Aggregation of Lady Beetles on the Shores of Lakes (Coleoptera: Coccinellidae)

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ABSTRACT: Aggregations of lady beetles, predominately *Hippodamia convergens* and *H. tredecimpunctata,* were commonly observed on the shores of lakes in the Upper Midwest during the autumn and spring. The beetles remain on the shore for only a short time, usually dispersing within 2-3 weeks. Lady bettles from autumn shore aggregations and overwintering aggregations are characterized by the presence of large amounts of fat, reproductive inactivitiy, empty digestive tracts, a skew in the sex ratio favoring females and the behavioral tendency to form aggregations. *Hippodamia convergens,* the most commonly observed coccinellid in shore aggregations, undergoes long migratory flights to and from overwintering sites in California. It is suggested that similar migratory activity occurs in the Upper Midwest and that during these flights the beetles may be blown into the water and washed ashore, thus forming the aggregations. However, in contrast with the overwintering aggregations in California, the shore aggregations reported in this study appear to be temporary shoreline collections and not the overwintering site.

INTRODUCTION

The aggregation of lady beetles on the shores of lakes in the Upper Midwest is a phenomenon commonly known to local residents, although it has received little attention in the scientific literature. The beetles in these shore aggregations may be so numerous that 5000-10,000 living individuals may be collected in 1 hr.

As early as 1850, LeConte reported collections of lady beetles on the shore of Lake Superior. Additional observations of coccinellids on lake shores were made by Wheeler (1887), Snow (1902), Needham (1900, 1904, 1917) and Park (1930) on Lake Michigan, Schwarz (1890) on Lake Superior, and Smith (1966) on Lake Ontario. In 1975, Simpson and Welborn reported a mixed aggregation of lady beetles and alfalfa weevils [*Hypera postica* (*Gyllenhal*)] along a reservoir in Colorado. Savoiskaya (1965) referred to masses of coccinellids on the shores of lakes, including Lake Ala-kul and Lake Balkhash in Kazakhstan, USSR. Accumulations of coccinellids have also been reported on ocean shores in England (Marriner, 1939; Riggall, 1953), the United States (Hagen, 1962) and Egypt (Oliver, 1943). Oliver describes a drift line of dead *Coccinella 11-punctata L.* at least 13 miles long with 70,000 beetles per ft run.

These reports are restricted to species lists and general notes based upon limited observations at single shore sites. In order to determine the significance shore aggregations have in the biology of lady beetles, additional information is required. The purpose of this study is twofold: (1) to provide a detailed description of these shore aggregations, and (2) to determine the relationship of these aggregations to the life history of coccinellids.

METHODS AND MATERIALS

Periodically from April through November in the years 1975-1978, the shores of lakes were examined for the presence of lady beetle aggregations. A shore site was considered to have an aggregation if it was possible to collect 50 or more beetles in a 15-20 min search, while sites without aggregations generally yielded fewer than five individuals during the search period. However, on most occasions when an aggregation was present several hundred and often more than 1000 beetles could

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be collected during this search period. During the course of this study, Park Point, Duluth, Minnesota, on the SW corner of Lake Superior, and Mille Lacs Lake in central Minnesota were sampled intensively during both the autumn and spring. Additional samples were collected primarily in the autumn at other lakes throughout the Upper Midwest.

In order to determine the ability of *Hippodamia convergens* Guerin and *H. tredecimpunctata* (Say) to overwinter on Park Point, beetles naturally aggregating on this beach were collected on 26 October 1975, and placed in fine mesh bags. The bags were placed in a protected site beneath the low-hanging branches of *Juniperus communis* approximately 40 m from the water in the lake dune portion of Park Point. In addition, nearly 1000 free-living beetles were marked with fingernail polish at seven sites 5-25 m from the high water line. Bags and sites were checked on 3 April 1976.

To test the ability of *Hippodamia convergens* to survive on the surface of water, single individuals were placed in 500 ml Erlenmeyer flasks partially filled with 200 ml of tap water and held at room temperature. Survival was checked daily.

