

ARTICLES

THE EFFECT OF TEMPERATURES ON DEVELOPMENT
OF EIGHT MOSQUITO SPECIES¹ROBERT M. SHELTON²Entomology Research Division, Agr. Res. Serv., U. S. Department of Agriculture
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ABSTRACT. Larvae of *Culiseta inornata* (Williston), *Culex restuans* Theobald, *Culex pipiens quinquefasciatus* Say, *Culex salinarius* Coquillett, *Anopheles albimanus* Wiedemann, *Anopheles quadrimaculatus* Say, *Aedes sollicitans* (Walker), and *Aedes triseriatus* (Say) were raised at constant temperatures of 12, 15, 20, 23, 26, 29, 32, or 35° C in compartments of a temperature gradient tank. Only *Culex p. quinquefasciatus*,

Culex salinarius and *Culex restuans* produced adults at 12° C; only *Anopheles albimanus* and *Aedes sollicitans* emerged as adults at 35° C. The average body weight of adult females and the time required for the immature cycle of most species decreased as the temperature increased; survival to adults was highest at the mid range of temperatures.

INTRODUCTION. The effects of temperature on pre- and post-adult development of various mosquito species has been studied by Trpiš and Shemanchuk (1969), Trpiš and Shemanchuk (1970), Bar-Zeev (1958), Brust (1967), Haney and Brust (1967), and others. However, most of these studies were limited to one or two species. A study was therefore made in 1970-1971 at the Gulf Coast Marsh and Rice Field Mosquito Investigations Laboratory, Lake Charles, Louisiana to determine the effect of eight temperatures on the development of *Culiseta inornata* (Williston), *Culex restuans* Theobald, *Culex pipiens quinquefasciatus* Say, *Culex salinarius* Coquillett, *Anopheles albimanus* Wiedemann, *Anopheles quadrimaculatus* Say, *Aedes sollicitans* (Walker) and *Aedes triseriatus* (Say) exposed to similar conditions.

MATERIALS AND METHODS. Eggs collected from breeding sites in the field or from laboratory colonies were hatched in an insectary maintained at $27 \pm 3^\circ \text{C}$. One hour after hatching, 20 larvae were placed in 500 ml of distilled water in containers (11 x 13 x 8 cm), and the containers were

then floated in water compartments of a temperature gradient tank maintained at 12, 15, 20, 23, 26, 29, 32, or 35° C ($\pm 0.3^\circ \text{C}$). A maximum variation of $\pm 1.7^\circ \text{C}$ occurred in single containers of *Aedes sollicitans*, *Culex p. quinquefasciatus*, and *Culex restuans* during a 2-day period. The culicine larvae were fed finely ground rabbit chow, and the anopheline larvae were fed a mixture of whole wheat flour, brewer's yeast, dried beef blood, and non-fat powdered milk. All species were reared at similar conditions except for differences in food; thus, temperature was the only variable. Containers were checked three to four times daily, and larval development was recorded. The adults were removed from the test containers, anesthetized with carbon dioxide (CO₂), and weighed to an accuracy of 0.1 mg. one hour or more after they emerged. Each test was replicated one or more times, and all values reported are means of the replications. The length of the immature cycle (larva and pupa) is the mean time from hatching to the appearance of the first individual in each stage of development.

RESULTS AND DISCUSSION. The results are shown in Figures 1-10. Although *Culiseta inornata* was normally found breeding during the cooler months in Louisiana, it was unable to complete its aquatic

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development at 12° C, 29° C, 32° C, or 35° C. (Fig. 1). Twenty-two percent of the larvae pupated at 12° C but all pupae died before adult emergence. A temperature increase from 15 to 20° C reduced the length of the immature cycle by 5 days, but survival to adults (Fig. 1) and average body weight of adult females (Fig. 10) remained the same. Then as the temperature increased from 20 to 23° C, a decrease of 0.6 mg in average body

weight and from 60 to 35 percent in adult survival was noted, although the time from hatching to adults differed by less than 5 hours. As the temperature increased from 23 to 26° C, survival remained constant, but a 56 percent loss in body weight (3.2 mg) occurred; at 29° C, 12% developed to pupae but failed to emerge as adults.

