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Commercial filbert orchards throughout the Willamette Valley were surveyed for natural enemies of the filbert aphid, *Myzocallis coryli* (Goetze). A large number of predaceous insects were found to prey upon *M. coryli*, particularly members of the families Coccinellidae, Miridae, Chrysopidae, Hemerobiidae, and Syrphidae. Also, a parasitic Hymenopteran (*Mesidiopsis* sp.) and a fungal pathogen (*Triplosporium fresenii*) were found to attack this aphid species.

Populations of major predators were monitored closely during 1981 to determine phenology and synchrony with aphid populations and to determine their relative importance. *Adalia bipunctata*, *Deraeocoris brevis*, *Chrysopa* sp. and *Hemerobius* sp. were found to be extremely well synchronized with aphid population development cycles.

Laboratory feeding trials demonstrated that all 4 predaceous insects tested (*Deraeocoris brevis*, *Heterotoma meriopterum*, *Compsidolon salicellum* and *Adalia bipunctata*) had a severe impact upon filbert aphid population growth. *A. bipunctata* was more voracious than the other 3 species, but could not live as long in the absence of aphid prey.

Several insecticides were tested both in the laboratory and field to determine their relative toxicity to filbert aphids and the major natural enemies. Field tests showed Metasystox-R to be the most effective against filbert aphids, while Diazinon, Systox, Zolone, and Thiodan were moderately effective. Sevin was relatively ineffective. All insecticides tested in the field severely disrupted the predator complex. Laboratory tests showed all insecticides to be very toxic to *Adalia bipunctata* and *Deraeocoris brevis*, although Zolone caused a significantly lower mortality.

Samples from a block of trees sprayed twice with Sevin showed higher aphid numbers late in the season than a comparable unsprayed block. This is interpreted as an indication that many aphid problems in commercial orchards are induced by insecticide disruption of natural biological control. Possible solutions to this problem are discussed.

THE BIOLOGY OF THE PREDATOR COMPLEX OF THE FILBERT APHID, MYZOCALLIS CORYLI GOETZE, IN WESTERN OREGON

BY

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Biology of the Predator Complex of the Filbert Aphid, *Myzocallis coryli* (Goetze), in Western Oregon

I. Introduction

Over 95% of the filbert (hazel) nuts produced in the United States are grown in the Willamette Valley of Oregon. In 1980 an estimated 20,000 to 25,000 acres of trees yielded 14,000 tons of nuts, which, after processing, represented a 20 million dollar addition to the state's economy (Baron and Stebbins, 1981). At the present time the filbert acreage is expanding as rapidly as nursery stock is made available, and it is expected that during the next 10 years filberts will become one of the major agricultural commodities in Oregon.

The filbert aphid, *Myzocallis coryli* (Goetze), is considered to be one of the most important insect pests of Oregon filberts. A number of commercial orchards experience explosive aphid outbreaks, with population densities reaching as high as 500 aphids per leaf. These large populations, by removing plant sap with their sucking mouthparts, are reported to reduce tree vigor and the size and percent fill of nuts. Also, the secretion of large quantities of honeydew may cause leaf scorch and staining of the nuts (AliNiazee, 1980).

A direct-mail survey of Oregon filbert producers conducted with the aid of the Oregon State Extension Service indicated that approximately 75% of the filbert acreage in the state is directly treated with chemical insecticides for the purpose of aphid control. A wide variety of chemicals, combinations of chemicals, and varying concentrations were reported in use, and a full 29% of the acreage covered in the survey was treated with unregistered insecticides for aphid control. Aphicides were applied as early as mid-April and as late as August 6. Approximately 20% of the acreage was sprayed two or more times exclusively for aphid control. There is, in general, a vast amount of disagreement among filbert growers as to what causes aphid outbreaks, how detrimental they are, and when and how to control them.

In other tree fruit and nut crops, aphid species have become resistant to certain heavily applied insecticides, with a consequent breakdown in effective chemical control (Glass, 1975). The filbert aphid may be developing resistance to the widely used carbamate insecticide, carbaryl (Sevin®). Jones et al. (1959) reported that Sevin spray or dust at 2.5 pounds of active ingredient per acre offered fairly good control of the filbert aphid, but at the present time this insecticide is generally considered to be ineffective against this species. If a similar problem develops with the commonly used organophosphates, growers may face an increasing problem with failures in chemical control of filbert aphids.

A large number of predatory insects are associated with filbert aphids in the Willamette Valley, and several of these are presumed to be important in natural biological control. However, most commercial growers regularly apply broad-spectrum insecticides on a calendar basis for pest control, thus upsetting the predator complex. Most of the generalist predators found in filbert orchards have been shown to be very susceptible to these insecticides (Croft and Brown, 1975). Application of non-selective insecticides in other crop systems has been shown to result in the resurgence of the target pest, due to interference with natural biological control (Stern, et al., 1959; Glass, 1975).

The purpose of this research was to help evaluate the potential for natural biological control of the filbert aphid in the Willamette Valley of Oregon. The objectives of the study were:

I. To survey for predatory insects associated with commercial filbert culture in the Willamette Valley; to catalog the predators (and other natural enemies) that may be of importance in biological control.

II. To study the seasonal life cycle of the filbert aphid and its predators; to document the abundance, distribution, and phenology of important predatory species.

III. To assess the potential of the predatory insects to control aphid populations under field conditions.

IV. To study the disruptive effects of some commonly used pesticides on biological control in filbert orchards, with particular reference to the filbert aphid.

II. LITERATURE REVIEW

The Filbert Aphid

Haidari (1959) did a thesis research project on the biology of the filbert aphid, *Myzocallis coryli*, and much of the following information is derived from his work.

M. coryli was first described from Europe in 1778; it was reported in the U.S. for the first time from Berkeley, California in 1903, and has since been recorded in several western states. It feeds on both wild and cultivated hazel species, and has been found as well on the following hosts: alder (*Alnus glutinosa* Gaerth.), birch (*Betula* sp.), hornbeam (*Carpinus betulus* L.), and oak (*Quercus* sp).

In Oregon, the filbert aphid is present on cultivated filberts, *Corylus avellana* L., throughout the entire year. It overwinters in the egg stage, eggs being deposited singly in crevices, leaf scars, around the buds, and under the scales of bark. Eggs are more common on two to three year old and older wood; the one year old twigs being smooth and devoid of bark scales are not favorable for oviposition. Oviposition occurs in October-December, and eggs are present in the field until the first part of April. They are pale yellow when first laid, but later turn shiny black.

Hatching occurs during March-early April, giving rise to the stem mother nymph, or fundatrix. These nymphs feed on the buds and young leaves, molt four times during a period of two to three weeks, and almost immediately upon reaching the adult stage give birth to young parthenogenetically. Adult stem mothers are winged, as are all adult aphids except for the generation of oviparous females in the fall.

The offspring of the stem mother are called the viviparae. This is the common summer form which occurs from late April until October in the field. They have a very high reproductive potential, giving birth parthenogenetically to live young immediately after the last molt, producing six to eight young aphids per day at first and gradually tapering off to one or two per day for the life of the female. There are about ten generations per year, including the fundatrix. Summer forms are reported to be very adundant in May and June, with numbers declining during July at the time when high temperatures first occur.

The summer forms give birth to sexual forms in October, including winged males and wingless egg-laying females, in a ratio of 1:5, respectively. Mating occurs in mid-October on the underside of the leaves, and eggs are deposited from late October until the end of November. The adults fall along with the falling leaves in December. Life-history information is summarized in the following figure (Figure 1) taken from Haidari (1959).

The damage caused by the filbert aphid is not clearly understood. Most growers feel that dense aphid populations feeding on the unfolding buds and young leaves in the early spring may impose a severe nutrient drain upon the trees. A closely related aphid infesting walnut trees in California has been proven to reduce nut size, yield, and staminate flower production (Barnes and Moffit, 1978). Some researchers feel that the filbert aphid, by producing up to 20 gallons per tree of honeydew,

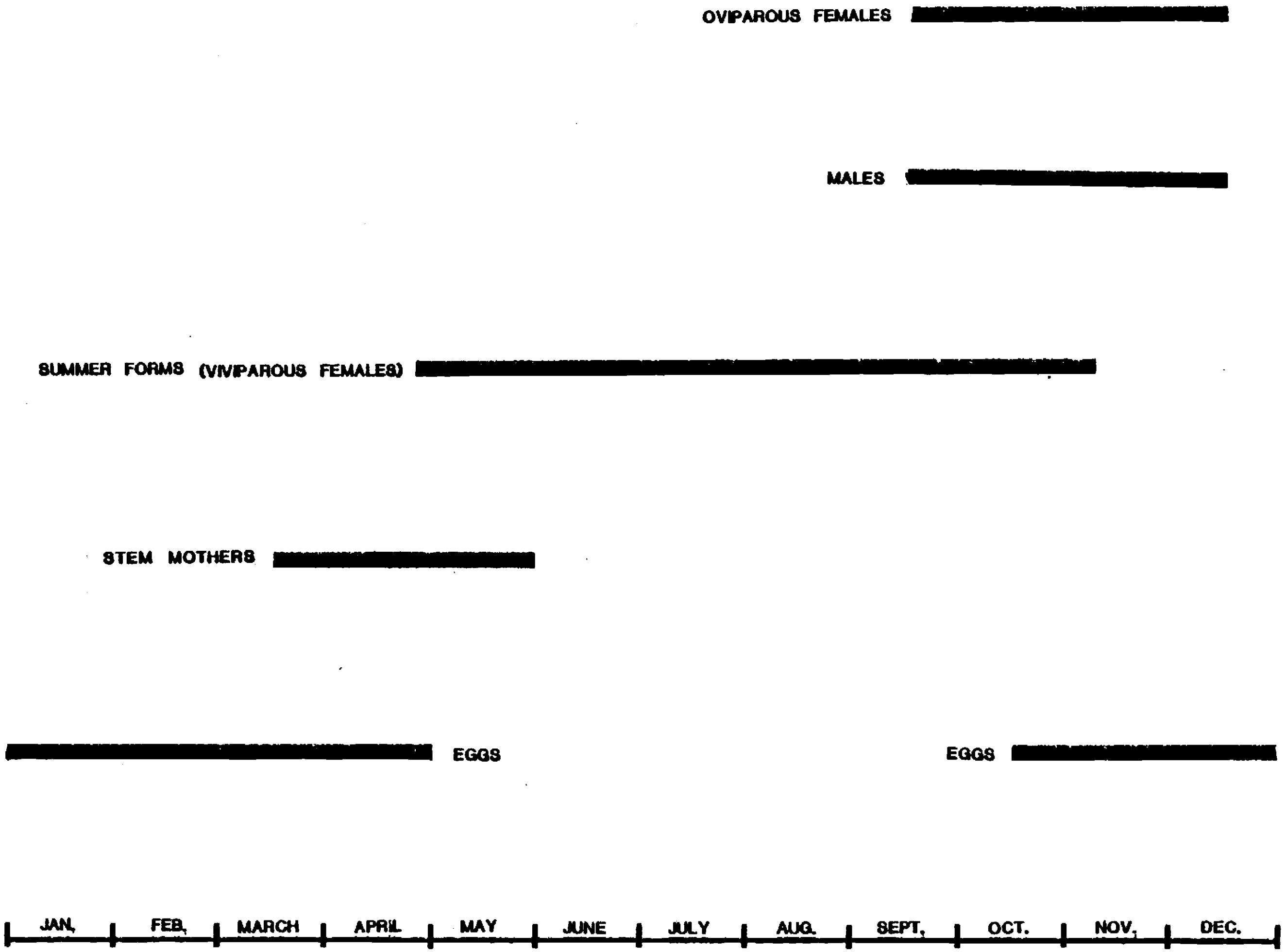


Figure 1. Season occurrence of the various life forms of *Myzocallis coryli* in the Willamette Valley (modified from Haidari, 1959).

may cause tremendous moisture loss from this shallow-rooted, non-irrigated crop - thus causing reduced leaf size, premature aging and leaf drop, and reduced shoot growth (Lagerstedt, personal communication). McWhorter et al. (1934) reported that this aphid causes serious damage to filbert leaves, and Lovett (1923) states that the aphid disseminates filbert blight disease. AliNiazee (1980) states that "feeding damage reduces tree vigor and quality of the nuts produced. Aphids also secrete large quantities of honeydew which may cause severe leaf burn, scorch, or staining of the nuts." Many growers also state that the aphid honeydew causes many sticky leaves to fall and dirty their equipment, and honeydew is generally considered to be a nuisance in the orchards. Jones, et al. (1959) reported several attempts to determine the effect of filbert aphids upon the quantity and quality of nuts produced, but the results were inconclusive. However, it is standard practice for commercial filbert growers to apply an organophosphate insecticide in the spring for filbert aphid control (Fisher and MacSwan, 1981).

M. coryli is well distributed in a number of European countries; however, its severity as a pest is unknown. In England it is commonly found on the underside of the leaves of hazel nut (Buckton, 1880). Theobald (1926) states that the filbert aphid is "very abundant in some years, especially in the Kent (England) nut plantations. It swarms over the leaf stalks and shoots, and now and then does some harm, but it is seldom that spraying has to be resorted to. Some years it is quite scarce."

AliNiazee (1980) pointed out that filbert aphids may be controlled biologically by a number of predaceous and parasitic insects, and specifically mentioned members of the families Coccinellidae, Syrphidae, Chrysopidae, and Miridae. There is an enormous wealth of literature on all aspects of the biology of these and other aphidophagous predators, and it is beyond the scope of this paper to adequately review all of the significant findings. Readers are referred to the excellent review by Hagen and van den Bosch (1968), and the proceedings of a symposium on the ecology of aphidophagous insects edited by Hodek (1966). What follows is a brief review of the basic bionomics of the predatory insects most commonly found in Willamette Valley filbert orchards.

Anthocoris antevolans White

Much of the following information is taken from Anderson (1958).

Anthocoris antevolans (Hemiptera:Anthocoridae) is widespread in western North America, having been recorded in a number of states and Canadian provinces. It is a small (3-5 mm) Hemipteran; the adult typically black with white markings, while the nymphs show a characteristic reddish-mahogany color. It occurs on a wide range of deciduous trees and shrubs, most commonly willow (*Salix* spp.) and various orchard trees, but also on birch (*Betula* spp.), oak (*Quercus* spp.), and hazel (*Corylus* spp.). It usually occurs in association with aphids and mites.

A. antevolans overwinters as mated adult females beneath bark scales or in cracks and crevices on trees. In pear orchards, accumulations of dry orchard trash on the ground are also used as overwintering sites, and adults exhibit aggregational behavior during hibernation (McMullen and Jong, 1967a). At Corvallis, Anderson (1958) found a female: male overwintering ratio of 8:1, with all females apparently mated and with large fat reserves.

Adults emerge from hibernation in late March in the Corvallis area, and dispersal begins when daily maximum temperatures exceed 50°F. (McMullen and Jong, 1967a). Adults are often found aggregating on willow catkins, from which they may derive some nutrition. The first eggs of the season appear several weeks later. Eggs are inserted into tender leaf tissue, and are usually deposited near a food source - often in an aphid or mite colony. The life cycle from egg to adult is approximately four weeks, which, with a pre-oviposition period of two weeks allows a complete generation every six weeks in the field. Evidence points towards three or possibly four complete generations each year. Summer generation adults are long-lived, the life span being approximately 50-100 days in the field. A closely related species, _A. nemorum_, is reported to lay up to 200 eggs during the life of a female (Collyer, 1953). Anderson (1962b) suggests that the number of eggs deposited is proportional to the quality and quantity of prey available.

A. antevolans attacks various species of aphids, psyllids, and mites. First instar nymphs can ingest two to three aphids per day; larger nymphs may eat at least ten aphids per day. The pattern of food consumption of _A. antevolans_ appears similar to that of _A. nemorum_, which is reported to consume 500 to 600 aphids in a life-time (Collyer, 1953). _A. nemorum_ has been recorded feeding on 35 species of insects and mites representing 10 different orders, but different prey items led to different growth and mortality rates for this and other *Anthocoris* species (Anderson, 1962b). *A. antevolans* has been observed in the Willamette Valley on both wild and cultivated hazel (*Corylus californica* and *Corylus avellana*, respectively), and has been reared in the lab from first instar to adult on a diet of filbert aphids, *Myzocallis coryli* (Anderson, personal communication).

A. antevolans seems to be of major importance in the biological control of pear psylla, *Psylla pyricola* Foerster, in commercial pear orchards in the Pacific Northwest (McMullen and Jong, 1967a; Madsen et al., 1963; Madsen and Wong, 1964; Nickel et al. 1965). However, the predator appears effective only in unsprayed orchards, as insecticide applications for codling moth cause severe predator mortality. In field experiments measuring the effects of insecticide application, *A. antevolans* was found to be highly tolerant to DDT, but highly susceptible to azinphosmethyl (Guthion) and Ryania (McMullen and Jong, 1967b).

Collyer (1953) reported that in sprayed orchards of England anthocorids were among the first predators to recolonize the treated areas, indicating their versatility as they have a wide range of host plants and prey species.

Orius tristicolor White

This is a minute anthrocorid common throughout the Pacific Northwest. It overwinters as an adult in protected places, emerges in late April or early May, and, probably has three generations each year. O. tristicolor occurs on a wide range of plants, particularly common on the flower heads of alfalfa, dandelion, and umbellifera. It is reported to feed on a wide variety of insects, mites, and eggs, in addition to being partially phytophagous (Anderson 1962a).

Coccinellidae

The family Coccinellidae is probably the most extensively studied of the aphidophagous predators, and a vast literature exists on this group of insects. Some excellent reviews include works by Hagen (1962), and Hodek (1967, 1973).

The two-spotted lady beetle, Adalia bipunctata (L.) has been widely studied throughout its Holartic distribution. It has been recorded in association with a wide variety of aphid species and a wide range of host plants, including potatoes, beets, beans, nettles and a great number of deciduous trees and bushes (Hodek, 1967). It is considered more arboreal in habit than most other coccinellid species. Several authors have noted an early season preference for fruit trees, followed by a dispersal to ornamental shrubs and herbaceous plants (Lusis, 1961; Savoiskaya, p. 139 in Hodek, 1966).

A. bipunctata overwinters in the adult stage, but overwintering aggregations typical of many coccinellids in the tribes Coccinellini and Hippodamini have been noticed infrequently (Hagen 1962). In central Europe, some A. bipunctata hibernate singly or in small groups under tree bark, litter, or in the upper layers of the soil; while another part of the population hibernates in buildings or on the tops of hills

(Hodek, 1967). Overwintering mortality seems to be an important factor in population regulation of this species. Lipa, et al. (1975) reported 20 percent overwintering mortality caused mainly by *Nosema coccinellae* (a protozoan), *Beauveria bassiana* (a fungus), and *Perilitus coccinellae* (a braconid parasite).

A. bipunctata could be classified as univoltine, bivoltine, or multivoltine (type 1,2,3 as per Hagen 1962) depending upon the location.

A large number of aphid species have been reported as prey for *A. bipunctata*, but not all species are equally suitable, and several have been shown to be toxic (Hodek, 1966). Blackman (p. 41 in Hodek, 1966) found that *Myzus persicae*, *Aulacorthum circumflexum*, *Acyrthosiphon pisum* and *Microlophium evansi* were all suitable for *A. bipunctata* development. *Aphis fabae* and *Aphis sambuci* were less satisfactory, resulting in slower development and production of smaller adults; while *Megoura viciae* was found to be fatally toxic. Within certain limits, consumption of food is positively correlated with the population density of the prey. Food consumption also increases with increasing temperature, but is, however, most strongly stimulated by an alternation of temperatures. Food searching behaviour is essentially random, with detection of prey occuring only after direct physical contact. A "tight-search" pattern usually follows initial prey contact. Cannibalism, especially of eggs by first instar larvae, has been observed in the majority of coccinellids studied, and may be an important factor in longevity of early instars when prey populations are at a low density.

The voracity of *A. bipunctata* varies with the prey species being fed upon. Consumption is greatest in ovipositing females, followed by non-ovipositing females and males. Clausen (1916) showed *A. bipunctata* larvae to eat an average of 16.7 aphids per day for a period of 15 days, using the rose aphid, *Macrosiphum rosae*. Iperti (p.61 in Hodek, 1966) reported that *A. bipunctata* larvae consumed an average of 17 small *M. perscia* nymphs per day in the first two instars, and 25 medium sized aphids per day during the last two instars.

Cycloneda polita Csy., the second most common coccinellid found in Oregon filbert orchards, has been little studied in this or other agricultural systems. Rockwood (1952) reported the species to be common in vetch and alfalfa fields in Oregon. He determined larvae to eat an average of 148 aphids each during a developmental period of 18 days in the lab using the aphid, *Macrosiphum pisi*. Adults consumed an average of 344 aphids each over a period of 31 days. Westigard (1968) recorded *C. polita* in pear orchards in southern Oregon.

Perhaps other aspects of *C. polita's* biology may be inferred by comparing it with a congeneric species, *C. sanguinea*, and a series of other predaceous coccinllids common in California. Information in the following table (Table 1) is taken from Clausen (1916). The other coccinellid species in this table are all predators of the filbert aphid in Willamette Valley filbert orchards.

Chrysopidae

Chrysopa carnea Steph. is a Holarctic insect that has attracted attention both for its interesting biology and its economic

Table 1. Development, Oviposition and Feeding Records From Some* California Coccinellidae (from Clausen, 1916).

	Number of days from egg to adult	Length of Oviposition period in days	Average number of eggs deposited per day	Total number of eggs deposited	Number of Aphids consumed by larvae per day †
Adalia bipunctata	26.7	28.2	6.7	190	14.1
Coccinella trifasciata	31.8	29.2	8.4	249	15.8
Coccinella californica	29.1	31.0	8.0	207	24.9
Hippodamia convergens	28.8	33.3	8.9	299	20.7
Cycloneda sanguinea	25.3	28.8	7.0	201	14.5

* Numbers represent means for approximately 10 - 15 individuals.

† The species used as prey was the rose aphid, *Macrosiphum rosae*.

value as an aphid predator. Balduf (1939) classifies it with those chrysopids of "intermediate habitats," that is, intermediate between arboreal species and those that inhabit low vegetation. Although some workers think that it prefers open fields (Dr. P. Adams, personal communication), it has also been recorded as a predator of possible importance in orchard situations (Westigard et al. 1968; McMullen and Jong, 1967).

C. carnea is one of the few chrysopids that overwinters in the adult stage, typically in wood piles, houses, under loose bark, and other protected places. Balduf (1939) reports it to undergo a conspicuous change in appearance, the normal green color of summer giving way to brownish wings and a reddish body as feeding discontinues during autumn. Toschi (1965) found an overwintering sex ratio of 1:1.

Oviposition in the spring usually occurs on the underside of leaves, eggs being laid singly and attached to the end of a characteristic stalk, or pedicel. In *C. carnea* usually only one egg is attached per leaf, in contrast to other chrysopid species which may oviposit closely spaced groups of eggs. Cannibalism of eggs by newly hatched larvae is apparently very common in this species, as the first instar larvae must feed within 24 hours after hatching or death will occur (Toschi, 1965). In the lab at 24°C., he found the developmental time from egg to adult to be 38 days. Killington (1937) reports two generations per year in Britain, whereas Toschi (1965) found 3-5 generations per year in Berkeley, California. Sundby (1966) reported an oviposition period of 35 days and an average fecundity of 477 eggs per *C. carnea* female maintained at 21°C.

The larvae of C. carnea have been noted to feed on a wide variety of small, soft bodied arthropods. Their principal food is aphids, but they also consume coccids, thrips, mites, and eggs and small larvae of Lepidoptera (Balduf 1939). Sundby (1966) reported an average lifetime consumption of 393 green peach aphids, Myzus persicae, per C. carnea larva.

C. carnea adults differ from those of most other chrysopids in that they feed primarily on honeydew and perhaps pollen, and are not considered aphidophagous. Fecundity of the adult depends upon the quantity and quality of honeydew that it ingests, and thus high aphid densities may be required before adults are attracted and induced to oviposit (Hagen and van den Bosch, 1968). Hagen (1950) has shown that ingestion of a specially prepared synthetic honeydew can increase egg production in C. carnea.

Although this species is abundant in a number of crops and has been recorded as a predator of many pest species, its efficacy in biocontrol is hindered both by its concentrated honeydew requirements and its susceptibility in the larval stage to a large number of parasites (Clancy, 1946). Also, larvae and adults have been shown to be susceptible to a wide range of pesticides (Bartlett, 1969).

The other chrysopid found in Oregon filbert orchards is an uncommon species, Chrysopa placita Banks, whose life history has never been published. However, it is a near relative of C. bimaculata and C. lineaticornis, some aspects of whose biology are known. The larvae of these species are known as "trash-carriers", from their habit of covering the dorsum with bits of lichen, cast skins, and other debris. These larvae are thus readily distinguished from those of *C. carnea* in the field, as the latter species in not a "trash-carrier". *C. lineaticornis* is classified as an arboreal species by Balduf (1939).

C. lineaticornis, *C. bimaculata*, and most of the other *Chrysopa* species studied by Smith (1922) differed from *C. carnea* in that overwintering occurred in the pre-pupal rather than the adult stage, and also in that adults were aphidophagous, consuming the same prey as larvae in most cases.

Hemerobiidae

The hemerobiids have long been regarded as important biological control agents for soft-bodied agrticultural pests (Balduf, 1939), but their biologies are not well known. Four species have been found in Willamette Valley filbert orchards, all belonging to the genus *Hemerobius*.

Hemerobius humulinus Linn. overwinters in the pupal stage, as do most members of this genus. In Europe, adults are present in the field from March to October, with several generations per year (Killington, 1937). The average developmental time from hatching to adult has been reported in Europe as 35 days (Killington, 1937), and in the U.S. as 25 days (Smith, 1923). Oviposition takes place both on upper and lower leaf surfaces, eggs being deposited singly and without the pedicel characteristic of Chrysopide. Smith (1923) reports a single female to have deposited 460 eggs.

Like the chrysopids, hemerobiid larvae are carnivorous upon a variety of soft-bodied arthropods including aphids, leaf hoppers, and mites (Balduf, 1939). *H. stigma* Stephens, although collected in filbert orchards, is reported to be associated "exclusively" with conifers (Killington, 1937) and may be an incidental or migrant in the filbert system. The same author reports that *H. humulinus* is found on a variety of deciduous trees and shrubs, and "seems to show a marked preference for hazel."

