Project No. RP-6

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
January 1,1993 - December 31, 1994

PROJECT TITLE: Insects In Flooded Rice Fields

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LEVEL OF 1994 FUNDING: $27,543.00

OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

The overall intent of this project is to analyze the current and future consequences for insect pest management of the winter flooding plan being adopted widely in rice fields across the Sacramento Valley. This goal has necessitated detailed study of four major objectives:

I. Determine the effects of winter flooding on arthropod food webs in rice:

a. Determine relative pest outbreak potential and natural enemy population sizes for a wide range of arthropods in winter-flooded rice fields and non-flooded rice fields.

b. Determine within-field spatial distribution of a wide range of pests and beneficial insects due to winter flooding.

c. Determine changes in these pest and beneficial insect populations through time.

II. Determine effects of organic and conventional management on arthropod food webs in rice:

a. Ascertain winter-flooding effect in organically managed fields to provide an indication of the range of flooding effects observed in the absence of carbofuran.

b. Determine a. through c. above for organic vs. conventionally managed fields.

c. Evaluate effect of weedy vegetation on arthropod populations in organic rice fields.

III. Evaluate the importance of generalist predators in limiting California rice pests:

a. Identify likely direct and indirect effects of aquatic wolf spiders on occasional rice pests including rice water weevil, and test them through direct experimentation and observation.

b. Estimate strengths of interactions between other numerically important natural enemies and potential pests.

IV. Assess the differences in arthropod data obtained from on-farm research vs. Maxwell experimental fields:

a. Evaluate overall differences between pest and beneficial insect populations collected from grower's fields and those derived from experimental research plots.

b. Assess whether data on winter-flooding effects differ between grower's fields and experimental research plots.

Experiments conducted in 1994 to accomplish objectives, by location:

Arthropod Community Monitoring and Quantification
-- *Maxwell, Willows, Nelson and Richvale, CA* --

To assess differences in the pest and beneficial arthropod communities between winter-flooded and non-flooded rice cultivation treatments (Objective I) as well as organic vs. conventional management practices (Objective II), I monitored seasonal changes in numerous insect and spider populations in fifteen farm sites and at the Maxwell experiment site. I used a wide variety of comparative sampling methods to collect a diverse array of pests and enemies in order to construct accurate food webs, and thus to assess relative pest outbreak potential and natural enemy population sizes. I am analyzing these data using both analysis of variance and path analysis to compare across independent variables and to untangle the complex web of interactions among the pest and beneficial species in the field (Objective III). By contrasting data collected on-farm with those collected at the experimental sites, I can contribute important empirical evidence of differences and similarities between these two experimental situations (Objective IV).

Small Manipulative Experiments
-- *Willows, CA* --

To directly test the strength of interactions between particular species (Objectives IIIa and IIIb), the effects of weediness on pest and beneficial interactions (Objective IIb), and to further evaluate the importance of plot size to the arthropod community structure, I initiated small manipulative studies within rice fields. These consisted of wolf spider inclusions and exclusions, and small scale weed removals in organically managed fields.

SUMMARY OF 1994 RESEARCH (MAJOR ACCOMPLISHMENTS) BY OBJECTIVE:

During 1994, I primarily focussed my efforts in three areas: Site selection (April and May); pest and beneficial sampling and preservation (May-October); and arthropod sorting and identification, data input and analysis (November-present). This third research area is still very much in progress, as I have collected large numbers of samples and am performing a wide array of statistical analyses to best utilize the information obtained. I expect this third phase to be completed by mid-January, only shortly before I begin collecting data for the 1995 field season.

Reported below are my accomplishments to date. Where appropriate, I indicate the status of data analysis and results that are available. The full third phase summary will be available in my 1995 research report.

I and II. Effects of winter flooding and organic and conventional management on arthropod food webs in rice.

In 1994 I was fortunate to locate 6 adjacent farm fields in the Willows area (Figure 1), and 9 interspersed farms in the Richvale-Nelson area (Figure 2). I chose sites owned by Tariq Kahn and the Spooner family outside of Willows, as well as fields owned by John and Chetty Sheppard and WEHAH Lundberg surrounding Richvale and Nelson, which represent a different climate and soil type. For each location I was able to select both winter-flooded and winter-dry fields, and organic and conventionally managed systems. In all, I monitored 7 winter-flooded and 8 winter-dry fields (9 conventional + 6 organic). I chose sites roughly paired both by off-season flooding regimes and by organic vs. conventional treatments. The unbalanced sampling design was necessary to favor physical proximity among the treatments. In addition, I chose these farms to maximize the interspersion of treatments in order to strengthen the comparisons between them. The ready cooperation of many different rice growers allowed me to select fields so as to maximize the generality and power of my research results. Because I utilized both organic and conventional fields among the winter-flooded and winter-dry fields, I can use the data I have gathered to assess the interaction between these two management methods, and in particular to gauge the effects of winter flooding on fields that have not been treated with carbofuran (IIc).

Starting in late May, just after the rice was planted, with the assistance of three undergraduate field assistants, I extensively sampled initial insect and plant populations in the 15 study fields as well as the experiment plots at Maxwell (Figure 3). From the beginning of the season until harvest in late October, we repeated the vegetation and arthropod sampling techniques described below at two-week intervals in all fields. The wide variety of sampling techniques we used was important because my preliminary 1993 data showed that documentation of the responses to winter flooding depends upon using a variety of collection techniques, which also ensures sufficient collection of the most common species.

We quantified the density of the rice and other plants by measuring frequency and percent cover for each species within three 1 m2 quadrats per field placed in a stratified random configuration, for a total of 66 total sampling locations across 22 fields. We also sampled the arthropod communities at each site used for vegetation characterization, using the following techniques:

A. *Timed visual sampling* of the foliage, seeds and roots of existing vegetation for sessile phloem feeders and water weevils,

B. Aquatic bottle traps for diving beetles and other insects and crustaceans,
C. Floating sticky traps for wolf spiders, striders and other water-surface inhabitants.

