TEMPERATURE-RELATED GROWTH AND MORTALITY RATES OF FOUR MOSQUITO SPECIES

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INTRODUCTION

The purpose of this research was to determine growth rates of common species of mosquitoes in Alameda County. *Culex pipiens* L., *Culex tarsalis* Coquillett, *Culiseta incidens* (Thomson), and *Culiseta inornata* (Williston) were reared at temperatures normally found in the field. The results are used in a computer simulation model that will enable technicians to schedule treatments by simulating the growth of the larvae since the last inspection.

Many researchers have studied temperature-related growth rates of mosquitoes (Pritchard and Mutch 1985, Shelton 1973, Bailey and Gieke 1968, and others). However, we felt it necessary to rear the local species rather than use published data, since variation in the species may exist due to climate or locality.

The following was needed for the model: the time required for the immature period from the first instar to the adult stage at various temperatures, and the average time required for each instar and pupal period. A rate summation method, as described by Wagner et al. (1985), is used in the computer model because this method avoids the need to determine maximum and minimum threshold temperatures in larval development. We have assumed that the growth rates obtained in the laboratory will represent those in the field.

MATERIALS AND METHODS

Egg rafts were collected in the field and hatched at room temperature. Larvae were transferred to four or five white enamel pans (41 x 25 x 6 cm) partially filled with aged tap water (about 3 liters); then reared at 49 ±1.5°F (in the refrigerator), 66 ±3.3°F (room temperature) and several temperatures ranging from 72-90 ±0.7°F, depending on that normally encountered by the species. These pans were each heated with a 25 or 50 watt submersible aquarium heater ("Dansea" and "Thermal Compact"). Thirty to 100 larvae were reared per pan. One gram of dry bakers yeast was dissolved in 50 mls of water, and 2 mls of this solution were given per 10 larvae each day. The pans were covered with a plexiglass lid and a small net was attached over an opening in the center to collect the adults. Black plastic was used to cover the lid during the adult emergence stage. For each species, this procedure was repeated up to six times depending on the availability of egg rafts. The number of larvae in each growth stage, time of day, and temperature were recorded twice daily.

The time for the immature period was calculated from the start of the recording period to 50% adult emergence. Linear regression was used to determine the cumulative days to the nearest tenth at 50% emergence.

Percent survival was that which survived to the adult stage from the number of larvae at the start of the recording period. Mortality rate per day was calculated using the compound interest formula $M = [(A/L)^{1/n} - 1]$ where M is the mortality rate, A is the number surviving to the adult stage, L is the beginning number of larvae, and n is the number of days to 50% adult emergence or complete mortality. When a sample did not survive to the adult stage, 0.1 was used as the value for A. Instar boundaries were determined to be when 50% of an immature stage reached the next stage. The first instar began with the start of the recording period. Linear regression was used to determine the time when the population was composed of 50% of each stage.

RESULTS AND DISCUSSION

Linear regression equations were developed to represent the growth rate at various temperatures for each species (Figure 1). The results showed a similarity of growth rates between species of the same genera. The growth rates of the two *Culiseta* species were found to be less responsive to temperature than the two *Culex* species as indicated by the slope of the equations. The *Culiseta* species tolerated the lower temperatures while the *Culex* species tolerated higher temperatures (see also Table 1). Overall, *Culex pipiens* exhibited the highest growth rate at temperatures above 65°F, as indicated by its position on the graph.

The growth rates obtained at temperatures higher than indicated by the regression lines in Figure 1 were not included in the calculations since plotting the inverse of time results in a straight line for the middle range temperatures only (Clement 1963). The developmental time for *Cs. incidens* at 84°F increased rather than decreased (Table 1), indicating this to be an extreme temperature for the species. This increase in developmental time at high temperatures occurred for *Cx. pipiens* at 90°F. Other mathematical formulas have been developed by researchers that include the temperature extremes in a nonlinear prediction equation (McHugh and Olson 1982).

Many of the results obtained in this study compared favorably with results of other work. The total development times obtained for *Cs. inornata* at 69° and 74°F (Table 1) were similar to the results of Shelton (1973). The larval period obtained for *Cx. tarsalis* at all temperatures up to

Table 1.-Mean duration per stage and percent survival at various temperatures.

