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POPULATION ECOLOGY OF *PARDOSA RAMULOSA* (ARANEAE, LYCOSIDAE) IN FLOODED RICE FIELDS OF NORTHERN CALIFORNIA

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ABSTRACT

The phenology, abundance, and habitat preferences of *Pardosa ramulosa* (McCook) in California rice fields were studied. Analysis of pitfall and floating sticky-trap samples showed that this spider apparently had one generation per year and overwintered in the immature stage. The population on the levees peaked in June and preceded the buildup in the paddies. Colonization of the paddies was possible after emergent vegetation was present. Before this *P. ramulosa* was observed being blown over the water surface. This may have contributed to its ability to disperse within the rice agroecosystem. In the paddies, *P. ramulosa* was associated with patches of aquatic broadleaf weeds where potential prey, including occasional pest species, was most abundant. *P. ramulosa* possesses many attributes thought to be desirable for a natural enemy in an annual agroecosystem, and may be an important predator of some pest species in rice.

INTRODUCTION

The importance of spiders as biological control agents has received considerable attention over the past two decades (see Luczak 1979; Riechert and Lockley 1984; Nyffeler and Benz 1987 for references). In spite of this, much controversy still remains concerning their perceived benefit. Clearly, much more information needs to be gathered (especially pertaining to the population and feeding ecology of spiders) before any definitive statement can be made regarding the role these generalist predators play in influencing prey levels. One habitat type where spiders appear to be a particularly important predator group is in swamp ecosystems, including flooded rice fields (Nyffeler and Benz 1987). We previously reported that *P. ramulosa* comprised ca 68% of all the spiders collected from California rice paddies, and suggested that it was the spider most likely to contribute to biological control in this agroecosystem (Oraze et al. 1988). Based on this and the importance of spiders found in rice fields in other parts of the world (Ito et al. 1962; Kiritani et al. 1972; Kiritani and Kakiya 1975; Kang and Kiritani 1978; Chiu 1979; Kenmore 1980), we felt additional study of *P. ramulosa* was warranted.

Various aspects of the population ecology of *P. ramulosa* have been studied in a number of habitats (Leigh and Hunter 1969; Yeargan and Cothran 1974; Van Dyke and Lowrie 1975; Hydorn 1977; Greenstone 1978), but little is known of its ecology in rice. The present study was undertaken to determine the phenology, seasonal abundance and microhabitat preferences of *P. ramulosa* in California rice fields so as to better understand the potential of this predator for reducing insect pest levels.

MATERIALS AND METHODS

Phenology and seasonal abundance.—Ten pitfall and ten floating sticky traps were used to monitor *P. ramulosa* population fluctuations on the levees and in the paddies, respectively, at the Lattemore seedfield section of the Rice Experiment Station near Biggs, (Butte County) California. The traps were installed and serviced as described by Oraze et al. (1988). Both trap types were placed in designated locations for four to seven days once each month during the growing season. Additional sampling with pitfall traps was conducted throughout the fall and winter months between the 1984-85 growing seasons to determine overwintering phenology and abundance.

Habitat preference (paddy).—The abundances of *P. ramulosa* and potential prey items in vegetation types associated with the paddies were determined by randomized complete-block design experiments conducted at the Rice Experiment Station in 1984, and repeated with modifications in 1985. There were three treatments (vegetation types) in 1984 and two in 1985. Four blocks were used in both years. The experiments were located along the west margins of four adjacent fields in 1984 and along the east margins of two adjacent fields in 1985. Plots measured 6 by 6 m and were separated from one another by aluminum barriers that were 38 cm high and 6 m long.

The three treatments—rice only, rice plus weeds and weeds only—were achieved through various manipulations. In 1984 the rice was eliminated from the weedy plots by hand removal. This was followed with the transplanting of twenty-five ducksalad (*Heteranthera limosa* (Sw.) Willd.) plants. In 1985 glyphosate at 1.12 kg (AI)/ha with a 1% solution of Herbimax® oil adjuvant was used to selectively remove the rice from the weedy plots. It was applied after the rice but before the weeds had emerged through the water. Transplanting of weeds was not necessary in 1985. In both years the species complex of the weedy plots consisted primarily of ducksalad and monochoria (*Monochoria vaginalis* (Burm. f.) Presl.), with lesser amounts of California arrowhead (*Sagittaria montevidensis* Cham. and Schlecht.), waterplantain (*Alisma triviale* Pursh.), and roughseed bulrush (*Scirpus mucronatus* L.). The rice-only plots were treated with bentazon or 4EC MCPA at 1.12 kg (AI)/ha as required to remove the above-mentioned aquatic weeds. The rice plus weeds treatment of 1984 was left undisturbed.

