ECOLOGICAL ASPECTS OF THE TRANSITION FROM OLD FORESTS TO NEW[1]

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We are to-day almost in the geographic center of the most outstanding coniferous forest region of the world, the region between the Pacific Ocean and the summits of the Cascade and Sierra Mountains from northern British Columbia to central California. Here most of the land surface was covered originally with a dense, luxuriant growth of trees and associated shrubs and lesser plants. With an insular climate peculiarly favorable to coniferous trees, the forests are notable for the great height and diameter of the trees. The big trees of this region are the colossi of the vegetable kingdom, superb in their graceful proportions and in their enormity. Besides being the largest, they are probably also the oldest members of the plant or animal world. These forests are of great economic significance, both present and prospective, not only to the region in which they occur but to the whole country.

In the coastal strip in western Oregon and Washington alone, 125 miles wide from the Cascades to the ocean, from 350 miles north of Eugene to 150 miles south, which I will call the Douglas fir region, there is 500 billion feet of timber, or a quarter of that in the entire United States. This region produces annually 10 billion board feet of lumber, or more than a quarter of that cut in the whole United States. It is used by the factories and house builders from California to New England, and by the countries across both oceans. Here the principal industry is the conversion of virgin forests into useful products, and that process is going on apace.

It is appropriate, therefore, at a meeting here in the heart of this forest region that scientists give thought to the many biological and physical problems that bear on the natural life history and perpetuation of the forest.

The particular phase of this subject which I have been asked to discuss is ecological aspects of the transition from old forests to new. In treating this subject I will discuss only the so-called Douglas fir region of western Oregon and Washington, the most important economically and perhaps the most interesting scientifically of all the Pacific Coast forests. It has, however, much in common with the redwood and the sugar pine forests to the south and with the spruce-hemlock belt to the north.

The transition from old forests to new is a process which has been going on through the ages. In the natural woods there is a constant shuffling of the age groups and a shifting of the species represented. Never is the forest static. The trees of a forest make their growth, mature, become senile, fall a prey to disease, tempest or fire, and the places they have vacated are taken by the next generation of the same or other species. The forest goes on forever. In the untrammeled wilderness free from interference by man the transition from the old forest to a new is usually made successfully, though often piecemeal and not without delays.

But when man enters the scene with fire and with axe the replacement of the old forest by a new is precarious and may or may not be effected, or the new forest may not be at all of the same character as that which would have succeeded under primeval conditions.

I want first to sketch rather briefly the normal life cycle of the forests of the Douglas fir region and point to some of the natural factors that shape their destinies. Following that I want to bring man's activities into the picture and show how he may very radically affect either for better or worse this transition from old forests to new.

Let us imagine ourselves back in the days before Lewis and Clark, when there were no lumbering operations, and the natural elements and a few aborigines held full sway. Written historical description goes back but a short time, but forests have a way of writing the biography of each individual tree in a very complete and accurate fashion by means of annual rings. So it is easy to reconstruct the primeval forest of the past and to trace its transitions up to the present.

In the region of which I speak the principal actors in this forest drama of the past are Douglas fir, western hemlock, western red cedar and several species of balsam fir. There are other trees of consequence such as Sitka spruce and Port Orford cedar in the fog belt, western white pine here and there, yew as an understory, and various hardwoods in specialized localities. Douglas fir is intolerant of shade and ordinarily grows in even-aged stands, not reproducing in small openings between or underneath the mother trees. All the other species—hemlock, cedar and balsam firs—are tolerant of shade, reproduce underneath the mother trees, so inevitably tend to form uneven-aged stands.

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In a mixed forest of these species left to itself where an old Douglas fir succumbs to senility, the hole that it left in the crown canopy is not adequate for the seeding in of its own kind, but is favorable to the more tolerant hemlock and cedar. So in time the old Douglas firs all disappear, their places are taken by hemlocks, cedars or more rarely balsam firs, and the composition of the forest has changed. This is the normal climax association of all but the driest parts of the region. There are extensive areas within this so-called Douglas fir region which have no Douglas fir, though the soil and climate are admirably adapted to the species. It is absent merely because in the conflict of the centuries the tolerant hemlock and cedar have taken exclusive possession. On these grounds it might be expected that the primeval forests of this territory would all be the climax association—but this is far from the case. The anomaly of the situation is this, that a type map of the forests of Lewis and Clark's day would probably show 65 per cent. by volume to be Douglas fir. There were probably stands of all ages from one year up and no small amount of timber 100 or so years old. Perhaps 25 per cent. of the pre-white man forest was under 150 years of age.

