Ecology of the Redwoods

by Dr. Edward C. Stone, 1965

In regard to the introduction, I was impressed by the fact that I've been very active in dormancy. Now last week Professor Baker developed the background of two redwoods: Sequoiadendron giganteum, commonly known as the Sierra Big Tree, and Sequoia sempervirens, commonly known as the coast redwood. He also touched briefly on some of the ecology of these two redwoods. Tonight my assignment is to develop in considerably more detail the ecology of the Sequoia sempervirens or coast redwood; so when I speak tonight of redwood, this is the species of which I am speaking.

The term ecology comes from the Greek root of "otis," meaning at home, and "logos," meaning study or discord, so literally ecology refers to the organism at home. Now home, to the coast redwood, consists of about a 450-mile coastal strip where there are a variety of environments. This coastal strip extends from southern Monterey County to southern Curry County which lies just north of the Oregon-California border. The ecologist investigating redwood is interested in a number of different questions: first of all, he is interested in where these redwoods grow; next he is interested in the types of plants that associate with redwood; then he is interested in why redwood grows where it does; and conversely, he is interested in why redwood does not grow where it does not; and what are the short term and long term changes. Changes generally referred to by the ecologist are successional changes - changes that can be expected in the composition of the vegetated mosaic of which redwood is a part.

Now, recognizing that I could not possibly treat each one of these questions in any detail, I organized my talk tonight along slightly different lines. First I want to touch lightly on the different kinds of forest communities in which the redwood finds itself; next, I want to examine briefly the physiological characteristics of redwood that enable it to compete successfully in these plant communities; then I want to consider for purposes of illustration the way in which redwood and associated plants sort themselves out under the impact of competition along one particular environmental grading; and finally, I want to speak briefly about the preservation of redwood.

So now let us begin by taking a look at a few of the plant communities in which redwood is found. There has been some minor reduction in the range of redwood due to agriculture clearing, but in general it is probably much the same today as it was five hundred or even a thousand years ago. It is convenient, I believe, and it also supplies, to me at least, the proper prospective, to view this species as a relic fighting to- hold on to each piece of land that it now occupies around which a number of more aggressive species crowd eager to take over, should the redwood relinquish its hold for even a moment. This is not to suggest that redwood is incapable of growing in other places, because it can. Provided competition from other species could be eliminated, it could successfully go much farther north, much farther south and into certain parts of the Sierra foothills and into a number of different countries

Now, I believe that the public's interest in the redwoods today centers around trees such as those which reach diameters up to 20 feet and heights up to 355 feet. Speaking as an ecologist, I consider that this narrow public interest is unfortunate. It leaves too many other interesting redwood communities vulnerable to destruction while the public's attention is directed elsewhere.

In actuality, the bulk of the redwoods occur as part of a vegetated mosaic. There are grass covered openings, referred to locally as prairies. There are stands of redwood along the river flats. There are stands of Douglas fir and there are mixed stands of Douglas fir and redwood. At its northern limit the redwood is found on the slopes some ' distance up from the river flats. It occurs there is a mixture with Douglas fir which is the dominant tree in some stands. One stand lies above the Chetko River and is within the boundaries of the Siskiyou National Forest. Until recently this stand was scheduled for cutting and at the moment I'm not sure what the status is. Personally, I think that some effort should be made to keep these representatives of this type of the northern extremity intact. Now on the southern limit, redwood is restricted to canes. One particular area lies within the Los Padres National Forest and at the moment is not threatened in any way.

In between these northern and southern limits, redwood associates with a number of different tree species. In Del Norte County we often 'find it associated with hemlock. Examples of this community type occur in the Del Norte Redwoods State Park. Near the coast from Del Norte County well down into Humboldt County, redwood also includes spruce among its associates, along with grand fir, Douglas fir, and hemlock. Spruce, which are an important compliment of this vegetated type, obtain their best development a way north in British Columbia and southeast Alaska. Examples of this community type occur in Del Norte County and also in Del Norte Redwoods and Prairie Creek state parks. farther south and near its eastern limits, southeast of Willits, we find redwood growing in association with ponderosa pine and Douglas fir. This is a particularly interesting community type because ponderosa pine is a species that can withstand the long dry summers of the Inner Coast Range and the Sierra. To me it appeared to be a relic of a formerly water climate, overrun by ponderosa pine sometime perhaps thousands of years ago when the summers become increasingly drier. Now it's becoming overrun by Douglas fir, since wild fires have been brought under control. This area is in private ownership and as far as I know there are no plans for public purchase or preservation.

Farther to the south in an area lying between Boonville and Point Arena, redwood associates with sugar pine. Sugar pines have long branches often with long cones hanging from them. They often attain quite a good diameter. This community type is best developed just below the tops of the ridges. Soil depth and fire have undoubtedly played an important role in its establishment. There are a few good examples of this community type still intact on the flanks of Gualala Peak. As far I know all this type is in private ownership and there are no plans for public purchase or preservation.

Farther south and again confined to the ridge top, redwood associated with knobcone pine. An excellent example of this community type is located on Flicker Ridge just to the east of the Redwood Regional Park in the Oakland Hills. Shallow soils and fire are responsible for the deterioration of this area; part of this area now falls within the East Bay Municipal Utility District, the rest is on private land which is destined for subdivision in the not too distant future. As we approach the southern limit of redwood, we find it slopes south of the Tehachapis. Like ponderosa pine, sugar pine and knobcone pine, coulter pine can withstand long periods of drought. Gradually as the climate has become increasingly dry over the last thousand years or so, it appears to have moved in around these isolated pockets of redwoods.

