

Parasites of the Filbert Worm¹

S. M. DOHANIAN,² U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine

Since 1937 an investigation of the filbert worm, *Melissopus latiferreanus* (Wlsm.),³ has been under way at the Bureau of Entomology and Plant Quarantine laboratory at Eugene, Oregon. A preliminary paper on the problem (Dohanian 1940) included brief mention of six parasites of this insect which had been reared. Further information on these species has been accumulated and 13 additional species have since been reared.⁴

No attempt has been made to study any of the parasite species in detail, since the work has necessarily been concentrated on the host. However, as the parasites appeared, notes were made concerning them under various conditions and circumstances. The accumulation of these fragmentary notes has furnished considerable information relative to the distribution, life history, and economic importance of most of the species.

For the purpose of these investigations collections from the common food plants of the filbert worm were made in the western portions of Washington and Oregon during the period 1938-41 and in the western half of California in 1938 and 1939. In addition to filberts, *Corylus avellana*, the following were collected in large numbers for study: Hazelnuts, *Corylus americana* and *C. cornuta*; acorns, *Quercus* spp.; galls formed by *Andricus californicus* (Bassett) on the branches and twigs of *Q. garryana*; galls formed on the leaves of this oak by *Cynips maculipennis* (Gillette); and the fruit of the Catalina cherry, *Prunus lyonii* Sargent.

SEASONAL HISTORY OF THE FILBERT WORM.—The discussion of the parasites may be aided by a brief résumé of the life history of their host. The filbert worm

hibernates as a full-grown larva. The time of emergence of the adults varies with the food plant, but in general moths may be found in the field from June 25 to August 15, and during this period the eggs may be seen on the foliage or on the fruit of the food plants. The eggs hatch about 8 days after deposition. As soon as the newly hatched larva can locate the host fruit, it bores into the fruit and develops rapidly. In about 3 weeks the worm is fully fed and ready for hibernation. It forms a flimsy, thin cocoon when hibernation takes place within the nut or other food, but a tough and impervious cocoon when hibernation occurs in the ground, usually within the first inch of soil. There is normally but one generation a year in the Pacific Northwest, whereas two generations are indicated in the southern half of California.

PARASITES REARED DURING THE STUDY.—Nineteen species of parasites have appeared in the material reared at the Eugene laboratory during the past 4 seasons (Table 1). Of these, 13 species were definitely parasitic on the filbert worm. The host relationship of the remaining species has not been definitely ascertained, but the evidence obtained regarding the insects present in numerous collections of the common food plants of the filbert worm from the entire West Coast supports the belief that all the parasitic forms listed were attacking and developing on *Melissopus latiferreanus*. Five families of Hymenoptera and one of Diptera are represented.

Bassus nusicola.—This is one of the several new species (Muesebeck 1940) discovered during the investigations at the Eugene laboratory. Although thousands of representatives of the known common food plants of the filbert worm have been retained for study at the laboratory, *Bassus nusicola* has been reared only from filbert worms infesting acorns and the galls formed by *Andricus*. More than 200 specimens of the parasite have issued from such material collected in the territory between the Columbia River in Oregon and San Luis Obispo County in California, at elevations ranging up to 2,100 feet above sea level.

¹ Pacific Slope Branch Program, Salt Lake City, 1942.

² The author acknowledges his indebtedness to Robert M. Fouts for assistance in rearing the parasites discussed in this paper.

³ Order Lepidoptera, family Olethreutidae, subfamily Laspysiniinae.

⁴ The author expresses appreciation to the following members of the Bureau of Entomology and Plant Quarantine for determination of parasite specimens and descriptions of species found to be new: C. F. W. Muesebeck (Braconidae, Bethyloidea), R. A. Cushman (Ichneumonidae), A. B. Gahan (Trichogrammatidae, Eulophidae), and D. G. Hall (Tachinidae). He gratefully acknowledges field-collected material received from G. E. Woodhams, Commissioner of Agriculture, San Bernardino, Calif., and A. A. Conrad, Santa Catalina Island, Calif.; and from E. J. Newcomer and Perez Simmons, of the Bureau of Entomology and Plant Quarantine.

