

develop in progeny of healthy females reared in the laboratory, but larvae from some egg masses of *M. pluviale* collected in the field became spontaneously infected with a polyhedral virus and with a bacterial disease. Larvae from healthy colonies had a high survival under the methods of rearing.

Acknowledgments

I am indebted to officers of the Canada Experimental Farm at Beaver Lodge, Alta., for cuttings of Siberian crab and for current weather records, to several officers of the Forest Biology Division, Canada Department of Agriculture, for collections of eggs of *M. pluviale* in British Columbia, and to Mr. D. Farnsworth for technical assistance.

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Life-History and Habits of *Scolytus tsugae* (Swaine) (Coleoptera: Scolytidae) in the Interior of British Columbia¹

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Introduction

Scolytus tsugae (Swaine) is a bark beetle that occurs throughout the Pacific Coast and Rocky Mountain Region and is common in the interior of British Columbia. Although Bedard (1938) reported that it had killed small areas of Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) reproduction, it is of minor economic importance and usually confines its attack to tops, limbs, and logging slash. A knowledge of the life-history and habits of this insect is desirable for an understanding of the effects of interspecific competition on the development of the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopk., with which it is often associated in Douglas fir.

The study described in this paper was made during 1956, 1957, and the spring of 1958 near Lumby and Lac la Hache, B.C., at elevations of 2100 and 2800 feet, respectively. Gallery systems were tagged as the beetles initiated their attacks on three trees felled near Lumby in early July, 1956, and later examined at various ages for the presence of parents and progeny, gallery length, and larval mine length. These data were supplemented in 1957 and 1958 by observing additional material attacked by the beetles. All host material studied was Douglas fir unless otherwise indicated.

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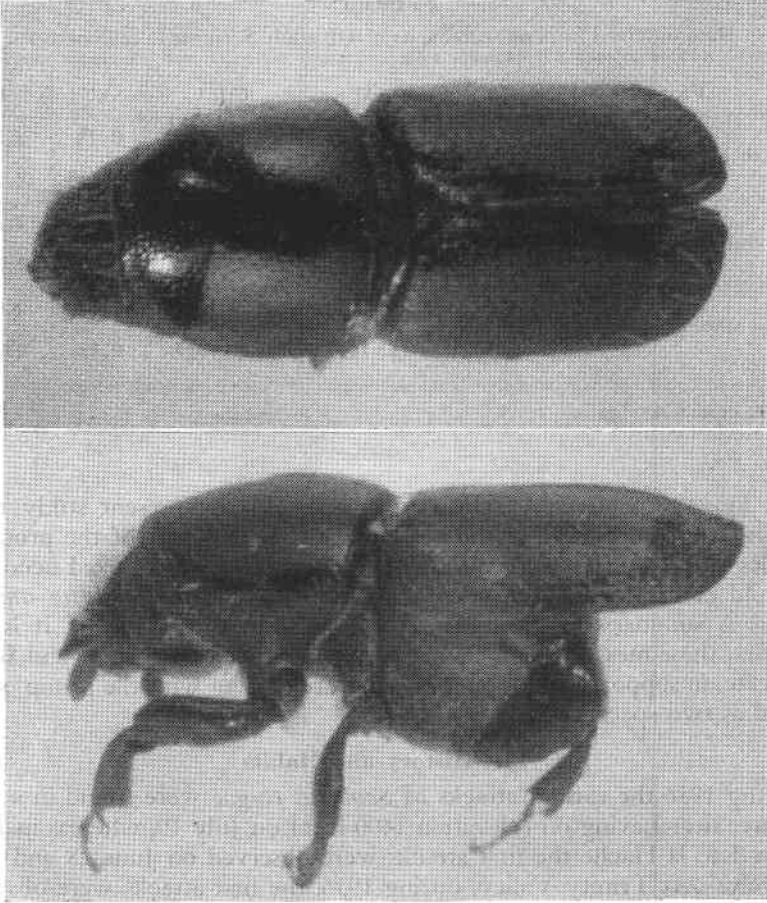


Fig. 1. Dorsal and lateral views of the adult of *S. tsugae*.