To explain why redwood is able to compete with such a variety of associates, it is necessary to examine its physiological potential. This potential is determined by a number of points: seed production; seed germination; seedling establishment; vegetated reproduction; fire resistance; growth response to soil nutrients; temperature and moist stress; tolerance to flooding and subsequent alluvial deposits; resistance to pathogens and insects.

As far as we can determine redwood produces seed fairly regularly over most of its entire range. There are some exceptions to this; however, in some places the production is much heavier than in others and at some places the percent of viable seed is higher than in others. Data collected by Bolder and Hanson gives you some general idea of the variation in seed fall over the range of redwood.

Now, the seed germinates quite readily where it falls; but initial survival is closely tied to the presence of exposed mineral soil. On an deposit left by last years flood on where the seeds fell became more or less a green lawn of seedlings. Why its necessary to have mineral soil exposed is not yet entirely clear, but the evidence collected to date suggests that one or more fungi residing in the decomposing organic layer f s responsible; the presence of mineral soil is why you get so much obvious germination and early survival. On organic soil that you would normally get where there isn't flooding you get germination but survival is very poor.

When the soil is sterilized by irradiation - experimentally this is done in the cyclotron - and the microorganisms in the soil including the fungi are destroyed. When this is accomplished seedling growth much improved. There is a definite effect on the root system from removal of the fungi and other micro-organisms. Some workers have suggested that this is merely due to a release of nitrogen and other nutrients from the killed soil microorganisms, but it seems to me if this were so we should expect that we could attain the same effect by adding nutrient; but we added nutrients and actually there is a depression in this particular case, so I don't think we can ascribe this to or assign the responsibility of this to nutrients. Even when the bare mineral soil is available as it often is in growth such as that following flooding, seedlings will not survive under dense shade. Openings are required to let the light in. These openings can be created by windfall, fire, landslides, road clearings or by logging, and this light is necessary if the seedling is to survive.

More important ecologically than its ability to produce seed is the ability of the redwood to sprout. And here you can see a mass of dormant and advantageous buds located just above the root crown of a one year old seedling. Here is the point I'm speaking of; those small dormant buds are ready to pop out if anything happens to the tree. Now, in the case of a seven year old tree, many sprouts began to come up from the root crown. In this particular case the impact that brought these up, we think, was the flooding of this particular sample. As the tree becomes older many of these buds are killed. Some, however, continue to develop and grow out with the tree. They are suppressed in part by the regular flow of growth regulators moving down the tree from the crown; when this supply of growth regulators is interrupted by fire, or as in this case by cutting the top off the tree, these buds break and end up shoots.

In another example, shoots or sprouts as they are generally referred to, come out three years after a tree was cut down to make way for a section of freeway south of Eureka. After another 10 years, not all the sprouts will be the same size. Some sprouts are gradually going to be crowded out and die; one may take off and catch up with another one; but sometimes you may only have one sprout for a stump, sometimes you may have two, three or four going right on into maturity. As an example of how they would look in another 30 or 40 years, in one particular situation a tree was cut with a high stump and a little of it is still remaining. It was cut with a high stump, as they used to cut in the 1800s, and subsequent to this the whole area, including that stump, was burned a number of times. The present sprouts are not the original ones that developed when the tree was cut in the late 1880s. They may be secondary or maybe they are tertiary, but at least secondary sprouts that have developed following the last fire.

Id like to explain here how fairy rings like the one at Muir Woods, which I think many of you have seen, develop. It starts with a tree when it is burned down or injured in some way. You have these sprouts coming in; they then develop for a considerable period of time. In the Muir Woods case, were talking about trees maybe up to three or four feet in diameter. These sprouts then in turn are injured or burned down and you have another secession of sprouts right around each one of these. Now, you may have 30 or 40 sprouts but of those 30 or 40 sprout maybe only two or three or sometimes only one developed. Now you can visualize when all the rest die out then we have a ring or fairy ring

Sprouting in some trees is very persistent. In one area north of Eureka which was logged 40 or so years ago and then subsequently developed for pasture, the sprouts have been cut repeatedly but they till persist; they have been cut back a number of times but they come back again. But some stumps do not sprout. There is a stump in that same freeway clearing that did not sprout. In part this sprouting ability is related to the size which in turn is related to the age of the tree. Almost all the trees under 40 inches in diameter at least 90% sprout if they're cut down; but only about 50% of the trees nine feet and over sprout. At the moment were not sure what the physiological explanation for this is. No one has examined it very closely to see if they can explain it. The difference between the growth rate of redwood from sprouts and seedlings is very marked; if it were not for the rapid ability of redwood to sprout and then for the subsequent rapid growth of the sprouts, it is highly doubtful whether redwood would be with us today; there may be some argument to that but then I think I can find quite a bit of evidence for that statement.

