Not for publication

PROBLEM ANALYSIS
LARCH CASEBEARER IN B. C.

by

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CANADIAN FORESTRY SERVICE
VICTORIA, BRITISH COLUMBIA

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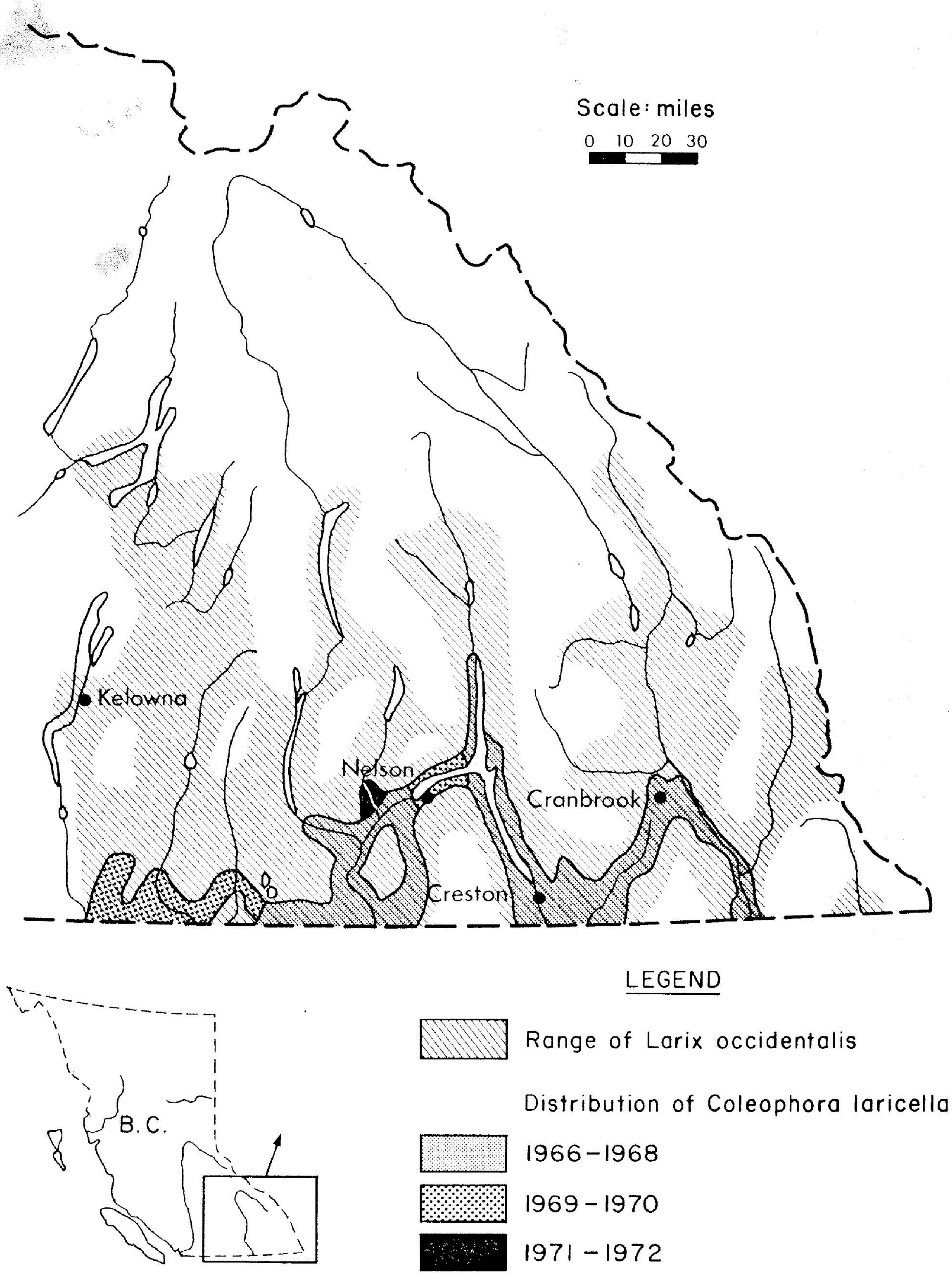
Scale: miles
0 10 20 30
Kelowna
Nelson
Cranbrook
Creston
B.C.
LEGEND
Range of Larix occidentalis
Distribution of Coleophora laricella
1966-1968
1969-1970
1971-1972