Nonshore collections of coccinellids were made in order to provide data (*i.e.*, fat content, reproductive state, parasitism and sex ratio) comparative to that obtained from the shore aggregations. Summer collections were made from cornfields on the St. Paul Campus, University of Minnesota, St. Paul. As no overwintering aggregations of *Hippodamia convergens* were found in the Minnesota area, samples collected from winter aggregation sites near Grass Valley, Nevada Co., California, were purchased from the Bio-Control Co., Auburn, California. Overwintering *H. tredecimpunctata* were collected from a heterospecific aggregation, composed mainly of *Coleomegilla maculata lengi* (Timberlake) located in Winona Co. in southeastern Minnesota. An additional collection was made on the evening of 14 July 1977, at the Itasca State Park, Clearwater Co., Minn., when a large number of *H. tredecimpunctata* were attracted to building lights.

Samples were analyzed for the occurrence and relative abundance of each coccinellid species. The sex ratio for *Hippodamia convergens* and *H. tredecimpunctata* was determined for most samples. Generally, a portion of the sample was fixed in Kahle's solution for later dissection after the method of Stewart *et al.* (1967). If possible, 20 males and females of both *H. convergens* and *H. tredecimpunctata* in each sample were dissected and examined for fat content, reproductive state and the presence of the braconid parasite, *Perilitus coccinellae* (Schrank). An individual with high fat content was characterized by a distended abdomen and the presence of a large amount of internal fat globules. Reproductively active females were indicated by the presence of at least two and usually five or more developing eggs 1 mm or more long.

Chi-square statistics using a 2x2 contingency table were used for data analysis (Snedecor and Cochran, 1967).

Dr. Robert Gordon, Systematic Entomology Laboratory, U.S. Dep. Agric., determined the reference collection used in this study. A voucher collection has been deposited in the Entomology Museum, Department of Entomology, Fisheries, and Wildlife, University of Minnesota, St. Paul.

RESULTS

General observations.—Shore aggregations were observed primarily during late August, September, October and May (Table 1). In addition, I received 19 reports or samples of beetles from persons who had observed shore aggregations. Seventeen of these aggregations occurred in late August or September, while the remainder were observed in May. The largest aggregations took place in September when beetles were sometimes so numerous that 5000-10,000 individuals could be collected

in 1 hr. Aggregations in other months were often considerably smaller. The probability of finding an aggregation at a particular site was quite variable, even during months when aggregations were most common. September aggregations were observed at only 33% of the site visits (Table 1).

The aggregations appeared to arrive suddenly on the shore with most of the beetles gradually leaving the area within 2-3 weeks. August and early September aggregations dispersed more rapidly, perhaps due to the warmer temperatures, than those observed in October.

On one occasion, 5 May 1978, large numbers of coccinellids were found dead in the water along the western shore of Mille Lacs Lake. At this time the ice was nearly off the lake; however, at several sites, fist-sized and smaller fragments of ice lined the beach, sometimes extending as much as 100 m out from the shore. The dead beetles were observed floating among this fringe of ice.

On lake shores the greatest concentration of lady beetles was observed within 3 m of the high water line, where they were found clinging near the top of driftwood, rocks, vegetation and any other available object. The distribution of the coccinellids ranged from scattered individuals to clusters numbering in the hundreds. Very few dead beetles were observed in these drift-line aggregations. Some individuals exhibited a darkened elytral coloration similar to ones which had been experimentally held in water.

Park Point is a narrow finger of land separating the Duluth Harbor from Lake Superior. Shore aggregations were found only on the lake side of Park Point.

On windy days the beetles moved into protected nooks and crevices. During the day the activity of the beetles appeared to be related to temperature. If disturbed on warm days, the beetles moved about rapidly and sometimes took flight, while on colder days they responded by moving slowly or dropping to the ground.

Copulating pairs of *Hippodamia convergens* were found frequently in both autumn and spring shore aggregations. No ovipositing females or larval lady beetles were observed on the beaches, although on two occasions several single eggs resembling those of lady beetles were encountered on driftwood. Lady beetles were not observed feeding while on the shore, except on two occasions when an adult *H. convergens* was feeding on a conspecific. Furthermore, dissections of more than 1000 individuals of *H. convergens* and *H. tredecimpunctata* collected in both the autumn and the spring revealed that the gut was nearly always empty. This fact contrasts with beetles collected in cornfields during the summer when digestive tracts were usually distended with parts of aphids.

Geographic distribution.—Shore aggregations were found on lakes throughout the Upper Midwest. Aggregations were observed at one or more sites on the shores of Lake Superior, L. Michigan, L. Huron, Mille Lacs L., L. Winnipeg and L. Manitoba. Additional samples of lady beetles were received from autumn shore aggregations on Upper Red L., Lake of the Woods and Pelican L., Ottertail Co., in W-central Minnesota. The shore sites at which these aggregations were located are shown on Figure 1. Spring shore aggregations were observed on Mille Lacs Lake and on Lake Superior.

