HABITS AND RELATIVE POPULATION DENSITIES OF SOME HYDROPHILIDS IN CALIFORNIA RICE FIELDS

Frank G. ZALOM[1], Albert A. GRIGARICK & Michael O. WAY

Department of Entomology, University of California, Davis, California 95616 USA

[1] Present address: Department of Entomology, Fisheries, and Wildlife, University of Minnesota, St. Paul, MN 55108 USA

Received October 26, 1979

Keywords: *Berosus styliferus, Hydrophilus triangularis, Tropisternus lateralis,* seasonal abundance, California, rice field, population dynamics, colonization

Abstract

Populations of the hydrophilids *Berosus styliferus* Horn, *Hydrophilus triangularis* Say, and *Tropisternus lateralis* (Fabricius) were observed in northern California rice paddies. Relative adult and larval density for each species was determined using aquatic light traps adjacent to the water margin, and at 5 m and 30 m distances from the levee. Egg cases were monitored by recording numbers per unit area.

The seasonal patterns of abundance indicate each species has a univoltine life cycle. All stages of *B. styliferus* and *H. triangularis* are more abundant nearer the levees. *T. lateralis* adults are commonly found at the levees during the first 10 weeks post-flood, whereas *T. lateralis* larvae and egg cases are most numerous at the 30 m distance.

Colonication of the paddies occurs through water connections, flight, and adult overwintering.

Introduction

Rice is one of the major field crops grown in California. The production season typically runs from late April through October, with the fields flooded to a depth of 32 cm to 42 cm during much of that period. Therefore, the paddies become a suitable habitat for various aquatic insects which are normally associated with semi-permanent ponds in the Sacramento Valley.

Elsewhere Zalom *et al.* (1979) have shown that 8 species of water scavenger beetles (Hydrophilidae) are regularly associated with rice in northern California. In this paper we analyze the habits, density, and colonization of *Berosus styliferus* Horn, *Hydrophilus triangularis* Say, and *Tropisternus lateralis* (Fabricius). The study of these hydrophilids is important due to their potential economic impact as pests (Lange & Grigarick, 1970) or natural control agents (Veneski & Washino, 1970; Zalom *et al.*, 1978). Both James (1964) and Fernando & Galbraith (1973) noted the lack of biological data on the developmental stages of the aquatic Coleoptera, and have stressed the need for such studies.

Methods

This study was conducted during the production seasons of 1977 and 1978, in 2 rectangular 4 hectare paddies at the California Cooperative Rice Research Foundation Field Station near Biggs, Butte Co., CA. The fields were disced, plowed, and then flooded on 28 April, 1977, and 8 May, 1978. No insecticides were applied to the paddies during either season.

Adult and larval populations were monitored with aquatic light traps consisting of 6 volt incandescent light sources within glass cylinders as described by Washino & Hokama (1968). Chloroform fumes served as the killing agent. The traps were deployed 12 m apart in rows of 4 within 1 m of the southern levee and at distances of 5 m and 30 m from the southern levee. This spacing was chosen to demonstrate edge densities as opposed to hydrophilid densities well within the paddies. They were operated weekly during all hours of darkness beginning the first week after flooding. Vegetation was removed for a distance of 1 m from each trap.

The number of eggs per unit area were monitored weekly. A 1 m x 10 m area was searched at each distance from the water margin. The procedure was replicated 4 times.

The within-field distribution of the life stages of each species was determined by paired sample t-tests for differences between the number of adults or larvae captured per trap or the number of egg cases observed per unit area at the levee and the 5 m distances, and at the 5 m and 30 m distances for each year.

Comments on overwintering are from observations, and from data obtained from 10.2 cm-diameter core sam-

Hydrobiologia 75, 195-200 (1980). 0018-8158/80/0753-0195$01.20.

ples taken monthly from the crown of levees at the research station.

The potential for paddy colonization via the inlet canal was monitored weekly using 4 aquatic light traps placed 12 m apart in the inlet canal. Colonization by flight was examined by using 0.9692 m-diameter metal rings placed at 2 m, 4 m, 8 m, 16 m, and 32 m distances from the 4 field margins. The base of each ring was embedded in the substrate to prevent swimming to or from the rings. The rice within each ring was thinned or transplanted to approximate the density of the surrounding plant stand. Following each weekly canvass, all hydrophilids were removed from the rings using a strainer.

