Culex nigripalpus: Seasonal Shift in the Bird-Mammal Feeding Ratio in a Mosquito Vector of Human Encephalitis

Abstract. *Blood-engorged* Culex nigripalpus *(Theob.) collected throughout the year in two Florida localities were serologically tested to determine the host range of this mosquito in nature. A proportional increase in feeding on mammals occurred in early summer, reached a maximum between July and October, and was followed by a shift back to avian hosts which dominated the feeding pattern during winter and spring. This finding strengthens the hypothesis that a biphasic pattern of feeding is a basic characteristic of an enzootic vector that, in epidemic years, also serves as the primary vector of avian arbovirus to man.*

Serologic identification of the vertebrate-blood meal in naturally engorged mosquitoes is providing reliable data on the feeding patterns of mosquitoes in nature. Mosquitoes appear to fall into four groups based on their feeding patterns. These are species that feed (i) primarily on mammals, (ii) primarily on birds, (iii) primarily on cold-blooded vertebrates, and (iv) on a wide variety of hosts. Species with the fourth pattern might be expected to show the same diversity throughout the year, their feeding pattern always reflecting the local availability of hosts. Generally this is true. In temperate climates, populations of most mosquitoes are active for only a few weeks, providing little opportunity for seasonal differences in feeding. A notable exception is *Culex tarsalis* (Coq.), a species active for 6 months or more in parts of central, southern, and western United States. This species shows a seasonal change in its feeding pattern in all geographic areas investigated, the degree of change varying between localities (*1*). The well-established role of *C. tarsalis* in arbovirus transmission (both enzootic and epidemic) suggests that a seasonal change in feeding may have special disease significance (*2*).

The vector of St. Louis encephalitis virus in Florida (*3*), *Culex nigripalpus*, is another species suitable for the study of seasonal feeding patterns since the subtropical climate permits activity all year. Distributed throughout the Caribbean, this mosquito reaches peak abundance in Florida in late summer (August and September) but is relatively scarce and more difficult to collect during the dry season (February to May). Blood-engorged specimens were obtained from two localities on opposite sides of peninsular Florida (near Tampa on the west coast and Vero Beach on the east). The Tampa site is within the area of the outbreaks of St. Louis encephalitis in 1959 to 1962. Both collection sites are wooded swamp habitats of less than 100 acres. Engorged mosquitoes were processed, and the blood meals were serologically identified by means of precipitin tests (*4*).

Culex nigripalpus showed a marked seasonal change in feeding at both localities (Fig. 1). The pattern is characterized by a proportional increase in feeding on mammals which starts in early summer, reaches a maximum between July and October, and is followed in autumn by a return to mainly avian hosts which prevail during winter and spring. The shift to mammals occurred about 6 weeks earlier in 1967 than in 1966, whereas the shift back to birds occurred about the same time in both years. Also at both sites, the maximum feeding on mammals was greater in 1967. The net result was a longer period with higher levels of feeding on mammals in 1967. Slight, but similar, differences in the pattern between the two sites occurred both years. In general, the shift to mammals exceeded the proportions described for *C. tarsalis*, but the timing and trend of the patterns are similar in both species.

A large proportion of the Tampa mosquitoes fed on birds and mammals different from those fed on at Vero Beach; thus the shift in feeding, similar at both sites, cannot be related to any parallel shift in the availability of one or two hosts common at both sites. Domestic fowl, unavailable at Vero Beach, were the main source of avian blood at Tampa. Rabbits were common

