CALIFORNIA OAKWORM

Integrated Pest Management for Home Gardeners and Landscape Professionals

The California oakworm (*Phryganidia californica*, family Dioptidae) is one of many species of caterpillars that feeds on oaks. It is the most important oak-feeding caterpillar (Fig. 1) throughout its range, which extends along the coast and through the coastal mountains of California. Damage is most common on coast live oak (*Quercus agrifolia*) in the San Francisco Bay and Monterey Bay regions. Populations vary unpredictably year to year from very high to undetectably low. Healthy oaks generally tolerate extensive loss of leaves (defoliation) without serious harm, so treatment to control oakworms usually is not recommended.

IDENTIFICATION

The adult, called an oak moth, is a uniform tan to gray or silvery color and is distinguished by its prominent wing veins. The body is about 1/2 inch long, and the wingspread is about 1 1/4 inches. Unlike females, males have feathery antennae.

The female lays tiny, round eggs in groups of about two or three dozen, mostly on the underside of leaves. The eggs initially are white but develop

Figure 1. California oakworm larva

red centers that become pinkish to brownish gray before hatching into the larval stage (caterpillars).

Despite their common name, young oakworms are not wormlike but are small, yellowish green caterpillars with large, brown heads and dark stripes on their sides. Older caterpillars vary in color, commonly dark with prominent, lengthwise yellow or olive stripes.

Caterpillars range from 1/10 inch long when newly hatched to about 1 inch when fully grown. In the pupal stage they are white, yellowish, or pinkish with black markings, 1/2 inch long, and suspend from limbs, leaves, trunks, or objects near trees. Inside the colorful pupal case, also called a chrysalis, the oakworm develops into a moth.

Other Leaf-eating Species. The fruittree leafroller (*Archips argyrospila*) is the most common defoliator of oaks in the warmer Central Valley of California. Larvae are green with brown or black heads and 3/4 to 1 inch long at maturity (Fig. 2). When disturbed, they often wiggle vigorously and drop from leaves while suspended on silken threads. Larvae feed on buds and developing leaves, webbing them together to form a protective case. Initial damage includes leaf skeletonization. As the larvae mature, they may consume entire leaves.

Tussock moths (*Orgyia* species) and tent caterpillars (*Malacosoma* species) also feed on oaks throughout the state. Unlike the greenish, relatively smooth surface of California oakworm and fruittree leafroller larvae, tent caterpillar and tussock moth larvae are quite hairy (Figs. 3-4).

Figure 2. Fruittree leafroller larva

Figure 3. Tent caterpillar larva

Figure 4. Tussock moth larva

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LIFE CYCLE

Two oakworm generations a year typically occur in Northern California as described below and in Table 1. A third generation sometimes occurs at warmer and inland sites and in Northern California in years of uncommonly warm, dry winters. Insect development in Southern California and other warmer sites is especially variable, and oak moths may appear almost any time from March through November.

Fall-to-Spring (Overwintering) Generation. During fall, females lay eggs that hatch within a few weeks. The emerging oakworms overwinter as young caterpillars on the lower leaf surface of evergreen oaks. They develop through five, increasingly larger stages (instars) and mature into pupae during May or early June in Northern California. Overwintering caterpillars rarely occur on deciduous oaks, because they shed their leaves in the fall along with any oakworm eggs and larvae, causing any oakworms attempting to overwinter there to die.

Summer Generation. Moths emerge from pupal cases during June and July. Oak moths may be seen during summer fluttering around oaks in the late afternoon. Female moths lay eggs that soon hatch into a new generation of oakworms that feed from July through September, pupate, then emerge as oak moths in fall (Fig. 5).

