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Observations on the Ecology of Water Striders

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OBSERVATIONS ON THE ECOLOGY OF WATER STRIDERS

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OBSERVATIONS ON THE ECOLOGY OF WATER STRIDERS.

I. Introduction.

The present paper treats of some of the general ecological relations of water striders. The species that were studied are *Gerris remigis* Say and *Gerris marginatus* Say. The observations recorded are not only with reference to the water striders themselves, but also with reference to the physical conditions of the environment to which the animals respond as they exist near Urbana, Muncie, and White Heath, Illinois.

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II. Running Water Habitats.

In the discussion of aquatic habitats, it is obvious that some definite scheme of grouping is useful. It assists in the comparison of one sort of habitat with that of another, and it also helps to avoid confusion. Therefore in our
consideration of water strider habitats we shall speak of the ravine-brook-creek-river series, as these represent stages in the ideal development of the stream environment. The evolution of the environment toward permanent stream conditions will be traced through as many stages as are found in this vicinity. The physical conditions that seem to be necessary for the existence of water striders will be pointed out, and attention will be directed to the earliest appearance of the water striders in the developing stream series.

1. Ravines. The ravine is the earliest stage in the development of the stream environment. Good examples are found near Urbana, Muncie, and White Heath. These ravines are found on both steep and gentle slopes. About 2 km. northeast of Urbana are many ravines, in various stages of development, on the steep sides of a deep gravel pit. In this locality the soil is a sandy clay and is easily eroded by the rains; frost and wind are also agents which aid in this degradation to some extent. The ravines in the earlier stages of formation are shallow, being but 60 cm. — 1 m. deep, and they have cut back from the gravel pit a few meters only. Others, in later stages of development, have eroded channels, in some instances, to a depth of 4 m. or more, and they extend back from the gravel pit for a distance of about 85 m. In the younger ravines the banks are steep, while in the older ones, they tend to have a somewhat more gradual slope.

Such ravines owe their existence chiefly to heavy rain storms. During a severe downpour a considerable volume of water rushes down the larger ravines. The slope being so steep, this surface water quickly passes off after the storm
ceases. At such times the process of erosion is much in evidence, and the ravines are cut back rapidly. These ravines have no connection with permanent water bodies. The water that flows down their channels passes into the gravel pit. In many of them, holes are formed, which are due to the combined agency of the current and the grinding process of the coarser debris. In such places pools of water frequently linger for several days after a rain, and make possible temporary habitats for water striders.

It has been mentioned that the ravine represents a very early stage of development in a stream habitat. Running water is present during rains only, and is therefore a temporary condition. Pools exist for a short time after the rain is over. The ravines described are not connected with permanent streams, therefore *Gerris remigis*, which is a wingless form, cannot reach such pools. *Gerris marginatus*, being a winged form, can readily migrate to such a location. It is possible for it to live there just so long as the conditions - water and food - remain favorable.

From evidence that will be discussed later, the writer believes that *Gerris marginatus* would be found occasionally in the temporary pools of the larger ravines, if it were not for the meager food supply. The sandy clay banks of the gravel pit are bare of vegetation, and there is little insect life that would be likely to form floating food for water striders. *G. marginatus* is found in considerable

1. The writer has found two winged specimens during a year of collecting.
numbers not more than 150, distant from the gravel pit, and G. remigis is also occasionally taken. However, neither species have been observed in any of these ravines connected with the gravel pit, although these pools have been examined after rains.

About 1.5 km. north-east of Muncie, there are high clay bluffs on the north bank of Stony Creek. The general physiographic conditions closely resemble those described at the gravel pit near Urbana. Here are also seen the initial stages of stream development. There are ravines which have been cut by the erosion of rains, much in the same way as in the gravel bank already described. Some of these have reached a depth of 1.5 m., with a total length approximately of 50 m. The bluffs are perhaps 17 m. or more in height and very steep. The water from the ravines flows directly into Stony Creek.

The eastern portion of the bluffs is devoid of vegetation, but at the top, and extending back from the creek is an abundance of grass and common meadow plants. In this vegetational zone erosion is not taking place so rapidly. The ravines are not of sufficient depth to form anything more than the smallest and most temporary pools. Farther east the bluffs are higher, but not so steep, receding from the creek more gradually. Here the ravines are of somewhat greater length, and small temporary pools are sometimes formed. There is considerable vegetation on the face of this slope, consisting of forest trees, bushes, and herbaceous plants. In both situations where vegetation is found there is considerable insect life.

None of the ravines have really progressed far enough in stages of stream development to form suitable water strider
habitats, although on one occasion a stray *Gerris marginatus* was found about 6 m. from the edge of the creek on the less steep slope farther to the west, in one of the larger ravine pools. These pools in the ravines are too small and of too temporary a character, and the streams are too swift, existing during rains only. However, there is a plentiful food supply, and this would be in favor of the water striders; but with the one exception, the writer has not observed water striders in any of these situations.

However, it is not difficult to predict, with a considerable degree of accuracy, the changes that will result from the continued process of erosion. These ravines will have so far developed toward the permanent stream stage that their channels will be much deeper and broader. They will retain more of the surface water and for a longer period of time, as their courses will be less steep. In the course of years they will have cut deep enough to receive ground water through seepage. Such a stage of development will tend to make these ravines more favorable habitats for water striders, as there will be a larger amount of water present, and it will be more permanent. There are several small streams, of more or less permanence, emptying into Stony Creek, in this immediate vicinity, which have already passed through such stages as have been described. This is inferred from the general contour of the region. One of them is so far developed toward the stage of permanent stream habitat that specimens of *Gerris marginatus* are frequently found on its surface.

About 1.5 km. north west of White Heath, on the banks of the Sangamon River, again are found the active, early stages
of stream development. Ravines from 60 cm. to 1.5 m. in depth have been formed. These are constantly being deepened and cut back from the banks of the river by the process of erosion. The beds of the ravines are steep at the points where they connect with the river. Here, cutting goes on rapidly, as the water rushes down the slope with considerable velocity.

Certain environmental conditions are to be noticed here as contrasted with those described at Urbana and Muncie. Small pools of water are frequently found lingering in the deeper ravines after the rains. The soil is not so sandy, being black, and there is also more shade; therefore these temporary pools do not evaporate so quickly. Vegetation in the form of forest trees, bushes, herbs, and grasses is abundant. The presence of this vegetation is a condition much more favorable to insect life. Frequently, there are considerable numbers of insects found floating on the surface of the pools, which fall from the trees and bushes, and are also blown into the water by the wind from the herbs and grasses.

At White Heath, then, it may be said that the ravine conditions are more favorable as temporary water strider habitats than any of those thus far described. Occasionally, specimens of Gerris marginatus are observed in these ravine pools, but they are very few in number, usually pairs and single individuals. They are probably migratory stragglers. No specimens of Gerris remigis have been found in such situations.

Notwithstanding the fact that Gerris marginatus is occasionally found in the temporary pools of ravines, in general it may be stated that this ravine stage of stream development seems to be a little too early for the formation of habitats.
entirely favorable to water striders. Although in some instances the food supply is abundant, yet the water supply is too meager and intermittent to form permanent habitats for these insects.

2. Springs. Many small springs issue from the foot of the steep banks along the Sangamon River, near White Heath. Some of them are found near the water's edge, while others may be 3 - 7 m. away. The region is forested and has a black soil. In this sort of environment there is probably much less evaporation than is the case in a more open situation, as for example on the bare clay bluffs at Muncie that have already been described. Transeau (1906, p. 231) has shown that the amount of evaporation occurring in a forest ravine is about six times less than in an open situation. Some of these springs are permanent and this is due in part to the lessened evaporation.

A number of these springs, where they bubble out of the ground, erode bowl-like depressions that form small permanent pools. The water, in the form of miniature streams often less than an inch deep, trickles down to the river. Gerris marginatus is occasionally found in such situations. The water, although small in amount, is relatively permanent. The region being covered with forest trees and smaller vegetation, there is abundant food, in the form of floating insects, for water striders.

Small springs are found in some ravines that have been cut down to ground water level, primarily by the run off. Springs in such situations also assist in the ravine erosion, so they are a factor in the process of development toward
permanent stream conditions. Such springs often form little pools in which *Gerris marginatus* is sometimes found.

Springs are also found on the timbered banks of Stony Creek, near Muncie. Many of these springs are found where the banks have a more gradual slope than is the case at White Heath. Some of them are found about 8 m. from the margin of the creek, and are of a permanent character. They trickle down the side of the bank into Stony Creek. Occasionally small pools are formed along the course of such miniature streams. Infrequently *Gerris marginatus* is found in these pools.

Bueno (1910, pp. 177, 179, 181) refers to a related form, *Microvelia americana* Uhler, being found in similar situations.

Some of these springs at White Heath and Muncie illustrate a somewhat more advanced stage in the process of development of water strider stream habitats than do ravines. This is true in regard to ravine springs, and some of those flowing down gradually sloping banks, for it has been stated that these springs are permanent. Springs may or may not evolve into permanent streams. In regard to the suitableness of such springs as water strider habitats compared with ravines, it may be stated that the food supply is moderately abundant, and the water supply, while small in amount, in many instances is relatively permanent. *Gerris remipennis* has not been observed in such situations, but *Gerris marginatus* is occasionally found there. While water striders, then, are very few in numbers, yet they are taken more often than in ravines.