The explanation for the failure of the climax type to prevail is fire. The positive evidence is ample, if the theoretical evidence were not convincing, that fires have been present from time immemorial and have been a very important ecological factor in the life history of the pre-white man forests.

Fires in this region are apt to be very destructive and therefore have a cataclysmic effect on the life cycle of the forest. Imagine a severe fire hitting an old mixed forest, killing most of the trees over a considerable area and leaving the ground bare and exposed to summer drought. On such an area hemlocks, cedars, etc., can not establish themselves, but Douglas fir can. Result—the burn springs up to Douglas fir almost to the exclusion of everything else and a pure young forest of this species replaces the fire-killed mixed stand. As this young forest develops, hemlocks, cedars and balsam firs appear in the shade of the Douglas fir, sometimes forming a sort of slow-growing understory. As the new forest ages these tolerant interlopers come more and more into prominence and replace the Douglas fir, and the cycle is completed.

Hence it is that the forests that come to us as the heritage of the past are not all or even mostly the superannuated stands of the climax association, but there are young stands and middle-aged stands in which Douglas fir, the most useful species of the association, is always in the preponderance. The forest fire which we now so properly condemn did a good turn in prehistoric times by renewing some of the old decadent stands and keeping up the representation of Douglas fir in immature thrifty age classes.

There is another side of the story, however. Sometimes these prehistoric fires—whether set by Indians or Zeus—came too frequently or covered too big an area for natural reseeding, or were not followed soon enough by a seed crop, with the result that instead of a heritage of normally well-stocked stands the first white men found many unproductive old burns, brush fields and thinly stocked stands.

But in spite of lightning bolts and the incendiarism of the Indians we must conclude that the forest was holding its own over the region at large through the prehistoric centuries. The natural reproductive power of the native tree species, aided by the favorable climate, offset the destructive agencies that were at work.

This natural balance was, however, rudely upset when the axe was added to the destructive agencies. About 75 years ago lumbering began in this region, at first on a very small scale, but rapidly accelerating in the last thirty years. Now approximately 250,000 acres are logged each year in western Oregon and western Washington. Ninety-five per cent. of this is on private lands where, except in a few isolated cases, there is no conscious effort made to promote the regeneration of the forest. The remaining 5 per cent. of the logging is mostly on national forests where provision is made at some expense to assist nature in the reforestation of the cut-over area.

The method of logging necessitated by the large trees and dense stands, and almost universally employed, is to cut absolutely clear and remove the logs by power machinery. Following the logging the débris-covered area is burned broadcast, effectually killing all vegetation at least to the ground. The area is then left black and barren, without seed trees, without saplings and often without humus. In any other forest region where the trees were not of sprouting species, such treatment would likely result in complete annihilation of the forest and its restoration only by the slow process of migration with perhaps intermediate stages of brush and temporary tree association. That some of the Douglas fir lands so clean cut and broadcast burned are regenerating naturally to Douglas fir is a tribute to the reproductive vigor of this species and to the favorable physical conditions of soil and climate and is economically very good luck.

Probably a half of the lands now being logged are not regenerating naturally to a real forest growth. This is a very serious situation in this region where forests are the only crop for three quarters of the land area and where the potentialities for timber production are so great. It becomes an ecological problem of the first magnitude to discover the factors which militate for and against the establishment of a new forest after the removal of the old.

I should like to mention briefly some of the ecological conditions, brought about by present logging practices, that influence the perpetuation of the forest. The facts that I shall give are taken largely from the research of the Pacific Northwest Forest Experiment Station, especially from the work done by Mr. L. A. Isaac, of this station.