Description

The species (Fig. 1) was first described by Swaine in 1917. Due to the controversy over the validity of the generic name, much of the earlier literature refers to the group as the genus *Eccoptogaster*. Blackman clarified the issue in his revision of the genus in 1934. However, there is some doubt regarding the specific identification in that this species is very closely related to *Scolytus monticolae* (Swaine). Blackman states "This form (in reference to *S. monticolae*) is very closely allied to *Scolytus tsugae* and specimens assigned to *monticolae* are sometimes found in field series of *tsugae*. Also there are many intergradations between the more coarsely sculptured forms with the ventral abdomen opaque which are representative of *tsugae* and the more smoothly sculptured *monticolae* with the venter shining. The writer is somewhat at a loss in definitely assigning certain of these intermediate forms to either species." Hopping² believes that *tsugae* and *monticolae* comprise one variable species and that the name *tsugae* takes precedence.

Swaine (1917) described *S. tsugae* and *S. monticolae* as being 3.4 and 2.8 mm. in length, respectively, while Blackman stated that they are 2.7 to 3.4 and 2.2 to

²Hopping, G. R. In correspondence.

TABLE I
Data obtained from measurements of 110 adult *S. tsugae* in millimetres

Feature	Sex	Mean	C.L. ¹	s ²	Range
Total length.....	♂	3.21	3.08-3.34	0.28	2.59-3.64
	♀	3.23	3.14-3.32	0.44	2.75-3.80
Length exclusive of head.....	♂	2.89	2.79-2.99	0.25	2.30-3.27
	♀	3.01	2.92-3.10	0.40	2.50-3.60
Width of prothorax.....	♂	1.13	1.09-1.17	0.08	0.97-1.25
	♀	1.14	1.11-1.17	0.12	0.73-1.33

¹95 per cent confidence limits.

²Standard deviation.

2.8 mm. long, respectively, exclusive of head. In the present study the total length, the length exclusive of the head, and the widest part of the prothorax of 86 females and 24 males were measured. The beetles were sexed according to the method described by McMullen and Atkins (1956) for *Scolytus unispinosus* Leconte. A summary of the measurements is shown in Table I. It is worthy of note that these measurements lie between those given by Swaine and Blackman and indicate, in support of Hopping, that we are dealing with the group originally described as two species.

Life-History and Habits

During 1956 the earliest attacks of *Scolytus tsugae* were found in a recently burned area near Lavington (elevation 1400 feet) on July 10, whereas in 1957 and 1958 near Lac la Hache the first attacks were observed on June 28 and May 29, respectively. At Trinity Valley, during 1956, the first attacks were observed on July 14 on the top of a tree felled on June 29. On three trees felled on July 14, 1956, the first attacks were observed on July 16, with the peak attack occurring on July 19. The beetles continued to initiate galleries until August 29. No attacks occurred on trees felled at intervals of 15 days from May 15 to June 15 nor on trees felled on April 20. At Lac la Hache, in 1957, however, the beetles attacked Douglas-fir poles which were felled on May 6 and May 18 and four trees which had been girdled to the heartwood on May 17. In 1958, the attacks occurred largely on freshly felled material. In addition, in the spring of 1958, four pairs of window flight-traps similar to those described by Chapman and Kinghorn (1955) were used to sample flying insects in a forested area near Lac la Hache. These traps indicated that *S. tsugae* started flying on May 22, and continued until July 30 reaching their peak on June 17. This flight period greatly overlaps that of *S. unispinosus* making it necessary to check the identity of all the beetles captured. The pattern of the flying population is shown with the corresponding weather records in Fig. 2.