3. Small Temporary Streams. Small streams or brooks are frequently of a more or less temporary nature. They represent a stage in the history of the development of the
permanent stream environment that is considerably more advanced than either of those already described. There are several such streams in the vicinity of Urbana, Muncie, and White Heath. As these streams are very similar in character, two only will be discussed, one near Urbana, and the other near Muncie. These two are of somewhat different types, so that a comparison will be of interest.

The stream near Urbana is located about 1 km. north east of that place, and flows in a general northwesterly direction. It receives some sewage, but the water is usually clear. The brook has a muddy bottom, with vegetation growing along its margin. In width it varies from about 60 cm. — 1.5 m., with a depth seldom more than 10 cm., and frequently less than this. The current is sluggish in many places, while in others it runs somewhat more rapidly. However, in general it would be said that the current is slow. It will be noticed later that such a habitat is quite different from that inhabited by Gerris remigis, and this form has not been found anywhere on the brook. Then further, this form is an apterous one, and so could not reach such a location, for the stream is not connected with any other water body on which G. remigis is found. Specimens of Gerris marginatus have frequently been taken on its surface. They are often found congregated in small groups on the water film; and again they are found along the margin, among the aquatic plants. A number of these forms were captured there this spring during the months of April and May.

Near Muncie there is another of these small temporary brooks. The stream flows in a northerly direction. The water is clear, and the bottom sandy. It is seldom more than
50 cm. in width, and 3 - 6 cm. in depth. The vegetation along its banks is composed chiefly of grasses. While the stream flows near Stony Creek, already mentioned, it has no connection with it, but loses itself in a small swamp. There is an abundance of food Duplino, but no specimens of Gerris remigis have been taken from this brook, but a few Gerris marginatus have been found at rare intervals. There are several reasons, perhaps, why G. marginatus is not found there in greater numbers. In the first place the stream is small, and being isolated, is not easily found. Then there are a number of more favorable water strider habitats in the immediate vicinity. G. remigis being a wingless form could not reach such a location. Both streams frequently become dry during the summer months, so that they are but temporary habitats at the best.

a. Tile-drains and Temporary Streams. Some of the temporary streams in this vicinity are due largely to the water that comes from tile-drains. Such streams originate at the points where the tile emerge from the ground. The discussion will be limited to two examples of these temporary streams, each possessing its own peculiarities. One of these is located near Muncie, and the other in the neighborhood of White Heath.

The first stream to be considered is found approximately 600 m. north west of Muncie. It empties into Stony Creek near the foot of the east end of the clay bluffs that have been mentioned in another connection. With reference to the development of the water strider permanent stream habitat, this stream represents a somewhat later stage than that discussed in the previous section, and a much later stage than is represented in the initial formation of ravines. From the general contour
of the region, it is evident that the bluffs formerly extended much farther to the east and south, following the course of Stony Creek. This stream that we are considering has evidently cut its way down through the former bluffs at some earlier period. It is fed by three smaller tributaries near its head. Nearer its mouth lateral ravines carry the run off into its channel. It contains running water during the greater portion of the year, and during the periods of greatest rainfall it forms a not inconsiderable stream. At such times it has an average width of about 1 m.; near its mouth it is somewhat wider, and varies from 6 - 40 cm. in depth. The water is clear and contains abundant food for water striders. There is much vegetation in the water and along the banks. There is considerable gravel and silt in the bed of the stream. Near its mouth its channel is cut down to the sandstone. There are alternating pools and rapids along its course. No specimens of *Gerris remigis* have been taken from this stream so far as the writer is aware. It possesses all the physical conditions necessary for a suitable habitat for this form except one. It becomes entirely dry during the drier weeks of midsummer, not even a pool remaining. Last summer the writer walked along the entire length of the stream without finding a drop of water. It is true that *G. remigis* could migrate downstream into Stony Creek if it did not become trapped in one of the temporary pools. However, this species does not appear to go down stream, because it responds against the current. *Gerris marginatus* has been frequently found on this stream. This spring the writer obtained a number of these forms from its surface. The presence of water striders in situations of this character
furnishes evidence that, as soon as the ravine gives way to a stage in stream development when the presence of water is a condition of more or less permanence, this species is likely to be among the first to invade such a habitat.

The second stream that will be considered is located about 1.5 km. north of White Heath. It differs considerably from the one just described. In the first place its bed has been artificially lowered for drainage purposes. Its sides are steeper and more abrupt than is the case of the stream at Muncie. There is some aquatic vegetation, chiefly grasses, growing in the water along its margin, and willows are found on its banks. The water is unusually clear, with a sluggish current, but at low water there is practically none, and the bottom is of mud. The stream varies in depth from about 30 cm. at its upper end to approximately 60 cm. at its lower end. It is readily seen from the description that this is not a typical habitat for Gerris remigis, and no examples of this species have been observed on its surface. The fact that it often becomes dry in the summer is a condition that is unfavorable to a wingless form like G. remigis. However, Gerris marginatus is usually found here in considerable numbers. There is generally sufficient food for these forms, and the physical conditions, such as quiet water, is well adapted to this species of strider.

Gerris marginatus is usually found here the greater part of the year, but it is much more in evidence during the spring than it is later in the year. During periods of flood these forms are more plentiful than they are during drier times. The stream lies to the east of the Sangamon River, between it and the river is a large ox-bow pond. This is connected with
the stream under discussion, which in turn is connected with
the Sangamon River, by means of a permanent brook, and this
connection with the brook is near the latter’s confluence with
the river. During high water in the spring the brook often
overflows its banks near its mouth. This is partially due
to the backing up of the river water into the channel of the
brook. A considerable volume of this overflow water passes
into the ox-bow pond, already mentioned, and as this increases
in size, it in turn backs up into the temporary stream under dis-
cussion. At such times the stream overflows its banks so that
its course can hardly be distinguished except for the current
and the willows along its banks. The writer has taken
G. marginatus at such times in large numbers. During the
spring of 1912 such conditions existed on several occasions.
So extensive was the overflow that several acres of ground, on
each side of the stream, was under water. An environment of
this sort seems to be especially well adapted to G. marginatus,
for they were found here in great abundance. They were actively
engaged in feeding and breeding. As the water withdraws into
its accustomed channel, these forms seem to decrease in numbers.
After the overflow has receded entirely within the banks of the
stream, while G. marginatus are still observed on its surface,
they are not present in such large numbers as during the height
of the flood.

4. Permanent Brooks. In this vicinity brooks of medium
size, with clear water, a current of moderate velocity, and a
bed of silt, sand, gravel, and rock, appear to present the most
desirable condition for Gerris remigis Say. There is usually
a succession of rapids and pools in streams of this nature.
Such brooks frequently have high overhanging banks, due to erosion by the current. The brook which was studied most carefully has its confluence with the Sangamon River at a point about 1 km. north east of White Heath and is of this general type. It is a meandering stream from 1 - 3 m. in width, with a flood plain approximately 100 m. wide at certain places along its course; frequently it is narrower than this. From a point about three quarters of a mile from its mouth the stream flows through or along the borders of a forest region. Further up stream, as far as observations have been made, there are willows, herbaceous plants, and grasses growing along its banks. Throughout this area food is abundant. The stream flows in a general northwesterly direction. Such a brook presents the optimum (Figure 1) stream condition for *Gerris remiges*. Observations were made from the mouth to a point about two miles up stream.

Water striders do not belong to the "social insects", such as ants, and bees, yet they are often found congregated. As many as fifty have been counted in one gathering, but that is a larger number than is usually present in one place. Generally the groups do not average more than six or eight Gerrids. Very frequently they are found in small aggregations of two and three or more individuals. Sometimes solitary specimens are observed on the look out for drifting food material. My records indicate that the groups tend to be smaller in the spring than in the autumn. These groups of water striders are not formed on any or all parts of the brook, are not they formed in a haphazard fashion. Observations disclose
that the Gerrids gather at definite localized places on the surface film, and that there is a cause for such gatherings.

Certain definite processes of change are taking place on both banks of the brook as it curves and winds about in its course. At every bend the strong current is deflected from the center of the channel against the outer bank which is continually being eroded more or less rapidly. The inner bank is being built up by the deposit of debris brought down by the stream. The water striders gather at the foot of these eroded outer banks, where the current is swifter than it is near the other shore. At such places the banks are frequently high (Figure 2) and overhang the water. As one follows along the course of the brook, it is possible to predict with a reasonable degree of certainty where the insects will be congregated. Seldom, indeed, is it that one is not confronted by a group of the creatures at such a bend of the brook. It is the stronger current that brings them to such places. They respond with considerable precision to the current. They feed very largely upon drifting insects that are transported by the current, and as this current is stronger near the outer bank, the food is conveyed to that side of the stream. Therefore the responses of the water striders to food and current explain why they are found congregated in the situation mentioned.

