from two bark beetles, *Dendroctonus valens* Lec. and *Ips pini* (Say), and the pales weevil, *H. pales.*

References

(1) Böving, A. G. 1929. Taxonomic characters for the identification of the mature larvae of *Pissodes strobi* Peck and *Pissodes approximatus* Hopkins (Fam. Curculionidae). Proc. Ent. Soc. Wash. 3: 182-187.

(2) Britton, W. E. 1918. *In* Seventeenth report of the Connecticut State Entomologist for 1917. Conn. Agri. Expt. Sta., Bull. 203. 231-370.

(3) Easterling, G. R. 1934. A study of the insect fauna of a coniferous reforestation area in southeastern Ohio. Ohio J. Sci. 34: 129-146.

(4) Felt, E. P. 1935. The important shade tree insects in 1934. J. Econ. Ent. 28: 390-393.

(5) Finnegan, R. J. 1956. Weevils attacking pines in southern Ontario. Can. Dept. Agric., Div. For. Biol. Bi-monthly Prog. Rept. 12 (2): 3.

(6) Ghent, A. W. 1956. Linear increment in width of the head capsule of two species of sawflies. Can. Ent. 88: 17-23.

(7) Holt, W. R. 1956. Certain aspects of the biology of four weevils attacking coniferous plantations in central Pennsylvania. M. For. Thesis, Pennsylvania State University.

(8) Hopkins, A. D. 1911. I. Contributions toward a monograph of the bark-weevils of the genus *Pissodes.* U.S.D.A., Bur. Ent., Tech. Ser., No. 20.

(9) Plummer, C. C., and A. E. Pillsbury. 1929. The white pine weevil in New Hampshire. N.H. Expt. Sta., Bull. 247.

(10) Schaffner, J. V. Jr. 1944. *In* Forty-third report of the Connecticut State Entomologist for 1953. Conn. Agri. Expt. Sta., Bull. 481, pp. 307-313.

(11) Smith, S. G. 1956. Chromosomal polymorphism in a bark weevil. Nature 177: 386.

(12) Wallace, D. R. 1954. The pine root-collar weevil in Ontario. Can. Dept. Agric., Div. For. Biol. Bi-monthly Prog. Rept. 10 (3): 2.

(Received December 16, 1957)

Effects of 1956 Spring and Summer Temperatures on Spruce Budworm Populations (*Choristoneura fumiferana* Clem.) in the Gaspé Peninsula[1]

By J. R. Blais
Forest Biology Laboratory, Quebec, Que.

Introduction

In 1956, the spruce budworm infestation which had been in progress in the Lower St. Lawrence and Gaspe Peninsula for about eight years, covered the whole territory from the Rimouski River to the eastern tip of the Peninsula (Fig. 1). In many localities throughout the region repeated defoliation had been severe enough to cause some trees to die (3). Had it not been for the extensive aerial spraying operations practised in this region since 1954, tree mortality would undoubtedly have been even more widespread.

Until 1957, insect populations were maintaining themselves at high levels in unsprayed territories and were gradually re-invading those that had been sprayed. In 1957, a considerable reduction was noted in the number of spruce budworm over a territory of 1,600 square miles in the region of the Shickshock Mountains which represents approximately 20 per cent of the area under infestation (Fig. 1). Observations made in the course of biological studies with respect to the spraying program in this region indicated that the reduction was due to the unusually cool weather that prevailed during the spring and summer of 1956. These observations were based mainly on the early larval population surveys conducted

[1]Contribution No. 454, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada.

