

INFORMATION TO USERS

This material was produced from a microfilm copy of the original document. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the original submitted.

The following explanation of techniques is provided to help you understand markings or patterns which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting thru an image and duplicating adjacent pages to insure you complete continuity.
2. When an image on the film is obliterated with a large round black mark, it is an indication that the photographer suspected that the copy may have moved during exposure and thus cause a blurred image. You will find a good image of the page in the adjacent frame.
3. When a map, drawing or chart, etc., was part of the material being photographed the photographer followed a definite method in "sectioning" the material. It is customary to begin photoing at the upper left hand corner of a large sheet and to continue photoing from left to right in equal sections with a small overlap. If necessary, sectioning is continued again — beginning below the first row and continuing on until complete.
4. The majority of users indicate that the textual content is of greatest value, however, a somewhat higher quality reproduction could be made from "photographs" if essential to the understanding of the dissertation. Silver prints of "photographs" may be ordered at additional charge by writing the Order Department, giving the catalog number, title, author and specific pages you wish reproduced.
5. PLEASE NOTE: Some pages may have indistinct print. Filmed as received.

Xerox University Microfilms

300 North Zeeb Road
Ann Arbor, Michigan 48106

74-23,365

McDONALD, John LeRoy, 1937-
BIONOMICS OF MOSQUITOES IN SEMI-ARID
URBAN AREAS.

The University of Arizona, Ph.D., 1974
Entomology

University Microfilms, A XEROX Company, Ann Arbor, Michigan

**BIONOMICS OF MOSQUITOES IN
SEMI-ARID URBAN AREAS**

by

John LeRoy McDonald

**A Dissertation Submitted to the Faculty of the
DEPARTMENT OF ENTOMOLOGY
In Partial Fulfillment of the Requirements
For the Degree of
DOCTOR OF PHILOSOPHY
In the Graduate College
THE UNIVERSITY OF ARIZONA**

1 9 7 4

THE UNIVERSITY OF ARIZONA

GRADUATE COLLEGE

I hereby recommend that this dissertation prepared under my
direction by John LeRoy McDonald

entitled BIONOMICS OF MOSQUITOES IN SEMI-ARID URBAN AREAS

be accepted as fulfilling the dissertation requirement of the
degree of Doctor of Philosophy

[Signature] Dissertation Director Date MAY 16, 1974

After inspection of the final copy of the dissertation, the
following members of the Final Examination Committee concur in
its approval and recommend its acceptance:*

<u>[Signature]</u>	<u>May 16, 1974</u>
<u>William D. Muttig</u>	<u>May 16, 1974</u>
<u>L. W. Dewhurst</u>	<u>May 16, 1974</u>
<u>R. E. Reed</u>	<u>May 16, 1974</u>
<u>[Signature]</u>	<u>May 16, 1974</u>

*This approval and acceptance is contingent on the candidate's
adequate performance and defense of this dissertation at the
final oral examination. The inclusion of this sheet bound into
the library copy of the dissertation is evidence of satisfactory
performance at the final examination.

STATEMENT BY AUTHOR

This dissertation has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this dissertation are allowable without special permission, provided that acknowledgment of the source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his judgment the proposed use of the material is in the interest of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: _____

John L. McDonald

ACKNOWLEDGMENTS

I am most grateful to the United States Navy for providing me the support and opportunity to return to graduate training here at The University of Arizona. Thanks are also extended to the Office of Naval Research for providing the financial resources to conduct this study.

It was my privilege to work with Dr. G. S. Olton during this investigation and throughout most of my graduate studies. His ability to guide and direct without dictating has been especially appreciated.

The cooperation of the Pima County Health Department was invaluable. Without their help the study would not have been possible. Along these lines, I would particularly like to thank Mr. Jack Hensley for his tireless support and constructive criticisms and suggestions.

I am especially grateful to: Dr. L. W. Dewhirst whose unflagging confidence in me has been nothing short of an inspiration; Dr. W. L. Nutting who devoted so much time and effort in helping to review my dissertation; Dr. G. W. Ware who was instrumental in making the completion of my graduate studies possible within such a limited allotted time; and the entire Military Entomology Information Service (MEIS) who worked so hard to obtain and provide so many reprints, some of which would have been otherwise unobtainable.

BIOGRAPHICAL

John L. McDonald was born in Albany, New York, on 22 March, 1937. He attended public schools in Delmar, New York, and was graduated from Bethlehem Central High School, Delmar, New York, in 1954.

On March 31, 1955, he entered the U.S. Marine Corps as a private and was honorably discharged four years later at the rank of sergeant.

He obtained his undergraduate education at Cornell University, Ithaca, New York, where in 1963 he was awarded the Bachelor of Science degree in Agriculture with a major in economics.

From 1963 to 1964, he was a Teaching Assistant at Cornell and was awarded the degree of Master of Science in 1964. From 1964 to 1965, he was a graduate student at The University of Arizona until he reentered the armed service in 1965. This time he joined the Navy as a medical entomologist and has served in that capacity to the present. Duties as a Navy Entomologist have included service in the United States but particularly in the Far East.

In 1972 he was assigned to duty as a graduate student again at The University of Arizona resuming a course of study leading to the degree of Doctor of Philosophy in Entomology with a minor in Veterinary Science.

He is married to the former Joyce Marie Spaford of Binghamton, New York. They have a daughter, Anastasia, and a son, Walter James.

TABLE OF CONTENTS

	Page
LIST OF ILLUSTRATIONS	viii
LIST OF TABLES.	xiii
ABSTRACT.	xiv
INTRODUCTION	1
REVIEW OF LITERATURE	5
OBJECTIVES	7
MATERIALS AND METHODS	8
Study Area.	8
Sampling Technique	9
Mosquito Complaints	9
Light Traps	10
Larval Dip Method	14
Sentinel Barrels	14
Weather	14
Chemicals Used	17
Equipment.	17
Description of Major Test Sites.	18
Sentinel Barrel Locations.	31
Mosquito Suppression Studies	32
RESULTS AND DISCUSSION	33
Nuisance Complaints.	33
Seasonal Incidence of Adult Mosquitoes in Light Traps	33
Larval Breeding Sites and Response to Control Treatments	47
Sentinel Barrel Mosquito Breeding Response to Control Treatments	59
Miscellaneous Experiments	87
<u>Methods and Procedures:</u> Experiment I	88
<u>Discussion:</u> Experiment I	89
<u>Conclusions:</u> Experiment I	90
<u>Methods and Procedures:</u> Experiment II	92
<u>Discussion:</u> Experiment II	93
<u>Conclusions:</u> Experiment II	94

TABLE OF CONTENTS--Continued

	Page
SUMMARY AND SUGGESTIONS	97
LITERATURE CITED.	101

LIST OF ILLUSTRATIONS

Figure	Page
1. New Jersey type mosquito light trap	11
2. Mosquito rearing cages used in the laboratory	15
3. Sentinel water barrels	16
4. Test Site A - a ground pool mosquito breeding site	19
5. Test Site B - sewage lagoon with waters heavily laden with organic matter	20
6. Test Site C - university dairy farm mosquito breeding site looking northeast	21
7. Test Site C - university dairy farm mosquito breeding site looking east	22
8. Test Site D - a wash mosquito breeding site	24
9. Test Site E - a wash mosquito breeding site	25
10. Test Site F - sewage lagoon	26
11. Test Site G - automatically refilled watering barrel for horses	28
12. Test Site H - small watering barrels used for watering horses which were emptied daily	29
13. Test Site I - ornamental fish pond	30
14. Pima County Health Department mosquito complaints for 1971 versus temperature and rainfall of that year	34
15. Pima County Health Department mosquito complaints for 1972 versus temperature and rainfall of that year	35
16. Pima County Health Department mosquito complaints for 1973 versus temperature and rainfall of that year	36

LIST OF ILLUSTRATIONS--Continued

Figure	Page
17. Profile of all mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.	37
18. Profile of all <u>Anopheles</u> mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.	39
19. Profile of all <u>Aedes vexans</u> mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.	40
20. Profile of all <u>Psorophora confinnis</u> mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.	41
21. Profile of all <u>Culex tarsalis</u> mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.	42
22. Profile of all <u>Culiseta</u> mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.	44
23. Profile of all <u>Psorophora signipennis</u> mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.	45
24. Profile of all <u>Culex pipiens quinquefasciatus</u> mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.	46
25. Number of mosquito larvae in test Site A versus mosquito larval control measures, breeding site water temperature, ambient temperature and rainfall.	49
26. Number of mosquito larvae in oxidation ponds at Site B versus mosquito larval control measures, breeding site water temperature, ambient temperature and rainfall.	51

LIST OF ILLUSTRATIONS--Continued

Figure	Page
27. Number of mosquito larvae in test Site C versus mosquito larval control measures, breeding site water temperature, ambient temperature and rainfall.	53
28. Number of mosquito larvae in test Site D versus mosquito larval control measures, breeding site water temperature, ambient temperature and rainfall.	55
29. Number of mosquito larvae in test Site E versus mosquito larval control measures, breeding site water temperature, ambient temperature and rainfall.	56
30. Number of mosquito larvae in oxidation pond test Site F versus mosquito larval control measures, breeding site water temperature, ambient temperature and rainfall. . . .	58
31. Number of mosquito larvae in the Site G upper ornamental fish pond versus the temperature of the water in the pond and mosquito larval control measures.	60
32. Number of mosquito larvae in the Site G lower ornamental fish pond versus the temperature of the water in the pond and mosquito larval control measures.	60
33. Number of mosquito larvae in the Site C sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.	61
34. Number of mosquito larvae in the Site A sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.	61
35. Number of mosquito larvae in the Site L sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.	64
36. Number of mosquito larvae in the Site M sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.	64
37. Number of mosquito larvae in the Site N sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.	67

LIST OF ILLUSTRATIONS--Continued

Figure	Page
38. Number of mosquito larvae in the Site O sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.	67
39. Number of mosquito larvae in the Site P sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.	68
40. Number of mosquito larvae in the Site Q sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.	68
41. Number of mosquito larvae in the Site R sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.	70
42. Number of mosquito larvae in the Site E sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.	70
43. Number of mosquito larvae in the Site G water barrels versus the temperature of the standing water in the barrels and mosquito larval control measures.	72
44. Number of mosquito larvae in the Site H water barrels versus the temperature of the fresh water added daily. . .	72
45. Sewage lagoon after the edge vegetation was removed. . . .	75
46. Site C - former mosquito breeding site looking northeast.	76
47. Site C - former mosquito breeding site looking east. . . .	77
48. Rainfall collecting site formerly used for agricultural purposes which became a major mosquito breeding site. . .	78
49. Mosquito breeding site completely and permanently eliminated by reopening the natural drainage system.	79
50. A concrete lined irrigation ditch improperly maintained. .	81
51. A concrete lined irrigation ditch properly maintained. . .	81
52. Overwatering of lawn produced a mosquito breeding site. .	82

LIST OF ILLUSTRATIONS--Continued

Figure	Page
53. Mosquito breeding site completely eliminated by proper management of lawn watering program.	82
54. Mosquito breeding site at Site D, after excavation, looking southwest.	83
55. Mosquito breeding site at Site D, after excavation, looking south.	83
56. Mosquito breeding site created by water standing in roadside ditch with vegetation growing in it.	85
57. Mosquito breeding site in roadside ditch completely eliminated by scraping the ditch and removing vegetation.	85
58. Information Flow and County Mosquito Control and Management Network.	86

LIST OF TABLES

Table		Page
I	Affects of Dursban Briquettes on <u>C. p. quinquefasciatus</u> Larvae, Pupae and Adults.	91
II	Affects of Flit MLO on <u>C. p. quinquefasciatus</u> Eggs, Larvae, Pupae and Adults in Barrels of Water.	95
III	Affects of Flit MLO on <u>C. p. quinquefasciatus</u> Eggs, Larvae and Pupae in the laboratory	96

ABSTRACT

This study was concerned with the determination of the seasonal abundance and the seasonality of mosquitoes found in the semi-arid urban area, Tucson, Arizona. Evidence indicated that there were definite periods of mosquito production and that such periods occurred essentially at the time when people complained of biting mosquitoes.

Differences in the presence or absence of various species of mosquitoes were found to be a function of ambient temperatures and rainfall. It was also determined that the species of mosquitoes that appear in any given area were largely dependent on the characteristics of the breeding site. Species of mosquitoes normally found in flood water areas such as Aedes vexans and Psorophora signipennis were consistently found only in such breeding sites and polluted water breeders such as Culex pipiens quinquefasciatus were also found only breeding in this type of environment.

A difference in activities of both Culex tarsalis and C. p. quinquefasciatus was noted. Although both species of mosquitoes were taken in mosquito light traps in Tucson throughout the year, the overall numbers fluctuated very little. Even more surprising was that neither species was noted to be a part of the biting mosquito problems. Since these two species occupy important roles in arbovirus transmission, perhaps this accounts for the seeming lack of mosquito-borne encephalitis in and around the Tucson area.

The abundance of mosquitoes varied directly with temperature and rainfall, the greatest density and largest breeding sites created by summer rains. Mosquito dispersal was also apparently possible during summer rains when ambient humidity was higher and there was less loss or hazard through desiccation while on the wing.

Natural wash areas, ground pools, livestock watering troughs and overwatering were all found to contribute to the production of mosquitoes.

A continuous program of environmental sanitation, chemical control, utilization of mosquito fish, reopening of natural drainage and prudent use and management of water for irrigation are recommended.

INTRODUCTION

Problems with mosquitoes are not new to Arizona. Barnes (1960, p. 127) states, "Camp Goodwin was extremely unhealthy. Malaria-carrying mosquitoes swarmed and the soldiers sickened. This necessitated the abandonment of the post.....Old Camp Goodwin was vacated permanently on March 14, 1871". Since that time, Arizona's mosquitoes have continued to pose significant threats to the health of residents of the State. Smith (1960) suggested that return of malaria to the human population could occur quite easily since the Anopheline vectors are present and an infected person or persons with the disease could set off a new cycle of disease transmission.

Probably the most important mosquito-borne disease occurring in Arizona is encephalitis. A six year study conducted by Smith et al. (1969) revealed consistent isolations of both St. Louis encephalitis virus (SLE) and western equine encephalitis (WEE) from C. p. quinquefasciatus Say and C. tarsalis Coquillett mosquitoes collected in the Tucson area. According to the U.S. Department of Health (1971) there were 150 reported cases of arboviral encephalitis in the United States. This represented a 36% increase over 1970.

With encephalitis being essentially a non-treatable disease, incidence of this disease typically causes grave concern. Sudia and Newhouse reported occurrence of Venezuelan equine encephalitis (VEE) in Texas in 1971. According to the Arizona State Department of Health, there was an apparent movement of this disease toward Arizona in 1972.

In a report by Vuturo and McDonald (1973), they suggested that the potential problems posed by VEE for Arizona suggests that the threat of this disease is very real and prevention is an all-important approach.

Almost as an echo to these warnings, Magy (personal communication 1973) advises that many pools of C. tarsalis mosquitoes collected along the Colorado River near the Imperial Dam by the Bureau of Vector Control of the California State Health Department in 1972 were positive for St. Louis, Western and Turlock encephalitis viruses.

The mosquito problems in an urban desert area have a uniquely vigorous and dynamic compounding element. Mosquito breeding sites are sometimes created on a large scale while man pursues a totally different goal. They are created through urbanization programs in the desert. Large contained urban areas, such as rapidly built military installations and modern housing developments often come into being seemingly overnight.

According to the U.S. Bureau of the Census (1973), the population of the State of Arizona has increased at an astronomical rate. In 1870, the entire State of Arizona had only 9,658 people. Since that time, the rate of population growth in Arizona has been faster every decade than the growth of the United States as a whole. In 1970, the population of Arizona reached a total of 1,770,900 people, a 36% increase over the total population of 1,302,161 just ten years earlier.

A desert can be defined as a region with a dry or almost rainless climate (Cloudsley-Thompson, 1965). Rains that do occur are essentially unevenly distributed, in quantity and place, even when they are

supposedly seasonal. Much of the rainfall in the summer is in the form of thundershowers which are often very intense and produce local flash flooding. Characteristically, temperatures are high and humidity is low during the day.

In desert areas, water is both man's greatest friend and his greatest foe. The sparse scrub vegetation or open sandy areas have very little water holding or water absorbing capacities. When rains fall on the desert, the water typically evaporates seemingly immediately or becomes part of a massive run-off through gullies and washes causing flash floods. Flash floods are actually quantities of water moving unchecked. Roads are often built through, not over flash flood areas; thus, a sudden wall of water coming down the wash and across the road causes no small hazard to motorists and pedestrians.

According to the Vector Control section of the Pima County Health Department there is not a universal opinion as to the presence or absence of mosquitoes in the Tucson area. Unlike mosquito problems found in states such as Florida, Louisiana or Arkansas, Arizona's mosquito problems are scattered, sporadic, and discontinuous in almost every sense. Some people have lived in Arizona for 35 or 40 years and are yet to incur a single mosquito bite. Many of the mosquito problems in Tucson are essentially confined to: (1) areas near washes and ditches which hold water after rains; (2) cattle feeding areas or horse stables where watering troughs are seldom, if ever, emptied and mosquito breeding is continuous; (3) irrigation areas where poorly maintained ditches or

side pools, due to leaks, form mosquito breeding sites; and (4) both urban and rural areas where overwatering causes standing water and subsequent mosquito breeding sites.

REVIEW OF LITERATURE

Murphy (1953) published the first list of Arizona's mosquito species. Carpenter and La Casse (1955) provided a considerable amount of information about Arizona's mosquitoes and their work was significantly expanded by Richards, Nielsen and Rees (1956). Further taxonomic and distributional information was found in publications by Aitken (1945), Bohart (1948), and Belkin and McDonald (1957), McDonald and Belkin (1960), Rigby, Blakeslee and Forehand (1963), Burger (1965), and Nielsen, Arnell and Linam (1967), Nielsen et al. (1968), Nielsen, Wolff and Linam (1973), Rigby (1968), Zavortink (1968, 1969a, 1969b, 1970a, 1970b, 1972), Arnell and Nielsen (1972), McDonald et al. (1973), and Wolff, Nielsen and Linam (1974).

The following is a list of the mosquitoes known to occur in Arizona, as of March, 1974:

Aedes

* <u>aegypti</u> (L.)	<u>muelleri</u> Dyar
<u>burgeri</u> Zavortink	<u>nigromaculis</u> (Ludlow)
<u>cataphylla</u> Dyar	<u>papago</u> Zavortink
<u>dorsalis</u> (Meigen)	<u>pullatus</u> (Coquillett)
<u>epactius</u> Dyar and Knab	<u>purpureipes</u> Aitken
<u>fitchii</u> (Felt & Young)	<u>sollicitans</u> (Walker)
<u>implicatus</u> Vockeroth	<u>taeniorhynchus</u> (Wiedemann)
<u>increpitus</u> Dyar	<u>trivittatus</u> (Coquillett)
<u>infirmatus</u> Dyar & Knab	<u>varipalpus</u> (Coquillett)
<u>monticola</u> Belkin & McDonald	<u>vexans</u> (Meigen)

* Not collected in the past several years but may still exist in Arizona.

Anopheles

freeborni Aitken
judithea Zavortink
franciscanus McCracken

Culex

apicalis Adams
arizonensis Bohart
coronator Dyar & Knab
erythrothorax Dyar
nigripalpus Theobald
peus Speiser
pipiens quinquefasciatus Say
restuans Theobald
tarsalis Coquillett
territans Walker
thriambus Dyar

Culiseta

incidens (Thomson)
inornata (Williston)
particeps (Adams)

Orthopodomyia

kummi Edwards
signifera (Coquillett)

Psorophora

confinnis (Lynch-Arribalzagà)
discolor (Coquillett)
howardii Coquillett
signipennis (Coquillett)

Toxorhynchities sp. Theobald

Uranotaenia

anhydor Dyar

OBJECTIVES

The objectives of this study were as follows:

- (a) Conduct an intensive study of the mosquito fauna of Tucson to provide information concerning mosquito bionomics in the desert urban area, as well as the urban-rural interface areas.
- (b) Assess seasonal abundance and seasonality of given species of mosquitoes and determine which species are, in fact, the pest species.
- (c) Observe activities in both urban and rural areas that may directly or indirectly influence mosquito populations.
- (d) Assess the use of mosquito fish, Gambusia affinis (Baird and Girard) for mosquito control in various desert habitats.
- (e) Determine what methods and/or materials would lead to maximum mosquito reduction in desert urban and rural areas with minimum impact on the desert ecology per se.
- (f) Examine various pesticides in different physical forms to assess their usefulness and values for achieving specific mosquito control.

MATERIALS AND METHODS

Study Area

The city of Tucson is located on a valley floor which is circled by rugged hills and mountains. The valley floor is mostly flat or only slightly rolling and excessively lined with many dry washes. The ground elevation at the Tucson International Airport is 2,584 feet. The soil is alluvial dotted by scrub vegetation, cacti and small trees characteristic of low latitude deserts.

The relentless growth and development of the city of Tucson has spurred more and more construction on the periphery of the city, particularly the east side. This resulted in more and more people coming to live in and near many washes, streams, and water holding sites that were formerly outside the city. These rural-urban interface areas were often old mosquito breeding areas that became a part of the expanding city.

Along with the steady increase in population in Arizona, cities such as Tucson have grown disproportionately. By 1964, the Tucson urban area was estimated to cover approximately 272 square miles. The urbanization impact to this desert region was compounded by the nearby simultaneous growth of the Davis-Monthan Air Force Base. This air base, originally far from downtown Tucson, was 10,000 acres set aside for the Air Force. Construction and expansion of the existing runways to accommodate more and larger aircraft was necessary. By 1972, the

airstrip was 12,000 feet long. During heavy rainstorms, a super abundance of water had to be handled due to runoff from the runway and the paved access roads on the base. Paved areas and strips that formerly would have absorbed some of the water from downpours now absorbed no water at all. The expanding city with its increasing number of surfaced roads, coupled with the paved roads and runways from the Air Force base, all further increased the amount of runoff water in and around the city.

Sampling Techniques

Mosquito Complaints

The vector control office of the Pima County Health Department in Tucson annually receives many complaints about biting mosquitoes. Most of these mosquito complaints are by way of phone calls from disturbed residents in and around the city. The vector control office fills out a brief form on each complaint indicating name of the resident, address and date. Each complaint is then investigated by a member of the vector control office and he later completes the form indicating (1) whether or not mosquitoes were found, (2) type of breeding site, if any, (3) what remedial action was taken and (4) date of treatment or examination of the problem site. All of the mosquito complaint calls received by the Pima County Health Department for the years 1971-73 were generously made available for this study.

Light Traps

Ten New Jersey type mosquito light traps (Mulhern, 1934) were maintained in constant operation from February, 1973, through January, 1974, throughout the valley in and around Tucson (Figure 1), for the purpose of collecting night flying adult mosquitoes. Traps hung near a building or supporting structure are often damaged by striking such objects if the wind causes them to swing back and forth. However, if the suspending chains or ropes loosen or break and allow it to fall to the ground, severe damage to the light, motor or housing may occur. These damages are not only costly, but specimens are lost or not collected.

In southern Arizona during the months from November to April, wind speeds up to 32 mph are quite common while "dust devils" (desert whirlwinds) and thunderstorms are common during the summer months. To avoid damage to light traps, a simple device was developed which not only completely prevented wind-caused damage, but also provided a trap stand in flat or open areas where objects from which to hang a trap are not available (i.e., houses, trees, posts).

Figure 1 shows a light trap suspended in the ordinary manner but with the bottom held in place by a light-trap stabilizer. The stabilizer consists of two iron pipes, one a 3/8 inch outer diameter and the other of a slightly greater interior diameter. Both pipes are 4 feet long. A simple platform of slightly greater base diameter than the light trap is made of reinforcing rod welded to one end of the larger pipe. Directly beneath the light trap, the smaller pipe is driven into the ground. This pipe is slid over it. The larger pipe is equipped with a set-screw, which

permits it to be telescoped over the smaller pipe to the desired height setting. The outer pipe is raised until the base of the light trap rests lightly on the platform. The trap is held in a non-swinging position by upright "keepers" on the platform. The base of the trap can then be locked or tied to the platform as indicated in Figure 1.

Light-trap stabilizers are quite inexpensive and simple to build, yet highly effective in avoiding wind damage. During the windy months in Tucson, Arizona, none of our traps with stabilizers was damaged, whereas, all traps without stabilizers incurred damage ranging from broken collecting jars to motors which burned out when they fell to the ground while running.

Light trap locations were selected with an eye toward gathering as much information as possible from the various mosquito habitats in the Tucson valley.

The light trap at Site A (the Olton House) was located within 60 m of the Tanque Verde Wash where shaded pools were common and 0.5 km from a pool.

A light trap was operated at Site C (the University Farm) because of the large number of cattle in the area and the known nearby mosquito breeding site.

Although there are very few constant flowing streams in and around the Tucson valley there is one such stream in Sabino Canyon. A light trap, Site J, was operated within 2 k of the stream to capture mosquitoes produced in this ecological niche.

