REVEGETATION OF GOLD PLACER MINING SPOILS, STERLING CREEK, OREGON

by

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Today the creek winds down through the bottom of the small valley on its easy way to the Little Applegate. Cattle graze on the flats above the company workings and west of the old town. A number of houses are to be found along the creek, most of which are only summer residences. There are few year around residents of Sterling Creek. These few have nothing to do with mining.

Willows and other brush are growing up now to cover the scars of a century of placer mining. They only hide the scars, they don't heal them. No land ever recovers from placer mining on a large scale. Even so, when you stand today in the old cemetery above Sterlingville and look out over the small valley, it isn't hard to visualize the scene that greeted Jim Sterling's eyes in 1854.

--Francis D. Haines, Jr.,
Gold on Sterling Creek, A Century of Placer Mining

REVEGETATION OF GOLD PLACER MINING SPOILS,

STERLING CREEK, OREGON

ABSTRACT: Tree and shrub revegetation on mining spoils of an abandoned gold placer mine at Sterling Creek, Jackson County, Oregon were examined. Point-centered quarter and line-intercept methods of vegetation analysis were used to compile species lists and determine species density, frequency, mean basal area and dominance. A relation exists between the age and physical characteristics of the spoils and the above vegetation characteristics. Post herbaceous stages of plant succession were identified at the study site, and general characteristics of the successional trend determined.

INTRODUCTION

Sterling Creek is a tributary of the Little Applegate River within the Rogue River drainage located at section 33, T. 38 S., R. 2 W. in Jackson County, Oregon (Fig. 1). The creek and its channel are now owned by the Double D Lumber Company of Medford, Oregon. The Rogue River National Forest and private land border all sides of the property. The creek is approximately 7 mi. (11 km) long, disappearing below tailing deposits for 2.5 mi. (4 km) of the total length. The elevation at the source of Sterling Creek is 3,000 ft. (915 m), sloping to an elevation of 1,850 ft. (564 m) at the mouth near the old, abandoned mining town of Buncom.

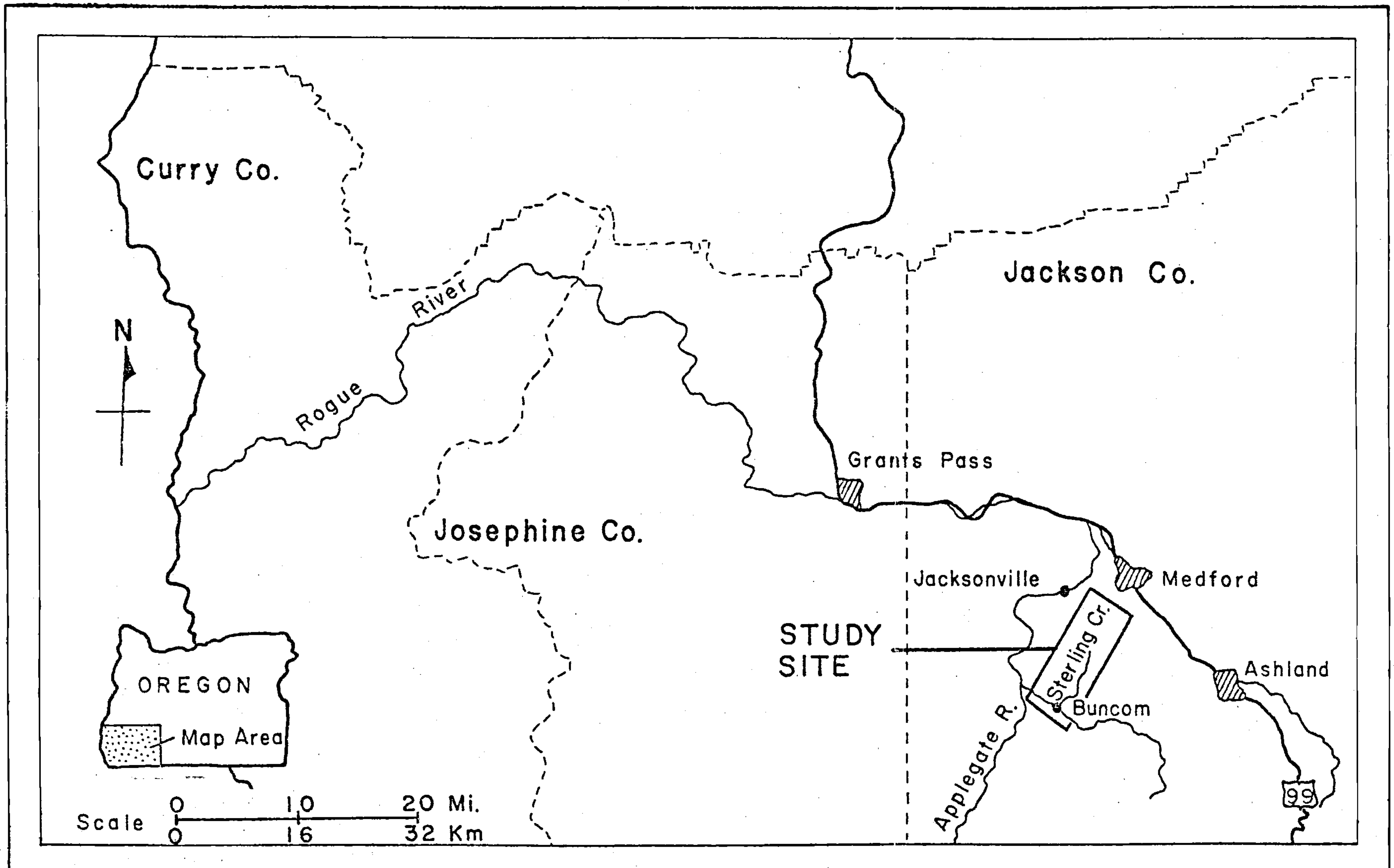

Fig. 1. Study site location, Sterling Creek, Oregon

Gold mining for the rich placer deposits lasted from 1854 until 1959.[1] The creek was diverted, dammed and filled with sediments. The environment surrounding Sterling Creek over this period was heavily disturbed with a loss of plant and animal life. What remained when the mining ceased, was a deep, wide channel filled with rocks, boulders and other debris created by the mining operations. The vegetation had been stripped from the landscape during mining operations to provide building materials for the flumes and sluice boxes, and to prevent clogging and destruction of the equipment. To date, the only vegetation present in and around the creek is that which has returned naturally through successional processes.

The purpose of this study is to assess the extent of the shrub and tree revegetation which has taken place since the cessation of gold mining activities on Sterling Creek. Vegetational characteristics of the area have been examined with respect to the age and nature of the tailings. From these data, successional trends may be discovered which may aid in the future revegetation and reclamation of this, and similarly-created sites.

PLACER MINING ON STERLING CREEK

Sterling Creek was named after James Sterling, a local farmer, who discovered gold in the creek in 1854 near its junction with Hopkins Gulch (Fig. 2).[2] The discovery was disclosed mysteriously, and within several days, claims had been staked the length of the creek below Dutch Gulch. The gold was in the form of rich creek and bench placers, and was easily recovered by the current placer mining methods.[3] As the surface placers diminished, the miners were forced to excavate deeper to recover the precious metal.