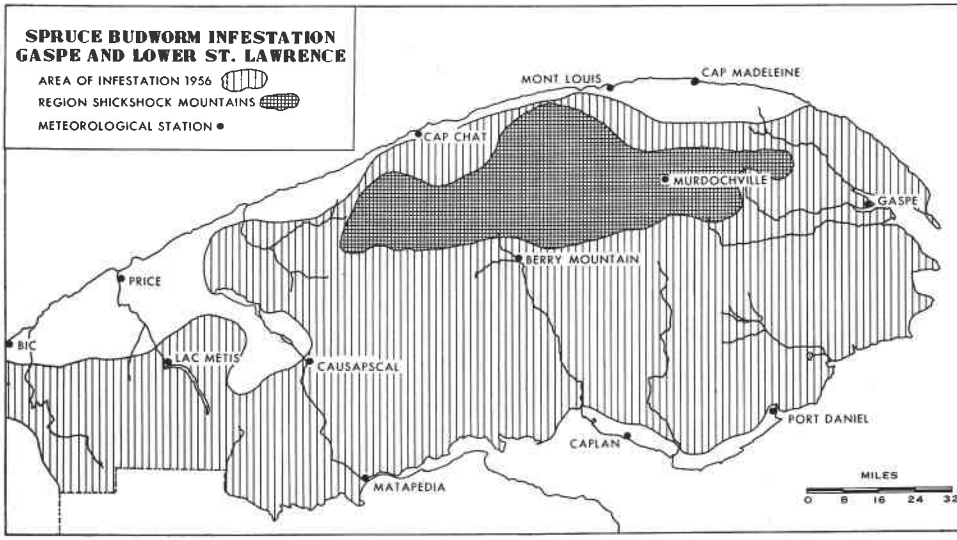

FIGURE 1

under the direction of the author, and on the egg-mass surveys conducted under the direction of R. Martineau in 1956 and 1957. These surveys took place in both sprayed and unsprayed localities throughout the region. Early larval populations were assessed by counting the insects on one 18-inch branch tip taken by means of pole pruners from the mid-crown of each of five dominant balsam fir trees from each of a number of localities. The egg-mass surveys were conducted according to the sequential sampling technique developed by Morris (8). In addition to the regular egg-mass survey in 1956, a number of localities were sampled for eggs by the author in the region of the Shickshock Mountains in November.

Weather Records

Table I gives the mean temperature (Fahrenheit) for May, June, July, and August 1956, for 13 localities (Fig. 1) and the divergence from the overall mean for 11 localities in the Lower St. Lawrence and Gaspe. The mean 1956 temperatures were calculated for each locality for each month by adding the mean maximum and mean minimum temperatures and dividing by two. The divergence from the overall mean was obtained by comparing the 1956 monthly mean with that obtained for all years of recorded temperatures for each of 11 stations. In all stations where divergence from the overall mean was noted the temperature was below normal for all four months. Berry Mountain Depot and Murdochville were newly established stations, and for this reason, it was impossible to compare the 1956 data from these stations with those of other years.

Table II gives the precipitation in inches for May, June, July, and August for 1956, and divergence from the normal for each of 11 localities. Precipitation for any one month varied somewhat between localities but when the area as a whole is considered the monthly precipitation did not differ greatly from the normal. Precipitation in July was equal to the normal, while in May, June, and August is was slightly less than normal.

Weather records for September and October are not given in detail for the region as a whole since in most localities the life-cycle of the spruce budworm

TABLE I

Mean(1) Temperature (Fahrenheit) for May, June, July, and August 1956, and Divergence from Overall Mean(2) for Various Stations in Lower St. Lawrence and Gaspe.

Station	No. of years of meteorological observation	Mean monthly temperature for 1956 and divergence from overall mean							
		May		June		July		August	
		Mean	Diver.	Mean	Diver.	Mean	Diver.	Mean	Diver.
Berry Mountain	1	37	–	52	–	58	–	52	–
Bic	50	44	−4.5	56	−2.8	60	−3.7	59	−1.3
Cap Chat	46	42	−2.6	52	−3.2	58	−3.4	57	−1.1
Caplan	8	43	−4.4	56	−2.0	61	−3.4	59	−1.9
Cap Madeleine	51	41	−3.8	54	−2.0	59	−3.2	61	−3.4
Gaspe	36	42	−2.3	55	−5.2	61	−6.7	58	−4.4
Causapscal	37	42	−6.0	57	−1.7	59	−3.8	57	−1.8
Lac Metis	28	–	–	55	−2.8	58	−4.4	57	−1.5
Murdochville	3	35	–	51	–	56	–	56	–
Matapedia	26	42	−4.8	57	−3.8	61	−3.8	57	−2.3
Mont Louis	19	41	−5.4	53	−4.4	62	−2.4	63	−3.2
Port Daniel	28	42	−2.5	53	−3.8	59	−5.2	58	−2.0
Price	23	43	−4.4	57	−1.7	60	−3.8	59	−2.7
Average		41	−4.1	54	−3.4	60	−4.0	58	−2.3

