POPULATION DYNAMICS OF LARVAE OF *CULEX TARSALIS* COQUILLETT AND *CULISETA INORNATA* (WILLISTON) AS RELATED TO FLOODING AND TEMPERATURE OF PONDS[1]

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ABSTRACT. A series of experiments was conducted in freshwater ponds located in the Coachella Valley of southern California. Responses of gravid females of *Culiseta inornata* (Williston) and *Culex tarsalis* Coquillett (Diptera:Culicidae) to density independent environmental factors are reported here.

In the first experiment the response of gravid females to flooding was investigated. Data obtained indicated that *C. tarsalis* was significantly attracted to freshly flooded ponds even though the control ponds (flooded for a longer period) were in the same immediate area and were of similar water chemistry.

During the second set of 3 experiments conducted during "winter," "spring" and "spring to summer" months *C. inornata* populations were influenced by high and low temperatures. When the water temperature approached a mean of about 5° C, *C. inornata* 1st instars were no longer present. When the water temperatures exceeded a maximum of 29° C, the 1st instars again ceased to exist.

C. tarsalis exhibited a greater tolerance, at least for the high temperatures. First instars were still present when the maximum water temperature reached 37° C, albeit at a very low general equilibrium position. When the two species existed together their total population density was higher than when either species was present by itself. It was also noted that the females of *C. tarsalis* always oviposited first in freshly flooded ponds.

Culex tarsalis Coquillett and *Culiseta inornata* (Williston) are two ubiquitous species of mosquitoes throughout the Sonoran Desert of Imperial and Riverside Counties in California (Chew and Gunstream, 1970). During the spring floods and rice field flooding, *C. tarsalis* becomes abundant throughout much of California up to the 9,000 foot level.

In light traps set in the Coachella Valley, Riverside Co. adults of *C. tarsalis* exhibited a bimodal density pattern with 1 peak in the fall and 1 in the spring, while *C. inornata* was most numerous during the winter and early spring, dropping off drastically from March onward (Chew and Gunstream, 1970). In Utah research has shown that the mean temperature of pools containing only *C. inornata* larvae is cooler than pools containing only *C. tarsalis*. Also it was noted that as temperatures increased, larval populations of *C. tarsalis* increased while *C. inornata* decreased (Graham and Bradley, 1969).

Does the *C. tarsalis* female oviposit in any available long standing water or is she more attracted to freshly flooded areas? Hagstrum and Gunstream (1971) concluded from their studies that *C. tarsalis* and *C. inornata* have broad tolerances and exhibit little preference for the particular concentrations of ions encountered in southern California. However, Ikeshoji and Mulla (1970) have demonstrated that for some mosquitoes, including *C. tarsalis*, there is a species specific ovipositional attractant that can be extracted from breeding water.

In preparation for a long term study of the population dynamics of pond organisms under regimens of chemical and biological mosquito abatement techniques[3] it

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became necessary to establish the ovipositional response of *C. tarsalis* and *C. inornata* to flooding. Also the response of the two species to temperature was delineated.

MATERIALS AND METHODS

REFLOODING EXPERIMENT. The ponds employed in this research are located near Oasis in the Coachella Valley of southern California, near the northern shore of the Salton Sea in the Sonoran Desert. They were described by Mulla *et al.*, 1969. They were filled from an artesian well supplying alkaline water which in combination with the fine, porous sand substrate and float valve system, yielded ponds with stable water chemistry and breeding conditions for mosquitoes (Mulla, unpublished data). The ponds were 6.0 M^2, with float valves. Each pond contained about 11,300 liters of water. The sides of the ponds were covered by nutgrass and the bottom was only sparsely covered with plant material. Emergent vegetation at the shore line was used as a sampling site. Samples were taken with the standard one pint dipper welded to a golf shank and handle.

In this experiment 5 samples were taken per pond each week. One sample was taken near each corner, plus 1 from the side with the emergent vegetation. Only 8 ponds were employed in data gathering since the remaining ponds were used as a border to permit thorough drying of the ponds to be flooded. Water removal from the samples was accomplished by using 125 mesh stainless steel strainers (Mulla *et al.*, 1969) and the concentrated samples were preserved by adding 95% ethyl alcohol.

