MODE OF ACTION OF FACTORS RESPONSIBLE FOR INCREASES IN *CULEX TARSALIS* COQ. POPULATIONS IN UTAH

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Introduction. This study, as the literature cited indicates, is part of a continuing study of mosquito populations in Salt Lake County, Utah.

Populations of mosquitoes in Salt Lake County, Utah have been observed to fluctuate greatly from year to year. Some, but not all of these fluctuations have been reported in the literature (Graham 1959, Graham and Rees 1961, Collett and Rees 1969, Graham and Collett 1964 and 1969). Population changes in *Culex tarsalis* Coq. are particularly important since this is the vector of western equine encephalitis and numerous studies have shown a relationship between numbers of this species and transmission of the disease to man and horses (Rees *et al.*, 1959, Loomis 1953, Hess and Hayes 1967, and Reeves 1968).

In 1958, northern Utah experienced a great increase in *C. tarsalis* and a subsequent outbreak of WEE. A number of papers were published linking certain weather factors to the outbreak. All agreed that the large amount of water available for irrigation as snowpack in the mountains was one factor. This is in agreement with studies in other areas (Loomis 1959, Hess and Hayes *op. cit.*). In addition, Graham and Anderson (1958) and Rees and Collett (1959) felt that high temperatures were also a factor. In 1969 Graham *et al.*, reported that the limited data available indicated that for Utah the factors causing increases in *C. tarsalis* and transmission of WEE were above-normal precipitation early in the year, followed by a hot and dry period for most of June, July and early August. Gebhardt *et al.*, (1964) attempted to correlate weather factors with *C. tarsalis* populations as measured by light trap catches of the Salt Lake City Mosquito Abatement District, and found the only factor with a positive correlation was the amount of sunshine. This is in agreement with results obtained by Graham *et al.*, (*op. cit.* 1960), since a relationship does exist between hot, dry periods and the amount of sunshine.

Surveillance for WEE programs in Utah since 1958 has confirmed the relationship of these factors to population changes of *C. tarsalis* (Graham and Collett 1964 *op. cit.*, 1969 *op. cit.*). This paper reports studies that explain how these factors influence populations of *C. tarsalis* in Utah.

Materials and Methods. Estimates of the relative abundance of mosquitoes can be obtained from both larval and adult populations and measurements of both types are attempted in Utah. New Jersey light traps and outdoor biting counts are used to determine adult population densities and both methods give valuable information. The most intensive work of this nature in Utah is done by mosquito abatement districts in Salt Lake County but the mosquito habitat is varied and populations differ greatly in different areas of the County. This makes estimates of total populations, even on a relative basis, difficult because the selection of collection sites is crucial and the sample is always inadequate for county-wide determinations. The Salt Lake City Mosquito Abatement District has maintained light traps in the same sites for many years and has obtained data of value for comparative purposes from year to year. Problems of measuring adult populations in other areas of Salt Lake County are more complex and efforts to obtain better sampling have necessitated changes in trap location with the result that data obtained are less valuable for comparative purposes. For these reasons, data from light trap and biting col-

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lections are not reported here, but we have referred to them to support other data, and have found them essentially in agreement.

In 1956, the South Salt Lake County Mosquito Abatement District began larval survey procedures in which every pool found producing larvae was sampled and data collected.

Larval data collection is done primarily by graduate students in entomology, or students under direct supervision of an entomologist. All inspectors are given special training to collect data, and are given some instruction in the statistical implications of the data they collect. Fig. 1 shows the form each inspector takes into the field with him, on which data are recorded. Ecological data include vegetation, water source, etc., but are not considered in this paper. The "average-number-of-larvae-per-dip" requires at least 10 dips after the first larva is found. The number per dip is coded into categories as follows, for punch cards and computer analysis:

1, 0–2 per dip; 2, 3–4 per dip; 3, 5–7 per dip; 4, 8–12 per dip; 5, 13–17 per dip; 6, 18–22 per dip; 7, 23 and over per dip.

