

PROCEEDINGS
of the Tenth Annual
WESTERN FOREST INSECT WORK CONFERENCE

Vancouver, British Columbia

February 26-28, 1959

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EXECUTIVE COMMITTEE (Tenth Conference)

R.W. Stark, Calgary	-	Chairman
M.G. Thomson, Vancouver	-	Immediate Past Chairman
J.M. Kinghorn, Victoria	-	Secretary-Treasurer
D.E. Parker, Ogden	-	Councilor (1956)
C.L. Massey, Albuquerque	-	Councilor (1957)
E.C. Clark, Moscow	-	Councilor (1959)

K. Graham, Vancouver		
H.A. Richmond, Nanaimo	-	Program Co-chairman

EXECUTIVE COMMITTEE ELECT

R.W. Stark, Berkeley	-	Chairman
M.G. Thomson, Vancouver	-	Immediate Past Chairman
J.M. Kinghorn, Victoria	-	Secretary-Treasurer
C.L. Massey, Albuquerque	-	Councilor (1957)
E.C. Clark, Moscow	-	Councilor (1958)
G.T. Silver, Victoria	-	Councilor (1959)

D.E. Parker	-	Program Co-chairmen
R.I. Washburn		

Prepared by the Secretary-Treasurer from summaries submitted by the Discussion Leaders named under each section. Stenographic and duplicating assistance was provided by the Forest Biology Division, Canada Department of Agriculture, through the services of Misses D.E. White and M.V. Mitchell of the Victoria Laboratory.

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MINUTES OF THE INITIAL BUSINESS MEETING

February 27, 1959.

The chairman, R.W. Stark, opened the meeting at 9:25 a.m. in the Board Room of the Forest Industries Building in downtown Vancouver.

A one minute silence was observed in memory of Mr. S. Murray Sager.

Dr. K. Graham introduced Dean G.S. Allen of the University of British Columbia's Faculty of Forestry. Dean Allen briefly, but warmly welcomed the group and stressed the value of this, and similar informal technical meetings.

Mr. H.A. Richmond then introduced Mr. H.S. Hepher, Chairman of the Pest Control Committee of the B.C. Loggers' Association. Mr. Hepher welcomed the group on behalf of the forest industries of British Columbia. He then outlined the formation and functioning of the Pest Control Committee and gave some detail of the black-headed budworm survey and control project on Vancouver Island. The problem of spray hazard to fish was stressed.

E.C. Clark moved the adoption of the minutes of the last meeting as presented in the 1958 Proceedings. Seconded by R.R. Lejeune. Carried.

The Secretary-Treasurer read the Secretary's Report and the Financial Statement for the period since the last meeting. A resumé of the executive meeting held the previous evening was then given.

In compliance with the wishes of the last meeting, the group approved Ogden, Utah, as next year's meeting place through a motion by R.R. Lejeune and seconded by N.D. Wygant.

A discussion of the place and theme for the 1961 conference left the decision for the 1960 gathering. Whether or not Ogden should be included in the "central triangle" of the conference area was debated, and the consensus of opinion was that a decision should be withheld pending the attendance at the 1960 meeting in that city.

Following the suggestion of the executive, P.C. Johnson moved that the theme of next year's meeting be "Criteria for Control Decisions". Seconded by H.A. Richmond. Carried.

The report of the Committee on Indexing of Reports and Publications was read by the Chairman for G.R. Hopping (see Appendix). K.H. Wright moved the adoption of the report. Seconded by Silver. Carried.

The chairman declared that there would be meetings of the Common Names Committee and the Education Committee in the evening. P.C. Johnson was appointed Chairman of the Nominating Committee assisted by R.R. Lejeune and R.L. Furniss. One councilor for a three-year term is to be nominated.

It was announced that Joseph Chamberlin's "Scolytidae of the Pacific Northwest" had now been released by the O.S.C. Press.

Conferees introduced to the group were:

H.S. Telford

J.E. Harris

E.D.A. Dyer

It was announced that a tour of the new Forest Products Laboratory at the University of British Columbia had been arranged for Saturday afternoon.

Upon a motion by R.R. Lejeune, the meeting was adjourned at 10:10 a.m.

REVIEW OF CURRENT FOREST INSECT CONDITIONS IN THE
WESTERN UNITED STATES OF AMERICA AND CANADA

Feb. 26, 10:00 - 11:00 a.m.

G. T. Silver

There was no broad over-all trend apparent in insect conditions throughout western North America in 1958. Of the eight regions two reported increases, two decreases, one no change, and three made no general statements regarding insect outbreaks. Fifty insects were reported upon of which 17 were bark beetles.

Spruce budworm. - The spruce budworm was reported from New Mexico to the Great Slave Lake in the Northwest Territories. The area of all outbreaks exceeded 6,000,000 acres.

Medium to heavy defoliation occurred along the Slave River in Alberta for 100 miles between Fort Smith and Great Slave Lake, and for 15 miles along Muddy River. In British Columbia the 2-year-cycle spruce budworm outbreak at Babine Lake increased in area to 1,300 square miles from 1,000 square miles in 1956. The area of the outbreak in the Lillooet and Fraser River region increased. Oregon and Washington reported only 315,000 acres defoliated in 1958 compared with 830,000 acres in 1957. Total area infested in New Mexico was 324,000 acres; the largest build-up here was on the Carson and Santa Fe National forests. Budworm defoliation in the Intermountain region totalled about 4,000,000 acres.

In Oregon a total of 818,000 acres were sprayed at a cost of \$.70 per acre, and 100,000 acres were sprayed in Arizona on the North Kaibab Plateau. Mortality in both operations was about 96 per cent. No control operations are planned for 1959.

Spruce budworm populations in the National Parks in Alberta decreased in 1958. Egg counts in the 2-year-cycle outbreak at Babine Lake increased, but similar counts of the 1-year-cycle budworm in the Lillooet-Fraser River area were not significantly less than in 1957. Decreases are expected in Oregon and Washington, and increases are expected in New Mexico, Colorado, and in some sections of the Intermountain Region.

Black-headed budworm. - The black-headed budworm was reported from Oregon and the Intermountain Region north to Alaska. The heavy outbreaks on northern Vancouver Island, British Columbia, and in Washington, Oregon, and Montana have all collapsed or are on their way out. The collapse of the outbreaks which are now subsiding completes a series of more or less continuous outbreaks which started in Alaska and worked south. Infestations were reported in Alaska in 1948, Portland Canal 1950, Queen Charlotte Islands 1951, Bella Coola and northern Vancouver Island 1954, and Washington, Oregon, and Montana, 1956. It is therefore of considerable interest that the black-headed budworm is increasing in the Ketchikan area of Alaska and in the Queen Charlotte Islands in 1958.

Douglas-fir beetle. - The Douglas-fir beetle was reported from all regions except Alberta and Alaska. With the exception of Arizona and New Mexico which reported a decreasing trend, increases in number of attacks and damage were general from California north into British Columbia.

Although Arizona and New Mexico reported a decrease based on area, losses in 1958 were 245 million bd. ft. compared with only 96 million bd. ft. in 1957. In California the outbreaks in the Grider Creek drainage continued. Distinct upward trends were noted in Regions 4 and 1 in 1958, but the increase in Oregon and Washington was most striking, 931,000 acres infested compared with only 18,400 acres in 1957. The Douglas-fir beetle was one of the most destructive insects in the Central Rocky Mountains, killing 4.8 million bd. ft. on 41,330 acres. A general increase was observed in British Columbia, but was most noticeable in the Cariboo region. The highest incidence of attack was in areas of greatest sawmill concentration and logging activity.

Engelmann spruce beetle. - It is noteworthy that the Engelmann spruce beetle populations are decreasing or remaining static in undisturbed areas. Outbreaks or increases in intensity of existing outbreaks have nearly all been associated with logging operations or blowdown.

The Engelmann spruce beetle is epidemic in several stands in Colorado, all adjacent to timber sales. A total of 7,970 infested trees on Missionary Ridge, San Juan National Forest, will either be logged or treated in 1959. Thousands of cull logs will also be treated in several areas. A decline is reported in Region 1, but increases were noted in Region 4 in widely scattered areas in or near recent, scattered logging operations. Control action, started in 1958, will be continued in some areas in 1959. A decrease in area infested was noted in Oregon, Washington, and British Columbia.

Mountain pine beetle. - Mountain pine beetle populations appear to be fluctuating by tree species. Downward trends were noted on lodgepole pine in some areas, while infestations on western white pine and ponderosa pine are static or increasing.

A total of 22 infestations on lodgepole pine were reported in Region 4, ranging in size up to 90,000 trees infested in the Wasatch National Forest. Six thousand ponderosa pine trees were removed or cut and burned in the Crystal Bay area, Nevada. Outbreaks on lodgepole pine in British Columbia decreased. In the Babine Lake area about 28 million cu. ft. have been killed since 1955. A general increase was noted on white pine in the Nelson District. Oregon and Washington reported 268,160 acres infested compared with 212,000 acres in 1957. Increases were in young ponderosa pine stands, decreases were noted on lodgepole pine. Increases were noted in lodgepole pine stands in three areas in California and in the Windy River District in the Rocky Mountain Region. Treatment of 11,810 trees in the Shoshone River Area in 1957 and 1958 has stabilized the population in that region.

Black hills beetle. - Control measures on the Dixie National Forest and Bryce Canyon National Park, Intermountain Region, resulted in a decrease in the outbreak on ponderosa pine. The 1957 outbreak on 17,000 acres in the Carson National Forest, New Mexico, was successfully controlled by treating more than 500 infested trees with a water emulsion and ethylene dibromide. A 4-fold increase in area infested was reported in Colorado and Wyoming. Control operations in the Black Hills will be continued in 1959.

