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Annual Report

1941

ANNUAL REPORT

1941

FOREST INSECT INVESTIGATIONS

VICTORIA, B.C.

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Report of Forest Insect Investigations, Victoria, B.C., in 1941.

INTRODUCTION

The Victoria unit of Forest Insect Investigations was organized in 1940 to handle forest insect problems on the islands and coastal district of British Columbia west of the Coast Range. In order to provide an immediate staff, Mr. K. Graham was transferred from the Vernon unit, and M.L. Prebble from the Fredericton unit, in June and July of 1940. In co-operative arrangements for the establishment of the service, the British Columbia Forest Branch provided a building at the Cowichan Lake Forest Experiment Station, and Division of Entomology financed the alterations needed to fit the building as a field laboratory.

The season of 1940 was spent in becoming familiar with forest conditions in the Cowichan Lake and other areas in southern Vancouver Island and in the lower Fraser valley. Various insect problems of interest to foresters in the Forest Branch were investigated in a preliminary manner, some projects carried out by W.G. Mathers from the Vancouver sub-laboratory were examined with a view to their continuation, and various new problems were considered, preparatory to drawing up plans for intensive investigations to be undertaken by the Victoria unit.

A number of long time projects were commenced in the 1941 season. These include (a) ambrosia beetle bionomics, damage and control, on which work in 1941 was carried out at Great Central Lake in co-operation with Bloedel, Stewart and Welch; (b) bionomics of and damage caused by Peronea variana in the McConnell Creek and Cottonwood Creek areas, with supplementary observations at other localities; (c) damage caused by Pissodes sitkensis in spruce plantations at Green Timbers, Echo Lake, and in natural stands, in relation to ecological factors; (d) and (e), the role of insects in seed production and in seedling establishment, in co-operation with foresters of the Provincial Forest Branch. Observations were also made on Dendroctonus pseudotsugae and other forest and shade tree insects as occasion permitted. Among these were the satin moth and the European lecanium scale, which were of particular interest in regards to parasitism by introduced parasites.

In addition to co-operative effort outlined in the foregoing paragraph, we have had helpful co-operation with Mr. H.F. Olds, of the Plant Protection Service, Vancouver, in connection with European pine shoot moth scouting; with Mr. R. Glendenning, of Field Crop Insect Investigations, Agassiz, in connection with scouting for European lecanium scale; and provided information and parasite material from the satin moth and the black-headed budworm to Mr. A.B. Baird, of the Belleville Laboratory, in connection with the establishment of colonies of parasites in other parts of Canada.

The present staff of two investigators is adequate only for carrying out the preliminary phases or restricted portions of the program of projects described in this report. For the development of the Forest Insect Service in this area of concentrated forest wealth and to maintain steady progress in the investigations, seasonal and clerical assistance is particularly required. It is to be hoped that deficiencies in staff, equipment, and quarters may be corrected as soon as circumstances permit.

E. 30.20-1 and E.30.20-2 Ambrosia beetles; bionomics, deterioration and control. M.L. Prebble and K. Graham.

The following progress report, which was distributed to cooperators and interested parties in February, 1942, summarizes the principal results of the 1941 investigations.

PRELIMINARY REPORT, AMBROSIA BEETLE INVESTIGATIONS

Great Central Lake, Vancouver Island, B.C., 1941

INTRODUCTION

Insects constitute an ever present risk to felled and bucked timber left on the ground during the warmer months. There are several species of ambrosia beetles which are in flight at somewhat different periods during the summer. They bore rather different types of galleries into the wood and have decidedly variable rates of penetration. Also, there are various other kinds of insects which attack felled and bucked timber in company with the ambrosia beetles, having as a rule a slower initial rate of penetration but which in the second season or later usually burrow quite deeply. Production losses, especially of clear knot-free lumber from the outer layers, may be serious where logs have been left too long before manufacture.

The investigations reported on here were undertaken in order to supply information on the relative importance of the various species of insects and their rate of penetration under varying conditions, and also to investigate the possibilities of preventing attack. Studies previously conducted on ambrosia beetles in British Columbia by officers of the Division of Entomology, Dominion Department of Agriculture, had brought out several important facts. In relation to the control of ambrosia beetles in freshly cut lumber, G.R. Hopping and J.R. Jenkins (1933, Can. Dept.Int.,For.Serv.Circ.no.38) determined minimum periods of kiln-drying at various temperatures and a constant relative humidity of 80%, in order to cause complete mortality of the insects contained in 3-inch lumber, as follows: 9 hours at 120 degrees F., 2½ hours at 140 degrees, and 1½ hours at 150 to 160 degrees. Air-seasoning did not prevent the development of a large proportion of the insects contained in the lumber at the time of sawing. In studies of the effect of time of felling upon ambrosia beetle attack, W.G. Mathers (B.C. Lumberman, August, 1935, p.14) found that logs present in the woods from the first of April to the last of September were almost certain to be attacked by one or more species of the beetles, regardless of the degree of seasoning in the logs, which would vary in relation to the time of felling.

Freedom from attack could only be assured by removal of logs before the flight period. In other unpublished studies, Mathers investigated the possibility of control by preventive sprays (various oils, lime sulphur, etc.) applied to the bark surface of hemlock logs, but discovered no spray that gave more than very temporary or only partial protection. Inflammable mixtures could not be used under usually existing conditions.

With this background, the present studies were undertaken with full realization of the difficulties of the problem and of the improbability of discovering any practical solution. It was believed, however, that there was a need for a more accurate determination of the actual depth attained by the insects in relation to time of attack and subsequent interval to manufacture, in order to bring out the importance of time element as clearly as possible. The collection of such information, to have any general applicability, is necessarily a gradual process, requiring more than one season especially where, as in the present circumstances, only a part of the investigators' time can be devoted to this particular problem. Some experiments were also undertaken to determine whether attack might be prevented by treatment of the wood prior to felling.

The investigations were carried out in marginal timber bordering a 1937 cut near Thunder Bay, Great Central Lake, on holdings of Bloedel, Stewart and Welch, Ltd. To Mr. J.W. Challenger, Felling and Bucking Supervisor, and to many other members of this organization, we gratefully acknowledge our indebtedness for assistance in transportation and accommodation and for continued interest in the progress of the investigations.

WOOD-BORING INSECTS

Three major groups of insects, viz. barkbeetles, the woodborers and the ambrosia beetles, occurred in hemlock logs at Great Central Lake in 1941.

Barkbeetles

This group includes many species which live in the cambial region and occasionally score the wood surface lightly. The barkbeetles are of no importance as agents of deterioration in felled timber. The species *Pseudohylesinus tsugae* Sw. occurred commonly in hemlock logs that were put down in April and May. The first brood galleries were started in May.

Wood-borers

Four types of wood-boring larvae were found in the hemlock logs, viz. grubs of long-horned beetles (Cerambycidae) and of the metallic wood borers (Buprestidae), which typically feed for some weeks in winding galleries between the cambium and wood surface before entering the wood; and grubs of a beetle (Serropalpus sp.) and of a wood wasp (Siricidae), both of which as young larvae bore directly into the wood, leaving no external evidence of attack.

The wood-borers, though present in considerable numbers, did not penetrate deeply enough in the first season to warrant detailed treatment of the data.

Ambrosia Beetles

Four species of ambrosia beetles were recorded during the observations in 1941. *Gnathotrichus sulcatus* Lec. was by far the most important under the conditions obtaining in the experimental area at Great Central Lake. *Platypus wilsoni* Sw. was less numerous but bored to great depths in a short period. The other two species were rare or absent in the experimental logs.

Trypodendron cavifrons Mannh.: The beetle is about 3½ mm. long by 1¼ mm. wide, very stout, brown with light coloured longitudinal bands on the back. The known hosts include Douglas fir, hemlock, balsam, pine, spruce and cedar, as well as birch and alder. The beetles become active early in the spring. Galleries were being cut into Douglas fir and hemlock logs on the ground, and in the exposed part of logs in the water, at Franklin River, Coleman Creek, Port Alberni and Great Central, by April 1st. Some galleries were already bored to a depth of 1/2 - 3/4 inch into the wood. The beetles occasionally enter logs through exposed wood surfaces in addition to the usual entry through the bark. The galleries typically extend to a depth of about an inch radially, and are then directed concentrically with the rings. Numerous "cradles" in which the young develop occur along the parent galleries. The galleries and cradles become conspicuously dark-stained with ambrosia fungus. This beetle requires wood in a partially seasoned condition and did not occur in hemlock logs put down in 1941, though it very probably will invade these logs in 1942.

Xyleborinus tsugae Sw.: This is a minute species, only about 2 mm. long by 2/3 mm. wide, more or less uniformly dark brown. The known hosts include Douglas fir and western hemlock. The entrance galleries are the smallest of those caused by the ambrosia beetles. They are enlarged at some depth in the wood into a general chamber in which the developing larvae feed in congress upon the ambrosia fungus. New attacks were noted in May and depths as great as 1½ inches were attained by autumn. Occasionally this small beetle made use of galleries abandoned by *Gnathotrichus sulcatus*, extending the abandoned gallery deeper into the wood. *Xyleborinus* was comparatively scarce in the hemlock logs studied in 1941.

Gnathotrichus sulcatus Lec.: The beetle is about 3½ mm. by 1 mm., uniformly dark brown. Known hosts include Douglas fir, grand fir, western hemlock, spruce, pines and cedar. The galleries extend radially for a short distance, then are directed concentrically at successive depths at intervals of about ½ to 1 inch. Many beetles constructed three or four of these lateral galleries in addition to the radial gallery in 1941. The young develop in cradles along the lateral galleries, some of which extend for eight or ten inches around the stem. Adults were active at Great Central Lake by early April, many galleries being started by the middle of the month. Additional attacks occurred in May and later in the summer; a small number were started after the end of August, and some of the beetles were still throwing out boring dust on Nov. 27. Some beetles enter logs at the end section, others where bark has been dislodged, but the more common habit is to enter through the bark.

Platypus wilsoni Sw.: This is the largest of the ambrosia beetles, about 5½ mm. long by 1⅓ mm. wide, dark brown, somewhat flattened. Known hosts include hemlock, grand fir, amabilis fir, Douglas fir and spruce. The galleries have the greatest diameter among those caused by native ambrosia beetles. They proceed more or less radially and ultimately reach a depth of about a foot or more. The beetles overwinter in the galleries and in the following year construct winding lateral branches. Eggs are deposited freely in the galleries and the ensuing grubs wander about in the galleries feeding on ambrosia fungus which grows on walls. At full growth the larvae cut cradles off from the main galleries, and the final developmental stages are passed therein.

This species comes into flight during late July or August and attacks occur over a period of about a month. New galleries were first noted in hemlock logs at Great Central Lake in late August and were already extended to a maximum depth of 4¾ inches. By November 30, a few galleries had attained a depth of 6 inches, and were actually much longer than indicated by this radial measurement.

This species was rather uncommon in 1941, occurring in only three logs out of over 50 that were available for attack during the flight period.

EXPERIMENTS ON PREVENTION OF ATTACK

The experiments on prevention of attack in the 1941 investigations were designed to determine whether wood could be made immune to ambrosia beetle attack by means of impregnation of the living sapwood with chemicals poisonous or repellent to the beetles. Much work has been done on the injection of chemicals into trees for such purposes as studying circulation within the tree, preservation of colouring of the wood, and the control of barkbeetle broods already established in the cambial region; but the question of ambrosia beetle control by such means seems to have received little attention. The technique has been extensively and successfully used for the control of barkbeetle outbreaks in various parts of the United States (Craighead and St.George, 1938, Jour.For. 36: 26-34; Bedard, 1938, Jour.For. 36:35-40; Whitten and Baker, 1939, Jour.Econ.Ent. 32:630-634). It consists essentially of attaching a rubber receptacle about the upright stem at a point where the ends of the vessels in the outer layers of wood have been exposed by cutting or sawing. the chemical in water solution is poured into the receptacle and is absorbed by the exposed vessels.

Twenty western hemlock trees at Great Central Lake were treated with zinc chloride or copper solution in three series. The first series consisted of ten trees treated in early April, the second series of seven trees treated in late May, and the third series of three trees treated in late August. Comparable check trees were included for each series of treated trees, nine check trees being studied altogether. A convenient time after the initial treatment, the trees were felled and cut into 10-foot log lengths. Sample discs were taken at 10-foot intervals in order to determine, by means of chemical tests, how far up the trunk and in what density the chemical had been absorbed. Finally, one-foot sections were cut from representative log lengths at successive intervals for detailed analysis of the insect attack. The data recorded for each section included 1) superficial area, 2) condition of the cambium, 3) number of attacks by each species or type of insect, 4) condition of the insect, brood or burrow (i.e., living, dead, gallery abandoned, etc.) and 5) the depth of penetration of all or of a representative sample of the galleries, to the nearest 1/16 inch.

Information of a more general character on the various insects found in the wood samples has been given in an earlier section. Conclusions relating to the effect of various factors upon impregnation, and to the effect of impregnation upon insect attack, are noted in the following paragraphs.

1. The factors which might be expected to influence absorption to varying heights and in varying degrees in the sapwood of well-crowned healthy trees include the kind and amount of chemical, amount of water used as a carrier, the nature of the cut into the sapwood, and the season of treatment.

(a) The two chemicals used were zinc chloride, commercial, in powder form, and copper sulphate, commercial, in crystal form. The evidence suggests that other things being equal, better distribution throughout the sapwood may be obtained with copper sulphate. Dense uniform deposits to a height of over 100 feet were obtained in one tree with this material. Some of the trees treated with zinc chloride approached this performance however, with moderately heavy and fairly uniform deposits to a height of 90 feet.

(b) "Paste" applications of zinc chloride were unsatisfactory, giving poor impregnation even as low as 20 feet above the point of treatment. Best results were obtained with the largest quantities of chemical and of water; in the case of zinc chloride this was about .19 pounds chemical and .14 quarts water, and in the case of copper sulphate, about .17 pounds chemical and .23 quarts water, per inch of circumference at the point of treatment. These upper limits were dictated only by the size of receptacle available.

(c) Saw cuts to a depth of ½ inch and also 1½ inch, as well as V-shaped axe cuts to a depth of ½ inch, were tried. The nature of the cut appeared to be unimportant, but the depth of the cut was important since the thickness of the ring of impregnated wood tended to be roughly the same as the width of exposed vessels. This is to be expected from the known facts of circulation within a tree trunk.

(d) Among trees which showed the most satisfactory impregnation, were ones treated on April 3, on May 20 and on August 26. Apparently within the limits of April to August, at least, there are no seasonal restrictions on satisfactory absorption.

2. The bark of treated trees seasoned more rapidly, following death of the cells due to the chemical, than the bark of untreated check trees. Seasoning was also more rapid in the lower portions of the trunk where impregnation was generally more complete than farther up in the crown. Similar trends occurred in browning and dropping of foliage. The rate of seasoning had considerable influence upon insect attack in that rapidly seasoning treated logs became suitable for general attack earlier than check logs.

3. It is of interest to determine the effect of impregnation upon barkbeetle attack, even though these insects are of secondary interest in the present study, because of the fact that other investigations on the effect of chemical injections have dealt largely with barkbeetles. The species Pseudohylesinus tsugae occurred commonly in treated and check logs put down in April. Sample sections of 36 logs were analyzed in June, August and November. Logs were classified as having good impregnation when over 50% of the periphery in the end sections had a heavy deposit of the chemical; medium impregnation, when about 50% of the periphery had at least a medium deposit; poor impregnation, when less than half of the periphery had a medium or lighter deposit. Data on the average density of attack and the degree of abandonment of the galleries (non-productive galleries) in logs segregated according to the nature of the impregnation, are summarized in table 1.

(a) The density of attack did not increase after June, since flight of these barkbeetles was over by the time the first analysis was made. The results for the treated logs seem to imply a causal relationship between degree of impregnation and density, heavy

Table 1.

Summary of density of attack and percentage of abandonment of galleries, *Pseudohylesinus tsugae*, in logs of the first series. Great Central Lake, 1941.

	June examination		August examination		Nov. examination	
	No. of attacks sq. ft.	% of galleries abandoned	No. of attacks sq. ft.	% of galleries abandoned	No. of attacks sq. ft.	% of galleries abandoned
Test logs						
(a) good impregnation	0.5	0	0.9	63	0.8	39
(b) medium "	4.4	17	4.6	9	4.3	35
(c) poor "	8.3	37	6.9	33	7.5	52
Check logs	2.4	95	1.6	88	1.8	80

impregnation discouraging attack. This relationship was however entirely spurious, and incidental to the main factor influencing attack, which appears to be bark thickness; attacks were concentrated in the upper trunk where bark is thin. Impregnation was poorest in these upper levels, and heaviest in lower, thick-barked sections of the trunk. The average density of attack for check logs was comparatively low because (i), logs from all parts of the trunk are included, there being no segregation of check logs into categories related to bark thickness, and (ii), seasoning of the bark of check trees was very slow and extended into and beyond the period of beetle flight.

(b) The degree of abandonment of galleries without deposition of eggs, was related to seasoning of the bark, and thus only indirectly to degree of impregnation. A majority of attacks made in sappy barks were non-productive due to the parent beetles being drowned or to their abandonment of the burrows at a very early date. This was particularly the case in check logs.

(c) There was a partial survival of some broods to the young adult stage, in logs known to have a medium impregnation of the chemicals.

(d) These results with <u>Pseudohylesinus</u> barkbeetles in western hemlock are at variance with results obtained by other investigators with other species of barkbeetles, especially <u>Dendroctonus</u> spp., in other host trees. An explanation for this is not yet at hand.

4. Analyses of attacks by the ambrosia beetle <u>Gnathotrichus sulcatus</u> are summarized for two series of logs put down in early April and late May in tables 2 and 3 respectively. The data for the second series are not as extensive as could be desired, particularly for occupied galleries, but this was an unavoidable consequence of the very high abandonment in these later galleries. Gaps in table 3 indicate that the records are so meagre that to include them would only be misleading. The main conclusions regarding the <u>Gnathotrichus</u> attack are as follows:

(a) Attack occurred earlier and in greater density in treated than in check logs. This was apparently due to the earlier seasoning of chemically killed bark. The density of attack increased somewhat from June through August to November in all types of logs, but remained heaviest in logs in which the best impregnation, and hence the most rapid seasoning of the bark, had been secured.