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THE PROBLEM

The larch casebearer, *Coleophora laricella* (Hubner), attacks native and hybrid larches in Europe and Asia, and is considered an important pest in central Europe (Thorpe, 1933). It was first recorded in North America in 1886 at Northampton, Mass. The first Canadian record was on European larch at Ottawa in 1905, and probably resulted from a separate introduction. The casebearer spread rapidly and, by 1947, infested most tamarack (*Larix laricina* (DuRoi) K. Koch) in the Maritimes, Newfoundland, Southern Quebec and Ontario, spreading west as far as Port Arthur (McGugan and Coppel, 1962). The westward spread continued and, by 1970, the pest was present in southeast Manitoba.

The first occurrence on western larch (*Larix occidentalis* Nutt.) was around St. Maries, Idaho, in 1957; spreading rapidly, it covered half the range of western larch by 1971. It was first discovered in British Columbia in 1966, but was probably present before that time. The distribution has been almost stable since 1968, but densities are still increasing. Initial spread was most rapid along the major larch stands in the valley bottoms (Fig. 1). Intensification was slowed in 1970, perhaps because of heavy larval mortality in the severe winter of 1969-70. Populations drop off at about 2,500 ft, with few casebearers above that altitude.

In British Columbia, western larch occurs mainly in the southeastern part of the Province. In 1970, the total volume was over 500,000,000 cu ft or 7% of the standing volume in that region (see Appendix). Larch is fast-growing, has good quality wood, and silvical characteristics which make it suitable for the clear-cut practices used in forestry today. Because of its pleasing light-green summer foliage and golden fall colors, it is a desired species for park and recreation areas. Thus, within its range, larch plays a small but significant role in the forest community and could become much more important in the future when we learn to manage it. As a part of our management system, we must reduce the populations of casebearer.

Repeated defoliation has led to reduced growth*, crown dieback and, subsequently, tree mortality in Europe and eastern North America (McGugan and Coppel, 1962) as well as in western U.S.A. (Tunnock, Denton, Carlson and Janssen, 1969). Without some means of controlling this pest we may allow larch to join the growing list of tree species that have severely restricted usefulness because of pest problems.

To the best of our knowledge, the larch casebearer is native to Europe, and occurs in the French and Italian Alps, through Austria, Germany, Holland, Southern and Central Russia as far as Finland and the Carpathians. It has been accidentally introduced with transplanted stock in Sweden and Great Britain. It was reported in 1919 from Japan where, presumably, it was introduced. The casebearer is a native of larch stands from western

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* Schwerdfeger and Schneider (1957) calculated increment losses in Europe of 33-45% after several years of continuous <u>severe</u> feeding. Ewald and Burst (1959) noted height increment stunted by 17% in 4 years of feeding by <u>Coleophora</u>. Denton (telephone communication) noted over 50% growth loss in a six-year period.

Russia throughout Siberia to the Amur Region on the Eastern shore. U.S.S.R. entomologists have identified two species of Coleophora throughout this range, and a number of parasites (Pozhkov, 1966), some of which may be common to both species. The source of western U.S. and Canadian populations is unknown and may have been the U.S.S.R. by way of Japan. This raises a taxonomic problem that should be investigated, together with the possibilities of trial introductions of parasites from Japan (and U.S.S.R., if available).

POPULATION CHANGES

In considering possibilities for control of this insect, one of the most important points to remember is that larch casebearer populations fluctuate considerably in Europe. Outbreaks are common, and defoliation is apparent in some area every year. The casebearer is aggressive, rapidly invading plantations beyond the normal range of larch. It attacks all species of larch, and their admixture with other tree species does not shield them from defoliation.

