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. This diversity contributes to the strong environmental impacts of rice.

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 crustaceans 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. However in recent years some instances of pecky rice have been seen and native stink bugs, in particular the redshouldered stink bug, appear to be causing this. 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.

Management actions...have effects on populations of invertebrates

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

Figure 1. Tadpole shrimp are detrimental in several ways. They will feed on germinating seed.

Figure 2. Large numbers of tadpole shrimp dislodge seedlings and cause turbidity in the water, limiting light penetration.

Tadpole shrimp, crayfish, seed midge, and rice leafminer all 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. Insecticidal management of this pest is targeted toward the adults so it is appropriate to consider this pest in this section.

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. About nine days after hatching, individuals reach the reproductive stage and readily feed on rice seeds, germinating spikes, and uproot seedlings while digging in the soil. The occurrence of floating seedlings, caste skins (shed skins produced as the animals develop), muddy water (Fig. 2), etc. are indicative of tadpole shrimp infestations. Cut leaves on the floating seedlings from tadpole shrimp can distinguish them from seedlings which are floating due to strong winds or other conditions. The muddy water can reduce light penetration and further inhibit seedling growth and establishment.

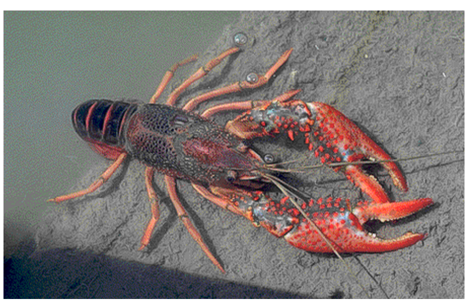

Figure 3. Crayfish can directly affect rice by feeding on the germinating seed.

Figure 4. Holes dug by crayfish may cause unwanted seepage.

Damage by **crayfish** (Fig. 3) is similar to tadpole shrimp's. Crayfish reside in tunnels (Fig. 4) which remain moist or water-laden. 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. The tunneling activity of crayfish creates another type of problem. Tunneling can cause seepage in levees which could result in the illegal release of pesticide-treated water.

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.

Figure 5. The rice seed midge can produce large swarms under certain conditions.

Figure 6. Rice seed midge developing larvae will feed on the germinating seed, killing it.

Management of all these seedling pests is similar. Pesticides are of some use. Pre-plant applications must be used due to the quick developing nature of the infestations after flushing. These could be of use especially for seed midge. Copper sulfate can reduce numbers of tadpole shrimp but the efficacy of this product appears to be reduced in recent years. Cultural practices are quite useful; actions that facilitate quick establishment of rice seedlings can mitigate damage from these pests. Since these invertebrates only damage rice seeds and "spikes", once these stages are past, the potential for damage is nil. Quick flooding and timely seeding, warm water, shallow water, etc. all play a role. Crop rotation can help manage crayfish and field draining can assist in managing tadpole shrimp and seed midge.

The **rice leafminer** was a significant pest of rice in California through the 1970's and even through the 1990's this pest could be found a low levels in most fields. Today, populations of rice leafminer are absent in many fields. 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

Figure 7. Rice leafminer larvae tunnel within the leaf eating the tissue.

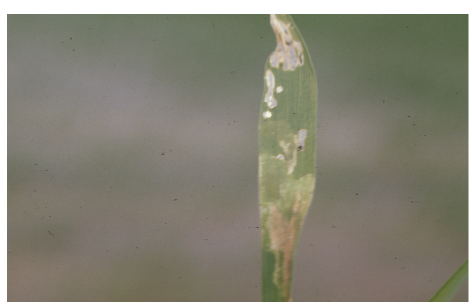

Figure 8. Large rice leafminer numbers can cause browning of the leaf and reduce photosynthesis.

The **rice water weevil** is the most important invertebrate pest of California rice. Weevil adults (Fig. 9) 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; however, coinciding with this the 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.

Figure 9. The most serious insect pest in rice is the rice water weevil. Actual size of the adult is ~ 1/8 inch.

Figure 10. Overwintering adults emerge in the spring to feed on rice leaves

The effects of rice water weevil injury on rice plant growth, development, and yield have been intensively studied. Grain losses from larval feeding of up to 45% have been recorded. Results support an economic threshold of about 1 larva per plant. A linear relationship exists between the percentage of plants with adult feeding scars and larval density. Prior to ~2000, quantification of adult feeding scars was used as a sampling tool to determine the necessity for a chemical control (e.g., post-flood application of Furadan® 5G, an insecticide that kills primarily larvae of this pest). However, the switch to an adult management program in the late 1990's resulted in this method being useless. As other types of insecticides are developed, this sampling method may again be useful.