In addition we used two other sampling techniques in each field that cannot be directly matched to a vegetation sampling site:

D. Antifreeze-filled pitfall traps along the levees for ground-dwelling beetles and other insects and spiders. We randomly placed six to eight traps around each study field.
E. Malaise traps (24 hour sampling periods) for Odonates, Hymenopterans, Dipterans and other vagile species. We placed one Malaise trap at each field at the Maxwell site.

I am using two methods to analyze my monitoring data. First, I am using analysis of variance (ANOVA) and analysis of covariance methods to look for differences both in the static patterns of biomass and abundance of arthropods in fields with differing treatments, and in rates of change in different components of the arthropod communities through time. For these comparisons, I use paired, two-way ANOVA models, and include measures of vegetational diversity and spatial location within fields as covariates.

Second, I will be using path analysis techniques to explore both the effects of winter flooding and organic management on arthropod communities, and to form and test hypotheses regarding the important interactions governing community structure in these communities (Sokal and Rohlf 1981, Wootton 1994). Path analysis, a multivariate statistical technique (Wright 1921), provides the tools neededto quantify associations among the large number of interacting organisms in a wetland food web. Using path and regression coefficients, it is possible to construct hypotheses about both the directions and the strengths of interactions between pairs of species, and to account for indirect as well as direct effects among the many species interacting within a community (see Wootton 1994). These hypotheses can then be tested against field data (Hayduk 1987, Wootton 1994).

We have now completed recording of species collected on sticky traps and are currently sorting and counting preserved pitfall, bottle and malaise trap samples. We have collected and are currently recording population sizes of 356 different arthropod species. I am using ANOVA techniques with these data to evaluate the roles of specific numerically important species, such as aquatic wolf spiders, and individual pest species including the rice water weevil. I am also generating overall patterns of effects on numbers of predatory and pest species (Table 1) and numbers of species in different taxa (Table 2). These data allow me to discern changes in between-field pest and natural enemy patterns (Ia&c, IIa&c)(Figure 4) as well as within-field distributions due to winter flooding(Ib)(Figure 5).

Using both my 1994 data and data from 1993, I am in the process of constructing path diagrams to contrast food web structures for winter-flooded vs. winter-dry and organic vs. conventional farms to assess the relative importance of pests and predators in each of these conditions. I will develop and refine the simplest explanation of species interactions of rice communities as a whole, and for each set of habitat conditions separately. Using these resulting food webs, I will be able to contrast the net influence of natural enemies on pest populations under different winter-flooding conditions (Ia) and on organic vs. conventional management (IIa). I am also using path diagrams to predict the net results of winter flooding on pest populations for both organic and conventional fields (IIc). Knowledge of pest-enemy food webs in California rice will provide information on possible modifications of winter flooding programs to offset any negative effects, or to enhance positive effects, for pest control.

Organic fields differ from conventional fields both in the lack of pesticide use and in their weediness. In order to use organic fields as models of conventional fields without carbofuran use, it is necessary to isolate the effects of weediness from those of pesticide application. In one of the organic fields in the Willows area, generous cooperation of the Spooner family allowed me to set up four weed removal experiments. To assess the importance of weeds on pest/enemy food web dynamics, I removed weeds from 4 replicates of 4 m2 areas within organically managed fields. I sampled insect populations in the weeded plots and paired control areas with sticky traps every two weeks, and then vacuum sampled them at the end of the season to obtain a broader range information. Using these data I will able to contrast the development of the insect communities in these diverse and homogeneous stands of rice on a far smaller spatial scale and in a more controlled environment than in the on-farm monitoring experiments. I am also using data from these trials to construct path diagrams to evaluate the importance of both weeds and plot size in determining arthropod community dynamics.

III. Importance of generalist predators in limiting California rice pests.

Generalist predators, such as spiders, are able to control pests only through a combination of direct and indirect effects on their prey. These effects are measurable primarily through consideration of the predator's cumulative effects on a suite of species, and may not be observed through simple species-pair experiments. Some generalist predators may be important enemies of potential rice pests. Because generalists are likely to be favored by holding water in fields in the winter, it is important to investigate their abilities to control rice pest species. However, it is necessary to consider the entire insect-spider community of rice in order to accurately predict responses to winter flooding or other habitat alterations.

In some parts of the world it has been argued that spiders are the key, overlooked control agent of pestiferous herbivores in rice, and that their eradication causes outbreaks of herbivores which might never otherwisé become pests (Kenmore 1980, Reichert and Lockley 1984, Provencher and Vickery 1988 and Nyffeler and Benz 1987 for references). Spiders are broad generalists, however, and their value as biological control agents has been challenged on the basis that they are assumed to prey on other predators in addition to the pest insects they consume.

Of particular interest in the rice ecosystem is the common wolf spider, *Pardosa ramulosa. P. ramulosa* has been described in a number of habitats in California, including both natural and rice wetlands (Greenstone 1980, 1979a,b, 1978, Oraze *et al.* 1989, 1988, Vogel 1971, 1972a,b), and it has been identified as an important predator in other cropping systems (Yeargan and Cothran 1974, Yeargan and Dondale 1974, Yeargan 1975a,b, Leigh and Hunter 1969). About 68% of the spiders collected in rice fields are *P. ramulosa* (Oraze *et al.* 1988), and the species is hypothesized to be a primary predator of midges, leafhoppers, and even mosquitoes (Hydorn 1977, Hickle 1981, Greenstone 1978, 1979b, Oraze and Grigarick1989).

P. ramulosa is well suited to the rice habitat in that it has the ability to move in flooded areas by walking on the water's surface tension, and it hunts both terrestrially and in the aquatic environment. *P. ramulosa* has even been reported to reach through the water surface to capture mosquito larvae residing below (Garcia and Schlinger 1972). This spider has been described in both natural and rice wetlands (Greenstone 1980, 1979a,b, 1978, Oraze 1989, 1988, Vogel 1971, 1972a,b), and it has been identified as an important natural enemy in other cropping systems (Yeargan and Dondale 1974, Yeargan and Cothran 1974 Yeargan 1975a,b, Leigh *et al.* 1969).

