

THE DISTRIBUTION OF FEMALE MOSQUITOES ABOUT A FLIGHT BARRIER^{1,2}

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ABSTRACT. A 6.1 m long suction trap, with multiple air inlets located on its upwind, top, ends and downwind sides, was placed on a freely pivoting raft moored in a large borrow pit. Air inlets on the downwind side made larger captures than those on the upwind side. Inlets near the top edge of the trap captured larger numbers than those at the bottom. Larger proportions of *Culex nigripalpus* and *Cx. erraticus* accumulated behind the horizontal and vertical edges of the trap than did other species. Mosquitoes near the ends of the trap could choose whether to fly over or around the trap; most *Cx. nigripalpus* and *Cx. erraticus* flew over the trap while only *Cx. pilosus* favored going around the ends. Other species appeared to fly over and around the trap in approximately equal numbers. No evidence was found that flight patterns changed with differing wind velocities.

INTRODUCTION

This study is a continuation of previous work on the effects of visual responses and wind upon the flight paths of female mosquitoes (Bidleymayer et al. 1985). When wind velocities are below mosquito flight speeds (approximately 1 meter per second), flight is upwind (Snow 1976, Gillies et al. 1978, Service 1980). However, attraction to visually conspicuous objects (Snow 1975, 1976; Bidleymayer and Hem 1980), e.g., large wooden suction traps, cause mosquitoes to deviate from a strictly upwind orientation. When distant from a visual target, the target may be seen in its entirety; however as the distance decreases, the target's apparent dimensions would grow with increasing rapidity until at very close range the target's boundaries would be abruptly lost (Mazokhin-Porshnyakov and Vishnevskaya, in Browne and Bennett 1981). The target is now perceived, not as a goal, but as an obstacle to further flight (Kellog and Wright 1962). As the closeness of approach to obstacles differ among species (Bidleymayer and Hem 1979), the females will have dissimilar views of it and, to circumvent it, are likely to behave differently. The objective of this study was to investigate the aerial distribution of mosquitoes about an obstacle to flight. The study was conducted during 1984 and 1985 in Indian River County, Florida.

MATERIALS AND METHODS

The study site was the same as used previously (Bidleymayer et al. 1985). An octagonal raft, 6.7 m in diameter, was moored in the center of a 215 × 215 m water-filled borrow pit. The

moored side of the raft was considered the bow; as the raft could swing freely about the mooring, the bow was always upwind. An anemometer and wind vane mounted on the bow measured wind movement during the night. The anemometer was a standard instrument (threshold speed 0.6 mps) and nights with very low mean wind velocities represent nights with long periods of air movement below its threshold. The raft's deviation from a true upwind-downwind orientation was measured by a trace formed by the wind direction recorder, which rarely ranged beyond 45° on either side of the raft's axis. A recording hygrothermograph was operated in a standard weather hut placed near the shoreline to monitor temperature and humidity changes.

A plywood suction trap, 6.1 × 1.2 × 1.2 m, painted flat black, was placed on the raft perpendicular to the raft's axis (Fig. 1). This design and placement was intended to simulate the physical conditions mosquitoes encounter near a low barrier to flight. The major advantages of this arrangement were that the trap lacked nearby competing visual attractants and the 2 long sides of the trap were consistently facing either into or away from the wind.

Thirty-four air inlets, 19 × 25 cm, each provided with a collection net, permitted air entry into the interior of the trap (Fig. 1). On the upwind and downwind sides of the trap, the inlets were arranged in 3 rows (A,B,C) of 4 columns (a,b,c,d). The rows were centered 20, 61 and 102 cm above the floor of the trap and the columns centered at distances of 22 and 145 cm from either end of the trap. Three inlets were centered on each end of the trap at the same elevations as the rows and 4 inlets were located along the midline of the top of the trap in line with the columns. Two 61-cm exhaust fans (220 v, ½ hp), each discharging about 102 m³ of air per minute, were placed within the trap between columns b and c and the 2 centrally located exhaust ducts. Air was drawn successively

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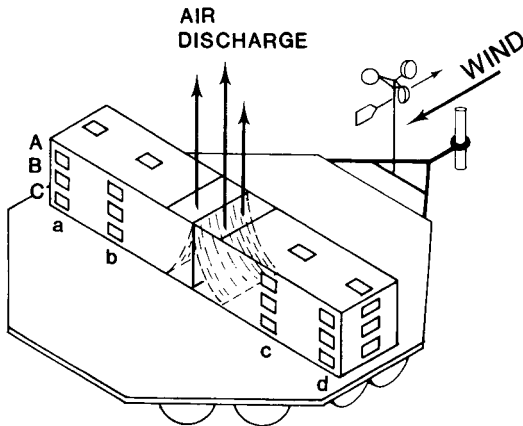


Fig. 1. The suction trap, mounted on a raft, showing wind instruments and the arrangement of air inlets into the trap.

through the inlets, the collection nets, the fan, and then discharged upward by a curved baffle.

