CIHM
Microfiche
Series
(Monographs)

ICMH
Collection de
microfiches
(monographies)

Canadian Institute for Historical Microreproductions / Institut canadien de microreproductions historiques

Technical and Bibliographic Notes / Notes techniques et bibliographiques

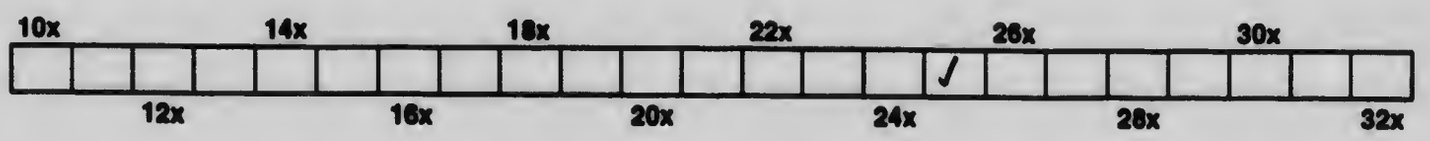
The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming are checked below.

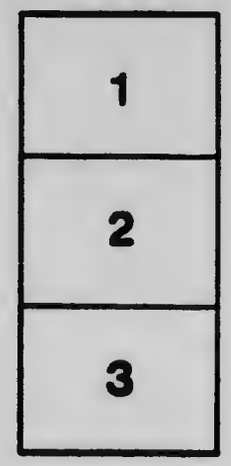
- [x] Coloured covers / Couverture de couleur
- [ ] Covers damaged / Couverture endommagée
- [ ] Covers restored and/or laminated / Couverture restaurée et/ou pelliculée
- [ ] Cover title missing / Le titre de couverture manque
- [ ] Coloured maps / Cartes géographiques en couleur
- [ ] Coloured ink (i.e. other than blue or black) / Encre de couleur (i.e. autre que bleue ou noire)
- [ ] Coloured plates and/or illustrations / Planches et/ou illustrations en couleur
- [ ] Bound with other material / Relié avec d'autres documents
- [ ] Only edition available / Seule édition disponible
- [ ] Tight binding may cause shadows or distortion along interior margin / La reliure serrée peut causer de l'ombre ou de la distorsion le long de la marge intérieure.
- [ ] Blank leaves added during restorations may appear within the text. Whenever possible, these have been omitted from filming / Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.
- [ ] Additional comments / Commentaires supplémentaires:

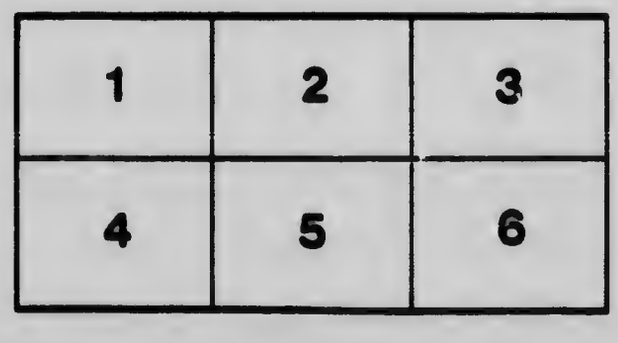
L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

- [ ] Coloured pages / Pages de couleur
- [ ] Pages damaged / Pages endommagées
- [ ] Pages restored and/or laminated / Pages restaurées et/ou pelliculées
- [x] Pages discoloured, stained or foxed / Pages décolorées, tachetées ou piquées
- [ ] Pages detached / Pages détachées
- [x] Showthrough / Transparence
- [ ] Quality of print varies / Qualité inégale de l'impression
- [ ] Includes supplementary material / Comprend du matériel supplémentaire
- [ ] Pages wholly or partially obscured by errata slips, tissues, etc., have been refilmed to ensure the best possible image / Les pages totalement ou partiellement obscurcies par un feuillet d'errata, une pelure, etc., ont été filmées à nouveau de façon à obtenir la meilleure image possible.
- [ ] Opposing pages with varying colouration or discolourations are filmed twice to ensure the best possible image / Les pages s'opposant ayant des colorations variables ou des décolorations sont filmées deux fois afin d'obtenir la meilleure image possible.

This item is filmed at the reduction ratio checked below / Ce document est filmé au taux de réduction indiqué ci-dessous.

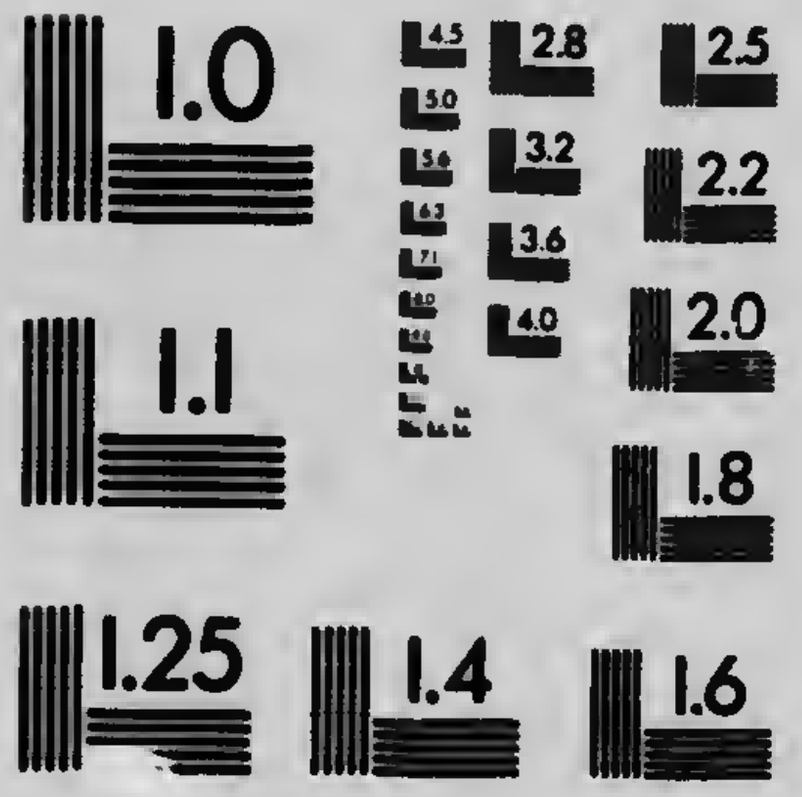






MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



APPLIED IMAGE Inc

1653 East Main Street
Rochester, New York 14609 USA
(716) 482 - 0300 - Phone
(716) 288 - 5989 - Fax

Commission of Conservation
Canada

COMMITTEE ON FORESTS

The Reproduction of Commercial Species in the Southern Coastal Forests of British Columbia