It has been stated that a brook of this character represents optimum conditions for Gerris remigis, but this does not necessarily preclude Gerris marginatus. From the evidence thus far presented, it appears that the latter form is found in a number of different situations. It has been observed on running water and on still water. It is found in this brook,
but in relatively few numbers. Its haunts are somewhat similar to those of G. remigis, being found near overhanging banks, but out of the current in quiet water. It also frequents the low shelving shores of the brook, where there is aquatic vegetation. Occasionally it is seen on the open water, but if disturbed it darts back among the marginal vegetation. Frequently it has been observed copulating and feeding in such situations. G. marginatus has been taken from the surface further down the stream and near its mouth, where there are several long reaches of deeper, quieter water. In these places it is sometimes found to be relatively abundant. It is certainly found in greater numbers than anywhere else on the brook. The two species of water striders are not found together. The writer has never observed both forms in the same group on the surface film. They appear to keep apart.

a. Behavior During Flood Conditions. High water is an environmental condition with which water striders have to contend at more or less frequent intervals. Unless they possess certain phases of behavior which are adapted to such conditions, they are likely to be carried down stream by the current into larger streams and so away from their optimum habitat. Although this would not necessarily be a process fatal to them, yet it would be a means of depopulating the brook. During any unusual disturbance of the water surface in the vicinity of their haunts, the water striders seek protection near the shore. Here they find quiet water and sheltered inlets often bordering upon steep overhanging banks. Large moving bodies, shadows, or prolonged agitation of the water film, will cause
them to go to such locations. Sometimes they seek the protection of the bank and still water, at other times they dart to those regions along the shore where there is aquatic vegetation. Their anterior pair of legs are well adapted for grasping purposes, as indicated by the manner in which the males seize the females during copulation, and in the manner in which all the Gerrids, so far as observed, seize their food. When they come in contact with the aquatic vegetation, their thigmotacti responses are invoked and the animals grasp the stem or leaf of the plant and remain firmly in contact with it. Such responses have frequently been observed, in fact they are among their commonest forms of behavior. Responses of this nature are adaptive, and are especially in evidence during high water.

On a number of occasions the writer has visited the brook at White Heath during periods of high water after several days of heavy rains. At such times it is a very unusual occurrence to observe a water strider anywhere on the open water. Until their habits were better understood, it was a somewhat puzzling matter to know what had become of them. After walking along the bank of the brook for approximately 500 m. and not seeing a solitary Gerrid, the idea suggested itself that possibly they had been carried down stream by the flood of water, although such a result seemed contrary to their usual responses. Anyone who has carefully watched specimens of Gerris remigis striding vigorously along the surface film against a strong current, or seen them ascend the face of a miniature water fall, assents to such an idea only with reluctance. A further detailed search among the aquatic vegetation disclosed their
whereabouts. They were found clinging tightly to grasses and sedges along the margin of the stream. Twenty individuals were discovered in such locations in a distance of less than 10 m. Their dark brown color is so much like that of the water during flood time, that when the stream is turbid and the day cloudy, it is very difficult to see them against the dark background of the current. At such times one frequently is compelled to lie flat on the bank so that the eye can glance along the water surface, in order to locate them in their concealed situations. Even during flood times there are places close against the overhanging banks where there are a few centimeters of quiet water, and Gerris remigis has been found in such locations.

If in time of flood the water surface is agitated with a stick or some similar object in the close vicinity of a water strider that is clasping a clump of grasses, frequently it is found that the animal, instead of leaving its position and striding onto the open water for safety, clings more tightly to its support. Sometimes it is possible to dislodge one, and such a specimen does not usually leave the protection of the shore, but "strides" over the surface film a short distance to other vegetation near by. Then again, water striders have occasionally been observed, both during high water and low water, on the surface of the swift current, and they are able to make headway against it. It is not unusual to see them clasping a leaf or stem of aquatic vegetation as it swings back and forth above the swift water, and so tenacious are

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1. It is an unusual thing to observe Gerris remigis far from shore on the surface of the current, when the brook flood is at its height.
their thigmotactic proclivities that the current is unable to dislodge them. Such responses are undoubtedly protective. It has been stated that specimens of *Gerris remigis* frequently have been found clinging tightly to vegetation during periods of high water. They may remain in such situations for several days; that they do so for many hours has been observed. As the water subsides, and the current becomes reduced both in volume and velocity, their thigmotactic responses seem to be reduced in intensity, for they are seen "striding" here and there on the water. Sometimes the brook overflows its banks in certain places, and the old cut offs and former channels are filled with water. After the flood recedes, pools remain in such situations in the form of small temporary ox-bow ponds. The writer has found *Gerris remigis* in such situations, and they have frequently been examined. At seasons of high water the brook may overflow near its mouth, this being due partially to the backing up of the river water, and partially to the overflow of the brook. In this manner the writer has seen many acres of land along the Sangamon River bottoms covered with water. If specimens of *Gerris remigis* are carried down stream during times of flood they would be found here in large numbers. The writer has walked along the margin of such temporary lakes for hundreds of meters, and has never observed a single individual of this species. He has also waded into the water, and searched carefully for many hours among the weeds and in the small inlets without success.

The observations already recorded appear to indicate that *Gerris remigis* remain near the margin of the water, usually clinging to some support, and advances or retreats with
the advancing or retreating flood. All the evidence so far produced seems to point to the fact that this form is not carried down stream out of its optimum during periods of high water to any very marked degree. Its general behavior adapts it to such conditions, and seems to be protective and beneficial.

b. Drought Conditions. Usually, during all seasons of the year a brook like the one at White Heath has a permanent supply of water. Even during the summer months, although the water supply diminishes to some extent, yet the stream retains its permanent character, but is much reduced in size. If the season should be very dry, a series of rather large pools is formed. They may vary in size, from 2 - 7 m. in length, and from 3 to 7 m. in width, with a varying depth of from 14 - 70 cm. The pools are connected by narrow and very shallow streams of water.

During such periods as these it is only with considerable difficulty that Gerris remigis is able to pass from one pool to another. However, this occasionally occurs as the writer observed during the summer of 1911, but he is inclined to believe that it is a somewhat rare proceeding. Thus the pools may be considered to form a succession of traps in which the water striders are confined. However, it is of no particular disadvantage to them, so far as the writer has been able to observe. They do not suffer for lack of food, although in some instances there may be some reduction in the total amount. But in other cases there may be a considerable concentration and even an actual increase in the food supply, for when the brook is in its normal condition, there is a considerable amount of drifting food material carried down stream past the
haunts of the water striders. Much insect food falls into the pools from the trees and vegetation along the banks of the brook. The winds also brings food to the water striders in these partially isolated water bodies. Then the small stream, connecting the various pools, carries some drifting food material from one to another.

If the water in these pools should become so stagnant that a heavy scum formed in the surface, it might result in the death of the water striders. But such a misfortune is averted by the stream flow. Small in volume as it is, yet it is sufficient to keep the pools clear and fresh, and the water in them slightly agitated.

c. Behavior During Conditions of Severe Drought.
There are occasional seasons when the water volume of the brook shrinks even more than has been stated. A very severe and extended drought occurred in this vicinity in the summer of 1911, and many streams, usually considered relatively permanent in character, were found to be absolutely dry. In the late summer, during the month of August, the water in the brook at White Heath was observed to be drying up so that it consisted of isolated pools only, and many of these were rather small. The conditions are evidenced when it is stated that the writer was able in many places to walk along the dry bed of the stream. In other parts the materials forming the bed of the brook were damp, especially in the vicinity of the pools, this being partially due to the water of small springs that trickled in from the banks and partially to the seepage from the pools themselves. But there was absolutely no stream as such remaining. The water striders were found to be congregated
in the pools. A few of the animals were found to be trapped in shallow pools of small surface area. As *Gerris remigis* is a wingless form it cannot fly to some other body of water, and serious results may accrue to the individuals isolated in such situations when the pools dry up. If the small pools should become dry, the water striders would be exterminated unless there is water in the immediate vicinity, as their means of migration is limited mainly at least to that on a water surface. However, as will be demonstrated later, it is difficult for them to find another pool of water even should it be close at hand.

There are no records, of which the writer is aware, that describe actual observations of the responses of the *Gerris remigis* during the late stages of the evaporation of its own habitat, or that describe its reactions after the water has actually disappeared. Fortunately he has been able to secure some data with reference to these points. While the information is neither so extensive nor so detailed as he would wish it to be, light is thrown on certain phases. The question as to what becomes of the water striders from an evaporated pool is certainly an interesting one. Some weeks later than the time already recorded, the writer visited the brook at White Heath. During this excursion he found a small pool that indicated rapid extinction unless precipitation occurred in the next few days. The approximate dimensions of the pool, at this time, were 1.5 m. in length, 60 cm. wide, with a depth varying from 1 cm. at the margin to 4 or 5 cm. in the deeper portions. As there were ten specimens of *G. remigis* on the surface of the pool, the writer was interested to see how
they would respond when the water disappeared. Several days later the pool was again examined, and it was found that the water barely covered the surface, and it was very much contracted in surface area, a portion of the bottom of the up stream end of the pool consisting of a muddy silt was already exposed. This was about 9:00 a.m., and it was evident that the water would all be evaporated before evening. The atmosphere was very dry and had been so for several days previously, and evaporation was taking place rapidly. On counting the water striders, it was possible to find eight only, and although a most careful search was made, the two other specimens could not be located. The writer spent the greater portion of the day at this pool. During this entire period, contrary to expectation he observed no behavior on the part of the water striders that indicated an attempt to escape from their extremely unfavorable surroundings. As the water became more and more reduced in size, they tended to confine their movements toward the center of the remaining water surface. There was a scum on the surface of the pool, and this impeded their movements in some degree. The high temperature of the water may have been a factor which modified their behavior. The maximum temperature for a number of days reached 90 degrees Fahrenheit. It is improbable that there was more than a few degrees difference in the temperature of the water and the air; the water felt hot to the hand. The high temperature may have so impinged on the animals that some of their usual responses were inhibited. Whatever the cause of causes may be, the bugs were comparatively quiet, occasionally "striding" slowly about on the surface film. The water disappeared
rapidly in the early afternoon, and as the silty bottom became exposed to the sun's rays, the remaining moisture was soon sucked out of it. By 4:30 P. M. there was nothing to indicate the former location of the former pool except an oval area of baked mud with a little damp silt in its center.