The records obtained during 1938 to 40 indicate strongly that this parasite is efficient in keeping the numbers of filbert worms in acorns and *Andricus* galls at a minimum. In 10 of the 18 collections of host material producing *Bassus nucicola* parasitization ranged from 10 to 87 per cent. This species is particularly effective in attacking filbert worms infesting *Andricus* galls.

Bassus laticinctus.—One adult of this species emerged on July 31, 1939, from a lot of 175 hazelnuts collected at South Tacoma, Wash., a week earlier. At the end of the season the nuts were cracked and it was found that 3 were infested by the filbert worm, 2 had no kernels in them, and 170 were not infested.

Macrocentrus ancyliivorus.—It is believed that the rearing of *Macrocentrus*

Table 1.—Parasites reared from the filbert worm, or material infested by it, Eugene, Oregon.

FAMILY	SPECIES	REARED FROM MATERIAL IN—
Braconidae	<i>Bassus nucicola</i> Mues.	Acorn, <i>Andricus</i> gall
	<i>Bassus laticinctus</i> (Cress.) ¹	Hazelnut
	<i>Macrocentrus ancyliivorus</i> Roh.	Acorn
	<i>Orgilus</i> n. sp.	Acorn
	<i>Phanerotoma tibialis</i> Hald.	Acorn, <i>Cynips</i> gall
Ichneumonidae	<i>Aenoplex carpocapsae</i> Cush.	Cocoon in soil
	<i>Angitia</i> sp.	Acorn, <i>Cynips</i> gall
	<i>Calliephialtes nucicola</i> Cush.	Filbert, Catalina cherry, <i>Andricus</i> gall, acorn, <i>Cynips</i> gall, hazelnut
	<i>Lissonota inconstans</i> Cush.	Filbert, Catalina cherry, walnut, acorn, hazelnut
	<i>Glypta rufiscutellaris</i> Cress.	Hazelnut
Trichogrammidae	<i>Trichogramma minutum</i> Riley	
Eulophidae	<i>Elachertus (Hyssopus) evetriae</i> Gir.	Filbert
Bethyilidae	<i>Goniozus</i> n. sp. ¹	<i>Cynips</i> gall
	<i>Perisierola gracilicornis</i> Kief. ¹	Hazelnut
	<i>Perisierola</i> sp. ¹	Hazelnut
	<i>Perisierola</i> n. sp.	<i>Cynips</i> gall
Tachinidae	<i>Anachaetopsis tortricis</i> (Coq.)	Filbert, acorn
	<i>Phorocera erecta</i> (Coq.) ¹	Filbert
	<i>Plectops</i> sp. ¹	<i>Cynips</i> gall, <i>Andricus</i> gall

¹ Not definitely reared from *Melissopus latiferreanus*.

Bassus nucicola is a solitary parasite and overwinters within the host larva. There may be either one or two generations a year. The adults of the overwintering generation issue in April or May, an indication of the need of an alternate host. Those of the summer generation emerge during July, August, and September, and occasionally in June and October. The life cycle, egg to adult, of overwintering individuals may range from 9 to 13 months, including those with only one generation a year, while that of the summer generation may be from 6 to 16 weeks. Six *Bassus* larvae of the summer generation, seen issuing from *Melissopus* larvae, approximated 9 weeks for the life cycle, which is about the average for that generation. The parasite larva spins its cocoon on the day of issuance from its host, the adult emerging therefrom 14 to 21 days later. On an average 18 days are spent within the cocoon.

ancyliivorus from *Melissopus latiferreanus* is the first record of the natural appearance of the species on the West Coast. Unlike the other more common parasites of the filbert worm, *M. ancyliivorus* confines its activity almost exclusively to its host infesting acorns. It has been reared from infested acorns from 10 localities in western Oregon and from Del Norte County in California. Only one specimen has been reared from food plants of the filbert worm other than acorns, and that was a female emerging on June 1, 1941, from infested Catalina cherries from Hope, Santa Barbara County, Calif. R. A. Cushman, of the Bureau of Entomology and Plant Quarantine, identified this specimen as *M. ancyliivorus*.