The conditions I will picture are characteristic of the larger logging operations, where practically all living trees are cut down or knocked down by the logging and the area is burned broadcast and where the edge of the standing timber is pushed back a quarter of a mile to a mile a year, and where many square miles of continuous logged-off land accrue in a few years.

The sudden and complete removal of the dense Douglas fir forest creates a very radical change in the environmental conditions. It is so great a shock that many of the plants of the virgin forest can not survive in the open. It is only because Douglas fir seedlings are inured to adversity and do not need the nurse effect of a partial overwood that they return after forest conditions have been destroyed.

The environmental conditions that are radically altered are obvious. The insulation on the ground, which is about 5 per cent. under timber, is increased to 100 per cent. The average daily evaporation during the growing season as indicated by Livingston cup atmometers is 26 cc in the open as compared with 14 cc under the timber. During the same period the averge daily surface soil maximum temperature was found to be 80° F. in the timber and 131° F. in the open, and the average amount of moisture in the soil at a 3-inch depth was 19 per cent. under the timber, 13 per cent. in the open. Much of the humus is burned out of the soil. In steep country where soil is loose and exposure complete, erosion frequently follows; where active erosion is not noticeable there is often enough creep in the surface soil during periods of heavy rain to uproot tiny seedlings.

Seed supply is a prime consideration, for without seed it is obvious that there can be no new forest with species that do not sprout from the stump. The Douglas firs in the natural woods bear seed quite abundantly from early life to old age. A good crop for a large tree would be 50,000 seeds, and perhaps 10 times that amount might be borne on an acre. However, seed production in Douglas fir is periodic; some years there is no seed over large areas; at intervals of three to five years the crop is heavy. Two thirds of the time it is light. There has not been a heavy seed crop on Douglas fir over most of the region since 1923.

The seed is a popular food of birds, mice, chipmunks and insects, all of which destroy a prodigious amount of it. It has been found that when the cone crop is light a much higher percentage of the cones are infested with insects than when the cones are plentiful. Likewise it seems probable that in light seed years when the seeds are most needed for regeneration the rodents and birds that must subsist get a large proportion of it.

The relation of the animal life to the seed supply is very important and an intriguing field of research for a forest biologist. Birds and rodents are not abundant in the virgin forest, and the broadcast slash fire probably decimates their number for a while. But as the cut-over area grows up to weeds and brush it becomes a more hospitable habitat and the birds and rodents build up their population. There is some reason to believe that the older cut-over areas become progressively more difficult for reforestation because of the inroads of these predators upon the seed supply. Even if seed is produced within dissemination distance of the deforested area it has slim chances of surviving for germination, except in years of a bumper crop.

This brings us to the question of seed dissemination. It has puzzled foresters a great deal to know to what distances from the mother tree the seed is scattered, because it is so difficult to be sure of the point of origin of any seed or seedlings. Apparently wind is the sole important agency in the dissemination of Douglas fir seed; its effectiveness in wide dispersal has been underestimated by some and much overestimated by others. Recently systematic work has been done to arrive at the laws of seed flight, with rather interesting results. Seed was dropped from kites and recovered on the snow and the natural fall from seed trees was trapped through the season. It appears that most of the seed is dispersed early in the fall, but a little is held in the cones until spring, illustrating very nicely the old adage that nature doesn't put all her eggs in one basket.

Through the season 83 per cent. of the seed scattered in one direction by an isolated block of timber fell within 500 feet of the edge of this timber, and one seed was recovered at a distance of 2,400 feet. In an 8-mile wind seed released from a kite at 200 feet fell in greatest density 1,200 feet from the point of release, and the maximum distance that any fell was 2,000 feet. This is for level ground. With other wind intensities the distances were proportional. All this goes to prove that it is the exceptional seed that is carried more than a quarter of a mile on level ground. This is not denying that seeds are probably carried by rising air currents, high winds or over crusted snow much greater distances, but natural reforestation can not be predicated on the unusual.

