Mosquitoes and Encephalitis *in the* Irrigated High Plains of Texas

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THE OCCURRENCE of human and equine encephalitis in the High Plains of northwestern Texas during 1940–50 and, particularly, the increased prevalence among humans in 1952 aroused the interest of local, State, and Federal public health officials. The possible relationship between conditions associated with the expansion of irrigation and the increase in encephalitis virus infections led to cooperative investigations in the Texas High Plains by the Public Health Service and the Texas State Department of Health during 1953–54.

Irrigated cropland on the Texas High Plains increased from 250,000 acres in 1940, to 1,860,000 acres in 1950 (*1*). Deep wells are the principal source of irrigation water for this area; the effluent from municipal sewage treatment plants is also used in some localities. The spectacular expansion of irrigation has caused major changes in the population, in agricultural practices, and in the economy of the region.

Records of the Texas State Department of Health and those of the Animal Disease and Parasite Research Branch, Agricultural Research Service, United States Department of Agriculture, show that cases of human and equine encephalitis were reported from irrigated sections of the Texas High Plains during most years of the period 1940–54. Outbreaks of the disease in humans occurred in 1952 and 1954, when 23 and 32 cases, respectively, were reported; 16 cases were reported in 1944 and 11 in 1953. The reported equine cases ranged from 3 in 1942 to 26 in 1944; 25 cases were reported in 1952.

Preliminary surveys were made in the vicinity of Lubbock and Plainview during the period August–October 1953 to obtain information on mosquito populations and the factors involved in their production. These surveys indicated that mosquito problems of public health significance occurred in the Texas High Plains and that the problems were related to both agricultural and municipal use and disposal of water.

In 1954, detailed entomological-engineering investigations were conducted throughout the season in representative areas of the Texas High Plains to determine: (*a*) the kinds and relative abundance of adult mosquitoes in urban and rural localities; (*b*) the frequency with which mosquitoes were infected with encephalitis

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viruses; (*c*) the specific conditions that resulted in mosquito production; and (*d*) the causes and possible corrections of these conditions.

The Texas High Plains

The High Plains of Texas cover approximately 20,000 square miles in the northwestern part of the State. They extend southward from the Canadian River Valley to the Pecos River Valley, a distance of about 200 miles. The region is bounded by an abrupt escarpment on all sides except the south, where it merges gradually into the lower, eroded plains bordering the Pecos River Valley. This vast tableland rises above the adjoining country by heights ranging from 50 to 300 feet. Its elevation above mean sea level varies from about 4,400 feet in the northwest to less than 3,000 feet in the southeast. The surface is flat to gently undulating, and has a generally uniform slope toward the east and southeast, averaging about 10 feet per mile.

Numerous playas, a few low hummocks, and small stream valleys provide the only prominent natural land features. Of these, the undrained natural depressions, or playas, are by far the most significant. The playas are scattered rather uniformly over the area, averaging about one per square mile. They range in size from less than 10 to more than 2,000 acres, and average 20 to 30 feet in depth. The playas are usually dry during the winter months but may be flooded during the growing season by surface runoff and irrigation waste water.

The climate of the region is typically semiarid, characterized by a dry atmosphere, hot summers, short, cold winters, and a large proportion of sunny days. The annual rainfall averages about 20 inches, with nearly three-fourths occurring during April through September. Evaporation losses are estimated at 99 percent of the average annual rainfall (*2*).

The irrigated area within the Texas High Plains comprises nearly 15,000 square miles and extends approximately 140 miles south from Amarillo. The predominant soil types throughout the irrigated areas are fine sandy loams and clay loams, both of which readily absorb water and therefore afford good vertical drainage. These soils are very productive under irrigation. The principal field crops are grain sorghum, cotton, small grains, alfalfa, and pasture. Irrigated truck crops, including potatoes, onions, and lettuce, are grown in some sections.

