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MAJOR DETERMINANTS OF A HERBACEOUS ASSOCIATION BETWEEN *PARYDRA QUADRITUBERCULATA* (DIPTERA: EPHYDRIDAE) AND DIATOMS (CHRYSOPHYTA) IN A MUDFLAT HABITAT

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ABSTRACT

An association between *Parydra quadrituberculata* Loew and diatoms was examined as to the major forces governing the distribution and gross abundance of each within a mudflat of a marsh. Diatoms were primarily under the influence of the physical environment. Diatoms were rare only when the product of soil moisture and light intensity at the surface of the mudflat was low. The presence of *P. quadrituberculata* was significantly associated with the presence of diatoms ($p = 0.01$; one-tailed Fishers Exact test). This was expected since the shore fly diets on diatoms. However, diatoms were always common when the shore fly was present, suggesting that the shore fly is not a major force controlling the distribution and gross abundance of the diatoms. Potential competitors of *P. quadrituberculata* are discussed for their possible impact on the distribution and abundance of the shore fly.

INTRODUCTION

Shore flies (Diptera: Ephydridae) comprise one of the largest nearctic acalyptrate families, with over 400 species represented (Deonier, 1979). The family has invaded a wide range of aquatic and semiaquatic habitats including marginal areas of lakes and streams (Schiering and Foote, 1973), hot springs (Wiegert and Mitchell, 1973), temporary pools, and even decomposing animals and feces (Bohart and Gressitt, 1951; Runyan and Deonier, 1979).

Many studies of the Ephydridae have concentrated on life histories and diets. The shore flies are mainly herbivorous, consuming algae (Deonier, 1972.). However, little is known concerning the impact the shore flies have on the algal community. Study of the algavorous species has lead to speculation by Foote (1977) of the possible value of using the flies to control undesirable algae, e.g., Cyanobacteria, in eutrophic waters.

In the following investigation, a mudflat community of shore flies was studied in respect to two objectives:

1. Examine an ephydrid-algal relationship as to the effect of each on the distribution of the other, and
2. Investigate physical and biotic controls on the abundance and distribution of the ephydrid and algae.

The shore fly, *Parydra quadrituberculata* Loew, was chosen for study because of its abundance in a local marsh. The shore fly's diet is made up of diatoms (Deonier and Regensburg, 1978; Deonier, 1972).

STUDY AREA

The study site was a mudflat within a marsh located 200m southwest of the campus of the College of DuPage (DuPage County, IL). As part of a preserve set within a residential location, the marsh is immediately bordered by thick stands of cattails, *Typha latifolia* L. and *T. angustifolia* L. Willows, *Sadix spp.*, lie beyond this border on the east and west ends. The oblong marsh is approximately 125m in length and 90m in width.

The mudflat first formed during 1984 on 18 June and eventually comprised the entire marsh when the marsh dried up by 1 September, 1984. Studies concentrated on the more secluded southwest sector of the mudflat.

MATERIALS AND METHODS

Observations began on 31 May, 1984, before the mudflats were exposed. Macroinvertebrates were surveyed from *Typha spp.* that were less than 10cm in height by taking 20 sweeps with an aerial net. A second collection was conducted on 8 June, 1984.

By 18 June, 1984, the mudflat was beginning to form at the cattail-water interface. Two sites were sampled, the first being 1m into the cattail from its interface with the emerging mudflat and the second at the interface. Preliminary measurements included temperature determinations of the air and within the top cm of soil, plus light intensity measurements above the cattails and at the surface of the soil using a Weston light meter. All samples were taken on sunny days. Then, visual observation for adult *P. quadrituberculata* and other invertebrates were taken from 10 quadrats (25 cm^2) that were delineated by scrawling into the mud a day before. Twenty sweeps with an aerial net over each site followed. Finally, mud samples from each site ($n = 20$; $4cm^2 \times 0.5cm$ depth) were collected for analysis of invertebrate fauna and microflora, as well as for the determination of moisture content. Preweighed moist mud was dried to a constant weight at room temperature over a two week period for determination of moisture content.

