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DEPARTMENT OF REGISTRATION AND EDUCATION
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A Study of the Malarial Mosquitoes of Southern Illinois

I. OPERATIONS OF 1918 AND 1919

BY

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ERRATA

Page 97, line 17, for first *larval* read *pupal.*
Page 112, in legend, for *jonessi* read *jonesii.*
Page 114, in legend, for *or* read *of.*
Page 125, line 4, for *Bonosa* read *Bonasa.*
Page 131, in legend, for *hirundinaceus* read *hirudinaceus.*
Page 138, last line, for *coccoon* read *cocoon.*
Plate XII, explanation page, next to last line, for *acrivora* read *aerivora.*
Plate XIII, explanation page, next to last line, for *White-grubs* read *White-grub.*
Page 293, Figure 5*a* was reversed in printing, and the two items of the legend should change places.
Page 515, second table, for *Pelocoris femorata* read *Pelocoris femoratus.*

ARTICLE XI.—*A Study of the Malarial Mosquitoes of Southern Illinois. I. Operations of 1918 and 1919.* BY STEWART C. CHANDLER.

INTRODUCTION

The Relation of Mosquitoes to Malaria.—The part which mosquitoes play in the transmission of malaria was established years ago, but we often find people who never heard of the relation between the two. It is therefore important to make clear, at the beginning of this report on mosquitoes, the facts in the case. Malaria was at first thought to be carried to men by damp night air. "Mal-aria," bad air, was the name given to the disease for that reason. It was later clearly established that mosquitoes breeding in the swamps and other damp places and biting at dusk are the sole carriers of the disease. A mosquito, upon biting a malaria patient in whom the disease parasites have developed for about ten days, sucks up the parasites into her mouth. Only the female mosquito bites and is capable of transmitting the disease. The germs now develop for a period of eight to ten days. In this time they break through the lining of the stomach wall and get into the salivary glands, from which they are readily transferred to man by the bite of the mosquito. Not all kinds of mosquitoes are malaria carriers. Only three species in this country (all belonging to the genus Anopheles) are implicated. There are in all twenty-four species of mosquitoes regional in Illinois.

Malaria in Southern Illinois.—Illinois is not usually regarded as a state in which malaria is common; and the northern two-thirds would not be so classed. Southern Illinois, however, has a reputation not so enviable. I have found it impossible to secure correct statistics on the extent of malarial disease. Most physicians whom I have consulted do not keep records of malaria such that they can say definitely how many cases they have treated in a year's time. They report irregularly or not at all on this disease to the State Board of Health. Estimates, of course, can be secured from them, and I have always found physicians whom I have consulted very willing to make as careful estimates as possible. Taking as examples the two towns in which I have done most of my survey work, Carbondale and Murphysboro, I found that the estimates gave Carbondale from a hundred and fifty to two hundred cases of malaria in an average year, and Murphysboro from two hundred to four hundred cases. As these are towns of six and eight thousand population, respectively, we find that from two to five out of every hundred men, women, and children are attacked by malaria each year. There are many other points in southern Illinois, especially along the Mississippi, Wabash, and Ohio rivers, which are greater malaria centers than the towns men-

tioned, but estimates from these places are so widely divergent that I am not presenting them at this point. The State Board of Health estimated, for the period of 1909 to 1914, (Vol. II, No. 6 of Illinois Health News,) that in ten of our southern Illinois counties at least 8 per cent. of the population was ill from malaria each year. They put the number of cases for the state at nineteen thousand per annum, and the number of deaths from malaria at ninety-five per annum. Most of the physicians whom I consulted said that deaths from this cause are becoming increasingly rare, because of increased drainage in some sections and the fact that most people now understand the value of quinine and more of them than formerly screen their houses. The State Board of Health, in an endeavor to assign a money loss attributable to the disease in the state, estimates that the average loss to the individual patient due to medical attendance, cost of remedies, and diminished earning power is $160.00, amounting to over three million dollars for the nineteen thousand cases. There is another form of loss which is not always taken into account in speaking of a disease, namely, loss of vitality. Very often the patient is able to work, but only with a greatly decreased vigor, resulting in a loss, if not to the worker, at least to his employer. This reduction of efficiency is recognized in southern Illinois especially by big corporations, like the railroads, which have large numbers of employees.

Object of the Survey.—It was in view of facts of this nature that the Southern Illinois Medical Society passed a resolution in the fall of 1917 requesting the State Natural History Survey to make a mosquito survey of southern Illinois in order to locate the breeding-places of malarial mosquitoes, with a view to eventual efforts for the control of the insects and the prevention of malarial disease. This work has been carried on during the seasons of 1918 and 1919 as continuously as was consistent with the press of other duties. It was thought best to limit the work to one or two towns chosen as typical rather than to attempt to cover a large territory more superficially.

It has been the main object of the survey to find the kinds of places in which malarial mosquitoes breed in southern Illinois and to learn which kinds are clearly preferred and how continuously and to what extent the various species abound through the year. From these data, together with those obtained from physicians, certain conclusions have been drawn in respect to the relation between the amount of malarial disease on the one hand and the number of malarial mosquitoes, the proximity of their breeding-areas, and the distances to which they are capable of flying, on the other.

Life History.—A brief account of the life history of the mosquitoes will aid those not familiar with their habits to appreciate the importance of a knowledge of their breeding-places.

In spring adult mosquitoes appear as the weather warms up, some as early as March in southern Illinois. The eggs are laid on some body of water, temporary or permanent, large or small. If the female finds

no water, she may die without reproducing, a fact to be borne in mind when control measures are considered. At least a day is necessary to bring the eggs to hatching—considerably more in late fall or early spring. The larval mosquitoes, commonly known as wigglers, are seen swimming in ponds, creeks, and other breeding-places, or floating at the surface, which they must visit at frequent intervals for a supply of air. They feed upon minute aquatic plants and animals. The larval period varies from one to three weeks, according to season and temperature. In the pupal stage, which is passed in the water and lasts from one to five or more days, the head and thorax are much larger than in the larva. The length of the entire life cycle depends on the time of year and the species. It is from ten to twenty-five days, being generally a little longer in the genus Anopheles, to which the malaria-carrying mosquitoes belong, than in other genera. One authority* (Howard Dyar, and Knab) gives twelve to twenty-four days as the total length in May and June for the Anopheles in Washington, D. C. In planning the treatment of breeding-places, we must remember that the entire life cycle of the mosquito may be passed in ten days, and that successive generations will be produced as long as warm weather continues and breeding-places are available. The stage of hibernation varies with the species, but it is fairly well established that of Anopheles only the females survive the winter. I have found these during the winter at Carbondale in cellars, culverts, and other sheltered places.