Methods

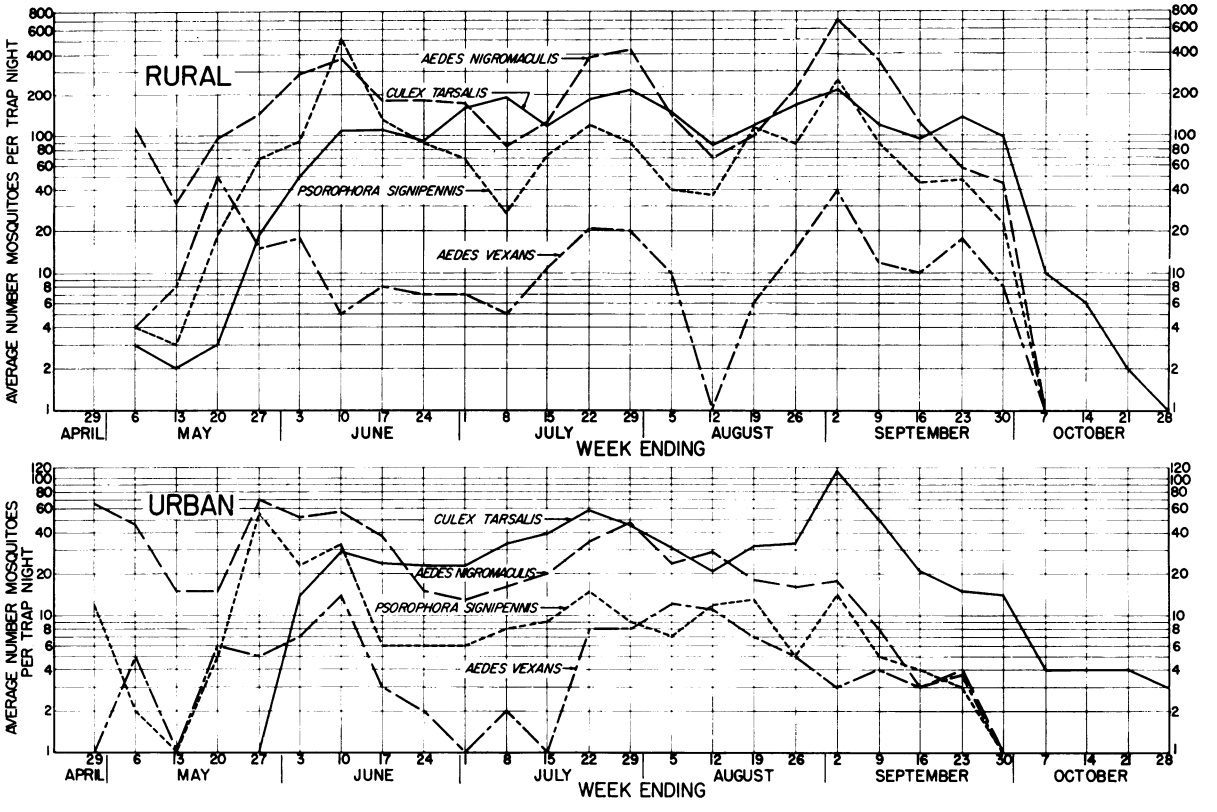
Between April 26 and October 28, 1954, adult mosquito populations in urban and rural areas

Table 1. Relative abundance of major mosquito species (females) in light trap collections, Texas High Plains, April 26–October 28, 1954

Species	Percentage of total specimens collected								
	Plainview		Hereford		Other localities [1]		All locations		
	Urban (1 trap)	Rural (4 traps)	Urban (1 trap)	Rural (1 trap)	Urban (3 traps)	Rural (1 trap)	Urban (5 traps)	Rural (6 traps)	Total (11 traps)
Aedes nigromaculis	36	46	6	10	12	45	19	44	41
Culex tarsalis	26	24	76	70	59	14	50	24	28
Psorophora signipennis	13	21	7	16	8	32	9	22	20
Psorophora discolor	9	4	<1	1	1	4	3	4	4
Aedes vexans	8	3	1	<1	1	3	3	3	3
Culex quinquefasciatus	2	<1	8	1	16	<1	11	1	2
Aedes dorsalis	5	1	<1	<1	2	1	3	1	1
Other species [2]	1	1	1	2	1	1	2	1	1
Total number of specimens	11, 047	189, 675	2, 911	4, 895	23, 364	24, 616	37, 322	219, 186	256, 508
Total number of trap-nights	120	402	98	130	437	82	655	614	1, 269