These categories were selected because they seem to reflect more accurately the estimates of larval density made by inspectors in the field. High density sources are not common. They usually result when sources lose water by evaporation and seepage, and decrease in volume. A sample of larvae from each pool is taken with efforts to get a representative sample, and the larvae are later identified in the laboratory by a technician.

The data obtained from this program were valuable from its inception. However, the techniques and procedures required several years of modifications resulting from experience to develop the present level of accuracy and precision of the larval survey program. It has become the most accurate and precise method now in use in Utah for measuring relative mosquito populations.

The data collected are tabulated, coded, placed on punch cards and then processed by the Univac 1108 at the University of Utah or the IBM 7040 at Brigham Young University utilizing a special program developed for this project.

DATE ______________

AREA 5

Insp.	W or D	Code#	Address	Ecological Data A	B	C	#/Dip	Inst.	Area	Flow	Temp.	Depth	Shade	Time	Treatment TPG	Spray
		5-1	7810 S 825 W													
		5-2	7900 S 825 W													
		5-3	7825 S 950 W													
		5-4	7875 S 940 W													
		5-5	7875 S 970 W													
		5-6	7810 S 1000 W													
		5-7	7950 S 875 W													
		5-8	8050 S 900 W													

FIG. 1.—Form for field data.

Fig. 2 is an example of the pages coming from the computer. The collection and analysis of the data are under the constant supervision of a statistician.

Variables such as number per dip and water temperature have a wide dispersion for any given species and/or any given time period. A stratification by species and half month has typically yielded sufficiently large stratum sizes such that stratum means reflect valid seasonal-species patterns and differences. For example, the mean temperature of *C. tarsalis* pools is higher than the mean temperature of

TABLE 25 CODED COMB. VS. NUM. PER DIP

CODED COMB	NUM. PER DIP							
	1	2	3	4	5	6	7	TOTAL
COMBNTION 1	343	78	68	61	5	14	34	603
COMBNTION 2	458	117	76	37	9	2	8	707
COMBNTION 3	565	128	86	62	8	12	21	882
COMBNTION 4	190	36	32	25	3	55	9	300
COMBNTION 5	186	28	33	24	4	10	23	308
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

FIG. 2.—Example of page from computer.

Culiseta inornata (Williston) pools. This difference is seasonally consistent for every year and, almost without exception, it is statistically significant at the 0.01 level for each half month period.

The data for this study have been collected over a period of 13 years. During this time more than 48,000 pools have been sampled. The cost of collecting this amount of data would be prohibitive if it were not incorporated as a routine part of the inspection procedures of a larviciding program. Obviously all the possible combinations of data and relationships evident over this period of time cannot be presented here and some judgment selection of data to be presented is necessary. We have for the most part selected recent data to illustrate the points made. All data collected so far support the points in the paper but we are considering here only a few environmental factors of the many operating in larval habitats; some fluctuations occasionally occur which cannot be explained on the basis of factors considered here.

The number of pools with larvae as determined by the larval survey is used as an index of mosquito abundance both for individual species and for the total. We are quite aware that other factors influence mosquito abundance, for example, the size of the source, and the density of mosquitoes in it. This index should not be regarded as precise because of these other factors but it is a close and very useful approximation. Such an index may not be practical for other areas because of the nature of the mosquito sources.

RESULTS. Graham and Bradley (1962) found that when larvae of any particular mosquito species were able to occupy a larval source without other mosquito larvae being present they were more abundant than when they had to share a habitat. In their paper several graphs were presented to show this relationship. All subsequent data confirm this observation and numbers per dip of *Aedes dorsalis* (Meigen) alone, *C. tarsalis* alone, and mixtures of the two for 1964 are presented here (Fig. 3) to demonstrate this relationship. A large number of graphs could be presented to show this relationship which always holds true in our data. The average number per dip for all pools when two species are found together is always less than the sum of the average number per dip when they are found alone but this relationship is not always as dramatic as shown in Fig. 3. Whether this is the result of competition between larvae or because the habitats which support two species are not ideally suited to either has not been determined. Obviously it is advantageous for a species, if its population is to increase, for it to be able to occupy a larval habitat by itself.