BY

C. D. HOWE Ph.D.

Reprinted from Seventh Publication of Canada, 1915-1916,
Conservation Commission

OTTAWA, 1917

Commission of Conservation
Canada

COMMITTEE ON FORESTS

The Reproduction of Commercial Species in the Southern Coastal Forests of British Columbia

BY

C. D. HOWE, Ph.D.

Reprinted from Forest Protection in Canada, 1913-1914,
Commission of Conservation

OTTAWA, 1915

A Ground Fire Burning the Slash

The shade of the debris and under vegetation is removed, the mineral soil is exposed and sufficient seed trees are left. Conditions favourable for the reproduction of Douglas fir.

The Probable Condition of the Area Shown Above After Twelve Years

The area represented here was logged and burned twelve years ago and it now contains 5,000 young fir trees, 1,300 cedar and 400 hemlock per acre.

The Reproduction of Commercial Species in the Southern Coastal Forests of British Columbia*

BY

C. D. HOWE, PH.D.

OBJECT OF THE WORK AND THE CONCLUSIONS IN BRIEF

EVEN the casual observer, employing the usual methods of travel in the southern coastal region of British Columbia, would doubtless be impressed by the abundance of forest reproduction, especially that of Douglas fir. He sees young trees, often in dense stands, on all sides. If he reflects upon the significance of what he sees he gets the impression that there is nothing to fear in regard to the establishment of future commercial forests. However, for the most part, he sees this reproduction only along the margin of green forests, adjacent to cleared fields, highways and burned areas, where the conditions for the re-establishment of the forest are the very best. Are the conditions the same throughout the logged-over and burned-over areas? That is, are these very extensive areas in an adequate manner reproducing the forest which has been removed? The investigations, described on the following pages, were made in order to answer this question. The results are based not upon general impressions, so often misleading even to a careful observer, but upon a painstaking enumeration of the young trees on measured areas laid out in such a manner as to include all kinds of conditions.

As the result of such investigations, the question stated above may be answered thus: On about one-half of the area logged and burned in the past 20 years, the forest reproduction is not sufficiently abundant to insure the re-establishment of the commercial forest. The other half, however, is well stocked with young trees, and, if not burned, a forest yielding saw-logs is assured.

*The investigations reported in the following pages were carried on by the Commission of Conservation in co-operation with the Forest Branch of British Columbia. The writer is deeply indebted to the Chief Forester and members of his staff for their hearty co-operation and aid in facilitating the work.

The barrenness, from the standpoint of young trees, on one-half of the logged area is due to the occurrence of repeated fires. One burning stimulates the reproduction of Douglas fir. In fact, it is regarded as necessary for the establishment of dense stands; but a second burning is very disastrous, because it kills both the seed trees and the young growth following the first fire. There is nothing left with which to start another crop of trees on the area.

Judging by the age of the fire scars on the older trees, and by the age of the stands following the first fire, the writer found that during the past 20 years four widespread fires occurred. That is, a severe fire occurred once in five years, the last one being four years ago. From 20 years to 100 years ago the average interval between widespread fires was 27 years, while from 100 years to 360 years ago severe and widespread fires took place at intervals of 86 years. Therefore, the rate of the occurrence of fires has increased enormously in the past few years. Practically all of these fires were upon the logged-over areas, and so endangered or killed the forest reproduction.

The significance of the increasing number of fires lies in the fact that the future supply of saw-logs must come from the logged-over areas. It takes, under average conditions, from 75 years to 100 years to make even the smallest trees now being used for saw-logs. The largest trees are from 400 to 900 years old. Adequate fire protection for the young growth on the logged-over areas should be installed at once.

NATURE OF THE INVESTIGATIONS

The following report upon the re-establishment of the forest after logging and after burning is the result of work on the eastern coast of Vancouver Island as far north as Union bay and on the mainland coast as far north as Powell river. The investigations extend inland about five miles in each case, so that the total area explored covered about 1,000 square miles. After areas of second growth of various ages had been located by a general exploration, the number of young trees on them was counted by means of strips 33 feet (one-half chain) wide and their ages determined. The length of the strips depended upon the density and uniformity of the stand, being shortest in the more dense and more uniform stands. With the exception of the stands less than 10 years old, however, all the strips were at least 20 rods (5 chains) long, and some of them were two miles in length, the average being about one-fourth mile (20 chains). From these sample strips, the number of trees on an acre was calculated and the results are given in the tables below. The total area of such sample strips on which the young trees were counted was over 43 acres. Besides this, sample strips of like nature, amounting to 28 acres, were made in the

cut-over areas to determine the number of seed trees remaining after the logging operations. At the same time, studies were made on the influence upon the re-establishment of the commercial species of various agencies, such as logging without burning, logging with burning, and the presence of underbrush.

After a brief description of the mature forests in the southern coastal forests of British Columbia, the following report passes to a description of the young forests (the forest reproduction) dominated by fir, hemlock or cedar (pp. 9-13). The section of the report following this deals with the agencies which accelerate or retard the establishment of young forests. The last topic is discussed under such headings as logging without burning, logging with burning and the under-vegetation (pp. 13-19). The recommendations based upon the results of the investigations are presented in the final section (pp. 19-21).