These procedures were repeated on 7 July, 25 July, and 22 August, 1984, at various locations along the growing mudflat. Samples were taken 1m into the reeds, at the reed-mudflat interface, and 2m into the mudflat on all dates. On July 27, additional measurements were taken 4m and 6m into the mudflat. On 22 August, samples were taken 6m, 12m, and 18m into the mudflat. Furthermore, visual observations of quadrats for invertebrates were raised to 20 replicates for the last two sampling dates.

Observation ceased on 13 September, 1984, approximately 2 weeks after the marsh dried up completely. No ephydrids were observed during aerial net sampling on September 1 and 13.

RESULTS AND DISCUSSION

The abundance of P. quadrituberculata and other macroinvertebrates

P. quadrituberculata was the most common shore fly collected throughout the study period (Table 1). Two shore flies, *Scatella stagnalis* (Fallen) and *Octhera mantis* (Degeer), were also collected. *S. stagnalis* is a generalist in diet and can be successfully reared on Cyanobacteria, such as *Anabaena* and *Gloeocapsa*, in addition to diatoms (Foote, 1977). So it is a potential competitor to *P. quadrituberculata*. However, adult *S. stagnalis* were rarely collected, casting doubt that the species affected the population of *P. quadrituberculata* in the marsh during 1984. *O. mantis* is an entomophagous species (Simpson, 1975). The species was observed between late July and the month of August. I was unable to examine if *O. mantis* has a negative effect on the distribution and abundance of *P. quadrituberculata*.

Another abundant grazer was a species of *Lymnaea* (Table 1). As algavores (Kesler, 1983), *Lymnaea* are known to have cellulase activity. Statistical discussion of the snail is given later.

Survey of the microflora

Table 2 lists the algae identified from analysis of the mud samples. A 16mm^2 slice off the surface of the mud was taken for each of 20 replicates per site. Mixed with a drop of distilled water, the mud was teased over a gridded microscope slide (1mm^2 grids). Gross counts of the diatoms, primarily *Navicula*, were taken. Diatoms were noted as rare if only 6.25×10^4 cells•m^{-2} of surface soil were counted. They were labeled common if 6.25×10^5 cells•m^{-2} or more were counted. No counts occurred between these measurements. Diatoms were given extra attention due to their importance as a food source to *P. quadrituberculata*. The relative contribution of each type of algae to the algal community was determined by visually estimating, under 400× magnification, the surface area covered by the particular algae and dividing this by the total surface area covered by all of the algae under view. This was done to show the floral diversity of the study site and the relative commonness of the other algae to diatoms.

Interrelationships among biotic and abiotic parameters.

The presence of *P. quadrituberculata* was tested for a positive association to the presence of diatoms using a 2 × 2 contingency table (Zar, 1984). Diatoms were given a value of 0 if they were absent or rare. The result was a significant association ($p = 0.01$; one-tailed Fishers Exact test). This was expected since diatoms compose the diet of *P. quadrituberculata*.

P. quadritubertculata and *Lymnaea* sp. were also positively associated ($p = 0.01$; one-tailed Fishers Exact test). However, *Lymnaea* sp. showed no association ($p>0.05$) with diatoms. The positive association between the shore fly and snail may be the result of *Lymnaea* sp. grazing on a broader spectrum of, or different, algae that generally occurred where diatoms were present (Table 2). *S. stagnalis* was not significantly ($p>0.05$) associated with either *P. quadrituberculata* or diatoms. The presence of diatoms was affected by the combination of moisture content of the mud and light intensity. Physical measurements were adjusted on a common scale ranging from 0-100 using the formula, $(x_i/x_{max})\bullet 100$, where x_i is the sample value with units of % moisture content, °C, or lumens, and x_{max} is the highest like measurement recorded during the experiment (Table 3). For an example of the calculations, the adjusted value of moisture content from soil collected within the cattail habitat on 18 June was $(16/69)\bullet 100$, or 23. Sixty-nine was the highest % moisture content recorded during the experiment taken from 2m into the mudflat on 7 July. This transformation offered to adjust the measurements on a common scale for reasons of comparing the synergistic effects of the different physical parameters on the distribution of diatoms. Except for the 27 July sampling of the cattail-mudlfat interface, diatoms were rare or absent only when the product of the adjusted % soil moisture and light intensity were low ($\leq 1.8 \times 10^3$, Table 4). Diatoms were always common when *P. quadrituberculata* was present, even when the shore fly occurred at higher densities. There was no evidence that the shore fly decimated and limited the distribution of the diatom population. Instead, diatoms were noticably rare only when the combined environmental conditions of soil moisture and light intensity were low, suggesting these physical parameters are the major controls on the distribution and abundance of the diatoms.

