Conditions Associated with Rice Plant Injury by Chironomid Midges in California[1]

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ABSTRACT

A 2-yr (1974–75) study of the conditions associated with rice injury by chironomid larvae (*Cricotopus sylvestris* (Fabr.), *Paratanytarsus* n.sp., and *Paralauterborniella* spp.) in California showed that greater damage occurred in the 1975 experimental plots that were flooded late in the planting season and to those planted 7 and 14 days after flooding than at one day. Also, more damage was detected in those plots which supported greater populations of *C. sylvestris*.

A developmental threshold temperature (12.8°C) for time from egg deposition to adult was determined in the laboratory for *Paratanytarsus* n.sp. High populations of 3rd and 4th instar larvae of this species were observed at 7 post-flood days [= ca. 120 accumulated day-degrees (°F)] in those plots with the highest levels of damage. Field life-history patterns of the other economic species paralleled those of *Paratanytarsus* n.sp. Rice growers are advised to flood their fields early in the planting season and to plant as soon as possible after flooding.

Chironomid midge damage to rice (*Oryza sativa* L.) was first recorded in California in 1953 (Darby 1962, Lange and Grigarick 1970) and sporadic damage has since been observed in certain years. When midge damage is extensive the number of plants per unit area is reduced and the grower may be forced to replant. The larvae damage rice by feeding on the roots and leaves of young developing seedlings. However, the most serious damage seems to occur when larvae burrow into germinating seeds and consume all or part of the embryo (Darby 1962, Lange and Grigarick 1970). Similar types of midge damage to rice have been observed in France (Risbec 1952) and Egypt (Aboul-Nasr et al. 1970).

The flooding of rice fields in California normally takes place from mid-April to mid-May and fields are seeded as soon as possible after flooding (Oelke et al. 1967). Newly flooded fields are quickly invaded by ovipositing chironomids and the potential then exists for injury to rice. We conducted a study at the Rice Research Facility, University of California, Davis and the Cooperative Rice Research Station, Biggs, California in spring 1974 and 1975 to investigate the conditions associated with rice damage by midge larvae. About 121 km separate the 2 research facilities which are situated near the two extremes of the major rice growing areas of Northern California.

This paper discusses the relationship of plant injury to the population trends of the economic species, *Paratanytarsus* n.sp., *Cricotopus sylvestris* (Fabr.), and *Paralauterborniella* (species complex), and to the time of flooding and the time of planting after flooding. The developmental rate of *Paratanytarsus* n.sp., a parthenogenetic species, was also examined under controlled laboratory conditions at various temperature regimes. From these studies a temperature threshold was established for this species and day-degree units were then computed in an attempt to correlate field developmental rates with the accumulation of thermal units.

Methods and Materials

Field Studies

A series of 6 replicated rice plots (ea. 3.7×4.6 m) were established at each study site. Ten days separated the flooding of 2 blocks, each with 3 plots. This design was used to compare midge life-history patterns in plots flooded at different times (i.e., flooding time 1 and flooding time 2 plots) and to examine the relationship of rice damage by midge larvae to the time of flooding and the time of planting after flooding.

Benthic samples were collected and processed in accordance with techniques and procedures outlined elsewhere (Clement et al. 1976). An insect emergence trap designed by Kimerle and Anderson (1967) was used to collect emerging chironomids. Collections were made every 2–4 days and each trap was relocated at random in the same plot following each collection. Since only one trap was employed per flooded block, data should be considered to be a relative measure illustrating adult (all species) emergence patterns in each block.

A thermograph was employed in each experimental area to continuously record water temperature midway between the water surface and the mud-water interface except at Davis in 1974. Water depths ranged from 10.2–17.8 cm. Air temperatures were recorded daily at weather stations at the two research facilities.