[1]Calculated by adding mean maximum and mean minimum temperatures and dividing by 2 for each month.

[2]Average for all years of observations for each month.

TABLE II

Precipitation in Inches and Divergence from Average(1) Precipitation for May, June, July, and August 1956 for Various Stations in Lower St. Lawrence and Gaspe.

Station	Precipitation in inches and divergence from mean							
	May		June		July		August	
	Pre.	Diver.	Pre.	Diver.	Pre.	Diver.	Pre.	Diver.
Bic	2.77	+0.15	2.01	−0.97	3.22	+0.11	2.75	−0.06
Cap Chat	2.30	−0.24	2.49	−0.66	4.78	+1.52	2.97	+0.07
Caplan	2.56	−0.70	3.53	+0.59	4.23	+0.59	3.70	+0.30
Cap Madeleine	0.56	−2.08	5.04	+2.21	2.11	−1.03	2.40	−0.62
Gaspe	0.75	−2.24	4.15	+1.33	2.64	−0.42	3.95	+1.12
Causapscal	2.58	+0.39	3.35	+0.21	3.09	−0.71	2.54	−0.66
Lac Metis	3.35	+0.60	1.87	−1.72	5.04	+1.01	2.11	−1.46
Matapedia	2.43	−0.59	3.27	−0.38	3.17	−0.79	3.55	−0.31
Mont Louis	0.20	−2.31	–	–	1.18	−1.85	2.23	−0.72
Port Daniel	2.23	−1.19	3.51	+0.35	4.46	+1.08	4.65	−0.81
Price	2.38	−0.34	2.68	−0.95	3.45	+0.08	2.70	−0.56
Average	2.03	−0.72	3.19	+0.01	3.40	−0.41	3.50	−0.34

[1]Average for all years of observations for each month.

https://doi.org/10.4039/Ent90354-6 Published online by Cambridge University Press

Table III

Mean Maximum and Minimum Temperatures, Mean Monthly Temperature (F°), and Mean Precipitation (Inches) for September and October 1956 for Two Stations in the Vicinity of the Shickshock Mountains, Gaspe.

Station	Month	Mean max. temp.	Mean min. temp.	Mean monthly temp.	Precipitation
Berry Mountain Depot	Sept.	61	34	47	2.35
	Oct.	55	29	42	1.51
Murdochville	Sept.	60	38	49	2.03
	Oct.	51	33	42	1.36

was completed at that time. At higher elevations, however, the insect was still active, and the records for two newly established meteorological stations in the immediate vicinity of the Shickshock Mountains (Berry Mountain Depot, and Murdochville) are shown in Table III. These records indicate that the days were relatively warm and sunny in September and October, while the nights were generally cold and frosty. At Berry Mountain Depot frosts were recorded for 13 nights in September, and 16 nights in October.

Status of the Insect in 1956

In the spring of 1956 emergence of the overwintering larvae began a week to ten days later than in previous years, about May 27 at the lower elevations and about June 8 in the region of the Shickshock Mountains. The average population per 18-inch branch tip for 56 unsprayed localities was 23.4 for the region as a whole; for 13 localities sampled in the region of the Shickshock Mountains it was 31.9 (Table IV).

In 1956 development of the insect was greatly retarded. At lower elevations it was two weeks behind that of 1955; the peak of adult emergence took place about July 30 in the western sector and about August 7 in the eastern sector. Oviposition took place over a period of three weeks from approximately July 23

Table IV

Average Number of Insects per 18-Inch Branch Tip Taken at the Time of the Third Instar in 1956 and 1957 for Various Unsprayed Regions in the Lower St. Lawrence and Gaspe.