Hemerobius pacificus Banks was studied in Oregon by Moznette (1913), and reported to prey on "almost all aphids," being particularly effective upon the rosey apple aphid (*Aphis sorbi* Katt.) and the current aphid (*Myzus ribis* Linn.). In feeding tests using *Aphis sorbi*, *Myzus persicae*, and *Phorodon humuli* as prey, he found *H. pacificus* larvae to consume an average of 25 aphids per larva per day, over an eight day period. Hemerobiid adults in general are predaceous, preying upon the same kinds of insects as the larvae.

Neuenschwander (1976) showed that *H. pacificus* has very low temperature thresholds for reproduction and development, and pointed out the importance of this in terms of continued activity in cool weather, particularly during early spring when many aphids are phenologically ahead of their predators. The number of lacewing eggs laid is closely correlated to fluctuations in aphid numbers, and this synchrony is known to be of critical importance in determining the effectiveness of aphid predators (van Emden, p. 227 in Hodek, 1966). Neuenschwander (1976) suggested that this cool weather activity may be characteristic of other species in the genus *Hemerobius*.

Miridae

Campyloneura virgula (H.-S.)

C. virgula is a predaceous mirid native to Europe, North Africa, Asia Minor, and Turkestan. It has been recorded on a variety of trees and shrubs, including *Alnus*, *Corylus*, *Crataegus*, *Fagus*, *Fraxinus*, *Quercus*, and *Tilia*. In British Columbia, specimens were collected from alder, *Alnus* sp.; poplar, *Populus*, and nettles, *Urtica* sp. (Lattin and Stonedahl 1981).

This species is reported to overwinter as an adult on the continent of Europe, but Southwood and Leston (1959) found it to overwinter as an egg on the British Isles, with adults occurring from July until October. Males are very rare, and it is assumed that reproduction is primarily via parthenogenesis.

C. virgula has been reported to feed upon spider mites, *Psocoptera*, greenflies, and occasionally upon honeydew. In the Pacific Northwest, it has been found associated with aphid species on a variety of trees and shrubs. Collyer (1953) reported all instars of *C. virgula* to be voracious feeders; in apple orchards the prey included lepidopterous larvae and the wooly apple aphid. In pear orchards, it fed upon a number of insects and mites, as well as being partly phytophagous.

Compsidolon salicellum (H.-S.)

This is a small, pale colored mirid whose natural range extends throughout western and central Europe. It reportedly occurs on several hosts, including *Salix* and *Corylus*, is apparently univoltine, and overwinters in the egg stage (Wagner and Weber, 1964). This genus has not previously been recorded in the United States.

Deraeocoris brevis (Uhler)

The adults of this species are dark brown to black, approximately five millimeters in length, punctate, and with characteristic dark bands across the wings. Nymphs are purple to reddish-brown, and often have a white, waxy appearance in the field.

D. brevis is widely distributed throughout western North America, from New Mexico and San Diego in the south to Mt. Yukon, Alaska in the north. It is found in many ecosystems, but it is most common in sagebrush vegetation (Artemesia sp.). It is recorded from a wide range of host plants, including Amelanchier alnifolia Nutt, Arbustus menzesii Pursh., Ceanothus velutinus Dougl., P. ponderosa Dougl., Abies sp., Castanopsis sp., Rubus sp., Ribes sp., Chamaebatiaria sp., Chrysothamnus sp., Anaphalis sp., and a variety of orchard trees (Razafimahatrata, 1981.) The host list includes at least 25 plant species, most of which are tall shrubs or trees, thus indicating a primarily arboreal mode of life (Westigard, 1973).

This is one of the few mirids that overwinters in the adult stage, primarily in heavy, dry trash (in orchard situations) and in cracks and crevices in the bark of trees. McMullen and Jong (1967a) found an overwintering sex ratio of 1:1 in British Columbia pear orchards; whereas Westigard (1973), upon examining 300 overwintering adults in southern Oregon, established a female to male ratio of 2:1. Westigard also found that many adult brevis overwintered near pear orchards in pine trees heavily infested with black pine scale (Nuculapsis californica Coleman) or in oak trees adjacent to infested pines. He found no adults in ground litter or duff within the groves of pines.

Adults become active in early April, and feed on a variety of soft bodied insects. In southern Oregon the early season prey included black pine scale as well as scales infesting madrone and manzanita, and also pear psylla, Psylla pyricola Foerster, and the apple grain aphid Rhopalosiphum Fitchii Sanderson. Mating and oviposition occur in April, eggs being deposited singly or in groups in the petioles of pear leaves. Oviposition by overwintering females extends over several weeks, so there is an overlap of generations in the field. Westigard (1973) measured generation time in the lab for D. brevis fed on pear psylla to be 25 days at 25°C. McMullen and Jong (1967) report at least four generations a year in British Columbia, with greatest abundance occuring in mid-summer through early fall.

D. brevis has been reported to feed on mites, aphids, psyllids, psocids, coccids, leafhopper nymphs, and small lepidopterous larvae (Razafimahatratra, 1981). Westigard (1973) found overwintered adults to eat approximately 40 eggs and nymphs of pear psylla per day in early spring; later generations of late instars and adults consumed from 14-30 pear psylla eggs and nymphs each day. The food intake approximately doubled for each of the first four instars, leveled off during the fifth instar, and decreased somewhat during the adult stage. A single D. brevis consumed, on the average, 400 eggs and nymphs of pear psylla during its development. Feeding commences early in the spring and continues until cold weather in October or November forces adults into hibernation. Feeding was occasionally observed on leaves and immature fruit, but no damage to the plant was apparent. Nymphs fed on psylla honeydew or on pears did not continue development.

In some situations, this mirid may play a key role in natural control of pear psylla (Westigard et al., 1968; Westigard, 1973; McMullen and Jong, 1967). However, the abundance of prey on native vegetation may delay its spring build-up in orchards, thus reducing its utility for biocontrol (Westigard, 1973).

McMullen and Jong (1967b) reported DDT to severely reduce populations of _D. brevis_, but tolerance was shown to azinphosmethyl (Guthion) and Ryania. Westigard (1973) found that direct application of organophosphates were highly toxic to _D. brevis_ nymphs, but showed some selectivity when applied to adults. Of the non-phosphates, endosulfan (Thiodan) caused only 20% adult and 31% nymphal mortality. Residue tests showed that some chemicals which were highly toxic when applied directly to nymphs caused less than 15% mortality to those placed on foliage treated seven days earlier, leading Westigard (1973) to suggest that "it may be feasible to use precise timings of some OP compounds as a method to encourage _D. brevis_ survival in commercial orchards."

Deraeocoris fasciolus Knight

This species appears similar to _D. brevis_, except that it is considerably larger, averaging about 7 mm in length and somewhat lighter in color. Nymphs also appear similar to _D. brevis_ nymphs, but can be distinguished by examining the setae on the dorsal surface. On *D. fasciolus*, the dorsum is covered with "simple long black setae and finer pale hairs"; while on *D. brevis*, the dorsum has "black spinose and clubbed setae with distinct notch at their apices." (Razafimahatratra, 1981).

D. fasciolus is widely distributed in North America from Oregon to New York, generally north of 40° latitude. It has been recorded on hazel (*Corylus* sp.), alder (*Alnus* sp), apple, and pear trees in Oregon (Razafimahatratra, 1981), and on *Cretaegus*, apple, and occasionally other plants in New York (Leonard, 1928).

This mirid overwinters in the egg stage; in pear trees the eggs are inserted deep in the bark of rough twigs and fruit spurs (McMullen and Jong, 1967a). In British Columbia, newly hatched nymphs appear in mid-May and adults are present from June to September. There are two generations per year in British Columbia, with greatest populations from mid-summer through early fall. Razafimahatratra (1981) reports one generation per year on hazel in Oregon.

D. fasciolus is reported to feed on phytophagous mites, codling moth, *Laspeyresia pomonella* eggs and larvae, eye-spotted bud moth, *Spilonota ocellana* (D. and S.) eggs and larvae, and various aphids (McPhee and Sanford, 1956). Also, it feeds upon pear psylla, (McMullen and Jong, 1967a); the rosey apple aphid, *Anuraphis roseus*, (Blatchley, 1926); and the filbert aphid (Razafimahatratra, 1981). In the lab, it was recorded feeding upon a wide range of small insects as well as upon leaves and plant materials (McMullen and Jong, 1967a). In Turkey, a species of the same genus, Deraeocoris ruber, was reported to feed on filbert aphids, adults consuming an average of 17 aphids per day (Viggiani, 1971).

D. fasciolus has been noted as a predator of possible importance in both apple (McPhee and Sanford, 1956) and pear (McMullen and Jong, 1967a) orchard ecosystems. When tested for susceptibility to several insecticides in the field, D. fasciolus responded the same as D. brevis: very susceptible to D.D.T., tolerant to azinphosimethyl, and unaffected by Ryania (McMullen and Jong, 1967b.) Other tests (MacPhee and Sanford, 1961) confirm these results, as well as showing susceptiblility to diazinon, malthion, parathion, and carbaryl.

Heterotoma meriopterum (Scopoli)

This distinctive mirid is easily recognized by the greatly enlarged second antennal segment. Early instars are red with pale greenish-yellow legs; later instars are darker and adults are dark brown to black. Males are reported to be darker than females (Kullenberg, 1944). This insect is active and quite agile, seemingly unhindered by the greatly enlarged antennae.

This species is widespread over the whole of Europe, Britain, Algeria and Tunisia (Butler, 1923). It was quite common in the Willamette Valley filbert orchards surveyed in the present study, but I find no mention of it in the predaceous insect surveys of other fruit and nut orchards in the Pacific Northwest.

Records from Europe show that H. meriopterum occurs on a variety of bushes and herbaceous plants, as well as being common in cultivated fruit tree orchards. In Germany it is most often found on *Prunus spinosa*, but also on willow (*Salix* spp.), alder (*Alnus* spp.), apple (*Pyrus malus*), and several species of *Rubus* (Kullengerg, 1944). In southern England it is abundant on nettles (*Urtica* spp.) as well as other shrubs and trees (Southwood and Leston, 1959).

In southern England, *H. meriopterum* overwinters in the egg stage, the young red larvae hatch out in late May or early June, and adults are present from mid-July to early October. Oviposition is presumed to take place upon *Prunus spinosa*, as well as *Urtica* sp., *Pyrus* sp., and *Ribes* sp. (Kullenberg, 1944).

The species is considered to feed equally well on both plant and animal material, the primary plant foods being *Prunus spinosa*, *Urtica dipica*, and *Rubus* spp. However, there is no record of this insect causing damage to cultivated plants. Larvae and adults also feed on aphids and other small insects (Southwood and Leston, 1959, Kullenberg, 1944) and are reported to be destructive to the eggs and larvae of certain lepidoptera (Butler, 1923).

Paraproba nigrinervis V. D.

This species was described by Van Duzce (1917) from specimens collected on grape vines in California. I have not been able to locate a single other reference to its biology, distribution, or habits in the literature.

Syrphidae

These aphidophagous Diptera are regarded as major natural enemies of pest aphids in many agricultural systems. The larvae are voracious feeders and often occur in great numbers in aphid colonies. Adults, however, feed upon pollen, nectar, and honeydew, and require pollen of sufficient quantity and quality as a prerequisite to normal ovarial development (Schneider, 1969).

Most syrphids overwinter as pupae. Some species are univoltine, while others are multi-voltine; and depending upon temperature there may be up to five or six generations per year. Barlow (1961) determined the reproductive capacity of *Syrphus corollae* adults maintained in the laboratory at 23°C. and fed hazel (*Corylus* sp.) pollen with honey: females produced a mean of 400 eggs during an 18 day oviposition period. Hazel pollen appeared to be among the most nutritious for certain syrphid adults (Hagen and van den Bosch, 1968). (However, in the Pacific Northwest, pollen from cultivated hazel is produced mainly during winter, when syrphids are in diapause).

Adult females normally oviposit in or very near aphid colonies in the field, and there may be a chemical stimulus from aphids or their excretions which elicits oviposition. Although syrphid adults are excellent fliers and may migrate for miles, they prefer to oviposit in areas where flowers are abundant enough to meet their nutritional requirements (Schneider, 1969).

The syrphid larvae are nonspecific predators and appear to feed upon a wide range of aphid species, although this is influenced by habitat and vertical distribution of the aphid colonies (Hagen and van den Bosch, 1968). The larvae are extremely voracious: in some tests, *Syrphus corollae* has consumed more than 800 aphids during a 10 day larval development period (Sundby, 1966).

The syrphids have been regarded as important predators in several agro-ecosystems, including deciduous fruit-tree orchards (Tamaki et. al., 1976). However, the family is highly susceptible to parasitization by a number of Hymenopterous species, particularly those of the ichneumonid subfamily Diplazoninae. They are also susceptible to a number of commonly used insecticides, including malathion, parathion, endrin, lindane, endosulphan, carbaryl, diazinon, and metasystox-R (Schneider, 1969), thus reducing their general effectiveness as aphid predators.

III. MATERIALS AND METHODS

A. General Predator Survey:

A total of nine orchards, three each from the northern, central, and southern portions of the Willamette Valley were surveyed during the 1981 growing season in order to collect, identify, and catalog the predaceous insects associated with commercial filbert production. The orchards in the central part of the Valley (Benton county) were sampled weekly as part of a more intensive phenological study. The northern and southern orchards (Washington and Lane counties, respectively) were sampled once early in the season (April-May), once during mid-season (June), and once very late in the season (November).

Ten trees were chosen at random in each orchard. The presence and relative abundance of predators in the filbert trees were determined by the limb-jarring method described by Lord (1949) and used by many other orchard researchers (McMullen and Jong, 1967; Nickel et al., 1965; Westigard, 1973). This consists of holding a square canvas sheet measuring 30 x 30 inches under the canopy; limbs are jarred with a rubber-covered mallet, and the insects dropping to the sheet are counted and collected. I counted three limbs approximately 120° apart around the circumference of the tree as one tree- sample. Limbs of approximately equal diameter (1-2 inches) and foliage density were chosen, and three sharp taps delivered to each before counting the insects on the canvas sheet. Aphids were sampled by collecting ten leaves (or twenty leaves for the intensive survey) chosen at random from around the circumferance of each of the ten trees, and placing them in plastic bags to be returned to the lab where various instars were more easily counted with better lighting. For the first few weeks of the season, newly opening buds containing an average of four leaves each were counted rather than individual leaves. The distribution and abundance of both aphids and predators were recorded throughout the growing season.

B. Phenological Survey

The three orchards which represent the central portion of the Willamette Valley were sampled approximately once a week during the entire growing season (April to November, 1981), in order to determine phenology and population trends of aphids and predators. A fourth orchard was sampled as well, weekly or biweekly, to assess the predaceous fauna following an early season application of a systemic insecticide, Metasystox-R. In each of these four orchards, a 10 by 10 block of trees was chosen as the study site, and each tree in the block was given a code number. On each sampling occasion, a random number table was used to insure complete lack of bias in choosing the ten trees to be sampled.

Three limbs per tree were jarred for predator counts, and twenty leaves per tree were collected for aphid counts, except for the Twedt orchard. Trees in the Twedt orchard were utilized for a field insecticide spray trial, and population data from the control or unsprayed trees were included in the phenological survey work. In this case, four limbs per tree were jarred for predator counts and ten leaves per tree were collected for aphid counts.

Because the aphid and predator population data for these four orchards will be discussed in some detail, it is relevant at this point to give a brief description of the location, condition, and management of each orchard.

Castillo Orchard:

The Castillo orchard is located on the corner of Bellfountain and Llewellyn roads approximately five miles southwest of Corvallis. It consists of six acres of 30 to 40 year old Barcelona and Daviana trees, maintained as a "u- pick" operation and receiving minimal management for a number of years. No herbicides, fungicides, or insecticides have been applied for at least the last eight years.

The groundcover of volunteer grass was mowed but once in 1980 and not at all in 1981. Urea was applied in 1981 but not in 1980, and no pruning or sucker control has been done for several years. The trees have an apparently healthy canopy of full foliage, and set a fairly good crop of nuts, but there are many broken and rotting limbs, and quite a few blank spaces in the orchard where trees have blown down or been removed. Most of the standing trunks and limbs are covered with mosses and lichens.

A large field to the west of the orchard is planted in wheat; other areas around the orchard are maintained as sheep pasture or rural-residential lots with gardens, fir trees, and ornamentals.

Buchanan Orchard:

The Buchanan orchard is located on Greenberry Road a mile west of Bellfountain Road, just a few miles from the Castillo orchard. There are 30 acres of filberts divided into two blocks; I worked in the upper block consisting of 10 acres of seven year old Barcelona and Daviana trees.

This is a young orchard not yet commercially productive, and has not been receiving the full pesticide load common in commercial orchards. It received no insecticide application in 1981, and probably none in 1980, although the owner's records are unclear. A cover spray of Malathion had been applied in 1979 and possibly 1980 for grasshopper control. Diazinon was applied in the spring of 1978. Kocide has been applied each year for control of bacterial blight disease.

In 1981 Round-up and Krenite were used for weed control; in 1980 Round-up and Simazine. Root suckers were controlled chemically as well.

Urea was applied at standard rates each year; however, no boron was applied.

Ground-cover in the orchard consisted of volunteer grasses and broadleaf weeds, flailed twice a year and disced and leveled before harvest. Fields on the north and east sides of the orchard were planted in ryegrass; those on the south and west were left as sheep pasture and contained a number of large oak trees.

Simonson Orchard:

The Simonson orchard is located on Bellfountain Road just one mile north of the Castillo orchard. It is a 5 acre block of older filberts, planted in the mid-1930's. Barcelona is the main cultivar, with Daviana pollinizers. Being nearly 50 years old, these trees showed many areas of dead wood and sparse foliage, although they continue to set a fair crop of nuts. Virtually all limbs and trunks are heavily matted with moss and lichens. In 1979 the grower applied one application of Sevin early in the season, but neglected the late season spray. In 1980, no insecticides were applied at all. During both years, the grower noticed severe filbert aphid infestations. In 1981 an aerial application of Metasystox-R was used for aphid control, but no further insecticides were applied for filbertworm or other pests. No herbicides or fungicides were used in the orchard for several years, nor was any pruning program followed. Root suckers were removed manually and standard rates of urea were applied.

The ground cover in the orchard was a mixture of wild grasses and broadleaf weeds, which the grower mowed three times in 1981. The fields surrounding the orchard were planted in wheat, oats, and ryegrass.

Twedt Orchard:

The Twedt orchard is located on Garden Avenue about two miles north of Corvallis near Highway 20. It is the largest, most commercial, and most intensively managed of the four orchards which were studied. It consists of 20 acres of Barcelona, Daviana, and DuChilly trees which are approximately eight years old. The usual insecticide spray program consists of two applications of azinphosmethyl (Guthion) for filbertworm control, at a rate of one-fourth pound active ingredient per acre. Simazine and paraquat were used for weed control in the tree rows, while the aisles were flailed five times in 1981. Fertilizer in the form of urea provided approximately one pound of actual nitrogen per tree. Fields surrounding the orchard were planted in strawberries, raspberries, wheat, and grass. The grower reported a yield in 1981 of approximately 500 pounds of dry nuts per acre.

C. Laboratory Feeding Trials

Predator feeding behavior was observed by examination of insects under laboratory conditions. The predatory insects were placed in small petri dishes; each dish contained a moistened piece of filter paper and a filbert leaf infested with filbert aphids. Feeding was observed using a stereomicroscope. In some cases predators were reared from early instars to adults by providing fresh aphids and moisture every few days.

Experiments were set up in a temperature-controlled environator to determine the voracity of different predators. A series of small feeding chambers was set up, each consisting of a paper dish containing a single filbert leaf. To prevent dehydration, the petiole of each leaf was inserted in a small glass vial, which was kept filled with water and plugged with wax to prevent evaporation. A known number of third and fourth instar aphids were transferred to the leaf in each dish using a fine camel-hair brush, and a single second or third instar predator was then added to each. The predators tested were *A. bipunctata*, *D. brevis*, *H. meriopterum*, and *C. salicellum*. Dishes were covered and kept at constant temperature and photoperiod (24°C.; 17 hours light: 7 hours dark) for the duration of the trial. The number of aphids remaining was counted each day, and new aphids were added when the populations reached lower than 10-15 aphids per leaf. Dishes containing aphid infested leaves without any predators served as controls. Another set of control dishes contained single predators without any aphids in order to test longevity and mortality without aphid food. The experiment was set up as a completely randomized design, with six replicates of each of the following eight treatments:

Treatment 1: a single *Heterotoma meriopterum* plus 25 aphids per dish
Treatment 2: a single *H. meriopterum*, no aphids per dish.
Treatment 3: a single *Deraeocoris brevis* plus 25 aphids per dish.
Treatment 4: a single *D. brevis*, no aphids per dish.
Treatment 5: a single *Compsidolon salicellum* plus 25 aphids per dish.
Treatment 6: a single *C. salicellum*, no aphids per dish.
Treatment 7: a single *Adalia bipunctata* plus 25 aphids per dish.
Treatment 8: 25 aphids , no predator per dish.

It had been determined in previous tests that coccinellid larvae died very quickly if not provided with aphid food; therefore, treatment 7 did not include a control dish with a single *A. bipunctata* and no aphids.

Estimates of the mean number of aphids eaten per predator per day were arrived at as follows:

N = (daily mortality in X-daily mortality in C) + (daily natality per adult in C-daily natality per adult in X) ÷ number of days in each trial.

Where: N = number of aphids eaten per predator per day.
X = mean of the experimental groups.
C = mean of the control groups.

D. Chemical Exclusion Test

Five single tree replicates in the Castillo orchard were sprayed with carbaryl (Sevin) at 1 lb. AI/100 gallons water in order to chemically exclude predators while having minimal impact on aphid numbers. These sprayed trees were compared with five unsprayed control trees to determine differences in predator impact. Trees were treated on July 8 and again on August 3, using a conventional handgun sprayer at 250 lbs. pressure and sprayed to the point of run-off. Aphids and predators were sampled once prior to spraying and once a week thereafter for the remainder of the growing season.

As part of another experiment being carried out by Dr. M. T. AliNiazee, a separate block of filbert trees in the Castillo orchard was sprayed with two applications of carbaryl, the compound most commonly used for filbertworm control. Samples were collected from both the treated block and a comparable untreated block to determine the impact of Sevin on aphids and predators. This served as a chemical exclusion test as described by DeBach (1964). Sevin was applied to 25 trees in a section of the orchard directly adjacent to that being sampled for the phenological survey; two applications were made, on August 4 and September 9, at a rate of 2 lbs. AI per 100 gallons water. In each case five trees were chosen at random from within the 25 tree block and compared to five untreated trees. Sampling for predators and aphids was carried out once prior to spraying and once a week thereafter for at least five weeks.

E. Pesticide trials: Laboratory and Field tests.

At Twedt's orchard a spray trial of commonly used filbert insecticides was conducted to determine toxicity to the filbert aphid as well as the amount of disruption of the well-established predator complex. The trial was set up as a completely randomized design with four single-tree replicates of each of the following eight treatments:

Treatment Number	Chemical	Rate: pounds AI/100 gal. water
1	endosulfan (Thiodan)	0.50
2	phosalone (Zolone)	0.38
3	carbaryl (Sevin)	1.00
4	Diazinon	0.50
5	demeton (Systox)	0.25
6	Metasystox-R (oxydemetonmethyl)	0.25
7	Sprayed with water only	
8	Unsprayed	

The rate used for each insecticide was that recommended in the Pacific Northwest Insect Control Handbook. Single tree replicates within a 400 tree block were chosen using a random number table and sprayed to the point of run-off. Buffer trees were left unsprayed around the perimeter of the experimental block and in between those that received chemical treatment. Aphids and predators were sampled once prior to spraying and once a week thereafter for a period of six weeks.

Tests were also conducted under lab conditions to determine the toxicity of field-tested insecticides to two major predators, _A. bipunctata_ and _D. brevis_.

A Potter spray tower was used to apply precisely 4 ml. under 12 lbs/sq. in. of pressure of each of the following chemical treatments:

Treatment Number	Chemical and Rate (lbs. A.I. per 100 gal.)	
1	Sevin	0.50
2	Diazinon	0.25
3	Metasystox-R	0.12
4	Zolone	0.18
5	Guthion	0.25
6	Water only (control)	

Each treatment unit consisted of a small dish holding ten adult predators. The insects were anaesthetized with carbon dioxide, placed in the Potter tower, sprayed with the chemical mist, and then allowed to recover at room temperature until all units were completed. The predators tested were the coccinellid _A. bipunctata_ and the mirid _D. brevis_; there were five replicates of each chemical treatment and ten adult insects per replicate. All units were then placed in a controlled-environment chamber (at 24°C. and 17L:7D) until 24-hour mortality counts could be taken.

IV. Results and Discussion

A. General Survey

1. Predator list

Based upon collections made in at least twelve filbert orchards throughout the Willamette Valley during 1980 and 1981, a list is developed (Table 2) which represents all known or suspected predaceous insects found in association with the filbert aphid. This list includes rare and occasional species as well as the more common and abundant ones.

Table 2. Predaceous Insects Found in Association with the Filbert Aphid in Willamette Valley Filbert Orchards, 1980-1981.

	COLEOPTERA
Cantharidae:	*Podabrus pruinous* Les.
Coccinellidae:	Anatis rathvoni Lec. *Adalia bipunctata* (L.) *Adalia frigida* Schn. *Calvia duodecimaculata* Gebl. *Calvia quatourdecimguttata* L. *Chilocorus* sp. *Coccinella* californica Mann. *Coccinella trifasciata subversa* Lec. *Coccinella trifasciata perplexa* Muls. *Coccinella unidecimpunctata* L. *Coccinella* sp. *Cycloneda* polita Csy. *Exochomus quadripustulatus* L. *Exochomus* sp. *Hippodamia* convergens G. M. *Hippodamia quinquesignata ambigua* Lec. Hippodamia sinuata spuria Lec. *Hippodamia sinuata disjuncta* Timb. *Mulsantina picta* Rand *Scymnus* sp.

	DERMAPTERA
Forficulidae:	*Forficula auricularia* L.
	DIPTERA
Syrphidae:	*Eupeodes voluris* (O.S.)
	Metasyrphus fumipennis (Thomsen)
	Syrphus opinatar (O.S.)
	Syrphus ribesii (L.) or *torvus* (O.S.)
	HEMIPTERA
Anthocoridae:	*Anthocoris antevolans* White
	Orius tristicolor White
Miridae:	*Atractotomus* sp.
	Campyloneura virgula (H.S.)
	Compsidolon salicellum (H.S.)
	Deraeocoris brevis (Uhler)
	Deraeocoris fasciolus Knight
	Diaphnocoris sp.
	Heterotoma meriopterum (Scop.)
	Lupus decolor (Fallen)
	Paraproba nigrinervis (V.D.)
	Phytocoris sp. A.
	Phytocoris sp. B.
	Pilophoris sp.
Nabidae:	*Nabis alternatus* Parshley
	NEUROPTERA
Chrysopidae:	*Chrysopa carnea* Steph.
	Chrysopa placita Banks.
Hemerobiidae:	*Hermerobius humulinus* Linn.
	Hemerobius ovalis
	Hemerobius pacificus Banks
	Hemerobius stigma Steph.
	ORTHOPTERA
Gryllidae:	*Oecanthus niveus* (DeGeer)
	Oecanthus nigricornis (Walker)
	RAPHIDIOPTERA
Raphidiidae:	*Agulla* sp.

