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ESTABLISHING AN ARTIFICIAL AQUATIC WEATHER STATION AND ITS RELATION TO ALAMEDA COUNTY MOSQUITO ABATEMENT DISTRICT'S COMPUTER SIMULATION (ECOSIM)

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ABSTRACT

Alameda County Mosquito Abatement District uses a temperature-dependent larval growth computer model (ECOSIM) for the simulation of larval mosquito growth. This paper discusses previous techniques used by the district to obtain temperature data for the model and present techniques and materials used in the artificial aquatic weather stations. Conclusions about the temperature data which is now available and the possible direction of future effort's by the district are also discussed.

Introduction.

A computer model (ECOSIM - Evolving COmputer SIMulation) has been developed in the Alameda County Mosquito Abatement District (ACMAD) to assist technicians in creating daily inspection/treatment schedules of larval mosquito sources (Roberts et al. 1990). The validity of the model is heavily dependent upon accurate predictions of larval source temperatures. Recent evaluations of the temperature subroutine used to predict source temperatures in ECOSIM suggested that improvements were necessary to bring the model to acceptable levels of reliability (Mead et al. 1990). This paper will discuss the design, operation, and evaluation of artificial aquatic weather stations aimed at accomplishing the desired improvements. The use of artificial stations was selected from a number of options because of their high potential to provide highly accurate, yet very economical, real time temperature data to simulate larval growth in ECOSIM.

Techniques.

Ideally, temperatures would be taken from each known source within the ACMAD and utilized in a model to simulate larval growth at each site. However, this technique is prohibitively costly, as well as being unwieldy in implementation. Therefore, techniques were devised which limited the number of sources necessary for monitoring. General source types, consisting of nine groupings, were used to characterize all sources within the district (Table 1). This technique allowed any technician to evaluate a source in terms of its potential for heating, and therefore its potential for larval growth.

An On-site Weather Logger (OWL) was used to obtain 24-hour water and air temperature profiles for a variety of larval sources. When these temperature profiles were compared, most sources exhibited one of three basic profiles (plus or minus a correction factor). Analysis of the physical attributes of these sources (Mead et al. 1990) indicated a distinct separation of the sources into three resultant source types: Shallow, Deep, and Subterranean. The first group, Shallow sources, are less than one foot deep and have relatively clear, still water. The second group, Deep sources, are deeper than one foot and have relatively clear water. The final group, Subterranean sources, are below ground level with a very stable 24-hour temperature profile, implying that underground larval production sources are buffered from extreme temperature fluctuations by the mass of concrete

Table 1. Categorization of larval sources found within ACMAD based upon temperature profiles and key indicator(s) used to characterize them.

	Source Type	Key Indicator(s)
1	subterranean (cold)	underground, open to air
2	subterranean (warm)	underground, closed to air
3	shallow (cold)	<12" deep, 50% shaded or flowing
4	shallow (warm)	<12" deep, little shade, not flowing
5	deep (no vegetation)	>12" deep, no vegetation
6	deep (vegetation, hot)	>12" deep, vegetation, no shade
7	deep (vegetation, cool)	>12" deep, vegetation, 50% shade
8	deep (turbid)	>12" deep, water turbid
9	very deep	>4' deep, deep source

and/or earth around them.

Further analysis suggested that ACMAD larval sources were divided into three distinct climate/temperature regions (Fig. 1). A statistical analysis of National Weather Service Data for the daily high temperatures in Alameda County further reinforced this conclusion. The three climate regions are designated: 1) South area, including the cities of Fremont and Union City; 2) North area, including Hayward, San Leandro, Oakland, Alameda, and Berkeley; and 3) East area including those areas east of the coastal hills including Pleasanton, Dublin, and Livermore.

History.

Having determined the type of sources needing to be monitored, it became apparent that specific data from each of the three source types (Shallow, Deep, Subterranean) as well as nearby ambient temperatures were necessary from within each of the previously defined climate regions (North, South, East).

Historically, it was a technician's duty to record temperatures in representative source types within their assigned area (zone) of responsibility. The technician would attempt to take larval source temperatures at the hottest point of the day, thereby obtaining a theoretical high temperature for that source for that day. This process introduced two possible sources of error: 1) selecting a representative source type and 2) measuring the high temperature at that source. Standardization of technique was difficult as no two sources or technicians were the same. Also, since temperatures were collected only three days a week, there was a time lag between temperature data collection and utilization of the data within the ECOSIM model. The ECOSIM model simulates larval mosquito growth by predicting that a generalized source type will produce adult mosquitoes in a certain number of days or weeks given the current temperature regime.