The statements in regard to the ages of the older trees are to be considered only as approximate. The age is determined by counting the annual growth rings on the stumps, so an addition must be made for the time taken by the young tree to reach stump height. This period varies according to the favour of the growth conditions in which the seedling found itself; it may have grown in height very slowly or very rapidly. For example, some seedlings in very dense stands on poor soil were found to make an average height growth of three inches a year for the first ten years, while, on the other hand, seedlings in the best soil conditions grew at the rate of over a foot a year in the same time. From the measurement of several hundred seedlings in various conditions of density and soil, the rate of six inches a year for the first ten years was taken as the average height growth, and the age of a tree to the height of the stump was calculated on this basis.

The young trees, whose ages were to be determined, were cut flush with the ground, so the results in this case are quite accurate. There are chances of error in determining the age of fire scars, as it may happen that a growth layer is not laid down in some years on the side of the tree where the rings were counted.

MATURE FORESTS

In the coastal region of British Columbia, included in this report, from sea level to an elevation of approximately 2,000 feet, Douglas fir is the predominant tree species in the mature forest, both as to numbers, since it comprises from 70 to 80 per cent of the stands, and as to growth conditions, since it overtops its associates in the forest and furnishes the greater portion of the lumber. If, however, the

immature and non-commercial trees were included in a tree census, the Western hemlock, for reasons to be stated later, would be found to outrank the fir in mere numbers.

The largest fir trees, from four to eight feet in diameter, and 200 to 300 feet high, occur in the deep sandy loam soils of the first bench lands above the lakes, streams and along the innumerable re-entrant arms of the sea. According to the writer's observations, they occur at present only in scattered groves, or relatively small patches, or scattered among trees of much smaller size. They are usually in situations well protected from fire, and this is doubtless the reason they have been spared. The medium-sized trees, from one and one-half to four feet in diameter, and from 150 to 200 feet high, are found on the stony loams and the sands of the second bench lands of the inland waters and of the old sea terraces of the coast. They are also found on soils of similar nature on the numerous glacial sand plains at the mouth of the mountain valleys. These medium-sized fir trees, in addition, extend up the lower slopes of the mountains to an elevation between 600 and 800 feet. The situations in which the medium-sized trees grow are very extensive, and they furnish by far the greater portion of the fir saw-logs.

Above an altitude of 600 to 800 feet the mature fir trees as a whole are small, from ten to thirteen inches in diameter, and from 75 to 125 feet high. Some medium-sized trees, however, may run up the ravines to the higher elevations. The soil is thin and very rocky, although, when not burned, the rocks are hidden by a luxuriant growth of mosses, ferns and small, woody undergrowth. The stands are dense and have every appearance of being "growth bound." This type of fir forest is quite extensive. Small mature trees also occupy the numerous gravel plains at lower elevations.

Western hemlock is the commonest associate of the Douglas fir in the coastal region under consideration, but it rarely, if ever, attains the proportions of the fir. Away from the immediate coast, it grows in rather more moist situations than the fir, or is more abundant and of larger size when it shares with the fir the better soil conditions. It is found in good development particularly along streams and on north-facing stream slopes, on flats at the head of lakes, in gullies and depressions in the sand plains. Hemlock occurs in suppressed condition, often in dense thickets, beneath nearly all of the mature fir stands whatever the kind of soil they may occupy, so that if these small trees be counted, the hemlock very often surpasses the fir in numbers, although the fir dominates the stand. The hemlock evidently recovers from its suppression when released by the death of the over-topping fir, for a break in the crown cover of the fir is usually occupied by

hemlock, so that even in the pure stands of fir there are scattered small groups of mature hemlock. At the higher elevations, the hemlock gradually displaces the fir in the forest.

Western cedar is much less common than the hemlock as an associate of the Douglas fir, but in its best situations it more nearly approaches the fir in size; in fact it sometimes surpasses the fir in diameter, but not in height. The largest cedars are found on moist flats along lakes, sea and streams. Cedar, however, like the hemlock, may be found in almost any soil condition, but it apparently does not reach large size on indifferent soils except on the immediate slopes of the shores.

Balsam, Sitka spruce and western white pine, so far as observed, occur only scatteringly in the Douglas fir forests. The balsam is the most common of the three.

One is impressed by the occurrence of a large number of stands of mature fir in which the trees are nearly all of the same age. The stands of medium-sized trees, for example, were prevailingly 315, 170 and 124 years old. In fact, representatives of these age classes were found on every area studied, whether on the island or on the mainland. The uniformity of age, however, was not so pronounced among the largest and oldest trees. The largest tree observed was seven feet in diameter and was 910 years old. Fire scars disclosed the fact that the tree was burned 856 and 335 years ago. The large trees, about six feet in diameter, at Chemainus, were 540 years old. Those near Cowichan lake and Gibson landing were 425 years old, with an average diameter of five feet. In both places they showed fire scars 230 year old. At Powell river they were 356 years old, and averaged four feet in diameter, while at Union bay they were 460 years old and six feet in diameter.

Younger stands, 70 and 100 years old, were also frequent on all of the areas investigated. These are the ages of most of the fir trees left after the logging operations at Shawnigan lake, Chemainus and Union bay, and also of the trees now standing on the logged-over areas on the north side of Burrard inlet, at Gibson landing and Powell river.

Judging by what we know of the method of re-establishing fir forests after the more recent fires, we are fairly safe in assuming that these mature Douglas fir forests were established as the result of fire. Moreover, all the five younger age classes mentioned above correspond with the ages of fire scars on the neighbouring older trees. This point may be made clear by describing the condition of affairs at Powell river, where a careful study of the history of the forest on a square mile was made. The majority of trees logged on the area would be approximately 315 years old if standing to-day. The fire scars on the

veterans were 316 and 70 years old. The scattered veterans were 356 years old, and they doubtless represent the remnants of the stand burned 316 years ago. One finds some trees 155 years old, but it is evident that they established themselves beneath an old stand, for they were suppressed for the first 55 years, being only two inches in diameter at that time. Something happened 100 years ago to release them, for they began to grow rapidly a few years after that date. It may have been the fire recorded by the scars 100 years ago on adjacent trees, although the stumps of the 155-year-old trees do not show fire scars of that date. Nearby stands, however, are 100 years old, and the effect of the fire recorded 70 years ago is to be found in adjacent stands of that age.