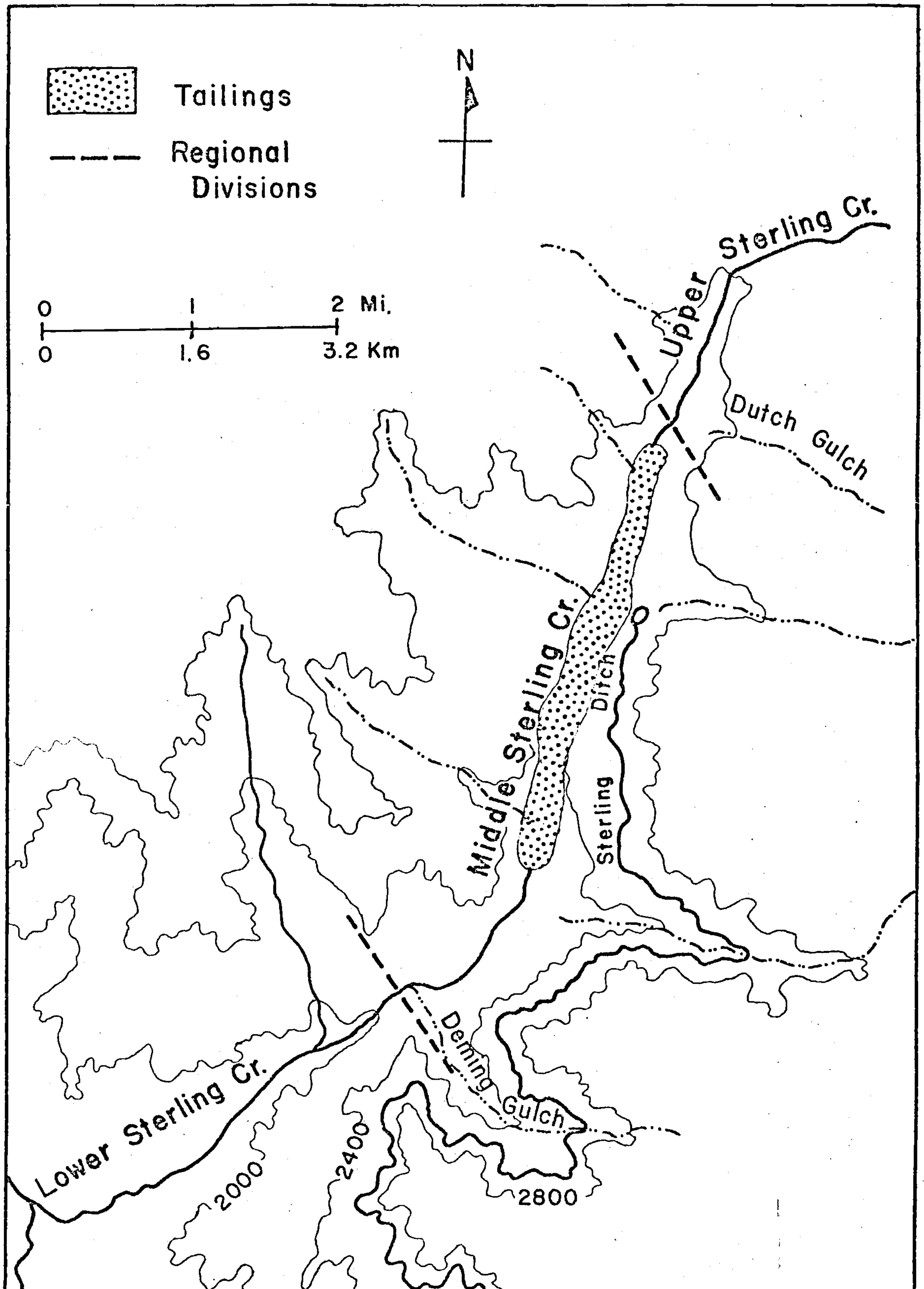

Fig. 2. Study site, upper, middle, and lower Sterling Creek.

Hydraulic mining was introduced in 1876 enabling miners to strip large quantities of overburden to reach the gold-bearing gravels.[4] By 1914, with the aid of the hydraulic, approximately $3,000,000 in gold had been recovered, and the Sterling Creek mine was acknowledged the largest placer mine in Oregon.[5] Hydraulic mining continued on Sterling Creek until 1959, and with the exception of the majority of land located above Dutch Gulch, no place along Sterling Creek had been left untouched by the placer miners.[6]

THREE REGIONS OF STERLING CREEK

For the purpose of this study, Sterling Creek can be divided into three regions. The divisions between these regions are based upon historical data of the type of mining activity employed within each region, and the dates of this activity.[7]

Lower Sterling Creek

Lower Sterling Creek is that portion of the creek south of Deming Gulch (Fig. 2). At the time of the discovery of gold, there was an Indian village located at the mouth of Sterling Creek. Fewer claims were staked along this portion of the creek since the miners were afraid the Indians might attack. It was not until the completion of the Gallagher Ditch in 1860 that mining began to flourish on a year-round basis on lower Sterling Creek.[8] In 1861 and again in 1864, floods swept through the channel, burying mining equipment and gold under thick layers of mud and rock washed downstream from the mines operating upstream.[9] Despite these disasters, mining activities resumed as soon as the flood waters had diminished. Placer mining continued on a relatively small scale until 1876. Attempts were made to mine hydraulically, but this proved uneconomical. The individual claims on lower Sterling Creek were abandoned.[10]

Middle Sterling Creek

The middle portion of Sterling Creek, located between Deming Gulch and Dutch Gulch, experienced the most extensive mining of the three regions (Fig. 2). The town of Sterlingville was established in 1854 on the west side of the creek while the miners worked claims on the east side. Between 1854 and 1856 the majority of claims were worked by individual miners using gold pans, picks, shovels, and sluice boxes.[11] As the surface placers began to disappear in 1856, the miners began to dig shafts down to bedrock. This method of mining lasted until 1876, when the hydraulic was introduced and the individual claims were consolidated into one claim owned by the Sterling Mining Company.[12]

Widespread use of the hydraulic on Sterling Creek was limited by water availability. It was not until July, 1877 that the water shortage problem was alleviated by construction of the Sterling Ditch. The ditch was designed to be 23 mi. (37 km) long,[13] and constructed to carry 75 cubic feet per second (cfs) (2.1 m^3/s)[14] of water from the Little Applegate River to a holding reservoir at Sterling Creek. The construction of flumes along portions of the ditch created a demand for lumber. As a result, a lumber mill was built in Sterlingville in August, 1877 which processed local lumber at a rate of 13,000 board feet per day.[15] The ditch was completed by mid-November, 1877, and two hydraulics with 8-inch (20 cm) nozzles were installed. In 1880 a third hydraulic was installed, and the size of the mining operations and resulting yields of placer gold were significantly increased. The winter of 1889-1890 was severe, and flooding resulted on Sterling Creek covering the hydraulics, the sluice boxes, and the unrecovered gold.[16] The following year two new hydraulics with 6-inch (15 cm) nozzles were installed and began operating.

As the miners continually worked upstream, the original ditch had to be extended until a final length of 26.5 mi. (42.6 km) was reached. At this point, sufficient head could no longer be created to power the hydraulics, and mining operations were curtailed.[17] In 1913 a high-pressure pump was obtained and installed at the creek. Hydraulic mining began anew and lasted until 1919, when large-scale operations ceased and the land was leased to single operators. Mining continued on a small scale until the Great Depression of the 1930's. At this time miners flocked to the creek and began placer mining for any gold which still remained.

