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By

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Some Natural Enemies of Mosquitoes in the Vicinity of Palmalmal, New Britain.

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Introduction.

Observations on the value of various aquatic animals as agents in the natural control of the Culicidae, were made in the course of a mosquito survey at Jacquinot Bay R.N.Z.A.F. Station, New Britain, during 1945.

At Palmalmal, Jacquinot Bay, it was observed that water bodies which outwardly bore a close resemblance to one another often held mosquito populations of markedly different constitution. When the mosquito faunas of two outwardly similar water bodies were compared, differences between them were often apparent both in the actual species present and in the relative number of individuals representing some particular species. While some pools held many larvae and pupae of Culicidae, others contained but few of these insects. There were pools that were quite uninhabited by mosquitoes, although superficially they seemed ideal mosquito breeding places.

Water bodies studied ranged from artificial temporary pools, such as those in wheel-ruts of recent origin, to natural permanent pools. Those which by reason of their temporary nature had no macroflora or predacious macrofauna often supported heavy populations of *Anopheles punctulatus* Dönitz (Laird, 1946b). Many kinds of aquatic insects inhabited longer-established pools, which generally supported a diverse macroflora. The composition of the macrofauna seemed to have an important bearing on the numbers and species of Culicidae present in such pools. Extreme cases were encountered where pools with heavy populations of other aquatic animals harboured no mosquitoes at all.

Much has been written on the subject of mosquito enemies. Some writers, like Howard (1900), claim that little practical importance can be attached to such enemies. This view has to be somewhat modified in view of the subsequent realization of the value of certain surface-feeding fish, such as top-minnows of the genus *Gambusia,* as agents in the biological control of anopheline mosquitoes (Van Dine, 1907; Hildebrand, 1921). Hamlyn-Harris (1929) sums up the position by declaring that: "The idea of controlling mosquitoes by means of their natural enemies sounds so exceedingly attractive that many are tempted to place an unwarranted amount of confidence in what has rarely proved to be of any great value. That natural enemies, under natural conditions, are capable of taking a large toll of mosquito life cannot be denied, and for that reason alone they are worthy of considerable encouragement." After commenting on the presence of many natural factors operating against the undue preponderance of most larval destructors, Hamlyn-Harris stresses the importance of our gaining a thorough knowledge of the natural enemies of mosquitoes in order to be able " to apportion them as opportunity affords, and to prevent their ruthless destruction due to ignorance."

The results of an investigation into the significance of various arthropods and of a few animals of other groups as factors in the natural control of mosquitoes at Palmalmal, are discussed in the following pages.

Most of the aquatic animals mentioned in this paper were captured with the aid of a small dip-net. Very small creatures were caught with a long-handled 250 cc. dipper in the same manner as mosquito larvae, and were transferred to the collecting bottle by means of a pipette.

Some difficulty was at first experienced in capturing water-striders, particularly the larger Gerridae, when these insects inhabited pools too shallow to admit a dip-net. It was subsequently found that the capture of such insects was rendered easy if they were first anaesthetized by spraying a little ether on the water surface.

Field estimations of hydrogen-ion concentrations were made with nitrazine indicator paper. This paper covers a range of pH 4·5 to pH 7·5, and allows estimations to be made to within 0·5 of a pH.

A light wooden press was used for the preparation of plant specimens. The extremely high humidity experienced during the survey favoured the rapid growth of moulds, and the satisfactory preservation of such specimens was thus rendered difficult.

Whenever opportunity afforded the press was hung out in the sun to dry. The newspaper used to aborb moisture from the drying plant material was changed as soon as it showed signs of dampness. When thoroughly dry the specimens were sprinkled with thymol and stored in a metal ammunition box containing silica gel as a dessicant. These steps served to keep plant specimens in fit state for identification.

MacGregor's solution (MacGregor, 1924b) proved a most satisfactory preservative for small aquatic animals. Lightly-chitinized delicate forms remained in excellent condition in this medium. Store-boxes holding insects preserved as dry mounts were impregnated before use with naphthalene dissolved in chloroform and thymol dissolved in alcohol. This treatment kept stored specimens free from mould, and excluded such pests as ants and mites from the boxes.

Some trouble was experienced in making permanent mounts of material for microscopic examination. The heat was such as to prevent Canada balsam from setting, and the high humidity made it hard to keep alcohol and xylol free from water. The following technique was developed to overcome the first of these difficulties. Discs of light glazed card were cut to the size of the coverslips used when making permanent slides. From one to three holes were pierced in each card disc with a 9/32 in. cork borer. The prepared cards were then fastened to glass slides with a thin smear of gum. In mounting, each of the cells so formed was filled with balsam, and a specimen was positioned in it. The cover slip was then applied, so that its rim coincided with that of the card disc. The latter materially increased the friction between cover slip and slide, thus preventing damage to the mount by movements of the cover slip in handling. At the same time it kept the weight of the cover slip from crushing the preparation. Slides prepared in this manner were much more convenient to handle than those made in the usual way.

A collection of the aquatic predators discussed in the following pages has been deposited at the Cawthron Institute, Nelson, New Zealand.

My thanks are due to Major-General Sir Fred Bowerbank, D.G.M.S. (Army and Air), Wing Commander Howard Marsh, R.N.Z.A.F., D.M.S. (Air), and Professor L. R. Richardson, of Victoria University College, for encouragement and assistance in the preparation of this paper; to the Royal Society of New Zealand, the New Zealand Department of Health, and the Cawthron Institute, for generous library facilities; to Professor J. Balfour-Browne, of the British Museum (Department of Entomology), for identifying the aquatic Coleoptera; to Mr. H. Womersley, Entomologist at the South Australian Museum, for his identification of the water-mite *Limnesia jamurensis* Oudemans; to Mr. R. R. Forster, of the Dominion Museum, Wellington, for his generic identification of the Araneida; and to Messrs. V. D. Zotov and A. J. Healy, of the Botany Division (N.Z.D.S.I.R.), for their identification of botanical material collected at Palmalmal.

I.—PREDATORS OF AQUATIC STAGES OF CULICIDAE.

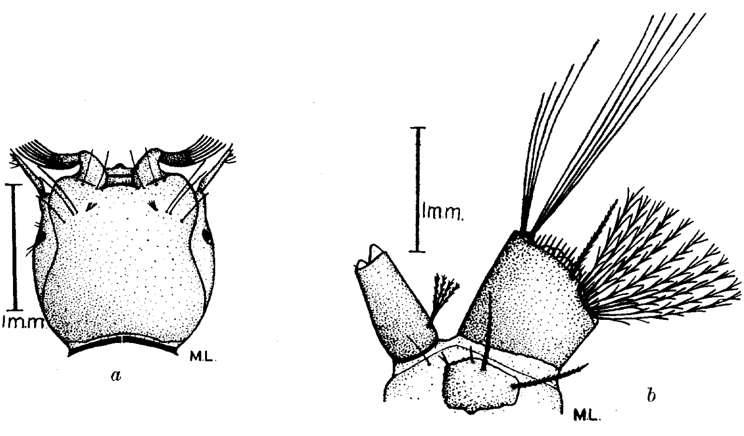
Class INSECTA.

Order DIPTERA.

Family CULICIDAE.

Megarhinus inornatus Walker, 1865. (Text-figs. 1a, 1b.)

