

ECOLOGICAL STUDIES OF *ARGIA MOESTA* HAGEN
(ODONATA: COENAGRIONIDAE) BY MEANS
OF MARKING.

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INTRODUCTION.

These studies were carried on during the summers of 1931 and 1932 along the Olentangy River about three miles north of Worthington, Ohio, and on the western portion of the Brown Fruit Farm, which borders the east side of the river at this point. It was noted at the outset that the different sexes and color forms of *A. moesta* seemed to occur in different proportions in different parts of the area studied; and the appearance of distinct color forms gave the impression that this species might be polychromatic, as a few species of dragonflies seem to be, or the color forms might be merely an indication of the age of the adult, as is the case with most of the color variations in adult dragonflies. In order to throw some light on the activities of this species, its distribution over the area, and the nature of its variation in color, considerable collecting was done along the river and on the western portion of the fruit farm. A system of marking was devised so that individual specimens could be recognized if recaptured and hence data concerning their movements and activities could be obtained.

Argia moesta Hagen.

According to Williamson (6)¹ there are five geographic variations in the color pattern of the males of this species. The form with which this paper deals is that described as Type II by Williamson, or as *putrida* by Hagen (5). Detailed descriptions of this form are given by Byers (1, 2), Garman (4), Hagen (5), and Williamson (6).

The adults in any given locality show distinct variations in general color. The color pattern of the thorax and abdomen consists of two colors, black and a lighter color. The black, except possibly in the male, comprises only a small portion of the body surface, and the general color of the insect is due to

¹Numbers in parentheses refer to the bibliography at the end of the paper.

the shade of the lighter color. Females may appear brown, blue, or entirely black. The older blue and dark individuals often have narrow light stripes on the mesepisternum just laterad of the dorsal carina. Both the blue and dark females may appear pruinose, but the pruinescence is confined to the ventral side of the thorax. The dark and some of the older blue females seem to be about equally pruinose. Males may appear brown and black, blue and black, or entirely whitish (pruinose). General specimens of both sexes are pale brown and soft-bodied, and the color pattern is not distinct. Rarely the pale areas of the thorax of the female appear streaked with brown and blue or blue and dark; occasionally the pale areas of the male appear intermediate in shade between brown and blue, or between blue and white (when the pruinescence is rather light).

Adults in tandem are frequently encountered along riffles. A single pair may remain in tandem for considerable time if undisturbed, during which it will fly back and forth along the riffles, alighting occasionally on such vegetation as water willow or on rocks. Oviposition occurs while in tandem; in this process the female thrusts her abdomen completely under water, so that the wings usually float on the surface. The eggs are deposited on submerged vegetation. The adults are not confined to the riffles, but frequently fly some distance from them. In doing so they prefer sunny situations to shaded ones, but prefer grassy areas or the edge of woods to bare areas.

AREA WHERE WORK WAS DONE.

This area, located along the Olentangy River and the western portion of the Brown Fruit Farm, is shown by the accompanying map (Fig. 3). The fence along the north side of the area is on the county line between Delaware and Franklin counties. The fruit farm lies between the two fences.

The river, as it flows south opposite the fruit farm, is shallow and rocky, and contains numerous riffles and water willow. The west bank is lined by trees, mostly willow, elm, and sycamore, beyond which there is a wide flood plain occupied by a golf course (the Mt. Air Golf Course).

Along the east side of the river is a high bank, varying in height from 50 to 80 feet, on which there are numerous outcroppings of shale. For the most part this bank drops steeply to the river's edge, but on the southeast and to a lesser degree on the northeast portion of the farm the steeper slope retreats

from the water's edge, giving way to a typical flood plain. Several steep-sided ravines cut back from the river into the woods and orchard.