To correlate the degree of injury with the time of planting, seedlings were examined in the 1974 plots following planting times of 2, 4 and 8 days after flooding and in 1975 following 1, 7, 14 days after flooding. A randomized complete block design was

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superimposed on each block of 3 plots in 1974 where each plot was divided into 3 equally sized quadrats for the different planting times. Thus each treatment or planting time occurred once in each plot for a total of 3 replications/flooded block. In 1975 a 3×3 latin square design was used for each flooding date.

Each replication was hand planted at the designated time and 50 (1974) or 100 (1975) seedlings per replication were examined for midge damage 8–15 days after planting. In 1974, 50 seedlings were hand collected from one randomly selected square foot area per quadrat. An aluminum ring was used to circumvent the sampling area. A more efficient sampling technique was designed for use in 1975 where 50 seeds were inserted between 2 layers (ea. 15.2×15.2 cm) of a synthetic fabric material. A few staples were used to bind the layers together. The dorsal layer was a woven shade fabric (30% actual shade, No. 5185709, Chicopee Manufacturing Co., Cornelia, Georgia) and the thicker screened ventral layer was a Tamisair® nylon netting material (Sullivan Co., San Francisco, CA). The mesh opening (ca. 2 mm) of both layers was sufficiently small enough to hold the seeds in place yet not impede the movement of larvae or the growth of the rice seedlings. Two of these 'seed packets' were randomly placed in each replicated treatment and each was anchored to the mud bottom with a small metal stake.

Damage was classified into 4 categories: (1) no damage to foliage and roots, (2) moderate feeding damage to foliage and roots; indicated by at least a 50% reduction in foliage and/or root surface area, (3) extensive feeding injury; indicated by complete consumption of foliage and/or root material, and (4) larval invasion of the seed; indicated by total or partial consumption of the embryo. These damage categories are shown in Fig. 1.

Tests of significance were performed on log transformations of the data in order to conform to the assumptions of the analysis of variance. Separate statistical analyses were performed on counts of seedlings with category 4 damage and on total damage (categories 2–4).

Laboratory Studies

A laboratory population of *Paratanytarsus* n.sp. was established from Davis samples and maintained at 16-h light at 24.4°C (±0.5°C) and 8-h dark at 12.8°C (±0.5°C). This temperature and photoperiod regime and one of 16-h light at 29.4°C (±0.5°C) and 8-h dark at 17.8°C (±0.5°C) were then selected for rearing experiments. Both regimes were similar to those of spring and early summer. Three replications were conducted at each regime.

Eggs were collected at the time of oviposition and placed in enamel rearing pans (30.5×17.8 cm). Two to three weeks prior to egg placement 750–800 ml of tap water was added to rearing pans and inoculated with algae and diatoms from Davis paddy water in order to provide sufficient food and case-building material for the larvae. This procedure was based on techniques developed by Nebeker (1973) in his rearing work with *Tanytarsus* (*Paratanytarsus*) *dissimilis* Joh., another parthenogenetic species. Tap water was added daily to adjust the water level to 1.5–1.7 cm or ca. 750 ml. A vibrator air pump was used to continuously aerate the cultures and every 3–5 days ca. 0.075 g of Tetramin E fish food (produced by Tetra-Werke, Melle, West Germany) was added as a food supplement. This procedure was followed for all rearing experiments.

For laboratory rearing of chironomid midges, Biever (1971) emphasized the importance of knowing the optimum density of larvae that particular rearing units will support. In this study, pilot experiments indicated that individual rearing pans could easily support 125–150 larvae, given ample quantities of food. Thus the number of eggs used in each cohort study ranged from 74–131.

Development and adult emergence were followed for 30 days in all rearing experiments. At 3–5 day intervals following egg hatching, 5 larvae were measured from each pan. The instar was determined by measuring the width of the head capsule (McCauley 1974).