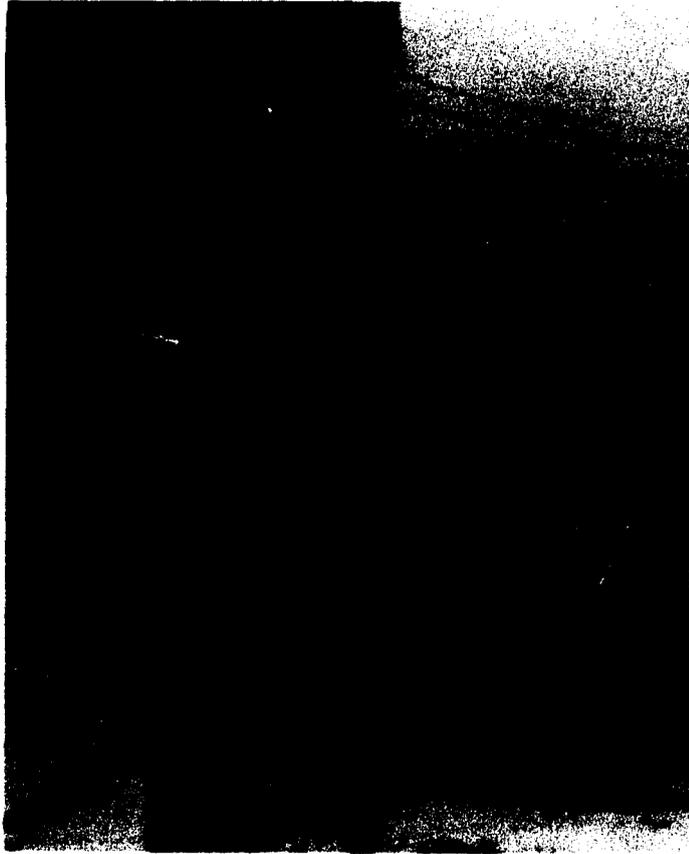


Figure 1. New Jersey type mosquito light trap

The light trap maintained at the Rillito riding stables, Site H, provided an opportunity to collect mosquitoes in an area sparsely populated with humans but densely populated with horses at the stables and intermittently at the adjacent race track.

The L Site (the McDonald House) was a very new housing development and located more than 2 k from the nearest known mosquito breeding site.

The light trap at Site M (the Sluss House) was located in one of the older residential areas with no known mosquito breeding sites in the vicinity with the possible exception of some artificial container breeders.

The light trap at the Starr B Morgan horse farm, Site N, was located there because, except for some irrigated crop lands, there were no other known mosquito breeding sites in this open, flat area.

A light trap was maintained at Site Q (the International Airport) for two reasons; this is an almost totally unpopulated area and if a new mosquito were accidentally introduced with one of the incoming aircraft perhaps it would be detected.

Site E (the Granger House) was a rather unusual location for a light trap because it was in a sparsely populated rural area immediately adjacent to a wash also used to conduct irrigation water and subsequently commonly contained pools.

In response to mosquito bite complaints to the Pima County Health Department from the city's El Rio golf course, a light trap was located in that area and designated as Site K.

Larval Dip Method

Mosquito larvae were collected by "dipping" samples of water from test sites. All dip counts were made with a 240-cc, white porcelain water dipper. Larvae were the most common aquatic mosquito form encountered. All dip counts were, therefore, based on larvae except where otherwise noted. Visual counts were made of each dip and were considered to be accurate counts up to 28. Counts in excess of 28 were indicated as TNTC (too numerous to count). All larval breeding sites, natural and artificial, as well as the light traps were visited and sampled at weekly intervals. Larvae collected in breeding sites were periodically reared in cages in the laboratory (Figure 2) for positive identification of species of mosquitoes involved.

Sentinel Barrels

Artificial mosquito breeding sites were provided through the use of fifty-five gallon barrels set out in pairs and filled with water. These sentinel barrels of water (Figure 3) greatly expanded the overall area that could be surveyed for mosquitoes but, more importantly, permitted manipulation and experimentation on water sources so much like the stock watering troughs found almost omnipresently in and around the Tucson metropolitan areas.

Weather

Weather data from the U.S. Weather Station, Tucson, were provided for the years 1971-73, by the U.S. Department of Commerce, Ashville, North Carolina.



Figure 2. Mosquito rearing cages used in the laboratory



Figure 3. Sentinel water barrels

Chemicals Used

Dursban briquettes, similar to those utilized by McDonald and Dickens (1970) were made up for treating standing pools of water and pretreating known flood water sites at a rate of 1100 g per ha. Two sizes of briquettes were used, 0.25 kg, and 1.0 kg. Each small briquette contained 1.5 cc of Dursban, and the larger briquettes contained 6.6 cc of Dursban. The small briquettes were applied at the rate of 1,400 per ha and the large ones at 355 briquettes per ha. Flit MLO was applied to water surfaces at a rate of 25 liters per hectare.

Equipment

A Weksler pencil style centigrade thermometer -10° to $110^{\circ} \pm 1^{\circ}$ was used to determine the temperatures of all waters examined before mosquito larvae appeared, while they were present and, if and when they disappeared. A Corning pH Meter, Model 10, was used for pH readings of water samples. Mosquito fish, G. affinis were provided by the Pima County Health Department.

Description of Major Test Sites

In addition to using light traps for surveillance of adult mosquito populations, several "natural" standing water sites were also kept under observation for studies of mosquito breeding habitats.

Test Site A (Figure 4) was a pool of water approximately 35 m long and 15 m wide. The water accumulated partly due to rainwater and partly due to a very high water table which also fed water into the pool when there was water in the nearby Tanque Verde Wash. In addition to having an almost steady supply of water to maintain the pool, it also was completely surrounded by trees whose overhanging branches shaded the entire body of water.

Site B was a solid waste sewage lagoon made up of two pools approximately 2 hectares each. These ponds (Figure 5) were used by one of the local dairies as settling and water evaporation sites for manure laden waters from the nearby dairy farm. Because water under pressure was used as the vehicle to move the manure through six-inch pipes, most of the manure became thoroughly mixed with the water while in transit. This resulted in organic solids in great abundance suspended in the water of the ponds.

Site C was located at the university dairy farm which was a grassy, tree-and brush-edged area where runoff rain waters often accumulated (Figures 6 and 7). Rain-caused flooding of this area was intermittent with subsequent mosquito production. Open sunlit stretches

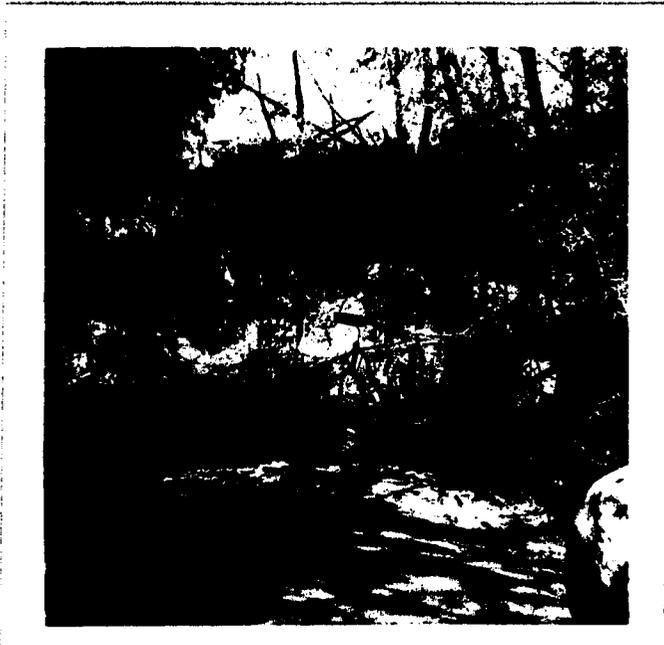


Figure 4. Test Site A - a ground pool mosquito breeding site

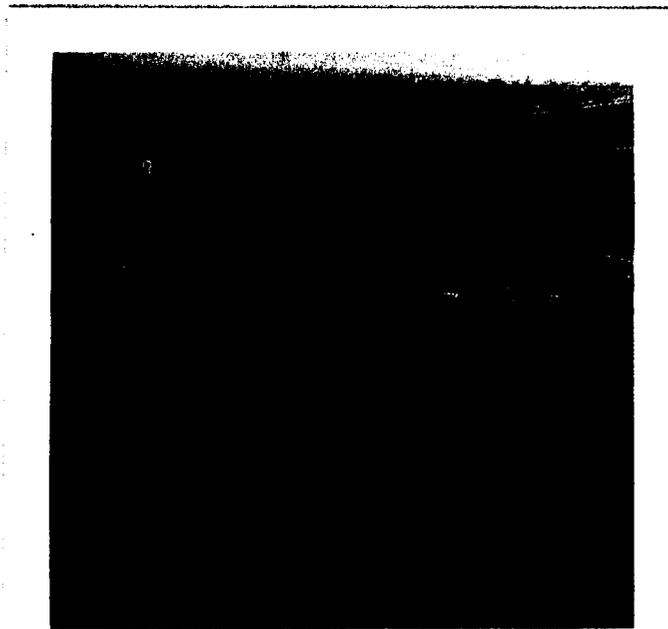


Figure 5. Test Site B - sewage lagoon with waters heavily laden with organic matter.

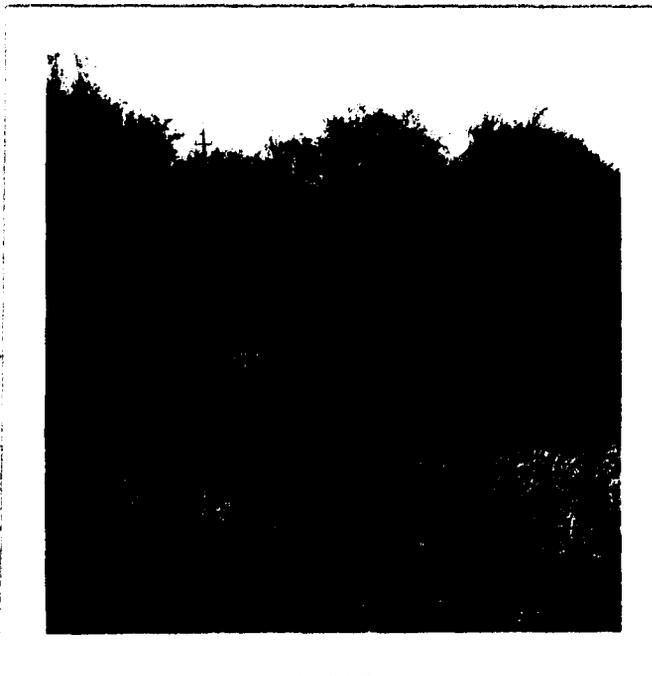


Figure 6. Test Site C - university dairy farm mosquito breeding site looking northeast



Figure 7. Test Site C - university dairy farm mosquito breeding site looking east.

of water could warm up quickly while those portions of the water in shaded areas remained cooler and less subject to rapid evaporation.

The mosquito breeding area at Site D had originally been the bottom of a very wide wash. Water could not escape laterally from this area because of large dikes that had been built along its sides to slow down the influx of rain water during flooding season. At the lower end of the wash where the water would have normally drained, the county had built a deep bedded black top road thus blocking escape of much of the water. As water gathered and stood in this area, over the years the soil stayed wet long enough to permit grass, brush and tree growth throughout the area (Figure 8).

The Site E was a portion of a well shaded wash area that often contained deep pools of standing water. Unlike most washes that are relatively even on the bottom due to the "scouring" effect of flash floods, this wash was also used as a means of moving irrigation water from an Indian reservation to a field crop area about 2km away. These slow moving, intermittently replenished waters commonly formed side pools which were not subject to rapid evaporation due to their shade cover (Figure 9).

One of the largest natural mosquito breeding sites kept under observation during this study was Site F, the Miracle Mile sewage lagoon, Figure 10. The pond was approximately 0.8 hectares in area, which was created by building an earthen dam across the opening of a small box canyon. Sewage water from a nearby housing development was pumped into the holding area forming a lagoon approximately 2 m deep in the middle.

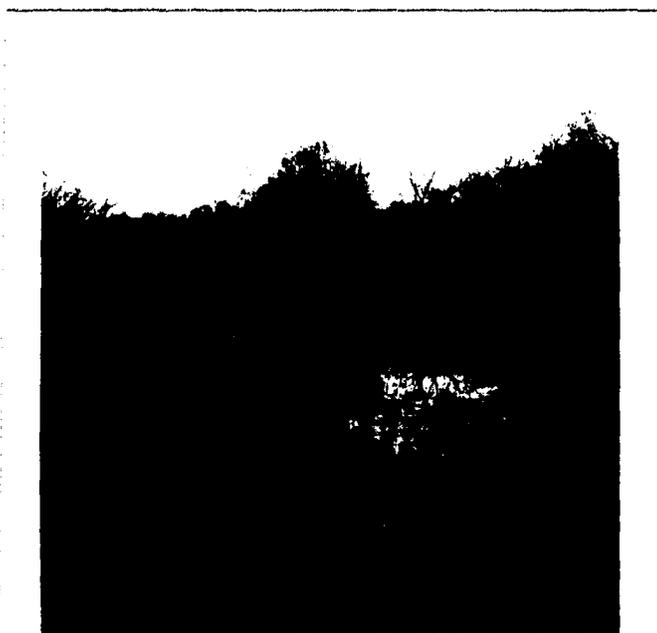


Figure 8. Test Site D - a wash mosquito breeding site



Figure 9. Test Site E - a wash mosquito breeding site

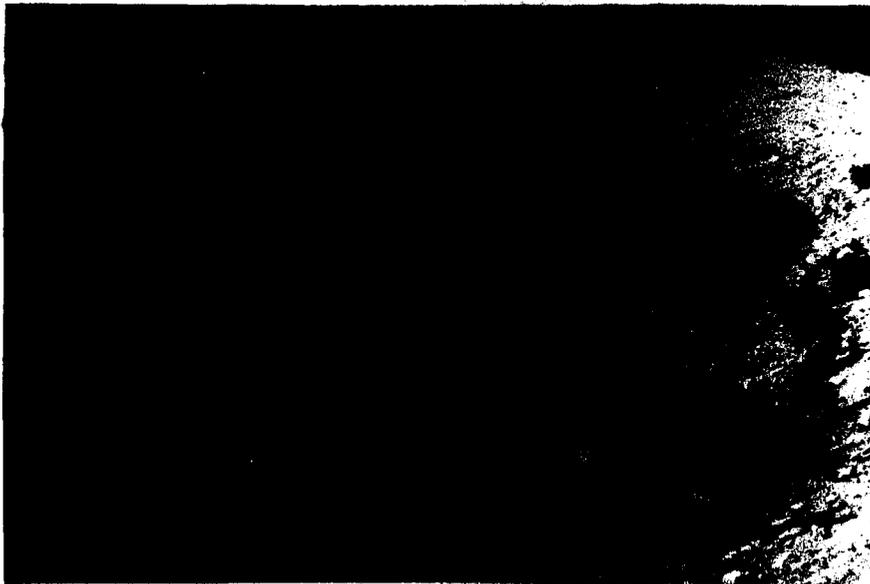


Figure 10. Test Site F - sewage lagoon

Water was replenished on an almost constant basis since some 80 - 100 families utilized this facility to handle their wastes. Because the water came from homes, all the water in the pond was warmed and heavily laden with organic matter.

As noted earlier, one of the commonest types of mosquito breeding site was the various watering troughs for the many horses kept in and around the city. At the Old Adobe Riding School, Site G, water for the horses was provided in upright 55-gallon barrels that were never emptied or cleaned because they were automatically refilled as the water level in barrels dropped (Figure 11). Larvae were commonly found in the water barrels at the Old Adobe Riding School. The barrels in stables 6, 7, 8, 9 and 10 were utilized for this study.

In contrast to the above stock watering system, the manager of the Rillito Riding Stables (Site H) agreed to water their horses only in 20-gallon galvanized pails which would be emptied on the ground before refilling with fresh water daily (Figure 12).

One of the most interesting types of mosquito breeding sites found in and around Tucson is the ornamental fish pond (Figure 13). At one residence (Site I), a rather convenient pair of ornamental fish ponds were discovered in that they were only two meters apart, but one was approximately one meter higher than the other. Both ponds were in an identical ecological setting but were physically separated by height and distance. Like so many ornamental fish ponds seen in Tucson, the home owners had gone to the expense of building the ponds and filling them with water, but failed to stock them with fish.

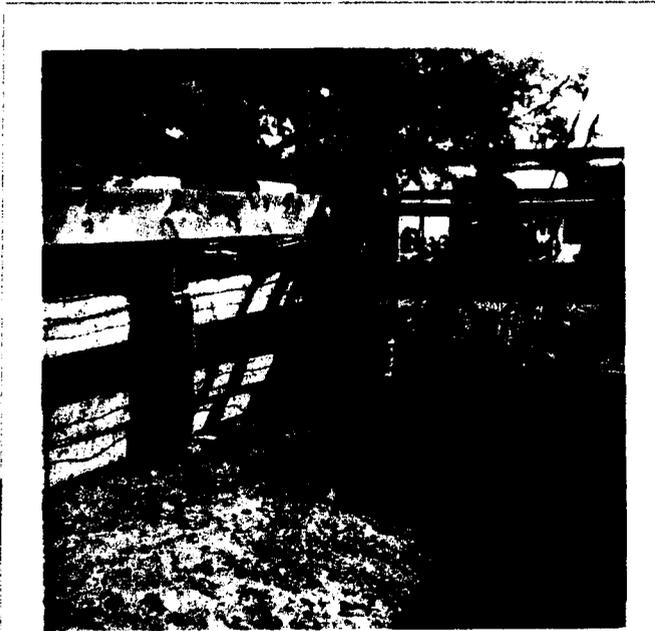


Figure 11. Test Site G - automatically refilled watering barrel for horses

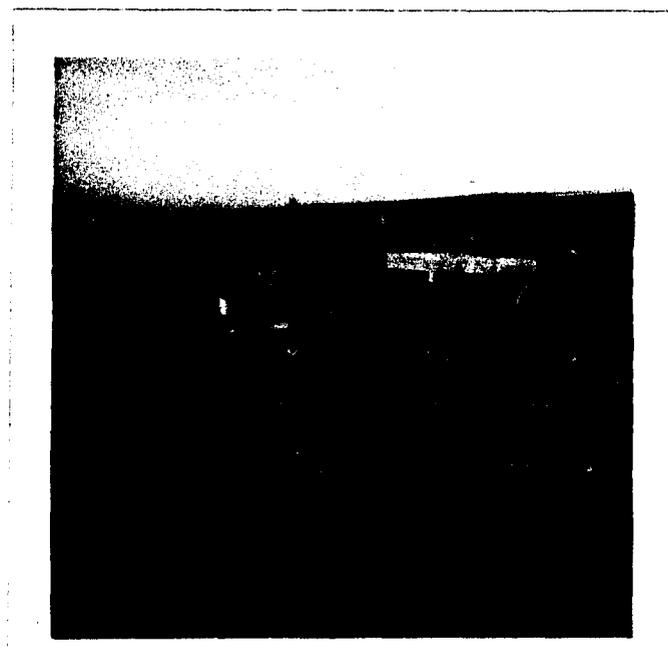


Figure 12. Test Site H - small watering barrels used for watering horses which were emptied daily.

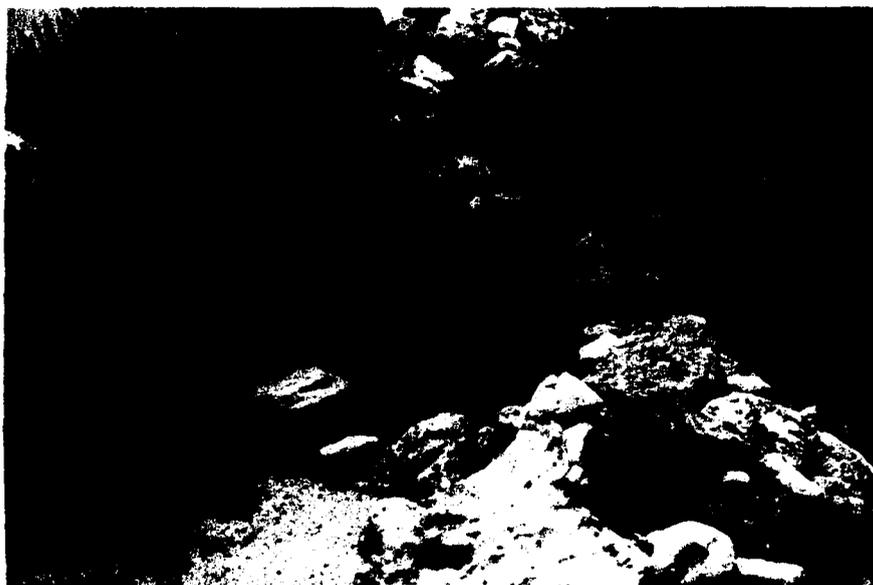


Figure 13. Test Site I - ornamental fish pond

Sentinel Barrel Locations

The two Site C barrels were located within 50 m of many livestock as well as only 400 m from one of the mosquito light traps.

Barrels at Site A were placed in a shaded location along a wash about 0.5 km from the ground pool at the site and approximately 300 m from the light trap at the Olton House.

Barrels were placed at the L Site location which was a new, very densely populated urban area with no known mosquito breeding sites nearby but within 30 m of the McDonald light trap.

A pair of barrels were in a shaded area of a highly populated older residential part of town where mosquito growth in artificial containers was not uncommon. These barrels were also within 40 m of the light trap at Site M (the Sluss House).

Another barrel site was a large, open area with a very low human population and a very high equine population. There the barrels were kept in a shaded area about 5 m from the Site N horse corral and 50 m from the Starr B Morgan light trap.

Site O was located on the western edge of the city where many of the homes were built on low rolling foothills. There were no known mosquito breeding sites within 2 km of this site.

Site P was an area of a medium human population density but surrounded by vast stretches of low bush desert and without any light trap in the area.

Two barrels were located at Site Q in the very minimally populated area near the Tucson International Airport. No known mosquito breeding sites were in the area but a light trap was at the Airport.

Site R was a fairly densely populated residential area which was a long time settled as indicated by the extensive tree and shrub growth around the dwellings. No light trap was located in this area.

A last pair of barrels was located in the sparsely populated area located 20 m from the wash at Site E and 20 m from the Granger light trap.

Mosquito Suppression Studies

Several studies were conducted using various means of controlling mosquitoes in the Tucson area without the need for adulticiding. As a result, most efforts were directed toward destruction of mosquitoes in their respective breeding sites, or by physical removal of these breeding sites.

Sentinel barrels of water simulating livestock water troughs were treated with mosquito fish, Dursban briquettes, Flit MLO or combinations of fish and Dursban briquettes or fish and Flit.

Standing pools of water were treated with Dursban briquettes, "pour-in" Dursban, Flit MLO, mosquito fish or combinations of the fish with the briquettes or Flit. Some of the standing pools of water were subjected to permanent control measures such as filling or draining to facilitate permanent source reduction.

Efforts were also put forth to properly manage irrigation water in areas where poorly maintained ditches or overwatering produced mosquito breeding sites.

RESULTS AND DISCUSSION

Nuisance Complaints

As indicated in Figures 14-16, mosquito complaints received by the Pima County Health Department were most abundant June through October. In 1971, the number of complaints very closely overlapped with the incidence of summer rains, but only after maximum temperatures recorded for that year were reached (Figure 14). In 1972, the number of complaints was concomitant with the incidence of the unusually long and heavy summer rains, but not with the fall rains. Fewer mosquito complaints during the fall rains were probably due to the decidedly cooler temperatures in October when heavy rains occurred in that month (Figure 15). In 1973, the number of complaints was again greatest in number during the summer rains. The unusually heavy rains of February and March which coincide with cooler temperatures, failed to produce significant mosquito complaints, (Figure 16). These data indicate that mosquito complaints and production of mosquitoes in Tucson are a function of high summer temperatures and simultaneous incidence of monsoon rains.