The Wilcoxon rank sum test was used for statistical analysis.

RELATIONSHIP OF TEMPERATURE TO FIRST INSTARS. Prior to flooding, which initiated each of these experiments, the ponds were thoroughly prepared by removing all vegetation. The vegetation had varied in quantity from pond to pond. The bottoms and sides were lightly plowed, sundried and raked and dried again.

The standard one pint dipper was employed for sampling. For these experiments a high degree of standardization was achieved as all sampling was carried out by one individual, the senior author, who without exception always employed the same techniques for taking the samples. The sampling was always conducted from 1000 to 1100 hours following the same pattern of approach. The statistical results from 3 years of pond research indicate a high degree of replicability.[3]

The dipping technique was further improved by the use of a biased sampling site. This consisted of a large handful of clean bedding straw bound in the middle by soft wire. An arched wire "tail" of 35 cm was then inserted into the pond bank in each of the four corners. The resultant straw bouquet was very stable, easy to sample and remained intact for the duration of an experiment. The 4 samples were concentrated by the use of an efficient aquatic sample concentrator,[3] and sampling was conducted on a thrice-weekly basis.

Water temperature was measured continuously during these experiments by a Tempscribe® remote-reading thermograph with its probe placed at the bottom of one pond. In another pond a Lambrecht® three pen distance thermograph was used to measure air, surface and bottom temperatures. A Taylor® maximum-minimum submerged thermometer was also used as a check.

The experiments were conducted in November 1969 through February 1970 (winter), January to April 1971 (spring) and end of May 1970 (spring to summer). By May the water temperatures in the Sonoran Desert of California are reaching 35° C and so May is regarded as "summer."

RESULTS

REFLOODING EXPERIMENT. The *C. inornata* larval population (Fig. 1) did not re-establish itself in the ponds after reflooding because their larval populations were on the decline already. The *C. tarsalis* population gained a high density after the

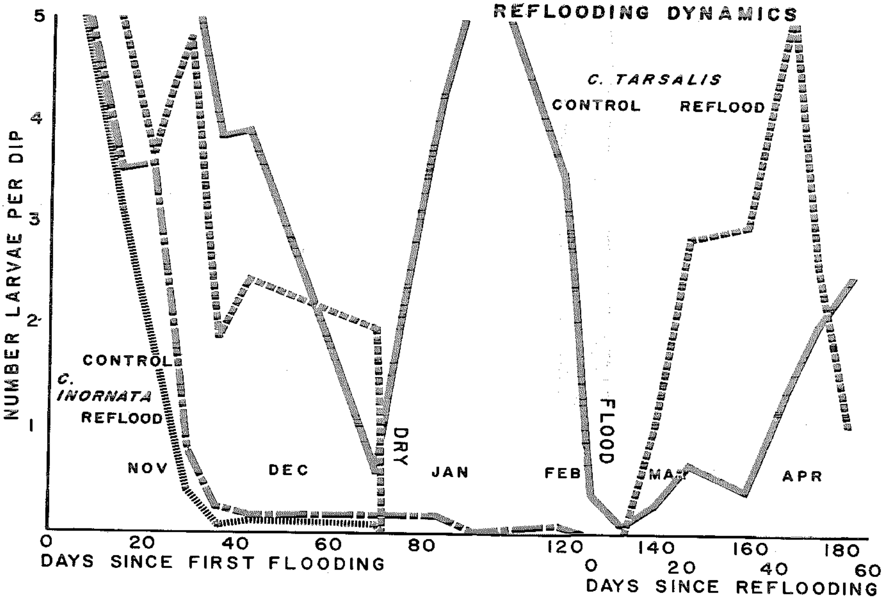

FIG. 1.—Population trends of the larvae of *C. inornata* and *C. tarsalis* in a flooding, drying, and reflooding experiment. (1968–1969). Control indicates continuous prolonged flooding.

first initial flooding followed by a decline. The control ponds exhibited a resurgence in January only to decline again in February. Then the control ponds exhibited an increase for a third cycle proceeding into May when *C. tarsalis* activity decreased greatly in response to the extremely high temperatures of the Sonoran Desert. The cycles were not in phase with the cycles exhibited by the reflooded ponds. The reflooded ponds experienced a peak of *C. tarsalis* during the low period for the controls.