Although the majority of attacks occur in material which is 2.5 to seven inches in diameter with a bark thickness of 0.1 to 0.4 inches, we have recorded this species in material 13 inches in diameter with a bark thickness of 0.7 inches at densities up to 2.5 attacks per square foot. In the smaller material 20 attacks per square foot are common.

Scolytus tsugae are monogamous within their galleries, although there is

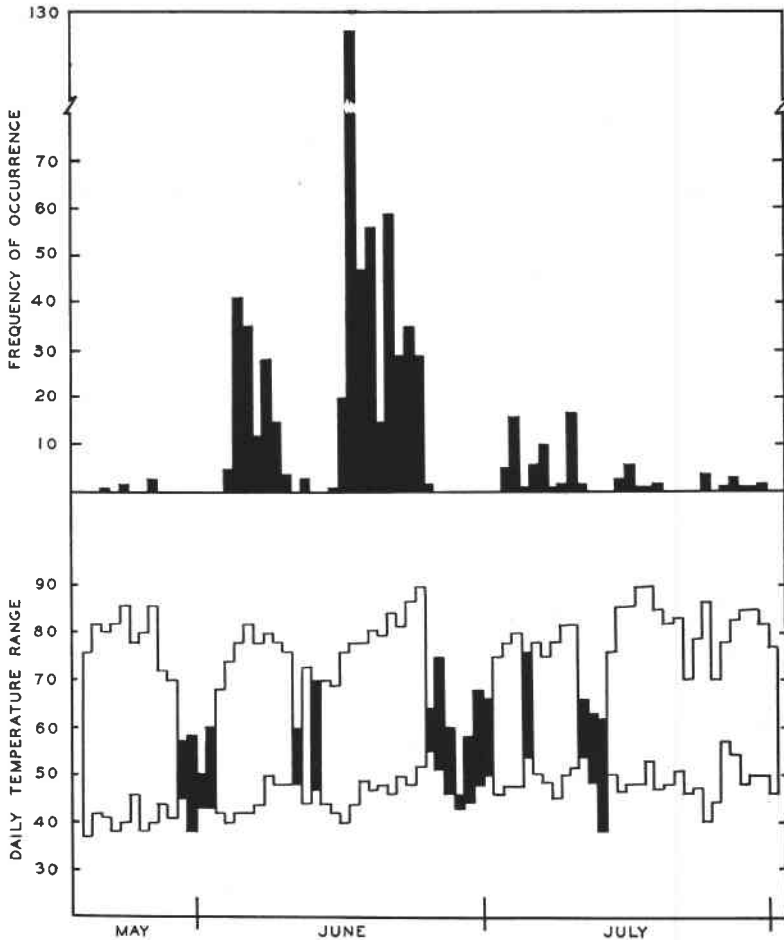


Fig. 2. Incidence of *S. tsugae* in flight traps with corresponding temperature data (black indicates days of heavy cloud or precipitation), Lac La Hache, B.C., 1958.

evidence (discussed later) that the males mate with more than one female, and the beetles work in pairs at least in the early stages of gallery construction. The entrance runs obliquely through the bark to the cambium where a small turning niche is cut. The female excavates the gallery (Fig. 3) longitudinally with the grain of the wood, in both directions from the turning niche, while the male remains in the entrance pushing out boring dust and presumably warding off intruders. The gallery is excavated at the cambial level, being approximately one-half in the wood and one-half in the bark. This feature readily distinguishes the gallery from that of *Pseudohylesinus nebulosus* (Leconte) which does not score the wood (Walters and McMullen, 1957). Also, the boring dust at the entrance to the gallery of *Scolytus tsugae* includes wood particles and thus has a whitish appearance, whereas that extruded by *P. nebulosus* is reddish.

The egg galleries of *S. tsugae* and *S. unispinosus*, which are very similar in appearance, can be separated on the basis of width; those of the former species are wider. An analysis of measurements of 50 gallery widths for each of the two species is presented in Table II.