Seasonal Incidence of Adult Mosquitoes in Light Traps

Figure 17 shows the total of all adult mosquitoes captured at all ten light trap sites from February, 1973, through January, 1974. By and large, most of the mosquitoes were taken in the months of July, August and September. Although rains occurred in early June, abundant numbers of

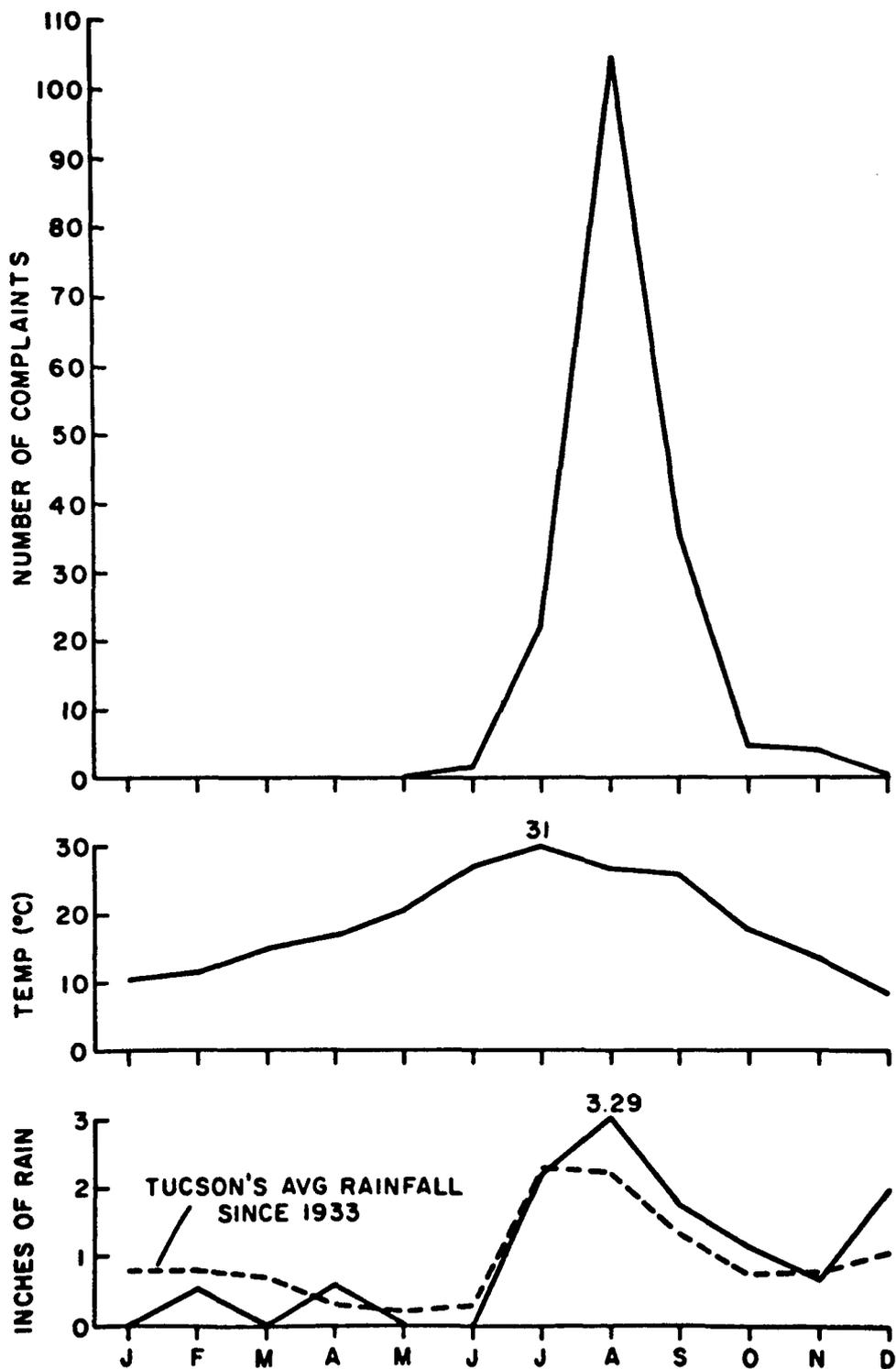


Figure 14. Pima County Health Department mosquito complaints for 1971 versus temperature and rainfall of that year.

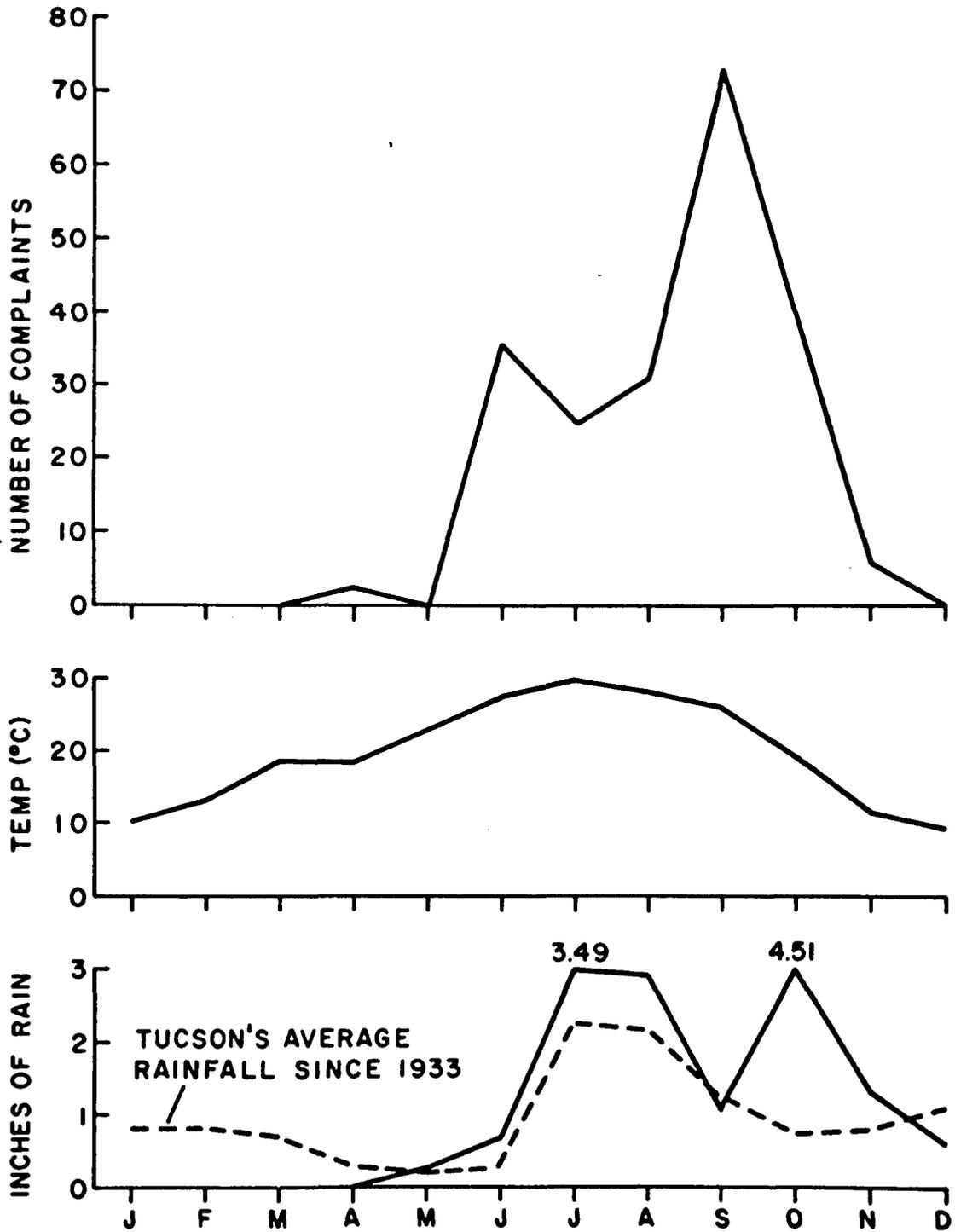


Figure 15. Pima County Health Department mosquito complaints for 1972 versus temperature and rainfall of that year.

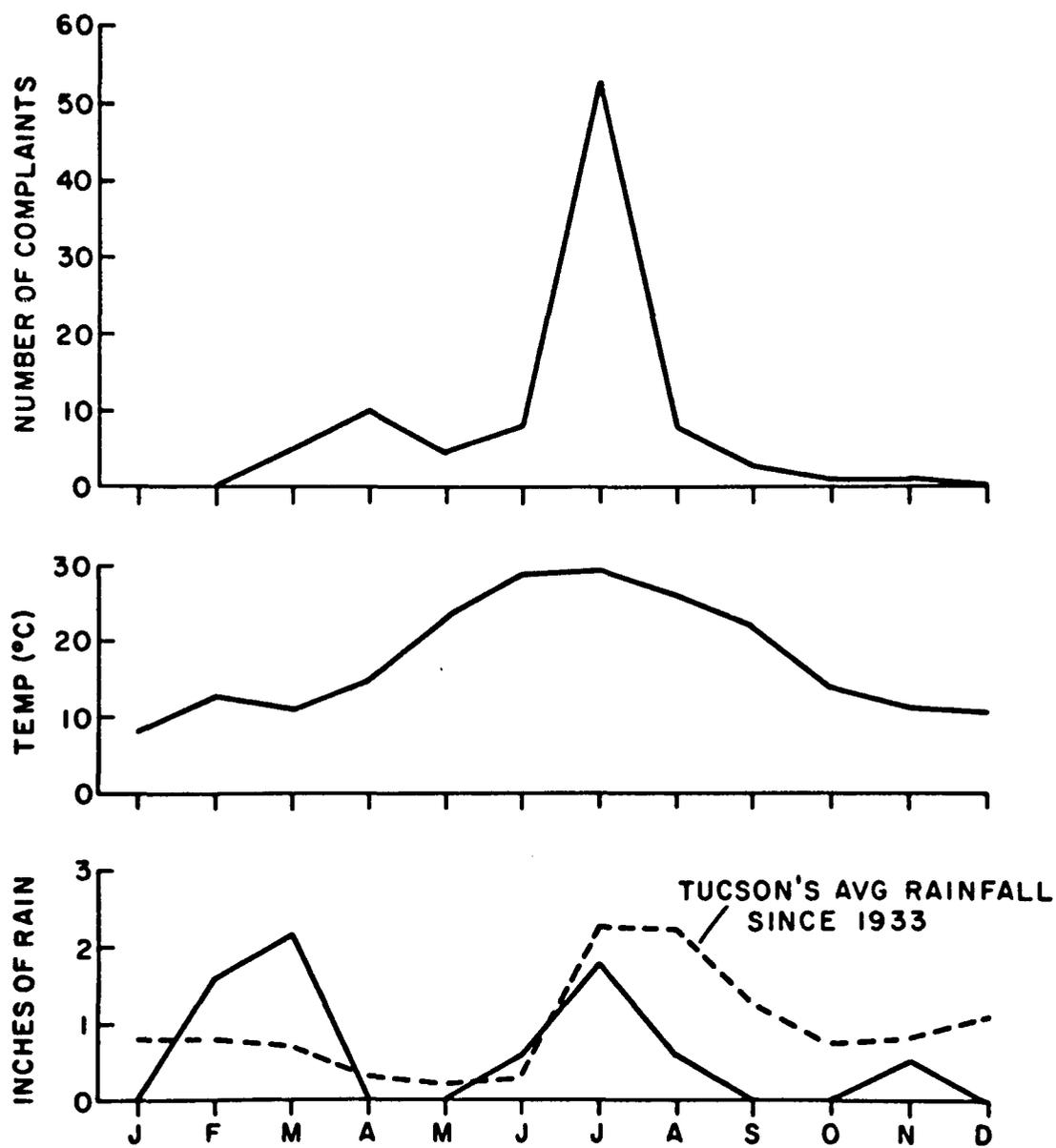


Figure 16. Pima County Health Department mosquito complaints for 1973 versus temperature and rainfall of that year.

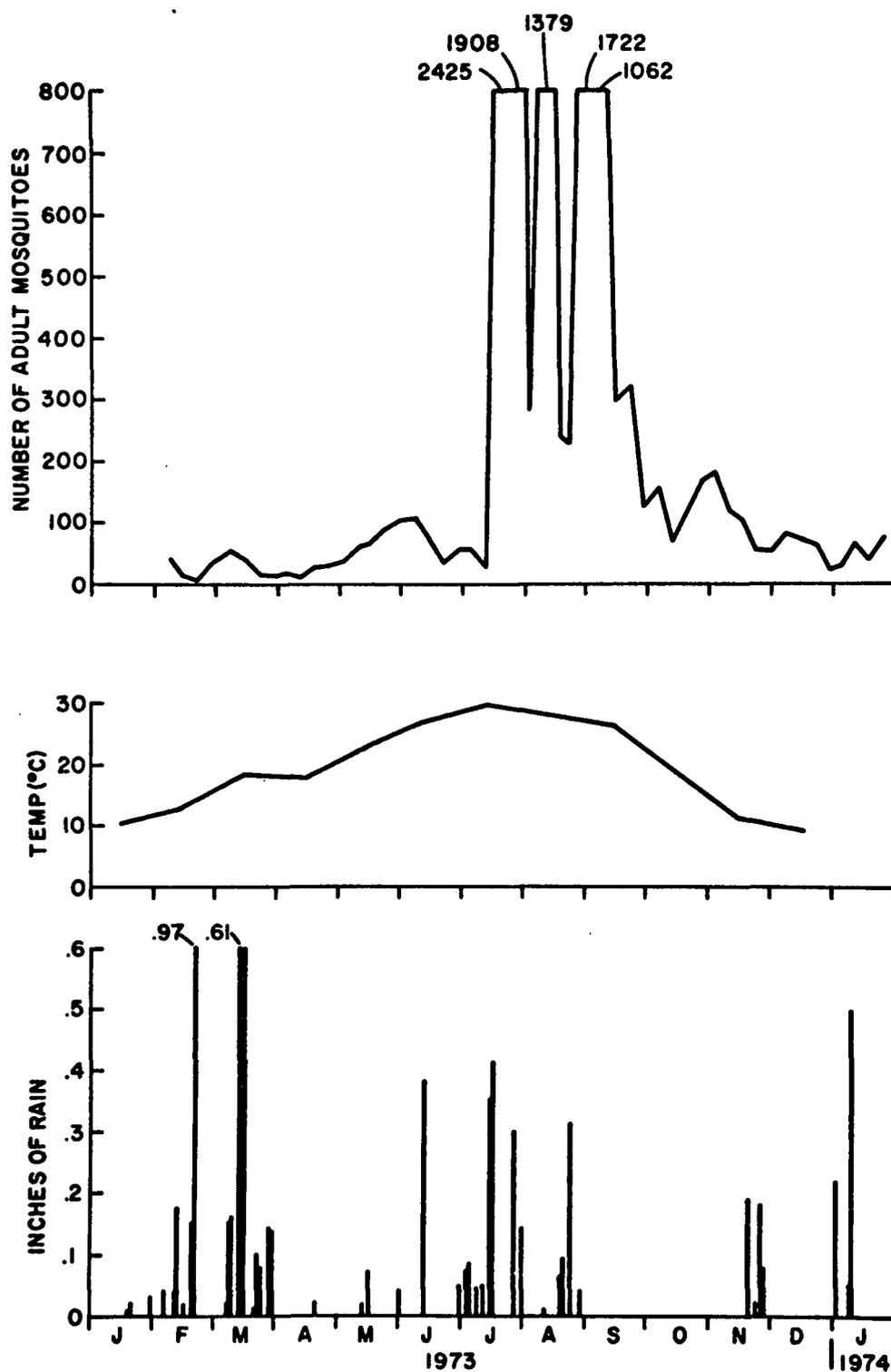


Figure 17. Profile of all mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.

mosquitoes were not taken in the traps until mid-July, following light, but steady rains. The rains in late July and late August again preceded large catches of mosquitoes in early August and early September respectively.

The number of adult Anopheles mosquitoes captured in all traps (Figure 18) indicates that most of the mosquitoes of this genus were produced in the months of August, September and October. All of the Anopheles taken in the light traps were A. p. franciscanus McCracken. The majority of these were collected in a light trap near the stream in Sabino Canyon. The incidence of these mosquitoes was apparently related to descending summer temperatures, and not with summer rains. This was probably due to preferred breeding sites in stream side pools rather than in flood water or stagnant water sites (Aitken, 1945).

The flood water mosquitoes, Aedes vexans, showed their greatest incidence in all light traps in July, August and September, being closely associated with high summer temperatures closely following monsoon rains (Figure 19).

Figure 20 indicated that Psorophora confinnis (Lynch-Arribalzaga) were taken in light traps almost exclusively in the two months of the highest mean temperatures, June and July. Their incidence apparently was coincident with the rains of June and July but not with those of August. Culex tarsalis are present throughout the year as indicated in Figure 21. Although May and June appear to be the months of highest

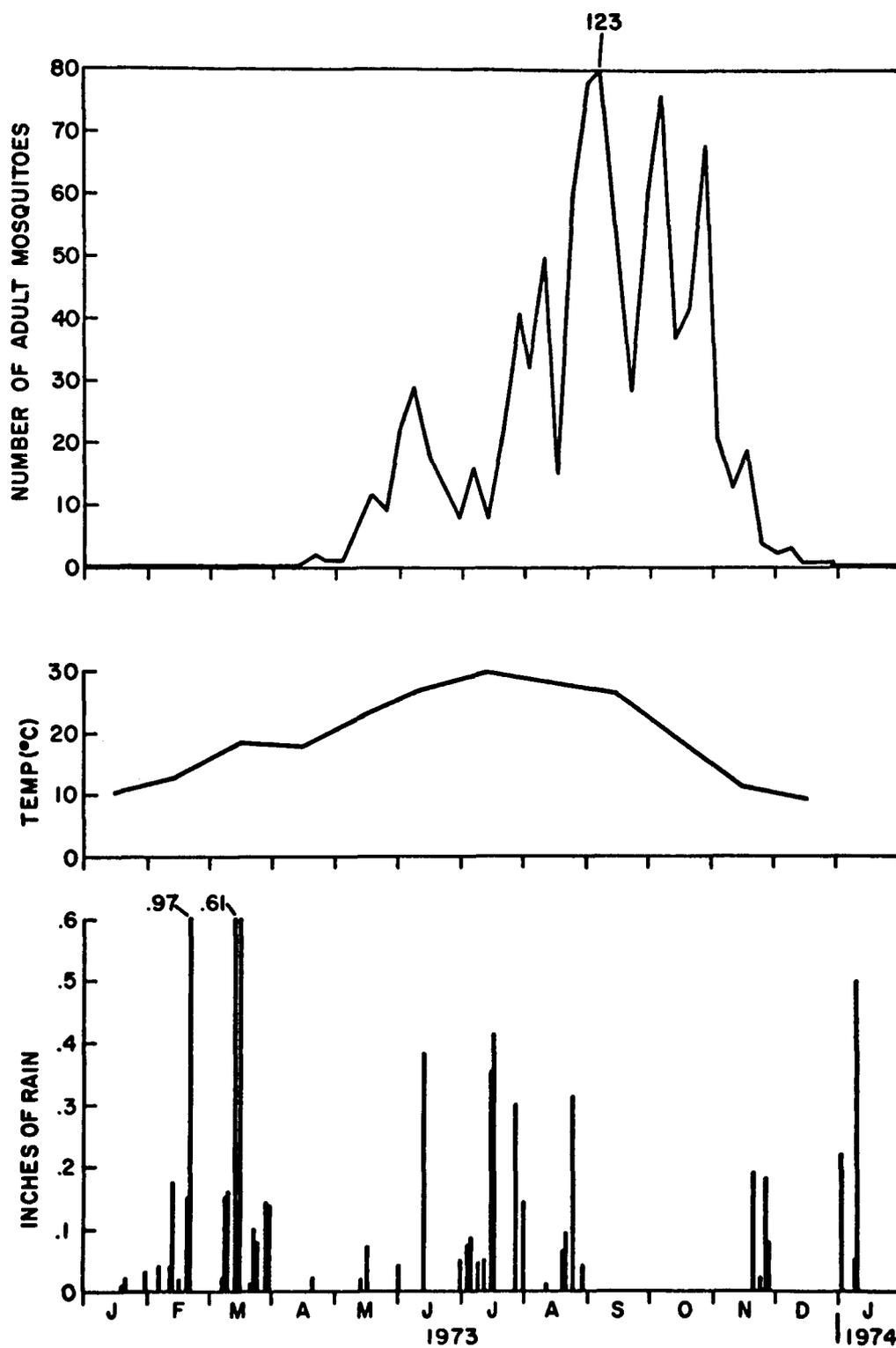


Figure 18. Profile of all *Anopheles* mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.

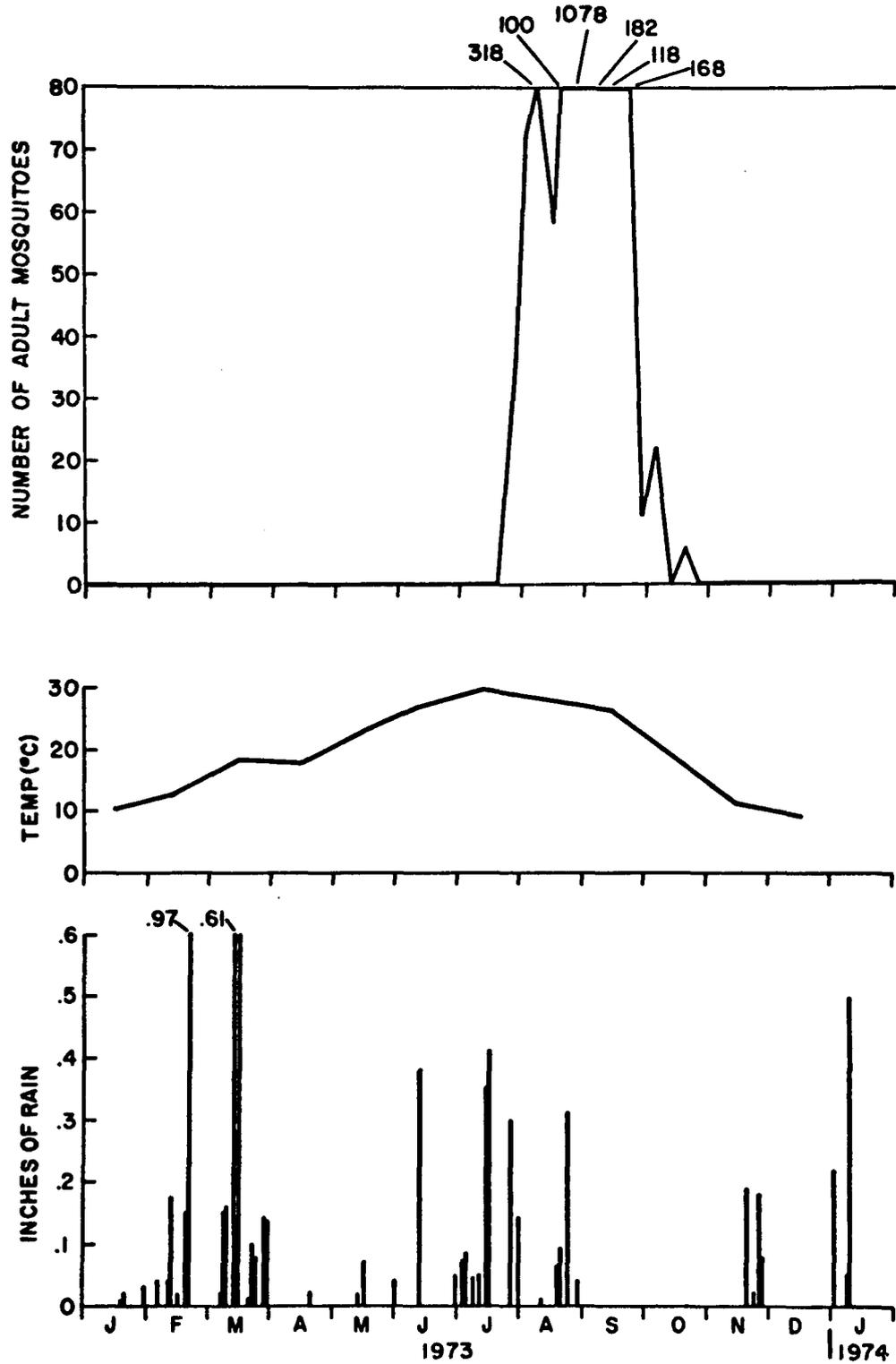


Figure 19. Profile of all *Aedes vexans* mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.