Region	Year	No. localities sampled	No. of 18-inch branches	No. of larvae per 18-inch branch
Lower St. Lawrence and Gaspe.	1956	56	280	23.4
Shickshock Mountains. . . .	1956	13	65	31.9
Lower St. Lawrence and Gaspe.	1957	59	295	34.0
Shickshock Mountains. . . . (valleys)	1957	9	45	4.4
Shickshock Mountains. . . . (elevations)	1957	11	55	0.8

to August 15. In the region of the Shickshock Mountains development was even more retarded; by mid-July pupation had not yet taken place and by the end of August 50 per cent of the pupae were still unemerged. Oviposition occurred mostly in September, over a period of several weeks.

In August and September of 1956, a spruce budworm egg survey was conducted as in past years throughout the Gaspe and the Lower St. Lawrence with the purpose of predicting populations for 1957 (3). A total of 612 localities (approximately one-half in sprayed and one-half in unsprayed areas) were sampled. Morris (8) estimated that a population of 200 egg-masses per 100 square feet of branch surface generally will give rise to a population capable of severely defoliating the following year's shoot growth. In the majority of the unsprayed localities the egg population was very heavy, the average number of egg-masses per 100 square feet of branch surface being 418. In the region of the Shickshock Mountains over 75 per cent of the 52 localities sampled outside of sprayed areas showed the egg population to be in the severe category, with an average of 326 egg-masses per 100 square feet of branch surface. However, the average number of eggs in 100 clusters examined was found to be only 11.0 ± 0.8, which is somewhat lower than some previous records obtained in New Brunswick (8) and in northwestern Ontario (1), where the average number was close to 20.

When the region of the Shickshock Mountains was visited in early November, all egg-masses in the valleys or at altitudes below 1,500 feet were hatched while at higher altitudes many unhatched egg-masses were found. One full-length branch was obtained from the mid-crown of each of five balsam fir trees from each of eight localities varying in altitude between 1,800 and 2,500 feet in the vicinity of Brandy Brook, Ste. Anne Lake, and Madeleine Lake. The branches were carefully examined for pupae, pupal exuviae, and for eggs.

Thirteen per cent of the pupae were unemerged, and when 63 of these were kept at room temperature, two *Phaeogenes hariolus* (Cress.) and three *Itoplectis conquisitor* Say were obtained in mid-November. These parasites usually emerge about the end of July in the Gaspe, but in 1956 were reared during the second week in August from pupae collected at lower elevations. After three weeks' exposure at room temperature the unemerged pupae were dissected. Fifty per cent contained dead hymenopterous parasites, the other 50 per cent had died as pupae in varying degrees of development.

In the eight localities sampled the egg-mass population was very high and ranged from 509 to 814 egg-masses per 100 square feet of branch surface. Of these egg-masses, 53 per cent were unhatched, 10 per cent partially hatched, and only 37 per cent totally hatched. In two localities as many as 80 per cent of the eggs were unhatched. The unhatched egg-masses gave the appearance of being healthy, but when 150 of them were kept at room temperature they soon showed signs of desiccation and none produced larvae. The non-viability of the eggs could not be attributed to their not having been fertilized since embryonic development was quite advanced in many of them.

In November 1956, a total of 86 unemerged egg-masses were marked by tagging the twigs on which they were found. These egg-masses were left *in situ*, and when they were re-examined on June 24, 1957, 60 per cent of the masses were dead and the remainder were missing. The masses remaining on the branches were dark brown and scale-like, and were readily detached from the needles. It is most probable that the missing masses had died before dropping off the needles.