Statistically there was no significant difference in larval population means between control ponds and ponds selected for reflooding prior to the drying. On February 27 the dried ponds were reflooded and within 15 days the combined first and second instar density was significantly higher than the controls. By 22 days the combined 3rd and 4th instars were also significantly more numerous in the reflooded ponds. This condition continued throughout the 43 days after reflooding.

After 50 days of reflooding, there was no significant difference between the 2 sets of ponds. However, by day 57 the combined 3rd and 4th instars of the reflooded ponds had dropped in density to such a degree that they were below the controls (P=0.05).

RELATIONSHIP OF TEMPERATURE TO FIRST INSTARS. In the winter experiment (Fig. 2) *C. inornata* first instars did not appear until 2 weeks after flooding. The 1st instar population increased slowly until it peaked at 24 days after flooding. The water temperatures were averaging 17° C maximum and 10° C minimum. The population decreased and remained at a general equilibrium position (GEP) until it dropped out. During that period the temperatures had dropped to 7° C maxi-

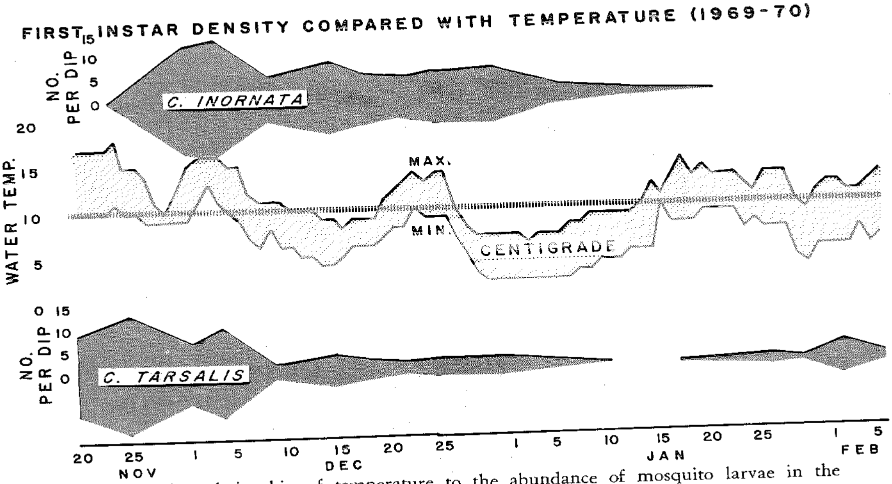

Fig. 2.—The relationship of temperature to the abundance of mosquito larvae in the 1969–1970 experiment.

mum and 3° C minimum. During this experiment *C. tarsalis* 1st instars appeared 10 days after flooding. Then the numbers dropped to a GEP and stayed there for about 1 month before declining to zero at the end of the cool spell. While only a few *C. inornata* appeared in February, when the temperatures again increased, the *C. tarsalis* population regained its former GEP as water temperatures increased.

In the spring to summer experiment (Fig. 4), *C. inornata* did not appear even though the temperatures were about 20° C maximum and 10° C minimum. The temperatures were high enough during this experiment that 3rd instars of *C. tarsalis* appeared 8 days after flooding. By 11 days after flooding the peak had been reached and a lower GEP was maintained until a sandstorm of several days duration reduced oviposition to a very low level. The population again increased and cycled until the maximum temperatures (over 35° C) of late May reduced it to a low level.

DISCUSSION AND CONCLUSIONS

Biased Sampling Sites. The employment of the straw bouquet biased sampling site resulted in lower variability between pond samples, but did not change species composition. Wada (1965) in his comprehensive study of *C. inornata* in a pond in Canada concluded that "an aggregated type of distribution was indicated." This appeared to be the situation at the Coachella Valley ponds before "shelter" was added. The biased sampling site became the focal point for the aggregations and facilitated sampling by the dipper technique. The straw may also have served as an ovipositional attractant. Murphey and Burbutis (1967) demonstrated that straw infusion had a pronounced attractiveness for gravid *Culex salinarius* Coquillett females. They concluded that it was due to chemical factors of a protein nature rather than shelter effect.