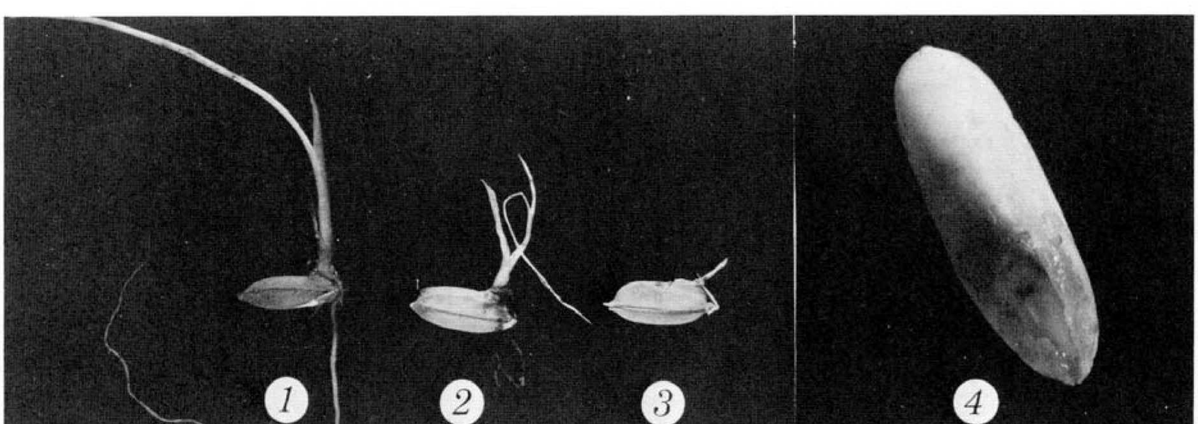


FIG. 1.—Numerical assignments to levels of injury by midge larvae to rice seedlings and seeds.

A temperature threshold value, or that temperature above which measurable development occurred, was established for *Paratanytarsus* n.sp. by rearing adult females from eggs at 6 constant temperatures (±2°C) at 16-h light and 8-h dark. Two to three cohorts were followed at each temperature. The mean number of days from egg deposition to the initial appearance of adults was determined at each temperature, then days were converted to percentage rate of development per day and plotted against respective temperatures. Extrapolating the computed regression line of rate of development to temperature back to the x-intercept provided an estimate of the temperature threshold of development (Arnold 1959). However, a threshold value established from laboratory rearing experiments was used to compute all day-degree accumulations. This laboratory value was compared with the estimate obtained by using Arnold's (1959) x-intercept method.

In the field, maximum and minimum daily temperatures (°F) from the air and water were used to compute day-degrees. When the daily minimum temperature dropped below the threshold temperature a program originally developed by N. E. Gilbert (University of British Columbia), but adapted for use on the WANG 720 C calculator, was used to compute day-degrees. All day-degree units are expressed in degrees Fahrenheit since temperatures in this thermometric scale were used to compute day-degrees with the WANG program.

Results

Field Studies

Figures 2 and 3 illustrate the life-history patterns of the older (i.e., 3rd and 4th instar) larvae of the economic species in the Biggs and Davis plots. The major conclusion from these data is that the later-flooded (flooding time 2) plots exhibited higher initial population levels 10–20 days (1974) and 7–14 days (1975) after flooding than did earlier-flooded (flooding time 1) plots at similar time intervals. Likewise, 1st adult emergence and peak emergence (all species) usually occurred in a shorter time in the later-flooded plots. These figures also contrast the relative larval densities of the economic species.

In 1974, little injury (<2% of seeds damaged) was detected in the experimental plots at both localities. Commercial rice fields were also relatively free of midge damage during that year based on our general observations and the lack of reports of midge injury from growers. In 1975, the experimental plots showed significant injury to rice by midges (Tables 1 and 2). Extensive injury was also observed in some commercial fields and growers reports of injury by midges were much more prevalent than in 1974.