[1] Urban traps located at Lubbock, Abernathy, and Hale Center; rural trap located near Kress. [2] Includes *Anopheles pseudopunctipennis, Anopheles punctipennis, Culex erraticus, Culex erythrothorax, Culiseta inornata, Psorophora ciliata, Psorophora cyanescens,* and *Uranotaenia syntheta.*

Figure 1. Seasonal abundance of adult female mosquitoes collected at rural and urban sites, Plainview and Hereford study areas, Texas High Plains, 1954.



were sampled by means of standard New Jersey light traps. Eleven traps, 5 urban and 6 rural, were operated from dusk to dawn at Plainview, Abernathy, Hereford, Hale Center, and Kress.

To determine the kinds and relative abundance of mosquitoes that attack man in the evening, biting collections were made at weekly intervals from July 20 to October 12 near the light trap sites in the town of Plainview and surrounding rural areas. The collections were made during 3 consecutive 15-minute periods beginning at sunset. Mosquitoes were caught by means of a killing tube or aspirator from the exposed legs of the collector. In contrast to the landing rate observations which are frequently made, these collections included only mosquitoes which had actually started to bite.

To obtain mosquitoes for encephalitis virus recovery tests, females of *Culex tarsalis* and other species were collected from diurnal resting shelters in urban and rural areas of Hale, Lubbock, and Swisher Counties from June 22 to October 26. The mosquitoes were collected with an aspirator and transferred to small bobbinet cages. They were held overnight and then shipped alive by air express to the State health department laboratory in Austin, Tex. The cages containing the live mosquitoes were enclosed in an insulated cardboard carton along with two frozen gel units for cooling purposes. Shipping techniques were adapted from those described by Brennan and Mail (*3*).

The mosquitoes invariably arrived at the laboratory in good condition after a 4-hour trip from Plainview. Upon arrival, they were anesthetized, identified, macerated, and suspended in buffered broth. The suspension was inoculated into infant mice, young adult mice, or day-old chicks. Suspicious material was inoculated into guinea pigs from which blood specimens were taken 21 to 30 days later and tested by complement fixation for western equine, eastern equine, and St. Louis encephalitis viruses.

Detailed mosquito production studies were made between April 20 and October 29 on plots

located in the vicinity of Plainview and Hereford. These plots were generally representative of irrigated areas in the Texas High Plains. At Plainview the study plots consisted of 22 sections (one square mile each), which included parts of the town and the surrounding agricultural area where diversified field crops were grown under irrigation. Sorghum and cotton were the principal crops and together comprised 77 percent of the total irrigated area (9,095 acres) on the plots. The combined acreage of alfalfa, small grains, pasture, corn, and Sudan grass accounted for the remaining 23 percent of the irrigated area. A small amount of pastureland on these plots was irrigated with treated sewage effluent. At Hereford the study plot included an area of approximately 6 square miles in which field and truck crops were grown under intensive irrigation. Sorghum and small grains were grown on 63 percent of the total irrigated area (3,395 acres) on the study plot, and truck crops including potatoes, lettuce, and onions covered 34 percent. Small acreages of cotton and alfalfa were grown under irrigation on the remainder of the plot. The furrow method of irrigation was employed on 82 percent of the irrigated cropland on the Plainview plots and on 94 percent of the irrigated acreage on the Hereford plot. Maps of the study plots were prepared showing the location and types of mosquito breeding places, location of wells and irrigation distribution systems, field boundaries, field acreages, crops, and methods and direction of irrigation.