Culex restuans, which is also a winter species in southern Louisiana, exhibited a

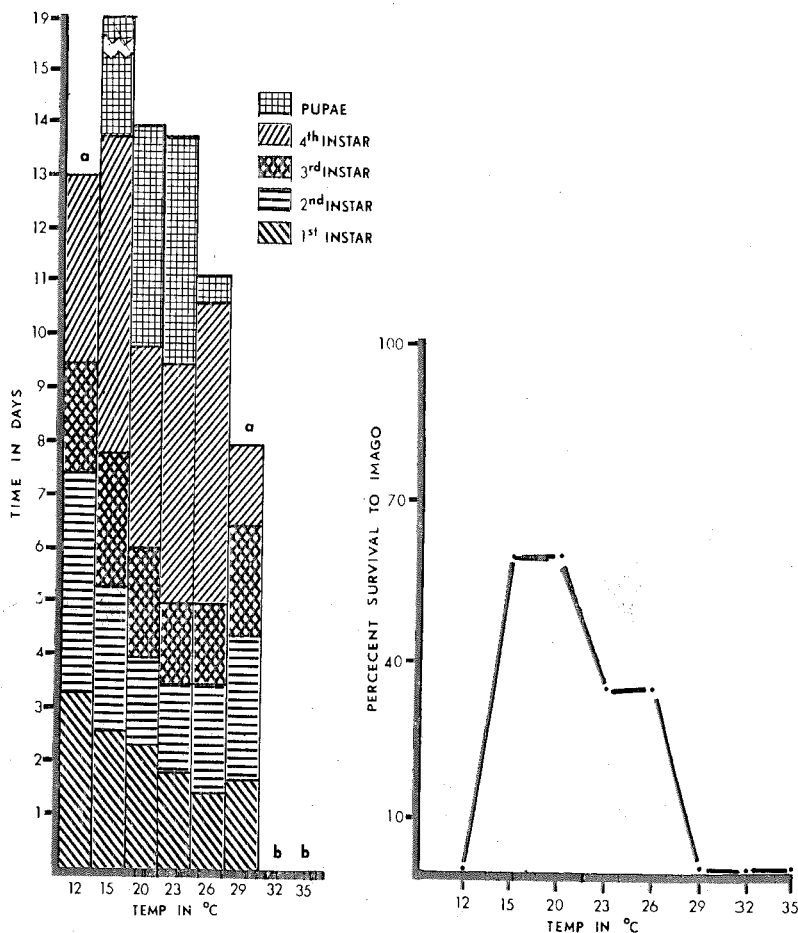


FIG. 1.—*Culiseta inornata*. Rate of growth and percentage survival to imago at 8 temperatures. (a) Larvae did not survive to next stage of development. (b) No development at indicated temperature.

broader tolerance to temperatures than *Culiseta inornata* since it completed its larval cycle at all temperatures except 32 and 35°C (Fig. 2). The percentage survival remained fairly steady at 12 to 26°C while the development time decreased from 25.3 to about 7 days. Although an increase from 26 to 29°C did not affect the body weight (Fig. 9), survival decreased 41 percent and the de-

velopmental stages were shortened by only 8 hours; 10 percent of the larvae molted to the fourth instar at 32°C but all died within 14 hours (Fig. 2).

Culex p. quinquefasciatus preferred the mid-range of the temperatures tested and showed its highest adult body weight 2.9 mg (Fig. 10) and 100 percent survival (Fig. 3) at temperatures of 20° and 23°C, respectively; a decrease in both body