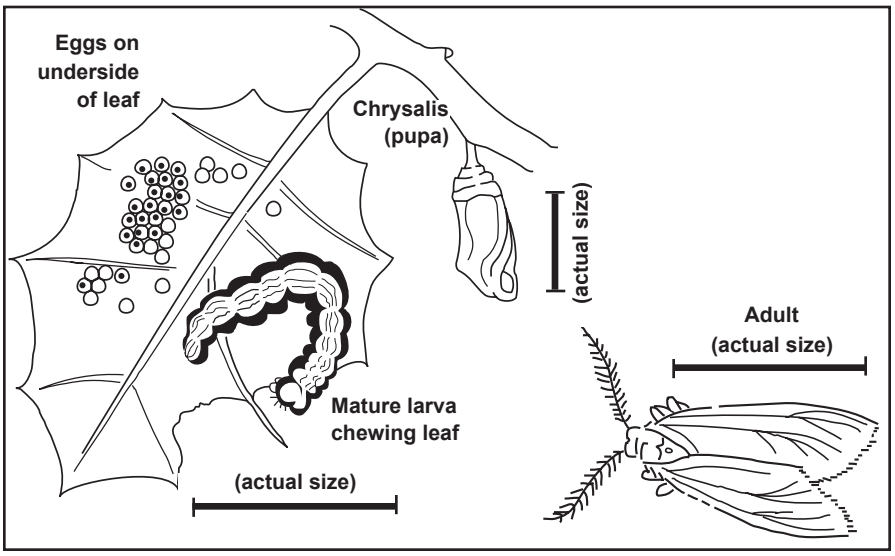

Figure 5. Life cycle of the California oakworm.

DAMAGE

Young oakworm caterpillars skeletonize the leaf surface of native oaks, while older caterpillars chew all the way through the leaf. Partially chewed leaves may turn brown and die. Viewed from a distance, the canopies of damaged trees may appear brown or gray overall because of the dead leaves and because chewed-away foliage makes branches more visible than normal. In some years, overwintering oakworms can completely defoliate trees by May or June. The subsequent summer generation may cause defoliation in July through September. During years when populations are high, oakworms may noticeably defoliate virtually every oak in a neighborhood, sometimes contiguously across acres of oak woodlands. Trees under stress from drought or other factors may decline if defoliated. Healthy trees can tolerate oakworm damage. Because defoliating outbreaks last usually only 1 or 2 years, oakworms rarely cause repeated defoliations that can severely harm or kill otherwise healthy trees.

Table 1.

The Seasonal Occurrence of Life Stages of the California Oakworm.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fall to Spring Generation												
Adults (moths)										■	■	
Eggs											■	■
Larvae	■	■	■	■	■							■
Pupae						■						
Summer Generation												
Adults (moths)						■	■					
Eggs							■	■				
Larvae								■	■			
Pupae										■	■	

Even when tree health is not threatened, caterpillars and moths may become a nuisance when populations are high. The caterpillars may move from defoliated oaks and travel on other surfaces in large numbers, such as across lawns and up walls of buildings. In the process, they sometimes enter homes and form harmless, but annoying, pupae attached to household surfaces such as drapes and walls.

Outbreak Populations. Oakworms occasionally become abundant in the landscape, with high (outbreak) populations occurring at irregular intervals followed by several years with no apparent damage. If most of the leaves on an oak have been eaten, many of the caterpillars may become malnourished and eventually die without developing into adults.

When outbreaks occur, oakworms can behave differently than during years when they are less common. Once they have extensively defoliated an oak, caterpillars may drop from the tree on silken webs and crawl away, seeking a new supply of food growing nearby. They may feed temporarily on non-oak species, sometimes extensively chewing and defoliating them. Although this may be alarming and annoying, these oakworms are unable to mature on non-oak plants, and most will die before becoming moths.

MANAGEMENT

Pesticide sprays applied to control oakworm usually are not warranted to protect the health or survival of oak trees. If you believe trees need protection from defoliation because they are stressed or because defoliation or abundant insects are not aesthetically tolerable, regularly inspect foliage for oakworms and spray least-toxic pesticides only when caterpillars reach levels warranting treatment. Control oakworm and protect oaks with an integrated pest management (IPM) program that relies primarily on the conservation of natural enemies and on good cultural practices.

Biological Control

Predators, parasites, and natural outbreaks of disease sometimes kill enough oakworms to control populations.

Predators. Predators include birds, spiders, and predatory insects. Green lacewing larvae (*Chrysopa* and *Chrysoperla* species), pirate bugs (*Orius* species), the spined soldier bug (*Podisus maculiventris*), and yellowjackets (*Vespula* and *Dolichovespula* species) are important oakworm predators (Fig. 6).

Green lacewing larvae, adults and nymphs of pirate bugs, and soldier bugs feed on oakworm eggs, larvae, and pupae, impaling prey with their tubular, sucking mouthparts. Yellowjackets carry oakworms back to their nests, where the wasp larvae eat them.

