Natural Control of Larval *Anopheles albimanus* (Diptera: Culicidae) by the Predator *Mesocyclops* (Copepoda: Cyclopoida)

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ABSTRACT Forty-two ground water sites on the Pacific and Atlantic coasts of Colombia were sampled quantitatively with a plankton net to assess the abundance of mosquito larvae and associated fauna. Many of the sites contained substantial numbers of *Anopheles albimanus* Wiedemann larvae, but the larvae were virtually absent wherever there were large populations of the copepods *Mesocyclops venezolanus, M. longisetus,* or *M. aspericornis. Mesocyclops* were observed to prey readily upon first-instar *An. albimanus* larvae in the laboratory, but smaller genera of cyclopoid copepods did not kill *An. albimanus* larvae. We conclude that *Mesocyclops* may prove useful for biological control of *Anopheles.*

KEY WORDS Insecta, Cyclopoida, *Anopheles albimanus*, biological control, predators

THE COPEPOD *Mesocyclops aspericornis* (Daday) is known to eliminate *Aedes* larvae from container breeding habitats (Rivière & Thirel 1981, Marten 1984, Suárez et al. 1984), but there has been no documentation of the effect that cyclopoid copepods have on *Anopheles* larvae. Cyclopoids are often abundant in aquatic habitats where anophelines breed, but their effect on anophelines may be different from their effect on *Aedes* because of ecological differences between *Anopheles* groundwater and *Aedes* container breeding habitats.

In July 1986, a negative association was observed between the presence of *Mesocyclops venezolanus* Dussart and the larvae of *Anopheles albimanus* Wiedemann in a series of ponds in the vicinity of Tumaco on the Pacific coast of Columbia (G.G.M., unpublished data). *Anopheles* larvae were absent from ponds containing *M. venezolanus* despite the fact that *An. albimanus* larvae were numerous in other ponds in the immediate vicinity.

Our research describes subsequent quantitative samples of the fauna in actual and putative breeding habitats of *An. albimanus* to evaluate more precisely the association between cyclopoid copepods and *An. albimanus.*

Materials and Methods

Ground water habitats were sampled at 27 sites in the vicinity of Tumaco on the Pacific coast of Columbia from October 1986 to April 1987 and at 15 sites near Cartagena and Carmen de Bolivar on the Atlantic coast of Colombia during May 1987. Each sample covered a discrete body of water. These "ponds" varied in size from roadside ditches several meters in length to cattle watering ponds up to 30 m across. Ponds near one another were often similar in size, general ecology, and flora and fauna, but they differed in the presence or absence of particular cyclopoid species.

The abundance of anophelines and cyclopoids was estimated by dragging a plankton net over a specified distance in each pond. The samples typically covered 10% of the pond area and a water volume ranging from 200 to 2,000 liters. To estimate abundance per square meter, the area swept by the net was calculated as the product of net width (20 cm) and the distance swept. To estimate abundance per liter, volume was calculated as the product of sweep distance and the area of the net's mouth (400 cm^2). Resulting samples often underestimated the actual abundance because of obstruction of the net's movement by aquatic vegetation or a shallow bottom.

Cyclopoid identifications followed Reid (1985) and Dussart (1987). The number of cyclopoids collected at a single site ranged from 0 to 67,000. The number of *An. albimanus* larvae (mostly first instars) ranged from 0 to 1,300. Five to 10 live specimens of most of the cyclopoid species were tested in the laboratory for larval predation by placing each cyclopoid in a spot dish with five first-instar *An. albimanus* for 24 h.

Several of the sampled ponds contained anopheline larvae other than *An. albimanus,* but the numbers collected were too small to draw conclusions concerning their association with cyclopoids. Because the same cyclopoid species were collected on the Pacific and Atlantic coasts, and because the ranges of cyclopoid and *An. albimanus* abundance were similar, results from the two areas were com-