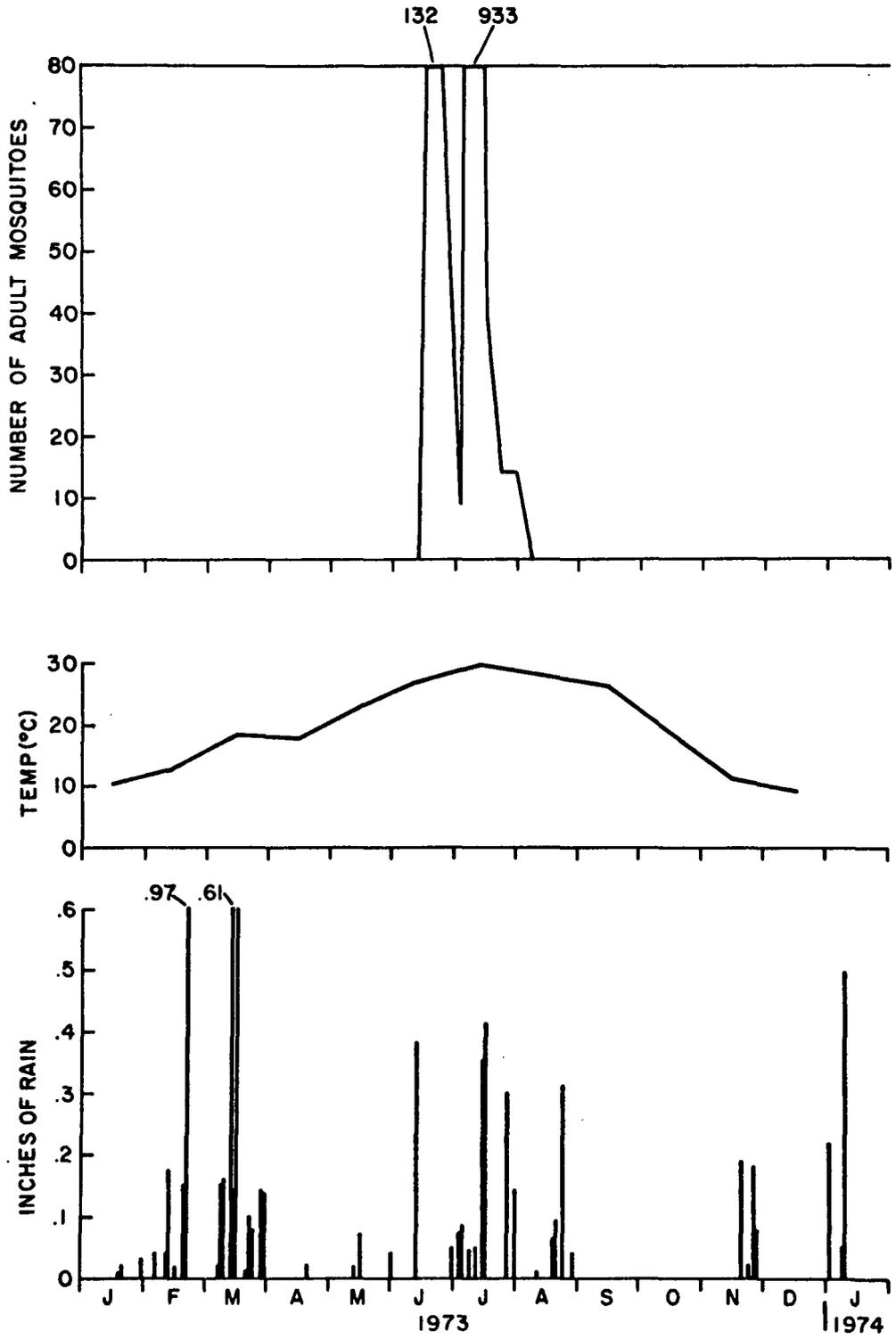


Figure 20. Profile of all Psorophora confinnis mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.

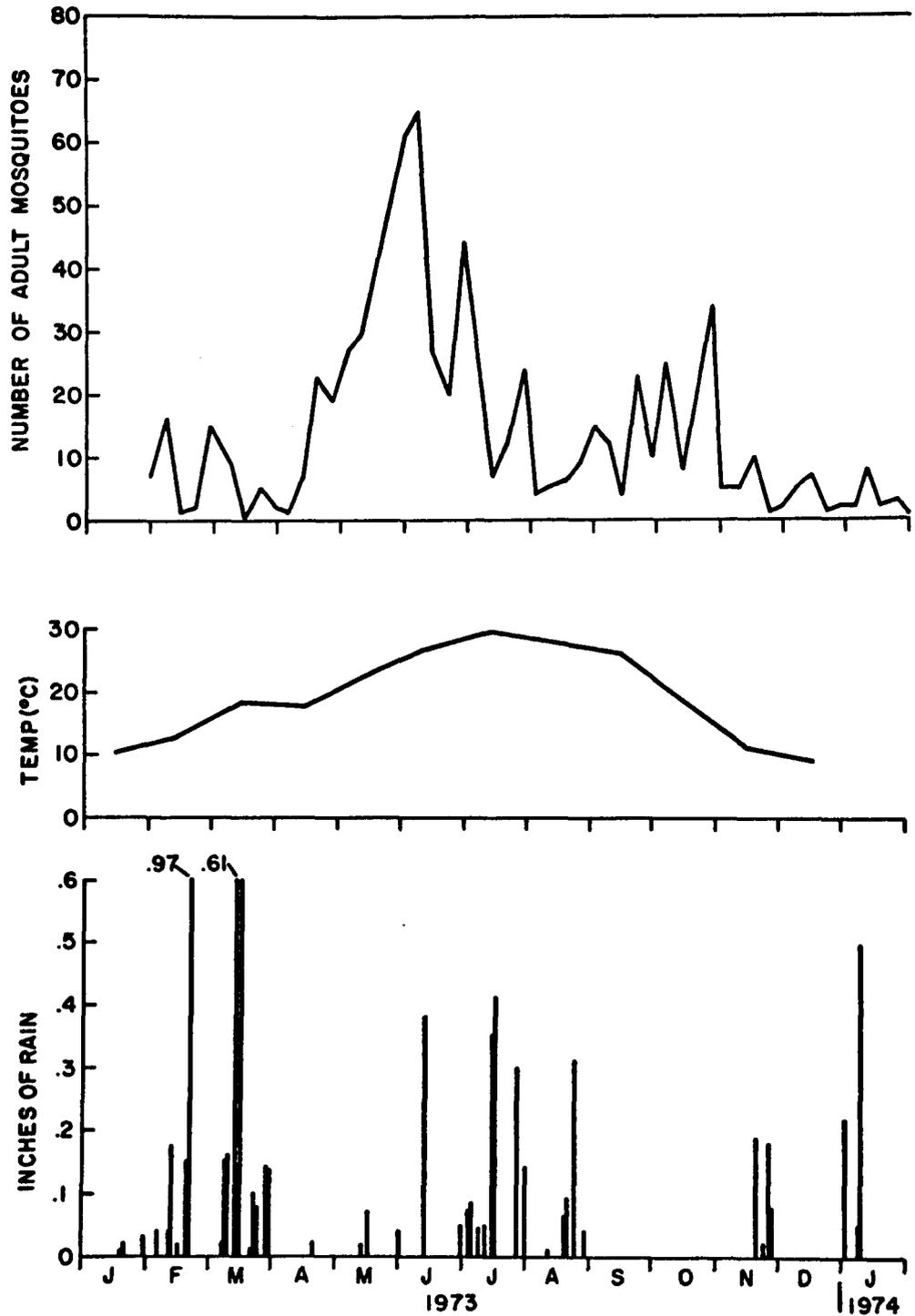


Figure 21. Profile of all Culex tarsalis mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.

incidence of these mosquitoes, at no time during the year were significant numbers captured. These findings are completely in concert with those of Smith et al., 1969.

During the year, two species of Culiseta mosquitoes were taken in light traps. These were Culiseta inornata (Williston) and Culiseta incidens (Thomson). Only approximately 10% were C. incidens whereas 90% were C. inornata. It is most interesting to note that no male C. inornata mosquitoes were taken throughout the study. Figure 22 reflects that the Culiseta taken in light traps were few in number during the spring, none in the hot summer months, and of greatest abundance in the fall and early winter.

Light trap incidence and abundance of Psorophora signipennis is shown in Figure 23. Their extremely great numbers, blood thirsty habits, and simultaneous occurrence with mosquito complaints for 1971 (Figure 14) indicate these mosquitoes are Tucson's most common pest mosquito. In all probability, control of this species here would largely relieve the mosquito menace-complaint problem.

Figure 24 indicates that C. p. quinquefasciatus, like C. tarsalis, is present throughout the year yet its numbers are very small. This species of mosquito exists, but appears to play little or no part in the overall mosquito problem in and around Tucson.

During this study it was found that natural mosquito breeding sites in and around the semi-arid urban area include wash areas, ground pools, sewage lagoons, ornamental fish ponds, roadside ditches, dike

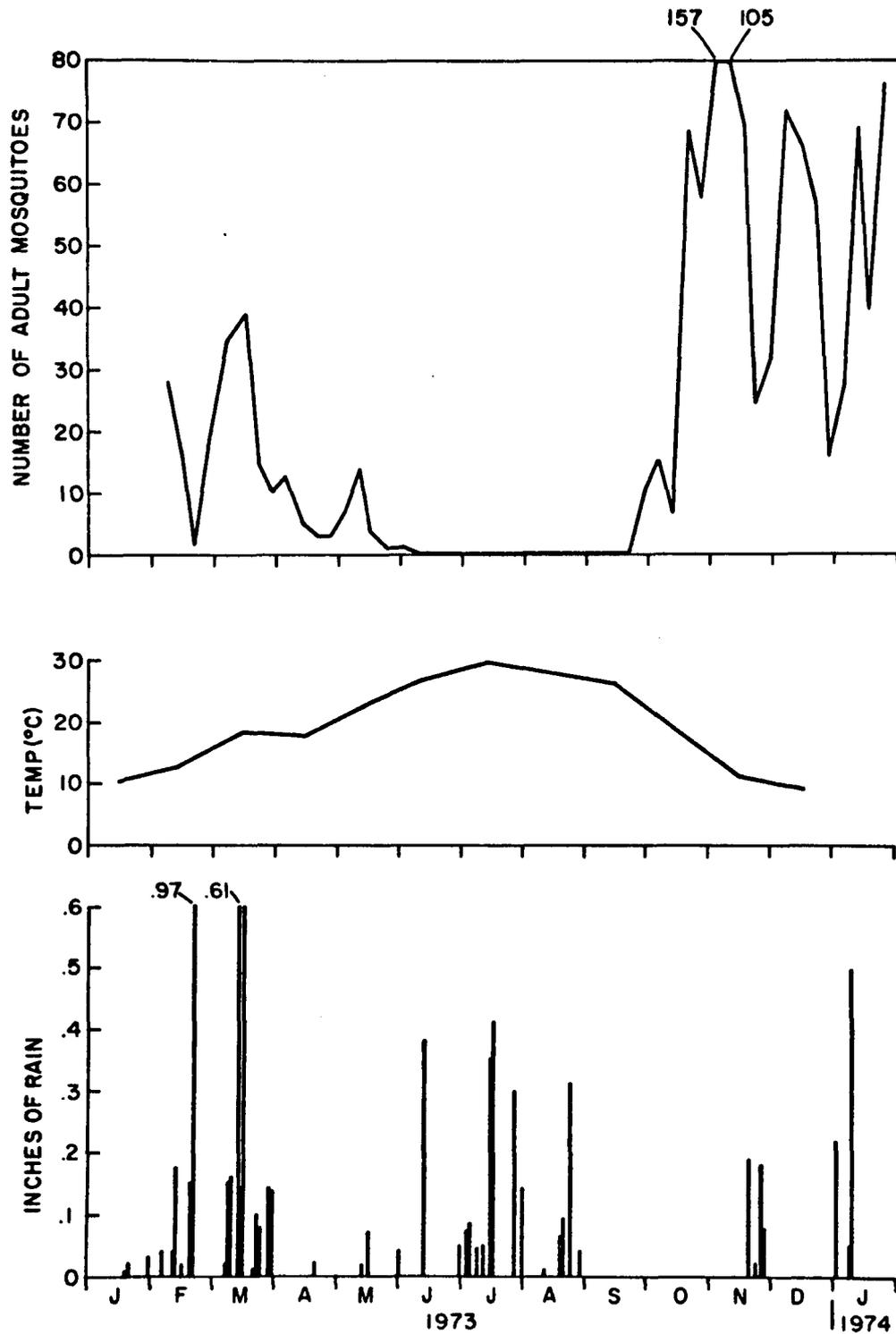


Figure 22. Profile of all *Culiseta* mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.

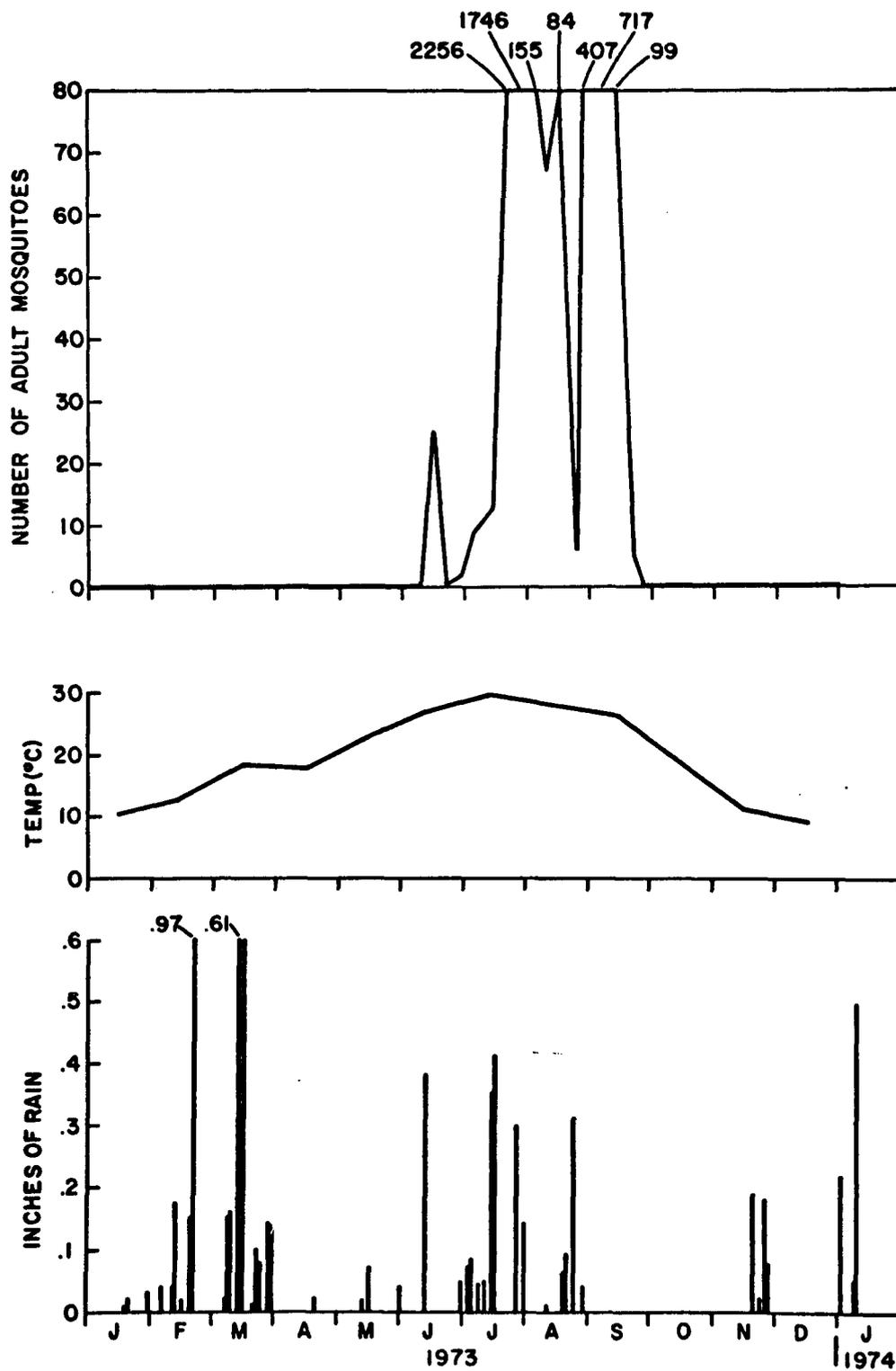


Figure 23. Profile of all *Psorophora signipennis* mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.

areas and various types of watering troughs. A great many of the mosquito problems were man-made often because water was mismanaged, even runoff rainwater.

Larval Breeding Sites and
Response to Control Treatments

Rainwater, the foe during the flooding, is the much needed friend during the rest of the year. Any means that slows the surge and volume of runoff water into washes immediately accomplishes two tasks:

- (1) reduces the danger of flash flooding;
- (2) allows temporarily confined water to seep and soak into the ground and recharge the ground water.

Over the years, a great number of dikes were built throughout the Tucson area to achieve the above and to protect agricultural cropland. The dikes succeed in slowing down runoff during the rainy season, as well as reducing the volume of water in the local rivers and washes during peak flooding. An unforeseen circumstance of this flood control technique is that a considerable amount of the trapped water occasionally fails to immediately soak into the soil or evaporate. When this occurs, the soils stay damp or wet long enough to permit low brush and taller vegetation to get established.

Here water stands for longer periods of time, ranging from days to weeks, protected from rapid evaporation by the shade of the trees and vegetation. Stagnant water-breeding mosquitoes such as C. p. quinquefasciatus and flood water mosquitoes such as A. vexans, P. signipennis and P. ciliata are provided their required ecological niches.

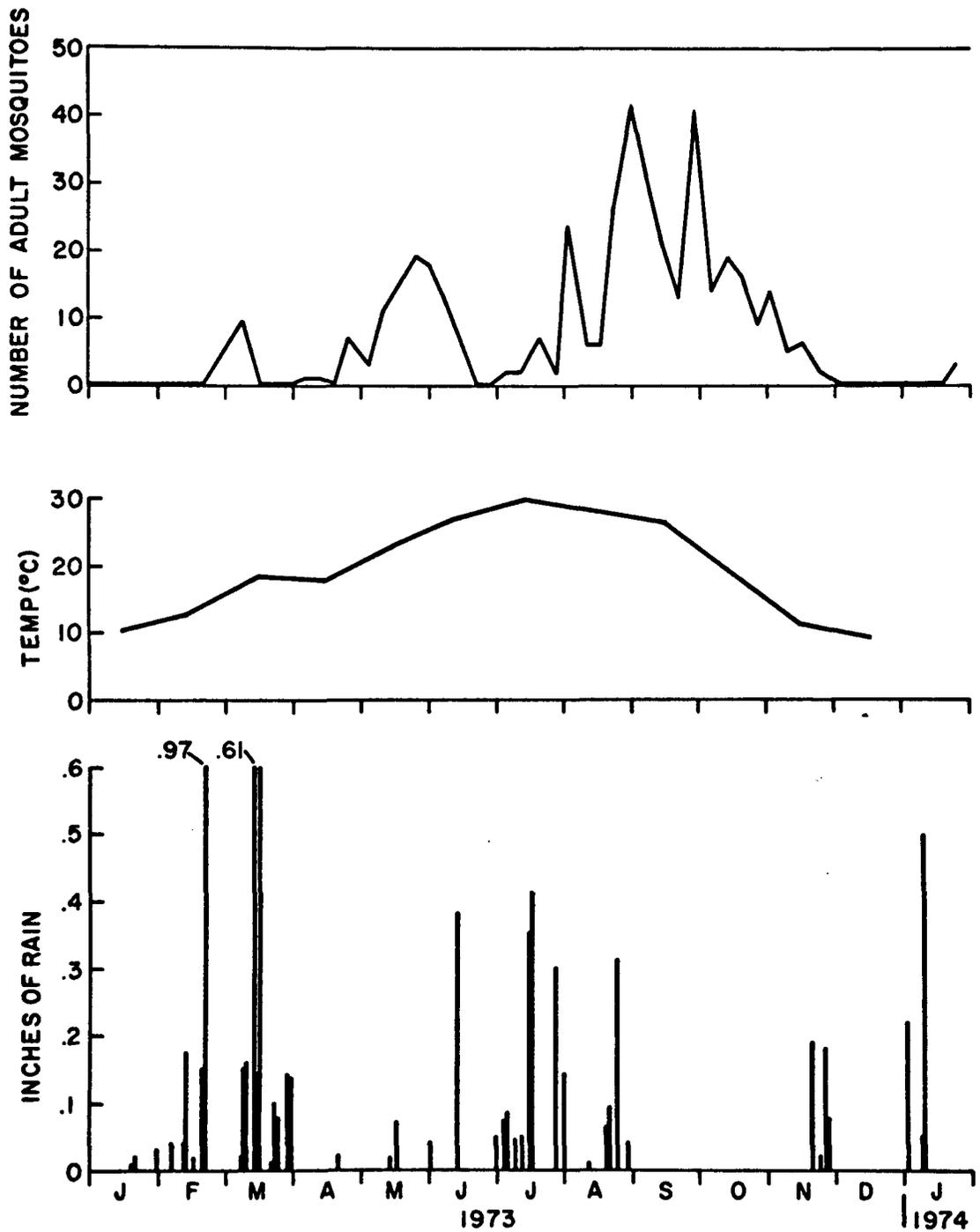


Figure 24. Profile of all *Culex pipiens quinquefasciatus* mosquitoes collected in all ten mosquito light traps operated from February, 1973, through January, 1974, versus temperature and rainfall.

One of the basic questions that could be asked concerning mosquito-borne diseases in Arizona is, "are there actually enough mosquitoes to constitute a health menace?" Quantitatively, the answers to this question are still incomplete at best. Qualitatively, a recent study by McDonald et al. (1973) indicated there were at least 43 species of mosquitoes found in the state. All of these circumstances combined led McDonald (1973) to conclude that Arizona must have mosquito abatement programs even if they exist only in the state's major urbanized areas.

Figure 25 indicates the response of mosquito larvae to treatment of Site A with Dursban briquettes and mosquito fish. In January and February, the number of C. inornata larvae in the water increased from one per dip to TNTC (too numerous to count). In mid-March the larval counts dropped to 15 per dip. Larval samples taken the following week indicated that larval counts again reached the TNTC level, but the larvae were now C. p. quinquefasciatus. When the larval dip counts remained at TNTC for three consecutive weeks, the pond was treated with the 1 k Dursban briquettes at a rate of 355 per hectare. On checking this site one week later, the larval dip count was zero. Two weeks later, 15 mosquito fish, G. affinis, were added to the Dursban treated waters. For the remainder of the season until the pond dried up at the end of August, no additional mosquito larvae were found breeding in the water pool. In mid-August, the fish appeared healthy and unharmed by the Dursban as evidenced by the water now containing an estimated 300 fish.

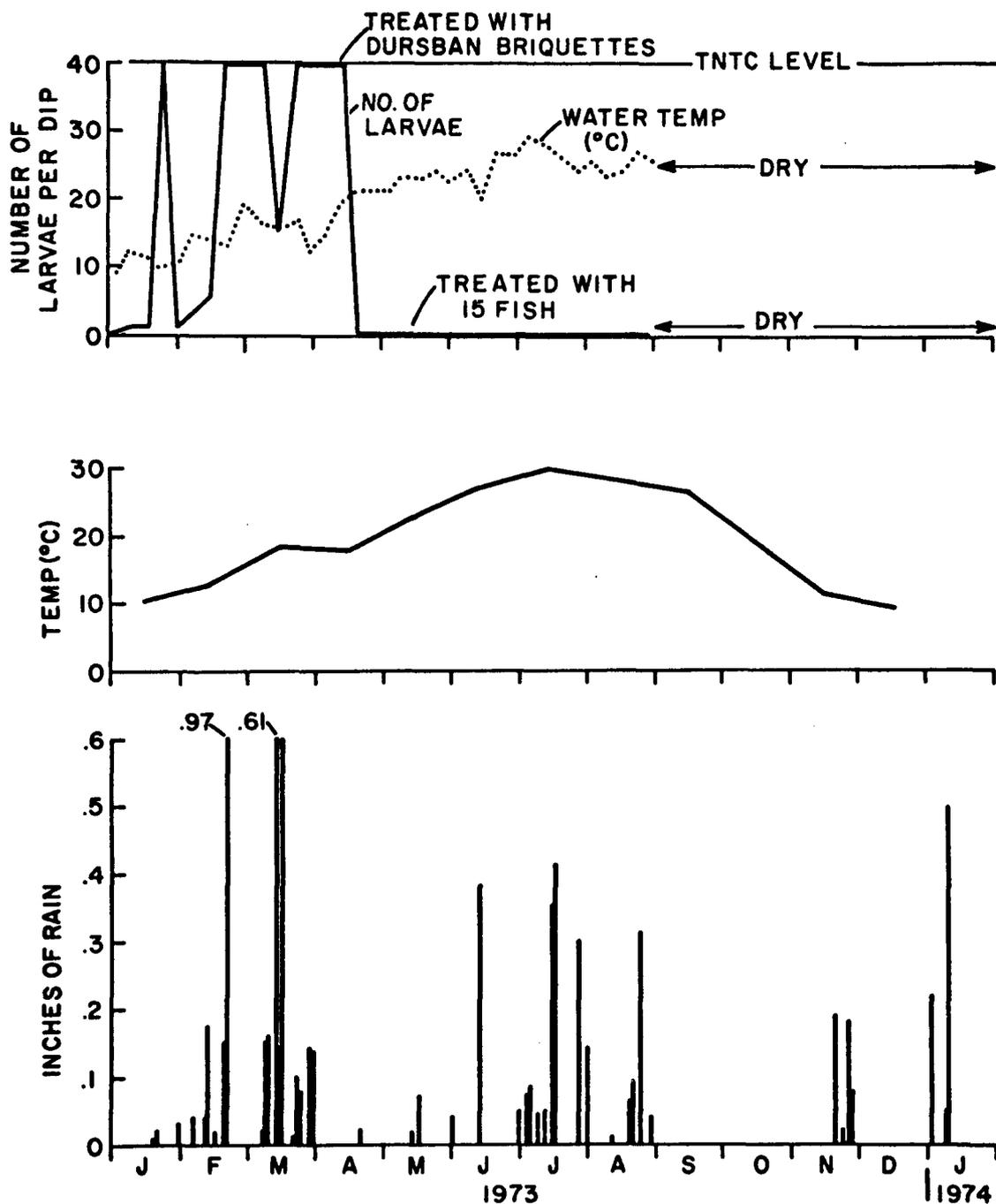


Figure 25. Number of mosquito larvae in test Site A versus mosquito larval control measures, breeding site water temperature, ambient temperature and rainfall.