Wolf spiders and their prey were collected in abundance both on the levees and throughout fields throughout the 1994 rice-growing season. Spiders were also caught in abundance in pitfall traps, although these samples are still being analyzed. Preliminary analyses indicate that overall levels of spiders were higher in winter-flooded fields. Using path analysis and ANOVA techniques I will be able to identify the strength and direction of key interactions between wolf spiders, other natural enemies, and selected rice pests, as well as how these interactions change as a result of winter flooding and insecticide use.

I am also using path analysis to evaluate the importance of wolf spiders and other generalist predators in the rice wetland system, summing direct and indirect interactions. Using the food webs generated for objectives I and II above will allow me to predict the effects of winter flooding on the efficacy of other different predators, such as damselflies and waterbeetles. I am thus developing testable hypotheses concerning the strengths of direct and indirect interactions between important species in the rice fields in order to be able to verify or disprove the accuracy of the correlational structures generated.

To more directly assess the actual importance of wolf spiders to other arthropods, I also created small scale inclusion and exclusion "cages" for *Pardosa ramulosa* and other wolf spiders. I used these cages to passively augment or reduce numbers of this spider as follows:

I used 40 centimeter high plastic strips to build corrals of one meter in diameter with a band of Tanglefoot around the inside or outside top edge of the plastic fence (Oraze *et al.* 1989b). Spiders are able to climb up to the top of the strip on the face with no Tanglefoot, but can not reach the top of the barrier on the side with the Tanglefoot. When the Tanglefoot is applied on the outside of the fence, the exclosure passively reduces the number of spiders inside, because they can climb to the top and jump out, but not vice versa. In contrast, if the Tanglefoot is applied to the inside, movement into the enclosure is free, but movement out is obstructed, passively augmenting the numbers of the spider inside the traps.

In May I established three replicates of the three treatments -- enclosure, exclosure, and control with no Tanglefoot -- for a total of 9 cages in an organically managed field. I then sampled using floating sticky traps every two weeks, and vacuum sampled the 'cages' at the end of the season to obtain a broader range information. Using these data I will able to assess the validity of the hypothesized interaction strengths between these spiders and potential pest insects.

IV. Differences in arthropod data obtained from on-farm research vs. Experimental plot study.

Although the replicated set of 1 acre winter-flooded vs. winter-dry sites in Maxwell, CA managed by the University of California at Davis represents a more thoroughly randomized and replicated set of winter flooding treatments than do the on-farm sites, they are much smaller in size, and so may differ from actual fields in pest and beneficial insect abundances and responses to flooding. Researchers in agricultural systems have long debated the validity of insect observations obtained under experimental conditions for on-farm applications. By contrasting population data for key natural enemies and insect pests collected in research plots at Maxwell with data I obtained in the on-farm studies I am examining both the importance of spatial scale in studies of insect pest management in rice generally, and more particularly as it pertains to winter flooding effects.

This effort is particularly important in the case of winter flooding of rice fields. My earliest data from 1993 showed that winter flooding may not only strongly influence pest and natural enemy numbers, but it influences them in opposite directions in the middle of fields as compared to the levees. This observation indicates that the spatial scale of the research plot (proximity to levee from center of field) may have large effects on responses of arthropods to winter flooding. Early 1994 data appears to corroborate this trend. Throughout the season, we sampled 8 of the Maxwell site plots every two weeks for arthropods as described above. Though much of the data is still being processed, overall numbers of pest and beneficial arthropod species from in-field sticky traps (reflecting mostly wolf spiders and hemipteran/homopterans but including such natural enemies as dragon and damselflies and waterstriders) in fact do show opposite trends between on-farm and experiment plot conditions (Figure 6).

BIBLIOGRAPHY

Garcia, R. and E.I. Schlinger. 1972. Studies of spider predation on Aedes dorsalis (Meigen) in a salt marsh. Pp.117-118, In Proceedings and Papers 40th Annual Conference California Mosquito Control Association.

Greenstone, M.H. 1978. A numerical response to prey availability of Pardosa ramulosa (McCook) (Aranae:Lycosidae) and its relationship to the role of spiders in the balance of nature. Symp. Zool. Soc. London 42:183-193.

____. 1979a. A line transect density index for wolf spiders (Pardosa spp.), and a note on the applicability of catch per unit effort methods to entomological studies. Ecol. Entomol. 4:23-29.

____. 1979b. Spider feeding behavior optimizes dietary essential amino acid composition. Nature, 282:501-503.

____. 1980. Contiguous allotopy of Pardosa ramulosa and Pardosa tuoba (Aranae:Lycosidae) in the San Francisco Bay region, and its implications for resource partitioning in the genus. American Midland Naturalist 104:305-311.

Hayduk, L.A. 1987. Structural equation modeling with LISTREL. John Hopkins University Press, Baltimore, Maryland, USA.

Hickle, L.A. 1981. The biology and ecology of Pardosa ramulosa (McCook), (Aranae, Lycosidae), in Imperial Valley, California. Dissertation. University of California, Berkeley.

Hydorn, S.E. 1977. The biology of Pardosa ramulosa. Dissertation. University of California, Berkeley.

Kenmore, P.E. 1980. Ecology and outbreaks of a tropical insect pest of the green revolution. Dissertation. University of California, Berkeley.

Leigh, T.F. and R.E. Hunter. 1969. Predacious spiders in California cotton. California Agric. 23:4-5.

Nyffeler, M. and G. Benz. 1987. Spiders in natural pest control: a review. J. Appl. Entomol. 103:321-339.

Oraze, M.J., A.A. Grigarick, J.H. Lynch and K.A. Smith. 1988, Spider fauna of flooded rice fields in northern California. J. Arachnol. 16:331-337.