Table 1 shows the levels of damage recorded in the 1975 Biggs plots at planting times of 1, 7 and 14 days after the 2 flooding dates. The data for category 4 damage indicated that significant ($P = 0.05$) injury to rice occurred at 7 and 14 day plant-

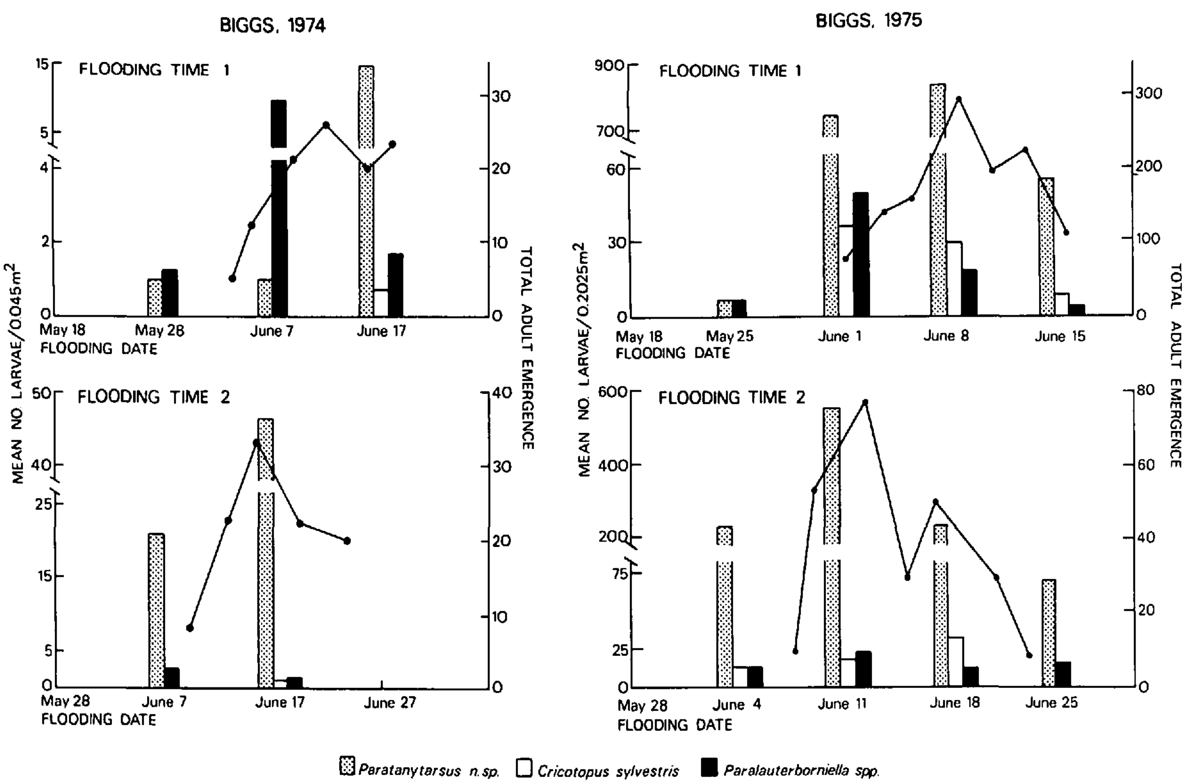
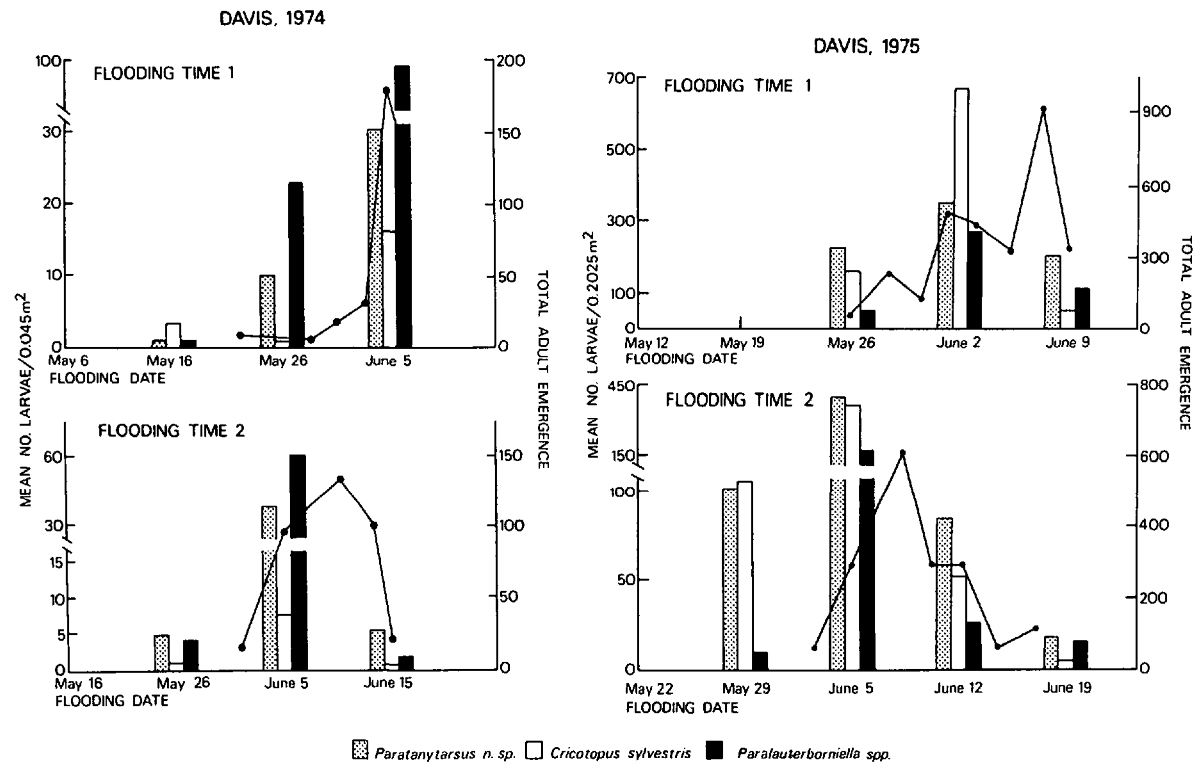