Species composition.—The most abundant coccinellid in all autumn shore aggre-

TABLE 1.—Number of shore site visits and percentage of sites with aggregations during 1975-1978 observations

	Month							
	A	M	J	J	A	S	O	N
No. of shore site visits	1	22	8	–	5	46	23	10
Percentage of sites with aggregations	0	41	0	–	20	33	65	20

gations was *Hippodamia convergens*. This species usually accounted for more than 99% of the collection sample. *Hippodamia tredecimpunctata* was the only other lady beetle collected in relatively large numbers. In one sample from Park Point, this species comprised 11% of the coccinellids in the aggregation. In spring shore aggregations, *H. tredecimpunctata* was generally more common than in autumn collections. In 1978, at Mille Lacs Lake in early May, this species constituted more than 98% of the individuals in shore aggregations; however, by 31 May it accounted for only 59% of the sample. In spring collections at Park Point *H. convergens* remained the most abundant species of coccinellid present, although on one occasion 17% of the sample was *H. tredecimpunctata*.

Other coccinellid species generally accounted for less than 0.5% of the shore aggregation collections. Table 2 summarizes lady beetle species collected at either Mille Lacs Lake or Park Point at any time during the study. The greatest species richness was observed on 5 May 1978 at Mille Lacs Lake when 19 coccinellid species were collected from a strip of shoreline 1 m wide and 30 m long. In even the largest autumn shore aggregations, fewer than eight species were typically observed, while spring samples commonly yielded 10 or more species. Overall, the species richness at Mille Lacs Lake was greater than that observed at Park Point (Table 2) even though fewer visits were made to Mille Lacs Lake.

Experimental overwintering on Park Point.—When the bags and sites of marked beetles were checked on 3 April 1976, Park Point was clear of snow, but large piles of broken ice still lined the shore. Temperatures were still so low that it is unlikely that beetles would have been able to disperse prior to this time. All beetles in the bags were dead. Extensive movements of sand caused by the action of wind and ice on the beach had buried four of the seven aggregation sites where free-living beetles had been marked. An extensive search of Park Point yielded only four living coccinellids, although over 200 dead individuals were observed. None of the marked beetles were recovered. Searches during November of other years produced very few, if any, living beetles. It appears that the large aggregations of beetles observed early in the autumn do not overwinter on Park Point and that the shore may not be an

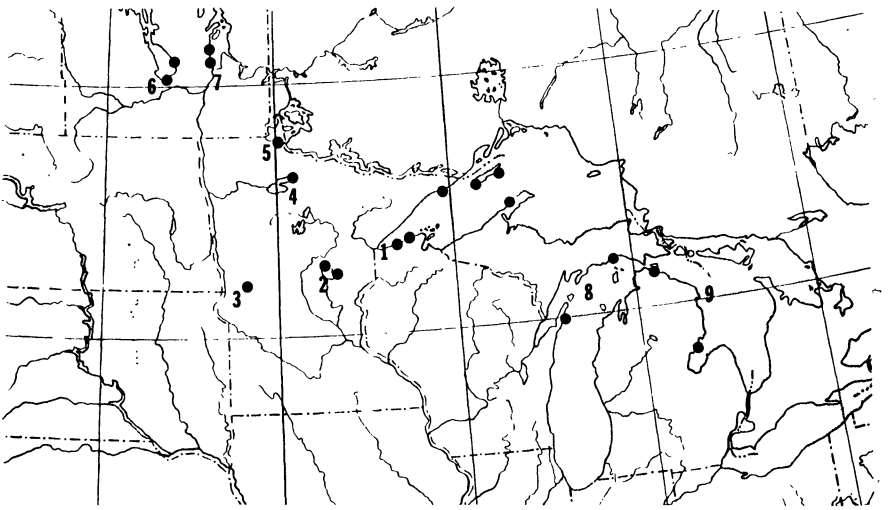

Fig. 1.—Lakeshore sites at which lady beetle aggregations were observed or from which samples were received: (1) Park Point, Lake Superior; (2) Mille Lacs L.; (3) Pelican L.; (4) Upper Red L.; (5) L. of the Woods; (6) L. Manitoba; (7) L. Winnipeg; (8) L. Michigan, and (9) L. Huron

inhabitable overwintering site.