The result of this relationship is shown most clearly by comparing the total number of *C. tarsalis* in 1958, the year of the latest outbreak of WEE in Utah, with other years and the number of *C. tarsalis* alone sources for 1958 and other years (Fig. 4 and 5). This crucial relationship is one important factor in western equine encephalitis surveillance in Utah (Graham and Collett 1964 *op. cit.*, 1969 *op. cit.*).

At this point we have shown that above normal precipitation early in the year followed by a hot dry period apparently are the weather factors responsible for *C. tarsalis* increases in Utah. We have also demonstrated the value to a species of occupying a larval habitat by itself and that *C. tarsalis* increases when larvae occupy more larval sources by itself than usual. The remaining question is the mode of action of these factors.

Mosquito production in Utah is primarily the result of man's activities. Irrigation practices create most mosquito sources. These sources result from seepage from canals and ditches, from excess irrigation and from accumulations of irrigation waste water. Early in the year, March, April, and May and sometimes the first part of June, precipitation either as rain or as runoff from snow melt in the mountains causes considerable mosquito production. After the runoff period in late May or early June, virtually all mosquito production is manmade until late August when small rain showers occur. On some occasions summer thunder storms result in significant mosquito production.

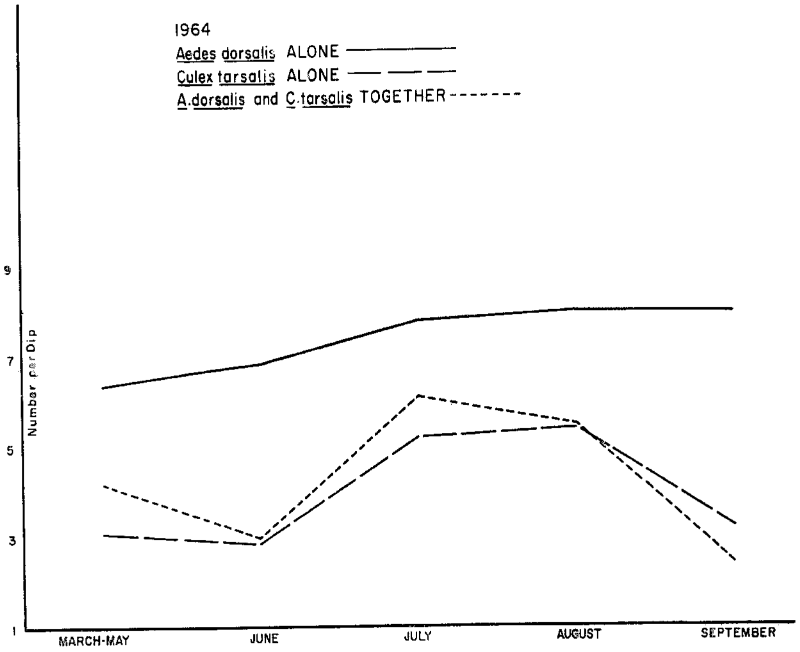

FIG. 3.—Number of larvae per dip for *A dorsalis* alone, *C. tarsalis* alone and mixtures of the two for 1964.

but this is rare. For example, average rainfall in July is less than ½ inch at the Salt Lake City Airport, and even this low average results from heavy storms which occur generally several years apart.

The seasonal pattern of *C. tarsalis* larval abundance as measured by the number of positive inspections is shown in Figs. 4 and 5. Obviously *C. tarsalis* abundance is related to irrigation since its peak occurs when almost all production is manmade. Figs. 6 and 7 show the seasonal pattern of relative importance of *A. dorsalis* and *C. tarsalis,* two of the most abundant mosquitoes in Utah.

During years with an abundant water supply, irrigators tend to use more water, canals are fuller, seep more and the water table is higher. The higher water table is most obvious in some marginal agricultural land with a normally high water table. These factors result in more stabilized water levels in most mosquito sources. In a dry year water levels in the sources fluctuate more and produce conditions more favorable to *Aedes* mosquitoes, particularly *A. dorsalis.* Heavy rain storms also cause water levels to fluctuate and favor *A. dorsalis,* generally to the detriment of *C. tarsalis.* The hatching of *A. dorsalis* eggs in *C. tarsalis* sources introduces another species into the environment which, as shown above, results in lower numbers of each species than in situations where the species are alone. A steady water state is conducive to *C. tarsalis* and *C. inornata* production but is detrimental to *A. dorsalis.* Water scarcity reduces numbers of all species and water abundance increases production of mosquitoes generally but not necessarily of all species. The pattern of water availability is as important as the amount to the various species.

