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FEEDING HABITS OF FIVE SPECIES OF *DEINOCERITES* MOSQUITOES COLLECTED IN PANAMA[1]

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Abstract: The host-feeding patterns of 5 species of *Deinocerites* mosquitoes were studied in Panama. These included *Deinocerites pseudes*, *D. epitedeus*, *D. dyari*, *D. melanophyllum*, and *D. cancer*. A total of 3185 blood meals were identified by the capillary precipitin method and the results indicated that 3 of these species, *D. pseudes*, *D. epitedeus*, and *D. cancer*, fed readily on both poikilothermic and homoiothermic animals, while *D. melanophyllum* and *D. dyari* preferred poikilothermic animals.

Two viral isolations have been made from *Deinocerites pseudes* Dyar & Knab, St. Louis encephalitis (SLE) virus (Grayson et al. 1967) and Venezuelan equine encephalitis (VEE) virus (Scherer, pers. commun.). These are the first viral isolations from this genus of mosquito, and are of particular interest, as Bates (1949) reported that the genus *Deinocerites* is "sometimes thought to have lost the blood-sucking habit." This report provides the first data on the vertebrate host-feeding patterns of 5 species of *Deinocerites* that were collected in Panama.

MATERIALS AND METHODS

Five species of mosquitoes were collected in Panama from 7 May 1967, through 22 August 1968: *D. pseudes*, *D. dyari* Dyar, *D. melanophyllum* Dyar & Knab, *D. cancer* Theobald, and *D. epitedeus* Knab. These species were collected at the following locations: all of the *D. pseudes* from Nueva Gorgona, all but 5 of the *D. dyari* were from Paitilla, all of the *D. melanophyllum* were from Colon, all of the *D. cancer* and all but 16 of the *D. epitedeus* were from Almirante.

Nueva Gorgona is located near the western end of the Province of Panama and has a population of about 400 persons. It is considered to be an area of low rainfall, with precipitation ranging between 102–127 cm (40–50 inches) a year. There is a long, severe dry season extending from mid-December to mid-May or early June. The area is mostly under cultivation with sorghum and grazing pasture, with deciduous tropical vegetation in the uncultivated areas. The seashore is a sandy beach used extensively for recreation. Inland from the beach there are a number of salt or brackish swamps covered by pure stands of red mangrove trees or mixed stands dominated by the "manzanillo" tree (*Hippomane mancinella*). The collecting site was just back of the beach on the eastern border of town. It was a strip of brackish marsh completely open in places and partly covered by manzanillo trees. The entire strip was pocked by numerous crab holes, mainly inhabited by the species *Cardisoma crassum*. Mammal populations were small except for domestic animals: the common opossum (*Didelphis marsupialis*), the three-toed sloth (*Bradypus griseus*), and a few species of rodents and bats. Shore birds, mainly pelicans, sea gulls, and frigate birds, were often seen. Wading birds such as Green Herons (*Butorides virescens*) and Yellow-crowned Night Herons (*Nyctanassa violacea*) were common in the marshes. Black (*Coragyps atratus*) and Turkey (*Cathartes aura*) Vultures, and the Lesser Black Hawk (*Buteogallus anthracinus*) were often seen perching in the trees. Migrant sandpipers were common in the fall and numerous passeriform birds were also present. The Ground Doves (*Columbigallina talpacoti*) and Anis (*Crotophaga sulcirostris*) were 2 of the most common resident birds. Reptilian fauna was dominant in the vegetation just back of the beach. The mangrove iguana (*Ctenosaura similis*) and the common ameiva lizard (*Ameiva ameiva*) were among the terrestrial reptiles observed around the crab holes. Two species of amphibians, the giant toad (*Bufo marinus*) and the tree frog (*Hyla gabba*), were common along the margins of the marshy areas.

Almirante is located in a tropical rain forest. A full description of the study area has been given by Galindo et al. (1966) and Grayson & Galindo (1968). Several collecting sites were used in this area but all were located in peridomestic habitats. Mammals, birds, and reptiles were common at all sites. Domestic animals, including dogs, cats, horses, cattle, chickens, and ducks, were available to the mosquitoes, as their resting holes were within a few meters from yards and buildings that housed these animals. Of the wild primates, the black howler

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(*Alouatta villosa*) was present in the mangrove trees at all times. Other wild mammals common in this area included semispiny rats (*Proechimys semispinosus*), kinkajou (*Potos flavus*), sloths, opossums, and several species of squirrels and bats. The avifauna was extremely varied and plentiful. At least 18 orders of birds were well represented at all times. Reptilian fauna was also very abundant, predominantly lizards, and included *Basiliscus basiliscus*, *C. similis*, *A. ameiva*, and several species of *Anolis*. The amphibians included the giant toad and the frog (*Rana palmipes*).

Colon collections were made on the southern boundary of this city along the "Colon Corridor," which is a 2-lane highway connecting Colon with the Canal Zone mainland. The collecting sites were 2 narrow strips of tidal marsh, one on each side of the corridor, supporting red mangrove trees. The avifauna consisted mainly of shore birds and herons with occasional passeriform birds. A fairly high proportion of the reptilian fauna was present and included the common iguana (*Iguana iguana*) and mangrove iguanas and ameiva lizards.