Survival in water.—Single individuals of *Hippodamia convergens* were able to survive an average of 10.6 days on the surface of still water (Table 3). Male and female survival times were similar.

Female reproductive activity.—*Hippodamia convergens* females from spring and autumn shore aggregations and overwintering aggregations were reproductively inactive as compared to females collected from cornfields in the summer (Table 4). These results contrast with the data obtained for *H. tredecimpunctata* in which 51.4% of the females from spring shore aggregations were reproductively active, as were those from summer and autumn shore samples.

Fat content.—In both *Hippodamia* species, fat content was highest in individuals from overwintering aggregations and lowest for those from spring shore aggregations (Table 5). Autumn shore aggregations were composed mainly of individuals with high fat content, although in a small proportion of the population large fat deposits were conspicuously absent. Females in this portion of the population often had well-developed reproductive structures, but lacked developing eggs. This condition suggests that these individuals had reproduced, but that without fat stores would be unable to survive the winter.

TABLE 2.—Summary of coccinellids collected from shore aggregations at Mille Lacs Lake and at Park Point on Lake Superior

	Mille Lacs Lake		Park Point	
	Spring	Autumn	Spring	Autumn
Adalia bipunctata (L.)	X	X		X
Anatis labiculata (Say)	X		X	X
A. mali (Say)	X		X	X
Anisosticta bitriangularis (Say)	X		X	
Brumoides septentrionis (Weise)	X		X	X
Calvia quatuorodecimguttata (L.)	X			
Chilocorus stigma (Say)	X		X	
Coccidula lepida LeConte	X			
Coccinella novemnotata Herbst				X
C. transversoguttata Brown	X	X		X
Coleomegilla maculata lengi (Timberlake)	X	X	X	X
Cycloneda munda (Say)		X		X
Hippodamia convergens Guerin	X	X	X	X
H. parenthesis (Say)	X	X	X	X
H. tredecimpunctata (Say)	X	X	X	X
Hysperaspis disconotata Muls.	X		X	
H. undulata (Say)	X		X	X
Hysperaspis sp.	X		X	
Macronaemia episcopalis (Kirby)	X		X	
Mulsantina hudsonica Casey	X			
M. picta (Randall)	X			X
Psyllobora vigintimaculata (Say)	X			
Total	20	7	13	13

TABLE 3.—Summary data for the survival of *Hippodamia convergens* in water

	Mean survival (days)	SD $\bar{X}$	Range	Sample size (n)
Female	10.7	1.4	2-15	15
Male	10.5	1.4	2-21	15
Total	10.6	0.8	2-21	30

Parasitism.—Adult coccinellids were commonly observed attached to cocoons of *Perilitus coccinellae* in autumn shore aggregations and during the summer in cornfields. Dissection revealed that the incidence of *P. coccinellae* larvae in *Hippodamia tredecimpunctata* was maintained at relatively constant levels throughout the year (Table 6). In contrast, summer and autumn shore collections of *H. convergens* were parasitized 5-6 times as heavily as those from overwintering or spring shore aggregations. *Hippodamia tredecimpunctata* was more heavily infected with *P. coccinellae* at all times of the year than was *H. convergens.*

Sex ratio.—In *Hippodamia convergens,* the proportion of females in the autumn

TABLE 4.—Mean percent of reproductively active females in samples of *Hippodamia convergens* and *H. tredecimpunctata.* The solid horizontal bar above the table indicates the lack of a significant difference at the 95% level between all means included by the bar as determined by chi-square tests; all other differences between means are significant at the 95% level

A. *Hippodamia convergens*

	Summer	Autumn shore aggregation	Spring shore aggregation	Winter aggregation
Reproductive females (%)	25.0	1.3	0.0	0.0
SD $\overline{X}$	4.8	0.5	—	—
Number of individuals (n)	80	464	26	40
Number of samples	4	24	2	2

B. *Hippodamia tredecimpunctata*

	Spring shore aggregation	Autumn shore aggregation	Summer	Summer at lights	Winter aggregation
Reproductive females (%)	51.4	34.6	27.5	0.0	0.0
SD $\overline{X}$	8.4	9.3	7.1	—	—
Number of individuals (n)	35	26	40	20	24
Number of samples	2	2	2	1	1

TABLE 5.—Mean percent of individuals with high fat content in samples of *Hippodamia convergens* and *H. tredecimpunctata.* Overscoring is described in Table 4