Hydraulic mining operations resumed on a large scale in 1935, continuing to move upstream along the ancient channel as far as technically and economically possible. Above this point, earth-moving equipment was utilized to strip-off the overburden and carry it downstream to a location where it could be dumped and washed through the sluices. Mining continued in this manner until 1937, when the mine was finally shut down. Between 1937 and 1959, one man leased the land from Sterling Mines, Inc., and continued hydraulic mining in areas not previously exploited by the larger operations. By 1959 mining had ceased on the 2,000 acres (809 ha) of Sterling Creek and the surrounding area.[18]

Upper Sterling Creek

Upper Sterling Creek is located between Dutch Gulch and the source of Sterling Creek (Fig. 2). Placer mining did not occur on the majority of this land. A dike crossed the creek near Dutch Gulch and few rich placer deposits were located above this. Farming and ranching were practiced on this portion of the creek throughout the gold mining days with only a few exceptions. Several shafts were constructed near Dutch Gulch between 1854 and 1935. When the earth-moving equipment was used between 1935 and 1937, an attempt was made to recover some of the gold in the overburden. The method of recovery was uneconomical, however, and mining operations did not proceed further north of the Dutch Gulch vicinity.

HYDRAULIC MINING METHOD

Placer mining was practiced at Sterling Creek over a span of approximately 100 years. The adverse effects upon the physical environment and vegetation destruction were not great until widespread use of the hydraulic began in 1877.

The first step in the establishment of the hydraulic mine on Sterling Creek was the removal of the vegetation in and around the areas chosen for hydraulic excavation. The timber was used for the construction of the flumes, sluice boxes, and reservoirs. The remaining vegetation and stumps were removed by burning.[19] Removal of vegetation not only supplied lumber, but also prevented accidents and the clogging of the sluice boxes.

The hydraulics were operated working upstream to excavate each side of the channel. A continuous jet of water under high pressure was forced through one or several nozzles of various diameters and aimed at the base of the bank. The water would undercut the bank, causing the entire bank to cave into the pit created at the base. Blasting powder and dynamite were used on occassion at Sterling Creek to break up the conglomerate which the hydraulic could not dislodge.[20] The gravel in the pit was further broken-up by the hydraulic spray, and washed into a sluice box where the gold would be caught by riffles in the sluice box. The remaining tailings issuing from the sluice box were deposited in immense heaps directly in the channel.[21]

PHYSICAL ENVIRONMENT CREATED BY HYDRAULIC MINING

The physical environment resulting from hydraulic mining on Sterling Creek is considerably different from that previously characteristic of the site. Revegetation has been primarily effected by the nature and size of the spoil piles, the bank structure and stability, the soil and nutrients available, and the water supply.

Spoil Piles

Hydraulic mining occured over a length of 4 mi. (6 km) of a 7 mi. (11 km) reach of Sterling Creek. The average thickness of the gravel mined was a ribbon 40 ft. (12 m) wide and 200-400 ft. (61-122 m) long, following the ancient channel.[22] The debris and tailings produced from the extensive mining operations were haphazardly deposited in heaps downstream in the previously-worked channel.

The largest concentration of spoil piles occurs in the middle portion of the creek. The piles are approximately 120 ft. (37 m) wide with a maximum height of approximately 30 ft. (9 m). These spoil piles are composed of unconsolidated, coarse materials ranging in size from angular gravels to boulders of andesite and quartz.[23] At one location within this portion of the creek, a rock crushing operation is now operating during the winter months. As a result of this operation, there are several uniform piles of rocks which have been produced from the crusher, along with a large pile of material which has been bulldozed and is waiting to be crushed.

There are few large, exposed spoil piles in the upper and lower portions of the creek. The upper portion has a few mounds of debris created from test borings taken in the 1940's and 1950's. These piles consist mainly of dirt and gravel. In the lower portion of the creek, the individual piles have been leveled by flooding and erosion. The appearance of the heaps in the lower portion resembles a broad, undulating deposit of andesite and quartz gravels and boulders filling the channel between the banks.

Channel Banks

Channel banks undercut during mining operations, are relatively unstable in many locations along the creek, especially in the areas which have been most recently mined. There are nearly vertical scarps in many places, and undercut banks in other places. The banks in the middle portion of the creek reach heights of approximately 40 ft. (12 m) but decrease in height upstream and downstream. The unconsolidated materials comprising the banks consist of gravels and boulders and are visually evident on the unvegetated portions of the banks. The upper portion of the creek does not have any banks created by mining and is smoothed into a flat meadow used for grazing. The banks in the lower portion of the creek have been partially stabilized, followed by revegetation.

Soil and Nutrients

Soil in significant quantities is not present in the tailing piles of the middle portion of the creek. During mining operations, the finer soil particles were washed downstream after issuing from the sluice boxes, and accumulated in the tailings of the lower portion of the creek, or were carried into the Little Applegate River. As a result, a nutrient deficiency was created for plant growth by the lack of soil and organic material, and this deficiency provided a major limitation to revegetation on the spoil piles. The spoils probably had a low, or complete lack of, organic matter content and nitrogen.[24] No nutrient studies have been conducted in this area, however. The soils present on the banks and in the surrounding areas are haploxerults which are continuously dry for much of the year.[25] These soils have a reddish-brown-to-red color and have acidic characteristics.[26] These soils are not conducive to rapid revegetation.

Leaves, pine needles, twigs and other organic debris blown or washed onto the spoil piles are evident in numerous locations throughout the middle and lower portions of the creek. The concentrations of organic matter are greatest in the lower portions of the creek. Soil is abundant in the upper portion of the creek, untouched by the hydraulic.

Water Supply

Coupled with the problems of uneven terrain and nonexistent or infertile soils is a lack of water. The Sterling Creek area receives an average of 23 in. (586 mm) of annual precipitation.[27] Less than

20 percent of this precipitation, however, falls during the growing season.[28] The amount and availability of surface and subsurface water in the creek is also limited as a result of the low yearly precipitation and runoff. The creek flows beneath the spoil piles throughout the middle portion of Sterling Creek, returning to the surface in the lower portion of the creek. Despite the fact that less evaporation takes place, surface vegetation is discouraged from rooting except in areas where surface pockets of water have accumulated temporarily on the spoils.

There are several abandoned holding reservoirs located along the length of the creek. Surface flow from these ponds into the creek does not exist, however, subsurface flow does exist. From the time the Sterling Ditch was in operation until the severe winter of 1964, which destroyed a large portion of the ditch, additional water flowed into Sterling Creek via this route. Since the ditch was never repaired, this inflow of water no longer exists.

METHODOLOGY

The purpose of this study is twofold: first, to assess the shrub and tree revegetation which has taken place since the cessation of gold mining; second, to examine the vegetational characteristics of the area with respect to the age of the tailings, and discover the successional patterns occurring on the disturbed areas.