The woods shown on the map consists chiefly of oak and hickory near the top of the high bank, and farther east of beech and maple. Two strips of varying width, the "air drains," have been cut through the woods between the river and the orchard to improve air drainage in the orchard. The vegetation in these air drains is for the most part not more than three or

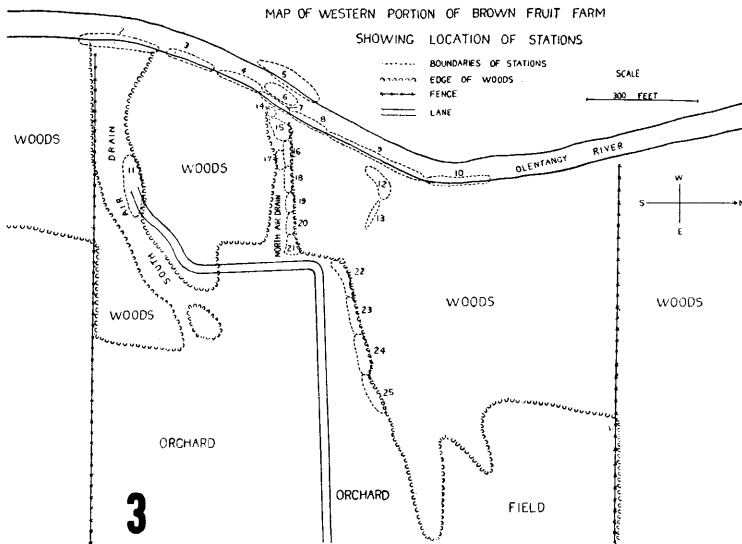


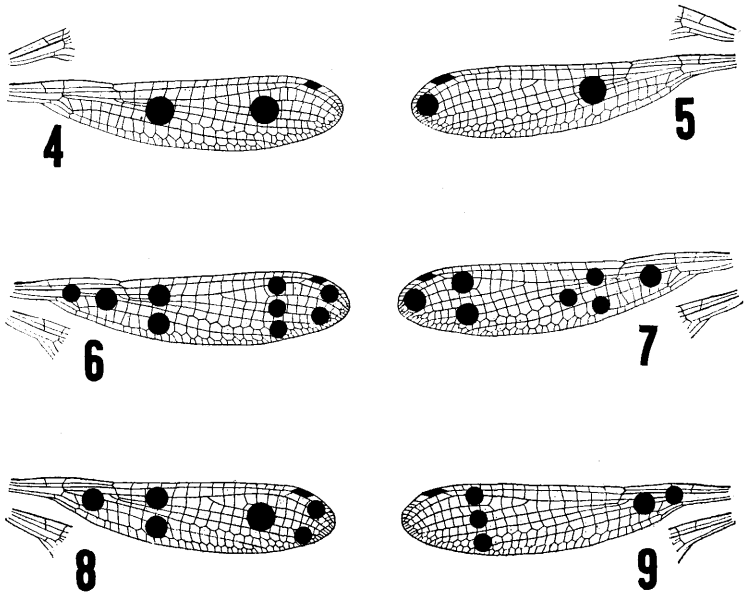
FIG. 3. Map of the area where the work was done.

four feet high, and consists of tree seedlings, shrubs, and herbaceous plants that have persisted from the woods or which have come in from the orchard. The orchard is an apple orchard, with the grass and weeds beneath the trees cut close to the ground.

Stations.—In order to facilitate the recording of data, that part of the area where the collecting was done was divided into 25 "stations," the locations of which are shown on the map. Station 1, which is not shown, is along a set of riffles about 250 yards south of the southern boundary of the farm. There are no riffles opposite stations 2 and 3, and very few opposite 9. Station 6 is along the riffles in the middle of the river opposite the north air drain. Station 14 is on the steep bank just below the west end of the north air drain.

MARKING.

Most of the experiments in marking insects mentioned in entomological literature have consisted of marking lots of insects and releasing them at some central point to determine their range of dispersion. The marking was usually done by applying some sort of stain, ink, paint, or enamel to the insect with an atomizer or spray gun. In only a few cases, notably the experiments with bees by Von Frisch (3), have insects been marked so that individual specimens could be recognized if recaptured; in such cases the marking was usually done with



FIGS. 4 TO 9. Figures illustrating the method of marking.