A. *Hippodamia convergens*

	Winter aggregation	Autumn shore aggregation	Summer	Spring shore aggregation
High fat (%)	98.8	86.7	59.4	51.4
SD $\overline{X}$	1.2	1.1	3.9	8.6
Number of individuals (n)	80	924	160	34
Number of samples	2	24	4	2

B. *Hippodamia tredecimpunctata*

	Winter aggregation	Summer at light	Autumn shore aggregation	Summer	Spring shore aggregation
High fat (%)	100.0	100.0	63.6	40.0	4.3
SD $\overline{X}$	—	—	7.3	5.5	2.4
Number of individuals (n)	24	40	44	80	70
Number of samples	1	1	2	2	2

and spring shore aggregations was comparable to that of winter aggregations, but contained significantly more females than summer samples (Table 7). At several shore sites over 70% of the individuals were female. The data for *H. tredecimpunctata* revealed no significant differences among the proportion of females from shore aggregations, winter aggregations, or summer samples.

DISCUSSION

The most striking behavioral characteristic of coccinellids is their formation of overwintering aggregations. Hagen (1962) describes an aggregation of *Hippodamia convergens* from which 600 gal of beetles having 70,000 beetles per gallon were collected. Beetles may remain in these aggregations for extended periods up to 10 months. This long dormancy period, described as an estivo-hibernation for some

TABLE 6.—Incidence of *Perilitus coccinellae* larvae parasitizing *Hippodamia convergens* and *H. tredecimpunctata*. Overscoring is described in Table 4

A. *Hippodamia convergens*

	Summer	Autumn shore aggregation	Winter aggregation	Spring shore aggregation
Infected (%)	18.8	18.3	3.8	2.7
SD $\overline{X}$	3.1	1.3	2.1	2.7
Number of individuals (n)	160	924	80	37
Number of samples	4	24	2	2

B. *Hippodamia tredecimpunctata*

	Spring shore aggregation	Winter aggregation	Summer	Autumn shore aggregation	Summer at lights
Infected (%)	34.3	33.3	31.3	25.0	22.5
SD $\overline{X}$	5.7	9.6	5.2	6.5	6.6
Number of individuals (n)	70	24	80	44	40
Number of samples	2	1	2	2	1

TABLE 7.—Mean percent of females in samples of *Hippodamia convergens* and *H. tredecimpunctata*. Overscoring is described in Table 4

A. *Hippodamia convergens*

	Autumn shore aggregation	Spring shore aggregation	Winter aggregation	Summer
Female (%)	57.3	56.5	54.3	48.4
SD $\overline{X}$	0.6	1.9	1.5	2.2
Number of individuals (n)	6263	701	1176	510
Number of samples	35	5	3	5

B. *Hippodamia tredecimpunctata*

	Spring shore aggregation	Autumn shore aggregation	Summer	Winter aggregation	Summer at lights
Female (%)	59.8	51.0	50.3	45.8	46.3
SD $\overline{X}$	2.2	3.5	2.8	10.2	3.5
Number of individuals (n)	513	202	324	24	205
Number of samples	5	2	4	1	1

species, is believed to synchronize the reproductive and feeding stages of the beetles with their aphid food supply (Hodek, 1973). Physiologically, beetles from overwintering aggregations are characterized by the presence of a well-developed fat body, a reduction in the size of the empty midgut as compared to actively feeding individuals, and a lack of ovigenesis (Hodek, 1973; McMullen, 1967).

Hippodamia convergens and *H. tredecimpunctata* from autumn shore aggregations share a number of characteristics with ones collected from winter aggregations. The highest levels of fat are found in beetles from these two groups. An empty and reduced gut and a lack of ovigenesis are additional shared traits. Aggregation formation is another prominent behavioral characteristic of both autumn shore and overwintering coccinellids.

Similarly, beetles from spring shore aggregations exhibit traits typical of individuals that have recently emerged from winter dormancy. In this study the spring beetles have a lowered fat content, as would be expected for beetles that had recently emerged from overwintering. The extremely low fat content of *Hippodamia tredecimpunctata* in early spring aggregations corresponds to the high reproductive activity of females at this time. Since no aphids were available prior to these early May collections, these data suggest that the fat reserves were used for egg production. High levels of fat for some individuals from summer collections may indicate that a portion of the adult population was produced that summer and was building up fat for overwintering.