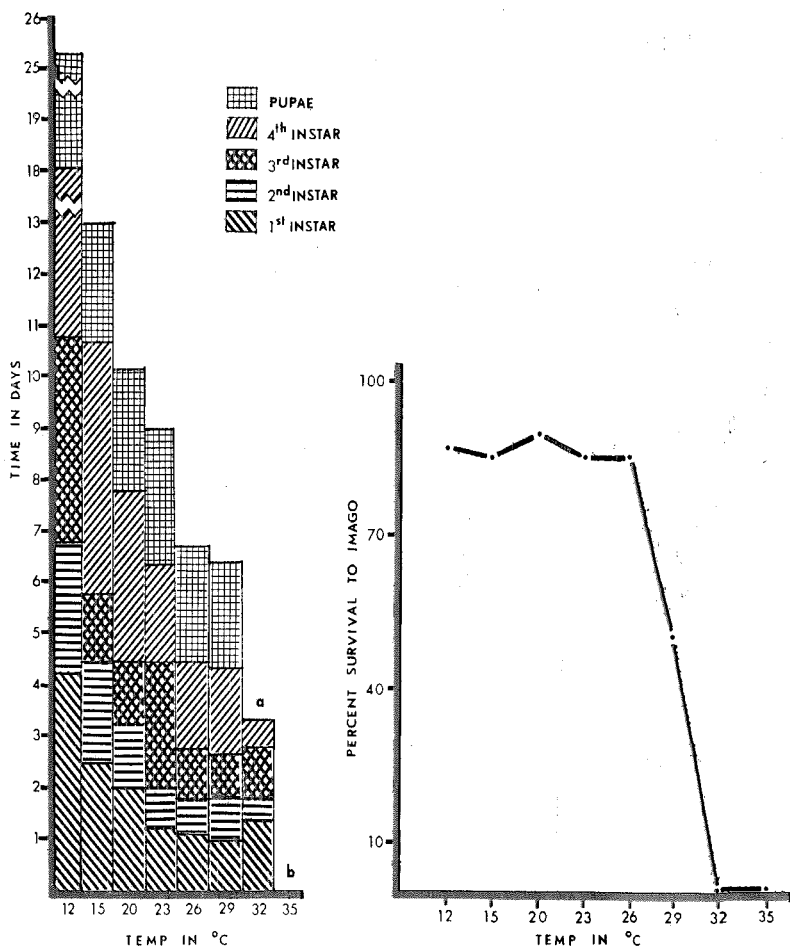


FIG. 2.—*Culex restuans*. Rate of growth and percentage survival to imago at 8 temperatures. (a) Larvae did not survive to next stage of development. (b) No development at indicated temperature.

weight and survival was noted at 12 and 32° C. Forty-seven percent survived to adults at 32° C; but none were able to develop to second instar larvae at 35° C.

Larvae of *Culex salinarius* died at 35° C, and only 35 percent survived to the third instar at 32° C (Fig. 4). As the temperature increased from 12 to 29° C, the period of aquatic development was reduced 26.8 days and the body weight was reduced from 2.8 to 1.1 mg, a decrease of 60 percent (Fig. 10); the percentage survival was fairly constant at both 12 and 29° C (Fig. 4).

Anopheles albimanus showed little or no aquatic development at 12 and 15° C; however, as the temperature increased from 20 to 29° C, the time required for aquatic development decreased by 50 percent or more to a minimum of almost 7 days (Fig. 5). Adult weights remained similar at all temperatures (Fig. 9), even though the survival ranged from 45 percent at 26° C to less than one percent at 35° C (Fig. 5). The conditions of the study did not favor this species since survival was low at all temperatures.

Although *Anopheles quadrimaculatus*

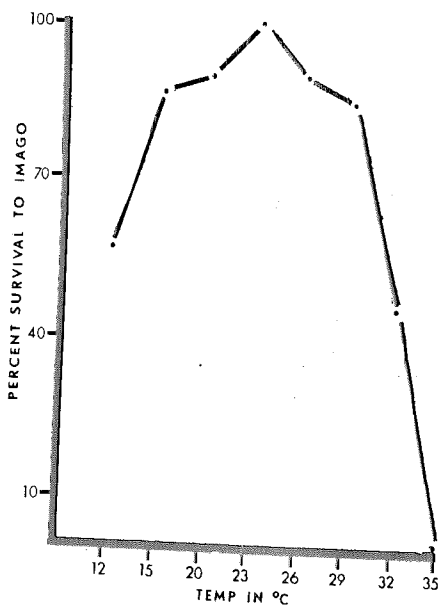
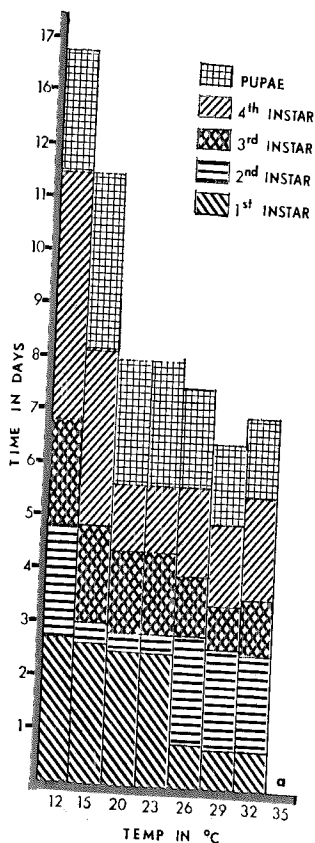


FIG. 3.—*Culex pipiens quinquefasciatus*. Rate of growth and percentage survival to imago at 8 temperatures. (a) No development at indicated temperature.