(b) A large proportion of the beetles died in or abandoned the galleries without depositing eggs and before the galleries attained what might be considered their normal depth. Close to 70% of the galleries started in the first series of logs were not completed, and over 90% of those started in the second series of logs.

Table 2

Summary of density of attack, percentage of abandonment and depth of galleries, *Gnathotrichus sulcatus*, in logs of the first series. Great Central Lake, 1941.

(Average and maximum depth of galleries expressed in 1/16's inch)

	June examination						August examination						Nov. examination					
	attacks sq.ft.	% abandoned	Depth occupied galleries av.	Depth occupied galleries mx.	Depth abandoned galleries av.	Depth abandoned galleries mx.	attacks sq.ft.	% abandoned	Depth occupied galleries av.	Depth occupied galleries mx.	Depth abandoned galleries av.	Depth abandoned galleries mx.	attacks sq. ft.	abandoned	Depth occupied galleries av.	Depth occupied galleries mx.	Depth abandoned galleries av.	Depth abandoned galleries mx.
Test logs																		
(a) good impreg.	3.31	76	13.7	21	10.8	23	4.17	79	23.0	40	10.1	29	4.85	69	35.6	96	14.3	35
(b) medium impreg.	3.36	47	14.5	31	7.6	14	3.58	71	32.0	49	16.2	48	4.68	(26)	42.5	56	22.0	53
(c) poor impreg.	1.70	18	12.2	29	9.5	29	3.58	50	19.4	48	13.3	27	4.09	62	27.0	53	16.3	40
Check logs	1.21	15	10.7	24	7.0	13	2.34	49	19.9	43	14.9	28	2.81	69	28.5	47	17.9	56

Note: Value in parenthesis based on meagre data, not considered reliable.

Table 3.

Summary of density of attack, percentage of abandonment and depth of galleries, *Gnathotrichus sulcatus*, in logs of the second series. Great Central Lake, 1941.

(Average and maximum depth of galleries expressed in 1/16's inch)

	August examination						November examination					
	Attacks sq. ft.	% abandoned	Depth occupied galleries av.	mx.	Depth abandoned galleries av.	mx.	Attacks sq. ft.	% abandoned	Depth occupied galleries av.	mx.	Depth abandoned galleries av.	mx.
Test logs												
(a) good impreg.	3.86	94	10.7	14	11.1	24	4.47	99	x	x	12.4	32
(b) med. impreg.	2.59	95	x	x	6.8	12	3.40	92	x	x	9.3	32
(c) poor impreg.	1.29	(100)	-	-	16.4	27	1.74	90	x	x	12.2	33
Check logs	(0.08)	x	x	x	x	x	(0.25)	x	x	x	x	x

Note: Values in parenthesis based on meagre data, not considered reliable.

'x' indicates data too few to justify tabulation.

Although extensive abandonment occurred first in well impregnated logs (table 2, June analysis), this was due to the more advanced attack in such logs. Later in the season, the percentage of abandonment in check logs was about the same as in treated logs.

(c) The average depth of occupied galleries, measured from the wood surface, increased from about 11 to 14 units (11/16 to 14/16 inches) in late June to about 27 to 42 units in late November. Apart from the galleries in medium impregnated logs, which inexplicably were significantly deeper than galleries in other categories of logs, there is no proof that the depth of galleries as of November was influenced by impregnation. For example, the difference between 35.6 and 28.5, representing depth in well impregnated and check logs respectively, is not statistically significant.

The greatest depth attained by *Gnathotrichus sulcatus* in the logs under observation in 1941 was 96/16 or six inches.

(d) The depth of abandoned galleries was consistently less than that of occupied galleries in the same log and at the same time. Though less serious than occupied galleries, particularly in respect of the general absence of lateral extensions from the main gallery, abandoned galleries cannot be ignored in deterioration studies.

(e) Part of the progeny of beetles which bored into well impregnated logs developed normally and had attained the adult stage by November.

(f) These results do not provide encouragement for a belief that ambrosia beetle damage can be prevented by treatment of the sapwood with zinc chloride or copper sulphate prior to felling. Incidentally, these materials are among the most satisfactory of a considerable number of chemicals reported by other investigators to be successful in barkbeetle control projects. The difference in results may be due to the food relationships of the ambrosia beetles, or to some effect peculiar to hemlock. Some additional research is planned to provide information on this point.

SCOPE OF FUTURE INVESTIGATIONS

The writers are of the opinion that a definite need exists for more intensive knowledge of the degree of damage likely to be caused by the various species of insects during the first year or two after felling. Deterioration rates over longer intervals would possibly be of value in special instances such as after fires or extensive blow-down. The question of short time rate of deterioration, however, must arise with great frequency under conditions of logging in the coastal area of British Columbia.

There is considerable room for improvement in the index of deterioration, since depth measurements represent only one aspect of damage. In the case of the ambrosia beetles particularly, the lateral extensions which arise from the essentially radial galleries occasion perhaps more serious damage than the radial galleries. Thus a log with only four or five attacks per square foot of surface, which if confined to radial galleries would perhaps not be very serious, may have the outer layers of the wood so riddled with the numerous and lengthy lateral extensions that it is impossible to obtain a clean radial cut. When depth is increasing at the lowest rate, later in the season, the boring of the lateral extensions is rapid. The difficulties of accumulating measurements involving both depth and lateral extension of ambrosia beetle galleries are considerable, especially where attacks are crowded, but it seems probable that some technique which would give the most useful type of information could be worked out.

It is our desire to be of service in this connection, accumulating data under various conditions of logging and at various intervals after felling, so that ultimately most of the more probable combinations of circumstances may be represented in a deterioration table. To this end we should welcome the opportunity to carry out periodic analyses of insect damage on logged areas where dates of felling are accurately recorded. Incidentally, the larger debris or cull logs of the ordinary operation would serve well for analysis, so that there need be little or no loss of timber values due to investigations of the type proposed.

E. 30.49-1 *Peronea variana* (Fern.); bionomics and damage.
M. L. Prebble and K. Graham.

The principal studies on *Peronea variana* in 1941 were carried out in the McConnell Creek infestation, which was of particular interest to the Forest Branch in relation to management plans for the valley, and in the Cottonwood Creek infestation, which occurs in an area of virgin timber not being operated at the present time. Separate progress reports were prepared for these two areas. In addition, some observations were made in other areas, and these are brought together in section (c). Finally, an annotated list of parasitic species reared from *Peronea* in 1940 and 1941 is included in section (d).

(a) REPORT ON INFESTATION OF PERONEA VARIANA (FERN.) in the McConnell Creek Area, 1940-1941

INTRODUCTION

This report summarizes information relating to the infestation of the black-headed budworm, *Peronea variana*, in the McConnell (Cascade) Creek area, obtained over the period Sept. 1940 to Sept. 1941, supplemented by detailed studies of radial increment of the three host trees back to the year 1920.

Trips into the infested area were made in September 1940, and in February, June, August and September 1941, providing fairly complete coverage of the essential facts of the seasonal development.

THE 1940 INFESTATION

The infestation, first reported by Mr. Harold Boucher in the summer of 1940, was in that year sufficiently heavy to cause the loss of about 10-20% of the new foliage of amabilis fir and about 75% of the new foliage of western and mountain hemlock, in an area of several square miles at the head of the valley. The infestation was considerably lighter farther down the valley and defoliation was scarcely noticeable in the margin of the stand just above the saw mill.

Moths were in flight early in September and many eggs were deposited on hemlock and balsam foliage. Subsequent counts indicated a density of approximately one budworm egg to every four buds of western hemlock, and to every 1½ buds of amabilis fir, in the middle portion of the infested area. The density was undoubtedly heavier farther up the valley, but it was not possible to secure counts. Despite the density relationship in relation to buds of the two hosts, indicated above, the density in relation to available food (the new needles) was much greater on western hemlock than on amabilis fir, owing to the great discrepancy in average size of the shoots of these two trees. This was reflected in the degree of defoliation of the two hosts concerned, in 1941.

THE 1941 INFESTATION

Mortality of budworm eggs before hatching in the spring was of rather small proportions. Minute parasites which overwintered in the budworm eggs caused mortality of about six per cent, and small numbers died from other causes. Hatching occurred during the first three weeks of June and many young larvae had entered unopened buds, or newly exposed shoots, by June 18. Sample counts on one western hemlock tree at that time showed some injury had already occurred in about 27% of the buds in the upper crown, and in about 8% of the buds in the lower crown.

Some of the young larvae were killed during early July by maturing parasites of a species (Ascogaster sp.) which overwinters as an egg in the budworm egg. Other budworm larvae were attacked during July and early August by adult parasites of several species, and by August 8, a disease had also become well established in the budworm population. Survival to the moth stage of nearly mature larvae collected at this time was only about 7-8%, and of pupae collected at the same time, only 3%. The low survival indicated by these figures was supported by an estimate (about 5%) based on numbers of insects taken in sample beatings in early August with emerged pupal skins taken in equivalent samples in early September. Very few moths were noted in flight during the four-day interval, Sept. 4-7.

Though the insect parasites were fairly numerous, the greatest cause of mortality in the budworm population was the disease which affected full grown larvae and pupae.

The 1942 budworm population is certain to be small and without practical importance so far as the condition of the stand is concerned.

DAMAGE TO THE STAND

The injury to the stand as of Sept. 1941 was restricted to loss of foliage and some loss of increment. Foliage injury amounted to nearly 100% loss of new foliage of western hemlock, about 75% loss of mountain hemlock, and about 50% loss of new foliage of amabilis fir, in the upper basin of McConnell Creek. Farther down the valley the defoliation injury was less severe and was practically negligible in the stand now being operated for shingle bolts. Nowhere was any tree mortality noted that could be attributed to defoliation injury.

Approximately 100 increment borings, at the rate of two borings per tree, were taken from each host species in the upper basin where the infestation was heaviest. Annual increment was measured for the period 1920 to 1941 for each core, and the data segregated for small, medium and large trees. Since there are no important differences in the growth patterns of trees of different size, it will be sufficient to treat of the pooled data for all trees within each species. The conclusions of immediate interest are as follows:

(1) Though western hemlock has been heavily defoliated of new growth in 1940 and 1941, there has been only a slight loss in radial increment so far, reflected chiefly in the 1941 ring. The effect on mountain hemlock is even less marked and of doubtful significance. Amabilis fir, moderately infested in 1940 and 1941, actually had an increased ring in 1941, due apparently to favorable moisture conditions.

(2) Variations in annual increment due to climatic variations tend to obscure the effects of insect attack. No entirely satisfactory check trees exist in McConnell Creek, apart from the three affected species, but an approximate solution of the problem may be obtained in the manner described herewith. Since amabilis fir has only been moderately defoliated, and shows as yet no decrease in increment due to recent feeding, it is possible to use the annual increment of this tree as a standard by which to interpret the growth curves for the two hemlock species. If the ratio "increment of hemlock : increment of balsam" is calculated for each year, we get a series of values which show the effect upon hemlock increment of factors influencing this tree only, variations due to climate being eliminated by the use of balsam increment as an annual denominator. Ratios for western and mountain hemlock show that current defoliation has retarded western hemlock increment slightly in 1941, but so far has had scarcely perceptible effect on mountain hemlock.

(3) The great depression of 1929, when western hemlock radial increment was only 33% of its 22-year average, that of mountain hemlock 44% of its 22-year average, and that of amabilis fir 57%, is of particular interest. The dry seasons of 1928 and 1929 were undoubtedly contributing factors for the depressed growth, but were not the sole cause. This conclusion is suggested by the variable decline in the three tree species, and moreover, the ratios of hemlock to balsam increment show a corresponding decline, proving the existence of some factor affecting hemlock much more than balsam. This suggests an insect with a preference for hemlock, of which there were two species, viz. the western hemlock looper (*Ellopia fiscellaria lugubrosa* Hlst.) and the black-headed budworm (*Peronea variana* (Fern.)) in outbreak proportions in the lower coastal area of the mainland in the general period 1928-1930. Both insect species show a preference for hemlock so the increment data

for this period can not at present be used to suggest which insect was most probably involved in the McConnell Creek area in the late 1920's. Ultimately this may be possible as knowledge of ring patterns caused by the two insects increases.

(4) The point of most practical importance is that the trees withstood in 1929 an evident weakening much more severe than has so far been reflected in the current *Peronea* infestation, without tree mortality. Increment may be reduced somewhat in 1942 as a result of existing injury to the crowns but there is no reason to believe that the stand will suffer any serious setback.

(b) INVESTIGATIONS OF PERONEA VARIANA (FERN.) in the Cottonwood Creek area, 1940-1941.

INTRODUCTION

The infestation of *Peronea variana* in the Cottonwood Creek area, discovered in August 1940, was in that year light at all points examined. Signs of feeding were evident at the upper part of the valley from an elevation of about 1700 feet to 2600 feet, but defoliation was heaviest on western hemlock at about 2200 feet, near the lower limit of the virgin stand. Even here it did not amount to more than 5% of the new foliage, and farther down the valley in the area of old logging the young reproduction trees of western hemlock were almost free of any signs of feeding. In the area of noticeable feeding, hosts in addition to western hemlock included mountain hemlock, amabilis and alpine fir, and Douglas fir.

Samples taken August 13 indicated that about 88% of the population had already pupated, the remaining 12% being nearly full grown larvae. In a small sample of 58 pupae, 60% were females and pupal parasitism was about 28%. Five parasite species were recovered, viz. *Actia* sp. which as a maggot occupies an integumental funnel in the side of the host larva; *Thysiotorus latifrons* Cushman, which is probably a secondary parasite; and three pupal parasites, *Itoplectis obesus* Cushman, *Phaeogenes hariolus* Cresson and *P. arcticus* Cushman. The recovery of *Itoplectis conquisitor* (Say) which was recorded in our 1940 report, is now known to be erroneous, being based on misidentification of certain specimens of the related species *obesus*.

Many eggs were deposited by the moths during August and September of 1940, and both the extent and intensity of the infestation were increased in 1941. So far as known, the area noticeably infested in 1941 did not exceed a square mile or so at the head of the valley, but rather heavy feeding occurred from the lower margin of the virgin stand at 2200 feet elevation up to the scrub growth above 3500 feet.

METHODS OF STUDY

Due to pressure of other work the investigations of the black-headed budworm had to be limited to observations and collections of material at more or less regular intervals during the developmental period. Ten such trips were made, May 14 and 28, June 7, July 10, 24 and 31, August 6, 15, 20 and 28. Material collected at these dates was reared at the Cowichan field laboratory for survival data and recovery of parasites.

Three locations within the infested area, representing various elevations and host species, were selected as observation stations. The descriptions follow:

Station A. elevation 2200 feet, margin of virgin timber just beyond old logging; slope moderate; stand consists chiefly of Douglas fir and western hemlock, with occasional trees of western white pine and western red cedar.

Station B. elevation 3000 feet, steep south slope; stand consists chiefly of western hemlock, mountain hemlock, alpine fir and amabilis fir, with some Douglas fir and yellow cedar. The trees are of fairly large diameter but approach the form of scrub trees at higher altitudes.

Station C. elevation 3500 feet, steep south slope; stand consists chiefly of western hemlock, mountain hemlock, amabilis fir, alpine fir and yellow cedar. The trees are short with rapid taper.

Most of the studies pertain to station A, only occasional visits being made to the other points as time permitted.

SEASONAL HISTORY

Hatching

Seasonal development in the infested area was considerably retarded in comparison with the Experiment Station at Cowichan Lake. On May 14 the new shoots of western hemlock at lake level (550 feet) were about 1/4 inch long, whereas at station A the buds were still enclosed, though swollen with scales conspicuously distended. About 3% of the eggs had already hatched, and partially developed embryos were visible in some others. The weather in May remained cool, and by May 28 the total hatch at Station A was only about 31%; most of the hemlock shoots were at this time 1/8 to 1/4 inch long, though some were still enclosed in the bud scales.

A third examination on June 7 indicated the total hatch to be 64%. Shoot development was not greatly changed from the condition noted on May 28, the average length being about 1/4 inch with the young needles still tightly appressed to the axis. Some larvae were already established in the shoots, and had caused a slight browning of the needles at the tip of the shoots.

At each examination date, unhatched eggs were brought to the field laboratory for further observation, providing the data summarized below.

Collection date	Total No. of eggs	Eventual hatch	Embryo developed but died	No development	Parasitized
May 14	117	23	85	8	1
May 28	242	191	43	7	1
June 7	253	201	48	3	1
Total	612	415	176	18	3*
%	100.0	67.8	28.8	2.9	0.5

(*Par'd eggs black; one parasite emerged, two died in pupal stage).

The death of so many developed embryos was undoubtedly due to desiccation, since no provision was made for keeping the needles and the eggs moist. Hence, the developed embryos should be added to the hatched eggs to provide the best estimate of total hatch under field conditions. This would be about 96%. Most of the failure to develop was apparently due to infertility (2.9%) and very little (0.5%) to egg parasitism.

Larval and Pupal Development

Data on the distribution of instars in representative samples of the population over the interval July 10-Aug. 15 are summarized in table 1.

The records indicate that larvae were present from mid-May (3% eggs hatched) to late August. This is a very protracted period for this insect, and was chiefly due to the cool weather of May and June which retarded early seasonal development. The data provide no evidence of a retardation at higher altitudes within the limits of 2200 to 3500 feet on the uniform southern slope represented in the three stations.

Pupation began about the third week in July and continued into late August. Emergence of the adults started in July, was heavy in latter part of August, and continued into September. Some oviposition occurred in August, but counts have not yet been made.

Table 1.

Distribution of larvae and pupae in samples of the population in the Cottonwood Creek area, 1941.

