HOST-SEEKING BEHAVIOR AND SEASONAL ABUNDANCE OF *CULICOIDES PARAENSIS* (DIPTERA: CERATOPOGONIDAE) IN BRAZIL[1]

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ABSTRACT. The ecology of *Culicoides paraensis* was studied with human bait collections at an agricultural research station near Belém and within 2 neighborhoods of Belém, Brazil, from 1977 to 1978. From collections conducted along transects that were centered on a house, we found most dense populations of host-seeking midges within and near the house. Host-seeking activity was least in areas fully exposed to sunlight compared to the levels of activity indoors and in shaded areas outside. Numbers of flies biting under shade trees and within the house increased during intervals of rain; concomitantly the levels of activity decreased in open areas. Seasonal population densities correlated with the pattern of rainfall, with a 2-month lag due to the long maturation time of immature *C. paraensis*. The effects of temperature and humidity on host-seeking activity are discussed.

INTRODUCTION

Culicoides paraensis (Goeldi) (Diptera: Ceratopogonidae) is the primary vector of Oropouche virus in urban areas within the Brazilian Amazon Basin (Pinheiro et al. 1981, 1982a, 1982b, Dixon et al. 1981, Roberts et al. 1981). With more than 130,000 cases reported from 1978 to 1980, Oropouche virus ranks as one of the more common causes of arboviral infections in South America (Borborema et al. 1981). The finding that meningitis is a complication of the acute illness serves to increase concern about this virus and its urban vector (Pinheiro et al. 1982a, 1982b).

The efficiency of transmission of Oropouche virus by *C. paraensis* is linked to the midge's association with man-made environments. This midge-domestic environmental association seems related to the midge's preference for breeding in banana plant refuse since banana plants are commonly cultivated in the urban centers of Amazonia (Hoch et al. 1986). Vector efficiency is also related to the midge's anthropophilic behavior.

Culicoides paraensis is the most common diurnal man-biting insect in urban areas (Roberts et al. 1981, Pinheiro et al. 1981, 1982a, 1982b, Dixon et al. 1981, Borborema et al. 1981). Peak biting activity occurs between 1700–1800 h, but the levels of activity at other times vary widely (Roberts et al. 1981, LeDuc et al. 1981) Environmental factors that contribute to differences in activity patterns of host-seeking *C. paraensis* populations are described in this report. In addition, the seasonality and associations of host-seeking *C. paraensis* populations with houses are quantified.

MATERIALS AND METHODS

Study site: All studies were conducted in and around Belém, Brazil, where major epidemics of Oropouche virus have occurred (Hoch et al. 1986). Studies on daily patterns of host-seeking activity and associations of *C. paraensis* with houses were conducted at the Agriculture Research Station (CEPLAC) on the periphery of Belém. Studies on the seasonal dynamics of *C. paraensis* populations were conducted in 2 separate zones of Belém.

The study site at CEPLAC encompassed an area of 10–15 ha, located where cacao was being cultivated and where dense populations of *C. paraensis* occurred. Four general habitat types were in the study area: mixed plots of mature cacao and banana trees; marsh; grassy areas; and a monoculture of maturing deciduous trees (Fig. 1). A more detailed ecological description has been presented in Hoch et al. 1986.

The houses (A and B) used in the study were constructed of stuccoed walls and tile roofs and were approximately 200 m apart. During the day, as is custom in tropical regions, the doors and windows were left open for ventilation. A few shade trees of various sizes and heights were maintained around the houses. A group of larger trees flanked one side of house A at a distance of 7–10 meters.

Eight members of one family lived in house A. They had a dog and a few caged chickens.