Redwood is a plant that is extremely sensitive to the fertility of the soil in which it grows; compare a Soquel soil, which is a fertile alluvial soil from Santa Cruz, and an Aiken soil, which is an infertile soil from the Sierra. By adding nitrogen phosphorus and potassium at the rate of 300 pounds per acre this is on that Aiken soil we can double the growth of redwood.

Now, redwood is a warm climate plant and temperature-wise it would be much happier centered around San Diego than around Eureka. Douglas fir on the other hand is a cool climate plant and happier from Eureka north. Consider the response of redwood seedlings that were grown in a temperature controlled greenhouse down at the California Institute of Technology by Henry Howards. One was exposed to a 45 degree night - that's a cool night or a cold night relatively speaking and another to a warm night of 73 degrees. Redwood continues to grow bigger and bigger as the temperatures increase right up to 75 degrees. The same is true where we have the warm night; it doesn't grow quite as big with the warm night as it does with the cool night but it continues to grow as the temperatures increase. But when redwood reaches down to 40 degrees, then it just closes up immediately and stops growing.

Where we're dealing with cool nights we find that Douglas fir more or less increases its growth in a straight line relationship from 45 to about 65, and then at 65 as the temperature is increased it drops off; so its quite a bit different, it doesn't like the warm climate as well as redwood; and where we get into the warm night the same relationship holds as the temperatures increase up to 65 degrees Douglas fir growth increases and then drops off at 75 degrees.

The reason redwood is not living in Southern California where the autumn temperatures are approached is because it cannot withstand soil moisture stress and also has very poor control over water loss from its leaves. Four other comparable species, that often grow in the same area that redwood does, dominate only where soil moisture stress and evaporation stress is much higher than that tolerated by redwood. Studies have shown that redwood seedlings succumbed even before the soil had dried down to the point at which some flowers and other moisture sensitive plants wilt. In the studies, the redwoods wilting point was at about six percent moisture content and at eight percent the redwoods all died. The other seedlings studied white fir, incense-cedar, ponderosa pine and Jeffrey pine were not only able to continue to remove soil moisture from the soil but in addition were able to stay alive for a considerably longer period of time. Consider, for example, the number of days in which 60% of the seedlings were alive. After 35 days 60% of the white fir were still alive; after about 45 days 60% of the incense-cedar were still alive; after about 80 days 60% of the ponderosa pine were alive, and after about 110 days 60% of the

Jeffrey pine were still alive. But the coast redwood died before the wilting point was reached.

Now, we believe that this moisture stress is responsible in part at least for the spike tops that so many of the older trees display. We have been studying this phenomenon over the last several years; but we have found it a bit difficult because of the distance one must climb up the tree to reach the study area. We have rigged five trees in the Rockefeller Grove of the Humboldt Redwoods State Park with pulleys so that we can hoist Mr. Dick Vasey, a graduate student, working with me on redwood ecology, at least two-thirds of the way up the tree before he has to start climbing with spurs and safety belt. Next year we hope to have ladders mounted up these trees, the tallest of which incidentally is 315 feet.

Now, the big trees on the alluvial flats are better able to store up large volumes of water in their trunks. Beginning in June one five foot diameter, 250 foot tall tree held roughly 8,000 gallons of water. To take care of all the evaporation stress throughout the summer, the redwood is apparently able to draw upon this reservoir and by September we find that it has lost about 2,000 gallons. That doesn't mean that water hasn't been supplied to this reservoir throughout the summer - it has - but the root system is not particularly efficient in redwood and it cannot keep up with the evaporation stress, so these large trees then take advantage of this reservoir; it is depleted and then refilled again during the fall, winter and spring months.

On many of the alluvial flats where the maximum size is obtained, as on Bold Creek Flat in Humboldt County, the trees are subjected to periodic flooding, resulting in silt deposits sometimes as much as four feet thick. Redwood is able to tolerate this periodic flooding and subsequent burial of its root system by flood-carried sediments by sending up vertically oriented roots into these sediments and then later sending out a horizontal root system right below the surface of the deposit. Under these conditions, instead of roots being sent down, the roots turn around and grow up. After a rain, for example, you can lie on the ground if you are inclined and you can look along the surface of the ground and you will see the little tips of the roots. These have probably not grown out of the ground but probably grown up to the surface of the ground, and then the rain has washed off a little bit of the soil exposing the tips; but you can go right along the top of the ground and pick off the tips of these roots that are growing straight up. Later a new root system is developed right out, just below the ground surface from the trunk. With each "deposit," a new root system is formed. Each one of these root systems subsequently dies and there is only one active root system at a time.

But first of all we have the upward growth and then the literal growth. In order to study this vertical growth replacement phenomenon, we decided to bury a number of root systems by bringing in material with dump trucks. One of the variables we wanted to examine was the relative development of roots under silt and gravel. We were able to bring in one three foot deposit of gravel. This approach, however, came to a grinding halt with the third broken axle in four days. There were trucks we had borrowed from the California Division of Beaches and Parks. To overcome this difficult logistics problem, w reasoned that we might be able to create the same effect by creating two foot root-free layer by pushing off the top two feet of soil with a bulldozer and then putting it back in place. This we did. It removed approximately 90% of the feeder root system. But before spreading the dirt back in place, we set out a number of wooden frames that had neither tops nor bottoms. These frames enabled us to separate the roots that grew vertically upward from below and the roots that grew horizontally from the side.

