Invertebrate Pest Management in Rice

Numerous species of invertebrate animals are found in rice fields. These species are adapted to utilize the short-term aquatic environments of a typical rice field. The changing nature of a rice field, i.e., dry, followed by flooded conditions, quickly developing plant material and finally drained soil with senescent plants, limits habitat to invertebrates with specialized life histories. Insects, spiders, crustaceans, and other groups comprise the invertebrates. In a study conducted in 1990, researchers sampled and identified about 60 different species of arthropods in a survey of a California rice field. More recent efforts from the 2000’s have confirmed this level of diversity in California rice fields. Most of these invertebrates inflict no damage to rice plants, whereas about ten species can hinder rice productivity and yield. Rice is most susceptible to damage during the first six weeks after seeding. A couple of species of insects and a crustacean hinder seedling establishment. During the vegetative growth phase, a few species potentially can be problematic by feeding on foliage, but populations are generally low. Invertebrate pests in California are uncommon during the grain-filling period. The rice stink bug pest that severely impacts grain quality of southern U.S. rice is absent in the California system. Similarly, leafhopper and planthopper species (and associated virus diseases they transmit) that severely impact Asian rice production, as well as stem borers, do not occur in California rice.

Another segment of the invertebrate complex in rice fields is the mosquito population and the natural enemies that feed upon aquatic mosquito eggs, larvae, and pupae. These individuals have no direct impact on rice plant productivity but are important from the “good neighbor” standpoint. Rice production practices can impact mosquito populations and their management. Mosquito management is gaining increased importance with the recent upswing in mosquito-vectored diseases, i.e., West Nile Virus.

A rice field is a definite “agroecosystem”. Management actions intended to facilitate seedling establishment, weed control, plant growth (fertilization), etc. have effects on population levels of invertebrates. These effects could be positive or negative. Discussions of management of invertebrate pests will be divided into three portions of the growing season:

1. Seeding to 4-5 leaf stage (0 to ~30 days after seeding),
2. 5-leaf stage to heading and flowering stage (30 to ~90 days after seeding),
3. Heading to harvest.
Seeding to 4-5 Leaf Stage

Tadpole shrimp, crayfish, seed midge, and rice leafminer all have the capacity to hinder rice seedling establishment and early-season plant growth. In addition, rice water weevil adults feed during this period; however, the primary damage is inflicted later in the growing season by the rice water weevil larvae that develop on roots under the soil. Insecticidal management of this pest is targeted toward the adults so it is appropriate to consider this pest in this section.

Tadpole Shrimp

Tadpole shrimp (fig. 1) persist during dry periods in the egg stage (surviving for several years) and hatch quickly in the spring with the addition of water. Eggs hatch two to three days after the flood is initiated. Young tadpole shrimp grow fast. Initially, they feed on algae and other small organisms. When their shells are about half the length of a rice seed, individuals readily feed on germinating rice seeds, preferring the emerging radicle and coleoptile (fig 2). Large tadpole shrimp can uproot seedlings while digging in the soil. The occurrence of floating seedlings, caste skins (shed skins produced as the tadpole shrimp molts), and muddy water are indicative of tadpole shrimp infestations. Cut roots on the floating seedlings that have been injured by tadpole shrimp distinguish them from seedlings which are floating due to strong winds or other conditions.

Muddy water can reduce light penetration and further inhibit seedling growth and establishment. Once seedlings have a well established root and the prophyll (spike) is emerged, they are less susceptible to tadpole shrimp injury.
Crayfish

Crayfish (fig. 3) make tunnels in levees near water boxes, compromising the structure of the levee. Crayfish’s tunneling activity can cause seepage in levees, which could result in the illegal release of pesticide-treated water. Crayfish feed on dead and decaying matter, insects, and plants. Their plant-feeding can be a problem on seedling rice. Muddy water, uprooted seedlings, and reduced stands result from crayfish infestations.

Seed midge

Seed midge also hinder seedling establishment; there are several species in this group. This insect, the adult of which is a small mosquito-like fly (they actually have no functional mouthparts so cannot bite like a mosquito), is extremely mobile (fig. 5). Upon flooding a field, thousands of these adults fly to the field in a swarm and deposit eggs on the water surface. These swarms are often misidentified as mosquitoes. The eggs hatch in one to two days and the larvae feed on the soil surface of the flooded field. Larvae feed on seeds and seedlings as well as on algae. They often destroy the seed before it can germinate in the water (fig. 6). Once the seedling is 3 to 4” long, it is not susceptible to midge damage.

Management of all these seedling pests is similar. Application of insecticides pre-plant or soon after seeding is effective due to the quick developing nature of the infestations after flooding. Actions that facilitate quick establishment of rice seedlings can mitigate damage from these
pests. Since these invertebrates only damage rice seeds and young seedlings, once these stages are past, the potential for damage is low. Quick flooding and timely seeding reduces the risk of injury by these pests. Crop rotation can help manage crayfish and field draining soon after seeding can assist in managing tadpole shrimp and seed midge.