Pre-adult stages of *Megarhinus inornatus* inhabit coconut husks and small artificial containers. The condition of the water in which



TEXT-FIG. 1.—*Megarhinus inornatus*, fourth instar larva. *a*, Head. *b*, Terminal abdominal segments.

development takes place varies from fresh and clear to murky and heavily charged with organic debris (Laird, 1946a). Tests of the water from several breeding places at Palmalmal showed hydrogen-ion concentrations ranging from pH 5·5 to pH 7·0. The species was only encountered in places heavily shaded by vegetation, and its breeding places were generally located just within the edge of the jungle which bordered the station.

Simple laboratory experiments were performed to investigate the importance of *M. inornatus* as a larvicidal agent. A single fourth instar *Megarhinus* larva was placed in each of eight 250 cc. beakers. These containers each held 5 cm. (approximately 160 cc.) of water from a natural breeding place of the predacious mosquito. Known numbers of both larval and pupal stages of three other mosquito species which showed habitat preferences like those of *M. inornatus* were added to each of these beakers.

Twenty late instar larvae of *Aëdes albolineatus* (Theobald, 1904) were isolated in containers 1a and 1b. A similar number of fully-developed larvae of *Aëdes scutellaris* (Walker, 1859), and of *Armigeres lacuum* Edwards, 1922, were added to containers 2a, 2b, and 3a, 3b respectively. Twenty pupae of a mixture of all three species were placed in containers 4a and 4b. The beakers were then covered with mosquito-netting to prevent any hatched imagines from escaping and so confusing the results of the investigation.

The surviving larvae and pupae were counted at 4 p.m. on each of the succeeding five days, and the numbers eaten by the *Megarhinus* larvae in each twenty-four hour period determined. Any larval or pupal remains present were removed, and the number of developmental stages in each container restored to twenty.

The results of the investigation on *M. inornatus* are set out in Table 1. Information under each experiment number in the table refers collectively to containers (a) and (b) of that number.

TABLE 1.

Experiment number.	1	2	3	4
Mosquito species supplied to the predator as food.	*Aëdes albolineatus.*	*Aëdes scutellaris.*	*Armigeres lacuum.*	Mixture of all three species.
Developmental stage supplied.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	Pupae.
Number of larvae or pupae eaten by 2 larvae of *M. inornatus* in 5 days.	68	59	36	7
Average number of larvae or pupae eaten by a single predator each day.	6.8	5.9	3.6	0.7

It will be seen that the predator destroyed fewer larvae of *Armigeres lacuum* than of either species of *Aëdes*. This is probably simply due to the fact that larvae of *Armigeres* are almost twice as large as those of the two species of *Aëdes* used in the experiments. The fact that very few pupae were destroyed by the predacious larvae was due to two main considerations. In the first place, the compact and heavily-chitinized condition of the bodies of pupae as compared with those of larvae make it difficult for *Megarhinus* larvae to seize them. Secondly, pupae can elude their pursuers by evasive darting movements, while larvae, with their long and lightly-armoured bodies and more predictable movements, seldom escape capture.

When not feeding, a larva of *M. inornatus* usually lies relaxed and almost motionless at the bottom of its container, only moving its head from time to time as it follows the progress of other larvae in its vicinity. Such a resting larva becomes tense just before making a sudden strike at a potential victim. Captured larvae are usually grasped by the posterior part of the abdomen near the base of the siphon, pupae in the neighbourhood of the paddles.

When a large and powerful larva such as that of *Armigeres lacuum* is seized, there is a brief initial struggle during which the victim drags its captor about the container in frenzied efforts to tear itself free. Such efforts, however, were never observed to meet with any measure of success. The effective nature of the predacious culicine's hold on a captured larva was strikingly demonstrated when an *Armigeres* larva was grasped with forceps and lifted from the water ten seconds after a *Megarhinus* larva had seized it. So firmly were the mouth-parts of the predator embedded in the tissues of its victim that the former, although swung gently back and forth in the air for thirty seconds, dangled below the *Armigeres* without relinquishing its grip. The insects were then replaced in their container, where the *M. inornatus* larva proceeded to consume its prey as though nothing untoward had happened.

After the initial struggle the *Megarhinus* larva rises to the surface for air, keeping its prey fully submerged meanwhile. As the victim's resistance grows weaker, its siphonal valves can be seen spasmodically opening and closing under water. *M. inornatus* larvae frequently commence feeding before their victims' struggles have ceased. Relatively small larvae such as those of *Aëdes* were observed to be swallowed bodily within two or three minutes, and the predator required about five minutes to deal with the abdomen and prothorax of a fully-grown larva of *Armigeres lacuum*. Siphons of large larvae are often rejected early in the swallowing process. The heavily-chitinized head-capsules of such larvae are rejected later, a *Megarhinus* larva sometimes remaining quiescent for as long as an hour with the head of a victim protruding from its mouth.

Besides feeding on the developmental stages of mosquitoes, including smaller members of their own species, these formidable larvae devour other small aquatic animals. They were observed to eat both larval and pupal stages of Chironomidae, small nymphs of dragonflies (Anisoptera), and even small tadpoles, in the laboratory at Palmalmal. Paine (1934) records that larvae of the Javanese *Megarhinus splendens* Wiedemann devour young tadpoles, and prey on the larvae of Tipulidae and Chironomidae as well as those of mosquitoes. Paine also observes that *M. splendens* does not find larvae with very hairy bodies distasteful. The same may be said of *M. inornatus,* for this species was seen to feed on fourth instar larvae of *Tripteroides quasi-ornata* (Taylor, 1915), a form with a dense covering of stellate hairs on the abdomen. For that matter, *Aëdes albolineatus* larvae, which figured in the laboratory experiments already discussed, bear abdominal hairs like those of *Tripteroides.*

Single coconut husks were never found to be occupied by more than three fourth instar *Megarhinus* larvae at Palmalmal. On all but one occasion developmental stages of other mosquito species were absent from husks containing such larvae (Laird, 1946a). Second and third instar larvae of the predator were observed attacking fully-grown larvae of *Aëdes scutellaris* and *Culex papuensis* (Taylor, 1914) in the field.

It is thus obvious that under natural conditions larvae of *M. inornatus* exercise an appreciable measure of control over the breeding of mosquitoes with similar habitat preferences. Furthermore, the adult female of this species does not suck blood. Therefore, *M. inornatus* is to be considered a beneficial insect.

Attempts have been made to introduce *M. inornatus* into other countries, as an agent in the biological control of disease-transmitting and pest mosquitoes. In 1929 consignments of this insect were sent from New Britain and liberated in heavily-shaded parts of Hawaii (Swezey, 1930). It was hoped that the predacious larvae would check the breeding of certain day-flying pest mosquitoes. However, after breeding for several generations in the neighbourhood of Honolulu, the *M. inornatus* colony died out within a year of its introduction (Swezey, 1931). An attempt to establish this mosquito in Fiji was made during 1933 (Paine, 1934). This also proved unsuccessful, although *Megarhinus splendens* appears to have become established in Fiji after its introduction from Java some years ago (Lever, 1943).