FIG. 2.—Phenological patterns of the economic species and total adult (all species) emergence patterns at Biggs, 1974 and 1975.



FIGS 3.—Phenological patterns of economic species and total adult (all species) emergence patterns at Davis, 1974 and 1975.

ing times but not at the 1 day planting time in those plots flooded on May 18. When total damage (categories 2–4) was examined, no significant (P=0.05) differences occurred between the 3 planting times. As tadpole shrimp (*Triops longicaudatus* LeConte) were also present in plots flooded on May 28, it was difficult to distinguish between midge and tadpole shrimp feeding damage to the foliage and roots (categories 2 and 3). Consequently, tests of significance were performed only on the category 4 damage for the May 28 flooding.

Table 2 summarizes the results for the 1975 Davis plots. Those plots flooded on May 12 resulted in significantly (P=0.05) more damage (category 4 and categories 2–4) at the 14 day planting time than at the 1 and 7 day planting times. In those plots flooded on May 22, significantly (P=0.05) more damage was recorded for the 7 and 14 day plantings than for the

Table 1.—Rice injury by midge larvae, Biggs 1975.

Flooding time	Post-flood planting time (in days)	Mean no. of damaged[a] seeds per 100—Damage Category 4	Mean no. of damaged[a] seeds and seedlings per 100—Damage Categories 2–4
May 18	1	1.33 a	10.00 a
	7	9.00 b	23.33 a
	14	10.33 b	19.33 a
May 28	1	5.00 a	—
	7	4.33 a	—
	14	6.67 a	—

[a] Means followed by the same letter in each column are not significantly different at the 5% level of probability (Duncan's new multiple range test).

Table 2.—Rice injury by midge larvae, Davis 1975.