To limit the effects of technique error, a technician was hired to measure larval source temperatures three days a week at all of the previously selected representative source types within each of the three climate regions. This technician further attempted to measure the sources at the coolest time of day (5 AM to 8 AM). This decision was based on the 24-hour temperature profiles which showed that a source's high temperature is reached for only a short while, but the low temperature generally occurs during an early morning window of time. This change in monitoring resulted in a reduction of error since the high temperature was often missed in monitoring.

Once the source low temperature had been obtained, a computer model utilizing National Weather Service Data for the corresponding high and low temperatures was used to mathematically derive an average temperature for that source type in that climate region, which could then be utilized by ACMAD's larval growth simulation ECOSIM model. ECOSIM applied this average temperature

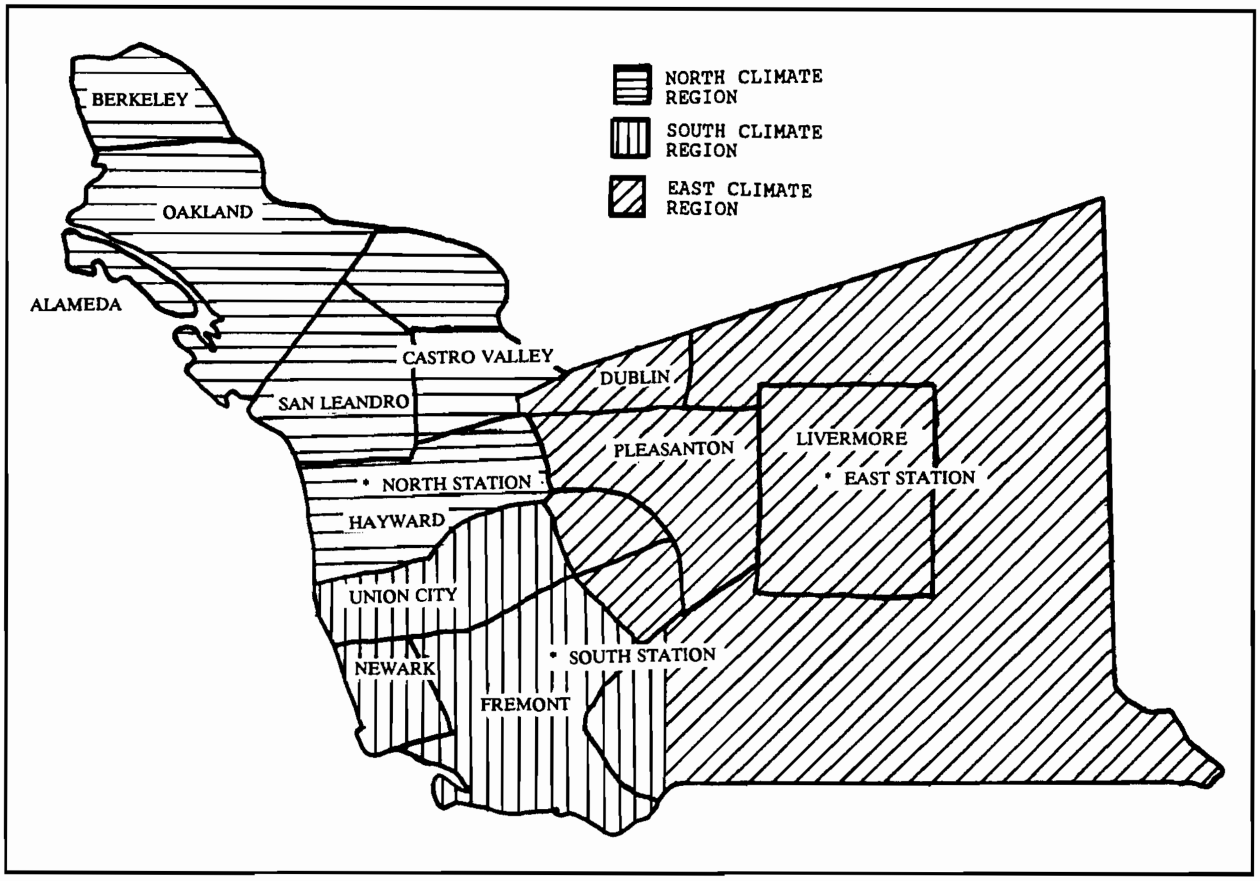

Figure 1. Map of ACMAD indicating the major cities, three climate regions, and three artificial aquatic weather stations established by the district to monitor weather parameters within each region.