Oraze, M.J., A.A. Grigarick and K.A. Smith. 1989. Population Ecology of Pardosa ramulosa (Aranae, Lycosidae) in flooded rice fields of northern California. J. Arachnol. 17:163-170.

Oraze, M.J. and A.A. Grigarick. 1989. Biological control of Aster Leafhopper (Homoptera: Cicadellidae) and midges (Diptera: Chironomidae) by Pardosa ramulosa (Aranae: Lycosidae) in California rice fields. Journal of Economic Entomology 82(3):745-749.

Provencher, L. and W. Vickery. 1988. Territoriality, vegetation complexity, and biological control: the case for spiders. American Naturalist 132(2):257-266.

Reichert, S.E. and T. Lockley. 1984. Spiders as biological control agents. Annu. Rev. Entomol. 29:299-320.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry (2nd ed.). W.H. Freeman, New York.

Vogel, B.R. 1971. Individual interactions of Pardosa. The Armadillo Papers 5:1-12.

_____. 1972a. Sympatric occurrence of some Pardosa species (Araneida:Lycosidae). The Armadillo Papers 6:1-12.

_____ 1972b. Apparent niche sharing of two Pardosa species. The Armadillo Papers 7:1-13.

Wootton, J. T. 1994. Predicting direct and indirect effects: an integrated approach using experiments and path analysis. Ecology 75:151-165.

Wright, S. 1921. Correlation and causation. J. Agric. Res. 20:557-585.

Yeargan, K.V. 1975a. Factors influencing the aerial dispersal of spiders (Arachnida, Aranidae). J. Kansas Entomol. Soc. 48:403-408.

____. 1975b. Prey and periodicity of Pardosa ramulosa (McCook) in alfalfa. Environmental Entomol. 4:137-141.

Yeargan, K.V. and W.R. Cothran. 1974. Population studies of Pardosa ramulosa (McCook) and other common spiders in alfalfa. Envir. Entomol. 3:989-993.
Yeargan, K.V. and C.D. Dondale. 1974. The spider fauna of alfalfa fields in northern California. Ann. Entomol. Soc. America 67:681-182.

PUBLICATIONS OR REPORTS:

Due to the multi-year structure of this project, results will not be published until the validity of observations has been confirmed through accumulation of two years of intensive field data.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

This year I have initiated a multi-species, food web ecology study of the effects of winter flooding of rice fields on natural enemy efficiency and pest population levels during the growing season. California rice fields historically have not experienced serious outbreaks of insect pests; nonetheless, rice growers use insecticides against some major arthropod pests such as the rice water weevil. In addition, seed midges,two species of armyworms, rice leafminer, and rice leafhoppers are herbivorous insects which sporadically cause problems in California now. However, in many parts of the world these and other major pests not currently found in California reach outbreak levels, causing significant economic damage both by feeding and by vectoring rice viruses. Widespread changes in the crop environment such as winter-flooding could strongly influence the biology of these and other potential pests. Further, even in California, organically grown rice produces much lower yields than does conventionally produced rice, although the extent to which the reduction in yield is due to herbivorous arthropods is unclear.

I have focussed my efforts this year primarily in three areas: Site selection (April and May); pest and beneficial arthropod (insect and spider) sampling and preservation (May-October); and arthropod sorting and identification, data input and analysis (November-present).

Through the ready collaboration of five local rice growers, the study was successfully laid out with 15 on-farm sites and an additional 8 plots at the Maxwell experimental site. I was able to sample all sites every two weeks from May through October, as well as complete exclusion trials and weed removals with the assistance of three very capable undergraduates. The May starting date, due to both logistical and financial considerations, was significantly later than I hope to accomplish in the coming year. To date I have collected 271 species of insect and spiders in the rice fields, many never before reported in rice. Of these 271, 21 are spiders, 29 are predatory and parasitic wasps, 15 are predatory bugs, 47 are beetles, and 18 are ants, predatory flies and other occasional beneficial insects. In contrast, we encountered 12 plant-sucking bugs (such as leafhoppers and aphids), 14 species of midges, 10 different cricket species, and 6 weevil species, including the rice water weevil. The remaining species are mostly scavengers, acting as general prey for some beneficials, but not affecting rice production to any degree.

The arthropod sorting and identification, as well as data input and analysis, is still very much in progress, as I have collected large numbers of samples and am performing a wide array of statistical analyses to best utilize the information I have gathered. However preliminary analyses indicate that overall levels of both pest and natural enemy species were higher in winter-flooded fields. I expect this third phase to be completed by mid-January, at which point I will begin collecting data for the 1995 field season. Full details of these results will be published in my 1995 research report.

This research will have significant applied value for rice management in the Sacramento Valley, contributing much-needed information on the effects of new management techniques -- particularly keeping rice fields flooded through the winter -- on natural enemy efficiency and non-chemical pest control potential in this important California crop. By using food web techniques in conjunction with applied, on-farm research, I am both quantifying and attempting to understand the reasons behind changes in the beneficial and pest insect food webs resulting from changing off-season farm management techniques. It will be important to continue this study for an additional year in order to both assess pre-season pest and beneficial species build-up and to evaluate year-to-year variation in flooding effects.

Table 1: Proportion of Likely (pending positive identification) Beneficial and Potential Pest Species Collected in Rice Fields, 1994

Beneficial Species (Predatory and Entomoparasitic at some stage):

Aranae:	21 spp. (Including *Pardosa ramulosa,* the aquatic wolf spider)
Ephemeroptera:	1 sp.
Odonata:	2 spp.
Hemiptera:	10 spp.
Coleoptera:	25 spp.
Diptera:	8 spp.
Hymenoptera:	29 spp.
TOTAL:	96 spp.