CONCLUSION

Diatoms seem to be the driving force in the *P. quadrituberculata*-diatom relationship. In contrast, the distribution and gross abundance of diatoms were controlled by the environment. Once the marsh completely dried up, huge cracks (10cm depth) sculptured the mudflat. The ephydrids left, but were quite common along the moist mudshore of an adjacent, deeper marsh.

Periodic desiccation is characteristic of the marsh habitat. The ephemerality of this type of habitat should select for primary producers that can grow rapidly when times are favorable, and seek refuge when the environment deteriorates. Consumers that center their life cycles around these producers also must adapt to the ephemerality of the food source placed upon by the environment. Therefore, the major forces affecting the distribution and abundance of the food chain in an ephemeral habitat can be expected to be the environment for the primary producers, and the availability of the primary producers to the herbivores. Since many of the algavorous Ephydridae have diversified into habitats that are ephemeral in nature and should be under the primary control of the physical environment, it is doubtful that the flies can be very useful in controlling nuisance types of algae occurring in these areas.

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Table 1. Abundance of adult Ephydridae and *Lymnaea* sp. in the marsh. Counts were taken visually from the mudflat and reeds. Captures using an aerial net were not included in counts unless stated otherwise.

Date	Habitat	Organism	Abundance•m^{-2}
6-18-84	Cattail	*Parydra quadrituberculata*	1200
		Scatella stagnalis	Captured in aerial net
		Lymnaea sp.	45800
	Cattail-mudflat interface	*P. quadrituberculata*	22400
		Lymnaea sp.	240500
7-7-84	Cattail	*P. quadrituberculata*	400
	Cattail-mudflat interface	*P. quadrituberculata*	Captured in aerial net
	2m into mudflat	*P. quadrituberculata*	3600
		Lymnaea sp.	2500
7-27-84	Cattail	*S. stagnalis*	Captured in aerial net
	Cattail-mudflat interface	None	
	2m into mudflat	*Ochthera mantis*	6000
	4m into mudflat	*P. quadrituberculata*	400
		O. mantis	7600
		Lymnaea sp.	3600
	6m into mudflat	*P. quadrituberculata*	6800
		S. stagnalis	400
		O. mantis	7600
		Lymnaea sp.	34400
8-22-84	Cattail	None	
	Cattail-mudflat interface	None	
	2m into mudflat	None	
	6m into mudflat	None	
	12m into mudflat	None	
	18m into mudflat	*P. quadrituberculata*	400
		O. mantis	2000
		Lymnaea sp.	63200
9-1-84		None	
9-13	84	None	

Table 2. The relative contribution (%) of different algae to the algal community. Only algae contributing at least 1% to the community are listed. Diatoms are notated as being rare (R) in samples if $\leqslant 6.25 \times 10^4$ cells•m^{-2} were counted, and common (C) if $\geqslant 6.25 \times 10^5$ cells•m^{-2} were counted.

Date	Habitat	Algae	Relative contribution $\bar{x} \pm s$; $n = 20$	
6-18-84	Cattail	Diatoms (Chrysophyta)	76 ± 22	(C)
		Oscillatoria (Cyanobacteria)	22 ± 22	
		Cholorcoccus (Chlorophtya)	1 ± 2	
	Cattail-mudflat interface	Diatoms	84 ± 20	(C)
		Oscillatoria	7 ± 9	
		Ankistrodesmus (Chlorophyta)	1 ± 3	
		Closterium (Chlorophyta)	1 ± 2	
7-7-84	Cattail	Diatoms	65 ± 36	(C)
		Oscillatroia	34 ± 35	
		Closterium	1 ± 3	
	Cattail-mudflat interface	Diatoms	93 ± 15	(C)
		Oscillatoria	8 ± 15	
	2m into mudflat	Diatoms	80 ± 38	(C)
		Nostoc (Cyanobacteria)	15 ± 37	
		Oscillatoria	5 ± 12	