It is noteworthy, judging from the evidence furnished by these rearings, that this solitary parasite appears to be more effective at the higher altitudes. With only one exception, the highest parasitization

by *Macrocentrus ancyliivorus* in collections of acorns made at elevations under 1,000 feet was 6 per cent or less, whereas in four collections of infested acorns from localities ranging from 1,100 to 2,750 feet above sea level parasitization by this species was 7, 28, 33, and 50 per cent.

From food-plant material of the filbert worm collected in July and prior to the middle of August, adults of *Macrocentrus ancyliivorus* emerged in August and September of the same year, whereas from collections made subsequent to mid-August adults emerged during June of the following year. In 1938, acorns were collected periodically in northwestern Oregon, beginning on July 20. Larvae of the filbert worm were found infesting those collected as early as July 30, but *M. ancyliivorus* was not found to have successfully parasitized the filbert worm larvae in acorns collected prior to August 18. These observations seem to indicate that the summer generations of this parasite in the Pacific Northwest must develop on one or more hosts other than the filbert worm.

Records of the sexes showed that 56 per cent of 100 adults of *Macrocentrus ancyliivorus* reared from the field during 3 years were females.

Orgilus, n. sp.—Only two adults of this species have been reared, both from acorns. One emerged on September 24, 1939, from acorns collected at Willits, Calif., only 6 weeks before that date. The other emerged from the cocoon of an isolated filbert worm larva on August 14, 1941, just 51 weeks after the acorns were collected at Myrtle Creek, Oregon. The absence of a pupal shell of the host in the *Melissopus* cocoon indicates that this species of *Orgilus* is a larval parasite. C. F. W. Muesebeck has advised the writer that this *Orgilus* is a new species.

Phanerotoma tibialis.—This is a common, widely distributed species with an apparently wide range of hosts. Thirty-six specimens have been reared from the material collected in the West Coast States in 1939, 1940, and 1941. *Phanerotoma tibialis* has been reared chiefly from infested acorns from western Oregon and southern Washington, collected at altitudes up to 2,750 feet and from filbert moth larvae infesting galls formed by *Cynips maculipennis*. Perhaps none of the parasites discussed in this paper has its life cycle better synchronized with that

of the filbert worm than *P. tibialis*. In these rearings *P. tibialis* has had but one generation a year, the adults emerging from the host late in July or very early in August. This is the period during which *Melissopus latiferreanus* larvae are most abundant in the field. The parasite overwinters as a larva in the hibernating larvae of its host, in the cocoon formed either in the soil or in the host food. In one instance a parasite larva was seen issuing from an isolated host larva on June 27. It immediately spun a white cocoon, and the adult parasite emerged therefrom on July 19. The earliest field collection of infested material producing this parasite was made on July 26.

Aenoplex carpocapsae.—One adult of this occasional codling moth parasite has been reared from the filbert worm. While conducting winter mortality studies in a filbert orchard at Goshen, Oregon, in the early spring of 1941, the writers found several hibernating cocoons of the filbert worm in the top inch of soil. A few days later, on April 4, an adult of *Aenoplex carpocapsae* issued from one of the cocoons.

Angitia sp.—*Melissopus latiferreanus* larvae infesting galls formed by *Cynips maculipennis* at Dundee, Oregon, and acorns at Chehalis, Wash., were hosts of this parasite. The acorns were collected on July 24, 1941, and on the following day a filbert worm issuing from one of them was isolated. Sometime prior to August 26, when the adult emerged, the parasitic larva had issued from the host larva and had formed its cocoon.

Other specimens were reared on April 26, 1939, and April 16, 1940, from acorns collected the preceding year at Monmouth and Aurora, Oregon.

It is apparent that the species has more than one generation a year, with one or possibly more alternate hosts.

