# SOME METEOROLOGICAL OBSERVATIONS IN RELATION TO THE SPRUCE BUDWORM

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In 1927 the writer was detailed to investigate the occurrence of the spruce budworm, **Cacoecia fumiferana** Clem., in British Columbia. At that time several outbreaks of this defoliator were active in the province. However, during the summers of 1927 and 1928 field studies were confined to local infestations on the south eastern portion of Vancouver Island. Then in the spring of 1929 the writer's activities were transferred to an extensive infestation in the Barkerville district where, with headquarters at Stanley, field studies were continued each summer during the next four years.

The outbreaks on Vancouver Island occurred at sea level in Douglas fir-balsam stands while the Barkerville infestation was active in alpine fir-Engelmann spruce stands occurring at from 3000 to 4500 feet above sea level. In this latter region the beginning of the growing season was fully one month later than at the coast.

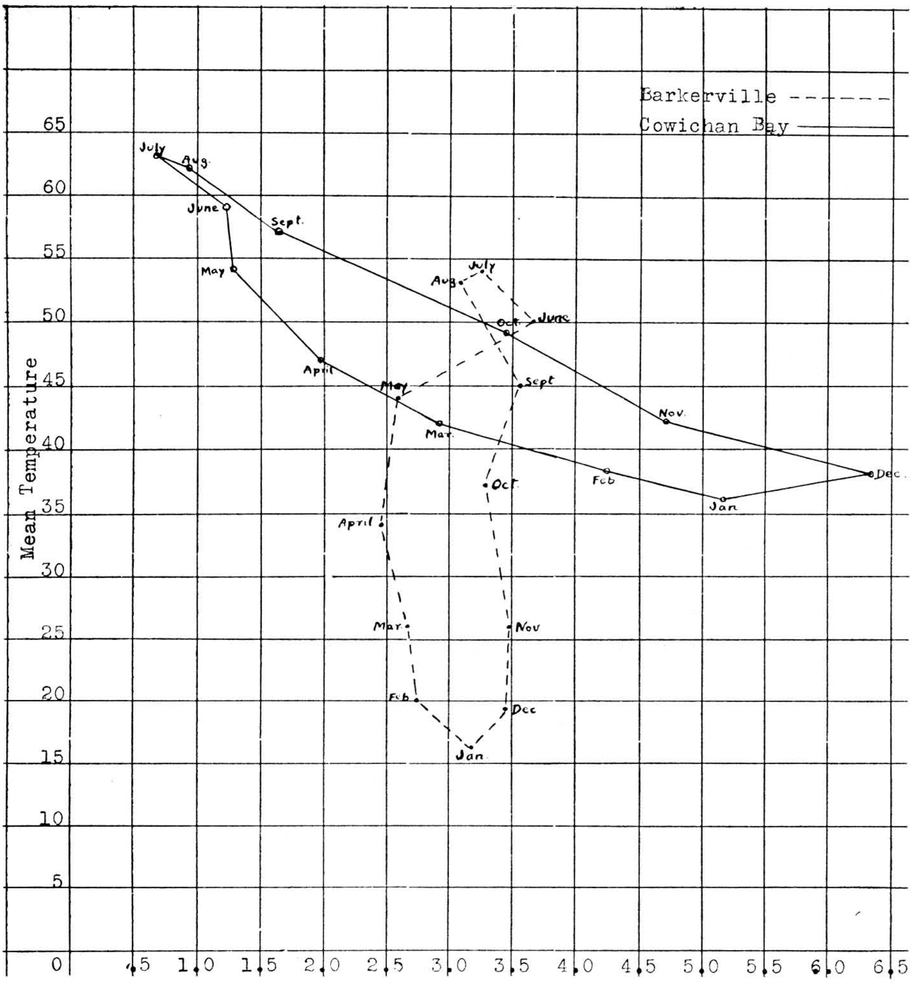
The marked difference in the climate of the two regions is indicated in the accompanying hythergraphs which are based on official government records taken at Barkerville over a period of 44 years, and at Cowichan Bay for a period of 18 years. In these graphs the vertical scale represents average mean temperature and the horizontal scale represents total precipitation.