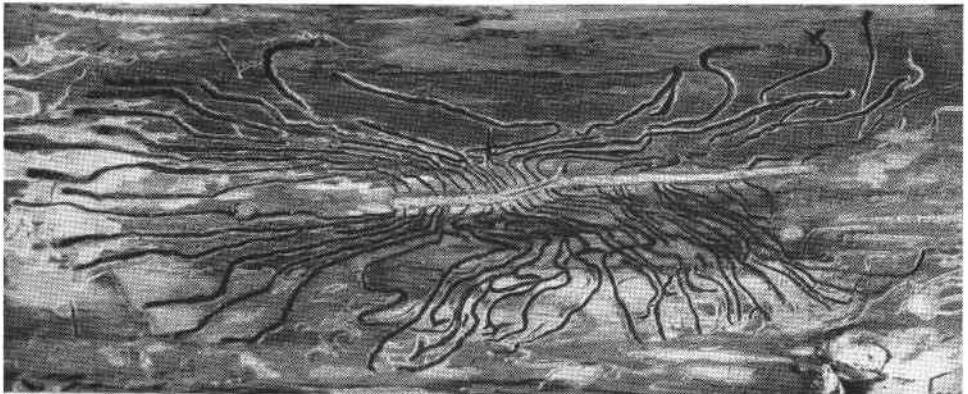


Fig. 3. Gallery system of *S. tsugae* (larval mines darkened with ink).

The gallery of *S. tsugae* is constructed at the rate of about 0.15 inches per day; the rate decreases after 15 or 16 days. The average length of 135 galleries was 2.01 inches with a maximum of 3.6 inches.

The eggs, which are small (averaging 0.81 x 0.57 mm.), oval, and white, are laid singly in niches about 0.06 inches apart on both sides of the gallery. The average number of eggs laid in 62 galleries was 36.7 with a maximum of 76. The incubation period ranged from nine to 12 days.

Larvae were first observed on July 27, 1956, but were not common until August 1. The larvae mine for a short distance at right angles to the egg gallery and diverge towards the ends of the gallery (Fig. 3). The average length of 100 larval mines was 1.95 inches with a maximum of 3.1 inches.

To determine the number of instars and the duration of stadia, larvae were collected from galleries of known age during the summer of 1956 and from galleries selected at random in mid-October, 1956, the spring of 1957 and the spring of 1958. Head-capsule widths of 1,843 larvae were measured with a calibrated ocular micrometer at a magnification of 100X to the nearest 0.014 mm. The ocular micrometer at 100X was too small to measure the larger specimens so an additional 569 were measured at 40X to the nearest 0.034 mm. A histogram of the frequency distribution of the head-capsule widths is presented in Fig. 4. The data were smoothed and analysed according to the method described by Forbes (1953). The frequency distribution and the analysis indicates four instars. Table III shows a summary of the head-capsule measurements.

To determine the durations of the stadia only those specimens whose head-capsule widths fell within the ranges of the means plus or minus their respective

TABLE II
Egg-gallery widths of *S. tsugae* and *S. unispinosus*

Species	Range in mm.	Mean in mm.	s	d.f.	t
<i>S. tsugae</i>	1.36-1.84	1.63	0.151	98	18.0000**
<i>S. unispinosus</i>	1.12-1.36	1.21	0.79		

**Significant at the 1 per cent level.

standard deviations were classified as to instar. The total number of each instar collected during the 1956 season was determined and the number of specimens of each instar collected at a given gallery age was recorded as a percentage of total for that instar. Then the accumulative percentage of each instar was plotted against gallery age; thus the difference in gallery age between successive instars at any given accumulative percentage should give the duration of the former