Rice Leafminer

The rice leafminer was a significant pest of rice in California through the 1970’s. During the 1990’s, this pest could be found at low levels in most fields. Today, populations of rice leafminer are very low or absent. The adult fly, similar to a small house fly, lays a single egg on leaves. The resulting larva (fig. 7) mines between the epidermal layers of the leaf (fig. 8). This injury can resemble that of rice water weevil adults with the difference being that the leafminer larva can be seen in the leaf when it is held up to the sunlight. There are multiple generations of rice leafminers per year (up to 11), but this insect only damages rice before the plants start to grow upright. Leaves laying on the water surface are susceptible to attack. Therefore, slow growing rice (cool weather and/or deep water) is most susceptible to attack. Biological control by parasitic wasps aids in managing this pest.

Rice Water Weevil

The rice water weevil (fig. 9) was considered one of the most damaging insect pests of rice in California after its discovery in the Sacramento Valley in the late 1950s. Currently, damage by rice water weevil is unusual and limited to areas with a history of rice water weevil pressure. Most likely, the use of new, more vigorous and productive varieties, and the intensive use of insecticides to manage tadpole shrimp explain the rice water weevil’s decline in importance.

Adult rice water weevils overwinter in a diapause (reduced activity) state. The overwintering sites include levees and ditch banks, crop residue in the basins, riparian areas, etc. As temperatures increase, adults feed on leaves of grasses and eventually break the diapause. This involves regenerating their flight muscles such that adults can fly for several miles (hypothesized to be up to 20 miles).
The spring flight (April to June) occurs during days characterized by warm, calm evenings. During these periods, the adults fly and prefer to infest newly flooded rice fields; those with rice plants emerging through the water are most susceptible to infestation. Adults feed on the leaves of rice plants, which result in characteristic longitudinal feeding scars (fig. 10). This feeding has no effects on rice growth or yield.

Adults oviposit in the rice leaf sheaths found just below the water level. Oviposition occurs in plants with 2 to 6 leaves. Eggs hatch in 5-7 days; the first instar larvae feed on the leaf tissue for a few days and then drop down through the water and soil to the roots (fig. 11). The remaining portion of the life cycle is spent in the flooded soil of rice fields. The larvae develop through four instars and feed on rice roots causing significant injury. Pupation occurs on rice roots (fig. 12) and new adults emerge in late July. These adults feed to a limited extent on rice leaves and then leave the rice fields for overwintering sites.

Rice water weevil larvae root feeding causes reduced plant growth, chlorosis, and reduced tillering. These symptoms become noticeable four to six weeks after seeding.

In California, damaging infestations of rice water weevil larvae are limited to areas up to 50 feet next to borders of fields and levees (fig. 13). Grain losses from larval feeding of up to 45% have been recorded. In California, research results support an economic threshold of about 1 larva per plant.

Management of rice water weevil in California relies on chemical and cultural controls. Biological control of this pest is nonexistent. Adult weevils infest rice fields a few days after flooding and before the establishment of plant canopy or other aquatic arthropods. The larval and pupal stages live in flooded soils, protected from the activity of most arthropods.
Some moderate host plant resistance has been identified for rice water weevil. However, incorporation into commercial varieties has not occurred as this does not appear to have the potential to be a stand-alone management tool. Cultural controls are useful for management of rice water weevil in California. Removal of levee vegetation in the spring helps reduce rice water weevil densities in adjacent rice basins. The additional herbicides required for this and the loss of wildlife habitat on levees are substantial drawbacks of this management technique. Two additional cultural methods assist in reducing rice water weevil densities, but may not fit all production schemes. They include dry seeding rice and delaying seeding dates. The reduced yields that can result from these techniques make them undesirable to growers. Additionally, research has shown that winter-flooding rice basins reduces rice water weevil populations the following spring, but the reasons for this reduction are unknown.

Chemical control of rice water weevil from the late 1970’s to the late 1990’s relied on the insecticide carbofuran. This granular insecticide was applied before flooding and was incorporated into the soil. A small percentage of the usage of this product was made post-flood to drained fields. Since higher rice water weevil densities occur near the field edges, border applications of carbofuran were commonplace, resulting in significant savings to growers and greatly reducing the amount of insecticide going into the rice agroecosystem. Due to its toxicity to birds, carbofuran registration was cancelled after the 2000 season. In 1999, diflubenzuron (Dimilin) and lambda-cyhalothrin (Warrior), were registered as alternatives to Furadan. In 2002, zeta-cypermethrin (Mustang) was also registered as well as generic formulations of lambda-cyhalo-
thrin. These insecticides are effective for RWW management in California; however, they have some limitations. They target rice water weevil adults, and have limited effects on rice water weevil larvae, which is the damaging stage. Dimilin sterilizes weevil adults (i.e., females produce no viable eggs) and the pyrethroid products kill adults, limiting egg laying. Application timing is of utmost importance since no control is possible with these products after a few days following oviposition. These insecticides are recommended to be sprayed at the 2-4 rice leaf stage. Additionally, lambda-cyhalothrin can be applied preflood up to five days before the field is flooded for seeding. Applications can be made to field borders and only 50 feet adjacent to the levee, in the same fashion carbofuran was used. Clothianidin (Belay), a third generation neonicotinoid, was registered in 2014. A post-flood application timing (~2-3 leaf stage) appears to be the optimal timing or this product; however, research has shown that clothianidin can be used as a rescue treatment when larvae are present in the field feeding on rice roots at the 5 to 6 leaf stage of rice. Chlorantraniliprole (Coragen), a diamide insecticide, received registration in 2017. Currently, this insecticide is only labeled for pre-flood applications.

