CORRELATION BETWEEN WING LENGTH AND PROTEIN CONTENT OF MOSQUITOES

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ABSTRACT. Wing length and protein content were compared in individual specimens of male and nonbloodfed, nongravid female mosquitoes. The following groups were tested: field-collected and colonized *Aedes aegypti*, field-collected *Culex nigripalpus* and *Aedes vexans*, and colonized *Culex quinquefasciatus* and *Psorophora columbiae*. The correlation coefficient varied from 0.91 in *Ae. aegypti* males to 0.98 in *Ae. vexans* females, and in each group the *P* value was less than 0.001. This close correlation suggests that both wing length and protein measurement are reliable expressions of size in adult mosquitoes.

INTRODUCTION

Adult body size in mosquitoes is usually equated with wing length. Since survivorship, parity and vector capability are often studied in relation to wing length as the only criterion for size (Nasci 1986, Landry and DeFoliart 1987), it would be useful to establish how closely wing length represents body size. Few reports are available on this relationship, and all are on laboratory-reared, colonized insects. To establish such a relationship in field-collected material, the weight and wing length should be determined in individual mosquitoes, a task that has attracted few investigators. Furthermore, weight varies with the unknown nutritional condition. Recently, protein measurement has been used as a sensitive parameter for larval growth (Van Handel 1986). This method appeared to be equally useful as a parameter for adult body size (cell mass), and we now report the correlation between protein content and wing length of 800 individual mosquitoes taken from the field and from laboratory colonies.

MATERIALS AND METHODS

Aedes aegypti (Linn.), *Culex quinquefasciatus* Say and *Psorophora columbiae* (Dyar and Knab) from established colonies were raised on a brewer's yeast/liver powder (3:1) diet under 12-hour light/12-hour dark at 26°C. Adults were maintained on 5% sucrose solution for 2–4 days prior to analysis. *Aedes aegypti, Ae. vexans* (Meigen) and *Cx. nigripalpus* Theobald were collected in the field by power aspirator and frozen until analysis. Wing length was measured with a calibrated optical micrometer (1 unit = 0.085 mm) from the notch where the posterior margin of the wing begins to expand to the distal tip of the wing, excluding the apical fringe. Individual mosquitoes of known wing length were placed in culture tubes (16 × 100 mm) and crushed in 5 ml alkaline solution (54 g crystalline sodium carbonate and 4 g sodium hydroxide/liter). Then 0.2 ml of copper reagent (0.5 g copper sulfate and 2 g K-Na tartrate/100 ml) and 0.2 ml Folin-Ciocalteau reagent were added and mixed immediately. The blue color was read after 30 min at 650 nm. The standard was 0.2 mg bovine serum albumin, treated as above (Van Handel 1986).

RESULTS

Eight hundred individual mosquitoes were analyzed for wing length and protein content. The nine groups represented five species of colonized and field-collected material (Table 1). Generally, protein content increased consistently with wing length. One exception (field-collected *Ae. aegypti* in the 2.6 mm wing length class) was probably due to the small number (4) and high standard error (20% of mean) of the sample. Field-collected material showed more variability in wing length than colonized mosquitoes. The smallest overall variability occurred in colonized male *Ae. aegypti* (wing length 2.2–2.5 mm; protein 157–184 μg), and the largest in field-collected female *Ae. aegypti* (wing length 2.2–3.4 mm; protein 120–370 μg) and *Ae. vexans* (wing length 2.7–4.2 mm; protein 145–425 μg).

The relationship between wing length and protein content was confirmed by statistical analysis (Table 2). The correlation coefficient (r) in each case exceeded 0.9. The squared correlation coefficient (r^2) ranged from 0.83 in laboratory-reared males of *Ae. aegypti* to 0.97 in field-collected *Ae. vexans*.

DISCUSSION

The common use of wing length as a parameter for size of mosquitoes rests on surprisingly meager evidence. Its correlation with weight has

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Table 1. Distribution of wing length and mean protein content ($\mu g \pm$ SE) of colonized and field-collected mosquitoes.