Survey Work at Carbondale

Frequency of Malarial Disease.—Four physicians who had practiced for many years in Carbondale, gave the following estimates of the number of cases of malaria treated in the town in an average year: Dr. J. W. Barrow, 200; Dr. Roscoe Lewis, several hundred; Dr. W. A. Brandon, 150; and Dr. H. C. Mitchell, 150. As the population of the town is about six thousand, it would appear that at least two or three out of every hundred are treated for malaria each year.

Mapping the Territory.—A map of Carbondale township—not reproduced in this report—was traced, on which I indicated most of the possible breeding-places of mosquitoes. It was my first intention to make examinations in the country as well as the town, and I designated on this map about twenty-five tributaries and feeders of Crab Orchard Creek, a stream about two miles east of Carbondale. The doctors whom I interviewed had told me of the continued occurrence of malaria among the farmers along this creek and I later found malarial mosquitoes breeding in these tributaries. Lack of time compelled me, however, to confine my attention to the town and immediate surroundings. The breeding-places were numbered in my notes and on the map for ease in recording findings. Larger maps of Carbondale and vicinity were

* "The Mosquitoes of North and Central America."

obtained from the Illinois Central Railway division office through the courtesy of Supt. W. Atwill, and from Mr. C. E. Cox, a former civil engineer. By means of these larger-scale maps I was able to indicate practically every possible breeding-place of mosquitoes which would be likely to affect the people of Carbondale. Although winds may carry mosquitoes for a distance of several miles (as will later be shown in the case of Anna and Jonesboro) it is usually believed that mosquitoes do not fly over half a mile from their breeding-places. Most of the places examined are within half a mile of the edges of town. (Maps, pp. 312, 313.)

Examinations and Collections.—Collections of larvae and pupae were made once, and sometimes twice, a month during the breeding seasons of 1918 and 1919 (with the exception of September, 1919) and were bred to the adult for identification. The wigglers were scooped up with a small strainer with a handle and a screen of about twenty meshes to the inch. They were removed with a small soft brush, such as is used in water-color work, and put temporarily into tin pill-boxes together with a little of the same water in which they were found. The contents of the pill-boxes were later emptied into glass jars in the insectary and more water with aquatic vegetation and some of the mud from the bottom was poured into the jars to furnish food and natural conditions. I usually secured this water from some one or two breeding-places which seemed to produce mosquitoes abundantly, taking care to exclude mosquito larvae and any animals which might be predaceous upon the mosquitoes. Notes were made as to the presence and abundance of the malarial and non-malarial mosquitoes in each breeding-place examined, and the species were later determined by Dr. C. P. Alexander and Mr. J. R. Malloch, of the Natural History Survey.

The Anopheline and Culicine larvae (carriers and non-carriers of malaria) are readily distinguished by the positions which they take while resting at the surface of the water, the Anophelines lying parallel to the surface while the Culicine larvae hang down at an angle of about forty-five degrees, with only their long breathing tubes touching the surface. The pupae are more difficult to distinguish and will not be discussed. The adults of our Anopheles are easily distinguished from Culex and other genera by the spots on the wings, the Culicine wing being clear. The palpi of the female are longer in Anopheles than in Culex. The body of the Anopheline adult forms an angle with the surface upon which it rests, while that of the Culicine is parallel to the surface.

BREEDING-PLACES

Mosquito breeding-places at Carbondale are typical of those in many other towns. In the following description I am grouping them in classes which will be readily recognized by residents of other places. The breeding-places were numbered, as shown on the maps (pp. 312-313), to facilitate the making of records. Plates XXXI—XXXV illustrate a few of the situations.

Class I, Swamps.—The swamps studied are of a type common in the southern end of the state. Most of them are grown up to cattail, the density of which will be realized by reference to Fig. 1 and 2. The water generally contains a great deal of decayed organic matter. Around the edges usually, and in the main channels (if there are any), the water is clearer. At Carbondale the railroad shops, round-house, and yards are in a series of these swamps (Nos. 54–57, 59, 61). The physicians in town have all spoken to me of the large number of cases of malaria among the railroad men, and I do not doubt that these swamps are partly responsible.

Class II, Marshes.—A marsh, as the term is here used, is not as deep as a swamp, does not contain so much organic matter, and contains a considerable growth of grass besides some cattails. In Carbondale such a place (No. 71) is found opposite the old cemetery near the negro school. This place (Fig. 3) produced many malarial mosquitoes.

Class III, Ponds.—The ponds at Carbondale are small bodies of water artificially formed. No. 58* in the A. & L. Tie Company's yards and their two "creosote lakes" (Nos. 66 and 67), No. 52 on Chestnut street, No. 45 east of Freeman street, and the pond on the campus of the State Normal School (No. 179) are examples. The growth in these ponds varies from none at all, as in the Tie Plant property, to that of a swamp.

Class IV, Roadside Ditches.—Especially along built roads there are often left ditches which contain water and are grown up to grass or cattail. Numbers 62 and 63*, near the Illinois Central yard office, are types. Many other ditches show no growth at all and, as will afterwards be shown, yield comparatively small numbers of mosquitoes.

Class V, Creeks and Streams.—Crab Orchard Creek and its tributaries, Pyles Fork and a creek (No. 53) running into the swamps north of town, are those which I watched most closely.

Class VI, Open Drains through Towns (Fig. 4, 5, 6, 7).—These drains may originally have been natural streams, but in the case of the two watched at Carbondale (Nos. 47 and 48), their courses have been somewhat altered.

Class VII, Lakes.—Thompson's Lake (No. 51, Table A) at the south edge of town is leased by the Country Club and is consequently much visited by many of the residents. It is also important because of its proximity to town.

Mosquito-producing Factors of Various Types.—While all of these kinds of breeding-places yielded Anopheles, it soon became apparent that some were much more productive than others.