YOUNG FORESTS

Under the heading of young forests are included all those areas where the young trees of the commercial species are in the process of reproducing a forest. A new forest may be in process of re-establishment beneath an old forest or upon areas wholly or partially cleared by fire or by logging or by both. Practically all of the reproduction of Douglas fir forests is taking place on areas cleared by fire alone or by logging and fire combined. A new hemlock forest, however, may be established beneath an old fir forest. This is because young hemlock trees can endure shade, while young fir trees will not grow well if shaded by the crown cover of larger trees.

The object in this section of the report is to show the decrease in the number of trees per acre as the stands grow older. The death rate is greater, the greater the density of the stand, yet the denser the young stand, the better will be the quality of the lumber produced by the surviving trees. As the shade is so dense that the side branches are killed off early in the life of the tree, the wood laid down on the stem after this is free from knots, hence the quality of the lumber is improved. Crowding also forces the young trees to grow more rapidly in height and more uniformly in thickness, with the final result of more logs to a tree and less taper in a log.

Dense young stands are necessary to produce the largest quantity of the best quality of commercial timber. For this reason the agencies which bring about dense stands should be encouraged and those which tend to retard or destroy their development should be eliminated.

For convenience of presentation, the description of the forest reproduction will be given under three sub-titles, namely, that in which Douglas fir predominates, that in which hemlock is the most abundant, and that in which cedar is the most numerous.

Douglas Fir Predominant

The table below gives the average density per acre of the young Douglas fir forests grouped into age classes of ten-year intervals. The actual age of these stands will be found under the section upon the influence of fires on forest reproduction.

TABLE I

NUMBER OF YOUNG TREES PER ACRE, ACCORDING TO AGE BY DECADES, BASED UPON 32 ACRES OF SAMPLE STRIPS

Age, by decades	Douglas fir	Hemlock	Cedar	Balsam	White pine	Total trees
Less than 10 years	53,300	1,000	3,300	..	..	57,600
10 to 20 years	3,900	270	470	30	5	4,670
20 to 30 years	1,100	220	170	20	5	1,510
30 to 40 years	410	270	100	10	..	790

PERCENTAGES OF YOUNG TREES PER ACRE, ACCORDING TO DECADES, AS ABOVE

Age, by decades	Douglas fir, Per cent	Hemlock, Per cent	Cedar, Per cent	Balsam, Per cent	White pine, Per cent
Less than 10 years	93.0	2.0	5.0	....	....
10 to 20 years	83.4	5.7	10.0	0.7	0.1
20 to 30 years	72.6	14.6	11.2	1.3	0.3
30 to 40 years	52.0	34.0	12.6	1.3	....

One frequently finds small patches of fir in which the number of trees on an acre was much higher than given in the table above. For example, four-year-old stands sometimes ran as high as 322,000 little trees upon an acre, and even in the 16- and 18-year-old stands the number per acre frequently reached 30,000. The figures in the table, however, give a good idea of the general condition of the reproduction, including the poor as well as the good.

The table above clearly shows the natural thinning-out that takes place as the trees increase in age and size. In the case of the 57,600, less than 10 years old on an average acre, a little tree occupies less than a square foot of soil. If all of these trees lived until they were a foot in diameter, the result would be a solid block of wood upon an acre. We know that trees do not grow that way. There is not room enough for them all, so the weak die and the strong survive. As shown by the table, in this case 91 per cent of the trees had died by the end of the nineteenth year, 97 per cent at the end of 29 years, and 98 per cent

were dead at the beginning of the fortieth year, or, in other words, only one in fifty of the original trees was alive, that is, if we assume that the forest between 30 and 40 years old started in the same manner as the present stands less than 10 years old. Stated in another way, the death rate per acre was 5,000 yearly during the second decade; 300 yearly during the third, and 70 trees per acre yearly during the fourth decade. It will be seen that the death rate was still more pronounced in the case of the fir alone, since less than one in a hundred of the original trees was alive at the end of the fourth decade.

By referring to the percentage table above, one will see that the proportion of the hemlock gradually increases as the stands grow older. This shows that the hemlock can endure crowding and shading better than the fir. The tendency of the hemlock to crowd out the fir as the forest gets older seems to be a general rule in the coastal forests of British Columbia. This is particularly true in the better soil conditions, and, as stated in the preceding section, (p. 7), the hemlock is beneath the stands of fir on the poorer soils, ready to take the place of the fir as soon as it is removed, that is, if the natural conditions are not too violently disturbed.

In travelling through the southern coastal region of British Columbia one is impressed by the vigorous reproduction of Douglas fir, yet the occurrence of well-stocked stands of young fir is scattering and patchy in nature. The mature forests which will arise from these young stands will not be as continuous and uniformly distributed as the present mature forest, and consequently the forest area of the future will not yield as much saw-log material. This prediction is based on the fact that large areas of young forests are being periodically burned, and, when the young growth is killed by fire, little or no young growth of commercial trees comes in to take its place. The reasons for this will be discussed in the section on the influence of fire upon forest reproduction.

Hemlock Predominant

Stands in which hemlock predominated, covering large areas, were much less frequent than those in which fir predominated. Young hemlock stands were plentiful, but they occur in relatively small groups, usually on the better soils of depressions and flats.

A Stand of Douglas Fir About 100 Years Old
Fire scars on adjacent older trees are of that age, s[illegible] and evidently followed the fire. It has not been burned since.

This Area has been Burned Twice
The young growth is scattered and patchy in distribution. The dead saplings indicate that it was once well covered with young trees.