Although not directly surveyed in this study, various spiders were frequently collected along with predaceous insects in the beating sheet samples. Several species in the families Salticidae and Thomisidae probably include filbert aphids as a part of their diet.

On one occasion a Formicine ant was observed carrying an aphid in its mandibles, however, aphid-tending by ants was not observed in the filbert trees.

2. Other Natural Enemies

Although predators were assumed to be the primary natural biological control agents of the filbert aphid, other natural enemies were also found to be significant.

In the Twedt filbert orchard, a fungal pathogen was responsible for a wide-scale, intense epizootic which severely decimated the filbert aphid population during June of 1981. This pathogen has been identified as *Triplosporium fresenii* (Nowakowski) Batko (= *Neozygites Fresenii* (Nowakowski) Witlaczil). Taxonomically, the fungus belongs to the class Zygomycetes, order Entomophthorales, and family Entomophthoraceae. The taxonomy of this group is currently being revised and is somewhat in a state of disarray, but the identification was confirmed with the help of Dr. R. A. Humber of the USDA-SEA, Ithaca, N. Y.. This fungus apparently plays a dominant role in reducing populations of filbert aphids under epidemic conditions.

A parasitic Hymenopteran of the superfamily Chalcidoidea was also observed to attack the filbert aphid. This parasite has been tentatively identified as belonging to the genus *Mesidiopsis* in the family Aphelinidae. If this identification is confirmed, it will be the first time a member of this genus has been recorded in North America. There is one record in the literature of *Mesidiopsis subflavescens* parasitizing the filbert aphid in France (Feriere, 1965).

3. Significance and Regional Distribution of Commonly Occurring Predators

Data in Table 3 show the percent of all predaceous insects in each sample represented by the various species. The composition of the predator complex in three distinct areas of the Willamette Valley is also provided. The results for the northern and southern parts of the valley represent data from one sample each for early, mid, and late season; while the results for the Central Valley represent the average for a series of samples taken as part of a phenological survey.

Among the Miridae, nymphs of *Paraproba nigrinervis* and *Compsidolon salicellum* could not be distinguished under field conditions; neither could *Deraeocoris brevis* nymphs be distinguished from *D. fasciolus*. Of the Neuroptera, some Chrysopidae larvae could be distinguished from those of Hemerobiidae (for example, "trash-carriers" can only belong to the Chrysopidae), but in other cases field identification was not feasible. None of the coccinellid larvae could be field identified to species level. In each case, the predators are categorized according to the narrowest field-identifiable taxon.

Although based on minimal sampling in the northern and southern portions of the valley (Washington and Lane counties, respectively), Table 3 is informative on several counts. The numerical contribution of

Table 3a. Species Composition of the Predator Fauna in Nine Willamette Valley Filbert Orchards.

Northern Willamette Valley

	Fern Hill	Wapato	Wallin
Early Season	*A. bipunctata* 54% *D. brevis* 23% *C. polita* 12%	*C. polita* 57% *D. brevis* 28% *A. bipunctata* 14%	*D. brevis* 38% *A. bipunctata* 22% *C. polita* 6% *Hemerobius* sp. 6%
Mid Season	*P. nigrinervis* & *C. salicellum* 40% Coccinellid larvae 34% *H. meriopterum* 11%	*P. nigrinervis* & *C. salicellum* 61% Coccinellid larvae 16% *Deraeocoris* spp. 8% ***	Coccinellid larvae 49% *Hemerobius* spp. 13% *Phytocoris* spp. 9% ***
Late Season	*D. brevis* 76% *A. bipunctata* 5% lacewing larvae 5%	*Chrysopa* spp. 33% lacewing larvae 33% *Hemerobius* spp. 17%	lacewing larvae 52% *Hemerobius* spp. 32% *D. brevis* 4% *Chrysopa* spp. 4%

*** indicates orchard treated with organophosphate insecticide during indicated period.

Table 3b. Species Composition of the Predator Fauna in Nine Willamette Valley Filbert Orchards.

Central Willamette Valley

	Castillo	Buchanan	Twedt
Early Season	*D. brevis* 28%	*A. bipunctata* 33%	*Deraeocoris* spp. 40%
	Hemerobius spp. 18%	*C. polita* 27%	Coccinellid larvae 20%
	C. polita 13%	*Hemerobius* spp. 10%	*A. bipunctata* 14%
Mid Season	*Deraeocoris* spp. 35%	Coccinellid larvae 35%	*P. nigrinervis* + *C. salicellum* 47%
	P. nigrinervis + *C. salicellum* 31%	*A. bipunctata* 15%	*Deraeocoris* spp. 25%
	H. meriopterum 17%	*H. meriopterum* 14%	Coccinellid larvae 20% ***
Late Season	*D. brevis* 62%	*D. brevis* 48%	*D. brevis* 36%
	H. Convergens 5%	*A. bipunctata* 30%	lacewing larvae 16%
	C. polita 4% *C. trifasciata* 4%	*Chrysopa* spp. 5%	*Hemerobius* spp. 15%

*** indicates orchard treated with organophosphate insecticide during indicated period.

Table 3c. Species Composition of the Predator Fauna in Nine Willamette Valley Filbert Orchards.

Southern Willamette Valley

	Cedar Flat	Springfield	Alton Baker
Early Season	*Hemerobius* spp. 32%	*Chrysopa* spp. 45%	*Hemerobius* spp. 55%
	Calvia spp. 29%	*C. polita* 19%	*C. polita* 20%
	C. polita 24%	*Hemerobius* spp. 13%	*C. trifasciata* 15%
Mid Season	*P. nigrinervis* & *C. salicellum* 34%	*P. nigrinervis* & *C. salicellum* 57%	*P. nigrinervis* & *C. salicellum* 64%
	Deraeocoris spp. 23%	*Deraeocoris* spp. 12%	*A. bipunctata* 9%
	coccinellid larvae 21% ***	*H. meriopterum* 6%	*Hemerobius* spp. 7%
Late Season	lacewing larvae 97%	lacewing larvae 40%	lacewing larvae 75%
	Hemerobius spp. 3%	*Hemerobius* spp. 40%	*Hemerobius* spp. 15%
		C. 11-notata 20%	*C. polita* 5%

***indicates orchard treated with organophosphate insecticide during indicated period.

various species is shown to differ considerably, even within individual counties, but the basic species complex remains fairly constant throughout the Willamette Valley. The major Coccinellids in terms of abundance were shown to be Adalia bipunctata and Cycloneda polita, while those of secondary abundance were Coccinella trifasciata, Hippodamia convergens, Coccinella californica, Calvia duodecimaculata, and Calvia quatourdecimaculata. Among the Miridae, the multivoltine Deraeocoris brevis was shown to be the most abundant predator early and late in the season, while univoltine mirids dominated during mid-season, especially Paraproba nigrinervis, Compsidolon salicellum, Deraeocoris fasciolus, and Heterotoma meriopterum. The various species of Chrysopa and Hemerobius could not be distinguished in the field, but both genera were well represented throughout the Willamette Valley. Syrphids and anthocorids were numerous in only one or two orchards and were not generally widespread and abundant.

Because the mere presence of a predator in association with an aphid species does not insure that a true predator-prey relationship exists, field and laboratory observations of actual feeding behavior were made. Table 4 shows the recorded observations and "proof of predation" for the most common predators feeding on the filbert aphid. It should be noted that the absence of an observation does not suggest the absence of the biological relationship.

Table 4. "Proof of Predation" for Insects Found in Association with Filbert Aphids (*M. coryli*) in the Willamette Valley, Oregon.

Species	Life Stage	Aphidophagy Reported in Literature	Widespread Association with *M. coryli*	Observed Feeding in Lab	Observed Feeding in Field	Reared to Adult on *M. coryli*
A. bipunctata	Adult	X	X	X	X	
A. bipunctata	Larva	X	X	X		X
C. californica	Adult	X	X	X		
C. trifasciata	Adult	X	X	X	X	
C. polita	Adult	X	X	X	X	
H. convergens	Adult	X	X	X		
D. brevis	Adult	X	X	X		
D. brevis	Nymph	X	X	X	X	X
D. fasciolus	Adult	X	X			
D. fasciolus	Nymph	X	X			
P. nigrinervis	Adult		X	X		
P. nigrinervis	Nymph		X	X		
C. salicellum	Adult		X	X		
C. salicellum	Nymph		X	X		X
H. meriopterum	Adult	X	X	X		
H. meriopterum	Nymph		X	X		X
Hemorobius spp.	Adult	X	X	X		
Hererobius spp.	Larva	X	X	X	X	X
C. placita	Adult	X ?	X			
C. placita	Larva	X	X	X		X
C. carnea	Adult		X			
C. carnea	Larva	X	X			
Syrphus	Larva	X	X	X	X	X
A. antevolans	Adult	X	X	X		
A. antevolans	Nymph	X	X	X		
O. tristicolor	Adult		X		X	
Oecanthus spp.	Adult	X		X		
F. auricularia	Adult	X	X	X		
F. auricularia	Nymph	X	X	X		
P. pruinous	Adult	X	X	X		

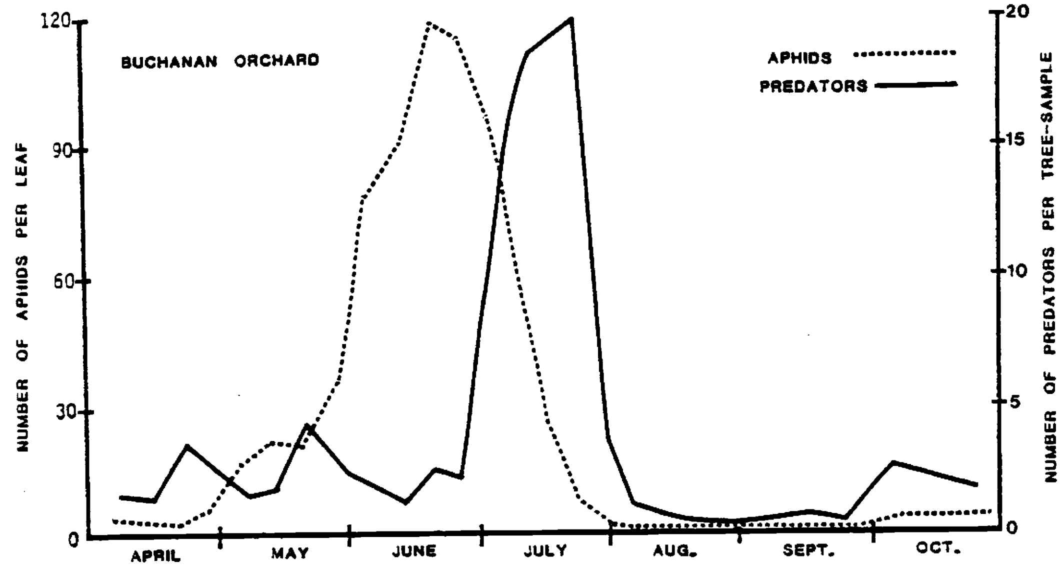
B. Predator-Prey Phenology

The field phenology of the filbert aphid and its more common predators was determined by weekly sampling in four Benton County filbert orchards during 1981. Figures 2-12 show the relative abundance of the various predators along with the aphid abundance curves for four orchards. It should be noted that an early season spray of Metasystox-R in the Simonson orchard severely depressed the aphid population as well as that of most predators.

The coccinellid _Adalia bipunctata_ was the single most important predator in natural biological control of the filbert aphid (Fig. 2, a-b). Data show that this predator is very well synchronized with aphid field phenology. Overwintering adults emerge quite early in the spring, and may occur in large numbers by early to mid-April.

In Buchanan's orchard, which had substantial aphid numbers but remained unsprayed throughout the season,there is evidence of a late season (mid-October) surge of _A. bipunctata_ adults. This suggests that adult _A. bipunctata_ might be overwintering right in the filbert orchards, aggregating perhaps in small clusters, but not undergoing the mass migrations and mountain aggregations of other aphidophagous coccinellids. Other observations tend to support this conclusion: for example, as early as March 17, I noted substantial numbers of adult _A. bipunctata_ present in a young filbert orchard in Linn County. Also, a sample at the Fern Hill orchard (Washington County) on April 22 showed nine of the ten sampled trees to have an average of 2.1 adult _A. bipunctata_ per tree, while the tenth yielded 26 adult _A. bipunctata_, Figures 2-12. Seasonal phenology of the filbert aphid and its predators in four Willamette Valley filbert orchards, 1981.