Mosquito control measures used on Site B are shown in Figure 26. Pond A was about 1 m higher than pond B which was only 4 meters away. No attempts were made to control the production of mosquitoes in pond B since it was considered the control. The mosquito larvae in these ponds were mostly C. p. quinquefasciatus except for a two week period during mid-June when about half of the larvae were C. p. quinquefasciatus and the other half were C. tarsalis.

The first attempt to control the mosquitoes at this breeding site was in April using 1 kg Dursban briquettes at a rate of 355 per hectare. As indicated in Figure 26, the number of larvae dropped, but not to zero, and returned to the TNTC level three weeks after the briquettes were added to the water. Apparently the Dursban released from the briquettes was active on the mosquito larvae only until it was absorbed or adsorbed and neutralized by the organic matter in the bottom of the ponds, as well as that suspended in the water.

In an effort to overcome neutralization of the slow-released Dursban from briquettes by the organic matter, Dursban 4E was poured directly into the upper pond at a rate of 660 cc per hectare. Immediately after using the Dursban pour-in treatment, the mosquito larval count dropped to zero, while that in the lower (control) pond remained at the TNTC level. Both ponds dried up four weeks after the Dursban pour-in treatment. Nine weeks later the ponds were reflooded. Mosquito larvae appeared again in the lower control pond almost immediately, reaching and maintaining the TNTC larvae level for a week before it tapered off.

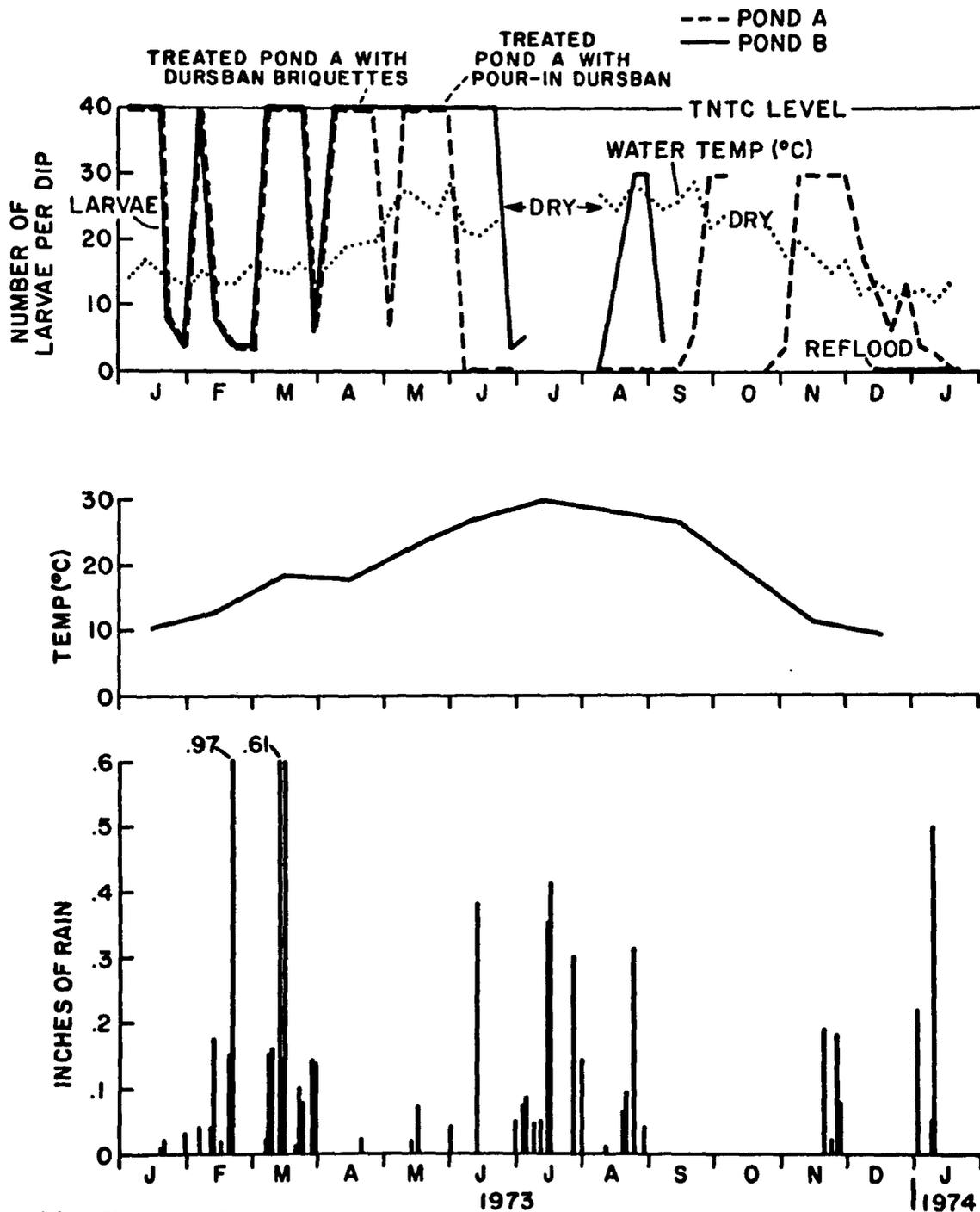


Figure 26. Number of mosquito larvae in sewage lagoon at Site B versus mosquito larval control measures, breeding site water temperature, ambient temperature and rainfall.

However, when the Dursban pour-in treated pond was reflooded, no mosquito larvae reappeared until five weeks had passed. Their numbers then gradually rose to the TNTC level within two weeks.

In late April Site C was treated with the small Dursban briquettes (0.4 kg) at a rate of 1,400 per hectare in an effort to prevent future accumulating runoff rainwater from producing mosquitoes. As noted in Figure 27, following July rains mosquito larvae grew in the waters without any apparent ill effects from the briquettes. Some larvae were even seen vigorously feeding and swimming over and around the briquettes in the Site C water. Five of these briquettes and one litre of water containing larvae and pupae were removed from the site for tests in the laboratory, then new Dursban briquettes, of the same size, were added to the breeding site at the same dosage rate as used in April. Within twenty-four hours, all mosquito larvae in the retreated areas were dead.

The water taken from Site C was found to have a pH reading of 7.35. Water drawn from the laboratory tap had a pH reading of 7.26. The mosquito larvae were removed from their breeding site water and placed in 250 ml beakers containing 200 ml of tap water at room temperature (23°C). The briquettes that had been in the breeding site water were smashed with a hammer and 0.40 g chips were added to five of the beakers of tap water which contained 50 larvae each. Three additional beakers with tap water and 50 larvae each were used as controls. Within four hours, all the larvae in the beakers which contained the briquette

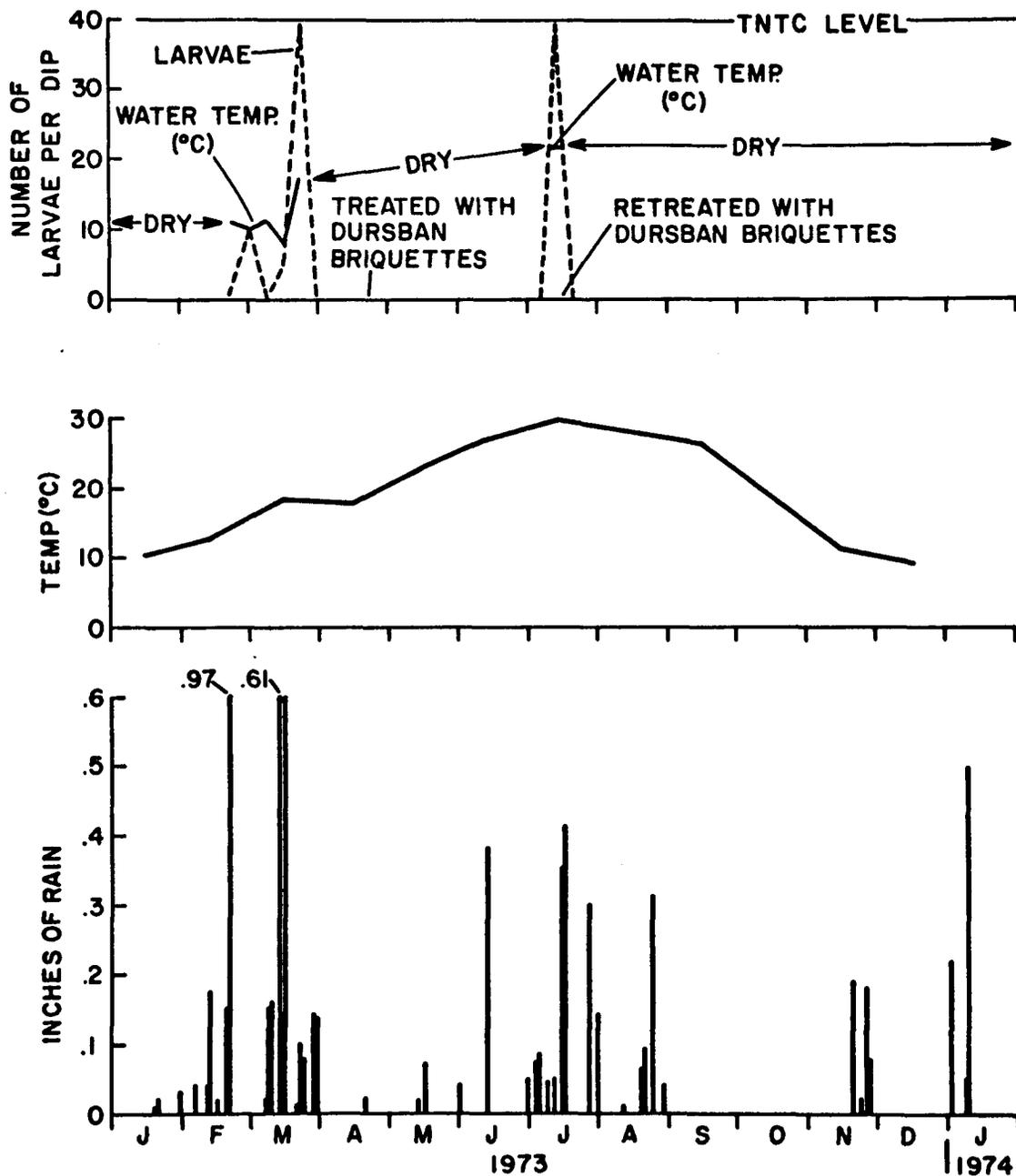


Figure 27. Number of mosquito larvae in test Site C versus mosquito larval control measures, breeding site water temperature, ambient temperature and rainfall.

chips were dead, whereas the larvae in the control beakers were active and without any apparent ill effects. This suggested that newly exposed surfaces of the broken briquettes were releasing insecticide whereas those surfaces previously exposed to water did not.

Figure 28 indicates the mosquito growth and control measures carried out at Site D. When the wash flooded in late March due to rainwater runoff (Figure 8), the site was treated with the small Dursban briquettes (0.4 kg) at a rate of 1,400 per hectare. The mosquito larvae were all dead within twenty-four hours. Within a week all the water had dried up and the briquettes were left in place in hopes of preventing further mosquito production at this site if further flooding by rains occurred. In early July the site reflooded, but as indicated in Figure 28, the mosquito larvae again went on to develop at TNC levels. This site was then retreated with the same size briquettes at the same rates and again all the larvae in the retreated areas were dead within twenty-four hours.

Site E, the Drexel Road Wash, Figure 9, had low levels of mosquito larvae growing in water pools during the months of March, April and May (Figure 29). To bring the production of larvae under control, large Dursban briquettes, 1 kg, were added to the waters at a rate of 355 per hectare. Again within twenty-four hours all larvae were dead. Within a week after treatment, this water had dried up and the briquettes were left behind hopefully to prevent further mosquito production. In July the area was reflooded and small numbers of P. confinnis were found breeding in the areas previously treated with

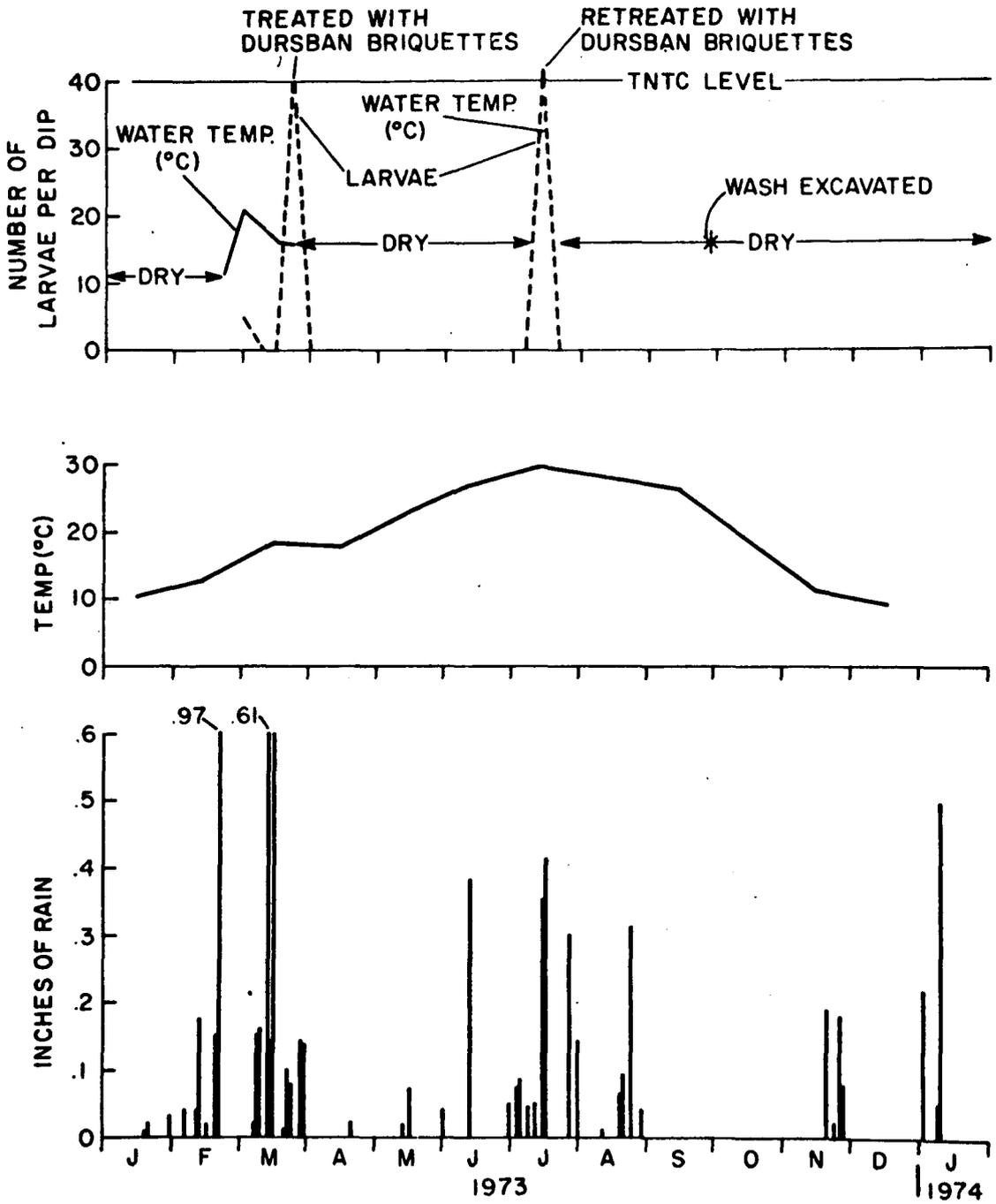


Figure 28. Number of mosquito larvae in test Site D versus mosquito larval control measures, breeding site water temperature, ambient temperature and rainfall.

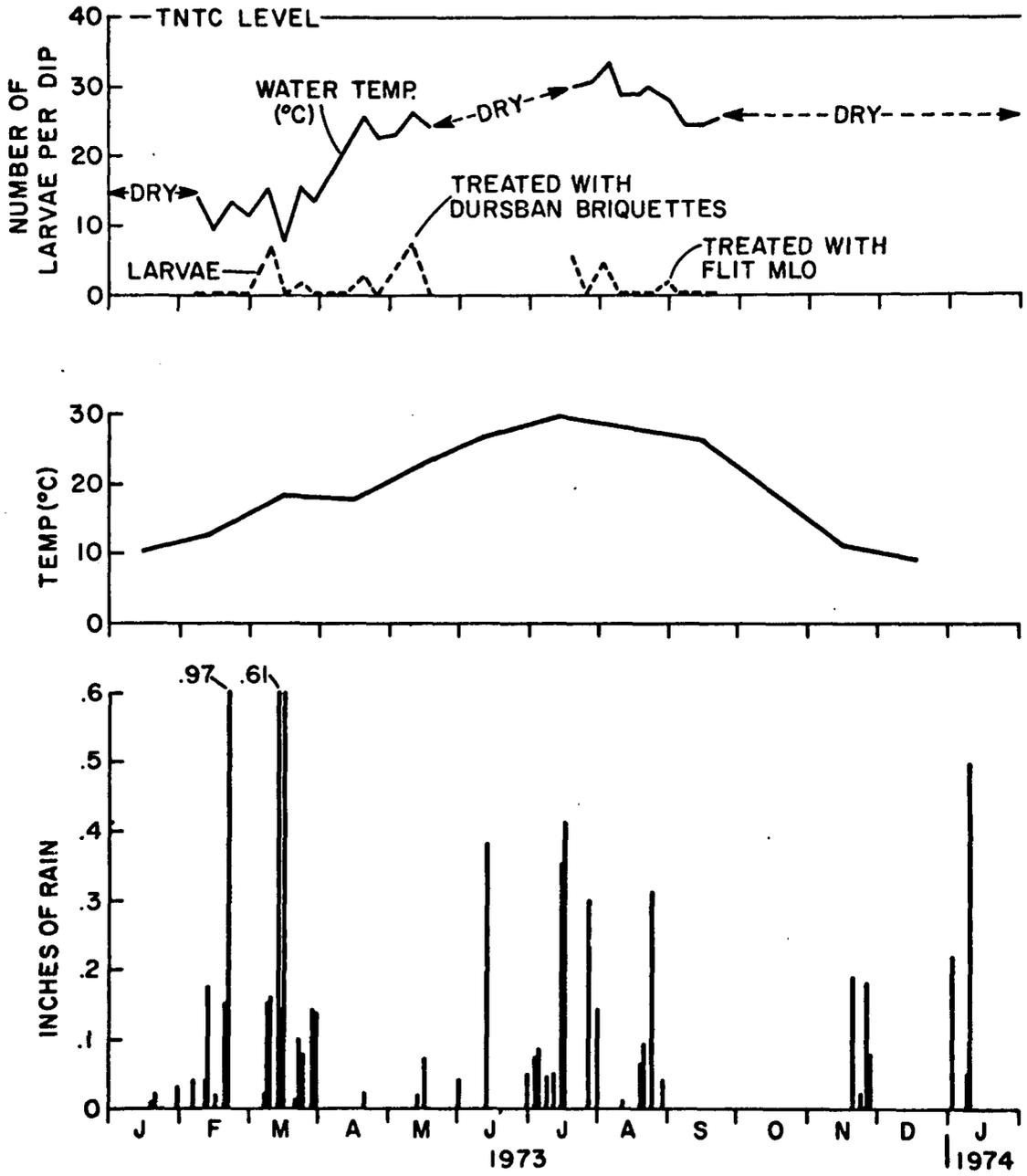


Figure 29. Number of mosquito larvae in test Site E versus mosquito larval control measures, breeding site water temperature, ambient temperature and rainfall.

the briquettes. In late August the pools of water were treated with Flit MLO and all larvae and pupae in the waters were dead within two hours after application of this material.

The numbers of mosquito larvae found at Site F are shown in Figure 30. At this location the numbers of larvae remained low to moderate in January, then as the water temperature rose in February, the larvae again reached the TNTC level and remained there. At the end of February, 80 G. affinis mosquito fish were added to the pond at a rate of 100 per hectare.

Within seven days after adding the fish to the water, larval dip counts dropped from TNTC per dip to only 3 per dip. Fourteen days post-treatment of the pond with the fish, the mosquito larval dip counts reached zero and remained at that level until the month of May. During April, a considerable amount of emerging grassy vegetation began to grow along the edges of the pond (Figure 10), giving mosquito larvae a protected area for growth where the mosquito fish apparently could not find them. However, during this period greater and greater numbers of fish were seen in the waters. By late May the emerging vegetation along the edges was found to have young fish infiltrating those areas. Apparently the pressure of sheer numbers of fish was enough so that by early June no more mosquito larvae could be found in the vegetation along the edges, but occasionally young fish were taken in the dipper when sampling for mosquito larvae. By August it was common to take 5 fish with each dipper of water along the edges

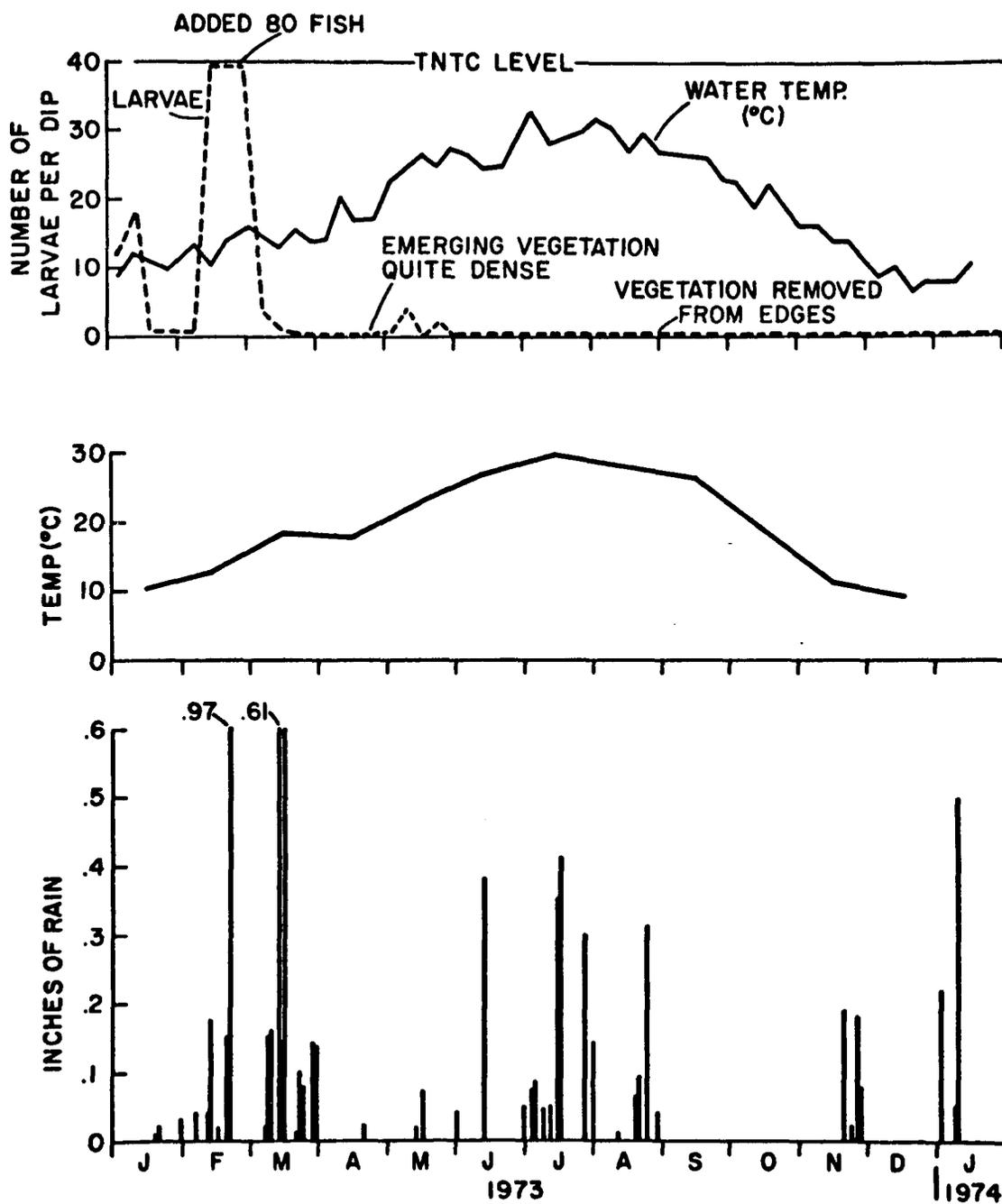


Figure 30. Number of mosquito larvae in oxidation pond test Site F versus mosquito larval control measures, breeding site water temperature, ambient temperature and rainfall.

while checking for mosquito larvae. Once the mosquito larvae were brought under control by the fish in late May, none were seen again in the waters for the remainder of the year.

The comparative numbers of mosquito larvae in the upper and lower ornamental fish ponds at Site I are indicated in Figures 31 and 32 respectively. As shown in Figure 31, the upper pond mosquito larvae were present in small numbers from January to June then dropped off to zero. Small numbers of mosquito larvae reappeared in October and remained for the rest of the year.