TABLE II

NUMBER OF YOUNG TREES PER ACRE, ACCORDING TO AGE BY DECADES, BASED UPON 11 ACRES OF SAMPLE STRIPS

Age, by decades	Hemlock	Douglas fir	Cedar	Total trees
Less than 10 years	44,900	5,000	4,990	54,800
10 to 20 years	7,770	400	170	8,340
20 to 30 years	6,170	180	100	6,450
30 to 40 years	3,900	100	160	4,160

PERCENTAGE OF YOUNG TREES PER ACRE, ACCORDING TO DECADES, AS ABOVE

Age, by decades	Hemlock, Per cent	Douglas fir, Per cent	Cedar, Per cent
Less than 10 years	82	9	9.0
10 to 20 years	93	5	2.0
20 to 30 years	95	3	1.4
30 to 40 years	94	2	4.0

As in the case of the fir, some of the young stands were much more dense than is indicated by the averages, as given in the table above. For example, a small plot in a four-year-old stand disclosed seedlings at the rate of 2,800,000 to the acre. By comparing this table (Table II) with that of the fir (Table I), one will see that there are many more hemlock trees per acre than there were fir trees for the corresponding ages, with the exception of the first age class. In other words, the death rate of the hemlock is not so great as that of the fir, since 82 per cent of the hemlock had died in the second decade, 86 in the third, and 90 per cent in the fourth decade. Whereas, in the case of the fir, less than one in a hundred of the original seedlings was represented in the stands at the end of 39 years; in case of the hemlock ten times as many were represented, that is 10 out of a hundred. The same thing is indicated in the percentage table, where it will be seen the relative proportion of hemlock in the stands does not decrease materially as the trees grow older. All this shows again that the hemlock can endure more crowding and shading than the fir, for it is evident that there would be more shade on an acre containing 4,160 than 790 trees of the same age.

Cedars are Short-lived

As shown in the tables on the preceding pages, cedar is a common associate of both fir and hemlock. On the average the greatest extent of this association is about one-eighth of the stand, but it sometimes ran as high as one-

third. On seaward slopes cedar seedlings and saplings frequently occurred as an under-story beneath well advanced second growth fir in such abundance that, if all the individuals were counted, the cedar would surpass the fir in number. The best cedar reproduction was found beneath alder and it will be discussed later under the section on the effect of various agencies upon reproduction. In other situations, such as on logged and burned areas, no young growth cedar over 10 years old was found, except in small patches, although seedlings from one to five years old occurred in large quantities everywhere and small plots containing a few square yards sometimes ran as high as at the rate of over 3,000,000 plants to the acre. They were found mostly about stumps, on decayed logs and under the protection of fallen trees. Why they do not fulfil their prophecy of a future forest is not known. It may be that they can not endure the dry summers.

EFFECT OF VARIOUS AGENCIES UPON FOREST REPRODUCTION

Logging Without Burning

Logged-over areas which have not been burned with at least a ground fire within four years after the logging operations were rather hard to find in the region explored. So far as the number of seed trees left after logging is concerned, the opportunities for the reproduction of the forest are good. No trees less than 18 inches in diameter are cut for saw-logs as a rule, and there is usually a goodly number of these in every stand. Sample strips to determine the number of trees six inches or more in diameter, left after logging, these being considered capable of bearing seed, total only five acres. On these, the seed trees averaged 44 hemlock. 22 fir, and 13 cedar per acre, 79 in all. The death rate of these in after years, if not burned, would probably not be sufficiently large to eliminate the possibility of good seeding of the ground. Of course, there are many areas, such as skidding yards and clearings about camps and mills, where no seed trees are left, but these, as a rule, are not too large to prevent seeding from the sides

The reproduction of the forest after logging without burning is rather difficult of attainment. The removal of the over-shading trees greatly stimulates the growth of the under-vegetation, such as salal, bracken fern, huckleberry, Oregon grape, and salmon berry. These grow abundantly and luxuriantly, and, together with the slash, make such a dense shade that the little fir seedlings which may spring up soon die. Cedar especially germinates abundantly under these conditions, but as stated before, does not last long. The shade is apparently too dense in such cases, even for the hemlock. One finds abundant seedlings up to four or five years old, but not such extensive dense stands as the number of seedlings would seem to suggest. It is

not a contradiction of the last statement to say that hemlock is the most abundant reproduction on the unburned logged areas. It apparently originates, however, not from seed distributed after the logging, but from the small trees which already existed beneath the mature fir stands before the logging. One can demonstrate this by counting the annual growth rings of the hemlock, when he will find that the trees are much older than the logging operations. It is also to be noticed that the growth rings become materially wider, the same year or the year after the logging operations, showing that the growth conditions for the hemlock were improved at that time, that is, by the removal of the overtopping fir trees. Some typical examples of the condition of hemlock reproduction after logging may be given. On an area logged four years ago, there were 416 hemlock saplings 16 years old and only 24 hemlock seedlings four years old, or less, on an acre. An area logged six years ago disclosed 730 hemlock saplings 18 years old on an acre and only 50 seedlings younger than the age of the logging. On an area logged 12 years ago, an acre showed 1,450 hemlock trees 24 years old and 200 seedlings which had come in since the logging.

The young growth hemlock on the unburned logged-over areas occurs in dense groups in the more moist soils and as scattered individuals on the drier soils, so that the trees as they grow older form a broken crown cover. The more open places may eventually fill up with fir. This is indicated by the presence of scattered fir seedlings about stumps and along the length of fallen trees. Although the exact history of the areas is not definitely known, it is probable that the older age classes of the hemlock, represented in Table II, originated on unburned logged-over areas. It will be seen that the proportion of fir is small, indicating that the conditions for the reproduction of hemlock were very much better than those of the fir.

Logging with Burning

As already intimated, much the greater portion of the cut-over areas has been burned at least once since logging and most of the studies of forest reproduction were made on areas of this kind. In fact, extensive areas of commercial forest burned before logging were not found in the region explored. Moreover, the impression was gained that the large-sized and medium-sized trees were not seriously injured by one fire, although a succession of fires gradually weakens the trees until they become sickly and finally die. The forests not quite ready for the axe, however, and the small-sized forests of the higher slopes are readily killed by fire; extensive burns of this kind were encountered.