There is another seed supply factor that must be taken into account besides the seed that is disseminated following the cutting, namely, the seed that may have been cast by the virgin forest prior to cutting and that has remained viable through the logging and slash burning process. How potent this source of seed is still remains a question. It is hard to account for the abundant reproduction on some of the older burns where no living seed trees survive over thousands of acres, except on the theory that seed was stored in the duff ready to germinate when heat and light were admitted by the burning of the mature trees. However, a series of experimental seed storage tests indicates that very, very little Douglas fir seed remains viable in the forest floor more than one year. Hence we are forced to the conclusion that unless there has been a good seed fall within a year prior to the cutting, little Douglas fir reproduction can be expected from seed stored in the duff. Even then much of it must be killed by the slash burning, though there is always a chance for some of it to survive where stirred in the mineral soil by the logging or where the fire has skipped.

Let us suppose now that our logged-off area has been wind sown with seed from nearby uncut timber and considerable of it has escaped the ravages of insects, birds, rodents and fire, or that some viable seed cast by the old forest just before it was cut still remains in the ground. What factors control the germination of the seed and the successful establishment of the seedling? It is indeed a precarious birth that Douglas fir has, as it is with the beginnings of most forms of life.

It is obvious that many of the seeds falling in this débris-strewn, logged-off land fall where they have no chance at all to germinate. The spring climate is ordinarily excellent for germination—plenty of surface moisture at a time when the temperature is right to start growth.

But the tender seedling has many dangers to avoid if it is to survive. Let me cite a few of the causes of infant mortality in Douglas fir which experimental work has demonstrated. Prominent among the causes for loss in very young seedlings is superheated surface soil. The first hot days of early summer when the seedlings are still succulent and about 1½ inches high give a surface soil temperature (in one area studied intensively) of 150° F. with an air temperature of 95° F. Now Douglas firs of this age succumb with a characteristic heat lesion on the stem when the surface soil temperature reaches 120° to 145° F. Hence seedlings on exposed south slopes or those standing in the full sunlight, unprotected by the shade of weeds, shrubs or logs, can be expected to die in an early summer hot spell and they do. The fact that much of this logged and burned land is blackened with charcoal makes the surface temperature even more unfavorable. On one area there was a difference of 17° F. in the surface temperature of a charcoal darkened soil and an adjoining plot of natural yellow-brown soil. On the blackened soil all the seedlings died in the first hot wave (the soil was still moist) while only 32 per cent. of the seedlings died on the adjoining lighter colored soil.

Another cause of early mortality is drought, for this is a region with little or no rain in July and August. Douglas fir strikes its taproot down vigorously and reaches a length of about five inches when two months old, but this is not always enough to overcome the terrific desiccation of the surface soil to which these stripped, burned lands are subjected.

On the top of heat and drought comes some loss due to fungi resulting in damping off. This, however, is not as serious apparently with seedlings in their natural environment as with seedlings crowded in a nursery bed.

It was somewhat of a surprise to find recently the rather large rôle that mice play in the infant mortality of seedlings. In one experimental area mice grazed off the tops of newly germinated seedlings, accounting for a loss of 95 per cent. in two or three days. This is perhaps unusual and was on an area not burned for five years where the rodent population had had a chance to build up.

Supposing now that our Douglas fir seedlings have successfully run the gamut of heat, drought, parasitic diseases and animal predators, they next come into very direct competition above and below ground with other native vegetation. For these logged and burned areas, black and barren as they are, become clothed surprisingly soon after slash burning with a luxuriant and varied assortment of weeds and shrubs, some of which are the residue from the flora of the virgin woods, like vine maple, Oregon grape and salal, and some have seeded in from afar like fireweed, hawkweed and senecio. This associated vegetation plays the dual rôle of nurse and executioner. It offers beneficial shade to the very young seedling, hence germination and early survival is much better on the north side of clumps of bushes than on the south.

