THE BIOLOGY AND DISTRIBUTION OF THE ROCKPOOL MOSQUITO, *AEDES ATROPALPUS* (COQ.)[1]

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INTRODUCTION. The rockpool mosquito is of interest and importance for several reasons. In the laboratory it is a known vector of organisms pathogenic to man. In the vicinity of its breeding habitat it is a persistent and annoying species, biting freely during the day. The distribution and biology of the species have not been well studied. The systematic relationships of the species are not clear; in fact, it is possible that this insect may prove to be a species complex. No detailed study of the habitat, i.e., rockpools, had been made. It has been difficult, if not impossible, to separate the instars of field-collected larvae.

For all of these reasons, it was concluded that an investigation of the biology and distribution of *Aedes atropalpus* would be fruitful. The studies were begun in 1956 and concluded in 1960. From July 1, 1956 to June 30, 1957 funds from U. S. Public Health Small Grant E1351 supported the work of the project.

During the course of the investigations, thousands of specimens were collected and several hundred were reared. Some 650 specimens were prepared as permanent mounts.

GEOGRAPHICAL DISTRIBUTION. Carpenter and Lacasse (1955) recorded *Aedes atropalpus* from Labrador to El Salvador. It extends from the eastern seacoast to Minnesota, Kansas, Missouri, Oklahoma, Texas and Arizona. In addition, Dyar, 1928, had reported this insect from Costa Rica and Nicaragua. Rees and Nielsen, 1955, recorded *Aedes atropalpus* from Utah. Pratt (1957) collected what he considered to be *Aedes atropalpus epactius* from Guatemala City, Guatemala. There are no published records of the presence of this mosquito along the Pacific coastal area of the United States, and correspondence with specialists indicated no knowledge of its occurrence on the West Coast.

The available records in many instances are far from specific. It was considered that detailed records indicating spatial and seasonal distribution would be valuable. The following represent new records obtained or first reported during these investigations.

Canada:—Cooper, Ontario, August 1955; Vockeroth, Tadoussac, Quebec, August 1939; Smith, Norway Bay, Quebec, August 1938; Shewell, St. Gideon, Quebec, July 1939, Smith.

Guatemala:—Guatemala City, October 1957, Pratt.

United States: Maine—Along shore (Anemone Cave—Otter Cliff), Mt. Desert Island, May–October, Shaw; Bernard, July 1956, Shaw; Popham Beach, 1956, Shaw; Salmon Falls, Saco River, 1939, Hanson; Baxter State Park, July 1948, Smith; Goose Rock, July 1956, Shaw.

New Hampshire: North Munroe, April, August 1956–57, Shaw; Woodsville, April, August 1956–57, Shaw.

Vermont: East Barnett, April–October 1956, Shaw; Passumsic, August 1956, Shaw; Halifax Gorge, Halifax, August 1956, Shaw; Route 103 near Ludlow, August 1956, Shaw and Lavigne.

Massachusetts: Charlemont, September 1934, Mass. Mosquito Survey; Chesterfield Gorge, Chesterfield, May–October 1957, Shaw and Maisey; Cohasset, August 1958, Wells; Florence, May 1957, Shaw and Maisey; Green River, Colrain, 1956, Shaw; Hull, 1955, Wells; Huntington, August 1957, Maisey; Loudville, April–November, 1956–58, Shaw and Maisey; Rockport, Au-

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gust 1957, Smith; Scituate, 1955, Wells; Turner's Falls, August 1957, Maisey; Waconah Falls, Dalton, September 1956, Shaw; Windsor Jams, Windsor, September 1956, Shaw.

New York: South Inlet, Webb, May 1951, Jamnback.

Maryland: Gunpowder River, Baltimore Co., May 1956, Craig.

Georgia: Milledgeville, Pratt; Tallulah Gorge, March 1950, Cole and Wall.

Texas: Onion Creek, Travis Co., September 1943, D.E.E.

Since this species frequently occurs in the vicinity of waterfalls and since there are commonly towns or cities near such locations, it is likely that *Aedes atropalpus* causes much more annoyance than is generally believed.

BIOLOGICAL OBSERVATIONS. *Aedes atropalpus* is multiple-brooded. In Loudville, Massachusetts (elevation approximately 400′), larvae have been collected from April 5 to November 13. In Chesterfield, Massachusetts (elevation approximately 700′), larvae were collected from May 9 to October 20. At East Barnett, Vermont, larvae were taken from April 7 to October 12. Larvae have been collected from Mt. Desert, Maine, from May 12 until October 22. It has been noted that the first instar larvae can be found in rock pools about the time when pussy willows and soft maples come into bloom.

Under field conditions in Massachusetts, it was observed that the larvae would develop from egg to the fourth instar in 22 days in late April and early May. During late May and early June, the same development required about 11 days. In July, development from the egg to the pupal stage was completed in 14 days. As cold weather approaches, the length of the developmental period increases, thus only fourth instar larvae and pupae were collected between October 16 and November 8, 1958. It is believed that this species overwinters only in the egg stage in this area.