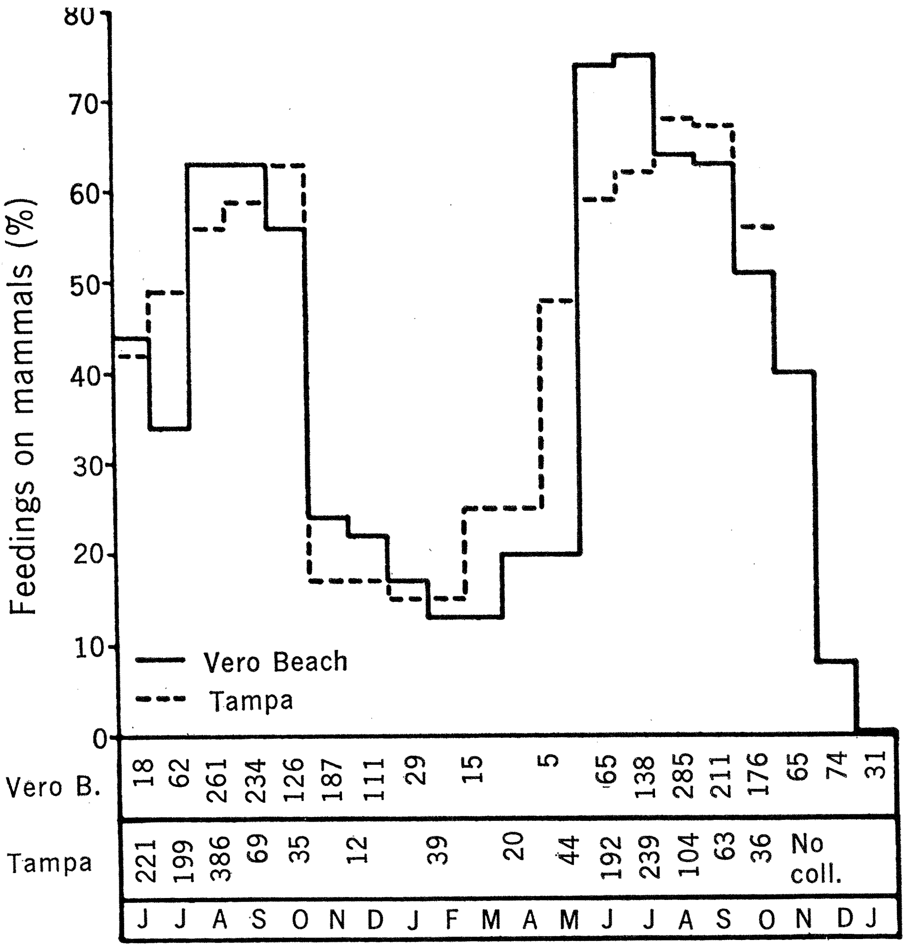

Fig. 1. Proportion of *Culex nigripalpus* feeding on mammals in two Florida localities during 18 consecutive months. Except for a few feedings on amphibians or reptiles, which never exceeded 1 percent in any month, the rest were on birds. The total number of feedings identified (June 1966 to January 1968) is indicated at the bottom of each monthly or bimonthly bar.

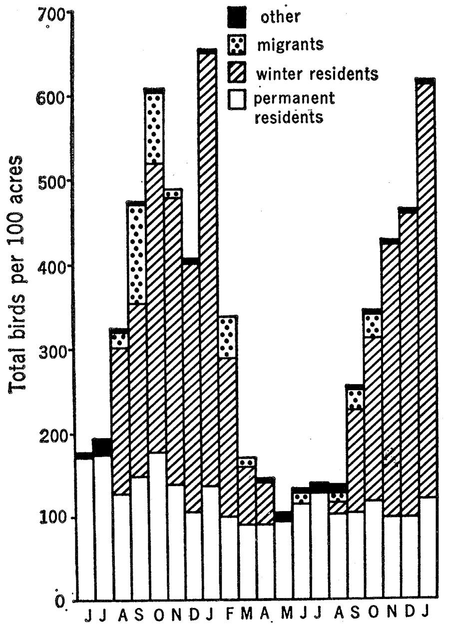

Fig. 2. Monthly average of bird populations estimated from counts per visit at Vero Beach locality (June 1966 to January 1968). Data exclude local birds visiting the site only by day. Solid black bar represents summer residents and estimates of less than ten migrants or winter residents.

at Tampa and frequently served as hosts, but they were uncommon at Vero Beach, where the larger armadillo population replaced them as one of the main sources of mammalian blood.