Despite the failure of previous attempts to utilize *M. inornatus* as an agent in the control of noxious mosquitoes, it is considered that further efforts in this direction would be well worth while. Closer attention should be paid to the habitat preferences of this insect in any future introduction attempts. It was mentioned earlier that *M. inornatus* and mosquitoes belonging to the *scutellaris* group of the genus *Aëdes* inhabit similar breeding places in nature. Members of the latter group play an important part in the transmission of filariasis, particularly in those eastern Polynesian islands where this disease is highly endemic. Great numbers of these mosquitoes develop in household containers or in husks and tins in open places where the shade-loving *M. inornatus* would not be expected to breed. Such breeding is easily brought under control by artificial means. However, this has the effect of forcing *Aëdes scutellaris* and related species to retreat to the shelter of the jungle, where their breeding places are much harder to locate. As such jungle breeding places are suited to the development of *M. inornatus,* this predator might well be of value in a campaign against the filaria-transmitting mosquitoes.

All the other aquatic predators studied inhabit long-established ground pools. The hydrogen-ion content of the water was found to range from pH 4·5 to pH 7·5, but did not appear to have any direct bearing on the composition of the macrofauna. The vegetation of such pools generally consists of masses of filamentous green algae (*Spirogyra* sp.), and various emergent and marginal plants. *Echinochloa colona* O. Kuntze, and *Eleusine indica* Gaerter, are typical of the grasses bordering these pools. Clumps of *Pennisetum macrostachyum* (Brongn.) and of *Centotheca latifolia* (Linnaeus) are often present. The marginal flora commonly includes *Ageratum conyzoides* Linnaeus (Compositae), *Sida* sp.? (Malvaceae), and *Clitoria* sp.? (Papilionaceae). At the edge of jungle clearings straggling masses of *Cucumis* sp.? (Cucurbitaceae) overhang pools. Fresh-water swamps have much the same macroflora as the smaller permanent pools, but generally contain a greater amount of emergent vegetation. A species of *Equisetum* (*E. variegatum* Schleicher ?) makes up the bulk of the swamp flora at Palmalmal.

These and other plants afford mosquito larvae shade and a degree of shelter (Laird, 1946b). Pools with a comprehensive macroflora are seldom without developmental stages of mosquitoes unless they are heavily populated with various kinds of animals which prey on these insects.

Anopheles farauti Laveran, 1902, and *Culex pullus* Theobald, 1905, are typical of the mosquito fauna of permanent pools in the Jacquinot Bay area. Third and fourth instar larvae of these two species were used in the feeding experiments with various predacious inhabitants of ground pools, discussed in the following pages. It was not deemed necessary to supply pupae to the predators in pure culture, as the habits and size of the two kinds of pupae concerned are very similar. The aim of these experiments was to find not only whether the predators concerned destroy mosquito larvae and pupae, but whether they exhibit any preference between anopheline and culicine larvae.

The following technique was employed in all the laboratory feeding experiments with aquatic predators which inhabit ground pools in nature. Eight enamelled metal basins 12 cm. in diameter were filled to a depth of 8 cm. with boiled and filtered water from a natural pool, the hydrogen-ion content of which averaged pH 6·5. These basins were placed on a shelf within the laboratory, so that they were shaded from the direct rays of the sun by the overhanging roof. The temperature of the water which they held did not differ markedly from that of shaded natural pools.

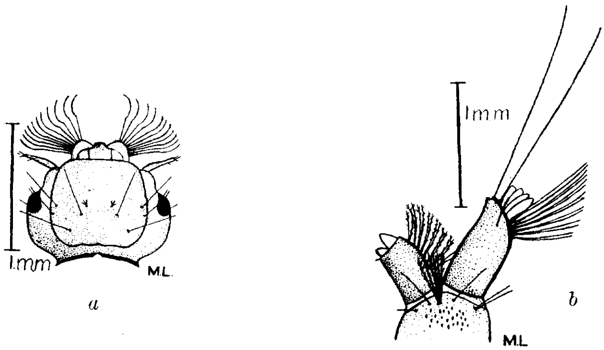
At the commencement of each experiment a single specimen of the predator concerned was placed in each basin. Twenty* late instar larvae of *A. farauti* were placed in each of containers 1a and 1b, and the same number of *C. pullus* larvae in containers 2a and 2b. Ten† larvae of each of these species were placed in containers 3a and 3b; and twenty pupae of a mixture of both species were added to containers 4a and 4b. The basins were then covered with mosquito-netting, to prevent the escape of hatched imagines.

Daily counts of the number of the developmental stages of both genera eaten by the predators were made in the manner already described for the experiments with *M. inornatus* (p. 456), and were continued for five days in each case. The information under each experiment number in Tables 2–9 again refers collectively to containers (a) and (b) of the number concerned.

Culex (Lutzia) halifaxi Theobald, 1903. (Text-figs. 2a, 2b).

The habitat preferences of this predacious mosquito resemble those of *A. farauti* and *C. pullus* (Laird, 1946a). The results of feeding experiments carried out with fourth instar *C. halifaxi* larvae are given in Table 2.

* Fifty and † twenty-five in the cases of two large and exceedingly voracious predators, *Orthetrum villosovittatum* (Odonata) and *Hydaticus litigiosus* (Coleoptera).



TEXT-FIG. 2.—*Culex (Lutzia) halifaxi*, fourth instar larva. *a*, Head. *b*, Terminal abdominal segments.

TABLE 2.

Experiment number.	1	2	3		4
Mosquito species supplied to the predator as food.	*Anopheles farauti.*	*Culex pullus.*	*Anopheles farauti.*	*Culex pullus.*	Mixture of both species.
Developmental stage supplied.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	Pupae.
Number of larvae or pupae eaten by 2 larvae of *C. halifaxi* in 5 days.	49	37	40	10	9
Average number of larvae or pupae eaten by a single predator each day.	4.9	3.7	4.0	1.0	0.9

It will be seen that there was little significant difference between the mean numbers of anopheline and culicine larvae destroyed in experiments 1 and 2, where larvae of one species only were available. In experiment 3, where larvae of both *Anopheles* and *Culex* were available, four times as many of the former as of the latter were consumed by the predacious larvae. As larvae of *C. halifaxi* rest at the surface of the water with their bodies very nearly parallel to the surface film, it would seem that their apparent preference for anopheline larvae as food is merely due to the fact that these surface-dwelling larvae are more convenient to capture than culicines. The mean number of pupae consumed by a single *C. halifaxi* larva in twenty-four hours was just under one. This predator was observed to meet with the same difficulty as did larvae of *M. inornatus* in capturing pupae.

C. halifaxi larvae capture their prey with a sudden lunge like that made by *M. inornatus*, and the feeding process closely resembles that of the latter insect. Unlike *M. inornatus*, *C. halifaxi* was rarely seen to swallow the more heavily chitinized parts of its victim. Late instar larvae of *C. halifaxi* show no reluctance to attack unwary members of their own kind. Haddow (1942) records that *Culex (Lutzia) tigripes* Grandpré and Charmoy displays similar cannibalistic tendencies.

Whenever *C. halifaxi* appeared in a pool already populated by other Culicidae, a decrease in the numbers of the other species present soon became apparent (Laird, 1946a). Haddow (1942) records parallel observations on *C. tigripes* at Kisumu, Kenya Colony, where he found this species the only mosquito present in borrow pits which had been swarming with larvae of *Anopheles gambiae* Giles a short time before.

