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INSECT AND OTHER FAUNA ASSOCIATED WITH THE ROCK POOL MOSQUITO *AEDES ATROPALPUS* (COQ.)

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Introduction. Although the rock pool mosquito, *Aedes atropalpus* (Coq.), is widely distributed in North America (Carpenter and LaCasse, 1955), it normally breeds only in rock pools along streams near rapids and waterfalls. It is a persistent biter near the breeding sites and is also a potential vector of pathogens of man and birds (Jakmaugh, 1940; Trembley, 1946). In Texas, Hedeen (1953) reported it from tree holes in hackberry, and Strom *et al.* (1960) stressed the importance of artificial containers, such as discarded aircraft tires, as a potential for disease transmission.

Though much has been published on its biology, little is known of its ecology, especially of relationships with other invertebrates in the normal breeding pools, except for observations made by Shaw and Maisey (1961). The present paper gives ecological data obtained in 1961 in investigation of an extensive breeding area at Cordova Mines, Ontario. Erosion of the precambrian bedrock by the Crowe River at this point produced many rock pools that are well populated with mosquito larvae throughout the summer and autumn.

Methods. Fifteen numbered pools from approximately 0.01 to 0.7 sq. meters in area were examined twice weekly from May 15 to November 15 for ten minutes or more each, to determine the presence of mosquito stages and those of other invertebrates. Specimens were collected for identification by means of a fine-meshed sieve 7.5 cm. in diameter or with a pipette. They were either preserved in 80 percent alcohol or reared to the adult stage in the laboratory.

The numbers of mosquitoes and associated invertebrates were investigated in ten additional pools of about the same sizes. Sampling was not feasible because of surface irregularities at the sides and bottom of the pools. Population data were obtained directly by taking a census: the pool was completely emptied, all macroscopic animals were collected for identification and counting, and the total water volume determined.

The feeding capacity of the predacious water-beetle, *Laccophilus maculosus* Germ. was determined in six series of pint Mason jars. Five series each comprised 5 jars and 1 control, and one series had 2 jars and 1 control. Each jar contained 400 ml. of strained pond water and was set up either with 25 early-instar larvae of *A. atropalpus,* 25 midge larvae, or with equal numbers (12) of midge and mosquito larvae (control, 12 midge + 12 mosquito larvae). The immatures in all jars but the control were then reared from three to five days with one adult or one mature larva of the predator.

MOSQUITO FAUNA OF THE POOLS. *Aedes atropalpus* was the most ubiquitous of four culicids found: its larvae occurred in all except a few small pools. However, no larvae were found before the spring break-up, though the temperature in thawed rock pools reached 35° F. on March 7. It is unlikely that any larvae were actually present, as Shaw and Maisey (1961) were unable to rear larvae at 40° and 50° F. Most of the pools, except those high up on the river bank, were completely submerged during spring flooding and did not contain larvae until isolated from the river at the end of May. Temperatures in unshaded pools ranged from 55° F. on May 31 to 93° F. on August 9. As this species is multibrooded in this area, larvae were found as late as October.

Larvae and pupae of three other mosquitoes, *Culex territans* Walk., *Culex restuans* Theob., and *Anopheles punctipennis* (Say), were found with the rockpool mosquito in that order of appearance. *C. territans* was not observed after August 20, but larvae of the other two species were found as late as November 10. Of 25 pools under observation, *A. punctipennis* occupied 15, *C. territans* 8, and *C. restuans* 5, but populations of the last were higher than those of either of the other two.

OTHER INVERTEBRATES. The numbers of species and (in parentheses) of specimens of invertebrates other than mosquitoes found in the rock pools were: Annelida 2 (102); Mollusca 2 (7); Arthropoda, total subclassified as Crustacea 6 (354), Insecta 30 (1296), and Arachnida (Pisauridae), 1 (6). The Insecta were: Ephemeroptera 3 (552); Odonata 1 (2); Hemiptera 4 (11); Trichoptera 1 (1); Coleoptera 16 (176); Diptera 5 (554). Many species were found during the regular inspection of the pools, but the greater number was obtained in the census counts, especially in the large pools. As a census was not taken in every pool the total list must be regarded as incomplete. All insects were immature when collected with the exception of species of Coleoptera, Hemiptera, and Diptera.