We found that within four year after removal of this root system - that is 90% of the feeder root system - a replacement root system comparable to the original one had been regenerated by vertical upward growth of roots from below. One year after the removal in 1960 there were about 10 roots per cubic foot of soil. In 1961 we had roughly 30; in 1962 roughly 35; and in 1963, 65, which is close enough to be back to the original setup. This is really quite a remarkable characteristic. I know of no other plant that has this capability.

Many of the plants that associate with redwood are absent from the alluvial flats that subject to periodic flooding. This is due largely to the fact that the redwood can tolerate flooding while many other species cannot. For example, a nearby young tan oak was killed by a silt deposit of three feet. A young Douglas-fir was also killed by that silt deposit. The redwood on the other hand does very well; except in 1957, one year after the l955-56 floods, there were a number of dead redwoods where silting had occurred. And when we dug pits around a number of the dead trees, we found that there was a considerable amount of organic matter of this type, like piles of logs, buried beneath the silt. To determine whether the buried organic matter is really critical, and also to determine the degree to which redwood can tolerate flooding, we have set up galvanized tanks up on the Oxford track at Berkeley, and filled them with silt from the Redwood Region.

Then we planted redwood trees in these. In some of these tanks, we also buried eight inches of organic matter consisting of redwood leaves and branches. Then we let these grow for two years until the roots had reached the bottoms of these tanks. And then we flooded half of these tanks and did not flood the other half. At the moment we are in the process of examining the root systems of these plants. We had inside each one of these tanks a framework so that the roots would not collapse when we took them out. We washed all the soil from around it. New roots grew in following the flooding. Not all the data is in yet, but we can report that redwood is very tolerant of flooding, and in many ways behaves like you'd expect a swamp species to behave. It can survive even when extremely low quantities of oxygen are present. Buried organic matter has an inhibiting effect both in the flooded soil and in the unflooded soil.

Redwood is also remarkably tolerant of fire. Its thick bark offers protection from fire and if the tree is seriously burned, it can sprout, from its base. Or, if merely the leaves and the twigs are burned off, it can develop a new crown. In one whole area that was burned about 15 years ago - these burned trees are referred to as fire columns - and had all their branches killed, not necessarily burned off, but at least killed by the fire. And in another area that was only burned three years ago the trees have already developed new branches. The tips grow up and will cover the dead tips very shortly. On the tip, the buds that will make the new tip start back at a point where the bark was thick enough to protect the cambium from the heat of the flames.

Redwood is not bothered to any extent by pathogens or insects. It is, however, bothered to some extent by the gray squirrel, which girdles the tree some distance back from the tip. It is also sometimes heavily browsed b,- deer. And it is occasionally attacked, believe it or not, by bears, who rip off the bark to get at the cambium layer beneath. In one area they were really doing very serious damage and the particular company involved was given a permit to go out and cut down on the bear population. But ecologically, animals, in general, are not a very important part of the ecology of redwoods.

Death to the redwood comes mostly by windthrow, but a few trees just lose their balance and fall over. They fall over when there is not even a breath of wind. When we consider the immense size of these trees, the importance of balance is obvious. Their disproportionately small root systems cannot possibly hold them up once they become unbalanced. And balance in a tree such as this can only be maintained as long as the tree is healthy and producing copious amounts of cellulose. Only then can it correct for the lean by laying cellulose down along the underside of the lean, which it does in response to gravitational forces. For example, if you cut into a tree that had a slight lean to one side, you would find that there is a disproportionately large amount of wood being laid down on that side, which is to correct for the lean. This is in response to the growth substances moving down the tree and responding to gravitational forces on that far side.

At the moment I favor the year to year variation in temperature as an explanation for the variation in growth rate of the redwood. Mr. Vasey favors a year-to-year variation in evaporative stresses as an explanation. And there's some question as to who will win out. I'm the major professor. Now the vegetative pattern or mosaic that involves redwood and other plants is determined in part by the various environmental gradients that exist in the area. It is determined in part by a differential ability or a physiological capability of the species to take advantage of this environmental gradient. and it is determined in part by a differential ability of the species present to alter this environmental gradient.

To illustrate this point, I would like to consider how plants sort themselves out along one particular environmental gradient. In my example the environment gradient is the amount of available soil moisture in August in the Humboldt Redwoods State Park. Now soil moisture in this park decreases with elevation. In this particular case, its primarily a function of soil depth. As we go up in elevation the available soil moisture decreases. So along this moisture gradient we have a segregation of the various species. In August in the alluvial flats, which are at 150 feet elevation, roughly 60% of the total moisture holding capacity of the soil is available. At the higher elevations, there is very little, maybe one or two percent available moisture. This is a moisture gradient. It happens that as you increase in elevation there is less moisture. Now the plants are able to find this out very quickly. And so they segregate out along different ways. Consider the Sequoia sempervirens. It has a minimum available moisture in August on a scale of zero to 100. It covers a wide range of moisture. Now actually of redwood, probably your best grove would be obtained without competition. But Douglas fir, black oak, tan oak and madrone, all are found where the available moisture is less than 40% and they all peak out pretty close to around 15 or 20%, something on that order of magnitude.