C. halifaxi larvae readily consume developmental stages of other Diptera as well as those of mosquitoes. They were observed under natural conditions attacking larvae of Stratiomyiidae and Syrphidae, and both larvae and pupae of Chironomidae. In the laboratory they fed on very small nymphs of Anisoptera and Ephemeroptera, but would not attack young tadpoles. MacGregor (1924a) makes reference to *C. tigripes* eating chironomid larvae, small nematode worms, live insects fallen into the water, and even young minnows. It was of particular interest to find that a *C. halifaxi* larva attacking a Syrphid larva seized the latter at the point of junction of the air-tube and the abdomen. Lamborn (1920) records a precisely similar observation on *C. tigripes* in Nyasaland.

It follows from the laboratory and field observations outlined above that larvae of *C. halifaxi* play a not unimportant part in the natural control of those mosquitoes which share their breeding places in the vicinity of Jacquinot Bay. Larvae of *A. farauti* are particularly vulnerable to the attacks of this predator, because of their similar habitat preferences and surface-dwelling habit. Although larvae of *C. halifaxi* were often observed at Palmalmal, imagines were seldom encountered in the field, and were never known to bite man (Laird, 1946a). Cooling (1924) states that this mosquito rarely bites man under Australian conditions.

Due to the fact that in Australia this species is not plentiful enough in nature to exercise any check on noxious species of mosquitoes, Cooling considers that it is of little practical importance in anti-mosquito work. Hamlyn-Harris (1929) comes to the same conclusion, pointing out that *C. halifaxi* is of distinctly seasonal occurrence in Brisbane.

Mosquitoes of the sub-genus *Lutzia* have been used in anti-mosquito campaigns in other parts of the world. Howard (1910) records such use of *Culex* (*Lutzia*) *bigotii* Bellardi, stating that the predacious larvae of this insect effectively destroyed larvae of *Aëdes aegypti* Linnaeus, which were breeding in artificial containers in Rio de Janeiro.

Order ODONATA.

Suborder ANISOPTERA.

Nymphal stages of several genera and species of the Anisoptera were found to be plentiful in the more permanent ground pools at Jacquinot Bay. Four of the most abundant species belong to the superfamily Libelluloidea. These are *Orthetrum caledonicum* (Brauer, 1865), *O. villosovittatum* (Brauer, 1867) (Libellulinae), *Neurothemis stigmatizans* (Fabricius, 1758) (Sympetrinae), and *Pantala flavescens* (Fabricius, 1758) (Trameinae). The nymphs of these species were most often seen on the bottoms of pools or clinging to marginal vegetation.

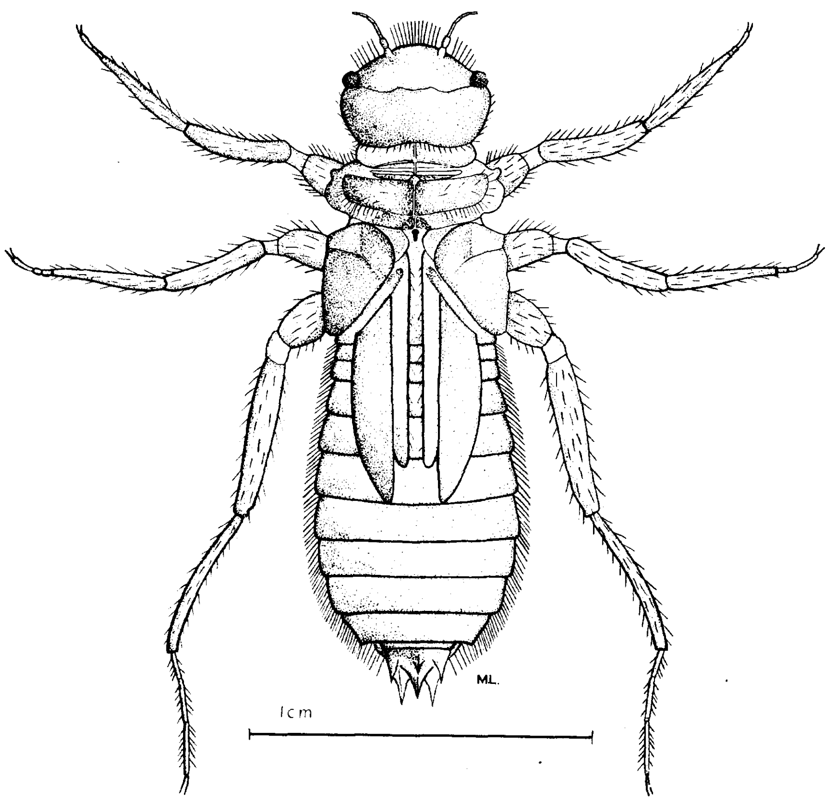
Orthetrum villosovittatum (Brauer, 1867). (Text-fig. 3.)

The results of feeding experiments carried out with fully-grown nymphs of *O. villosovittatum* are set out in Table 3.

TABLE 3.

Experiment number.	1	2	3		4
Mosquito species supplied to the predator as food.	*Anopheles farauti.*	*Culex pullus.*	*Anopheles farauti.*	*Culex pullus.*	Mixture of both species.
Developmental stage supplied.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	Pupae.
Number of larvae or pupae eaten by 2 nymphs of *O. villosovittatum* in 5 days.	36	252	27	198	103
Average number of larvae or pupae eaten by a single predator each day.	3.6	25.2	2.7	19.8	10.3

It will be seen from the above table that seven times as many larvae of *C. pullus* as of *A. farauti* were destroyed when these larvae were in pure culture (experiments 1 and 2). When both genera were accessible to the dragonfly nymphs (experiment 3) rather more than seven times as many culicines as anophelines were consumed. At the end of this group of experiments water was emptied from all the containers holding both mosquito larvae and odonate nymphs, until there was barely enough left to cover the nymphs. *O. villosovittatum*



TEXT-FIG. 3.—*Orthetrum villosovittatum*, fully-grown nymph.

then seized larvae of *A. farauti* and *C. pullus* without discrimination. Thus it seems that the bottom-dwelling habit of this odonate nymph prevents its encountering the surface-dwelling larvae of *Anopheles* in the normal course of events, and leads to its apparent preference for culicine larvae as food.

The number of pupae eaten daily by each nymph of *O. villosovittatum* averaged 10·3. That less pupae than culicine larvae were destroyed was largely consequent on the erratic movements of the former affording them some degree of protection from their formidable enemy.

Nymphs of *O. villosovittatum* and of other Anisoptera kept under observation in the laboratory consumed larvae and pupae of Chironomidae, odonate nymphs smaller than themselves, and young tadpoles, as well as the developmental stages of mosquitoes. Garman (1927) considers that dragonfly nymphs probably devour members of all aquatic families of insects as well as other aquatic animals outside this class. Young (1921) used nymphs of *Pantala flavescens* in feeding experiments at Manaos, Brazil. He records that these nymphs destroyed large numbers of larvae of *Stegomyia calopus* Meigen (=*Aëdes aegypti* Linnaeus) in the laboratory and under natural conditions.

Anisopterid nymphs must destroy a great many larvae and pupae of mosquitoes in nature. Nevertheless, larvae, particularly those of *Anopheles,* were often found in abundance at Palmalmal in small pools inhabited by dragonfly nymphs; and the latter consumed few anophelines as compared with culicines in the laboratory experiments. Obviously, as Hearle (1926) points out in regard to his work in British Columbia, the value of dragonfly nymphs as mosquito enemies is limited by their bottom-feeding habits.