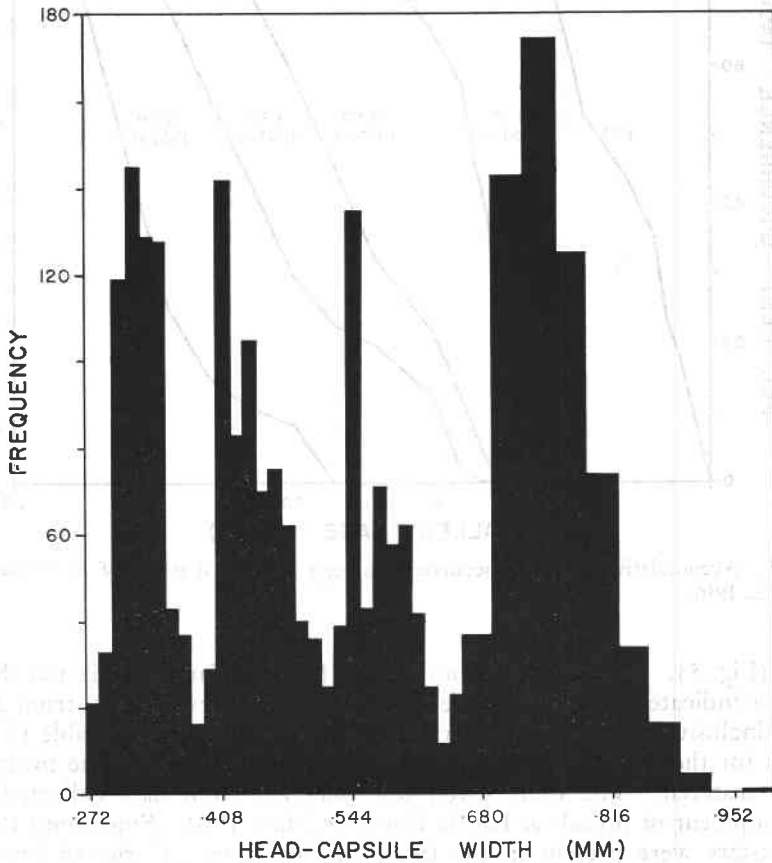


Fig. 4. Histogram of frequency distribution of 2,412 head-capsule widths of *S. tsugae*, Trinity Valley, B.C., 1956.

TABLE III

Head-capsule widths (mm.) of the larval instars of 2,412 *S. tsugae*, collected during 1956

Instar	Head-capsule width	
	Mean	Standard deviation
1	0.321	0.024
2	0.422	0.016
3	0.552	0.027
4	0.732	0.063

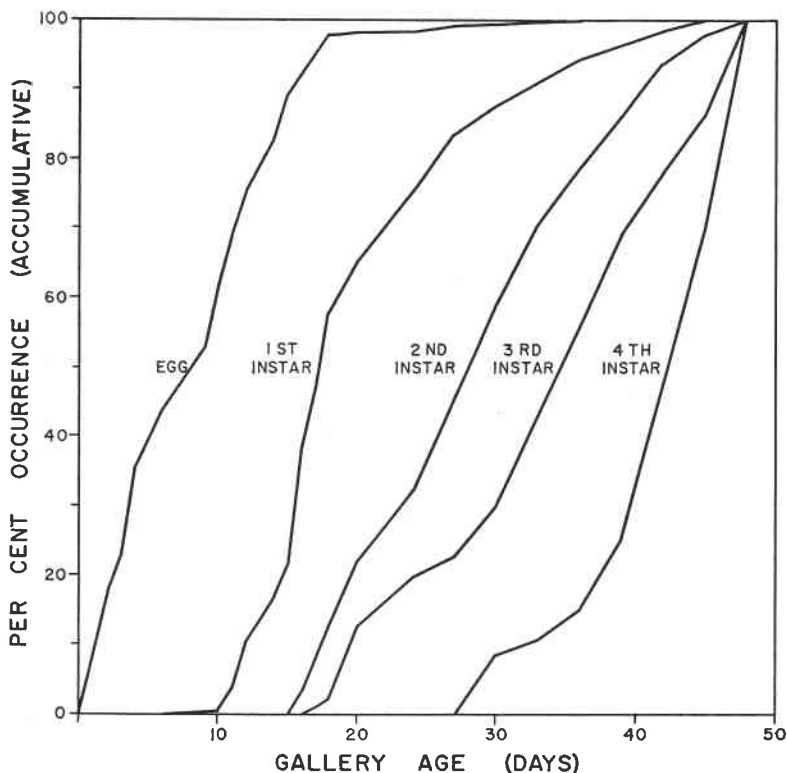


Fig. 5. Accumulative per cent occurrence of egg and larval stadia of *S. tsugae*, Trinity Valley, B.C., 1956.

