MOSQUITO FLIGHT PATHS IN RELATION TO THE ENVIRONMENT
EFFECT OF THE FOREST EDGE UPON TRAP CATCHES IN THE FIELD

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ABSTRACT. A few species of mosquitoes rest in grassland during the day (field species) and are active in the same habitat at night. A number of other species rest in woodland during the day (woodland species) but at night fly out into grasslands. Collections from nocturnally-operated suction traps at distances of approximately 11 or 87 m from woodland showed equal numbers of field species at both distances whereas woodland species were taken in reduced numbers at 87 m. It is proposed that woodland species maintain visual contact with tall silhouettes such as the woodland edge.

INTRODUCTION

An earlier publication (Bidlingmayer 1971) reported on the daytime resting behavior and the nocturnal aerial densities of adult mosquitoes in Indian River County, Florida. Mosquitoes were captured (a) during daylight with a vehicle aspirator to collect mosquitoes resting on the ground, and (b) at night in large suction traps placed on transects across a wooded swamp and into an adjacent open field to measure aerial densities in flight. Those mosquitoes found resting primarily in grassland were classified as field species, and those primarily in forest litter as woodland species. A few mosquitoes were found to rest in greatest numbers in old fields and secondary forest areas. The suction traps showed that at night field species of mosquitoes also flew in larger numbers in the fields than in wooded areas. However, while at night some woodland species were more numerous in woodland than in fields, other species were more numerous in the fields. These latter woodland species commute daily between their woodland resting areas and their open field foraging areas. Aerial densities of those species resting in old fields and secondary growth were greatest along the forest edge.

In 1974 a new research area, 15 km to the north of the first area, was developed (Bidlingmayer and Hem 1980). Both research areas were quite similar but the greater expanse of open field at the new area permitted collections to be made at greater distances from the edge of the woodland. It is the object of this report to expand the findings of the 1971 study in regard to the distribution of mosquitoes in the field and to consider the effect of long range visual orientation upon mosquito distribution.

PROCEDURES

The old and new research areas, referred to hereinafter as areas A and B, respectively, each possessed a red maple *(Acer rubrum)* swamp with a dense understory of water-tolerant shrubs *(Myrica, Clethra)* and ferns. Immediately adjacent to the wooded swamps was an open field containing pasture grasses. A complete description of the 2 study areas and the suction traps employed in both has been given (Bidlingmayer 1971, Bidlingmayer and Hem 1980). The principal difference between the 2 areas was that at area A the open field adjacent to the swamp had a width of about 20 m whereas at area B the width exceeded 150 m. At area A suction traps in the field were only 11 m distant from the swamp edge while at area B the traps in the field were spaced at various distances of from 65 to 110 m from the edge of the swamp. The primary purpose of the work at area B had been to evaluate the responses of mosquitoes to visual targets (Bidlingmayer and Hem 1980), and in the field the number of traps operated each night varied from 8 to 20. Four additional suction traps, placed from 10 to 50 m within the swamp also were operated each night. In the first study at area A, collections were made during a 5-day period centered on new moon for 1 year from 5 August 1967 to 26 July 1968. In this study only those collections made during a 9-day period centered on new moon between 19 June 1974, and 9 June 1975, were included. Field suction traps exposed to air discharged from another trap made smaller collections in proportion to the number of discharging traps (Bidlingmayer and Hem 1980). Catches from the exposed traps were increased by approximately 35% to compensate for the exposure. All collection data were transformed into the logarithm (x + 1) before the analysis of variance calculations were performed. The results are presented as Williams mean (M_w), the antilog-1 of Σ log (x + 1)/N.

RESULTS

The species captured during this study were *Aedes vexans* (F), *Anopheles crucians* Weidemann, *An. quadrimaculatus* Say, *Culex nigripalpus* Theobald, *Cx. (Melanoconion)* Theobald and *Cx. (Mochlostyrax)* (Dyar and Knab) spp. (principally *pilosus* (Dyar and Knab)), *Culiseta melanura* (Coquillett), *Psorophora ciliata* (F), *Ps. columbiae* (Dyar and Knab), *Uranotaenia lowii* Theobald, and *Ur. sapphirina* (Osten Sacken).