It is probable that light ground fires even stimulate the reproduction of hemlock, for the very best stands were found where fire had

extended a short distance beneath the green forest. Evidence in many cases seems to indicate that the under-story of hemlock so common beneath old stands of fir was established as the result of ground fires. The root system of hemlock seedlings is shallower than that of fir. This means that hemlock must have soils moister near the surface than is necessary for the fir, a condition supplied by the cover of the older trees checking evaporation. Another condition, however, is perhaps more important, and this is the cover of moss which usually follows surface fires beneath old stands. The moss cover conserves the moisture of the surface soil and forms an ideal germinating medium for the hemlock. Fir also germinates in these moss beds, but it soon dies out on account of the shade, while the hemlock, capable of enduring more shade than the fir, persists. Where moss is lacking the bracken fern or salal forms the protecting cover. One also finds abundant reproduction of hemlock, as represented by seedlings, on burned-over areas along the margins of dense undergrowth which has escaped the fire. This undergrowth furnishes protection from strong light and keeps the surface soil moist, while the adjacent burned places have too much light and are too dry for the hemlock.

The most extensive Douglas fir reproduction was found on burned areas. In fact, it is believed that moderate burning is necessary to establish pure stands of fir. The young seedlings, to grow vigorously, must have considerable overhead light, a condition secured by burning away the slash and the dense growth of under-vegetation. On approximately half of the area covered by adequate reproduction the trees were either four years or 16 years old, with the two ages about equally divided, and nearly one-fourth was eight or twelve years old, and again the two age classes were about equally divided. Reproduction of these four ages was met with on every area where detailed studies were made, and general observation showed them to be prevalent over the entire region. That these stands originated as the result of fire is indicated by the fact that fire scars of the same age or one year older were found in every case on adjacent trees. The next most frequent stands were 24 and 30 years of age. Other ages of fir which had evidently risen after burning, were 10, 26, 34, 40, 44 and 50. Besides these are the two age classes mentioned on p. 8, namely, 70 years and 100 years. These, too, were accompanied by fire scars, of approximately the same age, on standing older trees. All this indicates that fires have been frequent and that they have been particularly extensive within the past 20 years, the period of the great development of the lumber industry and of settlement in the region. The average interval between widespread fires during this period is five years. Stands 30, 70 and 100 years old, evidently fol-

THIS AREA HAD 2,000 YOUNG TREES PER ACRE UNTIL IT WAS BURNED A SECOND TIME
Now it has only 20 living trees. The green forest, shown dimly in the background, is too far away to re-establish the forest on this area by seeding.

BURNED SEVERAL TIMES
The reproduction which followed the first fire has been killed. No seed trees are left to make another crop. Planting is the only method by which the commercial forest can be re-established on areas like this.

lowing fire, were also found in all the places of detailed study. Thus, in the 80 years previous to the period beginning 20 years ago, the average interval between extensive fires was 27 years. If the study of the life history of the forest at Powell river may be taken as a standard, the average interval between fires from 100 years to 360 years ago was 86 years.

From his investigations of the areas logged and burned within the past 20 years, the writer is convinced that young fir stands sufficiently uniform and dense to reproduce the original commercial forests are found on only about one-half of such areas. The reason for this is the occurrence of two or more fires on the balance of these areas. The disastrous effect of repeated fires is two-fold, through the killing of seed trees and through the destruction of the young forests already established. In regard to the killing of seed trees, it may be said that the first fire which brings the reproduction of fir into existence materially reduces the number of seed trees. Sample strips, totalling ten acres were made in areas burned once after logging and the average number of seed trees per acre was found to be as follows: Fir, 20; hemlock, 10; and cedar, 5; total, 35. Comparing this with the number given on p. 13 for the logged areas not burned, we find that, on the average, the total number of trees has been reduced by more than one-half. It would appear that hemlock and cedar suffer most. Sample strips, totalling 13 acres, were made on areas burned twice since logging and the average acre was found to contain 5 fir, 0·2 hemlock, and 0·5 cedar seed trees, a total of less than 6. This is only about one-sixth of the number on areas burned only once, and one-thirteenth of the number on logged areas not burned. At this rate the third fire would kill them all. The figures for the areas burned twice are descriptive only of the very best conditions, for sample strips were not made in the numerous large areas burned twice on which there were no seed trees, such areas sometimes being a mile square. Even six seed trees per acre would not be enough to seed an area in adequate numbers, since some of them are weakened by fire and will eventually die and others will be wind-thrown. Making allowance for the usual death rate, the number of trees left after the first burning is about the minimum to insure adequate seeding, even when the condition of the ground is favourable for germination.

A still more disastrous effect of a second burning, however, lies in the fact that it kills the young forests which are to be the forests of the future. Since the second fire, as shown above, has reduced the number of seed trees below the point of efficiency, no natural means are at hand to start the process of forest reproduction over again. Reproduction from the edge of the green forest may

gradually work its way across the areas on which the young trees have been killed, but the time consumed in doing this will be very long. therefore such areas will remain waste land for many years so far as the raising of timber in commercial quantities is concerned.

Moreover, good evidence exists for the belief that the dense stands of Douglas fir which follow the first fire come not from one crop of seeds, but from several crops that have accumulated on the ground. where they await a favourable opportunity for germination, that is, the removal of the over-shading trees and undergrowth. This has been clearly demonstrated by Dr. Hofman, on the Columbia national forest in the state of Washington. A large area was so severely burned in 1902 that practically all the seed trees were killed. In 1913, dense stands of young fir, not over eleven years old, were found two and three miles from any seed trees, and no relationship could be established between the amount of reproduction and the distance fr .n the seed trees, the reproduction often being more dense far from seed trees than near them. This would seem to indicate that seed was not blown to the areas of reproduction by the wind. If, on the other hand, the reproduction started from seed of trees escaping the fire, but dying since, then unburned cones or cone-scales should have been found on the ground beneath the stands. As a matter of fact, diligent search failed to discover any unburned cones or cone-scales, but they were always found in charred condition.