Another important consideration is that there is a density-dependent behavior pattern in the larval populations (Quednau, pers comm.). When larvae leave the mines and become free-moving, they interfere with each other through "silking" and crawling, causing some larvae to leave their cases, resulting in their death. This behavior tends to reduce the population density to one larva per spur shoot. This prevents over-population and starvation of surviving insects, guarantees maximum use of the resource, and provides moths with a good egg potential. From a biological control point of view, per cent parasitism is not too meaningful and control is only important when casebearer numbers are reduced below the density of one per spur shoot. In any case, all insects killed above this density are superfluous.

Webb (1952) indicated that casebearer populations fluctuate widely on an eight-year-cycle in the Maritime Provinces. Sloan and Coppel (1965), at the University of Wisconsin Arboretum, noted that climate, weather, avian predation on overwintering cases, invertebrate predators of eggs, and native and introduced parasites were all implicated in population fluctuations. Webb and Quednau (1971) state that European studies suggest that population increases are a function of suitable weather during adult casebearer emergence, copulation and oviposition, of site conditions, and of the vigor of foliage growth on the host.

The eastern North American casebearer populations were at high density levels until the mid-1950's, then they gradually decreased and have generally remained at low levels through the 1960's. Recent minor outbreaks have been localized and of relatively short duration. European parasites were released, starting in the 1930's, and continued through to the 1950's. As the decline in casebearer populations coincided with the parasite introductions, control of the casebearer has been credited to the biological control program, i.e., to *Agathis pumila* (Ratz.) and *Chrysocharis laricinellae* (Ratz.). Unfortunately, not enough life table work has been done to critically evaluate the role of parasites, thus we may only assume that they were the effective agents.

The casebearer populations in Western North America are probably too recent to show a pattern of fluctuations, except with climatic change. Such a fluctuation was apparent in British Columbia after the severe winter of 1969, when sampling in the valley bottoms indicated a 70% reduction. The population density had recovered by the fall of 1970. Since little population fluctuation has occurred, it is possible that the climate in the Kootenays is exceptionally favorable, in which case the larch casebearer may remain permanently in an outbreak phase and the larch growth rates could be reduced below a competitive position.

One of the effects of repeated defoliation is a retardation of foliage flushing dates. This, plus other tree reactions, may be a feedback mechanism that could reduce casebearer populations. This could start a cyclic fluctuation of the casebearer, or the pest and the host could adapt to live with one another with the pest population being at a lower density, but with the larch being much more scattered and slow growing. Under the latter situation, larch would probably cease to be a commercial species.

Native parasites could eventually play an important role in casebearer population fluctuations. They have been reared every year from 1966 to 1972 in small numbers in British Columbia. Higher percentage parasitism by the same native species have been recorded in Idaho and Montana, where the pest has been longer established. It is reasonable to assume that the larch casebearer has not been present sufficiently long in western North America for even the introduced parasites to become established in their ultimate role in affecting the population density.

CLIMATIC CONSIDERATIONS

In considering climate as a limiting factor of either the pest insect or of an introduced parasite, we can look to both eastern Canada and Europe, and compare them to the B.C. situation.

Winter temperature minimums appear to offer little problem to the spread of casebearer in B.C., even though it hibernates on the branches exposed to extreme conditions. On the average, one per cent of the hourly temperatures of January in the larch area fall below -34 C, while in eastern Canada, the northern edge of the distribution follows the -40 C isotherm. The extreme lowest temperature from 1921 to 1950 was -40 C in the East Kootenays, while in eastern Canada, it was -48 C. In some areas of Canada, it might be expected that even though the casebearer can persist in an area, the occurrence of temperatures below the casebearer supercooling point might be frequent enough to prevent large populations from building to destructive densities. In 1970, following a winter of extremely low temperatures, there was 70% mortality in the valley bottoms. Temperatures in southern B.C. are colder than in central Europe where native larch is infested (extremes of -24 to -30 C), but warmer than in some parts of Ontario where the casebearer occurs. The mean January daily minimum along the northern edge of the distribution in Ontario is -23 C, while in B.C., the valley-bottom larch stands occur where the mean January daily minimum is -12 C. The areas in Ontario, Quebec and the Maritimes where outbreaks occurred had temperatures in the range of -12 to -18 C. This indicates that the frequency of temperatures below the supercooling point in the valley bottoms in B.C. is generally rare enough that populations will not be greatly affected. However, the prevention of spread into northern Ontario and to higher elevations in B.C. may be due to cold winter temperatures.