Although only days with light winds were chosen to take air flow measurements through the inlets, as the wind velocities were variable, successive measurements differed by 9–17%. Mean inlet velocities were highest in row B [1.17 ± 0.15 meters per second (mps)]. Velocities were 8–10% lower in rows A and C, probably due to friction caused by the top and floor of the trap. Air flow through the individual inlets was not equal. Due to wind pressure, air flow through inlets on the upwind side of the trap was greater than on the downwind side. Because of turbulence caused by the trap's angular shape, the amount of air movement on the downwind side would differ between inlet positions. The airflow entering the inlets on the ends of the trap and through the fans was linear and would encounter less friction than air entering through the top or sides. Furthermore, the magnitude of the differences between inlets would be expected to vary with differing wind velocities. An effort to equalize air flows through the inlets seemed impractical.

The tests were started at sunset and terminated about 2–3 hr after sunrise, when the collection nets were removed. Only meteorological data for the period between sunset and sunrise were used. The numbers of mosquitoes captured each night by the trap would usually have been considered adequate if the night's catch had comprised a single collection; the same catch divided among the individual inlets often resulted in small collections. Therefore those species taken in numbers too small for analysis were pooled to create a larger sample. Although pooled data are not applicable to any one species, they do suggest the possibility of alternate

flight patterns. As will be shown, where non-culicine behaviors could be examined separately, these were more similar than among the culicines. Any night in which one-half or more of the collection nets failed to contain specimens of a particular species or specimens for the pool was excluded from the analysis. Catch data were transformed into the logarithm of $x + 1$ before statistical calculations. Differences between means were tested by 1 and 2-way analysis of variance, comparisons being made among catches taken at different wind velocities and among inlets according to their position on the trap. The data are presented as Williams' mean (M_w), the antilog $- 1$ of $\Sigma x + 1/N$.

The physiological states of the females were not determined since previous work had shown that wooden suction traps of similar size captured principally unfed females in egg stages I and II (Bidlingmayer 1974). Females of *Aedes taeniorhynchus* (Wiedemann), *Psorophora columbiae* (Dyar and Knab) and *Culex nigripalpus* Theobald in these stages had comprised 83%, 93% and 95% of their respective catches. Few males of any species were taken. It was concluded the traps served as visual attractants to blood-seeking females.

In experiment 1, only the 24 inlets on the upwind and downwind sides of the trap were operated and all others were sealed. Comparisons were made, at differing mean wind velocities, between the means of upwind and downwind catches, for differences among rows and between inboard (columns b,c) and outboard (columns a,d) inlets. Inlets in rows A and C were sealed in experiment 2 and the inlets in the top and ends of the trap opened to evaluate the passage of mosquitoes over or around the trap.

RESULTS

All minimum temperatures exceeded 18°C and thus nights with small catches were not caused by low temperatures.

Experiment 1. Tables 1 and 2 show the M_w number of female mosquitoes taken per inlet night at differing mean wind velocities for the downwind and upwind sides of the trap. The year 1984 was characterized by below average mosquito populations and catches were small. Data are shown for *Cx. nigripalpus*, *Culex erraticus* Dyar and Knab and *Culex pilosus* (Dyar and Knab), with all other species—none in the genus *Culex*—pooled to increase sample size. The pooled species were mostly *Ps. columbiae*, *Anopheles crucians* Wiedemann, *Aedes vexans* (Meigen), *Uranotaenia* spp. and *Culiseta melanura* (Coquillett).

Where differences between the M_w numbers

Table 1. Experiment 1. Mean_w number of female mosquitoes taken per inlet per night at differing wind velocities on the downwind side of the trap. Data arranged by rows (A, B, C) and by inboard and outboard columns (b, c, and a, d, respectively). Across row means with the same letter do not differ significantly.