Newly hatched larvae were segregated and reared at room temperatures during July and August. The length of the developmental period varied from 12–17 days with a mode of 13. The first two instars each required 2 to 3 days with a mode of 2 days, the third instar required 2–3 days with a mode of 3 days, and the fourth instar 4–5 days with a mode of 4. The pupal stage required from 2–3 days with a mode of 2.

The insects were reared from newly hatched larvae to the adult stage at constant temperatures of 60°, 70°, 80°, 90° and 93° F. Attempts to rear larvae at temperatures of 40° and 50° F. were not successful. A summary of the results is given in Table 1.

TABLE 1.—Relationship of temperature to length of development from newly hatched larva to adult stage of *Aedes atropalpus*

Temperature ° F.	Length of development in days
60	31
70	17.2
80	11
90	8.1
93	7.7

It was concluded that the threshold of development was between 40° and 50° F. and that the optimum was in the vicinity of 90°. It will be noted that a shorter developmental period occurred at 93° F. but approximately 20 percent fewer insects emerged than at 90°.

In an attempt to determine the sex ratio and whether or not both sexes emerged at the same time, 25 fourth instar larvae and 25 pupae were segregated. From these, 38 adults emerged, of which 20 were males and 18 were females. The males emerged in greater numbers at first, thus by the second day of the pupal period 12 males but only 5 females had emerged.

In another study, 119 pupae were collected in the field. From these 95 females and 24 males were reared. It is possible that some of the males had already emerged by the time the collection was made.

Attempts to induce oviposition were not very successful. In the few instances where the females oviposited, it was noted that the period from emergence to oviposition was from 5–7 days. Some eggs were deposited by females in the laboratory, but the bulk of the eggs was collected in the field or obtained from Dr. George Craig.

In nature, the insect overwinters in the egg stage. The factors causing hatching are not known but it is believed that temperature must be related to hatching. When eggs are recovered in the field and brought to the laboratory, they usually hatch within 2–4 days.

Effects of Some Ecological Factors. In order to determine the effects of some of the physical factors in the environment on the immature stages of the rockpool mosquito, certain measurements were made.

The temperatures of the water in the rock pools, of the rock surface adjacent to the pools and of the air were recorded. Larvae were found in water at temperatures as low as 40° F. and as high as 96° F. Temperatures of the rock surfaces near the pools ranged from 60°–116° F.

To determine the influence of salinity, samples of water from the rock pools were taken to the laboratory. Using the Mohr test, the salinity was found to be 0.6–2.5 ppm. Unfortunately, samples of water from rock pools near the ocean were not analyzed. Undoubtedly these would have had a higher salinity.

Samples of water were analyzed for oxygen and carbon dioxide. They were found to average 7.3 and 3 ppm respectively.

During the greater part of the investigations, the acidity or alkalinity of the water was determined using Hydrion pH test papers. By this means, pH was found to vary from 3.5–5.5 with a mean of 4.3. During the latter part of the studies, it was possible to determine the acidity or alkalinity using a Beckman pH meter. By this means the pH was determined to lie between 6.4 and 7.5 with a mean of 7.07.

While making collections of larval *Aedes atropalpus* several other insects were noted. Most of these were species of mosquitoes, but predacious diving beetles and dragonfly naiads were also found. It is believed that both of these latter forms prey on *Aedes atropalpus,* since it has been noted that where these occur the larval populations of the rockpool mosquito were relatively low.

Our observations on the insects associated with larval rockpool mosquitoes are summarized in Table 2.

TABLE 2.—Organisms found living in association with *Aedes atropalpus*

Name of organism	Number of observations
Culex restuans	16
Culex pipiens	7
Culex territans	5
Anopheles punctipennis	7
Aedes canadensis	1
Aedes vexans	1
Chironomidae	3
Dytiscidae	2
Odonata naiads	2
Cyclops	4

It was observed that *Aedes atropalpus* appeared to thrive in water containing green algae, probably *Spirogyra.* In fact, larvae were observed to feed on this plant.

Most of the rock pools contained residues of decomposing leaves, twigs and other organic matter. These materials, together with the bacteria and protozoa associated with them, are believed to be the major sources of food for this mosquito in nature.

Biometrical Observations. Shaw made measurements of the various structures of 220 mounted larvae. He found the siphonal index to vary from 1.59–3.33 with a mean of 2.16. The width of the head capsule varied from .825–1.095 mm with a mean of .965 mm. The number of pecten teeth varied from 11–29 with a mean of 21.2. The number of comb scales was found to vary from 14–64 with a mean of 36. Both the upper and lower head hairs were single in all but two instances. In these the left hairs were two-branched. The number of branches of the antennal hair varied from 1–6 with a mode of 3 and a mean of 3.9. The siphonal tuft was found to be within the pecten in all but two instances, the number of teeth beyond the tuft varying from 0–4 with a mean of 2.6 and a mode of 2.0.