If there were no competition along this environmental gradient, where do you think we would find these plants? We would find them along the entire length from zero to 100 and probably its best growth would be found up, well, it might not go quite to 100, but almost to 100, and probably its best growth would be found somewhere around 80%. And the same I think is true for the black oak, the tan oak and the madrone. The only place we find the incense-cedar along this moisture gradient is where its quite dry, that is, 20% or less. This isn't because incense cedar couldn't prefer to grow elsewhere if there were no competition, but this is where it sorts out along this moisture gradient in response to competition. The only place we find the bigleaf maple is at the wet end from 60% to 100. It peaks up there around so and if there were no competition, I think we might find bigleaf maple coming down maybe to 30%. But I don't think we would find it on the dry end. One that is very intriguing to me is the California bay. It has two peaks, but is not found in between. We find this then up on the drier slopes where it is able to compete and we find it down on the very wet slope where it is also able to compete.

And we don't find it in between black cottonwood, like maple, occurs only up at the wet end. In competition its able to maintain itself there. Manzanita would be much happier if it had a little bit of moisture available to it, but competition wise its been shoved right down to the driest part of this particular environmental gradient.

Now the last point I want to touch on tonight is preservation of the coast redwoods. Preservation is a fairly emotional subject these days, and there are a variety of objectives. I want to speak about three of these objectives tonight. One would be the preservation of the individual tree, which I think is a legitimate objective.

Next would be the preservation of the redwood community types. I'll go back and talk again about the ones I spoke of earlier. I think the preservation of these types is a legitimate objective. And last of all, preservation of redwood as a source of lumber and cellulose. And I think that this is also a legitimate objective.

The Palo Alto tree that Professor Baker spoke to you about last week, which Portola referred to as a land mark when he visited the region in 1789, was narrowly missed by the Southern Pacific Railroad track when laid there over so years ago, which really seems inconceivable these days. But several years ago, after many years of inattention, the city fathers in Palo Alto became concerned with the health of this tree and have gone to considerable effort to try and restore its vitality. They have, in their efforts, installed a sprinkler system in the top of this tree, with which they hope to mediate the evaporative stress. And now they are trying to bring about the development of a more effective root system by roto-tilling and so on. I would imagine they have already invested several thousand dollars in this operation, and I personally think that this is quite justified considering the historic importance of this particular tree.

To preserve representative samples of the different community types of which redwood is an important element is also going to require considerable effort and money. I, at the moment anyway, do not feel it will be necessary to put sprinklers in the tops of the redwood trees on Bull Creek Flat. But it will be necessary to control competing species either with fire, with the ax, with a chain saw, with a bulldozer, with chemicals or with a combination of all these. Consider Rockefeller Grove, near Bull Creek. There are the silt deposits left during last years flood. There is an understory of tanoak and there is tanoak that was killed by this deposit. Now once periodic flooding is arrested, and this is the plan at the moment, some other method will be required to keep the tanoak and understory Douglas fir under control. If this is not done, as these large trees fall and they are certainly going to fall, they will be replaced by a mixture of tanoak, bay and Douglas fir. Douglas fir quickly seeded in a similar stand following the creation of an opening by a big tree falling to the ground. And unless something is done, it will continue to dominate that area, keeping any more redwoods from coming in. Fire could be used to prevent this, that is, either pre vent it or eliminate Douglas fir. But tanoak and tanoak sprouts would then probably come in so you have to use something other than fire. You'd have to use chemicals to keep it under control.

Another difficulty we face in preserving the alluvial flat redwood community type is the very limited distribution of age classes. If we assume an average life span of 500 to 700 years, our children's children's children's children are going to be viewing a pretty sorry spectacle, unless we can begin to set aside today some younger age classes. Most of the alluvial flats that we have set aide are in the older age classes and they will begin to break up sometime if not within the next 100 years, within the next 200 years, and we need a series of plants coming up to replace them. Now on the northern limit of redwoods, to maintain that particular community type, I think we'll have to use some type of elective logging, so as to increase the amount of redwood in the stands. There is a Douglas fir with just a few redwoods scattered throughout. And I think we can with a selective logging system increase and maintain redwood at its northern extremities, If that happens to be our desire.

To maintain the particular community redwood type which I spoke of earlier, which is a mixture of redwood, hemlock and Douglas fir, fire protection appears to be the number one requirement. Occasional spot clearing will also be necessary to insure adequate redwood seedlings in the future. The same type of management will need to be applied to the redwood community type which consists of a mixture of redwood, hemlock, Sitka spruce, Douglas-fir and grand fir.

Fire has been an important factor in the development of all redwood community types that contain pine as a major element. It does not follow, however, that if we now set fire to these types, their preservation will be assured. To maintain the ponderosa pine element in the unique redwood community which lies south of Willits, considerable preliminary clearing will be required. Subsequent chemicals and carefully controlled spot burning can probably be used to maintain ponderosa pine in this type. To maintain the sugar pine element in still another redwood community type should not be particularly difficult. Some control of the Douglas fir and tanoak will be necessary. But this can be accomplished with chain saw, or a stump grinder; I don't know if you've all seen what a stump grinder looks like, but its a bunch of saws together that just grind the stump right out of the ground so you can't see it anymore. So if you have a chain saw, a stump grinder and chemicals, you could maintain this type without too much effort.