Fig. 4. No. RH0110.

Fig. 6. No. RF2232.

Fig. 8. No. RF1212.

Fig. 5. No. LH0101.

Fig. 7. No. LF1321.

Fig. 9. No. LF2030.

a small brush or stick. As far as the writer is aware, no marking experiments of any sort have been carried out on dragonflies.

In this study, specimens of *Argia moesta* were marked on the ventral surface of the wings with dots of india ink, a different combination of dots being put on each insect. The ink was applied with a small pointed stick. The dots were placed at one or more of four different positions on the wing, and the number of dots placed in each of these four positions made a four-figure number which was the identification number of

the insect marked (see Figs. 4 to 9, inc.). By this method a great many different combinations can be devised, and records can be kept of a large number of individual specimens.

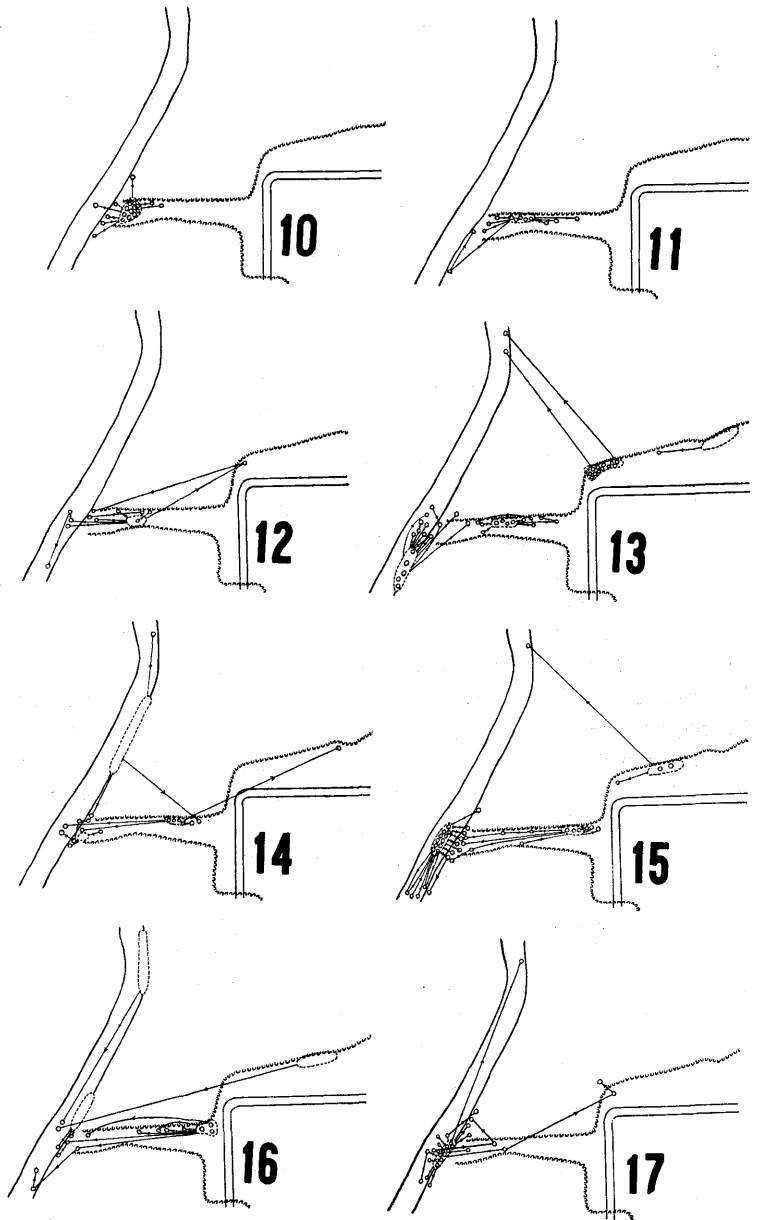
Little difficulty was experienced in applying the ink to the wings, and the insects were in no way injured by the treatment. The marking was done in the field where the insects were captured, and the insects were released immediately after marking. This method worked very satisfactorily, and individuals recaptured as long as 24 days after being marked still retained the marks on their wings distinct enough to be read. In cases of returns where the marks were partly rubbed off so that there was a question as to the identity of the specimen (such cases were relatively few), the record was discarded.