The Paitilla collecting site was a very narrow strip of mixed red and black mangrove trees located at the mouth of the Manzanillo River, within the City of Panama. It was surrounded on 3 sides by human habitations, including a boys' school and a drive-in theater. Fauna was relatively low within the strip of mangrove. A few shore birds and black vultures roosted in the mangrove trees. Passeriform birds were common. There were few wild mammals, except for black rats (*Rattus rattus*), but domestic mammals, particularly dogs, scavenged along the stream. Reptilian fauna was not plentiful, but mangrove iguanas and ameiva lizards were present.

Deinocerites adults were obtained by placing a midge net over the mouth of a crab hole and blowing smoke into the hole or by flooding the hole with water, thus forcing the mosquitoes to fly into the net. Mosquitoes were transferred from the midge nets to plaster-of-Paris-lined 0.18 or 0.24 l (6 or 8 ounce) glass jars and brought to the central laboratory. To slow down digestion of blood, all jars were kept on ice at 4°C until they could be transported to the laboratory, where mosquitoes were immediately sorted according to species and sex. Abdomens of blooded females were removed from the thorax with sharp micro-scissors, sorted by species into gelatin capsules, and kept at −20°C in a deep freeze until ready to be shipped to California. When a sufficient quantity of capsules was accumulated, they were packed in dry ice and sent in insulated shipping boxes to the University of California by air express.

The 5 species of mosquitoes that were studied took smaller blood meals than most mosquito species previously tested. Due to the smaller blood capacity of these mosquitoes, all blood meals were suspended in 0.75 ml phosphate buffered physiologic saline pH 7.2, rather than the 1.0 ml volume previously described (Tempelis & Lofy 1963).

Early in the program it became apparent that other changes were required in our usual test system (Tempelis et al. 1967). Initial tests were done with 3 antisera: a broadly reacting screening antiserum for mammals, a broadly reacting screening antiserum for birds, and a specific anti-lizard serum. If a blood meal was positive to either the mammal or bird antiserum, it was tested further, using the basic sequence of antisera previously reported (Tempelis et al. 1967), and additional antisera were prepared and added to the tests to identify blood from animals found in Central America but not in North America.

Approximately 28% of the mosquito blood meals failed to react with any of the initial antisera, which had minimum titers of 1 : 10,000. Of these mosquito blood meals, 757 were tested with the benzidine reagent for the detection of hemoglobin and 25% failed to react. The blood meals that were positive by the benzidine test were tested further with specific anti-mammal sera that titered 1 : 40,000 and 95 of these blood meals were identified.

RESULTS

A total of 3185 blood meals from 5 species of *Deinocerites* mosquitoes were identified. The results are summarized in TABLE 1. Four species fed mostly on cold-blooded animals, primarily lizards. Two of the species, *D. dyari* and *D. melanophyllum*, fed almost entirely on lizards. Two species, *D. pseudes* and *D. epitedeus*, fed on lizards at the rate of 45.9% and 49.5% respectively, but also fed commonly on mammals and birds. The fifth species, *D. cancer*, fed predominantly on warm-blooded animals; the majority of feedings were on birds, principally members of the order Ciconiiformes (34.7%).

No seasonal change in feeding patterns was observed.

Five double feedings were detected: 3 by *D. epitedeus*, 1 by *D. pseudes*, and 1 by *D. dyari*.

DISCUSSION

Recent studies on the feeding habits of mosquitoes have indicated several basic host preference patterns. Some mosquito species show a high degree

TABLE 1. Summary of the feeding patterns of 5 *Deinocerites* mosquitoes collected in the Republic of Panama from May 1967–August 1968.

	Species of mosquito				
	Deinocerites pseudes	*Deinocerites epitedeus*	*Deinocerites dyari*	*Deinocerites melanophyllum*	*Deinocerites cancer*
No. of mosquitoes tested	445	2,716	349	151	686
No. of mosquitoes reacted	337	1,996	338	133	381
Host			Percent		
Mammalia					
Dog	1.2	2.8	0.9	0.0	6.6
Horse	8.0	1.7	0.3	0.0	7.9
Bovine	5.9	11.0	0.3	0.8	4.7
Sloth	0.6	0.3	0.0	11.2	0.0
Man	0.0	0.1	0.0	0.0	0.3
Monkey	0.0	0.8	0.0	0.0	0.3
Opossum	0.0	1.4	0.0	1.5	0.8
Other	0.0	0.8[a]	0.3	0.0	2.1[b]
Negative	0.9	0.9	0.0	0.0	1.3
Subtotal	16.6	19.8	1.8	13.5	24.0
Aves					
Chicken	0.9	1.2	0.0	0.0	4.2
Columbiformes	9.8	2.8	1.8	0.8	5.5
Passeriformes	9.8	4.4	0.0	0.0	0.5
Ciconiiformes	4.4	10.6	2.4	2.2	34.7
Pelecaniformes	0.3	<0.1	0.0	0.0	0.0
Anseriformes	0.3	0.7	0.0	0.0	1.1
Gruiformes	0.0	1.2	0.0	0.0	12.8
Other	0.3[c]	0.5[d]	0.0	0.0	0.0
Negative	5.9	5.0	0.6	0.0	8.7
Subtotal	31.7	26.4	4.8	3.0	67.5
Reptilia					
Lizard	45.9	49.5	93.4	83.5	7.1
Subtotal	45.9	49.5	93.4	83.5	7.1
Amphibia					
Frog	4.1	4.1	0.0	0.0	0.3
Toad	1.7	0.2	0.0	0.0	1.1
Subtotal	5.8	4.3	0.0	0.0	1.4
Totals	100.0	100.0	100.0	100.0	100.0