The abundances of *P. ramulosa*, aster leafhopper (*Macrosteles fascifrons* Stål) and small flies (primarily Culicidae, Ephydridae and Chironomidae) were obtained from floating sticky traps (one trap per plot) that were placed in the plots for a single seven-day sampling period. Aphid densities were estimated by taking five subsamples per plot with a UC-VAC suction device (Summers et al. 1984) and unit-area-sampler as described by Oraze et al. (1988). The mean number per sticky trap per day or the mean number per m^2 within each plot were transformed, $(X + 1/2)^{1/2}$, and analyzed with a two-way analysis of variance (1984) or paired *t*-test (1985).

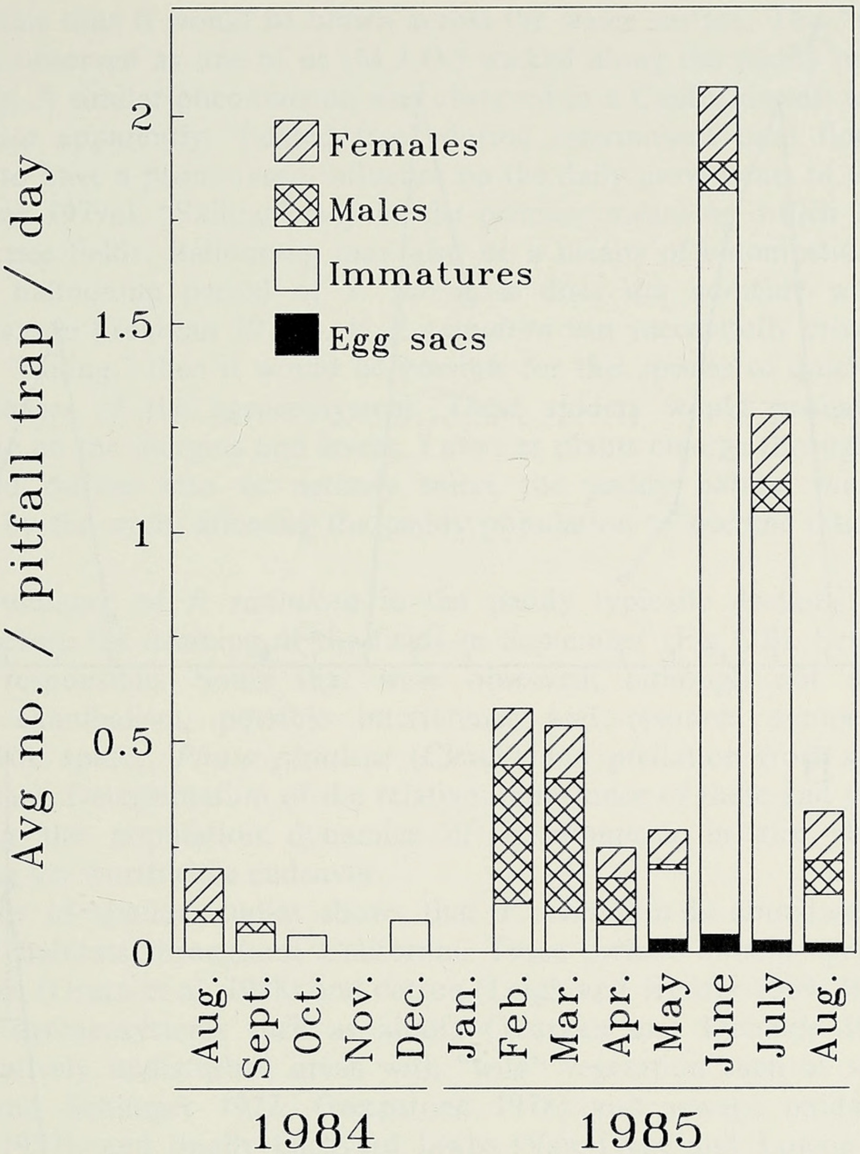

Figure 1.—Phenology and abundance of *Pardosa ramulosa* on rice field levees for 1984-85. Data obtained from a 4-7 day sampling period each month. Adults were separated from immatures by the presence of a fully developed palpal organ (males) or epigynum (females).