Selection of the Study Site

After examination of several abandoned placer mines located in southwestern Oregon, Sterling Creek was chosen as the study site for this research. The following attributes were responsible for this selection:

1) Sterling Creek was easily accessible both by road and on foot;

2) with the exception of the rock crushing operation, the creek had been left undisturbed since mining operations came to a hault;

3) the natural revegetation had begun without artificial inputs;

4) a complete history of Sterling Creek was available which included information on dates and methods of placer mining utilized on the creek;

5) the transition between the mined portions of the creek and the unmined portions was easily identifiable; and,

6) favorable weather existed throughout late spring, summer, and early fall for the completion of vegetation sampling.

Vegetation Sampling

From a review of the historical literature and a visual examination of the creek, three major regions were identified and designated for purposes of this study: lower Sterling Creek (Region A), middle Sterling Creek (Region B), and upper Sterling Creek (Region C). Lower Sterling Creek experienced surface and shaft mining between 1860 and 1876, and flooding in 1861 and 1864. Middle Sterling Creek received the most extensive mining in the form of hydraulic mining between 1854 and 1959. The lower portion of upper Sterling Creek was mined by shafts between 1854 and 1935, and by earth-moving equipment between 1935 and 1937. The remaining portion of upper Sterling Creek was used for farming and grazing.

Vegetation sampling was undertaken in the three regions and a control area during the late spring, summer, and early fall of 1976. The control area was located on the east side of the creek, and was approximately halfway between the source and mouth of Sterling Creek. The control area, itself being undisturbed, and representing a portion of the Mixed-Evergreen Zone, bordered the disturbed areas of the creek. Within Region C there was an excess of surface and standing water in the form of a holding pond and exposed creek. This portion of Region C contained distinct species not identified in the other portions of Region C; therefore, a fourth region, Region D, was added to the study area which sampled creekside and holding pond revegetation.

Since sampling was conducted during the dry portion of the year, the herb layer vegetation was not included in this study. Individual sampling sites were located as close to the center of each region as possible. However, in the upper Sterling Creek region, sampling was conducted in the lower portion where mining had been practiced.

To assess the tree revegetation on the spoils and control area, the point-centered quarter method was used. This method did not require a correction factor, was simple to use, and required less time and equipment in the field than would have other distance methods.[29] A complete description of the method, and an explanation of its applicability and data analysis have been presented in detail by Dieter Mueller-Dombois and Heinz Ellenberg following Curtis and McIntosh et al.[30]

A modified line-intercept method was utilized to sample shrub revegetation on spoils and in the control area.[31] Except for absolute density, standard vegetational measurements such as frequency and percent cover could be obtained by this technique.[32]

Twenty-three transects were established perpendicular to the creek at the study site; 8 transects in Region A, 6 in Region B, 4 in Region C, and 5 in the control area. Wherever possible, transects extended from bank to bank, and were placed 10 meters apart. In the control area, transects were located in the most homogeneous and least disturbed stand of vegetation. Transect lengths and number were determined by the width of the creek (the narrower the channel, the more transects established), the homogeneity of the vegetation sampled, and the total number of sampling points required within the region. Transects established within each region were used for both point-centered quarter and line-intercept sampling.

Sampling by the point-centered quarter method was at 10-meter intervals along each transect. At each sampling point, four quarters were established. A distance measurement was taken to the closest tree in each quarter, the tree species noted, and the diameter at breast height (dbh) of the tree recorded. This same procedure was undertaken at each of the 178 sampling points along all the transects. There were 46 sampling points in Region A, 42 in Region B, 36 in Region C, 4 in Region D, and 50 in the control area.

Sampling for the line-intercept method occured along the entire length of each transect. Each contiguous 2-meter segment along every transect was considered as one unit. Species present and estimated linear percent cover of each species within each 2-meter segment was recorded. Trees less than 2 m high were considered shrubs for purposes of this study, and were included in the 801 sampling segments. There were 184 2-meter segments in Region A, 222 in Region B, 170 in Region C, 0 in Region D, and 225 in the control area.

RESULTS AND DISCUSSION--POINT-CENTERED QUARTER METHOD

A species list of trees greater than 2 m in height which were included in vegetation sampling has been compiled (Table 1). Species density (Table 2), percent frequency (Table 3), species basal area

(Table 4), and species dominance (Table 5) have all been calculated from the raw data gathered in the field.

Tree Species

Tree species identified growing in the four regions and control are given in Table 1. Castanopsis chrysophylla, which is often considered a shrub, has been included with the tree species in this study because of the large sizes of individual plants (over 2 m).

The tree species identified at Sterling Creek are similar to the tree species associated with the Mixed-Evergreen Zone of the Siskiyou Mountains described by J. F. Franklin and C. T. Dyrness, although there are variations resulting from the disturbance created by the mining activities.[33] The dominant tree species associated with this zone include: Pseudotsuga menziesii, Pinus ponderosa, Arbutus menziesii, and Quercus garryana. Additional species found at Sterling Creek which are not included with the dominant Mixed-Evergreen Zone species described by Franklin and Dyrness are Acer macrophyllum, Alnus rhombifolia, Quercus kelloggii, Salix spp., Populus trichocarpa, and Calocedrus decurrens. Acer macrophyllum, Alnus rhombifolia, Salix spp., and Calocedrus decurrens are associated with cool or shady sites.[34] The majority of individuals of these species were found growing near the west bank of the creek, or near the holding ponds. Quercus kelloggii, another tree species omitted by Franklin and Dyrness, is associated with valleys with gravel floors.[35] This species was only encountered in Region A.

TABLE 1.--TREE SPECIES AT STERLING CREEK

Scientific Name[a]		Common Name
Acer macrophyllum		Bigleaf maple
Alnus rhombifolia		White alder
Arbutus menziesii		Pacific madrone
Calocedrus decurrens		Incense cedar
Pinus ponderosa		Ponderosa pine
Populus trichocarpa		Black poplar
Pseudotsuga menziesii		Douglas-fir
Quercus garryana		Oregon white oak
Quercus kelloggii		California black oak
Salix lasiandra Salix lasiolepis	Salix spp.	Willow

[a] Nomenclature based on Philip A. Munz and David D. Keck, A California Flora. Berkeley: University of California Press, 1963.

Species Density

The density or number of individuals of a species per hectare for each region under investigation has been tabulated and appears in Table 2. Total density of all tree species combined within each region increases with age of disturbance. The control region is the most densely vegetated area (1,550 trees per hectare), followed by Regions D (589), A (235), B (187) and C (133). The control area is approximately 12 times more densely vegetated than Region C. The density for Region D, a very moist area surrounding a holding pond, should not be directly compared with the density of the other regions since available moisture is one of the limiting factors to growth and reproduction in all the regions of the study except Region D.

In the control area *Pseudotsuga menziesii* and *Quercus garryana* have the highest density values. *Pinus ponderosa* and *Arbutus menziesii* have the next highest density values. These four species are the dominant tree species of the Mixed-Evergreen Zone. *Calocedrus decurrens* is the only other species present within the control area. This species is not found in any of the other regions sampled.