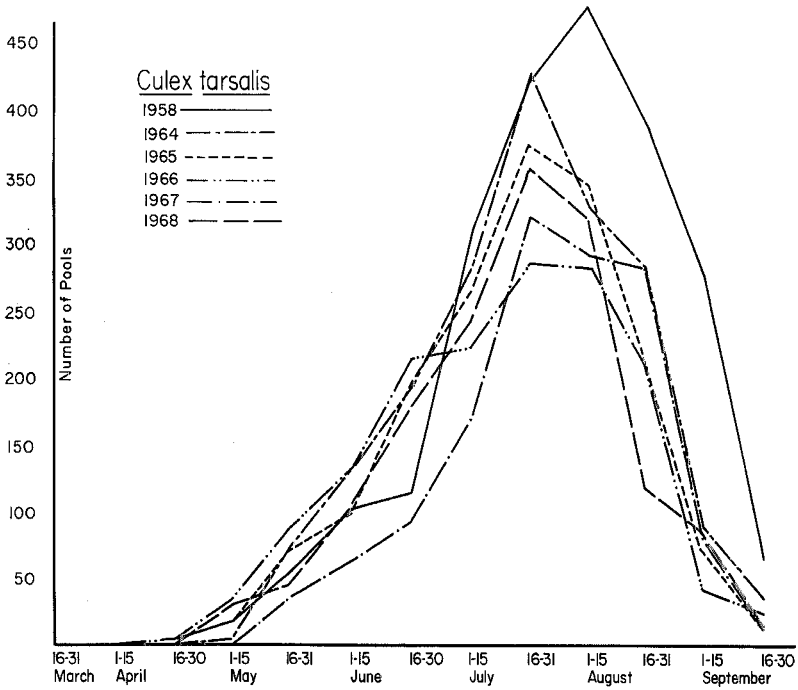

FIG. 4.—Total *C. tarsalis* sites for 1958 and 1964–1968.

The data for 1958 when large numbers of *C. tarsalis* were evident show that *C. tarsalis* was found alone more often than usual (Fig. 5). As mentioned above, Gebhardt *et al.* (*op. cit.*) correlated sunshine with *C. tarsalis* populations and Graham and others *(op. cit.)* indicated a hot dry period was necessary. Since a steady water level does not in itself favor either *C. tarsalis* or *C. inornata* but apparently favors both of them equally some other factor apparently operates to favor one or the other and the indication is that this factor is temperature.

C. inornata, both as larvae and adults, is abundant in Utah throughout the summer, but in many parts of the United States disappears during hot months and the pattern of geographic distribution indicates that high temperatures are detrimental. Graham and Bradley (1965) demonstrated that *C. inornata* larvae in Utah were found in cooler water than *C. tarsalis* larvae and concluded that water temperature was a crucial factor in determining production of these two species. Data collected since that publication confirm these results and Fig. 8 demonstrates temperature differences for water with *C. tarsalis, C. inornata,* and the two species when found together.

C. tarsalis apparently originated in the tropics while the genus *Culiseta* has apparently always been temperate or arctic in its distribution (Ross 1964). This perhaps accounts for the preference of *C. tarsalis* to inhabit warmer water in the larval stage than *C. inornata.*

Rosay (personal communication) has found in the laboratory that *C. tarsalis,* hatched and reared under constant temperature, complete larval development faster at higher temperatures. In her experiments, she used temperatures of 19° C. and 24° C. The mean time required for *C. tarsalis* to complete larval development was 22.9 days and 10.5 days respectively. The population growth curve of *C. tarsalis*