The writer was interested to see whether after the water had evaporated in the pool, the water striders would burrow into the mud before it became too dry, or into the banks of the brook, and so remain in a quiescent state - a condition of aestivation - until a period of precipitation occurred. Uhler (1634, p. 268) in describing some of the habits of Gerris regimis, states that these insects hibernate under the banks of streams, or in the mud. According to this same author (loc. cit., p. 275) a related form, Hebrus americanus, also spends the winter months beneath the overhanging banks of small streams. Kellogg (1905, p. 196) says that water striders hibernate in the mud at the bottom of pools. Mc Cook (1907, p. 265) also makes the statement that Hygrotrechus regimis burrows into the mud and remains there during the winter. According to these statements water striders hibernate in the mud or in the banks of streams. Now Tower (1906, p. 245) writes that, "Hibernation and aestivation are fundamentally one and the same process, the term hibernation being applied to the dormant period produced by lowered temperatures, and aestivation to that which follows the coming on of the dry season in the warmer parts of the earth". If it is true that hibernation and aestivation form but one phenomenon, and also true that water striders hibernate in the mud and banks of streams, it was not an unreasonable question to ask whether these striders
would not burrow into the ground and remain there until a period of wet weather should intervene. However, no such responses occurred. For some time it appeared as if the water striders would remain in the same spot, and die as the mud dried up. About 6:30 p.m. they commenced to move away. It is not possible for me to state the nature of the initial stimulus that brought about such a response. First one and then another moved away from the site of the pool. They walk and jump in an ungainly fashion in the dry bed of the stream, but are able to make considerable progress in this manner.

There was a much larger pool approximately 12 m. farther down the bed of the brook, and the writer was on the qui vive to see whether any of the water striders would reach it. It has been stated that there were eight specimens of *Gerris remigis* present. Four of these wandered in an aimless, awkward manner down the dry bed of the stream; two moved up the bed of the brook; and the other specimens walked toward the opposite bank of the stream. It was a task of no small difficulty to watch all the water striders, although they frequently came to rest against obstacles in their pathway. The color of the insects was so similar to their background, that they were very inconspicuous and the writer would frequently lose them. Finally no further move was made to trace the movement of all the individuals, as it was feared that no definite data would be obtained in this manner, and perhaps all the specimens would be lost to sight. The two bugs that wandered up stream remained well in the center of the dry bed, but after they had travelled about 4 m. away from their starting point, no further observations were made with reference to them. The path of the two *Gerrids*
that had moved toward the bank of the stream was traced for some time, but on returning from an observation of those that were going down the stream bed, they were unable to be found. They had disappeared, whether into some hole or crevice, or were simply unable to be located because of the background, it is impossible to say. Attention was now concentrated upon the four specimens that were moving down the bed of the stream. While it is true that they wandered back and forth making many deviations from a straight path with many resting periods, the general direction was toward the large pool already mentioned. When the foremost water strider was approximately 2 m. from the pool one of them came to rest near a large rock, and finally crawled beneath its edge. There were a number of rocks with much gravel and small stones intermingled along the upper margin of the pool. When the other three insects reached this situation, they stumbled along following a path parallel to the ridge formed by this small pile of stream debris, two of them going in one direction, and the third in the opposite direction. The latter specimen, after wandering along this ridge for half the circumference of the pool and had so reached its down stream end, stopped in a depression near a small ridge of gravel. After it had remained in that position for 15 minutes without making any effort to get away, no further attention was paid to it. It should be stated here that Gerris regimis is possessed of strong positive thigmotactic proclivities, and this form of contact response may probably explain why various individuals came to rest against solid bodies. The two remaining Gerrids, after several wandering
movements back and forth, reached the down stream side of the pool, where its margin sloped down to the water. They walked perhaps for 40 cm. along the margin and gradually onto the surface film, after a journey of 12 m. down stream. During the last half of the journey, their movements were very hesitating, and interspersed with periods of rest. Their legs and bodies were well sprinkled with the dust gathered from the dry bed of the brook.

So far as the writer was able to observe, the entire journey of the water striders to the pool was a process consisting of a series of "random movements". The fact that two out of the original eight specimens reached the water, seemed to be nothing more than a matter of "chance". The writer is unable to see any good reason why we should assume that the animals responded to a hydrostatic or direction sense, or to anything of that nature. The whole series of movements, from the time when they left their starting point until they reached the pool of water, seemed to be aimless, without order or precision, and utterly devoid of the adaptableness in response that the exigencies of the case demanded. Kirkaldy (1895, pp. 109 - 110), in writing of Gerris lacustris Linn. under somewhat similar environmental conditions, makes the following statement: "In small wayside pools or streamlets which dry up periodically, it is obvious that the apterous inhabitants will die out unless their habitat is sufficiently near to a larger stream of pond; a severe drought occurring over a fairly large area, prolonged sufficiently to dry up all the water within that area, would cause all the species represented in that year by apterous individuals only to become extinct". The writer is in accord
with Kirkaldy's general statement. Further he seriously doubts, during such periods of drought, whether many water striders would usually be preserved, even if there were permanent water bodies in the immediate vicinity, especially after witnessing the responses of *Gerris remigis* that have been described. *G. remigis* is adapted to the conditions as they generally exist in permanent brooks. Such drought conditions as have been described occur so infrequently that it is not to be expected that this form will display responses which are well adapted to such foreign and unusual environmental changes. If such peculiarly abnormal conditions should occur that the entire aquatic habitat becomes dry, it is improbable that many apterous water striders survive.

5. Creeks. Creeks are streams that represent a stage in development beyond that of the permanent brook. They are usually of considerable size with a large water volume and strong current. Two of these have been studied, from the point of view of water strider habitats, and as they represent different types there is opportunity for some comparison.

The one that will be studied first, has already been mentioned several times, it is found about 800 m. north east of Muncie, and is known as Stony Creek. It flows in a general southeasterly direction. It is a stream of clear water flowing over a bed of silt, gravel, and sandstone rocks, and carries a considerable volume of water. In many places it is from 20 — 25 m. wide and, during normal conditions of precipitation, has a depth varying from about 30 cm. — 1.5 m. From a point near the clay bluffs on its north bank, described in a previous section, for several kilometers down stream, it
flows over a rocky bed. The water is in a constant state of agitation, and while there is some quiet water at the bends of the creek, this region of the stream is not well adapted as a habitat for Gerris remigis. A very few are occasionally taken in these places of quiet waters, but in general it may be said that this portion of the creek is not suitable for them. Throughout this region its banks are forested with considerable underbrush in some parts, along its margin there are a certain amount of herbaceous plants, and in the water some aquatic vegetation. It should be stated that drifting insect food is plentiful. Up stream, 100 m. or so from the bluffs, the current flows more quietly. Near the banks and at the bends of the stream, there is much quiet water. Specimens of G. remigis are frequently taken in these quieter portions of the stream, but never in large numbers, usually pairs and single individuals. It is of interest to note that late last fall a winged form of G. remigis was taken near the bank on the surface of the sluggish water. At the same time two others of the usual apterous form were captured. Frequently G. marginatus is also taken on these quiet portions of the creek. They are often found relatively abundant near the banks in sheltered places copulating and feeding.

In this region there is a branch that enters Stony Creek from the north. This tributary is more like a brook in character. It has many shallow rapids and pools of deeper water. There is abundance of water strider food in the form of floating insects. Gerris remigis is found on the pools in greater numbers than on the larger main stream. There are several old stream channels which fill with water during times
of flood. These form small ox-bow ponds, and at such seasons *Cerri* *marginatus* has been found on them, but *C. remigis* has not been observed in such locations.

a. Drainage-ditch. The second type of creek that we shall consider is found to the north and east of Urbana, and is known locally as the drainage-ditch. It is a much modified creek whose channel has been artificially deepened and straightened for drainage purposes. In the vicinity of Urbana the drainage-ditch flows in an easterly direction. In general it extends along the course of West Branch, which is a tributary of Salt Fork, one of the tributaries of the Vermillion River. The dredging necessary to construct the drainage ditch has resulted in a stream of much different character from the old winding channel of West Branch. In general the banks are somewhat steep and high, and in many situations there is much herbaceous vegetation, while in others they are rather bare, especially where cuts have been made through clay bluffs. Considerable aquatic vegetation is found along its margin, and *Elodea* grows luxuriantly in the deeper water. Under normal conditions the stream has a current of moderate velocity, and the water is frequently turbid on account of the muddy bottom and the presence of sewage. In many places both the depth and the current are relatively uniform, and the bottom is level. The constant flow of the current causes the smaller particles of the bottom to be continually in motion, so that the result is a soft muddy bed. In wading the stream, the writer has frequently found locations where he would sink 60 cm. or more in the mud. This condition is probably due to the dredging, because some of the undredged tributaries and the old channels
of West Branch are found to have a bottom of much firmer materials. Wilson and Clark (1912, pp. 14–15) have described somewhat similar conditions on the Yellow River in Indiana. In other places the depth of the water varies, as it also does at different seasons. During normal conditions of water volume it has an approximate depth of from 30 cm. to 1.5 m., but varies very much from this. A very severe and extended drought was experienced during the summer of 1911, and during this period the water was much lower than has been stated, during floods it is considerably deeper, the writer having found depths from 2–2.5 m.