Wind velocity		Rows					Columns			
Meters/sec	Nights	M _w	A	B	C	Among rows	Inboard	Outboard	Between Columns	% Out-board
<i>Culex nigripalpus</i>										
0.00-0.09	14	14.4	28.7 ^a	12.9 ^b	7.9 ^b	**	14.5	14.4		
0.10-0.24	21	14.9	32.6 ^a	13.7 ^b	7.2 ^c	**	14.0	15.9		
0.25-0.49	14	7.4	15.7 ^a	6.6 ^b	3.7 ^b	**	6.8	8.0		
>0.50	14	7.9	16.8 ^a	6.9 ^b	4.1 ^b	**	7.2	8.8		
All velocities	65 ^w	10.9 ^x	22.9 ^a	9.8 ^b	5.5 ^c	**	10.4	11.8		53
% in row			60	26	14					
<i>Culex erraticus</i>										
0.00-0.09	12	1.9	3.4 ^a	1.4 ^b	1.2 ^b	**	1.6	2.1		
0.10-0.24	20	2.0	4.4 ^a	1.4 ^b	1.1 ^b	**	1.8	2.3		
0.25-0.49	10	2.3	5.5 ^a	1.9 ^b	1.0 ^b	**	1.8	2.9	*	
>0.50	9	2.1	3.3 ^a	2.2 ^{ab}	1.1 ^b	**	2.0	2.2		
All velocities	51	2.0	4.1 ^a	1.6 ^b	1.1 ^b	**	1.8	2.4	*	57
% in row			60	24	16					
<i>Culex pilosus</i>										
All velocities	16	0.9	1.1	1.0	0.6		1.1	0.7		39
% in row			41	37	22					
Non-culicine species										
0.00-0.09	12	2.2	3.0	2.0	1.8		2.8	1.7	**	
0.10-0.24	13	1.5 ^y	1.9	1.3	1.4		2.0	1.1	**	
0.25-0.49	8	0.8	1.5 ^a	0.6 ^b	0.5 ^b	**	0.9	0.7		
>0.50	9	1.3 ^z	1.6	1.1	1.3		2.0	0.8	**	
All velocities	42	1.5 ^x	2.0 ^a	1.3 ^b	1.3 ^b	**	1.9	1.1	**	37
% in row										

^w Two nights without wind records included.

^x For difference between velocity groups 0.00-0.24 and 0.25->0.50, P = <0.01.

^y For difference between velocity groups 0.00-0.09 and 0.10-0.24, P = <0.01.

^z For difference between velocity groups 0.25-0.49 and >0.50, P = <0.05.

* P = <0.05.

** P = <0.01.

taken per inlet night at different velocities were significant, catches of *Cx. nigripalpus* at the 2 lower velocities were greater than those taken at the higher velocities (Tables 1 and 2). Catches of *Cx. erraticus* appeared to be unaffected by wind speed on the downwind side of the trap but were smaller at the higher velocities on the upwind side. For the non-culicine mosquito group, the significant differences found among velocity classes seemed unrelated to velocity.

All species were captured in largest numbers in row A, the upper row of inlets. Differences between the M_w numbers of *Culex* spp. taken in rows B and C were usually not significant, although captures in row B were often greater. The disparity in the proportions captured in rows A (60%) and C (14-16%) was greater for *Cx. nigripalpus* and *Cx. erraticus* than for other species. Differences were not found between the means of rows B and C for the non-culicine group.

The M_w numbers of *Cx. nigripalpus* taken per inlet night in inboard and outboard inlets with

rows combined, did not differ (Tables 1 and 2). *Culex erraticus* was taken in greater numbers in the outboard inlets (downwind only) whereas catches of *Cx. pilosus* and the non-culicines were greater in the inboard inlets. However, significant interactions were found among the rows and columns for *Cx. nigripalpus* and *Cx. erraticus* (Table 3). The interactions were due to the greater range of M_w catches among rows in the outboard than in the inboard columns, viz., in row A the outboard catches were greater than inboard whereas in row C the outboard catches were smaller. Thus these 2 species reached their highest and lowest aerial densities behind the upper and lower corners of the trap.

A comparison by row or by inboard and outboard inlets between downwind and upwind catches (Tables 1 and 2) did not indicate any important differences in the distribution of mosquitoes from the 2 sides of the trap. The greater wind velocities on the upwind side, while only slightly affecting mosquito distribution, probably reduced the numbers captured. However, the

Table 2. Experiment 1. Mean_w number of female mosquitoes taken per inlet per night at differing wind velocities on the upwind side of the trap. Data arranged by rows (A, B, C) and by inboard and outboard columns (b, c, and a, d, respectively). Across row means with the same letter do not differ significantly. The ratio between all upwind and downwind (Table 1) catches is also shown.