Eidman (1965) suggested that adults and first-instar larvae are particularly susceptible to inclement weather. Desiccation of the needles, particularly mined needles, during extreme heat, conceivably could cause high first-instar larval mortality. Mean July daily maximums are around 27 C in the West Kootenays, which is somewhat higher than for eastern Canada (24-27 C) or Europe. This, plus the low summer rainfall (half that of eastern Canada and Europe) and humidities, could have quite a desiccating effect. On the other hand, in Germany, a sudden increase in casebearers was attributed to a hot dry summer. Perhaps southern B.C. presents a climate suitable for outbreak conditions nearly every year!

The frost-free period is similar in the East Kootenays to that of eastern Canada and Europe and, because of the warmer summers, the casebearer's development would be more rapid. Only at high elevations could length of season be important. (Generally in British Columbia, the larch casebearer is most abundant at lower elevations).

Distribution of _A. pumila_ and _C. laricinellae_ seems to follow that of the casebearer, indicating that there is no specific climatic limitation for these two parasites.

In summary, it would appear that the climate of the larch stands of B.C., particularly in the valley bottoms, is favorable for the casebearer, excluding exceptionally hot dry summers. To date, summer temperatures do not seem to have inhibited the casebearer, but such should be kept in mind in the selection of parasitic species.

PARASITE INTERACTIONS

About a dozen species of larch casebearer parasites have been released in the U.S.A., and five species in Canada. Included was _Diadegma nana_ (Grav.), the most successful casebearer parasite in England.

Only two species increased to high numbers and spread from the introduction points: Agathis pumila (Ratz.) and Chrysocharis laricinellae (Ratz.). They have been credited as the agents contributing to the significant reduction in numbers of casebearers in eastern North America, to the point where outbreaks are moderate, and tree growth loss is slight.

Agathis pumila is a solitary internal parasitoid with one generation per year. It is well synchronized with its host, attacks first- and, in Eastern Canada, second-instar larvae, spreads rapidly, but with only one generation per year; its numerical response is low. Chrysocharis laricinellae has three generations per year but is not well synchronized with the host. A. pumila retards casebearer development in the last instar enough to provide a host in time for the second generation of C. laricinellae. The latter species is said to have increased significantly where A. pumila is well established, tending to replace A. pumila. Where this occurs, one would expect a cyclic population reaction, but no one has measured populations over a sufficient number of years to record such an effect. There has been a good deal of controversy over the above theory, and the current U.S.F.S. program is intended to sort out the problem of single vs. multiple parasitism. At the present time, parasitism in the larch stands of Europe is low, and Agathis and Chrysocharis are the only ones available in numbers sufficient to undertake quantitative studies. All others would require culturing in Canada to increase numbers sufficient for release. It is probably more efficient to obtain Agathis and Chrysocharis from Eastern Canada.

In northwestern U.S.A., Agathis pumila was released in the early 1960's. The program was not well documented in the past and the impact on casebearer was not clear. One aspect that has emerged is that these parasites are not dispersing adequately in western larch stands. In eastern Canada, a spread rate of 21 miles per year has been recorded for *A. pumila*, while in the western U.S.A., it has been less than a mile (Denton, 1972). Denton suggests that when the casebearer becomes less abundant, *Agathis* may disperse more readily.

Agathis was introduced by the Canadian Forest Service at two locations in the Kootenays in 1969; the parasite has been recovered in small numbers at both release points.