to all similar larval source types (Shallow, Deep, Subterranean) for that climate region (North, South, East) to predict the rate of larval growth in that area. Although this methodology was able to further reduce the temperature collection error problems encountered before, the district model still relied on a mathematically derived average temperature. Additionally, this technique still collected data only three days a week, introducing the possibility that the data time lag was leading to a certain amount of inaccuracy within the model for temperature data derivation. This technique also required one technician to devote three days a week to temperature collection, thereby increasing the expense and liability incurred by the district.

A more timely system which would offer more precise data was of primary concern to the district. Rather then having technicians or other district personnel collect temperatures, it was decided that some form of electronic temperature measuring and storage device should be used. This system would eliminate not only the standardization problem but also the time lag problem by using a telephone line and modem to transmit data daily. In theory, a temperature logging device would be placed in each of the three climate regions on a site that contained all three naturally occurring source types in close proximity. However, no such pre-existing natural sites occurred within the county. Therefore, artificial sources, sources that closely mimic actual sources, would have to be established in each climate region.

A study was conducted in which 24-hour temperature profiles for various commercially available containers were compared with profiles of nearby natural sources. Only containers that fit the source type definition were compared against the corresponding natural source type, e.g., a tray with depth less then 12 inches was compared with a Shallow source, a container of depth greater then 12 inches was compared with a Deep source, etc. The container with the most favorable comparison between its profile and the natural source profile was chosen as the artificial source and was included into the artificial aquatic weather station (Fig. 2).

Paralleling this study, a search was conducted for the best electronic measuring and storage device. Four major factors were considered in the selection process: 1) Ease of use - the device should be simple to use for both trained and untrained personnel; 2) Versatility - more than one weather parameter should be able to be measured at the same time thereby allowing the district the ability to incorporate more factors into the model as needed; 3) Cost - the cost should be low enough so that multiple units could be purchased without taxing the district's budget; and 4) Accuracy - the unit should give an accurate reading for any parameter chosen.

Initially, public and private agencies were contacted for available for weather data collection devices. Literature studies were then conducted on those devices mentioned most frequently by the agencies contacted. After an extended study, the best device for the job was determined to be the On-site Weather Logger (OWL) already in the district's possession. Because the OWL features a Tandy laptop computer programmable in BASIC, it is easy to use and cost efficient. Since the laptop computer includes a built-in modem, it has the capability to transmit data over the phone line. Also, the OWL has the ability to measure 15 different weather parameters (eight at any one time), thereby making it the most versatile of all devices studied.

Materials.

Having completed the necessary studies, the district was ready to implement the concept. Implementation required that suitable sites be found for locating the weather stations, so a survey was conducted for the best site available in each of the three climate regions. Each possible site was evaluated with respect to its security, exposure to weather, proximity to a phone line, ease of access, and its probable length of service. In general, property publicly owned, by either a city or the

