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The Hymenopterous Parasites Agathis Pumila (Braconidae) and Epilampsis Laricinellae (Eulophidae) on the Larch Casebearer (Lepidoptera: Coleophoridae) in the Northern Lake States

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THE HYMENOPTEROUS PARASITES AGATHIS PUMILA (BRACONIDAE) AND EPILAMPSIS LARICINELLAE (EULOPHIDAE) ON THE LARCH CASEBEARER (LEPIDOPTERA: COLEOPHORIDAE) IN THE NORTHERN LAKE STATES

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The larch casebearer *Coleophora laricella* (Hübner) is a defoliator of larch (*Larix* spp.). The insect was introduced into North America from Europe at some time prior to 1886, and since has spread steadily westward. It was causing heavy defoliation by the early 1920's near Ann Arbor in southern Michigan and was recorded in northeast Wisconsin in 1939, at Sault Ste. Marie, Ontario in 1942, and Port Arthur, Ontario in 1947.

Many native parasites attack the casebearer but seem to effect little control. Parasites were imported from Europe beginning in 1928, but the first attempts to establish them were unsuccessful. In 1932, the United States Bureau of Entomology and Plant Quarantine made releases of *Agathis pumila* (Ratz.) at Lynwood, Massachusetts, and *Epilampsis laricinellae* (Ratz.) in Lunenburg Township, Massachusetts. These two species were successfully established.

Agathis pumila was released near Ann Arbor, Michigan, in 1937. Following release and establishment of *pumila,* the casebearer population declined sharply and no conspicuous defoliation has been observed since. Studies in 1950, 1951 and 1953 (Webb, 1953) showed that *pumila* was well established throughout the Lower Peninsula of Michigan and was spreading into the Upper Peninsula across the Straits of Mackinac and around the southern tip of Lake Michigan to Jefferson County, Wisconsin. The first recovery of the species in the Upper Peninsula was in 1951 near St. Ignace in Mackinac County. During the same year, Webb released the parasite at Elmwood in Iron County.

During the period 1951-53, larch stands throughout the Upper Peninsula were heavily defoliated by the casebearer. In 1953, the population dropped sharply and by 1954 areas of heavy defoliation were reported only from Schoolcraft, Delta, and Dickinson Counties. While driving across the Upper Peninsula in June 1954, S.A. Graham noticed only two areas of heavy defoliation, one in Schoolcraft County and one in

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Delta County. Since these areas are approximately equidistant from the recovery point of *pumila* in 1951 at St. Ignace and the point of release by Webb at Elmwood in the same year, it was suggested that perhaps the spread of *pumila* could be associated with the disappearance of defoliation to the east and west of these points.

PARASITES OF *COLEOPHORA LARICELLA*

Native Parasites

Many native parasites have been known to attack the larch casebearer. Webb (1953) reported fifty-three. All are hymenopterous, nine families being represented. To our knowledge, no dipterous parasites of the casebearer have been reported. Of the native parasites, none has achieved any appreciable control of the host species. They are mostly general parasites known to attack other small Lepidoptera and, in some instances, other hymenopterous parasites. Only three species cause more than 5% parasitism.

Introduced Parasites

Five species of parasites of the casebearer have been introduced from Europe into the United States and Canada. Only two, *Agathis pumila* and *Epilampsis laricinellae* have become established. Apparently both are able to spread rapidly and exert considerable control. Although *pumila* is usually considered to be the most effective, Graham (1948) believes that the two in combination may achieve the most rapid control.

Although the present study is concerned primarily with the rate of spread of *pumila*, the interactions between *pumila* and *laricinellae* necessitate discussions of the biology of both parasites.

Biology of *Agathis pumila* (Ratz.)

The species has only one generation per year. It hibernates in the first larval instar within the host larva and remains in this stage until the host completes its larval development during May or early June. When the host case is tied up for pupation, the larva of *pumila* continues its development and later pupates within the host during the second or third week in June. Meanwhile, the host larva does not seem to be affected by the presence of the parasite until the latter is near pupation. However, the parasite prevents pupation of the casebearer. Thus the parasitized casebearer larva remains in the larval stage for an additional ten to fourteen days.

Adults of *pumila* emerge during late June and early July, and the females lay their eggs in the tiny needle-mining casebearer larvae. The incubation period is not known, but first stage parasite larvae have been found early in August. Thus, *pumila* has a single generation, the first instar larva remaining in the host from late July until the following year. *Coleophora laricella* is the only known host of *Agathis pumila*.