RESULTS AND DISCUSSION

Phenology and seasonal abundance.—It appears that *Pardosa ramulosa* had a single generation per year and overwintered in the immature stage, based on detailed analysis of pitfall-trap samples for 1984-85 (Fig. 1). These data, along with other data from trap catches, should be interpreted cautiously, as they reflect spider activity as well as abundance. Even so, similar conclusions have been reported for *P. ramulosa* in other habitats of northern California (Yeargan and Cothran 1974; Hydorn 1977).

The population peak on the levees occurred in June in each of the three years we sampled. In addition, the population decline on the levees coincided to some degree with the rise of the population in the paddies (Fig. 2A and B). This suggests that movement from the levees into the paddies contributed, at least in part, to the decline of the levee population. Similar seasonal movements have been described for *P. ramulosa* in other habitats (Hydorn 1977).

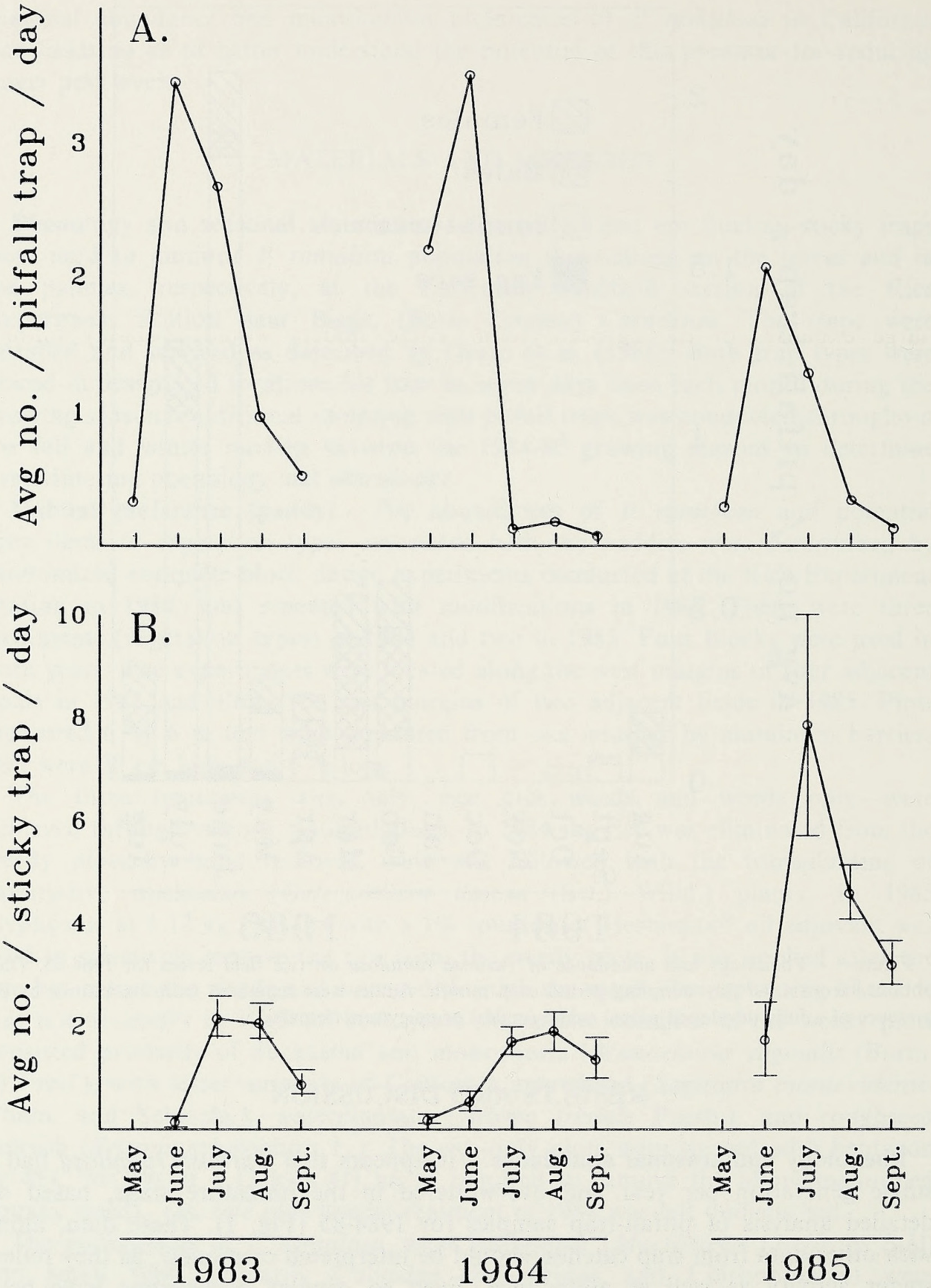

Figure 2.—Seasonal abundance of *Pardosa ramulosa* (adults and immatures) on levees (A), and in paddies (B) of flooded rice fields. Vertical lines represent SEM. No measure of variation could be calculated in "A" because of the combining of individual trap contents prior to counting.

The presumed dispersal from the levees into the paddies may be related to the seasonal succession of the paddy environment. Early in the cropping cycle, before emergent vegetation exists in the paddies, the spiders were apparently limited to the terrestrial habitats of the agroecosystem. If a spider was to walk into the paddy at this time it would be blown across the water surface. This "sailing" was frequently observed as one of us (M.J.O.) walked along the paddy margins on a breezy day. A similar phenomenon was observed in a California salt marsh where *P. ramulosa* apparently "floated free" during intermittent tidal flooding. This appeared to have a pronounced influence on the daily movements of these spiders (Greenstone 1979a). "Sailing" may be the primary means by which *P. ramulosa* colonizes rice fields. Ballooning may also be a means of colonization, although the peak ballooning period of *P. ramulosa* does not coincide