

***Appendix Q. Integrated Pest Management
Plan For Walnut Production on the
Sacramento River National Wildlife
Refuge***

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INTRODUCTION

The US Fish and Wildlife Service (Service) manages the Sacramento River National Wildlife Refuge (SRNWR), one of six national wildlife refuges in the Sacramento National Wildlife Refuge Complex (SNWRC) located within the Sacramento Valley of northern California (Figure 1). The primary objectives of the Sacramento River National Wildlife Refuge include: 1) provide habitat and manage for endangered, threatened, or sensitive species of concern; 2) protect and provide habitat for neotropical migratory land birds; 3) preserve a natural diversity and abundance of flora and fauna; 4) provide feeding and resting habitat for migrating and wintering waterfowl and other waterbirds; 5) provide opportunities for understanding and appreciation of wildlife ecology, the human role in the environment, and provide high-quality, wildlife dependent recreation and education; and 6) provide an area for compatible, management-oriented research. These objectives fall under a broader mission statement of the National Wildlife Refuge System, which is “to administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans.”

In 1989 Congress authorized formation of the Sacramento River National Wildlife Refuge (SRNWR) to preserve and restore riparian habitat along the Sacramento River between Red Bluff and Colusa. Since that authorization SRNWR has acquired 26 properties along the River towards a goal of 18,000 acres. Currently, those SRNWR properties consist of 10,304 acres including various riparian and agricultural lands of which 3,204 have been restored to native riparian species. While the Service did not wish to acquire or manage producing agricultural properties; most of the parcels offered by willing sellers included parts that were agricultural. The SRNWR currently has within its boundaries 1,529 acres of walnuts that are managed for wildlife habitat and commercial nut production. Through a partnership with The Nature Conservancy (TNC), walnut orchards are leased to farmers who commercially grow the walnut crop until the removal of the orchards.

Any net proceeds from the crop fund riparian restoration at SRNWR units. The two to five year goal is to eliminate these orchards and replace them with native riparian vegetation to provide habitat for indigenous aquatic and terrestrial species, some of which are threatened or endangered. In the interim the tenet farmers use Integrated Pest Management (IPM) for walnut production. Without immediate funds to restore the orchards to riparian habitat, it is important that the walnuts be managed rather than abandoned. While the Service is obligated to both fulfill its primary mission and refuge goals, failure to manage these walnut orchards would provide a habitat for pests, including insects, weeds, diseases, and vertebrates, to potentially cause off site impacts to neighboring walnut farmers along the River.

The purpose of this plan is to: 1) identify those walnut pest control methods/materials currently approved for use in the SRNWR; 2) incorporate their use into an IPM program consistent with the goals of the SRNWR; and 3) provide long-term planning to meet the Service's goal of reducing effects of pesticide use on Department of Interior (DOI) trust resources to the greatest extent possible.

REFUGE DESCRIPTION

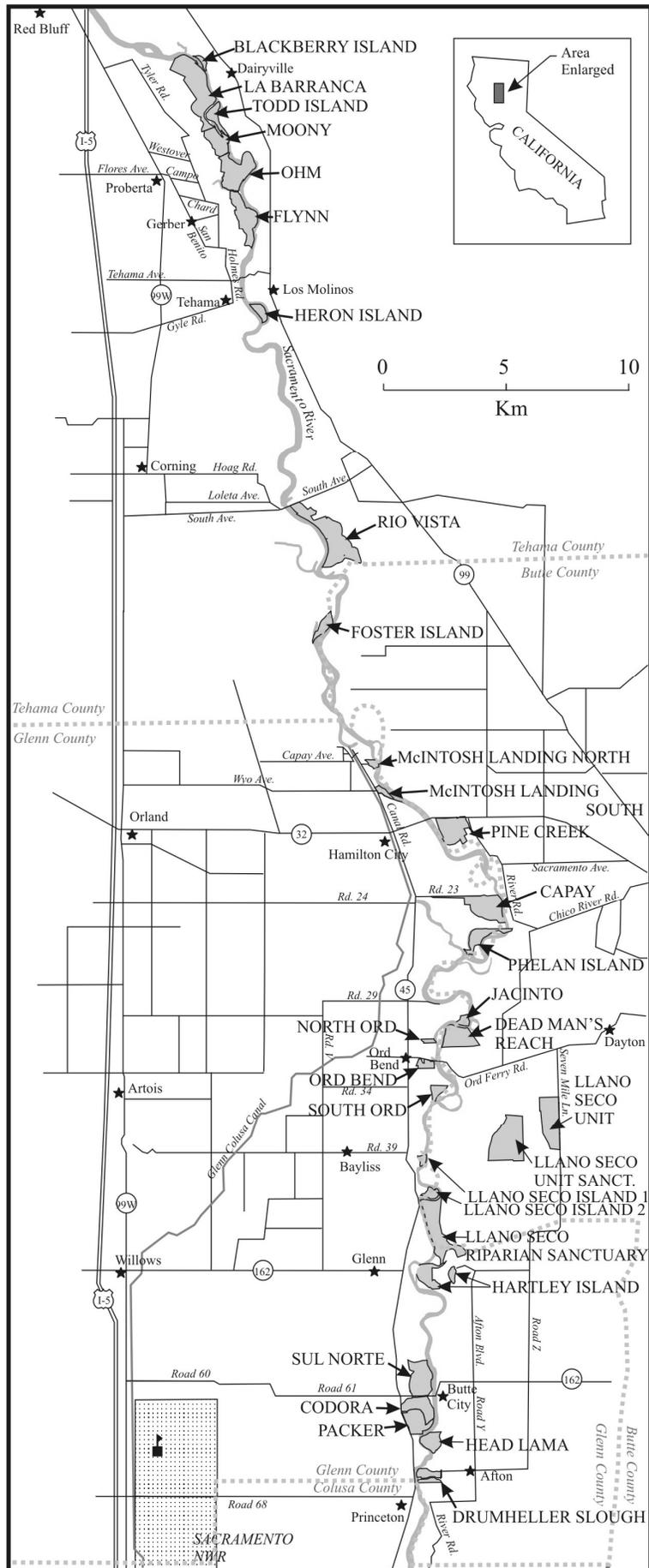
HISTORICAL

Vast acreage of natural wetlands was created when the Sacramento River flooded during annual winter storms. This cycle provided habitat for millions of waterfowl and other wildlife. In the early and mid-1900's levees were constructed along the rivers to reduce flood hazard to agricultural development. This reduced wetland habitat by approximately 95 percent in the Sacramento Valley. Due to loss of wetlands, crop depredation by waterfowl became a major problem. This problem and consideration for migratory bird conservation led to establishing a number of wildlife refuges, including those of the SNWRC during the period from 1937 to present. The SNWRC is composed of six refuges in the northern Sacramento Valley of California: Sacramento, Delevan, Colusa, Sutter, Butte Sink, and Sacramento River.

PHYSICAL

For the past twelve years the Service has been acquiring parcels of land to establish the Sacramento River National Wildlife Refuge (SRNWR) (Figure 2). The Service's goal is to purchase remnant forests and oxbow sloughs adjacent to or near the Sacramento River. These properties, along the riparian corridor, often include commercial farmland that includes English walnuts, *Juglans regia*, prunes, *Prunus domestica*, almonds, *Prunus amygdalus*, and various field crops. Currently the SRNWR has 2,685 acres of agricultural land that includes; 1,529 acres of walnuts (Table 1), 262 acres of almonds, no acres of prunes, and 100 acres of fallow fields. The remaining refuge acreage consists mostly of mixed riparian forest, cottonwood riparian forest, herbland cover, riparian willow scrub, valley oak woodland and savannah, elderberry savannah, gravel bar, grasslands and the 3,204 acres that have been restored to native riparian communities.

SACRAMENTO RIVER NATIONAL WILDLIFE REFUGE



Soils on the SRNWR are primarily loamy to gravelly floodplain soils in an active meander belt. Slope on the SRNWR units range for 0-3 percent; elevation is 70–160 feet MSL; average rainfall is 17-24 inches. Maximum daily temperatures can exceed 90 degrees Fahrenheit from May into October.

The understory vegetation in the majority of walnut orchards is a managed cover composed of nonnative annual winter weeds; and annual and perennial summer weeds usually Bermuda grass, *Cyanodon dactylon*. The orchards are part of the river flood plain and have a year round cover of resident vegetation which limits the run off of pest control materials. The surface vegetation is mowed during the summer and winter; the walnut orchard units are not disked.

