PREDICTION OF LARVAL SOURCE TEMPERATURES BY ECOSIM

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Alameda County Mosquito Abatement District currently uses a computer simulation to assist technicians in determining when treatment of breeding sources should occur (Roberts et al. 1990). ECOSIM (Evolving Computer Simulation of Mosquitoes) was designed to predict the number of days required for larvae to reach an established treatment-threshold. Initial developement of ECOSIM focused on determining temperature-related growth rates of *Culex pipiens* L., *Culex tarsalis* Coquillett, *Culiseta inornata* (Williston) and *Culiseta incidens* (Thomson) (Mead and Conner 1987). Following this, a temperature model, which operates as a subroutine in ECOSIM, was developed to determine the temperature of mosquito breeding sources. This study describes the development of the temperature model, compares the results with actual values, and makes recommendations to improve the accuracy of the temperature predictions.

Thermal characteristics of sources.

Studies of the Coyote Hills Freshwater Marsh provided a starting point in understanding the thermal characteristics of aquatic habitats (Collins and Meyer 1985). Temperature fluctuations of the marsh occured on a daily cycle, with the high reached by mid-afternoon and the low by early morning. The correlation between ambient and source temperatures established in the study was initially used by ECOSIM as the means to predict all larval source temperatures in the county. This approach failed, as many of the sources in the county did not have the same thermal characteristics as the Coyote Hills Marsh.

To overcome this problem, source types were studied and grouped according to their similar response to ambient temperature. An Onsite Weather Logger (OWL) with a Tandy 102 portable computer facilitated in the analysis of the source types by recording ambient, surface, and 6" depth temperatures at hourly intervals for 24 hours. The data collected produced temperature profiles by which three groups were defined, based on the response of surface temperature to ambient temperature (Fig. 1):

1) Sources in which temperatures rose or fell readily with a rise or fall in ambient temperature.
2) Sources that tended to respond less dramatically with changes in ambient temperature.
3) Sources in which little or no rise in temperature occured with the daily increase or decrease in ambient temperature.

Sources in group 1 will be referred to as "shallow", though this group also included some deep sources which had profiles similar to shallow sources. Sources within this group were generally less than one foot in depth, had a static flow and were 50% or more sunlit. Sources greater than one foot in depth tended to contain dense submerged vegetation throughout.

Sources in group 2 will be referred to as "deep", though this group also included shallow sources. Sources within this group were generally greater than one foot in depth with clear water. Any sources in this group less than one foot in depth were flowing and were 50% or more shaded.

Group 3, the "subterranean" group, included all manmade underground sources such as catch basins, storm drains and utility vaults.

The temperature model.

The temperature model was based upon certain assumptions. First, the growth rates of the larvae are influenced mainly by the temperature at the 1/2" depth (Stewart 1974). Second, mosquito growth rates are driven by the 24-hour mean temperature with no significant influence caused by temperature fluctuation (Milby and Meyers 1985). Third, the average temperature derived from the daily high and low is not significantly different from that derived by the 24 hourly temperatures. And last, warming of the water surface is assumed to be correlated with ambient temperature, and can be represented by a constant.

The model requires, as input, high ambient and low source temperatures. To collect the low source temperatures, a county-wide monitoring program was established, dividing the county into four regions with three monitor sources in each. Low source tempertures were collected three times weekly between 6 and 9 AM. These values were