Wind velocity		Rows			Columns			Ratio			
Meters/sec	Nights	M _w	A	B	C	Among rows	Inboard	Outboard	Between columns	% out-board	Downwind Upwind
<i>Culex nigripalpus</i>											
0.00-0.09	14	2.0	5.4 ^a	1.0 ^b	1.0 ^b	**	1.9	2.0			
0.10-0.24	21	1.6	4.1 ^a	1.0 ^b	0.7 ^b	**	1.6	1.7			
0.25-0.49	14	0.8	1.8 ^a	0.6 ^b	0.3 ^b	**	0.8	0.8			
>0.50	14	0.5	1.0 ^a	0.2 ^b	0.4 ^b	*	0.6	0.5			
All velocities	65 ^w	1.2 ^x	2.8 ^a	0.7 ^b	0.6 ^b	**	1.2	1.2		50	9
% in rows			68	17	15						
<i>Culex erraticus</i>											
0.00-0.09	12	0.2	0.3	0.1	0.2		0.2	0.2			
0.10-0.24	20	0.2	0.3 ^a	0.1 ^b	0.3 ^a	*	0.2	0.2			
0.25-0.49	10	0.1	0.2	>0.0	0.1		0.2	>0.0	**		
>0.50	9	0.1	0.2	>0.0	0.2		0.1	0.1			
All velocities	51	0.2 ^x	0.3 ^a	0.1 ^b	0.2 ^a	**	0.2	0.2			10
% in row			—	—	—						
<i>Culex pilosus</i>											
All velocities	16	0.2	0.4 ^a	0.1 ^b	0.1 ^b	**	0.2	0.2			6
% in row			—	—	—						
Non-culicine species											
0.00-0.09	12	0.7	1.1	0.6	0.7		1.2	0.4	**		
0.10-0.24	13	0.5 ^x	0.7	0.4	0.4		0.7	0.3	**		
0.25-0.49	8	0.2	0.3	0.1	0.1		0.2	0.1			
>0.50	9	0.5 ^y	0.6	0.4	0.4		0.6	0.4			
All velocities	42	0.5 ^x	0.7 ^a	0.4 ^b	0.4 ^b	**	0.7	0.3	**	30	3
% in row			47	27	2						

^w Two nights without wind records included.

^x For difference between velocity groups 0.00-0.24 and 0.25->0.50, $P = <0.01$.

^y For difference between velocity groups 0.00-0.09 and 0.10-0.24, $P = <0.01$.

^z For difference between velocity groups 0.25-0.49 and >0.50, $P = >0.05$.

* $P = <0.05$.

** $P = <0.01$.

Table 3. Experiment 1. Mean_w numbers of female mosquitoes captured on the downwind side of the trap by row and column position.

Columns:	<i>Culex nigripalpus</i>		<i>Culex erraticus</i>		<i>Culex pilosus</i>		Other species	
	Inboard	Outboard	Inboard	Outboard	Inboard	Outboard	Inboard	Outboard
Row: A	18.6	29.2	2.9	5.7	1.0	1.2	2.3	1.8
B	8.6	11.4	1.3	2.0	1.2	0.7	1.7	0.9
C	6.9	4.6	1.4	0.9	1.0	0.3	1.9	0.8
Ratio ^a	2.7	6.3	2.1	6.3	1.0	4.0	1.2	2.3

^a Row A/row C. Interactions between rows and columns significant for *Culex nigripalpus* and *Culex erraticus* ($P = <0.01$).

larger downwind/upwind ratios found for the culicines (Table 2) indicate that the delay in departing from the raft occurred primarily on the downwind side of the trap. The catch patterns found among downwind rows and columns (cf. Table 3) did not occur among the upwind inlets (data not shown).

Experiment 2. Significant differences between the 2 lower wind velocity classes had not been found in the previous experiment and because

nights with low velocities occurred less frequently in this experiment than during the first, these 2 classes were combined. The relationship between wind velocity and the numbers of females captured per inlet night is shown in Table 4. The expected inverse relationship between wind velocity and numbers captured was even less clear here than in experiment 1. Significantly greater numbers of *Cx. pilosus* and *An. crucians* were taken at the middle wind-velocity

class (0.25–0.49 mps) than at the lowest and for most species catches taken at the lowest wind velocities could not be separated from those at the highest.