Potential Pest Species (Occasional or common rice herbivores):

Aranae:	2 spp.
Orthoptera:	10 spp.
Hemiptera:	15 spp
Homoptera:	12 spp. (Aphids and Leafhoppers)
Coleoptera:	25 spp. (Including *Lissorhoptrus oryzophilus,* the rice water weevil)
Diptera:	~20 spp. (Including seed midges)
Lepidoptera:	6 spp. (including armyworms)
TOTAL:	~90 spp.

(note: some species are both predatory and herbivorous, due to different ecological roles as larvae and adults)

Table 2: Proportion of Arthropod Species Collected in Rice Fields in 1994, by Taxon

Aranae		
	Spiders:	21 spp.
	Mites:	2 spp.
Crustacea:		> 6 spp.
Collembola:		undet. spp.
Thysanura:		undet. spp.
Ephemeroptera:		1 sp.
Odonata:		2 spp.
Orthoptera:		10 spp.
Mantodea:		1 sp.
Blattaria:		4 spp.
Dermaptera:		3 spp.
Homoptera		
	Leafhoppers:	11 spp.
	Aphid:	2 spp.
Coleoptera:		
	Weevils:	6 spp.
	Other beetles:	69 spp.
Diptera		
	Midges and gnats:	15 spp.
	Mosquitoes:	3 spp.
	Flies:	39 spp.
Lepidoptera:		9 spp.
Hymenoptera		
	Wasps:	29 spp.
	Ants:	7 spp.
TOTAL:		>271 spp.

Hemiptera: 25 spp.