Suborder ZYGOPTERA.

Family AGRIONIDAE.

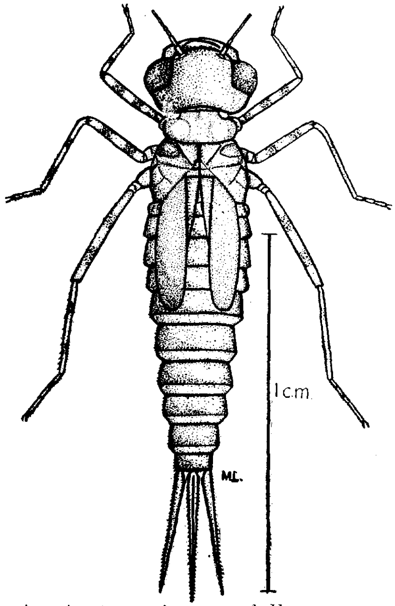
Austroagrion sp. (Text-fig. 4.)

Damselfly nymphs were commonly found swimming near the surface of the more permanent ground pools about Palmalmal. Feeding experiments were carried out with fully grown nymphs of an unidentified species belonging to the genus *Austroagrion* (Table 4).

TABLE 4.

Experiment number.	1	2	3		4
Mosquito species supplied to the predator as food.	*Anopheles farauti.*	*Culex pullus.*	*Anopheles farauti.*	*Culex pullus.*	Mixture of both species.
Developmental stage supplied.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	Pupae.
Number of larvae or pupae eaten by 2 nymphs of *Austroagrian* sp. in 5 days.	101	93	37	48	54
Average number of larvae or pupae eaten by a single predator each day.	10.1	9.3	3.7	4.8	5.4

In this case the predator ate anopheline and culicine larvae in almost equal numbers, whether they were supplied in pure or mixed culture. Zygopterid nymphs feed at the surface and intermediate



TEXT-FIG. 4.—*Austroagrion* sp., fully-grown nymph.

levels of pools as well as at the bottom, and thus, unlike the nymphs of Anisoptera, encounter larvae of *Anopheles* as readily as those of *Culex*. Mosquito pupae are destroyed in some numbers by the nymphs of *Austroagrion*. The former evidently gain a degree of protection by their habit of progressing by sudden darting movements, and only half as many pupae as larvae were destroyed each day by the agrionid nymphs kept under observation at Jacquinot Bay (Table 4).

As well as attacking the aquatic stages of mosquitoes, the zygopterid nymphs studied ate any other small aquatic animals that they were able to overpower. It is considered that because of their free-swimming habits nymphs of agrionid damselflies are of greater importance as enemies of Culicidae, particularly of larvae of the genus *Anopheles*, than are those of Anisoptera.

Order HEMIPTERA.
Suborder HETEROPTERA.
Family NOTONECTIDAE.

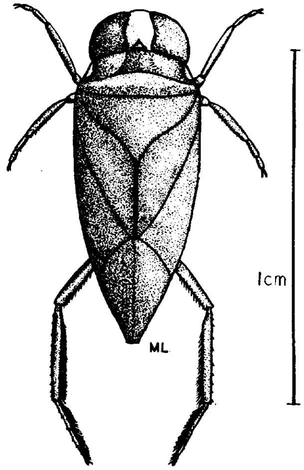
Enithares bergrothi Montandon, 1892. (Text-fig. 5.)

E. bergrothi was commonly recorded in long-established pools at Palmalmal. This species has been recorded from Australia and from several islands in the Pacific (Hale, 1923). The feeding habits of imagines of this notonectid were studied in the laboratory (Table 5).

TABLE 5.

Experiment number.	1	2	3		4
Mosquito species supplied to the predator as food.	*Anopheles farauti.*	*Culex pullus.*	*Anopheles farauti.*	*Culex pullus.*	Mixture of both species.
Developmental stage supplied.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	Pupae.
Number of larvae or pupae eaten by 2 adults of *E. bergrothi* in 5 days.	52	97	32	89	21
Average number of larvae or pupae eaten by a single predator each day.	5.2	9.7	3.2	8.9	2.1

Reference to Table 5 will show that while *Enithares* destroyed a large number of larvae of both anophelines and culicines, almost twice as many of the latter were eaten. This fact can perhaps be explained by the circumstance that anophelines, lying parallel to the water-surface, are not so readily seen by back-swimmers as culicine larvae which hang head downwards from the surface. Few pupae were destroyed by this predator during the laboratory investigation. Wladimirow and Smirnov (1932) report that a species of *Notonecta* which they studied ate up to twenty-five mosquito larvae a day. They carried out experiments on several species of notonectids, most of which destroyed more culicines than anophelines. Graham (1939) states that the New Zealand back-swimmer *Anisops assimilis* White, devours mosquito larvae readily, but only eats pupae in the absence of larvae.



TEXT-FIG. 5.—*Enithares bergrothi.*

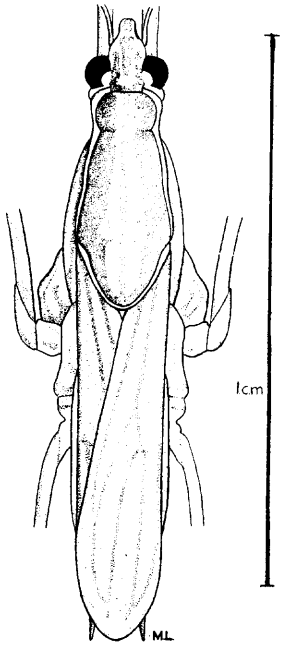
At Palmalmal, ten adults of *E. bergrothi* were introduced into an uncovered water drum heavily populated with larvae of *Aëdes scutellaris.* The numbers of the latter declined very sharply, and a search five days later resulted in the finding of only nine late instar larvae of *A. scutellaris* in this drum.

Dempwolff (1904), working in what was then German New Guinea, observed that waters which contained many notonectids harboured no mosquito larvae. Within a week this investigator brought about the destruction of all the mosquito larvae in seventeen water tanks by introducing *Notonecta* into them.

E. bergrothi was seldom sufficiently plentiful in nature to act as a really efficient check on the breeding of mosquitoes in ground pools. As Hale (1923) has pointed out, this species leads a solitary rather than a gregarious existence. Its usefulness as a mosquito enemy under natural conditions is thus curtailed. However, like many other notonectids, *E. bergrothi* can be put to good use in the control of mosquito larvae in artificial containers.

Family GERRIDAE.

Species of the genera *Limnogonus, Mesovelia,* and *Microvelia* were commonly present on the surface film of the more permanent ground pools at Palmalmal. Unfortunately, there was insufficient time available to carry out feeding experiments with these insects before my departure from New Britain.



TEXT-FIG. 6.—*Limnogonus fossarum.*

A large gerrid, *Limnogonus fossarum* (Fabricius, 1775) (Text-fig. 6), was observed in the field sucking the body juices of a newly-hatched imago of *Culex fraudatrix* Theobald, 1905. Other specimens of this insect were seen to attack late instar anopheline larvae. It appears, however, that various terrestrial and aerial insects that have fallen into the water provide the main source of food for *Limnogonus* and other genera of water-striders.