[a]Includes 7 feedings on spiny rat, 2 armadillo, 5 pig, 1 cat, and 1 bat.
[b]Includes 6 feedings on cat, 1 pig, and 1 spiny rat.
[c]Includes 1 feeding on a Falconiformes.
[d]Includes 6 feedings on Cuculiformes and 4 Charadriiformes.

of host specificity, e.g., *Culiseta inornata* Williston feeds predominantly on cattle and *Culex peus* Speiser on passeriform birds (Tempelis et al. 1967, Tempelis & Washino 1967); *Culex quinquefasciatus* Say frequently feeds on both birds and mammals (Tempelis et al., in press); and for *Culex tarsalis* Coquillet and *Culex nigripalpis* Theobald, the proportion of feedings on birds and mammals varies during the early and late summer period (Tempelis et al. 1965, Edman & Taylor 1968). Species within all of the foregoing feeding groups have been shown to be naturally infected with arboviruses and are known to be important vectors of disease in some parts of the world.

No mosquito group or species studied to date has shown the range of host feeding found with *D. pseudes*, *D. epitedeus*, and *D. cancer*, as these mosquitoes fed on members of all 4 classes of land vertebrates. The significance of this feeding versatility has been enhanced by recent reports of Western equine (WEE) and Eastern equine encephalitis (EEE) virus isolations from frogs, snakes, and turtles (Burton et al. 1966, Gebhardt et al. 1964). In addition, serum neutralizing antibodies to WEE virus have been reported in frogs and snakes (Spalatin et al. 1964, Burton et al. 1966). Thomas and co-workers (1958) suggested that reptiles may play a part in the overwintering and maintenance of WEE virus in nature. These investigators were able, under laboratory conditions, to infect garter snakes with WEE virus, and to subsequently infect *C. tarsalis* by feeding them on the snakes. The mosquitoes in turn transmitted the virus to susceptible chicks (Thomas & Eklund 1960, 1962). Similar experiments were successfully carried out by Gebhardt and co-workers (1960, 1966).

Although some investigators have reported that various mosquito species feed on amphibians and reptiles (Crans & Rockel 1968, Henderson & Senior 1961, DeFoliart 1967), no mosquito in nature has been shown to have commonly the versatility to feed on both cold-blooded and warm-blooded animals. Versatility of host feedings would be a necessary criterion, if arboviruses such as WEE virus were to be transmitted from a possible overwintering reptilian host to birds, the amplifying host, and finally to man and domestic animals, the epidemic hosts. For example, in the western United States, *C. tarsalis* is the principal vector of WEE virus. Although this mosquito demonstrated extensive feeding versatility between birds and mammals, few wild mosquitoes were found that had fed on cold-blooded animals (Tempelis et al. 1965). In fact, no western mosquito that was naturally engorged has been reported to have fed with significant frequency on both poikilothermic and homoiothermic animals. From the presently available data, it would appear that more than 1 mosquito must be shown to be involved in the basic transmission cycle of WEE virus before snakes or frogs can be considered as important overwintering hosts for WEE virus.

To date, SLE and VEE viruses have been isolated from *D. pseudes* (Grayson et al. 1967, and Scherer, pers. commun.). This mosquito has proven to be an efficient vector of VEE virus in the laboratory (Grayson & Galindo, unpubl. results). The significance of these findings in the overall epidemiology of SLE and VEE viruses in Panama has yet to be determined.

It is of interest that at the beginning of this study, it was assumed that *D. cancer* was not present in Panama. Females of *D. cancer* cannot be differentiated from female *D. melanophyllum*. During the course of this study, additional examinations of males were made and it was found that *D. cancer* was the species collected at Almirante; while at Colon, the species *D. melanophyllum* was collected. Our data confirm the taxonomic separation of these 2 species in that *D. cancer* fed mostly on homoiothermic animals, and *D. melanophyllum* on poikilothermic animals.

This report demonstrates that at least 3 New World mosquito species feed readily on both poikilothermic and homoiothermic animals. If poikilothermic animals are shown to be important overwintering hosts for arboviruses, a mosquito vector that would transfer infection between major classes of hosts must demonstrate a feeding versatility such as that shown by *D. pseudes*, *D. epitedeus*, and *D. cancer*.

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