Table 2. Relative abundance of mosquito species taken on human hosts within 45 minutes after sunset in weekly biting collections near the light trap sites, Plainview, Tex., July 20–October 12, 1954

Species	4 rural sites [1]		1 urban site [1]	
	Number	Percent	Number	Percent
Aedes nigromaculis	626	37	92	12
Aedes vexans	562	34	514	69
Culex tarsalis	357	21	100	14
Aedes dorsalis	38	2	20	3
Psorophora discolor	34	2	1	<1
Psorophora signipennis	26	2	8	1
Anopheles punctipennis	16	1	0	0
Culex erraticus	5	<1	0	0
Culiseta inornata	1	<1	3	<1
Culex erythrothorax	0	0	1	<1
Total	1, 665	100	739	100

[1] Forty-nine periods of 15 minutes.

Table 3. Number of female mosquitoes processed for encephalitis virus isolations, Texas High Plains, June 22–October 26, 1954

Species	Counties from which collected			Total
	Hale	Lubbock	Swisher	
Culex quinquefasciatus	1, 625	1, 647	52	3, 324
Culex tarsalis	350	590	375	1, 315
Anopheles punctipennis	0	52	0	52
Anopheles pseudopunctipennis	0	42	0	42
Total number of specimens	1, 975	2, 331	427	4, 733
Total number of collections	14	16	4	34

Potential mosquito breeding places were arbitrarily classified into five types: playa lakes, surface pools, irrigation laterals, borrow pits and roadside ditches, and stream margins. All temporary water areas on the study plots were sampled for mature larvae and pupae following each flooding. The permanent and semipermanent water areas were sampled once each week. Each water area was sampled with a pint-size, white-enamel dipper; the number of dips taken was proportionate to the extent of the breeding area. When mature larvae were present, representative samples were collected for identification. During each inspection, the data obtained included: (*a*) the average number of fourth-instar larvae and pupae per dip, (*b*) an estimate of the total water area, (*c*) an estimate of the breeding area, and (*d*) the source of water.

In order to evaluate the relative mosquito production potential of the various habitats on the plots, production indexes were determined by use of the following formula:

Production index = (average number of fourth-instar larvae and pupae per dip) × (breeding area in acres).

In addition to the detailed investigations on the plots at Plainview and Hereford, weekly

mosquito production studies were made in the following habitats associated with municipal sewage disposal: (*a*) the sewage lagoon at Abernathy, (*b*) the oxidation ponds at Petersburg, and (*c*) the sewage polluted streams at Plainview and Tulia.

Adult Mosquito Populations

The relative abundance of the major mosquito species collected in 5 urban and 6 rural light traps is presented in table 1. A total of 256,508 females, representing 16 species, was taken during 1,269 trap-nights from April 26 to October 28. The average nightly collection of all species was 202 for all locations combined, 385 at Plainview, 34 at Hereford, and 92 for the other four localities together.

A total of 37,322 female mosquitoes was collected in the 5 urban traps. Of these, the predominant species were *C. tarsalis*, 50 percent; *Aedes nigromaculis*, 19 percent; *Culex quinquefasciatus*, 11 percent; and *Psorophora signipennis*, 9 percent. Of 219,186 females taken in the 6 rural traps, *A. nigromaculis* comprised 44 percent; *C. tarsalis*, 24 percent; and *P. signipennis*, 22 percent. The average nightly collection of all species in the rural traps was 357, as compared with 57 in the urban traps. The average collection per trap-night and the seasonal distribution of the major species for both urban and rural sites at Plainview and Hereford (the two principal study areas) are shown by weekly periods in figure 1.

Figure 2. Mosquito production by habitat and source of water, Plainview study area, Texas High Plains, 1954.