In this region the drainage ditch represents one of the optimum situations for Gerris marginatus. The general physical conditions described are very favorably adapted to the needs of this species. The writer has found them in large numbers during the greater portion of the year. In this region there are no rapids or falls in the stream, so that there is presented an unbroken surface for many kilometers. Such a condition resembles that of a pond, a condition which is extremely well suited to the general habits of these Gerrids. It has been stated that there is considerable current, but along both margins there is quiet water from 30–90 cm. in width. In such situations G. marginatus is found in abundance, here all their varied responses are evidenced to the best advantage. Seldom are they observed in the middle of the stream where the current is strongest. Occasionally they are seen there, and it is interesting to notice that they orient themselves with the head pointing up-stream. They are able to make headway against the current, but they are much
less powerful in this respect than *Gerris remigis*. The writer has never observed *G. marginatus* "stride" farther than a few meters against a strong current, nor has he seen individuals seeking food where the stream flows swiftly. *Gerris marginatus* responds negatively to large moving objects and shadows. The general response to such stimuli is to dart away from the shore toward open water. This frequently carries them to the region of the current where another response is invoked by the movement of the water, and they "stride" up-stream for a few meters. Usually this up-stream movement continues for a few moments only, when they dart back to the shore often in a line at right angles to the current. Instead of returning to the shore at once it is not unusual for them to seize the stem of some aquatic plant that may be in the path of the current. They may remain in such a place for several minutes or even longer, but sooner or later they come back to the shore and the shelter of the marginal vegetation. They sometimes respond to moving objects in another manner. Instead of "striding" out onto the open water, they dart toward the shore and seize the stem of some aquatic plant. They may respond in a similar way to a strong current in times of flood, and also during a rain storm. They may respond to a moving object by darting under an overhanging bank along the stream.

Their normal haunts are along the shore away from the current. *Gerris marginatus* does not appear to depend upon the current as a food transporting agent to as large a degree as does *Gerris remigis*. The situations where *G. marginatus*...
is found most frequently, are largely free from swift currents, although it is true that sometimes there may be a sluggish movement of the water. Some food is brought to their haunts in this way, but a large amount of it comes from the bank and margin of the stream.

During times of high water *Cerris marginatus* is not seen away from the shore. They remain along the margin of the stream. At such times they respond strongly to contact, so that they are found clinging to the leaves and stems of aquatic vegetation. All the common responses, such as copulation and feeding, appear to be inhibited during times of flood. It is possible that the strong thigmotactic responses may hold in check some of the other responses. When the water is high and the current swift there is danger of being swept down stream, if they leave the protection of the shore and the marginal vegetation, while it is true that they are able to make some headway against a current of moderate velocity, they do not venture from the banks at such times. During rains they also seek the shore, and they are found clinging to the aquatic plants. As long as the rain continues they remain in such positions. As the level of the water rises in the drainage-ditch they of course rise with it. They remain in contact with the plants to which they are clinging until these are submerged, then they leave them for others in the immediate vicinity that still remain above the surface of the water. Mc Cook (*loc. cit.,* pp. 267 – 269) has made observations on water striders during high water of a somewhat similar nature as those just described.

The environmental conditions of the drainage-ditch are
very different from those of the brooks, and while they are well adapted to the needs of *Gerris marginatus*, they are not suitable for *Gerris remigis*. The later form is relatively rare in this stream. The writer has taken three specimens only, and one of these was a winged form. They were all taken at the same place, and at the same time.

6. Rivers. The river represents a relatively final stage in the development of the running water series of water strider habitats. The Sangamon River is the stream that received attention as an example of this. The observations in this connection have been less extensive than on any of the earlier stages of the series. The part of the river that was studied the most is situated about 1.5 km. north west of White Heath, at the point where the Illinois Central Railroad bridge crosses the river. In this region the water is turbid, with a relatively sluggish current, and the bottom is of mud. In some places the banks are steep and 6 - 12 m. or more in height, while at other points they are much lower and slope gradually to the water's edge. Both banks of the river are forested, and frequently considerable herbaceous vegetation is found along the margin. Observations have been made for a distance of perhaps 1.5 km. both up and down the river from the railroad bridge.

On the surface of the main stream no water striders so far have been observed, neither *Gerris remigis* nor *Gerris marginatus*. Careful search was made on a number of occasions, but without success. It is probable that some of the back waters and bayous may present suitable environmental conditions
for *G. marginatus*, and that after further investigations have been made they will be found there. The physical conditions differ so much from the optimum of *G. remigis* that it is very questionable whether this form will be found.

a. **Ox-bow ponds.** The Sangamon River has a very tortuous channel, and these meanders have resulted in the formation of several cut-offs. Frequently these form relatively large ox-bow ponds, and as they develop by the activity of the stream they are a part of the stream series. Some of them are permanent throughout the year, while others become dry during the hot weeks of midsummer. Several of these have been studied, and two of them will be considered here. Both of these are located a few hundred meters to the north of the railroad bridge and on the east bank of the river. They are relatively permanent water bodies, and do not become dry during summers of average rainfall.

Both of these ox-bow ponds lie practically parallel with the channel of the river. The one nearest the main stream will be considered first. Its dimensions are approximately 175 x 20 m., and it is of a somewhat crescent shape, with trees and underbrush along its banks. There is a moderate supply of floating insect food. Specimens of *Gerris marginatus* are frequently found in considerable numbers on the surface of this pond. They are generally observed along the shore where insects are apt to fall into the water, and thus form water strider food. They have also been found copulating near the shore. There is no current in such a water body, except an occasional surface current caused by
the wind. Therefore the water striders are frequently found on the surface of the open water, a form of behavior that was seldom observed on the part of *G. marginatus* on the drainage-ditch. They also feed and copulate on the open water. They are often seen in such situations quietly resting on the upper surfaces of aquatic plants. Their responses to moving objects are much the same as was noticed on the drainage-ditch. They may either "stride" close up to the shore, or else dart away onto the open water in response to such stimuli. When the latter response occurs, not having a current to contend with, they may remain on the open water for a considerable time before returning to the shore.

Their thigmotactic proclivities appear to be well developed, for when they are either near the shore or on the surface of the open water, they are frequently found to be clasping some solid body, such as the stem or leaf of an aquatic plant. The usual thigmotactic response is often overcome by the copulatory response. Of course the latter is also a form of contact response. In general the thigmotactic response is less in evidence than on the drainage ditch, for on this ox-bow pond *G. marginatus* is frequently found "striding" about on the surface of the open water away from the shore and the vegetation.

The second ox-bow pond is situated a short distance to the south east of the one just described, and is about eight times its size, with a much more irregular shore line. This pond has no trees along its shores, but there is vegetation of a smaller size, chiefly grasses. The pond has been mentioned
before in connection with a ditch-like stream, connected with it at the east end. It has also been stated in our discussion of the brook, that the west end of the pond is connected with the river at high water, for at such times it has continuous connection with a brook that flows into the river about 100 m. beyond the west end of the pond. During times of flood the ditch, pond, and overflow from the brook form one continuous body of water, covering several acres of ground. At such times *Gerris marginatus* is extremely abundant throughout this entire water area. During one excursion to this place on April 20th, 1912, sixtyfive specimens of *G. marginatus* were taken along the east shore within a distance of 75 m. On April 27th the same place was visited again, and it was found that the water had lowered and was much reduced in area. The water was so low that the connection was broken with the brook already mentioned. This does not mean that conditions of low water existed, for the water was much higher than normal. At the place where the water striders were so numerous the previous week, not more than three or four specimens were taken. The writer walked entirely around the pond and succeeded in capturing six water striders only. The mouth of the brook was examined carefully, and also the surface of the river above and below the point where the brook enters, but no *G. marginatus* could be found. The ox-bow pond next to the river was then examined, and *G. marginatus* was found here in moderate numbers. The writer is unable to state what became of the striders. They had not gone to the pond just mentioned, because *G. marginatus* was not present
in sufficiently large numbers for such an explanation. It is possible that *C. marginatus* takes flight from a pond of this nature in open situations, when the water rapidly recedes.

No specimens of *Gerris remigis* were ever found on the surface of these ponds. In this vicinity *G. remigis* is not found on quiet, standing water bodies, but is found on running water, and the permanent brooks is its optimum habitat. On the other hand *Gerris marginatus* is found in almost any sort of a situation, which it can reach by flight where there is water and food.