Western pine beetle. - Oregon and Washington reported an upward trend in the Ochoca National Forests and Warm Springs Indian Reservation. There was a statewide decrease in California, and the beetle remained at a low level in Regions 1 and 4.

Pine bark beetles. - An association of Ips and Dendroctonus spp. killed pine on 534,860 acres in Arizona and New Mexico. The initial attack was usually made by Ips in the upper crown with the Dendroctonus spp. filling in beneath. The damage is decreasing in intensity.

Balsam woolly aphid. - A decrease in the intensity of damage by the balsam woolly aphid was noted in Oregon and Washington with the exception of attacks on subalpine fir stands in the Cascade Range. This was the first decrease since 1954. Heaviest damage occurred in drainages in the Gilford Pinchot National Forest. The insect was discovered in Mt. Rainier National Park for the first time. Six imported species of predators were released in 1958 of which at least two are temporarily established.

The balsam woolly aphid was discovered in British Columbia in the greater Vancouver area. Amabilis fir is the major host. Tree mortality has been light to date but 80 per cent of the amabilis fir in the infested stands are attacked.

Aspen leaf-miner. - Many patches of dead aspen, ranging in size up to 10 acres, are appearing on four National Forests in Western Wyoming, and south-eastern Idaho where the aspen leaf-miner has been in epidemic status for about 10 years. The insect caused heavy mining to trembling aspen leaves throughout most of the range of the host tree in British Columbia.

Lodgepole needle-miner. - Lodgepole needle-miner outbreaks are present throughout most of the Cassia Division of the Sawtooth National Forest in Idaho, and in 50,000 acres in Yosemite National Park in California. Experiments in California indicate that the needle-miner can be controlled with malathion sprays applied by helicopters if large enough volumes of spray are put on.

Douglas-fir tussock moth. - A 10,000 acre outbreak in southern Idaho was practically eliminated by virus disease. A sharp increase in population was noted in Arizona and New Mexico where three new outbreaks were found in 1958. Total area infested is 19,000 acres. About 100 acres were treated in June with 1 lb. DDT in 1 gal. of fuel oil with limited effectiveness.

Larch sawfly. - An outbreak of larch sawfly was discovered in Missoula Co., Montana, in 1958, the first record in the northern Rocky Mountains since 1944. The insect also caused light to severe damage over a large area in Alberta from Calgary north to Fort Smith in the Northwest Territories.

Tent caterpillars. - Malacosoma disstria was abundant and increasing in Alberta, and Regions 1 and 4. M. fragilis defoliated 131,000 acres in Colorado, and 1,180 acres of aspen were classified as dead as a result of continued defoliation for nine years. Area of defoliation in Arizona and New Mexico decreased in 1958 to 223,620 acres from 250,690 acres in 1957. Control by parasites and virus disease was recorded only in the Intermountain region.

Neodiprion sawflies. - Outbreaks or high populations of Neodiprion sawflies were recorded from Alaska, British Columbia, Oregon and Washington, New Mexico, and the Rocky Mountain region.

Spear-marked black moth. - This moth was prevalent over 5,829,000 acres of paper birch in Alaska in 1958. Heavy defoliation occurred on 333,000 acres. A decrease in population as a result of parasites and a virus disease is expected to continue.

Seed and cone insects. - Seed and cone insects destroyed about 75 per cent of a good Douglas-fir cone crop in California. Jeffrey and ponderosa pine cones also suffered heavy losses.

Mites. - The outbreaks of the spruce mite in Montana following spraying of spruce budworm persisted in 1958. Without exception mite populations were insignificant in areas that were not sprayed.

Loopers. - Populations of the hemlock looper and green-striped forest looper were noted in British Columbia in 1958. An increase is expected in 1959.

Discussion:

To a question by Trostle, A.D. Telford replied that a dosage of 20 gallons per acre was applied with helicopter against the needle miner. Malathion in oil caused excessive needle drop. Silver replied to Furniss that a method was not available for detecting low infestations of Chermes.

Johnson supported the continuance of the insect outbreak reports and suggested that they should be publicized more widely. He suggested that each region include a map with its summary. Hepher suggested that the material be given to trade magazines for publicity. Stark thought a committee could be struck to investigate ways and means of furthering publicity. On the other hand, Furniss recalled that the earlier policy of the work conference was to leave publicity and control support to action groups. He stressed that excursions into the field of publicity would be outside the responsibilities of the work conference. Wygant mentioned that at least one journal (The Timberman) does print outbreak information gathered independently from the work conference summaries. Furniss, supported by Richmond, again urged that the conference refrain from the type of work being undertaken by regional action committees.

I. DEFINITIONS AND SCOPE OF PROGRAM

Feb. 26, 11:00 - 11:20 a.m.

K. Graham

Graham opened the first session of the theme by defining the scope of the subject "Biotic and Biological Control". In the more limited sense, biological control simply means the use of one organism to combat another. But this field really includes in addition to parasite introductions and redistributions, also manipulations of the environment that affect parasites and predators as well as the host. For example, direct control often governs the extent of biotic control. Similarly, silvicultural control affects the functioning of the parasite-host complex through changes in the environment.

In connection with chemical control, he mentioned that sprays applied as an emergency measure, may have subsequent, as well as immediate effects

on the pest population by influencing the efficiency of density dependent factors. The subsequent effect may be beneficial if the proportion of parasites to host is not reduced. Excessively intense chemical control can theoretically be disadvantageous in environments favoring chronic outbreaks; under this condition the parasite is reduced by host scarcity while the host is free to increase in a favorable environment.

Selective chemical methods offer an approach to control that may leave the parasite and predators relatively unharmed, while at the same time reducing the pest population. Often use of highly selective poisons may be limited by economic factors. For example, a universal poison such as DDT is so inexpensive, that it may be more economical to use than a more efficient, but highly expensive pesticide.

The environment may also be changed by cutting and planting practices. This may still be a relatively unknown sphere, but it is fairly obvious that insect populations remain stabilized in mixed stands compared with violent fluctuations that frequently occur in pure stands. Another case where changes in the environment influence biotic control is where flood levels in larch stands affect the well-being of predaceous small mammals. When flood level is favourable to the small mammals, effective control is exercised on the larch sawfly.

As yet, the field of breeding parasites and predators with superior characteristics of selectivity and adaptability has not been given much attention. Selection of strains of insect pathogens for virulence appears to be a distinct possibility.

In summary, therefore, the scope of the program encompasses any manipulation that changes host-biotic agent relationships, either through environmental change, direct control, or restraint of direct control.

II. EVALUATION OF THE EFFECTS OF BIOTIC AGENTS

Feb. 26, 11:20 - 12:00 noon
1:15 - 2:15 p.m.

Discussion Leader: R.W. Stark

This section of the program has been divided into three parts: Methods of evaluation, theories involved in expressing mortality, and considerations of instigating introduction of biotic agents. Because of the broad scope of all of these sections we have been forced to speak generally rather than particularly and hope that we have left enough time for particulars, either question or example, to be raised from the floor.

(1) Methods of Evaluation (R.W. Stark)

Biological control, whether natural or manipulated, usually includes control by parasitic, predatory and pathogenic organisms. My remarks on methods of evaluations are, therefore, fitted into this frame.

(a) Parasites Endo- and ecto-parasites differ from our point of view only in that the ecto parasites are visible and hence their numbers can be measured more easily and more often. Most endoparasites, like those in the needle miner parasite complex, are not visible until the larval period of the host is nearly completed. This means that we can measure only the surviving population of parasites and have no easy way of determining parasite mortality.

Estimating parasite populations is usually directed at their immature stages and is also usually a by-product of measuring host populations. With this in mind, there are several pitfalls we must keep in mind when determining parasite population figures.

First, a sampling system derived for the host is designed to yield a population estimate within certain error limits for the host population. It does not necessarily follow that the same error limits will apply to the parasite population. If the distribution of the parasite is identical to that of the host, and if the variation in numbers is the same, then the sample will give a true picture of the parasite-host number relationship. Too often, these conditions are not met, as for example the difference in distribution of Apanteles and Glypta on spruce budworm within the tree crown.

Second, there are variations in timing to be considered. Each species of parasite behaves in a different manner; some parasitize the egg while still in the host, some when it is laid and others throughout the developmental period. Others as mentioned above, are invisible until some later host stage such as the mature larva or pupa. These stress the importance of knowing the bionomics and behaviour of all species of parasite involved. Unless practicable techniques are developed for determining the hidden stages of parasites only a minimal estimate is possible.

Third, hosts vary considerably in their life cycles and often two or even three different sampling systems are necessary. A good example is the larch sawfly which requires different sampling treatment for eggs, larvae and pupae. These difficulties naturally are transmitted to parasite sampling. In fact, they by their behaviour may introduce further complications.

Fourth, are the parasites host specific, or is their effect scattered over a wide variety of hosts? Some parasites have been overcome by host resistance which adds another complication. Presence of the parasite may not be lethal. For example, the larch sawfly is able to encist Mesoleus parasites.

These are a few of the difficulties involved in assessing parasite populations. I hope they will bring to mind others. Some workers have made estimates of adult parasite populations by various trapping methods (e.g. DeBack in California). While these are of value in giving seasonal trends of numbers of adult parasites, they cannot reflect the host-parasite relationship unless the parasites efficiency and the biology of both parasite and host are thoroughly known.