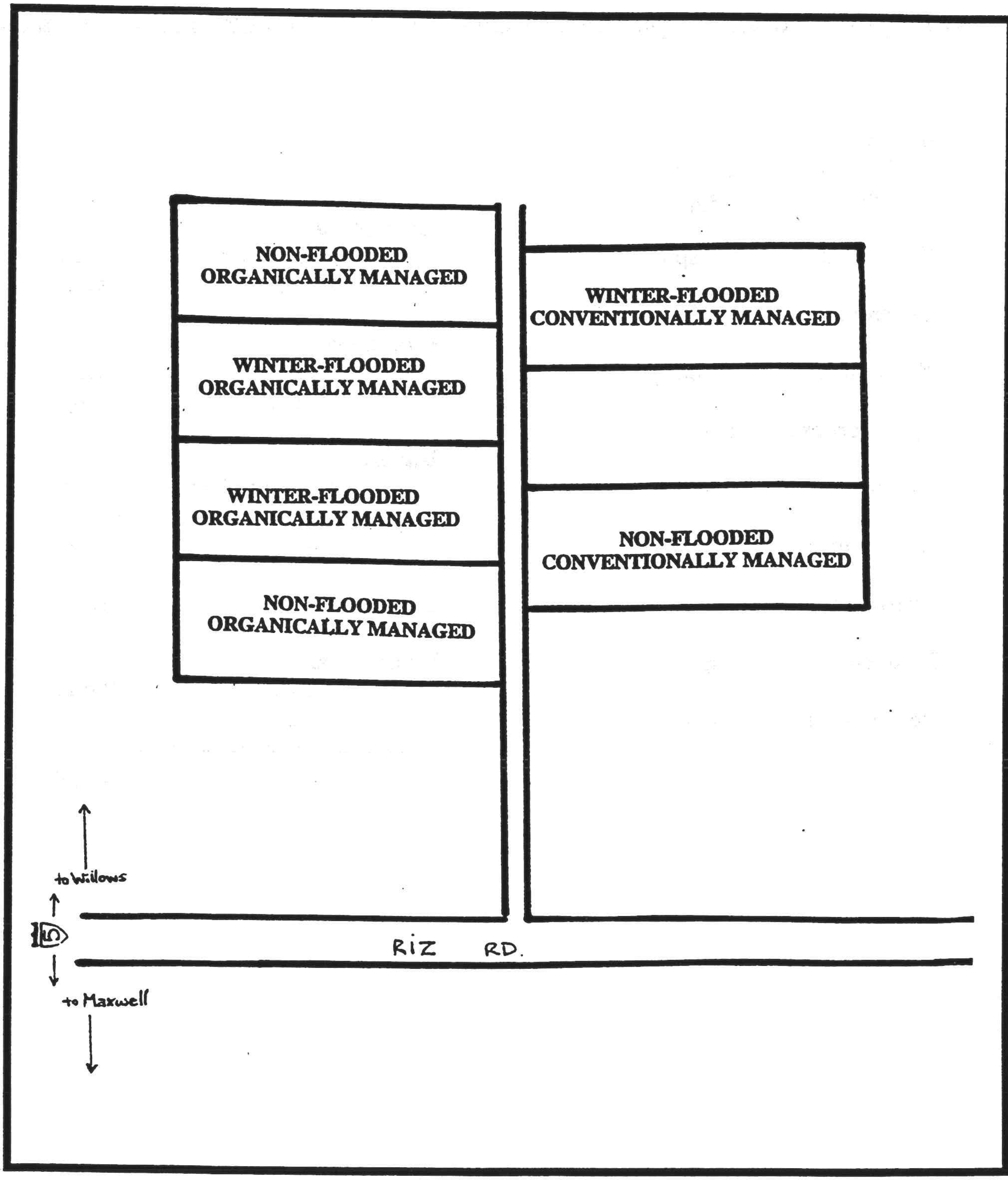

Figure 1. On-Farm Monitoring Sites, Willows Area, CA

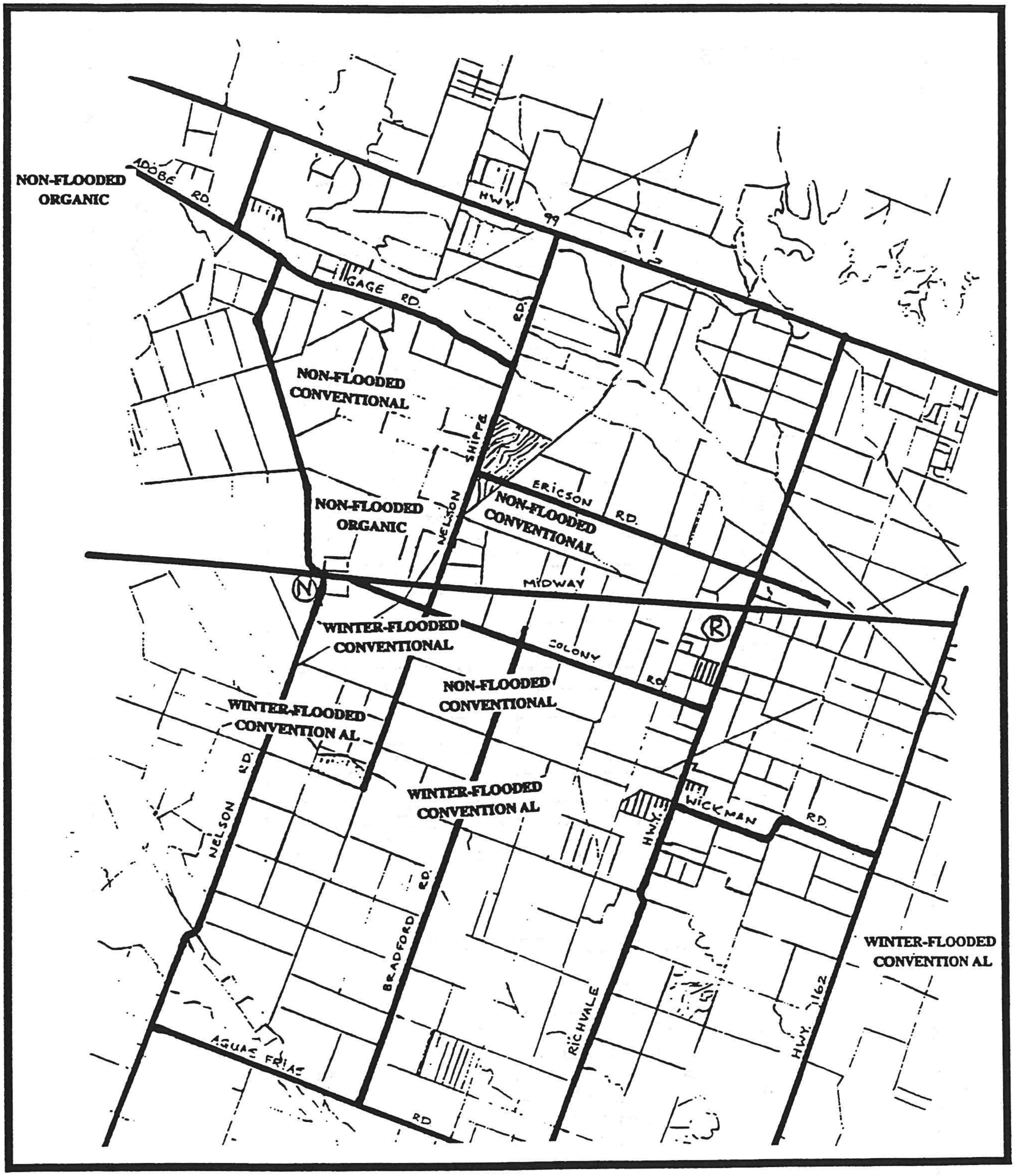

Figure 2. On-Farm Monitoring Sites, Richvale and Nelson Area, CA

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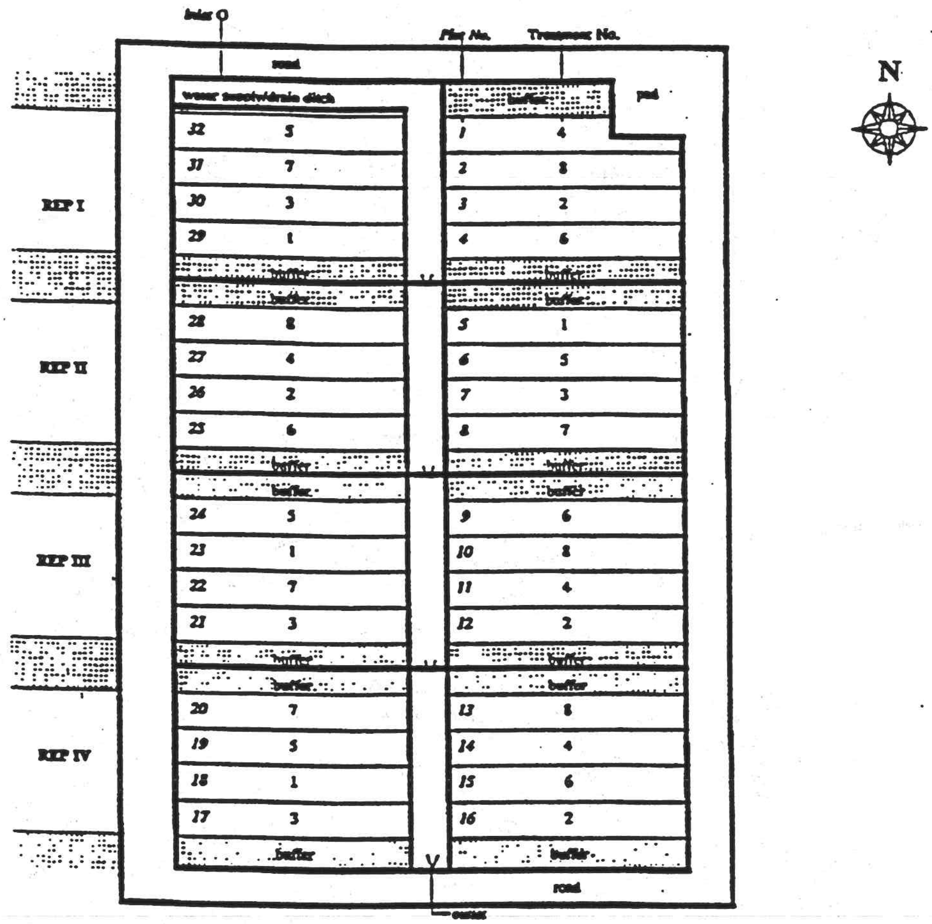

