Role of Crayfish (Decapoda: Astacidae) as Pests of Rice in California and their Control[1]

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ABSTRACT

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Studies in 3 successive years with *Procambarus clarki* (Girard) in rice fields showed significant reductions in rice seedling establishment when the associations were both as natural and confined populations. The natural infestations resulted in seedling reductions of 70 to 100%, whereas confined crayfish caused losses in seedlings ranging from 9% at 0.34 crayfish per m^2 to 94% at $2.4/m^2$. Methyl parathion at 566.5 g/ha was highly effective in controlling *P. clarki* and *Orconectes virilis* (Hagen). Fenthion at 112.1 g/ha resulted in high mortality of the former species but not the latter.

Procambarus clarki (Girard) has adapted well to the rice fields in the Central Valley of California since it was introduced to the state as a potential food item. A viable crayfish industry exists in the southern states that utilizes rice fields, particularly Louisiana (Williams and Avault 1977). In California, crayfish are commercially trapped in rivers and streams, and the most desirable species sought for export is *Pacifastecus ichiusculus* (Dana) (Comeaux 1978). Rice farmers in California often consider crayfish to be pests because of their burrowing habits. *P. clarki* and *Orconectes virilis* (Hagen) are reported to damage irrigation systems by undermining weir boxes (gates between paddies) and causing the collapse of levees as a result of their tunneling (Riegel 1959, Chang and Lange 1967, Lange and Miller 1970, Miller 1980).

In 1973, a commercial rice field in Sutter County showed a considerable reduction in rice seedlings 1 to 20 m from the margin of the levees in association with a large population of crayfish. We did not see the field until after a chemical treatment had eliminated the population, so we were not able to conduct tests on plant injury. In 1979, several experiments in a rice field at the Rice Experiment Station in Butte County were abandoned due to the absence of an adequate stand of rice seedlings. The water in the field was murky, parts of leaf tissue from weeds and rice were floating, and close examination of the bottom showed openings to underwater burrows every few meters. Crayfish were occasionally observed during the day, but they are reportedly most active at night and remain hidden in vegetation or in their burrows during the brightest hours (Penn 1943).

From 1979 to 1981, experiments were conducted to determine the role of crayfish as a rice plant pest and to provide information on their control, and the results are reported here.

Materials and Methods

Experiments on Seedling Establishment.

Tests during all 3 years included four treatments arranged in randomized complete blocks. Four replications were used in 1979 and 1981, and five in 1980. In 1979, each treatment included a 0.837-m^2 area with 300 presoaked seeds of variety 'Calrose 76' that were broadcast in the water on 6 June. The same number of seeds of variety 'S6' were broadcast in a circular area of 0.74 m^2 on 12 May 1980, and 1,600 seeds of variety 'M-401' were sown in a circular area of 2.96 m^2 on 7 May 1981, for each treatment. The seed was untreated in 1979 and 1980 but treated with the fungicide captan at 68 g of AI/45.4 kg of seed in 1981. Standard cultural practices with preplant applications of the fertilizer $(NH_4)_2SO_4$ and the herbicide Ordram were followed each year. The fields were flooded on 8, 9, and 6 May on the successive years, and water depths were maintained at 100 to 150 mm.

In 1979 and 1980, treatments were designed to measure the impact on rice seedlings by natural populations of crayfish and introduced crayfish in confinement with the seedlings. The crayfish used during these years were all from the rice field, and all specimens sampled were identified as *P. clarki*. A natural infestation was not present in the rice field of the 1981 test, so crayfish were collected from a canal adjacent to a rice field. The collections contained the species *P. clarki* and *O. virilis*. Three of the treatments in 1979 included a 0.915-m^2 cage of ca. 15 mesh per linear 2.5 cm. Two of these caged treatments had their bases through the water and buried in the mud, one to exclude crayfish and the other to confine two animals per cage. One cage was set so that the base just touched the water surface and allowed free movement below and shade above. The fourth treatment was the same-sized square area open and without a cage above. In 1980, aluminum rings 30.5 cm high were set with their bases 7 to 10 cm in the mud and the tops above water for three treatments. One set of rings was used to exclude crayfish, and the other two to confine one or two crayfish per ring. A fourth treatment defined the same sized circular area for planting with several stakes but allowed free movement of the natural population of crayfish. The 1981 test used aluminum rings with no crayfish and with one, two, or four animals per ring. The crayfish confined in all tests were 8 to 13 cm in length (claw to telson). They were introduced on 6 June, 12 May, and 12 May for the successive years. The number of seedlings that remained in each treatment (rooted with leaves above water) were counted on 19, 4, and 3 June for the successive years. The seedling

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count was subjected to a two-way analysis of variance (ANOVA).

Experiments on Chemical Control.