Date	Sta.	Host	No. in sample	% in different instars I	II	III	IV	V	Pupae
July 10	A	W.hemlock	518	---	0.8	10.8	79.4	8.9	---
" 24	A	" "	308	---	---	---	1.0	95.7	3.2
	B	" "	345	---	---	---	5.8	93.9	0.3
" 31	A	W.hemlock and D.fir	823	---	---	---	0.4	77.3	22.3
	B	W.hemlock-alpine fir	593	---	---	0.2	0.5	76.9	22.4
	C	Mt.hemlock	311	---	---	0.7	1.0	74.8	23.5
Aug. 6	A	W.hemlock	534	---	---	---	0.2	66.9	32.9
" 15	A	W.hemlock	770	---	---	---	---	5.5	94.5
	B	" "	470	---	---	---	---	3.0	97.0
	C	Mt.hemlock	366	---	---	---	0.3	6.3	93.4

Sex Ratio

The sex ratio is of general interest from the viewpoint of epidemiology. Some preliminary observations by K. Graham in 1941 indicate that the sex of the older larvae of Peronea variana can be determined macroscopically but it was not possible to undertake large scale sex segregation of the larval samples in 1941. However, the sex of pupae and moths that ensued in field samples of larvae and pupae was determined, with results summarized in table 2.

It is obvious that the calculated sex ratio (which is a value of importance with respect to the rate of population increase) will vary greatly in relation to the time and stage of material taken as a basis. Very late larval collections or pupal collections at either extreme are not reliable, since males tend to pupate and emerge earlier than females. The larval collections indicated that females made up 64.1% to 63.5% of the population prior to the period of pupation in the field; whereas female pupae comprised 47.8% of the total number of pupae taken in samples over a four-week period, and moths emerging therefrom consisted of 51.7% females. This last estimate is probably the closest to the true sex ratio of the moth population in the field. It would imply that female larvae had a greater mortality rate than males, if the larval sex ratio of about 64% is reliable. However, the extreme difficulty of having early and late sample lots proportionately balanced inherently weakens calculations of this kind, and the only way in which a precise determination of adult sex ratio in the field can be realized is by analysis of emerged pupal skins collected after emergence is complete.

Table 2.

Distribution of the sexes in various lots of budworms collected at Cottonwood Creek, 1941.

Expt No.	Stage collected	Date	Ensuing pupae MALE	Ensuing pupae FEMALE	Ensuing moths MALE	Ensuing moths FEMALE
	Larvae					
220 F	II - IV	July 11	10	8	10	8
221 F	IV - V	" 11	43	33	39	30
222 F	IV - V	" 11	90	68	81	59
224 F	V	" 24	169	207	120	173
225 F	V	" 24	125	99	108	58
226 F	V	" 24	114	105	94	86
230 F	V	Aug. 1	131	358	114	300
232 F	V	" 1	69	176	58	149
234 F	V	" 1	33	93	28	84
238 F	V	" 6	33	276	30	210
248 F	V	" 15	5	46	5	42
	Totals, larval collections		822	1469 64.1%	687	1199 63.5%
	Pupae					
231 F		Aug. 1	153	13	5	1
233 F		" 1	98	26	22	7
235 F		" 1	75	--	19	-
243 F		" 6	135	40	83	24
245 F		" 15	361	353	215	193
246 F		" 15	249	202	173	134
247 F		" 15	205	137	51	8
252 F		" 28	184	367	85	241
253 F		" 28	184	368	100	200
	Totals, pupal collections		1644	1506 47.8%	753	808 51.7%

NATURAL CONTROL

Control of the Egg

Egg samples taken in May and early June (cf. page 17) indicated that mortality was at least 3.4%, apparent infertility accounting for 2.9%, and egg parasites (presumably Trichogramma) for 0.5%. There may also have been some mortality of developed embryos in the field, but this phase could not be studied due to pressure of other work.

Control of the Larvae

Larval samples collected over the period July 11 to Aug. 15, and reared indoors in small cages, provided parasitism data summarized in table 3. The Braconid, Ascogaster sp. near provancheri D.T. was the commonest larval parasite. This species oviposits in the Peronea egg, and the full grown grub issues from the host larva, most commonly in the fourth instar. The larval parasite of second place, Angitia sp., also commonly issues from the fourth instar host larva. Thus the highest figures of percentage parasitism were obtained in collections consisting predominantly of fourth instar host larvae; parasitism at this stage was about 12% to 15%. Fifth instar larvae contained occasional specimens of at least 13 species of parasites as noted in table 3; the Tachinids included Phorocera tortricis and Actia sp. (probably interrupta). The last species was rare in the Cottonwood Creek area in comparison with McConnell Creek, where in 1941 it was plentiful in nearly full grown host larvae. In fact all parasites of the older larvae were scarce at Cottonwood Creek, the average percentage parasitism of fifth instar larvae collected from July 24 to Aug. 15 being only 1.25%.

The recovery of a/specimens few of Itoplectis obesus from host material collected in the larval stage is to be regarded as exceptional, since this parasite commonly attacks the pupal stage of the host (cf. table 4).

The predaceous stink bug, Podisus serieventris, was commonly taken in samples at Station A (2200 feet), but was not recovered at Stations B or C (3000 - 3500 feet). At Station A, as many as seven nymphs wer e recovered in beatings from a single tree, July 31 to Aug. 15, and occurred at the average rate of one bug to every 60 host larvae and pupae. Podisus adults were plentiful at the end of August.

Disease was not a factor affecting the field population. Practically all larvae appeared to be healthy and over 82% of 2472 fifth instar larvae collected from July 24 to Aug. 15 pupated successfully, and 67% eventually emerged as moths, despite rather unsatisfactory rearing conditions in a few lots.

Control of the Pupae

Parasite recoveries from pupal collections are summarized in table 4. At least 14 species were recovered, and this will be increased to fifteen if two unidentified specimens prove to be

Table 3.
Larval parasite recoveries, Cottonwood Creek, 1941.

[Corrections re Angitia and Campoplex made Dec 30/42. W.H.P.]

No. of parasites recovered by species

Expt No.	Sta.	Date	No. and stage of larvae	Inareolata sp.	Campoplex sp.	Angitia sp.	Ascogaster sp.	Exochus annulicrus	Exochus sp.	Agrypon sp.	Blaptocampus sp.	Hemiteles tenellus	Oncophanes atriceps	Meteorus trachynotus	Eubadizon pleuralis	Eubadizon gracile	Itoplectis obesus	Unidentified Hymenoptera*	Tachinid sp. **	% Parasitism
220F	A	July 11	4 II, 52 III, 71V	1	~~4~~ 1	~~7~~ 1	-	-	-	-	-	-	-	-	1	-	-	1	-	7.9
221F	A	" 11	131 IV, 17 V	-	~~1~~ 3	~~2~~ 0	11	-	-	-	-	-	-	-	-	-	-	4	-	12.2
222F	A	" 11	256 IV, 28 V	-	~~4~~ 6	~~10~~ 4	20	2	-	-	-	-	-	-	-	-	-	10	-	14.8
224F	A	" 24	455 V	-	-	-	-	-	1	1	-	-	-	-	-	-	1	1	1	1.1
225F	A	" 24	271 V	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	2	1.5
226F	B	" 24	274 V	-	-	1	-	-	-	-	-	-	-	-	-	1	-	2	1	1.8
230F	A	Aug. 1	559 V	-	-	-	-	1	-	-	1	1	-	-	-	-	-	-	-	0.5
232F	B	" 1	327 V	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	0.3
234F	C	" 1	170 V	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	0.6
238F	A	" 6	1 IV, 338 V	-	-	-	1	1	-	1	-	-	-	-	-	-	-	-	4	2.1
248F	A,B C	" 15	77 V	-	-	-	-	-	-	-	-	-	-	1	-	-	-	4	-	6.5
			Totals	1	~~1~~ 10	~~15~~ 6	32	5	1	2	1	1	1	1	1	1	3	22	8	

* Died in immature stages - ** Actia sp. and Phorocera tortricis are included.

Table 4.
Pupal parasite recoveries, Cottonwood Creek, 1941.

Expt No.	Sta.	Date	No. of pupae	Itoplectis obesus	Phaeogenes arcticus	Phaeogenes hariolus	Apechthis ontario	Pimpla ? exareolata	Pimpla n. sp.	Exochus annulicrus	Angitia sp.	Blaptocampus sp.	Amblymerus sp.	Hemiteles tenellus	Thysiotorus latifrons	Gelis sp.	Hemiteles apantelis	Mastrus sciculatus	Unidentified Hymenoptera *	% Parasitism
				No. of parasites recovered by species																
231F	A	Aug. 1	166	10	8	3	-	-	-	1	-	-	-	-	-	-	-	-	8	21.7
233F	B	" 1	124	17	3	3	-	-	-	-	-	-	-	-	-	-	-	-	7	24.2
235F	C	" 1	75	1	1	3	-	-	-	-	1	-	-	-	-	-	-	-	-	8.0
243F	A	" 6	175	29	3	-	-	-	-	-	-	1	-	-	-	-	-	-	1	19.4
245F	A	" 15	714	78	11	4	1	1	-	2	-	-	-	3	-	-	-	-	12	15.7
246F	B	" 15	451	49	12	1	1	-	-	-	-	-	-	1	1	-	-	-	4	15.3
247F	C	" 15	342	12	4	7	-	-	-	-	-	-	-	-	-	-	-	-	8	9.1
252F	A	" 28	551	47	20	1	-	-	1	-	-	2	-	15	1	1	-	-	20	19.6
253F	B	" 28	552	102	23	7	10	-	-	-	-	-	8	4	4	1	1	1	7	28.8**
		Totals	3150	345	85	29	12	1	1	3	1	3	8	23	6	2	1	1	67	18.6 Av.

* Died in immature stages.

**Based on killed pupae; several specimens of <u>Amblymerus</u> emerged from a single host.

distinct. Angitia sp. and Thysiotorus latifrons, which were recovered in small numbers from pupal hosts, sometimes issue from the larval instars. Itoplectis obesus was by far the most important pupal parasite, accounting for at least 59% of all parasitized pupae. Phaeogenes arcticus and P. hariolus were second and third in importance, and Apechthis ontario was a low fourth among the primary parasites. Hemiteles tenellus, which appeared in the later samples, and Thysiotorus latifrons, are probably secondary parasites. Average pupal parasitism was 18.6% but parasitism at Station C was significantly lower than at the lower altitudes, in the relation of 8.9% to 20.1%. Results at Stations A and B were quantitatively and qualitatively similar.

When the data are classified on the basis of the sex of the pupae, it is apparent that parasitism of male pupae was higher than that of females in the ratio of 20.9% to 16.0% (table 5). The difference is strongly significant, P being less than .01, but is at this time without adequate explanation.

There was considerable mortality of pupae beyond that caused by parasites. The data included in the following synopsis were obtained in samples reared inside, and indicate non-parasitic mortality of about 16% to 18% in the case of pupae reared from larvae which were collected in the field, and of about 30% to 33% among individuals collected as pupae in the field.

Mortality of pupae

	Males			Females		
	Total No.	% emerged	% non-par. mortality	Total No.	% emerged	% non-par. mort'y
Individuals collected in field as larvae	822	83.7	16.0	1469	81.5	17.8
Individuals collected in field as pupae	1644	45.8	33.3	1506	53.7	30.3

Most of the individuals which died without parasitism contained remains of partly developed imagos.

BUDWORM POPULATION AND DEFOLIATION INJURY

Various counts of the budworm population were made during the egg and larval and pupal stages, and while the data are not comprehensive they are of some value as an indication of population density.

Eggs and 1940 shoots were counted on a number of western hemlock branches at Station A on May 14, giving 18 eggs to 474 shoots.

If it be assumed that 1940 and 1941 shoots were equally numerous, this would indicate a density of one egg to 26 shoots.

In the weeks following hatching many of the larvae entered one newly exposed hemlock bud after another, frequently killing the shoots when they were only 1/8 - 1/4 inch long. Counts of western hemlock shoots at Station A on July 10 (cf. synopsis) indicated that about 32% of the young shoots had been attacked, with a concentration in the mid-crown section.

Table 5.

Classification of pupal parasitism by sex of pupae.

Expt No.	Male pupae Total No.	Parasitized No.	%	Female pupae Total No.	Parasitized No.	%
231 F	153	35	22.9	13	1	7.7
233F	98	22	22.5	26	8	30.8
235 F	75	6	8.0	-	-	—
243 F	135	32	23.7	40	2	5.0
245 F	361	72	20.0	353	40	11.3
246 F	249	46	18.4	202	23	11.4
247 F	205	20	9.8	137	11	8.0
252 F	184	52	28.3	367	56	15.3
253 F	184	59	32.1	368	100	27.2
Totals	1644	344	20.9%	1506	241	16.0%

Chi-square test of Independence
(frequencies expected on the theory of independence of host sex and degree of parasitism appear in parentheses).

	Male pupae	Female pupae	Totals
Parasitized	344 (305)	241 (280)	585
Not parasitized	1300 (1339)	1265 (1226)	2565
Totals	1644	1506	3150

Chi-square = 12.8, degrees freedom = 1, P is beyond .01

Counts of 1941 shoots, western hemlock, Station A, July 10, 1941

Position in crown	No.branches examined	No.1941 shoots	% of 1941 shoots attacked
upper crown	4	2598	32.9
mid crown	2	2984	48.6
lower crown	2	2627	15.2
	Total	8209	32.3%

The 2648 attacked shoots were examined in detail, yielding 538 Peronea larvae, or an average of one larva for every 4.93 attacked shoots, or one larva for every 15.2 new shoots of all sizes and conditions.

Subsequent samples were obtainedby the method of beating the foliage over a standard mat (7' x 7'). The data are summarized herewith:

Living *Peronea* obtained in beatings, Cottonwood Creek, 1941

Date	Station	Host	Larvae	Pupae	Total	Remarks
July 24	A	W.hemlock	ca. 250	ca. 10	ca. 260	
	B	" "	ca. 450	ca. 5	ca. 455	
July 31	A	W.hemlock	149	41	190	ave.of 4
	A	Douglas fir	44	9	53	
	B	W.hemlock	186	31	217	
	B	Alpine fir	274	101	375	
	C	Mt.hemlock	119	36	155	ave.of 2
Aug. 6	A	W.hemlock	90	44	134	ave.of 4
Aug.15	A	W.hemlock	8	144	152	ave.of 5
	B	" "	7	226	233	ave.of 2
	C	Mt. "	8	114	122	ave.of 3

Population density was greatest in the vicinity of Station B, at an elevation of about 3000 feet, but by most standards the infestation was "heavy" throughout the area.

The samples of Aug. 15 were taken with a modification of the usual procedure of beating, in order to provide a measure of the effectiveness of the method in recovering larvae and pupae of

Peronea variana. All the insects were cleared off the mat after a first normal beating, which consisted of about 10 to 12 stout strokes of a ten-foot pole. The same foliage was then beaten a second time with equal severity and the dropping insects again recovered. The results from 10 trees indicated that the larvae are dislodged more readily than the pupae, since the number of larvae and pupae taken after the second beatings amounted to 12.6% and 25.4% of their respective totals. Emerged pupal skins are not recovered equally as well as living pupae, since the wriggling movements of the latter play an important part in releasing the cremaster from its anchorage in the shelter. In all probability, it would be necessary to base studies of emerged pupae upon detailed examination of the foliage.

Defoliation injury varied considerably among the various hosts. At Station A, western hemlock was the preferred host and lost about half of the 1941 foliage. There was a lighter population on Douglas fir and injury was scarcely noticeable owing to the rapid growth of the shoots.

At Station B, defoliation was about equally severe on western hemlock, mountain hemlock and alpine fir; practically all new shoots were attacked and possibly three-quarters of the 1941 needles destroyed. Amabilis fir was rather lightly injured and Douglas fir hardly at all.

At Station C, medium defoliation occurred on western hemlock and mountain hemlock, whereas the injury on alpine fir and amabilis fir was concentrated in the tops of the tree crowns, which were conspicuously red at the first of August.

The influence of defoliation on radial increment has not been studied as yet, but will be investigated as the infestation progresses. Already there has been considerable bud killing on western hemlock. Many eggs were deposited in the autumn of 1941 and a further intensification of the infestation may be expected in 1942.

(c) PERONEA VARIANA IN OTHER LOCALITIES, 1941.

The black-headed budworm occurred in light to medium infestation locally, at a number of scattered points, as noted below:

Vancouver - on amabilis fir in the vicinity of Angus Park, on sitka spruce on the Point Grey Golf Course; on western hemlock and alpine hemlock, alpine fir, amabilis fir, grand fir, sitka spruce, engelmann spruce and Douglas fir in the University of British Columbia woodlot and adjacent Botanical Gardens.

Green Timbers - on western hemlock and sitka spruce.

Victoria - on grand fir in Beacon Hill Park, and on spruce in other parts of the city.

Courtenay - on amabilis fir in the Forbidden Plateau.

Great Central Lake - on western hemlock, the cones being especially eaten by the young larvae in May.

The Courtenay infestation, judging from the density of eggs in March 1941, was apparently a moderately heavy one but due to comparative inaccessibility and pressure of other work, could not be followed up during the summer. Of the other infestations listed above, only that at the University of British Columbia was of any considerable proportion. The infestation was first noted in the Botanical Gardens and adjacent forest on June 12, and defoliation was becoming noticeable, with about 10% - 20% of the new shoots of western hemlock affected, and some of the larvae already in the fifth instar. Subsequently the affected trees in the Gardens were treated by the caretaker and the infestation controlled, but the infestation in the woodlot followed its natural course. By Aug. 7 the western hemlock trees were quite brown, mature trees having lost up to about 75% of the new foliage; the loss in small sheltered trees was much less, in some not exceeding 15%. Larval collections from the U.B.C. infestation were notable for the recovery of two parasites (*Eubadizon pleuralis* and *E. gracile*) which were very rare in 1941.

(d) ANNOTATED LIST OF PARASITES OF *Peronea variana* Reared in British Columbia, 1940-1941

Appended to the following list of the parasitic insects, which are arranged by family, are some notes pertaining to the predator *Podisus serieventris*, and to a disease of the larvae.

ICHNEUMONIDAE

Angitia basizona (Vier.), Beacon Hill Park, Victoria, 1941;

larval host attacked, parasite adult emerged in late June and early July. The parasite was also recovered from Batodes angustoriana on ornamental yew in Victoria. Rare.