However, in the lower pool (Figure 32) identical populations of mosquitoes to those in the upper pool were present until May, when 5 fish were added. When the pool was checked the following week for mosquito larvae, none could be found then nor for the rest of the year.

Sentinel Barrel Mosquito Breeding Response to Control Treatments

Figure 33 indicates mosquito activity in the pair of barrels located at Site C near the University farm site. C. p. quinquefasciatus mosquito larvae first appeared in the barrels in early April and stayed at low levels until the end of that month, when they suddenly rose significantly and by mid-May reached the TNTC level. Barrel A was treated with 5 mosquito fish and barrel B was left untreated. The larval counts in barrel A dropped to 14 per dip one week later and to zero two weeks later. In contrast, the larval counts in barrel B stayed at the TNTC level except for a one week temporary drop to 15 larvae per dip in late June then immediately returned to the TNTC level.

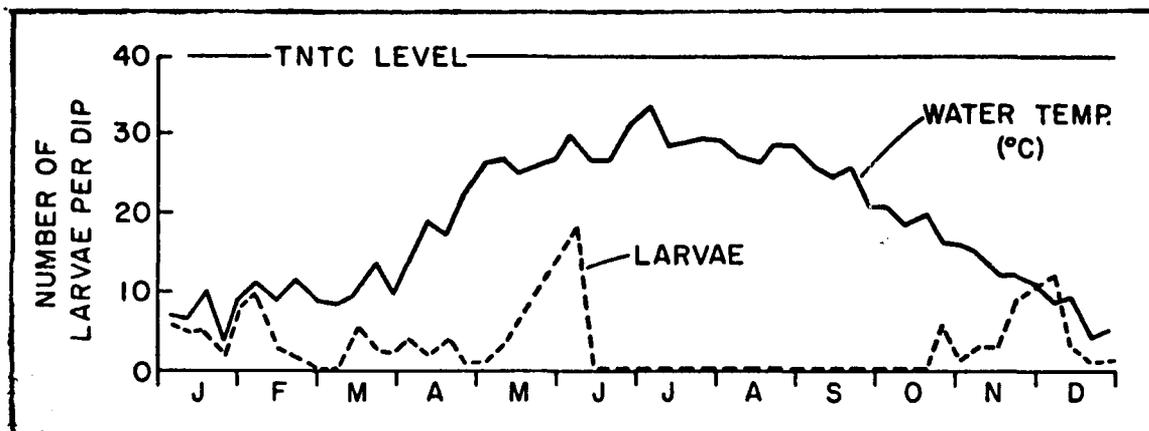


Figure 31. Number of mosquito larvae in the Site G upper ornamental fish pond versus the temperature of the water in the pond and mosquito larval control measures.

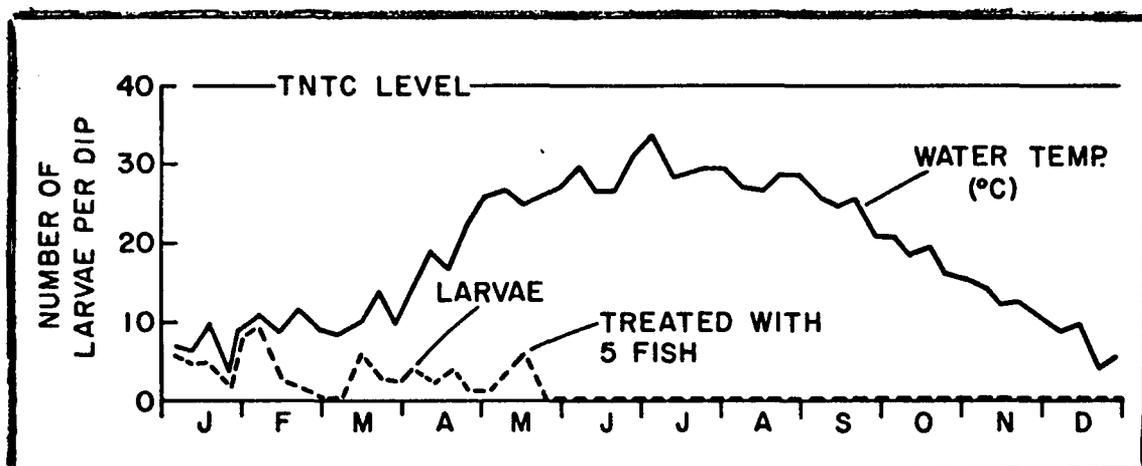


Figure 32. Number of mosquito larvae in the Site G lower ornamental fish pond versus the temperature of the water in the pond and mosquito larval control measures.

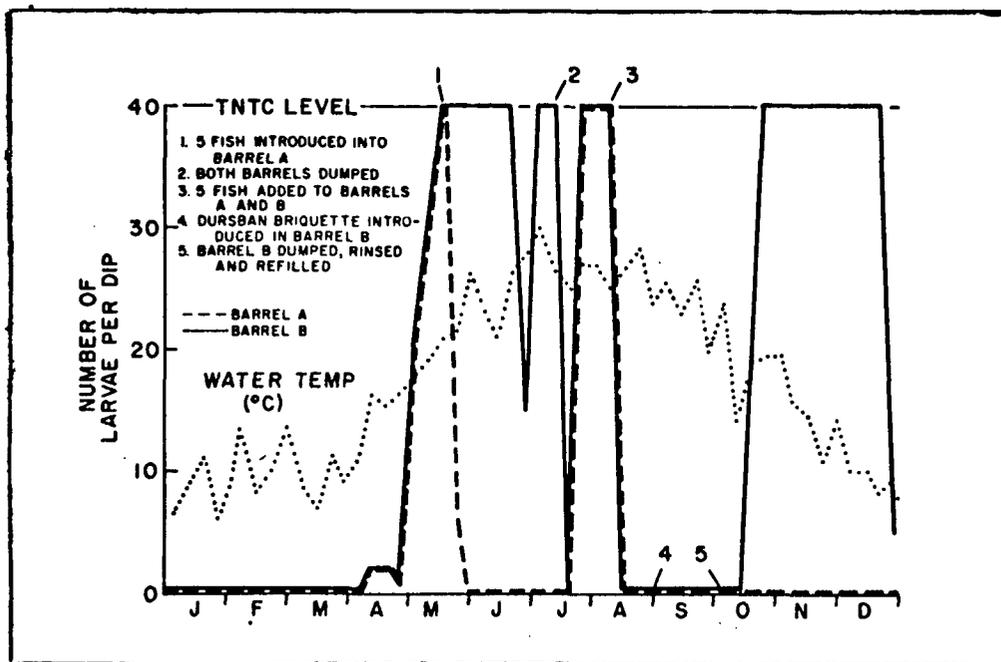


Figure 33. Number of mosquito larvae in the Site C sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.

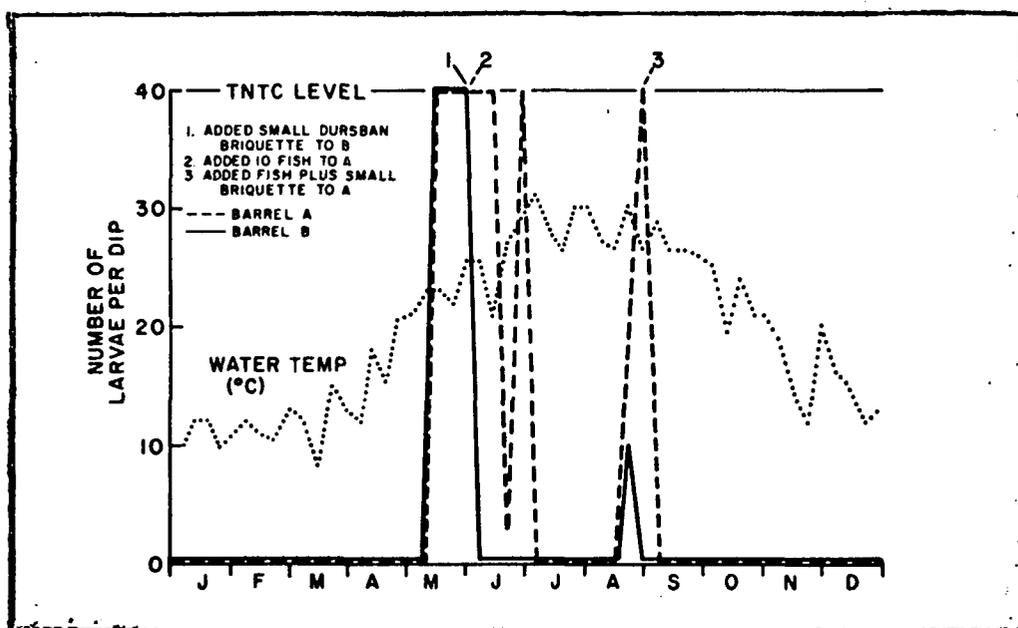


Figure 34. Number of mosquito larvae in the Site A sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.

In mid-July both barrels A and B were knocked over by vandals which resulted in the loss of water from both barrels and the fish that had been in barrel A. Both barrels were refilled with fresh water and by the following week, the mosquito larval counts in both barrels were again TNTC. Two weeks later when the larvae counts were still TNTC, 5 mosquito fish were added to each barrel. By the following week the larval counts in both barrels were zero.

Three weeks after the fish were added to the barrels, a small (0.25 kg) Dursban briquette was added to barrel B. Subsequent observations of fish in this barrel showed that they, like those in barrel A appeared quite active and healthy even though in the waters with the Dursban briquette. In early October, the water, fish and briquette in barrel B were dumped out and the barrel was rinsed with water then refilled with fresh water. Within one week, the C. p. quinquefasciatus mosquito larvae reappeared at the TNTC level and stayed at that level until late December when the numbers finally dropped.

The pair of barrels at Site A (Figure 34) showed no mosquito larvae until early May when their numbers rose from zero to the TNTC level within one week. After the counts had stayed at this level for two weeks, a small (0.25 kg) Dursban briquette was added to barrel B while 10 mosquito fish were added to barrel A. One week later no larvae were found in barrel B which contained the briquette, whereas larvae were still at the TNTC level in barrel A.

Except for a single occasion in late August when ten larvae per dip were taken one week, no larvae were found in barrel B. It is particularly interesting to note that although barrel B did not produce mosquito larvae, female mosquitoes continued to oviposit in the water in the barrel in great numbers. It was very common to take as many as 5 Culex mosquito egg rafts per dip when checking the barrels for larvae. These egg rafts were typically cream colored when freshly laid, then turned the normal brownish color. However, apparently due to the Dursban in the water, the egg rafts took on the appearance of mummification and turned black and rotten on the water surface.

In mid-August, a pack-rat climbed into barrel A, probably to get a drink of water. It apparently lost its footing and fell into the barrel of water and drowned. The rapidly decomposing body of the rat polluted the water, causing the fish to die. Although the carcass of the rat was removed when it was found, the lack of fish permitted mosquito larvae to become reestablished. Within two weeks the larvae in barrel A were again at the TNTC level.

At the end of August a small (0.25 kg) Dursban briquette and 15 fish were added simultaneously to barrel A. The fish were observed to immediately feed on both the egg rafts in the water and the young larvae. Within one week, and for the remainder of the season, no more larvae were seen in barrel A.

The two barrels at Site L (Figure 35) showed no mosquito activity until mid-April, when C. p. quinquefasciatus larvae were discovered at 6 per dip. From that time on, numbers of larvae continued to gradually

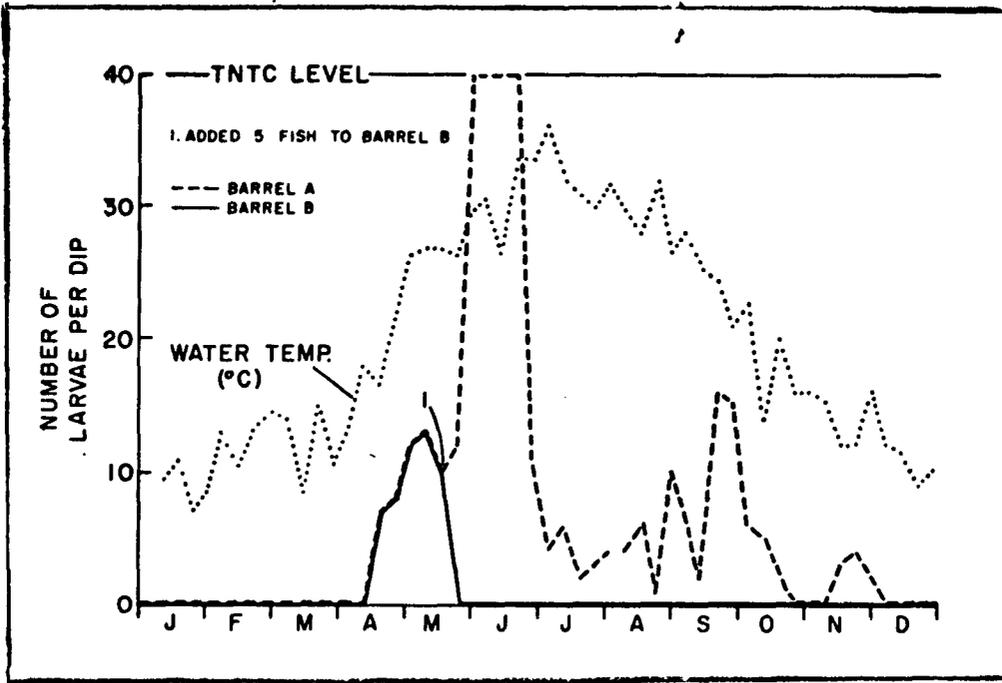


Figure 35. Number of mosquito larvae in the Site L sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.

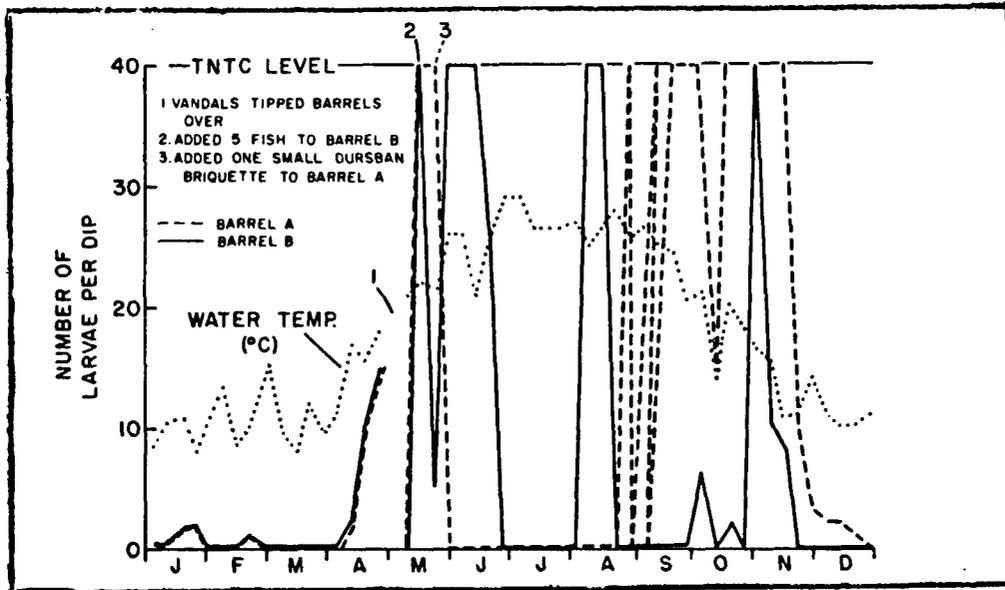


Figure 36. Number of mosquito larvae in the Site M sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.

increase until mid-May. At that time 5 mosquito fish were added to barrel B. The following week, the number of mosquito larvae in barrel B was zero whereas those in barrel A began to increase again.

For the remainder of the season no further larvae were noted in barrel B, while in barrel A varying numbers of larvae were seen until late December when the study was terminated. At that time, when the barrels were emptied, the fish in barrel B were still very active and appeared quite healthy.

Two barrels placed at the M Site, (Figure 36) had Culex mosquito larvae present within one week after they were set in place and filled with water. However, the number of larvae remained quite low until mid-April when they began to rapidly increase. Unfortunately, both barrels were tipped over by vandals in late April, so they had to be refilled and the observations resumed in early May. One week following the refilling of the barrels, mosquito larvae again appeared in both barrels, this time at TNTC levels. At that time 5 mosquito fish were added to barrel B and the following week a small (0.25 kg) Dursban briquette was added to barrel A.

As indicated in Figure 36, even though 5 fish were alive and healthy in barrel B, larval counts were often quite high apparently due to mosquito production rate in the barrel being greater than the fish consumption rate of the larvae.

When barrel A was treated with the briquette in late May, mosquito larval dip counts dropped to zero the following week and did not show any more larvae until a little over three months later

in August when larvae suddenly reappeared at the TNTC level. This was the shortest period of time the Dursban briquette maintained control of mosquito production in any of the barrels tested. When barrel B was emptied at the end of the study in December, all fish were found active and in apparently healthy condition.

Barrels set out at the N Site (Figure 37), showed very few mosquito larvae until September when Culex larval counts in barrel A reached the TNTC level while the counts in barrel B remained significantly lower. In late September, barrel A was treated with 1 cc of Flit MLO. One week later, and for the next four weeks, larvae counts in barrel A remained at zero, while those of barrel B continued at low levels.

Figure 38 indicates the mosquito activity in the two barrels at the O Site. Both barrels remained at the zero larval level until mid-April when the Culex larval counts began a slow steady rise in numbers. In late April, barrel B was treated with one small (0.25 kg) Dursban briquette. One week later the mosquito larval count was zero while that of barrel A remained at significant levels.

Five weeks after the briquette was added to barrel B, 15 fish were also added to the water. At the end of the study in December, all of the fish were found to be alive and healthy.

The two barrels at the P Site, (Figure 39) produced no Culex mosquito larvae until late May. When the larval dip counts reached 20 per dip, barrel A was treated with a small (0.25 kg) Dursban

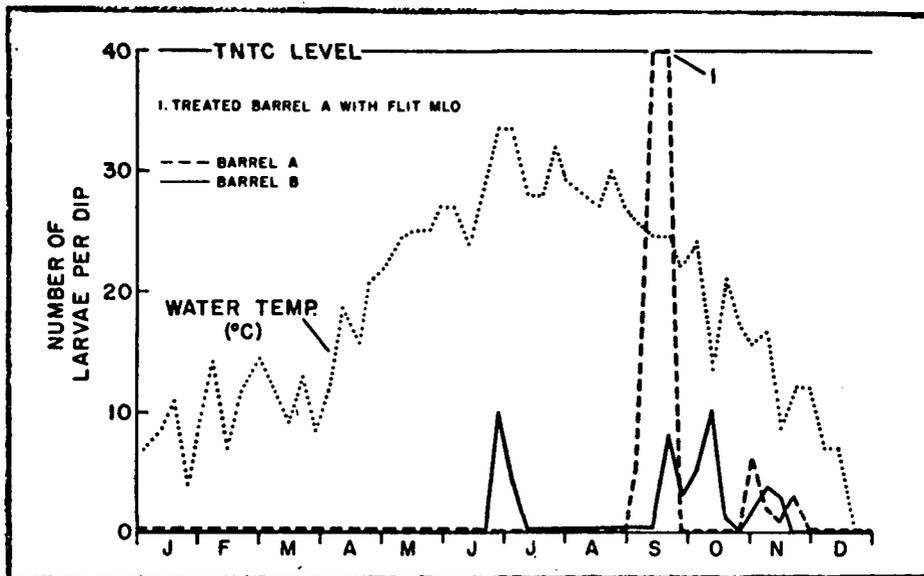


Figure 37. Number of mosquito larvae in the Site N sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.

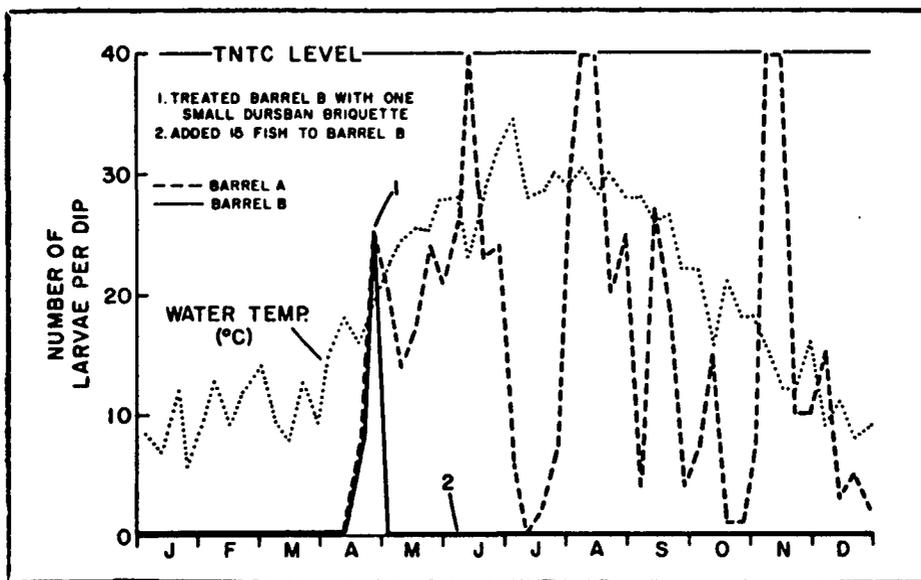


Figure 38. Number of mosquito larvae in the Site O sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.

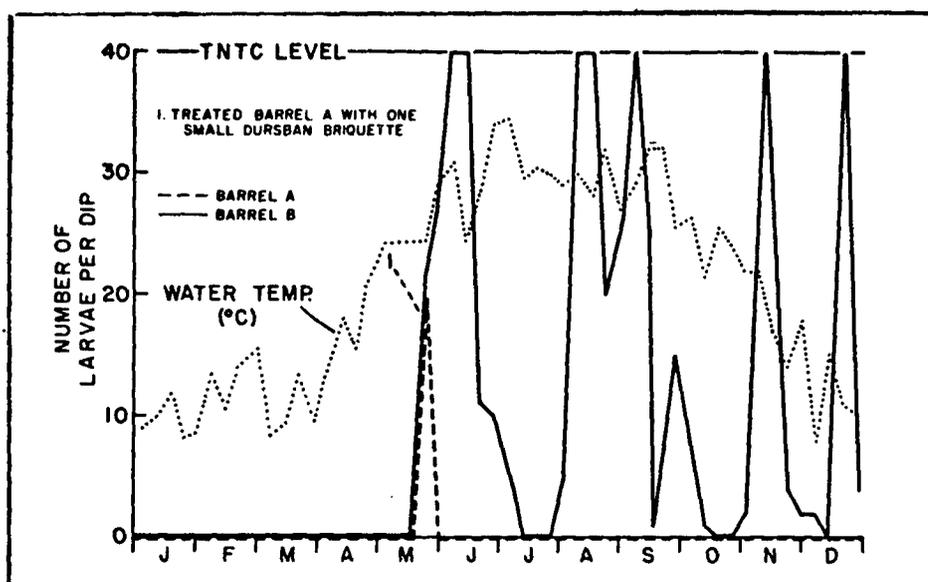


Figure 39. Number of mosquito larvae in the Site P sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.

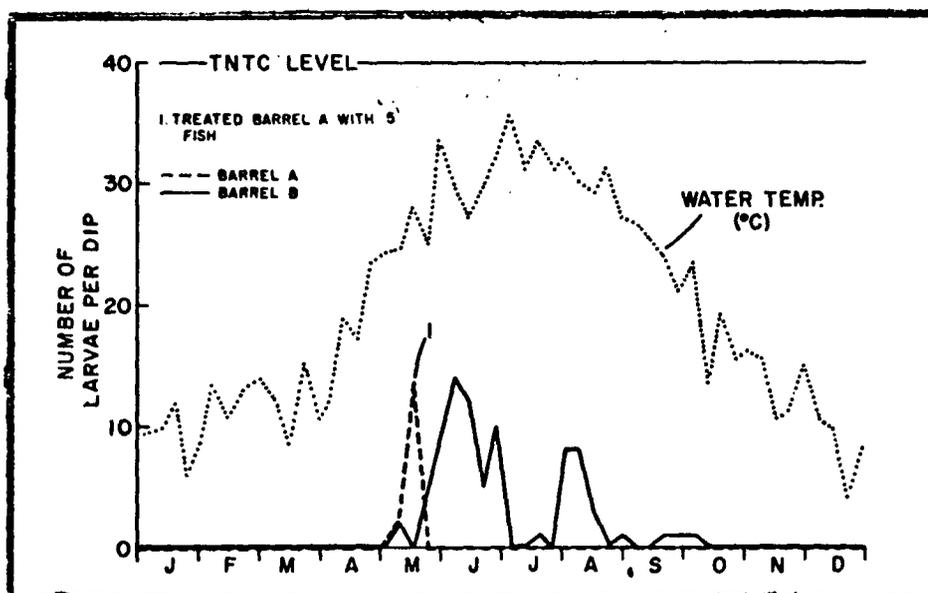


Figure 40. Number of mosquito larvae in the Site Q sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.

briquette. No further larvae were noted in barrel A for the rest of the year, whereas barrel B continued to produce varying numbers of mosquito larvae.