It also may be possible to use fire as a tool but if so only to a very limited extent. Now to maintain the knobcone pine element in its redwood community site, periodic broadcast burning can be done following suppression of the regenerative capacity of the brush. A previous application of chemicals will probably be necessary. To maintain the coulter pine, which I referred to earlier, in its redwood community type will require brush clearing, the use of chemicals, and the use of spot, and perhaps, broadcast burning.

In every case that I know of, preservation of specific community types will require considerable effort, which will not necessarily be cheap. In addition, trained professionals will be needed to plan and supervise the work - trained professionals that we have not trained. One problem that we are also already running into in dealing with preservation is the pseudo-specialist who is able to operate only because it takes so long in this type of work to determine whether a certain treatment has achieved the desired result. You usually do not find that the specialist was wrong until long after he has been buried and put away. In particular, I am concerned with the fire enthusiast who is ready to solve all our vegetative preservation problems with a torch. Often there is just enough truth in what he says to convince not only a certain segment of the public but the park and the forest administrator as well.

To preserve a source of redwood lumber and cellulose is really a relatively simple task compared with the preservation of specific redwood community types. Here, for example, is how a highly productive site appeared immediately following cutting in 1962. Here is what the site looked like earlier this year. This is what the site should look like about 1970. And this is what the site should look like by the year 2000.

Questions and Answers

QUESTION: May I ask about vines that grow up the redwood. Do they act as a parasite or do they kill the seeds?

ANSWER: Well, I know of no parasitic vines in the redwood area. I know of one though that's a very uncomfortable one, that's poison oak. And quite often in a redwood you'll find poison oak that will be six or eight inches in diameter and will go up for 50 or 100 feet, and it does not, as far as we know, have any impact on the tree at all. For our climbers it has an impact.

QUESTION: You just mentioned fog as a climatic factor which is often brought up in literature. If it does function as a climatic factor, is it due to the fact that it allows the tree to maintain its moisture, in other words, decrease the evaporation?

ANSWER: Well, there is a fine balance here. That is, the redwood is very inefficient in taking up moisture from the soil. It has a root system that doesn't do this very well. So over a long period of time it has become restricted to areas where this doesn't matter very much. So what you get is it occurring in a fog area in part. But it grows outside the fog area too. I mean this is not an absolute line. So it grows outside, beyond it, but if there's too much very strong evaporative stress on the top of the plant, then its not able to pick up enough moisture from the soil to balance this and so then it dies. I think some of these large redwoods have this tank effect or reservoir effect that helps out quite a bit.

QUESTION: Can you go into the tank effect in a little more detail?

ANSWER: Well, its just that there's roughly 8,000 gallons of water in one of those trees. And the tree is able to draw on that water throughout the summer months. It draws it down to roughly 6,000 gallons. So its behind 2,000 gallons of water from absorption from the roots. So if you have this on an alluvial flat and you had a high evaporative stress at the top of the tree, you might be able to get away ahead of the root absorption and you might exceed the storage capacity of the tree and then you would get death of the tree. We think what were getting here in many cases is the spike top, when this occurs.

QUESTION: Do you have other ways to cut down evaporation, too?

ANSWER: Its a very inefficient tree. It doesn't do this well at all.

QUESTION: How low can that reservoir get?

ANSWER: We collected data on this last summer. I don't really know what the percentage would be. Its different in the heartwood and in the sapwood. I don't have the slide here to show you the percentages. But if you'd like to drop down to the office we'll dig it out.

QUESTION: Your map of the Eureka Area showed the redwood cutting inland. Why don't they grow along the coast?

ANSWER: Well, I assume there's a number of things involved here. When you evaluate why redwood is growing where it does, you really have to go back to the operational environment, at the time redwood was established there, which might have been a thousand years ago. So there may have been some factor at that time operable that did not allow it to establish close to the coast. Or you may be seeing here just competition. Quite often close to the coast you find the bishop pine, and you don't find the redwood at all. But as you go a little inland you'll find both redwood and bishop pine. So again this competition that depends on the environmental gradient not necessarily a moisture gradient but one that we haven't measured yet. So any time you come to an area where there's redwood and there's not redwood, it may be a very complicated thing that happened a thousand or two thousand years ago. Redwood is holding on, perhaps, only because its able to sprout. Every once in a while, maybe every 200 or 300 years, there is an adequate seed bed, or another combination of other circumstances such that the seed can germinate, and start growing well, and you get redwood coming along. But it has to have this combination of circumstances and it has a good chance of reaching these because it has this long life due to the sprouts. I see no reason why some of those sprouts couldn't be 1,000, 2,000, 3,000 years old, that is, the germ plasm anyway.

QUESTION: How do you measure the amount of water?

ANSWER: By either climbing up the tree or dropping the tree and then taking samples; that is, taking actual wood samples. We take a core and then divide this up and dry the moisture off in an oven and find out the weight of loss.

QUESTION: After logging, about how long would it take to repair a terminal forest?

ANSWER: Well, you'll have to tell me what you think a terminal forest is?

QUESTION: I've heard this term.