Several workers have shown in the past few years that parasites are not always as effective control agents as formerly believed. Their claimed success was largely due to inadequate sampling and, I am sure, innocent misrepresentation of mortality data. Mr. Shepherd will discuss the latter, but I would like to say that the time has either come, or is near at hand, when we must attempt to sample parasite populations in a manner similar to that becoming popular for hosts -- in a periodic, systematic way such as used for life table compilation.

(b) Predators The evaluation of the effects of predators is far more complex than that of parasites. Predators generally are birds, small mammals, insects and possibly others such as lizards. Their effects are by and large sporadic, unspecific and unpredictable. Again we must know thoroughly the biology of the predator with respect to the host population.

Is the predator host-specific, relying only on the insect for its food? How much does it eat? What are its feeding habits with respect to host distribution? The effect of a predator gorging itself in a small niche of a large outbreak is liable to be negligible. Also, predators are considered to be inefficient in their choice of prey and may actually have a detrimental effect on parasite populations, which are conceded to be more efficient control agents. We have one notable exception to this, where small mammals, shrews and the like, are able to distinguish between parasitized and unparasitized cocoons. Unfortunately most predators are not so clever or discriminating.

The problems of measuring the actual loss to an insect population by birds eating moths on the wing are great, much more so than that of measuring the loss due to predators which leave visible evidence of their work such as some small mammals, and predatory insects.

Most are familiar with the work done outside of this group, I am sure. Various methods have been used -- counting of caches of cocoons and pupae by various small mammals, analysis of stomach contents of feeding mammals and birds, estimation of predator populations by trapping, marking, releasing and retrapping, straight observations by spotters, particularly of birds and so on.

One further comment is that action of predators contributes to the variability of the host population, including parasite and disease populations, thereby increasing sampling difficulties. Predator action accentuates the patchiness of host distribution.

Discussion:

Comments on bird predation of spruce budworm were given by Carolin who cited some of Morris' work. The direct numerical response of bird predators is given by a survey of the number of nesting pairs per acre, but the functional response must take into account the per cent of total food that the budworm represents. The number of nesting pairs is determined by census lines which must be run yearly over the budworm outbreak period. Bird species are identified by their songs. Three bird species have a direct numerical response to the increase in budworm populations. After a slight delay of about one year, the bird population could not keep pace with that of the insect. At low population levels, the consumption of budworm may represent a considerable effect. One nest of warblers may destroy 15,000 budworms, although the insect represents only 40 per cent of the birds' food.

Wilford, citing work by Knight and Baldwin, outlined census methods for woodpeckers preying on the Engelmann spruce beetle. Three species are common: the Downy, the Hairy, and the Northern 3-tip woodpeckers. Woodpecker predation was eliminated by hardware cloth cages placed at intervals up the boles. Muslin cages were also used to prevent insect parasites and predators from reaching the beetles. Continuous monthly census of bark beetles were obtained in some outbreak areas. Woodpecker census was obtained in 25-chain plots. At 5-chain intervals, woodpeckers were surveyed by listening and watching for the birds. Bird species were identified by ocular observation. The heaviest woodpecker work occurred on trees heavily infested by bark beetles. In these trees, woodpeckers exerted a much higher percentage of control than in lightly infested trees. It is felt that woodpeckers have been highly effective in curbing small spruce beetle outbreaks in the Rocky Mountain Region. Woodpecker effectiveness is reduced on down-trees. To a question by Lejeune, Wilford replied that woodpecker work is less

in trees on the ground partly because of snow cover, but mostly because the birds are wary of venturing close to the ground where they are more susceptible to predation.

Stark commented that ocular estimates for woodpeckers are satisfactory since there is little chance of recounting the same bird.

Wygant mentioned that a graduate student in his region recently tested several bird census techniques.

A.D. Telford re-emphasized the fact that a census of the numbers of birds alone does not adequately assess their effectiveness because the pest insect may constitute a higher proportion of the birds' total food as the outbreak progresses.

(c) Pathogens About diseases little can be said except that estimates of disease effectiveness are arrived at in the same way as for internal parasites, by examination of the samples taken for estimating host population. The difficulties here lie in determination facilities are not available for identification and determination of diseases. Also, so little is known of forest insect diseases that it is not possible to determine whether a pathogen is lethal or not. A further difficulty in estimating effect is that while a disease may not have a lethal effect, it may have a profound effect in reducing fecundity -- e.g. as found in some spruce budworm populations in Eastern Canada.

Another complication arises from host resistance to disease. That is, the insect may develop a method of overcoming, or become resistant to, the toxicity of a disease.

All of these considerations complicate the job of assessing the effectiveness of biotic agents. With diseases, in particular, we can assume mortality only when the insect shrivels and dies with our present state of knowledge, unlike parasites we cannot conclude that presence of a disease in a living larva or pupa means death.

One concluding remark to add to the confusion is how do you rate the effectiveness of a parasite which permits the organism to complete its life cycle and wreak its damage before doing it in? Its effect on the succeeding generation is obvious but from a strictly economic point of view it seems rather inefficient.

Nematodes are a problem which has recently become of importance. Again so little is known of their effects that it is not certain whether they act as a control factor or not. It appears they affect fecundity in some insects but are not in themselves lethal. Estimates of presence would have to be by dissection and of effect by much more detailed studies.

I hope that this very broad outline of the problems involved will stimulate discussion and particularize specific problems. If anyone wishes to elucidate on techniques which they have found useful now is the time.

(2) Theory Involved in Expressing Mortality (R.F. Shepherd)

Percentage mortality figures by themselves do not adequately indicate the degree of control caused by a mortality factor. Such figures depend upon

the method of calculation, and the interpretation of the results depends upon the knowledge of the distribution, abundance, and biology of the insect, as well as other mortality factors affecting the insect.

The percentage mortality is sometimes calculated as the number of insects killed over the number of insects at the beginning of the stage in which the mortality took place. For example if factor b is compared with the number of live larvae the apparent mortality is $\frac{200}{1000} \times 100 = 20\%$. (See accompanying tables.)

If this was an experiment in biological control where factor b is a predator that is actually being released, then you would want to know how much additional mortality you have caused by introducing the predator. The amount of predation could be determined by the difference between two samples, which took place one before and one after predation took place. In this case a control plot could indicate the natural control due to other factors than the predator. If in this plot, 50 larvae die out of 1000 due to other factors during the period predation was effective, then the control due to predation would be $\frac{950 - 800}{950} \times 100 = 15.79\%$.

Both of these figures express immediate reduction in population before and after the mortality factor becomes effective. If one is interested in the effect of the mortality on the whole generation, then the number of insects killed is compared with the number of eggs at the beginning of the generation. If, for instance, the 1000 larvae in the previous examples came from 1,500 eggs then the reduction of the whole generation caused by the predator is

$$\frac{950 - 800}{1500} \times 100 = 10\%$$

Many people prefer to measure the effectiveness of a mortality factor by the change that would have occurred in the surviving population if that mortality factor had not been present. In this example, if factor b was absent we would have obtained 72 adults instead of 24. The reduction in the generation due to factor b would be $\frac{72 - 24}{1500} \times 100 = 3.2\%$.

If one is interested in the changes of population from generation to generation this change in the number of surviving adults is more significant. This mortality factor results in an adult population which is only $\frac{24}{72} \times 100 = 33\%$ of what it would have been if the factor had been absent. In life table work this has been called the index of population trend and is calculated as the ratio of the number of insects of a certain stage, usually the egg, in consecutive generations expressed as a percentage. If the same number of eggs is present in two generations then the index is 100. In our example if factor b is operating then the index is $\frac{1200}{1500} \times 100 = 80\%$.

If it is not operating then it is $\frac{3600}{1500} \times 100 = 240\%$.

The importance of a certain mortality percentage cannot be judged by itself, but must be compared with the potential increase or fecundity of an insect. With an insect which has a low fecundity of say 10 eggs per female, then any increase in the total generation mortality above 80 per cent would lead to a decrease in the population. On the other hand, with an insect which has a fecundity of 200, mortality would have to surpass 99 per cent before any reduction would take place.

The importance of a mortality factor in causing fluctuations in

numbers over a long period of time depends, not on the amount or per cent of mortality, but upon the variation of that mortality from generation to generation. Thus a mortality of 90 per cent is unimportant to the fluctuations if it is constant. However, when considering the addition or change in mortality the level at which that change takes place is very important. If, for instance, the total larval mortality increases by 1 per cent from 90 to 91 per cent, the change in the number of surviving adults is a reduction of 2.4. But if the mortality of eggs increases by 1 per cent from 33 to 34 per cent, the resulting change in the surviving adults is a reduction of 0.3. Thus even though there are 10 insects or 1 per cent mortality involved in each case, that which was added to a 90 per cent mortality of a given stage produced a reduction eight times that which was added to a 33 per cent mortality. By the same inference, an increase in total mortality from 98 to 99 per cent would produce the same result in numbers as a 50 per cent reduction in fecundity - that is a change of from 100 to 50 eggs per female. When mortality factors act at the same time on a certain stage of an insect then the importance of small changes in the mortality of one depends upon the accumulative level of all these factors providing, of course, that there is no interference between factors, i.e. if factor b increases from 20 to 21 per cent it would have the effect of a factor changing from 90 to 91 per cent as this is the total mortality of all the factors affecting the larval stage.