At the Q Site (Figure 40), C. p. quinquefasciatus larvae were first discovered in early May. Barrel A was treated with 5 mosquito fish in late May, when the larval count reached 13 per dip. No further mosquito larvae were noted in barrel A for the remainder of the year.

Numbers of Culex larvae in barrel B seemed to increase slowly until early July when the water temperature in the barrels reached 35.5°C. At that time, the larval dip counts dropped to zero. In late July, A. p. franciscanus larvae were found in barrel B. From then on, only Anopheles larvae were taken in that barrel for the remainder of the year.

It is most interesting to note that at the end of the testing period, all five fish in barrel A were still alive and healthy appearing even though the temperature of the water they lived in had varied from a low of 4°C to a high of 35.5°C during the year.

Figure 41 indicates the mosquito activity in the two barrels at the R Site. No mosquito larvae were noted in the barrels until late May. When the number of Culex larvae reached 20 per dip in early June, barrel A was treated with 5 mosquito fish. One week later the larval dip count had risen to the TNTC level. However, by the end of the second week, following the addition of the fish, the mosquito larval count was zero. At the end of the testing period

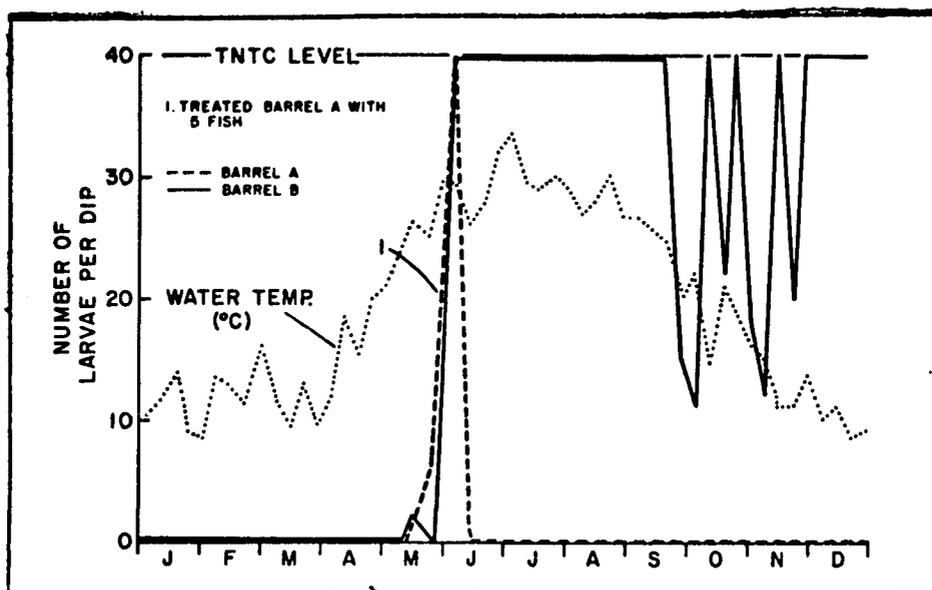


Figure 41. Number of mosquito larvae in the Site R sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.

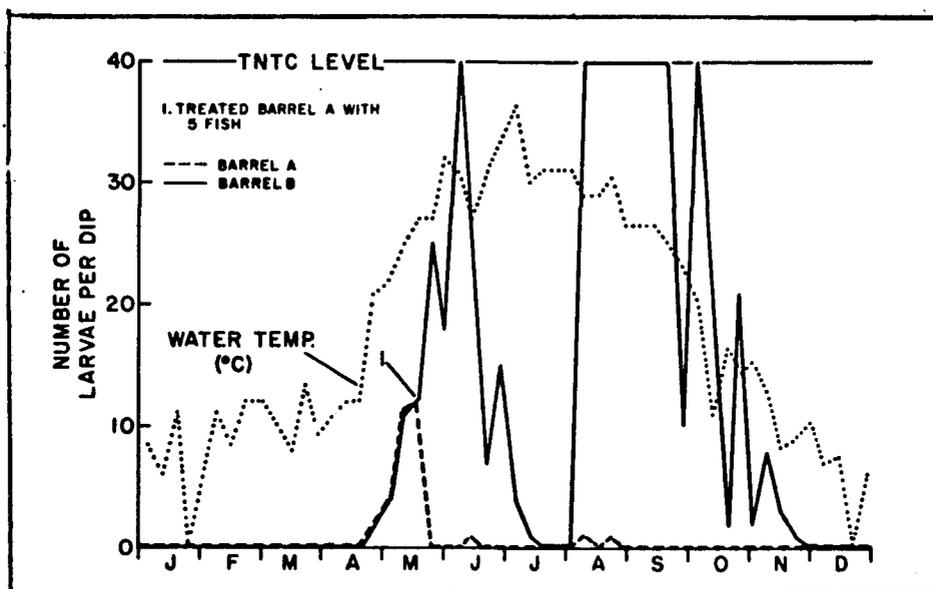


Figure 42. Number of mosquito larvae in the Site E sentinel barrels versus the temperature of the water in the barrels and mosquito larval control measures.

in December, the fish in barrel A were found to be alive and healthy. Larval counts in barrel B remained at the TNTC level almost all the rest of the year once they became established in May.

Two barrels at the E Site (Figure 42) were without mosquito larvae until late April, when Culex were discovered breeding there. When the larvae per dip count in barrel A reached 12 in May, 5 mosquito fish were added. By the following week the mosquito count in that barrel had dropped to zero and essentially stayed at that level for the remainder of the year, while the larval counts in barrel B continued, often at significantly high levels.

It is especially interesting to note that even though the water temperatures varied from a low of 0°C to a high of 36.5°C, the fish in barrel A survived and were quite active and healthy at the end of the study.

No mosquito larvae were found breeding in the G site barrels until late April. Within two weeks of the appearance of the first larvae in the barrels, their levels reached TNTC. When the larval counts were TNTC, 5 mosquito fish were added to each barrel. One week later the counts in barrels 6, 7, and 9 had dropped to 5 per dip whereas those of barrels 8 and 10 stayed at TNTC. The following week 5 more fish were added to barrel 8. As seen in Figure 43, the second treatment of barrel 8 brought its mosquito larval count to zero with that of 6, 7, and 9, while that of number 10 stayed at TNTC. At the end of June, 5 more fish were added to barrel 10 and the larval count dropped to zero with the others by the following

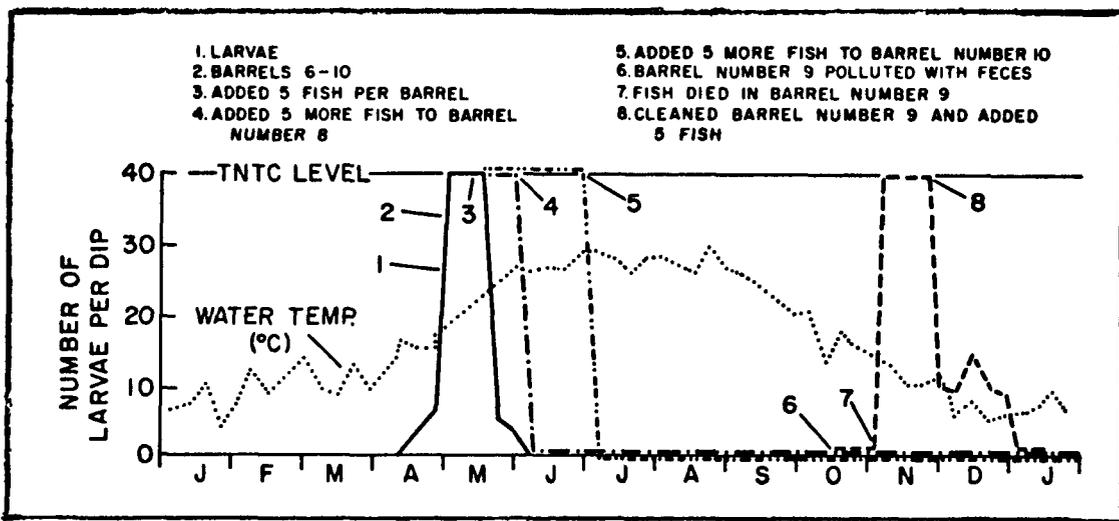


Figure 43. Number of mosquito larvae in the Site G water barrels correlated with the temperature of the standing water in the barrels and mosquito larval control measures.

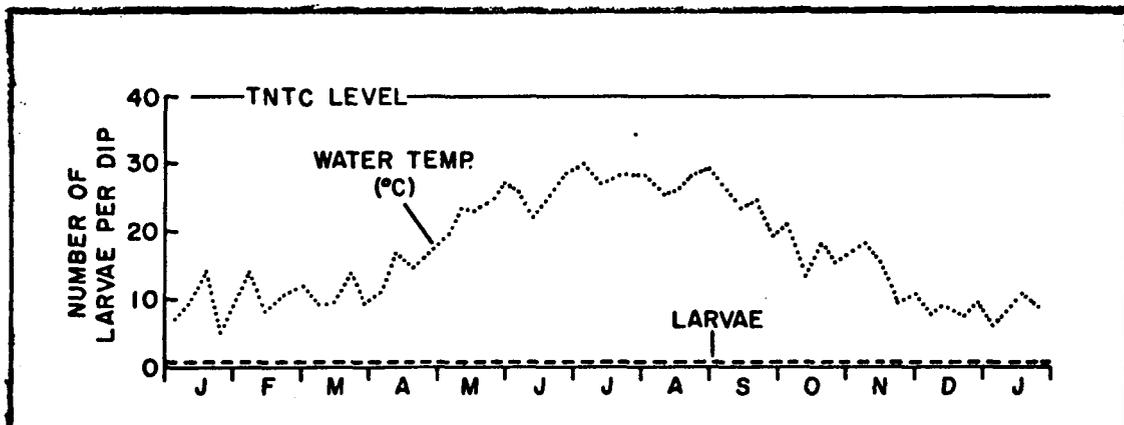


Figure 44. Number of mosquito larvae in the Site H water barrels versus the temperature of the fresh water added daily.

week. No further changes took place in any of the barrels until mid-October when the water in the barrel in stable number 9 was noted to be heavily polluted with horse feces. So severe was this pollution of the water that one week later the fish in that barrel were dead and floating on the surface of the water.

In early November, a week after the fish were found dead in number 9 barrel, mosquito larvae appeared and immediately reached the TNTC level again. The managers of the stables were advised of the return of the mosquitoes to the subject barrel because of the polluted water and subsequent death of the mosquito fish. Two weeks later, the polluted water was removed from barrel number 9 and fresh water, and 5 more fish were added. Four weeks later, all the barrels including number 9 had zero counts of larvae (Figure 43).

Clearly in contrast to the non-emptied water barrels at Site G the water barrels at Site H were emptied daily and refilled with fresh, clean water. As noted in Figure 44, not a single mosquito larva was taken from the H site water barrels during the entire year.

Due to the fact that mosquito breeding sites in cities like Tucson are relatively small, discontinuous or isolated, most mosquito control can be carried out through utilization of source reduction techniques. All of these techniques would have to do essentially with environmental sanitation, proper management of water, maintenance

of ditches, avoidance of overwatering and permitting water to drain from areas where it would otherwise accumulate and stand following rains.

Mosquito breeding was substantially reduced at Site F, the Miracle Mile sewage lagoon, merely through removal of the vegetation along the edges. Figure 45 is a view of the same pond as shown in Figure 10, except the emerging vegetation along the edge has been removed. The removal of the vegetation not only eliminated the shaded mosquito breeding site along the edge, but also permitted fish unobstructed access to any mosquito larvae that might have been there.

Figures 46 and 47 are the same views of the former mosquito breeding site indicated in Figures 6 and 7 respectively. Through a conscientious and extensive effort on the part of the University, rainwaters now collect at the University dairy farm in a large open recess where the waters can be treated with oil or stocked with fish, thus completely obviating mosquito breeding at this site.

An extremely large mosquito breeding site on the east side of Tucson had been unintentionally created in an effort to collect rainwater for agricultural purposes (Figure 48). Growth of the city out to and around this site not only resulted in discontinued use of the water for agriculture, but also caused a large mosquito breeding site to be located in a newly created residential area. The mosquito problem on this site was completely eliminated (Figure 49) by re-opening the natural waterway, a wash, to permit the water to drain off to the larger nearby wash.



Figure 45. Sewage lagoon after the edge vegetation was removed.

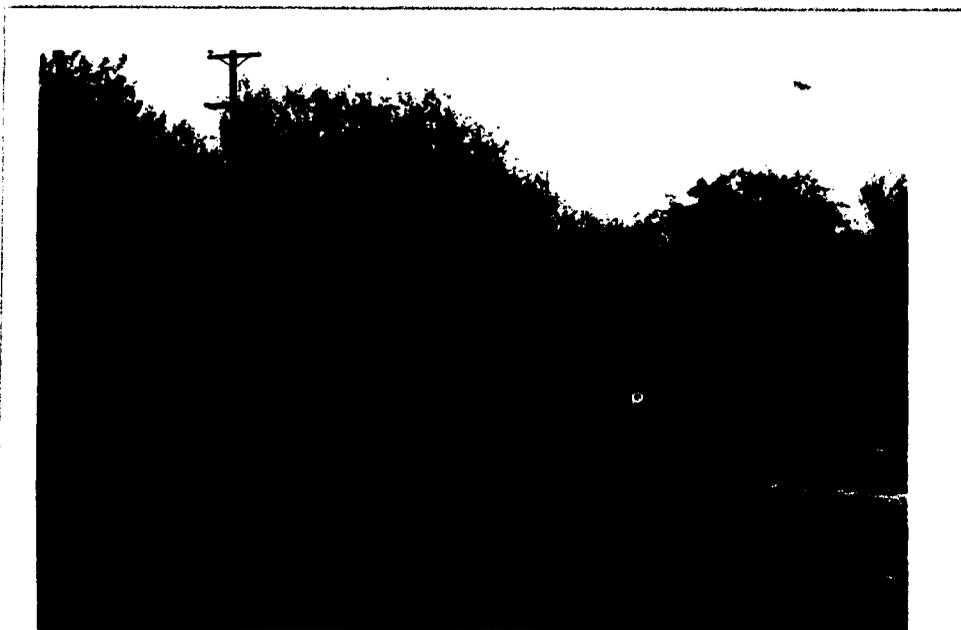


Figure 46. Site C - former mosquito breeding site looking northeast.

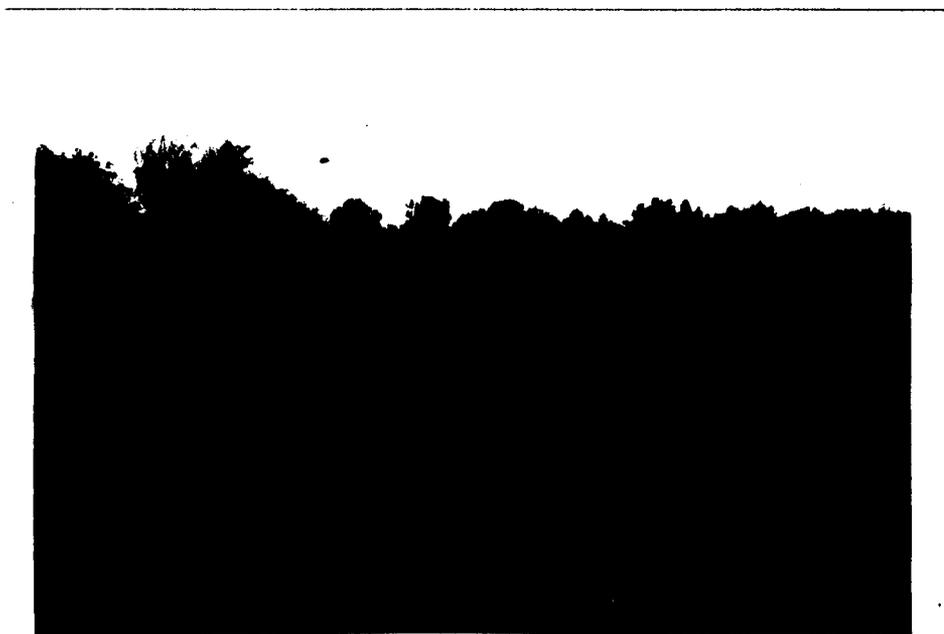


Figure 47. Site C - former mosquito breeding site looking east.

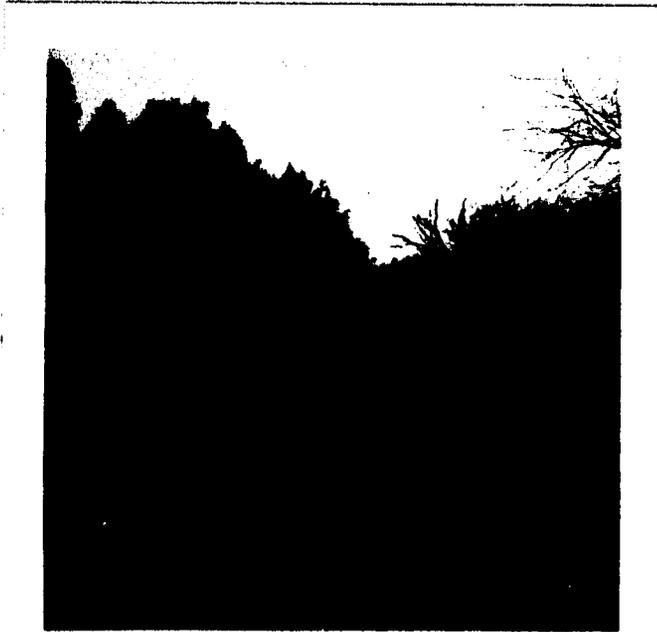


Figure 48. Rainfall collecting site formerly used for agricultural purposes which became a major mosquito breeding site.

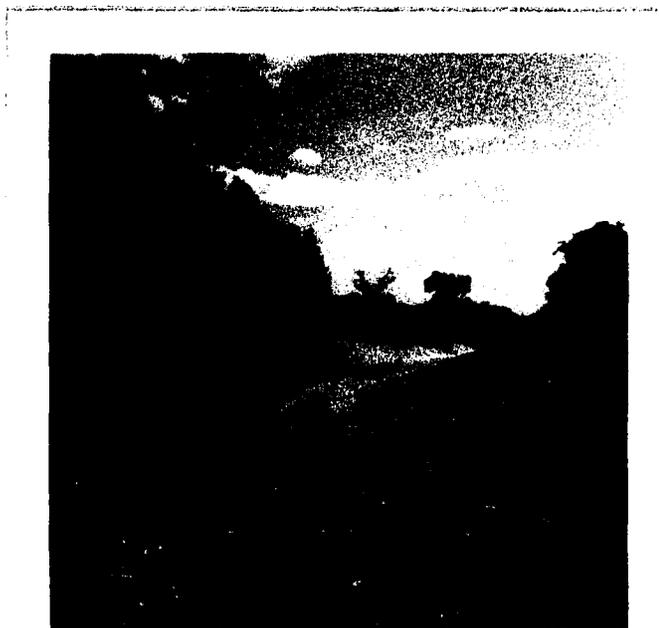


Figure 49. Mosquito breeding site completely and permanently eliminated by reopening the natural drainage system.

Improper maintenance of irrigation ditches was found to be a most common problem causing mosquito breeding sites around Tucson. Figure 50 shows a concrete lined ditch that was improperly maintained. The same ditch (Figure 51) three months later was cleaned and free of aquatic mosquito forms.

One of the most common types of mosquito breeding sites encountered in Tucson was due to overwatering. As indicated in Figure 52, water for the school lawns was so excessive that pools of water, where mosquitoes were found breeding, formed over extensive areas and caused them to be so wet the grass could not be mowed. Figure 53 shows the same area one week later after proper lawn water management was brought into play, and mosquito breeding site pools had dried up and the soil was dry enough to permit mowing the grass.

The extensive mosquito breeding site indicated in Figure 8 was a result of blocking a natural drainage way and compounded by a nearby dike designed to facilitate water seepage into the ground to recharge the underground water system. This same area as seen in Figures 54 and 55 clearly indicates that by reopening the natural drainage way, the previous mosquito breeding site was totally eliminated.

Some of the most common mosquito breeding sites in and around the city are in the roadside ditches where water stands following rains. One of these roadside breeding sites is indicated in Figure 56. Due to an on-going street and road improvement program carried on by the city and county, many of these mosquito breeding sites are controlled or eliminated by merely keeping the ditches open and weed free



Figure 50. A concrete lined irrigation ditch improperly maintained.



Figure 51. A concrete lined irrigation ditch properly maintained.



Figure 52. Overwatering of lawn produced a mosquito breeding site.



Figure 53. Mosquito breeding site completely eliminated by proper management of lawn watering program.



Figure 54. Mosquito breeding site at Site D, after excavation, looking southwest.

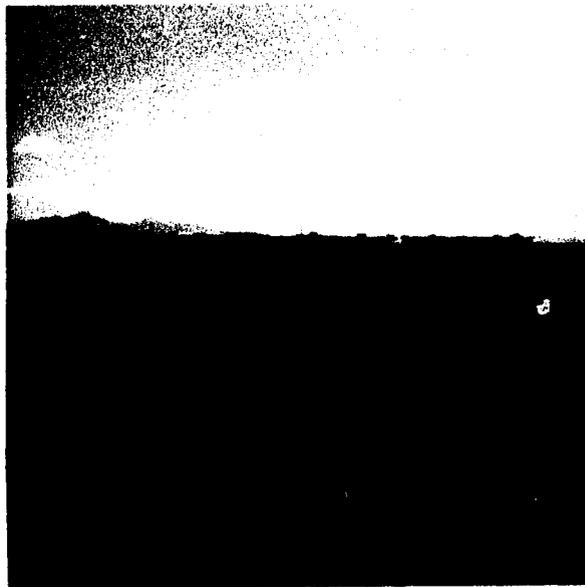


Figure 55. Mosquito breeding site at Site D, after excavation, looking south.

by scraping. As seen in Figure 57, the mosquito breeding site in Figure 56 was eliminated by merely keeping the roadside ditch scraped clean of vegetation.

Much of the actual surveillance for mosquitoes in a city such as Tucson is, in effect, carried out by the citizen. As indicated in Figure 58, the resident provides information about mosquitoes presence in the form of a complaint. Interaction between the resident and County government, with subsequent mosquito control, generates not only information flow and feedback, but also promotes and develops a high level of mosquito control.



Figure 56. Mosquito breeding site created by water standing in roadside ditch with vegetation growing in it.

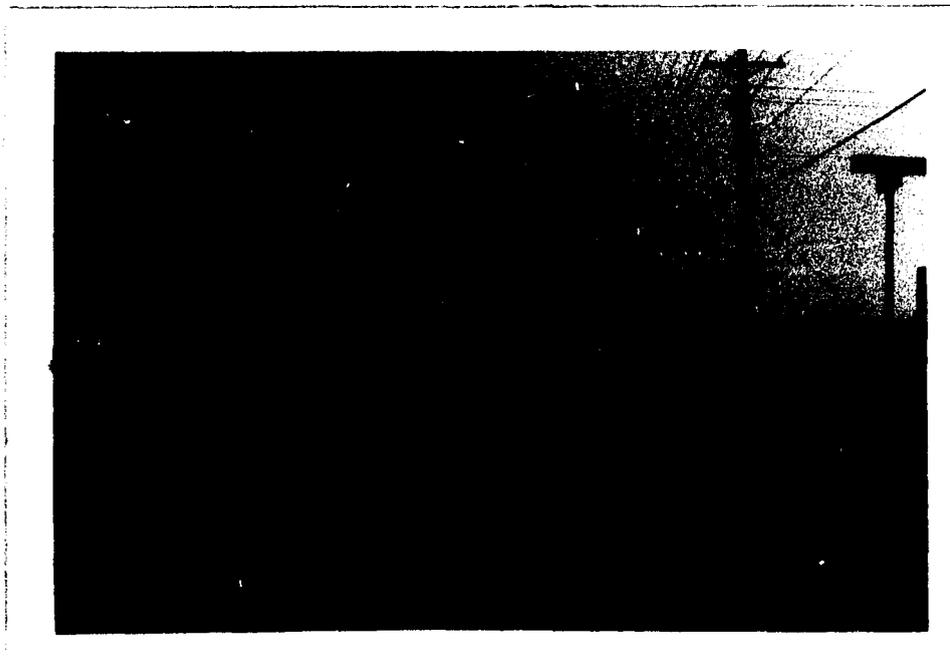


Figure 57. Mosquito breeding site in roadside ditch completely eliminated by scraping the ditch and removing vegetation.