Figure 2a. *A. bipunctata*



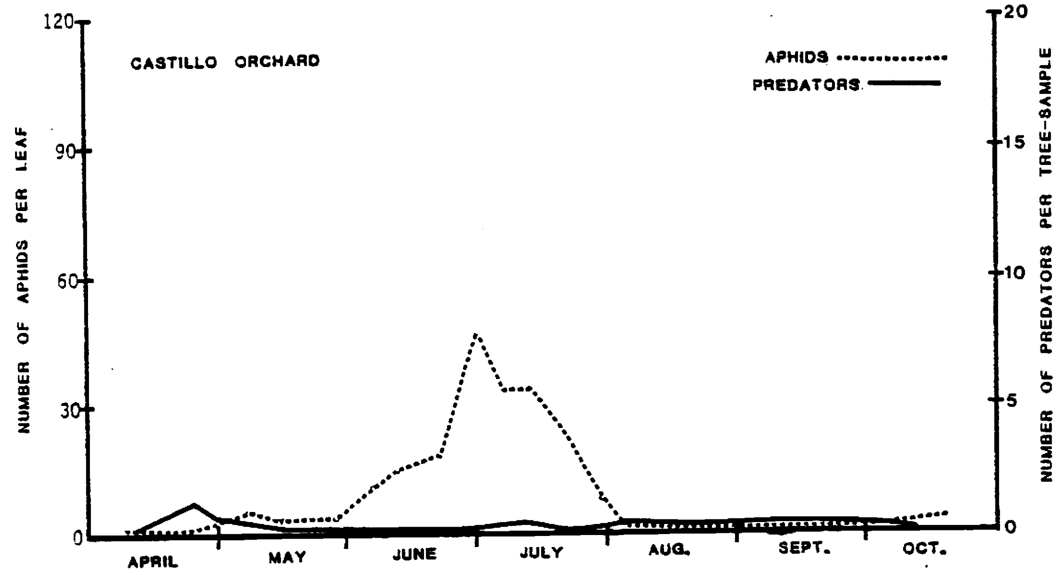


Figure 2b. A. bipunctata

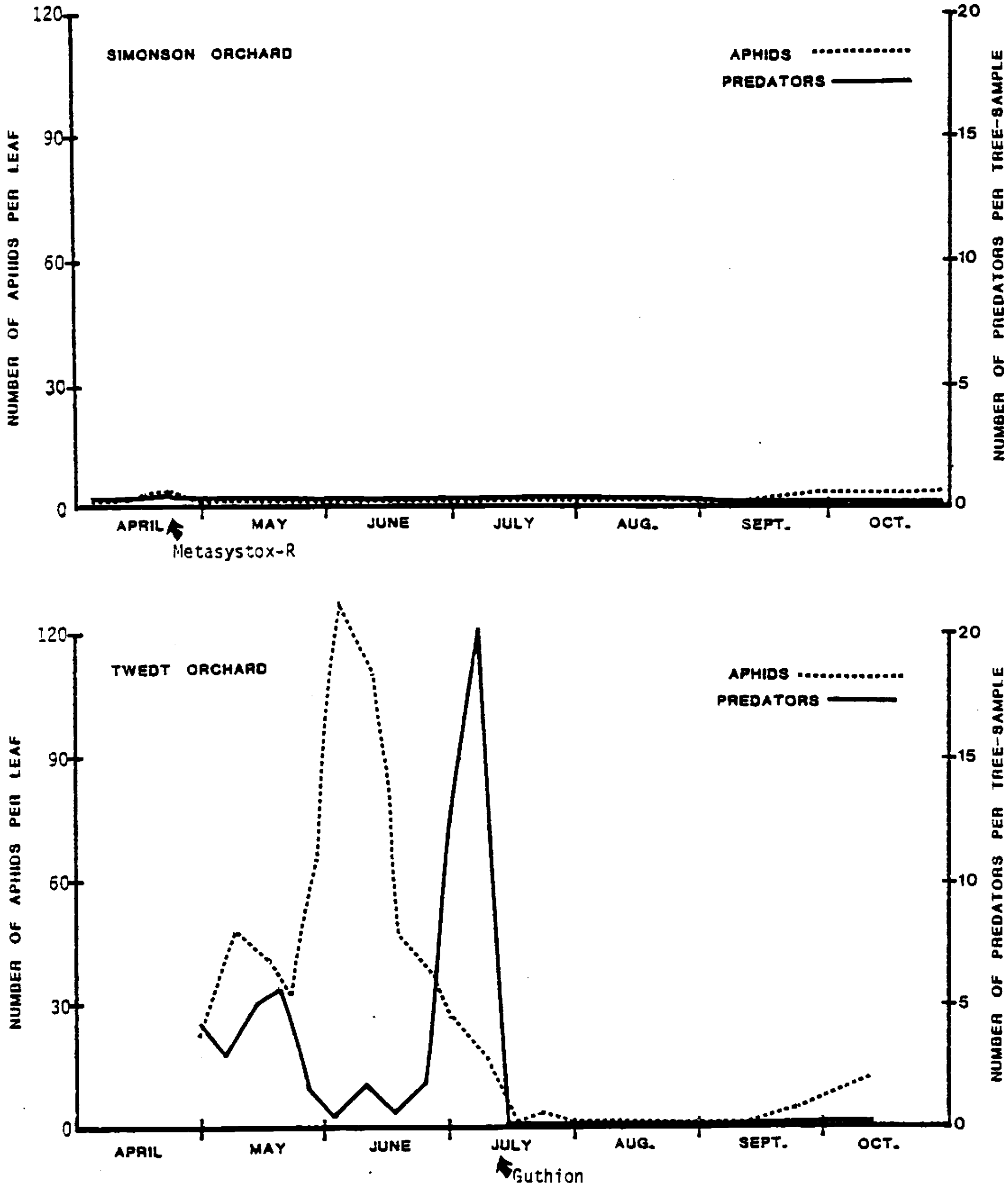


Figure 3a. C. polita

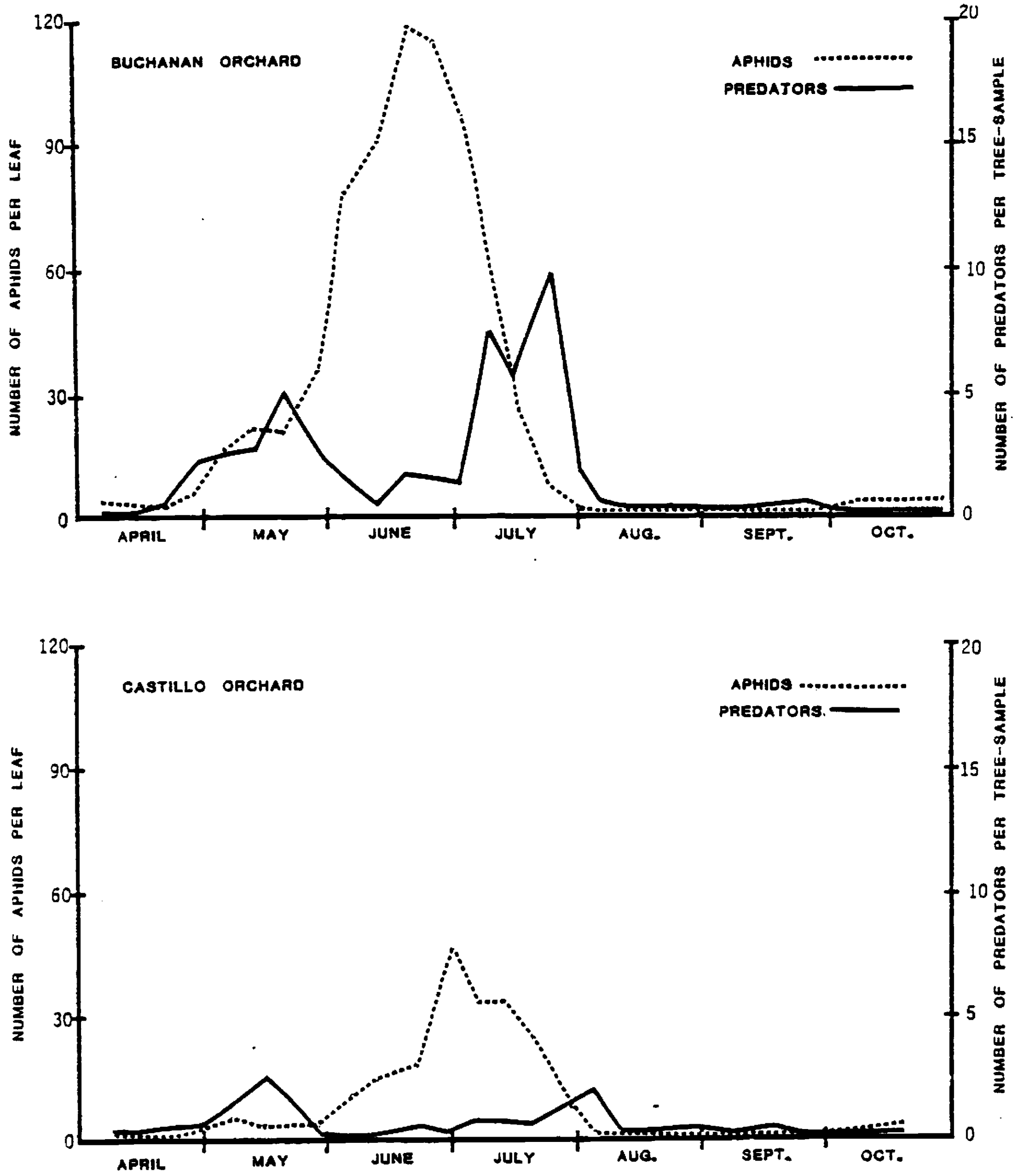


Figure 3b. *C. polita*

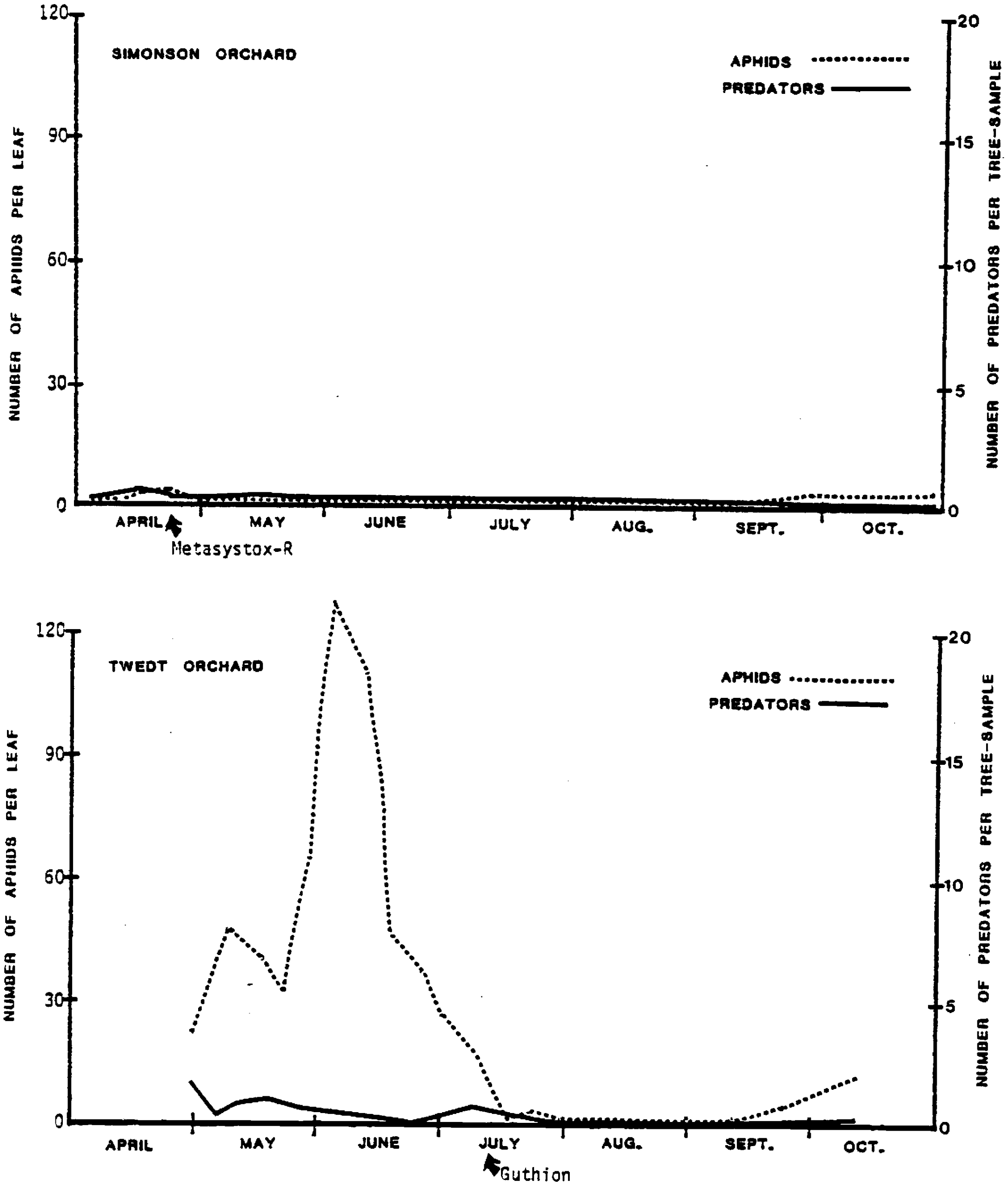


Figure 4a. Total coccinellids

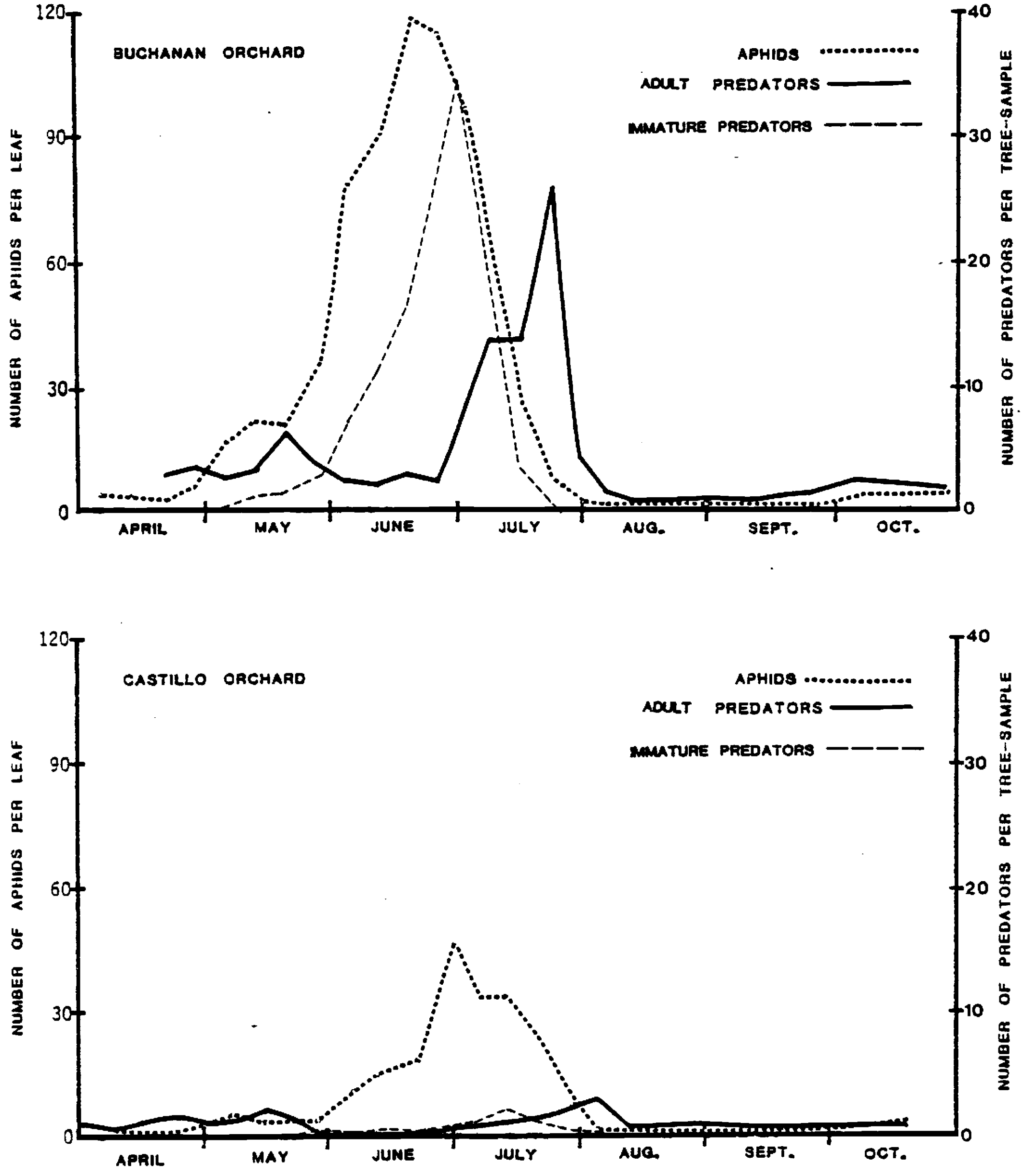


Figure 4b. Total coccinellids

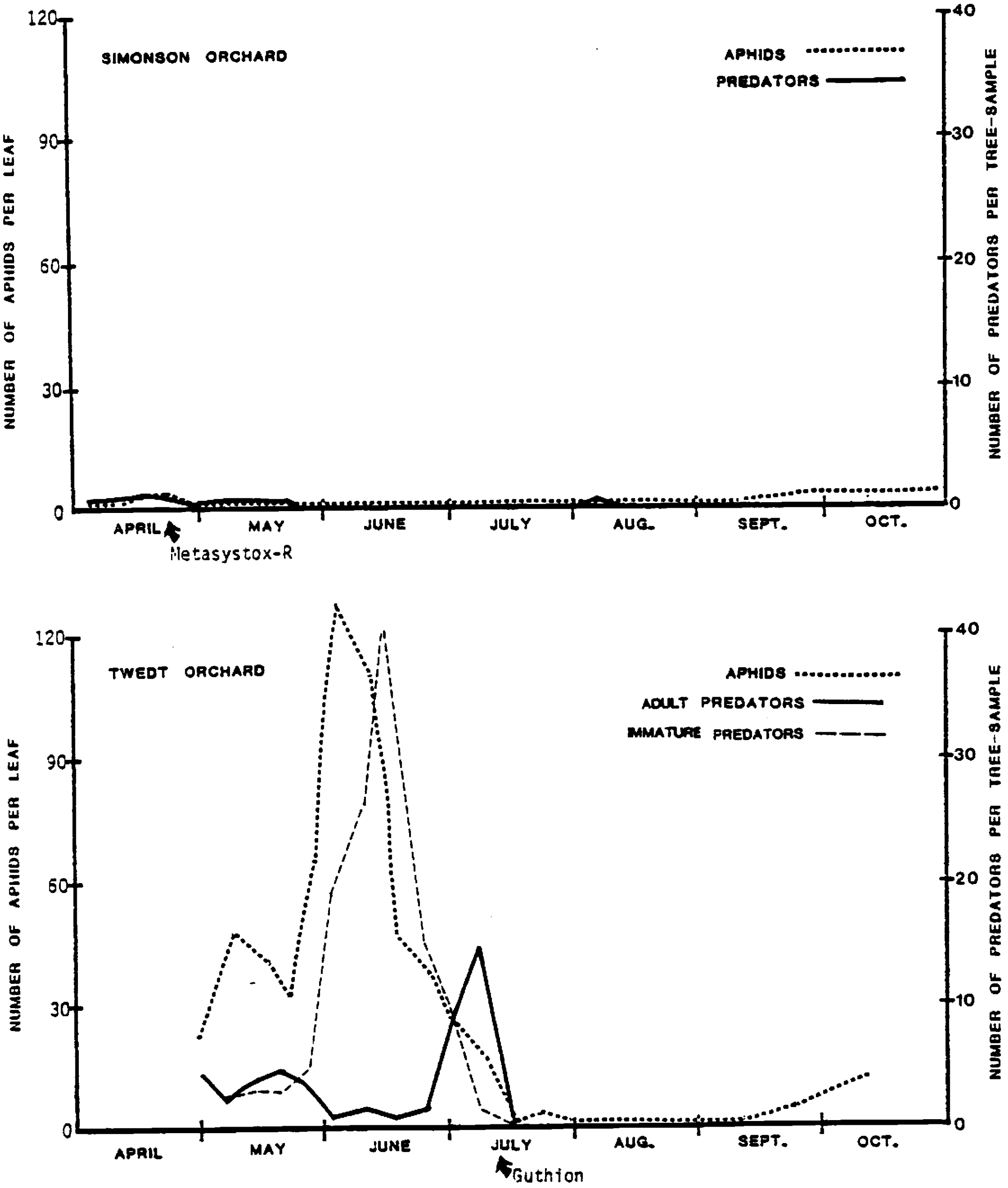


Figure 5a. *D. brevis*

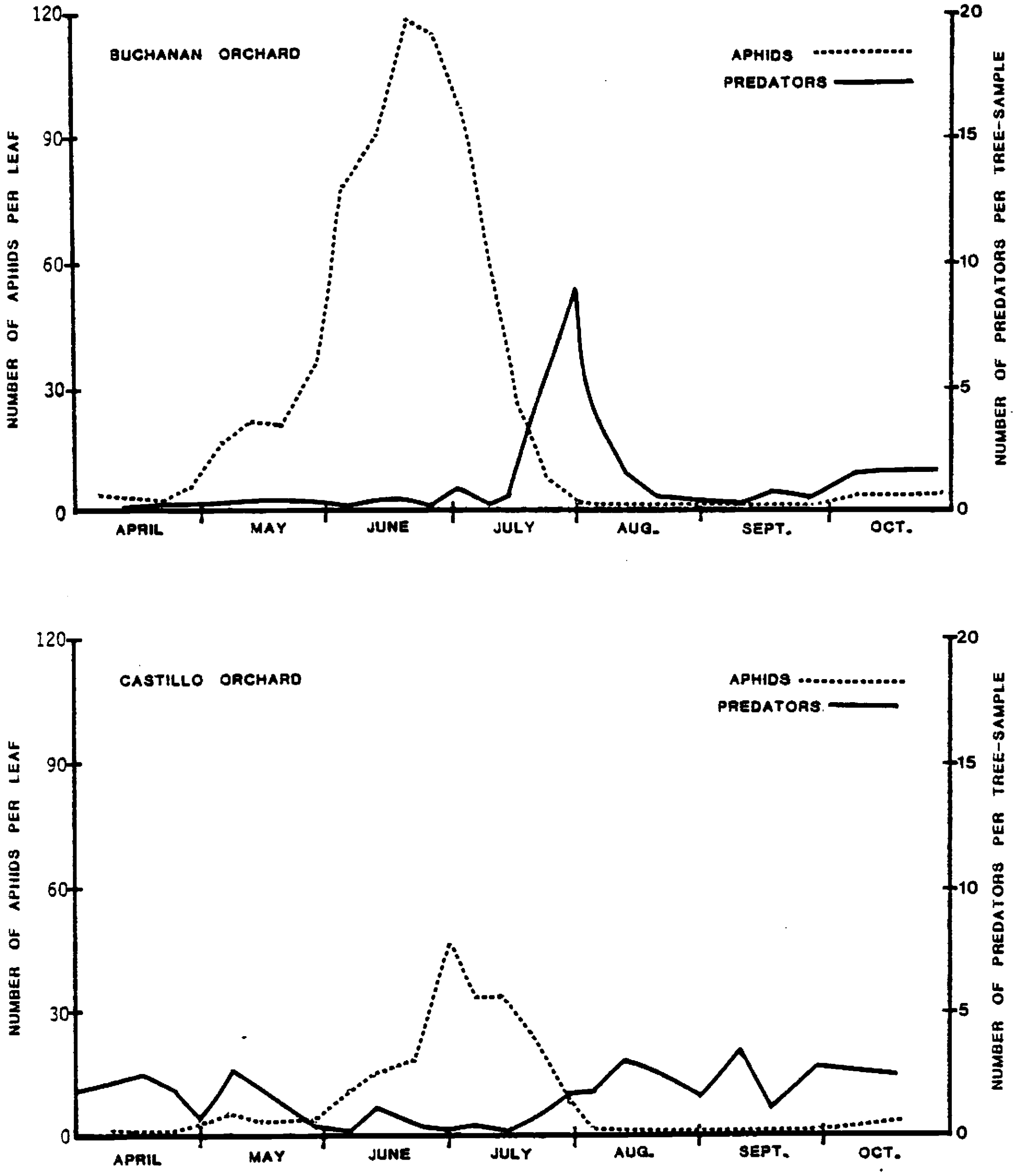


Figure 5b. D. brevis