This relationship between the ultimate effect on the population and the level at which changes in mortality takes place depends upon one assumption which is not always met, particularly with mortality due to parasitism. The above condition holds only when the per cent mortality of the factors in the rest of the life cycle remain the same. That is they are able to remove 31 per cent or 45 per cent of the population regardless of the number involved. If, however, the mortality factors which follow a change remove the same number of individuals each time, their per cent mortality will shift and the change in the generation mortality will be the same no matter at what level it occurs. But in this case another factor is important. If the mortality in the egg stage is increased by 1 per cent to 34 per cent the ultimate decrease survival to adult is 10. If we increase the mortality of the pupal stage by 1 per cent to 32 per cent the change in survival is only 1. Thus there is a tenfold difference between equal changes in per cent mortality depending upon the order in which the factors act. An early factor has a much greater effect upon a surviving population than a later factor.

In summary we can say that:

Percentage mortality figures can be presented in many different ways, but unless the basis of such figures are given they mean very little. Such figures can only be interpreted properly if we have a good knowledge of the biology and fecundity of the insect as well as the other mortality factors involved.

If most of the mortality factors remove the same percentage at all population levels then their effect is the same regardless of the order in which they act. But the effectiveness of variations of these factors are closely related to the level around which these variations revolve. Small changes in factors which cause a large mortality are much more important than the same changes of factors causing a small amount of mortality.

If the mortality factors remove the same number of individuals at all population levels then the effect of small variations is independent of the amount of mortality during the stage, but is dependent upon the sequence in which mortality occurs. Small changes of factors acting early in the life cycle are much more important than those acting later.

CONSTANT % MORTALITY

CONSTANT NUMBER KILLED

Level important

Level not important

Order not important

Order important

1500	500	33%	1500	510	34%
1000	200	20%	990	200	20.1%
	300	30%		300	30.3%
	410	<u>41%</u>		400	<u>40.5%</u>
		91%			90.9%
90			90		
	26.9	31%		31	34.4%
	40.5	45%		45	50.0%
Adults	22.6		Adults	14	
1500	510	34%	1500	500	33%
990	198	20%	1000	200	20%
	297	30%		300	30%
	396	<u>40%</u>		400	<u>40%</u>
		90%			90%
99			100		
	30.7	31%		32	32%
	44.6	45%		45	50.0%
Adults	23.7		Adults	23	

Stage	Mortality factor	Number of insects present at the beginning of the stage	Number died	Apparent mortality of that stage
eggs	a	1500	500	33%
larvae	b	1000	200	20%
	c		300	30%
	d		400	40%
				<u>90%</u>
pupae	e	100	31	31%
	f		45	45%
				<u>76%</u>
adults		24		
	50: 50 Sex ratio.			
	Number of females	12		
	Fecundity 100/♀			
	Eggs of next generation	1200		

(3) Considerations of instigating introduction of biotic agents (D.E. Parker)

Webster states that to instigate is to goad or spur--especially to evil or wickedness. So the title gives me the right to goad this dignified and serious group to evil or wickedness. If that is all I had to do it might be easy--it also might be fun. It is unfortunate that there was not time to assign a substitute on the panel. Ron asked that I prepare something to get the stage set for discussion on introduction of biotic agents.

There are many facets to the problem of introducing biotic agents in our battle with forest insects. We are confronted with two primary considerations--are the pests native or introduced? They are separate problems. Having had some experience with forest insects from foreign lands established in eastern areas of the United States, it might be well to discuss some of the problems that arose in considering introduction of parasites and predators.

One of the first phases to be studied concerns the primary host itself. What natural enemies--parasites, predators, disease--may have accompanied the introduced pest? What parasites or predators that are present locally on other hosts may be attacking the newly arrived pest?

Before considering the introduction of biotic agents we should have quite complete knowledge of all that are present in the area and what they are doing to control the host.

What are the problems of establishment of natural enemies in the case of an introduced pest? They are many and diverse. There are organizations that

can obtain natural enemies in the native home of such pests. This is relatively simple to arrange. However, it is not just a matter of receiving shipments and colonizing parasites. Special facilities must be available for handling material to insure that parasites or predators are free from harmful insects or possibly diseases. It may be necessary to conduct rearing under controlled conditions to insure that pure cultures are available for colonization. It may be advisable to establish rearing procedures to increase numbers of individuals before colonization is attempted. I recall an instance where 19 mated females of a parasite of the satin moth served as a source of all colonies in the northeastern states for several years. It was possible to rear the parasite on a different host in the laboratory—a host that could be handled more easily than the satin moth. This enabled us to maintain breeding stock and continue colonization with ease.

Research is necessary to determine habits and life-history of individual species. Is the life cycle synchronized with that of the host? Is it a multiple-brooded creature that must depend upon an alternate host? Is it a species that attacks a wide range of alternate hosts? One of the tachinid parasites of the gypsy moth introduced from Europe proved to be very non-selective. As a result it multiplied and spread far beyond the limits of the area infested by gypsy moth attacking a wide range of other lepidopterous species.

One might assume that environmental factors of the native source must compare with those in the area of introduction. I do not believe that this is necessarily true. I believe that some parasites can adapt themselves to areas that seem quite different in character from the habitat to which they were collected.

A word on hyperparasitism and competition. Hyperparasitism is a common occurrence. Thus in dealing with imported parasitic species to be introduced to combat a pest that may have come from foreign lands, there is need for extreme care. Some of the species that act as primary parasites also act as hyperparasites. Decisions must be reached after careful evaluation whether these species should be liberated or not. Mistakes can and will be made. What appears to be a mistake can take on the form of a blessing at times. One introduced Pteromalid in the northeastern states proved to be quite destructive to a primary parasite of the gypsy moth while the parasite was in the cocoon stage. There was considerable feeling that a painful mistake had been made in allowing the establishment of this particular species. Later, however, it appeared as an effective parasite of larvae of the satin moth. While it acts adversely in one case it is very beneficial in the second.

When a pest is subject to attack by a series of parasites competition results. There are several feelings regarding the introduction of as many species as can be found. Some feel that fewer of the more effective species might accomplish more by reducing competition; others feel that the more the merrier. I have a feeling that we need to know more about measuring the actual effectiveness of individual species and concerted action by groups of species before we can make statements that carry much authority.

In the case of colonization of parasites or predators one is faced with making a choice of distribution. Should he put all of his eggs in one basket or scatter his supply. There are advantages in both schemes. Setting up one colony furnishes an opportunity to gather data on ability of the species to spread and allows considerable opportunity to conduct studies where the initial stocking is known. On the other hand, scattering of colonies lessens

the chances of failure of establishment by allowing wider selection in environments.

Perhaps I have spent an unreasonable time in considering imported pests and introduction of biotic agents. In the West we are concerned mostly with native insects at present. However, we do have the larch casebearer in Idaho at the present time. It came from Europe originally many years ago. Until it was discovered in Idaho in 1957, it was believed that it occurred no further west than the Lake States. The smaller European scolytid associated with Dutch elm disease has spread westward rapidly in recent years. The balsam woolly aphid is another example of an imported pest now quite active in Oregon. I feel we may find more introduced species in the West as time goes on.

What are the chances of introducing biotic agents in the case of our native species? Obviously, they appear less favorable than in the case of a new pest in the area. Many people feel that there is little opportunity of increasing the complex of biotic agents in the case of native pests. I do not feel that this is necessarily true.

First, it is my impression that we do not know all we should about the complex of biotic agents now present and active in the case of our native pests. Thus, the first step is obvious--get the information as rapidly as possible.

What are the chances of building up parasites or predators now present at extremely low levels? My experience has been that it might as well be forgotten. Simple mathematical calculation often reveals that there are more individuals present even at these extremely low levels than could be reared by the most efficient methods for liberation. There could be possibilities, however, that widespread and isolated populations of some of our native insects may not have the same series of parasites and predators. If so, colonization might be effective.

By this time all of you are aware that my remarks have been confined to parasites and predators and in the case of predators primarily insect predators. We have others, of course. We know that birds are sometimes effective - woodpeckers often being extremely important in bark beetle epidemics. Rodents and other mammals can be quite important at times by destroying pupae or hibernating forms in the soil. Unfortunately, they also destroy puparia of dipterous parasites in the soil. Not being too familiar with the birds and the animals, I leave it to capable individuals in the group to expand this item. However, since the topic involves introduction of biotic agents, I want nothing to do with colonizing skunks to root out pupae in order to control an outbreak!

The field of insect diseases is one in which I have had little experience. I feel, however, that we can expand our activity in the field to great advantage. Work done in Canada and the northeastern states with Neodiprion sertifer, a sawfly on red pine, shows what can be done utilizing a virus applied by airplane in control of this pest. The Douglas-fir tussock moth in the West is subject to infection by a virus. We believe that while the virus eventually will develop in most of our outbreaks and reduce the populations, it might be possible to speed the rate of control. Often the insect causes considerable mortality before the virus overcomes the population. By dissemination of virus earlier in the cycle of an outbreak it might be possible to prevent some of the mortality.

Based on our limited experience with disease organisms it appears that their use with our native species could reduce the need for widespread application of insecticides. Aerial spraying with insecticides requires care in swathing and thoroughness in application to avoid misses, etc. With virus on tussock moth or Great Basin tent caterpillar, for example, it might even be advisable to spray only every other swath and let the virus spread on its own and infect larvae in between swaths. Survivors might be beneficial by carrying over virus in a light residual population. There are men here today who can discuss this phase better than I.

I would summarize my feelings on the introduction of biotic agents as follows:

1. Let us determine what we have now working on each of our serious pests.
2. Let us improve our measurement and interpretation of the effectiveness of biotic agents--a low percentage at the right time might be decisive.
3. Let us expand our research on the complex interrelationships that exist between hosts, primary parasites and predators, diseases, environmental factors - in fact every ecological happening that constitutes a part of the biology of our pests.
4. Let us use biotic agents whenever we determine that they will help in reducing populations. It may not be as striking as using insecticides, but they may be more beneficial in the long run.