DATA.

Marking Data.—During the two seasons a total of 830 specimens of *A. moesta*² were marked, of which 178 (21.5%) were recaptured. Many of these were recaptured more than once; thus a total of 227 recaptures was obtained. These returns have brought out some interesting facts concerning the movements, color change, and length of adult life of this species.

Movements.—The movements of this species, as indicated by the recaptures of individuals marked at 18 of the 25 stations, are shown graphically by the maps in Figs. 10 to 17, inclusive. There is quite a bit of movement upstream and downstream for short distances, but only a few cases of individuals flying for any great distance up- or downstream. There is considerable movement of individuals to and from the river, chiefly via the air drains. A large proportion of the recaptures (93 out of the 227) was obtained in the same station in which the specimens were marked, indicating that many individuals remain in one locality for a considerable length of time. Movement from one station to another is apparently rather slow. Of the specimens taken along the edge of the woods and orchard (stations 22 to 25), some seem to have come from the river via the air drain, while others may have come through the woods from further upstream (see Figs. 13 and 15).

²During these two seasons 77 specimens representing 9 other species of Odonata were also marked. These species, with the number of individuals of each marked, are as follows: *Argia sedula* Hagen, 32; *Hetaerina americana* Fab., 27; *Argia apicalis* Hagen, 7; *Ischnura verticalis* Say, 3; *Enallagma exsulans* Hagen, 2; *Platheimis lydia* Drury, 2; *Sympetrum vicinum* Hagen, 2; *Argia violacea* Hagen, 1; *Libellula luctuosa* Burm., 1. Only six returns from these were obtained, four being *H. americana* and two *A. sedula*. The returns were obtained after from two to seven days; they indicated very little movement, and no color change.



FIGS. 10 TO 17. Maps Showing Movements of Individuals.

These maps represent the central portion of the area shown in Fig. 3; the scale is the same. Each map shows the recaptures obtained from individuals marked at one or more stations. The stations where the individuals were marked are indicated by broken lines; the small circles indicate points of recapture; the lines connecting the circles to the marking station show the direction of movement. Circles within the marking station indicate recaptures in the station where the

Color Change.—The data concerning color change may be summarized as follows:

	Records	Maximum No. of Days
REMAINING THE SAME COLOR:		
Brown (males and females).....	22	6
Blue (males and females).....	71	24
Pruinose (males).....	39	24
Dark (females).....	3	4
	Records	Days Elapsing
CHANGING COLOR:		
Brown to blue (males and females).....	24	2 to 19
Brown to dark (females).....	3	13 to 16
Brown to pruinose (male).....	1	18
Blue to dark (females).....	15	2 to 15
Blue to pruinose (males).....	2	4 to 5
Dark to blue (females).....	11	2 to 9
Blue to dark, then black to blue (females)...	2	2 and 4 to 15 and 19

Color in the males seems to be directly correlated with age, the brown individuals being the youngest and the pruinose ones the oldest. In the females the brown individuals are the youngest, and the blue and dark individuals the oldest; since they may change from brown to blue in two days and from brown to dark in apparently not less than 13 days, it would seem that the brown individuals turn blue first and later turn dark. Since dark individuals may turn blue again, it appears that the dark condition is, in most cases at least, only temporary. The fact that practically all the dark females were taken along the riffles in tandem with males suggests that possibly the dark color is brought about by certain internal phenomena correlated with sexual maturity.

