

EFFECT OF PHOTOPERIOD ON WING AREA IN
ANOPHELES QUADRIMACULATUS (DIPTERA: CULICIDAE)

CARMINE A. LANCIANI AND RONALD EDWARDS
Department of Zoology, University of Florida
Gainesville, FL 32611, U.S.A.

ABSTRACT

The effect of photoperiod on wing area of a mosquito in the species complex *Anopheles quadrimaculatus* was tested on adults reared from a field sample. Short-photoperiod [8:16 (L:D)] individuals of each sex had greater wing areas than did their long-photoperiod [16:8 (L:D)] siblings of the same wing length or body weight. The greater wing areas of short-photoperiod mosquitoes, given any wing length, established that short-photoperiod individuals had broader wings. The greater wing areas of short-photoperiod mosquitoes, given any body weight, established that short-photoperiod individuals had a greater wing area per unit body weight.

Key Words: Wing dimensions, wing loading, mosquito, light.

RESUMEN

El efecto del fotoperíodo sobre el área de la ala de una especie de mosquito del complejo de *Anopheles quadrimaculatus* fué ensayado en adultos criados de muestreos de campo. Individuos de ambos sexos expuestos a fotoperíodo corto [8:16 (L:D)] tuvieron áreas de las alas mas grandes que las tuvieron sus hermanos de la misma largura de ala y del mismo peso del cuerpo los cuales fueron expuestos a fotoperíodos largos [16:8 (L:D)]. El area más grande de alas de mosquitos expuestos a fotoperíodos cortos, dado cualquier largura de ala, estableció que individuos expuestos a fotoperíodo corto tuvieron alas mas anchas. El area de ala más grande de las alas de mosquito expuestos a fotoperíodos cortos, dado cualquier peso, estableció que los individuos expuestos a fotoperíodo corto tenían un área más grande de ala por unidad de peso del cuerpo.

Mosquitoes reared under different photoperiods develop different wing lengths: individuals exposed to short photoperiods consistently develop disproportionately longer wings than do those exposed to long photoperiods (Lanciani 1992). The present study was done to determine whether wing area, too, is affected by photoperiod because of the importance of wing area to flight (Vogel 1988, Nachtigall 1989). Our particular objectives were to determine if the relationships between (1) wing area and wing length and (2) wing area and body weight change under different developmental photoperiods. If the wing area-wing length relationship changes, then wing shape must vary under different photoperiods; if the wing area-body weight relationship changes, then body weight transported per unit wing area must vary under different photoperiods. To attain these objectives, we reared members of the mosquito species complex *Anopheles quadrimaculatus* (probably species A on the basis of locale and habitat; Kaiser et al. 1988) under short and long photoperiods. We then analyzed their body weights, wing lengths, and wing areas. We have observed blood-fed and gravid females throughout the year in the area of study (Alachua County, Florida, U.S.A.), so flight during both long-photoperiod, warm seasons and short-photoperiod, cool seasons is known to occur in this species.

MATERIALS AND METHODS

Cultures

Rearing followed the procedure described in Lanciani (1992). Gravid females were collected on 13-I-1992 from the shore of a river (Styx) near Gainesville, Florida and were held in separate vials in a constant-temperature chamber set at 28° C and a 12-h light-dark cycle. Only a single batch of eggs, laid by the first ovipositing female, was reared to ensure that all analyzed mosquitoes were siblings. Half of the eggs from this batch were put in a short-photoperiod constant-temperature chamber [8:16 (L:D)] set at 28° C and the other half in a long-photoperiod constant-temperature chamber [16:8 (L:D)] also set at 28° C. At a latitude of 30° (close to that of Gainesville), the longest photoperiod (including 56 min of twilight) is 15 h and 1 min, and the shortest photoperiod (including 52 min of twilight) is 11 h and 4 min (List 1971). The experimental photoperiods, although different from the natural photoperiods, were selected because our study could be more readily compared with other studies that use these common experimental photoperiods and because these photoperiods have been shown to produce different wing lengths and body weights in this species (Lanciani 1992).