But Douglas fir after a few weeks becomes very demanding of light, and plants that have much shade do not thrive. The character and density of the weed and shrub vegetation are of immense importance to the survival of the Douglas fir seedlings. This vegetation varies from area to area and changes from year to year in a most interesting ecological succession not perfectly understood. If the area has never been burned following logging the composition of the flora is very different from that on burned areas and is more stable. By and large each year after logging the cover becomes denser, so that in a 10-year cutting the ground is matted with dried vegetation and in midsummer the weeds and shrubs often make a head-high jungle where open spots are few and far between. In such an area seed has little chance to find a germinating bed or tiny seedlings to survive the competition of a continuous cover of six-foot plants. It may be concluded that when the natural vegetation is dense from about the third year after logging the establishment of seedlings becomes more and more difficult. Areas therefore which are not seeded rather soon after cutting have a diminishing chance of ever becoming restocked with Douglas fir, even with a constant seed supply. This would not be true of poor soils where the herbage was sparse or on exposed slopes where the secondary plants help rather than obstruct the Douglas firs.

When the trees get a head start on the weeds and shrubs or are able to find plenty of light in spite of this competition, they make vigorous growth and after the first three years begin to shoot up at the rate of a foot, then a foot and a half and even two feet a year, so that by eight or ten years they are past the danger of being smothered by lack of light. Then the Douglas firs come into competition with each other, which is another story.

The young Douglas fir forest after it is abreast of the weeds and brush is a very thrifty crop, singularly free of pests and vigorous in its production of useful wood fiber. The owner of such an established stand of saplings can begin to count the profits such a new forest will yield 30, 40 or 50 years hence—except for one thing, the constant hazard of fire. The great danger of fire is an ever-present accompaniment of the transition from old forests to new. It has been estimated that the fire hazard on cut-over land is 25 times as acute as in virgin Douglas fir forests. The peak is reached when the fresh slash still litters the ground. Broadcast burning consumes only a part of the mass of logging débris, and the weeds and bushes soon add their annual contribution of tinder. It takes but a spark in midsummer to reburn the whole area, Douglas fir seedlings and all. At present quite a percentage of the cut-over lands of the region are reburned annually. After each fire the process of natural regeneration of the area becomes more difficult, especially because of the decreased chances of a seed supply in the vicinity.

Only when the trees have grown large enough to shade out the annual weeds and to make a solid canopy that will keep the ground moist does the fire hazard diminish and begin to equal that of the old-growth forest. The character of the low vegetation that follows logging has much to do with the fire hazard, whether it be fireweed, bracken fern, deciduous bushes, etc. Perhaps it may be found that by modifying the methods of disposing of the slashings or by other treatment of the area, such as the grazing of livestock, the character of this vegetation can be modified to lessen the fire danger during this critical period in the inception of the new forest.

This recital of the ecological factors that bear upon the reestablishment of the Douglas fir forest after logging and fires would be incomplete unless I pointed the moral of the story. It is this. Man's industry in converting the forest into useful products is having a cataclysmic effect on land productivity. Present logging methods practically annihilate every vestige of the old forest and make it very difficult for a new one to become established. Man's ingenuity must now be employed to devise ways of logging and of fire control that will ameliorate the inevitable destructive operation of timber harvesting and help a new forest to come back in the ashes of the old. I speak, of course, only of those lands which are not adapted and not needed for agricultural crops—lands whose highest use for the present is production of forest crops. It is very roughly estimated that from 80 to 90 per cent. of the Douglas fir lands now being logged are of this category, and unless reforested they will lie idle and unproductive.

The technique of making conditions possible for the natural regeneration of this aggressive pioneering species, Douglas fir, in this favorable climate is not difficult or impracticable. It entails first of all seeing to it that there is an adequate source of seed, especially by organizing the cutting so that each block of cut-over land can reseed from adjoining timber, or by leaving single seed trees of low commercial value. Sometimes artificial planting of nursery-grown trees may be the cheapest and surest procedure.

A further important step, which the preceding discussion of ecological factors has suggested, is discrimination in the slash burning so that areas of extreme exposure or those that are already sprinkled with seed or seedlings may be spared from destructive burning, unless this operation is essential to safety from fire and really lowers the inflammability over a term of years.

The exclusion of fires from areas already slash burned or already reproducing is essential, and here there are preventive measures which if assiduously performed will help greatly to control the fire menace. Time does not permit detailing the several operations which could be performed to make conditions better and safer for reforestation.