Length of Adult Life.—This can be deduced from the data given in the table above. Although some individuals remained brown for 6 days, most of the recaptures of brown individuals

individuals were marked. In some cases, recaptures of individuals marked at two or more stations are shown on the same map. Due to the limitations of space, not all the recaptures obtained are shown, but those shown are typical.

- Fig. 10. Recaptures of individuals marked at station 15.
- Fig. 11. Recaptures of individuals marked at station 16.
- Fig. 12. Recaptures of individuals marked at station 17.
- Fig. 13. Recaptures of individuals marked at stations 4, 18, 22, and 25.
- Fig. 14. Recaptures of individuals marked at stations 9, 14, and 19.
- Fig. 15. Recaptures of individuals marked at stations 6, 20, and 23.
- Fig. 16. Recaptures of individuals marked at stations 8, 10, 21, and 24.
- Fig. 17. Recaptures of individuals marked at station 7.

were obtained after only 1, 2, or 3 days. Most of the recaptures of blue (female) and pruinose (male) individuals were obtained after periods considerably shorter than 24 days. The maximum length of adult life is about four weeks, the average probably being about three weeks.

Population Data.—During the seasons of 1931 and 1932 a total of 1,542 records of *A. moesta* were obtained, as compared with 402 records of 24 other species of Odonata.³ Of the 1,542 records, 545 were obtained along the river, 789 in the air

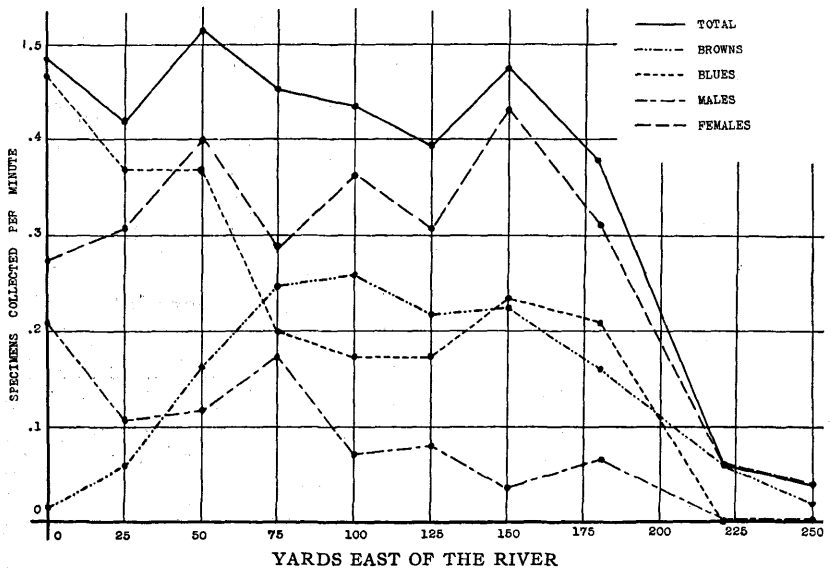


FIG. 1. Graph showing the relative abundance of sexes and color forms along and east of the river (1932).

drains, 54 in the woods, and 154 along the edge of the woods and orchard. No specimens were taken east of station 25. The analysis of these records has brought out certain facts regarding the sex ratio, distribution of sexes and color forms, and daily abundance of this species.

Sex Ratio.—During both seasons the females were more abundant than the males. In 1931 the ratio was 31.41% males and 68.59% females; in 1932 it was 32.73% males and 67.27% females. There are thus more than twice as many females as males.

³The Odonata of the Brown Fruit Farm, as observed by the writer during these two seasons, are discussed in a paper to be published in the near future in a bulletin of the Ohio Biological Survey.