The cattail swamps might be supposed, from their large area, to breed more malarial mosquitoes than any other waters, and they are no doubt important, although they present certain features which seem to decrease the output. I have found some of them yielding these mosquitoes in

* No. missing on map.

[Continued on p. 317.]

North half of Carbondale. (North at left side)

South half of Carbondale. (North at top)

A

PREVALENCE OF MOSQUITO LARVAE IN CARBONDALE BREEDING PLACES

Type of breeding place	B. P. No.	Season of 1918				Season of 1919			
		Date	Anopheline	Culicine	Remarks	Date	Anopheline	Culicine	Remarks
		April				April			
Cattail swamps.....	54	18	None.....	Few.....		2	None.....	None	
	54	.....	.....	.....		28	None.....	None	
	55	19	None.....	Few.....		24	None.....	None	
	56	18	None.....	Few.....		24	None.....	None	
	57	18	None.....	Few.....		24	None.....	None	
	59	.....	.....	.....	No examination	24	None.....	None	
	60	.....	.....	.....	No examination	.....	.....	.....	No examination
	61	18	None.....	Many.....		24	None.....	None	
Marsh.....	71	.....	.....	.....	No examination	30	Fair numbers	Few	
Pond.....	179	.....	.....	.....	No examination	30	None.....	None	
Roadside ditch.....	62	.....	.....	.....	No examination	24	None.....	None	
	63	18	None.....	Many.....		24	None.....	Few	
Stream.....	53	.....	.....	.....	No examination	3	None.....	None	
Open drains.....	47	.....	.....	.....	No examination	24	None.....	None	
	48	.....	.....	.....	No examination	24	None.....	None	
Lakes.....	51	.....	.....	.....	No examination	2	None.....	Many	
		May				May			
Cattail swamps.....	54	14	None.....	Few.....		28	None.....	Fair numbers	
	55	.....	.....	.....	No examination	28	Fair numbers	Few	
	56	15	None.....	Few.....		27	None.....	Many	
	57	14	Very few.....	Very few.....	1 adult Anopheline	28	Few.....	Few	
	59	.....	.....	.....	No examination	28	None.....	Few	
	60	.....	.....	.....	No examination	28	Few.....	Fair numbers	
	61	15	None.....	Few.....		27	Many.....	Few	
Marsh.....	71	16	Fair numbers	Fair numbers		15	Many.....	Fair numbers	
Pond.....	179	.....	.....	.....	No examination	27	Few.....	None	
Roadside ditches....	62	.....	.....	.....	No examination	27	Fair numbers	Fair numbers	
	63	14	Few.....	Few.....		27	Few.....	Few	
Streams.....	53	.....	.....	.....	No examination	27	Fair numbers	Fair numbers	
Open drains.....	47	17	None.....	None.....	Rain, strong current	27	Fair numbers	Few	
	48	16	None.....	Few.....	Adults	27	None.....	Many	
Lakes.....	51	17	None.....	Fair numbers		28	Fair numbers	Fair numbers	
		June				June			
Cattail swamps.....	54	29	Fair numbers	No record....		.....	.....	.....	No examination
	55	24	Few.....	Few.....		17	Many.....	Very few	
	56	24	Many.....	?		17	Fair numbers	None	
	57	3	Fair numbers	Fair numbers		17	Many	None	

	59	24	.....	.....	Dried up	17	Many.....	Very few	
	60	24	.....	.....	Dried up	17	Many.....	Very few	
	61	24	Few.....	?		.....	.....	.....	No examination
Marsh	71	24	.....	.....	Dried up	18	Many.....	Very few	
Ponds	179	10	Fair numbers	Few.....		.....	.....	.....	No examination
Roadside ditches	62	25	.....	.....	Dried up	.....	.....	.....	No examination
	63	3	Fair numbers	Fair numbers		.....	.....	.....	No examination
	63	20	Fair numbers	?					
Streams	53	3	Many.....	Many.....		.....	.....	.....	No examination
Open drains	47	3	Many.....	Very few.....		18	Very many...	None	
	48	4	Few.....	Very many...		18	Many.....	Very few	
Lakes	51	4	Few.....	?		.....	.....	.....	No examination
		July				July			
Cattail swamps	54	19	.....	.....	Dry	.....	.....	.....	No examination
	55	19	None.....	None.....	Dry, except in main channel	4	Many.....	None	
	56	18	None.....	None.....	Dry, except in main channel		.....	.....	No examination
	57	19	None.....	None.....	Dry except in main channel		.....	.....	No examination
	59	.....	.....	.....	No examination		.....	.....	No examination
	60	.....	.....	.....	No examination		.....	.....	No examination
	61	18	None.....	None.....	Water in main channel only		.....	.....	No examination
Marsh	71	.....	.....	.....	No examination	4	.....	.....	Dry
Pond	179	18	Fair numbers	Fair numbers			.....	.....	No examination
Roadside ditches	62	.....	.....	.....	No examination				
	63	18	None.....	None.....	Nearly dry	4	Many.....	None	
Streams	53	13	Fair numbers	?		.....	.....	.....	No examination
Open drains	47	17	Many.....	Many.....	Nearly dry	4	Many.....	None	
	48	16	None.....	Very many...		.....	Many.....	None	
Lakes	51	20	.....	.....	Lake lowered 8 feet	.....	.....	.....	No examination
		Aug.				Aug.			
Cattail swamps	54	15	.....	.....	Dry	2	Very few.....	None	
	55	15	None.....	None.....	Nearly dry	2	Fair numbers	Few	
	56	16	Few.....	None.....		2	None.....	None	
	57	15	Few.....	Few.....	Water low	2	None.....	None	
	59	.....	.....	.....	No examination	2	Few.....	None	
	60	.....	.....	.....	No examination	2	.....	.....	Dry
	61	15	Fair numbers	Fair numbers		2	None	None	
Marsh	71	16	.....	.....	Dry	2	None.....	None.....	Dry
Pond	179	14	Fair numbers	?		2	Few.....	Very few	
Roadside ditches	62	16	Many.....	Fair.....	Waste water draining in	2	Very few	None	
	63	16	None.....	Very many...		2	Fair numbers	Few	
Streams	53	16	Fair numbers	?		.....	.....	.....	No examination
Open drains	47	12	Few.....	Fair numbers		2	Fair numbers	None	
	48	12	Very few.....	Very few.....	Almost dry	2	.....	.....	Dry
Lakes	51	.....	.....	.....	No examination	2	Fair numbers	Fair numbers	