GENERAL WALNUT MANAGEMENT PRACTICES

Walnut production within the SRNWR requires progressive management to protect habitat and species while maintaining healthy, productive trees that avoid pest problems. Typical activities include: irrigation management to match tree-water use, mechanization for rapid walnut harvest, mechanized towers with hydraulic saws/clippers for pruning, mowing to control weed growth, herbicide “strip” sprays to control weeds on the bermed up tree rows, and ground driven “air blast” sprayers for pesticides, and occasionally aerial application of plant growth regulators.

The walnut orchards that are or may be acquired are primarily older orchards, 20 – 40 years of age. There are University Of California (UC) and privately selected cultivars (CV’s) grown on these units including Ashley, Chico, Serr, Chandler, Hartley, Tehama, Vina, Blackmere, Franquette. The CV differences include maturity dates, height, and disease and insect susceptibility. Many of the orchard units are mixed with alternating CV’s. While the shorter statured Vinas and Ashleys remain at 30 –40 feet many of the older blocks are more than 50 feet tall and fully canopied.

Table 1. Sacramento River National Wildlife Refuge Walnut Unit CV makeup.

Unit	Acres	Varieties	Height (feet)
La Barranca	404	Ashley, Chico, Serr, Hartley	35 – 50
McIntosh Landing South	28	Hartley	50
Pine Creek	65	Hartley	50
Jacinto	13	Hartley	50
Deadman’s Reach	350	Hartley	35 – 50
Hartley Island	318	Ashley, Blackmere	40 – 50
Codora	285	Ashley, Chandler, Hartley, Tehama	40 - 50

PEST ABATEMENT ACTIVITIES

The University of California Integrated Pest Management Program (UC IPM) for Walnuts has been used as the guideline for management and monitoring decisions for the past eight years producing walnuts on the SRNWR properties. The objective of

controlling pests or avoiding their damage is favored by maintaining healthy, vigorous trees. Only tenet farmers who incorporate such practices as: pruning to keep an open canopy, adequate fertilization, optimal irrigation, and rapid harvest when using IPM practices can expect to realize sufficient revenues to avoid abandoning the walnut orchards.

There are many species that are considered pests in walnut production. For management decision making by the tenet farmers they are categorized into arthropods (insects and mites), diseases, weeds, and vertebrate pests. Because these orchard units will be removed and restored within two to five years some pest and disease problems will not be addressed, including Fall Webworm, *Hyphantria cunea*, Nematodes, *Pratylenchus vulnus* or *Macroposthonia xenoplax*, Blackline syndrome, Crown Rot, *Armillaria mellea*, or Deep Bark Canker, *Erwinia rubrifaciens*. The focus of the pest abatement activities will be on those programs that will reduce pests that could become a source of infestation to neighboring orchards outside the refuge or make commercial management unfeasible.

The primary pest Codling Moth, *Laspeyresia pomonella*, will be treated in depth because control of codling moth affects other pests and molds that make the crop unmarketable. The other significant pests; Navel Orange Worm, Web Spinning Mites, Walnut Husk Fly, San Jose Scale, Aphids, Walnut Blight, vertebrate pests and weeds will be addressed and control measures recommended.

PEST BIOLOGY FROM UC IPM WALNUT PEST MANAGEMENT

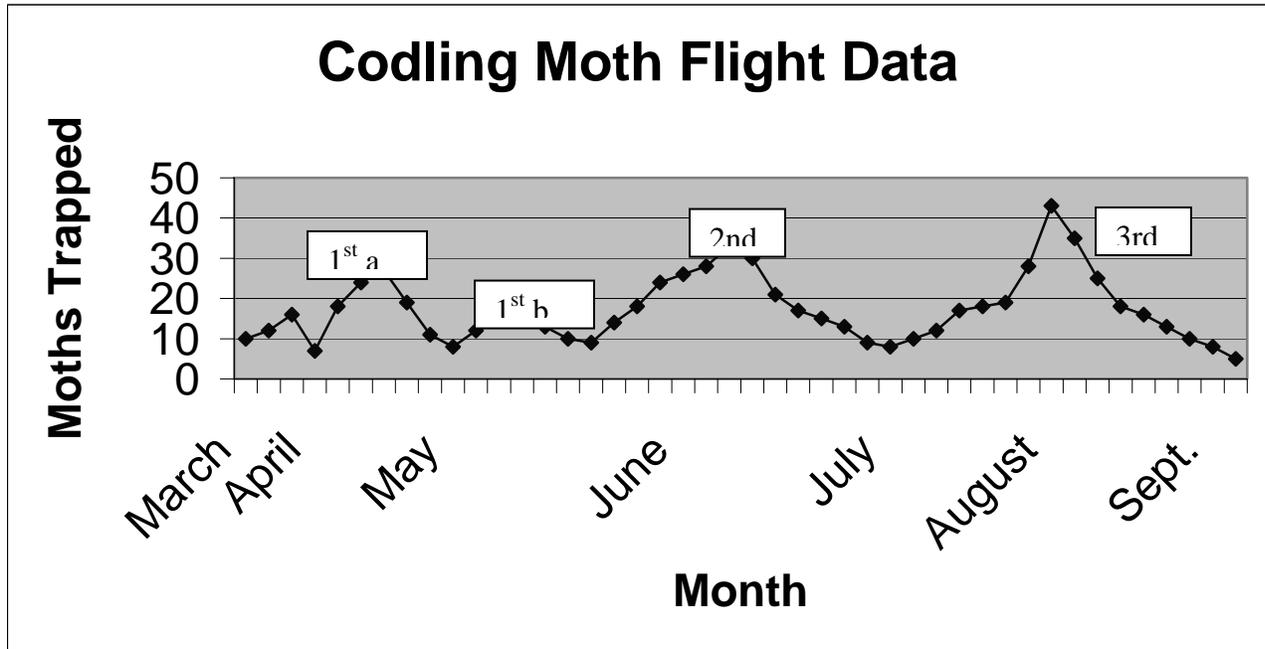
ARTHORPOD PESTS

CODLING MOTH, *Laspeyresia pomonella*

Codling moth is the major pest of walnuts. Not only does it cause direct nut damage reducing a farmer's production and grade, but also its presence provides an entry point for secondary pests, such as the navel orangeworm. Further, extent and decision for types and timing of chemical treatment or other alternative management strategies required for its control, impacts the farmer's entire seasonal IPM program. There are several generations of codling moth:

Over-winter generation: Codling moth over-winters as mature larvae in a thick silken cocoon under loose scales of bark or in trash on the ground near the trunk. Adult emergence usually occurs in mid-late March just following budbreak of walnut CV's that leaf-out early in the season (e.g. Ashley, Chico, Serr). There are usually three complete subsequent generations and a partial fourth in Sacramento valley walnut orchards (see Fig. 3).

Figure 3. Codling moth seasonal populations.



1st generation: Adult codling moths emerging from the over-wintering population of mature larvae in mid – late March is referred to as the “first flight”. When a sustained, 1st flight adult catch is obtained in pheromone traps, this is referred to as a “biofix” and developmental temperatures (50°F minimum and 88°F maximum) are recorded to determine and predict various life stages of this pest and best treatment times. The first flight of adult moths may have two distinct peaks of activity (peak 1a and peak 1b) and can last several months due to variable, often cool and rainy, spring weather. These moths begin to lay eggs when sunset temperatures reach 62°F that give rise to the “first generation” (Figure 3).

Each over-wintered female codling moth deposits about 30 eggs singly on leaves near nuts (later generations of females will lay an average 60 eggs on leaves or nuts). Duration of first generation codling moth egg laying is dependent on temperatures but typically lasts 4-6 weeks. The first eggs hatch after 5 to 20 days depending on the temperature but usually when the nuts reach a diameter of 3/8” – 1/2”. Duration of egg hatch is important for timing sprays. In cool springs or cool locations, the flight of the over-wintering moths and subsequent egg laying lasts longer and may require two chemical treatments for adequate control.

The newly hatched larvae bore into nutlets through the blossom end. Most nuts damaged by 1st generation larvae drop to the ground, however nuts infested by larvae emerging late in the generation, as a result of flight peak 1b, remain in the tree.