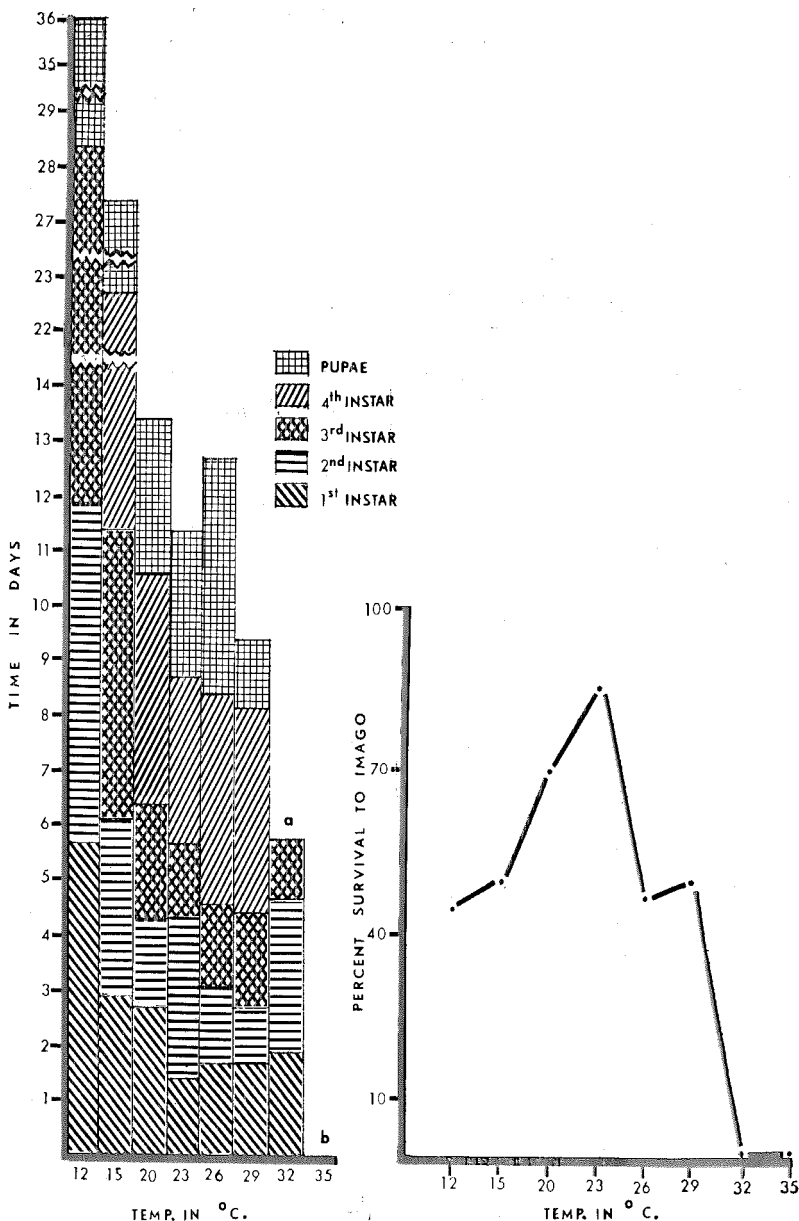


FIG. 4.—*Culex salinarius*. Rate of growth and percentage survival to imago at 8 temperatures. (a) Larvae did not survive to next stage of development. (b) No development at indicated temperature.

breeds during the entire year in Louisiana, it was only able to complete aquatic development between temperatures of 20 and 32° C (Fig. 6). Less than one percent survived beyond the third instar at 12° C; 30 percent reached the pupal stage at 15° C; and 15 percent were successful in molting to the fourth instar at 35° C, but none survived to the adult stage. The aquatic development was shortened 3.5 days as the temperature increased from 20 to 23° C, and survival increased from 42 to 63 percent (Fig. 6). However, when temperatures were increased from 23 to 32° C, the immature period was again shortened 3.2 days though survival de-

creased from 63 to less than 1.0 percent. As the temperature increased from 20 to 29° C, the adult body weight decreased 39 percent (Fig. 9).

Ten percent of *Aedes sollicitans* pupated at 12° C (Fig. 7), but a temperature of 15° C was required for emergence of adults. The time from hatching to adult decreased by 14.4 days, and the body weight decreased from 4.1 to 2.0 mg as the temperature was increased from 15 to 35° C (Fig. 9). Fifty percent survival occurred at both 15° and 35° C (Fig. 7).

The first larva of *Aedes triseriatus* molted to the fourth instar on the 24th day at 12° C, and all remaining larvae (95