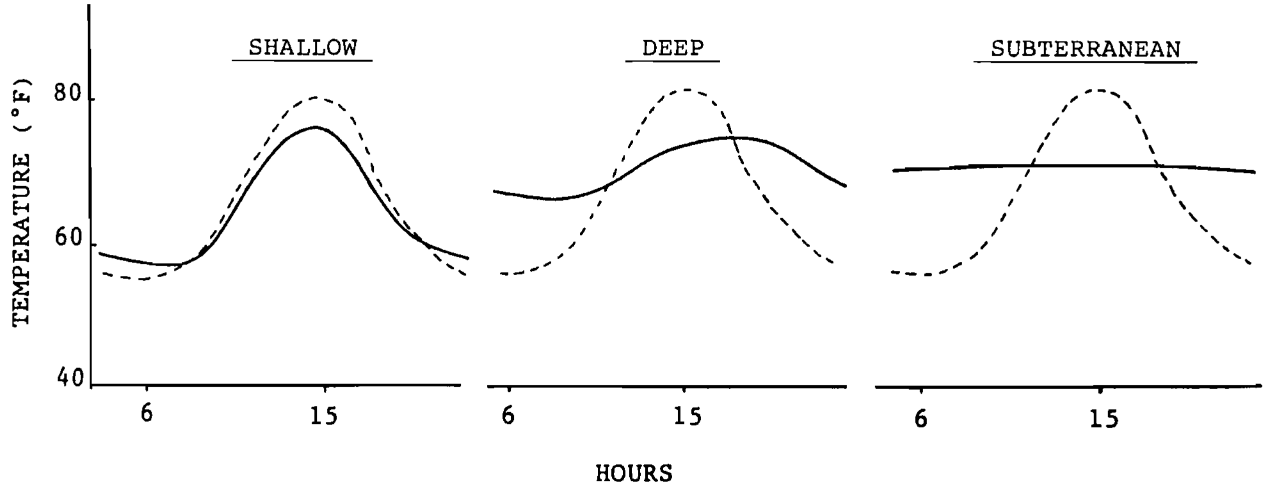

Figure 1. Typical daily temperature profiles (----- water surface, - - - air) for the three groups of sources.

used by the temperature model as the low source temperatures for similar sources in each region. The high ambient temperature reported by the National Weather Service was collected daily for eight cities.

The model derives the high source temperature by using the high ambient and the low source temperatures. The high ambient temperature is considered the potential high a source may reach; the actual increase, however, is proportionate to that potential, and is determined by a warming coefficient. The high source temperature is then averaged with the low to provide the 24 hour mean (Fig. 2).

Three warming coefficients were established, from sample OWL profiles representing the three source groups. The coefficient is derived by dividing the actual increase in temperature (high source minus low source) by the potential increase (high ambient minus low source).

Comparison of results.

The temperatures predicted by the model were compared to the actual temperatures recorded by the OWL, which was placed in 25 locations for a minimum of two days each, over the course of one year. Afterwards, a simulation was run for each location. The values compared in the analysis were the 24-hour mean, low source, high source, and high ambient temperatures. Low source and high source temperatures were at the surface (1/2" depth). The 6" depth temperatures were not used in this study.

Twenty-four hour mean temperature. In Figures 3 through 5, the plots are shown with an ideal correlation line and limit lines of plus or minus five degrees Fahrenheit. The limit lines were based on the temperature-related growth rates of the species simulated (Mead and Conner 1987), resulting in a one to two day treatment-threshold error.

Shallow sources showed a strong correlation between the actual and simulated temperatures (Fig. 3). The majority of data fell within the limit lines. The slope, however, indicated that at the lower temperatures (cooler months) the simulated temperatures were warmer than the actual values, while at the higher temperatures (hotter months) the simulated temperatures were cooler than the actual values.

The deep sources also showed a strong correlation between the actual and simulated temperatures (Fig. 4). The majority of data fell within the limit lines.

No correlation existed for the subterranean group (Fig. 5). About half of the data points fell outside of the limit lines. It was found that these points represented data from storm drains and utility vaults, while the data inside the limit lines represented catchbasins.

Low source temperatures. Monitored low source temperatures used in each of the simulations were compared to the actual temperatures recorded by the OWL (Table 1). For each source group, the differences were significant using the paired comparisons test at a 95% confidence level.

High ambient temperatures. The high ambient temperatures, as reported by the National Weather

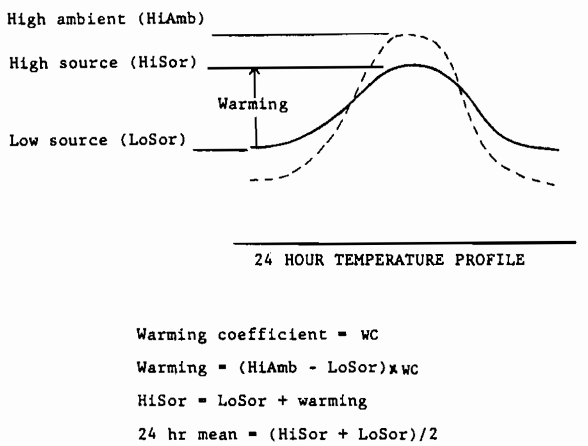

Figure 2. Derivation of the 24-hour mean temperature of a larval source.