PREVALENCE OF MOSQUITO LARVAE IN CARBONDALE BREEDING PLACES—Concluded

Type of Breeding Places	B. P. No.	Season of 1918				Season of 1919			
		Date	Anopheline	Culicine	Remarks	Date	Anopheline	Culicine	Remarks
Cattail swamps	54	Sept. 3	Many	Many	(Rain on Sept. 2)	No September examinations, 1919			
	55	3	Many	Few					
	56	5	Fair numbers	Fair numbers					
	57	5	Few	Fair numbers					
	59	3	None	Fair numbers	Water low				
	60	3	None	Many					
	61	5	Few	Many					
Marsh	71	3	None	Many					
Pond	179	5	Fair numbers	Few					
Roadside ditches	62	4	Many	?					
	63	4	Fair numbers	Many					
Stream	53	4	Fair numbers	?					
Open drains	47	6	Fair numbers	?					
	48	6	None	Few	Nearly dry				
Lakes	51	.....	.....	.....	No examination				
Cattail swamps	54	Oct. 17	Few	Fair numbers		Oct. 24	None	None	
	55	17	Few	?		24	Fair numbers	None	
	56	17	None	None		24	None	Many	
	57	17	None	None		24	Fair numbers	None	
	59	17	None	Fair numbers		24	Very few	None	
	60	.....	.....	.....	No examination	.....	.....	.....	No examination
	61	17	None	Fair numbers		24	None	None	
Marsh	71	17	.....	.....	Dry	24	Very few	Very few	
Pond	179	18	None	None		24	Few	Few	
Roadside ditches	62	17	Fair numbers	?		24	None	Few	
	63	17	Many	?		24	None	Few	
Streams	53	17	Fair numbers	?		24	Few	Few	
Open drains	47	17	Fair numbers	Many		24	Fair numbers	Fair numbers	
	48	17	None	Very many					
						24	None	None	
Lakes	51	.....	.....	.....	No examination	24	Few	None	
Cattail swamps		Nov.				Nov.			
	55	.....	.....	.....	No examination	15	None	None	
	56	.....	.....	.....	No examination	15	None	None	
	57	.....	.....	.....	No examination	15	None	None	
Pond	179	18	None	None		.....	.....	.....	No examination
Stream	53	18	None	None		.....	.....	.....	No examination
	47	18	Many	Fair numbers		.....	.....	.....	No examination
Open drains	48	18	None	None		.....	.....	.....	No examination

every month of the season, but not in numbers corresponding to their area. The large amount of organic matter which they contain seems to be detrimental to Anopheles larvae. At one time during a summer drouth the common duckweed (*Lemna minor*) completely covered the surface of a part of the swamp where cattails were absent, and I could find no mosquito larvae around the edges of this area.

The marshes (Class II) seem to produce more Anopheles than the swamps, probably because of a more favorable vegetation, as already noted.

Ponds (Class III) are dangerous if they contain sufficient vegetation to give shelter and protection to mosquito larvae. Grass, reeds, rushes, and cattails favor their escape from small fishes and predaceous insects. I was never able to find any mosquitoes breeding in Pond No. 58, in the Tie Plant yard, or in the "creosote lakes," the latter probably because of the cresote waste emptied into them. No breeding was found in No. 52 and very little in No. 45. The three Tie Plant ponds and No. 52 have no vegetation along the edges to furnish protection. No. 45 showed a growth of water-lilies which did furnish some protection, although not as effective as grass. The pond on the Normal campus (No. 179; Fig. 8 and 9) has a good deal of plant growth along the edges, and I found some Anopheles breeding there practically every time I looked for them. As some of this vegetation was cut down in the fall of 1918, it was not quite so abundant in 1919 as the year before, and Anopheles were also less abundant. Several physicians have spoken to me of the number of cases of malaria in the Normal dormitory, and I found Anopheles breeding within twenty feet of it (Fig. 8).

Roadside ditches (Class IV) generally contain less water than the other types, but they are likely to be mosquito breeders unless they dry up. Some of them, however, have no vegetation whatever and usually contain few or no wigglers. Numbers 62 and 63, by the Illinois Central yard office, lined with overhanging grass and filled with other vegetation, hold their water well through the season and furnish quite ideal conditions for Anopheles.

In creeks and streams (Class V) mosquito breeding is limited not only by vegetation and water supply, but also by strength of current and purity of water. In the main stream of Crab Orchard and Sycamore creeks and of Pyles Fork I found very little or no breeding except when, as in the case of Pyles Fork, dry weather reduced the stream to a series of pools. In the backwaters and in small tributaries with little current, Anopheles were often quite abundant. Small streams with little current, such as No. 53, running into the swamps, especially those with grassy banks,* may be prolific breeders. When waste water of any kind pollutes the stream it is likely to reduce mosquito production.

Practically the same may be said of Class VI (open drains) as of creeks and streams. They are, perhaps, more likely to become polluted

* See Fig. 12—a stream at Murphysboro.

by garbage or through sewer leaks, in which case I have noticed that the production of malarial mosquitoes is much more reduced than that of the non-malarial species. Where drains are left with weedy edges, as in Carbondale, they are a serious menace to the health of the town. Figures 4 to 6 show the ideal breeding conditions which these drains afford, and records of physicians show frequent cases of malaria in houses situated close to them. Fig. 6 shows the proximity of one ditch to a city school building.

The Thompson's Lake (Fig. 10) type of breeding-place is dangerous, providing there is sufficient protective growth along the edge to mask wave action, since this seems to be detrimental to the development of mosquito larvae. I am inclined to think, however, from the past season's experience, that Anopheles larvae prefer shallower water than is found even along edges of this lake, and that consequently it is not as important as some other breeding-places before mentioned. However, I found at least a few Anopheles upon practically every visit, and as there is a long shore-line the lake must have some effect on the amount of malaria.