Angitia sp., ~~McConnell Creek~~, Vancouver (U.B.C.), Cottonwood Creek at 2200', 3000' and 3500', 1941.
Attack occured in the larval stage of the host, and the grub usually issued from the host larva, to spin a whitish cocoon; in a few instances the parasite adult issued from the Peronea pupa. Emergence in July and August. Occasional.

Agrypon sp., Cottonwood Creek, 2200' only, 1941.

Attack occurred in the larval stage of Peronea, and the adult parasite emerged from the host pupa in late August, early September. Rare.

Apechthis ontario (Cress.), McConnell Creek, 1940, Cottonwood Creek, 2200' and 3000', 1941.
Attack occurs in the pupal stage of the host, from which the adult parasites emerge from late August to October. In one instance, the parasite carried over in the host pupa, emerging in the spring. Occasional.

Blaptocampus sp., Cottonwood Creek, 2200' only, 1941.

Attack occurred in the larval stages for certain, possibly also in the pupa; adult parasites emerged from host pupa in late August and September. Rare.

Campoplex sp., McConnell Ck; Cottonwood Creek, 2200' only, 1941.

Attack occurred in larval stage, parasite grub issued from dead larval host and spun cocoon; adult emergence late July + early August. ~~Rare.~~ Occasional.

Exochus annulicrus Walsh, Cottonwood Creek, 2200' only, 1941.

Attacked host larvae, and adults emerged from host pupae in August and September. Occasional at this one collecting area.

Exochus sp., Cottonwood Creek, 2200' only, 1941.

Attacked host larva, adult emerged from host pupa in August. Rare.

Gelis sp., Cottonwood Creek, 2200' and 3000', 1941.

Winged males were recovered from Peronea pupae in Sept. and Oct. Rare.

Hemiteles apantelis Cush., Cottonwood Creek, 3000' only, 1941.

Adult recovered from overwintered host pupa. Rare.

Hemiteles tenellus Say, Cottonwood Creek, 2200' and 3000', 1941.

Attack occurred in host larvae for certain, possibly in host pupae as well; some parasites issued from the host larvae but the more typical habit was for adults to emerge from host pupae, during Sept. and Oct.; a few carried over the winter in host pupae. Of 24 specimens, all were females. Occasional, in the two collecting areas.

Hemiteles sp., Beacon Hill Park, Victoria, 1941.

Attacked the host larva, issued and spun cocoon, adult emerged in July. Rare.

Inareolata sp., Vancouver (U.B.C.), Cottonwood Creek, 2200' only, 1941.

Attacked the host larvae, issued and spun cocoons, emerged as adults in June and July. Rare.

Itoplectis obesus Cush., McConnell Creek, Cottonwood Creek, 2200', 3000' and 3500', 1940 and 1941, also Vancouver (U.B.C.), 1941.

Attack occasionally occurred in the host larval stage, and rarely, the parasite grub issued from the dead larval host; typically, however, attack occurred in host pupae from which the adults emerged in Aug., Sept. and Oct. One individual overwintered as a larva and pupated in the spring. This parasite was the most numerous of the 31 species so far recovered in British Columbia.

Mastrus aciculatus (Prov.), Cottonwood Creek, 3000' only, 1941.

Adult recovered in spring from overwintered pupa. Rare.

Phaeogenes arcticus Cush., McConnell Creek, 1940 and 1941, Cottonwood Creek, 2200', 3000' and 3500', 1941.

Attacked pupal stage of host, and emerged as adults therefrom in Aug. and Sept. An important parasite.

Phaeogenes hariolus Cress., Cottonwood Creek, 2200', 3000' and 3500', 1940 and 1941, McConnell Creek and Vancouver (U.B.C.) 1941.

Habits as for *arcticus*. Common, but less important than *arcticus*.

Pimpla ? exfeolata (Ashm.), Cottonwood Creek, 2200' only, 1941.

Recovered in August from host pupa. Rare.

Pimpla sp., apparently undescribed, Cottonwood Creek, 2200' only, 1941.
Recovered in Oct. from host pupae. Rare.

Scambus sp., Victoria, 1941.

Attacked larval stage of host, grub issued to spin cocoon, adult emerged in July. Rare.

Thysiotorus latifrons Cush., Cowichan Lake, 1941, Cottonwood Creek, 2200' and 3000', 1940-1941.
One individual was recovered from an exposed cocoon, but more typically the adults were recovered from *Peronea* pupae collected in the field, not from material originating as larval collections; emergence in Aug., Sept. and Oct., occasionally carried over the winter in host pupae, emerging in spring. Occasional, and considered to be a secondary parasite.

BRACONIDAE

Ascogaster sp. near *provancheri* D.T., McConnell Creek, Vancouver (U.B.C.), Cottonwood Creek, 2200' only, 1941.
The attack presumably occurs in the egg stage of the host (not proven from B.C. data as yet), and the grub issues from host larva in stage IV or V and spins a white cocoon. Adult emergence in July and August. Fairly important parasite.

Eubadizon ? *gracile* Prov., Vancouver (U.B.C.), Cottonwood Creek, 3000' only, 1941.
Attack occurs in larval stage, from which the parasite grub issues to spin cocoon; adult emergence in July and August. Rare.

Eubadizon pleuralis Cress., Vancouver (U.B.C.), Cottonwood Creek, 2200' only, 1941.
Data the same as for *gracile*.

Meteorus trachynotus Vier., Vancouver (U.B.C.), Cottonwood Creek, 1941.
Attack occurs in larval stage, from which the grubs issue to spin cocoons; adult emergence June, July, Sept. Occasional.

Microgaster peroneae Walley, McConnell Creek, 1941.

Attack occurs in larval stage, grubs issue from fifth stage host, spin cocoons; adult emergence in the following spring. Important parasite in the limited area where found.

Oncophanes atriceps (Ashm.), Cottonwood Creek, 3500' only, 1941.

Attack occurs in host larvae, from which adult was recovered in August. Rare.

CHALCIDOIDEA

Amblymerus sp., Cottonwood Creek, 3000' only, 1941.

Recovered from host pupae in Sept. Several parasites per host. Rare.

? Trichogramma sp. (257 F-1), McConnell Creek, Cottonwood Ck, courtenay, 1941.

Minute parasites overwintering in host eggs, emerging in spring. Affected about 0.5% eggs at Cottonwood Ck, about 5.7% eggs at McConnell Ck.

TACHINIDAE

Actia sp. probably interrupta Curran, Cottonwood Ck and McConnell Ck, 1940-1941.

Oviposition in the larval host, which develops mesothoracic integumental funnel in 5th stage; maggot issues from larva, forms puparium in which it overwinters; adults emerge in early summer. Rare at Cottonwood Creek, but numerous at McConnell Creek in 1941.

Phorocera tortricis Coq., McConnell Ck,1940, Cottonwood Ck,1941.

Egg laid externally on fifth instar host; maggot issues (from larva ?) to form puparium, adults emerge in Aug. and Sept. Apparently quite rare.

The Pentatomid, Podisus serieventris Uhler.

This predator was recovered in 1941 from one locality only, viz. Cottonwood Creek, at the 2200-foot level, but not in extensive beatings at 3000 feet or higher. Nymphs were common in July and early August, and adults from late August onwards.

Disease of Peronea larvae, McConnell Creek, 1941.

The most important factor of mortality in the McConnell Creek infestation (c.f. section (a)) was a disease affecting the nearly full grown larvae, causing death before or after pupation. From nearly 1400 fifth instar larvae collected in early August and reared in the laboratory, the total survival of moths and parasites was 21%, and from 176 pupae, survival of moths and parasites was 22%. Excluding the parasites, the figures of moth survival were 7% and 2.3% respectively. According to these data the disease caused the death of about 78% to 79% of the fifth stage larvae and pupae of Peronea variana and in many cases contained parasites as well. The Tachinid, Actia sp., was especially affected, many maggots in the integumental funnels being killed at the death of their larval hosts.

In smear slides of diseased pupae examined by K. Graham were found minute refractile crystalline, irregularly-shaped bodies comparing in size with the polyhedra associated with virus diseases of insects, as described by Escherich (1914). These were distinguished from bacteria and tissue fragments by their shape and non-staining in eosin and fuchsin; from fat globules by size, shape and insolubility in xylol; and from salt crystals by insolubility in water. Similar bodies in smears from diseased *Notolophus* and *Neodiprion* larvae were further distinguished from fat globules by their staining in picric acid and non-staining in Sudan III; and from uric acid crystals by the murexide test. Additional observations are required in 1942 on the distribution of the "polyhedra" among diseased and healthy larvae and pupae, and on the transmission of the disease to healthy stocks of *Peronea variana*.

E.30.41-1 *Pissodes sitchensis*; damage. K.Graham and M.L. Prebble.

A progress report including the essential observations since the initiation of this project by W.G. Mathers in 1937 was prepared in April, 1942, for submittal to the Forest Branch, B.C. Department of Lands, which is the principal collaborator. Since the progress report was written, a start has been made on the propagation, by cuttings, of particular trees in the Green Timbers plantations which are notable for high susceptibility or for immunity (non-attack in vicinity of heavy attacks) over the interval 1936-1941.

INVESTIGATIONS OF THE SITKA SPRUCE WEEVIL IN BRITISH COLUMBIA *

Introduction

The sitka spruce weevil, *Pissodes sitchensis* Hopk., occurs as a pest of young sitka spruce throughout the distribution range of the tree, and is also abundant in the lower Fraser Valley and parts of Vancouver Island where this tree does not normally occur in quantity. Damage is notably conspicuous in plantations at Green Timbers on the mainland, and is starting to appear in more recent plantations at Echo Lake in the Campbell River area, on Vancouver Island. A small infestation occurs in a young natural stand of spruce intermixed with Douglas fir, lodgepole pine and hardwood species at Coombs.

The investigations which are briefly summarized here have been directed along three main lines of study, as follows:

1), observations on the seasonal history and natural enemies, the principal contributions to date having been made by Mathers, from 1937 to 1939.

2), sample plot studies, intended to provide information on many phases of the problem, including (a) trend of attack from year to year; (b) ultimate effect of weevil attack in terms of tree growth and form, along with factors influencing recovery from attack; (c) factors relating to regional differences in intensity of attack; (d) factors relating to distribution of attack within a stand and the susceptibility of individual trees, such studies comprising, i, observations on size, vigour and exposure of trees in relation to attack, ii, statistical comparison of actual distributions of attack

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* W.G. Mathers of the Vernon staff, formerly located at Vancouver, initiated the studies at Green Timbers in 1937, established plots on which records were kept until 1939, and made extensive observations on seasonal history, population density and factors of control. The writers took up the problem in 1940, continued records at Green Timbers, extended plot studies to other areas, and laid the foundation for further experimental studies of factors influencing host selection.

with theoretical distributions, calculated on the basis of random selection of host trees, and iii, field experiments consisting in the elimination of multiple leadership which sets up a considerable bias favouring re-attack of trees once injured.

3), Detailed analysis of infested leaders, providing data on the effect of such features as size, length, etc. on survival rate of the weevil brood.

The principal objects of the investigations are to provide an understanding of the factors affecting susceptibility of the tree to the insect, and to discover whether there may be regional differences, due to climatic or other factors, which merit consideration in reforestation or management plans involving sitka spruce.

Bionomics

SEASONAL HISTORY *

The adult weevils emerge from hibernation and are in flight and copulation early in the spring, flying in bright sunlight or when air temperature is above 70°F. They feed through punctures in the bark, made chiefly in the leader of the preceding year, but sometimes on growth up to four years old, and occasionally on lateral branches and unopened buds. Pitch exudations mark the points of feeding. The weevils deposit eggs singly or occasionally two together in punctures in the bark, the latter soon healing† over the eggs. Typically many eggs are inserted at one or more points anywhere in the leader of the previous year, usually towards the tip. As the grubs appear and begin to feed downwards, they cause the death of all growth above their lowest point of feeding. Pupation occurs during mid-summer in oval cells cut by the full grown larvae in the wood or pith of the leader. Young adults emerge late in the summer, and feed for a considerable period before going into hibernation.

In 1939, overwintered weevils were in flight at Green Timbers from March 21 to July 5, with the greatest numbers from mid-April to mid-May. Copulation occurred from March 21 to June 9 at least. Oviposition began in April, before bud bursting of many of the host trees, and continued into June, with the main period from mid-April to late May; eggs were present as late as July 8. An indication of the number of eggs per leader was obtained in counts of larvae in leaders over the period June 1 to 15; the average of 24 leaders was 67 with a maximum of 164. The incubation period as estimated from observations of dissected leaders was about two weeks in the early

* Based largely on data gathered by W.G. Mathers and R. Longmore, 1937-1939.

part of the season. Larval development required about six weeks and all larvae were fully developed by Aug. 15. Pupal cells were noted as early as June 8, but the first pupae not until 20 days later. Over half the population was pupated by July 17. The pupal stage, lasting about two weeks was ended by Aug. 18 in 1939, but in 1941 occasional living pupae occurred at Green Timbers as late as September 16, and at Coombs as late as Oct. 14. Adults occurred in the pupal cells in 1939 from July 18 onwards, and in the field from Aug. 4. Copulation apparently did not occur in the late summer. The sex ratio based on 2014 adults emerged in 1938 was approximately 1 : 1.

Drooping of attacked leaders in 1939 occurred in June when the larvae were about half-grown. However, there was considerable variation among trees in the relation between shoot growth and weevil attack. This was shown by examination of 210 attacked trees; in 8.6%, the terminal buds failed to open; in 60%, the new leader did not exceed two inches before death, and in the remaining trees the new leaders ranged up to 14 inches, and in one exceptional case to 22 inches, before death due to weeviling.

NATURAL CONTROL

<u>Survival Rate</u> Competition for food among the gregariously feeding larvae is probably one of the main causes of mortality. In conjunction with other factors such as high temperature and low moisture, it probably accounts for low survival in small leaders.

The progressive reduction in the number of living weevils in the leaders with advance of the season is indicated by counts obtained in 1939 (W.G. Mathers):

Period	No. of leaders	Average no. living weevils per leader
June 1-15	24	67
July 1-15	22	28
Aug. 1-15	23	9

Seasonal variability in ultimate survival as based on emergence of adults from the leaders is illustrated by the data in the following synopsis:

Year	No.leaders examined	Average emergence
1937	61	18
1938	150	13
1939	150	9

Some of the inter-seasonal variability is possibly due to variation in leader size. That this factor does influence the number of weevils reaching maturity is indicated by the following data from Echo Lake material in 1941, the leaders being grouped according to basal diameter (1940 growth):

Basal diameter in 1/16's inch	No. of leaders	Av. emergence per leader
4	3	1.0
5	11	2.0
6	11	5.1
7	4	13.2
8	2	15.0

There had been considerable mortality among the small larvae in this Echo Lake material, and in addition, a very heavy loss even after the pupal cells had been excavated by the full grown larvae. In a sample of 25 infested leaders, the mean number of pupal cells was 19.7 (range, 0 to 52) and the mean number of adult emergence holes was 5.2 (range, 0 to 21). This represents a loss of about 74% even after full larval development.

NATURAL ENEMIES

Enemies of the sitka spruce weevil include parasitic and predaceous insects as well as birds. The insects so far recovered from infested leaders are summarized in table 1.

The importance of these natural enemies has not yet been determined quantitatively. Some indication of their abundance was afforded by counts carried out in 1939 (W.G. Mathers); in 150 infested leaders examined from July 10 to Sept. 14, the mean number of parasites, predators and scavengers was 4.54. Some further indication of their relative importance at Echo Lake in 1941 was obtained by comparison of the average number of various enemies with the number of surviving weevils in 25 leaders:

Chalcidoid larvae,	Av.	4.4	(parasitic)
Hymenopterous "	"	1.5	"
Dipterous "	"	0.2	(predaceous)
Emerged weevils	"	5.2	

These figures suggest that about half of the well developed weevils were destroyed by natural enemies.

In rather small samples of weeviled leaders from Coombs in 1941, large predatory Dipterous larvae were relatively more numerous, and parasitic Hymenoptera relatively fewer, than in the Echo Lake material summarized ~~at the top of the page.~~ in the preceding paragraph.

Despite the mortality from the various factors enumerated in the fore-going paragraphs, survival is usually sufficient to maintain an active infestation. Assuming that the weevil complement of the average leader represents the progeny of a single female, survival could drop to between one and two weevils per leader without causing decline in population level. Overwintering mortality of the hibernating weevils, which has not yet been studied, is probably an

Table 1.

Insects recovered from infested sitka spruce leaders

Species	Locality and Year	Emergence
Rhopalicus pulchripennis (Wfd.)	Green Timbers 1938,1939 W.G.M.	Summer of attack, following spring.
Chalcid similar to above (1214 B-3)	Echo Lake 1941. K.G.	Summer, one year after attack.
Eurytoma sp.	Green Timbers 1938,1939 W.G.M.	Summer of attack, following spring.
Eurytoma pissodes	Green Timbers 1939. W.G.M.	Spring following year of attack.
Eurytoma sp. (1214B-1, 1214B-2)	Echo Lake 1940,1941. K.G.	Autumn of attack, following spring.
Microbracon pini (Mues.)	Green Timbers 1938,1939. W.G.M.	Summer of attack, following spring.
" " "	Echo Lake 1941,1942. K.G.	Autumn of attack, following spring.
Coeloides sp.	Green Timbers 1939. W.G.M.	Summer of attack.
Calliephialtes comstocki (Cress.)	Green Timbers 1938. W.G.M.	Summer of attack.
Eupelmella sp.	Green Timbers 1939. W.G.M.	Spring following year of attack.
species of tribe Phygadeuonini	Green Timbers 1939. W.G.M.	Summer of attack.
Chalcid, exp.no. 1215 B-1	Green Timbers 1942. K.G.	Spring following year of attack.
Lonchaea watsoni	Green Timbers 1939. W.G.M.	Spring following year of attack
Lonchaea sp.	Coombs 1942 K.G.	Spring following year of attack.
Cnemodon sp.	Green Timbers 1938,1939. W.G.M.	Summer of attack, following spring.
" "	Coombs 1942. K.G.	Spring following year of attack.

important factor tending to reduce the rate of population increase implied by such high rates of adult emergence per leader as have been observed at Green Timbers and Echo Lake .

