1	11	+2	+2			+2	+1	+1	21⊛	+1
Vaccinium ovatum													+2	+2	+1	+1					+2	+2				

TABLE IX-5, CONTINUED

Area #	Naciamento Summit 7			Big Sur 4		N.S. 7	B.S. 4	Redwood Gulch West 6			Redwood Gulch North 6			Coastal Canyons 5				Big Sur Canyons 4						Big Sur Alluvial 4		
Plot #	670717	670716	650917	650907	650911	650916	650908	670718	670719	670721	670720	670723	670722	650910	650909	650915	650914	650903	650906	650905	650912	650913	650901	670724	650904	650902
Acer macrophyllum				+1K			+1K																			+1K
Adiantum pedatum				12				+1						+1							+2⊕	22				
Aralia californica				+2⊕		21								+2⊕								32⊕				
Athurium filix-fem.										+1		+1	+2		+2							21		+1		
Disporum hookeri				+1		+1								+2⊕	+1	21⊕		+1	21⊕		12⊕	+1⊕	11	+1⊕	11	
Disporum smithii																	21						11			
Oxalis ore. (rubra)				54				32⊕	12⊕	43⊕				55	55	22		12		44	55⊕	55⊕	22	54⊕	22	22
Rhamnus purshiana																12			+1K							
Rubus parviflorus								21		12	21⊕			+2	+1	+2					+1					+1
Smilacina racemosa				11⊕	+1	+1			+1		+1⊕	+2	11	+1⊕	+1⊕	21⊕	22	+1	+1	11⊕	+1	+1⊕	+1	11	+1⊕	
Stachys emersonii			+1					11⊕	+1	+1	+1		12		+1	+1		+1			+1	+2		+1		11
Woodwardia fimbriata				+2		21		+1						+2					11	33				+1	22	+1
Umbellularia calif.		+2		+1				+1						+1				12	+2	11						+1
Umbellularia cal. K	+1			+1	+1		+1							+1		+1			+1							+1
Polystichum califor.				12						+1	+2			+1					12	11						
Polypodium scouleri																	+2					+2				
Polypodium glycyrhiz.								+1	+2	+2				+1										+2		
Chrysoplenium oppos.				+1																		+1				
Echinocystis oreg.							+1										+1				+1	+1				
Equisetum telmateia																										
Galium aparnie								+1			+1⊕	+1⊕	+1⊕													
Rubus spectabilis									22⊕																	

TABLE IX-5, CONTINUED

Area #	Naciamento Summit 7			Big Sur 4		N.S. 7	B.S. 4	Redwood Gulch West 6			Redwood Gulch North 6			Coastal Canyons 5				Big Sur Canyons 4						Big Sur Alluvial 4		
Plot #	670717	670716	650917	650907	650911	650916	650908	670718	670719	670721	670720	670723	670722	650910	650909	650915	650914	650903	650906	650905	650912	650913	650901	670724	650904	650902
Thalictrum albiflor.								21			+1															
Festuca subulata																			+2⊗				+1⊗			+2⊗
Osmaronia cerasifor.												+1	+1													
Hieracium albiflor.									+2		11						+1⊗		+1							
Hierochloe occident.														+2⊗					+2					12⊗		22⊗
Festuca occidentalis			+2															+2⊗								+2⊗
Dentaria californica								+1	+1	+1†	+1†	21†	22⊗			+1⊗†	21⊗†							11†		
Lathyrus panciflora								+1				+1														
Carex sp.	12⊗		12⊗			+2⊗	+2⊗											+2⊗	+2⊗						+2⊗	+2
Iris douglasii			+1		+1		12			+2								+2	+2	+1			+2	+1⊗		21
Osmorhiza nuda										+1⊗			11		21	+1⊗					11⊗			+1⊗		
Pteridium aquilinum						11	+1	+1				+1	+1	+1	+1	+1		21			+1	+1	+1	+1	+1	32
Whipplea modesta	+1	+1⊗																								
Quercus chrysolepis	+1K																									
Quercus wislezenii	+2	½2																								
Rhus diversiloba	+1	22	+1				+1	+1	+1	+1	+1	+1	+1	+1	+1	32	+2								+1	+1
MOSS LAYER SOIL																										
Cover (%) soil	15	1	1	10	0	5	1	30	15	1	5	1	1	0	0	0	0	0	1	1	1	1	0	1	0	0
Cover (%) rocks				80										80	80											