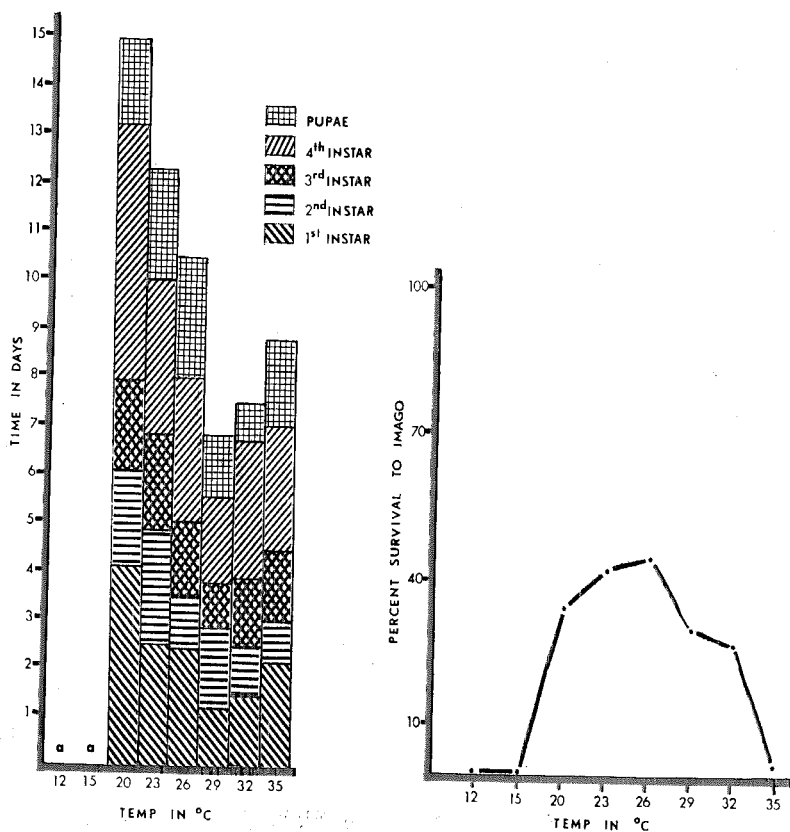


FIG. 5.—*Anopheles albimanus*. Rate of growth and percentage survival to imago at 8 temperatures.
(a) Larvae did not survive to next stage of development.

percent) were in the fourth instar when the test was terminated after 50 days (Fig. 8). As the temperature increased from 15 to 32° C, the aquatic development decreased 11.6 days or 46 percent

(Fig. 8), and the adult body weight decreased 1.4 mg or 62 percent (Fig. 10). Also, the survival steadily decreased from 100 to 20 percent as the temperatures increased from 15 to 32° C; about 15 per-

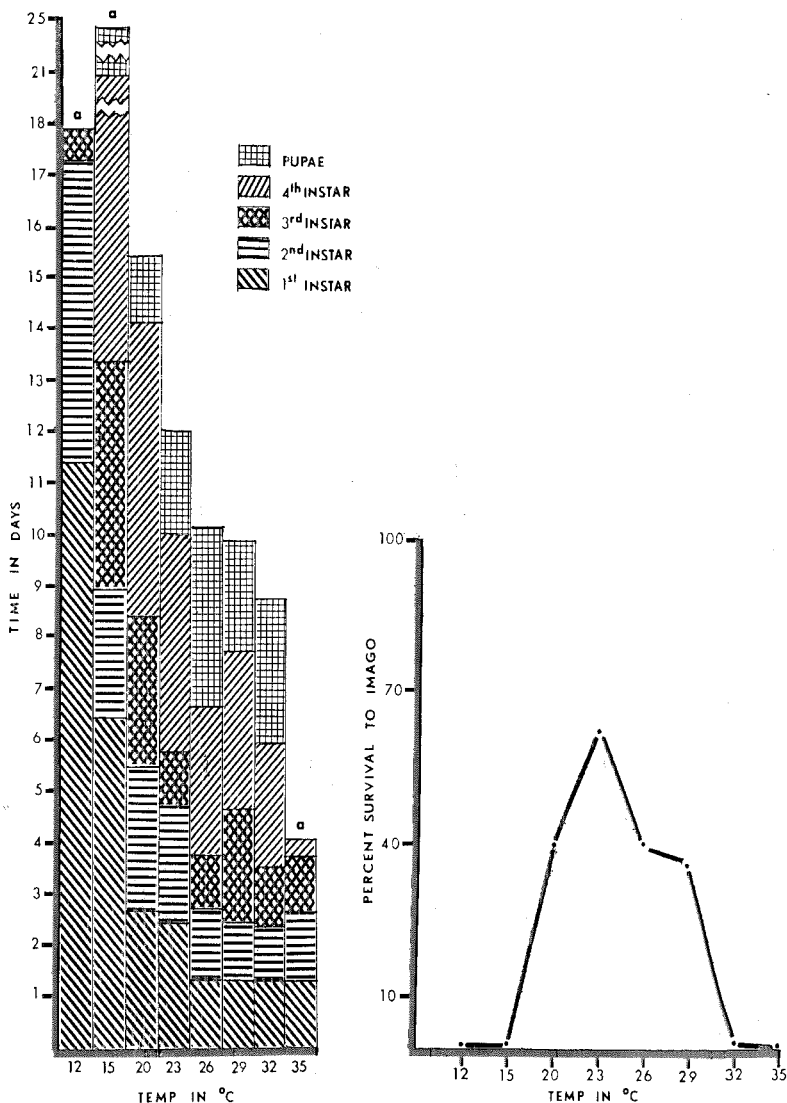


FIG. 6.—*Anopheles quadrimaculatus*. Rate of growth and percentage of survival to imago at 8 temperatures. (a) Larvae did not survive to next stage of development.

cent of the larvae reached the second instar at 35° C but died before further development occurred.