Parasitic Wasps. Two small wasps (*Itoplectis behrensii*, family Ichneumonidae, and *Brachymeria ovata*, family Chalcididae) are reported to be the most important parasites (Fig. 6). In both species, the wasps' immature stages—egg, larva, and pupa—occur within oakworm pupae. An irregularly rounded hole chewed by an emerging adult wasp can be seen in parasite-killed oakworm pupae. The adult *Brachymeria ovata* is stout, black and yellow, and about 1/4 inch long with enlarged rear basal leg segments. The *Itoplectis behrensii* adult is slender with a long, narrow abdomen and a body length of about 1/4 to 2/3 inch. This wasp is mostly black but has long legs that are orange with yellow and black bands.

Parasitic Flies. At least two parasitic tachinid flies (*Actia flavipes* and *Hyphantrophaga virillis* [formerly *Zenillia virillis*], family Tachinidae) kill oakworm larvae (Fig. 6). The female fly lays one or more eggs on an oakworm. The emerging larvae bore down and feed inside the oakworm. As the parasitized caterpillar begins to pupate, the fly larvae inside kill their host and emerge to form oblong, reddish to dark brown pupal cases that may be seen on or beneath oaks. The dry, deflated skins of tachinid-killed oakworms often remain attached to twigs or bark.

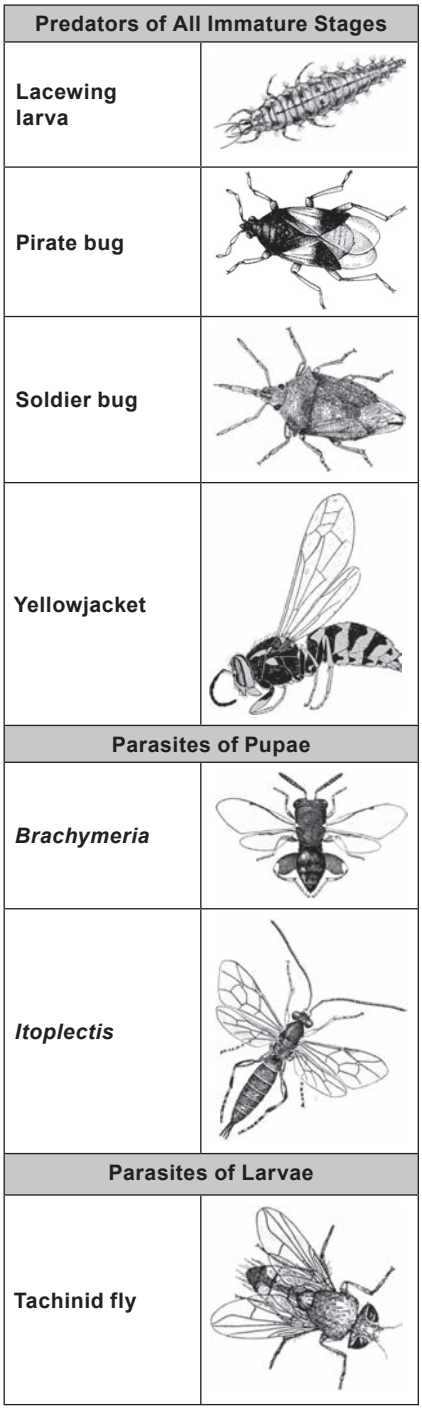

Figure 6. Natural enemies of the California oakworm and the stage of the pest they attack.

Pathogens. Naturally occurring pathogens including a nuclear polyhedrosis virus (NPV) and a fungus (*Beauveria bassiana*) often kill oakworms. Symptoms of virus infection are dark, soft, limp larval carcasses hanging from foliage or twigs; these carcasses eventually degenerate into a sack of liquefied contents. Whitish fungal growth may cover *Beauveria*-infected oakworms and produce an unpleasant odor.

When infected insects are broken, they release pathogen particles, which infect other oakworms. Disease outbreaks rapidly can reduce populations under favorable conditions, although outbreaks are difficult to predict and may not occur until oakworm populations have become high.

Cultural Controls

Good cultural care of oaks is an essential component of integrated pest management and will enable trees to tolerate moderate levels of defoliation without harm. Healthy trees can better sustain some foliage feeding or defoliation than trees under stress.

Provide irrigation only when needed to minimize drought stress. This will depend on whether precipitation has been normal; soil type and conditions such as shallow soil, soil compaction, or the presence of fill or pavement that can divert rain water; location; oak species; and whether the tree recently suffered any root injury. Protect roots and trunks from damage, and properly prune trees when needed.