To be sure that a constant temperature of 28° C was maintained in both short and long-photoperiod chambers, we set temperature controls lower during light periods to compensate for heat given off by the lights (a pair of 20W fluorescent lights in each chamber). Before experiments began, these controls were adjusted while temperature was checked with a thermometer placed in a water-filled 250-ml Erlenmeyer flask located next to the larval rearing pans. These thermometer readings agreed with average thermocouple readings recorded from the top 5 mm of water in different parts of the rearing pans. Thus, the temperature experienced by the mosquito larvae, which occupy the upper few mm of water, was probably the same at both photoperiods. Thermometers were monitored throughout the experiments to verify that temperature remained at 28° C.

Eggs were held in 500 ml of tap water in a white enamel pan, and, on the day after oviposition, 0.05 g of a 2:1 mixture of baby-fish food and brewer's yeast was added to each pan. Two days later, groups of approximately 40 larvae of similar size were selected from each photoperiod group and placed in separate pans containing 500 ml of tap water and 0.06 g of food. On subsequent days, larvae were transferred to clean pans with 500 ml of fresh tap water and fed successively 0.06, 0.07, and then 0.09 g of food per pan until pupation. The pans were covered with clear plastic sheets to reduce evaporation. As pupae appeared, they were held individually in screen-covered vials in the same constant-temperature chamber in which they developed. Pupation occurred an average of 7.35 days after oviposition (standard error = 0.05) in short-photoperiod individuals and an average of 7.05 days after oviposition (standard error = 0.03) in long-photoperiod individuals. Although the difference in time to pupation was statistically significant (*F* test: $F = 24.33$; $df = 1, 156$; $P = 0.0001$), other rearings of this species in our laboratory have shown no consistent differences in time to pupation between photoperiod groups.

Measurements

Adults were removed from constant-temperature chambers within 8 h of emergence and were frozen. Later they were dried for 2 days at 60° C and weighed individually to the nearest 0.002 mg. (Dry weight rather than live weight was used throughout the analysis because it is a more consistent indicator of weight in small organisms.) One wing was removed from each specimen, briefly immersed in 70% ethanol to remove

wrinkles, and mounted in a drop of Hoyer's medium. Wing length was measured from the axillary incision to the apex, excluding scales.

Wing area was measured on the slide-mounted material. Wing images were transmitted to a microcomputer with a microscope attachment and video camera. From 25 to 30 points along the perimeter of each wing image were digitized for analysis by MicroComp software (Southern Micro Instruments).

Statistical Analysis

We used analysis of covariance to determine how photoperiod affected wing area. In an analysis of covariance, the effect of photoperiod on wing area can be seen after the effects of other variables, such as wing length, body weight, and gender, have been removed (Packard & Boardman 1987). Two analyses were run with wing area as a dependent variable: one with the independent variables wing length, gender, and photoperiod and the other with the independent variables body weight (dry), gender, and photoperiod. Wing area, wing length, and body weight were logarithmically transformed before the analysis to improve the linear relationship among these variables. Statistical analyses were executed using SuperANOVA software (Abacus Concepts).

RESULTS

Average wing lengths, wing areas, and body weights of adult mosquitoes reared under short and long photoperiods are listed in Table 1. In the analysis of covariance involving wing length as an independent variable, wing area was significantly affected by photoperiod ($F = 11.69$; $df = 1, 154$; $P = 0.0008$), gender ($F = 95.56$; $df = 1, 154$; $P = 0.0001$), and wing length ($F = 70.61$; $df = 1, 154$; $P = 0.0001$). Specifically, wing areas were greater in short-photoperiod, female, and long-winged individuals. From the covariance model, we predicted wing areas to be (1) 3.428 mm² and 3.296 mm² in short and long-photoperiod individuals having the same average wing length of 3.565 mm and (2) 3.090 mm² and 3.656 mm² in males and females of that same average wing length. Thus, given the same wing length and gender, the average short-photoperiod mosquito had a greater wing area than did the average long-photoperiod one. Also, given the same wing length and photoperiod, the average female had a greater wing area than did the average male.

In the analysis of covariance involving body weight as an independent variable, wing area was again significantly affected in the same way by photoperiod ($F = 67.69$; $df = 1, 152$; $P = 0.0001$) and gender ($F = 17.77$; $df = 1, 152$; $P = 0.0001$). In addition, wing area was significantly affected by body weight ($F = 31.92$; $df = 1, 152$; $P = 0.0001$), i.e., heavier individuals had greater wing areas; a gender by photoperiod interaction (F

TABLE 1. AVERAGE WING LENGTH (MM), AVERAGE WING AREA (MM²), AND AVERAGE DRY BODY WEIGHT (MG) IN ADULT MOSQUITOES OF THE *ANOPHELES QUADRIMACULATUS* COMPLEX REARED UNDER SHORT AND LONG PHOTOPERIODS.