While most of the trees were eleven years old, indicating that they germinated the season following the fire which took place in the fall, some representatives occurred in every year down to five years old in 1913. Since the seed from which the trees sprang was not blown in by the wind, it must have lain in the litter and retained its capacity for germination for one to six years after the fire passed over. From the results of these and similar investigations, Dr. Hofman believes that the seeds of Douglas fir and hemlock can lie on the ground and retain their vitality for at least six years. This gives an opportunity for the accumulation of several seed crops from which the dense stands arise. In this connection it should be pointed out that, if the fire is sufficiently hot to burn the litter clean to the mineral soil, most of the seeds lying in the partially decayed vegetable matter would probably be destroyed and reproduction would fail. This is indicated by the fact that little or no reproduction followed on the area of the investigations where the fire was very severe.

No dense stands of reproduction were found by the writer as far as two or three miles from seed trees, but such stands were found one-half mile to three-fourths mile from them. These stands were just as dense, about 20,000 trees 16 years old to the acre, three-fourths

mile from seed trees as adjacent to them. It seems hardly possible that wind could distribute the seeds so evenly in one season, since practically all of the trees were of the same age. Moreover, several measurements were made to determine the distances to which seeds of fir were normally carried by the wind. The result of one of these may be given as a typical example. The area had been burned twice, eleven years and four years ago, and was uniformly covered with a light stand of bracken fern. A line was run approaching the green forest from a point one-fourth mile (20 chains) away and the seedlings counted on a strip 33 feet wide. Twenty to fifteen chains from seed trees, the seedlings occurred at the rate of 12 per acre; 15 to 10 chains, 50 seedlings per acre; 10 to 5 chains, 500 seedlings to the acre, 5 chains to the edge of the forest, 3,000 seedlings per acre. None of the seedlings were over four years old. If this be taken as typical, really efficient seeding of the ground does not take place at a distance of more than five chains (20 rods) from seed trees. These were medium-sized healthy trees on the margin of a forest well exposed to the light, the area seeded was in the leeward direction of the prevailing winds, the condition of the soil and soil cover furnished favourable conditions for germination, yet with several seed crops the trees could not raise more than 3,000 seedlings per acre at a distance of twenty rods, whereas the stands mentioned above had over six times as many trees at a distance twelve times as far from seed trees.

These facts, and the results of the investigations in the state of Washington, denote the probability of the dense stands of Douglas fir reproduction arising from several seed crops accumulated in the soil. The important point of these investigations is this: *Where the seed trees have been killed by the first or second fire, the dense stands of young trees killed by fire cannot be replaced by natural methods.* As stated above, one-half of the area logged over in the past twenty years is not now supporting adequate reproduction of commercial species because it has been burned at least twice.

Under-vegetation

Alder—The presence of alder, so commonly distributed on the seaward-facing slopes, usually acts as a deterrent and often excludes the reproduction of Douglas fir. Only once was fir found to be reproducing itself in potentially commercial quantities beneath alder, and this at the rate of 1,600 small trees on an acre, although the alder formed a complete crown cover. Fir is frequently associated with alder, however, but it occurs in groups or singly in the more open places. The fir is always conspicuous in this association, for, although it may be the same age, in the older stands it much surpasses the alder in height; also, as the

dark green of the fir foliage contrasts sharply with the lighter green of the alder foliage, it can be seen from long distances.

As stated above, the best reproduction of cedar was found under the protection of alder stands. A few of the sample plots may be described. Beneath alder twelve years old, cedar occurred at the rate of 2,000. fir and hemlock each at the rate of 160 per acre. A strip was run from the bottom to the top of an alder-covered slope, the alder being sixteen years old. At the bottom it formed a complete crown cover, and there were beneath it 3,700 cedar on an acre. About half way up the slope, where there were frequent open patches in the crown cover, cedar occurred at the rate of 1,260 per acre, fir 1,000. and hemlock 240 on an acre. Near the top of the slope the alder formed not more than one-half the crown cover and there were 1,400 fir, 940 cedar and 20 hemlock on an acre. As the alder disappeared the fir became more abundant, until finally it reached 2,200 per acre. In another place beneath a complete crown cover of alder 24 years old, were found 86 cedar, 28 hemlock and 8 fir on an acre. These were sixteen years old. The area also contained 24 fir trees, the same age as the alder, which surpassed it in height by twenty feet. One often found more than twice as many dead as living cedar trees beneath the alder, indicating that the shade was too heavy.

No sample plots were made in the younger stages of hemlock reproduction beneath alder, but their presence was frequently noted. In a stand twenty years old hemlock occurred at the rate of 800, balsam 200, and fir 60 per acre. Beneath another stand of alder 25 years old there were 1,600 hemlock, 1,280 cedar, 40 fir and 10 spruce saplings on the average acre.

On flats not far above tide-water and along streams alder stands, with their under-vegetation, occur in such density and luxuriance of growth as entirely to exclude the reproduction of commercial trees. Often a secondary cover of vine maple and a third layer of bracken fern or salmon berry shut off most of the light which gets through the crown cover of the alder.

Salal—An undergrowth of salal is found almost everywhere in the more open forests; it does not occur as a rule beneath the dense second growth stands, and it does not usually form a complete cover on areas severely burned. It seems to grow most luxuriantly in conditions of medium shade. Light ground fires seem to stimulate its development and heavy fires to retard it. When not much more than a foot high, and when there are spots of bare soil or patches of moss, it makes favourable conditions for the germination of all the commercial trees. For example, a square yard plot containing 150 shoots of salal had

SLASH LEFT ON THE GROUND AFTER LOGGING.
The slash not only increases the fire hazard but it makes conditions unfavourable for th reproduction of Douglas fir.