My rambling remarks have only touched lightly on a few of the many facets of the problem. I hope that it will satisfy one objective--that of stimulating all of you to continued discussion of the subject.

III. PROSPECTS AND PROGRESS IN BIOLOGICAL CONTROL OF MAJOR FOREST PESTS

Feb. 26, 2:00 - 5:00 p.m.

Discussion Leader: R.R. Lejeune

Lejeune introduced the following general considerations to serve as a framework for discussion of specific pests. These remarks apply primarily to native insects.

- a) A thorough knowledge of the biological control complex might serve as a useful indicator of the status of an outbreak.
- b) Assessment of degree of control exerted by biological agents useful in determining if supplementary control measures are needed.
- c) Effect of sprays on parasites and predators.
- d) Modify environment to favour parasites and predators.
- e) Breeding programs to improve adaptation of biological control organisms.
- f) Diseases offer a fertile field for investigations but there have been important limitations to their successful use. Their two big advantages

are that they are self-multiplying and avoid the toxicity of insecticides.

(1) General Discussion

Stark. Cited an instance in Germany where a phase difference between a parasite and its bark beetle host caused a release of the host population.

Clark. Attempts to increase cold tolerance of a parasite of a scale on citrus by inducing mutation with radiation were described. Apparently it is very difficult to obtain both cold and heat tolerance together.

McGugan. The Forest Biology Division is making several approaches to increasing the pathogenicity of insect disease organisms. At Sault Ste. Marie viruses attacking sawflies have been studied with an interest in their specificity and the possible effects of transfers etc. More recently it has been hoped that micro-organisms might be found or produced, by mutation or genetic selection, which would be more pathogenic or have a wide range of pathogenicity to insects. It has been necessary, however, to explore the fundamental basis of microbial pathogenicity towards insects. Besides elucidating some of the enzyme actions involved, an alkali-resistant strain of bacterium has been developed by selection which appears better able to withstand the high pH values of the mid gut of most Lepidoptera.

Another worker has obtained some interesting preliminary results using various chemicals as additives in virus sprays. These chemicals are thought to either influence cell metabolism in the host or stimulate the pathogen itself. The end result in either case is a much higher host mortality.

The Forest Insect Survey is also on the watch for evidence of high disease mortality in field populations in the hope that highly pathogenic organisms may be obtained.

Massey. There is a difference in pathogenicity of disease organisms of Malacosoma. An increase in pathogenicity was obtained by transferring the organisms from one species of Malacosoma to another.

A.D. Telford. Described work being done in California to rear viruses outside of the host insects on tissue cultures.

(2) Discussion re Bark Beetles

Massey. The main parasites and predators of bark beetles are woodpeckers, Coeloides and nematodes. Two earlier workers, Thorne on D. monticolae and associated nematodes, and Fuchs, realized the importance of nematodes but did not evaluate their effects on the beetles. In a recent paper in 1955 Massey described his own work on assessing their importance and listed one new species, Sphaerularia dendroctoni, and Aphelenchulus reversus, a species described by Thorne.

The technique of evaluation was as follows. Twenty-five logs were used per test. To the logs he added pairs of beetles and after egg laying was completed the beetles were examined for nematodes. He found an average reduction in fecundity of 50 per cent in females infested. With Ips, the eggs laid per beetle averaged 12.6 per infested beetle and 26 per uninfested beetle. A higher percentage of the brood was infested by nematodes when the female or both parents were infested than when only the male was infested.

The most common nemtic parasites of bark beetles fall into the following genera:

Parastadhelenchus, Aphelenchulus, Parasitylenchus, Sphaerularia, and Rhabditis.

Massey had hoped to obtain a correlation between percentage occurrence of nematodes and the trend of bark beetle populations but was not able to establish this.

Atkins. Mentioned nemtic associates in relation to flight. Nematodes do not interfere with the flight response or the flight capacity of the Douglas-fir beetle, although the latter study is not yet complete. In earlier studies internal nemas appeared to increase the wing-beat frequency but in recent studies this has proved false. The nematodes do not seem to affect the wing-beat amplitude but clumps of mites on the tips of the elytra act as a wing-loading device. Nematode complex (10 genera, 18 species) make studies difficult since adults do not identify immature stages present.

Thomas. Outlined a research program on diseases of bark beetles which he is developing. Broad objectives are to determine what organisms affect bark beetles, to isolate the organisms, to determine whether or not they are pathogens, to determine pathogenicity and mode of infection, and to test their effect on a population. To date 35 bacteria, 5 yeasts and 4 fungi have been isolated. In one instance a pathogen, still unidentified, wiped out 80 per cent of a D. monticolae brood.

Advantages of disease as control agents were outlined:

- (1) Harmless to other organisms even at high doses.
- (2) Highly specific - no harmful effect on beneficial associates.
- (3) Reared inexpensively on artificial media.
- (4) Sprayed as dusts, etc., thus requiring no special equipment.
- (5) Could be permanent, thereby reducing frequency of application.
- (6) Can be used along with chemicals or other control agents.

The pathogens could be applied as bark sprays (spores), by releasing inoculated adults, or by releasing inoculated parasites, predators or scavengers associated with bark beetles.

Graham. Reported on a severe infestation of the Douglas-fir beetle on Vancouver Island that collapsed without the presence of the usual parasites and predators. However, he found a high incidence of a protozoan in the larval population.

Furniss. Requested information on attempts to vary the environment to increase parasite-predator populations. No one could report on a satisfactory assessment of such attempts but the following suggestions have been made.

- (1) Leave stumps of pine because that area is favoured by Clerids (Bedard).

- (2) Leave thin-barked slash to allow the parasite Coeloides to build-up its population on the Douglas-fir beetle and other secondary bark beetles (Atkins and McMullen).
- (3) Increase sites for small mammals to prey on beetles hibernating in the duff (Reid).

Discussion re defoliators

Carolin. For the 1-year-cycle spruce budworm there are about 60 known primary parasites recorded in North America; in the Pacific Northwest and in most other regions the complex consists of about 30-35 primary species. Predators are not well explored. In our area they are important in attacking overwintering larvae. A clerid, carabid, and a neuropteran are known to kill a fair number of budworms. In light infestations about 30 per cent of the overwintering larvae have been killed by predators, whereas in heavier infestations the average has been about 15 per cent. These values may prove useful as indicators. The role of spiders is difficult to assess. True bugs have been listed as predators but appear to be of minor importance.

Disease has been largely overlooked in field studies in the Northwest. From one collection in Oregon it was determined that 20-24 per cent of the budworms were infected with polyhedral and capsule virus but this is regarded as normal and not particularly damaging to a population. Fungi (particularly Beauveria bassiana) are important in some locations.

Introduction of parasites of the western spruce budworm into infestations in the Northeast was attempted during the period 1944-49. The liberations were made mostly in eastern Canada, although three species were liberated in New York and Maine. The success of these is in doubt at this time.

McGugan. The results of the biological control efforts against the spruce budworm in eastern Canada may be of interest. None of the parasites of related budworms in Europe that were liberated have ever been recovered. Slight evidence has been obtained for the limited survival of three of the species relocated from British Columbia. None of these have had any measurable effect on the spruce budworm outbreaks in eastern Canada.

It should be realized that biological control attempts begin long before specimens are liberated in the field. The search for, collection, and shipment of parasites and predators from other parts of the world is a costly and difficult business that deserves the interest of those facing the primary problem at home. There still remains an argument as to how a biological control program is best conducted. Some recommend the importing in quantity of any agents known to attack the pest on the premise that a direct trial is the best test possible. Others feel further study of the potential predator and parasite complex is most desirable so that only those elements that appear suited to the new environment need be selected for collection and liberation. Efforts in Canada to date have been largely of the first type and the score for successes is quite low. However, it may be argued that the few successes more than compensate for the many failures. Current planning is directed toward an intermediate course of action; a reasonable amount of study and experimental liberations prior to attempts at wholesale collection, colonization, and liberation.

Shepherd. On the 2-year-cycle budworm larval parasitism is only 2-3 per cent. There is a higher incidence of disease in non-outbreak areas, believed to be due to the higher precipitation and relative humidity in these areas.

Carolin. Forty species of insect parasites have been recorded from the black-headed budworm. Parasitism is usually light in the early stages of an outbreak, increasing in the later stages. Few data are available on the action of spiders and birds. There is often a high incidence of disease during outbreaks, leading to their collapse. A polyhedral virus was cited by Prebble and Graham as the most important factor in terminating an outbreak on Vancouver Island in 1944, while McCambridge stated that a fungus, Empusa grylli was instrumental in ending the outbreak in Alaska. A microsporidian disease was found at the end of a recent outbreak in western Washington. In this outbreak parasites accounted for twice as many larvae as disease in the sample plots.

The chances of successfully introducing or manipulating biological control agents appears more promising in the case of the black-headed budworm than for the spruce budworm. It is possible that another insect such as the fall webworm may act as an alternate host for one of the black-headed budworm diseases.

Silver. In the recent collapse of the black-headed budworm outbreak on Vancouver Island there was no evidence of disease. The decline was attributed to a prolonged cool wet spell during the late-larval period.

Wright. Balsam woolly aphid now infests $\frac{1}{2}$ - 1 million acres in Washington and Oregon. The three main hosts are native species of Abies plus 11 additional exotics. Heaviest damage has been in commercial-size mature Pacific silver fir stands, although very heavy killing has also occurred in subalpine fir of non-commercial value, but of considerable importance for watershed and recreation use. There is presently no silvicultural or chemical control so that the main hope is being placed on the introduction of predators.