Species	Mean Temp (°F)	n+	Days per Stage 1	2	3	4	P	Total Days	% Surv.
Culex pipiens	49	2	8.5	30	38	...	...	101*	0
	64	1	2.5	1.9	2.2	4.0	3.7	14.3	84
	67	3	2.8	2.6	1.6	5.4	3.2	15.6	80
	73	2	1.9	1.5	1.6	3.0	1.9	9.8	91
	78	3	1.3	1.3	1.2	2.7	2.3	8.8	78
	87	1	1.3	0.8	++	++	1.5	6.1	48
	90	1	++	++	++	++	++	9.3	65
Culex tarsalis	50	2	15	12	23	...	...	55*	0
	67	3	3.3	2.6	2.3	6.6	3.9	18.7	65
	73	1	2.7	2.0	1.9	5.5	2.5	14.6	44
	81	2	1.4	1.1	1.9	++	++	11.5	74
	85	2	1.6	1.3	1.3	++	++	9.3	68
	88	1	1.1	1.0	1.2	2.6	1.5	7.4	76
Culiseta incidens	49	2	10	15	19	30	15	89	46
	64	1	3.5	4.0	3.3	6.4	5.4	22.6	95
	67	4	2.3	2.7	3.1	5.3	4.5	17.9	86
	74	4	1.5	2.2	2.1	5.2	3.3	14.3	83
	79	2	1.4	1.8	2.0	5.1	2.3	12.5	52
	83	2	0.7	1.8	1.6	3.9	2.7	10.7	47
	84	3	2.0	2.4	3.0	++	++	16.8	8
Culiseta inornata	51	1	8.2	7.2	7.7	14.5	10.6	48.2	88
	62	1	3.2	2.4	2.6	5.5	5.1	18.8	91
	69	2	3.2	1.7	2.4	4.0	3.9	15.2	89
	74	3	2.3	1.8	1.8	4.2	3.2	13.3	87
	78	1	1.7	1.6	...	...	...	8.0*	0

*Total days to complete mortality

++Instar boundaries could not be determined

+number of samples

85°F were similar to both lab and field results of Bailey and Gieke (1968).

The original experimental objectives did not include obtaining survival data. However, the information is considered useful because it will provide mortality due to temperature in the computer model. Percent survival to the adult stage at each temperature is given in Table 1 and mortality rates per day are shown in Figure 2. The mortality rates of the species did not appear to vary in relation to temperature unless the temperatures were in the high or low extremes for the species (Figure 2). Rates for *Cx. tarsalis* were variable and appeared to be caused by factors other than temperature. Analysis of the data, however, indicated that the larval densities used in this study did not affect mortality rates.

The mortality rate curves also show a similarity between genera of the species studied. The mortality rates of the *Culiseta* species increased rapidly at temperatures above 75°F. *Cs. inornata* showed the most sensitivity to temperature increase and the most tolerance to low temperatures. It appears the high temperatures selected for this study approached the lethal threshold of the *Culiseta* species, while the low temperatures remained at optimal levels. The *Culex* species showed higher mortality rates at the low temperature range and variable mortality at the higher temperatures. The highest temperatures used for the *Culex* species did not reach lethal levels.

The computer simulation of larval development required knowledge of the duration of each immature stage (Table 1). For this purpose, the time for each stage was converted to a percentage of the total developmental time and averaged for each species (Figure 3). The times calculated for