2nd generation: Mature 1st generation larvae leave the nut after completing their development and pupate under loose bark on the tree. Adults of the first generation

begin to emerge from the end of May to as late as the last week of June depending on the season and location. Eggs laid by these 1st generation moths give rise to 2nd generation larvae. Because of higher temperatures at this time of year, eggs hatch and larvae develop faster than the 1st generation.

Newly hatched, second generation larvae enter the walnut husk anywhere on its surface but prefer the spot where two nuts touch. The larvae then proceed under the husk around the shell and enter the nut at the stem end, the weakest point of the shell seal. These larvae develop in the nuts, emerge and pupate under the tree bark, and emerge as adults by late July or the beginning of August. Nuts infested by this generation of larvae remain in the trees until harvest and thus have the potential to influence walnut quality and the farmer's grade sheet.

3rd and 4th generation: In the Sacramento Valley, 2nd generation adult codling moths produce a third generation of larvae in early August. This generation can cause significant damage at harvest by damaging kernels. Although these larvae leave the nuts when they are mature, only a few will pupate and then give rise to a 4th generation of larvae. The majority will spin cocoons and over-winter for the next year's population. Larvae developing as a fourth generation develop too late to cause economic damage to walnuts.

Occasionally some third generation codling moth larvae may be present in harvested nuts however most larvae found in nuts at harvest are the secondary pest, navel orangeworm that enters the nut through codling moth injury from late 1st, 2nd, or 3rd generation larval injury.

NAVEL ORANGEWORM, *Amyelois transitella*

Navel orangeworm (NOW) is the most common "worm" pest found in harvested walnuts and is usually regarded as the cause of worm damage and reason for reduced grade. However, it is a "secondary" pest. That is it cannot infest sound nuts (i.e. nuts that have not been previously injured) so its presence is often a direct result of nuts previously injured by codling moth, walnut blight, and/or sunburn. A grower's inability to manage these pests results in substantial NOW damage potential. NOW also infests nuts once hulls split prior to harvest so allowing nuts with split hulls to remain on trees past when they could be first harvested encourages infestation.

NOW over-winters as both larvae and pupae inside "mummy" nuts left in the tree following shaking and in trash nuts left on the ground, including those around hullers. Adult emergence begins in mid-March and may continue through early May – timing of adult emergence usually follows patterns of codling moth emergence closely. Female moths of the over-wintered generation lay their eggs singly on mummy nuts, current season's codling moth infested and/or blight infested nuts. The first generation, and most of the second, is completed in previous season's nuts or those infested with codling moth or infected with blight in the current season. In late summer, third generation larvae infest the crop as the husks begin to split. Females emerging at this time prefer to lay

eggs on the opened husk or on the exposed shell. Attention to mummy nut removal by dormant tree shaking and codling moth and blight control during the season minimizes the size of the generation that will infest nuts at harvest.

RED-HUMPED CATERPILLAR, *Schizura concinna*

Red-humped caterpillars damage walnut trees by feeding on leaves. Extensive feeding results in exposure of nuts and branches to sunburn, reducing both production and nut quality.

Three generations of red-humped caterpillars occur per year. The brown moths that give rise to first generation larvae emerge in early May. After mating, the females lay pearly white, spherical eggs in masses of 25 to 100 on the underside of leaves. The young larvae are quite gregarious and feed in large groups, quickly skeletonizing leaves. Once mature, they disperse and feed singly before falling to the ground to pupate. Additional generations occur in July and in September.

Usually red-humped caterpillar damage occurs before farmers or their Pest Control Advisors (PCAs) realize it; that is, it is too late for control as the “damage has been done”. Because a number of natural enemies attack red-humped caterpillars, including two species of parasitic wasps, *Hyposoter fugitives* and *Apanteles* spp., and birds, they frequently do not recur preventing them from becoming a continually destructive pest in the orchard.

WALNUT HUSK FLY, *Rhagoletis completa*

Walnut husk fly (WHF) is a major pest of walnuts in the Sacramento valley. The fly oviposits in walnut husks during August and September prior to harvest. The maggots develop by feeding on husk tissue, which irreparably stains the walnut shell making it unsuitable for the in-shell trade. Nuts infested more than four weeks prior to harvest also sustain kernel color loss, reducing their grade. Black walnut, *Juglans hindsii*, which is found in the riparian areas, is the preferred host, but English walnut is also an excellent host for husk fly.

WHF has one generation per year. They over-winter as pupae in the soil and emerge as adults from late June until early September. Peak emergence is usually in mid-August. The female deposits eggs in groups of 15 below the surface of the husk. Eggs hatch into white maggots within 5 days. Older maggots are yellow with black mouthparts. After feeding on the husk for 3 to 5 weeks mature maggots drop to the ground and burrow several inches into the soil to pupate. Most emerge as adults the following summer but some remain in the soil for 2 years or longer. Some early maturing varieties, such as Ashley and Chico, can escape serious damage in most years simply because they harvest before serious damage occurs. Mid-late maturing varieties, such as Eureka, Chandler, and Hartley that have more exposure to WHF feeding before harvest are most susceptible to damage.

WEB-SPINNING SPIDER MITES

TWO-SPOTTED SPIDER MITE, *Tetranychus urticae*

PACIFIC MITE, *Tetranychus pacificus*

The web-spinning mites, Two-spot and Pacific, feed on the leaves causes stippling and leaf browning. Clusters of brown leaves are often the first sign of a mite population. Heavy populations produce copious webbing, and their feeding causes leaves to desiccate and drop. Defoliation early in the season will reduce nut yield and quality by shriveling kernels and increasing sunburn potential; defoliation late in the season will interfere with harvest. Early season infestations will also reduce subsequent crops as flower bud formation will likely be reduced.

Web-spinning mites over-winter as reddish orange, mature females in protected places on the tree, in the soil, and in trash on the ground. Eggs are spherical and translucent when first laid, becoming opaque soon before hatching. Immature mites molt three times before becoming adults. The first stage mites have six legs; later stages and adults have eight legs. During periods of active feeding the two-spotted mites have a dark spot on each side of the body, thus the name “two-spotted spider mite”.

During warm weather in spring, over-wintered females begin feeding on walnut leaves and ground cover in the orchard. Colonies develop on the underside of leaves and also on the upper sides when heavy populations build up. These mites reproduce rapidly in hot weather and may become numerous in June or July. They produce many generations a year. If temperature and food supply are favorable, a generation can be completed in 7 days.

NON-WEB-SPINNING MITES

EUROPEAN RED MITE, *Panonychus ulmi*

The European Red Mite (ERM) populations develop in walnuts while weather is cool. While feeding by ERM does not result in leaf drop like web spinning mites, research has shown that when heavy populations are left un-treated for three years nut yield is reduced. In low numbers, that are by far the more common occurrence, the ERM can be beneficial by providing a food source for the western predatory mite, *Metaseiulus (Galendromus) occidentalis*, which can manage web spinning mite populations.

The ERM overwinters in the egg stage on twigs and branches. Eggs hatch in early spring when the walnuts leaf out. Immature mites are bright red; adult females have a brick red, globular body with four rows of long, curved hairs arising from white dorsal spots. Adult males are brownish and smaller than the females. ERM feeds on cell contents in leaf tissue. Initially, the feeding causes light leaf stippling. Prolonged feeding by a heavy population will gradually give leaves a bronzed appearance. They have multiple generations each season and do not produce webbing.

APHIDS

WALNUT APHID, *Chromaphis juglandicola*

Walnut aphid can be a serious pest of English walnut. Its feeding reduces tree vigor, nut size, yield, and quality. In addition to direct feeding damage, they excrete copious amounts of honey-dew that falls onto nuts, leaves and shoots. Honey-dew supports growth of the black sooty mold fungus. This fungus reduces light penetration to the leaf surface reducing its photosynthetic capacity. Being black, it also absorbs heat to predispose nuts to sunburn and subsequent kernel quality loss due to high temperatures. High populations of aphids may also cause leaf drop, exposing more nuts to sunburn. If heavy populations are allowed to develop (i.e. > 15 aphids per walnut leaflet) and remain for as little as 14 days uncontrolled, current seasons nut quality is reduced along with a substantial reduction in the following season's crop (Barnes, Sibbett, 1990.).

Walnut aphid over-winters in the egg stage on twigs. Eggs hatch as soon as leaf buds on early leafing CV's begin to open. These aphids settle on the leaflets (usually on the undersides of the leaf), mature, and reproduce without mating, giving birth to live nymphs. The aphids pass through many generations a year, depending upon temperature; hot temperatures seem to depress activity. In fall, wingless females mate with smaller, winged males and they lay the over-wintering eggs.