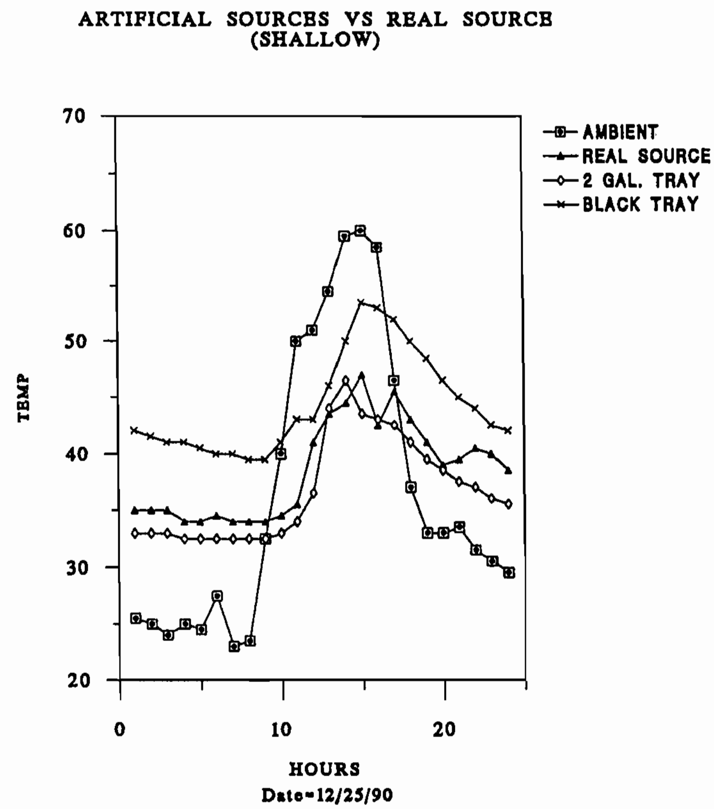

Figure 2. Example data generated from one of 14 separate tests to determine the best artificial source for a source type. Generally 2-6 commercially available containers were compared per test.

county, best fulfilled the needed prerequisites. Again, county agencies and municipalities were contacted and told of our needs. Through this process, suitable sites were obtained from the cities of Fremont and Livermore and construction of the artificial weather stations began.

Each artificial aquatic weather station consists of a 5' X 5' plot of land on which three artificial sources are constructed, representing the three main source types in the district. The artificial shallow source consists of a 12" X 18" X 4" tray of water and the artificial deep source is a 10 gallon circular bucket with a diameter of 18" and a depth of 16 inches. Both of these sources are buried in the soil to more accurately simulate real sources. The artificial subterranean source is a 6" diameter ABS plastic pipe buried to a depth of 6 feet. Located at the bottom of this pipe is a small ABS plastic "cup" that holds the water from which the temperature is obtained. The water levels in the artificial deep and shallow sources are maintained for the short term by float valves connected to a five gallon reservoir. Temperature probes from the OWL are placed in each source to obtain the necessary data and ambient temperature is measured by a probe located at a height of six feet above ground level.

To decrease the likelihood of small animals and people falling into the sources, a cage was constructed to shield the station but not to interfere with the sources' interaction with the environment. The OWL strobes the temperature probes every two minutes and logs the data to memory every hour. Just before midnight, at a pre-programmed time, the OWL dials up the district's computers and downloads the day's data over the phone line. The data is then made available to the district's ECOSIM model. ECOSIM derives a 24-hour average from this data for each source type and applies this temperature to the model. Each station is serviced on a biweekly basis by a technician, who replaces the used battery with a recharged one, and tops off the reservoir with water.

Future Plans.

With the installation of the monitoring device, the system as described above is expected to increase the reliability of ECOSIM. Figure 3 shows an example comparison of the artificial weather station's shallow sources with the temperature profile from a nearby real shallow source. The accuracy of the artificial source in mimicking the ambient temperature and heating and cooling of the real source is demonstrated by the relatively high correlation coefficients (r^2) of 0.88 and 0.93, respectively. Future validation studies will be conducted to determine the increase in general reliability. In the meantime, however, the most important future tests of the stations will be definitive statistical studies comparing concurrent temperature data from existing sources with that data obtained from the artificial sources. Towards this end, the district is obtaining a portable device that will provide 24-hour temperature profiles for any source. This device will be used to validate and/or refine the present sources contained in the stations.

Another envisioned refinement is the establishment of other artificial aquatic weather stations within the county. This development will help define the climate regions within the district and may actually lead to the establishment of a fourth climate region. This change is dependant, however, on the validation process mentioned above.

Another envisioned modification involves the ECOSIM model itself. Because the data received from each station is in the form of an hourly reading, the data could be used by the model to "grow" the mosquitos on an hourly basis, adding another significant advance in reliability since, at present, ECOSIM uses the data on a daily basis by obtaining a 24-hour average and then applies this figure to a mosquito growth algorithm. Incorporation of this iterative modification would be dependant on two factors: 1) Would this added complexity actually amount to any more efficiency in the real world? and 2) Is there a computer processor that could perform the calculations in a timely fashion and still be cost efficient?

Conclusions.

In conclusion, the artificial aquatic weather stations are viewed by the district as the most efficient and economical way to provide temperature data to support district computer simulations. The inception of this system eliminated previous data collection errors inherent in the older methods. Moreover, the new system provides a 24-hour temperature profile as opposed to the singular temperature provided by the previous methods. Also, the data is much closer to real time data, making it more useful to the district (Table 2). With future refinements, it is expected that the artificial aquatic weather stations will provide the district with even more accurate, usable data.