Prevalence of Mosquitoes and Abundance of Malaria.—In the following table I am showing the presence and abundance of the mosquito larvae in the breeding-places which I was able to watch fairly continuously throughout the year. The six terms used to indicate the numbers of Anopheles—none, very few, few, moderate numbers, many, and very many—are given grades of 0, 1, 2, 3, 4, and 5, respectively, and the data for each month are figured separately, the records for the two years being combined. This table shows for each month the number of visits at which each of the six grades of abundance was found, the average abundance per visit for each month, and, in the lowest line of the table, the percentages of abundance, taking the highest grade (very many) as the base of the computation. In April, for example, the average abundance of larvae of malarial mosquitoes was 2.7 per cent. of "very many;" in May this average was 30.8 per cent.; in June, 67; and so on.

It was found impossible to obtain accurate figures on the prevalence of malaria in Carbondale, but from the medical record of the Illinois Central Railroad employees in town, kept by Dr. H. C. Mitchell, division surgeon, it is evident that the increase and decrease of the number of cases of malaria are closely correlated with the abundance and scarcity of the Anopheles mosquitoes.

Species.—The accompanying table (C) contains a list of the species of mosquitoes which were either taken as adults, or bred to the adult stage from larvae and pupae, during the last two seasons. It also shows the types of breeding-places in which they were found and the months in which the collections were made. The numbers used are those of the foregoing description of types, viz.: Class I, cattail swamps; Class II, marsh; Class III, ponds; Class IV, roadside ditches; Class V, streams; Class VI, open drains; Class VII, lakes.

B

ABUNDANCE OF MALARIAL MOSQUITOES IN DIFFERENT MONTHS AND DIFFERENT BREEDING PLACES, CARBONDALE, 1918 AND 1919.

Grades of abundance	April		May		June		July		August		September		October		November	
	No. of breeding places	Products	No. of breeding places	Products	No. of breeding places	Products	No. of breeding places	Products	No. of breeding places	Products	No. of breeding places	Products	No. of breeding places	Products	No. of breeding places	Products
None.....0	21	0	10	0	0	0	6	0	5	0	4	0	12	0	6	0
Very few.....1	0	0	1	1	0	0	0	0	3	3	0	0	2	2	0	0
Few.....2	0	0	5	10	4	8	1	2	5	10	2	4	5	10	0	0
Moderate numbers.3	1	3	6	18	6	18	2	6	7	21	5	15	6	18	0	0
Many.....4	0	0	2	8	9	36	4	16	1	4	3	12	1	4	1	4
Very many.....5	0	0	0	0	1	5	0	0	0	0	0	0	0	0	0	0
Totals of grades.	.....	3	.....	37	.....	67	.....	24	.....	38	.....	31	.....	34	.....	4
Totals of breeding places.....	22	.....	24	.....	20	.....	13	.....	21	.....	14	.....	26	.....	7	.....
Average abundance per breeding place	0.137		1.54		3.35		1.85		1.81		2.22		1.31		0.57	
Percentages of abundance,.....	2.7		30.8		67.		37.		36.2		44.3		26.2		11.2	

SPECIES OF MOSQUITOES TAKEN AS ADULT OR BRED FROM IMMATURE STAGES AT CARBONDALE AND MURPHYSBORO, 1918 AND 1919.

Species	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Uranotaenia sapphirina (O. S.) Lynch Arribalzaga.						7					1918 1919
Anopheles guttulatus Harris			house, 6	1, 6, 7 7	1	1, 4	4	3			1918 1919
Anopheles punctipennis (Say) Say		house 7	5 1, 2, 4, 5, 6, 7	2, 3, 4, 5, 6, 7 1, 3, 5, 6, 7	6	5, 6 1	6	1, 4, 5 1, 2 3 5, 6			1918 1919
Culiseta inornata (Williston) Dyar			4, 5, 6 2	6							1918 1919
Culex saxatilis Grossbeck			1, 2, 4	6 1				5		6	1918 1919
Culex territans, Walker			6							6	1918 1919
Culex pipiens Linn				5	6	5					1918 1919
Culex salinarius Coquillett			1, 3	1, 6		6	6	1 1, 6			1918 1919
Culex species (close to *jamaicensis* Theobald, which it is in sense of Felt but not of H. D. & K.)			3, 5								1918
Psorophora ciliata (Fabricius) Robineau-Desvoidy			7								1918 1919
Psorophora sayi D. & K			4, 7								1918 1919
Aëdes canadensis (Theob.) D. & K			1 5	2 1							1918 1919
Aëdes sylvestris (Theob.) D. & K		7	1, 3, 4, 6 5, 6, 7	1, 2, 7				1, 4			1918 1919
Aëdes sp. [near *taeniorhynchus* (Wiedemann) Busck]	1 adult near house Mar. 18										1918

Explanation of above table:—Under the columns for the months of the year the figures given (1 to 7) refer to the seven classes of breeding-places already described in the foregoing pages. The word "house" is self-explanatory, simply meaning taken in a house.

RELATIVE ABUNDANCE OF MALARIAL MOSQUITOES, CARBONDALE, 1919

A number of writers have raised a question as to the comparative importance of *Anopheles guttulatus* and *A. punctipennis* as carriers of malarial disease, it being believed by some that *guttulatus* is the more active carrier. The preponderance of *punctipennis* in my records indicates that this can hardly be the case. In 1918 *guttulatus* was taken in only four different collections during the year, while *punctipennis* was taken in nineteen. In 1919 seventy-six adults were obtained at Carbondale and only six were *guttulatus*. *Guttulatus* being so rare in Carbondale, I think the other species must be held responsible for most of the malaria present.

Mr. H. R. Carter and associates, of the U. S. Public Health Service,* report that they found *guttulatus* predominating in Alabama and South Carolina in their August and September surveys, and *punctipennis* in spring to June 15 and in fall. They qualify this, however, by saying that in August and September the live water contains most of the *punctipennis* and the bayou water the *guttulatus*. The following table shows the relative numbers of adults of each species collected in Carbondale from May to October, 1919.