HISTORY OF KNOWN INFESTATIONS

Green Timbers Plantations

Ten plots, each 74x74 feet, were laid out by W.G. Mathers in 1937. Four of these were in plantation no.68, which was planted in 1930 to 1932 with 1-1 stock, consisting of pure spruce with residual shrubs and sucker growth, mostly willow. The other six plots were in plantation no.84, which was planted in 1931 to 1932 with 1-1 stock, consisting of a mixture of Douglas fir and sitka spruce. A summary of the annual weevil attacks on the plots appears in the synopsis.

	No. of trees	Trees and leaders attacked by years *					% of trees attacked **
		1936-1937	1938	1939	1940	1941	
Plots in pl'n no.68	515	74 (78)	127 (132)	97 (106)	184 (215)	132 (148)	72.3
Plots in pl'n no.84	359	91 (93)	233 (246)	109 (142)	171 (236)	141 (184)	91.0
Totals	874	165 (171)	360 (378)	206 (248)	355 (451)	273 (332)	80.5

* Figures in parentheses indicate number of attacked leaders.
** These are percentages of all trees which have been attacked at least once between 1936 and 1941 incl.

The 1941 attack, though lighter than that of 1938 and of 1940, affected 31.2% of all trees on the plots. Of the 132 trees attacked in plantation no.68, 38 were attacked for the first time in 1941, the others had been attacked in earlier years as well. Of the 141 trees attacked in plantation no.84, only four were attacked for the first time in 1941. This draws attention to the fact of repetitive attack on certain trees beyond the probability of chance alone. An adequate explanation for the phenomenon is not yet at hand, but will have to take account of at least four factors as follows: 1) the effect of multiple leadership following earlier attack, creating a bias in favour of re-attack; 2) possibility of genetic differences in susceptibility; 3) susceptibility due to environmental causes (exposure, growth rate, etc.); and 4) possibility of concentration of the insects in various parts of the plantations, related to earlier attacks, etc.

Echo Lake Plantation

This plantation consists of four acres of sitka spruce planted in 1933 with 1-2 stock 8 inches high, at the rate of 588 trees per acre. The area had been logged and burned, has a slight slope to the north, with sandy or gravelly loam soil. Vegetation apart from the planted spruce trees was still largely confined to grasses and herbaceous growth in 1941. Survival of the spruce has been high, and for practical purposes, all the trees are uniformly and thoroughly exposed.

Studies on this area were started in the autumn of 1941, when 600 trees on two plots were tagged and described. Additional plots will be established as time permits, and experimental studies involving the trimming of infested trees to a single leader are contemplated, with a view to determining the influence on recovery from attack and upon recurrent infestation of individual trees.

The history of attacks in the 600 tagged trees is as follows: 1938, one tree; 1939, 6; 1940, 15; and 1941, 67. The intensity of attack has thus increased each year since its inception, and the majority of the trees are now entering possibly the most susceptible period.

Coombs

One sample plot including 98 sitka spruce trees in a natural stand consisting predominantly of Douglas fir, with intermixed lodgepole pine, willow, alder and crab apple, was established at Coombs in 1941. The soil is a "Maywood" poorly drained clay loam, the A_1 horizon having a relatively high base-exchange capacity (R. Spilsbury), and appears to be well suited to very rapid tree growth.

The history of the weevil attack in this small plot was traced back to 1930, with results as shown in the synopsis.

Coombs plot, 98 spruce trees

Year	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941
No. of attacks	3	1	6	9	7	11	12	9	10*	13**	8	8

* one double attack, therefore 11 leaders
** " " " , " 14 "

The infestation has remained more or less constant for the past ten years. An exceptional feature of the infestation is the rapid recovery of the trees from attack, with a minimum of distortion of the trunk.

EFFECT OF ATTACK ON TREE FORM AND GROWTH

Weevil attack results in the killing of all leader growth of the current year, usually all of the leader produced a year previously, and frequently part of the two-year old growth. The reduction in living height of trees attacked at Echo Lake in 1941 amounted to 18.9 inches, made up of 5.4 inches 1941 growth, 11.7 inches of the 1940 growth, the total of which was 13.2 inches; and 1.8 inches of the 1939 growth, as based on averages of 25 attacked trees.

Competition for leadership among a varying number of the laterals, follows death of the leader. In some trees, one or more laterals attain or share leadership in the same year as the attack, while in other trees the process is not accomplished until a year later. Recovery varies according to the time of attack and killing in relation to seasonal development, to tree vigour, to competition and to the severity of stem killing.

As an illustration of the gross effect of weeviling on the young stand, one may cite data from Green Timbers plots. In plantation no.68, 500 trees were in 1941 classified as follows:

40 stunted by rabbit browsing - 8 of these attacked by Pissodes

460 non-browsed trees
- 211 trees with multiple leaders, averaging 3 per tree
- 223 trees with single leaders (107 of these weeviled)
- 26 trees with no leader established - most of these were 1941 attacks.

Similar data are available for 355 trees in plantation no.84, as follows:

3 trees stunted by browsing - 2 of these attacked by Pissodes

352 non-browsed trees
- 213 trees with multiple leaders, averaging 3.7 per tree
- 131 trees with single leaders (100 of these weeviled)
- 8 trees with no leader established.

As indicated elsewhere, one of the feature of multiple leadership is the bias which it creates for re-infestation of the already distorted tree.

SUSCEPTIBILITY OF INDIVIDUAL TREES TO ATTACK

In the Green Timbers and Coombs plots, some trees have been attacked more or less repeatedly in different years, as shown by the synopses in which the trees are arranged according to the distribution of single, double, triple, etc. years of attack.

Green Timbers plots, 1936 - 1941 (severely browsed trees omitted)

Plantation no.68	No. of years in which attacked 0	1	2	3	4	5	6	Totals all classes
No. of trees	124	147	140	40	13	2	0	466
" " single attacks*	-	146	258	104	40	6	-	554
" " double "	-	1	22	15	9	4	-	51
" " triple "	-	-	-	1	3	-	-	4
" " quadruple "	-	-	-	-	-	-	-	-

Plantation no.84	0	1	2	3	4	5	6	Totals all classes
No. of trees	31	62	124	90	27	6	1	341
" " single attacks	-	62	214	218	78	21	5	598
" " double "	-	-	32	40	24	7	1	104
" " triple "	-	-	1	11	6	2	-	20
" " quadruple "	-	-	1	1	-	-	-	2

*Single attacks indicate that on an individual tree, one leader was attacked in one year, double attacks, that on an individual tree, two leaders were attacked in one year; and so on, to three and four leaders being attacked on an individual tree in one year.

Coombs plot, 1930 - 1941.

	No. of years attacked 0	1	2	3	4	5	Total all classes
No. of trees	55	15	14	5	6	3	98

The total number of attacks in the period was 97, plus two double attacks.

If the number of trees with 0 to 12 annual attacks in the interval 1930 - 1941 is calculated by expansion of the appropriate bionomial, where p, the probability of attack in any one year, is:

$$p = \frac{97}{98 \times 12} = .0825$$

and q is accordingly .9175, the theoretical distribution on the basis of chance alone is as follows:

trees not attacked at all	34,874
" attacked in just 1 year	37,629
" " " " 2 years	18,619
" " " 3 or more "	6,887
	98,009

Calculating the goodness of fit of theoretical and actual distributions, we get a Chi-square value of 33.7, which with three degrees of freedom, indicates a probability of less than .01. In other words, the actual distribution of trees with repeated attacks cannot logically be attributed to chance alone.

The calculations above are based on assumptions of even age and absence of multiple leadership, which are not wholly true of the Coombs plot. The technique is appropriate for investigations on plantations, especially where multiple leadership is eliminated.

The preliminary results support general observation that some trees are more susceptible than others, but so far there is no indication of whether this may be due to environmental or genetic factors. As a test of the latter possibility, it is planned to take cuttings from trees in the Green Timbers plots and thus establish clones of presumably susceptible and resistant stock, which should be investigated under various environmental conditions and at various localities where _Pissodes sitchensis_ is known to occur.

E.30.37-6 Insects affecting seed production of coniferous trees; bionomics, damage. K. Graham and M.L. Prebble.

Studies in 1941 were confined to Douglas fir in the Langford and Cowichan Lake area. A summary report of the investigations follows.

INVESTIGATIONS OF THE ROLE OF INSECTS

IN RELATION TO SEED PRODUCTION IN DOUGLAS FIR

Introduction

The studies described in this report were undertaken in co-operation with officers of the Economics Division of the Forest Branch, British Columbia Department of Lands, to determine the insects associated with seed production in Douglas fir, their habits and relative importance as agencies of destruction. Preliminary observations were made in the late summer of 1940, and systematic studies were begun early in the spring of 1941.

The studies were conducted at two areas, 1) near the lookout station at Langford, and 2) at the Cowichan Lake Experiment Station. The two areas differ little in elevation or temperature characteristics during the growing season but widely in precipitation. Mean annual precipitation at Langford is approximately 25 inches, of which about three inches occur from April to August, inclusive. The annual precipitation near the lower end of Cowichan Lake averages about 76 inches, of which about 12 inches occur from April to August.

Further differentiation of the sampling location within each main area was as follows:

Langford: a) the flat, b) a steep south slope.

Cowichan Lake: a) mature tree on gravelly flat, b) young trees on dry slope, c) 35-year old tree at lakelevel, which was characterized by very large cones.

Methods

Samples of cones were collected periodically for detailed analysis. This consisted of the dismemberment of each cone separately and the recording of the condition of each cone scale and ovule. The Douglas fir cones were found to be divided into three distinct regions on the basis of scale and ovule development, as follows:

a, basal section, consisting of about 9 to 21 small scales with only rudimentary or underdeveloped ovules, never with sound ovules.

b, intermediate section, consisting of about 20 to 52 developed scales, each of which normally bears two developed ovules. Many of the ovules are destroyed, cease developing or abort before maturity.

c, apical section, consisting of about 3 to 8 small scales with only rudimentary ovules, never with sound ovules.

The chief interest lies in the scales and ovules of the intermediate section of the cone, for these are most affected by such factors as the parent tree, the site, insects and fungi. The ovules in the intermediate section were accordingly classified as sound, destroyed by insects, aborted or underdeveloped, on the basis of certain characteristics which are described in the following paragraph. The details of the classification are shown in the left hand margin of table 1.* It is important to realize that all figures given in this and other tables refer to the number of cone scales and ovules, and not to the number of insects. The relation between the two varies for the different insects; for example, each Chalcid larva destroys a single ovule during its life, each lepidopterous larva may destroy few to many ovules as it bores through and feeds upon the tissue of cone scales and ovules alike, and the Cecidomyidae occur in small colonies in the cone scales and may or may not injure ovules according to circumstance. In order to obtain a thorough record of the distribution of the insects in the cones, the occurrence of insects or their injury in the non-productive basal and apical regions of the cone was also recorded; here the unit of classification was the half-scale, which corresponds to the ovule in the productive region.

Sound ovules have the seed coat well developed and the female gametophyte full, fresh and firm. Ovules destroyed by insects are those which, otherwise sound, have the gametophyte eaten by the larvae of the Chalcids or Lepidoptera, or shrunken through the influence of Cecidomyid galls in the adjacent scale tissue. Aborted ovules have a well developed seed coat, but shrivelled gametophyte. Underdeveloped ovules are those with small seed coats and little or no development of the gametophyte. Some damage to cone scales and ovules, apparently caused by a fungus, was found at Cowichan Lake particularly. The scales, bracts and ovules in affected cones were mottled or entirely brown in early May, later becoming dry and hard. Dr. J.E. Bier obtained the fungus Cladosporium sp. in cultures from affected cones. Further observations are necessary before it will be possible to determine precisely the causes of injury of this type.

In addition to analysis of cones that were fully exposed throughout the season, and thus a part of the natural population of cones in the stand, analyses were also made of cones that were

*p.50

isolated in paper bags for various periods. The object of these analyses was to provide comparative data on the flight periods of the various insects, and the effect of protection at different times on ovule development. The periods of isolation and other details for five series of samples for the slope and flat at Langford are shown in tables 3 and 4; similar data for series isolated during the period of pollination by G.S. Allen are included in table 5.

INSECT SPECIES ASSOCIATED WITH DOUGLAS FIR CONES

The insects so far found commonly within Douglas fir cones belong to one or another of the following groups:

Family Cecidomyidae, the gall gnats

The small orange coloured larvae of these gnats were very common in fir cones at Cowichan Lake and Langford. They occur in colonies, producing small, irregular, woody swellings in the cone scales, particularly at the base underlying the ovule. They occur frequently in scales associated with aborted and underdeveloped ovules, and their disproportionate occurrence in association with these ovules, compared with the relative frequency of the latter, provides presumptive evidence that the galls are at least in some instances causally related to abortion and underdevelopment of the ovules, possibly by interference with the vascular system of the scale. The effect of the suspected interference is sometimes quite apparent in a wilted condition of the well developed gametophyte. However, many ovules are aborted or remain underdeveloped in the absence of Cecidomyid galls. The galls have also been found quite frequently in scale tissue adjacent to healthy, well formed, sound ovules. From this contradictory evidence it would appear that the role of the Cecidomyids varies according to circumstance.

Small bodies considered to be the eggs of gall gnats were found between the base of cone scales and adjacent bracts in young cones at Langford on March 28, 1941. At this time the pollen grains were nearly spherical and clearly distinct from the so-called eggs, but later the developing pollen tubes confused the evidence. ✓ However, young larvae lying adjacent to the tender ovules were noted on April 10, and deformity of the scale tissue on May 26. The general occurrence of Cecidomyids in cones isolated from March 27 to the end of the season proves that oviposition occurred prior to March 27. A few gnats also occurred in cones isolated by G.S. Allen over the period March 14 - April 17 (table 5), and the evidence here is strong that oviposition had occurred prior to March 14 and not subsequent to April 17. It seems probable that these delicate insects lay their eggs between the scales and bracts about the time that the winter scales of the cones are being cast.

The species of gall gnats have not been satisfactorily determined to date, owing to inadequate knowledge of this group of insects. One species, possibly belonging to the genus *Asynapta*, emerged from Cowichan Lake material in October, 1940.

Another gnat, *Sciara* sp., emerged in July 1941 from Cowichan Lake cones collected in August 1940.

Family Chalcididae, the chalcid flies.

The white larvae of chalcid flies occur singly within well developed ovules, and destroy the gametophyte. The integuments are left intact and the damage can only be detected by dissection of the seed. Oviposition occurred during May and early June at Langford in 1941. The only known phytophagous species recovered, viz. *Megastigmus spermotrophus*, emerged in May 1941 from Cowichan Lake cones collected in August 1940. The full grown larvae apparently overwinter.

Two other chalcid species, viz. *Tetrastichus* sp. and *Amblymerus* sp., which emerged at Cowichan Lake in the autumn from newly ripened cones, are probably parasitic species. Their primary host is presumably one or another of the phytophagous insects herein mentioned, but so far no suggestive evidence is at hand.

Cone moths, of the order Lepidoptera

The larvae of three species of moths occurred in Douglas fir cones at Cowichan Lake. The commonest was *Dioryctria* sp., possibly *ponderosae* (family Pyralidae), the larvae of which are pink or flesh coloured, about 3/4 inch long at full growth, which occurs in late July and August. Some individuals develop to the adult stage in the autumn, others overwinter as pupae. Larvae of this species also occurred commonly in the swollen tissue of blister rust cankers on small white pine trees at Cowichan Lake.

The second moth species was *Commophila fuscodorsana* Kft. (family Phaloniidae), adults of which were recovered in June 1941 from cones collected in 1940. Phaloniid larvae, 1/8 to 1/4 inch long, presumed to be this species, occurred in fir cones in late May, 1941; pupae are at present overwintering.

The third Lepidopteron is *Holcocera* sp., possibly *immaculella* McD. (family Blastobasidae), and is represented by a single specimen which emerged in June 1941 from cones collected in 1940.

Although these records refer specifically to Cowichan Lake, it is probable that the first two species at least, were included among the larval forms taken at Langford in 1941. Here the small caterpillars were established in the cones early in May; indirect evidence from the series of isolated cones indicates that eggs were laid on or in the cones prior to April 8.

The lepidopterous larvae were frequently responsible for considerable destruction of ovules. Later in the season as the cones dried, the larvae occasionally attacked Cecidomyid maggots within the galls in the cone scales.

EARLY ABORTION OF CONES

Observations in the Langford area were commenced March 27,1941. The staminate flowers of trees growing on the slope were already dry, the pollen having been liberated; the young cones were still erect, well exposed from the bud scales, bracts well open, and pollen grains well distributed in the region of the micropyle of each ovule. Conditions were not quite so far advanced on the flat, many of the male flowers being still enclosed in the bud scales; nevertheless, pollen occurred generally in the micropyle region, as the young cones were well freed of the bud scales.

The cones began to assume the pendulant position about April 5-10 (G.S. Allen), and the first evidence of physiological disturbance was noted on April 10, when a marked browning of the axis of the still very small cones was noted in eight out of 15 cones from trees growing on the slope. In most instances there was still no external evidence of disturbance. Affected cones were entirely brown and shrivelled by May 13. Counts of normal and aborted cones made at different times are summarized below.

	Langford flat	Langford slope
May 13, counts on exposed branches	65% aborted	5% aborted
June 2, counts of cones isolated in bags from late March or early April	42% "	6% "
July 5, counts of cones isolated from late March or early April	36% "	10% "
Pooled data of May 13, June 2, July 5.	50.6% "	6.7% "

Insects had nothing to do with these early losses of entire cones.

The cone crop which survived the period of early abortion was heavy in the Langford area and also quite generally in the south-eastern part of Vancouver Island.

RESULTS OF QUANTITATIVE ANALYSES OF MATURE CONES

The data obtained from individual analysis of 515 Douglas fir cones representing various locations, trees and periods of isolation, are summarized in tables 1, 2, 3, 4 and 5. Statistical analyses of certain aspects of these data appear in tables 1a, 2a, 3a, 4a, 6 and 7.

The standard error of the mean difference between series compared in the tables was calculated by pooling degrees of freedom, and the sums of squared deviations of the respective series (cf. Goulden, 1939, Methods of Statistical Analysis, pp.40-41). The significance of differences has been tested by the method of "t", and significant differences are indicated in the tables by underlining.