Only the *Culex* (*quinquefasciatus*, *salinarius*, and *restuans*) developed and emerged at 12° C. Although *C. restuans* showed the highest survival (87 percent), *C. p. quinquefasciatus* developed in 16.7 days compared with 25.3 days for *C. restuans*. *Culiseta inornata*, a winter species

in Louisiana, did not develop beyond the fourth instar in three tests conducted at 12° C. Also, *A. albimanus* and *A. quadrimaculatus* were the only two species unable to mature to adults at 15° C. Only two species successfully survived to adults at a temperature of 35° C; less than one percent of the *Anopheles albimanus* and 50 percent of the *Aedes sollicitans*.

Although *C. p. quinquefasciatus* were

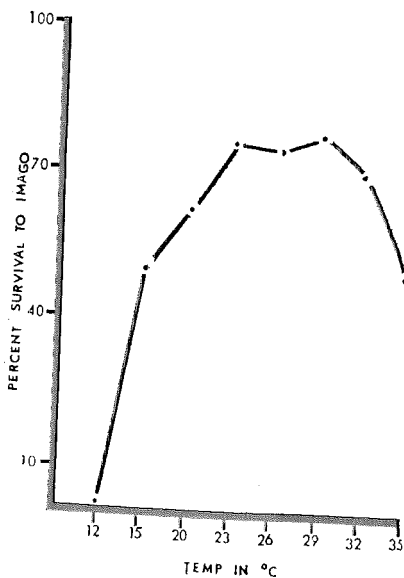
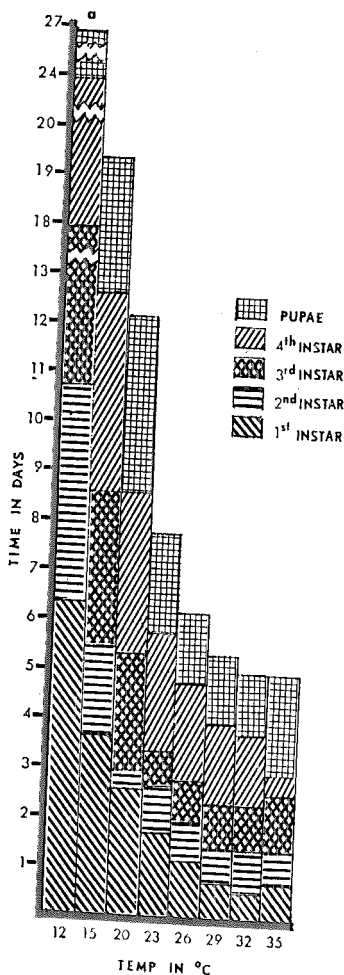


FIG. 7.—*Aedes sollicitans*. Rate of growth and percentage survival to imago at 8 temperatures. (a) Larvae did not survive to next stage of development.