Calliophialtes nucicola.—This species has a wide distribution on the West Coast, representatives having been reared from the larvae of the filbert worm from many localities in the territory between Tacoma, Wash., and Santa Barbara and Santa Catalina Island, Calif. It has been reared from all the six common food plants of the filbert worm studied at Eugene, but is particularly effective in attacking that insect infesting galls on oak formed by *Andricus*. In more than half of the 31

collections of these galls in the Pacific Coast States, in which the parasite was found, parasitization exceeded 10 per cent, a maximum of 75 per cent being recorded for Springfield, Oregon, in 1939. *Calliophialtes nucicola* has been reared in small numbers in the following materials infested by *Melissopus latiferreanus*: Acorns from Santa Catalina Island, Calif., and the Willamette Valley, Oregon; filbert nuts from Oregon; Catalina cherry from Santa Barbara, Calif.; *Cynips* galls from western Oregon; and hazelnuts collected in Minnehaha, Clark County, Wash.

The rearing records indicate the existence of two generations a year for *Calliophialtes nucicola*, although occasionally it may have but one. Adults of the summer generation emerge from late July to early September, whereas those of the single-generation strain issue from early May to about the middle of July. The life cycle of the overwintering generation (egg to adult) is from 8 to 12 months, whereas the summer generation develops in from 7 to 12 weeks. In one instance a pupa found on August 21, 1941, in a filbert nut from Albany, Oregon, transformed to the imago on September 4, an indication that the insect was at least 14 days in the pupal stage. One year earlier five pupae of the parasite were found in one *Andricus* gall from Scappoose, Oregon, when the gall was dissected on August 8. Two of the pupae, which were held in place by a few strands of silk within the cavity eaten out by the filbert worm, transformed to adults on August 10 and 12. The other three did not produce adults and when found had been dislodged from their silky support, probably during the dissection. Before transformation the larva spins just enough silk strands to hold the pupa firmly in place and thus to facilitate the emergence of the adult. The structure has the general form of a cocoon, but it lacks sufficient texture to be classified as such. Larval head capsules of *Melissopus latiferreanus* were present in each of the cells containing the "cocoon" of *C. nucicola*, an indication that this solitary parasite emerges from the larva of its host.

The sexes were recorded for 58 of 123 adults of *Calliophialtes nucicola* reared from field-collected material and 64 per cent were females.

Lissonota inconstans.—This is another of the new species (Cushman 1940) dis-

covered in the investigations conducted at Eugene. This parasite has been found along the West Coast from the Columbia River to southern California. It has been reared from the larvae of *Melissopus latiferreanus* infesting filberts, walnuts, acorns, and hazelnuts from Oregon as well as Catalina cherry growing in Santa Barbara County, and acorns from Fresno County, Calif. This parasite has not been reared from filbert worm larvae infesting Catalina cherries collected on Santa Catalina Island, to which island the plant is indigenous.

Material infested by the filbert worm collected in the field during the period from June to early October has produced adults of *Lissonota inconstans* almost invariably only during the month of March of the following year. Since no filbert worm larvae are available for attack during the 4 months following emergence of the parasites, except those hibernating in their cocoons in the ground, obviously this species must have one or more earlier generations on one or more alternate hosts.

Lissonota inconstans has been recovered from *Melissopus latiferreanus* in greater numbers than any of the other parasites discussed in this paper. It has been found almost as abundantly at altitudes of 2,000 feet as near sea level. According to the records, *L. inconstans* seems to prefer as hosts filbert worms in Catalina cherry, acorns, filberts, hazelnuts, and walnuts, in the order given. The proportion of sexes in the field, as noted in 198 cases, was 31 per cent males to 69 per cent females.