with the rice growing season (Yeargan 1975a). If *P. ramulosa* can successfully cross a flooded paddy by "sailing," then it would be possible for this species to quickly infiltrate large expanses of the agroecosystem. These spiders would probably initially accumulate on the margins and levees. Later, as plants emerge through the water, they could diffuse into or actively select the paddy habitat without being displaced by the wind, allowing the paddy population to become established and increase.

The abundance of *P. ramulosa* in the paddy typically declined late in the summer before the draining of the fields in September (Fig. 2B). Several factors may be responsible. Some that were observed, although not documented, included: cannibalism, possible interference and resource competition with another wolf spider, *Pirata piraticus* (Clerck) and predation from spider wasps (Pompilidae). Determination of the relative importance of these and other factors influencing the population dynamics of *P. ramulosa* in rice should be a challenging yet worthwhile endeavor.

A review of similar studies shows that *P. ramulosa* is abundant in a wide variety of habitats throughout California. These include annual agroecosystems such as rice (Oraze et al. 1988) and cotton (Leigh and Hunter 1969; Hickle 1981), perennial agroecosystems such as alfalfa (Yeargan and Dondale 1974; Hickle 1981), relatively undisturbed areas with "wild" vegetation such as salt marshes (Garcia and Schlinger 1972; Greenstone 1978) and sewage oxidation ponds (Hydorn 1977), and finally backyard lawns (Van Dyke and Lowrie 1975). The ability of *P. ramulosa* to inhabit such a diverse array of habitats (from coastal salt marshes to irrigated desert cotton fields) indicates that it probably possesses broad physiological tolerances and flexible behavior patterns. One might expect to find this spider wherever its moisture requirements are satisfied within its range. This may include more habitats than would be initially obvious. For example, soil cracks appeared to provide *P. ramulosa* refuge between irrigations in alfalfa and cotton fields (Yeargan and Cothran 1974; Hickle 1981) and in some ephemeral aquatic habitats such as vernal ponds (Hydorn 1977; Greenstone 1980).