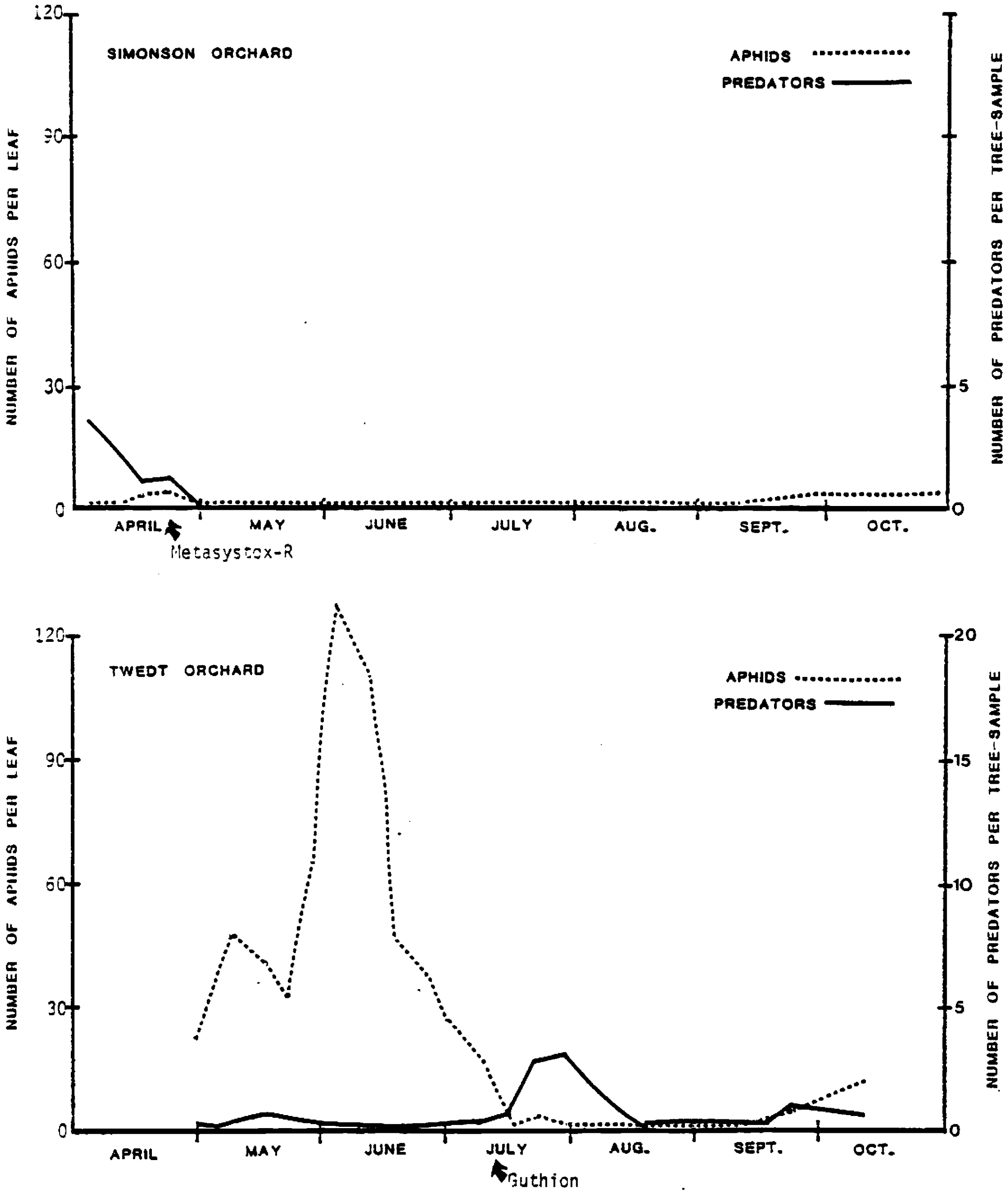


Figure 6a. D. fasciolus

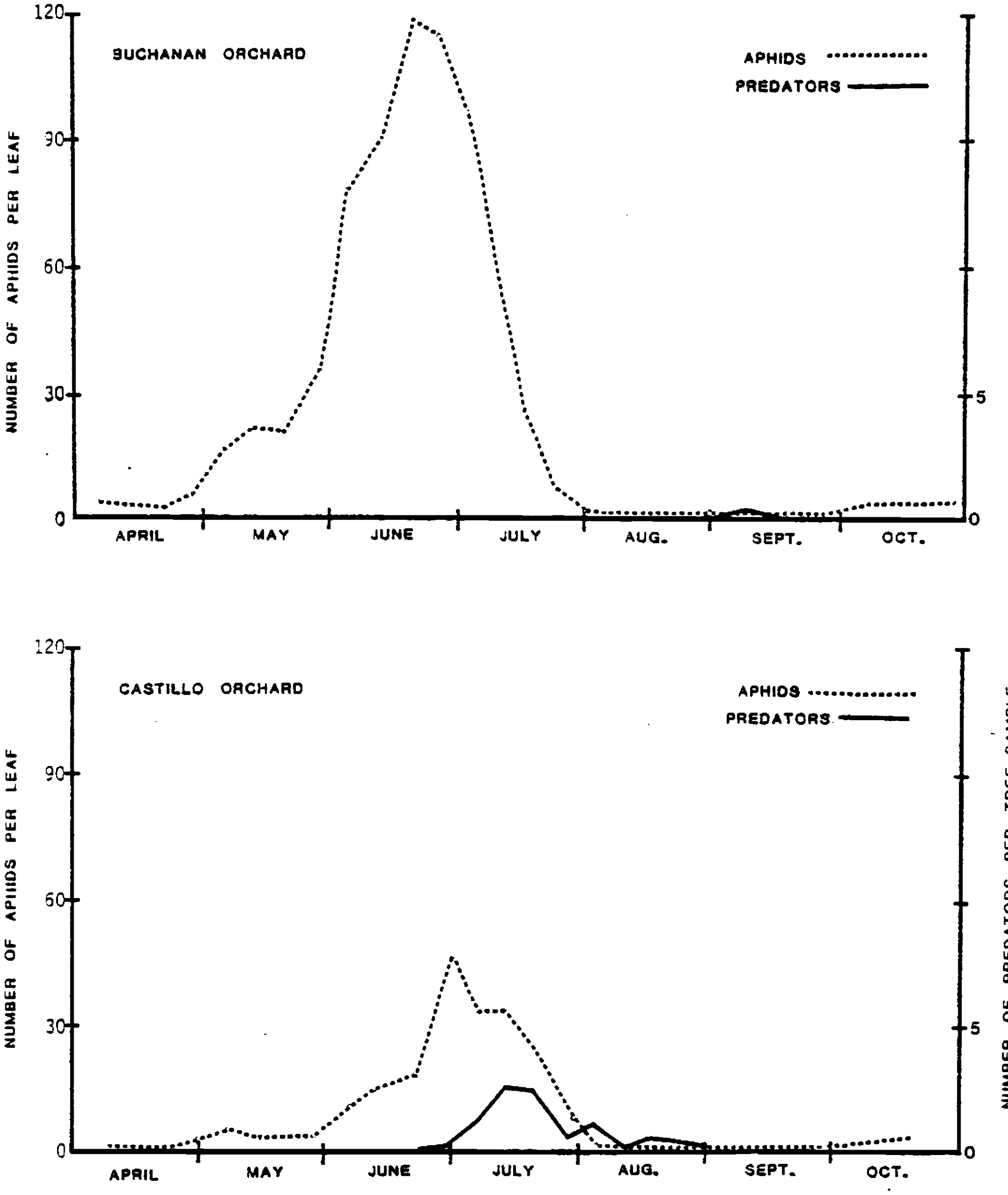


Figure 6b. *D. fasciolus*

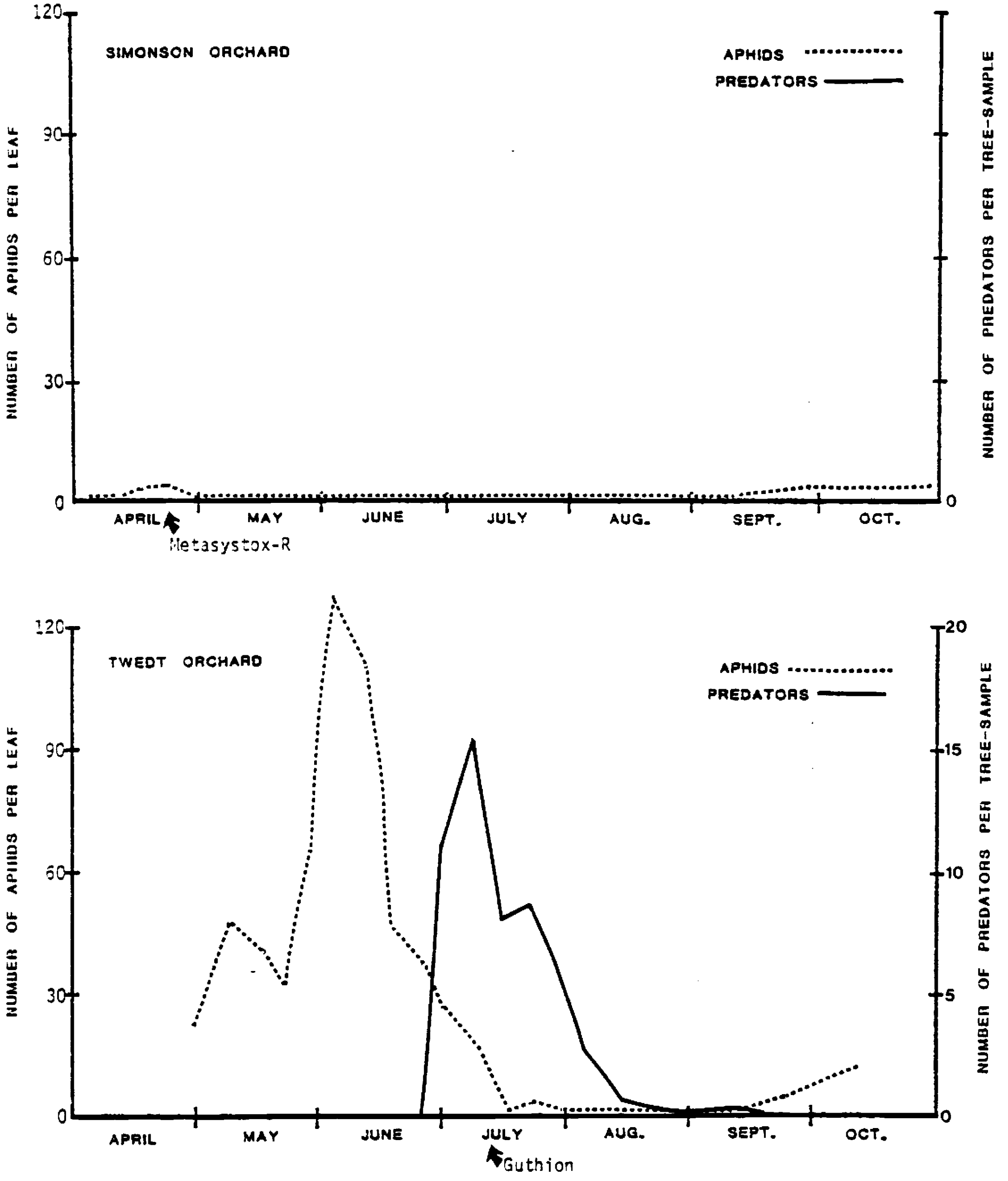


Figure 7a. *H. meriopterum*

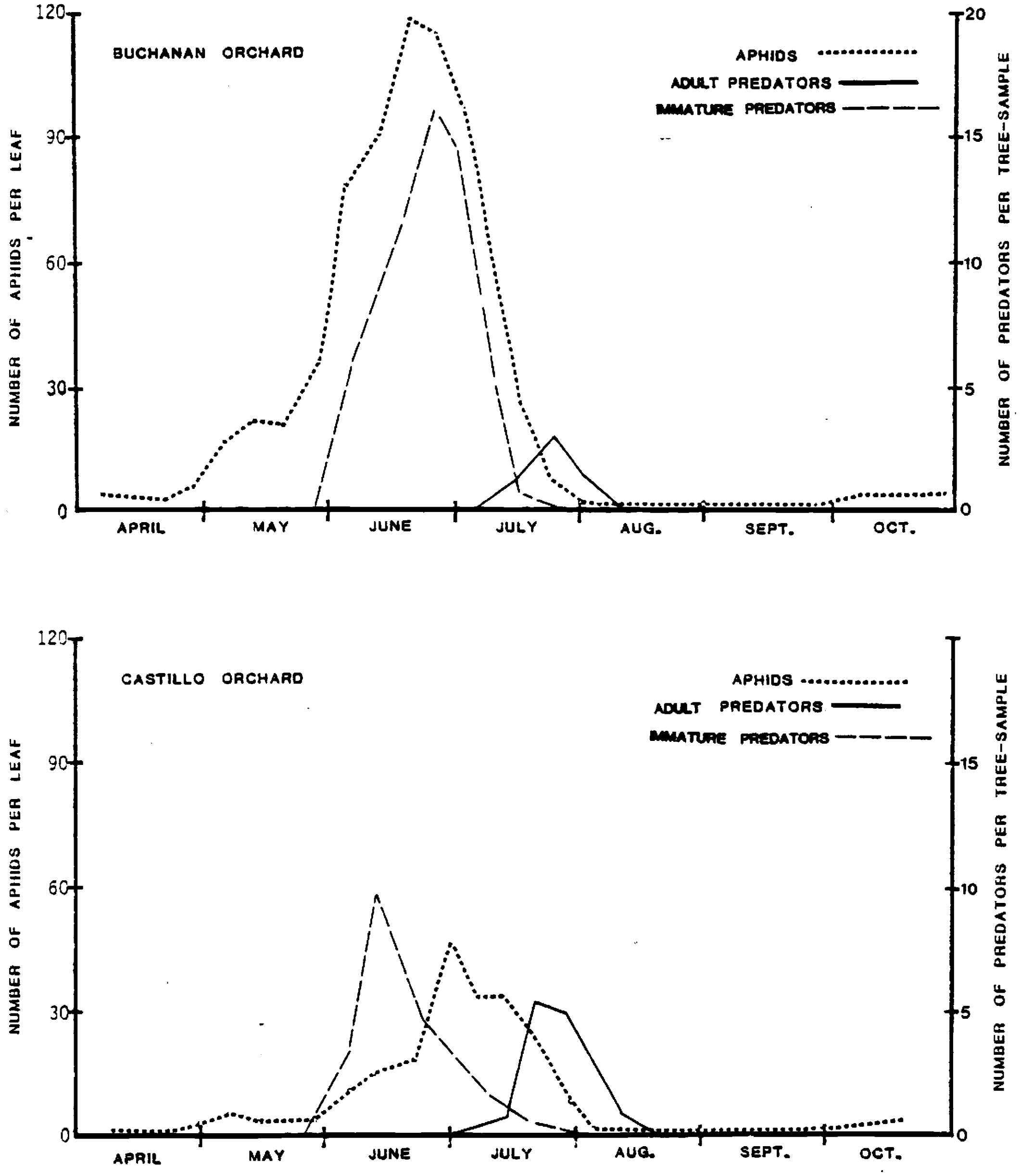


Figure 7b. <u>H. meriopterum</u>

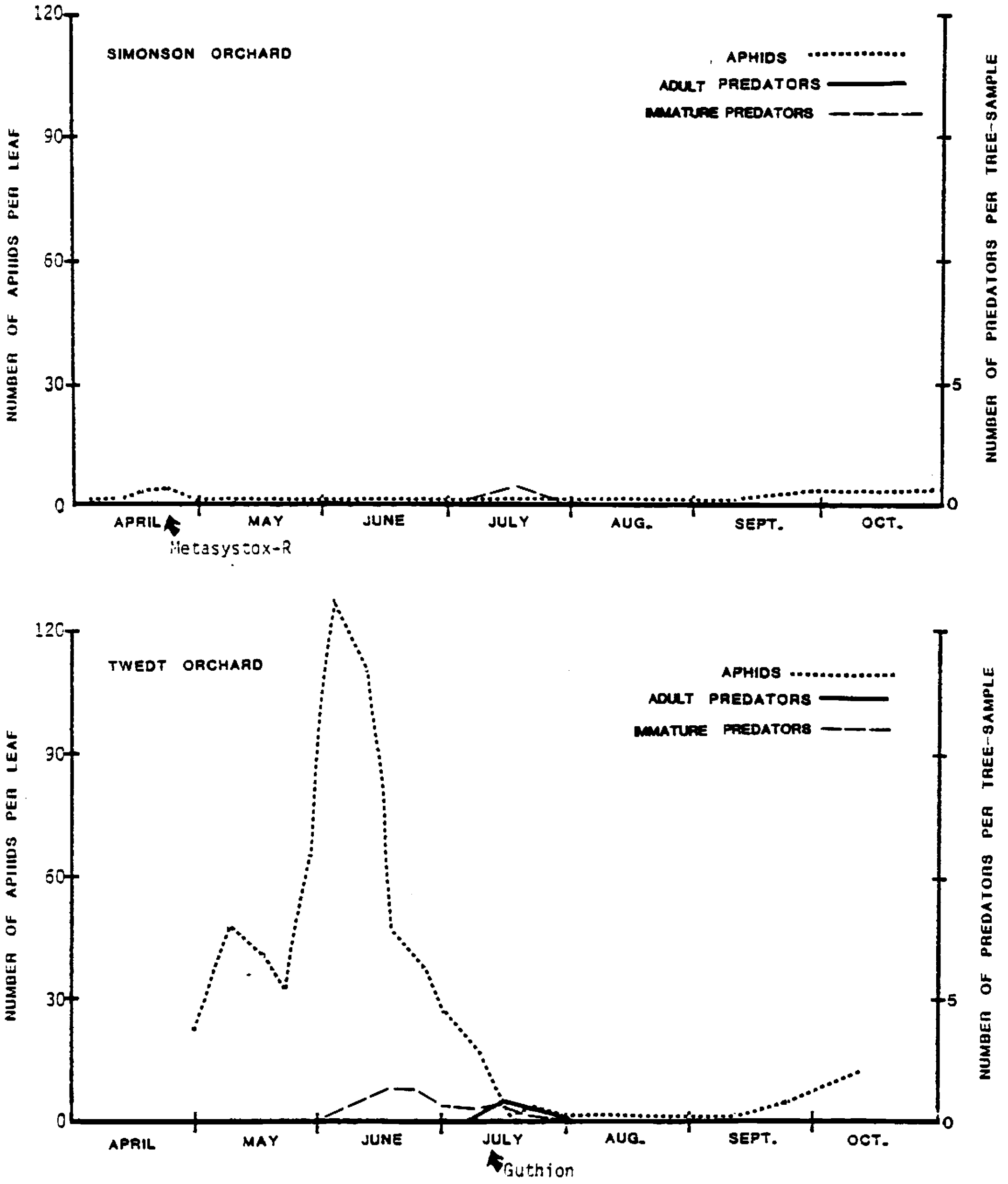


Figure 8a. *P. nigrinervis*

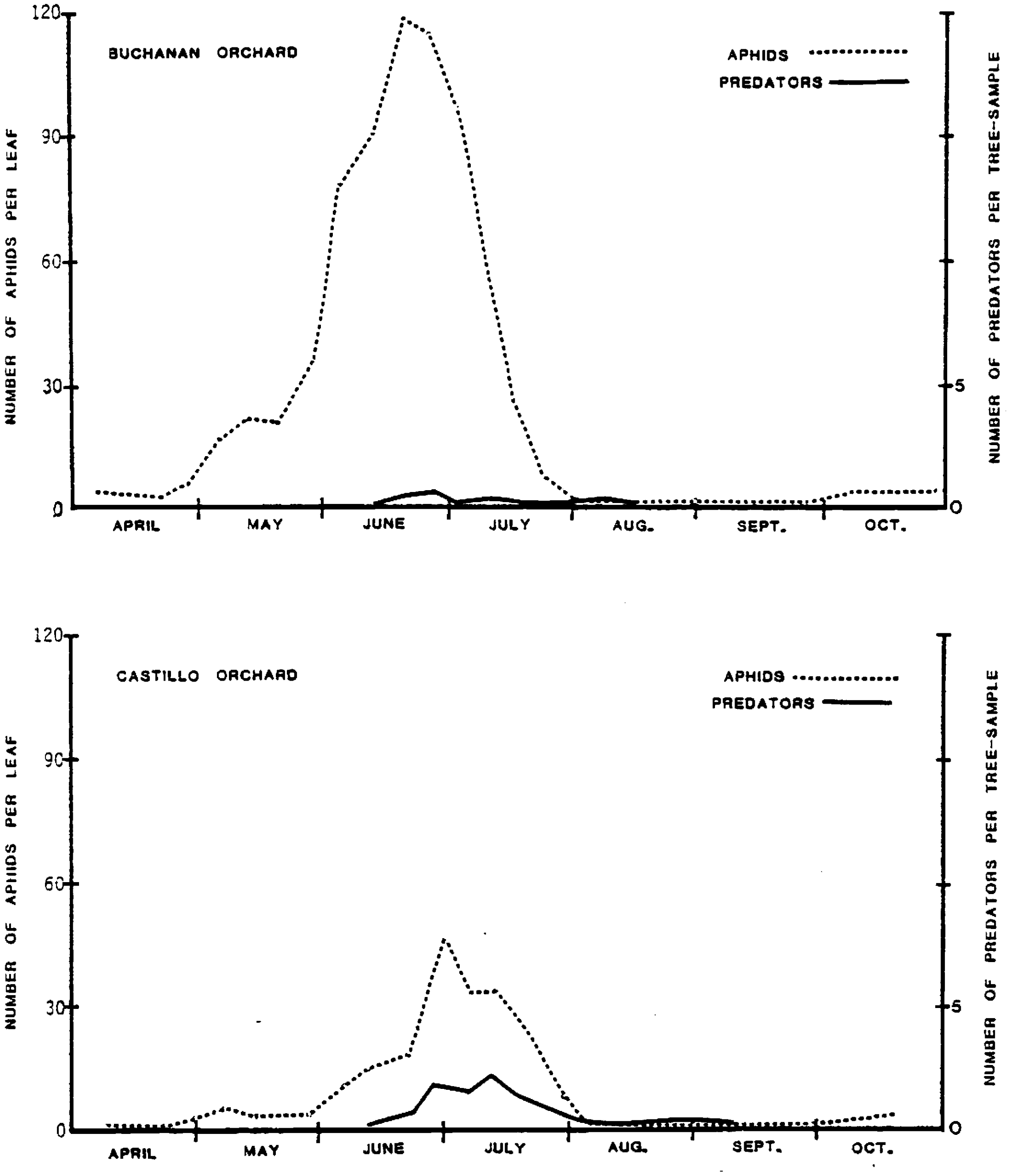


Figure 8b. P. nigrinervis

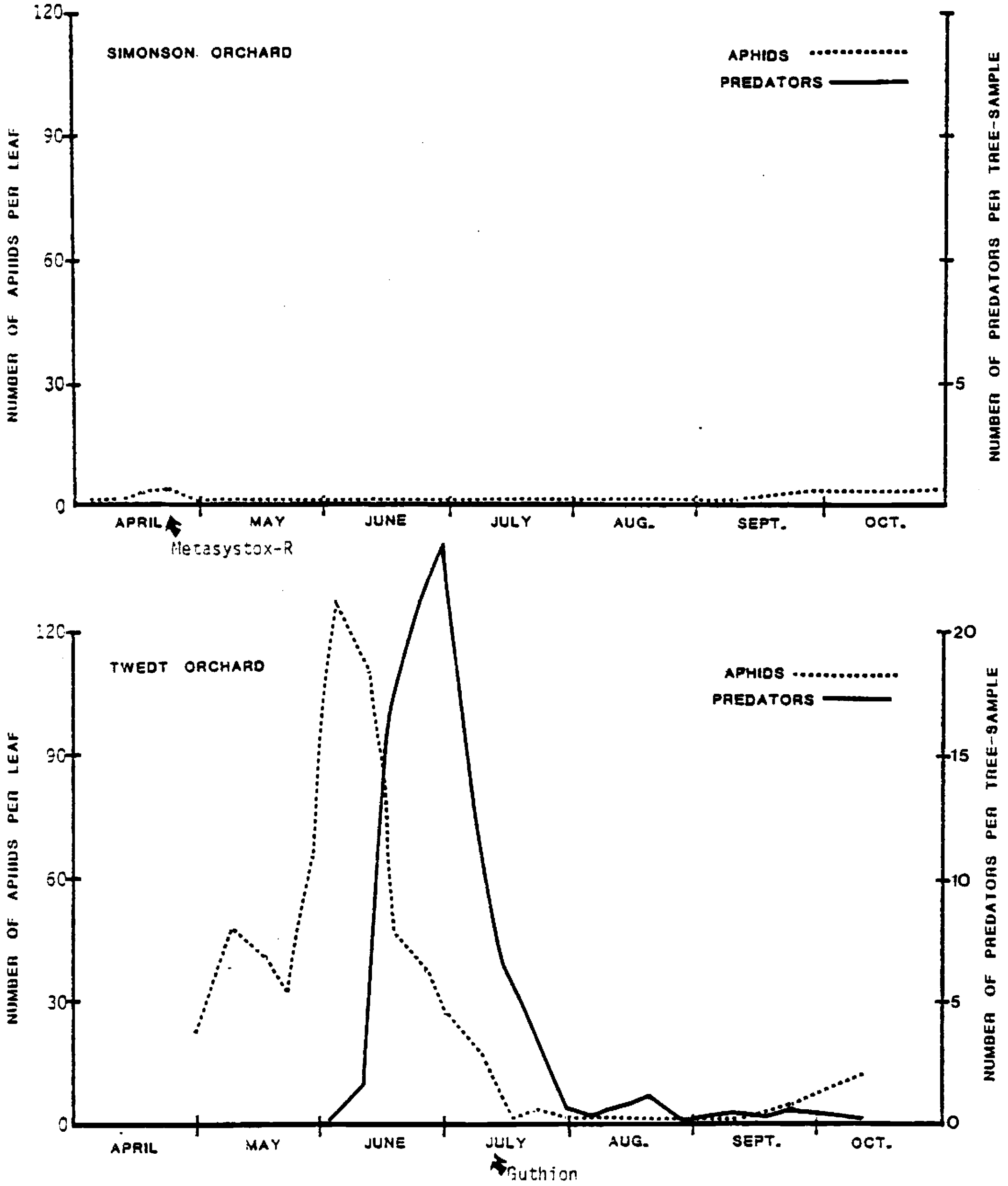
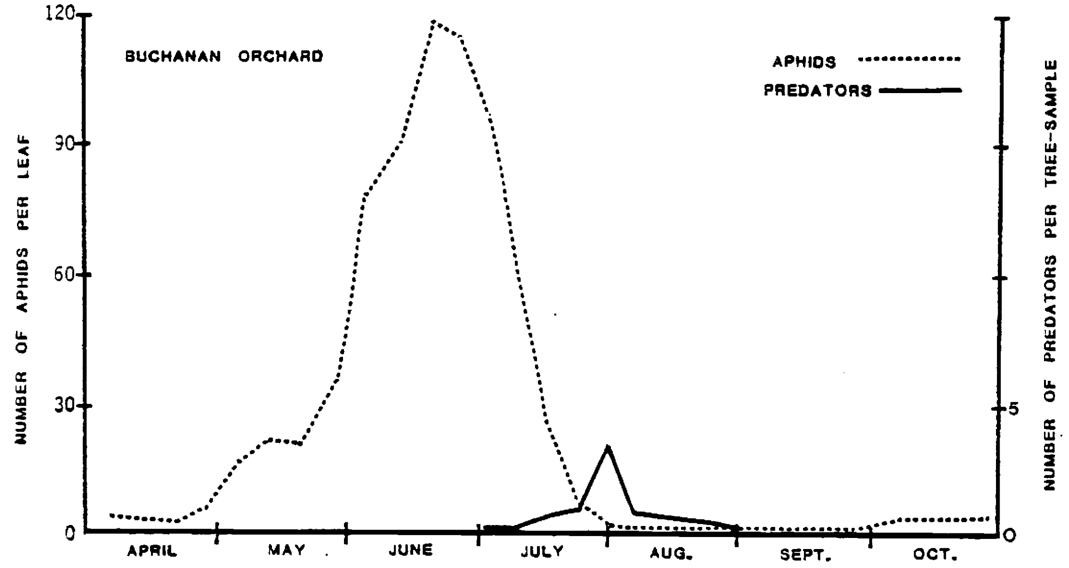