Region A, the region which most closely resembles the control area in growing conditions and vegetation, has four species with high densities. *Alnus rhombifolia* has the highest density of all species occurring in this region. Sterling Creek flows through this region providing moisture with which this species is associated. Also, since this species is a nitrogen-fixing species, nitrogen is locally available for growth in this area. *Pseudotsuga menziesii*, *Pinus ponderosa* and *Quercus garryana* have the next highest densities. Except for the high density of Alnus rhombifolia, the order of density values appearing in Region A is

TABLE 2.--TREE SPECIES DENSITY PER HECTARE BY REGION

	Region A	Region B	Region C	Region D	Control
No. of sampling points	46	42	36	4	50
Mean distance per tree (m)	6.53	7.32	8.66	4.12	2.54
Total density for all trees	234.6	186.6	133.3	589.3	1,550.4
Acer macrophyllum	0.0	0.0	4.6	0.0	0.0
Alnus rhombifolia	80.3	14.6	12.0	0.0	0.0
Arbutus menziesii	6.4	9.7	6.5	0.0	155.0
Calocedrus decurrens	0.0	0.0	0.0	0.0	90.4
Castanopsis chrysophylla	0.0	53.5	52.8	184.2	0.0
Pinus ponderosa	57.4	28.3	39.8	36.8	297.2
Populus trichocarpa	0.0	0.0	0.0	0.0	0.0
Pseudotsuga menziesii	59.9	79.7	5.6	0.0	1,033.6
Quercus garryana	29.3	1.0	4.6	0.0	1,007.8
Quercus kelloggii	1.3	0.0	0.0	0.0	0.0
Salix spp.	0.0	0.0	7.4	368.3	0.0

similar to the order in the control area, but the values are not as great.

Region B species appear to have densities similar to those in Regions A and C. Pseudotsuga menziesii has the highest density as was the case in Region A, followed by Castanopsis chrysophylla and Pinus ponderosa as in Region C. In Region A there are few unvegetated areas, whereas in Region B there are large spaces devoid of vegetation, resembling Region C. Castanopsis chrysophylla and Pinus ponderosa grow in these open spaces. Pseudotsuga menziesii and Alnus rhombifolia grow in the cooler, moister locations. For this reason, the density values for species in Region B appear transitional between the values in Region A and C.

In Region C, the most recently disturbed area, Castanopsis chrysophylla and Pinus ponderosa have the highest densities. Since Region C has been disturbed most recently, there are extensive, exposed and dry areas which permit growth and spread of Pinus ponderosa and Castanopsis chrysophylla. In comparison with the control area, density values for these species within Region C are quite low. The short period of time for revegetation and poor growing conditions in Region C are assumed to cause low densities.

Tree species densities at Sterling Creek reflect growing conditions found within each region and are related to time lapsed since site disturbance. Moisture stress and shade tolerance are two factors which may affect the change in density values for species in the three regions. Species on Sterling Creek with a high tolerance to moisture stress include: Quercus garryana, Pinus ponderosa and Arbutus menziesii.[36] These species have the highest density values in Regions C and B, the regions most recently disturbed. Pseudotsuga menziesii, which has a lower tolerance to moisture stress, has the highest density values in the control area and Region A. The most shade tolerant species is Pseudotsuga menziesii, followed by Pinus ponderosa, Arbutus menziesii and Quercus garryana.[37] Pinus ponderosa decreases in density within the regions as Pseudotsuga menziesii increases in density. The change in species from Pinus ponderosa, which is dominant on the most recently disturbed sites, to Pseudotsuga menziesii is evident on Sterling Creek. Species which are adapted to dry, hot habitats have high density values in the most recently disturbed sites. As these species create more shading, conditions begin to favor shade-tolerant species and species with low moisture stress thresholds. Shade-intolerant species and species with high moisture stress thresholds are out-competed, gradually decreasing in density.

Percent Frequency

Frequency refers to the number of times a species occurs in a given set of sampling points. Frequencies for each species expressed as percent are given in Table 3.

Within the control area Pseudotsuga menziesii has the largest frequency, followed by Quercus garryana. Pinus ponderosa is midway between the most and least frequently occuring species. Arbutus menziesii and Calocedrus decurrens have the lowest frequencies. Species not found in the control area include: Acer macrophyllum, Alnus rhombifolia, Castanopsis chrysophylla, Quercus kelloggii and Salix spp.

Region A has the same frequency pattern as the control area with one exception. Instead of Quercus garryana having the second highest fre-

TABLE 3.--TREE SPECIES PERCENT FREQUENCY BY REGION

	Region A	Region B	Region C	Region D	Control
No. of sampling points	46	42	36	4	50
Acer macrophyllum	0.0	0.0	13.9	0.0	0.0
Alnus rhombifolia	63.0	20.8	22.2	0.0	0.0
Arbutus menziesii	10.9	18.8	16.7	0.0	18.0
Calocedrus decurrens	0.0	0.0	0.0	0.0	12.0
Castanopsis chrysophylla	0.0	41.7	75.0	50.0	0.0
Pinus ponderosa	60.9	41.7	58.3	25.0	36.0
Populus trichocarpa	0.0	0.0	0.0	0.0	0.0
Pseudotsuga menziesii	67.4	79.2	16.7	0.0	88.0
Quercus garryana	30.4	2.1	13.9	0.0	76.0
Quercus kelloggii	2.2	0.0	0.0	0.0	0.0
Salix spp.	0.0	0.0	22.2	75.0	0.0

quency, Alnus rhombifolia has. This reversal is caused by the presence of a short section of exposed creek where Alnus rhombifolia is associated with the increased moisture. The frequency of Pseudotsuga menziesii is less in Region A than in the control, however, the frequency of Pinus ponderosa in Region A is greater than in the control. Pinus ponderosa is a pioneer species in this area requiring more light and better drained soils. As the Pseudotsuga menziesii increases in abundance, Pinus ponderosa decreases.

The most frequently occuring species in Region B include: Pseudotsuga menziesii, Pinus ponderosa, and Castanopsis chrysophylla. Since Region B has more open space, exposed tailing piles, and less moisture relative to the control area and Region A, Castanopsis chrysophylla occurs with a higher frequency.

Castanopsis chrysophylla has the highest frequency of all species in Region C. Other species with prominent frequencies include: Pinus ponderosa, Alnus rhombifolia and Salix spp.

Only three species are encountered in Region D. Since this area is extremely moist, the most frequently occuring is Salix spp. Pinus ponderosa and Castanopsis chrysophylla occur in this region; however, these species occur away from the holding pond, in the drier area adjacent Region C.

In summary, Pseudotsuga menziesii has a higher frequency in the undisturbed area, decreasing in frequency as the length of time since the disturbance decreases. Pinus ponderosa and Castanopsis chrysophylla occur most frequently in the drier, more open locations, decreasing in frequency as the length of time since the disturbance increases. Alnus rhombifolia and Salix spp. occur most frequently in the moist, protected locations. Calocedrus decurrens only occurs in the control area. Frequencies of Arbutus menziesii and Quercus garryana do not show significant patterns in the study site; however, they occur in all regions except Region D.

Tree Basal Area and Dominance

Mean basal area (stem cover) per hectare for individual tree species in the four regions and control area appear in Table 4. Basal areas for each tree were calculated from diameter at breast height (dbh) measurements. Total basal area and mean basal area for each species was determined.

A dominance rank was assigned to each species within each region and control. Dominance was determined by multiplying the mean basal area of the species by species density within each region. Species within each region were ranked according to dominance value, the largest was assigned the rank of 1. Dominance ranks of individual tree species within each region sampled appear in Table 5.