It is obvious that many differences between series will be due to sampling fluctuations alone. Fortunately, by the method of analysis, such non-significant differences can be ignored. On the other hand, several of the statistically significant differences in various tables receive no support from the comparison of equivalent sample series, and are probably due to peculiar conditions of one or another of the series being compared. For example, cones on a particular tree, isolated for a certain period, may be very distinct from cones on other trees isolated for the same or adjacent periods; but the peculiarity may be one of the tree rather than one resulting from isolation at a certain time. Fortunately, several sets of comparable series are available for testing the validity of most conclusions. Only conclusions that are well supported, or that are of particular interest, are discussed below.

1. Cone size and ovule development were quite consistent in different crown regions of a large mature tree at Cowichan Lake (tables 2 and 2a). Minor differences were a) greater proportion of aborted ovules in the upper crown, and b) greater proportion of underdeveloped ovules in the lower crown. There was some evidence of greater lepidopterous injury in the middle and lower crown.

2. Cones on the two sites at Langford were very similar in size (tables 1 and 1a, comparison a), but there were some differences in the fate of ovules; a) more sound ovules on the flat, and b) conversely, more aborted and underdeveloped ovules on the slope. The apparent differences in the distribution of Cecidomyid galls on the two sites, seemingly associated more with otherwise sound ovules on the flat and with aborted and underdeveloped ovules on the slope, might have been due to variable interpretation of the affected ovules.

3. Cones on a mature tree on the flat, and on young trees on the slope at Cowichan Lake, had approximately the same number of productive scales (tables 1 and 1a, comparison c). Injury caused by Cecidomyids, Lepidoptera and fungus was more severe in the cones on the young trees, whereas abortion was more severe on the old tree.

4. Cones on a 35-year old tree at Cowichan Lake were very large, with many more scales in the intermediate productive region of the cone, than cones which developed on young trees growing on the slope (tables 1 and 1a, comparison d). In terms of proportions of the ovules (table 6), these unusually large cones were notable in a) slight destruction of ovules by insects, b) high degree of abortion, c) high degree of underdevelopment apparently caused by fungus.

5. Comparing samples from the slope at Langford with samples from the slope at Cowichan Lake (tables 1 and 1a, comparison b), we note that at Langford a) chalcids were more destructive, b) Cecidomyids and Lepidoptera were less destructive, c) abortion was greater, d) underdevelopment due to all causes was about the same, but e) underdevelopment due to fungus alone was less important than at Cowichan Lake.

6. The conclusions noted above merely emphasize that the factors causing seed destruction in Douglas fir cones vary in degree between trees, sites and localities. This is further shown by the percentage distribution into the different categories of ovules in samples of exposed cones, in table 6.

7. The experiments involving series of cones isolated at various times (tables 3, 4 and 5) yielded less marked distinctions from the series of exposed cones than was anticipated, owing to the fact that oviposition of some of the insects occurred prior to the earliest isolation. However, several conclusions may be derived from the results.

a. Chalcid larvae were almost totally absent in cones isolated during April and May, indicating that attack occurs at this time. A few chalcids appeared in cones isolated from April 8 to June 2, then exposed, suggesting that some oviposition occurred after June 2.

b. The evidence indicates that the degree of abortion of ovules was not consistently nor significantly altered by isolation at any period after March 27, at which time pollination had already occurred. Abortion is to a large extent independent of the insects found in the cones. The degree of abortion was greatly increased in cones isolated during the pollination period (table 5), and it is possible that failure of fertilization may be a factor in abortion. In this connection it is of interest that aborted ovules seem to be distributed at random throughout the intermediate region of the cone. Lack of moisture may also be a factor, but our records of 1941 have no direct bearing upon this feature.

c. There was no consistent nor significant relation between degree of underdevelopment of ovules and period of isolation. The cause of underdevelopment, apart from that traceable to injury of the cone scales caused by insects and fungi, is unknown.

The records presented here, while having no application beyond the time and location of their origin, serve to indicate what factors influence seed production in Douglas fir, and to provide sample evaluations of their relative importance in a year of heavy cone crop. It cannot, however, be assumed that these relationships will be the same as cone crops vary in density. The investigations will be extended to include cone crops in succeeding years and in other areas, if this proves to be practicable. At the present time much remains to be learned of the biology of the various insects associated with Douglas fir cones.

Table 1.

Summary of average condition of exposed Douglas fir cones at Langford and Cowichan Lake, showing number of scales and sound, injured, aborted and underdeveloped ovules, with associated insects.

	Langford		Cowichan Lake		
	Trees on Flat	Trees on Slope	Mature Tree Flat	Young trees Slope	35-year old tree Lake Level
No. cones in sample	56	113	43	35	16
1. Basal scales	14.10	13.31	18.12	12.54	17.62
a) ½ scales inj. Cecid.	0.91	0.79	0.07	2.74	0.81
b) ½ scales inj. Lepid.	0.12	0.07	0.37	0.06	0.19
2. Intermediate scales	28.80	29.60	29.70	28.14	46.44
a) sound ovules, total no.	33.50	26.40	23.35	21.80	39.12
i , assoc. Cecid.	0.23	0.74	0.05	0.94	- -
ii, assoc. Lepid.	0.01	0.08	- -	0.26	- -
b) destroyed ovules	1.71	0.64	0.05	1.91	- -
i , by Cecidomyids					
ii , by Chalcids	3.97	1.97	0.09	0.06	0.19
iii, by Lepidoptera	1.43	1.33	1.80	6.89	0.12
c) aborted ovules					
i , insect-free	9.35	16.00	28.14	8.20	33.19
ii , assoc. Cecid.	0.91	2.69	1.09	2.09	1.62
iii, assoc. Lepid.	0.27	0.12	0.42	1.43	- -
d) underdeveloped ovules					
i , insect-free	5.58	7.58	4.05	4.54	5.62
ii , assoc. Cecid.	0.57	2.55	0.30	2.69	1.12
iii, assoc. Lepid.	0.25	0.16	0.05	3.60	0.25
iv , caused by fungus?	- -	0.03	- -	2.80	11.75
3. Apical scales	6.05	5.10	6.60	7.63	6.87
a) ½ scales inj. Cecid.	0.21	0.04	0.02	0.91	0.19
b) ½ scales inj. Lepid.	0.21	0.02	0.28	4.40	- -

Table 1 a.

Analysis of differences in number of sound ovules, destroyed ovules, aborted and underdeveloped ovules, between series of cones representing trees at Langford and Cowichan Lake. Data in table 1.

	Sound ovules		Ovules destroyed by Cecid's		Ovules destroyed by Chalcids		Ovules destroyed by Lepid's		Aborted ovules (insect-free)		Underdeveloped ovules (insect-free)		Underdeveloped ovules (killed by fungus)	
	Mean diff.	S.E.	Mean diff.	S.E.	Mean diff.	S.E.	Mean diff.	S.E.	Mean diff.	S.E.	Mean diff.	S.E.	Mean diff.	S.E.
a) Langford Trees on flat vs. Trees on slope	7.10	~~20.1~~ 2.01	1.07	0.30	2.00	1.37	0.10	0.27	-6.65	1.06	-2.00	0.79	-0.03	0.04
b) Langford Trees on slope vs. Cowichan Trees on slope	4.60	2.54	-1.27	0.31	1.81	0.38	-5.56	1.28	7.80	1.30	3.04	1.03	-2.77	0.44
c) Cowichan Lake Young trees on slope vs. Mature tree, flat	-1.55	2.49	1.91	0.38	-0.03	0.05	5.09	1.66	-19.94	1.70	0.49	0.75	2.80	0.72
d) Cowichan Lake Young trees slope vs. 35-year tree, lake level	-17.32	4.17	1.91	0.62	-0.13	0.11	6.77	2.33	-24.99	2.36	-1.08	1.39	-8.95	1.69

Sign and significance of differences as noted at the foot of table 2 a.

Table 2.

Summary of average condition of exposed cones in different crown levels of a mature Douglas fir tree at Cowichan Lake (tree No.4 of A.P. MacBean), showing number of cone scales and sound, injured, aborted and underdeveloped ovules, with associated insects.

	Top of crown	Upper crown	Middle crown	Two lower branches
No. cones in sample	8	15	12	8
1. <u>Basal scales</u>	18.62	18.52	19.25	16.50
a) ½ scales inj. Cecidomyids	- -	0.07	- -	0.25
b) ½ scales inj. Lepidoptera	- -	- -	0.92	0.62
2. <u>Intermediate scales</u>	26.87	30.27	29.42	31.87
a) sound ovules, total no.	22.87	22.53	22.75	26.25
i , assoc. Cecidomyids	- -	- -	0.08	0.12
ii, assoc. Lepidoptera	- -	- -	- -	- -
b) destroyed ovules				
i , by Cecidomyids	- -	- -	- -	0.25
ii , by Chalcids	- -	0.13	0.08	0.25
iii, by Lepidoptera	- -	- -	5.50	1.37
c) aborted ovules				
i , insect-free	27.00	33.40	23.92	25.75
ii , assoc. Cecidomyids	0.37	0.87	1.42	1.75
iii, assoc. Lepidoptera	- -	- -	0.75	1.12
d) underdeveloped ovules				
i , insect-free	3.37	3.20	3.83	6.62
ii , assoc. Cecidomyids	0.12	0.40	0.42	0.12
iii, assoc. Lepidoptera	- -	- -	0.16	- -
iv , caused by fungus ?	- -	- -	- -	- -
3. <u>Apical scales</u>	6.87	6.53	6.75	6.25
a) ½ scales inj. Cecidomyids	- -	- -	0.08	- -
b) ½ scales inj. Lepidoptera	- -	- -	1.00	- -

Table 2 a.

Analysis of differences in number of sound ovules, destroyed ovules, aborted and underdeveloped ovules between series of cones from different crown levels, mature tree at Cowichan Lake (tree no. 4 of A.P. MacBean). Data in table 2.

	Sound ovules		Ovules destroyed by Cecid's		Ovules destroyed by Chalcids		Ovules destroyed by Lepid's		Aborted ovules *		Underdevel-oped ovules *	
	Mean diff.	S.E.	Mean diff.	S.E.	Mean diff.	S.E.	Mean diff.	S.E.	Mean diff.	S.E.	Mean diff.	S.E.
a) Top of crown vs. upper crown	0.34	2.96	0		-0.13	0.39	0		<u>-6.90</u>	3.32	-0.11	0.82
b) Top of crown vs. middle crown	0.12	4.88	0		-0.08	0.17	-5.50	3.04	1.28	4.21	-0.92	1.16
c) Top of crown vs. lower branches	-3.38	3.82	-0.25	0.25	-0.25	0.16	-1.37	1.01	-1.25	3.31	<u>-3.25</u>	0.99
d) Upper crown vs. middle crown	0.22	3.52	0		0.05	0.13	<u>-5.50</u>	2.20	<u>8.18</u>	3.24	-0.81	0.89
e) Upper crown vs. lower branches	-3.72	2.82	-0.25	0.18	-0.12	0.14	-1.37	0.73	<u>5.65</u>	2.76	<u>-3.14</u>	0.79
f) Middle crown vs. lower branches	-3.50	4.76	-0.25	0.20	-0.17	0.17	4.13	3.15	-2.53	3.64	<u>-2.31</u>	1.13

* The difference values are based on all aborted and underdeveloped ovules, including those with or without associated insects.

NOTE: Differences except where otherwise noted are positive, indicating excess for first member of paired series. Underlined mean differences are statistically significant, others are not significant.

Table 3.

Summary of average condition of isolated Douglas fir cones at Langford, showing number of scales and sound, injured, aborted and underdeveloped ovules, with associated insects. The different series of cones were isolated for varying periods in order to demonstrate the time of oviposition of the insects and their importance in ovule destruction.

Langford, trees on the slope, 1941

Tree and series	1 A	5 A	5 B	5 C	1 E	4 F
Period of isolation	March 27 -August	April 8 -August	June 2 -Aug.	July 5 -Aug.	March 27 -June 2	April 8 -July 5
No. cones in sample	20	20	20	16	16	20
1. Basal scales	12.80	15.10	14.70	14.69	12.69	13.15
a) ½ scales inj. Cecid.	0.55	0.90	1.15	1.75	0.75	1.55
b) ½ " " Lepid.	--	--	--	--	0.06	--
2. Intermediate scales	30.95	27.45	29.60	27.00	31.19	26.30
a) sound ovules, total no.	34.65	24.70	30.90	26.00	30.00	14.00
i , assoc. Cecid.	0.45	0.55	1.55	1.06	0.81	0.15
ii, " Lepid.	--	--	--	--	--	--
b) destroyed ovules						
i , by Cecidomyids	0.50	0.65	0.35	0.50	0.06	0.05
ii , by Chalcids	--	--	0.70	0.69	--	--
iii, by Lepidoptera	--	--	1.00	--	1.00	--
c) aborted ovules						
i , insect-free	13.80	19.15	14.35	17.88	17.37	20.35
ii , assoc. Cecid.	2.70	4.50	3.00	4.18	2.00	5.00
iii, " Lepid.	--	--	0.50	--	--	--
d) underdeveloped ovules						
i , insect-free	6.55	3.65	4.65	2.87	6.06	10.95
ii , assoc. Cecid.	2.35	2.40	3.00	2.12	3.94	2.15
iii, " Lepid.	--	--	0.25	--	1.37	--
iv , caused by fungus?	--	--	--	--	--	0.05
3. Apical scales	5.40	6.15	5.55	6.44	4.50	5.10
a) ½ scales inj. Cecid.	0.45	0.15	--	0.62	0.12	--
b) ½ " " Lepid.	--	--	--	--	0.62	--

Table 3 a.

Analysis of differences in number of sound, destroyed, aborted and underdeveloped ovules, between series of cones exposed, or isolated during different periods. The series of cones exposed throughout the season (data in table 1, second column) is represented by "X". The data for the isolated series appear in table 3.

Langford, trees on the slope, 1941

Series compared	Period of isolation	Sound ovules		Ovules destroyed by Cecid's		Ovules destroyed by Chalcids		Ovules destroyed by Lepid's		Aborted ovules (insect-free)		Underdeveloped ovules (insect-free)	
		Mean diff.	S.E.	Mean diff.	S.E.	Mean diff.	S.E.	Mean diff.	S.E.	Mean diff.	S.E.	Mean diff.	S.E.
a) X -1E	March 27-June 2	-3.60	3.51	0.58	0.31	1.97	0.57	0.33	1.46	-1.37	1.94	1.52	1.42
b) X -4F	April 8- July 5	12.40	3.04	0.59	0.27	1.97	0.50	1.33	1.26	-4.35	1.74	-3.37	1.31
c) X -5A	April 8-August	1.70	3.06	-0.01	0.28	1.97	0.50	1.33	1.26	-3.15	1.72	3.93	1.26
d) X -5B	June 2- August	4.50	3.14	0.29	0.28	1.27	0.51	0.33	1.29	1.65	1.71	2.93	1.28
e) X -5C	July 5- August	0.40	3.36	0.14	0.32	1.28	0.57	1.33	1.41	-1.88	1.83	4.71	1.41
f) 5B -5A	June 2- August April 8-August	6.20	3.08	-0.30	0.22	0.70	0.28	1.00	0.74	-5.15	2.08	1.00	0.80
g) 5A -5C	April 8-August July 5- August	-1.30	2.44	0.15	0.25	-0.69	0.28	0	0	4.80	2.34	1.00	0.86
h) 5B -5C	June 2 -August July 5- August	4.90	3.12	-0.15	0.26	0.01	0.42	1.00	0.73	-3.53	1.85	1.78	0.89
i) 1E -4F	March 27-June 2 April 8- July 5	16.00	3.71	0.01	0.09	0	0	1.00	0.89	-2.98	2.90	-4.89	1.34
j) 1A -1E	March 27-August March 27-June 2	4.65	4.22	0.44	0.34	0	0	-1.00	0.89	-3.57	2.87	0.09	0.97
k) 5A -4F	April 8 -August April 8- July 5	10.70	2.39	0.60	0.16	0	0	0	0	-1.20	2.24	-7.30	0.98

Table 4.

Summary of average conditions of <u>isolated</u> Douglas fir cones at Langford, showing number of scales and sound, injured, aborted and underdeveloped ovules, with associated insects. The different series of cones were isolated for varying period in order to demonstrate the time of oviposition of the insects and their importance in ovule destruction.

<u>Langford, trees on the flat, 1941</u>

Tree and series	2 A	3 A	2 B	3 C	3 E	3 F
Period of isolation	March 27 -August	April 8 -Aug.	June 2 -Aug.	July 5 -Aug.	April 8 -June 2	April 8 -July 5
No. cones in sample	20	25	16	17	17	16
1. Basal scales	16.10	14.72	13.12	14.87	15.29	15.68
a) ¼ scales inj. Cecid.	- -	0.96	0.48	2.94	2.82	1.31
b) ½ " " Lepid.	- -	- -	- -	1.29	0.18	0.56
2. Intermediate Scales	26.05	28.32	27.44	28.46	27.71	28.87
a) sound ovules, total no.	36.30	33.12	37.72	21.74	32.82	29.81
i , assoc. Cecid.	- -	- -	0.81	0.12	0.47	0.19
ii, " Lepid.	- -	- -	- -	- -	- -	- -
b) destroyed ovules						
i , by Cecidomyids	- -	0.40	0.37	0.23	0.12	0.12
ii , by Chalcids	- -	- -	4.44	4.64	0.76	- -
iii, by Lepidoptera	- -	1.48	- -	0.25	- -	4.25
c) aborted ovules						
i , insect-free	7.30	10.92	5.62	15.76	11.12	11.55
ii , assoc. Cecid.	0.15	2.04	0.50	4.64	1.76	2.50
iii, assoc. Lepid.	- -	0.24	- -	- -	- -	1.81
d) underdeveloped ovules						
i , insect-free	8.15	7.48	5.87	7.47	8.06	6.44
ii , assoc. Cecid.	0.15	0.48	0.37	2.06	0.59	0.50
iii, assoc. Lepid.	- -	0.40	- -	0.06	0.18	1.06
iv , caused by fungus?	- -	0.04	- -	0.06	- -	- -
3. Apical scales	4.65	6.80	5.19	6.47	6.36	6.68
a) ¼ scales inj. Cecid.	- -	0.12	- -	1.00	0.65	0.56
b) ½ scales inj. Lepid.	- -	- -	- -	- -	- -	0.50

Table 4 a.