III. Food and Food Relations.

1. Nature and Source of Food. Water striders are very largely predatory animals. The living organisms upon which they feed vary considerably. These are chiefly insects or closely related forms and belong to a number of different orders and species. While some insects may be carried a considerable distance by the current, and others may be transported by the wind, observations disclose that generally the animals upon which these aquatic bugs feed are confined chiefly to four sources; the water, the surface film, the air above the surface, and the overhanging vegetation and banks of the stream. Regarding organisms that live habitually in the water, the only definite observations that the writer has been able to record are with reference to the larvae of midges and mosquitoes. This had been suspected for several months before definite evidence was obtained. On several occasions it was noticed that water striders attacked aquatic larvae,
but the writer did not succeed in taking them with the net until the autumn of 1911. It was then found that these forms were the larvae of *Chironomus* and *Culex*. Of the many animals that live on the surface film, only three species have been observed to be used as food by water striders, although it is strongly suspected that many others share the same fate. The organisms referred to are a species of small spider, and other water striders, both *G. remigis* and *G. marginatus*. Occasionally *G. remigis* leaps from the surface film at insects flying near. These are probably midges and mosquitoes. In this manner they seize, and afterwards suck the juices out of the adults of *Culex* and *Chironomus*. Many insects fall into the water from the banks of the brook and the vegetation thereon; some are swept in by the wind; while others jump or fly into the stream. Many of these become the prey of the water striders. *G. remigis* attacks and sucks the body juices of insects belonging to the order Orthoptera. While the writer frequently has observed water striders feeding upon these forms, the only definite record is with reference to *Melanoplus femur-rubrum* De G. They also use certain Neuroptera as food, for example *Chrysopa plorabunda* Fitch. Members of the order Diptera also become victims of these voracious water bugs. *G. remigis* has been captured while feeding upon *Mesogramma polita* Say, *Sarcophaga* and specimens of the family Tipulidae. Forms of the order Coleoptera are not exempt from the attacks of water striders, for specimens of *Cicindela* and *Hippodamia glacialis* Fabr. frequently become their prey. Both *G. remigis* and
G. marginatus preferably feed upon freshly killed and living insects, but they also suck the juices of stale and decaying food.

After the writer had studied the water striders in their natural habitat for several months, especially with reference to their food relations, he decided that G. remigis was entirely flesh-eating. However, on October 14th, 1911 this opinion was changed. Small red fruits were observed floating down the stream, and these seemed to attract the attention of the water striders at once. They seized them readily, and pushed the beak-like mouth parts through the outer skin down into the fruit. Some of the fruit drifted near the shore, and with the aid of a field glass, it was possible to see the sucking movements of the probosis. Several observations were recorded later than this of specimens of G. remigis sucking the juices of these berries. The plant from which these fruits came is commonly known as the Coral-berry, or Indian current — Symphoricarpos vulgaris Michx. It is very common along the banks of the brook at White Heath.

Students of aquatic Hemiptera have made comparatively few observations upon the kind of food used by water striders or by closely allied forms, or upon their food relations. Some of the more important records are brought together here. Uhler (1884, p. 267), in speaking of the family Hydrobatidae, states that, "Often in sunny, protected places where the food is abundant, all will be winged, while in exposed localities the same species will be found unwinged, with perchance a single, more vigorous specimen winged." He (loc. cit., p. 271)
also says that, "Metrobates hesperius Uhler -- -- -- has the habit of jumping from the water to grasp mosquitoes, flies, and other insects." His observations upon Mesovelia bisignata are of interest. He (loc. cit., p. 274) has found that "On the surface of the quiet waters which they inhabit, specimens may be seen at rest near the banks, or in the midst of leaves of pond weeds. There they watch for the arrival of some hasty gnat or other small insect which chances to fall into the water. This they eagerly grasp with the fore-feet and proceed to suck its juices." Butler (1893, pp. 233 - 234) has observed some of the food habits of Mesovelia furcata Muls. and Rey. He says, "I kept them supplied with a variety of small insects, and on different occasions saw them sucking a Smyththurus, a Crambus, a Chalcid, and apparently most unpromising of all, a Hydrometra. -- -- -- I should imagine that the usual food would be the small Diptera and Hymenoptera with which the leaves of the Potamogeton swarm, and that this is the reason for their selecting these leaves as their usual headquarters." Regarding the food of the marine strider Halobates Walker we know practically nothing. Walker (1893, p. 231) has found once or twice several specimens gathered round floating pieces of seaweed, as if obtaining nutriment. According to Arrow (1895, p. 112) Hydrometra stagnarum feeds upon Smyththurus niger until almost full grown. Kirkaldy (loc. cit., p. 153) remarks that Gerris apparently generally feeds upon dead insects. Miall (1903, p. 351) states that Gerris laeustris, a small species, Velia currens, suck the juices of dead or dying insects which have been blown into the water or reached it in some other
accidental way. According to Smith (1904, p. 90), "The water-striders or skaters get all their food on the surface and I have never seen Anopheles larvae where these insect occurred in numbers." In the autumn of 1911 the writer had some correspondence with the late Doctor John B. Smith regarding the food relations of mosquitoes and water striders. In a letter from him, from which he kindly permitted me to use an extract, he states that water striders capture larvae and pupae of mosquitoes and suck their juices. The following quotation is from Kellogg (1905, pp. 197 - 198), "Water-striders are predaceous, capturing smaller living insects by running or leaping, and with the prey held securely in the grasping fore legs, piercing and sucking the blood of the unfortunate victim, yet alive. ------ A few interesting Hydrobatids, belonging to the genus Halobates, live on the surface of the ocean, especially in subtropic and tropic latitudes. They are said to feed on the juices of dead animals floating on the surface." Mc Cook (1907, pp. 263 - 264) has observed that water striders feed upon Diptera and that they will also eat boiled beef. From the context, it is to be assumed that this writer refers to Hygrotrechus remigis. Bueno (1910, pp. 177 - 178) in his researches upon Microwelia americana Uhler has remarked that this form is carnivorous, as are all water striders, whether large or small. In their natural habitat he believes they feed upon Springtails, larvae of Diptera, and upon other soft bodied and feeble organisms, such as insects that are small enough to be overpowered. They may also feed upon larger forms which are drowned in the water. This naturalist has found
that Microvelia americana will eat house-flies and water-flies when confined in the aquarium. He has also noticed, when there is no living prey, that they do not hesitate to feed upon "long-dead and gamey food". He has seen these creatures feeding upon Diptera which had been dead for two or three days, and which were already decaying as evidenced by their unpleasant odor. In referring to Gerris remigis Say, Bueno (1911, p. 247) says: "Their food consists of such insects as have the misfortune to fall into the water." This author (loc. cit.) has also observed that Gerris marginatus Say is abundant on the surface of lakes and ponds, "where it preys on other insects. He (loc. cit., p. 249) also states that Gerris rufoscuteilatus Latreille is carnivorous in its food habits.

2. Food During Captivity. It has been noticed that Gerris remigis feeds upon a variety of insect food. Further light was thrown on this tendency toward omnivorous feeding, while studying water striders during confinement in aquaria. Many observations were recorded with reference to the kind of food that was eaten. It was found that both Gerris remigis and Gerris marginatus will feed upon the larvae and adults of Culex sp., small and large species of Tipulid flies, Syrphid flies, Lucilia caesar, Musca domestica, and Drosophila ampelopila. C. remigis frequently seizes and sucks the body juices of weaker members of its own species, and also of G. marginatus; and G. marginatus often feeds upon weaker individuals of the former and also of its own species. These cannibalistic traits are more in evidence when the animals have been deprived of food for a week or more. This
statement regarding the cannibalism is somewhat at variance with
the observations of McCook (loc.cit., p. 267), who has not seen
such food habits in the case of water striders. Both
C. remigis and G. marginatus will feed upon the soft parts of
banana fruit, also upon the inner softer portions of the skin.

The writer has found during his observations on the
food habits of water striders in captivity that while they
seem to prefer fresh food they have been seen to feed upon
recently dead insects, and also upon those that have been
dead so long that they are beginning to decay. Both
C. remigis and G. marginatus have been observed to eat freshly
killed and stale specimens of their own kind, also specimens
of Musca domestica and Drosophila ampelopile in a similar
condition. During confinement in aquariums both species suck
the juices of freshly killed Physa and Planorbis and also
small pieces of fresh beef.

3. Transportation of Food by Water Currents. Some
of the food materials, in running water habitats, as in the
brook near White Heath, may be brought to the haunts of water
striders from a considerable distance up stream. However,
this is not so reliable or constant a food supply as one might
imagine. The writer has frequently traced the drifting
insect food in order to observe how far it would be carried
from the point where it entered the stream. It is a surprising
fact to learn the number of obstacles that tend to modify the
work of the current in its relation to food transportation.
Dams cross the brook, caused by debris transported during
high water, frequently impede the progress of and strain out
the food. These dams may be either temporary or permanent. Sand bars and rocks in the channel, or jutting out from the banks often prevent some of the food from drifting farther. Then as the current is deflected from one bank of the stream to the other, part of the floating food material occasionally may be deposited thereon. Frequently the drifting insects come in contact with the aquatic vegetation. If the animals are still alive, this contact acts as a stimulus which induces their thigmotactic proclivities, and they cling to the vegetation as a support, thus escaping from the current. Water striders themselves and other insect members of the water film association, often destroy much of the food materials before they drift for any great distance. Various kinds of fishes in the brook, also feed upon this floating insect food. It must also be kept in mind that the living insects may readily escape from their unpleasant environment, when the drifting movement ceases, by coming in contact with certain of the obstacles mentioned. At times they can crawl or even swim ashore. Nevertheless, there is a certain amount of water strider food that may be carried considerable distances from the points where it entered the water. While some food is carried in this manner at low water, yet by far the greater amount is transported during flood periods. At such times drifting insect food is swept with ease over and past obstacles which at low water are almost insurmountable barriers. At such times the dams and sand bars may be destroyed and their materials distributed further down stream.
However, there are long reaches in the brook, sometimes extending for approximately 300 m. that are comparatively free from obstacles which impede the current. In such reaches, the dams formed by drifted debris, may be entirely absent, or else they are wing dams. In such cases larger amounts of food materials can be transported for considerable distances. Comparatively few of the dams stop entirely all the drifting food. Generally it gets by and is carried farther down stream. But as was mentioned in another part of the paper, much of the food material comes from the immediate vicinity of the water strider haunts, or else is transported by the current for distances of a few hundred meters.