The occurrence of native parasites of larch casebearer has not been well documented, at least until very recently. In British Columbia, native parasites have been low in number of species and in per cent of casebearers attacked. In the western U.S.A., Denton (1972) noted that 16 species of native hymenopterous parasites have been recovered, with an aggregate parasitism of 17%. Tunnock (pers comm.) also demonstrated that two introduced and one native species showed preference for differing parts of the infested tree crown: *Agathis* - the upper-outer crown, *Spilochalcis* - the lower-outer crown, and *Dicladocerus* - the inner-whole crown. This may indicate relatively little competition among these species.

There is a great deal of difference in eastern and western larch forests, which should be kept in mind when examining parasite interactions. The tamarack of the east is a bog species, growing in cold, wet, poorly-drained sites mixed with black spruce. It will grow better on upland sites, but is shade intolerant and cannot compete under these conditions. Western larch is a fast-growing tree of deep, porous, moist soils. It is also shade intolerant and does best in even-aged stands, usually mixed with other conifers such as Douglas-fir, white pine, lodgepole pine, Engelmann spruce, alpine fir, western hemlock or ponderosa pine. The casebearer seems to do well in both situations, but the parasites introduced to date apparently have not spread satisfactorily in the western stands.

To summarize the parasite problem, four questions need to be answered:

1. Is there a relationship between insect host density and rate of parasite spread, i.e., when hosts are abundant is the rate of spread slower than when hosts are at a low density? *Agathis* may be a good insect to test this theory.
2. In western larch stands, are multiple-species releases of greater benefit than single-species releases?
3. Are there any parasites from eastern Europe or Japan that would be of greater benefit in the western larch habitat than the parasites that were successful in the tamarack forest of the east?
4. Will the native parasites in the region gradually increase to become a significant mortality factor for casebearer?

U.S.F.S. AND CANADIAN PROGRAM IN WESTERN N. AMERICA

The larch casebearer was discovered in Idaho in 1957, and a biological control program was started in 1960. Because of its success in eastern North America, *Agathis pumila* was released in 270 infested larch stands in the western U.S.A. over about a 10-year period. It appeared by that time that *A. pumila* was not satisfactory in western larch stands because of apparent slow buildup and dispersal. In 1969, *Agathis* had been recovered at 42% of the release locations (where branches containing parasitized casebearer larvae were attached to infested host trees); the majority were recovered within half a mile of the release point.

The U.S.F.S. work has recently been reviewed and a new program initiated. In 1971, a biological control project was proposed and accepted to test the multiple-versus single-species parasite introduction strategy. Four situations, in addition to an untreated control, were to be tested: *A. pumila* only, *A. pumila* with *C. laricinellae*, *A. pumila* with *Diadegma nana*, and *A. pumila* with *C. laricinellae* and *Diadegma nana*. It was intended that this series of test plots be replicated in six different areas and run by personnel from six different organizations.

The program has been held up, in part, by the difficulties of obtaining adequate supplies of *Chrysochoris* and *Diadegma* from Europe. Only one set of plots has been established but, in the meantime, Ryan has worked out techniques for rearing casebearers on potted plants similar to the method of Quednau. No work has been done with rearing on an artificial diet.

A sample system was developed to determine the autumn mean casebearer density, to predict defoliation the following spring (Ciesla and Bousfield, 1971). Four 15-inch branches are taken from the mid-crown of each of 10 trees and the number of casebearers and parasites determined per 100 spur shoots. Recently an X-ray technique was devised to determine contents of unopened cases to speed parasite surveillance (Amman and Tunnock, 1971).

In autumn 1972, a proposal was put forward by the U.S.F.S.

seeking funding for a much larger integrated program for which biological control is just one aspect. The probable list of participants includes 14 agencies. Their five-year requests for funds were:

Assessing and predicting populations and impact	$3,385,000
Biological control with introduced parasites	1,250,000
Cultural practices and genetics	1,020,000
Integrated approach	965,000
Native predators and parasites	700,000
Chemical toxicants	650,000
	$8,880,000

Assessing and predicting populations is a proposal to develop a sound sample system based on land area or measurable units of trees. This will be necessary to predict populations, measure effects of applied controls, and assess the amount of defoliation.