In the Barkerville district the budworm is active in June, July, and August, whereas on Vancouver Island the period of budworm activity was in May, June and July. Comparing the weather for the years the field studies were made, we find an average mean temperature of approximately 52 degrees for the months of June, July and August in the Barkerville district and an average mean temperature of from 56 to 60 degrees for May, June and July on Vancouver Island. Moreover the total rainfall for the three months in the latter district only ranged from 2 to 3.5 inches while in the Barkerville district the rainfall for June, July and August averaged more than 10 inches and summer frosts were not common.

In the course of the studies under two such different types of conditions the influence of the climatic factors on the growth and development of the spruce budworm was very marked. The most important finding, and one which explains the persistency of the infestation in the Barkerville district under such apparent adverse weather conditions, was that in this locality the spruce budworm was found to

## HYTHERGRAPH SHOWING VARIATIONS IN CLIMATE

Between Barkerville, B.C., and Cowichan Bay, B.C.




Total Precipitation in Inches

require two years to complete its life cycle whereas the normal life cycle is complete in one year.

In the normal life cycle of the budworm, such as described in all previous accounts of this species and as found on Vancouver Island, the young overwintering larvae emerge from their hibernacula or overwintering cocoons in the spring, coincident with, or a few days before, the opening of the buds of the host trees. The larvae immediately commence to feed either directly on the new growth, if such is present, or by mining into the unopened buds. The feeding period under average conditions may vary from 30 to 40 days. Pupation occurs in a loose silken shelter spun among the foliage and the pupal period varies from 12 to 18 days. Egg laying takes place soon after the moths emerge. The eggs are laid in masses on the needles and hatch within 9 to 12 days. On hatching, the young caterpillars seek a sheltered nook such as between bud scales, under lichen, or at the base of twigs where it spins a hibernaculum in which it remains until the following spring.

However, in the Barkerville district in 1929, the young over-wintering larvae, although emerging about the middle of June at the time of the opening of the buds of the host trees, returned to hibernation after only developing to the third and fourth instars. These cocoons differ from the primary hibernacula only in their larger size. Then in June of the following year the larvae re-emerged and completed their development, the flight period and egg laying taking place in August. In 1931 and 1932 a similar two year cycle was traced in which the caterpillars of the new brood reached only the third and fourth instars in 1931 and then completed their development in 1932.

This prolonged life cycle was without doubt a direct result of the adverse weather conditions characteristic of the Barkerville district. In the field studies the influence of the climatic conditions was evident throughout the entire life of the budworm. The date of emergence of the caterpillars in the spring was governed by the existing weather conditions. For example, in the Barkerville district the first emergence was fully one month later than on Vancouver Island where more favourable weather was experienced. Moreover, at the coast infestation in 1928 when the mean temperature for May was approximately 56 degrees the first activities of the larvae occurred about ten days earlier than in 1927 when the average mean temperature for May was only about 52 degrees.

During spells of wet and cold weather the larvae were found to remain more or less dormant and to refrain from feeding. Hence when such conditions were general the rate of development was greatly retarded. For example, at Stanley in 1929, the average length of the larvae at the end of thirty days following the commencement of activity in the spring was still not over 5.5 mm., while at the coast, under more ideal conditions, the average length of the caterpillars at the end of the first month was not less than 15 mm. The effect of inclement weather is also plainly shown in a comparision of the development of the budworm larvae at Stanley during the two years 1930 and 1932. At this station in 1930 rain occurred on 11 of the last 12 days of June and with an average mean temperature for the 12 days of 47 degrees, while in July of the same year the weather was much more favourable, the mean temperature for the month being 52 degrees. However, in 1932 the reverse was the case with rain on only 4 of the last 12 days of June and the mean temperature 51 degrees, while in July the mean temperature was only 47 degrees and rain was general. Hence in 1930 the budworm larvae developed very slowly in June and the first pupa was not recovered until July 15th. However, the first moth was taken on July 28th. On the other hand, growth was comparatively rapid in June 1932 and the first pupa was recovered as early as June 27th that year. During the next three weeks the daily maximum temperature at no time exceeded 66 degrees and further development was almost negligible, so that although the first pupa was taken almost three weeks earlier than in 1930 the first moth did not emerge until July 26th, just two days earlier than in the previous flight year.

The effects of adverse weather on the duration of the incubation period of the eggs were found to be similar, because in the Barkerville district in 1932 the length of this period ranged from 17 to 33 days whereas at the coast, variations of from only 9 to 12 days were recorded.