4. Time of Feeding. Many observations were made with reference to the time when Gerris remigis and Gerris marginatus feed most actively. During the very early morning hours the temperature is relatively low, and there is comparatively little insect life stirring. The water striders are not much in evidence, as their bodily activities are largely in a passive condition. It is rarely that these Gerrids are observed feeding at such a time. There is a gradual increase in temperature and amount of insect food until early afternoon. It is usually interesting to notice that there is an approximately corresponding increase in the movements and responses of the water striders. For hours at a time they are in motion, gliding about on the surface film in their search for food. There is a large amount of energy being set free at this time as evidenced by the constant physical activity of the animals. To supply this expenditure, much
food must be secured in the form of the body juices of drifting insects. As the day approaches its close, there is a gradual reduction in temperature and in insect activity, and so of food materials. There is also a gradual subsidence in the active behavior and food reactions of the water striders.

It will be noticed, from the statements that have been made, that the food activities of water striders, along with other responses, are least in evidence in the early morning and late evening, but that in the middle of the day they are most prominent. Water striders feed chiefly during the middle of the day. My records indicate that a large percentage of their food is obtained from about 9:00 - 10:00 a. m. until 3:00 - 4:00 p. m. During these hours they are most active. They are constantly "striding" here and there over the water film. Their metabolic processes are probably more rapid at this time than at any other period during the twenty four hours. This period of active feeding is due in large part to the stimuli of high temperature and abundant food supply.

5. Response to Water Currents and its Relation to Food.
The observations recorded here are with special reference to *Gerris remigis*. Specimens of this species respond readily to water currents as has been frequently observed in the brook near White Heath. This is one of the animal's most pronounced forms of behavior in its natural environment. This response is among the first to claim the attention of the observer. As one watches the water striders in the brook, it is noticed that generally they assume a rather definite position with
with regard to the current. They so orient themselves with reference to this stimulus that they face it with their heads pointing up stream. Whenever the current is of medium strength this is the relative position of the animals with reference to it. This form of response has a special bearing upon their food habits. As much of the food is insect material that drifts along with the stream, this rheotactic form of reaction to the current is beneficial to the water striders. They are so oriented that they can readily see the floating insects upon which they depend for food. Such a position with regard to the current aids them in securing food material, before it has drifted out of their reach.

Water striders are frequently found in situations not only where the currents are of medium velocity, but also where they are comparatively swift. In such situations the long axes of their bodies usually lie parallel with the lines of force exerted by the current, however, there are many modifications of this position. Frequently water striders remain practically in the same position relatively to some object on the bank for hours at a time. They continually "stride" forward on the surface film against the force of the current. In this forward motion they give themselves just sufficient up stream momentum to compensate for the down stream drift. The precision and accuracy of this response is remarkable. Because of this form of behavior the Gerrids remain approximately in the same relative position for a considerable period of time. During all this time they are on the lookout for insect food which drifts down stream. At other
times, while they continue in the same general relative position with reference to some object on the bank of the brook, they make short detours to the right and left in search of food, or in order to attack some small insect, instead of moving directly up stream a few inches and then drifting back again. On other occasions the water striders dart rapidly across the current, at right angles to it, toward a drifting insect or some moving object. Not infrequently they make journeys of considerable length, "striding" vigorously up stream against the current. They will pass over rapids and up the front of miniature water falls, 30 - 50 cm. high. They have been observed to travel continuously for fifty feet up stream.

At present the writer is not prepared to state whether they will go farther than this during the same trip. He believes, however, that they do travel much longer distances than this, but in a succession of journeys which may extend over a period of several days.

At this time it is difficult to say what are the initial stimuli which result in responses that cause a water strider to move away from a location in which it may have lived for hours, or possibly for weeks. It is possible that a decrease in or an entire cessation of the drifting food materials may be the cause; possibly changes in the atmospheric density or air temperature may have some effect. It is probably not due to changes in the velocity of the water current, for Cerris remigis has been observed to move away many yards up stream when no such change has occurred. That a decrease
in food materials may be a factor has some support, for the writer has noticed on several occasions that when water striders would leave a certain location in which they had been for a half day at least that there was little or no food materials drifting past. However, the explanation may not lie with any one set of stimuli, but may be due to a complex set of stimuli.

6. Trial Method of Response to Moving Objects and its Relation to Food. The movements of _Cerriis remigis_, with reference to the current and to food, in the pools of the brook differ somewhat from those in the main current of the stream. In many of the pools the current from the brook is slight. In such situations it is noticed that the water striders respond to the current with less precision than they do when in the open stream. There is much less of a tendency for the long axes of their bodies to lie parallel with the direction of the lines of force. It is true that the anterior part of the body is usually turned against the current, but there are many deviations from such a position. The animals dart back and forth, in an "enquiring" sort of a manner, from one small object to another as these come drifting down stream into the pools. This movement is continued for hours at a time, frequently for an entire afternoon. This sort of behavior has been noted on different occasions for one hour, two hours, and even three hours at a time, and also for full afternoons. It has been observed in the case of a single individual, and also for a group of individuals. Behavior of this sort is directly related to the food habits of the animals, for they
feed largely upon dead and living insects that drift with the current. They respond to objects of different sizes from those of 1 - 2 mm. in diameter to those of 20 mm. in diameter; but it is not of infrequent occurrence to see them approach objects of much larger size, a drifting dead leaf for example. The object itself and the movement seem to be the two factors involved in attracting the attention of the water striders. It is true also that motionless objects receive attention from the water bugs, but not so often as moving ones, for the former are less easily seen. The writer often has noticed that specimens of G. remigis are less responsive to a stationary or slowly moving object than they are to some one that moves more rapidly. This is well illustrated in taking them with the net. It is frequently possible to capture them with a slow movement when it is not possible to take them in any other way. Similar facts are evidenced in connection with stationary and moving shadows. In all of these responses distance is an important element. The writer has not yet definitely determined how far away water striders are able to see effectively although he has discovered experimentally in aquaria that they immediately seize a house fly struggling in the surface film if it is not more than 10 cm. distant. The experiment has been tried at lesser distances, but not at greater ones. It should be stated that there is some difference between hungry and replete individuals. The former often notice the flies 10 cm. away when the latter offer no response. However, it is hardly probable that there is much variation in keenness of vision, but that the difference is a difference in the physio-
logical state of the animals. In their natural habitat water striders can certainly see moving objects on the water film at a distance of 10 cm. It is perhaps worth while, at this point to recall the work of some other writers with reference to the responses of Arthropods to moving objects. Plateau (1888, p. 436) performed experiments on various orders of insects and concludes that "visual perception of movement" is best developed among the Odonata, Lepidoptera, Diptera and Hymenoptera. The distance at which movements can be seen averages 1.5 m. for mural Lepidoptera, 66 cm. for Diptera, and 56 cm. for Hymenoptera. Movements cannot be seen farther away than 2 m. According to Bell (1906, pp. 629 - 631) the crayfish reacts to anything of fair size that is in motion. It does not seem to be able to avoid stationary objects in its path. Holmes (1911, p. 37) states that there is an involuntary tendency on the part of animals to follow the movements of objects which cross their field of vision. He also says that, "Vision in the lower animals is concerned much more with the movements than with the form of the objects."

The feeding responses of water striders are very suggestive of the so-called "trial" movements of many of the lower animals that have received so much attention of late years. Morgan (1894) and (1900), Thorndyke (1898), Jennings (1904), and others have discussed these forms of response with considerable fullness. It is probable that the water striders have formed an association between the stimuli of the water current and the appearance of food. Much of their food is brought to their haunts by the current from a longer or shorter
distance. The animals are easily attracted by moving objects on the surface of the water. Their attention is attracted by a small piece of drifting wood, or a portion of a dead leaf, and they move toward it and usually "stride" up in close contact with it, and not infrequently seize the object with the anterior pair of legs. They also swim up to and seize drifting insects. If the insect is alive, and struggling to escape from the water surface by movements of its appendages, water striders usually respond more quickly to the stimulus. But so far as the writer has been able to learn, they respond to any small drifting object just as readily as to a drifting insect.