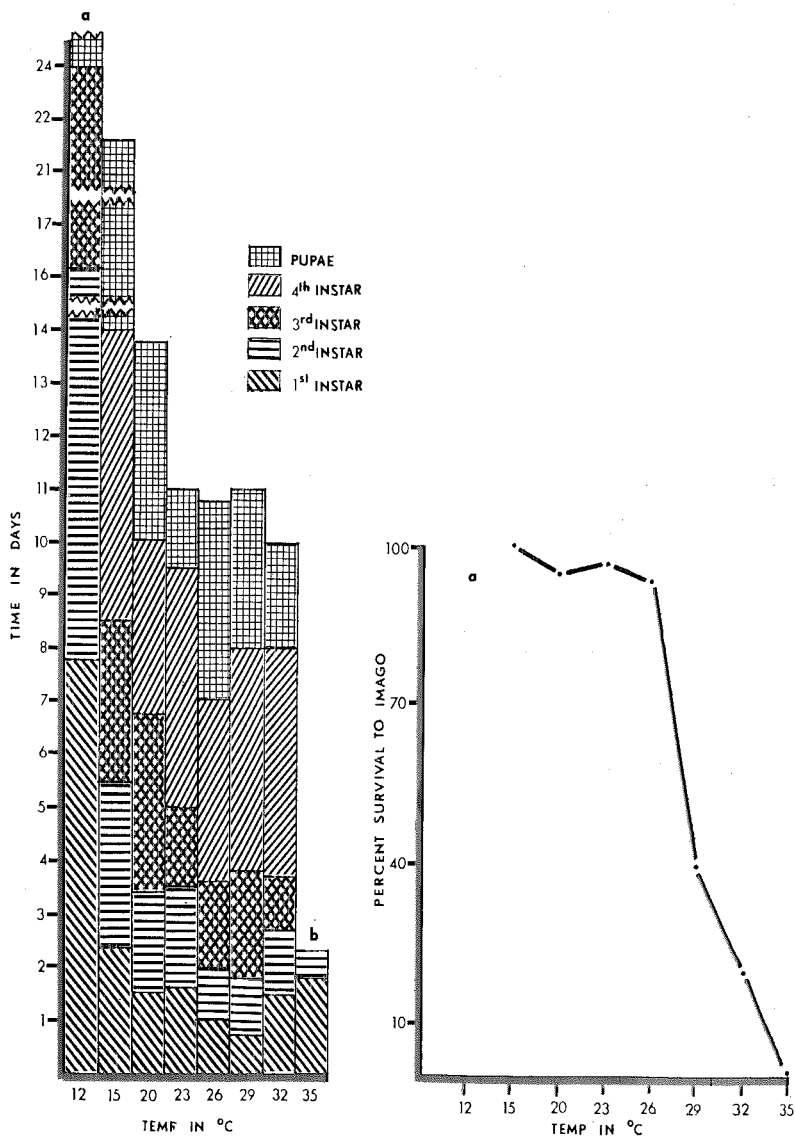


FIG. 8.—*Aedes triseriatus*. Rate of growth and percentage survival to imago at 8 temperatures. (a) Test discontinued after 50 days with all larvae in fourth instar. (b) Larvae did not survive to next stage of development.

unable to develop to adults at 35° C, the percentage survival was greater than that of all other species at all temperatures except for *C. restuans* at 12° C, *Aedes triseriatus* at 15° C, and *Aedes sollicitans* at 32° C. Also, the time required for adult emergence of *C. p. quinquefasciatus* was less than for any other species at all temperatures except for *C. restuans* at 26° C and *Aedes sollicitans* at 26° C and above. As the temperature increased, the average body weight of adult females de-

creased in all species except *Anopheles albimanus* and *C. p. quinquefasciatus*. The weight of *Anopheles albimanus* was similar at all temperatures; the weight of *C. p. quinquefasciatus* was highest at temperatures between 20 and 26° C and decreased as the temperature was raised or lowered.

CONCLUSIONS. Although each species of mosquito reacted differently at the various temperatures, the average body weight of adult females and the time required

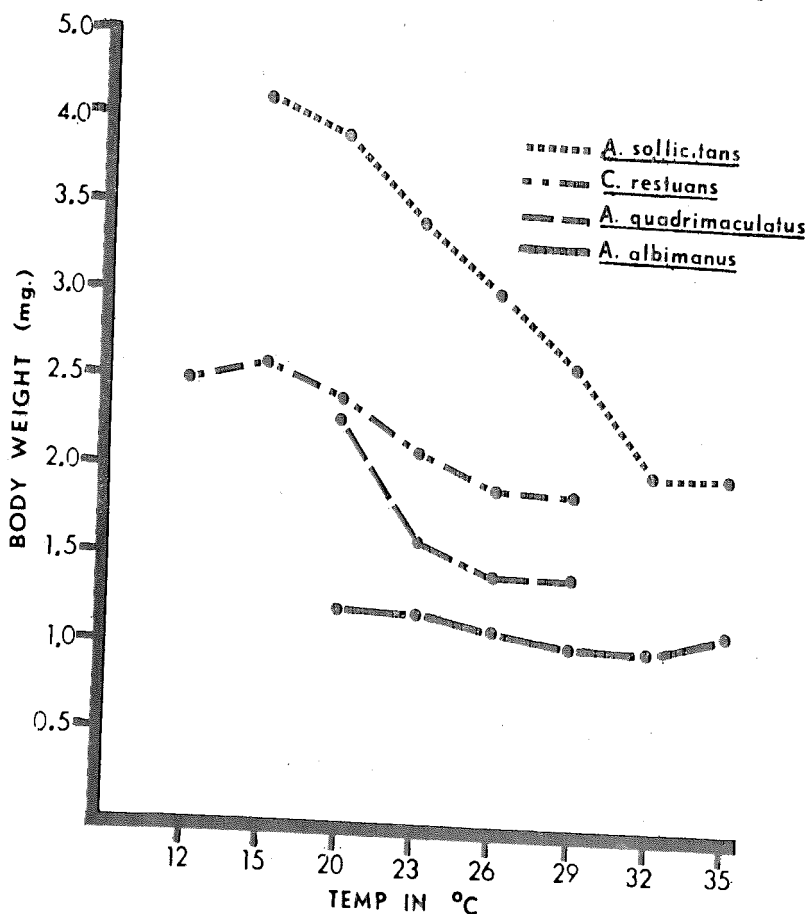


FIG. 9.—Mean body weight (mg) of *Aedes sollicitans*, *Culex restuans*, *Anopheles quadrimaculatus*, and *Anopheles albimanus* reared at 8 temperatures.