With the introduction of the wasp parasite, *Trioxys pallidus* by Robert Van Den Bosh in the early '70s, damaging populations of walnut aphid have generally disappeared statewide. Only in those cases where the parasite is killed with application of a broad-spectrum pesticide for control of another pest (e.g. codling moth) does walnut aphid become problematic.

DUSKY VEINED APHID, *Callaphis juglandis*)

The dusky veined aphid is a walnut pest that occurs mainly in the Sacramento valley. The life cycle of dusky veined aphid is similar to walnut aphid. It overwinters in the egg stage on twigs. Eggs hatch as soon as leaf buds on early cultivars begin to open where the young aphids settle on the leaflets, and they mature into larger, yellow aphids with dusky black spots, and reproduce without mating, giving birth to live nymphs. The aphids pass through many generations a year, depending upon temperature. In fall, wingless females mate with smaller, winged males and lay the overwinter eggs. In contrast to walnut aphid however, dusky veined aphids feed on the upper sides of leaves at the midrib. If 25% of a leaflet sample contains colonies of dusky veined aphids, economic quality damaged has been measured.

SCALE PESTS

Scales are insect pests that feed by extracting "plant sap" from limbs, branches, shoots, and leaves. When heavy infestations occur, substantial reduction and/or loss of tree growth occurs reducing production. Scales are classified as either "armored" or "un-armored". Armored scale adults have a hard, waxy coating that protects the insect from predation, parasitism, and, coincidentally, chemical insecticides. Un-armored scales have no such protection, their body remains soft and exposed, and is more easily parasitized and controlled with insecticides.

ARMORED SCALES

SAN JOSE SCALE, *Quadraspidiotus perniciosus*

The San Jose Scale (SJS) produces three generations a year or more if warm weather extends into the fall. It overwinters mainly as first instar nymphs, a “black cap” stage. The wingless females molt twice and the winged males molt four times and mature at the same time as the females. San Jose Scale bear live young and these tiny “crawlers” begin emerging in May. The crawlers soon settle down, insert their feeding stylet, initiate feeding and secrete the white waxy cover that becomes the “armor”. After two or three weeks these nymphs molt and complete their development. Heavy infestations of San Jose Scale kill scaffold limbs and branches within one to two years reducing production.

WALNUT SCALE, *Quadraspidiotus juglansregiae*

The walnut scale is often tan or brown and the same color as the bark of the walnut tree, making it difficult to detect. The scale is found in daisy shaped groups formed by the male crawler. The walnut scale produces two generations a year. The second generation overwinters as second instar females and males. The young female crawlers are active in mid May after hatching, and another generation develops in Mid August. Similar to San Jose Scale, heavy infestations can cause bark and limbs to crack.

UN-ARMORED SCALES

FROSTED SCALE, *Lecanium pruinosum*

EUROPEAN FRUIT LECANIUM SCALE, *Lecanium corni*

These are two very similar un-armored (i.e. soft-bodied) scales. They suck plant juices from leaves and twigs and heavy populations reduce terminal growth and vigor, resulting in smaller nuts and poor kernel quality. The secreted honeydew may cover nuts and offering a substrate for growth of the sooty mold fungus, increasing the chances for sunburn damage.

They have one generation per season, over-wintering as nymphs on twigs and small branches. In the spring the nymphs grow rapidly, secreting large amounts of honeydew. Mating occurs in late spring and the females lay a large number of eggs, protected under her body, then dies. The newly hatched yellow crawlers, looking quite similar to walnut aphids, emerge from beneath the old female body and migrate to the underside of leaves where they feed much like aphids do. In fall the crawlers molt and move back to the maturing current season’s shoots and permanently settle down to over-winter.

These soft scales are usually held in check by natural predators and parasites. It is only when the natural enemies have been eliminated, often through chemical upset, that these soft scales become a problem.

MICROBIAL PESTS

BACTERIAL DISEASES

WALNUT BLIGHT, *Xanthomonas campestris* pv. *juglandis*

Walnut blight is the only bacterial disease of walnut and infects leaves, flowers, and nuts. Economic loss occurs when nuts are infected. Nuts infected early in the season drop from the tree whereas those infected later, once shells begin to harden, have their kernels destroyed and provide a site for navel orangeworm infestation.

The walnut blight bacterium over-winters and survives either on or in dormant buds, catkins, and twig lesions from previous infections. When new tree growth resumes in spring the pathogen is moved to the new tissue in free moisture, usually rainfall. It enters the new plant tissue through natural openings such as the stomata. These primary infections produce more bacteria, which are spread to other sites in the tree, such as developing shoots, pistillate flowers, nuts and developing buds and catkins for the next season. Windblown raindrops or pollen can also carry walnut blight bacteria throughout the orchard. Thus, severity of blight each season depends upon amount of rainfall occurring during the primary infection period. Although all commercial walnut CV's are susceptible to blight, those that leaf out early in spring are most susceptible simply because of their coincident growth stage with highest probability for rain. Early leafing CV's such as Ashley, Payne, Vina, Sunland require major attention to blight whereas late leafing CV's such as Chandler require a minimal treatment regime. Interestingly, Serr, an early leafing CV, shows some field resistance to blight and is not severely infected even when conditions for infection occur.

VERTEBRATE PESTS

GROUND SQUIRRELS, *Spermophilus beecheyi*

Ground squirrels can live for five years and they emerge in February after winter hibernation from their burrows. The females have one litter of six to eight young in the spring. About six weeks after birth, the young emerge to feed above ground. The adults often go into a temporary state of inactivity (aestivation) for part of the hot summer and into hibernation in the winter. The young usually do not aestivate or hibernate during the first year.

Ground squirrels feed on young nuts and mature nuts on the ground or in the tree. They can climb trees and strip branches of large numbers of nuts. Ground squirrel burrows in the orchard can disrupt irrigation and cause erosion.

POCKET GOPHERS, *Thomomys* sp.

Gophers usually live alone, except for females with young or when breeding, in an underground burrow system that can cover 200 to 2,000 square feet. Gophers do not hibernate and may be active at any hour of the day. Gophers reach sexual maturity at about 1 year of age and can live up to 3 years. Litters of five or six gophers are produced by females up to three times per year. Gophers feed on roots and stems of weeds and occasionally they damage young walnut trees. They are a concern to walnut growers mainly because they dig burrows in the orchard, which interfere with mowing, harvesting operations, and irrigation.

WEED PESTS

Weeds cause many problems in walnut orchards if not well managed. Weeds: increase water use; enhance the potential for disease (e.g. crown rot) and rodent damage (meadow mice – *Microtis spp.*); make it difficult to recover nuts from the orchard floor; and they increase management time, thus costs.

Weeds in areas between the tree rows, i.e. row middles, are allowed to grow and are mown 2-3 times annually. All of the orchards in the SRNWR area are mown and not disked as these orchards are on an active flood plain.

POTENTIAL CONTROL METHODS AND MATERIALS

CULTURAL CONTROLS

Good walnut cultural practices minimize pests and their control costs. Here are some examples:

Irrigation: Maintaining non-water stressed trees is one of the most important cultural practices farmers use to maximize yield and avoid pest problems. For example, allowing trees to stress from poor water management encourages spider mite infestations that would not occur in well-irrigated orchards. Nut sunburn readily occurs on stressed trees; sunburned nuts are predisposed to infestation by Navel orangeworm. Also, water stress predisposes walnut trees to infection by the deep bark canker bacterium and too much water encourages phytophthora infection. Water management is clearly a major component of an integrated pest management program.

Shaking “mummy” nuts and shredding: Old mummy nuts left in the trees following harvest are over-wintering sites for navel orangeworm (NOW). Dormant tree shaking to remove these nuts, then shredding them in the orchard destroys the over-wintering stages of this insect. The result is that there no longer is a resident population of NOW within the orchard to infest nuts injured in-season. This practice alone is a major part of any program to manage this insect pest.

Pruning: Dormant pruning complements other good cultural practices in a pest management program. It thins out wood within the tree, invigorates shoot growth and confines trees to their allotted space. As such, it is quite helpful in a pest management program, for example, encouraging tree vigor minimizes such diseases as branch wilt that infects via sunburn injuries and spider mites that often prefer non-vigorous trees; dense, shaded trees are often more prone to walnut blight due to higher humidity conditions within the orchard.