The biological control program may include the importation of more than three species of parasites.

Laboratory investigations on chemical toxicants have been started, and malathion looks good. Mist blower tests were carried out against the prepupal stage of the casebearer. A field experiment is planned with malathion and zectran, plus any new promising chemicals. Bacillus thuringiensis was tested in 1972 with poor results; further tests may be carried out next year.

Use of behavior chemicals would entail isolation, bioassay and identification of sex pheromones and blockers of sex pheromones.

Greater knowledge is sought on native parasites and avian predators to enhance their effectiveness.

Under cultural practices, they plan to check the ability of larch to grow, while infested, at different densities, site conditions and fertilizer treatments. They also plan to investigate the influence of the tree upon the casebearer. They will look for tree resistance characteristics in native and European larch to see if improved genetic stock can be developed.

In Canada, the F.I.D.S. established five plots in the Kootenays in 1966 and released *Agathis pumila* at two of them (Arrow Creek and Fruitvale) in 1969. Native parasites were reared from each of five plots annually from 1966. *Agathis* was recovered from both release points in 1972. Rearing data are inadequate; however, they indicate that native and introduced parasites have had little, if any, impact on the pest to date.

SUMMARY

Nature of the defoliation by the larch casebearer and the ability of western larch to refoliate, decreases the necessity for hasty, temporary solutions for reducing casebearer numbers. Loss of wood production, although important, does not appear to be of immediate concern to foresters or to the public, and tree mortality is not likely to be significant, at least until there have been a few more years of severe foliage damage. Therefore, as there will be little call for extensive use of insecticides, emphasis should be on long-term solutions to the problem.

Two possibilities are present for long-term solutions: cultural and biological control. Cultural solutions involve manipulation of stands as to species mixtures, age, density, etc., and selection of resistant strains or species of larch. Observations in Europe and North America indicate that the casebearer is a rapidly dispersing, aggressive insect that quickly spreads to isolated stands or trees. On the basis of this, it is highly unlikely that stand management would have any satisfactory effect. Selection and propagation of resistant trees is also a possibility, but until a resistant mechanism is identified, the probability of success of such a program seems low. All species of larch planted in Europe appear to be susceptible.

Biological control seems to offer the best hope for a solution. It probably will not produce a permanent solution in all stands for all times, but should reduce casebearer populations to a tolerable level. We are encouraged in this view by the success of the program in Eastern North America, but this is tempered by lack of control of the insect in its native country, and by the initial trials in northwestern United States. However, it probably is still our best (and perhaps our only) hope of a satisfactory control.

Monroe (1971) and Turnbull and Chant (1961) indicate that the degree of success of biological control programs are related to the degree of effort placed on them. There is little point in releasing parasites in an ad hoc fashion, relying upon blind luck to bring success. This usually is a waste of time and money. Only by close follow-up of field trials, laboratory rearing programs, and appraisal of results through key factor analysis can the techniques of control be determined for a particular life system.

In the past, adequate data on the impact of a parasite upon a population as related to the total mortality and fecundity picture were only rarely taken. Similarly, rate of parasite dispersal as related to host and parasite density and habitat conditions have not been studied and, as a result, little progress has been made in developing adequate techniques, principles or theories on biological control. The larch casebearer offers a unique opportunity to explore some of these principles. The insect has arrived without its complement of native parasites. Rates of intensification and spread of each promising parasite can, therefore, be studied singly or in combination with others. Impact upon the casebearer, as well as the rates of spread and increase of the casebearer at different stages of invasion, can be followed relatively easily. Such an opportunity is rare and criticism will be long and severe if this chance is missed.

It should be pointed out that the insect has been present for at least seven years in some areas of B.C., and tree reaction is already apparent. It may take five years to work out adequate techniques; therefore, initiation of a program should be as prompt as possible.