stadium (Fig. 5). Average durations for the first two larval stadia and the pupal stadium as indicated at accumulative percentages in intervals of 10 from 20 to 80 per cent inclusive were used to arrive at the values presented in Table IV. Suitable data for the pupal stadium were not obtained during 1957 due to drying of the host material. The value given was obtained from data collected during the development of broods at Lac la Hache in May, 1958. Since both third and fourth instars were present in the last collection from galleries of known age in 1956, 100 per cent of each instar was reached at the same time. For this reason only those durations indicated by the four points from 20 to 50 per cent, inclusive, were used to determine the length of the third larval stadium. The instars which overwintered and their percentage occurrence, determined from collections on October 15, 1956, and April 15, 1957, were as follows: 2nd, 0.9 per cent; 3rd, 6.5 per cent; and 4th, 92.7 per cent.

The mean, mean maximum and mean minimum temperatures throughout the developmental periods are presented in Table V.

The fourth-instar larvae may pupate at the cambium-wood level or they may bore into the bark to complete their metamorphosis. In many cases they are found just beneath the scales of outer bark.

Table VI presents the disposition of the parents collected from galleries during 1956 and 1957. As is evident from this table, many of the beetles abandon their galleries. After the galleries were 16 to 20 days old, none contained more than one live parent. Nor do the number of dead parents account for all the

TABLE IV
Duration in days of the stadia of *S. tsugae*

Stadium	Duration	
	Mean	Range
Larval 1	8.1	7-9
2	5.6	4-6
3	9.3*	8-11*
4	overwinter	
Pupal	10.6	10-13

*Excluding the 6.5 per cent which overwintered.

missing ones. In an attempt to discover the fate of the parents which leave the galleries, infested material was placed in two cloth cages on August 1, 1956. Included in each cage were pieces of freshly cut Douglas fir, *Pinus contorta* Dougl., *Pinus ponderosa* Laws., *Pinus monticola* Dougl., *Picea engelmanni* Parry, and *Thuja plicata* Donn., along with approximately two inches of forest duff on the bottom of each cage. This material was examined in October, 1956, and in April, 1957, but no evidence was found of beetle activity outside of the originally infested material.

TABLE V
Mean weekly temperatures, in degrees Fahrenheit, during the development of *S. tsugae* at
Trinity Valley, 1956, and Lac la Hache, 1958

Date	Mean	Mean max.	Mean min.
1956			
July 2-8	59.0	71.0	47.0
9-15	66.0	80.0	50.0
16-22	66.0	78.0	52.0
23-29	62.0	80.0	50.0
30-5	58.0	71.0	46.0
Aug. 6-12	60.5	75.0	47.0
13-19	63.5	79.5	48.0
20-26	64.5	78.0	51.0
27-2	56.0	69.0	45.0
Sept. 3-9	50.0	65.0	35.5
1958			
April 21-27	36.0	47.0	24.0
28-4	49.0	62.0	31.0
May 5-11	49.5	64.0	35.0
12-18	48.0	66.0	30.5
19-25	60.0	79.5	40.5
26-1	54.0	67.0	41.0
June 2-8	59.0	74.5	43.0
9-15	58.0	71.0	45.5
16-22	64.0	80.0	48.0
23-29	58.0	68.0	49.0
30-6	61.0	74.0	49.0

TABLE VI

Disposition of parents of the 1956 brood in galleries of *S. tsugae*, Trinity Valley, B.C., 1956 and 1957

Gallery age (days) ¹	Number galleries examined	Per cent galleries containing				
		Living parents			Dead parents	
		2	1	0	2	1
1-10	72	88	9	3	0	2
11-20	75	46	46	8	0	7
21-30	20	0	63	37	10	10
31-40	15	0	70	30	10	10
41-50	15	0	65	35	0	20
Oct. 1956 ²	8	0	38	62	0	62
May 1957 ²	25	0	0	100	0	70
June 1957 ²	27	0	8	92	0	58

¹For gallery systems of known age.²Galleries selected at random.