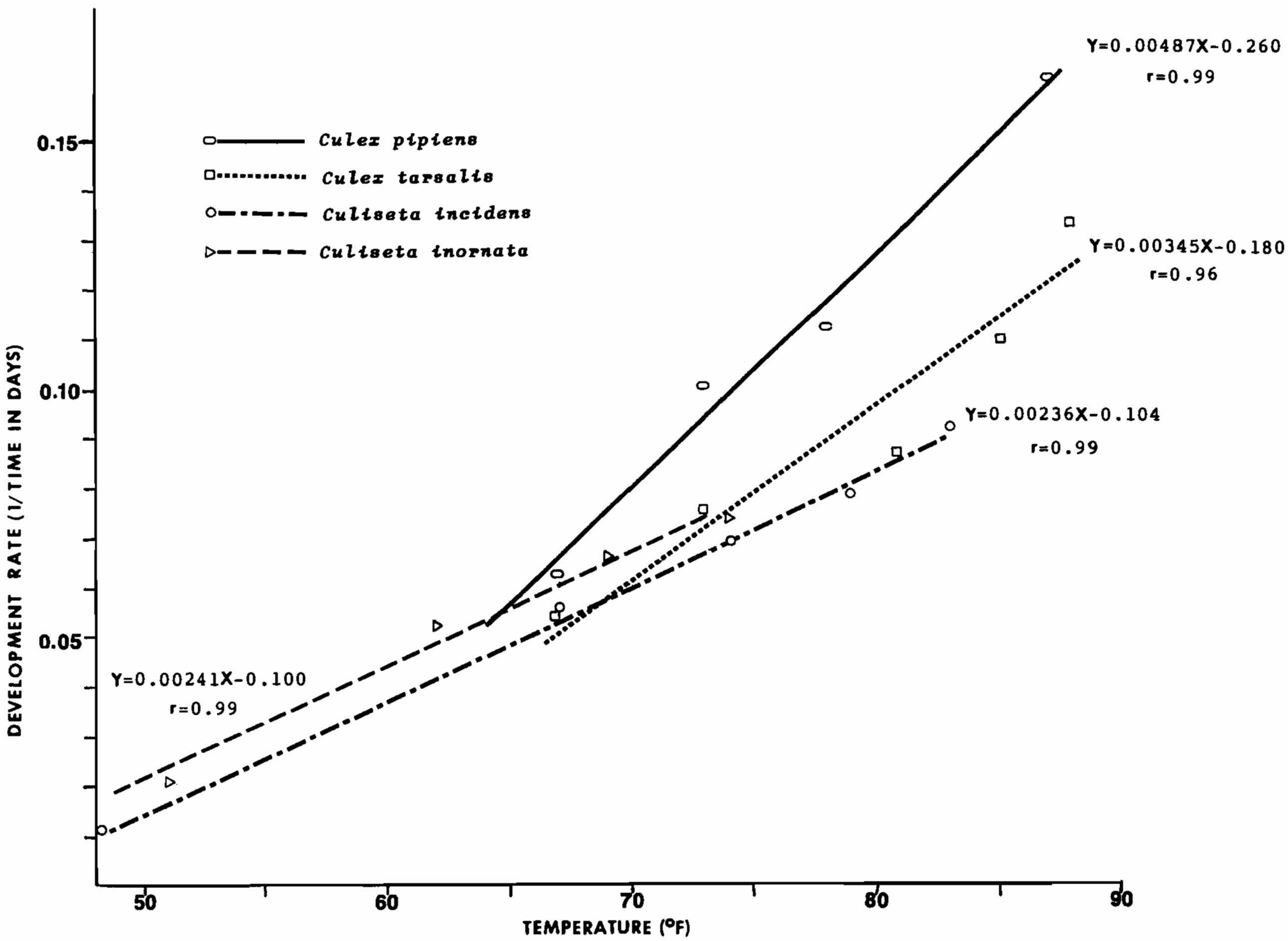

Figure 1.-Growth rates from early first instar to adult at various temperatures. Lines are a least-squared fit to points of mean development time.