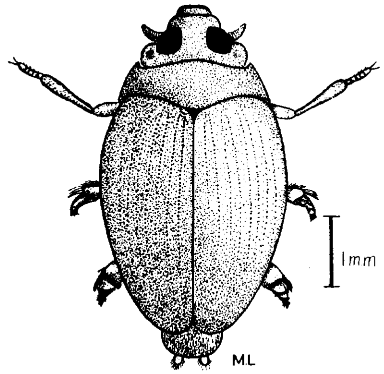
It was noticed that pools with heavy populations of gerrids never contained many anopheline larvae. This circumstance could not be ascribed solely to the presence of the water-striders, for other aquatic predators of proven value as mosquito enemies were always present as well. Nevertheless, by reason of the facts that Gerridae are of surface-feeding habit and that *Limnogonus* was actually observed to destroy larval and newly-emerged anophelines, it appears likely that members of this family are of some importance as mosquito enemies.

Order COLEOPTERA.

Family GYRINIDAE.

Gyrinus sericeolimbatus Régimbart, 1882. (Text-fig. 7.)

G. sericeolimbatus, a markedly gregarious insect, was occasionally encountered in permanent ground pools at Palmalmal. As many as two hundred adults of this active little "whirligig beetle" often occupy an area of only a square yard of the water surface.



TEXT-FIG. 7.—*Gyrinus sericeolimbatus.*

Adult specimens of *G. sericeolimbatus* brought to the laboratory refused to remain in their containers. Even when placed in a large basin covered with netting they spent most of their time out of the water. Thus a simple field experiment was undertaken with a view to gaining some idea of the part played by this gyrinid as a predator of the Culicidae. This experiment was carried out in a temporary rain pool averaging 11 ft. 6 in. in length, 4 ft. in breadth, and 9 in. in depth. It was estimated that the pool held about five hundred larvae of *Anopheles punctulatus* Dönitz. There were no other aquatic animals present with the exception of a few chironomid larvae. One hundred gyrinid beetles were collected from a permanent pool supporting a heavy population of these insects, and were transferred to the temporary rain pool. A visit was made to the latter pool twenty-four hours later, when a search revealed the presence of only forty-six anopheline larvae. After a further twenty-four hours no anopheline larvae whatsoever could be found.

While working in Mauritius, d'Emmerez de Charmoy (1902) found that three adults of the gyrinid *Dineutes indus* consumed fifty anopheline larvae in three hours. However, Derivaux (1916) observes that even when a certain North American species of the genus *Dineutes* is abundant in a natural pool anopheline larvae are not particularly difficult to find. He states that although anopheline larvae are soon captured and eaten by these beetles in a basin filled with clean water, only a few larvae are captured, and these apparently by accident, when surface debris in the form of twigs is added to the water in the basin. Derivaux thus considers it improbable that gyrinids are of much significance as moquito control agents, as natural pools usually contain sufficient surface debris to shelter *Anopheles* larvae from these beetles.

Anopheline larvae were seldom recorded from natural pools supporting populations of *G. sericeolimbatus* at Palmalmal, although these pools seemed admirably suited for the breeding of *Anopheles farauti*, and surface debris in the form of fallen branches and floating leaves was usually present. Owing to the fact that this species of *Gyrinus* only inhabits pools of a permanent nature, other predacious insects are always associated with it. Thus, the absence of anopheline larvae from pools containing *G. sericeolimbatus* could not be ascribed solely to the activities of the gyrinid. Nevertheless, by analogy with the experimental elimination of large numbers of *A. punctulatus* larvae by the introduction of *G. sericeolimbatus* into a temporary pool, it is evident that this gyrinid is of definite significance in the biological control of anopheline breeding, although its importance in this respect is limited by its comparative rarity in nature.

Family Dytiscidae.

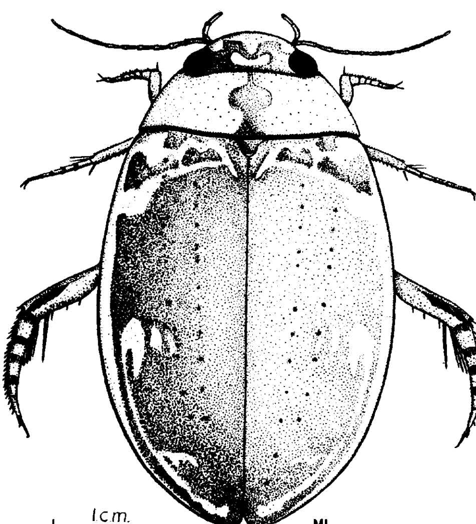
Hydaticus litigiosus Régimbart, 1887. (Text-fig. 8.)

Table 6 gives the results of feeding experiments carried out with imagines of this diving beetle, which was usually encountered in some numbers in permanent pools in the neighbourhood of Palmalmal.

Table 6.

Experiment number.	1	2	3		4
Mosquito species supplied to the predator as food.	*Anopheles farauti.*	*Culex pullus.*	*Anopheles farauti.*	*Culex pullus.*	Mixture of both species.
Developmental stage supplied.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	Pupae.
Number of larvae or pupae eaten by 2 adults of *H. litigiosus* in 5 days.	13	352	7	316	114
Average number of larvae or pupae eaten by a single predator each day.	1.3	35.2	0.7	31.6	11.4

It is evident from the above table that *H. litigiosus* destroyed about thirty times more larvae of *C. pullus* than of *A. farauti* when supplied with either pure or mixed cultures of these species. This



Text-fig. 8.—*Hydaticus litigiosus*,

apparent preference for culicine larvae as food is brought about by the head-downwards attitude assumed by the diving beetle when near the water surface. In this attitude it can detect larvae of *Culex*, but not those of the surface-dwelling *Anopheles*. Although anopheline larvae are normally protected from the attacks of *H. litigiosus* by virtue of their surface-dwelling habit, they are seized by the predator without discrimination when caused to leave the water surface.

Two dytiscids, a male and a female, were kept in a vessel containing 8 cm. (250 cc.) of boiled and filtered water. The water in this container was changed each week, but no animals other than larvae of *A. farauti* were admitted. Any anopheline pupae were removed as soon as their presence was noticed, and they were replaced with early instar larvae of the same species. At the end of three weeks the female *Hydaticus* died, its body being promptly eviscerated by the male. During all this time only thirty-five of the anopheline larvae in the beaker had been consumed by both beetles. After a further week fifty larvae of *C. pullus* were introduced into the beaker. The surviving water beetle immediately began to attack these larvae, eating eleven within the first five minutes. All the larvae had been consumed at the end of an hour.

It was found that an average of 11·4 pupae were consumed by a single *Hydaticus* adult each day. Like the predators already discussed, this diving beetle was often seen to be eluded by pupae, although larvae were seldom observed to avoid capture.

In feeding, *H. litigiosus* captures its prey with a sudden lunge of its forelegs, then rises slowly to the surface while guiding the victim to its mouthparts with its fore and middle legs. Usually both larvae and pupae are eaten bodily, but sometimes the more heavily chitinized parts are discarded.

Hargreaves (1932) records that an Italian dytiscid devoured larvae and pupae of all mosquito species fed to it, at the rate of twenty a day. Howard (1912) quotes Galli-Valerio and Rochaz de Jongh as stating that an adult of *Dytiscus marginalis* Linnaeus, although previously fed with meat, devoured great numbers of mosquito larvae and pupae. No observations on the predacity of water beetle larvae were made at Palmalmal, although many authors have referred to the voracity of dytiscid and hydrophilid larvae as mosquito destroyers.