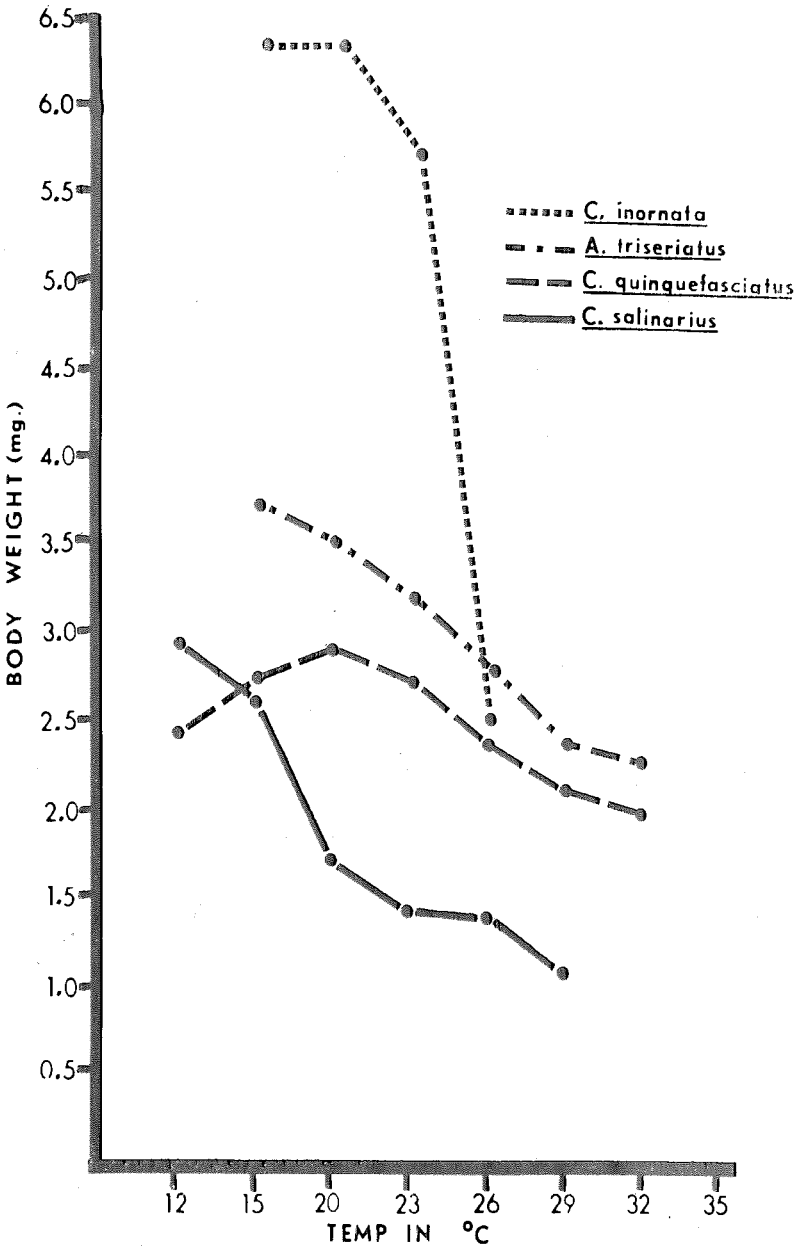


FIG. 10.—Mean body weight (mg) of *Culiseta inornata*, *Aedes triseriatus*, *Culex p. quinquefasciatus*, and *Culex salinarius* reared at 8 temperatures.

for the immature cycle tended to decrease as the temperature increased. Survival was highest at the middle temperatures and decreased at extremes.

Each mosquito species appears to have an optimum temperature for development. However, the optimum at which the highest percentage of larvae will develop to adults may not be the optimum at which development will occur in the least time or the optimum at which the largest and supposedly the strongest and healthiest adults are produced. For example, temperatures that produced the highest survival to adults resulted in a longer immature cycle. However, in nature, lengthening the aquatic cycle increases both the chances of stranding due to drying and the chance of a reduction by predators and pathogens. On the other hand, temperatures that allow the fastest rate of

development appear to result in decreased survival and in smaller adults.

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