	May	June	July	August	September	October
A. guttulatus.....	1	0	1	4		0
A. punctipennis.....	20	35	1	1		13

From this it would seem that the spring and fall results at Carbondale agree with those found in Alabama and South Carolina. The relation in July and August is doubtful, as not enough specimens were obtained for a definite conclusion. A point clearly brought out by the species table (p. 320) is the adaptability of *Anopheles punctipennis* to all types of breeding-places. Both in 1918 and 1919 it was found in all seven; and in June, 1918, and May and June, 1919, it was found in six of the seven types each month. *Aëdes taeniorhynchus* Weidemann has been recorded from Illinois by Dr. Ludlow, but Howard, Dyar, and Knab say that it does not occur in this state as it is supposed not to be found over forty miles from salt water. The species mentioned last in the list given on page 320 is very probably that recorded by Dr. Ludlow, but it is apparently different from *taeniorhynchus*. *Aëdes sylvestris* appears to be chiefly an early species. My records agree in this respect with the statement made by Howard, Dyar, and Knab:† "In the South the species [*Aëdes sylvestris*] partakes more of the character of an early spring species, the majority of the specimens developing early from over-

* U. S. Public Health Service, Pub. Health Bull. No. 79, pp. 11-17, by H. R. Carter, J. A. A. Le Prince, and T. H. D. Griffiths.

† "Mosquitoes of North and Central America," Vol. IV, p. 697.

wintered eggs; but this may be due to the fact that summers are drier, and favorable pools rarer, than they are in the North."

Survey Work in Murphysboro

My procedure in Murphysboro was similar to that at Carbondale. The leading physicians whom I interviewed gave two hundred to four hundred cases of malaria as their estimate for an average year. As the population is about eight thousand, this would mean that 2½ to 5 per cent. of the inhabitants are treated for malaria annually. A map of the township was traced, and all possible breeding-places were located; and examinations and collections were made, but, owing to other occupations, not very continuously throughout the season.

BREEDING-PLACES

Class I, Cattail Swamps.—No breeding-places of this type are near enough to affect Murphysboro. A large number which are in some respects similar, I am placing in a separate class (No. IX).

Class II, Marsh.—Not found in Murphysboro or immediate vicinity.

Class III, Ponds.—Railroad embankments very often form ponds by damming up water. One such pond, located close to the Brown shoe factory, I found to be a breeder of Anopheles. Pleasure and amusement parks may be mosquito-breeding grounds; and a few small ponds in the city park in Murphysboro contain Anopheles. In a ravine very close to the high school is a representative of this type (Fig. 11).

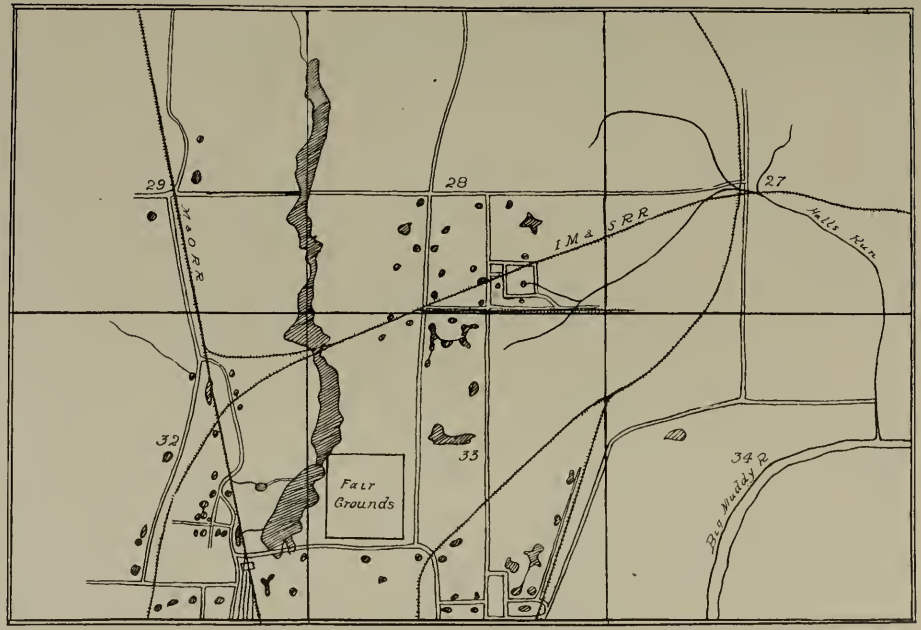
Class IV, Roadside Ditches.—This type is not noticeable in Murphysboro.

Class V, Streams.—Running through the city park is a slow stream (Fig. 12) with banks well covered with grass and affording ideal breeding conditions for Anopheles mosquitoes. The fact that the only park in town includes this stream is deplorable, as it probably accounts for much of the malaria. It should be remembered that a park is very often visited for picnics in the evening, when malarial mosquitoes bite.

Class VI, Open Drains.—One drain in the north end of town is responsible for the production of part of the Anopheles mosquitoes in Murphysboro.

Class VII, Lakes.—The situation at Carbon Lake, belonging to the Country Club of Murphysboro, is very similar to that at Thompson's Lake near Carbondale. Stecher's Lake is much more likely to breed Anopheles, especially because of its grassy edge (Fig. 13). Under the culvert at one end of the lake I was often able to make large collections of Anopheles adults.

Class VIII, Temporary Flooded Land.—This type is caused by overflow of the flats of the Big Muddy River, at the south edge of town. The high water lasts, however, for so short a time that I doubt whether many of the mosquitoes of Murphysboro can be traced to this source.



Sink-holes north of Murphysboro.

Class IX, Sink-holes.—The last permanent type is composed of breeding-places caused by the sinking of the ground over abandoned coal mines after the props have rotted down. These sink-holes fill with water, and grass and cattails spring up around the edges and sometimes in the center of the pond. Fig. 14 shows one of them. Fig. 15 was taken during the drouth of midsummer, 1919, when the water was everywhere very low. In many sink-holes the water-line had receded so far from the cattail growth that no protection was left for the mosquito larvae. As a consequence of this and of the concentration of predaceous insects and animals, there were practically no mosquito larvae in such situations. The significance of this fact will be brought out later under a discussion of control measures. The accompanying map shows the remarkably large number of these sink-holes (eighty in all) just north of Murphysboro. A considerable number are to be found in the vicinity of the Mobile and Ohio Railroad shops and yards, and Dr. O. B. Ormsby, of Murphysboro, told me that a rather high percentage of the railroad cases in town were malarial. While my work here could not be made continuous enough to warrant definite statements, these sink-holes are at least probably partly responsible for this condition.