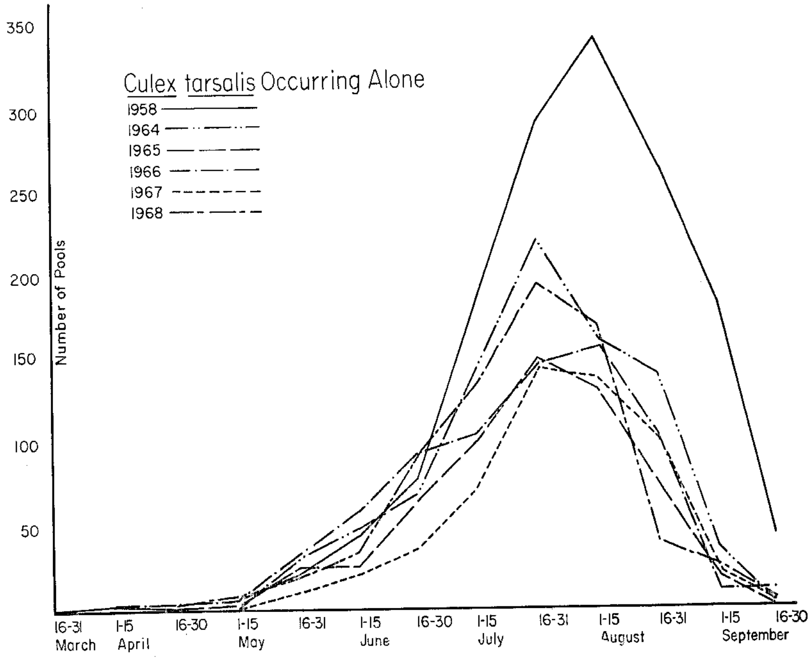

FIG. 5.—*C. tarsalis* sites alone for 1958 and 1964–1968.