The principal species of mosquitoes taken at area B are listed in Table 1 according to the percentage of the total number captured that were found in the field (Column 6). Column 1 indicates the diurnal resting areas occupied by each species (Bidlingmayer 1971). Although, because of their habit of resting in shelters, anopheline mosquitoes were not taken in vehicle aspirator collections during the earlier study, in this area only woodlands provide abundant shelter and these species are classified here as woodland species. Based upon nocturnal collections of mosquitoes in suction traps (Bidlingmayer 1971), certain woodland species are classified further as commuters because of their daily movement between woodland and fields.

The number of nights of operation and the mean numbers (M_w) captured per trap night at area B in suction traps in the field and in the swamp are shown in columns 2, 3, and 4. Only *Ps. columbiae* and *Ps. ciliata* were captured in significantly greater numbers by traps in the field than by traps in the swamp. Ninety-four and 93%, respectively, of all specimens of these species captured were taken in the field traps. For all remaining species except *Ae. vexans* field collections were small, as from only 37% of all *An. crucians* to 7% of all *Cx. nigripalpus* were captured in the field traps.

At area A (Bidlingmayer 1971), in contrast to area B, all species except *Cx. nigripalpus* and *Cs. melanura* occurred in greater numbers in the field than in the swamp (Col. 7). This finding provided the basis for the statement in the introduction that these species were commuting between field and swamp. Calculations of the percent reduction of the catch at area B from those obtained at area A (Col. 8) show differences between areas A and B were negligible for *Ps. ciliata* and *Ps. columbiae* but were substantial for all other species; e.g., for *Cx. nigripalpus* the percent taken in field traps declined from 23% at area A to 7% at area B, a reduction between areas of 70%. Except for the 2 field species, all mosquitoes showed large reductions in catches at area B.

The relationship between suction trap catches of mosquitoes taken in different habitats at area A, expressed as a ratio with field collections of each species = 1.00, have been previously reported (Bidlingmayer 1971, cf fig. 3). The last column in Table 1 expands fig. 3 by presenting the catch ratios that would have

Table 1. Mean number (M_w) of female mosquitoes captured at area B per trap night in suction traps in the field and in the swamp and the percentage of the catch taken in field traps (field/field + swamp). The percentage of the catch taken in field traps at area A (Bidlingmayer 1971) is also shown and the percent reduction in field trap catches at area B from those at area A⁺. The last column indicates the estimated catch ratio at area A (where all field catches at 11 m from the swamp = 1.00) if field traps had also been operated at 65–110 m from the swamp.

AREA:		B					A	B	A
			M_w						
Species	Daytime resting habitat	Nights[d]	field	swamp	P	% in field	% in field[e]	% reduction from area A	Estimated ratio at 65–110 m
Psorophora columbiae	field	90	6.10	0.39	**	94	93	−1	1.01
Psorophora ciliata	field	67	2.70	0.21	**	93	93	0	1.00
Aedes vexans	woodland[b]	83	9.88	8.39		54	70	23	.77
Anopheles crucians	woodland[b]	103	3.23	5.53	*	37	79	53	.47
Culex spp.[a]	woodland[b]	86	3.10	5.60	**	36	67	46	.54
Anopheles quadrimaculatus	woodland[c]	91	0.29	0.99	**	23	57	60	.40
Uranotaenia lowii	edge	101	1.11	4.75	**	19	60	68	.32
Uranotaenia sapphirina	edge	102	0.97	4.31	**	18	57	68	.32
Culiseta melanura	woodland	108	2.51	26.20	**	9	16	44	.56
Culex nigripalpus	woodland	107	17.22	212.68	**	7	23	70	.30

* $P = < 0.05$.
** $P = < 0.01$.
⁺ Field traps at area A and B were 11 and between 65–110 m, respectively, distant from the edge of the swamp.
[a] Principally *Culex (Mochlostyrax) pilosus* and some *Culex (Melanconion)*.
[b] Commuter species between swamp and field.
[c] Commuter species between swamp and field edge.
[d] From 8–20 traps operated nightly in the field and 4 traps nightly within the swamp.
[e] Calculated from means in Bidlingmayer 1971 (Table 1).
[f] Cf. Fig. 3 Bidlingmayer 1971.

been expected at area A if, in addition to the traps at 11 m, field traps had also been employed 65 to 110 m from the swamp edge.