ANSWER: Well, I think probably the term is used loosely. But probably what people have in mind when they speak of a terminal forest in an alluvial flat. On an alluvial flat the trees there are anywhere from 300 to 700 years old. Sometimes these are of more or less even age, that is, all being around 500 or 600 years of age. Sometimes, you will find, there may be three age classes in there. These age classes some times are closely related to flooding or silting in the past. I think we could take a young, say a good, fertile flat, and we could push these trees along very rapidly. And I would say that in a hundred years, we could certainly get a stand where we were dealing with trees six feet in diameter. But this would take management. You wouldn't just expect any old area to do this. You'd have to thin the area so that you could put the growth on a few trees. You might have the same total growth on 200 trees where they'd all average out maybe two feet in diameter but if you concentrated that growth on so trees then you might get them up to so feet in diameter. So, I think, with the tools available to us today, we could take some young growth, very young growth, push it along quite rapidly and we could get rid of the old stumps by grinding. And, I think, we would be able over a period of time then to have available for the public stands that are 100 years old, 200 years old, 300 years, 400, 500, 600. I think we need a little bit more alluvial flat than we have today. In fact, I think we need all the alluvial flat that there is, to accomplish this. But I'm not sure that this is a reasonable sort of thing to accomplish.

QUESTION: I would like to ask just exactly what you need for reproduction by seed. You mentioned something about mineral soil.

ANSWER: Well, you have to get a combination where you do have mineral soil. This allows for germination of the seedling and also for early survival. Apparently otherwise you get a problem with a fungus. This is one point. And then you have to have it light enough for these trees to continue to grow. Now supposing you had the mineral soil but then did not have the seed source that year, but you had a whole lot of Douglas fir. So Douglas fir would seed in while the redwood did not. And, therefore, the Douglas fir would take over. You see, this is a combination of circumstances. Does that answer your question?

QUESTION: Well, partly. But I had noticed something about the fir. Apparently its tied up with the amount of light available.

ANSWER: Well, any time you open up a stand of redwood so that there's lots of light beneath, you have all kinds of plants that want to get in there and all kinds of plants that are already in there ready to grow. If you have an alluvial flat the repeated flooding has pretty well kept the undergrowth out. So if one of those stands are opened up you have, in a sense, almost a pure stand of redwood. You do not have a supply then of Douglas fir seed droppings in the area. You have almost all pure redwood seed droppings without any competition. When one of those big flooded areas are opened up, it comes back into redwoods. But up on the slope or someplace up on a flat that has not been flooded, you have an undergrowth consisting of a variety of trees and brush species. Open that up and it will not go to redwood seedlings.

QUESTION: Under optimum conditions then for redwoods you will not get a new succession, will you?

ANSWER: Now wait, you got me. You blockea me on both ends on that one.

QUESTION: For optimum conditions for redwood ...

ANSWER: For optimum conditions of redwood. For optimum growth of redwood, there would be quite a bit of light, plenty of moisture; then, other things could seed in around it so that the redwood would not be able to seed in. That's quite correct. You see, if you took hemlock, it can seed in on its own logs. So you can take a stand of hemlock and fir, Douglas fir, and redwood and if you let this go long enough then you will gradually move to hemlock. Because hemlock is a very tolerant tree and it will go into hemlock. If this is what you wanted, that's what you" could do. But you probably want all the time to keep the redwood in as long as its sprouting and its able to maintain itself. But, you see, after these trees reach the age of 500 or 600 years or 700 years, then they can no longer sprout, so gradually through this process you can reduce the number of redwood in the land and finally eliminate them.

QUESTION: Is it good to cultivate a redwood tree? Is that good for them?

ANSWER: Do you mean is it good to cultivate around it?

QUESTION: You talked about Palo Alto ...

ANSWER: Well, the thing is that tree lost a good part of its root system with the Southern Pacific Railroad for one thing, and than it lost another good part of its foot system when they fixed the creek. They came away back up against the tree. So it only has a little bit of its root system left. Now what we feat about this was that from our studies, wed found that we could regenerate a new root system, very quickly, a good feeder root system, by cutting it off. and so we think, if you had a compacted soil for example, roto-tilling might be a very effective way of regenerating that root system. Now, whether you should do this every year, regenerate a new root system, this I don't know.

QUESTION: Towards the end of your discussion here, you were concerned with preserving redwood types, with regard, for example, to the redwood and the sugar pine. I didn't understand exactly what you were trying to do. Are you interested in preserving the whole ecological setup or trying to maintain the redwood as against its competition?

ANSWER: No. There are a number of types that have arisen as a result of this interplay, this ecological interplay. Now we've come upon the scene and I think these are very fascinating types and I think we ought to preserve samples of each one of these types. Now you cant preserve this by just standing back and putting a fence around it, because all - - kinds of changes are taking place. So I would like to preserve that v - particular type. So I would like to have s little sugar pine in it, a little bit of redwood in it, a little bit of fir in i-; but I always want to keep Some sugar pine, and always keep some fir and always keep some redwood.

QUESTION: If you did nothing, what would happen? The redwood would disappear?

ANSWER: No. If we did nothing there, right there, we would probably have redwood for a long period of time and then gradually it would be redwood and Douglas fir. This is what I think. So then we would just end up with a redwood, Douglas fir, which is an interesting type, but there's an awful lot of It.

QUESTION: In the case of the redwood, ponderosa pine would that go to redwood or ?

ANSWER: That would go to redwood - Douglas-fir, I think, unless we do something about it. It'll drop out. The pine is in there as result of fire in the past. But, boy, if you put a match to it today it would take the pine right out, take the Douglas fir right out, scar the redwood a little bit; then it would come back to redwood and fir. I'm speaking as a pseudo-specialist, you understand that?