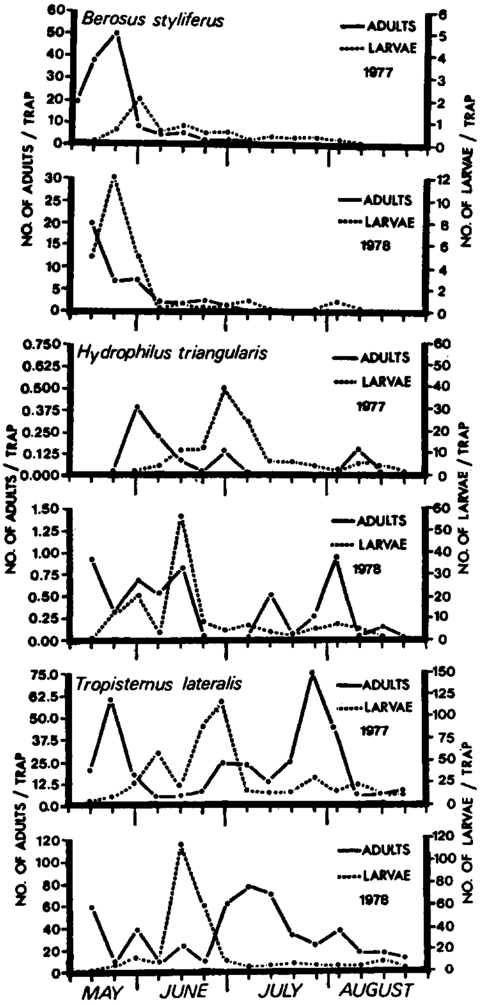

Fig. 1. $\bar{x}$ number of *Berosus styliferus, Hydrophilus triangularis*, and *Tropisternus lateralis* adults and larvae taken per aquatic light trap in 1977 and 1978. Catches at 5 m and 30 m distances from levee were totaled.

Weekly estimates of plant cover were determined by counting the number of rice plant tillers per m^2 adjacent to the levee, and at the 5 m and 30 m distances from the levee. Water temperatures were recorded weekly on a maximum-minimum thermometer placed on the substrate 30 m from the levee.

Results

Habits

Berosus styliferus. – In the fields, adults were most common during the first 3 weeks following flooding (Fig. 1), and were never collected after the first week of July. Egg cases are often attached to submerged debris and floating algal mats during May. Each egg case holds 3 to 5 eggs ($\bar{x} \pm 3.79$; SD = 0.92; n = 19). The greatest number of larvae is attracted to the traps in late May. Only 1st and 2nd instar larvae were captured in the aquatic light traps. Third instar larvae were often found buried in the substrate in association with the roots of rice plants.

Hydrophilus triangularis. – Adults were most abundant during late May and June (Fig. 1). Floating egg cases are attached to rafts that are constructed by the females from rice leaves. The cases are most often observed during June. The mean number of eggs counted per case was 85.52 (SD = 10.02; n = 21), which is somewhat less than that reported by Matheson (1914) and Wilson (1923a). Larvae were captured throughout much of the season, but peak abundance corresponded closely with that of peak egg case number. A second adult peak was recorded in August, which would indicate a new generation from the rice fields. It is unknown if the colonizing adults overwintered as adults or pupae, however Wilson (1923b) believes that winter survival is in the adult stasge. We have found both adults and pupae exposed during the fall following discing of the fields. It is possible that third instar *H. triangularis* larvae stranded in the paddies following draining could pupate in the remaining mud substrate.

Tropisternus lateralis. – Adults exhibit a bimodal pattern of abundance with seasonal peaks occurring in May and July (Fig. 1). Adults have been collected throughout the winter from core samples of soil and grass taken from the levees. We believe there is a single generation per year with individuals overwintering as adults. Egg cases were found from May through July, usually attached to rice

Table 1. - Within-field densities of Berosus styliferus. Paired sample t-tests for differences between traps at levee and 5m, and 5m and 30m distances. n = sample size.

SAMPLE	DIFFERENCE[1] (0m-5m)	n_{0m-5m}	t	CONCLUSION	DIFFERENCE[2] (5m-30m)	n_{5m-30m}	t	CONCLUSION
ADULTS 1977	--	--	--	--	5.00	28	1.270	P > 0.10
ADULTS 1978	4.75	24	0.968	P > 0.10	1.50	20	1.937	P < 0.05
LARVAE 1977	--	--	--	--	0.38	32	0.893	P > 0.10
LARVAE 1978	10.56	16	2.249	P < 0.025	0.83	24	0.752	P < 0.10
EGGS 1977	1.25	20	3.160	P < 0.01	0.75	8	6.255	P < 0.05
EGGS 1978	1.50	16	18.382	P < 0.0005	0.50	4	3.464	P < 0.025

[1]Positive number indicates a greater abundance near levee.
[2]Positive number indicates a greater abundance at 5m.

stems just below the water surface. The mean number of eggs per case was 13.54 (SD = 2.69; n = 24), which agrees with observations of Richmond (1920) and Wilson (1923b). Like *H. triangularis*, the larvae are at peak density in late June.