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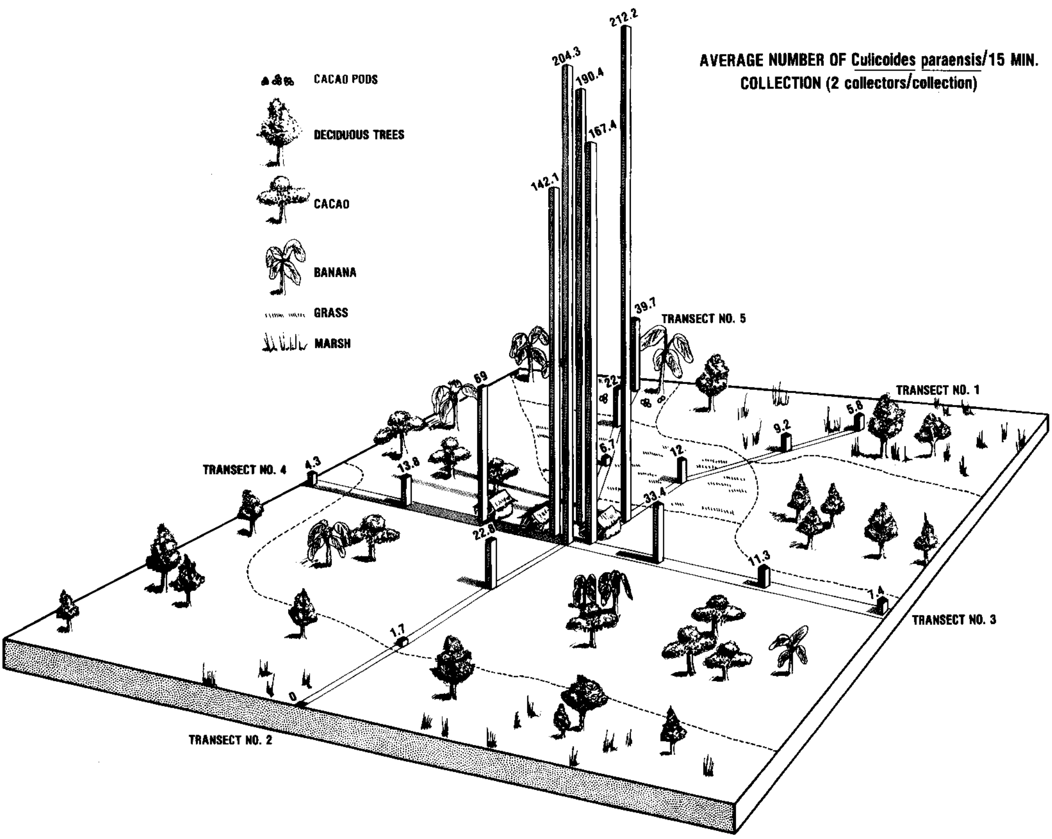

Fig. 1. Spatial distribution of host-seeking populations of *Culicoides paraensis*. Means calculated from 7–10 collections at each station (total of 188 collections). Collections were conducted at the Agriculture Research Station (CEPLAC) on the periphery of Belém, Brazil, in 1977. Transects centered on house B (house A not illustrated).

House B was a staging site for employees involved in maintaining the experimental cacao and banana trees and various human activities in or near the house occurred during each working day. No large domestic animals were within a 1-km radius of the study site; therefore, man was the primary large-animal host for the blood-feeding midges. Routine identifications were made and the diurnal population of midges in this area was composed primarily of specimens of *C. paraensis*.

Spatial distribution: The spatial distribution of host-seeking *C. paraensis* was studied at CEPLAC using transects (Fig. 1) centered on house B. Teams of 2 collectors using mouth aspirators were positioned at each of 4 locations separated by 20 m along each transect. Biting midges were aspirated from the collectors' exposed legs for a collecting period of 15 min. The *Culicoides* collected by each team were identified and counted while the 2-man teams changed locations along the transect, continuing until each team had rotated through each of the 4 locations along the transect. Collections were repeated along a series of 5 transects.