Arbutus menziesii has the largest basal area in the control area. Pinus ponderosa, Pseudotsuga menziesii, Calocedrus decurrens and Quercus garryana follow in decreasing order; however, when the dominance is calculated, the order may change. For instance, the dominance ranking for species within the control area is: Pseudotsuga menziesii, Quercus garryana, Pinus ponderosa, Arbutus menziesii and Calocedrus decurrens. The dominant species in the control area are the same dominant species found in the Mixed-Evergreen Zone.[38]

In Region A, Pseudotsuga menziesii, Quercus garryana, Alnus rhombifolia and Pinus ponderosa have the largest mean basal areas. Dominance

TABLE 4.--BASAL AREA PER TREE SPECIES BY REGION (cm^2/ha)

	Region A		Region B		Region C		Region D		Control	
No. of sampling points	46		42		36		4		50	
Basal area (cm^2/ha)	Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
Acer macrophyllum	0	0	0	0	83	17	0	0	0	0
Alnus rhombifolia	14,025	223	2,933	196	365	28	0	0	0	0
Arbutus menziesii	363	73	3,876	388	274	39	0	0	5,814	485
Calocedrus decurrens	0	0	0	0	0	0	0	0	1,571	225
Castanopsis chrysophylla	0	0	1,276	23	507	9	63	13	0	0
Pinus ponderosa	8,201	182	2,033	70	6,759	157	340	340	7,875	342
Populus trichocarpa	0	0	0	0	0	0	0	0	0	0
Pseudotsuga menziesii	17,512	373	8,820	108	2,882	480	0	0	24,838	311
Quercus garryana	8,416	366	419	419	347	69	0	0	9,981	128
Quercus kelloggii	3	3	0	0	0	0	0	0	0	0
Salix spp.	0	0	0	0	63	8	204	20	0	0

TABLE 5.--TREE SPECIES DOMINANCE BY REGION

	Dominance (cm^2/ha)	Dominance rank
Region A		
Alnus rhombifolia	17,907	2
Arbutus menziesii	436	5
Pinus ponderosa	10,391	4
Pseudotsuga menziesii	22,356	1
Quercus garryana	10,611	3
Quercus kelloggii	3	6
Region B		
Alnus rhombifolia	2,934	3
Arbutus menziesii	3,876	2
Castanopsis chrysophylla	1,253	5
Pinus ponderosa	1,963	4
Pseudotsuga menziesii	8,608	1
Quercus garryana	419	6
Region C		
Acer macrophyllum	83	7
Alnus rhombifolia	337	5
Arbutus menziesii	274	6
Castanopsis chrysophylla	472	3
Pinus ponderosa	6,288	1
Pseudotsuga menziesii	2,882	2
Quercus garryana	347	4
Salix spp.	55	8
Region D		
Castanopsis chrysophylla	2,395	3
Pinus ponderosa	12,512	1
Salix spp.	7,366	2
Control		
Arbutus menziesii	75,175	4
Calocedrus decurrens	20,340	5
Pinus ponderosa	101,642	3
Pseudotsuga menziesii	321,450	1
Quercus garryana	128,998	2

ranking in Region A is: Pseudotsuga menziesii, Alnus rhombifolia, Quercus garryana, Pinus ponderosa, and Arbutus menziesii. Dominance ranking in Region A is similar to the dominance ranking in the control area except for the addition of Alnus rhombifolia between Pseudotsuga menziesii and Quercus garryana. The localized moisture in Region A has permitted the Alnus rhombifolia to increase in size accounting for a dominance rank of 2.

Quercus garryana, Arbutus menziesii, Alnus rhombifolia, and Pseudotsuga menziesii have the largest mean basal areas in Region B; however, the dominance rank is: Pseudotsuga menziesii, Arbutus menziesii, Alnus rhombifolia, Pinus ponderosa and Castanopsis chrysophylla. Castanopsis chrysophylla, absent from Region A and the control, has become a significant species.

Species with the largest mean basal areas in Region C are: Pseudotsuga menziesii, Pinus ponderosa, and Quercus garryana. The dominant species of Region C include: Pinus ponderosa, Pseudotsuga menziesii, Castanopsis chrysophylla, Alnus rhombifolia and Quercus garryana. The increasing dominance of Pinus ponderosa and Castanopsis chrysophylla is related to the drier and more open environment of Region C.

Pinus ponderosa, Salix spp. and Castanopsis chrysophylla have the largest mean basal areas in Region D; and the dominance ranking is Pinus ponderosa, Salix spp., and Castanopsis chrysophylla.

It is apparent from Table 5 that Pseudotsuga menziesii is the dominant species in the control area, Region A and Region B. Growing conditions grade from quite poor in Region C to good in the control area. As the conditions improve toward a stable state, Pseudotsuga menziesii becomes dominant. Conditions in Region C are more limiting to growth since there is a lack of nutrients, soil, moisture and shading. The conditions favor pioneer species such as Castanopsis chrysophylla and Pinus ponderosa.

As growing conditions change from more xeric and open to more mesic, dominance changes from Pinus ponderosa and Castanopsis chrysophylla to Pseudotsuga menziesii, Quercus garryana, and Arbutus menziesii. Changes in mean basal area also reflect successional changes throughout the study site. Although, for the most part, the mean basal areas for the species are resulting from changes in growing conditions. For instance, the mean basal areas for Pinus ponderosa, Arbutus menziesii and Alnus rhombifolia all increased as the growing conditions improved from Region C, B and A to the control area. The individual trees were able to increase in size as the growing conditions improved. However, the opposite case occured with Pseudotsuga menziesii and Quercus garryana. As growing conditions improved from Region C to the control area, mean basal areas for these species decreased. One reason for this might be the effects of crowding and competition on the individuals of the species. As available space per individual decreases, competition for root space, soil moisture, and nutrient supplies increases. This decrease in space and increase in competition inhibits many individuals from reaching maximum size and vigor. However, a few individuals with deep rooting systems would not be affected by one of these conditions. Although the improved growing conditions favor the germination of more seeds and seedling growth, the ultimate ability of the individual plants to attain large basal areas is limited.

RESULTS AND DISCUSSION--LINE-INTERCEPT METHOD

Shrub species encountered at Sterling Creek have been compiled in Table 6. Other information attained from field investigation utilizing the line-intercept method include species frequency (Table 7) and relative dominance (Table 8).

Shrub Species

The majority of shrub species encountered at the study site are those which are associated with the Mixed-Evergreen Zone described by J. F. Franklin and C. T. Dyrness.[39] These species grow at mid-elevations on rocky or gravelly substrate, and under high levels of light. Many of the species are pioneer species such as Rubus spp., Symphoricarpus albus, Rosa gymnocarpa and Chrysothamnus nauseosus. The number of different shrub species encountered is considerably greater than the number of tree species encountered in the same area. In all, twenty species of shrub were identified growing at Sterling Creek.