Biology of *Epilampsis laricinellae* (Ratz.)

There are three generations annually. The species hibernates as a full

grown larva in the host larval case, and pupation takes place early in May. The adult parasite emerges a week or ten days later and deposits eggs in host larvae that have over-wintered. The host larva dies as soon as the parasite egg hatches. The immature stages and life history have been discussed by Quednau (1966).

The adults producing the second generation of *laricinellae* emerge from the middle of June to the middle of July. Those emerging earliest parasitize casebearer larvae that have already been parasitized by *pumila*. The smaller number that emerge later parasitize the very young needle-mining casebearer larvae. Thus, the *laricinellae* population is materially aided by the presence of larvae parasitized by *pumila*. The adults emerging from larvae developed in the young needle-mining casebearer larvae are much smaller than those developed from full-grown casebearer larvae. Pupation does not take place until the end of August or the first week of September.

Adults of *laricinellae* producing the third generation emerge from mid-September to early October. This generation develops entirely within the needle-mining host larvae. The adults which emerge the following spring are all very small. Emergence of the third generation of *laricinellae* usually coincides with the formation of the host case and the beginning of hibernation.

The incubation period of *laricinellae* is only a few days, and the larvae mature in a short time. After about two weeks, the larva is ready for hibernation within the host.

RATE OF SPREAD OF *AGATHIS PUMILA*

Studies of Michigan populations in 1950-51 (Webb, 1953) showed that for a fourteen year period *pumila* had spread from the point of introduction at an approximate rate of 21 miles per year. Following 1951, when the parasite first appeared near St. Ignace, Michigan, and was simultaneously released in Iron County, an unusual opportunity was afforded to check Webb's conclusions by direct observation in the Upper Peninsula. Thus we decided to study the invasion by *pumila* of localities already occupied by *laricinellae*, and to observe the interactions between these two parasites and their combined effects upon the casebearer population.

The investigations began in 1954 when casebearer pupae were collected at intervals from Mackinac County to Gogebic County, covering localities of both heavy and light defoliation. Adult parasites were reared from this collection.

In January and February 1963, another series of collections was made along U.S. Highway 2 from St. Ignace, Michigan, to Fosston, Minnesota (Fig. 1). Analysis of the data suggests that when the two parasites occur together, first one and then the other predominates in numbers.

1954 Collections

In June 1954, branch samples were collected from 12 locations

along U.S. Highway 2 from St. Ignace to Gogebic Lake. Nine additional samples were taken near the point where Webb made releases of *pumila* in 1951. All were carefully examined for the pupae of *Coleophora laricella*. These were removed from the branches and all specimens from each location were placed in a glass vial. The vials were examined daily for the emergence of adult parasites. Mounted specimens were sent to the Insect Identification and Parasite Introduction Research Branch, U.S. Department of Agriculture, Beltsville, Maryland, for identification.

After emergence of the parasites had ceased, all cases were dissected to determine the following:

1. Number of cases from which moths had emerged.
2. Number of cases from which parasites had emerged.
3. Number of cases from which nothing had emerged.

Where no emergence had occurred, the casebearer was carefully dissected in an attempt to determine whether or not it had been parasitized. The cases were soaked for a few minutes in a 5% solution of potassium hydroxide to soften the silk and make dissection easier.

A total of 1,808 casebearer pupae was collected, from which 385 parasites were reared. There was no emergence from 69 cases. These were determined to be parasitized, but the species was not identified. Of the reared parasites, 334 were identified as *laricinellae*. Thus total parasitism was 25%; 18% was due to *laricinellae*. Only six specimens of *pumila* were found.

Of the total collection, ten species of parasites from six families of Hymenoptera were reared. These included two undescribed insects of the family Pteromalidae; one was an unknown genus and the other was a new species of *Chrysolampus*. The species follow:

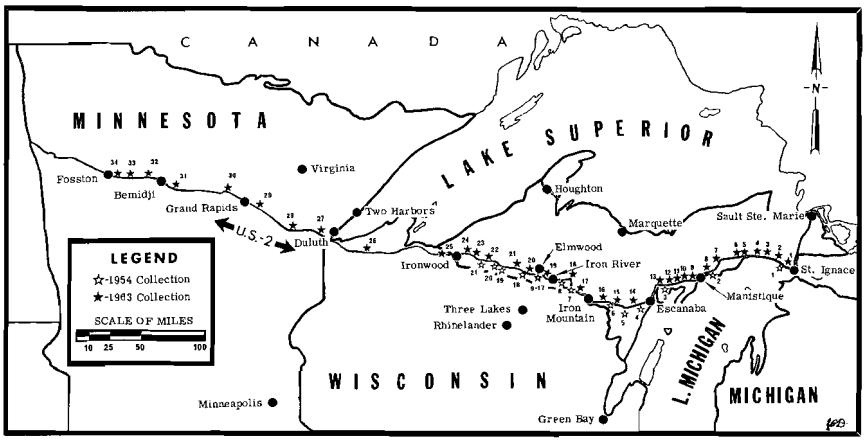

Figure 1. Stations along U.S. 2 at which casebearers were collected in 1954 and 1963. Drawn by Julian P. Donahue.

Braconidae: *Bracon pygmaeus* Prov.
Agathis pumila (Ratz.)
Ichneumonidae: *Gelis* sp. 1
Gelis sp. 2
Pteromalidae: *Habrocyctus phycidis* Ashm.
Unknown genus, *Pteromalini*
Chrysolampus, n. sp.
Eupelmidae: *Eupelmella vesicularis* (Ratz.)
Chalcididae: *Spilochalcis albifrons* (Walsh)
Eulophidae: *Epilampsis laricinellae* (Ratz.)

Table 1 lists the occurrence of *pumila* and *laricinellae*, the two species of most importance. Unexpectedly, *laricinellae* was by far the more abundant of the two, although *pumila* was present in several undefoliated locations. Figure 1 shows the location of collecting points and distances from points of release or prior recovery in 1951.

The recovery of *pumila* from collection point six, approximately 66 miles southeast of the nearest release point of Elmwood, where *pumila* had been released three years earlier, represents an average dispersal of 22 miles per year. This compares closely with the report of Webb (1953) which gave an average rate of spread of 21 miles per year. Because of the dependence of the second generation of *laricinellae* on the presence of casebearer larvae parasitized by *pumila*, we suspected that wherever parasitism of *laricinellae* was 20% or greater, *pumila* must also be present. If this is true, then *pumila* was probably present at collection point four, which is approximately 92 miles southeast of Elmwood. This would mean that the two populations of *pumila* had actually met, and that the parasite had spread at an average rate of 30 miles per year for three years.

Table 1. Results of 1954 Collections in Michigan.

Collection No. and County	No. Casebearer Cases	No. *A. pumila*	No. *E. laricinellae*	Other Parasites	Total % Parasitized	Defoliation
1. Mackinac	113	1	21	18	35.4	Light
2. Schoolcraft	105		2	2	3.8	Heavy
3. Delta	71		9	4	18.3	Heavy
4. Delta	223		28	10	17.0	Light-Mod.
5. Menominee	33		8	4	36.4	Light
6. Dickinson	101	1	15	12	27.7	"
7. Iron	63		15	3	28.6	"
8. Iron	16		1	0	6.3	"
9. Iron	85		7	2	10.6	"
10. Iron	88		32	8	45.0	"
11. Iron	155		28	8	23.2	"
12. Iron	98		39	4	43.9	"
13. Iron	47	1	3	4	17.0	"
14. Iron	106		32	6	35.9	"
15. Iron	172	1	30	9	23.3	"
16. Iron	14		3	2	35.7	"
17. Iron	19		4	1	26.3	"
18. Gogebic	41		9	4	31.7	"
19. Gogebic	136		31	8	28.7	"
20. Gogebic	51	1	12	3	31.4	"
21. Gogebic	71	1	5	2	11.3	"
TOTALS	1,808	6	334	114	25.1 (Total Mean Parasitism)	

This conclusion was accepted with caution, as further evidence was needed. In the winter of 1963 another set of collections was made.

1963 Collections

In January 1963, casebearer larvae were collected from points along U.S. Highway 2 extending from a locality a few miles west of St. Ignace to a point in Wisconsin approximately eight miles west of Ironwood, Michigan. Dissection of the larvae showed *pumila* to be present at all collection points. Parasitism by this species ranged from 3% at collection point six to 79% at collection point 24. Average parasitism was 45%.

Because *pumila* had been recovered at all points in the Upper Peninsula, it was decided to extend the collections along U.S. Highway 2 across northern Wisconsin and northern Minnesota in an attempt to determine how far the parasite had actually spread.