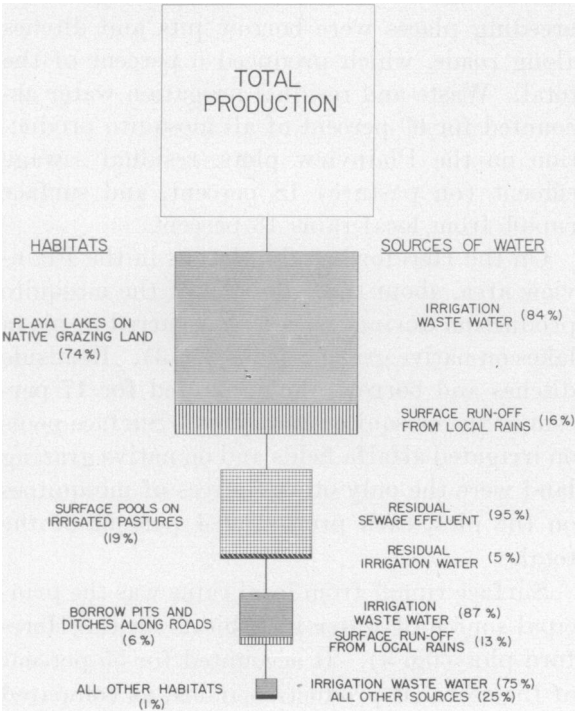
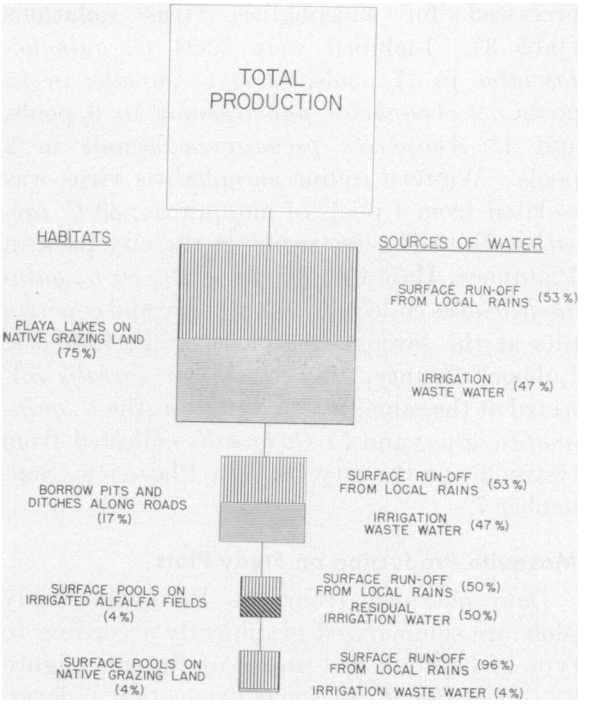


Figure 3. Mosquito production by habitat and source of water, Hereford study area, Texas High Plains, 1954.



The relative abundance of biting mosquitoes collected at weekly intervals on human hosts in the town of Plainview and in surrounding rural areas is shown in table 2. Of 2,404 mosquitoes taken in 98 collecting periods of 15 minutes each, *C. tarsalis*, the primary vector of western equine encephalitis, *A. nigromaculis*, and *Aedes vexans* were the principal species at both rural and urban sites. At the rural sites, the average attack rate for all species combined was 34 mosquitoes per period, and at urban sites, 15 mosquitoes. Both *A. nigromaculis* and *A. vexans* are severe pest mosquitoes and have been found naturally infected with western equine encephalitis (*4*, *5*); in the laboratory they have been found to be efficient vectors of encephalitis virus (*6*, *7*).

Encephalitis Virus Isolations

From June 22 to October 26, 4,733 female mosquitoes were collected and subsequently processed for encephalitis virus isolations (table 3). Included were 3,324 *C. quinquefasciatus* in 17 pools, 1,315 *C. tarsalis* in 15 pools, 52 *Anopheles punctipennis* in 6 pools, and 42 *Anopheles pseudopunctipennis* in 2 pools. Western equine encephalitis virus was isolated from 4 pools of mosquitoes: 39 *C. tarsalis* collected in restrooms at the city park in Plainview, Hale County, June 29; 80 *C. quinquefasciatus* collected in shrubbery and concrete pits at the sewage treatment plant, Lubbock, Lubbock County, July 27; 118 *C. tarsalis* collected at the same time and place as the *C. quinquefasciatus;* and 51 *C. tarsalis* collected from restrooms at the city park in Plainview, September 7.

Mosquito Production on Study Plots

Data obtained from the Plainview study plots are summarized graphically according to type of habitats and source of water in figure 2. According to seasonal production indexes, approximately three-fourths of all mosquito production on the plots occurred in playa lakes

Figure 4. Species composition of mosquito larvae collected from various aquatic habitats, Plainview study area, Texas High Plains, 1954.