Daily activity: Both indoor and outdoor collections were performed at house A to compare the effects of different environmental settings on the pattern of diurnal host-seeking activity. House A was selected for these studies because, unlike house B, it was continuously occupied by a family. There was one indoor and 2 collecting sites outside within 10–20 m of the house. One site outside was under shade trees while the other was in a clearing about 10 m from both shade trees and house.

A team of 2 collectors was stationed at each of the 3 collecting sites for 45 min/h. The teams were rotated between the sites each hour to prevent differences caused by collector efficiency. Continuous hourly captures, as previously described, were made between 0600 and 1845 h. Collecting containers were gathered each hour to identify and record the number of *Culicoides* captured. Hydrothermographs were used to monitor ambient temperature and relative humidity at each collection site. Series of collections were performed 3 days a week for approximately 1 month in March–April 1977.

Seasonal activity: Collections of *C. paraensis* were made within 10–20 m of each of several selected houses in 2 separate neighborhoods in Belém. Landing captures were performed by 2-man teams that collected midges attempting to feed on the lower legs (knee to ankle). Captures were made for 4 consecutive 30-min intervals from 1400 to 1600 h at each collection site for 2 consecutive days on alternate weeks. Rainfall data was obtained from the CEPLAC meteorological station located in the periphery of Belém.

Additional information on seasonal population densities was obtained by making captures near the house (described previously) at CEPLAC. The collection station was about 10 m from house B. The collections were conducted in a uniform manner (as described above) 0830–0915 h daily (excluding weekends and holidays) during the months of November 1977–July 1978.

RESULTS

Spatial distribution: On average, 92 of every 100 host-seeking *C. paraensis* collected were captured within a 20-m radius of the transect focus, near house B (Fig. 1). Low levels of biting activity (averages of 0–69/collection) were found for stations 3, 2 and 1 of transects 1, 2, 3 and 4. More specimens were captured at station 1 of transect 5 than at stations 2 and 3.

Daily activity: Brief periods of rainfall were recorded during most afternoons after 1300 h. Sequential collections before, during and after intervals of rainfall were compared. However, collections after 1645 h were excluded from this analysis to avoid bias due to the normal late afternoon increase in biting activity. The direct effect of rainfall, or indirect effect due to increased relative humidity, was expressed differently in different environmental settings. More specimens were collected indoors and under shade trees during periods of rainfall than in pre- or post-rainfall periods (Fig. 2). For example, an average of 37 midges were collected indoors pre-rainfall, followed by averages of 103 and 74.8 during rainfall and post-rainfall periods, respectively. In open areas fewer specimens were collected during the rainfall period and after rainfall there was a sharp increase in numbers collected. As a result of this finding, all data from pre-, during and post-rainfall periods were excluded from the analyses to delineate daily activity patterns of *C. paraensis*.

Daily activity patterns, ambient temperatures and relative humidities in different environments are presented in Fig. 3. Biting activity began at approximately 0600–0615 h. There was an early morning peak in the house and at the site fully exposed to sunlight. An early morning peak was not observed for the shaded peridomiciliary site; however, a general increase in biting activity was recorded until early afternoon when activity subsequently declined until 1700 h. At

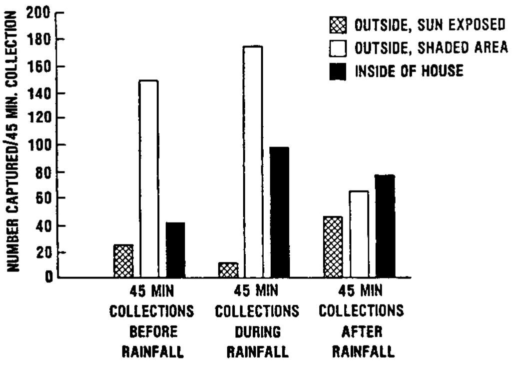

Fig. 2. Numbers of *Culicoides paraensis* captured in 45-min biting collections before, during and after intervals of rainfall. Collections were conducted at the Agriculture Research Station (CEPLAC) on the periphery of Belém, Brazil, in 1977.