The distribution of females among downwind, top, end and upwind inlets taken at differing wind velocities is also shown (Table 4). Over 50% of the catches of *Cx. nigripalpus* and *Cx. erraticus* were taken in the top inlets with approximately 33% in the downwind inlets. The end and downwind inlets took smaller proportions of these species than were found for any other species. The largest numbers of *Cx. pilosus* were taken in the downwind inlets and, in contrast to the other culicines, the smallest numbers were taken in the top inlets. The proportions taken in the end inlets for this species were also greater than for any other. The non-culicine species did not differ as greatly among species as did the culicines. The largest catches were taken by the downwind and top inlets with the

end and upwind inlets capturing greater proportions than were captured of *Cx. nigripalpus* or *Cx. erraticus*, but smaller than of *Cx. pilosus*. Differing wind velocities did not have a great effect upon these distributions; at the higher wind velocities the non-culicines were taken in somewhat larger proportions in the downwind inlets and smaller proportions in the upwind inlets.

Table 5 shows the M_w numbers of females taken per inlet night for the downwind, top and upwind sides of the trap as well as in the end inlets. *Culex nigripalpus* populations here were much larger than those during experiment 1. With the clear exception of downwind catches of *Cx. nigripalpus* and *Cx. erraticus*, the inboard inlets usually captured larger numbers of all species than the outboard inlets, whether those were downwind, top or end inlets. Row A inlets on both ends of the trap captured greater numbers of mosquitoes than inlets in rows B and C.

Table 4. Experiment 2. Mean_w number of female mosquitoes taken per inlet night at differing wind velocities. Means with the same letter do not differ significantly ($P < 0.05$). Distribution of catch in downwind, top, end and upwind inlets shown as percentages.

Wind velocity	Nights ^y	Percent of total catch				
		M_w	Downwind ^z	Top	End	Upwind ^z
<i>Culex nigripalpus</i>						
0.00–0.24	19	35.2 ^{ab}	34	55	9	2
0.25–0.49	26	44.5 ^b	34	56	8	2
>0.50	28	27.7 ^a	39	50	10	2
All velocities	73	34.9	36	53	9	2
<i>Culex erraticus</i>						
0.00–0.24	18	2.4 ^a	27	61	9	3
0.25–0.49	25	2.2 ^a	31	58	9	3
>0.50	23	1.6 ^b	30	58	10	2
All velocities	66	2.0	29	59	10	2
<i>Culex pilosus</i>						
0.00–0.24	7	1.5 ^a	51	10	27	13
0.25–0.49	10	2.6 ^b	46	11	33	10
>0.50	7	1.5 ^a	48	13	26	12
All velocities	24	1.9	48	11	29	12
<i>Psorophora columbiae</i>						
0.00–0.24	9	3.9 ^a	38	28	19	15
0.25–0.49	10	2.4 ^b	44	27	16	13
>0.50	11	2.6 ^{ab}	45	31	16	7
All velocities	30	2.9	43	29	17	11
<i>Anopheles crucians</i>						
0.00–0.24	9	0.8 ^a	34	42	13	10
0.25–0.49	9	1.2 ^b	36	40	15	9
>0.50	5	1.2 ^{ab}	44	39	13	4
All velocities	23	1.0	37	41	14	8
All other non-culicine species						
0.00–0.24	16	3.3 ^a	36	33	20	11
0.25–0.49	23	2.1 ^b	36	36	18	9
>0.50	19	2.3 ^b	44	34	17	6
All velocities	58	2.5	39	34	18	9

^y Eighteen inlets operated nightly.

^z Only row B inlets operated.

Table 5. Experiment 2. Mean_w number of female mosquitoes captured per inlet night with all wind velocities combined. For all means, N = nights × 2. Numbers taken in: I. Downwind (row B), top, and upwind (row C) catches taken in inboard (cols. b, c) and outboard (cols. a, d) inlets. II. End inlets (rows A, B, C). Means with the same letter do not differ significantly ($P = <0.05$ for *Anopheles crucians* and $P = <0.01$ for all others).