DISCUSSION

The percentage of *Ps. columbiae* and *Ps. ciliata* found in the field was high at both areas A and B, i.e., at 11 or between 65–110 m from the edge of the woodland, and thus these species appear to be quite uniformly distributed across open areas (Table 1, Col. 6). Since the adults of field species inhabit open fields throughout the diel, as dawn approaches and a daytime resting area is needed, these species may settle anywhere. The aerial densities of woodland commuter species at 65 to 110 m from the swamp edge (area B) were only about one-half or less as great as densities at 11 m (area A). Although leaving woodland at dusk for the field, most adults remain close to the forest edge and at dawn will be close to suitable daytime resting area. The percentages of edge and woodland species captured in the field were also greater at area A than at area B, again indicating a bias for the proximity of the wooded swamp. It appears that, except for species that rest during daylight hours in open fields, many species restrict their nocturnal flights in the open to the vicinity of potential daytime resting areas.

Three environmental factors that could affect mosquito densities in the field should be considered. Higher humidities in summer and autumn can affect the flight behavior of *Cx. nigripalpus* (Dow and Gerrish 1970, Provost 1974), but as the studies at area A and B each encompassed 1 calendrical year, the annual means obtained should be similarly affected. Wind velocities would normally be greater at a distance of 65 or more meters from a forest edge than those at 11 m and smaller catches would be expected in traps at the greater distance. Wind records were made at only a single field location at either area, and thus data for making comparisons between wind velocities and trap catches at various distances are not available. However, there is little reason to believe that at area B catches of the 2 field species would be almost unaffected by winds which reduced the numbers of other species captured by 23 to 70% (Table 1). Differing wind velocities are not believed to be of major significance here.

Mosquitoes are visually attracted to conspicuous objects and it has been estimated that in an open field most species respond to the suction traps from a distance of 15 to 20 m (Bidlingmayer and Hem 1980). The range of visual attraction for other objects is probably different due to variations in size, reflectance, and spacing. The field traps at area A were not more than 11 m from the edge of the field and various natural features as the swamp edge, shrubs, and an occasional tall pine tree, were within a 15–20 m radius. The effect of these features upon field trap collections at area A cannot be ascertained. The traps at area B had been spaced 15 m apart; therefore, the effective sampling distance between traps was only 7.5 m although a trap along the periphery of a group of traps would be visible to mosquitoes from a distance of 15 to 20 m on one or more, but not all, sides. Consequently, none of the traps was unaffected by competing visual attractants.

Gillies and Wilkes (1974) suggested there may be an interaction between chemical stimuli and the skyline to explain the vertical distribution of certain blood-seeking *Culex*. Employing directional flight (ramp) and suction traps, Snow (1977) captured mosquitoes apparently flying upwind at the top of a tower despite wind velocities apparently greater than mosquito flight speeds. He proposed that mosquitoes flying at elevations too high to maintain visual contact with the earth may respond to elevated visual features, such as the tower or trap and approach the object laterally with the final approach from the leeward where wind velocities would be lower. The forest edge at area A and B would also provide an elevated visual feature that may attract mosquitoes; however, as the distance to the forest decreased, its large size would result in the mosquito losing sight of it as a single entity as its separate components were perceived. Flight would then be directed toward one or another visual target. For species that return to woodland at dawn, attraction to high silhouettes would prevent the population from dispersing too far afield during the night.

Because of the presence of competitive visual attractants, none of the field suction traps at area A or B was taking maximum catches. Whether the effectiveness of field traps was greater at area A or at area B is not known. However, (a) if trap effectiveness is lower at area A than B, then the field species actually occur in smaller numbers at the greater distances, with the implication that field species also maintain visual contact with woodlands; (b) if trap effectiveness is greater at area A than B, e.g., 2 or 3 times greater, then woodland and edge species are actually uniformly distributed across the field while field species would occur in reduced numbers 11 m from the forest, again implying visual contact, although one of avoidance, with woodlands. Because the need to maintain contact with woodland is of less importance to field species than to those that rest in woodland, it seems that differences in the effectiveness of field suction traps at area A and B were not great and thus only woodland, woodland commuters, and edge species visually respond to the forest edge. Alternative (a), however, cannot be entirely discounted.

These findings suggest that space treatments to control adult mosquitoes may be more effective in the vicinity of a forest than at greater distances.

ACKNOWLEDGMENT

Sincere appreciation is extended to Dr. J. H. Frank, Dr. G. F. O'Meara and Dr. L. P. Lounibos for reviewing the manuscript. The assistance of Mrs. Barbara P. Franklin and Elaine F. Cody in performing the identifications is gratefully acknowledged.

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