QUESTION: If you did nothing, in the long run, the ponderosa pine would disappear?

ANSWER: Yes, that's right. It certainly will, because it will not re generate under the Douglas fir. The Douglas fir is moving in there very rapidly. And the redwood isn't regenerating at all, over there. But it'll stay there a long time as sprouts. I realize that some people look at redwoods mostly, as I said earlier, from the alluvial flat. But I would like to look at them in a little broader sense.

QUESTION: Suppose you have a reserve section on one of these alluvial flats, and you create windfalls or falls from maturity. Do you get sprouting from these trees?

ANSWER: Well, for a while, they will actually turn up, I mean buried branches will turn up, and sometimes you think you have a new growth. But on some of these trees, you find that at the base you have sprouts, and on others of them you don't. Now some of these trees, you have to realize, might be buried in 20 feet of silt and when they fall over you don't see the initial root crown at all. And this than be one of the reasons you have a low number of sprouts there. So sometimes yes, many times no.

QUESTION: Then with protection over a number of years, you could possibly eliminate the sprouting potential of, Bay, redwood

ANSWER: Well, if you could keep it alive up to the point where it could no longer sprout, yes. In other words, as they get older and older, they finally get to the point that they don't sprout. So if you keep them, if you can coax them along until they get up to 700 years of age, or 800 years, you see, then they wont sprout. Then when they all fall down you've wiped out your stand. This is the sort of thing you could do. One of the problems of preservation of this type, it goes rather slowly and by our time scale, were just looking at a small piece of it. But I think we have to look at it from the point of view that we want to maintain this for a thousand years. And to do that we have to do a lot more than just stand back and Bet it aside. It just wont work. We also have to set it aside though.

QUESTION How did it ever get to this today, if the redwoods are dying out and falling down from old age?

ANSWER: What you have is a combination of environments that have persisted in the past and you've come up on the scene at one particular time. You came upon the scene really when there were 2,000,000 acres of virgin redwood. And that's a lot of redwood. And now you're down to the point that you probably have about 700,000 acres of old-growth. But of that 700,000 acres you probably have about 300,000 that are virgin. So what we've done is taken and cut down a tremendous amount of the redwood, but in spite of that, we haven't reduced the range probably by more than 100,000 acres. And that's merely in clearing. The thing just keeps right on sprouting.

What we did, we came upon the scene at a particular time. Now this tree will continue to sprout. A certain percentage of these trees will continue to sprout, so redwood is able to maintain itself for among period of time. What you're asking is why didn't it wipe itself out before we came here. And my answer is we don't know what the operational environment was at the time it became established. And we may be just on the tail end of this relic. And we're just seeing the tail end of it. And if man had been here another 2,000 years earlier we might have been able to eliminate it. It just depends where you are in this picture. And, I think, if we want the big old trees, and I think this is the sort of thing lots of us would like to have, if we want these on display, for the public, we have to do something about it. We have to start getting some younger age classes and we have to start working. First of all you've got to set them aside. Then you've got to work on them.

QUESTION: We live in an area where there's second-growth redwood and we were told that the original trees there, the virgin trees, were cut down about 1910. Now the second-growth there is, I'd estimate, about 150 feet tall and about 3 feet in diameter. Does that sound reasonable?

ANSWER: It sounds very reasonable. And had you gone in and thinned it, you probably would have them up to four and a half or five feet, on that site, if it's that productive.

QUESTION: They're growing three and four around the original stumps. The original stumps are about eight to 10 or 12 feet in diameter.

ANSWER: Yes. Well, this is an amazing tree. On some of these alluvial flats, it has tremendous growth.

QUESTION: That's pretty rapid growth?

ANSWER: Yes. That's what this tree is capable of. This is one of the nice things. You see, right now, today, there's a lot of second-growth that's being logged. There's some beautiful land on the Jackson State Forest. There was some virgin left on that. It was a fairly poor quality virgin, but a good part of that was second-growth from the old Casper lumber company. There are some beautiful stands.

QUESTION: They'll never get my twelve acres. When they control the flooding, how are we still going to get the deposition of this ...?

ANSWER: We're not. So then we have to do something else. And our experience with dump trucks is that this is not a practical way to handle it.

QUESTION: If on cut-over land spruce and redwood are seeded in proportion, what are the chances of the redwood coming back?

ANSWER: Well, it entirely depends on the particular conditions on the site, whether its a southern slope, whether it's a west slope, whether there's very much brush on it, and, probably most important of all, what kind of soil it is. Now it's an interesting thing in the Redwood region that where you have a very fertile soil you often have the most difficult time in getting the redwood to come back in, that is from seed, because almost immediately the brush comes up - it likes the nutrient, too.

So its very hard, on some of these very fertile soils, to get redwood regenerated. On the other hand, if you have some of these soils that are low in nutrients, the brush does very poorly, the redwood has time to seed in and it comes in and takes over these poor sites. Now your question in regard to if I seeded in Douglas-fir, Sitka spruce and redwood altogether, what would happen? I don't know. Because there are just too many ifs, ands, and buts about it. In any particular area with study and with a proper retainer, I might be able to help you out.