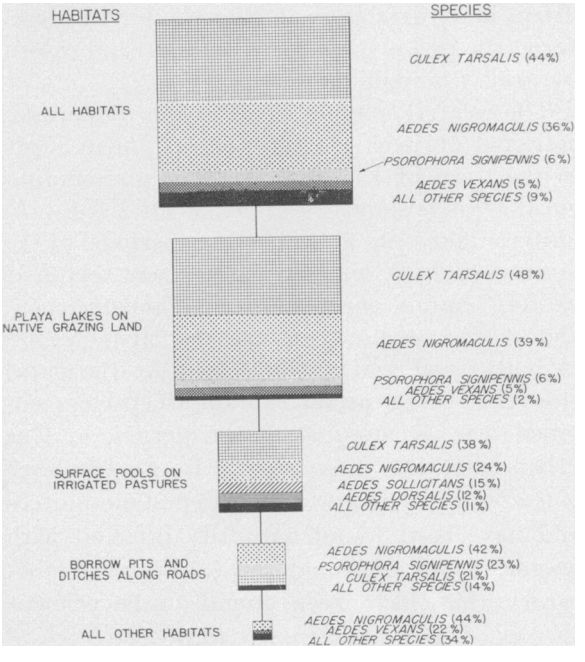
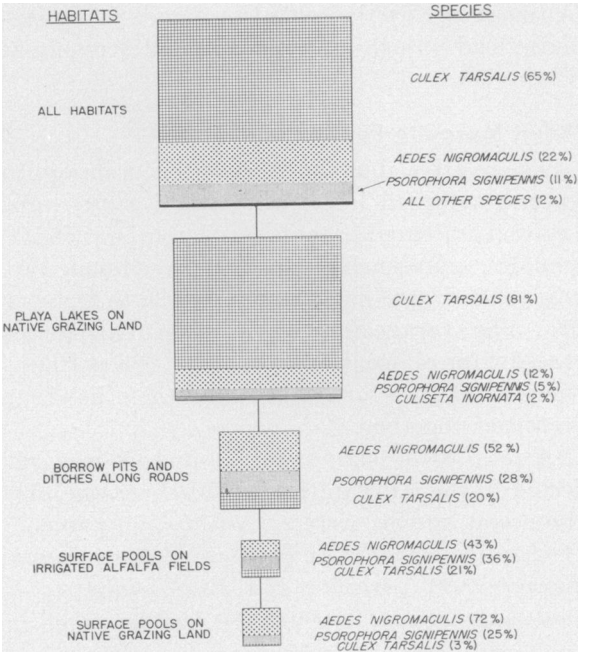


Figure 5. Species composition of mosquito larvae collected from various aquatic habitats, Hereford study area, Texas High Plains, 1954.



on native grazing land. About 20 percent of the mosquito production occurred in surface pools on irrigated pastures; of this production, 95 percent was on the pasture irrigated with sewage effluent. The only other significant breeding places were borrow pits and ditches along roads, which produced 6 percent of the total. Waste and residual irrigation water accounted for 69 percent of all mosquito production on the Plainview plots, residual sewage effluent (on pasture) 18 percent, and surface runoff from local rains 13 percent.

On the Hereford study plot, as in the Plainview area, about three-fourths of the mosquito production during the season occurred in playa lakes on native grazing land (fig. 3). Roadside ditches and borrow pits accounted for 17 percent of the mosquito production. Surface pools on irrigated alfalfa fields and on native grazing land were the only other sources of mosquitoes on the plot, each producing 4 percent of the total.

Surface runoff from local rains was the principal source of water in habitats on the Hereford plot (fig. 3). It accounted for 55 percent of the seasonal production index, as compared

with only 13 percent for the Plainview area. Waste water from irrigated fields accounted for 45 percent of the total mosquito production.