Analysis of differences in number of sound, destroyed, aborted and underdeveloped ovules, between series of cones exposed, or isolated during different periods. The series of cones exposed throughout the season (data in table 1, first column) is represented by "X". The data for the isolated series appear in table 4.

Langford, trees on the flat, 1941

Series compared	Period of isolation	Sound ovules Mean diff.	Sound ovules S.E.	Ovules destroyed by Cecid's Mean diff.	Ovules destroyed by Cecid's S.E.	Ovules destroyed by Chalcids Mean diff.	Ovules destroyed by Chalcids S.E.	Ovules destroyed by Lepid's Mean diff.	Ovules destroyed by Lepid's S.E.	Aborted ovules, (insect-free) Mean diff.	Aborted ovules, (insect-free) S.E.	Underdeveloped ovules, (insect-free) Mean diff.	Underdeveloped ovules, (insect-free) S.E.
a) X -3E	Apr. 8 - June 2	0.68	0.85	1.59	0.66	3.21	0.84	1.43	1.23	-1.77	1.33	-2.48	0.79
b) X -3F	Apr. 8 - July 5	3.69	3.26	1.59	0.68	3.97	0.84	-2.81	1.74	2.25	1.54	0.86	0.86
c) X -3A	Apr. 8 - August	0.38	2.44	1.31	0.44	3.97	0.67	-0.05	1.37	-1.57	1.41	-1.90	0.72
d) X -2B	June 2- August	-4.22	2.73	1.34	0.69	-0.47	0.94	1.43	1.27	3.73	1.41	0.29	0.83
e) X -3C	July 5- August	11.76	2.77	1.48	0.66	-0.67	0.92	1.18	1.23	6.41	1.61	1.89	0.84
f) 2B -2A	June 2- August March 27 - Aug.	1.42	2.29	0.37	0.23	4.44	0.71	0	0	-1.68	0.64	-2.28	1.09
g) 3A -3C	Apr. 8 - August July 5 - August	11.38	2.90	0.17	0.24	-4.64	0.65	1.23	1.25	-4.74	1.84	0.01	1.09
h) 2B -3C	June 2 - August July 5 - August	15.98	2.63	0.14	0.29	-0.20	1.15	-0.25	0.17	-10.14	1.90	-1.60	1.20
i) 3E -3F	Apr. 8 - June 2 Apr. 8 - July 5	3.01	3.98	0	0	0.76	0.31	-4.24	2.22	-0.43	1.76	1.62	1.14
j) 3A -3E	Apr. 8 - August Apr. 8 - June 2	0.30	2.71	0.28	0.22	-0.76	0.25	1.48	1.21	-0.20	1.49	-0.58	0.99
k) 3A -3F	Apr. 8 - August Apr. 8 - July 5	3.31	3.80	0.28	0.23	0	0	-2.76	2.22	-0.63	1.55	1.04	1.10

Table 5.

Summary of average condition of Douglas fir cones in two series, viz. exposed, and isolated, during the pollination period, at Langford, showing number of scales and sound, injured, aborted and underdeveloped ovules, with associated insects.

Trees E, J and T of G.S. Allen, Langford, 1941

	Exposed cones	Isolated cones *
No. cones in sample	14	15
1. Basal scales	19.42	18.60
a) ½ scales inj. Cecidomyids	0.21	- -
b) ½ scales inj. Lepidoptera	- -	- -
2. Intermediate scales	36.80	35.20
a) sound ovules, total no.	37.40	1.40
i , assoc. Cecidomyids	0.43	- -
ii, assoc. Lepidoptera	- -	- -
b) destroyed ovules		
i , by Cecidomyids	0.71	- -
ii , by Chalcids	0.29	0.20
iii, by Lepidoptera	- -	- -
c) aborted ovules		
i , insect-free	24.10	60.50
ii , assoc. Cecidomyids	0.86	0.13 **
iii, assoc. Lepidoptera	- -	- -
d) underdeveloped ovules		
i , insect-free	9.20	8.06
ii , assoc. Cecidomyids	0.28	- -
iii, assoc. Lepidoptera	- -	- -
iv , caused by fungus ?	- -	- -
3. Apical scales	7.06	7.52
a) ½ scales inj. Cecidomyids	- -	- -
b) ½ scales inj. Lepidoptera	- -	- -

* Period of isolation March 14 - April 17 for part of series, and March 25 or 27 - April 17 for remainder of series.

**The aborted ovules with associated Cecidomyids occurred in cones isolated March 14.

Table 7.

Percentage of sound, destroyed, aborted and underdeveloped ovules in the intermediate productive region of Douglas fir cones, isolated for various periods as indicated, at Langford, 1941. Data in tables 3 and 4.

Tree and series	Slope 1E	4F	1A - 5A	5B	5C	Flat 3E	3F	2A - 3A	2B	3C
Period of isolation	Mar.27 to June 2	Apr. 8 to July 5	Mar.27 -Apr.8 to August	June 2 to August	July 5 to August	Apr. 8 to June 2	Apr. 8 to July 5	Mar.27 -Apr.8 to August	June 2 to August	July 5 to August
Sound ovules	48.1	26.6	50.8	52.2	48.1	59.3	51.3	63.9	68.7	38.2
Destroyed ovules										
i , by Cecidomyids	0.1	0.1	1.8	0.6	0.9	0.2	0.2	0.4	0.7	0.4
ii , by Chalcids	- -	- -	- -	1.2	1.3	1.4	- -	- -	8.1	8.2
iii, by Lepidoptera	1.6	- -	- -	1.7	- -	- -	7.3	1.4	- -	0.4
Aborted ovules										
i , insect-free	27.9	38.6	28.2	24.2	33.1	20.0	19.9	16.8	10.2	27.7
ii , assoc. Cecid.	3.2	9.5	6.2	5.1	7.7	3.2	4.3	2.0	0.9	8.2
iii, assoc. Lepid.	- -	- -	- -	0.8	- -	- -	3.1	0.2	- -	- -
Underdeveloped ovules										
i , insect-free	9.7	20.8	8.7	7.9	5.3	14.6	11.1	14.4	10.7	13.2
ii , assoc. Cecid.	6.3	4.1	4.1	5.1	3.9	1.1	0.9	0.6	0.7	3.6
iii, assoc. Lepid.	2.2	- -	- -	0.4	- -	0.3	1.8	0.4	- -	0.1
iv , caused by fungus?	- -	0.1	- -	- -	- -	- -	- -	0.1	- -	0.1

Table 6.

Percentage of sound, destroyed, aborted and underdeveloped ovules in the intermediate productive region of Douglas fir cones, exposed for the entire season, at Langford and Cowichan Lake. Data in table 1.

	Langford		Cowichan Lake		
	Trees on Flat	Trees on Slope	Mature tree Flat	Young trees Slope	35-yr tree Lake level
Sound ovules	58.2	44.5	39.3	38.8	42.1
Destroyed ovules					
i , by Cecidomyids	3.0	1.1	0.1	3.4	- -
ii , by Chalcids	6.9	3.3	0.2	0.1	0.2
iii, by Lepidoptera	2.5	2.2	3.0	12.3	0.1
Aborted ovules					
i , insect-free	16.2	27.0	47.3	14.6	35.7
ii , assoc. Cecidomyids	1.6	4.5	1.8	3.7	1.7
iii, assoc. Lepidoptera	0.5	0.2	0.7	2.5	- -
Underdeveloped ovules					
i , insect-free	9.7	12.8	6.8	8.1	6.1
ii , assoc. Cecidomyids	1.0	4.3	0.5	4.8	1.2
iii, assoc. Lepidoptera	0.4	0.3	0.1	6.4	0.3
iv , caused by fungus ?	- -	0.1	- -	5.0	12.7

E. 30.37-7 Insects Affecting Seedling Establishment.
M.L. Prebble and K. Graham.

Investigations of the role of insects in establishment of coniferous seedlings are being carried out in co-operation with the Forest Branch at the Green Timbers Forest Nursery, and in connection with seeding experiments on logged and burned land.

Insects in Nurseries

Root weevils of the genus Brachyrhinus were in 1941 associated with seedling injury at Green Timbers and also in a commercial nursery near New Westminster. In the commercial nursery, B. sulcatus and B. ovatus were both present, along with numerous millipeds; injury was conspicuous on ornamentals of Chamaecyparis, Picea and Rhododendron varieties.

In the Green Timbers nursery, B. sulcatus only was found. Injury to two-year Douglas fir seedlings was discovered in February of 1941 when the seedlings were being lifted for shipment to planting crews in the field. Estimate of the amount of injury was impracticable because the foliage of girdled seedlings was still normal in colour, and because the root injury was concealed by ~~much~~ mud adhering to the roots. Seed beds where injury was known to be fairly heavy were passed by in the preparation of stock for shipment but in spite of this, some destroyed seedlings were sent out to planting crews. Evidence of this was noted in a 1941 plantation at Great Central, the weevil-injured trees turning red during the summer.

Root weevil injury to fir seedlings one year old was apparent in Green Timbers seed beds in June. Small patches of dead trees occurred in many seed beds but estimation of the damage was not attempted until September. At that time weevil-injured trees were blackish-brown, readily distinguished from trees killed by heat and drought in July, whose foliage was reddish in September. In estimating the amount of weevil injury, the number of square feet in each seed bed containing weeviled trees was estimated, and related to the area of the seed bed (183 square feet). Altogether 365 seedbeds were examined, representing, at the rate of 10,000 seedlings per bed, over 3½ million trees. Most of the seedbeds had no more than a trace of injury, approximated as 1/4 square foot, and none had more than about three square feet denuded of seedlings by root weevils. The average for 241 beds at the western portion of the nursery was 0.4 square feet, on an area basis equal to about 0.2%; and an average for 124 beds in the eastern part was only .03 square feet, equivalent to about .01%.

Seeding Experiments in Logged and Burned Areas

In this study we have assisted Mr. A.P. MacBean of the Forest Branch in establishment of plots near Cowichan Lake and in recording of data on germination and mortality. In addition we have made periodic lists of the flora becoming established after the burn, and collections of the various insects taken in flight and in the soil. The latter data cannot now be presented since practically no determinations have been obtained from the Systematic Division at this time of writing.

Extensive tables have been compiled by Mr. MacBean, showing the distribution of killed seedlings in the various plots, by cause and time of death. The greatest factors in mortality were drought, fungi (damping-off) and heat injury. Insects are certainly involved in injury to the cotyledons and to the stems, and injury of this character ranged from about 9% to 21% of the total seedling mortality in the various plots. The actual species of insect responsible have not been determined, however.

Continuation of the studies is planned in 1942.

E. 30.50-1. *Dendroctonus pseudotsugae*; epidemiology.
M.L. Prebble and K. Graham.

Investigations of the Douglas fir bark-beetle in 1941 were, due to the pressure of other work, restricted to occasional observations at Cowichan Lake and Great Central Lake, analysis of a number of trees in the Chemainus River infestation, and inspection in company with Dr. J.E. Bier of the Division of Botany, of trees dying along rights-of-way and the margins of stands on limits of Alberni and Pacific Lumber Company in the Elsie Lake district.

Attacks in windthrown trees at Cowichan Lake and Great Central Lake were started in the early part of April. Small larvae were present by the third week in May. There was no evidence of attack in standing healthy trees in the vicinity.

The infestation in the upper part of the Chemainus River valley, which was discovered in 1940, was again examined over the interval September 23-26, 1941. Mr. R.H. Spilsbury, of the British Columbia Forest Branch, accompanied the writers on the inspection and investigated soil conditions in one patch infestation as well as in healthy portions of the forest. While no detailed counts could be made, it was evident that the degree of tree mortality was considerably less in 1941 than a year earlier; only two of some 30 to 40 dead trees in one large patch were definitely killed in 1941. Three of the dead trees were felled for stem analyses; they varied in age at stump height from 225 to 242 years, which is not excessively old for this tree, in diameter from 27 to 28 inches, and in height above stump from 181 to 189 feet.

One tree, which died in 1939, had *Dendroctonus* galleries extending up to the 140 foot point in moderate to heavy intensity; survival in the basal 10 or 20 feet was moderate, with as many as nine emergence holes per square foot, but at levels from 20 feet to 110 feet, survival was poor and from 130 feet to 140 feet, the attack had been pitched out. Other elements in the attack included ambrosia beetles in the basal 30 feet, Cerambycids of various species from the base to 140 feet, Buprestids from 100 feet to 170 feet, and the bark-beetle *Pseudohylesinus nebulosus*, which dominated the stem from 160 feet upwards. Numerous conks of *Polystictus abietinus* and *Polyporus volvatus* occurred on the trunk, the latter fungus commonly being associated with the entrance holes of *Dendroctonus*. The wood was sap-rotted to a depth of one-half inch to one inch at all points between the base and 170 feet.

The two other trees examined appeared to have been killed in 1940. The pattern of insect attack was essentially the same as described above, except that the *Dendroctonus* galleries were predominantly unproductive (pitched out attacks, abandoned without oviposition, or brood killed by unfavourable conditions and by parasitism). Small and old conks of Polyporus volvatus were common, but deterioration of the wood was just beginning; in the basal 50 feet, more or less, deterioration was still confined to sap staining, in the section between 70 and 120 feet sap rot had begun, and above 130 feet the wood was still sound.

Insects found in the roots of dying and dead trees included weevil larvae, presumably of Pissodes fasciatus, larvae and adults of Hylastes nigrinus Mann., as well as a few Dipterous maggots. Probably these were all unrelated to the cause of death.

Although detailed studies of increment are as yet uncompleted, growth has been quite slow during the past decades. Mr. Spilsbury, in preliminary soil studies, found a high water table over impervious subsoil, which seemed to have caused the death of some rootlets.

From the observations to date it would appear that the Dendroctonus attack in the Chemainus valley has not been particularly vigorous, and has succeeded only in killing a number of trees which for one reason or another were in a state of low vitality.

The observations in the Elsie Lake district were similar to those noted above, since neither Dendroctonus nor the associated fungi (predominantly Polyporus volvatus) appeared to be a primary agent. The dying trees, which were about 250 years old, were recently exposed by cutting, and this disturbance is quite possibly related to the cause of death.

E. 30.37-4. Miscellaneous forest and shade tree insects.
M.L. Prebble and K. Graham.

In conducting the observations on miscellaneous forest and shade tree insects, both investigators have contributed to the data on most of the insect species, but responsibility for organization, handling material and compilation rested with one investigator whose name appears under the project sub-titles.

(a) THE SATIN MOTH, Stilpnotia salicis (Linn.)

M.L. Prebble.

Interest in this insect in 1941 was prompted by a request from the Dominion Parasite Laboratory for Apanteles solitarius cocoons, to be used in establishment of colonies of this parasite in Newfoundland. The request was received early in June, too late for effective action in 1941, especially in view of the generally low population level of the satin moth at most locations. However, small collections of host material provided considerable information on the parasitic species involved, as well as two new recovery records for this province. Also, a small infestation of satin moth was located at Cowichan Lake, and this may prove to be a suitable source of Apanteles material in 1942.

In the general scouting for the satin moth, attention was restricted to Lombardy poplar (Populus nigra italica), silver poplar (P. alba) and cottonwood (P. trichocarpa). The insect was found only on the two former hosts, though in the past it has been recorded from cottonwood, as well as aspen, and several species of willow in British Columbia.* On the small island in Cowichan Lake, where the infestation occurred in 1941, the range of hosts was larger and only native species were included, as follows: Populus tremuloides, P. trichocarpa, Salix sitchensis, S. lasiandra, Amelanchier alnifolia and wild crab (Pyrus diversifolia).

Moth emergence and parasite recovery from the various collections of satin moth material are summarized in the accompanying table. Apanteles solitarius was recovered at Cowichan Lake, Victoria, Vancouver and near Mission; Meteorus versicolor, which was recorded for British Columbia for the first time in 1941, was quite widely distributed, viz. Cowichan Lake, Victoria, Vancouver and Sumas; the introduced Tachinid, Compsilura concinnata, also recorded from British Columbia for the first time in 1941, was taken at Sumas, Mission and Agassiz, but not on Vancouver Island. The parasitic complex was most extensive in the Cowichan Lake infestation, there being at least four or five species not recovered elsewhere; Sarcophaga aldrichi was the most numerous of these.

* R. Glendenning, 1929. The Satin Moth in British Columbia. Can. Dept. Agric. Pamphlet No.50 (revised).

Summary of satin moth collections,
Cowichan Lake, Victoria, Vancouver and lower Fraser valley, 1941,
with special reference to moth emergence and parasite recoveries.