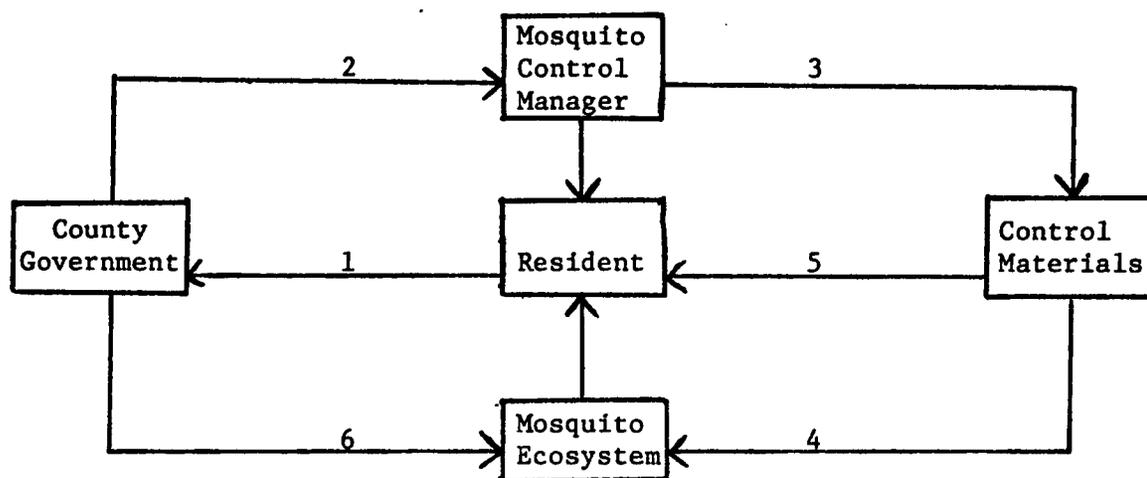


Figure 58. Information Flow and County Mosquito Control and Management Network

1. Complaint to County Government
2. County Government alerts mosquito control manager
3. Mosquito control manager makes control decisions
4. Application of control techniques
5. Information feedback to residents
6. County Government responsible for mosquito control
7. Reduction in number of pest mosquitoes affecting residents
8. Information feedback to residents

Miscellaneous Experiments

To elucidate the effects of selected insecticides on various stages of mosquitoes, the following studies were conducted in the laboratory.

Effects of Dursban released from briquettes on *Culex pipiens quinquefasciatus* mosquito larvae, pupae and adults. The pupal stage of mosquitoes is one of the least studied of the four stages of this all-important insect. Perhaps the reason for such limited attention to the pupa is because, for most species, it usually exists for only two or three days. Nevertheless, the mosquito must pass through this second aquatic stage to become an adult. This is the last stage in the mosquito's life cycle when man can exert control measures on this blood sucking insect before it takes wing.

Most culicidologists who have studied the pupa are rather awestruck by what they see. Wesenbug-Lund (1921) considered the mosquito pupae as "peculiar" because it is so very active at times. As pointed out by Bates (1965), the mosquito pupa is indeed unusual because it is not the stage of aestivation as in other insects; on the contrary, the mosquito hibernates or estivates as an egg, larva or adult. This same author goes on to point out that even though the mosquito pupa is quite active, it has no means for taking food due to vestigial mouthparts.

McDonald and Dickens (1970) observed that, when waters which contained mosquito larvae and pupae were treated with Dursban briquettes, the larvae died, the pupae remained apparently unaffected, and the adults appeared to die during emergence. To examine this suggestion, several experiments were carried out to determine if only mosquito larvae and adults are killed by the Dursban in the water, and the pupae left unharmed.

Methods and Procedures: Experiment I

Specimens of *C. p. quinquefasciatus* mosquitoes were obtained locally from standing pools of polluted water in Tucson. Since males and females are essentially indistinguishable in the larval and pupal stages, these aquatic forms were taken at random from the breeding sites and brought back to the laboratory.

Aquatic mosquito forms were placed in 250 ml beakers containing 200 ml of water from the mosquito breeding site. Each beaker of water contained 50 larvae and 50 pupae at the beginning of each test. After placing the aquatic forms in the water, a chip of a Dursban briquette, weighing 0.40 g, was added to each beaker. This dosage rate of 0.0024 cc of Dursban per beaker was equivalent to 1100 g per hectare. Treated and untreated beakers were then placed in one foot cube rearing cages for observation.

Beakers were observed at hourly intervals. Larvae were considered dead when they sank to the bottom of the beaker. Pupae were considered dead if they did not move when irritated with a needle probe. Table I indicates the findings of these experiments.

Discussion: Experiment I

Pupae are commonly found at the surface of the water, passively floating there because they are lighter than water. This buoyancy is caused by an air pocket in the thoracic region (Swammerdam, 1758). According to Brumpt (1941), this air pocket is an enclosure which forms between the integument of the pupa and the developing adult. Roubaud (1932), indicates that in the pupal stage, preexisting muscles from the larvae are broken down and completely new ones come into existence. Likewise, Richins (1938) revealed that, during this period of transformation, an entirely new midgut is produced as the old larval midgut degenerates. Probably the strongest evidence of intense transformation in the mosquito pupal stage is reported by Clements (1963), who noted that the entire hindgut of the larva is converted to the hindgut of the adult in only 12 hours. The newly formed pupa is light in color, becoming increasingly darker as it develops. This darkening, according to Thompson (1905), is due to the formation of scales between the imaginal and pupal integuments. This space between the two integuments, according to Brumpt (1941), becomes filled with air. In a sense the developing adult is wrapped in an envelope of air, insulating it from the outer integument of the pupa.

As the emergence takes place, the mosquito transforms from the aquatic state to the aerial stage. The floating split pupal case acts as a resting pad for the emerging adult. The mosquito places its two

hind legs on the pupal skin while the four forward legs rest on the water surface (Horsfall, 1972).

Mosquito "source reduction" control programs using insecticides to kill the aquatic stages are usually directed toward larvae because pupae are apparently unaffected by most materials used. Horsfall (1972) suggests that the pupal "resistance" may be due to the double wall surrounding the pupa disallowing chemical penetration to the organism.

Conclusions: Experiment I

These findings with respect to the protective capacity of the pupal integument were completely in concert with those suggested by Horsfall (1972). Apparently the double wall barrier and/or the air layer between is a very effective protector-insulator for the pupae even when Dursban is used in the water. However, the protective mechanisms of the pupal integument were insufficient to protect the emerging adult which apparently picked up a lethal dose of Dursban through the fore- and midleg tarsal integument as the adult stood on the surface of the water during emergence.

TABLE I Affects of Dursban Briquettes on C. p. quinquefasciatus Larvae, Pupae and Adults.

Time Lapse	Beaker A treated	Beaker B untreated (control)	Beaker C treated
4 hours	larvae settling to bottom pupae: no change	larvae: no change pupae: no change	larvae: settling to bottom pupae: no change
16 hours	larvae: all dead pupae: no change adults: dead or dying on water surface and cage floor	larvae: no change pupae: no change adults: hatching and flying about in cage	larvae: all dead pupae: no change adults: dead or dying on water surface and cage floor
48 hours	pupae: all hatched adults: all dead on water surface or cage floor	larvae: 4 remained pupae: 16 remained adults: all alive and flying about in cage	pupae: all hatched adults: all dead on water surface or cage floor

Responses of *Culex pipiens quinquefasciatus* eggs, larvae, pupae and adults to additions of Flit MLO to their breeding site water. One of the most promising insecticides of recent years is the Exxon Oil Company's product, Flit MLO. The usefulness of this material has been well established for safe mosquito control without danger to non-target fauna and flora after application. Because many of Tucson's mosquitoes apparently come from stock watering troughs, studies were conducted to determine how effective Flit MLO may be for these local problems.

Methods and Procedures: Experiment II

Specimens of *C. p. quinquefasciatus* mosquitoes were found breeding in ground pools of polluted, as well as in barrels of, standing water. The first tests were conducted in barrels of water which contained all stages of developing mosquitoes, including eggs. Temperature of the water was 26.7^o C. Two barrels of water, which contained aquatic forms of mosquitoes, were used for each test. One was for the tests while the other was a control. Larval counts were TNTC. In addition to larvae, the waters contained 5-6 mosquito egg rafts per dip. One milliliter of Flit MLO was dripped onto the surface of the water in the barrels.

To permit an unobstructed view of the action of the Flit MLO on the aquatic forms of the mosquitoes, eggs, larvae and pupae, were brought into the laboratory and placed in 250 ml beakers containing 200 ml of water from the mosquito breeding sites. Each beaker

contained ten larvae, ten pupae and six egg rafts. After placing the mosquitoes in the water, 0.2 ml of Flit MLO were added to the test beakers. The beakers were then placed in one-foot-cube rearing cages for observation. Tables 2 and 3 indicate the findings of these experiments.

Discussion: Experiment II

Other investigators have reported similar findings with respect to the toxic action of Flit MLO on larvae and pupae. However, none are known to have noted the activity of this material on mosquito egg rafts. The rapid dispersal of the Flit to the edges of the containers caused the larvae and pupae to immediately detach and drown with subsequent death often observed in as little as 2-3 minutes, but never showing signs of life beyond 20 minutes after application of the Flit.

It was most interesting to note that as the oil spread over the water surface, egg rafts were likewise affected. Those in the middle near the point of application in the barrels and beakers were affected first. Instead of the Flit going around the egg rafts, as was expected, it spread across the water surface to the eggs. The egg rafts suddenly seemed to lose their hydrophobic properties and become progressively wetter. The wetting action of the egg rafts was similar to the movement of water in a dry paper napkin. When the entire egg raft became wet, it settled into the water just below the surface but did not sink deeper. This entire action was completed within 30 seconds of when the Flit was applied to the water surface. Forty-eight hours after the Flit was

applied to the water, the eggs were rotted and disintegrated with none observed to hatch. The reason why the adult mosquitoes failed to rest on the water surface for purposes of laying eggs or otherwise is not clear. Perhaps future research in this area will explain this phenomenon.

Conclusions: Experiment II

The findings of these experiments clearly indicate that Flit MLO, in addition to rapidly bringing mosquito larvae and pupae under control, due to its surfacant properties, also leads to the death of those mosquitoes still in the egg stage.

TABLE II Affects of Flit MLO on C. p. quinquefasciatus Eggs, Larvae, Pupae and Adults in Barrels of Water.

Time Lapse	Barrel A (Treated)	Barrel B (Control)
15 seconds	Larvae and pupae detached from surface, larvae appear to be biting the end of their siphons; egg rafts beginning to get wet, no adults on water surface.	Larvae and pupae, no change; eggs, no change; adults resting on the water surface.
30 seconds	Some larvae and pupae rise to, but immediately withdraw when in contact with, the surface; eggs resting just below the water surface; no adults on water surface.	Larvae and pupae, no change; eggs, no change; adults resting on the water surface.
5 minutes	Larvae and pupae wriggling below water surface; eggs remain just below the water surface; adults appear to be repelled by water surface.	Larvae and pupae, no change; eggs, no change; adults resting on water surface.
20 minutes	Larvae and pupae dead; eggs, no further change.	Larvae and pupae, no change, eggs, no change.
48 hours	Larvae and pupae dead, eggs rotting and falling apart; no adults resting on the water surface.	Pupae hatching; egg rafts hatched; adults resting on water surface.

TABLE III Affects of Flit MLO on C. p. quinquefasciatus Eggs, Larvae, and Pupae in the laboratory.

Time Lapse	Beaker A (Treated)	Beaker B (Control)
15 seconds	Larvae and pupae detached from surface; larvae appear to be biting the end of their siphons; egg rafts beginning to get wet.	Larvae and pupae, no change; eggs, no change.
30 seconds	Some larvae and pupae rise to the water surface but immediately sound when they touch it; eggs resting just below the water surface.	Larvae and pupae, no change; eggs, no change.
5 minutes	Larvae and pupae wriggling on beaker bottom; eggs remain just below the water surface.	Larvae and pupae, no change; eggs, no change.
20 minutes	Larvae and pupae dead; eggs no further change.	Larvae and pupae, no change; eggs, no change.
48 hours	Larvae and pupae dead; eggs rotting and falling apart.	Pupae hatching; larvae pupating; eggs hatched.

SUMMARY AND SUGGESTIONS

Incidence of biting mosquitoes in the semi-arid areas, as represented by Tucson, Arizona, is a function of temperature and rainfall. Although eight different species of mosquitoes were collected during the year (Psorophora signipennis, Psorophora confinnis, Aedes vexans, Culiseta inornata, Culiseta incidens, Anopheles pseudopunctipennis franciscanus, Culex pipiens quinquefasciatus and Culex tarsalis), biting mosquito problems and subsequent mosquito complaints were associated with only three of these, P. signipennis, P. confinnis, and A. vexans. All of these pest mosquitoes are flood water mosquitoes which are produced in their respective breeding sites in astronomical numbers when required temperature and rainfall for flooding occur.

The most common and omnipresent mosquito found in Tucson throughout this study was C. p. quinquefasciatus. This mosquito was found breeding in large numbers in watering troughs, sewage lagoons, overwatering sites, fish ponds, ground pools and artificial containers. None of the complaints of biting mosquitoes were caused by this species. This species is normally anthropophilic in nature, however in this locality it is suspected to be zoophilic. The number of larvae and pupae in breeding sites consistently failed to be reflected in light trap catches. These findings are similar to those of Muirhead-Thomson (1968), who found that when Anopheles mediopunctatus and

Anopheles shannoni in Brazil were found nearby in pools, they could not be readily found in homes or on exposed bait at ground level.

The lack of adult C. p. quinquefasciatus mosquitoes in the light traps may be due to a deficient ecological requirement. As pointed out by Corbet (1961) and Standfast (1965), mosquitoes are phototactically attracted to light traps only if they are not engaged in other biological activities such as feeding, mating or laying eggs.

Significant mosquito control can be realized in many of the mosquito breeding sites where standing water is permanent or semi-permanent if mosquito fish, G. affinis, are stocked in such waters. The effectiveness of these fish for mosquito control is directly related to their numbers. When stocked with adequate numbers of these fish, even oxidation ponds and natural ground pools remain completely mosquito free. In instances such as watering troughs, they too can remain mosquito free if they are stocked early enough in the season before the buildup of the mosquito population. In watering troughs which have large populations of mosquito larvae when the fish are added, the mosquitoes often reproduce faster than the fish can consume them. Additions of Flit MLO to the water immediately reduces the mosquito population to permit the fish to then maintain control. The "Fish and Flit" technique is a highly effective means to bring large numbers of mosquitoes under control rapidly and keep them under control without the need of exposing

livestock to toxic insecticides. Mosquito fish showed no ill-effects when in waters with Dursban briquettes at recommended dosages. Thus in areas where mosquitoes must immediately be brought under control while waiting for the number of fish to increase the "Dursban and Fish" technique may be used.

Treatment of flood water mosquito breeding sites with Dursban briquettes in the alkaline soils typically found in the semi-arid southwest is contraindicated. Apparently alkalinity of these soils deactivates or neutralizes the slow released toxic qualities of this material on mosquitoes.

An interesting technique for helping to bring under control stagnant water breeding mosquitoes, such as C. P. quinquefasciatus, is the use of barrels of water which contain a Dursban briquette. In effect, these oviposition sites, "Judas barrels", act as dead ends for all the offspring of the female depositing her eggs there.

Since breeding sites for many, if not most, of the flood water mosquitoes were created by man's interference of natural drainage ways, control of these mosquitoes is best effected by source reduction techniques through physical alteration of the habitat. Such alterations include reopening of natural water drainage ways and modification on non-draining dikes.

Production of mosquitoes in Tucson's roadside ditches will continue to be thwarted by road graders which remove vegetation as they maintain those sites. Efforts to keep irrigation ditches open will not only prevent them from being mosquito breeding sites, but will also keep them functional.

Increased awareness and development of mosquito consciousness by residents of Tucson will help avoid the creation of mosquito breeding sites by over watering while conserving water.

For an effective and efficient mosquito control program to be maintained in a city such as Tucson, time and emphasis must be placed on controlling the mosquitoes at their breeding site (source reduction). This may entail draining and filling of low areas or additions of mosquito-fish or oil to the surface of permanent standing pools and ponds of water. Most unfortunately, the average citizen is more concerned with destruction of adult mosquitoes on his property than all other phases of mosquito control combined. It is difficult, indeed, to get the taxpayer interested in source reduction programs which he seldom knows are underway. Studies conducted by Meisch, Lancaster and Meek (1971), Meisch, Lancaster and Coombes (1973), and Lee, Meisch and Lancaster (1971), showed that mosquito control programs can be very effective on a community basis even if the community is located in a rice-growing area of Arkansas. Nevertheless, these authors admitted that the relatively inexpensive source reduction techniques were absolutely necessary to reduce or totally avoid the need for the more expensive aerial spray of insecticides to control the adult mosquitoes.

REFERENCES CITED

- Aitken, T.H.G. 1945. Studies on the anopheline complex of western America. Univ. Calif. Publ. Entomol. 7: 273-364.
- Arizona State Department of Health, 1972, Weekly Morbidity Report- Selected Diseases. 47th week ending 11-25-72.
- Arnell, J.H., and Nielsen, L.T. 1972. Mosquito studies (Diptera, Culicidae) XXVII. The varipalpus group of Aedes (Ochlerotatus). Contrib. Amer. Entomol. Inst. 8 (2): 1-48.
- Barnes, Will C. 1960. Arizona Place Names. University of Arizona Press, Tucson. 519 pp.
- Bates, M. 1965. The Natural History of Mosquitoes. The Macmillan Co., New York. 379 pp.
- Belkin, John N. and McDonald, W.A. 1957. A new species of Aedes (Ochlerotatus) from tree holes in southern Arizona and a discussion of the varipalpus complex (Diptera: Culicidae). Ann. Entomol. Soc. Amer. 50 (2): 179-191.
- Bohart, R.M. 1948. The subgenus Neoculex in America north of Mexico. Ann. Entomol. Soc. Amer. 41 (3): 330-345.
- Brumpt, E. 1941. Mécanisme D'éclosion des Moustiques. Ann. Parasit. hum. comp. 18: 75-94.
- Burger, J.F. 1965. Aedes kompi Vargas and Downs 1950, new to the United States. Mosq. News 25 (4): 396-398.
- Carpenter, S.J. and LaCasse, W.J. 1955. Mosquitoes of North America (North of Mexico). University of California Press, Berkeley and Los Angeles. 360 pp.
- Clements, A.N. 1963. The Physiology of Mosquitoes. Pergamon Press, Oxford. 393 pp.
- Cloudsley-Thompson, J.L. 1965. Desert Life. Pergamon Press, London. 86 pp.
- Corbet, R.S. 1961. Entomological studies from a high tower in Mpanga Forest, Uganda, VI. Nocturnal flight activity of Culicidae and Tabanidae as indicated by light traps. Trans. R. Soc. ent. London. 113, 301-314.

- Horsfall, W.R. 1972. Mosquitoes their Bionomics and Relation to Disease. Hafner Publ. Co., New York. 723 pp.
- Lee, J.T., Meisch, M.V. and Lancaster, J.L. Jr. 1971. Community mosquito control program: evaluation of second year's program. Ark. Farm Res. 20 (6): 6.
- Magy, H.I. 1973. Southern California Regional Representative of the Vector Control Section (Arboviruses) Calif. Dept. of Health (Personal communication).
- McDonald, J.L. 1973. Does Arizona need a mosquito abatement program? Mosq. News 33 (3): 385-387.
- McDonald, J.L. and Dickens, T.H. 1970. Field evaluations of Dursban insecticide briquettes when used as mosquito larvacide materials. Mosq. News 30 (4): 563-66. R
- McDonald, J.L., Sluss, T.P., Lang, J.D. and Roan, C.C. 1973. Mosquitoes of Arizona. University of Arizona Technical Bull. 205, 21 pp.
- McDonald, W.A. and Belkin, J.N. 1960. Orthopodomyia kummi new to the United States. Proc. Entomol. Soc. Wash. 62 (4): 249-250.
- Meisch, M.V., Lancaster, J.L. Jr. and Coombes, L.E. 1973. Demonstration of mosquito control in a ricefield community, 1970-1972. Ark. Farm Res. 22 (3): 6.
- Meisch, M.V., Lancaster, J.L. Jr. and Meek, C.L. 1971. Value of a mosquito control program in a small community in the rice area. Ark. Farm Res. 20 (2): 13.
- Muirhead-Thomson, R.C. 1968. Ecology of Insect Vector Populations Academic Press, London. 174 pp.
- Mulhern, T.D. 1934. A new development of mosquito traps. Proc. New. Jers. Mosq. Exterm. Assoc. 21: 137-140.
- Murphy, D.R. 1953. Collection records of some Arizona mosquitoes, Entomol. News. 64:233-238.
- Nielsen, L.T., Arnell, J.H. and Linam, J.H. 1967. A report on the distribution and biology of the treehole mosquitoes in the western United States. Proc. and Papers of the Thirty-fifth Ann. Conf. of the Calif. Mosq. Cont. Assoc. 72-76.

- Nielsen, L.T., Linam, J.H., Arnell, J.H., and Zavortink, T.J. 1968. Distribution and biological notes on the treehole mosquitoes of the western United States. *Mosq. News*. 28 (3): 361-365.
- Nielsen, L.T., Wolff, T.A. and Linam, J.H. 1973. New distribution records for snowpool Aedes mosquitoes in the mountains of Arizona and New Mexico. *Mosq. News*. 33 (3): 378-380.
- Richards, C.S., Nielson, L.T., Rees, D.M. 1956. Mosquito records from the Great Basin and the drainage of the lower Colorado River. *Mosq. News*. 16 (1): 10-17.
- Richins, C.A. 1938. The metamorphosis of the digestive tract of Aedes dorsalis Meigen. *Ann. Entomol. Soc. Amer.* 31: 74-87.
- Rigby, P.T. 1968. Occurrence of Aedes infirmatus D. and K. in Arizona. *Mosq. News* 28 (2): 239.
- Rigby, P.T., Blakeslee, T.E., and Forehand, C.E., 1963. The occurrence of Aedes taeniorhynchus (Wiedemann), Anopheles barberi Coquillett, and Culex thriambus Dyar in Arizona. *Mosq. News* 23 (1): 50.
- Roubaud, E. 1932. Des phenomenes d'histolyse larvaire postnumphale et d'alimentation imaginal autotrophe chez le moustique commun (Culex pipiens). *C.R. Acad. Sci.; Paris* 194: 389-91.
- Smith, H.H. 1960. Arthropod-borne disease of man in Arizona. *Ariz. Med.* 17 (1): 1-9.
- Smith, H.H., Jansen, R.J., Mail, G.A. and Wood, S.A. 1969. Arbovirus activity in southern Arizona, *Amer. J. Trop. Med. & Hyg.* 18 (3): 448-454.
- Standfast, H.A. 1965. A miniature light trap which automatically segregates the catch into hourly samples. *Mosq. News*. 25 (1): 48-53.
- Sudia, W.D. and Newhouse, V.F. 1971. Venezuelan equine encephalitis in Texas. 1971. Information Report. *Mosq. News*, 31 (3): 350-351.
- Swammerdam, J. 1758. The history of insects. In Mosquitoes their Bionomics and Relation to Disease. W.R. Horsfall, 1972. Hafner Publ. Co., New York. 723 pp.

- Thompson, M.T. 1905. Alimentary canal of the mosquito. Proc. Boston Soc. Nat. Hist. 32: 145-202.
- U.S. Bureau of the Census. U.S. Census of Population Vol. I, Characteristics of the Population, Arizona. 1973. 889 pp.
- U.S. Department of Health, Education and Welfare, Neurotropic Viral Diseases Surveillance; Encephalitis, July, 1973. Annual Encephalitis Summary 1971. 25 pp.
- Vuturo, A.F. and McDonald, J.L. 1973. Venezuelan equine encephalitis potential problem for Arizona. Ariz. Med., 553-554.
- Wesenberg-Lund, C. 1921. Contributions to the Biology of the Danish Culicidae. Mem. Acad. R. Sci. & Letters, Copenhagen 210 pp.
- Wolff, T.A., Nielsen, L.T., Linam, J.H., 1974. Additional records of culicine and chaoborine mosquitoes from the mountains of Arizona and New Mexico. Proc. and Papers of the Forty-second Annual Conf. of the Calif. Mosq. Cont. Assoc. (in press).
- Zavortink, T.J. 1968. Mosquito Studies (Diptera, Culicidae) VIII. A prodrome of the genus Orthopodomya. Contrib. Amer. Entomol. Inst. 3 (2): 1-221.
- _____ 1969a. Mosquito Studies (Diptera, Culicidae) XV. A new species of the treehole breeding Anopheles from the southwestern United States. Contrib. Amer. Entomol. Inst. 4 (4): 27-38.
- _____ 1969b. New species and records of treehole mosquitoes from the southwestern United States. Mosq. Syst. Newsletter 1 (2): 22.
- _____ 1970a. Mosquito Studies (Diptera, Culicidae) XIX. The treehole Anopheles of the New World. Contrib. Amer. Entomol. Inst. 5 (2): 10-12.
- _____ 1970b. Mosquito Studies (Diptera, Culicidae) XXVIII. A new subgenus and species of Aedes from Arizona. Contrib. Amer. Entomol. Inst. 7 (1): 2-9.
- _____ 1972. Mosquito Studies (Diptera, Culicidae) XXVIII. The New World species formerly placed in Aedes (Finlaya). Contrib. Amer. Entomol. Inst. 8 (3): 1-206.