Figure 11. The small, legless larva drop to the soil where they feed on the roots causing the most significant amount of damage.

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 arthropod community. 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 occurredas 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. Research has shown that winter-flooding rice basins reduces rice water weevil populations the following spring, but the reasons for this reduction are unknown.

Figure 12. Feeding from the larvae will prune the root system and retard the growth of the plant resulting in costly yield reductions.

Chemical control of rice water weevil relied on carbofuran (Furadan® 5G) from the late 1970's to the late 1990's. 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 Furadan 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, Furadan 5G 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 followed later in the 2000's by Declare® (gamma-cyhalothrin) as well as generic formulations of lambda-cyhalothrin. These insecticides were proven effective for RWW management in California; however, they have some limitations and required changes in management practices. They have limited effects on rice water weevil larvae, which is the damaging stage and therefore target the adults to minimize the deposition of viable rice water weevil eggs. Dimilin sterilizes weevil adults (i.e., females produce no viable eggs) and the pyrethroid products kill adults. 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, Warrior can be applied preflood up to five days before the field is flooded for seeding. Applications can be made to field borders only 50 feet adjacent to the levee, in the same fashion Furadan was used. Belay insecticide containing clothianidin, a third generation neonicotinoid, was registered for the 2014 season. A post-flood application timing (~2-3 leaf stage) appears to be the optimal timing for this product for rice water weevil control.

Figure 13. A floating barrier trap was developed to monitor for early season Rice Water Weevil populations in the water.

The post-flood application nature of these new insecticides and relatively short residual introduced two other questions in terms of rice water weevil management, 1) how long is control of this insect pest needed, and 2) what threshold is applicable to assess the need for treatment. Studies were conducted for two years to examine yield loses from rice water weevil at various plant growth stages. In one year, no yield losses occurred with infestations at the ~4-leaf stage or later, whereas in the second year, yield losses were found even when infestations occured much later into the season, (~7-leaf stage rice). It makes sense that the plant is more tolerant of root damage as it becomes older, but the exact timing is still being examined. Threshold values to determine the need for treatment developed for Furadan use were inadequate with the adulticide approach for rice water weevil management. A floating barrier trap that had been developed at the Univ. of Arkansas was evaluated for use under California conditions. The traps (Fig. 13), which are not commercially available, can be constructed from readily available components. Traps (eight per every 40 acres) should be placed into the field immediately after flooding (fields need about 4 inches of water for the traps to float). Anchor the trap about 5 feet into the field from the levee. The weevil adults invade fields as soon as water is present so the traps can be placed into the fields before seeding. Count the number of trapped adults daily, or at most, every other day. If one or more rice water weevil adult per trap per day is collected, this indicates that the field should be treated with an insecticide to prevent rice water weevil larval damage. Once the seedlings are present (about the 2 leaf stage) the traps do not effectively collect the adults and their use should be discontinued. Other techniques to determine the need for treatment for rice water weevil include examining weeds on the levees for adult feeding scars before seeding the rice as well as past history of the field in terms of weevil infestation levels. Certain fields/areas tend to be "hot spots" for this pest and other areas typically have low populations.

5-leaf Stage to Heading and Flowering Stage

Two species of **armyworms**, true armyworm and western yellowstriped armyworm, may occasionally be found in rice fields in mid-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 in the paddy. 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. Usually only one generation a year will be spent on rice. 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).

Figure 14. Larval feeding can cause significant damage.

Figure 15. The caterpillars eat the rice leaves reducing the plants level of photosynthesis.

Damage by armyworms is most serious during periods of stem elongation and grain formation. Larvae defoliate plants, typically by chewing angular pieces off leaves (Fig. 15). They may also feed on the panicle near the developing kernels causing these kernels to dry before filling. This feeding causes all or parts of the panicle to turn white. 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% at 2 to 3 weeks before heading.

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 August through early September. Treat for panicle loss if 10% of the panicles in the area sampled are damaged and armyworms are observed. Insecticides, including the biological material, Bacillus thuringiensis (Bt), are effective.

Heading to Harvest

Figure 16. Redshouldered stink bug

Armyworms can also damage panicles during this part of the season. They are the only invertebrate pest which commonly damages rice in this stage. A few instances of "pecky" rice have occurred in California in recent years. Research has been ongoing to see if this damage is being caused by an insect. 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. 16) (Thyanta pallidovirens [= T. accerra]). This insect was found at very low numbers. However, cage studies showed that this species does have the potential to feed on developing kernels and cause damaged rice kernels. This is not a new species to California but rather populations seem to be increasing and they are more common in rice fields with higher levels of weeds, fields near natural/riparian areas, and rice fields interspersed with other crops. Threshold numbers resulting in damage and possible management options are still being investigated.

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.