Anopheline larvae were often present in large numbers in pools inhabited by *H. litigiosus*, although species of *Culex* were seldom found in any numbers in association with the beetle. From this circumstance, and the results of the laboratory-feeding experiments outlined above, it appears that while *H. litigiosus* plays a significant part in the natural control of culicine mosquito breeding at Palmalmal, this beetle is of little importance as a factor in anopheline control.

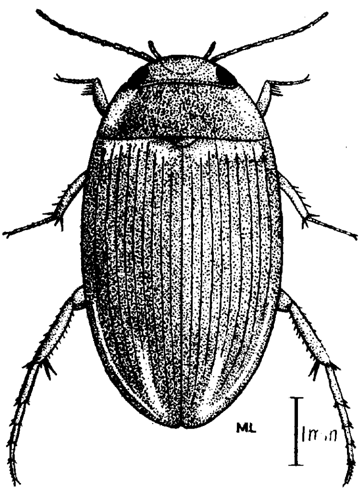
Copelatus sp. (Text-fig. 9.)

This little dytiscid is a new species as yet undescribed, but for which Balfour-Browne proposes the name of *Copelatus lairdii*. It was commonly encountered in permanent pools throughout the Jacquinot Bay area. The results of feeding experiments with imagines of this water beetle are tabulated below.

TABLE 7.

Experiment number.	1	2	3		4
Mosquito species supplied to the predator as food.	*Anopheles farauti.*	*Culex pullus.*	*Anopheles farauti.*	*Culex pullus.*	Mixture of both species.
Developmental stage supplied.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	3rd and 4th instar larvae.	Pupae.
Number of larvae or pupae eaten by 2 adults of *Copelatus* sp. in 5 days.	46	58	29	37	1
Average number of larvae or pupae eaten by a single predator each day.	4.6	5.8	2.9	3.7	0.1

It will be seen that *Copelatus* sp., in contrast to *H. litigiosus,* devoured very nearly the same number of *Anopheles* and *Culex* larvae. The reason for this is that *Copelatus* sp., unlike *H. litigiosus,* spends



TEXT-FIG. 9.—*Copelatus* sp.

much of its time in hunting prey near the water surface and thus has an equal chance of encountering larvae of both genera. Only a single pupa was destroyed by one of these predators during the investigation. The small size of this diving beetle makes the capturing of such vigorous and heavily-chitinized prey a difficult matter.

Although a single adult of *Copelatus* sp. was unable to account for any great number of mosquito larvae each day, the species was often present in natural pools in such numbers as to act as an important check on mosquito breeding.

Class ARACHNIDA.
Order ACARINA.
Family HYGROBATIDAE.

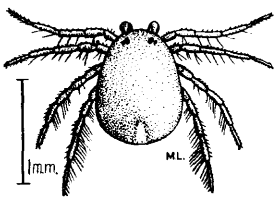
Limnesia jamurensis Oudemans, 1905. (Text-fig. 10.)

Although adults of this large water-mite did not attack mosquito pupae or later instar larvae in the laboratory, they readily consumed eggs and very small larvae of both *A. farauti* and *C. pullus,* Feeding experiments with this species were carried out in the manner previously described, except that early instar larvae and eggs of *A. farauti* and *C. pullus* were used in place of late instar larvae and pupae. The results of these experiments are set out in Table 8.

TABLE 8.

Experiment number.	1	2	3		4
Mosquito species supplied to the predator as food.	*Anopheles farauti.*	*Culex pullus.*	*Anopheles farauti.*	*Culex pullus.*	Mixture of both species.
Developmental stage supplied.	1st instar larvae.	1st instar larvae.	1st instar larvae.	1st instar larvae.	Eggs.
Number of larvae or eggs eaten by 2 adults of *L. jamurensis* in 5 days.	66	77	38	23	178
Average number of larvae or eggs eaten by a single predator each day.	6.6	7.7	3.8	2.3	17.8

Table 8 shows that there was little difference between the numbers of early instar larvae of *Anopheles* and *Culex* destroyed by *L. jamurensis.* This active mite incessantly swims about near the water surface, where it can seize larvae of either of these mosquito genera. Almost three times as many eggs as larvae were destroyed by the hydrachnid during the experiments.



TEXT-FIG. 10.—*Limnesia jamurensis.*

L. jamurensis adults inhabit long-established ground pools at Palmalmal. Larvae of this water-mite were collected from the thorax and abdomen of mosquito imagines. Female imagines of *Culex pullus* were occasionally captured with from one to four or these larvae clinging to them, usually on the sides of the abdomen at the junction of two of the segments. Eleven larvae were obtained from the abdomen and thoracic pleura of a female *Aëdes* belonging to an undescribed species.

Uchida (1935) describes the life-history of a Japanese water-mite, the larvae of which attach themselves to mosquito pupae, transferring from these to the imagines at hatching. The adult mosquitoes carry these larvae to other pools, where the hydrachnids resume an aquatic existence. It would seem that *L. jamurensis* is transported from pool to pool in a similar manner.

Lamborn (1890) records that a species of red mite was observed to attack the eggs of Odonata, and Hearle (1926) states that a hydrachnid found in cottonwood swamps in British Columbia makes mosquito larvae its chief food.

From the results of the laboratory investigation on *L. jamurensis*, and the fact that mosquito larvae were not recorded in any numbers in natural pools containing many of these hydrachnids, it is evident that this mite plays a useful role as a predator of the early aquatic stages of *Anopheles* and *Culex*.

Class CRUSTACEA.
Order DECAPODA.
Family ATYIDAE.

Caridina typus Milne-Edwards, 1837.

Small decapods, apparently *Caridina typus* although differing from this species in a few minor features, occurred plentifully in pot-holes of streams flowing through limestone ravines at Palmalmal. *Uranotaenia argyrotarsis* Leicester, 1908, was the only mosquito found in association with these decapods. Some of the latter were kept in the laboratory for several weeks. They never attacked living mosquito larvae, although they were observed to feed on dead larvae. An adult of *C. typus* was seen to take just over a minute to sever the head and clean out the thoracic contents of a dead larva of *U. argyrotarsis*.

Although various crustaceans have been found to be useful mosquito control agents in other parts of the world (Apfelbeck, 1925; McCay, 1941; *Tanganyika Territory Rep.*, 1927), it appears that such animals are of no significance in this respect at Jacquinot Bay.

Class AMPHIBIA.
Order SALIENTA.
Family RANIDAE.

Rana sp.

Ground pools at Palmalmal, those of a temporary nature in particular, were often found to be swarming with tadpoles belonging to the genus *Rana*. Fully grown tadpoles kept in the laboratory devoured neither pupae nor late instar larvae of mosquitoes. Imagines emerged from all the pupae concerned; although several of these adults were knocked over and drowned during hatching by the vigorously moving tadpoles.

The results of experiments in which tadpoles of *Rana* sp. 2·5 cm. in length were supplied with early instar larvae and eggs of Culicidae as food are detailed in the following table.

TABLE 9.