There is a need to establish predators to reduce bole infestations below tree-killing density, and others to attack aphids on twigs to prevent gout. A complex of predators is desirable due to the long period of activity of the aphid - about 9 to 10 months in Oregon.

Desirable characteristics of predators are:

- (1) adaptation to extremes of climate,
- (2) synchronization with the aphid,
- (3) high fecundity and rapid build-up,
- (4) searching ability for original establishment and maintenance,
- (5) prefers the aphid but should have host flexibility.

The aphid doesn't cause much damage in Europe, largely due to host resistance.

A large number of predator introductions have been made in North America. Since 1933 in eastern Canada 11 species have been brought in, 4 Coleoptera, 5 Diptera and 2 Neuroptera. Three of the 11 are established at least locally and 1 dipteran is present throughout the range of the aphid on the Canadian mainland and Maine.

One coleopteron, Laricobius erichsonii, and 1 dipteran, Neoleucopis obscura, are fairly successful in reducing tree killing due to bole infestation, but being poor searchers, twig infestations and gout still occur.

Several introductions have been made in Washington and Oregon:

- 1) 1957 - 2,000 individuals of a dipteran, Aphidoletes thompsoni, released.

- 2) 1958 - 6 species from Europe and 1 from Japan. 13,000 individuals of 3 coleopterons and 3 dipterons released.

In 1957 some dipterous larvae were found and in the summer of 1958 large numbers of the fly were seen. In 1958 there was positive recovery of 2 (Laricobius and Aphidoletes) and possibly 3 (Cremitania nigrocellulata) predators. The effects of predation by the first two named on heavy bole infestations are quite spectacular. So far there has been no evidence of parasitism of the introduced Diptera.

Stark. Detailed life-table records have been kept over a number of years for the lodgepole needle miner. Both the host and parasites appear to fluctuate with climate and parasitism does not appear to be related to host density.

IV. METHODS OF BIOLOGICAL CONTROL

Feb. 27, 8:30 - 10:00 a.m.

Discussion Leader: E.C. Clark

Carolin discussed the general problems involved in parasite introduction programs. At each stage in the program, transportation into the area of introduction, laboratory propagation to increase numbers, and colonization, there are a variety of alternative procedures available, and selection has to be made according to the requirements of the specific problem.

Transportation problems have often required the design of special containers to provide some control over humidity and temperature conditions. Appropriate arrangements for special handling of air-shipments can reduce the time involved to minimize exposure to adverse condition. There is an advantage to shipment in a non-active stage wherever possible to avoid physical injury.

Propagation in the laboratory to increase numbers for field colonization can involve very interesting problems in the insectary handling of parasites. The rearing of a natural host for parasite production may in itself be very difficult or inefficient and alternative or unnatural hosts may prove advantageous. Artificial media for entomophagous insects would be a very valuable asset in parasite introduction programs, and some research is being carried out in this field. In addition to a suitable food source, suitable equipment and methods to obtain mating, oviposition, and for handling the large numbers of progeny must be developed. In particular it was noted that sterilization of handling equipment may be required to avoid high mortality.

Colonization of the parasite on a field population of its host may often be best accomplished with mated females. The minimum number of females to initiate establishment is an important question. In some cases 200-500 mated females has been regarded as a minimum. Transportation of parasites across country for field colonization may require retardation or acceleration of parasite development to ensure synchronization.

Washburn reported on a current research project in Utah on developing more adequate control of the spruce mealybug, Puto sp. The insect is presumed to be a native, but no native predators or parasites are known. The insect is typically a high altitude species and interest is currently centered on exotic coccinellids native to high altitude habitats.

Mitchell discussed the methods in use in a program of introduction of predators of the balsam woolly aphid into Oregon and Washington. The program

is cooperative with the Division of Forest Biology, the Pacific Northwest Experiment Station, and Oregon State College involved. Predators such as the coccinilid, Pullus impexus were collected in Europe by caging chermid infested trees. Adults were shipped to North America. More fragile insects, such as the Diptera, were sent in the immature stage. Since 1951, all predators have been transported by air. As little time as five days has been required to move parasites from eastern Europe to Portland. High mortality in some shipments from Japan has suggested that it may be necessary to use pressurized aircraft for shipments.

In Oregon, insects have been colonized in the field either freely or caged with their hosts. The method used depended upon how fast the insect dispersed or other individual characteristics of the species. Generally beetles are released free and flies caged. An attempt is made to separate release areas enough to permit studies on dispersal. A rule of thumb used in eastern Canada is 50 miles between release points.

The question of economic feasibility of recolonization has been open to some discussion. The advantages appear to prevail. The most important advantage is that adults do not have to be handled because of the absence of hyperparasitism.

Probably the most difficult problem of all is that of evaluating effectiveness. The method used by the Portland station, photographic records, is a variation of the method devised by the New Brunswick laboratory.

McGugan pointed out the interesting policy question on predator introduction projects, whether there should be a general introduction of all primary parasites and predators found or introduction of only those species for which detailed studies in the area of origin suggest a high probability of success. Actual figures on the results of general introduction for forest insects in Canada are: 140 species have been introduced or distinctly relocated in projects against 42 pests; 38 species have been established on 17 or 18 pest species for which they were intended, and have also been recorded on more than 100 native species; effectiveness in control by the 38 species established has ranged from 2 or 3 quite dramatic, a few modest and some very little. Better fundamental ecological information and greater support for preliminary studies may make a high degree of selectivity possible.

Clark reported on methods of distributing disease-causing microorganisms in control. Production of large volumes of the infectious agent is still a problem in many projects. There is now available for experimental use a commercially produced preparation of a bacterium, Bacillus thuringiensis Berliner, pathogenic for insects.

Tests with the virus of tent caterpillars conducted in 1956 and followed through 1957 suggest that the virus was established in a disease-free area and increased heavily the following year.

Massey described more extensive tests of application of the same virus as in 1958. The use of sugar in the water suspension of the virus apparently resulted in an important reduction in evaporation loss. Fairly high mortality was achieved during the year of treatment.

V. EFFECTS OF DIRECT CONTROL ON BIOTIC CONTROL

Feb. 27, 10:00 - 12:00 a.m.
1:30 - 5:00 p.m.

Discussion leader: Philip C. Johnson

Discussion leader Philip C. Johnson introduced the topic of the effects of direct control on biotic control with some general remarks concerning problems stemming from direct control treatments of forest pests.

There have been increasing applications of direct control treatments against forest pests in the United States and Canada since World War II. For the first time chemicals could be sprayed efficiently from airplanes for the control of a number of defoliating insects. In many instances single direct control treatments were effective in reducing epidemic outbreaks so that damage resulting from them was either limited or reduced to tolerable levels. In other instances, however, control treatments were less successful and some of these are currently the cause for some concern by entomologists and others engaged in forest pest control work.

It is suggested that treatments which probably show the greatest effectiveness may have been directed against short-lived outbreaks or against outbreaks whose cycles were either at a peak or on the decline. Examples of these successful treatments are those against the Douglas-fir tussock moth in Idaho in 1947, recent black-headed budworm outbreaks on Vancouver Island and in Glacier National Park, Montana, the mountain pine beetle in lodgepole pine forests in Montana, and the spruce budworm in Douglas-fir forests in eastern Oregon and Washington.

Other direct control treatments, however, appear to have run into difficulties. In some, the mortality of the pest has not been adequate. In others there has been a rapid resurgence of pest populations following the treatment. In still others the pest has been replaced by other pests of equal or greater economic importance. Further complicating the picture has been some adverse side effects on other forest fauna directly or indirectly associated with the control treatment. I think most of you are familiar with some of the more outstanding examples. Aerial spraying in the northern Rockies, for instance, has not achieved lasting control of the spruce budworm and rapid resurgence of budworm populations has been a frequent occurrence. The same spraying has also caused extensive outbreaks of the spruce spider mite and, in one instance, seemingly replaced the budworm with a species of Diorycytria which has established itself as an economic pest of some prominence. We are all familiar, too, with the effects of aerial spraying in recent years on both salt and fresh water game fish and stream bottom arthropods.

In our zeal to control major forest insect pests with new tools we are constantly outrunning research findings and running headlong, instead, into problems dealing with the bionomics of forest pests. We are finding that direct control of forest pests is turning up some of the same problems which have long confronted those engaged in control of agricultural pests. In addition, forest entomologists are finding other problems unique to the forest environment.

It is our purpose today to discuss some of the problems arising from direct control treatments, particularly those affecting biotic control of the pests involved. Each of the panel members is prepared to discuss certain aspects of this overall topic. It is hoped that discussion will bring out some of the ways in which direct control can complement natural control or

where it can at least be accomplished without serious adverse effects on biotic control agents.

A.D. Telford then summarized the effects of pesticide application upon densities of beneficial arthropods and the overall control objective.

In essence, the discussion of this topic involves the problem of pest resurgence following pesticide application. Pest resurgence due primarily to the harmful effects of pesticides upon beneficial arthropods is currently a problem in other phases of agriculture. The suspected resurgence of mites following applications of DDT for the spruce budworm in Montana may indicate that forest pests can react in the same manner. In an effort to prevent further resurgence problems, forest entomologists must develop methods of their own which may be based upon the experience of agricultural entomologists. Some fundamentals of combating the resurgence problem are:

- a) An adequate knowledge of the bionomics of forest pests and their natural enemies.
- b) An ability to determine whether or not natural enemies can effectively reduce specific pest populations or prevent secondary pest outbreaks.
- c) When biotic agents do not normally maintain sub-economic pest densities and there is no danger of secondary pest resurgence, the control effort may be directed toward 100 per cent kill with the best available pesticide.
- d) When natural enemies are essential to a lasting pest reduction, the control effort must be directed toward the restoration of a favorable pest-natural enemy ratio at a pest density below the economic threshold --not localized eradication.
- e) All available methods of integrated control should be combined to achieve this end. The proper choice of insecticides and the manner in which they are employed is of prime importance. Selective pesticides should be used whenever they are available. When non-selective materials must be used, beneficial species may be spared by correct dosage, formulation, method of application and timing.