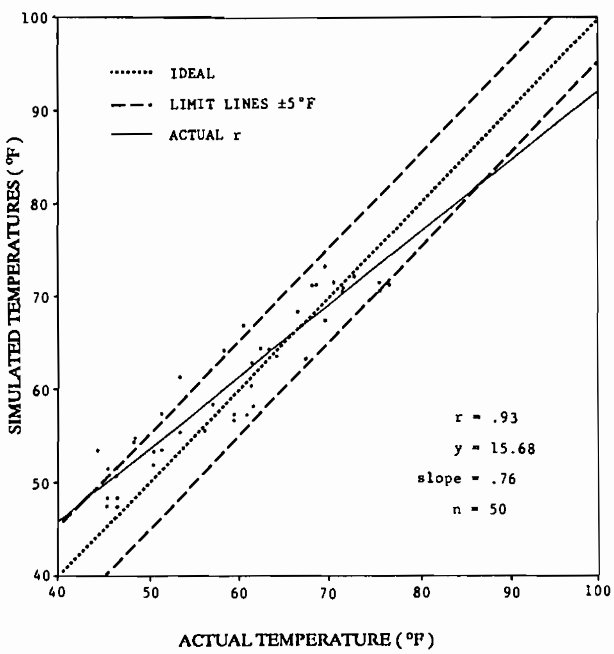

Figure 3. Comparison between simulated and actual 24-hour mean temperatures for shallow sources.

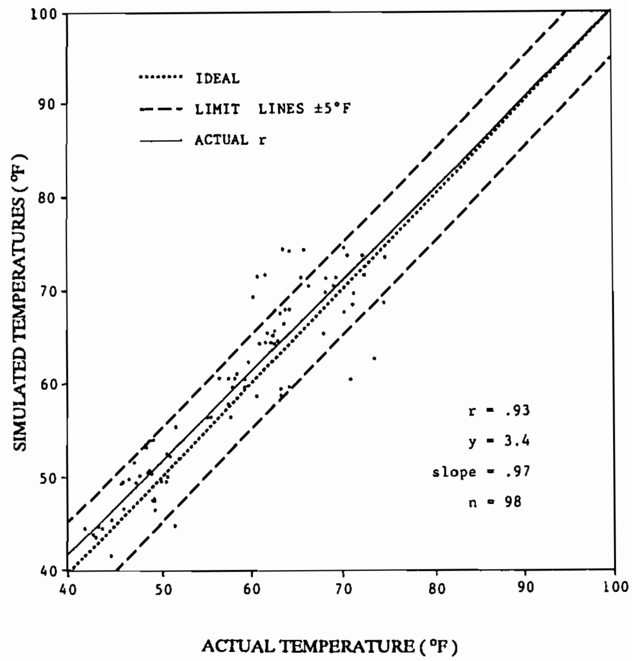

Figure 4. Comparison between simulated and actual 24-hour mean temperatures for deep sources.