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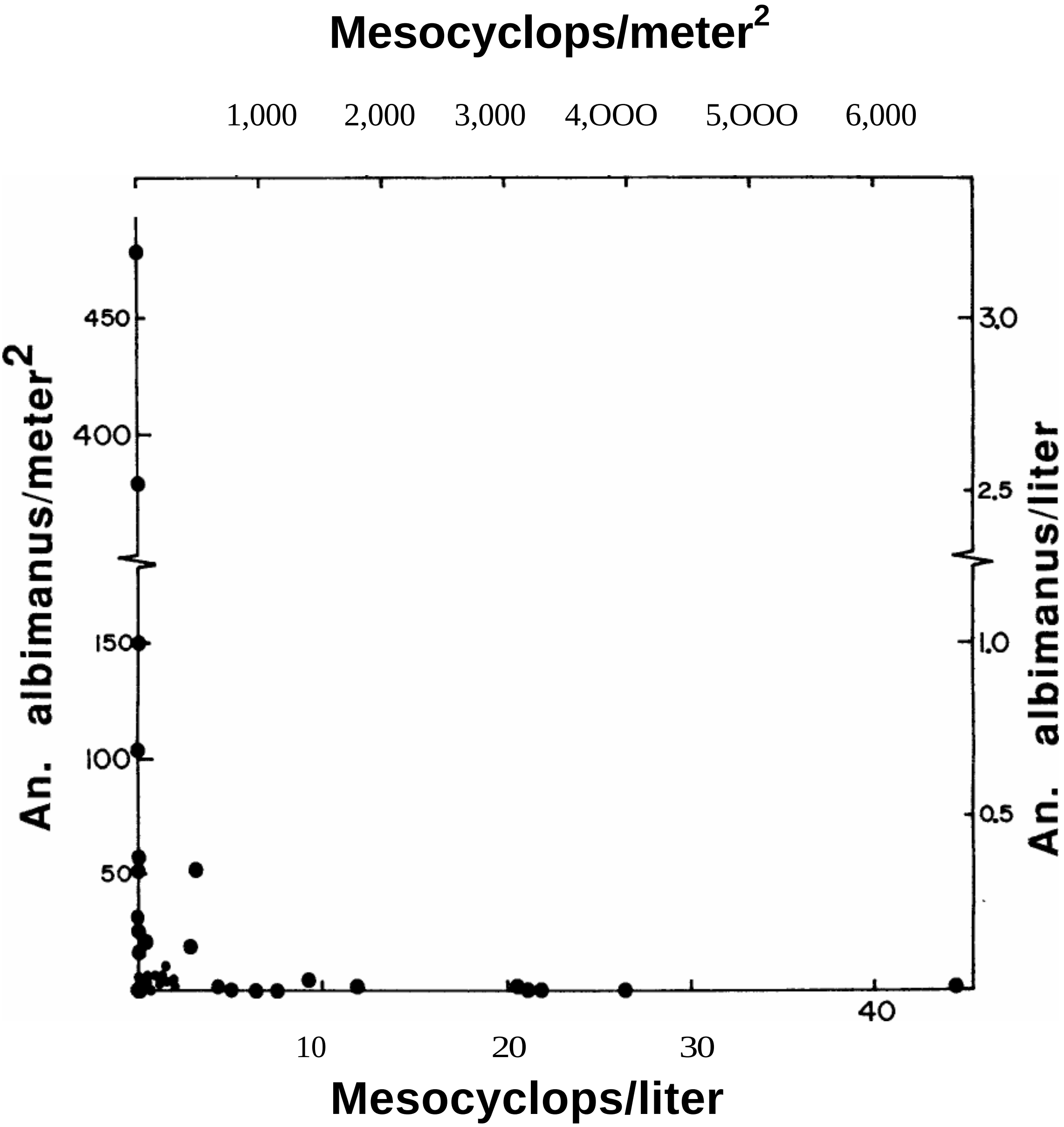

Fig. 1. Abundance of *An. albimanus* (second to fourth instars plus pupae) and adult *Mesocyclops* spp. in plankton net samples from ground water habitats on the Pacific and Atlantic coasts of Colombia. The large dot at the origin represents eight samples with zero (or near zero) abundance of both *Mesocyclops* spp. and *An. albimanus.*

bined to calculate correlations between the abundance of cyclopoids and *An. albimanus* larvae.

Results

There were three species of *Mesocyclops* in the samples. Most common was *M. venezolanus,* which was the smallest (adult female body length, 1.2 mm excluding caudal setae). The other common species was *Mesocyclops longisetus* Thiebaud, which was the largest (adult female body length, 1.5 mm). *M. venezolanus* was the only *Mesocyclops* at 29% of the sites, and *M. longisetus* was the only *Mesocyclops* at 11% of the sites. Both species occurred together at 22% of the sites. A third species, *M. aspericornis,* was found at one of the sites. The combined abundance of these species was more than 10 adult *Mesocyclops* per liter in at least 14% of the sampled ponds.

All adults and last-stage copepodids of all three *Mesocyclops* species preyed upon first-instar *An. albimanus* larvae when tested in the laboratory, usually consuming all five larvae within 24 h. *M. longisetus* preyed readily on second instars as well. Attacks occurred when random movements brought *Mesocyclops* within a few millimeters of their prey, close enough to detect prey movement from mechanical disturbances in the water (Williamson 1986). *Mesocyclops* attacked by lunging and seizing larvae on any part of the body. They then chewed until everything was consumed except the head capsule, a process that usually required only 2 or 3 min.