Whether forest pests might increase by developing resistance to pesticides is not debated here. However, it should be made clear that although resistance and resurgence both result in pest increase, they are motivated by very different mechanisms. The development of resistance may take repeated exposure to pesticides over a considerable period of time--resurgence may be initiated by a single pesticide application.

Carolyn reviewed a more specific instance of the effects of pesticide application on beneficial arthropods by discussing the effects of spraying on spruce budworm parasites and associated defoliators.

Extensive studies on the effects of spraying in Oregon and Washington were initiated in 1951. Because of a general scarcity of biological information prior to spraying, these studies were based chiefly on a comparison of sprayed and unsprayed areas. General findings were that, in the sprayed areas, (1) parasites attacking hibernating larvae exerted equal or greater effects on the host, (2) parasite species attacking full-grown larvae were reduced in number, with those species recovered generally exerting a reduced effect on the host, and (3) no resurgence of budworm populations has occurred, where

control was properly applied, for a period of 7 to 8 years.

Intensive studies were initiated in 1958 to obtain information on effects of spraying where biological data had been obtained for a period of years previous to spraying. Three plots were involved - a check plot, one-half mile outside the spray area, and two widely separated plots in the spray area. Population counts and collections were made for larvae attacking the buds and full-grown larvae, and collections only, for pupae. In addition a comparison of survival on paired small trees of pine and fir was made. The use of the check plot as planned was nullified by direct deposit of spray late during the spraying period; however, studies were transferred to a part of the check area subject only to light spray drift.

The general findings are as follows:

1. Many of the larvae surviving until 10 days after spraying subsequently died from delayed effects of the insecticide.
2. Many of the larvae surviving spraying produced parasites which had attacked hibernating larvae. The ratio of surviving parasite adults to surviving budworm adults was much in favor of the parasites.
3. Parasites attacking full-grown larvae were greatly reduced in effectiveness. Three species - Phytodietus fumiferanae, Ceromasia auricaudata, and Madremyia saundersii were recovered in the sprayed area, all exerting less than 1 per cent parasitism.
4. Comparison of 6-9 foot fir and ponderosa pine showed much higher survival of spruce budworm on the pine.
5. Parasitism of pupae, obtained from collections of budworm on pine, was comparable with pre-spray records of parasitism on fir.
6. Two species of associated defoliators, Griselda radicana and Argyrotaenia dorsalana, appeared to be unaffected by the spraying. Tentatively, it appears that Acleris variana and Zeiraphera griseana suffered somewhat less mortality from the spraying than did the spruce budworm.

The studies will be continued in 1959 to determine actual survival the year following spraying.

Scott discussed the effects of spruce budworm spraying in Montana on a possible latent defoliator--Diorycetria sp. He also briefly reviewed an administrative study conducted by the Forest Service in Montana in 1958 to study the effect of insecticide-miticide formulations on spruce spider mite populations.

Administrators working on insect control projects make many general observations while they are in the field. All of us realize that many of these observations are known facts to research workers. However, there are some that apparently have merit and should be reported. For example, many administrators believe that a foliage feeding Diorycetria is increasing in some of our Douglas-fir forests following a budworm spray project. Field collections in several sprayed areas indicated that Diorycetria moths outnumbered spruce budworm about 10 to 1 the year following the spray job. Another example of a general observation which indicates a Diorycetria population buildup after a spray project was a mass flight of Diorycetria moths in Butte, Montana, on

August 12, 1958. Of 30 small moths collected off the top of my sedan at 4:30 that morning, only four were spruce budworms, while 20 were Dioryctria moths. The remaining six I did not identify. A check of other cars along the same street indicated about the same percentage of Dioryctria moths to spruce budworm moths. Although this flight was not as large in total numbers as the spruce budworm flights that I have witnessed, it may indicate this is a latent pest important enough to warrant control. If this is so, we would like to kill both the budworm and Dioryctria with the same spray application. The question is, can this be done?

In August, 1957, Phil Johnson detected a spruce spider mite infestation near Helena, Montana. Extensive surveys followed. They indicated over 750,000 acres of the control units sprayed in 1956 were infested with the spruce spider mite. Administrators became gravely concerned and decided the 1958 spray program would be limited to an administrative study. The purpose of which would be to determine if a miticide added to the DDT formulation being used could prevent a mite buildup after spraying.

With this in mind, six spray blocks of approximately 2,500 acres each were laid out in Deep Creek on the Helena National Forest. Two control areas were also established. These blocks were systematically selected so that different treatments could be tried on two different aspects and at two different elevations.

The Missoula Forest Insect Laboratory recommended the miticide, Genite. Thus, two blocks were established to be treated with the DDT formulation only, two blocks were treated with the DDT plus one pound of technical grade Genite, and the remaining two blocks were treated with the DDT plus one-half pound of Genite. An aerial observer followed the spray plane and plotted the line of flight on the mosaic map board, checked height of flight and recorded air temperatures at spray height. Spray deposition was determined by sensitized cards placed at right angles to the line of flight, oil spots on indicator plants, and death webs that shrouded the sprayed trees. Control percentages as determined by mortality lines were within acceptable limits for spruce budworm spray jobs.

Fellin then reviewed in detail some of the general remarks made by Scott concerning the administrative study conducted in Montana to study some effects of spraying on spruce spider mite populations.

Almost 800,000 acres of Douglas-fir timber in Montana became infested with the spruce spider mite in 1957 following aerial spraying with DDT to control spruce budworm infestations on these lands in 1956. As a result of these mite infestations an administrative study was conducted by the Forest Service in 1958 on a 20,000-acre tract of budworm-infested Douglas-fir timber on the Helena National Forest in Montana.

The objectives of the study were three, to determine: (1) mortality of spruce budworm populations with varying dosages of insecticide-miticide formulations, (2) natural population abundance of the spider mite, and (3) mortality and/or prevention of spruce spider mite populations with the insecticide-miticide formulations.

The study was designed as a randomized block experiment with four treatments and two replications. The 20,000-acre tract was divided into eight 2500-acre blocks, two each of which received one of the following treatments:

- (a) 1# DDT

(b) 1# DDT, 1# Genite 923

(c) 1# DDT, $\frac{1}{2}$ # Genite 923

(d) check, no spray

All three treatments employed fuel oil solutions which were dispersed from a DC-2 aircraft. Spraying commenced in a given block as soon as 60 per cent of the developing budworm larvae in that block were in the 5th and 6th instar. Spraying began on June 26 and ended on July 2.

Two of the study objectives were achieved in 1958. We found that all three insecticide-miticide formulations were equally effective in killing spruce budworm larvae. Acceptable spruce budworm mortality was achieved on all spray blocks. Mortality ranged from 94.6 to 99.6 per cent on individual spray blocks and averaged 97.7 per cent for the entire study. We were also able to determine natural populations of the spruce spider mite from periodic sampling in the check blocks during the summer. There were approximately 0.03 mites per linear inch of Douglas-fir foliage on these unsprayed check blocks.

No significant changes were found in spruce spider mite or predaceous mite populations on any of the spray or check blocks between the last day of spraying on July 2 and the completion of sampling on September 2. The ratio of spruce spider mites to predaceous mites during this sampling period was approximately 1:1. Full effects of the spray treatments on the spruce spider mite and predaceous mites will not be fully known until the end of the summer of 1959.

In addition to the administrative study described above, another study was made by the Missoula Forest Insect Laboratory to determine spider mite population densities on Douglas-fir forests sprayed in 1956 and 1957 for the control of the spruce budworm and to compare these populations to those on adjacent unsprayed forests.

Some of the more significant results of this study are as follows:

1. Without exception, no appreciable mite populations were found during this study outside of areas sprayed in 1956 and 1957 for spruce budworm control.
2. Predaceous mites of the families Phytoseiidae and Trombidiidae were those found most commonly associated with populations of the spruce mite. They were found to be more abundant on sprayed areas than they were on unsprayed forests.
3. On areas sprayed both in 1956 and 1957, populations of the spruce spider mite were from 20 to 30 times as large as predaceous mite populations; however, on unsprayed areas spider mite and predaceous mite populations were found to be about equal.
4. Although it is not certain at the present time how many spruce spider mites on any area, tree, or unit of foliage constitute an epidemic, there is an indication that when the number of mites on a 15-inch branch sample reach 0.1 per linear inch of foliage that damage to the host tree will be visible.

VI. EFFECTS OF FORESTRY PRACTICES ON BIOTIC CONTROL

Feb. 28, 8:30 - 9:45 a.m.

Discussion leader: H.A. Richmond

The discussion leader called upon Benton Howard to open the topic. Man, as a biotic factor, is a predator in the forest and therefore by his influence may indirectly adjust pest population. Man is now a major factor in the forest who has the opportunity to adapt or change the environment. It should be recognized that biological conflicts in the forest constantly occur, so that the expression "balance of nature" is largely meaningless and should not be used. Many of man's influences on the forests are neither helpful nor harmful to pest populations. Man's intervention can be very helpful in reducing pest problems, but it is necessary to determine what changes in the biological complex are wrought by certain actions. It is imperative that scientists determine what these forest influences are, in order for administrators to integrate these with other management factors.