In 1979, the 856-m^2 field that contained the rice seedlings experiment was treated with fenthion, 839 g/liter EC, at 112.1 g (AI)/ha on 16 August. It was applied with a CO_2-powered backback sprayer with 93.6 liters of water per ha. Irrigation water inflow and outflow were stopped during the test. Two-hour pretreatment and 1- and 4-day posttreatment samples of the natural population of crayfish were made at nine areas of the field. Each sample consisted of a rectangular area of 0.82 m^2 that was swept with a rectangular aquatic net. Plant canopy in the field was minimal, but submerged weeds were plentiful.

Chemical tests on 20 June 1980 and 11 August 1981 utilized the aluminum rings and plot design after the completion of the seedling experiments. Table 2 gives chemicals, formulations and rates used. In 1980 and 1981, a CO_2-powered microapplicator was used with the same rate of water per ha that was used in 1979. Crystals were applied by hand. The rings were free of rice plants but contained several species of submerged and floating weeds in 1980. All weeds were removed in 1981. Five 8- to 13-cm-long crayfish were caught and placed in each ring in 1980, and 15 (8 to 16 cm long) crayfish were used in the larger rings in 1981. The ringed areas were swept for crayfish 3 days after the treatments in 1980 and 2 days after in 1981. The source of crayfish for the 3 years was the same as indicated in the methods of seedling establishment. The numbers of live and dead crayfish were compared in a two-way ANOVA.

Table 1.—Rice seedling establishment with natural and confined infestations of crayfish, Biggs, Calif.

Treatment and yr	Surviving seedlings/m^2[a]	% Seedling reduction
1979[b]		
Crayfish excluded	54.7a*	—
2.40 Crayfish/m^2	3.3b	94.0
Natural infestation	1.0b	98.2
Natural infestation—shaded	0.0b	100.0
1980[b]		
Crayfish excluded	298.2a**	—
1.35 Crayfish/m^2	188.4ab	36.8
2.70 Crayfish/m^2	73.2b	75.5
Natural infestation	92.6b	68.9
1981[c]		
Crayfish excluded	328.0a*	—
0.34 Crayfish/m^2	299.7ab	8.6
0.68 Crayfish/m^2	255.5b	22.1
1.35 Crayfish/m^2	124.5c	62.0

[a]Numbers not having a letter in common are not significantly different at the * (1%) or ** (5%) level, by Duncan's multiple range test.
[b]All specimens were *P. clarki*.
[c]A mixed population of *P. clarki* and *O. virilis*.

Results

Seedling Establishment

Table 1 gives results of all 3 years. In 1979, the highest reduction in rice seedlings occurred with the natural infestations of crayfish, but the number of surviving seedlings was not significantly different from the number found with a confined population of 2.4 crayfish per m^2. The natural infestation of crayfish in 1980 reduced the rice seedling stand ca. 30% less than in 1979, and the number of surviving seedlings was not significantly different from the seedlings confined with 2.7 or 1.35 crayfish per m^2. There were 39% more seedlings with the latter population of crayfish than at 2.7/m^2. The test in 1981 did not evaluate the effect of a natural infestation of crayfish, but the confined animals caused a 25% greater reduction in seedlings than the same population the previous year. During all 3 years, significantly fewer rice seedlings occurred with some population level of crayfish when compared with seedlings that were protected.

Chemical Control

In 1979, pretreatment counts averaged 7.8 live crayfish per m^2. At 1 day posttreatment with fenthion (112.1 g/ha), no live crayfish and 1.3 dead crayfish per m^2 were recovered. At 4 days posttreatment, 0.12/m^2 were found alive and 0.8/m^2 dead. Table 2 gives results of the 1980 test. Fenthion at the same rate as used in 1979 gave 100% control. Carbaryl and $CuSO_4$ (bluestone) showed no significant differences from the untreated in the number of dead recovered. There were significance differences in the number of live crayfish recovered. Significantly fewer live crayfish were recovered from the carbaryl treatment than from the untreated but not the $CuSO_4$. The total crayfish recovered from the carbaryl treatment averaged less than half those introduced. We assume the remainder escaped.

The counts from the test in 1981 (Table 2) showed the parathion treatment not to significantly differ from the untreated in live or dead crayfish. Methyl parathion produced 100% mortality and fenthion 67%. Not all introduced crayfish were recovered, and the lowest numbers found were from the parathion treatment.

Discussion

The association of natural or confined populations of *P. clarki* with newly planted rice during all 3 years of experiments was detrimental to the establishment of optimum stands. The low number of surviving rice seedlings in the area excluding crayfish in 1979 as compared with the same treatments in 1980 and 1981 is due to an abnormal late planting time of 31 days after flooding. The field was planted 3 days after flooding in 1980 and 1 day after flooding in 1981. Damage was noted to both the seed and foliage. The factors that influence crayfish to select rice over other sources of food are not known, but the selection of plant foliage by this group of animals as a part of their diet has been known for many years. Fisher (1912) reported the elimination of large stands of

Table 2.—Chemical control of crayfish, Biggs, Calif.