Mowing: Mowing is a direct weed control practice and a component of integrated pest management. Keeping weeds short minimizes problems weeds cause, such as, water use and rodent habitat. Although not well researched, mowing weeds or a cover crop also has

been suggested as a method of encouraging insect predators to move up into the tree-tops.

Harvesting: Prompt harvest and processing have long been shown to maximize kernel quality and minimize insect and mold damage. Once walnut hulls dehisce, the nut becomes a primary site for navel orangeworm infestation. Minimizing the opportunity time for infestation minimizes percent damage. Prompt harvest also minimizes damage from Walnut husk fly and kernel molds.

Rodex® Rodent Control: Recent development of a concussion device for control of pocket gophers and ground squirrels, Brand name “Rodex”, has the ability to spot treat problem areas without use of anticoagulant baits, fumigants, or poisons. This method quickly exterminates existing pocket gophers and ground squirrels, collapsing the burrow system, and retarding re-colonization. The use of this method will be limited to less than 5% of the acreage selectively eliminating populations at pumps, levees, and neighboring farming and restoration borders where large populations cause damage.

Table 2. Cultural Control Methods for Walnut Pests

Control Technique	Objective	Usage	Advantage(s)	Disadvantage(s)
Irrigation	Create a healthier walnut tree to resist pests and to prevent sunburn.	100% - to produce healthy, productive walnut trees.	Reduces sunburn, secondary infestations of NOW, and maximizes production. Provides water for all species.	Minor expense
Shaking and shredding “mummy” nuts	To eliminate overwintering navel orangeworm from the orchard.	Preventative; tree shaking is occasionally used. All tenets mow the fallen walnuts by March 15 providing floodwaters allow.	Reduces NOW populations.	Tree shaking is expensive. Winter weather flooding often prevents performance of this operation.
Pruning	To keep tree structure open and encourage air circulation to lessen impact of humidity on walnut blight. To provide conditions that minimizes spider mite infestations. A more open canopy allows more complete spray deposition when pest control measures must be applied.	Preventative; the use of pruning is primarily to increase production. Inadvertent pest control is obtained. Tenant farmers usually perform this operation up until the last two years of the orchard’s life.	Reduces damage from walnut blight. Achieves better control of codling moth and other pests by ensuring conditions for optimal spray coverage.	Pruning is expensive and returns due to increased productivity are not realized for several years.
Mowing	Control weeds.	100% - Preventative.	Reduces need for herbicides.	Removes orchard vegetative structure, creates dust, may cause compaction.
Harvest	Prompt removal of the ripe walnuts.	Prevents damage from NOW, ants molds,	Prompt harvest minimizes pests and maximizes nut quality.	Not all walnut orchards can be harvested at one time. Some will be delayed due to infrastructure constraints.
Rodex® Rodent Control	Control pocket gophers, ground squirrels.	Selective control and preventative	Limits use of baits, fumigants, and poisons.	Equipment expense and labor.

BIOLOGICAL CONTROL

BIRDS, GENERAL

Codling moth: A USDA study in 1911 reported 36 bird species to be important codling moth predators (McAtee 1911). In California apple systems, a study funded by the Organic Farming Research Foundation showed up to 83 percent depredation of codling moth larvae by birds during the winter (Baumgartner 2000).

Currently few of the orchards in the SRNWR have high populations of codling moth, i.e. over 5% from harvest “crack out” results conducted by The Nature Conservancy (CERUS Consulting 2000). Surveys conducted on SRNWR properties indicate that bird species richness was highest in riparian vegetation, followed by restoration sites, and grasslands with orchards being lowest (Small et al 1999). The bird diversity increases at the restoration sites with age (Small et al 2000). Although lacking solid research of birds’ diets surveyed by Point Reyes Bird Observatory (PRBO), considering Baumgartner’s research, it is believed birds in general; particularly; scrub jays, American robin, European starlings, Brewers blackbirds, and many woodpeckers have a substantial influence on suppressing the Codling Moth populations year round.

Rodents: For the pocket gopher, *Thomomys sp.*, barn owls, *Tyto alba*, can represent a substantial biological control that can be manipulated with the placement of barn owl nest boxes around and in the orchard. Research work in California examined contents of barn owl nest boxes in the San Joaquin and Sacramento Valley around prunes, vines and pecans. Results showed pocket gophers represented over 50 percent of the barn owl diet representing an average of 215 gophers ‘taken’ during the breeding and nestling phase, the balance consisted of *Microtus sp.*, 30% and other birds 20%. (Gallaway et al 1999).

It is doubtful this level of efficacy would be achieved in these walnut units where abundant habitat and alternate prey exist. Further, barn owls prefer to hunt away from their nests and in open areas. In tall dense walnut orchards, some predation in the more open areas may occur, but would be considerably less than in vineyards or prunes.

BATS

MEXICAN FREE-TAILED, *Tadarida brasiliensis*

YUMA MYOTIS BATS, *Myotis yumanensis*

Recent research in California indicates that the indigenous migratory bats, such as, Mexican free-tailed and Yuma myotis bats, may particularly play a large role in insect control. Research shows they consume a considerable quantity and diversity of insects after they have migrated to the Sacramento Valley in summer; from April through September 50% - 90% of the diet consisted of moths (Long 1998). Bats are also known to chase away moths with echolocation; moths, including cutworms, armyworms, and bollworms turn and dive to the ground up to 130 feet away from bats. While work has not been done on codling moth or navel orangeworm in walnuts or other crops, bats may be a

substantial natural predator of these pests and bat habitat and populations should be encouraged.

PARASITIC ARTHROPODS

Trichogramma platneri

The parasitic wasp was first isolated in Yuba County California attacking codling moth eggs in walnuts in 1986 (Bob Hanke, pers. comm.). Now, these egg parasites can be purchased from several insectaries for release in walnut orchards. Through testing by the University of California (Mills et al 1995) a suggested level of augmentive releases has been established for this pest. The University of California Pest Management guidelines (Mills and Pickel 1999) suggest releasing 200,000 *T. platneri* every week for four weeks during the egg laying period for second and third generations of codling moth. These guidelines suggest this augmentive release program has given 50-70 percent control of codling moth when populations are low to moderate.

Application of *T. platneri* egg cards to every tree in the orchard eight times a season is labor intensive and expensive. Aerial applications of *T. platneri* with 98 percent survival and recovery is possible (Stocker 2000). The expense of 5 applications eliminates this as an option.

Mastrus ridibundus, Liotryphon caudatus, Mastrus rufipes

Three parasitoid species on codling moth have been introduced: *M. ridibundus*, *L. caudatus* (ichneumonids), and *M. rufipes* (a braconid). The two ichneumonid species are cocoon parasitoids and the braconid wasp is a larval parasitoid that attacks the mid-stage codling moth larvae inside fruit. These parasitoids typically cause 30 – 50% parasitism of the codling moth in Kazakhstan apples (Mills 1997).

The two ichneumonid cocoon parasitoids were reared in the laboratory and there have been field releases of 41,000 *Liotryphon* and 95,500 *Mastrus* in walnut orchards throughout the Sacramento and San Joaquin Valleys between 1995 and 1997. In 1997 both species were recovered in walnut orchards outside of the release sites, indicating they had successfully overwintered. *M. rufipes* has failed to breed in captivity. As cocoon parasitoids the extent of these introductions on SRNWR walnuts has not been evaluated, but would be a very valuable research addition.

Trioxys pallidus

The parasitic wasp, *T. pallidus*, currently controls the walnut aphid. This wasp, introduced from France and Iran in the 1960's, has virtually eliminated walnut aphid as a pest in most orchards. Monitoring by TNC on properties farmed with existing IPM methodology for the past several years has confirmed an abundance of *T. pallidus* parasitized aphids exist indicating that the parasitoid is well established on the SRNWR walnut properties (CERUS Consulting 2000).

BACTERIAL AGENTS

B.t. (*Bacillus thuringiensis* var. kurstaki)

B.t. is a bacterium that has demonstrated selective larvacidal activity against all lepidopteran species including codling moth, navel orangeworm, and red-humped caterpillar. B.t. produces a crystalline protein (delta-endotoxin) that, when ingested by the susceptible insect, causes paralysis of cells in the gut, interfering with normal digestion and feeding. It must be applied prior to egg hatching and throughout the egg-hatching period. While the use of B.t. is common in apple orchards in Washington for codling moth control, it is relatively unused in walnut production in California. Several factors greatly reduce the efficacy of B.t. in walnut: tree height (often in excess of 40 to 50 feet tall), precludes the required thorough coverage, rapidly growing foliage during the first generation of codling moth would require frequent application for adequate control, and the protein has short term (5 day) effectiveness before it is degraded by sunlight. Because of the 5-8 applications per season this is an unused method for Codling Moth.