Flooding time	Post-flood planting time (in days)	Mean no. of damaged[a] seeds per 100—Damage Category 4	Mean no. of damaged[a] seeds and seedlings per 100—Damage Categories 2–4
May 12	1	1.67 a	6.67 a
	7	3.33 a	12.00 a
	14	16.00 b	35.67 b
May 22	1	3.67 a	10.00 a
	7	16.33 b	38.67 b
	14	36.00 b	55.33 b

[a] Means followed by the same letter in each column are not significantly different at the 5% level of probability (Duncan's new multiple range test).

one day plantings. Severe levels of total damage were observed at the 14 day plantings (up to 36% injury) in the May 12 plots and at the 7 and 14 day plantings (up to 55% injury) in the May 22 plots.

Laboratory Studies

It is evident from a frequency distribution of the head capsule widths of 200 *Paratanytarsus* n.sp. larvae that this species possesses 4 larval instars. These data are shown in Figure 4 where the respective head capsule widths for 1st, 2nd, 3rd and 4th-instar larvae ranged from 0.053–0.076, 0.091–0.112, 0.131–0.168, and 0.190–0.224 mm.

Evidence from a few laboratory tests indicated that 3rd and 4th instars of *Paratanytarsus* n.sp. inflict the most serious damage to rice. In these tests, larvae < 1.5 mm in length (mostly 1st and 2nd instars) did not initiate any damage to germinating rice seeds. In the field, only older larvae from all the economic species have been associated with damaged rice.

At the 24.4° (16-h light) and 12.8°C (8-h dark) regime, 3rd instar larvae were initially detected at an average of 17±1.7 days after egg deposition and initial adult emergence occurred at an average of 24.3±1.5 days. Third instar larvae and adults first appeared 8.7±0.6 days and 13.3±0.7 days, respectively, after newly laid eggs were placed in rearing pans held at 29.4° (16-h light) and 17.8°C (8-h dark).

A threshold temperature for *Paratanytarsus* n.sp. was determined from rearing experiments to be ca. 12.8°C. This value compares favorably with the estimated threshold (ca. 12°C) derived from the x-intercept method of extrapolating the regression line $y = a + bT$ for development from egg-to-adult at 3 constant temperatures (Fig. 5). Of the 6 constant temperatures used to develop a threshold, the 2 highest temperatures (30° and 32.2°C) appeared to be deleterious to the larvae and no significant egg-to-adult development occurred at 12.8°C. In addition, no adult emergence occurred within 30 days when 3rd and 4th instar larvae were removed from a regime of 24.4° (16-h light) and 12.8°C (8-h dark) and placed directly into rearing pans held at 12.8°C. Although a few eggs did hatch at 12.8°C in one replication, the larvae died soon after hatching. The precise threshold value probably lies between 11.7° and 12.8°C but Arnold (1959) concluded that differences from the threshold temperature of a degree or two were of little practical importance in computing thermal units.

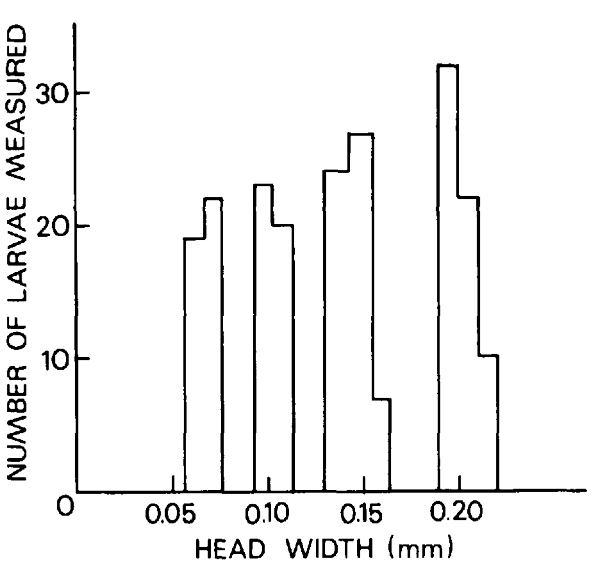


FIG. 4.—Frequency distributions for head capsule widths of *Paratanytarsus* n.sp.