STRAW MANAGEMENT TREATMENTS

1. Straw burned, winter flooded
2. Straw burned, non-flooded
3. Straw incorporated, winter flooded
4. Straw incorporated, non-flooded
5. Straw rolled, winter flooded (flood, then cage roll)
6. Straw rolled, non-flooded
7. Straw baled, winter flooded
8. Straw baled, non-flooded

Figure Courtesy of U.C. Davis Agronomy Dept

Figure 3: U.C. Experimental Plots. Maxwell, CA

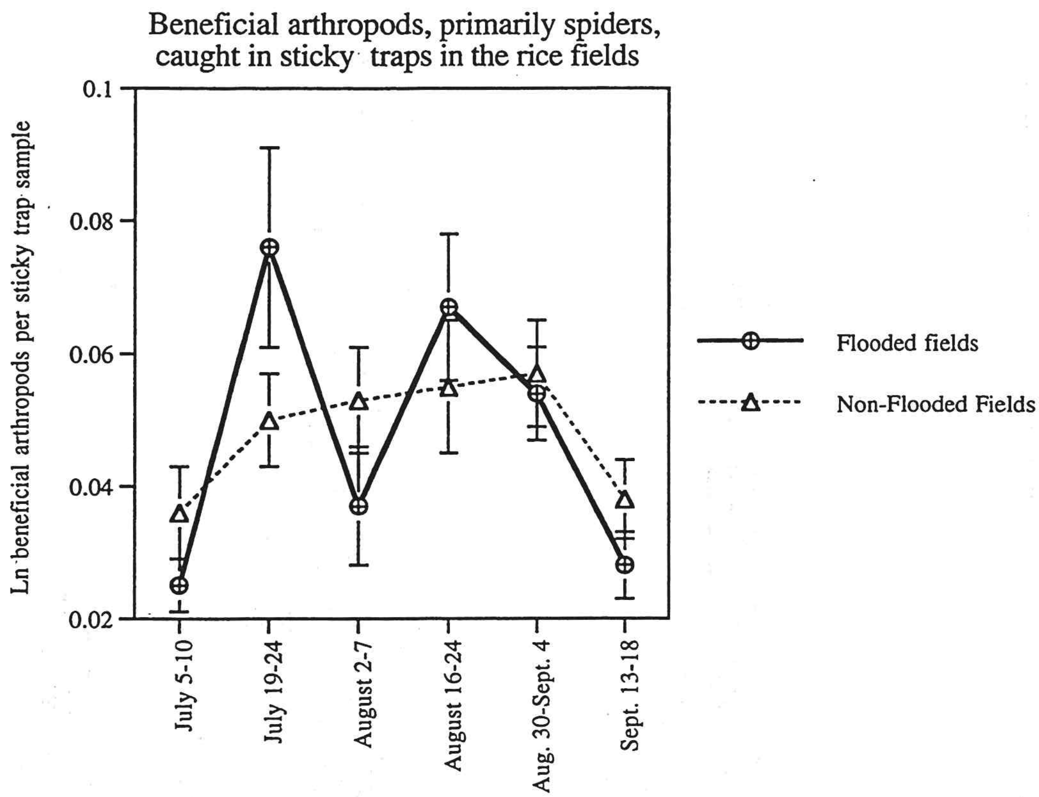

Figure 4: Even where overall predator numbers are quite similar between winter- flooded and non- flooded fields, from an agronomic standpoint phenomena such as increased variability - or risk- can be quite important. Here it is possible to detect greater fluctuation in beneficial insect numbers due to the conditions presented when fields are flooded through the wintertime. This trend could be good, if it reflects the spiders' greater ability to respond to pest numbers in the field. It will be critical to complete further data analyses and field work to dissect the meaning of such differences for farmers.