Table 3. Biological Controls of Walnut Pests.

Control Technique	Pest Control Objective	Usage	Advantages	Disadvantages
Birds, General	Encourage presence of general bird predators for control of codling moth, navelorange worm and other insect pests	Opportunistic and passive method of insect control.	Little supplemental expense.	A passive method of insect control that cannot be managed.
Barn Owl	Rodent control.	Opportunistic and passive.	Low cost.	Efficacy impaired in dense orchards. barn owls may not be active in densely canopied walnut orchards.
Bats	Encourage presence of general bat predators for the control of codling moth and navelorange worm.	Opportunistic and passive method of insect control.	Little supplemental expense.	A passive method of control but with abundance of habitat at refuge sites, it may not be worth time or labor to establish bat houses on these units.
<i>Trichogramma platneri</i>	Codling moth control.	Augmentive and opportunistic.	A control method using a California native parasitoid wasp. Does not impact secondary pests.	Expense. Cost of stapling <i>T. platneri</i> to tree leaves eight times a season is considerably more expensive than other control methods and is less effective than chemical control.
<i>Mastrus ridibundus</i> , <i>Liotryhon caudatus</i> , <i>Mastrus rufipes</i>	Codling moth control.	Opportunistic and passive.	Ease of establishment. These parasitic wasps may become established with little change in management.	None. Susceptibility to broad-spectrum insecticides unknown.
<i>Trioxys pallidus</i>	Control of walnut aphid.	Opportunistic and passive.	Currently well established in the units.	Susceptible to broad-spectrum insecticides.
<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	Control of red-humped caterpillar	Augmentive and active.	Does not impact secondary pests or wildlife.	Expense. The cost of labor and equipment to apply the bacteria.

CHEMICAL CONTROLS

TEBUFENOZIDE (Confirm)

Tebufenozide is an Insect Growth Regulator (IGR), which acts by binding to the ecdysone receptor protein causing the molting process of codling moth larvae to become lethally accelerated. When applied at 200 to 250 degree days (hours of temperature over a threshold, i.e. 14° C since egg laying) from biofix and thorough coverage is obtained, including combinations of ground and/or aerial applications on large trees, good control is obtained. Tebufenozide is the primary IPM pesticide material used by tenet farmers for codling moth control. Since the SRNWR abandoned the use of synthetic pyrethroids in 2000, the use of tebufenozide has accounted for 95% of the control of codling moth on the SRNWR walnuts.

Tebufenozide has moderate aquatic toxicity by Service standards and will be mitigated by the buffer zones of 200 feet by ground and 300 feet by aerial applications.

PHEROMONE MIXTURE, MATING DISRUPTION (Isomate C+)

Considerable interest in using codling moth mating disruption technology has existed since development of Codlemone, a synthetic sex attractant pheromone. However, success similar to that of apples and pears using a pheromone dispenser technique in other parts of the United States was not realized for walnuts in early California trials; the size and volume of large trees has kept most growers from utilizing the technique. Growers with young walnuts have used the technique but often report partial failures.

Two recent walnut studies however have shown this to be an effective method, albeit time consuming, control of codling moth. A three-year Walnut Biologically Integrated Orchard Systems program (BIOS) in San Joaquin County, using Isomate C Plus had comparable damage levels to the conventionally managed blocks (Grant 2000). Because the dispensers need to be hung during a short, two week period of time in late March, this method has not been adopted by tenet farmers. The option on some blocks will remain within this IPM plan in the event that other methods should fail to be efficacious.

PHEROMONE MIXTURE, MATING DISRUPTION (CheckMate CM-F, 3M MEC-CM)

In addition to the potential use of Isomate C+, which has been approved by the Service, two new sprayable formulations of codlemone have been granted registration by EPA in 2002. Both products have been field tested by local PCAs and the University of California on properties adjacent to refuge properties. The results have been encouraging in controlling codling moth mating disruption, although with high risk CVs and high moth populations the disruption failed and tebufenozide was needed to control the 2nd or 3rd generations (Cliff Kitayama pers. comm.)

These sprayable formulations of the codlemone are easily applied by the tenet farmers, which facilitates their use and adoption of mating disruption. If the methodology can be

proven successful and cost effective, pheromone disruption will be strongly supported on refuge properties because of its low impact to wildlife and natural predators.

MALATHION and NU LURE BAIT

Malathion, developed in 1950, is one of the oldest organophosphate insecticides. Even though it is toxic to aquatic insect species it is rapidly biodegraded. Malathion has been the chemical recommended for control of walnut husk fly. The current and recommended method is to apply malathion with a food attractant, Nu-Lure Bait, to every third row, with a coarse spray to the lower half of the tree. This is the site where walnut husk flies live after emerging from the ground.

SPINOSAD (GF-120 NF Naturalyte)

In 2002 the use of spinosad with a bait attractant was approved by US EPA for use in walnuts for walnut husk fly. The active ingredient is produced from the aerobic fermentation of the naturally occurring actinomyceete, *Saccharopolyspora spinosa*. This natural product, approved for organic production systems by OMRI, has a novel mode of action that affects the insect nervous system at the nicotinic acetylcholine receptors. It provides excel control through both contact and ingestion, yet is generally safe to beneficial insects. The product will be tested on walnut orchards in the area and if it is efficacious, will be an improved alternative in the control of walnut husk fly.

CLOFENTEZINE (Apollo)

In most years mites are controlled in walnuts by good cultural practices (e.g. water management) or natural enemies such as the western predatory mite, *Metaseiulus (Galendromus) occidentalis*. In some seasons, however, they require control.

Clofentezine has been recommended in the past on Service units because it is relatively nontoxic to fish. Because the miticide interferes with the breathing tube of the egg stage of the mite, it must be applied before a truly threatening population level has been reached contrary to IPM practices. More tenet farmers will be encouraged to use narrow range oils and partial treatments with clofentezine in mite hot spots as part of the IPM program.

NARROW RANGE OIL

Agricultural oils will effectively control many insect pests by suffocation. Narrow range oils are recommended in the UC IPM Guidelines for mites. Most of the tenet farmers have not used narrow range oil in the past because they were both concerned about phytotoxicity and there were more effective materials available. Now that the number of available products for mite control has been reduced to clofentezine more tenet farmers will be encouraged to try oil as part of their mite control programs.

COPPER HYDROXIDE (Kocide 101)

Copper is a broad-spectrum fungicide/bactericide. Copper, in the form of copper hydroxide, has been used for control of walnut blight for many years. Regular applications for control of walnut blight are made based on temperature and rainfall

events or every 10 to 14 days through the leaf out and bloom period. Presently there is not an IPM control program for walnut blight and the application of copper as a preventative is the only option.

MANGANESE ETHYLENEBISDITHIOCARBAMATE (Manex)

Some orchards have developed copper resistant strains of walnut blight. It is suggested that where such strains exist, Manex be included with the copper to increase control. For the past six years the State of California has issued a Section 18 Emergency Exemption label for the use of Manex.

ETHEPHON (Ethrel)

The plant growth regulator ethephon is an important and integral part of the SRNWR IPM plan for walnut production. Ethephon acts by liberating ethylene gas resulting in an acceleration of hull dehiscence. This can advance harvest by 10 to 16 days. Ethephon is used by many of the tenet farmers because it eliminates additional inputs of pesticides, facilitates an earlier harvest, and delivers a superior quality product. The use of ethephon to hasten harvest avoids damage from 4th generation navel orange worms and from walnut husk fly.

GLYPHOSATE (Roundup Ultra®)

Glyphosate is used on all of the walnut units for weed control. The absence of weeds in the tree rows, around the walnut trunks, and around sprinklers facilitates management and harvest. As noted above under “Weeds”, absence also reduces problems associated with trunk girdling by *Microtus* sp and by crown and phytophthora rot root. Walnut unit farmers do not control weeds outside the orchard edge because they wish to maintain a solid vegetative filter strip around the perimeters to reduce off site movement of water, soil, nutrients or chemicals.

