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BioScience, Vol. 32, No. 5 (May, 1982), 337-338.

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From *Annals of the Entomological Society of America*

Larval Diapause Variation in a Tree-Hole Mosquito

S. R. Sims

A condensation of "Larval diapause variation in the Eastern tree-hole mosquito, *Aedes triseriatus*: latitudinal variation in induction and intensity," published in *Annals of the Entomological Society of America*, Vol. 75 No. 2 (March). The author is with the Department of Entomology, North Carolina State University, 840 Method Rd., Unit 1, Raleigh, NC 27607.

Synchronization of insect growth and development with the appropriate season is frequently achieved by perception of and response to photoperiod, the most reliable environmental indicator of impending seasonal change. Photoresponse may result in diapause, a complex physiological state of developmental arrest (see Beck 1980).

Photoperiod-sensitive insect species occurring over wide latitudinal ranges usually display clinal variation in diapause response. This results from increasingly severe climatic regimes and progressively shortened growth seasons with increasing latitude. Since the maximum summer day length and rate of photoperiod change also increase with latitude, a positive relationship is typically found between the latitude of population origin and the length of the photoperiod sufficient to induce diapause.

Populations of the Eastern tree-hole mosquito, *Aedes triseriatus*, occur over an extensive latitudinal range, from southern Florida (26° N) to Manitoba (50° N). Unlike most other insects with demonstrated latitude-diapause variation, *A. triseriatus* has two diapause forms, an embryonic (egg) diapause and a fourth (final) instar larval diapause. In both cases, diapause is determined primarily by photoperiod and modified by temperature (Shroyer and Craig 1980). Long days and warm temperatures, similar to those of late spring and early summer, promote the development of nondiapause, hatchable

eggs and larvae, which proceed directly from the fourth instar to pupae and adults. Short days, cool temperatures, and, in the case of larvae, food deficiency, invoke and maintain diapause.

Previous studies of egg diapause induction have shown that critical photoperiod (CP: that photoperiod inducing a 50% diapause response in the test population) increases about 1 hour per 4.2° increase in population latitude (Shroyer 1979). The present research surveys the potential for larval diapause induction and subsequent diapause intensity over most of the latitudinal range of *A. triseriatus*, compares this to previous work on egg diapause, and analyzes the ecological significance of the results.

All populations studied, from 26° N to 46° N, were capable of larval diapause under short-day cool conditions (10 h light, 14 h dark (LD 10:14), 16°). Diapause response to short days was nearly complete ($\geq 94\%$) in the middle portion of the range, but was significantly reduced in subtropical Florida and from Indiana north. Critical photoperiod for larval diapause induction is plotted as a function of latitude in Figure 1. In contrast to results of Holzapfel and Bradshaw (1981), only a slight, insignificant increase of CP with latitude was found (about 1.3 h over 20°, $p > 0.235$).

The CP values for egg diapause induction of three northern populations (Figure 1) show significant correlation ($p < 0.025$) with latitude and closely agree with previous work (Shroyer 1979). CP was undefined in Florida populations, since there was less than 50% egg diapause at any photoperiod tested.

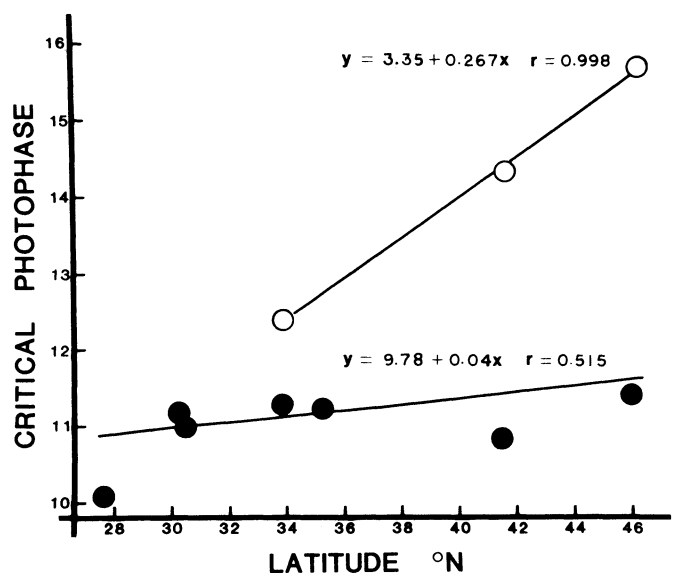


Figure 1. Critical photophases (hours light/24 hours inducing 50% diapause in test sample) for induction of egg (○) and larval (●) diapause in populations of *A. triseriatus*.