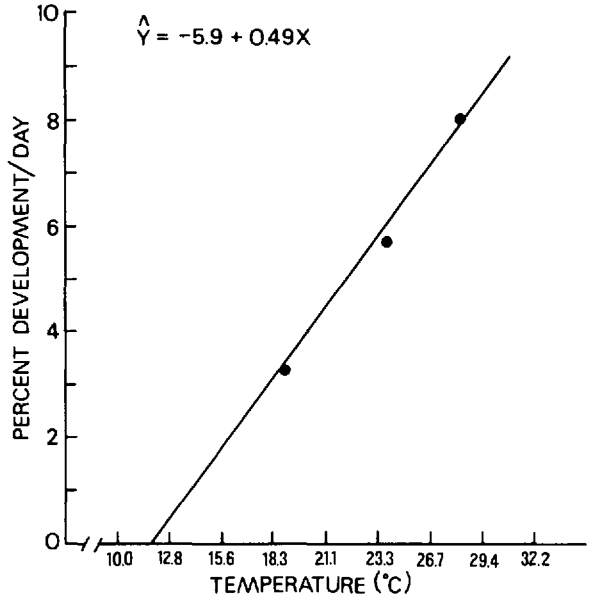


FIG. 5.—Graphical estimation of the threshold temperature for time from egg deposition to adult of *Paratanytarsus* n.sp.

Discussion

Differences in the initial relative abundances of *Paratanytarsus* n.sp. larvae at the 2 flooding periods (Fig. 2–3) are probably due to warmer temperatures during the first 7 or 10 days in most of the later flooded plots. In 1975 (both localities), daily minimum water temperatures were consistently above 12.8°C during the 1st week in these plots (Clement et al. 1976). Since water temperatures were dependent on air temperatures (Clement et al. 1976), we were able to use the latter to also compute day-degrees. Table 3 shows the accumulative number of day-degrees for 10 (1974) and 7 (1975) days after flooding. These values indicate the close relationship between water and air temperatures and also the usual occurrence of warmer temperatures at later flooding periods. The Davis 1974 plots were the exception with regard to warmer temperatures in the later-flooded plots and Fig. 3 shows that low numbers of larvae were collected on the 1st sampling date in these plots.

The data presented in this paper associates the

Table 3.—Days-degrees accumulations (°F) for *Paratanytarsus* n.sp. larval populations at 10 (1974) and 7 (1975) days after flooding.

	1974		1975	
	Flooding time			
Location	1	2	1	2
Biggs				
Water	—	195	91	147
Air	169	181	102	144
Davis				
Water	—	—	110	123
Air	123	102	99	134

faster rate of development of *Paratanytarsus* n.sp. larvae with the greater accumulation of heat units. The same result, as one might expect, can be assumed for the other economic species, *C. sylvestris* and *Paralauterborniella* (species complex), since their life-history patterns corresponded with those of *Paratanytarsus* n.sp. (Fig. 2–3). Only a rough estimate of the time from egg-to-3rd instar is possible from the field data since sampling was conducted every 10 (1974) and 7 (1975) days (Fig. 2–3) but the data presented in Table 3 suggest that high field populations of older instar larvae of *Paratanytarsus* n.sp. coincide with the accumulation of ca. 120 day-degrees (based on water and/or air temperatures (°F)).

The data (Tables 1 and 2) also reveal that in 1975 higher levels of damage occurred in Davis than in Biggs where fewer numbers of *C. sylvestris* larvae were recovered (Fig. 2–3). Very few larvae of this species were detected in the 1974 plots in either area. Thus, *C. sylvestris* may be the principle economic species.

Results from this study suggest that several conditions are collectively associated with rice injury in California. High populations of 3rd and 4th instars were detected as soon as 7 post-flood days when optimum water temperatures prevailed in those plots flooded late in the planting season. Higher levels of damage occurred when planting times corresponded with these high larval populations (especially *C. sylvestris*). In general, rice growers are advised to avoid flooding late in the planting period and to plant as soon as possible after flooding to avoid subjecting the germinating seeds and young seedlings to higher numbers of larvae and to older instar larvae.

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