Percent Frequency

Shrub species are more numerous in regions which have undergone disturbance than in the undisturbed area. Shrub species appear earlier in the successional sequence than trees, creating an environment favorable to tree seed germination and seedling growth. As the tree vegetation increases in stature and density, the shrubs are out-competed, and gradually begin to decrease in frequency. This is apparent in the sample regions of Sterling Creek. The control area has the fewest number of shrub species present, and the greatest percent of bare ground exposed (Table 7). Regions A and B, midway through the successional

TABLE 6.--SHRUB SPECIES AT STERLING CREEK

Scientific Name[a]	Common Name
Alnus rhombifolia	White alder
Arbutus menziesii	Pacific madrone
Arctostaphylos cinerea	Manzanita
Berberis nervosa	Oregon grape
Castanopsis chrysophylla	Golden chinkapin
Ceanothus cuneatus	Narrowleaf buckbrush
Ceanothus integerrimus	Deerbrush
Chrysothamnus nauseosus	Rabbit brush
Holodiscus discolor	Ocean spray
Philadelphus lewisii	Mock orange
Pinus ponderosa	Ponderosa pine
Pseudotsuga menziesii	Douglas-fir
Quercus chrysolepis	Canyon live oak
Quercus garryana	Oregon white oak
Rhus diversiloba	Poison oak
Rosa gymnocarpa	Woodrose
Rubus discolor	Himalayan blackberry
Rubus laciniatus	Evergreen blackberry
Salix spp.	Willow
Symphoricarpus albus	Common snowberry

[a] Nomenclature based on Philip A. Munz and David D. Keck, *A California Flora*. Berkeley: University of California Press, 1963.

TABLE 7.--SHRUB SPECIES PERCENT FREQUENCY AND MEAN PERCENT BARE GROUND

	Region A	Region B	Region C	Region D[a]	Control
No. of 2-meter segments	184	222	170	0	225
Alnus rhombifolia	5.4	0.0	5.9		0.0
Abrutus menziesii	0.0	1.8	1.2		0.0
Arctostaphylos cinerea	0.5	0.9	5.9		1.3
Berberis nervosa	0.5	0.5	0.0		7.6
Castanopsis chrysophylla	0.0	21.6	20.7		0.0
Ceanothus cuneatus	0.0	0.5	0.0		0.0
Ceanothus integerrimus	0.0	0.0	0.0		8.4
Chrysothamnus nauseosus	0.0	0.0	3.6		0.0
Holodiscus discolor	3.8	0.0	0.0		1.8
Philadelphus lewisii	2.2	0.0	0.0		0.0
Pinus ponderosa	4.3	4.5	5.3		0.0
Pseudotsuga menziesii	1.6	9.5	7.7		7.1
Quercus chrysolepis	1.1	0.0	0.0		0.0
Quercus garryana	9.2	0.9	2.4		9.8
Rhus diversiloba	1.6	0.5	0.6		0.2
Rosa gymnocarpa	2.7	0.0	0.0		1.8
Rubus discolor	8.7	0.0	1.2		0.0
Rubus laciniatus	8.2	2.3	1.2		0.0
Salix spp.	0.0	0.9	1.2		0.0
Symphoricarpus albus	0.0	1.8	0.0		0.0
Percent bare ground	57.1	57.2	53.8		65.8

[a] There were no shrubs encountered in Region D.

pattern have less bare ground exposed and more species. Region C, the most recently disturbed area has the same number of species as Region B, but slightly less exposed bare ground than any of the other regions.

Several shrub species exhibit distinct patterns of occurence and percent frequency throughout the various regions of the study site. Presence of species is related to the environmental conditions and successional trends identified at Sterling Creek. For instance, Pinus ponderosa seedlings were most frequently encountered in Region C, less frequently encountered in Regions B and A, and not encountered at all in the control area. Shrub class Castanopsis chrysophylla was encountered in Regions C and B, and Chrysothamnus nauseosus was only encountered in Region C. On the other hand, Holodiscus discolor and Rosa gymnocarpa are found only in the control area and Region A. These species can only survive in the moister, cooler environments with well-developed soils farther along in the successional stages of development. Other species such as Berberis nervosa, Quercus garryana seedlings, Rubus lacinatus and Rubus discolor have their greatest frequency in the control area or Region A and taper in frequency with diminishing time since the disturbance.

Relative Dominance

The relative dominance of the species within each region is presented in Table 8. In this case, the relative dominance refers to the percent of the line intercepted. Within the control area, Quercus chrysolepis, Ceanothus integerrimus, Berberis nervosa and Pseudotsuga menziesii are the most dominant species. These species are well-adapted to the environment of the control area, and probably represent the

TABLE 8.--SHRUB SPECIES RELATIVE DOMINANCE BY REGION

	Region A	Region B	Region C	Region D[a]	Control
No. of 2-meter segments	184	222	170	0	225
Alnus rhombifolia	13.2	0.0	10.2		0.0
Arbutus menziesii	0.0	3.1	0.7		0.0
Arctostaphylos cinerea	1.2	0.8	5.7		5.8
Berberis nervosa	0.9	0.8	0.0		19.8
Castanopsis chrysophylla	0.0	68.9	62.5		0.0
Ceanothus cuneatus	0.0	1.1	0.0		0.0
Ceanothus integerrimus	0.0	0.0	0.0		21.7
Chrysothamnus nauseosus	0.0	0.0	7.6		0.0
Holodiscus discolor	9.8	0.0	0.0		3.9
Philadelphus lewisii	8.1	0.0	0.0		0.0
Pinus ponderosa	8.8	3.7	6.8		0.0
Pseudotsuga menziesii	1.8	11.4	2.4		15.7
Quercus chrysolepis	2.9	0.0	0.0		0.0
Quercus garryana	10.9	0.8	0.6		24.8
Rhus diversiloba	1.2	0.7	0.2		4.5
Rosa gymnocarpa	6.7	0.0	0.0		3.7
Rubus discolor	16.8	0.0	0.6		0.0
Rubus laciniatus	17.7	2.7	0.9		0.0
Salix spp.	0.0	3.1	1.7		0.0
Symphoricarpus albus	0.0	2.8	0.0		0.0

[a] There were no shrubs encountered in Region D.

climax shrub strata species associated with the Mixed-Evergreen Zone.

Dominant shrub species of Region A include: Rubus spp., Alnus rhombifolia , Quercus garryana seedlings, Holodiscus discolor, Pinus ponderosa seedlings, and Philadelphus lewisii. Philadelphus lewisii and Alnus rhombifolia are associated with the moisture available in the creek which traverses this region; however, other regions exhibit the successional species characteristic of an area closely resembling the control area, but still successionally distinct from the climax stage.

Region B is closer to the pioneer stages of the successional pattern than Region A. This is evident by the dominant shrub species encountered in Region B. Castanopsis chrysophylla is by far the dominant species, followed by Pseudotsuga menziesii seedlings, and Pinus ponderosa seedlings.

Castanopsis chrysophylla is the dominant species of Region C, along with Chrysothamnus nauseosus and Pinus ponderosa seedlings. These species represent the pioneer shrub strata species characteristic of this region. Alnus rhombifolia was encountered frequently, but the majority of these individuals were located along the border between Region C and Region D, characteristic of the creekside or holding pond vegetation.

Species dominance in each region clearly supports the existence of successional trends at Sterling Creek. The species dominant on the most recently disturbed sites aid in the establishment of a more suitable environment for additional species. Also, the number of tree and shrub species present or species number diversity decreases as time increases.

CONCLUSIONS

Sterling Creek, Jackson County, Oregon experienced extensive placer mining for nearly 100 years. Damage to the environment and removal of vegetation was not widespread until the introduction of the hydraulic in 1876. Despite the devastated landscape and adverse growing conditions, vegetation has become established on the spoil piles and mined areas in portions of the creek. Physical factors which have affected this revegetation include: the nature and size of the spoil piles, the bank structure and stability, soil and available nutrient supplies, and available moisture. Probable physiological controls of the colonizing species include: tolerance to moisture stress, shade tolerance, and nutrient requirements.