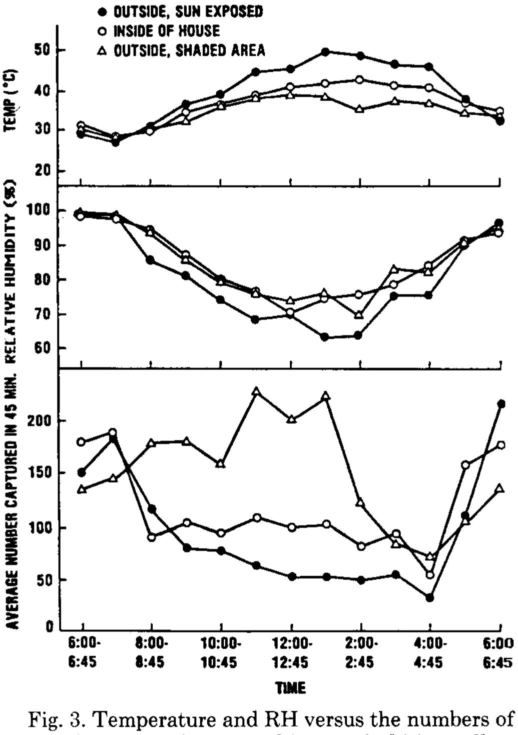

Fig. 3. Temperature and RH versus the numbers of *Culicoides paraensis* captured in 45-min biting collections under different environmental conditions. Collections were conducted at the Agriculture Research Station (CEPLAC) on the periphery of Belém, Brazil, in 1977.

1700 h a marked increase in biting activity occurred at all sites. Shortly after 1830 h all biting activity ceased. There was intense biting activity with averages of 137 to 216/collection from 1800 to 1830 h, followed by a rapid drop in numbers biting as the sun set. No systematic collections were conducted after sunset simply because cessation of activity following sunset has been amply demonstrated in previous studies (Roberts et al. 1981).

The early morning and late evening temperatures were similar for the 3 collection sites; while mid-afternoon temperatures (1300–1600 h) were highest for the site exposed to full sunlight.

Relative humidity readings were near 100% in the early morning but fell below 90% between the hours of 0800 and 1700. The lowest level of humidity was recorded for the exposed peridomiciliary site.

Seasonal activity: Populations of *C. paraensis* were active in the urban areas throughout the year, exhibiting a trimodal increase in numbers of specimens for the 13-month observation period (Fig. 4). Numbers fluctuated from 7 to 25 *Culicoides* per hour per month, with peaks of activity occurring in the months of September–November, January–February and May–June. In only 1 month (November) was the total rainfall measured below 75 mm. Monthly rainfall was seasonal with the months of December to March recording the most rainfall.

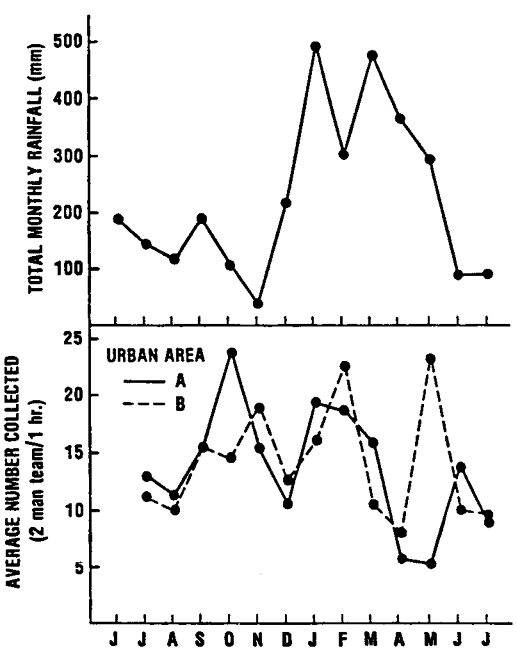

Fig. 4. Total monthly rainfall (mm) and mean number of *Culicoides paraensis* captured in 2 neighborhoods in Belém, Brazil, from 1977 to 1978.