Richmond stated that important logging management problems such as allowable cuts, logging methods and schedules, and fire control, often preclude actions that could reduce pest hazards. Leads from entomologists are necessary, and these must be fitted into the overall picture.

Lejeune reviewed Buckner's work on the effects of changes of the environment on small mammal predation of the larch sawfly. In 1952 and ensuing years plots were established in larch stands to study the small mammal complex. Populations of shrews were about 5 per acre. In the plots studied, about one-quarter of the forest floor was covered with water. Sorex cinerious predominated. When the water level was lowered three feet by a drainage ditch, an immediate change started to take place in the composition of the shrew population. Sorex arcticus soon replaced S. cinerious as the predominant species. Both shrews are insectivorous, but S. arcticus destroys twice as many larch sawfly cocoons as S. cinerious. The result was a notable drop in the sawfly population.

Richmond called for discussion of the effect of slash, and slash disposal on pest, parasite and predator populations. Lauterbach stated that immediate problems resulting from slash in the northwest coastal region are not great. Trostle in speaking of pine engraver beetle problems, noted that California is divided into five districts that have different slash laws. They, however, are more for fire, than for insect control. Little is known about characteristics of parasite and predator populations in slash infested by engraver beetles.

Graham reported an example of a complex of organisms on Fraser River islands where Cryptorhynchus lapathi is attacking plantations of exotic hybrid poplars. Voles which may be detrimental to the weevils, also are damaging the trees by stripping the bark. If the voles are killed with a rodenticide such as endrin, the weevil population may be released.

Richmond noted that large ambrosia beetle populations in the coastal region of British Columbia contrast with the apparent lack of the problem on the coast of Washington and Oregon. Furniss, in reply, agreed that ambrosia beetles in his region do not cause particular concern. Perhaps the difference in apparent abundance is due more to climatic variation rather than to differences in parasite or predator effects.

Wygant observed that heavy loss of beetles occurs during the flight periods. Although birds are suspects, he enquired of specific cases.

Chapman and Atkins noted birds feeding on Trypodendron lineatum during spring flight and attack of the beetle. The instance was recorded in one place and only in one year; it seemed likely that cool weather that spring deprived the birds (mainly robins and whiskey-jacks) of their more usual foods.

Graham quoted a U.B.C. ornithologist as saying that birds will not tire of one food, and that they will readily switch their diet to the most common food available. He also mentioned that mixed stands are less susceptible to devastating insect outbreaks than pure stands. Perhaps the difference is due to higher, and more varied bird and other predator populations in the mixed stands. Carolin told of a study line in northern Maine that crossed a pure balsam stand into a mixed balsam-hardwood stand. Percentage parasitism of budworm was higher in the mixed, than in the pure stand.

Finally, in a discussion of the effect of flooding on pest insects, Lejeune spoke of heavy larch sawfly mortality when the larvae dropped into pools on relatively wet land.

MINUTES OF THE FINAL BUSINESS MEETING

February 28, 1959.

The chairman, R.W. Stark, called the meeting to order at 10:15 a.m. in the Board Room of the B.C. Lumberman's Building, Vancouver, B.C.

Minutes of the initial business meeting on February 26 were read by the Secretary. G.C. Trostle moved adoption of the minutes as read. Seconded by M.D. Atkins. Carried.

Discussion of the program and outbreak reports brought out the following:

D. McComb recommended that time be allocated in the program for summaries of current research projects.

R.R. Lejeune suggested that an excellent speaker be obtained to get the program off to a good start. It was moved by E.C. Clark that the program committee obtain one outstanding speaker for the next meeting. Seconded by K. Graham. Carried.

R.L. Furniss urged that the program committee formulate plans for the next meeting well in advance so that chances for obtaining a good speaker and better contributions would be improved. He also asked for an airing of the merit of slide sessions. The meeting favoured the idea, and R.I. Washburn suggested that outstanding black and white photographs could also be displayed.

The Chairman instructed the Secretary to continue binding the outbreak reports. G.T. Silver suggested that maps be included with the summaries. The Chairman approved the suggestion and asked if a map showing U.S. Regions and National Forests could also be included. B.H. Wilford volunteered to provide such a map.

P.W. Orr urged that all strive for greater uniformity of the outbreak reports, and suggested that each summary include a set of standards describing the meaning of infestation intensity designations.

The Chairman called for committee reports.

R.L. Furniss reported for the Common Names Committee. Common names for 41 species of forest insects have been submitted to the Common Names Committee of the Entomological Society of America for approval. About one-half of these were rejected for various reasons. The committee's work has dealt with the large back-log of insects that urgently required approved common names. Work in the future will probably be restricted to specific cases as the need arises. No names were received in response to a request by the committee for suggestions, but the opportunity to submit proposals will be kept open. P.C. Johnson was appointed new chairman of the committee to replace retiring chairman R.L. Furniss.

R.W. Stark reported for the Education Committee as follows:

Slight changes in approach have been decided upon in view of various developments. It was not possible to evaluate the summary of the Education Committee's views prior to this meeting.

It has been decided that the views of the committee will be prepared in a manner suitable for publication and will be published in as many sources as possible to meet as wide a range of interested people as possible.

The Society of American Foresters will be contacted as they are at present conducting a review of the forestry training program in the United States. We will attempt to determine their stand on the place of forest entomology in the forester's curriculum and present our opinions to them for our use.

Also, to determine the attitude within the profession of forestry towards forest entomology training, it is proposed that we conduct a poll of practicing foresters. This work is being organized by E.C. Clark and I urge all members to attend to the matter immediately if they are asked to aid in this work. We shall attempt to have the questionnaires for the poll ready for the spring meetings of various branches of forestry associations throughout western Canada and the western United States. Further details will be forthcoming.

The report of the Committee on Indexing of Reports and Publications is in the Appendix.

Due to an outstanding performance, W.E. Cole was appointed new chairman of the Ethical Practices Committee. He was presented with a brief memento as a reminder of the responsibility of his position.

The Nominating Committee report was given by P.C. Johnson. G.T. Silver was nominated to a 3-year term of councilor. No response was received to a call for nominations from the floor, so the Chairman declared G.T. Silver councilor by acclamation.

The Chairman appointed D.E. Parker and R.I. Washburn program co-chairmen for the 1960 meeting.

H.A. Richmond asked that the Secretary be instructed to write a letter of appreciation to the British Columbia Manufacturers' Association for use of the Board Room and other facilities.

Upon a motion by H.A. Richmond the meeting was adjourned.

APPENDIX

WESTERN FOREST INSECT WORK CONFERENCE

Report of the Committee on Indexing of Reports
and Publications

Six of ten regional laboratories have now completed indexing of reports. The following is the present status of indexing as given earlier and at the current meeting:

Alaska - Index has been completed up to April, 1958.
Calgary - " " " " " " Dec. 31, 1958.
Vernon - " " " " " " Dec. 31, 1956.
Victoria - " " " " " " Feb. 15, 1958.
Missoula - " " " " " " Jan. 31, 1959.
Portland - No progress to report.
Ft. Collins - No progress to report.
Ogden - Index now In Press.
Berkeley - No progress to report.
Albuquerque - Index has been completed up to March, 1958.

G. R. Hopping,
Chairman.

MEMBERSHIP ROSTER

WESTERN FOREST INSECT WORK CONFERENCE

Note: Active members registered at the conference in Vancouver, British Columbia, February 26-28, 1959, are indicated by an asterisk (*)

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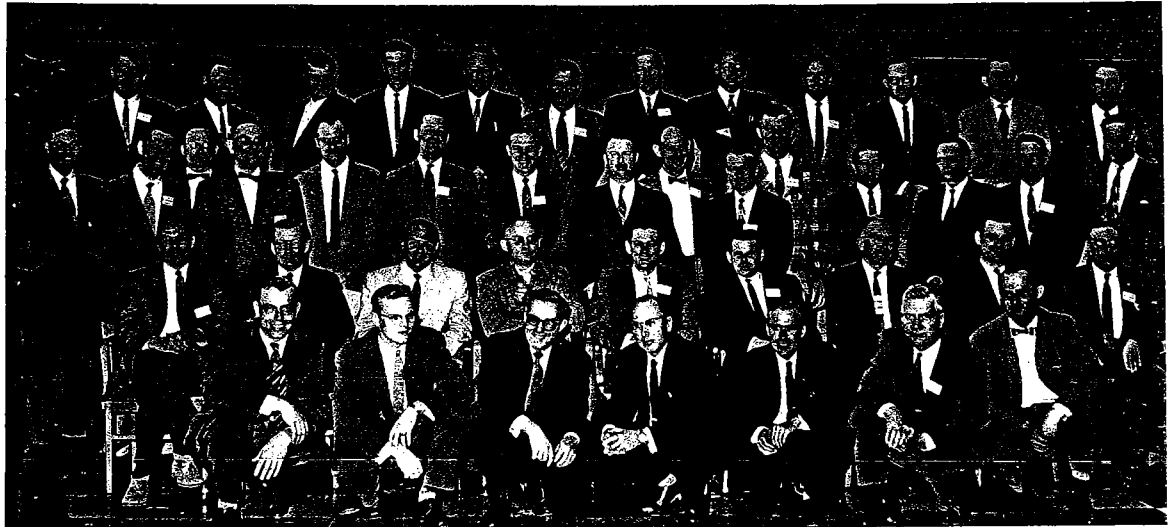
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Vancouver, B.C., February 27, 1959.

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