Experiment number.	1	2	3		4
Mosquito species supplied to the predator as food.	*Anopheles farauti.*	*Culex pullus.*	*Anopheles farauti.*	*Culex pullus.*	Mixture of both species.
Developmental stage supplied.	1st instar larvae.	1st instar larvae.	1st instar larvae.	1st instar larvae.	Eggs.
Number of larvae or eggs eaten by 2 tadpoles of *Rana* sp. in 5 days.	15	9	7	4	28
Average number of larvae or eggs eaten by a single predator each day.	1.5	0.9	0.7	0.4	2.8

The few larvae and eggs destroyed in this investigation seemed to be encountered accidentally, rather than sought out, by the surface-feeding tadpoles.

Temporary pools containing great numbers of tadpoles were often heavily populated with the developmental stages of *Anopheles punctulatus* as well. Ross (1900) records that numbers of frogs and tadpoles inhabiting anopheline breeding places at Freetown, Sierra Leone, were apparently living at peace with the mosquito larvae.

It is evident from these field and laboratory observations that tadpoles are of little if any significance as predators of the Culicidae; although when large numbers of tadpoles and mosquito larvae inhabit the same pool it is probable that a proportion of the emerging mosquitoes are knocked over and drowned as a consequence of the constant agitation of the water surface by the tadpoles.

Such indirect control forms a natural parallel of various types of artificial control which aim at causing agitation of the water surface. An example of this type of artificial control is mentioned by Covell (1943), who states that in parts of Malaya pools on hillsides are fed by water from split bamboo conduits, the ends of which are supported about four feet above each pool. The resultant constant splashing and rippling of the water surface inhibits mosquito breeding.

II.—Predators of Adult Culicidae.

Class ARACHNIDA.

Order ARANEIDA.

Family Argiopidae.

The horizontal orb webs of a spider of the genus *Epeira* often span narrow ground pools in New Britain, and are commonly found stretched among the grasses bordering larger water bodies. Vertical orb webs are built in similar situations by spiders belonging to the genus *Meta*. Such webs trap many newly-hatched insects which are leaving the pools, and the remains of adult mosquitoes and midges were commonly found in them at Palmalmal.

Spiders undoubtedly capture many newly-emerged mosquitoes and probably older ovipositing insects as well, thus playing a part in the biological control of Culicidae.

Miscellaneous Predators.

Many insects, especially adult dragonflies, are known to feed on mosquito imagines. The activities of the majority of such insect predators are restricted to the daylight hours, and they are thus of little use in the control of adult *Anopheles*, which are most active in the evening. Small bats which capture flying insects attracted to lights in the early evening, and the common house gecko *Gehyra oceanica* (Lesson, 1830) which devours insects settling on the walls of buildings, must be numbered among the more important predators of adult anopheline mosquitoes in the Jacquinot Bay district.

Conclusions.

It must be emphasized that with the exception of *Megarhinus inornatus*, the predators of mosquitoes at Palmalmal are of purely local significance. As Hinman (1934) states, the frequent association of mosquito enemies with their prey indicates that their usefulness is probably limited to artificial containers or small collections of water (c.f. *Enithares bergrothi*, p. 465). It was found that the presence of even large numbers of any one species of predator reduced, but by no means eliminated, mosquito breeding in numerous pools at Palmalmal. Nevertheless, mosquitoes were never abundant, if present at all, in permanent pools which contained stable associations of several kinds of aquatic predators.

As was proved on many malarious islands during the recent war in the Pacific, an area of reasonable size can be rendered free from malaria by an intensive control programme. Such an anti-malaria campaign involves control of both the *Plasmodium* in the human being and of the anopheline vector of the *Plasmodium*. The first of these requirements is accomplished by treatment or removal of gametocyte carriers in the local population, and by suppressive therapy involving the use of such drugs as atebrine; the second, by measures directed against the adult and developmental stages of *Anopheles*.

One of the most generally useful mosquito-control measures is the treatment of such breeding places as it is impracticable to drain or fill, with various larvicides. During the later war years D.D.T. (dichloro-diphenyl-trichloro-ethane) largely replaced other chemicals used as larvicides.

In such a campaign, all pools suitable for the development of *Anopheles* should, of course, be subjected to full control *if sufficient personnel and materiel are available for control to be maintained efficiently*. Where a control project involves the protection of only a small number of men—such as the staff of a radar post or coast-watching station—labour and materials will very likely be in short supply. It might be possible in the initial stages of occupation of such a post to spray every anopheline breeding place within what is considered a safe radius with a D.D.T.-base larvicide. Now, although the wholesale application of D.D.T. to breeding places affords an excellent means of controlling mosquitoes, it must be borne in mind that not only mosquito larvae but their predators as well will be killed. If it proves impossible to maintain larvicidal treatments on a weekly basis, due to a drawing-in of the control perimeter, or a shortage of personnel or materiel, mosquito breeding will recommence; and permanent pools which had previously harboured a minimal number of mosquitoes because they contained a stable predacious macrofauna, will become major centres of mosquito breeding. Such pools would have served as reservoirs for mosquito enemies, and the number of anophelines developing in them would have been insignificant, if they had not been treated with D.D.T. in the first place.

It is suggested that before the commencement of a mosquito-control project an entomological-survey team should enumerate those permanent pools where the presence of aquatic predators keeps the breeding of Culicidae down to a low minimum. These pools should not be sprayed with D.D.T. unless there is a definite assurance that regular control can be maintained. This suggestion applies only to small camps of a temporary nature. Full anopheline control should, of course, be maintained within a sufficient radius of all permanent camps and airfields in malarious zones, without reference to the predacious macrofauna of the breeding places concerned.

SUMMARY.

The results of field and laboratory observations indicate that larvae of *Culex* (*Lutzia*) *halifaxi* (Dipt. Culicidae) and of Zygoptera (Odonata), and adults of *Gyrinus sericeolimbatus* (Col. Gyrinidae), *Limnesia jamurensis* (Acarina, Hygrobatidae), and perhaps of various species of Gerridae (Hemiptera) are among the most effective predators of larval anopheline mosquitoes at Palmalmal.

Of lesser importance in the control of *Anopheles*, although useful predators of culicine mosquitoes, are *Hydaticus litigiosus*, *Copelatus* sp. (Col. Dytiscidae), *Enithares bergrothi* (Hem. Notonectidae), and *Orthetrum villosovittatum* and other Anisoptera (Odonata).

Spiders of the genera *Epeira* and *Meta*, which spin webs over breeding pools, bats, and the house gecko *Gehyra oceanica* are of some importance as predators of adult mosquitoes.

Megarhinus inornatus (Dipt. Culicidae) is worthy of consideration as a biological ally in future campaigns against the *scutellaris* group of the genus *Aëdes*, as its breeding habits parallel those of the latter mosquitoes.

The introduction of *Enithares bergrothi* into metal tanks and drums in the Jacquinot Bay area should provide a practicable means of controlling the breeding of "domestic" mosquitoes when other methods are undesirable.

With the exception of *M. inornatus*, the predators discussed in this paper are probably of purely local importance.

There may be sufficient aquatic predators in certain permanent pools to control the breeding of anopheline mosquitoes effectively. Treatment with such larvicides as D.D.T. will destroy these predators as well as any mosquitoes present. Unless larvicidal treatment is repeated on a weekly basis, Culicidae will quickly establish themselves in the absence of their enemies; and pools that had been of little importance as mosquito breeding places will become major centres of anopheline development.

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