Threshold values to determine the need for treatment developed for carbofuran were inadequate for use with the new insecticides registered for rice water weevil management. Currently, the need for insecticide applications against rice water weevil rely on grower experience and the history of the field.

5-leaf Stage to Heading and Flowering Stage

Two species of armyworms, true armyworm and western yellowstriped armyworm, are found in rice fields during the summer. In recent years, damage from these pests appears to be on the upswing.

The armyworm moth lays its eggs in linear masses with the leaf tied around the eggs in a roll on either rice or on other grass species around and in rice fields. Larvae of both species are striped and vary in body color (fig. 14). Larvae feed predominantly at night or during cloudy days. They develop to full size and pupate in about 3 to 4 weeks in the summer. Pupation normally takes place in the upper surface of the soil or in debris, consequently many mature larvae drown in flooded paddies before reaching a suitable pupation site. However, some are able to pupate lodged between leaves or tillers. Adult moths of both species have a wing span of about 1.5 inches and are predominantly silver and gray (western yellowstriped armyworm) or buff colored (true armyworm).
Damage by armyworms is most serious during periods of stem elongation (early summer) and grain formation (late summer). Larvae defoliate plants, typically by chewing angular pieces off leaves (fig. 15). During outbreaks, defoliation to the water level can occur (fig. 16). Armyworm larvae may also feed on the panicle, specifically on the rachis near the developing kernels causing these kernels to dry before filling. This feeding causes all or parts of the panicle to turn white (fig. 17). The seriousness of armyworm injury depends on the maturity of the plant and the amount of tissue consumed. Significant yield reduction can occur if defoliation is greater than 25% during the early summer infestation or if panicle injury is higher than 10% later in the summer.

True armyworm outbreaks occurred in 2015, 2016 and 2017. Pheromone moth trapping is being used to predict armyworm activity and improve timing of field monitoring (fig. 18). The pyrethroid insecticides (lambda-cyhalothrin and zeta-cypermethrin) are ineffective controlling armyworms. The insect growth regulator diflubenzuron (Dimilin) is effective; however, it has an 80 day pre-harvest interval which prevents its use during the heading stage. The biological insecticide *Bacillus thuringiensis* is effective when applied against small armyworms, which can be difficult to find timely in the field. The insect growth regulator methoxyfenozide (Intrepid) has received a Section 18 registration, allowing its use on rice on a yearly basis. Currently, the search for alternative insecticides is ongoing.

Various natural factors cause mortality of armyworms in the rice paddy. Many caterpillars drown or are killed by natural enemies including predators, pathogenic microorganisms, and parasites. Insecticide treatments are justified if more than 25% defoliation occurs and armyworms are present on the plants from late June through early July. Treatment for panicle loss is justified if 10% of the panicles in the area sampled are damaged and armyworms are observed.
Heading to Harvest

A few instances of pecky rice (fig. 19) have occurred in California in recent years. Pecky rice refers to kernels that show a discoloration after hulling and milling. This discoloration can be caused by insects, but can also be caused by pathogens developing on the kernel due to excess moisture caused by rain or lodged rice. In fields that produced some pecky rice and some quality downgrades the previous year, collections were made in early September of a native stink bug called the redshouldered stink bug (fig. 20) (*Thyanta pallidovirens* [= *T. accerra*]).

Cage studies showed that this and other common stink bug species have the potential to feed on developing kernels and cause peck. Stink bugs can be common in rice fields with higher levels of weeds, fields near natural/riparian areas, and rice fields interspersed with other crops. Nevertheless, in most fields, stink bugs are present at very low levels and do not constitute a problem.
**Additional Information:**

The UC Pest Management Guidelines for Rice maintains up-to-date information on management of key invertebrate pests of rice (UC IPM Pest Management Guidelines: Rice, UC ANR Publication 3465; http://www.ipm.ucdavis.edu/PMG/selectnewpest.rice.html). In addition, the publication entitled, Integrated Pest Management for Rice, 3rd Edition (UC ANR Publication 3280) is a good resource for rice IPM.