Nights	Inlets	Inboard	Outboard	P	% Out-board	End inlets			Ratio ^z
						Row	Mean	% in row	
<i>Culex nigripalpus</i>									
73	Downwind	58.0	152.8	**	72	A	69.2 ^a	72	1.69*
	Top	168.5	116.9	*	41	B	16.7 ^b	17	
	Upwind	5.1	5.0		50	C	10.8 ^c	11	
<i>Culex erraticus</i>									
66	Downwind	2.9	4.2	**	59	A	2.9 ^a	71	1.97**
	Top	8.5	5.7	**	40	B	0.6 ^b	15	
	Upwind	0.4	0.2	*	33	C	0.6 ^b	15	
<i>Culex pilosus</i>									
24	Downwind	4.9	3.2		40	A	3.0	41	0.30**
	Top	1.0	0.9		47	B	2.0	27	
	Upwind	0.9	1.0		53	C	2.3	32	
<i>Psorophora columbiae</i>									
30	Downwind	7.3	4.2	*	37	A	3.2 ^a	47	0.91
	Top	4.8	2.9	*	38	B	1.7 ^b	25	
	Upwind	2.3	0.9	**	28	C	1.9 ^{ab}	28	
<i>Anopheles crucians</i>									
23	Downwind	1.7	1.7		50	A	0.9 ^a	45	1.56
	Top	2.5	1.4	*	36	B	0.5 ^b	25	
	Upwind	0.3	0.4		57	C	0.6 ^b	30	
All other non-culicine species									
58	Downwind	5.1	3.6	*	41	A	3.1 ^a	49	1.03
	Top	4.5	3.2	*	42	B	1.4 ^b	22	
	Upwind	1.2	0.7	**	37	C	1.8 ^b	29	

* $P = <0.05$.

** $P = <0.01$.

^z Top inlets (outboard)/End inlets (Row A).

The percentage of the catch found in row A for rows A, B and C were again much greater for *Cx. nigripalpus* and *Cx. erraticus* than for other species.

DISCUSSION

In an earlier study, mosquito catches on the raft were monitored by a pair of suction traps, which showed that the flight behavior of *Cx. nigripalpus*, *Cx. erraticus* and *Cx. pilosus* differed from those of all other species (Bidlingmayer et al. 1985). The important findings reported then were: 1. In contrast to other species, the 3 culicines were taken in greater numbers in traps on the raft than in traps on land (raft/land trap ratios >1.0). This pattern was more clearly shown in *Cx. nigripalpus* and *Cx. erraticus* than in *Cx. pilosus*. 2. The *Culex* species flew at a lower elevation over the traps than other species—which increased their chances of capture. 3. The pattern of catches indicated that culicine females, after leaving the wind shelter in the lee of the trap, made repeated short flights into the wind only to fall back again, each sortie lengthening the time spent on the raft and also increas-

ing their risk of capture. Non-culicine females spent less time in this activity before departing (mosquitoes were not found on the raft after sunrise). 4. Therefore, the large catches of culicines on the raft did not demonstrate that these species arrived on the raft in greater numbers than non-culicines.

As the volume of air entering the various inlets was unequal, differences between inlet catches for a particular species would not be strictly comparable. Compared with standardized airflows, the catches taken here from the upwind and end inlets were probably greater, and downwind catches, particularly those in row C, smaller than expected. It is not believed, however, that the bias was so great as to entirely preclude comparisons. Interspecific comparisons for particular inlets, however, would be valid as the population composition near an inlet would not be affected by the airflow rate. Thus, the catch pattern obtained for one species may be evaluated by comparison with the catch pattern of others.

Differing wind velocities could affect the size of the collections and/or the distribution of mosquitoes about the trap. Due to chance, periods

of low wind velocities may coincide with times when adult populations are low and high velocities may occur when populations are large. Consequently, the expected inverse relationship between velocity and numbers would not be found. Such events may have caused the irregular relationships found here between velocity and catches (Tables 1, 2 and 4). More importantly, although the size of the catch may have been affected, little evidence was found that differing wind velocities appreciably affected the distribution of mosquitoes about the trap.