Density

Berosus styliferus. - There was a tendency for adults and larvae to be located nearer the field margins rather than the center of the field (Table 1), though the difference was not always significant at the 5% level. In 1978, larvae were found at the levee with significantly higher frequency ($P < 0.025$) than at the 5 m distance. The number of egg cases also decreased significantly in relation to the distance from the levee. Further, there was a significant linear correlation between number of egg cases (totaled at each distance for each season) and their respective distances from the levee ($P < 0.05$; $r = -0.791$; $\hat{Y} = 21.833 - 12.838x$; $n = 24$).

Hydrophilus triangularis. - There was a significant difference in both the margin to 5 m distance and the 5 m to 30 m distance among all *H. triangularis* life stages surveyed (Table 2). A greater abundance was found nearer the levee. As for *B. styliferus*, a significant negative linear correlation ($P < 0.05$) existed both seasons between the number of egg cases, and the corresponding distances from the levee ($r = -0.732$; $\hat{Y} = 20.096 - 9.634x$; $n = 24$). No correlation between numbers and distance was observed for adults or larvae.

Tropisternus lateralis. - Seasonally, there was no significant difference ($P > 0.25$) between the 5 m and the 30 m distances for *T. lateralis* adults or larvae (Table 3), although both tended to prefer the water margin to the 5 m distance ($P > 0.05$). The reverse was true for the number of egg cases ($P < 0.005$) found at the 30 m distance. No difference ($P > 0.25$) was observed between the levee and the 5 m samples. Further analysis revealed that adult *T. lateralis* were significantly more common nearer the levees during the 1st 10 weeks of the season, and more common at the 30 m distance thereafter (Table 4). The opposite situation existed for *T. lateralis* larvae which tended to be more

Table 2. - Within-field densities of Hydrophilus triangularis. Paired sample t-tests for differences between traps at levee and 5m, and 5m and 30m distances. n = sample size.

SAMPLE	DIFFERENCE[1] (0m-5m)	n_{0m-5m}	t	CONCLUSION	DIFFERENCE[2] (5m-30m)	n_{5m-30m}	t	CONCLUSION
ADULTS 1977	--	--	--	--	2.25	20	3.753	P < 0.001
ADULTS 1978	8.00	40	1.914	P < 0.05	0.88	16	1.852	P < 0.05
LARVAE 1977	--	--	--	--	1.90	44	1.390	P > 0.05
LARVAE 1978	92.75	52	1.917	P < 0.05	4.71	60	2.301	P < 0.025
EGGS 1977	1.75	20	16.040	P < 0.0005	0.50	4	3.464	P < 0.025
EGGS 1978	2.00	16	7.003	P < 0.0005	0.50	8	2.500	P < 0.025

[1]Positive number indicates a greater abundance near levee.
[2]Positive number undicates a greater abundance at 5m.

Table 3. - Within-field densities of Tropisternus lateralis. Paired sample t-tests for differences between traps at levee and 5m, and 5m and 30m distances. n = sample size.

SAMPLE	DIFFERENCE[1] (0m-5m)	n_{0m-5m}	t	CONCLUSION	DIFFERENCE[2] (5m-30m)	n_{5m-30m}	t	CONCLUSION
ADULTS 1977	--	--	--	--	0.94	64	0.365	$P > 0.25$
ADULTS 1978	274.25	60	0.887	$P > 0.05$	0.40	60	0.029	$P > 0.25$
LARVAE 1977	--	--	--	--	19.15	52	0.107	$P > 0.25$
LARVAE 1978	70.25	60	1.865	$P < 0.05$	6.13	60	0.279	$P > 0.25$
EGGS 1977	0.25	28	0.405	$P > 0.25$	1.00	28	4.316	$P < 0.0005$
EGGS 1978	0.25	12	0.245	$P > 0.25$	1.00	20	7.299	$P < 0.0005$

[1]Positive number indicates a greater abundance near levee.
[2]Positive number indicates a greater abundance at 5m.

common at the greater distance during the 1st 10 weeks post-flood, and nearer the water margin later in the season.