Habitat preference (paddy).—Plant type in the paddy had a significant influence on *P. ramulosa* abundance. *P. ramulosa* and nearly all of the potential prey types sampled were significantly more abundant in the weedy plots in both the 1984 and 1985 experiments (Tables 1 and 2). The weeds in the rice plus weeds treatment of the 1984 experiment eventually perished. This resulted in plots that were essentially the same as the rice-only plots by the time the samples were taken. There were no significant differences in the arthropod species sampled between these two treatments. Because of this, the rice plus weeds treatment was not included in the 1985 experiment.

Pardosa ramulosa associated in microhabitats of the paddy where potential prey, some of which are occasional pests of rice (e.g., aster leafhopper,

Table 1.—Mean number ± SEM of *Pardosa ramulosa* and potential prey in vegetation types associated with rice field paddies. Biggs, Calif. 1984. Samples were taken on 27 July 1984. Column means followed by the same letter are not significantly different ($P < 0.01$, Tukey's HSD method) (Systat Inc. 1987). Transformed data, $(X + 1/2)^{1/2}$, were analyzed with a two-way ANOVA, $df = 2,3$.

	Avg. no. per sticky trap per day			Avg. no. per m^2
Vegetation type	*Paradosa ramulosa*	Aster leafhopper	Small flies	Aphids
Rice	0.6 ± 0.1 a	0.4 ± 0.3 a	4.5 ± 1.5 a	208.3 ± 125.8 a
Rice + weeds	0.3 ± 0.1 a	0.2 ± 0.1 a	4.8 ± 1.2 a	225.5 ± 110.4 a
Weeds	2.8 ± 0.3 b	11.3 ± 1.6 b	41.5 ± 4.1 b	5795.3 ± 3423.2 b
F statistic	73.221	55.148	82.933	8.825
P value	<0.000	<0.000	<0.000	0.018

mosquitoes, seed midges and leaf miners), were most abundant. This behavior does not appear to be unusual for spiders (Riechert and Lockley 1984). However, in a related study Greenstone (1978) found no correlation between prey availability and *P. ramulosa* density among the small pools from which he sampled in an estuarine salt marsh. He noted that the spiders reached their highest densities along the margins of the pools, irrespective of prey availability, even though this varied enormously among pools. If *P. ramulosa* actively selected weedy areas of the rice paddy, as the data of this study suggest, then it is not clear exactly to what factor(s) (e.g., prey availability, temperature-humidity regime, cover for protection, etc.) *P. ramulosa* was responding. This would seem to be a fruitful area for future research.

Pardosa ramulosa exhibited characteristics that are thought to be desirable for a natural enemy in an annual agroecosystem (Ehler and Miller 1978). It was a good colonizer, probably because of its "sailing" ability. It appears to have broad physiological tolerances and the behavioral flexibility (based on its occurrence in a number of very diverse ecosystems, as was discussed earlier) that probably help it to survive the adverse conditions that typically exist during the early phases of a cropping cycle. In addition, perceived limitations of generalist predators (like *P. ramulosa*) such as cannibalism, territoriality (Hydorn 1977) and polyphagy (Yeargan 1975b; Greenstone 1979b) might also enhance early season survivability by mitigating the effects of temporal shortages of preferred prey. Finally, *P. ramulosa* preceded potential pests into the paddy and later associated in microhabitats where they were most abundant. Based on these findings, the role of *P. ramulosa* in reducing levels of selected pests in California rice should be investigated.

Table 2.—Mean number ± SEM of *Pardosa ramulosa* and potential prey in vegetation types associated with rice field paddies. Biggs, Calif. 1985. Samples were taken on 30 July 1985. Column means followed by the same letter are not significantly different ($P < 0.05$). Transformed data, $(X + 1/2)^{1/2}$, were analyzed with a paired *t*-test, $df = 1,3$.

	Avg. no. per sticky trap per day			Avg. no. per m^2
Vegetation type	*Paradosa ramulosa*	Aster leafhopper	Small flies	Aphids
Rice	1.0 ± 0.1 a	14.0 ± 3.3 a	21.7 ± 8.4 a	22.2 ± 6.2 a
Weeds	2.9 ± 0.6 b	38.9 ± 10.0 b	51.5 ± 13.2 a	474.3 ± 169.8 b
t statistic	23.392	11.603	4.108	14.284
P value	0.017	0.042	0.136	0.032

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