Distribution of Sexes and Color Forms.—The relative abundance of the different sexes and color forms along the river and at different distances east of it in the north air drain and orchard is shown graphically in Fig. 1. In this graph relative abundance has been indicated in terms of specimens collected per minute. The increased abundance of the blue (older) individuals along the river is undoubtedly due to the fact that mating and oviposition, activities of only the older individuals, take place there. The increased abundance of individuals at 150 yards

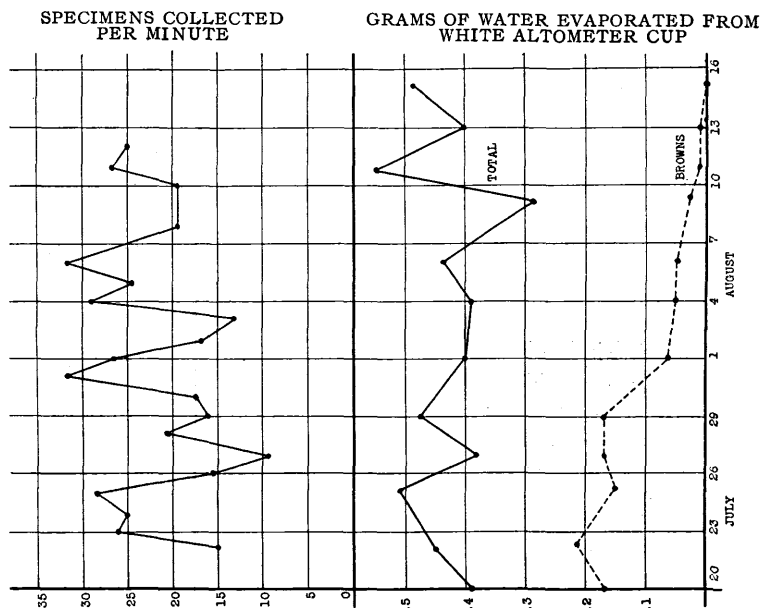


FIG. 2. Graph showing the relative daily abundance and evaporation data (1932).

from the river (the end of the air drain and the beginning of the orchard) is probably due to the fact that some of the individuals taken there (stations 21 and 22, particularly 22) came from the river by way of the air drain, while others came through the woods from further upstream.

Daily Abundance.—The relative abundance of all adults, the relative abundance of brown adults, and the evaporation data, for the season of 1932, are shown graphically in Fig. 2. It is interesting to note that the relative abundance of brown individuals, and consequently the rate of emergence of adults, decreased during the period of observation. Another interesting

point, which the graph does not show, is that the abundance of individuals in the air drain and orchard fell considerably near the end of the period of observation. During August most of the collecting was done along the river, where the individuals were most abundant; hence the relative abundance of all adults does not decrease with the decrease in rate of emergence.

During the two seasons various meteorological data were obtained, but none showed much correlation with dragonfly abundance except evaporation data. It will be noted from the graph that in general, periods of high evaporation are characterized by increased abundance. However, this increase is probably only apparent, due to the increased activity of the insects during these periods.

An attempt was made, using the information obtained from marking and collecting data, to calculate the actual daily population of *A. moesta* on the area. The calculations were based on the relative number of marked individuals recaptured on successive days, with allowances made for shifts in population due to movements in and out of the area and to death and emergence. Such calculations indicate that the daily population is probably several hundred.

Only a small fraction (never more than 100) of the total population was ever taken on any one day. This may have been due to the way in which the collecting was done, viz., time was taken to mark practically all individuals taken; or to the fact that the entire area was not worked each day; or many individuals may simply have been overlooked, due to their habit of remaining for long periods perched on some exposed leaf.

DISCUSSION.

Since no brown individuals except some very teneral ones were taken along the river, it would seem that within a few hours after emergence, as soon as the body hardens sufficiently, the adults fly away from the river, up into the woods or air drains. There they remain for several days, feeding and moving from place to place rather slowly. In some cases they do not seem to move more than 25 yards in two or three days. General movement, as from one station to another, is not to be confused with rate of flight. Individuals of *A. moesta* may fly quite rapidly at times, but the results of this study indicate that they do not fly rapidly for any great distance, but remain for a considerable time in the same locality (station). By the time

the adults are a week or ten days old, they move about a little more rapidly. They may return to the river for a time, and then fly back into the air drains. Females fly up into the air drains to a greater extent than males.