1993
Beneficial arthropod populations (mid-season)

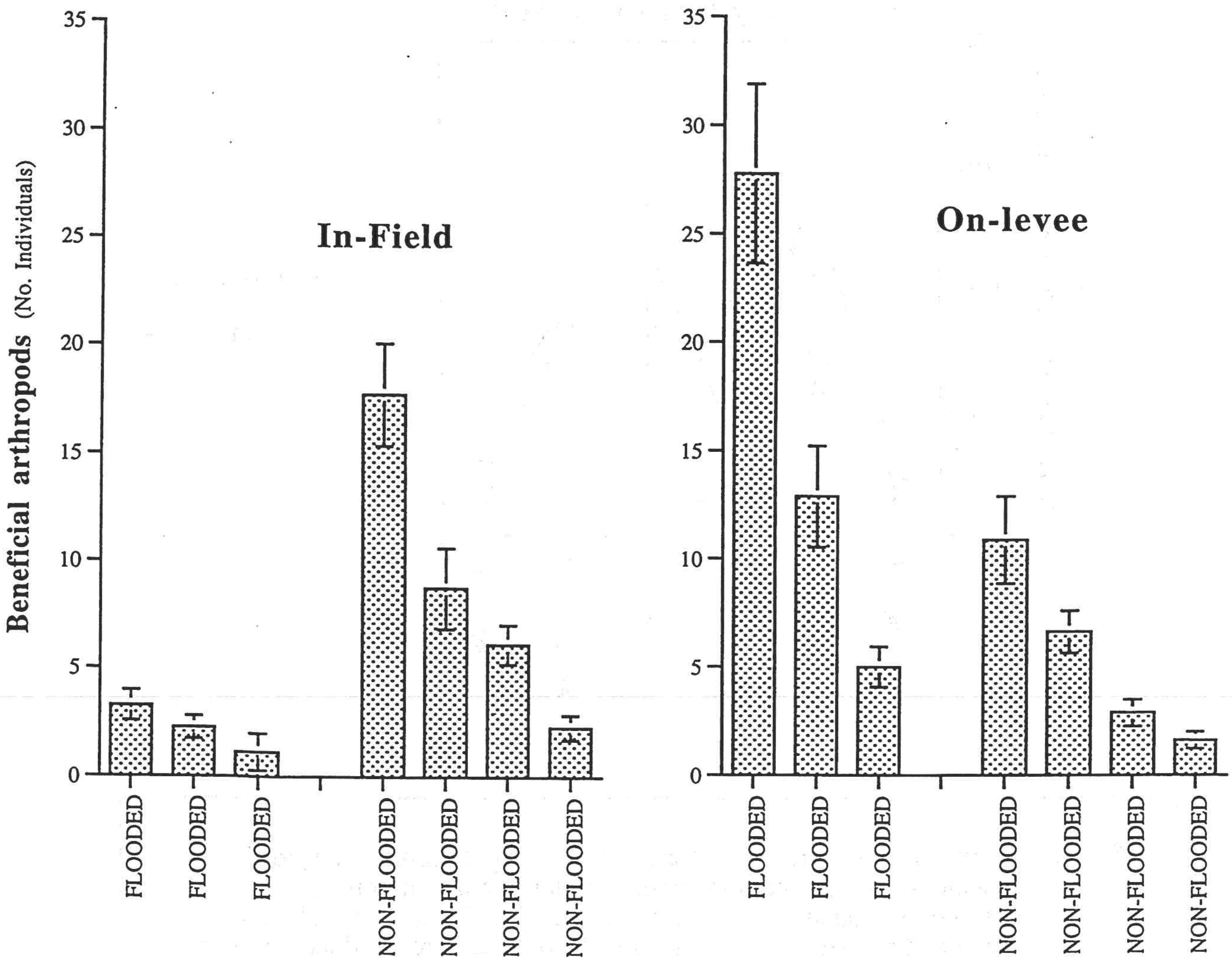

Figure 5: 1993 data showed that arthropod predators appear to be concentrated on the levees, where they may be more effective at controlling overwintering pest populations, by the practice of flooding fields during the winter time.

1994
Beneficial arthropods (primarily spiders) collected on sticky traps in rice fields

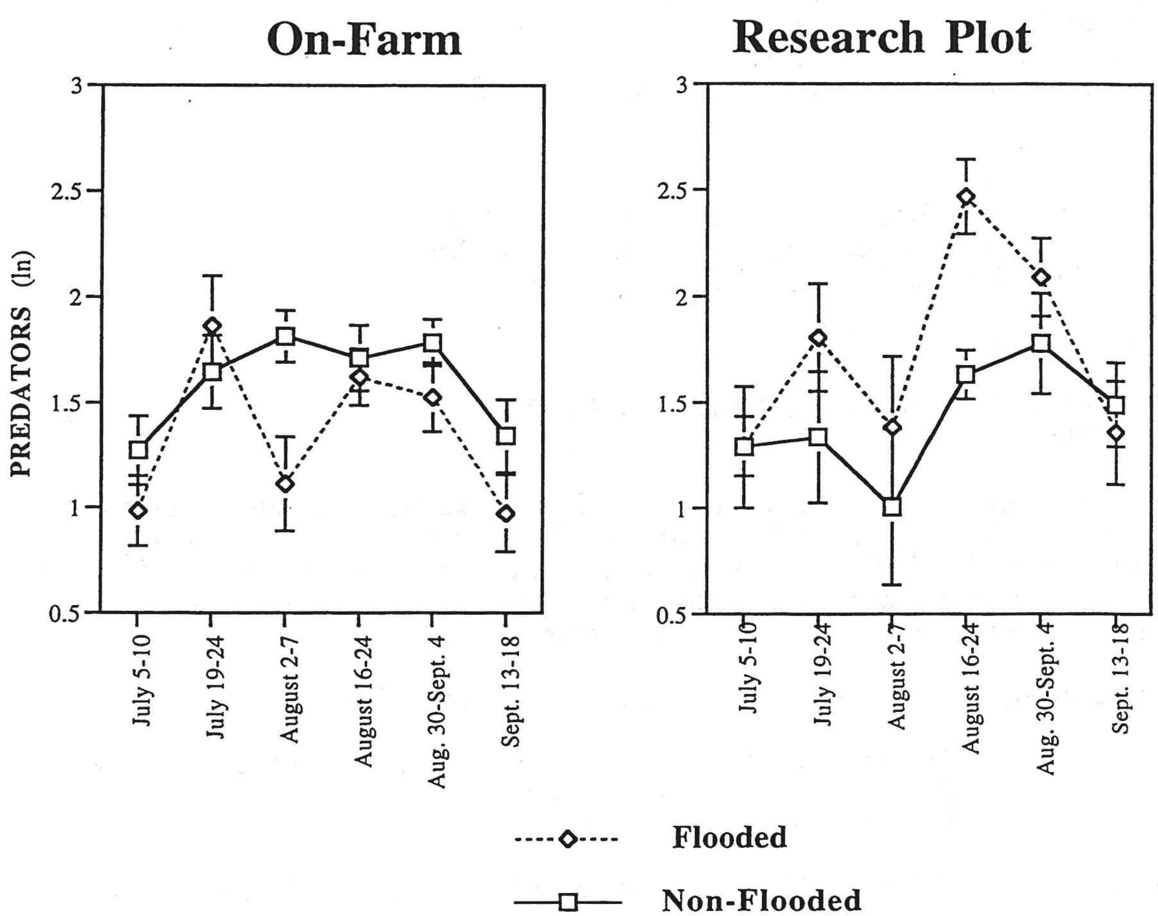

Figure 6: Flooding appears to create opposite trends in effects on mid to late season beneficial arthropod numbers between experiment plot environment and on-farm conditions.