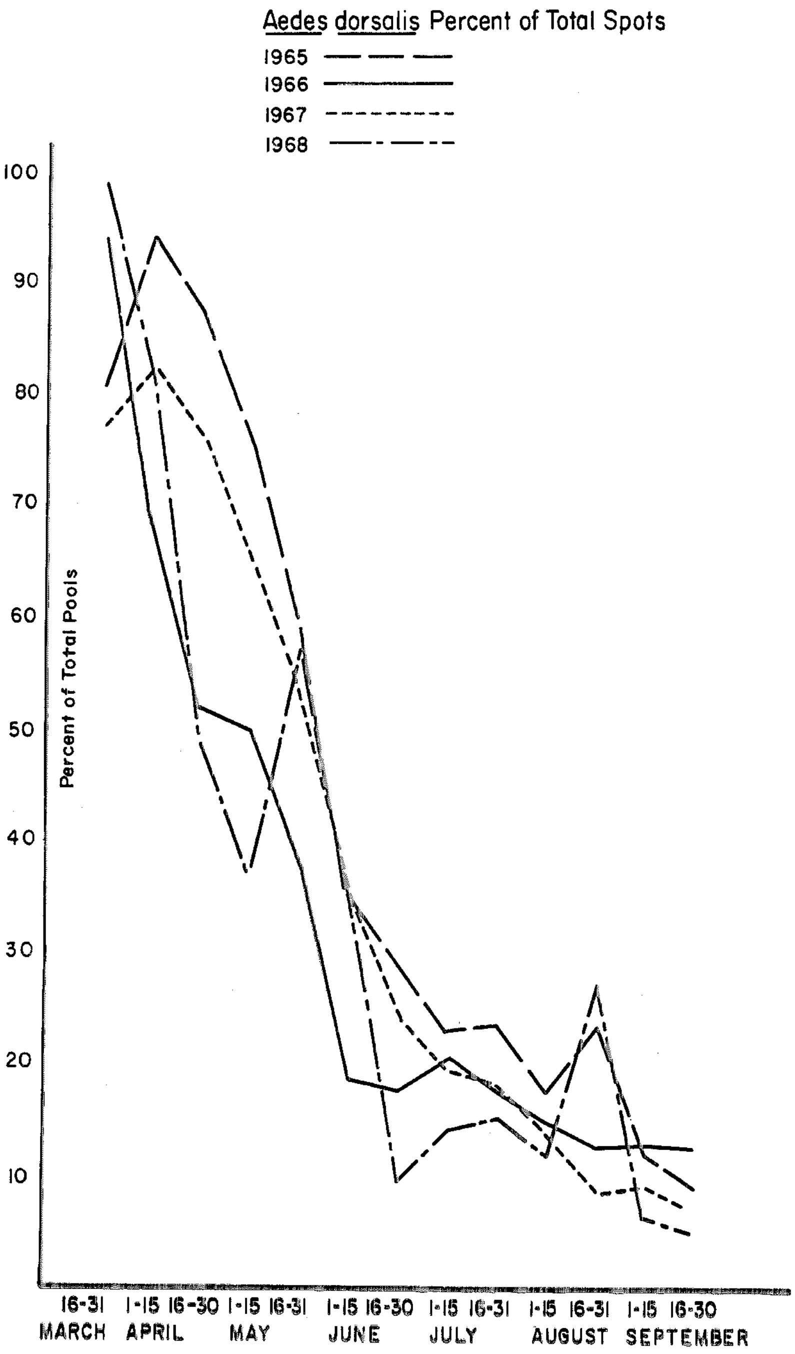

FIG. 6.—Seasonal pattern of relative importance of *A. dorsalis*.

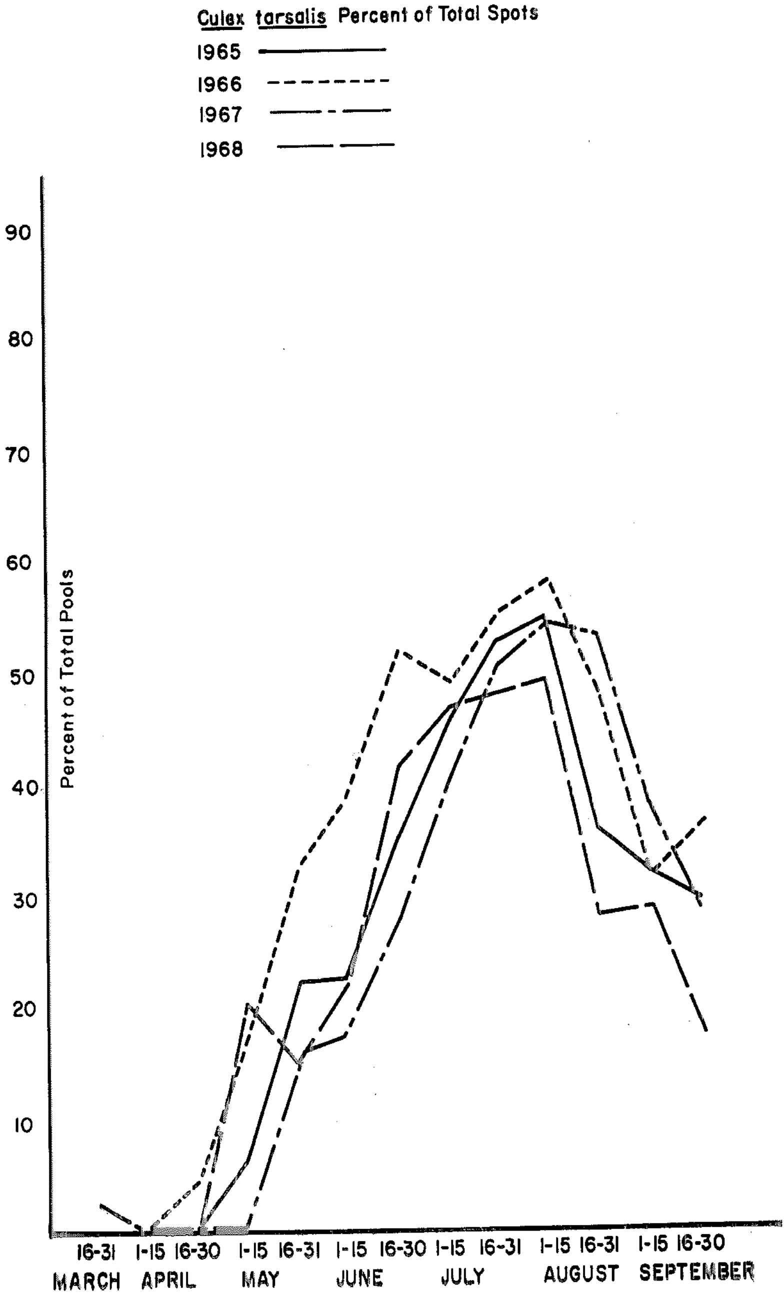

Fig. 7.—Seasonal pattern of relative importance of *C. tarsalis*.