Limiting factors. - Rice stand density and developing plant cover (Fig. 2) is undoubtedly a factor affecting the density of beetles by its effect on food or on shelter from predators. The amount of plant cover is determined by the original plant density and the extent of tillering of each plant. *B. styliferus* typically completes much of its life cycle before the mid-tillering stage (ca. 8 weeks post-flood). Until that time, algae and debris, which are usually distributed near the levees by wind and wave action early in the season, provides suitable alternatives for attachment and shelter for this species. The lack of a dense plant stand could also explain the distribution of *H. triangularis* egg cases, as prevailing winds move the floating cases to the field margins.

Adult *T. lateralis* attach egg cases to plants below the water line at a greater distance from the levees than the other species. During the 1st 10 weeks post-flood the larvae of *T. lateralis* remain at that distance. This period corresponds to the peak larval abundance of *H. triangularis* which has been shown to prey upon *T. lateralis* larvae, and to compete for similar prey (Zalom *et al.*, 1978). One explanation for this spatial pattern is avoidance of *H. triangularis* larvae by the smaller *T. lateralis*. An alternative explanation is that because *T. lateralis* egg cases are attached to plants, they can't be blown to the levee as are those of *H. triangularis*. Further, in temporary habitats the attachment of egg cases in deeper water would insure the submergence required for respiration in *T. lateralis*.

Table 4. - Within-field densities of Tropisternus lateralis. Two sample t-tests for differences between weeks 1 - 10 and 11 - 16 post-flood. n = sample size.

SAMPLE	DIFFERENCE WEEK 1-10	DIFFERENCE WEEK 11-16	n_{1-10}	n_{11-16}	t	CONCLUSION
ADULTS 1977	4.40	-5.83	40	24	2.14	$P < 0.025$
ADULTS 1978	5.20	-11.60	40	20	2.58	$P < 0.01$
LARVAE 1977	-37.13	9.60	32	20	1.87	$P < 0.05$
LARVAE 1978	-9.70	1.00	40	20	1.08	$P > 0.10$

As water is continuously circulating within the field, temperature gradients between the areas studied should be minimal. Maximum water temperature occurs in early June, before the dense rice plant canopy forms (Fig. 2). Further, our traps were located in an area of uniform mixing according to the type IV rice paddy current pattern of Surtees (1970).

Colonization

Rice paddies are temporary habitats for aquatic organisms, and must be seasonally colonized. This can occur through water connections, flight, overwintering, or transplants by man or machinery.

Migration through water connections was monitored with aquatic light traps in the inlet canal. In both years, *H. triangularis* adults and larvae were first captured in the rice paddies the 2nd week and 3rd week post-flood, respectively. *T. lateralis* larvae were also captured as early as the 3rd week post-flood. All species were captured in the canal at least one week prior to their capture in the paddy traps.

Zalom *et al.* (1979) reported that the seasonal flights of *B. styliferus* were initiated in April or early May. We found that rings placed in the paddies were colonized by *B. styliferus* as early as the 1st week post-flood. Throughout the season, a negative linear correlation ($P < 0.05$) existed between the total number of all hydrophilid species per ring, and the distance from the levees ($r = -0.438$; $\hat{Y} = 16.234 - 2.072x$; $n = 20$).

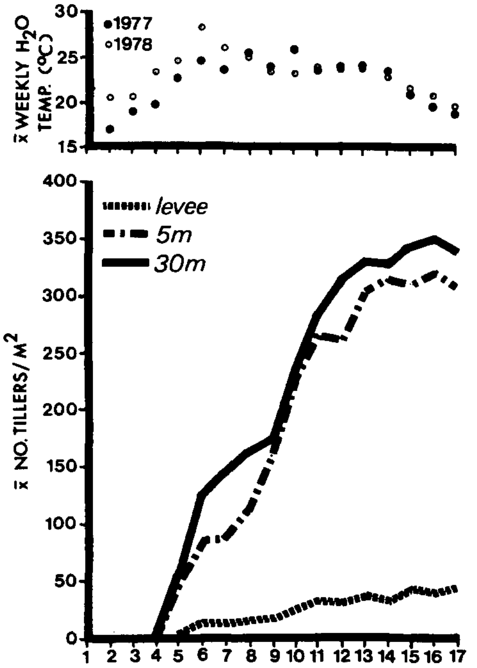

Fig. 2. Rice plant cover at different areas of the rice field.