In comparison with pests, the more common and serious problems that injure or kill oaks include inappropriate irrigation, physical injury to trunks and roots, and soil changes such as compaction or changes in the grade. Do not fertilize oaks unless laboratory testing of properly collected leaf samples reveals that a nitrogen deficiency exists.

Many landscape trees are stressed or dying because of poor growing conditions and inappropriate cultural care. See publications such as *Living Among the Oaks* listed in References.

MANAGEMENT IF OAKS MIGHT BE SPRAYED

If considering spraying, monitor regularly to determine whether caterpillars are abundant and to identify the most effective time to spray them. Monitoring is important, because oakworm populations are cyclic in nature, causing the pest to be common in some years and virtually absent in others. Outbreaks do not occur every year, and treatment by spraying is of no benefit during most years. If you hire others to care for your trees, make sure any decision to spray is based on monitoring. Apply least-toxic pesticides if young oakworm caterpillars become abundant.

Monitoring

Monitor to determine whether insect populations are going up or down, if control is warranted, and, if so, to properly time management efforts. You also should monitor trees at least once after taking control action to assess the effectiveness.

Oakworm monitoring. Regularly inspect foliage for oakworms or damage. Because caterpillars usually are more abundant in the western part of the tree canopy, concentrate monitoring there to provide an earlier and more sensitive indication of damage. No thresholds have been established, but as a guide inspect 25 young, lighter green shoot terminals, representing the current season's leaf flush. If you observe more than 8 to 10 oakworms more than 1/4 inch long, defoliation may occur if oaks are not sprayed. Alternatively, a density of 25 oakworms per 100 shoot terminals has been suggested as a treatment threshold.

When monitoring, look closely for the presence of predators, parasites, diseased caterpillars, and other evidence of biological control, and record this information. Evidence of natural enemy activity includes dead pupae or eggs with holes from which parasites emerged, oakworms or unhatched eggs that are discolored or darker than normal indicating they may contain parasites, or hatched caterpillar eggs with no evidence of caterpillars or damage. If you have an increasing number of pests but also many natural enemies, wait a few days before using insecticides. Monitor again to determine whether pest populations have declined or if natural enemies are increasing to levels that soon may cause pest numbers to decline.

Frass monitoring. Frass collection is another monitoring tool. The oakworm caterpillar excretes characteristic droppings, called frass, that fall to the ground beneath the tree. As the caterpillars grow, their dark fecal pellets increase in size. Greater numbers of pellets are produced either from an increased number of oakworms or from increased temperatures, which cause caterpillars to feed faster. Oakworm frass pellets are typically dark brown with a highly sculptured surface and may be observed lodged in bark crevices, spider webs, and ground cover plants beneath infested oaks.

To monitor, place 3 to 5 light-colored sticky cards, shallow trays, or cups beneath the canopy at regular intervals, such as a 24-hour period each week. Place these frass traps when no rain or sprinkler irrigation and little wind are expected. Save the frass or record its volume to compare with the amount collected on other sampling dates or from other oaks.

Initially you may want to conduct both frass monitoring and foliage inspection. This provides a record of the proportion of leaves eaten or the number of oakworms present and the corresponding density or volume of frass. With experience, frass monitoring alone may estimate caterpillar density and damage and aid in deciding if control is needed. Frass monitoring also helps to estimate the relative age of most oakworms by comparing frass pellet size. Average pellet lengths for first, third, and fifth instar stages are 1/100, 1/50, and 1/20 inches (0.3, 0.6, and 1.4 millimeters) respectively. Certain insecticides such as *Bacillus thuringiensis* (Bt) are most effective against younger caterpillars, when smaller frass pellets predominate.

Table 2.

Types of Pesticides and Some Products for Oakworm Control on Oaks.

Pesticide Type	Common Chemical Name	Commercial Product Name	
		Home Use	Professional Use
Microbial	*Bacillus thuringiensis* subspecies *aizawai*	NA	Xentari
Microbial	*Bacillus thuringiensis* subspecies *kurstaki*	Green Light BT Worm Killer, Safer Brand Caterpillar Killer	Dipel and other products
Microbial	Spinosad	Green Light Lawn & Garden Spray Spinosad, Monterey Garden Insect Spray	Conserve
Botanical	Pyrethrins plus piperonyl butoxide	Garden Safe Brand Multi-Purpose Garden Insect Killer, Spectracide Garden Insect Killer	Pyrenone
Botanical	Pyrethrins plus rotenone	NA	Pyrellin E. C.
Insect growth regulator	Diflubenzuron	NA	Dimilin

Check current labels for permitted uses. NA—Not available or availability uncertain.