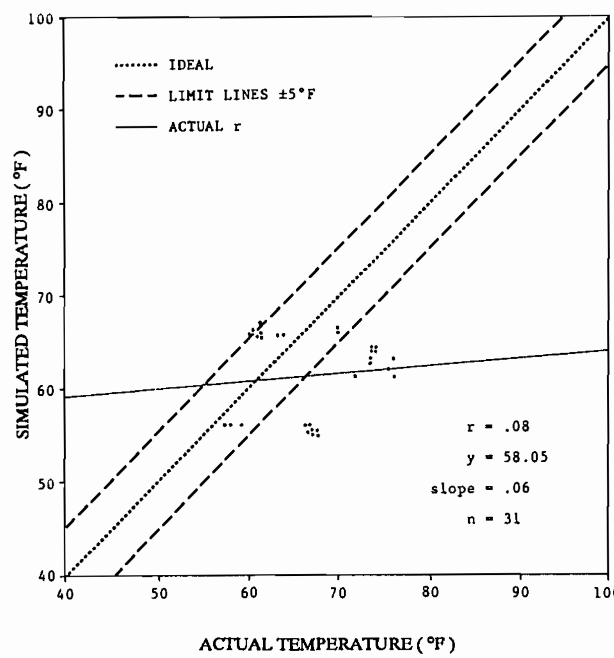

Figure 5. Comparison between simulated and actual 24-hour mean temperatures for subterranean sources.

Table 1. Differences between monitor source temperatures used in the simulation and actual low source temperatures (^{o} F). M_D= Mean of the differences (simulation - actual). SD= Standard deviation.

Group	Pairs	M_D	SD
Shallow	50	5.1	3.6
Deep	98	1.8	4.6
Subterranean	31	-4.4	7.7

Table 2. Differences between simulated high source temperatures and actual temperatures (^{o} F). M_D= Mean of the differences (simulation - actual). SD= Standard deviation. WC= Warming coefficient.

Group	Pairs	M_D	SD	WC
Shallow	50	-5.1	8.1	.545
Deep	98	-2.7	3.5	.255
Subterranean	31	-1.6	1.8	.053

paired comparisons test. OWL data was subtracted from weather service data, and resulted in a mean difference of 0.35 and standard deviation of 5.8. The differences were not significant at the 95% confidence level.

High source derivation. The warming coefficients were tested for accuracy by first eliminating known sources of error. The simulations were rerun using OWL data for the low source and high ambient temperatures, and then the derived high source temperatures were compared to the OWL high source temperatures using the paired comparisons test (Table 2). The test indicated a significant difference between the derived and actual temperatures at the 95% confidence level for each warming coefficient.

Discussion.

Shallow sources. Errors in simulated temperatures for shallow sources need correction in both the warming coefficient and monitor source values. Error in the calculation of the 24-hour mean was sometimes reduced by the process of averaging the low source and the high source temperatures. The negatively skewed error of the warming coefficient was offset by the positively skewed error of the monitor source temperatures (Tables 1 and 2). A negative high source difference indicates that the value for the warming coefficient should be larger. Analysis of monitor source data indicated that error was introduced by using the shallow edge of a lake to monitor temperatures rather than using sources with an average shallow depth. This resulted in significant discrepancy at these locations; that is, the low source temperatures were high, since deep sources cool at a slower rate. Shallow monitor sources should be carefully selected to insure the temperatures collected represent those of other shallow sources in the region. The difficulty of keeping a shallow monitor source year around may possibly be solved by the use of an artficial source which is currently being investigated. Data from deep vegetated sources were not sufficient to be included in this study.

Deep sources. The temperature model currently provides acceptable levels of accuracy for deep sources. However, with the additional OWL data gained since the warming coefficients were established, revision of the coefficients could provide even greater accuracy. Data from turbid sources were not included since they seemed to have characteristics that were common to both the shallow and deep groups. Further study is needed before turbid sources can be simulated.

Subterranean sources. Although individual sources in the subterranean group varied only slightly in temperature in the daily cycle, they varied significantly in temperature from source to source. The error in temperature simulation was due primarily to the monitor source temperatures. Subterranean sources should be studied to determine if it is necessary to create additional classes within this group based upon their low source temperatures. Minor adjustment to the warming coefficient should also improve the results.

Conclusions.

The following is recommended: revision of the warming coefficients, reselection of some monitor sources, and further investigation of subterranean, turbid, and vegetated sources.

The purpose of the statistical analysis was not to measure the magnitude of error as much as it was to point out where error could be reduced. The required level of accuracy for the temperature model in relation to ECOSIM has yet not been established. The predictions of the ECOSIM model are currently at acceptable levels 80% of the time, with an ultimate goal of 90% (Roberts et al. 1990). Improvement of the temperature model should increase the accuracy of the predictions and bring the ECOSIM model closer to its stated goals.

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