Discussion

Landin (1976) found that in Swedish ponds, the hydrophilids *Anacaena limbata* Fabr., *Helophorus strongifrons* Thoms., and *Hydrobius fuscipes* L. are at maximal abundance during spring, minimal abundance during summer, and sometimes at a smaller peak during late summer and autumn. This pattern fits a univoltine life cycle, where the beetles lay eggs during early summer and hibernate as adults. In northern California rice paddies, adult *H. triangularis* and *T. lateralis* exhibited similar patterns. *B. styliferus* was an early colonizer and didn't show a second adult peak.

Adults, larvae, and egg cases of *B. styliferus* and *H. triangularis* were found in greater abundance nearer the leeves. *T. lateralis* adults were found in larger numbers nearer the levees during the 1st weeks post-flood, and farther within the field thereafter. The relative densities of *T. lateralis* larvae and egg cases showed the reverse pattern. The peak larval abundance of *H. triangularis* corresponded to the peak larval abundance of *T. lateralis*. Further, Veneski & Washino (1970) and Zalom *et al.* (1978) have shown that *H. triangularis* larvae commonly prey upon *T. lateralis* larvae, and compete for the same prey. Clearly, such direct competition in the same habitat would be harmful for *T. lateralis* if food was limited. The behavioral mechanisms for interspecific differences in relative densities at different distances from the levee are unknown but several possibilities exist. One explanation could be avoidance, where *T. lateralis* adults preferentially lay eggs farther from the levee. Second, the attachment of egg cases to vegetation would effectively limit drift due to wind. Another hypothesis is the submergence requirement of the egg which could be overcome in temporary habitats by attachment below the surface in deep water. Finally, it is possible that predation by *H. triangularis* on *T. lateralis* larvae is so great near the shore that the population of *T. lateralis* is noticeably reduced.

Acknowledgements

We would like to thank Drs. V. H. Resh and R. K. Washino for reviewing this manuscript, and C. K. Fukushima for technical assistance. This research was supported in part by the California Cooperative Rice Research Foundation.

References

Fernando, C. H. & Galbraith, D. 1973. Seasonality and dynamics of aquatic insects colonizing small habitats. Verh. Internat. Verein. Limnol. 18: 1564-1575.

James, H. G. 1964. The role of Coleoptera in the natural control of mosquitoes in Canada. Proc. Internat. Congr. Entomol., London. 12: 357-358.

Lange, W. H. & Grigarick, A. A. 1970. Insects and other animal pests of rice. Calif. Agr. Exp. Sta. Circ. 555: 3-16.

Landin, J. 1976. Seasonal patterns in abundance of water-beetles belonging to the Hydrophiloidea (Coleoptera). Freshwat. Biol. 6: 89-108.

Matheson, R. 1914. Notes on Hydrophilus triangularis Say. Can. Entomol. 46: 337-343.

Richmond, E. A. 1920. Studies on the biology of the aquatic Hydrophilidae. Bull. Amer. Mus. Nat. Hist. 42: 1-95.

Surtees, G. 1970. Studies on water movements and dispersion of mosquito larvae with special reference to control in rice fields. Bull. Entomol. Res. 60: 275-283.

Veneski, R. & Washino, R. K. 1970. Ecological studies of Hydrophilus triangularis Say in the laboratory and in a rice field habitat. Proc. Calif. Mosq. Contr. Assn. 38: 92-93.

Washino, R. K. & Hokama, Y. 1968. Quantitative sampling of aquatic insects in a shallow-water habitat. Ann. Entomol. Soc. Amer. 61: 785-786.

Wilson, C. B. 1923a. Life history of the scavenger water beetle, Hydrous (Hydrophilus) tringularis and its economic relation to

fish breeding. Bull. U. S. Bur. Fish. 39: 9-38.
Wilson, C. B. 1923b. Water beetles in relation to pondfish culture, with life histories of those found in fishponds at Fairport, Iowa. Bull. U. S. Bur. Fish. 39: 231-345.
Zalom, F. G., Grigarick, A. A. & Way, M. O. 1978. Predation by the larvae of Tropisternus lateralis (Fabricius) in California rice fields. Proc. Calif. Mosq. Contr. Assn. 46: 82-84.
Zalom, F. G., Grigarick, A. A. & Way, M. O. 1979. Seasonal and diel flight periodicities of rice field Hydrophilidae. Environ. Entomol. (In press).