Although the unusually cool weather that prevailed in the spring and summer of 1956 was largely responsible for the drastic retardation in the development of the spruce budworm at high altitudes, it was not the only factor involved. The year 1956 was one of heavy flower production for balsam fir and the spruces throughout Gaspe. As a consequence of this heavy flower production, shoot growth was much reduced especially on balsam fir (7). The staminate flowers provided favourable food conditions for the early larval instars (1) (4), but when the flowers were spent the larvae quickly consumed the meagre current year's foliage. Once all the current year's growth was consumed, the larvae had no alternative but to feed on the old foliage. As a consequence, approximately two years' growth was destroyed on balsam fir, white spruce, and black spruce trees in the region of the Shickshock Mountains. It has been shown that a diet of old foliage greatly retards development of the insect (1). Therefore, the situation that prevailed because of poor weather was aggravated by a shortage of proper food. This would also explain the occurrence of the small egg-masses referred to above since Miller (6) found that, if a population is subject to larval starvation, the resultant small adults tend to lay smaller egg-masses.

Status of the Insect in 1957

About the third week in June, in 1957, early larval population counts were made in nine localities in valleys, and eleven localities at elevations above 1,800 feet in the region of the Shickshock Mountains. The average number of larvae per 18-inch branch tip for localities at lower elevations and those at higher elevations was 4.4 and 0.8 respectively. As can be seen populations were almost six times greater at lower than at higher elevations. However, even at the low elevations populations were considerably less than those of the previous year for the same area, or those of the same year for other areas in the Gaspe (Table IV).

Even after the reduction in the egg population due to mortality at the higher elevations in the fall of 1956, enough larvae had emerged to constitute a large population the following spring. Furthermore, in the valleys where the egg count had been high and where there had been no egg mortality, the larval population in the spring of 1957 should have been very high. Evidently, populations of the spruce budworm were affected at all elevations in the region of the Shickshock Mountains by some factor or complex of factors which acted in the interval of time between egg hatching in the fall of 1956 and establishment of the larvae in the spring of 1957.

Weather conditions in winter or spring, even when extreme, do not appear to be seriously detrimental to spruce budworm. It is known that this insect can withstand prolonged winter temperatures of 40 and 50 degrees below freezing. Also, in the spring of 1953, very unfavourable weather conditions caused the almost complete disappearance of a forest tent caterpillar (*Malacosoma disstria* Hbn.) infestation over a territory of 43,000 square miles in Central Canada (2), yet, these same conditions apparently had no effect on the spruce budworm that was in an epidemic state throughout most of the territory. Late spring frosts occasionally affect the insect indirectly by killing the young shoots on balsam fir and white spruce, thereby depriving the larvae of food (4), but this did not occur in the spring of 1957 in the Gaspe.

It is probable that the same conditions that prevented some of the eggs from hatching in the region of the Shickshock Mountains in the fall of 1956, were responsible for the mortality of first-instar larvae. On emerging from the eggs the larvae immediately spin hibernacula, and this usually takes place in early August when the weather is considerably warmer than in September, at which time emergence occurred in the mountainous regions in 1956. In these regions conditions for hatching, even in the valleys, were certainly marginal, and it is likely that, even if the larvae succeeded in emerging, their activity would have been arrested by the cold fall weather with subsequent failure to establish hibernacula. Another factor that might have been of importance in causing the eggs and the young larvae to die is the amplitude of the September temperature changes. At Berry Mountain Depot, a maximum of 78°F. was recorded for September 5, 6, and 7, while a minimum of 24°F. was recorded for September 9 and 10.

Throughout the summer of 1957, the action of the many biological and physical factors that normally affect the late-instar larvae and pupae of the spruce budworm further reduced the already heavily diminished population. At the time of the late pupal stage in 1957, populations were again counted in the same manner, and on the same trees that were sampled for the early larval population survey in the 11 localities in the valleys and in the nine localities at the higher elevations. The residual population per 18-inch branch was very low; an average of 0.1 and 0.03 insects was obtained for localities in the valleys and at high altitudes respectively.