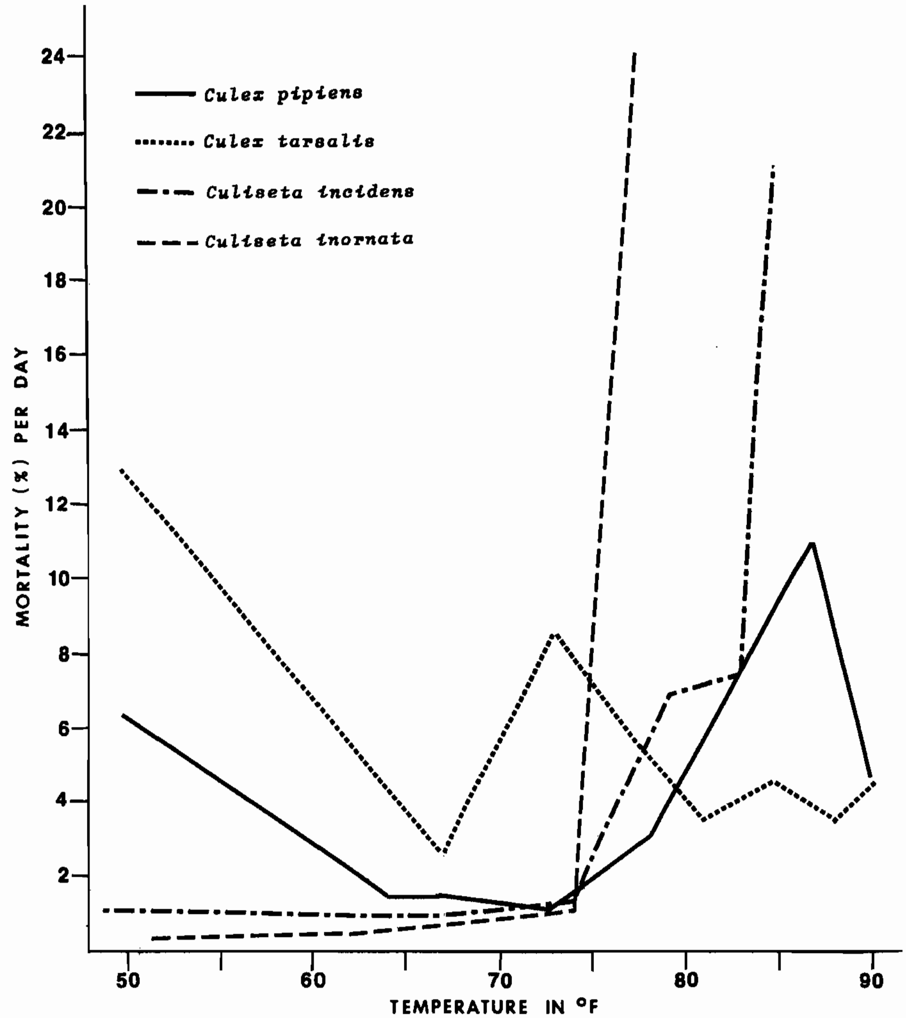

Figure 2.-Mean mortality rate per day at various temperatures.

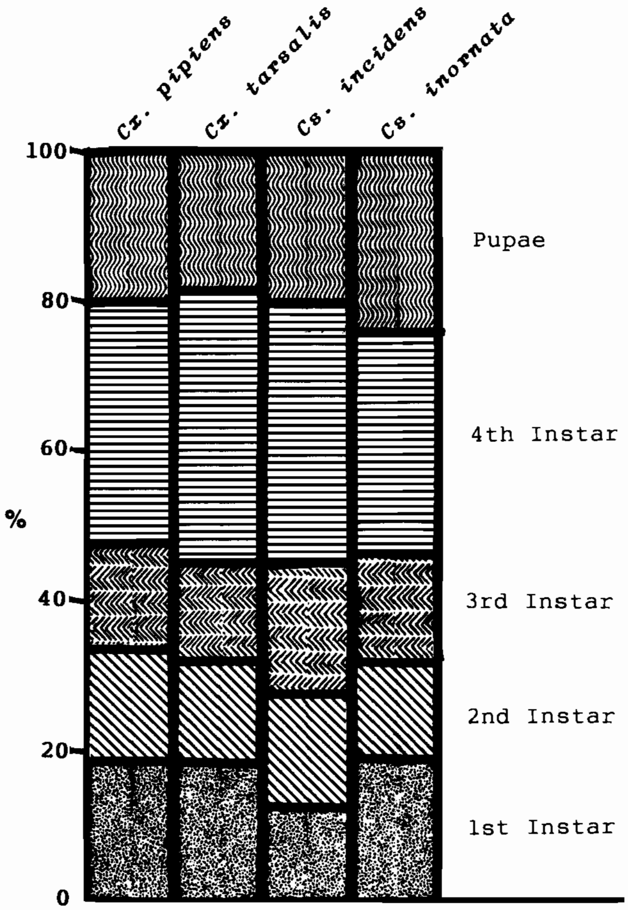

Figure 3.-Duration (%) of each immature stage for *Cx. pipiens* at 64-78°F, *Cx. tarsalis* at 67-73°F, *Cs. incidens* at 49-79°F, and *Cs. inornata* at 51-74°F.

high temperatures were not accurate because sampling could not occur often enough; therefore, only the percentages below 80°F were used. The differences between species appear to be insignificant but will be used in the simulation model to represent the appropriate species.

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