Gender	Photoperiod	Avg WL ± SE	Avg WA ± SE	Avg DBW ± SE	N
Male	Short	3.486 ± 0.015	3.063 ± 0.021	0.633 ± 0.007	48
	Long	3.330 ± 0.014	2.827 ± 0.025	0.613 ± 0.007	47
Female	Short	4.012 ± 0.018	4.285 ± 0.042	0.821 ± 0.015	31
	Long	3.648 ± 0.013	3.656 ± 0.037	0.631 ± 0.010	32

TABLE 2. PARAMETERS OF REGRESSION EQUATIONS PREDICTING LOG WING AREA (MM²) FROM LOG DRY BODY WEIGHT (MG) IN ADULT MOSQUITOES OF THE *ANOPHELES QUADRIMACULATUS* COMPLEX REARED UNDER SHORT AND LONG PHOTOPERIODS.

Gender	Photoperiod	Slope ¹	Intercept ¹
Male	Short	0.376	0.560
	Long	0.376	0.531
Female	Short	0.137	0.643
	Long	0.137	0.590

¹The equations are of the form $Y = bX + a$, in which Y is log wing area, b is the slope, X is log dry body weight, and a is the Y intercept. For example in short-photoperiod males, log wing area = (0.376) log dry body weight + 0.560.

= 5.508; $df = 1, 152$; $P = 0.0202$); and a gender by body weight interaction ($F = 6.93$; $df = 1, 152$; $P = 0.0094$). This model, which accounted for 91.2% of the variation in wing area, produced 4 regression equations relating wing area to body weight (Table 2). The greater wing area of short-photoperiod mosquitoes is reflected by the larger intercept of the short-photoperiod equation within each gender.

DISCUSSION

Photoperiod significantly changed wing dimensions in this species of the *An. quadrimaculatus* complex. Individuals reared under a short photoperiod developed greater wing areas at all wing lengths and body weights than did siblings reared under a long photoperiod. The different wing areas of short and long-photoperiod mosquitoes, given any wing length, established that photoperiod affected wing shape; short-photoperiod individuals had broader wings. The different wing areas of short and long-photoperiod mosquitoes, given any body weight, established that photoperiod affected wing area per unit body weight; short-photoperiod individuals had a greater wing area per unit body weight. Thus, short-photoperiod mosquitoes in flight would carry less weight per unit wing area and would therefore have a lower wing loading (body weight divided by wing area; Lighthill 1977).

Photoperiod thus influences allometric development in the wings of this species. Other photoperiod-induced effects in insect morphology, physiology, and natural history have been documented (Giesel et al. 1989, Lanciani et al. 1990, and Lanciani 1992). Some of these same effects are also induced by temperature in mosquitoes (Hosoi 1954, van den Heuvel 1963, and Nayar 1968), emphasizing that insects often respond similarly to temperature and photoperiod.

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EVALUATION OF PROTEIN BAIT FORMULATIONS FOR THE CARIBBEAN FRUIT FLY (DIPTERA: TEPHRITIDAE)

NANCY D. EPSKY,¹ ROBERT R. HEATH,¹ JOHN M. SIVINSKI,¹
CARROL O. CALKINS,¹ RICHARD M. BARANOWSKI,² AND ANN H. FRITZ¹

¹U.S. Department of Agriculture
Agricultural Research Service
Insect Attractants, Behavior and Basic Biology
Research Laboratory
Gainesville, FL 32608

²Tropical Research & Education Center
University of Florida
Homestead, FL 33031

ABSTRACT

Laboratory and field trials were conducted to determine the preference of the Caribbean fruit fly, *Anastrepha suspensa* (Loew), for aqueous formulations of the protein bait NuLure® and standard torula yeast plus sodium borate (HTY-borax) pellets. Addition of 1-10% borax to 10% NuLure solution increased bait pH, and this increase was directly correlated with increase in number of female flies trapped in two-choice laboratory bioassays and in field trials conducted in three locations in south Florida during the spring of 1992. Overall, significantly more flies were attracted to volatiles from HTY-borax solution than to volatiles from any of the NuLure solutions. There was variation in the response of flies to baits observed among the three test locations. Age structures of the populations at the different locations were compared by determining