It was noted that whenever only one of the parents was present it was usually the female. It is possible that the male's behaviour of remaining in the entrance hole to rid the gallery of boring dust is partially responsible for his loss to the family group. Perhaps this activity makes him vulnerable to predacious animals wandering over the logs. One feature which tends to substantiate this hypothesis is the fact that mutilated parents were frequently found in the entrance. However, there is evidence that not all the males are lost due to predation. Since males known to have taken part in gallery construction (with boring dust adhering to sternites of posterior ventral concavity) have been observed running over the bark, it is quite possible that the males are polygamous and wander from gallery to gallery mating with more than one female. This is believed to be the case with *Scolytus multistriatus* Marsh. (Hoffman, 1940) and may be supported for *Scolytus tsugae* by the fact that the sex ratio is four to three in favour of females during flight.

The life-history of *S. tsugae* is presented diagrammatically in Figure 6.

Scolytus tsugae has been reported from *Tsuga mertensiana* (Bong.) Carr., *Pinus monticola*, *Abies grandis* (Dougl.) Lindl., *Abies* spp. (Chamberlin, 1939), and *Tsuga heterophylla* (Raf.) Sarg.³ as well as Douglas fir.

During the spring of 1958, an attempt was made to determine the host preference of this species. One section of Douglas fir, about two feet long and four inches in diameter, infested by *Scolytus tsugae* during 1957, was placed in each of four cloth cages. To each of the cages, freshly cut, three-foot sections of *Tsuga heterophylla*, *Pinus contorta*, *Pinus monticola*, *Pinus ponderosa*, *Juniperus scopulorum* Sarg., *Abies lasiocarpa* (Hook.) Nutt., *Picea engelmanni*, *Thuja plicata*, and *Larix occidentalis* Nutt., were added. In addition, Douglas fir was added to two of the four cages. The sections were examined after the beetles had emerged from the 1957 material and made their attacks on the fresh material. The resulting attacks are presented in Table VII.

Chamberlin (1939) pointed out that *S. monticolae* was the only species of *Scolytus* known to attack any species of *Pinus*, and suggested that *Pinus monticola*, from which the insect was collected, may have been an accidental host.

³Forest Insect Survey and Collection, Forest Biology Laboratories, Victoria and Vernon.