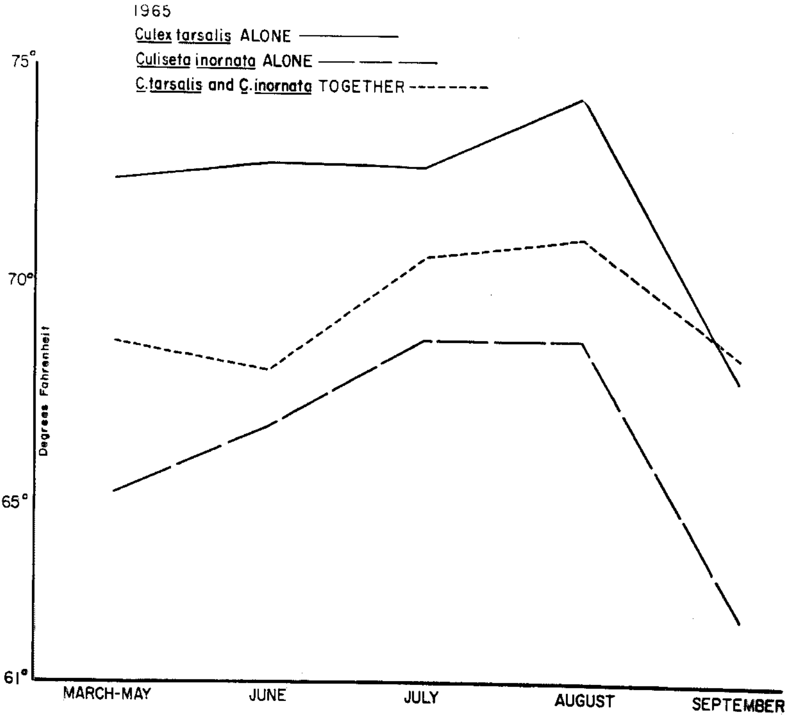

FIG. 8.—Temperature differences of water with *C. tarsalis, C. inornata,* and the two species when found together, for the year 1965.

in Utah shows a geometric increase as the season progresses (Figs. 4 and 5). A few degrees difference in water temperature which would occur with unusual amounts of sunshine would shorten the period of larval development and result in more generations per season. Such a result would have a great effect on the population peak because of the geometric nature of population growth. Conversely any factor which delays or interrupts the population progression would greatly reduce the population peak.

SUMMARY AND CONCLUSIONS. Studies of mosquito larval populations in Salt Lake County, Utah from 1956 through 1968 indicate that changes in *C. tarsalis* populations are the result of the interaction of man's water management, patterns of precipitation, temperature, and relationships between common species of mosquitoes in the area. Years having large amounts of available irrigation water and a hot dry period through late spring and early summer produce large numbers of *C. tarsalis.* The opposite conditions produce low numbers of this species. Most years are between the extremes. Large amounts of irrigation water in Salt Lake County, Utah produce a steady water state in mosquito sources favorable to *Culex* and *Culiseta* species. High temperatures increase *C. tarsalis* populations and lower *C. inornata* populations. *A. dorsalis* is favored by fluctuating water levels.

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IMPORTANT NOTICE

Beginning with Volume 30, No. 1, the price of reprints will be increased by 6 percent to correspond with the rise in costs of paper, handling, printing and mailing. The last increase in reprint prices was effective with the March, 1966 issue. Since that time both dues and subscription have been increased, but the additional cost of processing the reprints has not been met.

A revised "Prices of *Mosquito News* Reprints" will be published on the inside back cover of the March 1970 *Mosquito News*.