Survey Work in Anna and Jonesboro

Two days in August, 1918, were spent in survey work at Anna and Jonesboro. Previous inquiries as to the average number of malaria cases per year brought surprisingly different replies, as follows: for Jonesboro, 300, 2,000, 50; for Anna, 2,000, 1,500, 150, 600. Only one of these physicians makes the blood tests, and this may account for the widely different estimates, as this is the only method of certain diagnosis. He estimated 600 cases in Anna. One of the oldest doctors there told me that most physicians believe that there is likely to be some malaria in every case they are called upon to treat.

Breeding-places.—A majority of the physicians and of other citizens interviewed expressed the opinion that most of the malarial mosquitoes in the two towns were bred in the bottom-lands of the Mississippi, and I think that this is a source of a part of them. It is a matter of common knowledge in Anna and Jonesboro that when the wind blows steadily from the west and southwest for about two days, swarms of mosquitoes are carried in from the lakes and sloughs in the bottoms. These invasions are always followed, the doctors all told me, by a marked increase in the number of malaria cases. The fact that the nearest of these bottom-land breeding-places is six miles from town will serve to show the distance which mosquitoes may be carried by the wind. It also appears to be a matter of common knowledge that since the recent drainage of many of the sloughs and lakes, the severity of these periodic attacks by mosquitoes has been greatly lessened. It should be remembered that many residents of Anna and Jonesboro go to the Mississippi bottoms to fish

and hunt, or to look after their farms, and that they may thus contract malaria away from the towns.

There are, however, other much closer, and probably more important sources of malaria. In both Anna and Jonesboro small streams running in and close to town contained Anopheles in considerable numbers, and I do not doubt that these are among the chief sources of mosquitoes. Ponds in the fair-grounds of both towns and two other small pools examined, also showed Anopheles, and it is quite likely that such places furnish most of the mosquitoes in the vicinity.

Survey Work at Scott Field, Belleville

Upon request of Captain Bayliss, principal medical officer at Scott Aviation Field, investigations of the mosquito situation around the camp were made in the summer of 1918. This field has been located very close to a large swamp, which at one point was only a quarter of a mile away. There was an abundant growth of vegetation to shelter mosquito larvae, and those of Anopheles were found in considerable numbers. The ordinary swamp-land growth (Fig, 16) of trees, brush, and weeds was quite rank, and arrowhead especially abundant. Owing to an excessively dry summer the swamp practically dried up later, and no further examinations of it were made.

Within a few rods of the field boundary is a slow stream (Fig. 17). This was breeding Anopheles, and they were even more abundant a little later when the stream was reduced by the drouth to a series of pools. There was no current at that time to hinder development, and there was grass enough around the edges for protection.

Scouting Work in other Places

General scouting work was done in and around Thebes and Cairo, and in Williamson county, and additional types of breeding-places were observed in these places. Some inquiries were made as to the extent of malaria, and some maps were made.

Control Measures

1. *Drainage.*—Beyond a doubt, drainage is the most effective measure for the control of mosquitoes, with the exception of those living in running streams; and the first step in a clean-up campaign is the elimination of standing water.

At Carbondale a special effort was made to bring this subject to the attention of those in charge of property containing standing water. The opinion of the surveyors that the cattail swamps north of town could be drained into a tributary of Crab Orchard Creek by a ditch a little over a quarter of a mile long was laid before the division superintendent of the Illinois Central Railroad Company at Carbondale.

The presence of Anopheles in the pond at the Normal School was brought to the attention of the president, and the subject of drainage was broached. Objection was made that the water might be needed in case of fire, and I then suggested cleaning the edges of the pond as the next most efficient measure of control.

The importance of draining the marsh near the negro school was impressed upon the president of the city Board of Health, and he took the matter up with the City Commissioners.

2. *Cleaning the Edges of Breeding-places.*—Where drainage is impracticable, the next most effective means is cleaning the edges of protective vegetation. While some species of mosquitoes do not seem to care particularly for shade and protection, those of the genus Anopheles do, and thrive much better in it. Insects, small fish, and other animals which prey upon mosquitoes, have a much better opportunity to find and catch the wigglers when the protecting growth is removed. That they may often be exterminated by such means I am satisfied from the examinations of the Murphysboro sink-holes in the dry months of 1918 already referred to and illustrated in Fig. 15. As has been suggested, this method is especially useful with small streams, which of course can not be drained, and on which the use of the third remedy (oiling) is difficult. Open drains through town, which are not at all uncommon in southern Illinois, if they can not be replaced by covered drains, should at least be carefully cleaned. They should be covered, if possible, as this both removes protection and usually prevents the laying of eggs. If drains must be left open through town their beds should be so graded that the water will not form pools in dry weather.

A special effort was made in Carbondale to advise the city authorities on this subject through the Board of Health, and during Health Promotion Week illustrated talks were made by the writer on the local situation and all phases of control. It should be remembered that the edges of a pond or ditch should not be cleaned just once, and then left for the plants to grow up again, but that they should be kept clean continuously. Neglect of this precaution was illustrated in Thompson's Lake when it was lowered eight feet to destroy a growth of pond-lilies and cattails troublesome in boating. Much of the growth was killed, but so many plants grew up again that Anopheles bred almost as abundantly as before.

3. *Oiling.*—Oiling may be used to smother the mosquito larvae in the water, in conjunction with cleaning operations. The surface film thus formed prevents the larvae and pupae from reaching the air necessary to their respiration. A rate of application commonly recommended is an ounce of oil to fifteen square feet of water surface. Prof. W. B. Herms, of California, finds that application of oil by the dipperful is very wasteful and uses a knapsack sprayer instead. Flowing streams may be oiled by means of drip cans so arranged that oil will drip from them at a rate of about twenty drops a minute. A mixture of kerosene with a heavy fuel oil, half and half, is better than pure kerosene, because it spreads

well, is lasting, and resists the wind, while kerosene alone is easily blown aside. Oiling should be done every twelve days during the heat of the summer, but less frequently in spring and fall, according to temperature, which determines the rate of mosquito development. However, if it is desired to control other mosquitoes than the malaria carriers, an application once a week is necessary. Vegetation should first be removed, if possible, from the edges of the breeding-places, because it prevents the maintenance of a perfect film. Especially when a wind blows the plants back and forth, the surface film can not be kept unbroken.