Unfortunately, the only available meterological records for the work on Vancouver Island are those of the official government recording stations, the nearest of which was several miles from the centre of the investigations. However, daily readings were made at Stanley during the summers of 1930, 31 and 32, and in addition hygrothermograph records were obtained during 1931 and 1932. To supplement these records the readings of a government station at Barkerville, also located in the infested areas, were available.

In attempting to correlate the rate of development of the budworm with these weather records the daily mean temperature was found to be the most satisfactory reading for the purpose.

At Stanley in 1932, where data was secured from 83 individually reared specimens, a fairly uniform relationship was found to exist between the duration of the pupal period and the average mean temperature. The average mean temperature for a pupal period of 16 days was 53.7 degrees whereas with pupal periods of from 33 to 35 days the mean temperature was 47.3 degrees. During the same season the mean temperature for an incubation period of 17 days was found to be 54 degrees and for a period of 26 days, 51.7 degrees. On Vancouver Island in 1928 the incubation period varied from 9 to 15 days with an average mean temperature of from 69 down to 62 degrees. However, in both localities the intervening figures lacked the uniformity of those for the pupal period but such may be explained by the fact that the egg masses were present on trees in the open and so possibly subject to more or less direct sunlight.

In addition to computing the effects of the weather by using the mean temperatures an effort was made to establish the total amount of effective temperature, expressed in "degree days," necessary for both the pupal and egg stages. The total number of "degree days" for a given stage of development of an insect, is arrived at by taking each day from the commencement to the termination of the stage concerned, and by computing the number of degrees by which each day's mean temperature exceeds that of the threshold of development, and then summing the number of degrees so obtained for the whole period under consideration. As the threshold of development for the spruce budworm was not known the arbitrary figure of 42 degrees was adopted. Although fairly wide fluctuations occurred a certain uniformity in the totals was evident for each locality. At Stanley the total number of "degree days" varied from 178 to 214 for the pupal stage and from 206 to 264 for the egg stage. At the coast the number of "degree days" for the pupal period ranged from 272 to 311 and for the egg stage from 227 to 359.

Furthermore, as hygrothermograph records were available for the summer of 1932 at Stanley, the total number of hours occurring above 42 degrees were calculated for the pupal periods of the specimens reared individually that year. However, the resulting figures were of no value as an index to the effects of temperature on the development of the budworm. For instance only 294 hours occurred above 42 degrees during the pupal period of 16 days duration while 547 hours were recorded for the pupal period 35 days in length.

A quite interesting point is to be found in a comparision of pupal periods of similar duration in the two localities. Those on Vancouver Island experienced fully one hundred "degree days" more than for specimens at Stanley and the average mean temperature was also distinctly lower at the latter station. For example, the average mean temperature for a pupal period of 17 days at the coast was 60.3 degrees and the number of "degree days" 311, while for a pupal period of 16 days at Stanley the mean temperature was only approximately 54 degrees and the number of "degree days" 187. Somewhat similar results were obtained with the egg stage.

No definite explanation can be given for these variations. However, climatic factors without doubt play an important part, although the difference in host trees may have some influence and the possibility that the spruce budworm in the two regions may be of somewhat different strains cannot be overlooked.

This paper has been purposely confined to a discussion of the weather conditions as expressed by the temperature records. However, sufficient evidence has no doubt been presented to indicate the extremely complex relation existing between insect development and weather conditions. The need for more detailed studies of this relationship is quite apparent. In this regard a thorough investigation of the microclimatic conditions of the habitat in which a given species actually lives is most important. Only until such a time when such microclimatic conditions can be correlated with the standard meteorological observations will the latter be of full value.

The necessity for a new reliable method of computing the effects of variable temperature is also quite evident. The mean temperature does not present a true picture of the conditions while the summation of temperatures by means of "degree days" is, as now used, far from satisfactory. V. E. Shelford has done an enormous amount of work along these lines but his methods are too cumbersome to allow of their general adoption.

Climeographs, in which the horizontal scale represents humidity, and hythergraphs are gradually coming into more general use in the studying of distribution, fluctuations in the number, and seasonable development of insects. However, for such graphs to be of value, particularly in a study of seasonal development, the time unit should not exceed one week. Otherwise important variations in the weather factors will be lost.