Lissonota inconstans is subject to hyperparasitism, especially in southwestern Oregon. The severest recorded loss occurred in a collection of material from Talent, Oregon, made on August 12, 1940, at an elevation of 1,629 feet. This lot, of 548 acorns, was infested by 100 filbert worms, 17 of which were successfully parasitized by *L. inconstans* and 6 by another parasite. From the 17 *Lissonota* cocoons there emerged 11 adults of that species and 6 adults of *Perilampus fulvicornis* Ashm. The immature stage of *Perilampus* was visible within one end of the thin, glabrous, transparent cocoon of its host for some time prior to the emergence of the adult. It occupied about one-third to one-half of the space, whereas the normal *Lissonota* larva (or pupa) completely fills its cocoon.

Glypta rufiscutellaris.—Seven adults of this species of *Glypta*, a valuable parasite of the oriental fruit moth in the eastern part of the United States, have been reared from *Melissopus* larvae infesting hazelnuts collected at Willits, Calif., in the Willamette Valley, Oregon, and in western Washington.

Trichogramma minutum.—This common cosmopolitan species was first reared from eggs of *Melissopus latiferreanus* in 1937 by B. G. Thompson (1938), of the Oregon Agricultural Experiment Station, and was found in filbert worm eggs by the writer in the summer of 1940 in the Eugene area. Its effectiveness on this pest in the upper Willamette Valley has not exceeded 15 per cent in the last 5 years. In Eugene in the summer of 1940 the life cycle of *Trichogramma minutum*, from egg to adult, required 9 to 12 days, only one adult developing in each filbert moth egg.

Elachertus evetriae.—Nine larvae of this gregarious form issued on August 9, 1938, from one larva of *Melissopus latiferreanus* infesting a filbert nut, collected in Eugene on the morning of the same day. All nine larvae pupated on August 13, and all transformed into adults 2 weeks later, again on the same day, on August 27. The wasps paid no attention to any of the several filbert worms exposed to them for attack from time to time in the 4-inch glass vial in which they were kept and fed until the last wasp died.

Although during the ensuing 3 years several thousand filbert worms infesting filberts, acorns, galls, and hazelnuts have been isolated and watched, *E. evetriae* has not been reared again.

Goniozus, n. sp.—This species has been reared from galls of *Cynips maculipennis* formed on the leaves of *Quercus garryana*, collected in several parts of the Willamette Valley in western Oregon. Apparently it has a very short developmental period. One lot of galls, collected in Eugene on August 14, 1940, shortly after formation of the galls and while they had barely time to be infested by the filbert worm, produced three adults of *Goniozus* on August 26 and 28, 1940. C. F. W. Muesebeck has advised the writer that this is a new species of *Goniozus*.²

Perisierola gracilicornis.—A collection

of 141 hazelnuts from near Lindsey, Oregon, on August 29, 1938, produced two adults of *Perisierola gracilicornis* on September 1, only 3 days after collection, and one filbert worm moth, which emerged in 1939.

Perisierola sp.—One adult of this species was obtained on August 26, 1941, from hazelnuts collected in Orchards, Wash., the previous week.

Perisierola, n. sp.—Thirty-five *Cynips* galls were collected at Satus Creek, Yakima County, Wash., on September 5, 1941. According to C. F. W. Muesebeck, the three parasite adults issuing from this lot are apparently an undescribed species of *Perisierola*. It is a gregarious species, as many as five individuals developing in one host larva.

Anachaetopsis tortricis.—The records show that this dipterous species is a solitary primary parasite of *Melissopus latiferreanus* infesting acorns and filbert nuts. It has been reared from acorns collected in Yakima County, Wash., and directly from filbert worms from Lane and Jackson Counties, Oregon, at elevations extending to 2,750 feet above sea level.

This species normally overwinters in the larva and emerges from the pupa of its host. However, a specimen from Yakima emerged on August 17, 4 weeks after the infested acorns were collected, at which time *Melissopus latiferreanus* is normally in the larval stage, indicating that the fly may have more than one generation in a year.