Mesocyclops longisetus swam throughout the water column when observed with *An. albimanus* larvae in a 500-ml jar. They attacked larvae that were hanging at the water surface or diving.

Macrocyclops albidus (Jurine) was collected at one of the sites and *Diacyclops hispidus* Reid was at two of the sites. Both of these large cyclopoids preyed upon larvae in the laboratory, although *D. hispidus* was not an aggressive predator. The occurrence of these two species was too low to assess their association with *An. albimanus* larvae.

Smaller species of cyclopoids in the samples were (in decreasing order of occurrence): *Ectocyclops rubescens* Brady, *Microcyclops anceps* (Richard), *Eucyclops agilis* (Koch), *Apocyclops panamensis* (Marsh), *Thermocyclops decipiens* (Kiefer), *Thermocyclops tenuis* (Marsh), *Microcyclops alius* (Kiefer), and *Eucyclops bondi* Kiefer. All of these species were less than 1.0 mm in length and none killed first-instar *An. albimanus* larvae in the laboratory. There was no significant association between the abundance of these cyclopoids (as a group) and the abundance of *An. albimanus* larvae in the field samples (Spearman rank correlation, -0.09; df = 40; $P > 0.5$).

Mesocyclops spp. were the only cyclopoids having a significant association with *An. albimanus* larvae in the field samples (Fig. 1). In a stepwise multiple regression involving more than 80 biological and physical variables, the abundance of *An. albimanus* larvae was associated more negatively with the abundance of adult *Mesocyclops* than with any other variable, including fish and predatory aquatic insects. The same was true for pupae, suggesting that *Mesocyclops* was reducing not only the abundance of *An. albimanus* larvae but also the production of adults.

Fig. 1 shows that about half the ponds with no (or very few) *Mesocyclops* contained more than 10 *An. albimanus* larvae/m^2. In contrast, all 11 ponds with more than four *Mesocyclops* /liter shown in Fig. 1 contained no (or very few) *An. albimanus* larvae (Spearman rank correlation = -0.37, df = 40, $P < 0.01$). *Mesocyclops* abundance shown in Fig. 1 is probably an underestimate of actual density. Taking this into account, Fig. 1 indicates that *An. albimanus* larvae virtually were eliminated when *Mesocyclops* abundance exceeded about 10 adults/liter.

There was no significant association between *Mesocyclops* and *Culex* larvae in the field samples (Spearman rank correlation = -0.16, df = 40, $P > 0.5$). *Mesocyclops* were not very successful at killing first-instar *Culex* larvae in the laboratory, generally consuming less than one every 24 h. Attacks were frequent, but most attacks appeared to be deflected by the numerous long bristles on the *Culex* larvae. Even when seized, *Culex* larvae frequently escaped by thrashing their bodies violently.

Discussion

A certain measure of caution is necessary in interpreting the negative association shown in Fig. 1. There is always a possibility that low numbers of *An. albimanus* larvae are caused by unknown factors that are correlated with *Mesocyclops* rather than by the cyclopoids themselves. However, examination of the other biological and physical variables in the field survey revealed none that was correlated positively with *Mesocyclops* and negatively with *Anopheles* (or vice versa).

From the information available so far, it appears that *Mesocyclops* spp. prey upon *An. albimanus* larvae as effectively as they prey upon container-breeding *Aedes*. Because various species of *Mesocyclops* are common through much of the tropics and subtropics where *Anopheles* occurs (Petkovski 1986), these copepods could be of use for the biological control of numerous species of *Anopheles*. Adults and copepodids can survive in the soil when a pond dries up and return to activity within hours after water appears. The economics of biological control with *Mesocyclops* could be particularly favorable because they are inexpensive to produce and easy to transport (Rivière et al. 1987a).

The feasibility of establishing *Mesocyclops* spp. in *Anopheles* habitats where they are not already abundant remains to be explored. Judging from experience with container habitats (Rivière et al. 1987b; Marten in press), simple introduction may suffice in small bodies of water that lack a full complement of aquatic predators. However, the presence of *Mesocyclops* at a low level of abundance in some of the ponds in this study suggests that simple introduction cannot always be expected to suffice. Effective use of *Mesocyclops* spp. for biological control will require understanding the ecological conditions that favor or suppress these copepods. Fish may prove decisive, as they are known to affect strongly the abundance and species composition of zooplankton through their feeding preferences (Zaret 1980, Kerfoot & Sih 1987).

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