Figure 9a. C. salicellum



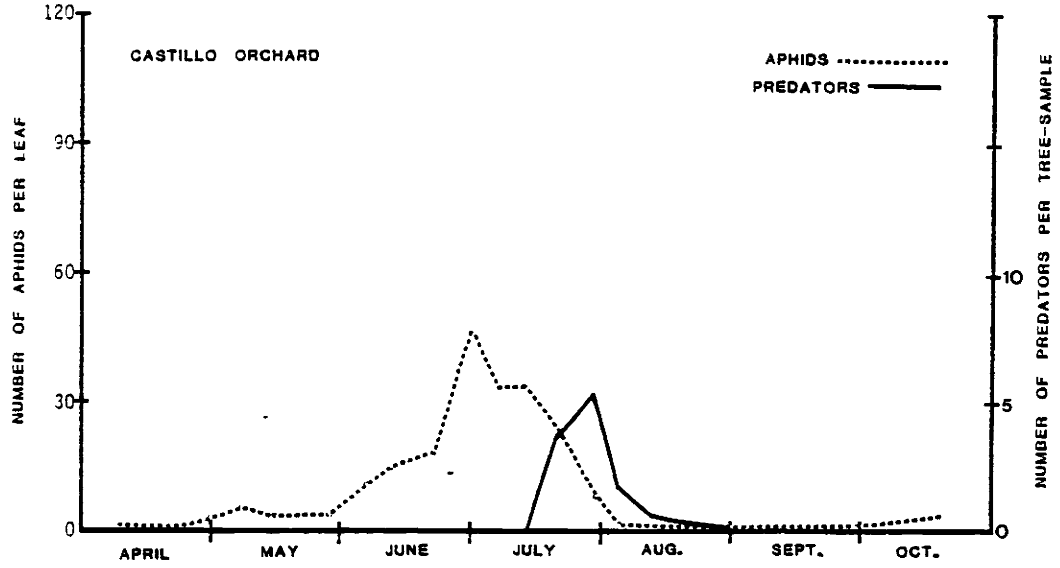


Figure 9b. C. salicellum

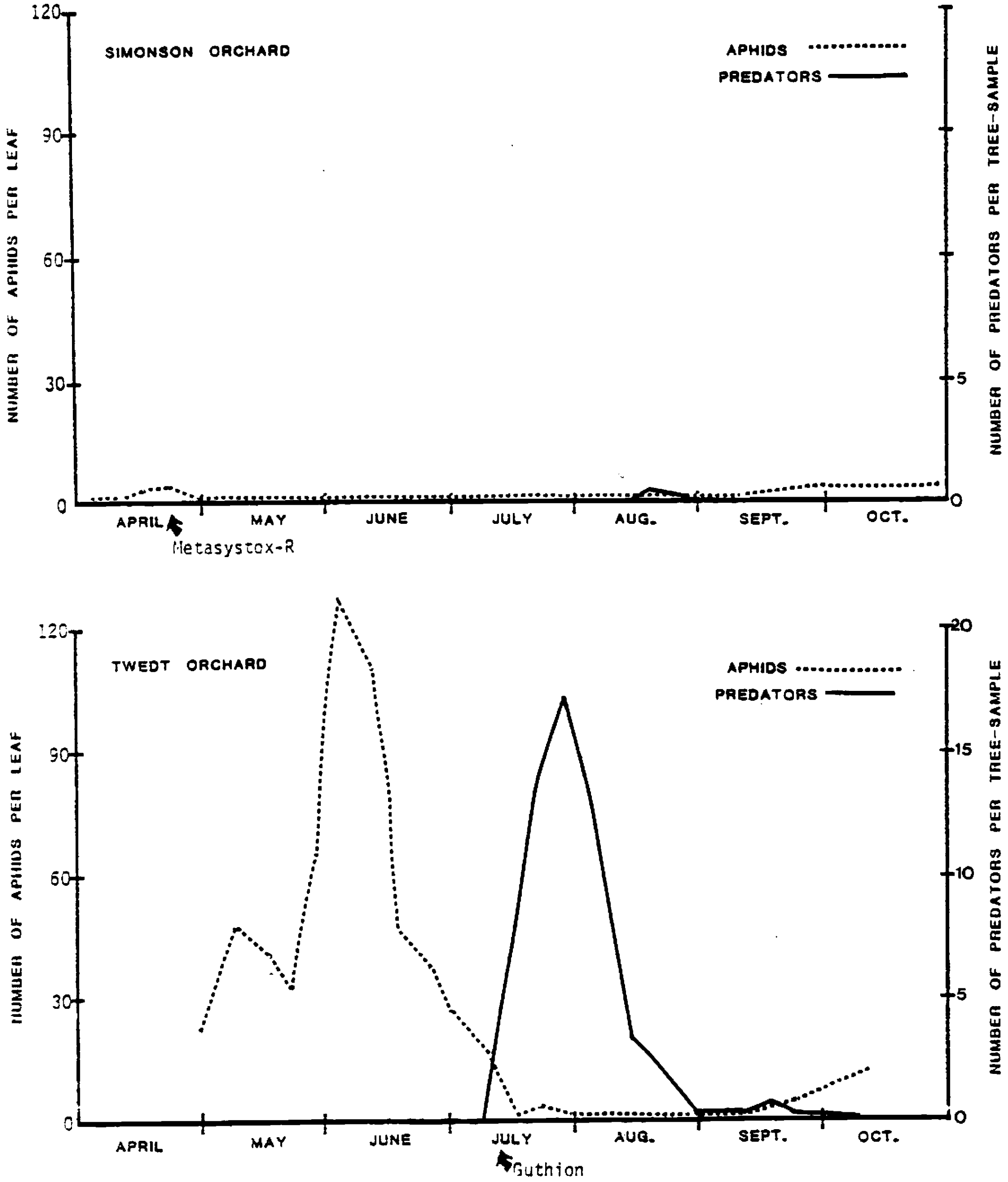


Figure 10a. Total lacewings

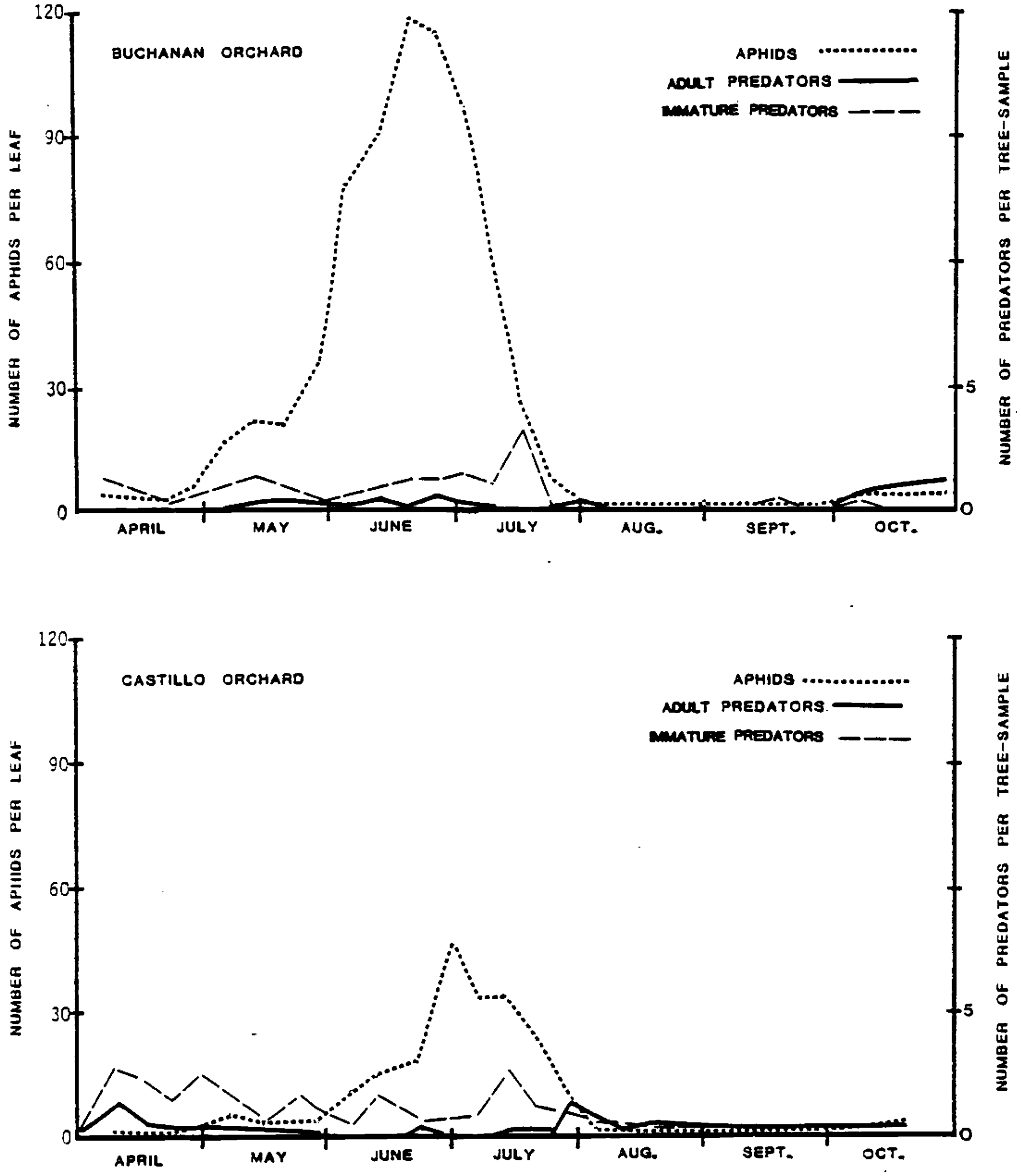


Figure 10b. Total lacewings

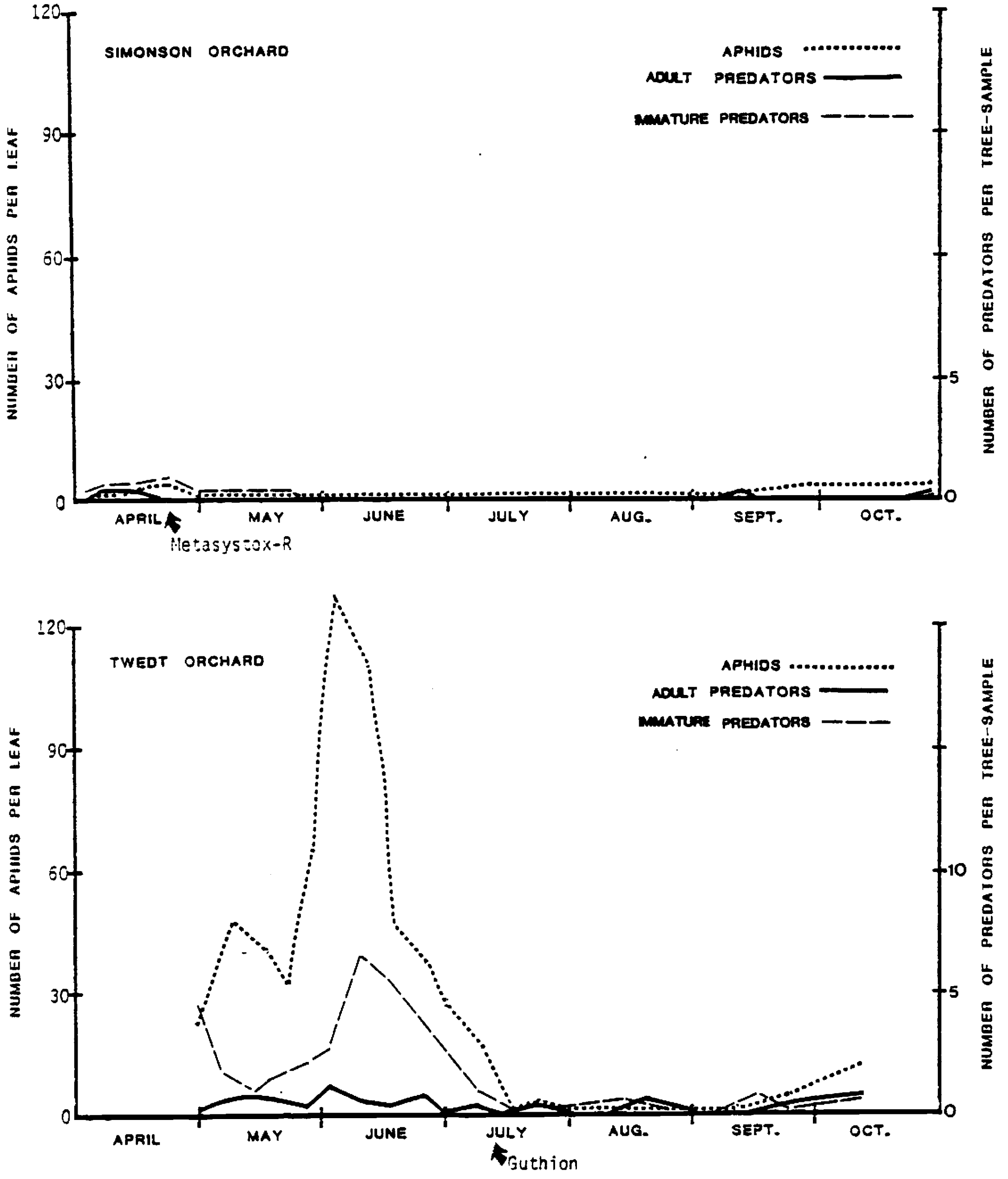


Figure 11a. Total syrphids

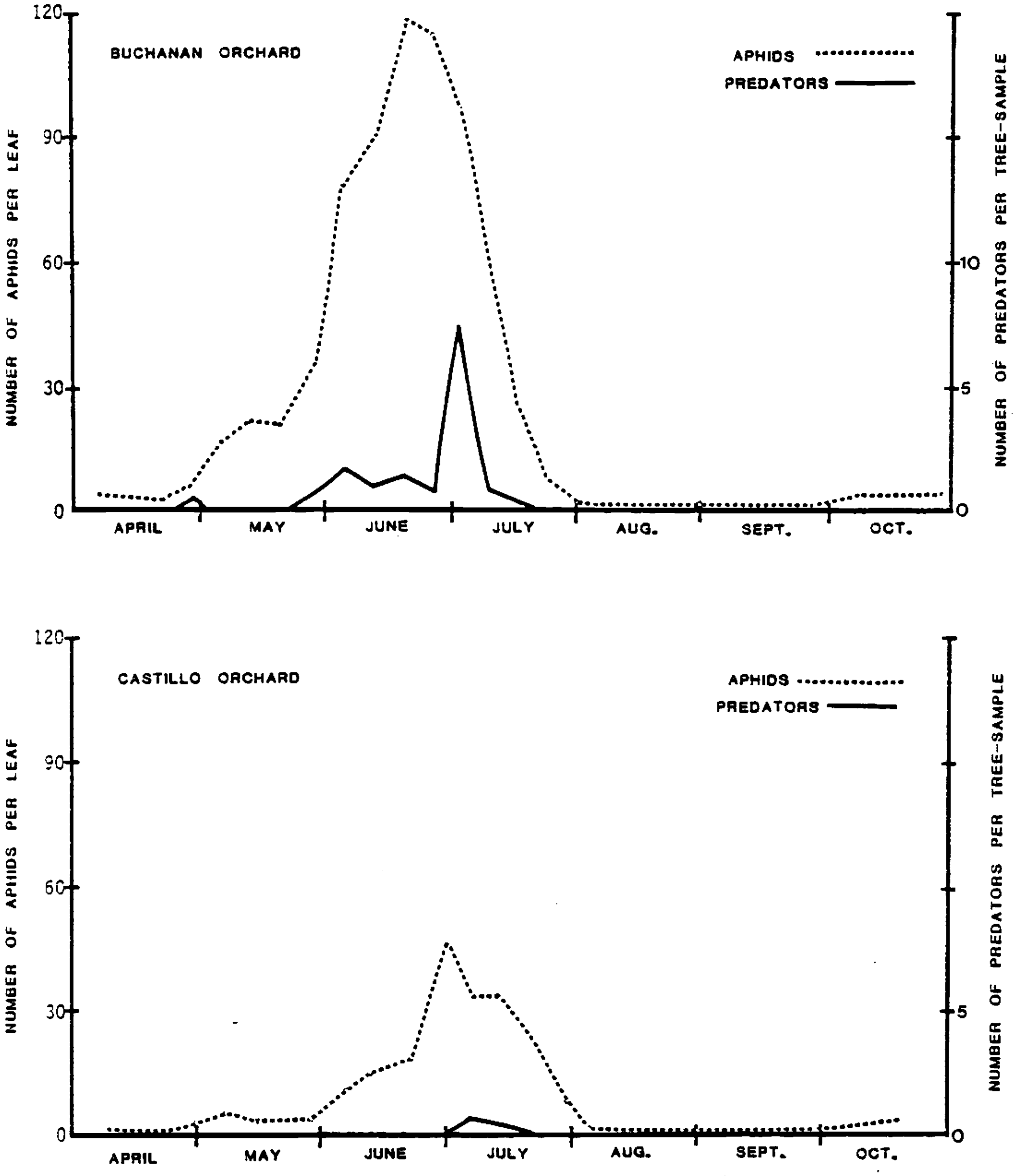


Figure 11b. Total syrphids

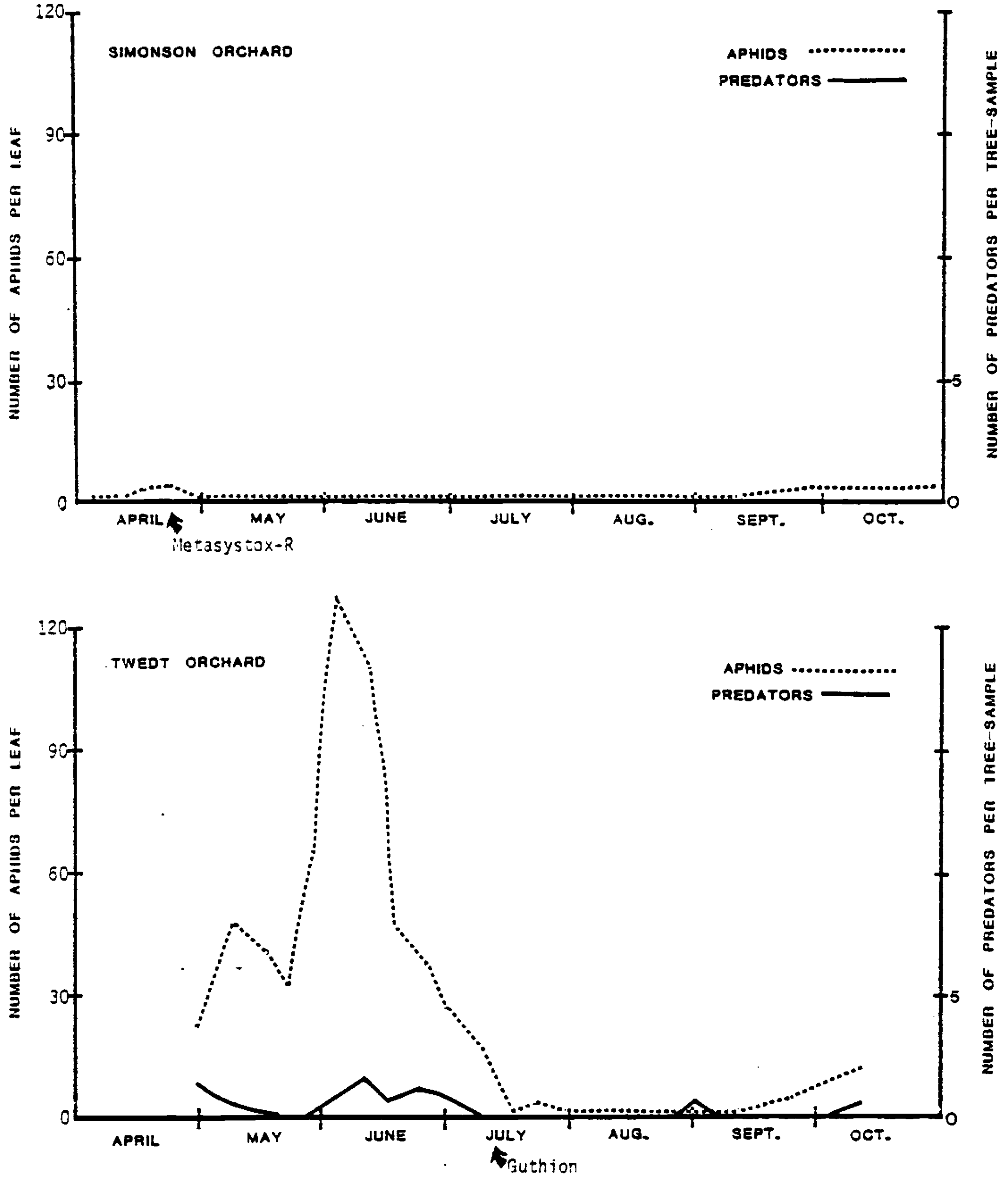


Figure 12a. A. antevolans

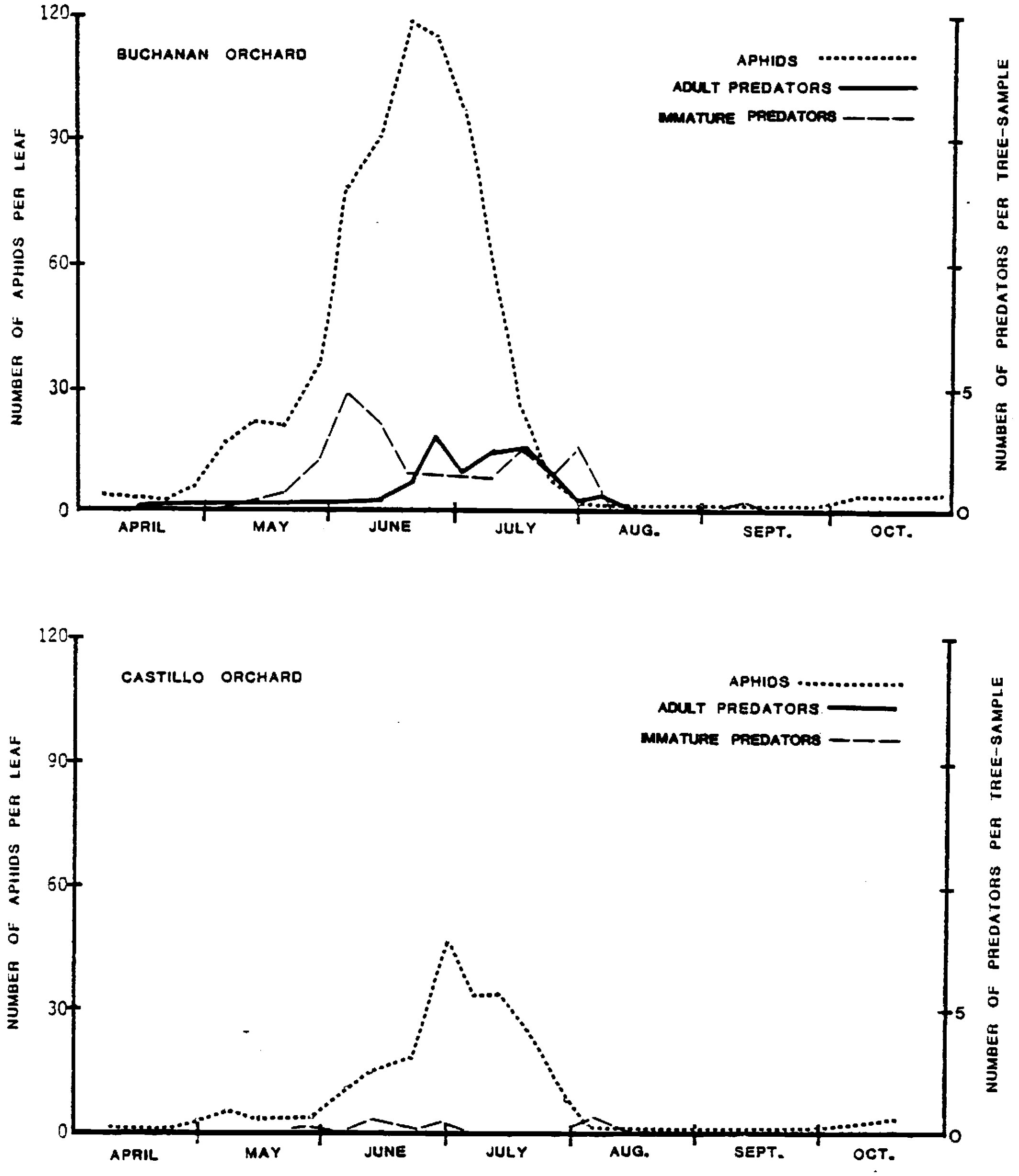
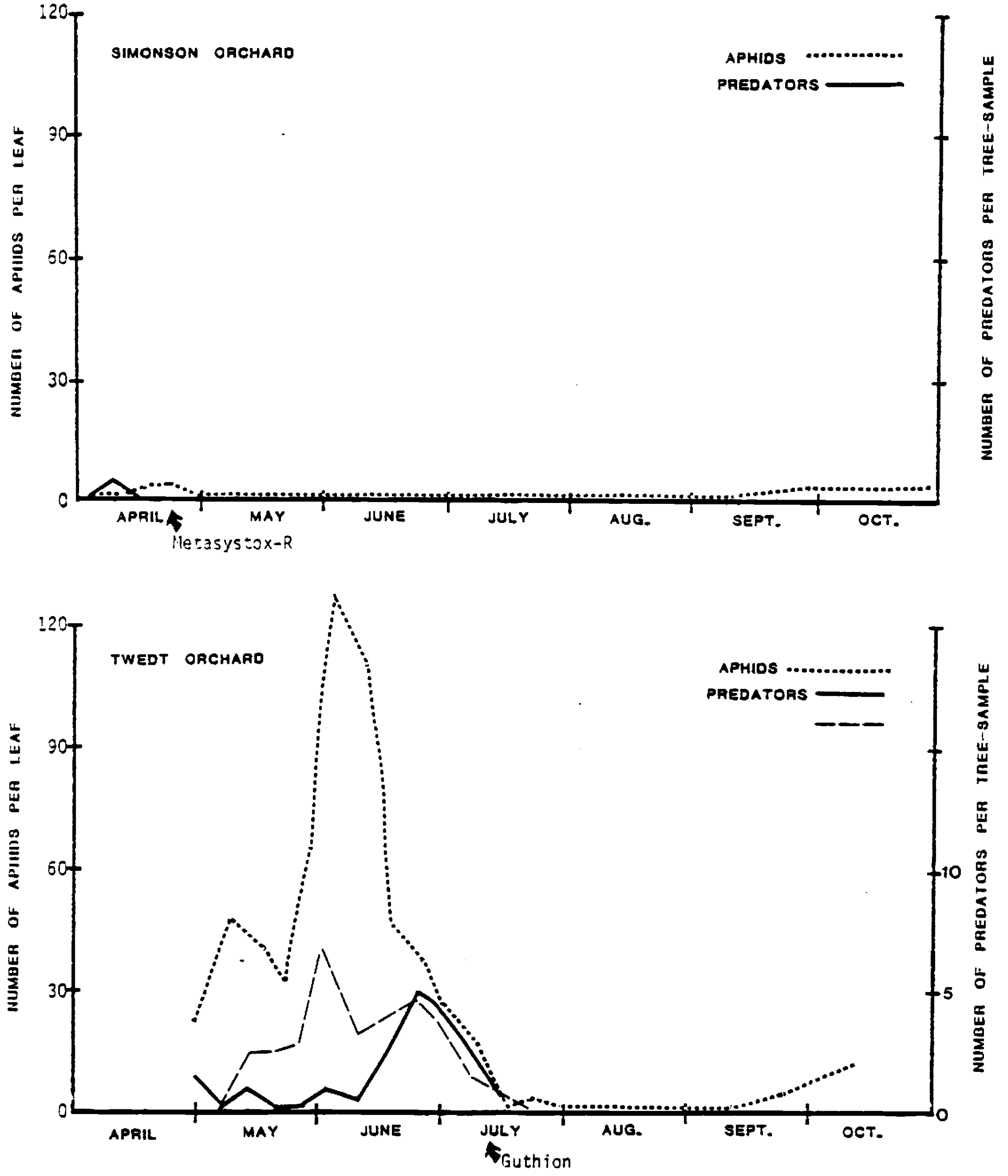


Figure 12b. A. antevolans



most of them from one limb. This indicates some degree of aggregation, and lends further support to the conclusion that within the Willamette Valley, *A. bipunctata* overwinters within the filbert orchards. This species has also been reported to overwinter in orchards in Europe (Hodek, 1973). The overwintering of *A. bipunctata* within the orchard is an important phenomenon, since it provides an immediate source of biological control when the filbert aphid hatches in the spring. Moreover, there is no gap or "lag time" in which aphid numbers can get a significant "head start," a problem with many other coccinellid aphid systems. (Hagen and van den Bosch, 1968).

Another aspect of *A. bipunctata* life history brought out by the data in Figure 2 is the distinct possibility that this species is bivoltine in the moderate climate of western Oregon. The graph from Buchanan's orchard shows a distinct peak in April-May, which represents the overwintering adults, another large peak in July, and a relatively small peak in October, which would then be the second generation and the one that carries over the next winter. The data from Twedt's orchard, although incomplete for the month of April, also seem to indicate the possibility of two distinct generations during the season. This conclusion is consistent with developmental data for the species, and bivoltinism has been reported for *A. bipunctata* in at least one other instance (Hagen, 1962). The importance of this bivoltinism is that it allows for a more efficient numerical response of the predator to the prey population.

An important factor in the reproductive success of a predator is the initial population density of the prey, and Dixon (1970) has shown that Adalia bipunctata first instar larvae require an initial aphid population density of 1.7 aphids per 100 cm^2 leaf area in order to survive. The data for Castillo's orchard (Figure 2a) show an initial colonization or emergence of overwintering A. bipunctata adults, which subsequently died out or emigrated, apparently due to the low numbers of aphids present in the orchard. This indicates the dependence of A. bipunctata upon the filbert aphid as a food source in filbert orchards early in the season.

The phenological data for the second most common coccinellid in the filbert orchards, Cycloneda polita, show the more typical univoltine life cycle, (Fig. 3, a,b). There is a peak in May which represents the overwintering adults, and a second peak in July depicting the next generation, which overwinters the following year. Small numbers of C. polita adults were found in early April but the peak of overwintering adults does not occur until mid-May. It is not known whether this is due to a higher temperature requirement for springtime activity than A. bipunctata, or because the C. polita overwinter outside the orchards and must recolonize each spring. In any event, the later arrival of C. polita may have enabled this species to successfully colonize and reproduce in the Castillo orchard whereas the A. bipunctata could not, as a higher aphid population was present at the later date.

The data for total coccinellids, adults and larvae of all species (Fig. 4, a,b) emphasize both (a) the requirement of sufficient aphid numbers early in the season for the adults to remain and reproduce in the orchards, and (b) the apparently effective numerical response to dense aphid populations later in the summer. The results from Twedt's orchard also point out the severe disruptive effects of organophosphate insecticides on the remaining coccinellid adults.

Among the Miridae, the most important predator of the filbert aphid is *Deraeocoris brevis*, whose seasonal phenology is depicted in Figure 5. Of all predaceous mirids in filberts, *D. brevis* alone has a multivoltine life cycle, as is shown most clearly in the data from Castillo's orchard. The multiple generations allow a greater opportunity for numerical response, which makes this a most valuable predator. Also, it may be seen from both Castillo's and Simonson's orchards that the overwintering *D. brevis* adults are active quite early in the spring. As with the coccinellid *A. bipunctata*, *D. brevis* was found in filbert trees in appreciable numbers both very early and very late in the season, suggesting that overwintering occurs directly on the filbert trees. In several filbert trees which were completely isolated in solid plastic enclosures from December until March for a pollination study, I found several adult *D. brevis* within the enclosures during the first week of March, thus indicating that they were overwintering on the tree. This allows for a very close synchrony between the predator and its prey. *D. brevis* adults were observed as late as November 11 to be actively feeding upon aphids in the field. An observation of possible significance is that the two orchards with the highest early season populations of *D. brevis* (Castillo and Simonson) were also the two that were the oldest and the most covered with lichens and mosses, thus providing ideal sites for the overwintering adults.

The other important predaceous mirids in the filbert ecosystem are *Deraeocoris fasciolus*, *Heterotoma meriopterum*, *Paraproba nigrinervis*, and *Compsidollon salicellum*, whose seasonal phenologies are shown in Figures 6, 7, 8, and 9 respectively. These four species are all univoltine, with overwintering eggs hatching in late spring, a single generation maturing through the summer, and adults mating and laying the next generation of eggs to overwinter. The populations of adult *P. nigrinervis* and *D. fasciolus* appear to peak in early to mid-July, while *H. meriopterum* and *C. salicellum* adults peak more towards the end of July or early August.

Appreciable numbers of lacewings were found in the study orchards. However, since the lacewings (Chrysopidae and Hemerobiidae) could not be field identified to species level, the phenology given for lacewings (Figure 10) is a total of at least four different species of the genus *Hemerobius* and two of the genus *Chrysopa*. The one important point these data bring out is the very early appearance of lacewing larvae in the field, again pointing towards a close synchrony between predator and prey. This is consistent with the data reported by Neunschwander (1976) for *Hemerobius pacificus* and possibly other *Hemerobius* species. Of the *Chrysopoids*, it was noted that the "trash-carrying" larvae, probably *Chrysopa placita*, appeared earlier in the season (early April - late May) than the non-trash carriers, *Chrysopa carnea*.

Syrphids were abundant in only one of the four orchards studied, and while specimens of at least four different species have been identified, it is not known which of these might be more common or widespread. Although the larvae are extremely voracious, the syrphids do not appear until very late in the season, and furthermore are very prone to parasitism.

Anthocoris antevolans was fairly abundant in two of the four orchards studied, but in both cases populations did not reach appreciable levels until quite late in the spring. Although *A. antevolans* overwinters in the adult stage and is reported to emerge from hibernation in late March in Corvallis (Anderson, 1958), it may be that the adults overwinter on hosts other than filbert (i.e., willow), and are somewhat slow to recolonize filbert orchards in the spring. The data from Buchanan's orchard do seem to indicate that *A. antevolans* emigrates from the orchards once the aphid population crashes, and are thus not present at the crucial "initiation phase" (Smith, p. 285 in Hodek 1966) the following season.

van Emden (p. 227 in Hodek, 1966) states that the effectiveness of aphidophagous insects is determined largely by considerations which fall into the three major categories of *voracity*, *synchronization*, and *reproductive rates*. The synchronization "of predator and prey in both time and space is the most critical element at the very beginning of the "initiation phase." Based upon this criterion the field data for filbert orchards show that *Adalia bipunctata*, *Deraeocoris brevis*, one or more species of Hemerobius, and possibly Chrysopa placita are the most effective predators of the filbert aphid.

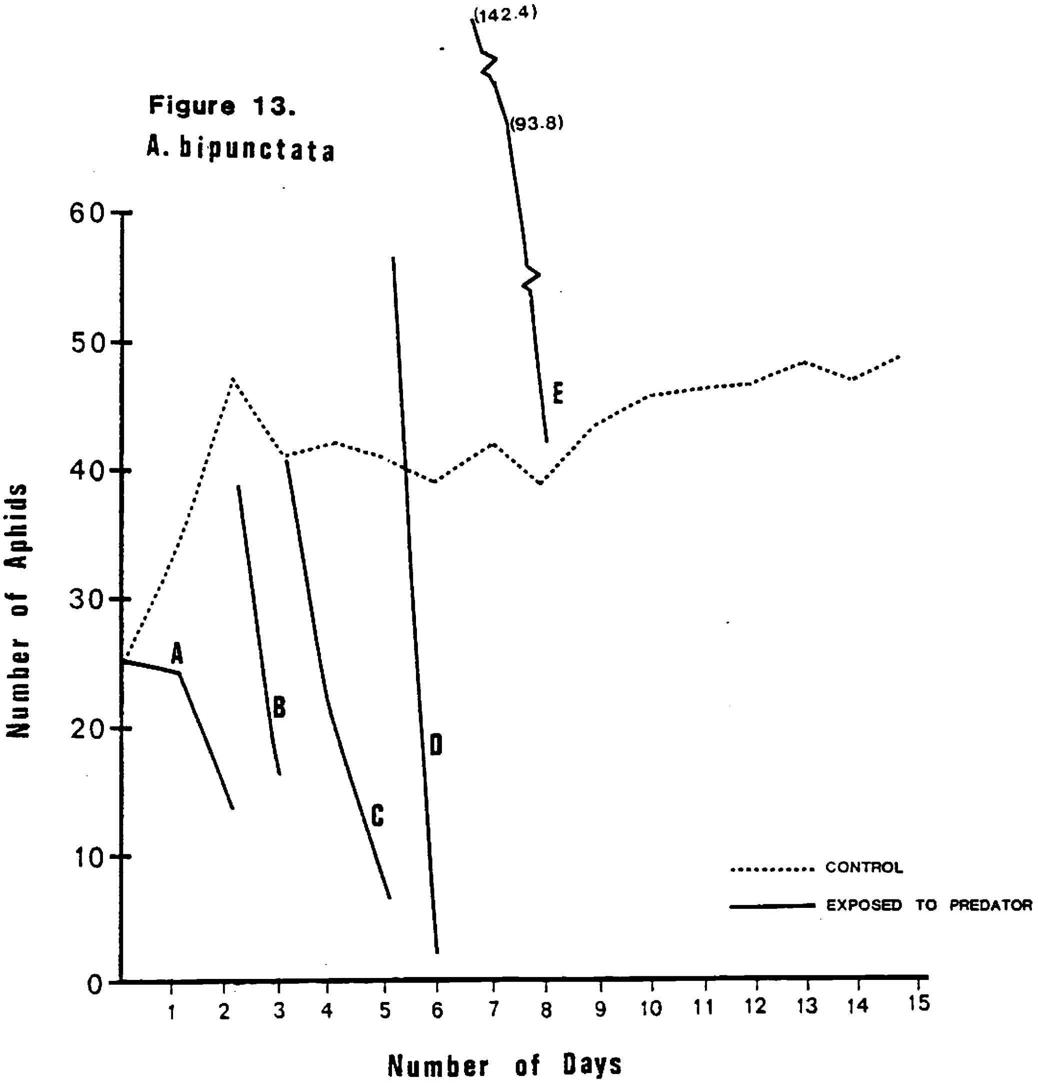
C. Feeding Potential of Common Predators

The voracity of several of the aphid predators as determined by laboratory feeding studies is indicated in Figures 13-16. In each figure the dashed line shows the mean of populations of aphids maintained as controls, while the series of solid lines indicates successive feeding trials of the predator, each new trial beginning with an input of more aphids following severe reductions due to predation.

It is clear from Figure 13 that the larvae of A. bipunctata had a severe impact on the aphid population, and were shown to be the most voracious of the predators tested. The slope of the line representing each successive trial becomes steeper, depicting the increased voracity of the larger, later instar coccinellids. The estimates of number of aphids eaten per A. bipunctata larvae per day are somewhat higher than that reported by Clausen (1916) and Iperti (P.189 Hodek, 1966) using other aphid species as prey. Also, first instar coccinellid larvae were seen to capture and devour full grown nymphs and even adult filbert aphids. This may reflect the relatively small size of M. coryli and possibly a weakness in physical defense responses.

Figures 13-16. Voracity of four filbert aphid predators as determined in laboratory feeding studies, 1981.