Phorocera erecta.—While cracking some infested filbert nuts from Springfield, Oregon, on August 20, 1938, the writer found a small dipterous puparium in one nut with a broken lepidopterous pupa. Undoubtedly the lepidopterous pupa was that of *Melissopus latiferreanus*, since the several thousand moths obtained from filberts have all been of that species. The small tachinid fly issuing from the puparium was identified as *Phorocera* sp. by D. G. Hall, who made the following comment: "This specimen runs to *Phorocera erecta* Coq. in Aldrich & Webber (1924), and agrees fairly well with the description and the type." Since *P. erecta* has a coast-to-coast distribution, and has definitely been previously recovered from Washington, Idaho, and California (Aldrich & Webber 1924), it seems likely that this fly is properly referable to that species.

¹ *Hyssopus*.

² A description of this species by Robert M. Fouts is in manuscript.

Plectops sp.—One adult of this small tachinid issued from *Andricus* galls on May 5, 1941, and two adults were obtained from *Cynips* galls on April 25 and May 12, 1942. The collections of the host material were made on July 26, 1940, in Dundee and July 30, 1941, in Hillsboro, Oregon, respectively.—7-4-42.

LITERATURE CITED

- Aldrich, J. M., and Webber, R. T. 1924. The North American species of parasitic two-winged flies belonging to the genus *Phorocera* and allied genera. U. S. Natl. Mus. Proc. 63(17): 77.
- Cushman, R. A. 1940. A new species of *Lissonota* (Hymenoptera: Ichneumonidae). Wash. Ent. Soc. Proc. 42(7): 156-8.
- Dohanian, S. M. 1940. *Melissopus latiferreanus* as a pest of filberts in the northwest. Jour. Econ. Ent. 33(6): 852-6.
- Muesebeck, C. F. W. 1940. Two new reared species of *Bassus* (Hymenoptera: Braconidae). Wash. Ent. Soc. Proc. 42(4): 91-3.
- Thompson, B. G. 1938. *Trichogramma evanescens* Westwood, a parasite of *Melissopus latiferreanus* Wlsm. Jour. Econ. Ent. 31(1): 129.

Laboratory Propagation of Two Predators of the Mountain Pine Beetle

G. R. STRUBLE, U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine

The application of direct control methods against the mountain pine beetle, *Dendroctonus monticolae* Hopk., in sugar pine kills many of the associated beneficial insects. Control by peeling and burning, or by sun-curing, destroys a high percentage of the coleopterous predators, particularly of those in the larval stage. Among them are the green trogositid *Temnochila virescens* (F.) and the red-bellied clerid *Enoclerus sphaeus* (F.) two predators which entomologists believe may be important natural agents in the control of this bark beetle.

Within recent years certain steps have been taken to protect these two predators by modifying control practices. The stumps of infested overwinter brood trees are now left intact, and this allows migrated larvae of *Enoclerus sphaeus* to develop to maturity. The curtailment of summer control by the peeling and sun-curing method, because it allows many of the adult bark beetles to emerge, gives larvae of *Temnochila virescens* a better chance to complete development. Even with these improvements in field practice, predators are seldom sufficiently abundant to have much influence in preventing destructive outbreaks of the mountain pine beetle.

The high cost of applying direct control methods against the mountain pine beetle in sugar pine has led forest entomologists

working on this problem to continue unceasingly the search for more effective techniques. In the field of biological control they have given consideration to coleopterous predators, since they are the only insect enemies of any importance which prey upon the bark beetle broods situated beneath the thick bark of the sugar pine. The possibilities of the red-bellied clerid, *Enoclerus sphaeus*, have been discussed by Böving & Champlain (1920), Keen (1928), and Doane *et al.* (1936). Essig (1926), Keen (1928), and Person (1940) have discussed the status of *Temnochila virescens* in the control of the western pine beetle, *Dendroctonus brevicornis* Lec. This predator also has high possibilities as a controlling agent of the mountain pine beetle.

One widely considered phase in the control of the mountain pine beetle has been the possibility of artificially rearing predators for liberation in the field where outbreaks are occurring. Repeated suggestions have resulted in recent studies to determine its feasibility. To rear the predators successfully would require the employment of specialized equipment and technique, allowing for the production of large numbers of healthy adults at low cost.

These factors were recognized in setting up experiments to determine (1) whether healthy adults may be reared in numbers