WALNUT PEST CONTROL TREATMENT EFFECTS

EFFECTS ON WALNUT PESTS

The primary insect pest species, codling moth, can be controlled with tebufenozide, pheromone mating disruption, or the combination of both products during years of heavy codling moth pressure. *T. platneri* releases can 50 to 70 percent control according to research but have never been utilized by farmers regionally and fail to control the populations during high pressure years. Walnut tree height of 45 plus feet has made the use of the insect growth regulator tebufenozide challenging because it is difficult to get the required full coverage in the upper third of the tree. Adequate control of codling moth may require both ground and aerial application of tebufenozide.

There is not a specific pesticide treatment for navel orangeworm, and the farmer tenets use secondary methods such as: shaking and shredding of mummy nuts, avoiding codling

moth damage, keeping the walnuts well watered to avoid sunburn, treating for walnut blight, and accelerating harvest with the growth regulator ethephon.

The third primary pest, walnut husk fly, is easily controlled by monitoring known areas of the orchard that harbor the pest and treating. By monitoring for gravid females and treating with malathion or spinosad combined with an attractant bait the pest is controlled and damage is avoided.

Mites can be controlled by an early application of clofentezine and narrow range oils for spot treatments based upon monitoring, although no farmer tenets have used this treatment for over five years. All other potential arthropod pests are rarely an economic problem and are controlled by the abundance of beneficial insects, birds, and bats.

The crop disease, walnut blight, is controlled by the farmer tenets preventatively with 2 to 4 ground and aerial applications of fixed coppers and Manex every 10 to 14 days during the susceptible stages of spring growth. This practice is usually done in late March and April, except when the orchard may be inundated by high water. Controlling blight reduces secondary infestations by navel orangeworm.

Vertebrate pest control measures are preformed at several spot locations on less than 5 percent of the walnut acres. Edges and structures, particularly pumps, levees, buildings, and adjacent, bare fields undergoing restoration favor squirrels. Damage to irrigation systems by gophers and squirrels sometimes require the farmer tenets to spot treat these mammals with the Rodex® concussion device.

Farmer tenets treat weeds with herbicides, glyphosate only on the tree rows and around structures - up to three times per year. Except for some shady orchards, 80% of the units are covered with vegetation and all perimeters of the orchards are 100% vegetated to provide buffer vegetation. These vegetated buffer edges are encouraged to prevent the off site movement of pesticides.

EFFECTS ON NON-TARGET ORGANISMS

Effects to non-target organisms can be: interference with normal biological systems and functions, loss of biomass, loss of diversity, interference with normal ecological relationships, bioaccumulation, and other known and unknown effects. The mission of SNWRC is to provide for the conservation of migratory birds, native anadromous fish, endangered and threatened species, native plants and other native animals and their habitats. There is concern that walnut pest control treatments interfere by reducing and contaminating existing food and water components of habitat. Rare insects or insects that may function as important pollinators for native plants, may also be impacted by walnut arthropod pest treatments. Significant bioaccumulation has not been associated with any of the approved chemical treatments referred to in this plan.

INVERTEBRATES IN AQUATIC ENVIRONMENTS

From Service data, invertebrates in aquatic environments are impacted by tebufenozide, malathion, spinosad, fixed coppers, and manganese ethylenebisdithiocarbamate. Wide unsprayed vegetated buffers (200 to 300 feet), reduced application rates (50 to 100 gallons per acre), low active ingredient concentrations, rapid degradation and soil binding, avoidance of applications during inversions or winds over 7mph, and the addition of drift control agents all reduce the opportunity for pesticides of concern to enter aquatic environments.

INVERTEBRATES OUTSIDE AQUATIC ENVIRONMENTS

Application of several of the pesticides are more likely to impact invertebrates that exist in orchards when they visit from the surrounding forests. For example, applications of malathion, tebufenozide, clofentezine, or spinosad can have an impact on arthropods which are not the target of concern including pollinators, beneficial insects, and the parasitoids of codling moth and aphids. Through the combined efforts of the Service and farmer tenets the broad spectrum and long lasting pyrethroids (Asana®) and organophosphates (Diazinon®, Sevin®, Imidan®) have been eliminated on the SRNWR over the past eight years. Impacts on other invertebrates, such as earth worms, snails, and nematodes may be short lived in an active flood plain orchard. These questions represent an area of considerable unknowns and opportunities for research on farm property that is acquired for eventual restoration.

SENSITIVE SPECIES AND HABITATS

Federal and State listed endangered and threatened species and federal candidate species, which occur or potentially occur at SRNWR are listed in Table 4. Because general pesticide toxicity levels for vertebrate species such as reptiles, birds, and mammals are at least a magnitude greater than terrestrial insects, it is likely that toxicity impacts in wetland or riparian habitats are not great because pesticides are not applied in riparian areas.

Table 4. Federal and State-listed Endangered, Threatened, and Candidate Species occurring or potentially occurring at Sacramento River National Wildlife Refuge.

Name	Scientific Name	Status
Bald Eagle	<i>Haliaeetus leucocephalus</i>	FT, SE
Giant Garter Snake	<i>Thamnophis gigas</i>	FT
Chinook Salmon, Sacramento River winter-run ESU	<i>Oncorhynchus tshawytscha</i>	FE, SE
Chinook Salmon, Central Valley spring-run ESU	<i>Oncorhynchus tshawytscha</i>	FT, ST
Steelhead, Central Valley ESU	<i>Oncorhynchus mykiss</i>	FT
Valley Elderberry Longhorn Beetle	<i>Desmocerus californicus diamorphus</i>	FT
Western Yellow-billed Cuckoo	<i>Coccyzus americanus occidentalis</i>	FC, SE
Willow Flycatcher	<i>Empidonax trailii</i>	SE
Bank Swallow	<i>Riparia riparia</i>	ST
Chinook Salmon, Central Valley fall-run and late fall-run ESU	<i>Oncorhynchus tshawytscha</i>	FC

ESU – Evolutionary Significant Unit

FE – Federal-listed Endangered Species

FT – Federal-listed Threatened Species

FC – Federal Candidate Species

SE – California State-listed Endangered Species

ST – California State-listed Threatened Species

Fish have been the focus of Federal and State clean water research and enforcement during the past 20 years. Studies have shown that lethal and sublethal effects from pesticides have impacted fish in the Sacramento River. Additionally both mining and urban usage have contributed to the levels of metals in the Sacramento River. Numerous cleanups, restrictions on discharge, and impending Total Maximum Daily Loads (TMDLs) have and are being undertaken (Cooke & Connor 1998). The implications of the past research on pesticides led the Service to ban the use of Diazinon in 1998 and pyrethroids in 2000 on the walnut properties.

Much of the current concerns about fish include not mortality but sub lethal behavior modifications including the inability to smell predators, inability to respond to scent signals given off by female fish about to release their eggs, and the inability to find migration routes. Considering the current use along Sacramento River drainages includes over 300,000 lbs of organophosphates(OPs) still applied to the region the, continued use of the spot treatment product, malathion is small. As noted above, the Service has not allowed any other OPs since 1998. Three pesticides used on the walnut properties are listed in literature indicating that they could be of concern to fish: Copper Hydroxide, Malathion, and Manex.

Research studies of, *Oncorhynchus mykiss*, have shown bioaccumulation of Copper (Kamunde and Wood 2003) with some studies showing minor accumulation giving the fish the ability to enhance tolerance to other metals during the migration along the river (Clearwater et al 2002). The current use on the Refuge properties is not considered detrimental for this metabolic metal. The approximately 10,000 lbs of metallic copper used on the properties for walnut blight is small in comparison to the regional use of over 4,000,000 lbs of copper on rice, walnuts, and peaches.

Malathion, used for the control of Walnut Husk Fly, is the only OP that is still used on refuge properties. As of 2003 the US EPA has not made an effect determination for malathion, a popular home and mosquito vector control product. With a variety of fish species researched, some of the potential effects of malathion at high dosage include behavioral signs and chronic effects of altered metabolism on immune organs (Galloway and Handy 2003). With regard to species of concern, studies with *Oncorhynchus mykiss*, indicated that malathion-exposed fish exhibited large decreases in distance and speed after 24 hours exposure, however even with 96 hours of continuous exposure they recovered fully 48 hours later (Brewer et al 2001). The current usage on refuge properties is approximately 400 lbs compared to a regional background of 20,000 lb in use for public health and walnuts. Malathion is closely controlled on the walnut orchards to a coarse baited spray every other row to draw the WHF to the malathion. Rapid degradation and extensive buffer strips prevent off site movement of the active ingredient.