An egg-mass survey was again conducted throughout the area in August of 1957. Although a reduction in egg population occurred in a number of sectors, it was especially pronounced in the region of the Shickshock Mountains. In this region a total of 42 localities were sampled in unsprayed areas; in 60 per cent of these localities no eggs were recorded, and in the remainder the egg population was light. There was an average of 10 egg-masses per 100 square feet of foliage for the 42 localities sampled. The magnitude of the reduction in population can best be appreciated when this figure is compared with that obtained in 1956 for the same region and referred to earlier, namely an average of 326 egg-masses per 100 square feet for the 52 localities sampled.

The aerial defoliation survey was conducted throughout the Lower St. Lawrence and Gaspe in August 1957. The aerial observations were confirmed by ground observations along all passable roads. Results of this survey indicated that the defoliation of the current year's growth was light (less than 10 per cent) for the region of the Shickshock Mountains while it was mostly severe (75 to 100 per cent) elsewhere (5).

Discussion

It is impossible to predict the final outcome of the drastic reduction in population of the spruce budworm in the region of the Shickshock Mountains. The residual population in this area may gradually increase to the point where numbers are again sufficient to cause serious damage to the forests, but, it is even more likely that the area will be re-invaded, in time, by insects coming from the surrounding heavily infested territories. In any event, the coniferous stands will benefit from a reduction in defoliation for some years to come, and many seriously weakened trees will show recovery.

Summary

In 1956, all coniferous stands in the Lower St. Lawrence and Gaspe were infested by the spruce budworm, and in many regions repeated defoliation had caused considerable damage. That year, throughout the region, temperatures

for May, June, July, and August were much cooler than normal; consequently, insect development was greatly retarded. In some regions, there was a shortage of current year's foliage on balsam fir and the spruces, and because the larvae were forced to feed on old foliage their development was retarded further. At higher elevations, in the Shickshock Mountains, development was retarded to the point where some pupae, and a considerable number of eggs failed to emerge before the onset of the cold autumn weather. Indications are that the same conditions that killed some of the eggs also killed many first-instar larvae. As a result, populations of this insect were very low in the region of the Shickshock Mountains in 1957. Elsewhere in the Gaspe, populations were high and there is no reason to believe that the infestation is coming to an end.

Acknowledgment

Mr. R. Martineau of the Forest Biology Laboratory in Quebec provided valuable data on egg populations. Dr. L. Daviault, Officer in Charge of the Forest Biology Laboratory in Quebec, and Dr. W. G. Wellington, Head Bioclimatology Section, Division of Forest Biology, very kindly reviewed the manuscript.

References

(1) Blais, J. R. 1952. The relationship of the spruce budworm (*Choristoneura fumiferana*, Clem.) to the flowering condition of balsam fir (*Abies balsamea* (L) Mill.). Can. J. Zool. 30: 1-29.

(2) ——————, R. M. Prentice, W. L. Sippell, and D. R. Wallace. 1955. Effects of weather on the forest tent caterpillar *Malacosoma disstria* Hbn., in Central Canada in the spring of 1953. Canad. Ent. 82: 1-8.

(3) ——————, and R. Martineau. 1957. Aerial spraying against spruce budworm in Quebec — 1956. Can. Dept. Agric., Div. For. Biol. Bi-Mon. Progress Rept. 13 (3): 2-3.

(4) ——————. 1957. Some relationships of the spruce budworm, *Choristoneura fumiferana* (Clem.) to black spruce, *Picea mariana* (Moench) Voss, For. Cron. 33: 364-372.

(5) —————— 1958. Status of the spruce budworm in Lower St. Lawrence and Gaspe, and results of spraying operations — 1957. Can. Dept. Agric., Div. For. Biol. Bi-Mon. Prog. Rept. 14 (1):

(6) Miller, C. A. 1957. A technique for estimating the fecundity of natural populations of the spruce budworm. Can. J. Zool. 35: 1-13.

(7) Morris, R. F. 1948. How old is a balsam tree? For. Chron. 24: 106-110.

(8) —————— 1954. A sequential sampling technique for spruce budworm egg surveys. Can. J. Zool. 32: 302-313.

(Received February 27, 1958)