Crustaceans were represented by the amphipod *Hyalella azteca* Sauss. and by the small Entomostraca *Daphnia pulex* Leydig, *Eurycercus lamellatus* Müller, and *Simocephalus serrulatus* Koch. These were abundant in two large pools and undoubtedly competed with mosquito larvae for microplankton.

Aquatic insects included 11 predacious beetles of the family Dytiscidae and 5 Hydrophilidae, as follows:

DYTISCIDAE

Acilius mediatus (Say)
Bidessus affinis Say
Desmopachria convexa (Aubé)
Hydroporus sp.
Hydroporus dentellus Fall
Hydroporus niger (Say)
Hydroporus paugus Fall
Hydroporus tristis (Payk.)
Hydroporus striola (Gyll.)
Hygrotus impressopunctatus (Schall.)
Laccophilus maculosus (Germ.)

HYDROPHILIDAE

Berosus sp.
Enochrus sp.
Hydrobius fuscipes L.
Laccobius sp.
Tropisternus natator d'Orch.

The majority of the Coleoptera were larvae and adults of the small dytiscid

Laccophilus maculosus, which was abundant. Adults of this predator were present in the large pools from June 27 to September 21. In one instance the larvae were observed feeding on red chironomids; in the laboratory they fed on chironomid larvae as well as early stage larvae of the rock pool mosquito. First-stage larvae of the predator were found also close to Black River, near Cooper, Ontario, on June 25. These larvae were reared in the laboratory on small mosquito larvae and *Daphnia* and completed their development to the adult stage at 24° C. in 28 to 32 days. According to Wilson (1923) both larvae and adults are excellent swimmers and are particularly predacious on dipterous larvae in fishponds. Zimmerman (1960) pointed out that the mature larvae, after leaving the water, are adept in running over the ground in search of a place to pupate. They would probably have no difficulty, therefore, in leaving rock pools, even those with vertical sides.

Mature larvae of *L. maculosus* were collected on September 24. This implies that either a second generation occurs in this area or that such larvae develop from late broods.

Shaw and Maisey (1961) found Dytiscidae, Odonata, and Chironomidae associated with the rock pool mosquito in Massachusetts. In their opinion, the predacious diving beetles were responsible for the low larval populations in some pools.

Two pools were found covered by brood-webs of a water spider, *Dolomedes* sp. (Family Pisauridae), and one web contained chironomid remains. Bristowe (1941) stated that adult pisaurids feed extensively on Nematocera near the ground.

VERTEBRATES. Seven vertebrates were either collected from or observed in the rock pools, though such animals belonged more to the river than to the rock pool fauna. Among these were two fishes: creek chub, *Semotilus atromaculatus* Mitchill, and blacknose dace, *Rhinichthys atratulus* (Hermann); the northern water snake, *Natrix sipedon sipedon* (Linné); and two small snapping turtles, *Chelydra serpentina* (Linné). Amphibia were represented by the pickerel frog, *Rana palustris* Le Conte; the leopard frog, *Rana pipiens* Schreber; and the green frog, *Rana clamitans* Latreille, which was the most abundant.

MOSQUITO POPULATIONS. The population levels of mosquito larvae and pupae and associated arthropods were obtained from the census counts. In Table 1 these data are arranged to compare the population densities of larvae and pupae of the rockpool mosquito and of *Anopheles punctipennis* with that of the predator *Laccophilus maculosus.* The results are shown also in order of decreasing water volume and pool area (not included). During late July and early August, when the pools were censused, pools 1 to 3 were approximately 0.5–0.8 sq. meters in area; pools 4 to 8 averaged 0.2–0.3 sq. m., and the remainder about 0.1 sq. m.

TABLE 1.—Numbers of mosquito larvae and pupae and *L. maculosus* per liter in a census of 10 pools.

Pool		*Aedes*	*Anoph.*	*Laccophilus*	
No.	Vol. (L)	*atro.*	*punct.*	Adults	Larvae
1	32.2	0.03	0.3	0.1	8.1
2	25.3	0.4	0.0	0.2	3.6
3	8.3	1.3	7.4	0.1	2.8
4	4.4	54.8	0.2	0.2	0.0
5	3.4	0.0	4.1	0.0	0.0
6	2.6	59.5	0.4	0.0	0.0
7	2.5	8.1	0.0	0.0	0.4
8	2.3	11.0	0.0	0.0	0.0
9	1.0	12.4	0.0	0.0	0.0
10	0.9	59.0	0.0	0.0	0.0