In February 1963, collections of larch casebearer larvae were made at nine points in Wisconsin and Minnesota (Table 2, Points 26-34); the most westerly point was near Fosston, Minnesota, on the edge of the prairie. Again *pumila* was present in all collections. Parasitism ranged from 50% at point 26 to 95% at point 28. Parasitism near Fosston was 64%. Average parasitism in the February collections was 82%, and the average parasitism from all 1963 collections was 51%. Surprisingly, parasitism was all due to *pumila*. No *laricinellae* larvae were found (Table 2).

Fosston is approximately 355 miles west of Elmwood. Thus, for the 12 year period 1951-1963, *pumila* had spread westward at an average rate of nearly 30 miles per year.

It cannot be said definitely that the westward spread of *pumila* is due entirely to the release made by Webb in 1951 at Elmwood, because in 1953 Shenefelt (Coppel and Shenefelt, 1960) collected casebearer pupae from Michigan areas where *pumila* had been established and placed them in larch stands near Rhinelander and Three Lakes, Wisconsin. In August of the same year, he released 347 adults of *pumila* and 443 adults of *laricinellae* at the same locations. Since Three Lakes is only 30 miles south and Rhinelander 45 miles south of Elmwood, it is possible that *pumila* had already spread to those two areas before Shenefelt made his release; but regardless of the source of the present *pumila* population in Minnesota, the parasite must have spread at least 30 miles per year, since both Rhinelander and Three Lakes are approximately the same distance from Fosston as is Elmwood. Since parasitism at Fosston was 64%, *pumila* must have been present there at least two years prior to 1963. If this is true, it would mean that this tiny parasite had spread at a rate of more than 35 miles per year for 12 years.

INTERACTIONS OF *AGATHIS PUMILA* AND *EPILAMPSIS LARICINELLAE*

Considerable confusion exists, and conflicting reports have been

written regarding the relative effectiveness of *pumila* and *laricinellae* as parasites of the casebearer. Webb (1953) reported that *laricinellae* occurred in New Brunswick, and that parasitism rose as high as 43% in the virtual absence of *pumila*. The exact opposite was true in southern Michigan where, following the release of *pumila* near Ann Arbor in 1937, the casebearer infestation was brought under control in the absence of *laricinellae*.

Two years after both parasites were released in Wisconsin in 1953, Coppel and Shenefelt (1960) reported that *laricinellae* was recovered, but *pumila* was not found. In a limited survey conducted during late May and early June in Dane and Polk Counties, both parasites were found, but *laricinellae* was present in greater numbers. A survey of the northern Wisconsin counties in 1959 showed parasitism by *pumila* to be high. In some instances, it seemed to be the only effective parasite.

In 1954 J.B. Cody found *laricinellae* to be present in considerable numbers, while only six specimens of *pumila* were reared. In 1963,

Table 2. Results of 1963 collections

Collection No. and county	No. case-bearer cases	No. *A. pumila*	% Parasitized
Michigan			
1 Mackinac	94	39	41.5
2 Mackinac	100	45	45.0
3 Mackinac	38	15	39.5
4 Mackinac	100	61	61.0
5 Mackinac	96	14	14.6
6 Mackinac	100	3	3.0
7 Mackinac	100	68	68.0
8 Schoolcraft	72	19	26.4
9 Schoolcraft	100	24	24.0
10 Schoolcraft	100	70	70.0
11 Delta	100	67	67.0
12 Delta	100	35	35.0
13 Delta	100	25	25.0
14 Delta	100	37	37.0
15 Menominee	100	59	59.0
16 Dickinson	100	25	25.0
17 Iron	100	3	3.0
18 Iron	56	36	64.3
19 Iron	11	8	72.7
20 Iron	51	9	17.6
21 Gogebic	100	45	45.0
22 Gogebic	100	66	66.0
23 Gogebic	91	71	78.0
24 Gogebic	100	79	79.0
Wisconsin			
25 Iron	100	78	78.0
26 Bayfield	4	2	50.0
Minnesota			
27 St. Louis	21	14	66.7
28 St. Louis	60	57	95.0
29 Itasca	75	60	80.0
30 Itasca	87	76	87.4
31 Hubbard	6	5	83.3
32 Beltrami	25	18	72.0
33 Clearwater	72	58	80.6
34 Polk	11	7	63.6
TOTALS	2,570	1,298	51% (Total mean parasitism)

however, *pumila* was present in large numbers and *laricinellae* was absent. It is interesting to note that in 1954 the decline of the casebearer population was in its second year, and heavy defoliation was still occurring in the central part of the Upper Peninsula, while in 1963 the casebearer population at all collection points was very low.