TABLE IX-5, CONTINUED

Area #	Naciamento Summit 7			Big Sur 4		N.S. 7	B.S. 4	Redwood Gulch West 6			Redwood Gulch North 6			Coastal Canyons 5				Big Sur Canyons 4						Big Sur Alluvial 4		
Plot #	670717	670716	650917	650907	650911	650916	650908	670718	670719	670721	670720	670723	670722	650910	650909	650915	650914	650903	650906	650905	650912	650913	650901	670724	650904	650902
Claopodium whipplea.	22		+2			+2			12		12	+2							+2	+2						
Fissidens limbatus	+2			+2					+2		12	+2						+2		+2	+2	+2		+2		
Isothecium cristatum												+2	+2													
Isothecium spiculif.		+2						33	23	+2														+2		+2
Pseudoisothecium st.				55R		33		+2						55R	55R											
Eurhynchium stokesii				12		+2		+2	+2		12			+2						+2	+2	12		12		
Dendroalsia abietnia				+2R		+1R		+2R																		
MOSS LAYER LOGS Cover (%)	30	0	30	80	0	30	80	90	20	40	40	40	40	90	80	1	0	80	70	80	60	80	40	30	80	80
Cladonia fimbriata	+2							+2						+2												
Cladonia cf macil.								+2								+2										
Isothecium cristatum	22		+2⊗	22		12	44							44	44	+2⊗			44	54	43	44	32		54	
Isothecium spiculif.	22					12		44	23	33	33	32		44	44			54			+2		32	32		54
Pseudoisothecium st.				44				22						33	33								12⊗			
Claopodium whipple.			+2																			+2				
Eurhynchium stokesii						12			+2													32⊗		22		
Icmadophila ericet.										+2⊗	+2⊗										+2	22				
Dendroalsia abietina									+2																	
Porothamnium begelo.														+2								12				
Dicranum strictum				+2					12																	

TABLE IX-6: A COMPARISON OF MINERAL CONSTITUENTS AND SURFACE WATER QUALITY OF REDWOOD AREAS IN MONTEREY COUNTY, CALIFORNIA

Area #:	1	2	3	4	5	6	7
pH Value	7.9	8.8	7.9	7.9	7.8	8.0	
Calcium (Ca)	13.9	16.7	27.0	35.8	42.5	38.8	*
Magnesium (Mg)	4.0	7.4	6.6	10.3	13.3	17.0	*
Sodium (Na)	14.0	21.3	8.2	12.7	8.4	11.3	*
Potassium (K)	1.5	1.0	0.9	2.0	0.5	0.9	*
Carbonate (CO_3)	0.0	11.9	0.0	0.0	0.0	0.0	*
Bicarbonates (HCO_3)	43	59	107	140	178	184	*
Sulfates (SO_4)	*	10.4	15.0	15.0	16.9	21.0	*
Chloride (Cl)	16.4	26.9	7.5	12.6	9.3	12.7	*
Nitrate (NO_3)	1.1	0.3	0.1	0.3	0.4	0.2	*
Fluoride (F)	*	*	*	*	*	*	*
Boron (B)	0.1	0.0	0.0	0.0	0.0	0.0	*
Total Dissolved Solids (TDS)	*	146	142	133	178	184	*
Summation of Analyzed Constituents	*	125	129	126	180	192	*
Total Hardness (TH)	51	72	95	132	162	167	*
Noncarbonate Hardness (NCH)	16	5	7	18	17	17	*

Data from Department of Water Resources Bulletin # 130-69, 1971: (p.69-73).

* No data available.

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