The subject assigned to me was obviously limited to the biological aspects of forest renewal, and I have discussed the reforestation problem only from that angle. There is another phase of this subject which I can not wholly pass by—the economics of reforestation under private ownership. The lumber industry of the Douglas fir region is operating under obstacles of overproduction, cut-throat competition in distant markets, the menace of fires from the operation itself as well as from sources beyond the control of the owner, and heavy carrying charges, particularly a system of taxation that taxes both the land and the value of the timber upon the land each year. In the face of these obstacles there is an urge to liquidate the capital investment; there is little interest in holding the land for continuous production, and an unwillingness to spend even a small amount to leave the land in productive condition. The silvicultural measures that would promote reforestation, the desirability of which are recognized by all, are not likely to be adopted except by the few strong and far-seeing companies until these economic obstacles are removed. It is the responsibility of the public to rectify the tax situation and eliminate the outside fire menace, as it is of the industry to remove the other obstacles; happily each year sees progress in this regard, but it is slow. The transition from old forests to new is too often a transition from old forests to worthless, blackened stump land whose return to a cover of useful trees will be a slow or expensive process.

OBITUARY

RECENT DEATHS

PROFESSOR WILLIAM DILLER MATTHEW, chairman of the department of paleontology of the University of California, died on September 24 at the age of fifty-nine years.

DR. NATHANIEL O. HOWARD, pathologist of the Department of Agriculture, stationed at Brown University and instructor in botany at the university, died on September 14 at the age of fifty years.

DR. ROSS HALL SKILLERN, well-known laryngologist and professor of laryngology in the graduate school of medicine of the University of Pennsylvania since 1918, died on September 20. He was fifty-four years old.

FREDERIC M. STROUSE, assistant professor of laryngology in the graduate school of medicine of the University of Pennsylvania, died on August 4 at the age of sixty-six years.

BROTHER AZARIAS MICHAEL, dean of the engineering school of Manhattan College, died on September 17 at the age of fifty-three years.

DR. MURRETT F. DE LORME, head of the Lindsay Laboratories, Inc., in Brooklyn, which he founded twenty years ago, and professor of clinical medicine at the Long Island Medical College, died on September 8, aged sixty-two years.

DR. ALONZO ROUSE KIEFFER, formerly professor of surgery and head of the department of clinics at the Barnes Medical College, died on August 13 in his seventy-fifth year.

MAJOR GENERAL SIR NEVILLE HOWSE, V. C., who was a medical officer in the Australian army and who was one of Australia's representatives at the fourth assembly of the League of Nations, has died at the age of sixty-seven years. He was a fellow of the Royal College of Surgery.

PROFESSOR H. B. DIXON, of Manchester University, England, regarded as one of the world's foremost experts on explosives, ex-president of the British Chemical Society and holder of the Royal Medal of the Royal Society, died on September 18 at the age of seventy-eight years.

MEMORIALS

A MEMORIAL to George Westinghouse, inventor and founder of the various Westinghouse industrial enterprises, will be dedicated in Pittsburgh on October 6, according to an announcement by A. L. Humphrey, chairman of the Westinghouse Memorial trustees. Leaders in industry, science and education have been invited to pay tribute on that day to the memory of the inventor of the airbrake and the steam turbine and the proponent of the alternating current. The ceremony will include the unveiling of a bronze statue by Daniel Chester French. The main unit of the memorial rises twenty feet from a Norwegian granite base and includes a dominating figure of the subject, in the prime of life. Beside him are two figures depicting a skilled workman and an engineer, typical of the thousands of artisans who assisted him during his life. Facing this group on a separate pedestal is a figure of an American youth studying the achievements made.

A MEMORIAL to Carl Ben Eielson, who lost his life in the Arctic regions last November while engaged in the work of bringing passengers and cargo by plane from the icebound steamer *Nanuk,* will be erected at the Alaska Agricultural School and College of Mines. The memorial will be a building for the Fairbanks school, which will house the "Colonel Carl Ben Eielson School of Aeronautical Engineering." It is expected that $15,000 to $25,000 will be raised at Fairbanks, toward which $4,000 has already been subscribed.