Tadpole shrimp, seen here from underside, utilizes strong mandibles to feed on bud sheath, roots, and leaves of rice seedlings.

Rice seed with bud sheath (coleoptile) chewed off by tadpole shrimp.

Buried tadpole shrimp eggs remain dormant until brought to the soil surface by cultivation and hatch when rice fields are flooded. (80X)

Controlling tadpole shrimp

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Copper sulfate works best on this rice-field pest

Use of chemicals to control the tadpole shrimp has resulted in some of the classic problems associated with this method: adverse effects on wildlife, ineffective control due to the wrong formulation or misapplication, phytotoxicity, and most recently, pesticide resistance.

The tadpole shrimp, *Triops longicaudatus* (LeConte), inhabits temporary fresh water bodies of the Americas, Japan, India, the West Indies, and a number of Pacific islands. The name tadpole was probably given to this shrimp because of its resemblance to the young of the bullfrog in color, swimming activity, and general outline. L. E. Rosenberg, University of California, Davis, first reported the tadpole shrimp as a pest of rice in northern California in 1946. Growers had seen it in rice fields earlier but didn't associate it with injury to the crop. These crustaceans may have existed in some of the first commercial rice plantings in 1912, since many of the fields are on land that was once part of temporary ponds in the flood plains of the Sacramento River.

Like a number of crustaceans, tadpole shrimp can survive drought or desiccation for several years in a resistant egg stage. The reddish eggs are laid at or close to the soil surface and hatch when flooded at temperatures above 59°F (15°C). Hatching may continue through a 2-week period, but most occurs within the first 2 to 3 days of flooding. Buried eggs remain dormant until they are brought to the soil surface by cultivation. After hatching, the larvae gradually increase in size with periodic molts; the hermaphroditic adults begin laying eggs in 9 to 12 days (over 500 eggs per individual have been recorded), and die in 20 to 30 days.

Microorganisms (fungi, bacteria, and minute animals) are the main food of tadpole shrimp during their early development (up to 4 to 6 days). As they grow, their diet includes higher plants and larger animals. With their strong mandibles, they can remove tissue from the bud sheath (coleoptile), roots, and leaves of rice seedlings. This feeding activity may also uproot seedlings, causing them to float to the water surface and eventually come to rest on the shoreline. The water of a rice field infested with shrimp is usually brown and turbid by the tenth day, because the shrimp stir the fine particles of the soil surface while feeding and laying eggs. The turbidity reduces light penetration and may retard seedling growth.

The tadpole shrimp is a pest of rice only from the time the seed germinates until the seedling emerges through the water. In California, rice is particularly susceptible, because seed is commonly broadcast to semipermanent water. The shrimp is not a pest in countries where a permanent flood is not applied until the seedlings are well developed or where they are transplanted to flooded paddies from nurseries. In fact, several species of tadpole shrimp are considered by researchers in Japan to be potential agents for biological control of small weeds in flooded paddies. The transplanted rice in these paddies is too large to be susceptible to the shrimp.

Early control and wildlife

The first chemical control of tadpole shrimp in California was developed by Rosenberg in 1946: DDT formulated as an emulsifiable concentrate, sprayed at 0.5 pound active ingredient per inch of water per acre, or copper sulfate (cupric sulfate pentahydrate) dust applied at 1 pound active ingredient per inch of water per acre. Both chemicals controlled the shrimp, but DDT became the most cost-effective and the most widely used.

In 1955, UC Davis scientists R. L. Rudd and R. E. Genelly reported bird mortality from DDT in California rice fields. They attributed this to airplane sowing of "DDT-coated" rice seed, which was eaten by pheasants, blackbirds, and ducks. Most aerially sown seed drops into flooded paddies, but some is unavoidably scattered on the soil surface of levees and field margins. To reduce operating costs, growers had combined the sowing and preventive chemical control phases. Rice did not receive "typical" seed treatment, but the chemical adhered to some of the seeds when DDT granules (formulated as a wettable powder) were placed in the plane hopper with presoaked rice seeds. The practice of combining sowing and treating was discontinued when the problems it caused for wild birds were discovered.

In the early 1960s, several fish kills in rice-field drainage waterways also coincided with DDT treatments for tadpole shrimp. In 1963, cooperative studies by California state agencies, the University of California, rice growers, and chemical company representatives demonstrated that DDT spray treatments at recommended rates caused acute fish toxicity in drainage waterways when water was allowed to drain freely after treatment but not when the water was held for 5 days before release. Since other chemicals were available for tadpole shrimp control, DDT was removed from University recommendations in 1964; its general use was banned in the United States in 1973.