Reflooding Experiment. The failure of *C. inornata* (Fig. 1) to repopulate the reflooded ponds is probably related to an absence of ovipositing females in that area by March (Chew and Gunstream, 1970). The absence of hosts for blood feeding would not have been a limiting factor

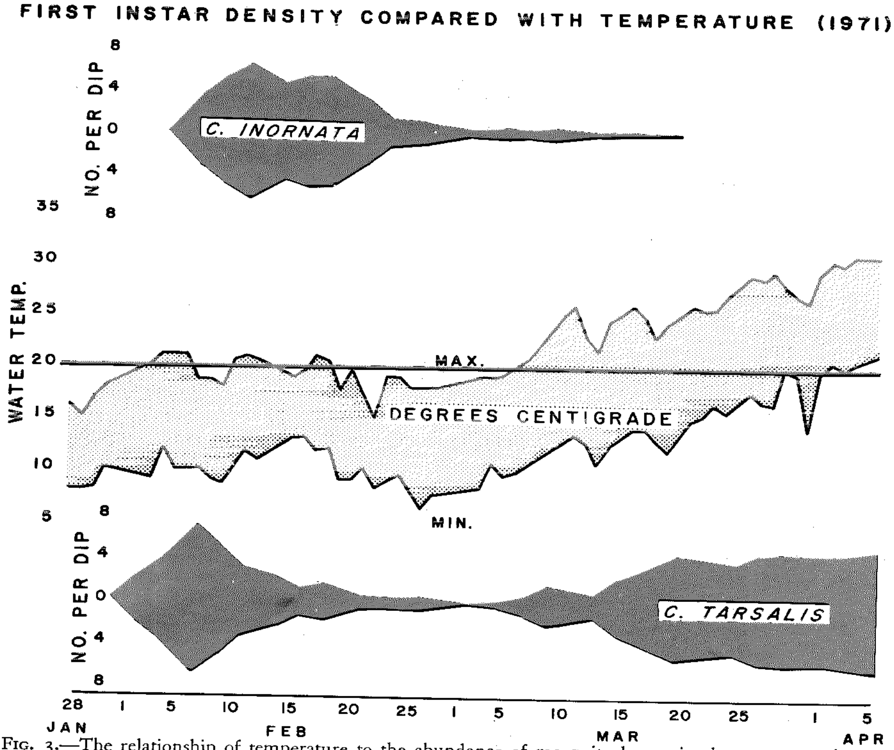

Fig. 3.—The relationship of temperature to the abundance of mosquito larvae in the 1971 experiment.

since the preferred hosts of *C. inornata* are mammals (Anderson *et al.*, 1967, Tempelis and Washino, 1967) and horses, dogs, cats, rabbits, and humans were continually present. Nielsen and Rees (1961) reported that *C. inornata* preferred permanent or semi-permanent, brackish or polluted water and Hagstrum and Gunstream (1971) concluded that *C. inornata* had a broad tolerance for the concentrations of ions encountered in southern California. Since these were the conditions and locale of the Coachella Valley ponds it would then appear that high temperature was the limiting factor mitigating against a resurgence of *C. inornata* after reflooding.

C. tarsalis typically demonstrates a cyclic pattern for its larval population at the Coachella Valley ponds. Several density dependent factors contributed to this pattern,[3] but will not be covered in this paper. The most notable result of the reflooding experiment was that reflooded ponds were significantly more attractive to ovipositing females of *C. tarsalis* than were the controls. Both had approximately the same stable water chemistry based on pH readings and the continuous flow of artesian water into all ponds. It has been suggested that the decomposition products of organic materials in waterlogged soil serve as attractants for *C. tarsalis* females (Ger-