Exp. No.	Locality	Collection Date	No. host forms	Moths emerged M.	Moths emerged F.	Primary parasites: Apanteles solitarius	Meteorus versicolor	Compsilura concinnata	Sarcophaga aldrichi	Sarcophaga sp.	Pseudosarcophaga affinis	Tachinomyia similis	Tachinid sp. 1516 E-10	Diptera died immature	Hymenoptera died imm.
1502 F	Superior St., Victoria	June 4	15 l.*	2	2	1	2	-	-	-	-	-	-	-	-
1503 F	Young St., Victoria	" 4	9 l.	-	-	1	1	-	-	-	-	-	-	1	-
1504 F	Richardson St., Victoria	" 4	5 l.	2	1	-	-	-	-	-	-	-	-	-	-
1505 F	Victoria	" 4	6 l.	-	-	-	1	-	-	-	-	-	-	-	-
1506 F	Craigflower, Victoria	" 5	2 l.	1	-	-	-	-	-	-	-	-	-	-	-
1507 F	U.B.C., Vancouver	" 12	(56 l. (3 p.**	1	3	1	17	-	-	-	-	-	-	-	2
1508 F	Barnaby	" 14	15 l.	3	3	-	-	-	-	-	-	-	-	2	-
1509 F	Sumas	" 16	20 l.	5	1	-	2	4	-	-	-	-	-	3	-
1510 F	Agassiz	" 17	12 l.	-	-	-	-	9	-	-	-	-	-	-	-
1511 F	Mission	" 17	(8 l. (2 p.	2	5	-	-	3	-	-	-	-	-	-	-
1512 F	5 M. west of Mission	" 19	22 l.	1	-	1	-	2	-	-	-	-	-	~~10~~ 0	-
1513 F	5 M. west of Mission	" 19	41 l.	5	3	1	-	16	-	-	-	-	-	10	-
1514 F	Superior St., Victoria	" 23	18 l.	-	1	1	9	-	-	-	-	-	-	2	1
1515 F	Young St., Victoria	" 23	3 l.	1	1	-	1	-	-	-	-	-	-	-	-
1516 F	Cowichan Lake	" 9	(66 l. (68 p.	12	20	6	1	-	36	2	2	3	2	6	-
		Totals	298 l. 73 p.	35 M.	40 F.	12	34	34	36	2	2	3	2	24	3

* larvae
** pupae

An interesting feature of *Meteorus versicolor* parasitism is that the parasite grub issues from the still living host caterpillar, which dies about a day or two afterwards. The Sarcophagid maggots occur frequently at the rate of several per host. A number of secondary parasites were reared from *Meteorus versicolor* and *Apanteles solitarius*, as indicated in the synopsis.

a) Secondaries from *M. versicolor*

Hemiteles tenellus Say (1516F-1-2)

Several undetermined Chalcids

e.g. 1514F-1-1 = Dibrachys cavus Wlk
1516 F-1-1 = Dibrachys cavus Wlk
1516 F-1-3 = Habrocytus inimicus Mues.
1516F-1-4 = Hebrocytus inimicus Mues.

b) Secondaries from *A. solitarius*

Hemiteles tenellus Say (1516F-2-2)

Mesochorus sp. (1503F-2)

undetermined Chalcids

e.g. 1516 F-2-1 = Dibrachys cavus Wlk.
1516 F-2-3 = Hebrocytus inimicus Wlk. Mues.

The Chalcid, 1516F-2-1, was particularly numerous in *Apanteles* cocoons collected at Goat Island, Cowichan Lake. In a total of 325 *Apanteles* cocoons collected at random July 9, 77 (23.7%) contained eggs, larvae, pupae or adults of the hyperparasite, or emergence holes through which they had already escaped. *Apanteles* emergence amounted to about 45%.

(b) THE EUROPEAN LECANIUM SCALE, *Eulecanium coryli* (L.)

K. Graham

The lecanium scale, *E. coryli*, in the Vancouver district, was brought under control by the Chalcid parasite *Blastothrix sericea* Dalm , liberated by Mr. R. Glendenning in 1928 and 1929. Nevertheless, since that time the scale continued to extend its distribution and its annual spread has been recorded by members of the Division of Foreign Pests Suppression, and by Mr. Glendenning. By spring 1941, Mr. Glendenning reported that the scale was present in considerable numbers over a wide area from Abbotsford to Chilliwack and across the Fraser River to Agassiz on various fruit and shade trees. It appeared to be little if at all parasitized. The matter was referred to Forest Insect Investigations.

In June 1941, an area including Vancouver and the lower Fraser valley as far east as Rosedale and Agassiz was scouted for scales, and the occurrence of the parasite was recorded. Further observations were made in July, August and September by Mr. Glendenning and Mr. H.G. Fulton. Observations in the Victoria district in June brought to notice a new and dense but localized infestation.

The distribution of scale in 1941 and the occurrence of the parasite are shown in the following table:

Distribution of *E. coryli* and parasitism in 1941.

Locality	Host	Scale density	Per cent parasitism	Observer
Hope	plum, apple, etc.	nil	-	R.G.
Flood	prune, etc.	"	-	"
Laidlaw	pear	very light	50	"
Popkum	plum, apple	" "	100	"
Rosedale	plum, alder, hazel	heavy- "	59 56	M.L.P.-K.G.
Agassiz	plum, hazel	light-v.l.	20	R.G.
Chilliwack	linden	heavy	59 47	M.L.P.-K.G.
"	ornamental plum	"	50 62	" "
"	apple, plum, prune	light-medium	50-95	H.G.F.
Harrison Bay	plum	medium	80	"
Sardis	plum, prune	light-heavy	25-95	"

Locality	Host	Scale density	Per cent parasitism	Observer
Deroche	plum	heavy	90	M.L.P.- K.G.
"	wild plum	light	80	H.G.F.
Nicomen Island	wild plum, apple	medium	80	"
Mission	maple, alder	light-medium	60	M.L.P.- K.G.
"	damson	very light	50	R.G.
Matsqui	plum	light	90	"
Huntingdon	"	"	50	"
Aldergrove	(cottonwood, (alder, maple, hazel	"	10	M.L.P.- K.G.
Coghlan	plum	nil	-	R.G.
Fort Langley	plum, hawthorn and chestnut	"	-	"
Langley Prairie	<u>Prunus pissardi</u>	very light	50	"
Cloverdale	plum	nil	-	"
Green Timbers	horse chestnut	heavy on occasional tree	70	M.L.P.- K.G.
Port Coquitlam	h.c., linden	light	90	" "
Essondale	" "	nil	-	R.G.
<u>Vancouver</u>				
Point Grey	horse chestnut	medium-heavy (some branches)	64	M.L.P.- K.G.
University	elm, maple	light-very light	47-100	" "
Third Beach	" "	medium-heavy	84	" "
South of Stanley Park Reservoir	Maple	light	14	" "
Reservoir, S.Park	alder	(medium-heavy, on (occasional branches	96	" "
Prospect Point	maple	light	94	" "

Locality	Host	Scale density	Per cent parasitism	Observer
Brocton Point	maple	light-medium	78	M.L.P.-K.G.
R.C.N.V.R.Stn	"	(medium-heavy, on (occasional branches	80	" "
Coal Harbour	"	light	67	" "
North Vancouver	alder	(medium-heavy, on (occasional tree	72	" "
" "	hawthorn and *Prunus pissardi*	light-medium	80-85	R.G.
Victoria	elm, linden	" -heavy	undetermined but very heavy	M.L.P. -K.G.

Studies on scale density and parasitism were undertaken in somewhat greater detail on overwintering nymphs from red elm in Victoria in December 1941, and the observations were continued in February and March 1942. Scale density was expressed in terms of numbers of scales per distal foot of twig. Parasitism in the December and February examinations was determined by microscopic examination of cleared and stained slide preparations; in March the scales and parasites were large enough to permit of rapid and accurate determinations by dissection under a dissecting microscope. In this latter period most of the parasitized scales were yellowish, but the colour was not an absolute indication of parasitism, nor its absence of non-parasitism.

Scale density on red elm and parasitism are shown in the following synopsis:

	Dec.19,1941	Feb.20,1942	March 16,1942
Av. No. living scales per ft of primary twig	76 (7 twigs) (range 30-172)	262 (4 twigs) (range 205-373)	56 (5 twigs) (range 37-71)
Av. No. living scales per ft of secondary twigs	256 (20 twigs)	53 (9 twigs)	not det'd
Av. percentage of dead, non-parasitized scales	10.4%	2.4% *	2.8% *
Percentage parasitism	36.7% (98 scales)	5% (377 scales)	8.6% (279 scales) (range 0%-22.5%)

* The apparent decline in number of dead scales probably is related to their being washed off by winter rains.

The significant fact arising from these observations is that while the mature female scales in the summer are very heavily parasitized, the young scales occurring from fall to spring are only lightly attacked. This appears to be true of both the mainland and Victoria districts. The importance of fall parasitism over summer parasitism derives from the fact that a single parasite is capable of killing an overwintering nymphal scale, whereas as many as seven parasites per adult female scale in the summer do not kill their host. In fact the egg-laying capacity of parasitized females may still be very great, as shown in examinations of scales from Vancouver on May 6 and Victoria on June 10, 1941; four scales containing 3, 5, 5 and 2 parasite larvae and pupae produced 1048, 970, 1442 and 2121 Eulecanium eggs respectively.

The study will be continued with the object of observing the spread and trend of the scale populations and of investigating the great difference in degree of parasitism between summer and fall.

(c) THE DOUGLAS FIR WEBWORM, Halisidota argentata Pack.

M.L. Prebble

Occasional colonies of the Douglas fir webworm were noted between late February and early May, 1941, at Vancouver, Victoria (Craigflower, Goldstream), Duncan, Chemainus, Parksville, Bowser, Cameron Lake, Alberni, Cowichan Lake and Lulu Island. Most of the colonies occurred on Douglas fir, but two were on lodgepole pine; damage was in all cases confined to defoliation of a few branches on the upper part of the crown of more or less isolated occasional trees. Moth emergence and parasite recoveries are summarized in the accompanying table. Moth survival was fairly high, about 36% from the well-developed larvae collected April-May. The parasite complex consisted of four, possibly five, species, of which the Tachinids Uromacquartia halisidotae T. and Rileymyia adusta Lw. were most numerous and best represented in the several collections.

The egg contents of four of the females from the Duncan collection varied from 261 to 468, with an average of 386 per female.

(See summary on next page)

Summary of Douglas fir webworm collections, 1941,
with reference to moth emergence and parasite recoveries

Locality	Collection Date	No. of Larvae	Moths M.	Moths F.	Uromoquartia hallsidotae	Rileymyia adusta	Tachinomyia similis	Meteorus hyphantriae	Meteorus sp. nr hyphantriae
Bowser	March 31	5	1	2	-	-	-	-	-
Duncan	April 5	92	19	20	9	18	-	-	1
Parksville	" 5	51	9	10	22	3	-	6	-
Cameron Lake	" 17	52	8	11	10	15	-	4	-
Alberni	" 17	27	*	*	6	4	-	2	-
Lulu Island	May 1	4	-	-	-	2	-	-	-
Cowichan Lake	" 29	4	1	2	-	-	1	-	-
	Totals	235	38	45	47	42	1	12	1

* (4 living pupae - emergence not taken)

(d) THE PINE NEEDLE SCALE, Chionaspis pinifoliae Fitch.

M.D. Prebble.

A number of collections of mature scales were examined in the spring for general information on the seasonal history and natural control. The typical history in the west, according to Keen (*), is for eggs to overwinter under the female scale, hatching occurring late in the spring, and maturity of the new scales by mid-summer. Observations in the Victoria district indicate a slight departure in that the mature females overwinter under the white scales, deposit eggs in March and April which hatch in late April and May. In numerous counts during the oviposition period, the maximum number of eggs found under a female scale was 68.

Some unexplained mortality was noted, and in addition, considerable mortality due to insect enemies. One of these was a small predaceous Coccinellid (exp. No. 117 F-1) which has not yet been identified. The minute black larvae occurred under host scales from early March onwards, devoured female insects and deposited eggs, and passed from scale to scale; cast skins were occasionally found under ravaged scales. The latter could be recognized by the irregular openings, usually along the margin. Pupation of the predator occurred early in May and adults appeared at mid-month.

The other insect enemy was a small chalcidoid, representing an unknown genus of the tribe Ectromini (exp. No. 117 F-2). This small parasite was first detected in early April, and occurred as a whitish larva within the body of the female Chionaspis. The parasitized host assumed a yellow colour in place of the normal purplish and this made detection of parasitism very simple. Diagnosis could be confirmed by the showing of the black gut of the parasite through the body of the host. Some of the affected Chionaspis females laid a few eggs, which were viable. At full growth of the parasite, the host scale was swollen, and at emergence of the Chalcidoid both the skin of the female Chionaspis and its white covering scale remained swollen, with a centrally located emergence hole. Emergence occurred from April to June.

Some data on the distribution and importance of these control agencies are included in the following synopsis:

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* F.P. Keen, 1938. Insect enemies of western forests. p.50.

Analyses of overwintered *Chionaspis* females,

Spring of 1941.

Date	Locality	Host	Total No. females	Living	Dead	Parasitized: Host living	Parasitized: Host dead	Parasitized: Parasite emergence	Scale preyed upon
March 14	Colwood	Douglas fir	40	30	-	-	-	-	10
" 24	"	" "	50	46	4	-	-	-	-
" 28	Langford	" "	4	1	2	-	-	-	1
April 8	"	" "	35	8	8	16	-	2	1
" 23	Colwood	" "	63	33	2	1	-	-	27
" 25	Cowichan Lake	Lodgepole pine	27	10	10	3	-	-	4
" 29	Oak Bay	Douglas fir	81	23	3	9	1*	1	44
May 1	Cowichan Lake	Lodgepole pine	119	4	35	2	-	1	77
" 30	Cottonwood Ck.	Western hemlock	29	1	11	11**	-	6	-
" 30	Cowichan Lake	Lodgepole pine	46	8	29	2	1*	-	6
		Totals	494	164	104	44	2	10	170

* Pupae of the chalcidoid occurred within the dead hosts.

** One of the hosts contained two parasite larvae.

(e) THE EUROPEAN PINE SHOOT MOTH, Rhyacionia buoliana Schiff.

K. Graham.

The European pine shoot moth was found at two locations only, Granville St. at 41st and 49th avenues in Vancouver, in a re-survey of the earlier infested area carried out in late April and early May in co-operation with officers of the Plant Protection Division. Trees of little value were removed by the owners and the infested tips of others were clipped off and destroyed. A native species of Pinipestis, probably zimmermanni Grt., also causing injury to shoots of lodgepole pine, was found on the Langara Golf Course, and on Lulu Island, where the host tree occurs naturally. Injury by this species occurs somewhat earlier than in the case of Rhyacionia, as shown by the smaller amount of growth attained by attacked shoots.

(f) THE HEMLOCK SAWFLY, Neodiprion tsugae Midd.

K. Graham.

Scattered colonies of larvae of the hemlock sawfly were found in 1940 and 1941 on western hemlock, mountain hemlock, and amabilis fir at Cottonwood Creek and on western hemlock at McConnell Creek. Defoliation was not very conspicuous despite the fact that the larvae could be recovered in some numbers by beating the trees. Some general observations were made on the bionomics of the insect on western hemlock at Cottonwood Creek.

In 1941, overwintered eggs in the margins of 1940 needles were still present as late as May 30. Larvae were nearly mature by the second week in August in 1940 and by the end of July in 1941. Spinning up in 1941 began by the end of July and was complete by the end of the third week in August. Adult emergence began by mid-September and continued into late fall in the field laboratory, and, under warmer conditions, emergence occurred as late as December 31. Emergence was, however, still not complete, since healthy larvae were present in some cocoons as late as April 1942. Species of parasites reared from the cocoons include the Tachinid Tsugaea nox Hall, the Ichneumonid, Lamachus sp. and Mesochorus sp., the latter being hyperparasitic. No parasites were reared from larvae.

Records for 235 larvae collected in late July, 1941, are as follows:

Larvae died prior to spinning up		27
Cocoons spun		208
Larvae died in cocoon	48	
Larvae did not metamorphose by April,1942	9	
Adult sawflies emerged: males	60	
females	83	
Tachinid parasites	5	
Lamachus sp.	2	
Mesochorus sp.	1	208

A higher mortality within the cocoon occurred in 53 cocoons collected in the field August 20, and kept in the field laboratory until December 12. No emergence occurred, although eight cocoons contained sound larvae and another contained a parasite larva. All of the others died in a flaccid condition and showed symptoms characteristic of a polyhedral disease. The same symptoms were shown in mid-August by larvae which failed to spin cocoons, and by larvae which died in cocoons in other rearings.

The bodies which appear to be polyhedra, occurring in the body fluids of diseased but not of healthy larvae, are visible with critical illumination at 1000 X magnification, using an oil-immersion objective of 1.25 N.A. They are broadly angled, transparent crystalline particles ranging in diameter from about 0.7 to 4.2 microns. They are insoluble in cold water, xylol and ethyl alcohol. They do not stain with the ordinary tissue stains such as eosin or methylene blue, nor with the fat-stain, Sudan III, but in common with other proteinaceous substances including uric acid, stain yellow with picric acid. But in distinction from uric acid obtained from post-emergence excreta of the sawfly, failed to give the distinct violet-red colour reaction with the murexide test in which dilute nitric acid is added, evaporated to dryness and subjected to ammonia fumes.

Further observations on the sawfly, its parasites and diseases are proposed for the coming season.

(g) THE COAST TENT CATERPILLAR, *Malacosoma pluvialis* Dyar

M.L. Prebble.

Tent caterpillars were very rare throughout the district in 1941. Occasional larvae were noted on trembling aspen in the U.B.C. Botanical Gardens, Vancouver, remnants of a nest at Cottonwood Creek, and a single flourishing colony on cultivated cherry in Victoria. There were 100 well grown larvae in the colony May 4, spinning of cocoons began May 14, adult emergence began June 10; eventual emergence totalled 33 males, 32 females. Although many of the caterpillars bore Tachinid eggs on the body surface when collected May 4, most of these were evidently sloughed off unhatched. The Tachinid was Tachinomyia similis Will. and only two specimens resulted from the entire colony.

(h) THE EUROPEAN ELM SCALE, Gossyparia spuria (Modeer).

M.L. Prebble.

The infestation of the European elm scale in the Granville area of Vancouver continued actively in 1941. Many young nymphs were noted on various species of elm at Marguerite and King Edward avenues early in August.

An infestation of this insect was discovered in the Gorge district of Victoria inJune 1941. It was moderately heavy on a few trees. Associated with the nearly mature female scales were very large numbers of a small brown mite, the status of which has not yet been determined.

(i) THE APRICOT MOTH, Batodes angustiorana Haw.

M.L. Prebble.

Larvae of the apricot moth were numerous on occasional ornamental yew trees on the grounds of the Parliament Buildings, Victoria, in March and April. The old feeding nests were conspicuous before the new growth started, and there was considerable feeding on the foliage and stems of the 1940 growth prior to the appearance of 1941 growth (April 7 and later).

There was about 50% moth emergence from early larval collections of rather small size. Three hymenopterous parasites were recovered, viz.: Angitia basizona Vier., which was also recovered from the black-headed budworm, Inareolata rosaceanae (Vier); and Hemiteles sp., which was probably a secondary parasite. Strangely, no parasites were recovered from host collections made in late April.

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