DISCUSSION

We quantified the association of *C. paraensis* populations with the domestic environment, the effect of different environmental and meteorological conditions on their host-seeking behavior, their seasonality in Belém, Brazil, and the influence of rainfall on population densities. From the transect studies we found a high concentration of the *C. paraensis* host-seeking populations around the house (station 4). Apparently, midges are attracted to the humans associated with the house, the house itself or to both. In either case their close association with human habitation is an important behavioral characteristic that facilitates transmission of disease to human populations.

At a later date we discovered that station 1 of transect 5 was located near a breeding habitat (a pile of discarded cacao hulls) for several species of midges, primarily *C. paraensis*. Close proximity of the breeding site may account for the higher number of *C. paraensis* recorded for station 1, transect 5. Other midge species were rarely present in the human bait collections.

Host-seeking activity indoors and at 2 separate sites outdoors varied with the environmental conditions at each collecting site. Biting activity in the house and at the shaded collecting site remained fairly high throughout the day. The relatively lower attack rates during midday at the site fully exposed to sunlight indicates that the *Culicoides* avoided those areas of higher temperature and/or lower humidity and concentrated in more protected areas. Such behavior favors contact between midges and humans, since humans and other animals also seek protected areas during midday. When temperature and humidity became more favorable after 1700 h, midge activity increased uniformly throughout the peridomiciliary area. In addition, we found that rainfall resulted in larger numbers of specimens being collected indoors. The same response did not occur in shaded areas outside as was demonstrated by a decreased collection size after the period of rainfall. As a consequence of air becoming cooler and more humid with precipitation, the midges may have widely dispersed outside and become less concentrated in shaded areas after a period of rainfall. The much larger number of specimens collected in the open area following the period of rainfall supports this speculation.

A third parameter, which was not monitored but which we think has a major effect on midge population activity, is light intensity. The early morning peak in biting activity was probably initiated by the rapid change in light intensity. There was a noticeable delay in the initiation of *Culicoides* biting activity during cloudy, overcast mornings.

Collection data from 2 neighborhoods in Belém demonstrated a rise and fall in the midge populations. Likewise there was a correlation in these patterns and the pattern of seasonal rainfall. The influence of rainfall on midge population densities was expected since *C. paraensis* breeds in aquatic to semiaquatic habitats. More specifically, decomposing banana stalks comprise the major breeding habitat for *C. paraensis* within the urban environment (Hoch et al. 1986). This is true even during short intervals of reduced rainfall due to the high water retention characteristics of the banana stalks. Nevertheless, the natural water losses from plant material must be renewed periodically by rainfall to maintain a viable breeding site.

A lag time of approximately 1 month occurred between the initial increase in rainfall and a corresponding increase in the midge population. This was particularly noticeable with the increase in rainfall in September followed by an increase in *Culicoides* population densities in October and November (Fig. 4). A lag in population abundance was observed again with the data from the January through February period. This phenomenon is probably due to the slow developmental time for *Culicoides* larvae. The developmental time for *C. paraensis* at room temperature in the laboratory is approximately 1 month (A. L. Hoch, unpublished data).

The results of these studies help to elucidate several behavioral characteristics of *C. paraensis* and the association of *C. paraensis* with the domestic environment and, specifically, with human populations as a blood source. We can describe this species as one that is day-active, partially endophagic, anthropophilic and dependent upon cultural practices for production of abundant favorable breeding sites in urban areas. The strong association of this midge with humans and its abundance in urban areas are undoubtedly key factors in the success of *C. paraensis* as the primary vector of Oropouche virus in urban Amazonia.

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