YOUNG FIR TREES ON AN AREA LOGGED AND BURNED ONCE.
They are sixteen years old and occur at the rate of 2,000 to the acre.

thirteen fir seedlings four years old, while on an adjacent plot under the same conditions, with salal waist high, no fir seedlings could be found, but there were six cedar seedlings. Numerous plots of this kind were made with like results. Cedar, hemlock and fir seedlings, however, were found in the dense larger salal stands where a fallen tree had crushed down the brush. The most luxuriant stands of salal on logged areas were on those not burned and often they were so dense as to make walking through them difficult. There was no adequate reproduction of commercial species on such areas.

Bracken Fern—The bracken fern, although very commonly distributed in nearly all conditions of shade and soil, forms the most extensive thickets on the burned areas, but it reaches its most luxuriant growth in pockets and depressions and upon moist flats, where there may be as many as 30 stalks on a square yard. These cast too much shade for the reproduction of fir, but not for that of cedar and hemlock. As generally distributed on old burns, it is not sufficiently dense to prevent the establishment of fir beneath it. In fact, with its divided leaves making about half-shade conditions, the plant makes favourable conditions for young fir. Where there were as many as 20 stalks to the square yard, fir seedlings four years old were found at the rate of 25,000 on an acre.

RECOMMENDATIONS

From a consideration of the statements on the preceding pages, it is evident that light burning of the slash and the dense undergrowth gives the best reproduction of Douglas fir. The two extremes, namely, too severe burning and no burning at all, should be avoided. This condition of affairs leads to two recommendations, namely, the regulated burning of the slash and of the dense under-vegetation, and a more rigid fire protection on the areas already covered with young growth.

Against the necessity of regulated burning of slash, it may be argued that in spite of the unregulated burning of the past, sufficient reproduction of fir to meet the requirements of the future has resulted. It appears so to the casual observer, especially if he observes only along the routes of travel, but to the investigator who studies conditions throughout the larger burned areas comes the conviction that the greater portion of such areas do not support adequate reproduction. The good reproduction is not uniform, being very patchy in its distribution. Not more than one-half of the cut-over and burned-over areas studied by the writer supports reproduction of the densities indicated in the tables on pages 9 and 11, the amount necessary to establish the commercial forest.

There is little doubt of the necessity of burning the slash and under-vegetation in order to get an adequate and uniformly distributed reproduction of fir on the logged lands. The ways and means of carrying out such operations, however, present serious difficulty. Under the depressed market conditions which have prevailed in British Columbia for several years past it seems inadvisable, even if it were possible, to add the cost of brush burning to the operating expenses of the limit-holder. Until the present over-production is relieved by enlarged markets, and until the margin of profit for the lumberman is increased, some temporary co-operative arrangement between the limit-holder and the Provincial Forest Branch might be advantageously made, the officers of the branch to conduct the slash burning and the limit-holders to furnish men. Since the object of the burning is as much to remove the luxuriant under-vegetation as to destroy the slash, broadcast burning is the proper method. Practically the only expense in this is the labour necessary to prevent the fire spreading beyond bounds. The numerous hauling lanes made by the steam logging operations almost universally employed on the coast, the spurs of the logging railways, moist flats and creeks furnish many natural fire breaks, conditions which lend themselves to comparatively safe broadcast burning. In addition, because of the heavy stands of timber, the area cut over in any operation in a year is comparatively small. Under proper conditions of dryness one year's logging operation could be burned over in a day or two, and a few men could control it. Therefore, the cost of slash burning would be comparatively small. In British Columbia small areas of Engelmann spruce and lodgepole pine have been burned experimentally at a cost of two and one-half cents per thousand feet. In the mixed coniferous forests of California, the burning of slash after it has been piled, costs three cents per thousand feet. According to Leavitt, broadcast burning has been done for twenty-five cents an acre, but, in most cases, it would probably cost from five to ten cents per thousand feet of lumber cut.

The second recommendation, namely, the better protection of the reproduction of fir already established, is based on the fact that second and subsequent fires have already destroyed about one-half of the fir reproduction originally established. The largest number of fires on such areas have occurred in the past twenty years. It is clearly evident that this cannot be allowed to continue, if a future supply is to be obtained from the present young growth.

While the forest protection service of the Provincial Forest Branch is very well organized and very efficiently administered, it has not, at present, the men or the money to give the young growth the protection which it deserves. In fact, from the standpoint of conservation, it

would prove a better investment, in the long run, if necessary, to withdraw some of the protection from the mature timber and concentrate it upon the young growth. Fire in young growth is much more disastrous than in old growth. The large mature fir trees are so fire-resistant that only a fire of exceptional intensity kills the majority of the trees. Even if commercial timber is destroyed, the forest-productiveness of the land is not destroyed, for, as we have seen, the first burning stimulates rather than retards the reproduction of Douglas fir. On the other hand, an ordinary fire kills the majority of the trees in a young stand. For reasons stated above, when young growth is once killed, it does not re-establish itself in commercial quantities on the same area and the result is idle non-productive land. Therefore, from the standpoint of the future forest-productiveness of the province, it would be better to concentrate the energies of fire protection on the areas of young growth.

The third recommendation is in reference to growth studies upon young fir. These are necessary in order to forecast future yields, and, as yet, very little work of this kind has been done upon trees below the present commercial size. The rate of growth is apparently remarkably rapid in certain situations and as remarkably slow in others. Studies should be made to determine the cause of this. The object could doubtless be best attained by establishing permanent sample plots, and investigating the various factors through a series of years. A related problem is that of the influence of density upon growth. Some of the stands of reproduction are evidently too dense to get the best commercial results in the future. Different degrees of thinning could be made upon permanent sample plots and the proper density for the best growth in this way determined.

The fourth recommendation is in regard to publicity as to the value of young growth and the necessity for its protection. The Forest Branch is to be highly commended for its publicity work in regard to forest protection and for the resultant attitude of the people toward forest fires. It is in striking contrast to the stolid indifference generally exhibited in the matter by the people of eastern Canada. This public demand for protection, however, as a rule is applied only to the mature timber. It should be extended to the young growth. By means of literature and placards similar to those already in use, the Forest Branch should educate public opinion to appreciate the value of the young growth.