In experiment 1, downwind inlets in row A captured larger numbers of all mosquitoes than were taken in rows B and C. The percentages of *Cx. nigripalpus* and *Cx. erraticus* taken in row A, however, were greater than for *Cx. pilosus* or the non-culicine species (Table 1). This finding indicates the first 2 species were more concentrated just below the top edge of the trap than other species, this area apparently being used as a staging area between forward sorties. *Culex pilosus* occupied a deeper staging area and had a vertical distribution similar to the non-culicines. While all upwind catches were quite small (Table 2), the distribution patterns of all mosquitoes on the downwind and upwind sides of the trap were not greatly different. The larger percentages, relative to other species, of *Cx. nigripalpus* and *Cx. erraticus* in row A, both downwind and upwind, would be due to these species delaying their departure from the raft. The small catches on the upwind side were probably caused to some extent by their exposure to higher wind velocities. However, apparently their visual responses were unaffected as their spatial distribution was little affected, (Gillies and Wilkes 1976, Snow 1982).

Downwind outboard catches of *Cx. nigripalpus* were only slightly greater than inboard catches in experiment 1; in experiment 2 catches in the outboard inlets were nearly 3 times greater (Table 1, 5). Both experiments support the conclusion that *Cx. nigripalpus* and also *Cx. erraticus*, in contrast to all other species, were more abundant in the outboard inlets. The greater accumulation of *Cx. nigripalpus* and *Cx. erraticus* near the ends of the trap, despite the absence of a flight barrier along one side, implies forward flight was more inhibited here than inboard. Just as these species were concentrated in row A—immediately below the top edge of the trap—they appear to be concentrated behind vertical edges as well.

The flight patterns of *Cx. nigripalpus*, *Cx. erraticus*, *Cx. pilosus* and the non-culicine species are shown schematically in Fig. 2. To facilitate comparisons between species, the M_w numbers captured in the downwind, top and end

inlets in experiment 2 (Table 3) were converted into percentages. Because the inlets in rows A and C were not operated, estimated values for these inlets based on the proportions found among rows A, B and C in experiment 1, were used. The interpretation of these data is also based upon the conclusions presented in the earlier paper.

The flight patterns of *Cx. nigripalpus* and *Cx. erraticus* were quite similar (Fig. 2). After arrival on the raft, their departure was delayed because of the many short sorties into the wind (Bidlingmayer et al. 1985). As shown by the large catches, the staging area was on the downwind side of the trap, mostly just below the top edge but also behind the vertical edge at the ends. The greater catches in the outboard inlets are probably due to lateral drift from the midsection of the trap which, due to the inhibitory effect of the vertical edge, results in an accumulation of females near the ends. Consequently, the larger captures in the top inlets and the smaller captures in the end inlets than for any other species indicates that flight over the top of the trap was the principal forward route (cf. Table 5. $\text{Ratio}^2 = 1.69, 1.97$).

The forward departure of *Cx. pilosus* from the downwind side was delayed by hovering in the wind shadow of the trap. This is indicated by the large catches in the inboard inlets. In contrast to the other *Culex*, the proportions captured in outboard inlets were smaller than those in the inboard inlets and aerial densities near the ends of the trap were low. Furthermore, catches in the end inlets were large, while the ratio^2 of 0.30 (Table 5) indicates that, at least near the ends of the trap, more females were going around the trap than over it. Unlike other culicines, the vertical edge of the trap did not inhibit flight. Thus the low raft/land ratio obtained for this species earlier (Bidlingmayer et al. 1985) was probably caused by their low flight elevation, which the traps used in that experiment had not been designed to sample.

The non-culicines had raft/land trap ratios of <1.0, which was interpreted to mean these species did not tarry on the raft (Bidlingmayer et al. 1985), i.e., the number of sorties made before departing from the raft was fewer than for the culicines. Their distribution on the downwind side of the raft was quite similar to that of *Cx. pilosus*. The principal difference between these species and *Cx. pilosus* is that, in addition to their more rapid departure from the raft, the non-culicines near the ends of the trap went either over or around the trap in about equal numbers, ($\text{ratio}^2 = 0.91, 1.56, 1.03$).

Because of differing flight behavior among species, these studies show catches can vary