Figure 13.
A. bipunctata



Mean number of aphids eaten per predator per day

A~13.1

B~25.8

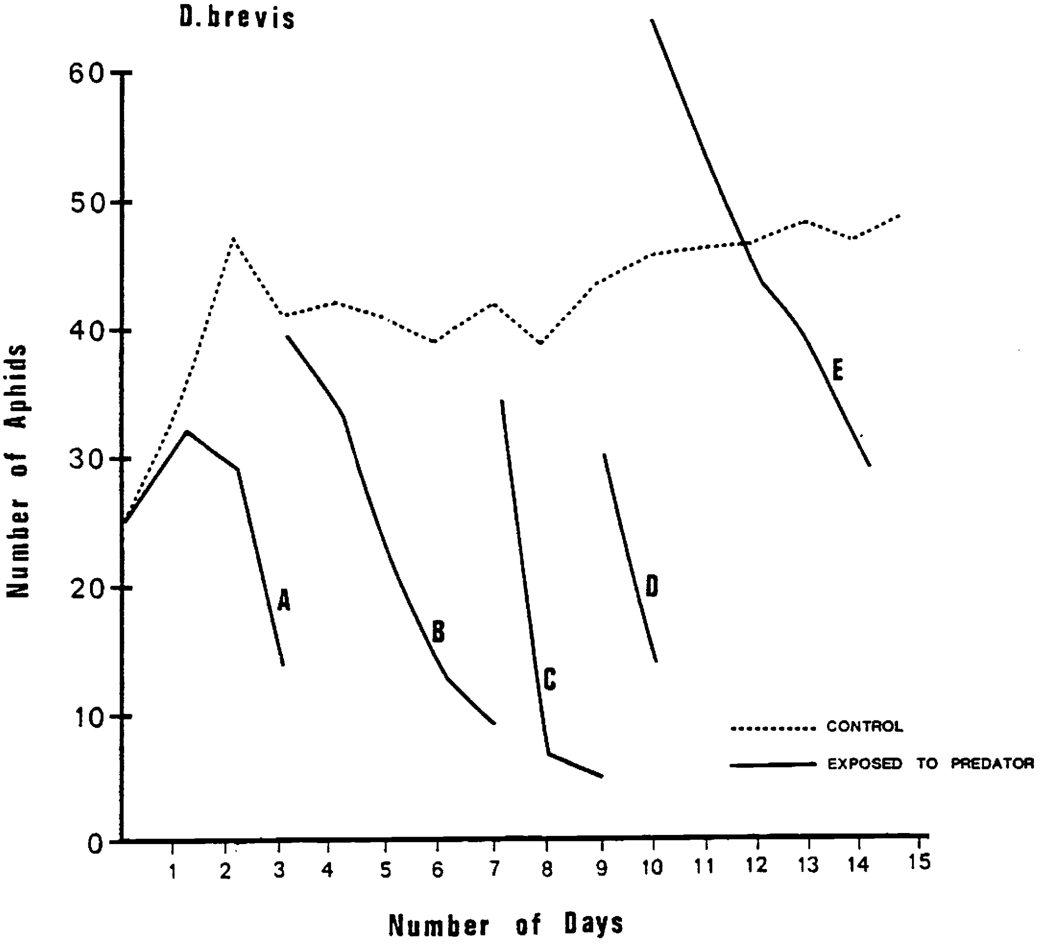
C~20.3

D~54.5

E~64.5

Figure 14.

D.brevis

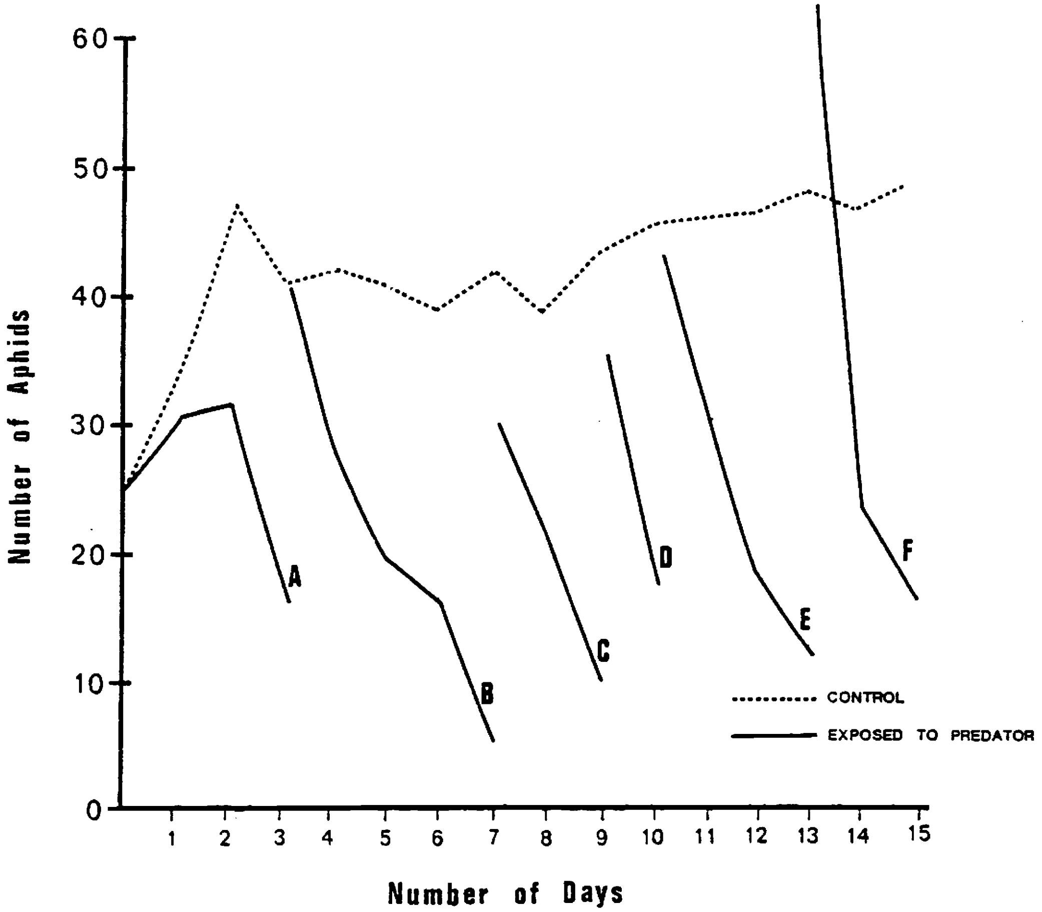


Mean number of aphids eaten per predator per day

A~9.1	D~18.9
B~8.8	E~20.3
C~13.4	

Figure 15.

H. meriopterum



Mean number of aphids eaten per predator per day

A~4.5

B~10.3

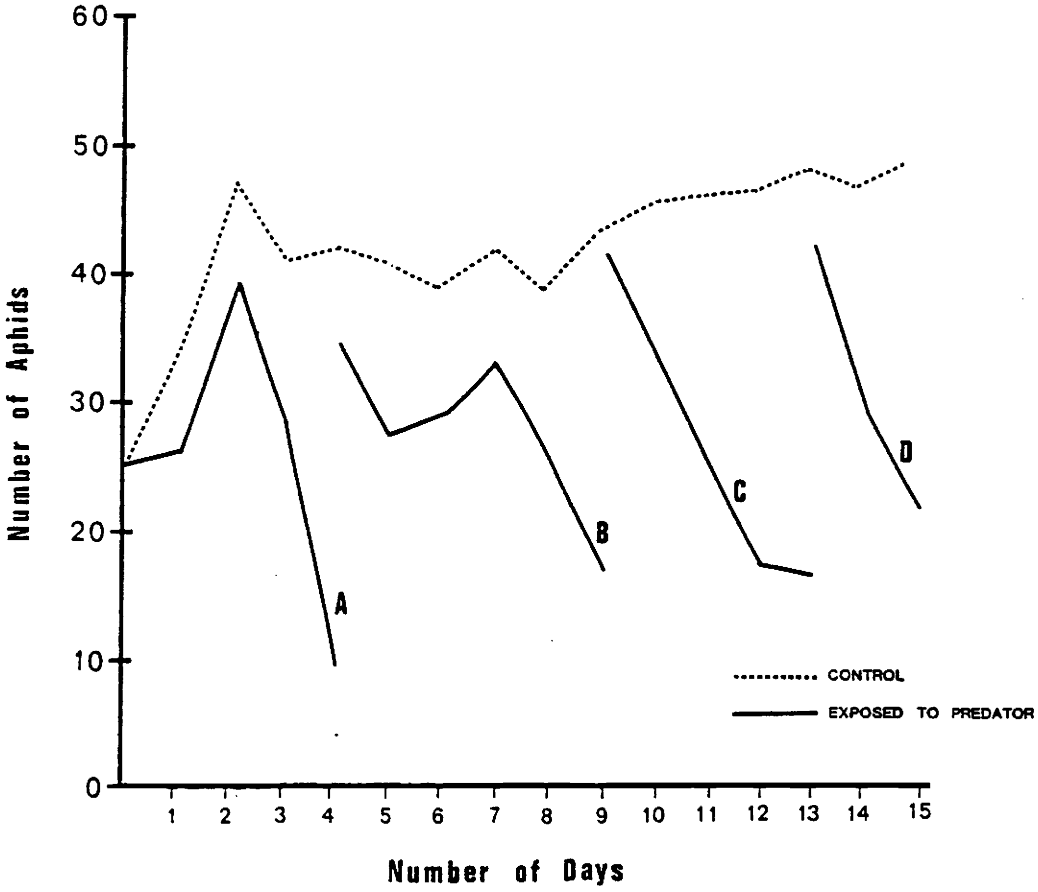
C~16.1

D~21.8

E~18.0

F~25.7

Figure 16.
C. salicellum



Mean number of aphids eaten per predator per day

A~ 5.5
B~7.4
C~11.6
D~17.3

The data for *D. brevis* (Figure 14) again show a profound impact upon the aphid population, although the voracity per predator per day is much less for the mirid than for the coccinellid. The pattern of consumption exhibited by *D. brevis* in this experiment is fairly close to that reported by Westigard (1973) using pear psylla as prey: an increased rate of consumption for instars one through four, a levelling off in the fifth instar, and a decrease in the adult stage.

The voracity of *H. meriopterum* (Figure 15) appeared similar to that of *D. brevis*, with later instars showing generally increased consumption and the number of aphids eaten per day of approximately the same magnitude. The main difference appears to be that the adult *H. meriopterum* do not show the decrease in prey consumption which appears typical of *D. brevis*.

The data for *C. salicellum* (Figure 16) show this to be the least voracious of the predators tested in this experiment. The relatively few numbers of aphids eaten per day probably indicate an increased use of phytophagy to meet the nutritional needs of this species. Most of the mirids present in the filbert system are thought to be partially phytophagous as well as aphidophagous (J. Lattin, personnal communication), and based on this feeding experiment, it appears that *C. salicellum* relies less upon the aphids as a food source. Nevertheless, the aphid populations exposed to *C. salicellum* did show a reduction in numbers and it may be concluded that this species does contribute to the overall natural biological control in the field.

Table 5 shows the average longevity under these experimental conditions for predators maintained with and without aphid food. These data bring out two important points about the predators' feeding biology. Firstly, the large difference in longevity between the coccinellid and the mirids kept without aphids illustrates the extreme dependence of the coccinellid larvae upon the aphids as a food source. The mirids, on the other hand, appear to sustain themselves for a considerable amount of time on nourishment derived from the plant material. This is important in that it may allow the mirids to become established or remain in an orchard during periods of aphid scarcity, whereas a coccinellid population might become locally extinct or would have to migrate.

Secondly, although the three species of Miridae which were tested lived for a considerable time period without aphid food, in each case they lived longer when they did have access to aphids as prey. Thus, although the mirids appear flexible with regard to the food they consume, they do experience greater longevity and perhaps greater overall reproductive success when aphid prey is available.

Table 5. Longevity of Predators Maintained with and Without Aphid Food Under Laboratory Conditions. (24°C. - 17L:7D)

Species	Mean Longevity (in days ± S.D):	
	with aphids	without aphids
A. bipunctata	13.0±3.2	2.3±0.5
D. brevis	14.0±0	10.5±3.5
H. meriopterum	14.0±0	10.6±2.7
C. salicellum	14.0±0	11.6±5.2

D. Effect Of Insecticides on Certain Selected Predators:

1. Field Trials

Tables 6a to 6h show the effects of commonly used insecticides on both aphids and predators as determined in a field spray trial at Twedt's orchard in Corvallis. Numbers showed a very large amount of variation, as is seen in the large standard deviation values (Table 6 a). This variation may be due in part to unaccounted differences between filbert varieties in the orchard.

The first week's post-treatment counts show that all insecticides severely reduced aphid numbers compared to unsprayed trees, but no statistical difference was noticed between various chemicals. Metasystox-R seemed to be the most effective chemical. Diazinon, Zolone, Systox, and Thiodan were moderately effective, and Sevin was the least effective of all the tested compounds. By the fourth week, statistically valid differences were recorded among the different treatments.

The data also reveal the approximate length of time each chemical remained effective in the field: Zolone, Thiodan and Systox show large aphid increases between the fourth and fifth week; Diazinon shows an increase between the third and fourth week; and Metasystox-R appears to be still quite effective five full weeks following application.

The data for the various predators (Tables 6b to 6h) do not show any clearcut differences between the different chemical treatments. While for some predators (*C. polita*, *D. brevis*) the numbers sampled were

Table 6a. Effect of Insecticides on the Filbert Aphid, Corvallis, Oregon, Treated May 1, 1981.

Chemical	Rate Lbs.AI/100 gal.	Pre treatment[1]	Post-treatment				
			1 wk	2 wk	3 wk	4 wk	5 wk
Diazinon	0.50	24.9±11.8a	0 a	4.5±1.4a	7.4±2.7a	23.6±8.0ab	43.1±19.2b
Zolone	0.37	16.4±24.5a	0.1±0.9a	0.8±1.0a	1.5±1.2a	4.4±4.4ab	38.5±11.3b
Metasystox R	0.25	24.5±18.0a	0.3±6.5a	0 a	0.1±1.3a	1.1±1.3a	6.1± 1.2a
Systox	0.22	21.5±19.5a	0 a	0.2±0.3a	0.6±1.0a	6.2±3.2ab	35.0±24.8ab
Thiodan	0.50	17.0±12.1a	0.8±13.1a	1.0±1.2a	3.7±4.0a	12.4±9.6ab	30.9± 7.6ab
Sevin	1.00	20.8±14.1a	6.5±69.8a	7.7±2.8a	10.2±8.1a	27.2±12.1b	90.3±36.3c
Control	----	25.3±14.7a	34.0±12.8b	47.7±25.3b	27.6±5.1b	54.0±10.8c	133.3±41.3d

[1] Average # of aphids per leaf ± standard deviation; within each column, means followed by a common letter do not differ significantly one from the other at the 5% level of probability.

Table 6b. Effect of Insecticides on <u>Adalia bipunctata</u> adults, Corvallis, Oregon, Treated May 1, 1981.

Chemical	Pre-treatment[1]	Post-treatment				
		1 wk	2 wk	3 wk	4 wk	5 wk
Diazinon	4.0 ± 0.8a	0 a	0 a	1.0 ± 0.8a	0.8 ± 1.0a	1.0 ± 1.2a
Zolone	3.2 ± 2.4a	0 a	0 a	0.2 ± 0.5a	0 a	0 a
Metasystox-R	3.5 ± 2.1a	0 a	0.2 ± 0.5a	0.5 ± 0.6a	0 a	0.5 ± 1.0a
Systox	2.8 ± 1.2a	0.2 ± 0.5a	0 a	0.5 ± 1.0a	0 a	0.5 ± 0.6a
Thiodan	6.0 ± 2.2a	0.8 ± 1.5a	0 a	0.8 ± 1.0a	0.2 ± 0.5a	0 a
Sevin	3.0 ± 1.4a	0 a	0.5 ± 0.6a	0.2 ± 0.5a	0.2 ± 0.5a	0 a
Control	4.2 ± 2.0a	2.2 ± 2.6b	6.2 ± 5.4b	.2 ± 5.0b	2.0 ± 2.8a	0.8 ± 1.0a

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[1] Average # of aphids per leaf ± standard deviation; within each column, means followed by a common letter do not differ significantly one from the other at the 5% level of probability.

Table 6c. Effect of insecticides on *Cycloneda polita* adults, Corvallis, Oregon, Treated May 1, 1981.

Chemical	Pre-treatment 1/	Post-treatment				
		1 wk	2 wk	3 wk	4 wk	5 wk
Diazinon	.25 ± .50a	0.2 ± 0.5a	0.5 ± 0.6a	0.2 ± 0.5a	0	0.8 ± 0.5a
Zolone	.75 ± 1.5a	0.2 ± 0.5a	0.5 ± 0.6a	0	0.2 ± 0.5a	0 a
Metasystox R	1.0 ± 1.4a	0.2 ± 0.5a	0 a	0.5 ± 0.6a	0 a	0.2 ± 0.5a
Systox	1.0 ± 2.0a	0 a	0 a	0 a	0 a	0 a
Thiodan	.25 ± .50a	0 a	0.2 ± 0.5a	1.0 ± 1.2a	0 a	0 a
Sevin	0.5 ± 0.6a	0 a	0 a	0 a	0 a	0 a
Control	1.8 ± 2.1a	0.2 ± 0.5a	1.2 ± 1.2a	0.2 ± 0.5a	0.8 ± 1.0a	0.2 ± 0.5a

1/ Average # of aphids per leaf ± standard deviation; within each column, means followed by a common letter do not differ significantly one from the other at the 5% level of probability.

Table 6d. Effect of Insecticide on Coccinellids, Corvallis, Oregon, Treated May 1, 1981.

Chemical	Pre-treatment[1]	Post-treatment				
		1 wk	2 wk	3 wk	4 wk	5 wk
Diazinon	6.2 ± 2.5a	0.2 ± 0.5a	1.2 ± 0.5a	3.0 ± 2.0a	1.2 ± 1.2a	3.2 ± 2.6a
Zolone	6.5 ± 2.4a	0.8 ± 0.5a	0.8 ± 0.5a	0.2 ± 0.5a	0.8 ± 0.5a	1.8 ± 1.5a
Metasystox R	7.2 ± 3.9a	0.2 ± .05a	1.0 ± 1.4a	1.5 ± 1.7a	0 a	1.5 ± 2.4a
Systox	6.2 ± 2.2a	0.5 ± 1.0a	0.2 ± 0.5a	1.2 ± 1.5a	2.5 ± 3.1a	2.2 ± 1.9a
Thiodan	8.5 ± 3.0a	1.5 ± 3.0a	0.5 ± 0.6a	1.8 ± 0.5a	1.2 ± 1.5a	1.5 ± 1.7a
Sevin	5.0 ± 1.6a	0.8 ± 1.5a	0.5 ± 0.6a	1.0 ± 1.4a	1.2 ± 1.5a	2.0 ± 2.4a
Control	8.5 ± 3.3a	5.0 ± 3.7b	11.2 ± 5.3b	8.8 ± 6.0b	15.0 ± 13.1b	32.0 ± 24.1b

[1] Average # of aphids per leaf ± standard deviation; within each column, means followed by a common letter do not differ significantly one from the other at the 5% level of probability.

Table 6e. Effect of Insecticide on Deraeocovis brevis, Corvallis, Oregon, Treated May 1, 1981

Chemical	Pre-treatment[1]	Post-treatment				
		1 wk	2 wk	3 wk	4 wk	5 wk
Diazinon	.75 ± .50a	0 a	0	0	0 a	0 a
Zolone	0 a	0.5 ± 0.6a	0	0.2 ± 0.5a	0 a	0 a
Metasystox R	.25 ± .50a	0 a	0.2 ± 0.5a	0 a	0 a	0 a
Systox	1.25 ± 2.5a	0.2 ± 0.5a	0 a	0 a	0 a	0 a
Thiodan	1.0 ± 1.4a	0 a	0 a	0.2 ± 0.5a	0 a	0 a
Sevin	.75 ± 1.5a	0.2 ± 0.5a	0 a	0.8 ± 0.5a	0 a	0 a
Control	0.25 ± 0.5a	0.2 ± 0.5a	0.5 ± 0.6a	0.5 ± 0.6a	0.2 ± 0.5a	0.2 ± 0.5a

[1] Average # of aphids per leaf ± standard deviation; within each column, means followed by a common letter do not differ significantly one from the other at the 5% level of probability.

Table 6f. Effect of Insecticides on Lacewings, Corvallis, Oregon, Treated May 1, 1981.

Chemical	Pre-treatment[1]	Post-treatment				
		1 wk	2 wk	3 wk	4 wk	5 wk
Diazinon	3.2 ± 3.3a	0 a	0.2 ± 0.5a	0.8 ± 1.0ab	0.5 ± 0.6a	2.0 ± 2.0a
Zolone	2.2 ± 2.2a	0 a	0.8 ± 0.5a	0 a	0 a	1.0 ± 0.8a
Metasystox R	5.8 ± 1.7a	0.5 ± 0.6a	0.2 ± 0.5a	1.2 ± 1.0ab	0.2 ± 0.5a	0.5 ± 0.6a
Systox	4.5 ± 0.6a	0.8 ± 0.5a	0.8 ± 1.5a	0.8 ± 1.0ab	0.2 ± 0.5a	1.2 ± 1.2a
Thiodan	4.5 ± 2.4a	0 a	0.2 ± 0.5a	1.0 ± 0.8ab	0.5 ± 0.6a	0.5 ± 1.0a
Sevin	3.2 ± 3.6a	0.2 ± 0.5a	0.8 ± 1.5a	0 a	0.2 ± 0.5a	0.5 ± 0.6a
Control	4.5 ± 1.0a	2.2 ± 3.7b	1.5 ± 1.3a	1.5 ± 1.0b	2.5 ± 0.6b	5.8 ± 2.1b

[1] Average # of aphids per leaf ± standard deviation; within each column, means followe by a common letter do not differ significantly one from the other at the 5% level of probability.

Table 6g. Effect of Insecticides on *Anthocarids*, Corvallis, Oregon, Treated May 1, 1981.

Chemical	Pre-treatment[1]	Post-treatment				
		1 wk	2 wk	3 wk	4 wk	5 wk
Diazinon	2.5 ± 1.0a	0 a	0 a	0 a	0 a	0 a
Zolone	.25 ± .50a	0.2 ± 0.5a	1.2 ± 1.0a	0.8 ± 1.0a	0 a	0.5 ± 0.6a
Metasystox R	1.0 ± 2.0a	0 a	0.2 ± 0.5a	0.5 ± 0.6a	0.2 ± 0.5a	0.2 ± 0.5a
Systox	3.2 ± 3.3a	0 a	0.2 ± 0.5a	1.0 ± 0.8a	3.2 ± 5.8a	0.2 ± 0.5a
Thiodan	1.0 ± 1.4a	0 a	0.2 ± 0.5a	0 a	0.8 ± 1.5a	0.2 ± 0.5a
Sevin	1.0 ± 1.4a	0 a	0 a	0.2 ± 0.5a	0.2 ± 0.5a	0.8 ± 1.5a
Control	1.5 ± 1.9a	0.2 ± 0.5a	2.8 ± 1.2b	3.0 ± 3.6a	3.5 ± 3.3a	4.2 ± 3.7b

[1] Average # of aphids per leaf ± standard deviation; within each column, means followed by a common letter do not differ significantly one from the other at the 5% level of probability.

Table 6h. Effect of Selected Insecticides on Total Predators, Corvallis, Oregon, Treated May 1, 1981.

Chemical	Pre-treatment[1/]	Post-treatment				
		1 wk	2 wk	3 wk	4 wk	5 wk
Diazinon	12.8 ± 6.0a	0.2 ± 0.5a	3.8 ± 2.4a	6.0 ± 2.9a	3.5 ± 1.9a	6.0 ± 3.6a
Zolone	9.0 ± 2.8a	1.5 ± 0.6a	4.2 ± 1.5a	3.5 ± 2.1a	1.5 ± 1.0a	5.0 ± 4.5a
Metasystox R	14.2 ± 1.7a	0.8 ± 1.0a	3.8 ± 1.0a	4.2 ± 2.8a	1.0 ± 0.8a	4.2 ± 3.5a
Systox	15.5 ± 4.6a	1.5 ± 1.3a	2.2 ± 1.7a	4.5 ± 3.1a	6.5 ± 9.7a	5.2 ± 4.4a
Thiodan	15.0 ± 7.0a	1.5 ± 3.0a	2.0 ± 1.8a	5.8 ± 4.8a	5.0 ± 3.9a	3.0 ± 1.8a
Sevin	10.0 ± 4.7a	1.2 ± 1.9a	2.0 ± 1.8a	3.5 ± 2.1a	2.8 ± 1.0a	3.8 ± 3.2a
Control	14.8 ± 2.2a	7.8 ± 3.2b	28.2 ± 10.7b	30.0 ± 13.0b	32.8 ± 15.6b	56.5 ± 21.6b

[1/] Average # of aphids per leaf ± standard deviation; within each column, means followed by a common letter do not differ significantly one from the other at the 5% level of probability.

quite low and didn't show any significant (0.05 level) differences between treatments, one can see from looking at the effect on total coccinellids (Table 6d), total lacewings (Table 6f), and especially total predators (Table 6h) that all of the chemicals tested severely disrupted the predator complex. Similar results have been reported by other workers (Bartlett, 1964; Schneider, 1969). This illustrates the disruptive effect that standard filbert orchard treatment programs have on biological control of the filbert aphid.

Although this experiment did not detect significant differences in the survivorship of predators exposed to these different chemicals, larger sample sizes, larger spray blocks to reduce immigration, and more precise laboratory experiments may yet point out such differences.

D. brevis has been reported to show some tolerance to Guthion (McMullen & Jong, 1967b), and Thiodan and Zolone (Westigard, 1973). Thus, in orchards where this mirid is abundant, these chemicals should be preferred when a leafroller or filbertworm treatment is necessary. At least one coccinellid, *H. convergens*, has also shown some tolerance to Thiodan (Moffit, et al., 1972).

2. Laboratory Insecticide Test

In order to more closely examine the relative effects of the insecticides on the major predators of the filbert aphid, a number of chemicals were tested in the lab against *A. bipunctata* and *D. brevis*. The results of this test are given in Table 7.

Although the rate of insecticide used was only one-half of that recommended for orchard use, the data show that with direct exposure these two important predators experienced virtually 100% mortality with every spray except Zolone. This reduced mortality with Zolone confirms some preliminary studies which were carried out in 1980.

Zolone is widely used among filbert growers for an early season aphid-leafroller treatment. Although the field insecticide tests reported in this study show it to be less effective against aphids than Metasystox-R, its reduced toxicity to the predators may make it a preferred aphicide. Referring to the field spray trial in this study, it should be noted that only a few individual trees in a large orchard were sprayed with each chemical, and the huge reservoir of undisturbed aphids undoubtedly facilitated the resurgence of aphid numbers in the Zolone treated trees. If, in orchard practice the entire crop were treated with Zolone, the resurgence might not be as rapid compared with the Metasystox-R treatment, and more of the valuable predators would be spared.