When seasonal changes in the relative abundance of birds and mammals are considered collectively (for each vertebrate class) there is still no evidence to explain the phenomenon adequately. A combination of avian census (*5*) and mammal trap (*6*) techniques provided monthly data on 1966 and 1967 populations at Vero Beach. Seasonal changes in the vertebrate populations were found, but these changes do not parallel the seasonal changes in the ratio of feeding on birds to that on mammals in *C. nigripalpus*. For example, wild bird populations increase greatly during migrations and certain periods of the winter (Fig. 2). The winter residents undoubtedly contribute to the avian feedings during this period, but they start to arrive in August and September (when feeding on mammals remains high) and they depart in February and March, at least 2 months before the decrease in feeding on birds. Likewise, no increase in feeding on birds occurred during the migration periods. This might be expected, however, since migrating birds are transient, usually flying at night (when *Culex* feed) and foraging and resting during the day (*7*).

If seasonal change in host availability (due to change in host numbers, behavior, age, and so forth) is eliminated as the primary cause for seasonal change in mosquito feeding, we are left with factors that directly or indirectly affect the behavior of the mosquito population. Present evidence suggests at least two possibilities. Periods of maximum feeding on mammals closely parallel the periods of peak abundance of mosquitoes. This is true for *C. tarsalis* as well and suggests that population size might have an important influence on mosquito behavior. Second, seasonal feeding patterns are closely related to the seasonal weather conditions, indicating that temperature and atmospheric moisture might influence the mosquito's feeding behavior or its ability to find one class of hosts more readily than the other. A combination of factors may be at play although the remarkable similarity in patterns between the two species in several biotically different localities would favor some factor common to all.

To be both the enzootic and epidemic vector (dual vector) of a virus enzootic in birds (such as St. Louis and western encephalitis), a mosquito must have a varied feeding pattern. Both *C. nigripalpus* and *C. tarsalis* meet this requirement, and both are efficient vectors of arbovirus. Evidence that *C. tarsalis* shifts from primarily avian hosts in the spring (probable enzootic period of virus buildup) to a high proportion of mammalian hosts in the summer and fall (epizootic and epidemic season), when considered with the similar finding in *C. nigripalpus*, strongly favors this "change in hosts" as a basic requirement of a dual vector.

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Raman Spectra of Crystalline Lysozyme, Pepsin, and Alpha Chymotrypsin

Abstract. *Satisfactory Raman spectra of crystalline lysozyme, pepsin, and alpha chymotrypsin were obtained with laser excitation. The spectra are very similar to each other, but show enough minor differences to make this a useful method of identification. The readily identified bands assignable to specific groupings are noted.*

The development of improved Raman spectrometers (*1*) assembled with ion-laser sources, double monochromators, and pulse-counting detection makes it possible to record the Raman spectra of many crystalline hormones and enzymes with good signal-to-noise ratios. Even though a strong fluorescence background is present in these materials, conditions can be adjusted to bring out the Raman lines (*2*).

I now report on the Raman spectra

Table 1. Observed Raman lines in enzymes. No Raman lines were observed between 30 and 500 cm^{-1}.

α-Chymotrypsin (cm^{-1})	Lysozyme (cm^{-1})	Pepsin (cm^{-1})
~3300	~3300	~3300 NH
3062	3053	3064 =CH
2968	2964	2967 CH
2936	2926	2935 CH
2875	2870	2885 CH
1667	1667	1674 amide C=O
1619	1625	1614 C=C
1578	1591	
1551	1512	1554 amide NH
1453	1430	1455 CH
1358	1356	1341
1341	1336	1313
1245	1251	1250
	1202	1207
		1177
		1156
1127	1050–1139	1126
1034	1011	1032
1007	1003	1006
976		
878	900	879
855	876	856
830		831
758	768	760
644		645
627		623
568		
512	505–595	521