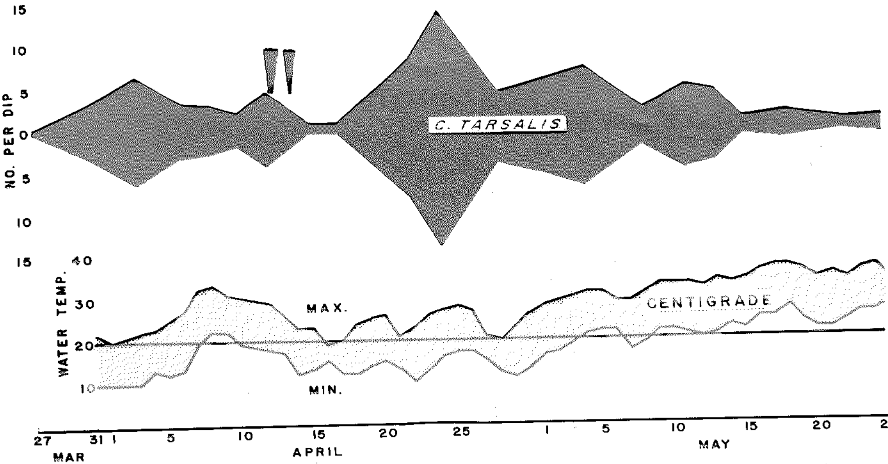

FIG. 4.—The relationship of temperature to the abundance of mosquito larvae in the 1970 experiment. Arrows mark a period of wind storms.

hardt, 1959). It is believed that these attractants are volatile and ether-extractable (Ikeshoji and Mulla 1970).

RELATIONSHIP OF TEMPERATURE TO FIRST INSTARS. As far north as Manitoba, Canada, *C. inornata* overwinters as an adult and becomes active as early as 15 April. However, only 10% of the eggs will hatch at 5° C while 90% will hatch at 10° C (Hanec and Brust, 1967). Brust (1967) gave 6° C as the lethal low temperature. In Figures 2 and 3 it appears that this low temperature was the limiting factor for *C. inornata*. In Figure 3 it should be noted that the cold snap was followed by rapidly rising temperatures which soon exceeded the lethal high temperature of 29° C (Brust, 1967).

Females of *C. tarsalis* appeared to be more sensitive to low temperatures than *C. inornata*, but continued ovipositing during the higher temperatures. A few *C. tarsalis* first instars were still present at the maximum temperature of 37° C with a mean of 32° C. This comparison with *C. inornata* behavior correlates with the findings of Graham and Bradley (1969) in Utah that the average water temperature for ponds containing *C. inornata* alone was lower than ponds containing *C. tarsalis*. It can also be concluded that *C. inornata* and *C. tarsalis*, when occurring together, form a larval population that has a higher density than when either population occurs alone. This was also the finding of Graham and Bradley (1962, 1969) who concluded that they occupy different "niches" (microhabitats?) in the general larval habitat and that competition is reduced. However, it may be that the optimum developmental temperatures for both species overlap enough that high densities for both species would be present at the same time even if they are competitive. Only at the extremes of tolerable temperatures would either species occur by itself, and at a lower GEP. Since *C. tarsalis* always oviposited earlier than *C. inornata* (2 days depending upon seasonal temperatures), then initially competition would also be reduced by this difference in the ovipositional response.

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CONTROL OF *AEDES TAENIORHYNCHUS* WIED. ON GRAND CAYMAN, WITH ULV BIORESMETHRIN

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ABSTRACT. Three hundred fifty hectares of mangrove swamp which allow extensive breeding of *Aedes taeniorhynchus* Wied., were treated by ground ULV drift spraying from a converted TIFA (Model 1503) machine. Rates of 3 g., and 1.5 g., of 5-benzyl-3-furylmethyl (+) *trans* chrysanthemate (bioresmethrin) were applied per hectare.

CDC light traps were used to determine levels of reduction. 3 g/ha and 1.5 g/ha gave 88%–92% reduction in numbers of adult mosquitoes when 50 ml/ha of solution were used.

Introduction. Ultra low volume (ULV) dispersion of malathion aerosols to control adult mosquitoes has been established for some years. Resistance to organophosphate and chlorinated insecticides and fear of environmental contamination have naturally encouraged a search for safer yet more effective materials, especially those which can be applied by ULV.

Recently at the Rothamsted Experimental Station in the United Kingdom, numbers of pyrethroids have been synthesised. Of these, the most active at present commercially available is 5-benzyl-3-furylmethyl (+) *trans* chrysanthemate (bioresmethrin. NRDC 107), first described by Elliott *et al.* (1967). Hadaway *et al.* (1970) showed this compound to have the greatest activity of several synthetic pyrethroids against *Anopheles stephensi* Liston. and *Aedes aegypti* L. using a topical application technique. Brooke and Evans (1971) showed it to be approximately 8 times as

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