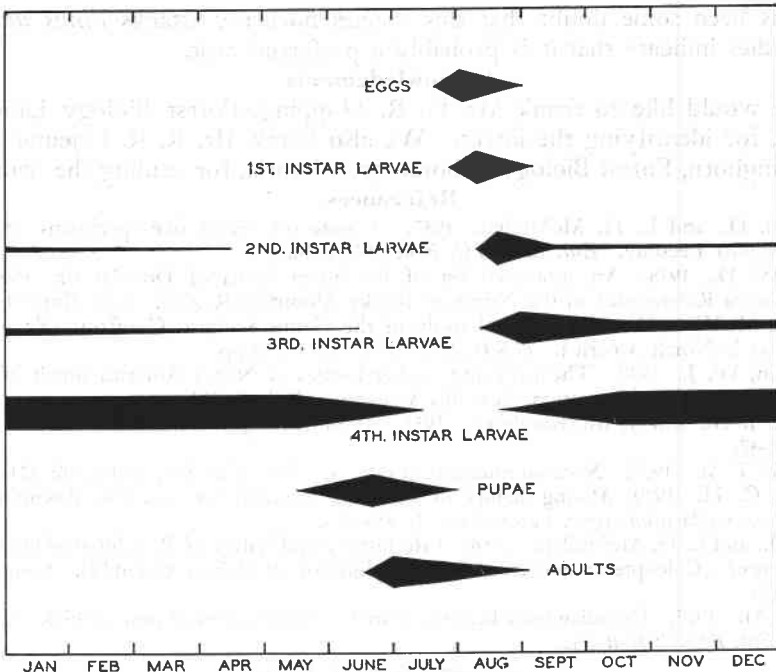


Fig. 6. Diagrammatic representation of life history of *S. tsugae* in the interior of British Columbia.

However, the results of this host preference study indicate that *Pinus monticola* is a true host of this group of *Scolytus*. In fact, the beetles seem to favour *P. monticola* along with *Tsuga heterophylla*, *Abies lasiocarpa* and *Larix occidentalis* as their hosts. The rejection of the Douglas fir may have been due to the pitchy condition of the material used.

Summary

The results of a study of the life history and habits of *Scolytus tsugae* (Swaine), made near Lumby and Lac la Hache, B.C., indicate that the beetle in the interior of the Province has a one-year life cycle with one brood per year. The beetle overwinters in the larval stage, chiefly in the fourth instar. Although

TABLE VII
Results of a cage study on the host preference of *S. tsugae* Swaine

Host species	Total area in sq. ft.	No. of attacks	Attacks per sq. ft.
<i>Tsuga heterophylla</i>	12.34	90	7.29
<i>Pinus contorta</i>	13.40	1(?)	0.07
<i>Pinus monticola</i>	12.61	149	11.02
<i>Pinus ponderosa</i>	11.80	1	0.09
<i>Juniperus scopulorum</i>	11.90	0	0.00
<i>Abies lasiocarpa</i>	11.88	28	2.35
<i>Picea engelmanni</i>	10.60	1 + 1(?)	0.19
<i>Thuja plicata</i>	11.80	0	0.00
<i>Larix occidentalis</i>	10.65	25	2.35
<i>Pseudotsuga menziesii</i>	5.35	10	1.86

(?)Not positively identified as *S. tsugae*.

there has been some doubt that this species normally attacks *Pinus monticola*, cage studies indicate that it is probably a preferred host.

Acknowledgments

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Four Hymenoptera Newly Recorded As Parasites of the Armyworm, *Pseudaletia unipuncta* (Haw.) (Lepidoptera: Noctuidae)¹

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At Ottawa, during studies on the parasites of the armyworm, *Pseudaletia unipuncta* (Haw.), in 1955, 1957, and 1958, 20 species of Hymenoptera were reared from larvae or pupae of the armyworm collected from fields in the area during July and August. Of the 15 species thus far identified, 12 were primary parasites; four of these, namely, *Euplectrus mellipes* Prov. (Eulophidae), *Hyposoter annulipes* (Cress.) (Ichneumonidae), *Microgaster auripes* Prov. (Braconidae), and *Therion sassacus* Vier. (Ichneumonidae), have not been previously recorded as parasites of *P. unipuncta*.

E. mellipes, an ectoparasite, was reared from six fourth-instar larvae of the armyworm in July, 1957, and from one in the third instar, four in the fourth, and one in the fifth in late July and August, 1958. Superparasitism always occurred, the number of parasite larvae per host ranging from five to 21 and averaging eight. The eggs of this species were laid in a mass on the dorsothoracic region of the host. The larvae fed gregariously on the immediate area where the eggs had been laid. As they increased in size their bodies formed a globular mass, the individual larvae being recognizable only by close examination. When fully grown, the parasite larvae dispersed over the body of the host, spun very loose cocoons, and transformed to pupae. The host larva became inactive as the parasite larvae neared maturity, and died about this time, its remains becoming enveloped by the parasite cocoons.

¹Contribution No. 3939, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.