It is evident that *Aedes atropalpus* occupied a wider range of pools than did *Anopheles punctipennis;* moreover the large pools, except No. 7, contained few *A. atropalpus* but high breeding populations of *Laccophilus.* It should be pointed out, however, that two pools also contained abundant larvae of other mosquitoes: pool 1 contained 19.1 larvae and pupae per liter of *Culex restuans;* and pool 3, contained 7.4 per liter of *Anopheles punctipennis.* The differences in populations of the three species are attributed to their feeding behaviour. Larvae of the rock pool mosquito are bottom feeders and hence would be relatively more vulnerable to *Laccophilus* whose larvae crawl over the bottom and sides of the pools. On the other hand, *Culex* and *Anopheles* larvae feed largely at the surface film where there would be fewer contacts with such predators.

Chironomid and mayfly larvae were also scarce in pools 1 to 3, which contained larvae of *Laccophilus.* Here, for example, the number of chironomids ranged from 0.7 to 9.0 (mean 4.2)/l. as compared to 0.0 to 72.3 (mean 18.4)/l. in the remaining pools. However, they would be alternate prey that would aid in maintaining the predator when mosquito larvae and other prey were scarce.

EFFICIENCY OF LACCOPHILUS MACULOSUS AS A PREDATOR. Laboratory and field tests showed that *L. maculosus* will feed on larvae of the rock pool mosquito and is capable of reducing their number in a pool. In the laboratory, female beetles destroyed more larvae than did the males, and under similar conditions females alone eliminated chironomid larvae within 24 hours (Table 2). When equal numbers of mosquito and chironomid larvae were exposed together, a similar number of each were eaten but the mosquito larvae were eaten first, probably because they were in more frequent contact with the predator.

The larvae of *L. maculosus* were also predacious. In one test 80.6 percent of the chironomids were eaten and in another a similar high mortality resulted when both midge and mosquito larvae were exposed together. The loss of midges in the controls appears to be due to cannibalism. In general, the larvae were less effective than the adults as predators, probably because they were unable to retain a footing in a glass container.

Predator larvae were also tested in a small rock pool from which all macroscopic animals were removed. The original water (5.2 liters) was strained and returned to the pool and 100 early-stage larvae of *A. atropalpus* and 3 third-stage predators were introduced. In a census taken five days later three predators and 65 mosquito larvae were recovered. Assuming that there were no losses to other predators, e.g., shore birds, then each predator destroyed a mean of 2.3 larvae per day.

The results of the above tests, together with the observed low population in the large pools suggest that *L. maculosus* plays a significant part in regulating the numbers of the rockpool mosquito.

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TABLE 2.—Results of feeding tests with *L. maculosus,* using mosquito and midge larvae as prey.

Stage of predator	Prey Species	Prey No.	Prey destroyed No.	Prey destroyed %	Prey lost in control	Mean no. of prey lost per predator in 24 hrs.
Adult (♀)	*A. atropalpus*	125	117	93.6	12.0	4.7
Adult (♂)	*A. atropalpus*	50	37	74.0	8.0	3.7
Adult (♀)	*Chironomus*	125	125	100.0	20.0	5.0
Adult (♂)	*A. atropalpus*	60	59	98.3	16.7	2.36
	Chironomus	60	60	100.0	66.7	2.4
Larva	*A. atropalpus*	60	49	81.6	0.0	1.96
	Chironomus	60	53	88.3	41.7	2.1
Larva	*Chironomus*	125	108	80.6	28.0	4.3

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RESULTS OF INSECTICIDE RESISTANCE TESTS AGAINST LARVAE OF *CULEX PIPIENS QUINQUEFASCIATUS* SAY IN BRITISH GUIANA

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The six insecticides in the World Health Organization kit for determining susceptibility or resistance of mosquito larvae to insecticides were tested against 3rd and 4th instar larvae of *Culex pipiens quinquefasciatus* in Georgetown, British Guiana, using the standard procedure (Brown, 1958). The larvae were obtained from pit latrines in Newtown, Kitty, on the outskirts of Georgetown. Stock solutions provided with the kit were diluted so as to give solutions of 0.0008, 0.004, 0.02, 0.1, 0.5, and 2.5 p.p.m. of DDT, dieldrin, BHC, diazinon, malathion, and Baytex. Each test bowl contained 25 larvae in natural water, and two control bowls accompanied each complete test, of which there were five replicates. Mortality readings were taken at varying intervals up to 24 hours following introduction of the larvae. The figures for dead and mori-

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