Table 2 Continued

Date	Habitat	Algae	Relative contribution $\bar{x} \pm s$; n = 20
7-27-84	Cattail	Diatoms	88 ± 29 (R)
		Oscillatoria	12 ± 29
	Cattail-mudflat interface	Diatoms	7 ± 21 (R)
		Oscillatoria	93 ± 21
	2m into mudflat	Diatoms	84 ± 27 (C)
		Arthrospira (Cyanobacteria)	1 ± 2
		Nostoc	1 ± 5
		Oscillatoria	12 ± 26
		Oedogonium (Chlorophyta)	2 ± 11
	4m into mudflats	Diatoms	41 ± 30 (C)
		Anabaena (Cyanobacteria)	13 ± 17
		Oscillatoria	46 ± 36
	6m into mudflat	Diatoms	87 ± 30 (C)
		Oscillatoria	9 ± 24
		Spirogyra (Chlorophyta)	4 ± 18
8-22-84	Cattail	Diatoms	90 ± 28 (R)
		Oscillatoria	10 ± 28
	Cattail-mudflat	*Oscillatoria*	1 ± 3 (n = 8; remaining replicates lacked the algae)
		Oedogonium	99 ± 3 (n = 14; remaining replicates lacked the algae)
8-22-84	2m into mudflat	*Oedogonium*	100 ± 1 (n = 1; remaining replicates lacked the algae)
	6m into mudflat	Diatoms	100 ± 1 (n = 4; remaining replicates lacked the algae; R)
	12m into mudflat	Diatoms	74 ± 30 (C)
		Oscillatoria	26 ± 30
	18m into mudflat	Diatoms	73 ± 34 (C)
		Nostoc	1 ± 2
		Oscillatoria	11 ± 15
		Spirogyra	12 ± 30

Table 3. Physical measurements, and adjusted values which are enclosed in parentheses, taken from the habitats at the marsh.

Date	Habitat	% Moisture Content	Temperature (°C)	Light Intensity (Lumens)
6-18-84	Cattail	16 (23)	25 (71)	2600 (100)
	Cattail-mudflat interface	50 (72)	27 (71)	2600 (100)
7-7-84	Cattail	62 (90)	32 (91)	2450 (94)
	Cattail-mudflat interface			
	2m into mudflat	69 (100)	29 (83)	2550 (98)
7-24-84	Cattail	42 (69)	20 (57)	750 (29)
	Cattail-mudflat interface	40 (58)	22 (63)	2450 (94)
	2m into mudflat	45 (65)	23 (66)	2450 (94)
	4m into mudflat	44 (64)	24 (69)	2450 (94)
	6m into mudflat	57 (83)	27 (77)	2450 (94)
8-22-84	Cattail	37 (54)	28 (80)	160 (6)
	Cattail-mudflat interface	4 (6)	32 (91)	2000 (77)
	2m into mudflat	3 (4)	35 (100)	2000 (77)
	6m into mudflat	1 (1)	34 (97)	2000 (77)
	12m into mudflat	22 (32)	33 (94)	2000 (77)
	18m into mudflat	27 (39)	32 (91)	2000 (77)
x_{max}		69	35	2600

Table 4. The adjusted products of (soil moisture • light intensity) ranked from highest to the lowest values and the commonness of diatoms associated with each value. C means the diatoms were common while R signifies rarity.

Adjusted Product of soil moisture and light intensity	Date	Location	Commonness of Diatoms
9.8×10^3	7/7/84	2m into mudflat	C
8.8×10^3	7/7/84	cattail-mudflat interface	C
8.5×10^3	7/7/84	cattail	C
7.8×10^3	7/27/84	6m into mudflat	C
7.2×10^3	6/18/84	cattail-mudflat interface	C
6.0×10^3	7/27/84	4m into mudflat	C
6.1×10^3	7/27/84	2m into mudflat	C
5.5×10^3	7/27/84	cattail-mudflat interface	R
3.0×10^3	8/22/84	18m into mudflat	C
2.5×10^3	8/22/84	12m into mudflat	C
2.3×10^3	6/18/84	Cattail	C
1.8×10^3	7/27/84	Cattail	R
4.6×10^2	8/22/84	Cattail-mudflat interface	Absent
3.2×10^2	8/22/84	Cattail	R
3.1×10^2	8/22/84	2m into mudflat	Absent
7.7×10^1	8/22/84	6m into mudflat	Absent