When the various reports are studied, an interesting pattern emerges. When both parasites are present and the casebearer population is high, *laricinellae* is the most numerous parasite. When the casebearer population drops to a low level, *pumila* is found in large numbers and *laricinellae* is virtually absent.

That *pumila*, by itself, is an effective parasite of the casebearer is evident from the sudden decline in the casebearer population in the southern part of the Lower Peninsula where *laricinellae* was not present. As pointed out earlier, *laricinellae* depends on the presence of pumila to provide host stock necessary for production of its third generation. Graham (1948) noted that the spread of *laricinellae* lagged behind that of *pumila* and that the former did not emerge as an effective parasite of the casebearer until parasitism by *pumila* had reached a high level. This was not reported by Coppel and Shenefelt (1960), but their survey was made two years after the parasites had been released. The presence of *pumila* can be obscured in June collections because of secondary parasitism by *laricinellae*.

It appears then that when a casebearer population is high and both parasites are present, the population of *pumila* first builds up to the point where it provides sufficient host stock for *laricinellae* to produce a large second generation. At such time *laricinellae*, because of its three annual generations, is able to build up rapidly and to reduce sharply the population of both the larch casebearer and *pumila*. The reduction in the *pumila* population inevitably reduces the population of *laricinellae* during the following season. Indeed, *laricinellae* may not be able to maintain itself at all at low casebearer populations. Dissection of 2,570 casebearer larvae from the 1963 collections failed to reveal a single larva of *laricinellae*. But as *laricinellae* has other hosts, such as *Fenusa pusilla* (Lep.), *Fenusa ulmi* Sund., and *Heterarthrus nemoratus* (Fall.), it would not be eliminated from a given locality and would be able to re-invade a casebearer population when conditions were again made favorable by an increase of *pumila*.

Although the facts at hand suggest that alternating high populations of *pumila* and *laricinellae* result from the interaction between these two parasites, proof will depend upon future annual observations.

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FORTHCOMING PUBLICATIONS

In the recent rush to reprint classics in the history of science, entomology has been sadly neglected. This is perhaps to be expected, as scholarly interest in the history of entomology is of fairly recent date, and early entomological works have been largely left to taxonomists searching for species descriptions. Now that the tide is turning, we expect to see numerous reprints of historical classics in entomology.

The most promising sign to date is the recent announcement of an extensive series to form part of the Curwen Facsimile Editions. The series, to be called the "Classica Entomologica," will be printed and published by the Curwen Press, London, England, using the latest techniques in photolithography. General editor of the series is the well-known entomologist and bibliographer E.W. Classey, F.R.E.S., late of the British Museum (Natural History). The works will include critical introductions by recognized authorities. Titles are being selected because of their rarity and inaccessibility to research workers, because of their historical or bibliographical interest, and in some cases for their aesthetic value. All will be reprinted in facsimile, including exact reproductions of colored plates.

Two titles will be published in 1967. The first of these, William Curtis' *A Short History of the Brown-Tail Moth* (1782), is the first published monograph in English on a single insect, and few copies are known. American entomologists will remember the havoc caused by *Euproctis chrysorrhoea* L. after its introduction into Massachusetts in the 1890s. Curtis' work will be published, with its color plate, at $6.00.

The second title, James Dutfield's *A New and Complete Natural History of English Moths and Butterflies* (1748-9), is certainly one of the scarcest of entomological publications. Only one copy is known, that in the British Museum (Natural History). The work was apparently never completed, and consists of six fascicles containing a total of twelve colored plates and appropriate text. The price of the reprint will be $105.00. Both works and their authors are discussed by Arthur A. Lisney in *A Bibliography of British Lepidoptera* (London, 1960).

Future titles will include W.W. Fowler's *The Coleoptera of the British Isles*; J. Petiver's *Papilionum Britanniae Icones*; E.L. Ragonot's *Monographie des Phycitinae et des Galleriinae* (Romanoff: *Mémoires sur les Lépidoptères*, Vol. 8); P. Poey's *Centurie de Lépidoptères de l' Ile de Cuba*, and M.W.S. MacLeay's *Annulosa Javanica*. Further enquiries should be directed to E.W. Classey, 353 Hanworth Road, Hampton, Middlesex, England. R.S.W.