Both shore and overwintering aggregations of *Hippodamia convergens* appear to have more females than those from summer breeding and feeding populations. These results suggest no differential mortality between the sexes through the winter (Table 7). Several other workers have reported more females in overwintering aggregations of *Coccinella 10-punctata* L. (Marriner, 1939) and *Coleomegilla maculata* (Parker *et al.*, 1977) and in summer samples of six additional coccinellids (Smith, 1966). Smith also reported a sample of *H. convergens* containing only 37.5% females from the shore of Lake Ontario in September. Although these data conflict with the results of this study, his sample consisted of only 35 individuals. A skew in the sex ratio favoring females appears to be another characteristic of overwintering aggregations of *H. convergens* shared by beetles in shore aggregations.

The flight of *Hippodamia tredecimpunctata* observed on 14 July 1977 appears to have been individuals en route to a site for estivo-hibernation. These beetles contained high levels of fat and had empty digestive tracts. The lack of reproductive activity was indicated by the absence of developing eggs or the presence of hypertrophied reproductive organs, commonly found in females which had laid eggs earlier that summer. Apparently, these lady beetles had emerged earlier that summer and were moving to a site for estivo-hibernation without reproducing during their 1st summer. Since high reproductive activity was observed in spring shore aggregations for *H. tredecimpunctata* (Table 4), it appears that this species begins reproduction earlier than *H. convergens*.

The overwintering habits of *Hippodamia convergens* in the Upper Midwest are unknown except for the reports of Hodson (1937) and Latta (1928). Both workers observed aggregations of less than 150 individuals beneath loose bark and in the open crevice of a fence post. No overwintering aggregations were located in this study. A brief summary of Hagen's work (1962) with this species in California is presented as a basis for discussion of the significance of his work to the data obtained in this study. In the Central Valley of northern California, *Hippodamia convergens* is univoltine, with feeding and reproduction occurring February through May or June. The emerging adults are carried by prevailing westerly winds during their migration of 50-100 miles to the Sierra Nevada Mountains where overwintering aggregations are formed. In February or March the beetles remigrate to the valleys

carried by northerly or easterly winds. Occasionally the returning beetles are carried beyond the Central Valley or from coastal mountain aggregations and are deposited in the Pacific Ocean, as evidenced by their dead bodies washed ashore on the beaches.

A number of characteristics associated with the shore aggregation phenomenon are consistent with the hypothesis that *Hippodamia convergens* undergoes an autumn and spring migration similar to the one observed by Hagen (1962) in California. In the Upper Midwest, *H. convergens* is commonly found feeding and reproducing in agricultural fields during the months of June, July and early August, while shore aggregations most commonly occur before or after this period. The high fat content, empty digestive tracts and reproductive inactivity of beetles from autumn shore aggregations are characteristics typical of individuals en route to overwintering sites. The lowered fat levels and increased reproductive activity in spring shore beetles are traits which would be expected for coccinellids emerging from overwintering sites. Even though *H. convergens* is carried by prevailing winds, Hagen (1962) points out that the autumn flights result in strongly directional migration, while spring movements are less directed, resembling simple dispersal. Autumn shore aggregations of *H. convergens* are much larger than those occurring in the spring. These observations are in accord with mass directional movements in the autumn and a less directional spring dispersal.

A number of factors suggest that lady beetles are washed ashore after falling into the water during their autumn and spring flights. Park Point extends along an NW-SE line bordering the Duluth harbor. The prevailing winds are from the E in May and from the W and NW in September, October and November (Anon., 1977). During a study of water movements in western Lake Superior, Ruschmeyer and Olson (1958) found that drift bottles released on a line between Two Harbors, Minnesota, and Port Wing, Wisconsin, were commonly washed ashore on Park Point. Thus, both the wind and water currents tend to move floating beetles onto Park Point.

Several other observations are consistent with this interpretation. First, on several occasions autumn shore aggregations were observed on Park Point, but not along the shore N of Duluth at the mouth of the Lester River and at Two Harbors. If lady beetles were actively selecting the shore, one might expect to find them on both sides of Park Point; however, during the course of this study no aggregations were observed on the harbor side of Park Point. The coccinellids that were observed floating among a wide fringe of ice fragments on Mille Lacs Lake had presumably been deposited by the action of wind and waves. Beetles in shore aggregations sometimes had dark elytral markings similar to ones experimentally held in water. Finally, the fact that *Hippodamia convergens* was able to survive for an average of 10.6 days on the surface of water (Table 3) suggests that the beetles could tolerate short periods of floating on lakes.

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