That water striders will seize unpalatable inanimate drifting objects, and living moving insects indiscriminately is illustrated by simple experiments upon these animals when in confinement, and especially if they have not been fed for several days. If a fine capillary glass tube, from which a small stream of compressed air is issuing, be placed in contact with the surface film of quiet water in an aquaria jar containing a specimen of *Perris remigis* an interesting series of events will take place. As the bubbles of air agitate the surface, the water strider quickly responds. If the tube is quietly touched to the surface film several centimeters away from the animal and behind it, the water strider immediately turns half way around toward the point of disturbance, or it may make a complete turn, which it usually does, and so face the source of stimulation. Frequently it darts at the small bubbles on the surface film
that are due to the entrance of the compressed air. It is of course unable to seize any solid object and acts in a manner that might indicate that it was somewhat at a loss. It may at once dart again at the moving surface, or it may "stride" about the spot for several seconds. Then it may again dart at the bubbling surface and again move about the immediate vicinity, or "stride" away from the place and so make no further response to the disturbance. This is a typical example of what occurs under such conditions, although the responses may be variously modified in minor details. If the water strider is facing the source of stimulation, its responses are much the same as described, it goes toward the agitated region. Should the long axis of the body of the animal be at right angles to the source of stimulation it turns toward it. A hungry animal, that has not been disturbed for some days, will dart at the blackened or unblackened end of a moving splinter of wood and will even seize it for a moment with its front legs. The writer has succeeded on at least two occasions in causing a water strider to dart toward a small moving object on the outside of the aquarium, but in close contact with the glass. Another simple experiment with aquaria specimens that are in a state of hunger and have not been disturbed by other stimuli for some time is suggestive. The water is disturbed in such a manner that a ripple of miniature waves is formed on the surface. A small strip of white glass with a flat surface may be used for this purpose; this being transparent is probably not seen by the water strider. The strider will usually respond by turning its head toward
the source of stimulation and also by moving over the water surface toward this source.

These responses seem to indicate that the water striders associate movement with something to be seized — with food. Perhaps we may be justified in saying that the animal associates movement in some crude fashion with a "pleasurable experience" — food. If this is true that the water striders have formed an association of this sort, then this response to movement, to currents and moving objects must be very "beneficial" to them from the standpoint of obtaining food. It has been stated that water striders respond to moving and drifting objects, both in their natural habitat and in confinement and that some of these objects are bits of wood, dead leaves, air bubbles and that some times they will even seize or attempt to seize such objects. Some of the animals' responses then result negatively so far as obtaining food is concerned. Other responses result in the animals seizing and obtaining food, and these may be considered as accomplishing a definite result. The water striders probably know nothing about the end to be accomplished. Therefore if the animal responds to a moving object and this proves to be a piece of wood then there is no further response along this particular direction — the animal does not retain its hold of the object and push its proboscis into it. Further positive response toward this object as food is inhibited, or perhaps better to say that the initial stimulus of movement toward this object is not followed by a food stimulus such as a floating insect would prove to be and so bring about further response as sucking the juices of
such insect. The water strider responds to the next moving object that comes first into its range of vision. This may prove to be another small piece of wood, a portion of a dead leaf, or some other such object, if so the animals leave it, and respond to some other drifting thing. If the moving object proves to be drifting insect food, the water strider retains its hold of the creature - perhaps the contact of the insect's body against the appendages of the water strider, or perhaps the odor of the insect, act as a further stimulus and the mouth parts are pushed into the insect and its juices are sucked out. Therefore this moving of the water strider back and forth from one drifting object to another consists of a series of trials. It seems to the writer that the food of the water strider is obtained according to the method of trial.

IV. Summary.

In the developmental series of running water habitats in this vicinity, ravines, springs, temporary streams, permanent brooks, creeks, and rivers are all represented. These illustrate a succession of related stages in the ideal development of the permanent stream environment. In our study of the responses of water striders to the physical conditions of such an environment, we find that they vary in different habitats, and that there is considerable adjustment exhibited between the organisms and the environment.

During the initial stages of development toward permanent stream conditions, Gerris marginatus appears to be
among the pioneers. Ravines on bare clay bluffs are entirely unsuited to the needs of water striders, because of the absence of food and the limited water supply. In ravines covered with shrubs and trees, evaporation is retarded, and the pools conserved. *G. marginatus* is occasionally observed in such situations. There is sufficient food for them, and they can exist until the water dries up when they migrate by flight. Springs also may be classed as one of the initial stages in stream development for they may develop into ravines, or, after the ravines which have been formed by the run off, have cut down to ground water level, springs issuing from their sides may assist in cutting the bed of the ravines still lower.

In such places small pools are frequently formed and *G. marginatus* is sometimes observed there. Occasionally *G. marginatus* is found in small bowl-like depressions formed by springs. The water in such places is relatively permanent and as there is usually a moderate amount of insect life, water striders are able to live there.

Small temporary streams illustrate a somewhat later stage in the formation of permanent stream habitats. Such streams generally become dry in midsummer, but the remainder of the year there is sufficient water and food, so that *Gerris marginatus* is frequently found in such places in considerable numbers.

Permanent brooks represent the optimum stage for *Gerris remigis*. They are found on such streams in abundance. Their haunts are at bends in the stream, where the current carries the food and where the water striders are sheltered.
by the bank. During flood conditions, *G. remigis* is not swept down the stream, because of its habit of seeking the shore where there is quieter water, and also because of its thigmotactic proclivities. When the brook overflows its banks, *G. marginatus* is frequently found on such shallow quiet water. At long intervals exceptionally severe droughts occur, and the brook may become a series of pools in which the water striders are trapped. If any such pools should become dry *G. remigis* may by "random movements" find another pool near by. Others probably do not find another body of water and are destroyed.

Creeks are a still later stage in the development of the stream series. Both *G. marginatus* and *G. remigis* may be found on such water bodies near the shores. If one of these creeks is connected into a drainage-ditch, it furnishes an excellent habitat for *G. marginatus*. There is abundance of food, and also quiet water near the banks which condition is adapted to their species. In general the surface of the water is unbroken by rapids. In this respect it is much unlike the brook which is the optimum for *G. remigis*. At high water *G. marginatus* protects itself by clinging to the marginal vegetation.

The river represents a relatively final stage in the development of the running water series of environments. Portions of the Sangamon River have been examined and neither *G. marginatus* or *G. remigis* have been found on the main stream. In the ox-bow ponds, produced by the old river channels, *G. marginatus* is abundant. Here it finds all the conditions adapted to its needs.
The food and food relations form a dominant factor in any ecological consideration of water striders. The nature of their food consists very largely of the body juices of living and dead insects from a number of different species. This is true both with reference to *Gerris remigis* and also *Gerris marginatus*. Such plants as the Coral-berry is also used as food by the former species. In captivity both species feed upon a great variety of insect food. They will also suck the juices from the inner skin and fruit of bananas.

A considerable part of the food of *Gerris remigis* is found in the immediate vicinity of its haunts in the brook, which represents its optimum habitat. While this is true there is also a quantity of food that is transported by the current for longer or shorter distances. There are many obstacles that modify the usefulness of the current as a food transporter, at least a portion of water strider food material from one part of the stream to another. *Gerris marginatus* more nearly represents a standing water type than it does a stream type, although it is found on the surface of streams. It depends as much upon food that is brought by the wind, or that falls from the banks, as it does upon that transported by the currents. *G. remigis* also depends to some extent upon the food carried by the wind.

*Gerris* feed most actively during the middle of the day. There is an abundance of insects in evidence and a relatively high temperature at such a time. Both of these are factors that influence the water striders with regard to their time of feeding. The water striders themselves are
most active at this time of the day, probably largely due to the temperature. Owing to their active responses, there is much expenditure of energy, and this loss is renewed by means of the abundant food materials in the form of insects.

Water striders respond readily to water currents in such a manner that they orient themselves with their heads pointing up stream. This places them in the best position to find drifting food materials. *Gerris remigis* not only can make headway against a swift current, but it is able to surmount miniature water falls. *Gerris marginatus* also responds to the current, but this form cannot "stride" so vigorously against it as *C. remigis*.

*Gerris remigis* responds to objects from 2 - 20 mm. in diameter. Moving objects are more readily found than stationary ones. They move toward any small object drifting with the current - and often seize it - as readily as toward moving food material. The water striders are very responsive to movements on the water surface. Laboratory observations have emphasized this feature of their behavior. The method of finding food is one of "trial". First one moving object is "tried" and then another. Many such responses are "errors", but such responses finally result in the animals obtaining the food necessary for their existence. These statements apply largely to *Gerris remigis*. 
V. Bibliography.

Arrow, G. J.

Bell, J. C.

Bueno, J. R. de la Torre.

Bueno, J. R. de la Torre.

Butler, E. A.

Holmes, S. J.

Jennings, H. S.

Kellogg, V. L.
Kirkaldy, G. W.

McCook, H. C.

Miall, L. C.

Plateau, P.

Smith, J. B.
1904. Report of the New Jersey Agricultural Experiment Station. 482 pp. Trenton.

Tower, W. L.

Transeau, E. N.

Uhler, P. R.
Walker, J. J.


Wilson, B. W. and Clark, H. W.


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Figure 1. Brook at White Heath showing optimum conditions for Gerris remigis Say. Current is shown to the left. Water striders are found on the pool to the right and on the water surface near the high (1.5 m.) bank on which the tree is shown.
Figure 2. Brook at White Heath showing pool near high bank (2.5 - 3 m) where aggregations of Gerris remigis Say are found. Current is shown to the left and to the right of the pool.