Other problems

Copper sulfate has been used by some rice growers to control tadpole shrimp since 1946, but during the late 1950s, many reported a lack of control at recommended rates. The problem was not resistance, as had been thought, but the formulation. Original control studies had used finely ground crystals of copper sulfate, but crystals of later commercial formulations were about the size of pea gravel (up to 10 mm). This was more economical but prevented the chemical from going into solution fast enough to be toxic to tadpole shrimp. Subsequently, copper sulfate was formulated as finely ground "rice" crystals, and the problem disappeared.

Copper sulfate is sometimes also used as an algicide in rice fields. At one time, to eliminate the cost of airplane application, the material was placed in metering devices at irrigation inlet boxes as a preventive treatment for algae and shrimp. The practice was stopped, because water currents distributed the chemical unevenly and because a high concentration of copper in water adjacent to the metering devices injured the rice.

Parathion at 0.1 pound active ingredient per acre was added to UC recommendations for tadpole shrimp control in 1965. Water spill is restricted from treated fields for 3 days, and no wildlife problems have been noted to date with this chemical at the recommended low rate of spray application. In the late 1970s and early 1980s, however, rice growers in several areas reported less than desirable control of tadpole shrimp with parathion. This was first attributed to improper treatment time or inadequate airplane coverage, since the practice was to spot-treat only turbid areas of the field or to spray in swaths that did not overlap.

We carefully monitored a commercial application of parathion for tadpole shrimp control in San Joaquin County in 1982. Although recommended time of treatment and application procedures were followed, the chemical was not effective.

Standardized laboratory tests, which we conducted in 1982, compared the susceptibility of tadpole shrimp from several localities with data from previous years. The test shrimp were reared from eggs collected in soil. When compared with 1964 and 1974 data from similar tests, the 1982 results indicated a reduction in level of control with parathion during the 18 years at the Butte County site (table 1). Tadpole shrimp from the Colusa County site were highly susceptible, but those from San Joaquin County showed a low level of mortality at exposure times comparable to those in other tests.

The most plausible conclusion from these tests is that tadpole shrimp have developed varying levels of resistance to parathion in different parts of the state. Several factors may affect the level of resistance at a particular site, but because tadpole shrimp are not usually transported in large numbers over great distances, the frequency of parathion use at the site is probably a major factor. Parathion is used at the same rate to control mosquitoes and the rice leafminer, so multiple applications may be made in some locations and resistance is likely to be greatest in these areas. Resistance to parathion also suggests that tadpole shrimp might be resistant to other organophosphates.

Present recommendations

Copper sulfate continues to be very effective in controlling the tadpole shrimp at recommended rates of 5 to 10 pounds of active ingredient per acre. Comparable rates of copper sulfate formulated in crystal form or as a liquid have resulted in similar mortality levels in replicated tests in the laboratory (table 2). Crystals are predominantly used now, but they may be replaced by the liquid formulation if it becomes economically advantageous.

Action guidelines for control of tadpole shrimp are given in the manual *Integrated Pest Management for Rice* (publication 3280, University of California Division of Agriculture and Natural Resources). Recommendations are based on the shrimp's presence during the critical period from planting to seedling emergence through the water, and the maximum number of plants desired per square foot. Seeding should be done as soon as possible after flooding, because most tadpole shrimp eggs hatch within 2 days after initial flooding, and the bigger the shrimp, the greater the potential for plant injury.

TABLE 1. Mortality of field-collected tadpole shrimp treated with parathion*

Location	Year	Time after treatment	Percent mortality	
			Untreated	Treated
		hr		
Butte County	1964	18	0	100
Butte County	1978	19	6	81
Butte County	1982	18	0	65
Colusa County	1982	7	0	100
San Joaquin County	1982	18	0	10

* Application rate: 0.1 pound active ingredient per ½ acre-foot of water.

TABLE 2. Mortality of field-collected tadpole shrimp treated with copper sulfate

Location	Year	Formulation	Rate*	Mortality after treatment†	
				4 hr‡	5 hr‡
			lb	%	%
Butte County	1978	Crystals	5	50	91
		Crystals	10	56	94
San Joaquin County	1982	Crystals	5	88	100
		Crystals	10	100	100
		Liq.(chelated)	5	94	100
		Liq.(chelated)	10	100	100
San Joaquin County	1984	Crystals	5	65	95
		Crystals	10	75	95
		Liquid	5	75	100
		Liquid	10	75	100

* Pounds active ingredient per ½ acre-foot of water

† No mortality in untreated controls occurred at these time intervals.

‡ Time intervals in 1984 were 3 hours 45 minutes and 4 hours 45 minutes.

To order the IPM rice manual, send check or money order for $15 payable to **The Regents, University of California** to: ANR Publications (Dept. CA), University of California, 6701 San Pablo Ave., Oakland, CA 94608. Foreign orders: Request ordering information and pro forma invoice, indicating number of copies and method of shipment (surface or air) desired. Do not send payment.

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