Within the eight populations studied, and particularly the southernmost four, females had a more intense diapause than males (Figure 2). Northernmost populations (northern Indiana, northern Michigan) had the greatest variance in intensity. A quadratic polynomial provided the best fit for both sexes over all populations but explained only 43% of the latitudinal variation in intensity. Intensity was greatest in the central part of the latitudinal range of *A. triseriatus*, being relatively weaker in northern and especially subtropical populations.

A comparison of egg and larval CP's (Figure 1) indicates that from Georgia north, egg diapause constitutes the major overwintering mode. Egg CP exceeds larval CP by one hour in Georgia and by more than four hours in northern Michigan, thereby insuring that, in this part of the range, most individuals will be in a nonhatchable egg diapause state well before the occurrence of conditions necessary for larval diapause induction. Such disparity between the photoinduction of the two dormancy forms has obvious selective advantage in regions where tree hole water freezes solid in winter, killing larvae. The tendency for partial egg hatches under short-day conditions in Florida is in accordance with field observations of fall-winter egg hatch and successful larval overwintering both as fourth and earlier instars there. Overwintering as slowly developing early instar larvae may also occur further north (Holzapfel and Bradshaw 1981), but with progressive decline in survival probability.

Larval diapause could be maintained in populations overwintering exclusively as eggs by the selective advantage of flexible development under vernal conditions. The relatively greater range of larval photoresponse, from continuous development under short days to diapause under long days, and high variance in diapause intensity of northern populations increases the spectrum of temperature-photoperiod values that induce and maintain diapause, resulting in increased dispersion of pupation time and emergence. This response would be advantageous in the highly unpredictable northern vernal climate where neither photoperiod nor current temperature accurately predict potential climatic disaster for continuous developers. Under these conditions, a "risk-spreading" extended pupation and emergence period with diapause characteristics similar to those found in this study would be predicted.

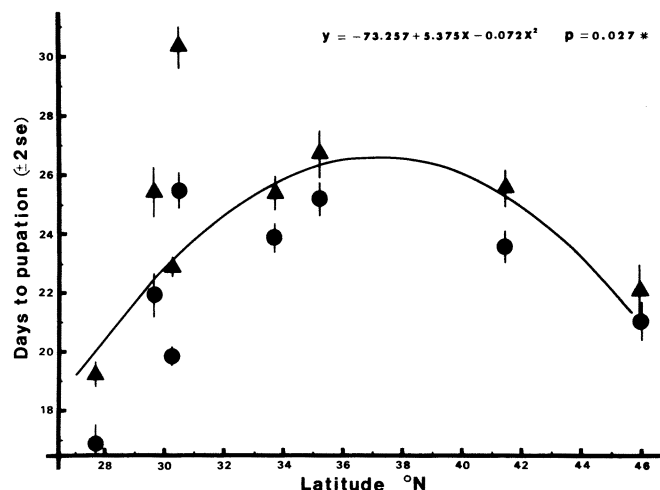


Figure 2. Diapause intensity (days to pupation at LD 16:8, 16°) in populations of *A. triseriatus*. Triangles indicate females, circles males.

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From *American Zoologist*

Locomotor Patterns in Actinopterygian Evolution

Paul W. Webb

A condensation of "Locomotor Patterns in the Evolution of Actinopterygian Fishes," published in *American Zoologist* Vol. 22 No. 2 (May). The author is with the School of Natural Resources, University of Michigan, Ann Arbor, MI 48109.

The body forms of living and extinct bony fishes are diverse. The locomotor functions of these numerous body and fin patterns can be evaluated using principles based on recent hydromechanical models and observations on modern fishes. Then, assuming that similar structures or suites of characters are functionally similar, the principles can be applied to interpret the locomotor function of other living or extinct fish shapes (Lighthill 1975, Webb, 1978). The models and experimental studies have shown that two major locomotor levels must be recognized. The first is caudal propulsion, developing high power for cruising, sprinting and acceleration. The second level is noncaudal propulsion, where paired and median fins are used in slow-swimming and precise maneuver. Caudal propulsion is further subdivided into unsteady swimming when linear and angular acceleration rates are high and steady swimming where speeds are more uniform.

Optimal morphologies (defined as those maximizing performance) can be recognized for various propulsion patterns, but optimal designs for different activities often appear to be exclusive. For example, specialization for noncaudal swimming appears to affect caudal swimming performance, although retention and development of high power caudal propulsion is a major theme in actinopterygian evolution. Further exclusive optimum morphologies are found for unsteady versus steady caudal propulsion. For the former, the caudal fin and general body area should be larger over the whole length of a flexible body, which should have a large propulsion of muscle. An example is *Serranus* in Figure 1E. For steady swimming, optimal morphological requirements are a deep caudal fin, but with a small area, attached to a stiff body via a narrow caudal peduncle. An example is *Thunnus* in