Table 2. Summary of improvements in larval source temperature data gained by utilizing artificial weather stations over historical measures.

	Artificial Station	Historically
1	Real time data	48-Hour time lag in data usage
2	Building a large data base for future analysis	Singular event data (one temperature reading)
3	24-Hour temperature average used	Hi/Lo average used
4	Actual high temperature used	Derived high temperature used
5	Eliminates manual data collection costs	High costs and maintenance requirements
6	Standardization of measurement techniques	No standardization of techniques
7	Sources remain constant throughout the year	Sources change seasonally
8	Flexibility in site modification (as needed)	No or little site modification possible
9	Ease in comparision of data (24-hour profile)	No comparisions available (see #2 above)

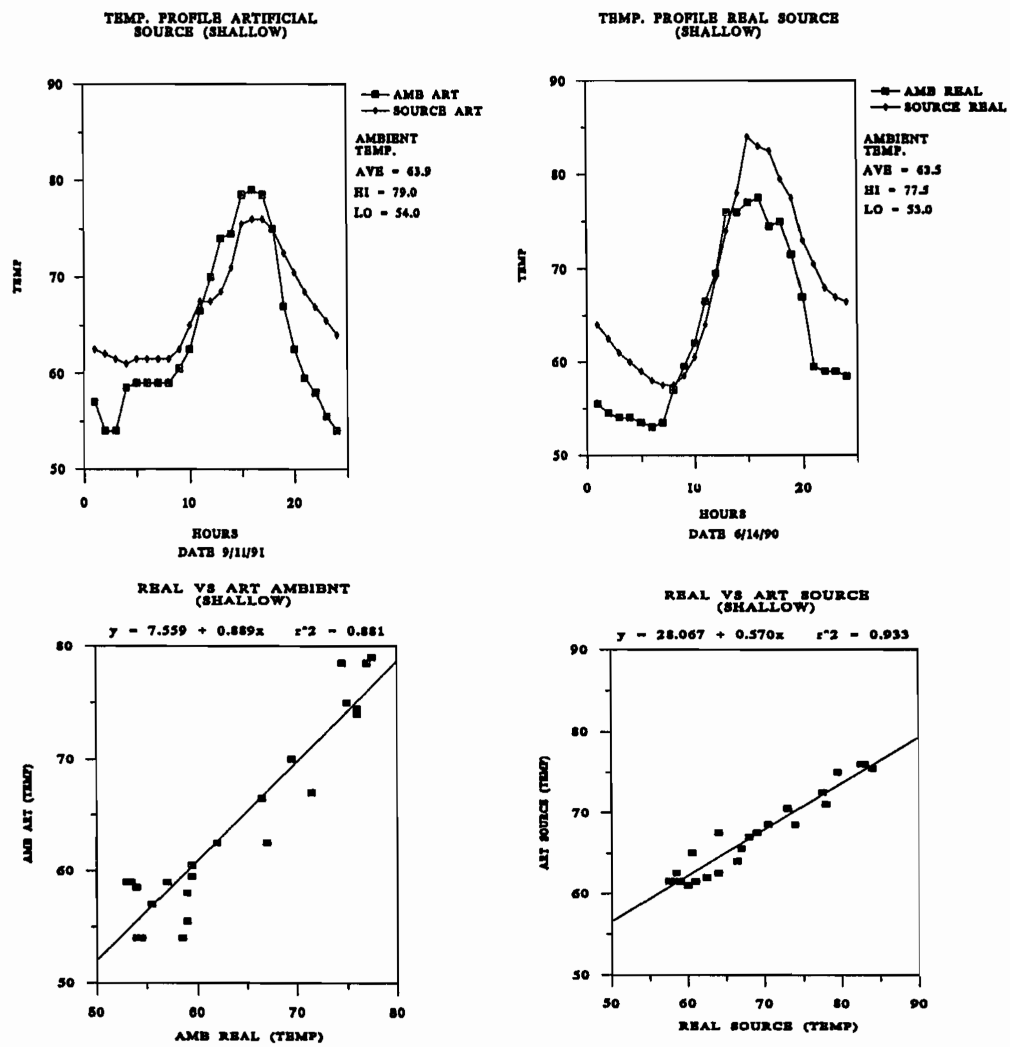

Figure 3. Comparison between real and artificial source (shallow) temperature data. Artificial and actual temperature data were compared if ambient temperature parameters were roughly the same (high, low, mean).

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