Maisey concluded, as a result of the measurement of 249 field-collected, unmounted larvae, that widths of the head capsules of the four instars of *Aedes atropalpus* were as follows (Table 3):

TABLE 3.—Head width of *Aedes atropalpus*, in mm

Instar	Mean	Range
1	.285	.252– .322
2	.442	.389– .489
3	.707	.616– .784
4	.980	.819–1.170

He also determined the width of siphon of 254 field-collected larvae as follows (Table 4):

TABLE 4.—Width of siphon of *Aedes atropalpus* in mm

Instar	Mean	Range
1	.075	.056–.102
2	.127	.111–.153
3	.219	.154–.263
4	.346	.266–.529

He determined the length of siphon of 250 field-collected, unmounted larvae to be as follows (Table 5):

TABLE 5.—Length of siphon of *Aedes atropalpus* in mm

Instar	Mean	Range
1	.085	.046–.112
2	.239	.168–.311
3	.412	.378–.448
4	.666	.462–.868

The siphonal index (length of siphon to its width) has been determined from Maisey's data to be as shown in Table 6.

TABLE 6.—Siphonal index of larvae of *Aedes atropalpus**

Instar	Mean index
1	1.13
2	1.88
3	1.88
4	1.92

* Based on mean widths and lengths of the siphon.

Carpenter and LaCasse indicate that the siphonal index varies from 1.6–2.0. Shaw found it to vary from 1.46–3.33 with a mean of 2.14, on the basis of measurements of larvae mounted on slides. Maisey's determinations based on the measurement of unmounted larvae indicate a mean of 1.13 for first instar and 1.92 for fourth instar larvae. It appears that measurements based on specimens mounted on slides are much more variable.

OBSERVATIONS ON THE VENTRAL BRUSH. In 1902, Dyar claimed that the fourth instar could be distinguished from the third and second by the ventral brush being confined to the barred area. The problem of the more proximal hairs in the ventral brush is a puzzling one, and various workers have not been consistent in their use of this term. Stone, Breland and Bohart, in their definitions of this term, have omitted reference to the proximal hairs of the ventral brush which may or may not have sclerotized bars but are detached from the lateral sclerotizations. Belkin, however, in his definition considers the detached hairs to be outside the barred area and states that they have a very small basal sclerotization which is not extended as a transverse bar. In this investigation, observations disclosed that usually the detached hairs of the third and fourth instar larvae have transverse bars. In addition, in most second instar larvae the hairs of the ventral brush have transverse bars but lack lateral sclerotizations.

Table 7 shows the results of observations made on the barred area of second, third and fourth instar larvae.

These results prove that the confinement of the ventral brush to the barred area cannot be used as a reliable criterion to distinguish 4th instar larvae from those of the 2nd and 3rd instars. Hence Dyar's supposition is repudiated.

It had been hoped that during this study some conclusions could be drawn concerning the validity of the two races *Aedes atropalpus atropalpus* and *Aedes atropalpus epactius* as recognized by Dyar in 1928. However, only a limited number (10) of specimens of the western race (*A. atropal-*

TABLE 7.—Distribution of Ventral Brush on the Barred Area

Larval instar	Confined	Not confined	No. of specimens observed
		Reared Larvae	
2nd	1	24	25
3rd	9	13	22
4th	20	1	21
		Field-Collected Larvae	
Larval instar	Confined	Not confined	No. of specimens observed
2nd	0	35	35
3rd	37	13	50
4th	52	3	55

pus epactius) were available. Through the kindness of Dr. Harry D. Pratt, four specimens of what were considered to be *epactius* from Guatemala were made available.

The width of the head capsules, length and width of the siphon, and the siphonal index of specimens from Texas, Guatemala and the northeastern United States were compared. With the exception that the size of the Texan and Guatemalan specimens was larger and the siphonal index less than in the material from the Northeast, the measurements seem to overlap. Due to the few specimens available of *Aedes atropalpus epactius,* it is unwise to attempt to draw conclusions at this time.

Summary and Conclusions

1. *Aedes atropalpus* (Coq.) is multiple-brooded. In Massachusetts, the immature stages have been recovered from early April to mid-November.

2. At room temperatures, the developmental period from newly hatched larvae to adult varied from 12–17 days with a mode of 13.

3. Based on rearing experiments in the laboratory, the threshold of development appears to be between 40°–50° F. and the optimum about 90° F.

4. Temperatures in rock pools during periods when *Aedes atropalpus* was developing ranged from 40° to 96° F. Temperatures of the rock surface near the pools varied from 60°–116° F.

5. The siphonal index based on measurements of mounted specimens ranged from 1.59–3.33 with a mean of 2.16. Similar measurements of unmounted specimens indicate means of 1.13, 1.88, 1.88 and 1.92 respectively for 1st, 2nd, 3rd and 4th instar larvae.

6. Dyar's hypothesis that the 4th instar larvae of *Aedes atropalpus* can be distinguished from earlier instars by the confinement of the ventral brush to the barred area is untenable.

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