RECOMMENDATIONS

1. A basic sample system should be developed for the egg, larval and pupal stages of the casebearer, suitable to appraise parasitism and mortality factors under different site, stand and defoliation conditions. An intensive method suitable for key-factor analysis and a survey method useful for extensive sampling is required. Cooperation should be maintained with the U.S.F.S. (suggest contract to a University).

2. A plan should be developed to determine the best approach to a biological control program of the larch casebearer. Such a plan could best be prepared at a meeting involving Prentice, Quednau, Webb, Turnock, Ryan, M. Furniss and Finlayson, as well as PFRC personnel.

Participation in the U.S.F.S. program should be considered, to take advantage of their experience. The questions previously outlined should be among those considered, i.e.: what has the greatest impact upon casebearer populations, multiple or single releases; is there a relationship between insect host density and rate of parasite spread; can we build a model of host-parasite interactions; are there superior parasites in Europe or Japan that haven't been exploited in North America; will the native parasites become a significant component in the casebearer mortality complex?

This meeting should be held early in 1973 to consider design, types of plots, rates of parasite release, etc. A request should be made for large collections of parasites to be made by CFS in Eastern Canada in 1973.

3. The western larch stands are ecologically quite different from the eastern tamarack stands, and there is a good chance that the

parasites which were successful there will be unsuccessful here. Therefore, it is recommended that the possibility of making collections in European areas, ecologically closer to those of B.C., be explored in cooperation with CIBC. Areas in the Carpathian mountains of Czechoslovakia and Poland, particularly, should be looked at. Greater efforts should be made in trying to locate suitable diseases of casebearer populations. IPRI should be contacted in this regard. If suitable parasites are found, we may have to undertake a large rearing and propagation program in Canada (suggest a contract to a University). If the western larch casebearer proves to be Japanese in origin (see Item #7), a similar parasite survey should be made in Japan.

4. There undoubtedly will be increasing pressures for recommendations of an effective insecticide to eliminate at least the unsightliness of defoliation caused by the larch casebearer in parks and on certain private lands. Testing should be carried out on different stages of casebearer with Bacillus thuringiensis, toxic chemicals, etc., for use from aircraft and vehicle-towed mistblowers. This could be done by CCRI and the chemical control officer of the PFRC.

5. Sufficient information on the impact of the casebearer upon the growth and survival of larch is lacking. It is recommended that the damage appraisal crew of the Forest Insect and Disease Survey, PFRC, investigate this problem. Study plots should be established immediately for annual measurements of defoliation and subsequent growth loss studies.

6. Pheromone traps would be extremely useful in studying the spread of the casebearer moths. It is recommended that IPRI (Weatherstone and associates) be asked to identify and develop a synthetic lure for the

casebearer.

7. The taxonomy of the larch casebearer is in doubt. It is recommended that the Entomology Research Institute be asked to compare the casebearers from Europe, Siberia, Japan, eastern North America and western North America for specific differences. This may involve breeding studies.

8. Winter larval mortality would appear to be a limiting factor in the northward and altitudinal spread of the casebearer. Mr. Prentice should be asked to find someone in the Canadian Forestry Service (C. Sullivan?) to study supercooling points of climatized larch casebearers.

9. A scientist at PFRC should be appointed and allowed time to supervise and coordinate all of these programs.

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APPENDIX

Statistics

from B.C.F.S.

Inventory of eastern and western larch in B.C.

4" + d.b.h. over 2,732,800,000 cu ft

Western larch in Nelson Forest District

7.1" + d.b.h. C.U.; less decay 508,189,000 cu ft

12 million cu ft of larch cut in 1970 in Nelson Forest District represents seven per cent of total cut for District.

1.2 million acres of mixed larch and Douglas-fir in Nelson Forest District.

Order of Importance in Nelson Forest District

	mature volume in cu ft
Spruce	4,663,989,000
Balsam	___________
Hemlock	___________
Red cedar	___________
Lodgepole pine	___________
Douglas-fir	1,148,570,000
Western larch	508,189,000