Chemical Control

Several pesticides of low toxicity to people and natural enemies are available to control oakworms. IPM-compatible pesticides include microbials, botanicals, and insect growth regulators. Although some are available to both homeowners and professional applicators (Table 2), most homeowners lack the equipment and experience to effectively treat large trees.

When hiring a professional applicator, discuss the specific pesticide to be applied and insist on using an IPM-compatible one. Avoid using broad-spectrum insecticides such as carbamates (carbaryl), organophosphates (acephate and malathion), or pyrethroids (fluvalinate and permethrin), because these materials kill both pests and beneficials and may induce outbreaks of spider mites or pest insects. IPM-compatible pesticides provide good control of target pests, reduce secondary outbreaks of other potential pests such as mites, and minimize hazards to people and pets. In part because of their more specialized and selective modes of action, these pesticides often require more knowledge, skill, and careful application to be effective. Some of these pesticides can be mixed and applied together to increase their effectiveness. For example, an insecticide that provides immediate control such as pyrethrins can be combined with a pesticide, such as Bt or diflubenzuron, that acts more slowly to kill insects.

Depending on factors such as insecticide choice, application coverage and timing, oakworm abundance, and the presence of nearby untreated trees, more than one application may be needed to provide good control. For example, during outbreak years and when applying Bt (discussed below), two sprays during each oakworm generation in Northern California may be needed to provide good control. Make applications when young and mid-instar oakworms are the most prevalent life stages, typically March through April and July through August. Decide the actual application times by monitoring oakworm populations.

Microbials. Microbial insecticides are naturally occurring microorganisms or their by-products produced commercially for pest control. *Bacillus thuringiensis*, commonly called Bt, is the most widely used and has been used effectively against oakworm for many years. Unlike broad-spectrum insecticides that kill on contact, oakworms must eat Bt-sprayed foliage to be killed. Bt destroys the oakworms' digestive system and causes larvae to stop feeding within about a day. Affected oakworms often die within a few days. Bt is not toxic to most non-caterpillar insects including natural enemies. Timing and thorough spray coverage, especially on the underside of leaves, are crucial for effective application.

- Apply Bt during warm, dry weather when oakworms are feeding actively. Young caterpillars are most susceptible to Bt. Because sunlight quickly decomposes Bt on foliage, most oakworms hatching after the application are not affected.
- A second application about 7 to 10 days after the first may be required.
- Some users add insecticidal soaps, oils, or pyrethrins to increase the efficacy of Bt sprays.
- Be sure to follow label directions for mixing and applying.

Spinosyns insecticides (i.e. spinosad) are produced by fermentation and are by-products from the bacterium *Saccharopolyspora spinosa*. Spinosyns are toxic to most caterpillars, fly larvae, thrips, and certain species of beetles and wasps. They are one of the most effective microbials and have relatively low toxicity to people and the adults of many natural enemies.

Botanicals. Botanical pesticides are derived from plants. One of the most common botanical insecticides, pyrethrum, is from chrysanthemum flowers grown in Africa and South America. This botanical is comprised of insecticidal compounds including several pyrethrins. The most effective products containing pyrethrins also include the synergistic compound piperonyl butoxide, which strengthens the effect. Insects may be only temporarily paralyzed (knocked down) and may recover from the effects of exposure to pyrethrins unless piperonyl butoxide is added.

Other Contact Sprays. During outbreaks when oakworms migrate to non-oaks, they can be thoroughly sprayed with horticultural or narrow-range oil (Sunspray, Volck), insecticidal soaps (Safer), or pyrethrins and soap combined (Safer Yard & Garden Insect Killer). Because these migrating oakworms cannot complete development on non-oaks and will die without producing another generation, consider not treating non-oak species and exercising patience until the oakworm outbreak subsides.

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ILLUSTRATIONS: **Figs. 1-4:** J. K. Clark; **Fig. 5.** V. Winemiller; **Fig. 6: lacewing larva** and **pirate bug** by Celeste Green in Smith, R. F. and K. S. Hagen. 1956. Enemies of spotted alfalfa aphid. Calif. Agric. 10 (4): 8-10. **Fig. 6: soldier bug**, ***Brachymeria***, ***Itoplectis***, and **tachinid fly** from Burke, H. E. and F. B. Herbert. 1920. **Fig. 6: yellowjacket** courtesy of U.S. Public Health Service.

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