A direct relation exists between the age of the spoil piles and the species present, density, frequency, mean basal area and dominance. Plant succession is occuring on the spoil piles of Sterling Creek. Pinus ponderosa and Castanopsis chrysophylla are pioneer tree species colonizing dry environments and are most abundant in most recently disturbed regions. As time since the disturbance increases, Pseudotsuga menziesii, Quercus garryana and Arbutus menziesii replace Pinus ponderosa and Castanopsis chrysophylla. The climax state resembles the Mixed-Evergreen Zone described by Franklin and Dyrness in which dominant species include Pseudotsuga menziesii, Quercus garryana, Arbutus menziesii and Pinus ponderosa.[40]

Species density within each region increases with age since disturbance. Pinus ponderosa and Castanopsis chrysophylla have the highest densities in the most recently disturbed locations. Pseudotsuga menziesii, Quercus garryana and Arbutus menziesii have the highest densities in the areas of oldest disturbance and in the undisturbed control area.

Calocedrus decurrens, Alnus rhombifolia and Salix spp. occur in moist areas. Calocedrus decurrens only occurs in the control area where sufficient shading, moisture and substrate are available. Alnus rhombifolia and Salix spp. are associated with abundant supplies of moisture adjacent to holding ponds and creek banks; however, Salix spp., is found only near standing or surface supplies of water.

Twenty-one species of trees and shrubs are encountered in the most recently disturbed areas within the study site. As the length of time since the disturbance increases, the numbers of shrub and tree species decreases. As succession progresses, the tree and shrub species number diversity diminishes.

Mean basal area of Alnus rhombifolia, Arbutus menziesii, and Pinus ponderosa increases inversely with time since disturbance; however, the mean basal area of Pseudotsuga menziesii and Quercus garryana decreases with time since disturbance.

Shrub species demonstrate the same basic trends as tree species at Sterling Creek. Pioneer species such as Castanopsis chrysophylla, Chrysothamnus nauseosus and Pinus ponderosa are prevalent in the most recently disturbed areas of the study site. As succession proceeds these species are replaced by Holodiscus discolor, Ceanothus integerrimus, Rosa gymnocarpa, and Berberis nervosa.

FOOTNOTES

1 Francis D. Haines and Vern S. Smith, Gold on Sterling Creek, a Century of Placer Mining (Medford: Gandee Printing Center, Inc., 1966), pp. 8-9 and p. 102.

2 Haines, op. cit., footnote 1, pp. 8-9.

3 A. H. Brooks, The Mineral Deposits of Alaska; Mineral Resources of Alaska, 1913, U.S. Geological Survey Bulletin, 592 (Washington, D. C.: U.S. Government Printing Office, 1914), pp. 25-32.

4 Haines, op. cit., footnote 1, p. 47.

5 H. C. Brooks, Gold and Silver in Oregon, Oregon State Department of Geology and Mineral Industries Bulletin, 61 (Portland: Oregon State Department of Geology and Mineral Industries, 1968), p. 238.

6 Haines, op. cit., footnote 1, p. 102.

7 Divisions determined by a review of the history of mining on the creek as presented in Haines, op. cit., footnote 1; and in personal communications with Bud Henderson, caretaker of Double D Lumber land and former gold miner on Sterling Creek, and Al Nelson, resident of Sterling Creek and former student at Sterlingville School.

8 Haines, op. cit., footnote 1, p. 37.

9 Haines, op. cit., footnote 1, p. 37 and p. 39.

10 Haines, op. cit., footnote 1, p. 48.

11 Brooks, op. cit., footnote 5, p. 238.

12 Haines, op. cit., footnote 1, p. 49.

13 Haines, op. cit., footnote 1, p. 47.

14 Oregon State Department of Geology and Mineral Industries, Metal Mines Handbook, Bulletin 14-C, Southwestern Oregon, Vol. 2, Sec. 2 [Jackson County] (Portland: Oregon State Department of Geology and Mineral Industries, 1943), p. 190.

15 Haines, op. cit., footnote 1, p. 50.

16 Haines, op. cit., footnote 1, p. 69.

17 Haines, op. cit., footnote 1, p. 87.

18 Haines, op. cit., footnote 1, p. 101.

19 Charles L. Ross and E. D. Gardner, Placer-Mining Methods of E. T. Fischer Co., Atlantic City, WY, U.S. Bureau of Mines Information Circular, 6846 (Washington, D.C.: U.S. Government Printing Office, 1935).

20 Haines, op. cit., footnote 1, p. 80.

21 E. D. Gardner and C. H. Johnson, Placer Mining in the Western United States. Pt. II. Hydraulicking, Treatment of Placer Concentrates, and Marketing of Gold, U.S. Bureau of Mines Information Circular, 6787 (Washington, D.C.: U.S. Government Printing Office, 1934).

22 Oregon State Department of Geology and Mineral Industries, op. cit., footnote 14, p. 190.

23 Oregon State Department of Geology and Mineral Industries, op. cit., footnote 14, p. 190.

24 G. Hunter and P. C. Whiteman, "Problems Associated With the Revegetation of Metal-Mining Wastes," Australian Institute of Agricultural Science, Journal, Vol. 40 (1974), pp. 270-278.

25 Jerry F. Franklin and C. T. Dyrness, Natural Vegetation of Oregon and Washington, U.S. Department of Agriculture Forest Service, General Technical Report, PNW-8 (Washington, D.C.: U.S. Government Printing Office, 1973), p. 14.

26 Franklin, op. cit., footnote 25, p. 137.

27 U.S. Weather Bureau, Climatological Data, Oregon (Washington, D.C.: U.S. Government Printing Office, 1954-1975). Average annual precipitation for Sterling Creek was derived from taking the average of the 1954-1975 precipitation figures.

28 Franklin, op. cit., footnote 25, p. 38.

29 D. Mueller-Dombois and Heinz Ellenberg, Aims and Methods of Vegetation Ecology (New York: John Wiley & Sons, 1974), p. 109.

30 Mueller-Dombois, op. cit., footnote 29, pp. 109-115.

31 Mueller-Dombois, op. cit., footnote 29, pp. 90-92. The method described by Mueller-Dombois utilized a uni-dimensional line from which to sample. For purposes of this study, the line was modified into a belt 2 ft. (.8 m) wide.

32 George W. Cox, Laboratory Manual of General Ecology (Dubuque, Iowa: Wm. C. Brown Company Publishers, 1972), p. 45.

33 Franklin, op. cit., footnote 25, pp. 133-136.

34 Willis L. Jepson, _A Manual of the Flowering Plants of California_ (Berkeley: University of California Press, 1970), pp. 263-267 and pp. 269-270.

35 Jepson, op. cit., footnote 34, p. 276.

36 Franklin, op. cit., footnote 25, p. 130.

37 Franklin, op. cit., footnote 25, pp. 130-131.

38 Franklin, op. cit., footnote 25, pp. 133-136.

39 Franklin, op. cit., footnote 25, pp. 133-136.

40 Franklin, op. cit., footnote 25, pp. 133-136.

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