E. Biological Control Potential:

To demonstrate the impact of the predator complex on aphid populations in the field, a trial was conducted in which five single-tree replicates were treated with Sevin to exclude predators and compared to five similar but untreated trees. Data (Fig. 17) showed no significant difference (0.05 level) in the mean numbers of aphids per leaf at any time during the sampling period. If the insecticide were toxic to the predators while causing minimal damage to the aphid population, and if the predators significantly reduced the aphid population increase, one would expect to see more aphids in the

Table 7. Effect of Some Selected Insecticides on the Two Major Predators of the Filbert Aphid (Laboratory Study, 1981).

Chemical	Rate (LBS AI/100 Gal)	Mean 24-Hour Mortality: *A. bipunctata*	*D. brevis*
Sevin	0.50	100%	100%
Diazinon	0.25	100%	100%
Metasystox-R	0.12	100%	98%
Zolone	0.18	86%	56%
Guthion	0.25	100%	98%
Control	-	0%	10%

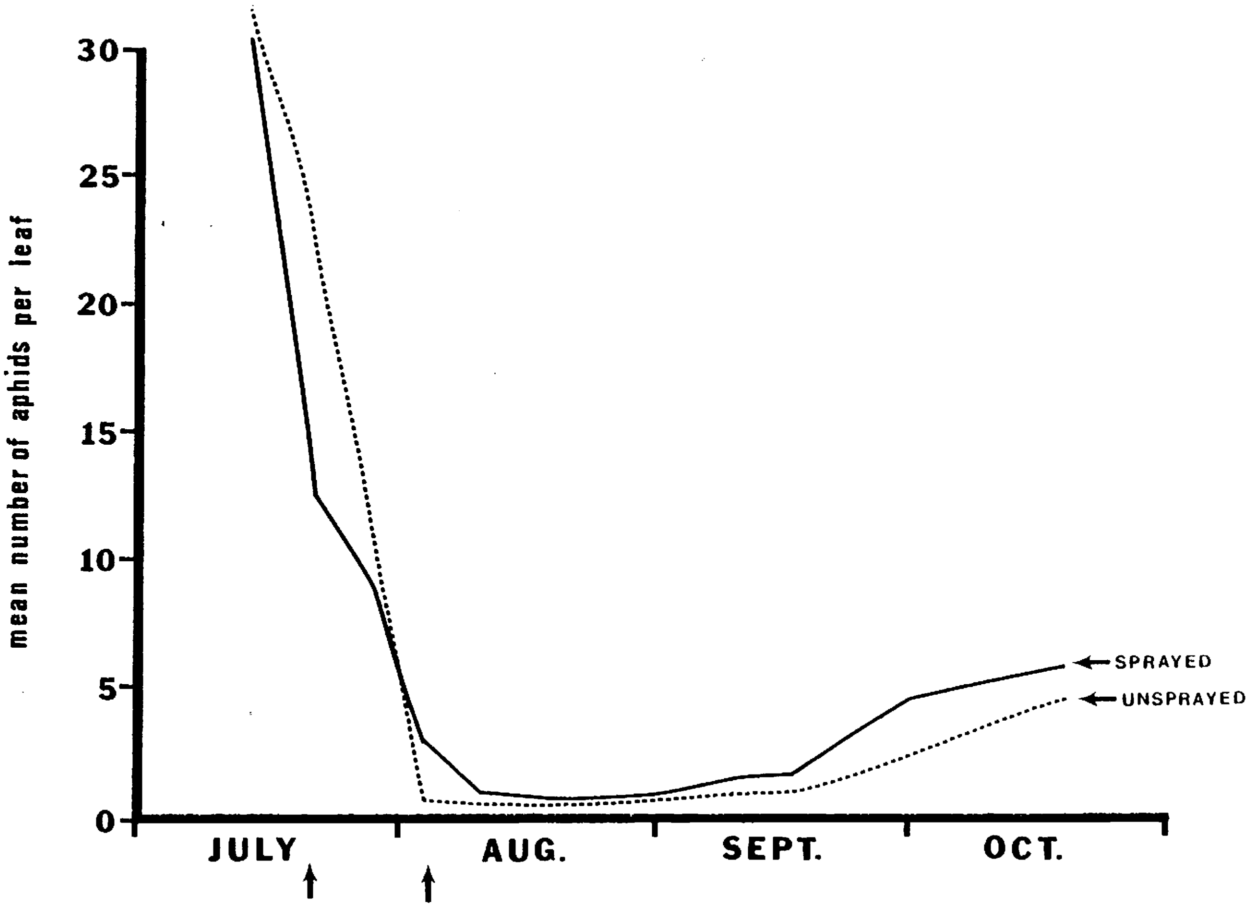


Figure 17. Results of a chemical exclusion test using single-tree replicates.
(arrows indicate dates of carbaryl application)

Sevin-treated trees. That this did not occur is probably due to the fact that the highly mobile predators re-colonized the sprayed trees. Because single-tree replicates were used, each sprayed tree was surrounded by at least eight unsprayed trees with high predator populations, which could serve to re-infest the treated trees.

In another trial, a 25-tree block was used to check for insecticide effect by minimizing the predator immigration. This block had received two carbaryl cover sprays during the season. Although it was realized that the entire block should have been replicated several times for statistical accuracy, this was not feasible at the time.

From within the single sprayed block, five trees were chosen at random each week and compared with five trees chosen at random from an unsprayed block. The results, illustrated in Figure 18, indicate that the block sprayed with carbaryl had significantly greater numbers of aphids at the end of the season than the control block. The exclusion of predators may have been responsible for this. Alternate hypotheses include the possibilities that soil or microclimate conditions affected leaf composition and indirectly aphid fecundity, or perhaps that the carbaryl actually had a direct stimulating effect on aphid reproduction.

In addition to gathering survey data on the biology and natural history of the filbert aphid and its natural enemies, this research attempted to document the impact of these enemies on aphid populations in the field. Although admittedly inconclusive, the results of the chemical exclusion test along with other indirect evidence point

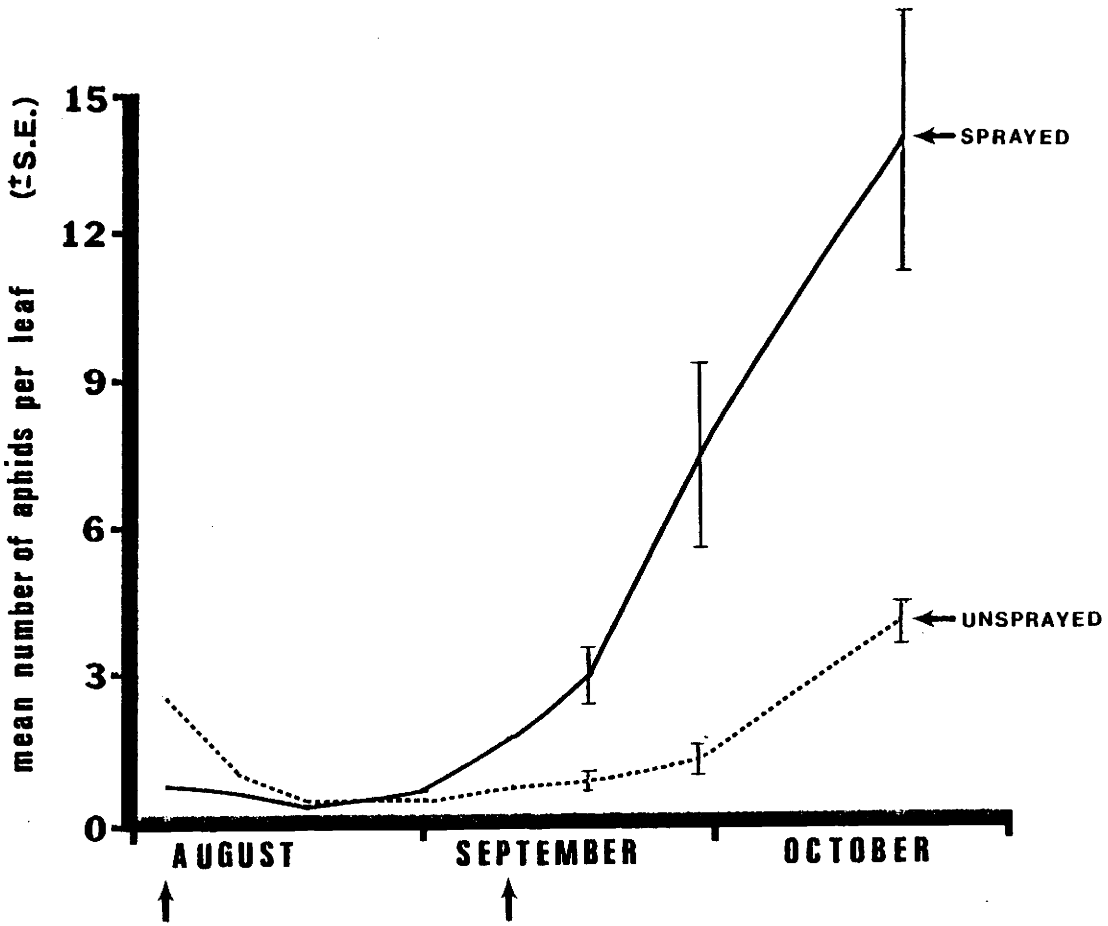


Figure 18. Results of a chemical exclusion test using a 25-tree sprayed block.
(arrows indicate dates of carbaryl application)

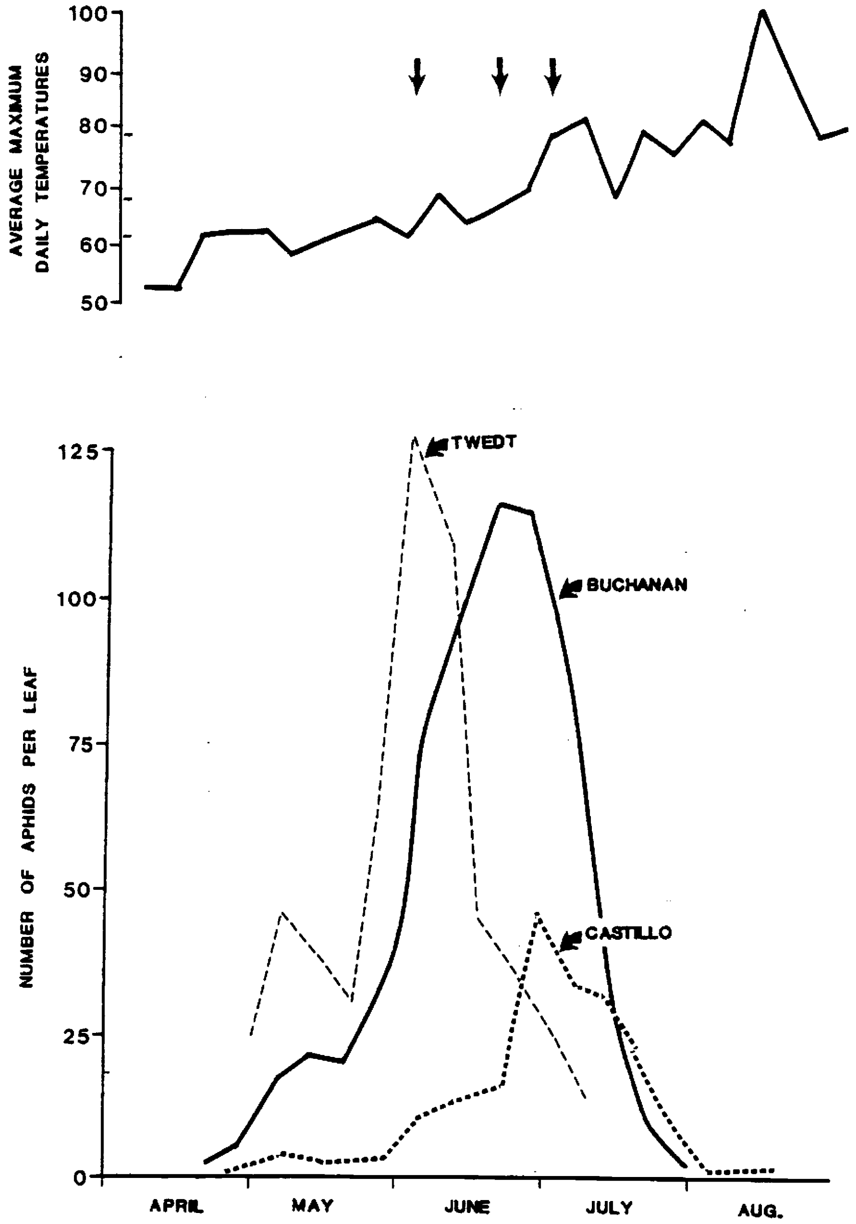


Figure 19. M. coryli population trends in three Benton County orchards, 1981- compared with daily maximum temperatures for the same period. (arrows indicate aphid peaks)

strongly towards the conclusion that predators exert a strong degree of natural biological control in Willamette Valley orchards.

It had been noted by Haidari (1959) and AliNiazee (1980) that the summer decline in filbert aphid numbers coincided with and was perhaps caused by the concurrent increase in daily maximum temperatures. While high temperatures may contribute to aphid mortality, it is the author's contention that the natural enemies are the primary factor causing the annual aphid crash.

In support of this contention, Figure 19 illustrates the filbert aphid population trends for three orchards in the Corvallis area in 1981, along with a record of maximum daily temperatures obtained from a Corvallis weather station. It may be seen that the peak and subsequent crash in aphid numbers occurred more than a month apart for the Twedt and Castillo orchards, even though both are within a ten mile radius of Corvallis and probably experienced temperatures within a few degrees of those recorded at the weather station. Both the Twedt and Buchanan orchards had aphid populations crash at a time when maximum daily temperatures averaged less than 70°F. (21°C). This would seem to indicate that high temperatures are not the primary cause of abrupt declines in aphid numbers.

Figure 20 shows the population trends for filbert aphids and the total predator complex, including all species and all life stages. In both the Twedt and Buchanan orchards, a rapid build-up of aphid numbers is followed closely by an increase in predator numbers, then a severe aphid crash, shortly before the predators reach their peak. Following

Figure 20. Seasonal phenology of the filbert aphid and its total predator complex in four Willamette Valley filbert orchards, 1981.

Figure 20a.

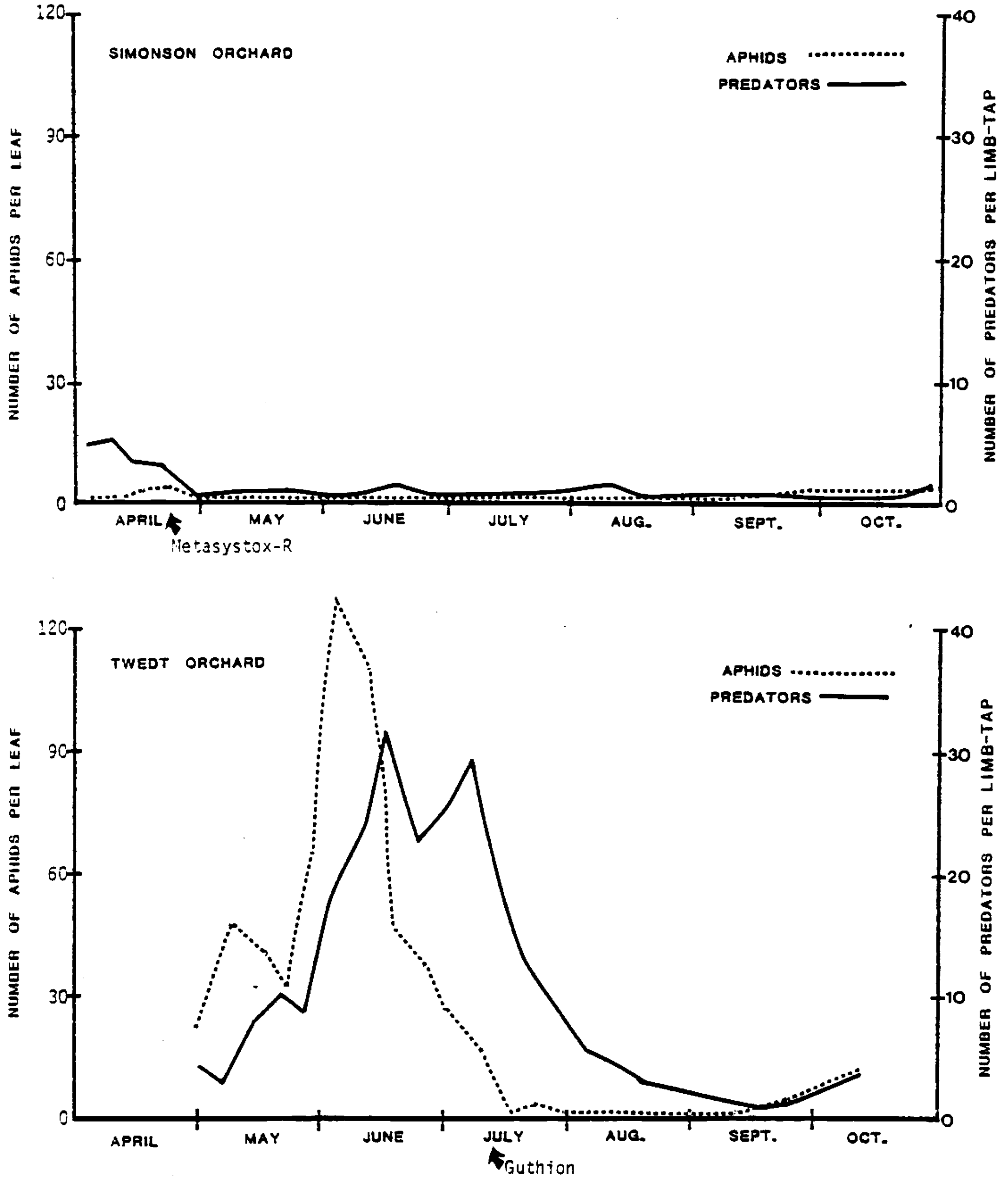
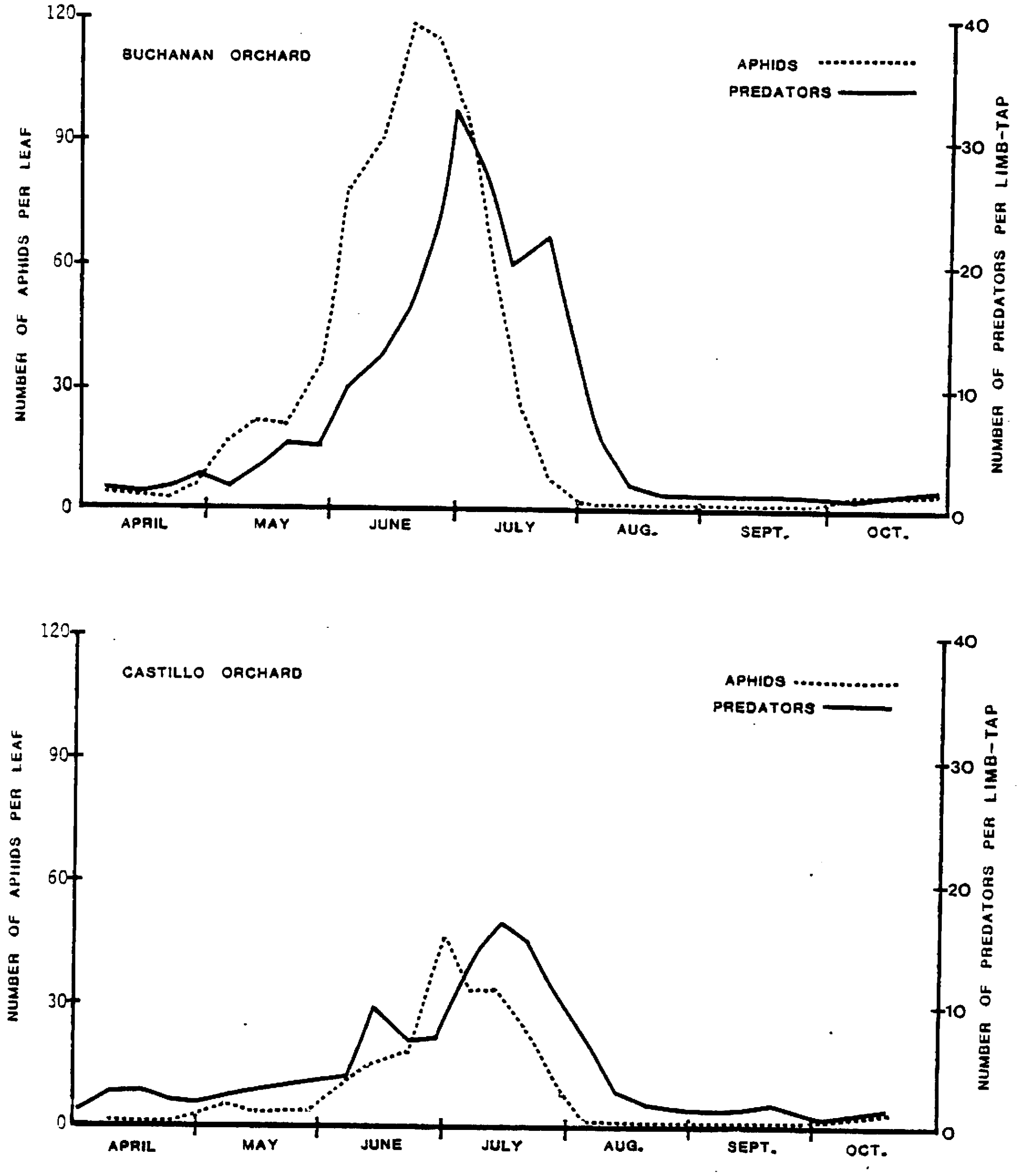

SIMONSON ORCHARD
APHIDS
PREDATORS
NUMBER OF APHIDS PER LEAF
NUMBER OF PREDATORS PER LIMB-TAP
120
90
60
30
0
40
30
20
10
0
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
Metasystox-R
TWEDT ORCHARD
APHIDS
PREDATORS
NUMBER OF APHIDS PER LEAF
NUMBER OF PREDATORS PER LIMB-TAP
120
90
60
30
0
40
30
20
10
0
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
Guthion

Figure 20b.


BUCHANAN ORCHARD
APHIDS
PREDATORS
NUMBER OF APHIDS PER LEAF
0
30
60
90
120
NUMBER OF PREDATORS PER LIMB-TAP
0
10
20
30
40
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
CASTILLO ORCHARD
APHIDS
PREDATORS
NUMBER OF APHIDS PER LEAF
0
30
60
90
120
NUMBER OF PREDATORS PER LIMB-TAP
0
10
20
30
40
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.

this, the predator numbers also crash. This illustrates a typical density dependant predator/prey cycle. In the Castillo orchard, the predator-aphid ratio appears significantly greater than the other orchards early in the season, and the subsequent population build-up is much less severe. While this type of correlative data cannot be taken to prove any cause-effect relationship, it is certainly consistent with the hypothesis that predators are numerically responding to aphid numbers and strongly influencing aphid population density.

Of particular interest is the temporary dip in aphid numbers which occurs in mid to late May and shows up quite dramatically in the Twedt orchard, less so in the Buchanan orchard, and just barely in the Castillo orchard. This is a feature of the aphid population curve which was not reported by Haidari (1959) but which may be of considerable significance. This early season dip may be the result of the voracious feeding by ovipositing female coccinellids, along with the combined impact of male coccinellids, overwintering D. brevis adults, and early-season Hemerobius activity. If the relationship between predator and aphid numbers can be correlated with subsequent aphid build-up with some degree of precision, it may be possible to determine in advance whether or not an aphicide treatment is required. The substantial impact which the predators have upon aphid population densities requires that predator sampling and conservation play a significant part in the overall integrated pest management in filbert orchards.

V. Summary and Conclusions

Filbert orchards throughout the Willamette Valley were surveyed to determine the natural enemies of the filbert aphid, *Myzocallis coryli* (Goetze). A large and diverse group of predaceous insects was found to prey upon the aphid, the most abundant being *Adalia bipunctata* and *Deraeocoris brevis*. A parasitic Hymenopteran (*Mesidiopsis* sp.) and a fungal pathogen (*Triplosporium fresenii*) were also found to attack the aphid.

Weekly sampling throughout the growing season showed that *A. bipunctata*, *D. brevis*, *Hemerobius* sp., and *Chrysopa placita* were the predators best synchronized with aphid field phenology, and most likely to affect aphid populations early in the season.

Laboratory feeding trials showed *A. bipunctata* to be a very voracious predator, severely reducing populations of the filbert aphid. *D. brevis*, *H. meriopterum*, and *C. salicellum* were less voracious than the coccinellid, but also strongly affected aphid numbers. Mirids lived longer without aphid food than the coccinellid.

Metasystox-R was shown to be the most effective chemical for aphid control in a field trial. Systox, Diazinon, Zolone, and Thiodan were moderately effective, while Sevin was relatively ineffective. Predators were very susceptible to all chemicals tested, although slightly less so to Zolone.

In at least one instance, aphids were shown to rebound in a sprayed block of trees to higher numbers than in a comperable unsprayed block. It is suggested that severe aphid outbreaks in commercial orchards are induced by insecticide disruption of natural biological control.

If one accepts this conclusion and considers predators to be a major factor in the control of filbert aphids, then a number of orchard management considerations become important, within the economic constraints of the grower. Of primary importance is a reduction in the pesticide load which impacts upon and disrupts the predator complex. This may be achieved by a variety of methods, including: a) The use of sampling and economic thresholds so as to spray only when necessary; b) the use of the minimum pesticide dosage necessary to control the target pest; c) the use of pheromone traps and other sampling techniques so as to improve the timing of insecticide applications and, where possible, to avoid the periods of peak predator activity; d) the use, where possible, of selective insecticides (e.g. Bacillus thuringiensis) which will control pests without affecting predaceous species; and e) possibly, the use of less than full cover sprays (i.e. spraying every other orchard row, or only the lower half of the tree canopy) so as to allow some predator survival as well as some aphid survival upon which the predators can feed.

Other avenues of consideration should include the use of various cover crops which might provide a pollen and nectar source for syrphid, coccinellid, and chrysopid adults, as well as host plants for non-economic aphids which might serve as alternate prey for the predators. Also, cultural techniques such as mowing, flailing and discing might be timed so as to induce movement of predators to the tree canopy at critical periods in the aphid life-cycle (Savoiskaya, p.317 in Hodek, 1966). In some cases inoculations of field-collected or laboratory-reared predators might prove a feasible, non-disruptive method of aphid control (Hodek, 1973). The creation of artificial overwintering shelters in or near the orchard (Iperti, p. 189 in Hodek, 1966) and the application of synthetic predator foods (Hagen, 1950) might also enhance the degree of natural biological control.

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