4. *The Use of Larvicides.*—A larvicide as used in mosquito control is a chemical put into the water and which mixes thoroughly with it to kill the larvae. It has been found satisfactory in some situations, especially in yellow-fever control work in the Canal Zone. The larvicide most commonly recommended is one tested out by the Ancon Hospital Board of Health Laboratory in 1911. The stock solution is made as follows:* "150 gallons of carbolic acid is heated in a tank to 212° F. Then 150 pounds of powdered or finely broken resin is poured in. Thirty pounds of caustic soda are then added, and the solution is kept at the same temperature until a perfectly dark emulsion without sediment is formed, constantly stirring after the resin is put in. One part of the emulsion to ten thousand of water is said to kill the larvae in less than one half hour, and one part to five thousand in five to ten minutes."

5. *Screening.*—Screening houses to keep out mosquitoes is very common, yet there are many houses, especially in the country, which are not protected by screens, and too frequently those used are torn, or do not fit tightly, really acting as traps, allowing the mosquitoes to get into the house but providing no exit which can be readily found. The malarial mosquitoes begin to bite at dusk, and if one keeps inside of a properly screened house in the evening, he is quite safe.

6. *Fumigation.*—Fumigation is of some value when mosquitoes get into a house or tent. In such cases burning powdered sulphur or a heap of pyrethrum powder should clear them out. Cresol, about four ounces to a thousand cubic feet of space, heated in a shallow vessel until vaporized, is often recommended.

7. *Use of Palliatives on Mosquito Bites.*—Those who are especially sensitive to mosquito bites will profit by recent experiments of Dr. H. E. Ewing.* He found rubbing helpful in diffusing the poison. Although it increased the itching at first it presently caused it to cease. Strong alcohol and strong ammonia were more useful than dilute alcohol, dilute ammonia, soap, or bay rum.

Summary

1. Malarial disease is common in southern Illinois, causing some loss of life and a large loss of time and money.

* Farmers' Bull. 444, U. S. Dept. Agr.
* "The Use of Palliatives for Mosquito Bites," Journ. Econ. Ent., Vol. XI, pp. 401-404.

2. Malaria is transmitted from man to man only by the bite of certain kinds of mosquitoes, which are common in the southern part of the state.

3. The larvae of these mosquitoes are found in all kinds of waters, but are most abundant in a fairly clean still water with an abundance of grass and weeds for their protection.

4. Control measures are (1) the drainage of breeding-places; (2) keeping the margins clear of vegetation; (3) maintaining a film of oil upon the water; (4) the use of larvicides for killing the larvae; and (5) the screening of houses. Additional, but much inferior, measures are (6) the fumigation of rooms to destroy adult mosquitoes; and (7) the use of repellents to drive them away. Palliatives may be used to diminish the effect of their bites.

PLATE XXXI

FIG. 1. Portion of cattail swamp.

FIG. 2. Near view of cattail growth.

PLATE XXXII

FIG. 3. Marsh; grass and weeds predominating.

FIG. 4. Open drain through Carbondale. Prolific breeder of malarial mosquitoes.

FIG. 5. Open drain through Carbondale. Mosquito-breeding abundant.

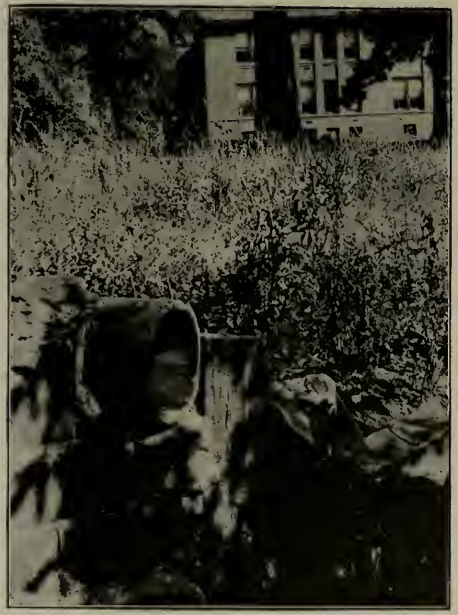


FIG. 6. Open drain through Carbondale. In neighborhood of school building.

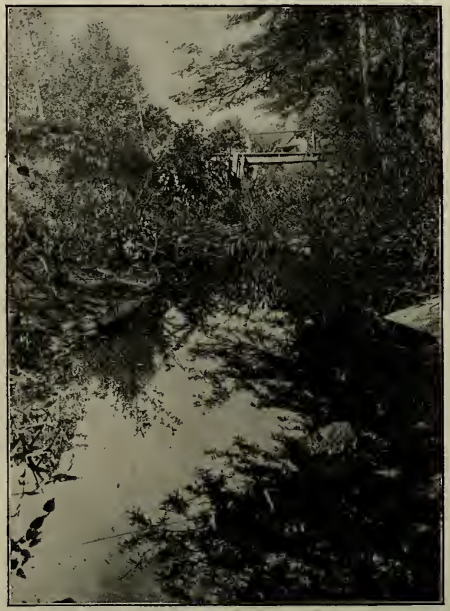


FIG. 7. The open drain shown in Fig. 6. Abundant growth of marginal vegetation.

FIG. 8. Pond on campus of State Normal School at Carbondale. Larvae of malarial mosquitoes found within twenty fect of dormitory shown in the picture.

PLATE XXXV

FIG. 9. Pond on Normal School campus, Carbondale, showing protecting vegetation around the edges.

FIG. 10. Thompson's Lake, showing protecting marginal vegetation.

FIG. 11. A pool in Murphysboro.

FIG. 12. Stream in city park at Murphysboro. Abundant protecting vegetation along the banks.

PLATE XXXVI

FIG. 13. Stecher's Lake, Murphysboro. The source of many of the malarial mosquitoes of the town.

FIG. 14. Sink-hole near Murphysboro, formed by sinking of the ground over abandoned mine.

PLATE XXXVIII

FIG. 15. Sink-hole in very dry weather. Edges clear of protecting vegetation.

FIG. 16. Swamp at Scott Aviation Field, near Belleville.

PLATE XXXIX

FIG. 17. Mosquito-producing creek, Scott Aviation Field, Belleville.