	Wing length (mm)																				
	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2
Aedes aegypti (field)																					
n	2		2	2	4	9	14	12	13	20	21	6	3								
$\bar{x}$	127		120	170	230	195	210	233	225	250	268	315	370								
SE	3		10	5	47	9	5	15	11	4	5	14	23								
Aedes aegypti (colony females)																					
n				2	10	11	14	21	9	3	2										
$\bar{x}$				160	137	210	210	225	245	260	300										
SE				0	4	8	5	6	7	14	0										
Aedes aegypti (colony males)																					
n	2	14	25	9																	
$\bar{x}$	157	177	178	184																	
SE	7	6	4	9																	
Culex quinquefasciatus (colony females)																					
n									3	7	19	36	40	34	3						
$\bar{x}$									195	235	245	270	295	313	305						
SE									17	9	7	6	5	5	5						
Culex quinquefasciatus (colony males)																					
n					2	5	7	9	14	8	5										
$\bar{x}$					185	216	230	230	246	268	280										
SE					5	4	7	4	3	6	6										
Psorophora columbiae (colony females)																					
n										2		7	6	10	9	12	18	6	2		
$\bar{x}$										245		310	310	325	357	385	400	440	480		
SE										15		22	18	17	16	14	11	21	0		
Psorophora columbiae (colony males)																					
n							5		6		7	9	11	11	17	6		1			
$\bar{x}$							205		205		223	240	270	275	320	335		380			
SE							40		4		20	7	16	12	7	10		0			
Aedes vexans (field)																					
n						3		6		12		21		18	20		18		13		7
$\bar{x}$						145		155		212		227		280	350		380		410		425
SE						12		8		9		8		7	12		10		15		9
Culex nigripalpus (field)																					
n										9	10	11	22	22	14	16	11				
$\bar{x}$										210	265	310	310	332	345	357	395				
SE										31	13	20	11	12	12	8	15				

Table 2. Correlation between wing length and protein content of mosquitoes.

Species	n	$r \pm SE^a$	r^2
Aedes aegypti (field, females)	108	0.94 ± 0.13	0.88
Aedes aegypti (colony, females)	72	0.97 ± 0.06	0.94
Aedes aegypti (colony, males)	50	0.91 ± 0.06	0.83
Culex quinquefasciatus (colony, females)	142	0.96 ± 0.06	0.92
Culex quinquefasciatus (colony, males)	50	0.98 ± 0.05	0.96
Psorophora columbiae (colony, females)	72	0.97 ± 0.08	0.94
Psorophora columbiae (colony, males)	73	0.92 ± 0.14	0.84
Aedes vexans (field, females)	118	0.99 ± 0.09	0.97
Culex nigripalpus (field, females)	115	0.95 ± 0.07	0.90

[a] $P < 0.001$

not been consistently studied, and only in colonized, laboratory-reared adults. Christophers (1960) reported a good correlation between fresh weight and wing length of laboratory-reared *Ae. aegypti* maintained on water after adult emergence. Nayar (1969) found fairly good agreement between wing length and dry weight (mosquitoes were weighed in groups) in unfed, laboratory-reared *Aedes taeniorhynchus* (Wiedemann). Shelton (1972) reported a good correlation between wing length (3.0–3.5 mm) and fresh weight (1.6–4.0 mg) in nine unfed specimens of laboratory-reared *Culex salinarius* Coquillett. McCombs[2] (1980) reported a significant correlation between wing length and dry weight ($n = 178$, $r = 0.94$, $P < 0.01$) in laboratory-reared *Aedes triseriatus* (Say). However, the correlation is primarily of interest in field-collected material where size may be more variable. In blood-engorged or gravid mosquitoes neither weight nor protein assay would be a precise expression of size. Weight, even in empty specimens, depends on the unknown nutritional status of the adult.

It is known that wing length remains constant for mosquitoes throughout life (Christophers 1960). The use of protein content as a parameter for size in field-collected material of unknown age depends on the assumption that protein is not significantly affected by age. To test this, newly emerged female *Ae. aegypti* were maintained on 10% sucrose for one week. During this time, the protein content diminished only 6%. These same sugar-fed mosquitoes were then starved for a week, during which interval there was no further decrease of protein. These results and the observed good correlation in field-collected specimens (Table 2) suggest that the effect of age on protein content was negligible.

In field studies, the size of males has not received much attention. We included three species of colonized males as a comparison, and it appeared that the correlation was equally reliable in males.

Protein assay of empty mosquitoes in this study was a reliable parameter for cell mass (size), and its close association with wing length in several species justified the use of wing length as an expression of size. Recently, we have established a positive correlation between wing length and nutritional reserves in field-collected *Aedes vexans* (Van Handel and Day 1988).

[2] McCombs, S. D. 1980. Effect of differential nutrition of larvae on adult fitness of *Aedes triseriatus*. M.S. Thesis, University of Notre Dame, IN. 123 pp.

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