The third chemical that is considered for use on the SRNWR that could be implicated in affecting fish is Manganese Ethylenebisdithiocarbamate (Manex®). In research, the chemical manex has been implicated in carcinogenic and mutagenic effects in rats (Deveci 1999). In studies conducted on *Oncorhynchus mykiss* the early fry stage appeared the most critical period (Van Leeuwen et al 1985). Manex® is currently used on the refuge properties in April in combination with copper to control walnut blight. The level of application averages about 1,000 lb per season on the refuge with regional use of over 500,000 lb.

Other species of concern that feed primarily on aerial insects probably have the greatest probability of being temporarily impacted by effects of pest control treatments. Although bats are not listed in Table 4, they would be a good example of a species group that could potentially be impacted by the loss of prey when the pest control treatments reduce populations of the nocturnal lepidopteron species.

Of the insectivorous birds listed in Table 4, Western Yellow Billed Cuckoo (YBCU), Willow Flycatcher (WIFL), and Bank Swallow (BASW) may be impacted by pest control treatments because their aerial invertebrate food base would be reduced. Pesticide applications made during June and July would coincide with YBCU and BASW nesting possibly impacting food resources available to feed nestlings although an abundance of non pest species rapidly recolonizes the walnut orchards from the adjacent wildlife areas.

Recent surveys have indicated that YBCU breed at the SRNWR in riparian vegetation. Swainson's Hawk (SWHA) and Bald Eagle (BAEA) are not insectivorous but will typically nest and/or roost in tall trees near open fields (SWHA) and open water (BAEA), possibly in walnut trees. Valley Elderberry Longhorn Beetles (VELB) may be present at the SRNWR on any areas containing blue elderberry plants, *Sambucus mexicana*. The use of buffers 300 feet or more between the walnut orchard pest control applications and blue elderberry plants should substantially help mitigate effect of applications of walnut pest control treatments on VELB. For the past five years, the Service at the SRNWR has only allowed the lepidopteron specific products, tebufenozide and pheromone disruption for the majority of the pest control applications. The application of malathion and eventually spinosad applied as a low volume bait only onto every third row of the orchard in combination with the 300 foot buffers substantially reduces any effect on VELB. The Giant Garter Snake (GGS) is an aquatic snake that inhabits relatively warm slow moving or standing water. The GGS does not occur near orchards at the refuge.

Introduction of parasitoids such as *T. pallidus* and *M. ridibimdis* or augmentive releases of the native, *T. platneri* may have a detrimental effect on native Ichneumonid and related wasps by reduction or competition for food sources. For the past ten years there has not been any known augmentive releases on the SRNWR properties. Resident populations of these biological control agents do reside in some of the walnut orchards after spreading from the University of California regional release programs.

TREATMENT THRESHOLDS

Treatment for the various pests of walnuts include both preventative treatments as is the case of Isomate C Plus which is applied to orchards before the emergence of codling moth larvae or copper hydroxide which is applied to walnut blight to keep the bacteria from spreading during rainy weather. The other treatments for walnut pests are primarily active controls in response to monitoring thresholds, orchard history, and the previous years pest levels of codling moth or walnut husk fly. The following Walnut IPM Treatment Summary (Table 5) outlines the anticipated active and preventative treatments during a normal year of walnut production with the treatment threshold and rate of treatment when required.

Figure 5. Walnut IPM Treatment Summary of Active and Preventive Chemical Controls

Pest/ Disease	Treatment	When to Treat	Rate of Treatment
Codling Moth	Tebufenozide (Confirm®)	Treat at 200 to 250 degree days after biofix for the overwintering, 1st and 2nd generations	1 to 2 pts per acre in 100 gallons of water
Codling Moth	Isomate C Plus®	Place pheromone dispensers in the upper third of the tree canopy before the first moth emergence in mid-March	Place 400 dispensers per acre
Codling Moth	Pheromone Mixture, Mating Disruption (3M MEC-CM®)	Apply at Biofix in the first generation and every 30 days up to five applications per season	Apply at 7.5 fl. oz./acre per application
Codling Moth	Pheromone Mixture, Mating Disruption (CheckMate CM- F®)	Apply at Biofix in the first generation and every 30 days up to five applications per season	Apply at 7.5 fl. oz./acre per application.
Walnut Husk Fly	Malathion with NuLure Bait	Monitor for flies with ammonium carbonate charged yellow sticky traps in areas of infestation. When eggs can first be squeezed from gravid females treat within 1 week	Apply 1.5 to 3 pt/acre mixed with NuLure bait every third row with a coarse spray to the lower half of the walnut tree
Walnut Husk Fly	Spinosad (GF-120 NF Naturalyte)	Monitor for flies with ammonium carbonate charged yellow sticky traps in areas of infestation. When eggs can first be squeezed from gravid females begin treatment.	Apply 1-3 fl. oz./per tree of undiluted spray solution. Repeat applications every 7-14 days.
Two Spotted Mite European Red Mite	Clofentezine (Apollo®)	Monitor regularly and treat if brown clusters of leaves are present on 10% of the trees and no predators are present	Apply 4 fl.oz/acre in 100 gallons of water
Walnut Blight	Copper Hydroxide (Kocide 101®)	Apply first treatment no later than first pistillate bloom, followed by additional treatments every 7 to 14 days depending on frequency of rainfall	Apply the equivalent of 4 lb of metallic copper per acre in 100 gallons of water
Walnut Blight	Manganese Ethylenebisdithioc arbamate (Manex®)	If registered in 2002 apply with each treatment of Kocide	Apply at 1.8 qts/acre of formulated product in 100 gallons of water
Weeds, General	Glyphosate (Roundup Ultra®)	Treat tree rows when weeds begin growing next to tree trunks or around buildings and irrigation structures	Apply 1 to 4 lb or a.i. per acre in 5 to 30 gallons of water

RESEARCH NEEDS

There are considerable areas to be researched regarding the effects of walnut management within the inner river area adjacent to the SRNWC units. The role of biological control from the riparian forest as well as the role of bats, birds, and generalist predators is yet not clearly understood. Success with pheromone disruption in walnuts in northern California is being explored but success has not been demonstrated on a large scale. Further research on the efficacy of pheromone disruption will be needed before this technology can be recommended for more than one third of the SRNWR walnuts.

Despite the existence of buffer strips to prevent off site movement or drift of the pest control materials there is still concern that the use of Malathion may have either a transitory or cumulative effects on the reduction of non-target aerial or terrestrial insects, especially those that are rare or serve as pollinators for rare plant species. Inventories of at risk species should be undertaken based on their susceptibility to Malathion treatments. Further field research on the alternative for walnut husk fly control, the spinosad bait, should be accelerated.

Research from other areas needs to continue to be evaluated for application to the SRNWR. Furthermore, as new methods or products become available to control walnut pests, those that can provide adequate control with less negative impacts than the existing methods should be evaluated for use on the refuge walnut units if appropriate and feasible.

SUMMARY

The SRNWR units, which contain managed walnut production units have in the past and are currently using the most efficacious methods of pest control for codling moth, navel orange worm, mites, and walnut husk fly all of which may require a chemical control. All decisions to use a chemical control are based upon monitoring by licensed Pest Control Advisors and are used when cultural and biological methods have failed to control the pests below significantly damaging levels. Failure to treat the pests codling moth and navel orangeworm, both of which have 3 or 4 generations, will result in population buildups that can impact neighboring walnut and almond orchards.

Failure to treat walnut husk fly or mites can cause a 10 to 20% portion of the crop to be unmarketable due to sunburn and secondary infestations from molds. Other preventative treatments, such as, copper hydroxide for the bacteria walnut blight are standard industry treatments that are required to prevent a 20 to 50% crop loss. It is important to keep the walnut crops managed by the tenet farmers who derive proceeds from the crop versus allowing the large units of walnuts to be unmanaged for years while funding is solicited for restoration. Currently there are not sufficient funds to restore the 1,529 acres of walnuts.

This IPM Plan will provide sufficient flexibility to keep the properties managed until further research and field experience with codling moth pheromone disruption and

spinosad bait can be evaluated and implemented. Until an acceptable pheromone disruption system is developed over the next three years, tebufenozide will be used as the primary codling moth control method on 95 percent of the acreage.

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