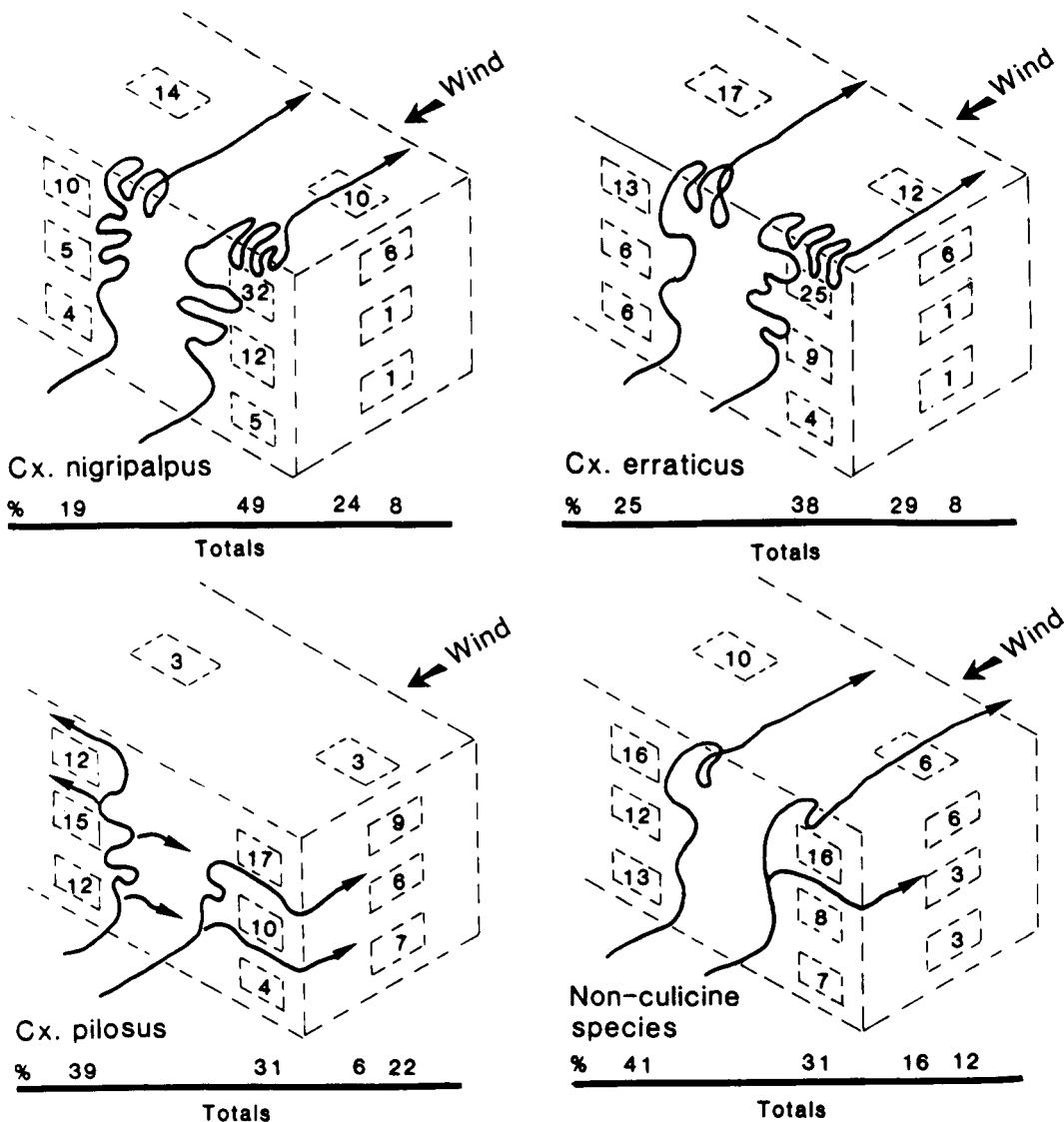


Fig. 2. Percent of catches taken in individual inlets on the downwind, end and top sides of the trap. Presumed mosquito flight paths shown by arrows. (For explanation, see text.)

greatly over short distances even if distances are much less than a meter. Such variability in aerial densities due to the physical features of the environment can have important effects upon host feeding or the measurement of mosquito populations. As examples, in a habitat characterized by small trees, shrubs, various structures or other physical obstacles, females that preferentially fly around barriers would be expected to encounter terrestrial hosts with greater frequency than those that fly over them. It may not be coincidental that the top/end ratios (Table 5) were lowest for *Cx. pilosus* (amphibians

and reptiles), followed by *Ps. columbiae* and *An. crucians* (mammals), then *Cx. nigripalpus* (mammals and birds) with the highest ratio for the bird-feeding *Cx. erraticus* (Edman 1971, 1974, 1979). In areas where barriers to flight are abundant, feeding patterns could be affected. The placement of traps is an important aspect of mosquito surveillance. The wide differences found here in the distribution of mosquitoes, captured in inlets spaced only 0.4–1.2 m apart, re-emphasizes the importance of the physical features about the immediate trap site upon the composition of trap collections.

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