Treatment and yr	Formulation	AI/ha (g)	Crayfish/ring[a]		% Mortality (of recovered)
			Live	Dead	
1980[b]					
Fenthion	839 g/L EC	112.1	0.0a	4.2a	100.0
Carbaryl	80% SP	2,241.7	2.0b	0.2b	9.1
$CuSO_4$	99% Crystals	11,208.5	3.4bc	0.2b	5.6
Untreated	—	—	4.8c	0.0b	0.0
1981[c]					
Methyl parathion	599 g/L EC	566.5	0.0a	14.0a	100.0
Fenthion	479 g/L EC	112.1	4.5b	9.0b	66.7
Parathion	479 g/L EC	112.1	10.0c	0.3c	2.9
Untreated	—	—	13.8c	0.0c	0.0

[a] Values with common letters in a column were not significantly different at the 1% level, by Duncan's multiple range test.
[b] All specimens were *P. clarki*.
[c] A mixed population of *P. clarki* and *O. virilis*.

cotton and corn by crayfish in Mississippi and Alabama. They would attack the seedlings before the secondary leaves developed and take them to their burrows. A total of 19,000 to 29,000 holes were reported per ha, which probably reflects a similar number of crayfish. Viosca (1931) and Martin and Uhler (1939) listed several species of aquatic weeds as food plants of *P. clarki*. The apparent compatibility of rice and crayfish in the southern states may be due to their method of culture during the first 3 weeks of plant growth. The rice seedlings in the South are periodically irrigated by rain or artificially until a "permanent" flooding at about 3 weeks from planting (Anonymous 1973). In California, the rice field is flooded (100 to 150 mm depth) and usually remains so until the end of the season (Miller 1980). The presoaked rice seeds are broadcast into the water, and the seedlings must emerge through it. There are several reasons for this, but it is primarily for weed control (Miller 1980). These small, young rice seedlings are the most susceptible to crayfish feeding. Anderson and Sedell (1979) reported that microbial growth is important to invertebrate consumers. Various fungi attack rice seeds and seedlings (Webster et al. 1970), so on the possibility that this association may influence crayfish feeding on the rice seeds or seedlings, seeds were treated with a commercial fungicide in 1981. A reduction in seedling establishment by crayfish was not eliminated by this fungicide treatment.

The extent of rice stand reduction by crayfish is undoubtedly influenced by the numbers of these animals. Populations large enough to reduce the rice stand to an economic level are not believed to be widespread at this time. We do not have a satisfactory method of evaluating the population of crayfish during the first 3 weeks of rice growth to accurately associate population size with an expected seedling reduction. The numbers of crayfish presented in Table 1 can only be used comparatively, because we were unable to fully confine the crayfish (due to their burrowing) during the entire test period. We do not know how early they escaped, so the ratio of crayfish to rice stand reduction would probably be different, and the plant injury would be greater, with longer confinement. In 1979, 63% of the crayfish in confinement were recovered at the 14-day seedling count, and in 1980 and 1981, none were recovered at 23 and 22 days. The collection procedure did not preclude the possibility of crayfish being in burrows in the area of confinement, nor does the method of confinement prevent crayfish from the natural population burrowing into the areas of "confinement," but the latter is unlikely.

The mixed populations of *P. clarki* and *O. virilis* in 1981 preclude a clear indictment of the latter species as a rice plant pest. In fact, we did not find *O. virilis* within a rice paddy during the studies nor did Chang and Lange (1967). The present study and the 1967 study observed *O. virilis* to prefer the waters of irrigation ditches, canals, and sluggish streams.

All chemicals used in the control tests and the rates at which they were used have federal registration to be used on rice for control of various rice production pests or medically important pests during the early stages of rice growth. Fenthion at 112.1 g of AI/ha was highly effective on *P. clarki* during all 3 years. The 67% mortality reported for this chemical in Table 2 in 1981 reflected mortality of members of *P. clarki* as the surviving crayfish were all *O. virilis*. This apparent selectivity could be considered advantageous if accidental drift or drainage resulted from treating a rice field infested with *P. clarki*. Methyl parathion at 566.5 g of AI/ha resulted in high mortality of both species. Carbaryl, $CuSO_4$, and parathion resulted in very low mortality at the selected rates. Carbaryl may have had an irritating effect that caused the crayfish to leave the rings, since only 44% of the introduced crayfish were recovered. Further mortality may have resulted outside the rings, because Chang and Lange (1967) reported carbaryl to control 40% of *P. clarki* populations in the field and ca. 85% in the laboratory at the same rate used in the present test. Their results with fenthion on *P. clarki* were similar to ours.

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