When the adults are about 14 days old they return to the river and mate. This species is rather promiscuous in its mating; a single female may mate with several different males, or a single male with several females. Only the older individuals mate. The males by this time are almost or entirely pruinose; the females are only pruinose ventrally, and are dark laterally and dorsally. After mating, the pruinose males remain white, but the dark females may become blue again. The older blue females thus seem to be individuals which have ceased laying eggs. These older blue females, often with muddy abdomens and wings, may fly back into the air drains again; the males after mating may fly to the top of the high bank, but never go as far from the river as do the older females. The adults of both sexes may live a week or more after the first mating.

Most of the movement that occurs is to and from the river via the air drains; there is relatively little movement upstream or downstream. During wet and cool weather the adults are more or less inactive, and spend most of the time perched on vegetation near the river. During high water, when the water willow is flooded, the older adults are forced up into the air drains.

The peak of abundance for this species is during the latter part of July. By the middle of August there are no more brown individuals present, indicating that emergence has ceased. Although no collections were made after August 15, it is quite likely that by the middle of September all the adults would have disappeared from the area.

SUMMARY.

These studies were carried out along the Olentangy River about three miles north of Worthington, Ohio, during the summers of 1931 and 1932. Collections were made of *A. moesta* in different parts of the area, and a system of marking was devised so that individual specimens could be marked and their activities studied. The method of marking consisted of applying different combinations of dots of india ink to the wings by means of a small pointed stick. During the two

seasons 830 individuals were marked, of which 178 (21.5%) were recaptured, from 1 to 24 days after being marked. From the recaptures of these marked individuals, and from collecting data, numerous facts were disclosed concerning the activities of this species.

The adults do not fly very far, and their movement from place to place is rather slow. Most of the movement is to and from the river; there is relatively little movement upstream or downstream. The adults undergo a definite color change during their life; they are brown for a few days after emergence, then they become blue and later pruinose; the males become entirely pruinose and appear whitish, while the females are only pruinose ventrally; at the time of mating the females become dark dorsally and ventrally, but may turn blue again later. The adults live three or four weeks after emergence.

The ratio of males to females is about 1 : 2; the two sexes occur in almost equal proportions along the river, but away from the river the females are much more abundant. Brown individuals are scarce along the river and at a considerable distance from it, but are fairly abundant about 100 yards from the river. Blue (older) individuals are most abundant along the river. During the season, periods of high evaporation seem to be accompanied by increased abundance. Calculations based on marking and collecting data indicate that the daily population of this species on the area studied is probably several hundred, although less than 100 were collected any one day. This species is distinctly a sun-loving insect, but shows no pronounced distaste for vegetation.

BIBLIOGRAPHY.

1. **Byers, C. Francis.** A contribution to the knowledge of Florida Odonata. Univ. of Florida Pub. No. 1, pp. 173-175. 1930.
2. **Byers, C. Francis.** *Argia Rambur*. In "A Handbook of the Dragonflies of North America," by J. G. Needham et al. C. C. Thomas Pub. Co., Springfield, Ill., pp. 284-286, 297-298. 1929.
3. **Frisch, Karl von.** Aus dem leben der bienen. Berlin, J. Springer. 1927.
4. **Garman, Phillip.** The Zygoptera or damselflies, of Illinois. Bull. Ill. St. Lab. of Nat. Hist., Vol. XII, Art. IV, pp. 507-510. 1917.
5. **Hagen, H. A.** Synopsis of the Neuroptera of North America. Smiths. Rept., pp. 94-96. 1861.
6. **Williamson, E. B.** The dragonfly *Argia moesta* and a new species (Odonata). Ent. News, 23: 196-203. 1912.