On the Plainview study plots, 36,510 larvae, comprising 12 species, were collected and identified (fig. 4). The most abundant species were: *C. tarsalis*, 44 percent; *A. nigromaculis*, 36 percent; *P. signipennis*, 6 percent; and *A. vexans*, 5 percent. Other species collected in smaller numbers included *Aedes dorsalis*, *Aedes sollicitans*, *A. pseudopunctipennis*, *A. punctipennis*, *C. quinquefasciatus*, *Culiseta inornata*, *Psorophora ciliata*, and *Psorophora discolor*. *C. tarsalis* was found in all types of habitats except irrigation laterals and was the predominant species in playa lakes, surface pools on pastures irrigated with sewage effluent, and the margins of the sewage polluted creek. *A. nigromaculis* was common in all habitats except the margins of the sewage polluted creek.

On the Hereford plot, 6,099 larvae, representing 5 species, were collected and identified (fig. 5). The principal species were: *C. tarsalis*, 65 percent; *A. nigromaculis*, 22 percent; and *P. signipennis*, 11 percent. These species were found in all types of habitats. Small numbers of *C. inornata* and *P. discolor* were also collected.

Mosquito Production and Sewage Disposal

Mosquito breeding occurred in all habitats associated with sewage disposal that were studied (table 4). The playa used as a sewage lagoon at Abernathy was by far the most important from the standpoint of total mosquito production. The entire flow of effluent from the Abernathy sewage treatment plant was often diverted for irrigation, which prevented the formation of a permanent lake in the playa. This resulted in marshy conditions in the playa which were very favorable for mosquito production.

The oxidation ponds at Petersburg consisted of a series of cells constructed with steep banks. Prolific production of mosquitoes occurred in densely vegetated portions of cells which were only partially filled because of low flows of effluent. In the cells which operated at normal level, mosquito production occurred only along the vegetated banks. The percentage of total water area that produced mosquitoes in the constructed ponds was much lower than for the natural playa at Abernathy. Mosquito production also occurred along the vegetated margins of the sewage polluted streams at Plainview and Tulia.

Table 4. Larval mosquito data collected from habitats associated with municipal sewage disposal, Texas High Plains, April 20–October 29, 1954

Collection data and species composition	Sewage lagoon (playa) Abernathy	Sewage oxidation ponds (constructed) Petersburg	Creek receiving Plainview sewage	Creek receiving Tulia sewage
Number of inspections [1]	17	27	26	27
Total estimated water area inspected (acres)	37. 4	71. 0	17. 1	12. 4
Total estimated breeding area inspected (acres)	13. 0	1. 3	. 4	1. 9
Average number of fourth–instar larvae and pupae per dip	34. 0	62. 5	1. 7	8. 2
Seasonal production index [2]	443. 1	81. 3	. 7	15. 6
	Percentage by habitat of fourth–instar larvae			
Aedes dorsalis	12	0	0	0
Aedes nigromaculis	17	<1	0	0
Culex quinquefasciatus	35	63	6	33
Culex tarsalis	32	25	94	65
Culiseta inornata	3	1	0	<1
All other species [3]	1	<1	0	1
Total number of specimens identified	4, 842	6, 251	453	3, 140

[1] Larval inspections made weekly when water was present. [2] Production index=(average number fourth–instar larvae and pupae per dip)×(breeding area in acres); seasonal production index=summation of production indexes for entire season. [3] Includes *Aedes sollicitans*, *Anopheles punctipennis*, and *Psorophora signipennis*.

C. tarsalis and *C. quinquefasciatus* were the predominant species in all habitats associated with municipal sewage disposal (table 4). These 2 species comprised 88 percent of over 14,000 larvae collected from the 4 habitats. *A. dorsalis* and *A. nigromaculis* together comprised more than one-fourth of over 4,800 larvae taken from the sewage lagoon at Abernathy.

Summary and Conclusions

Detailed studies during 1954 in representative areas of the irrigated High Plains in Texas showed that *Culex tarsalis*, the common encephalitis mosquito, was abundant from early June through September. It ranked second in the total number of female mosquitoes taken in light traps and was the most abundant species in larval collections. In biting collections on human hosts at Plainview, *C. tarsalis* ranked second at urban sites and third at rural sites. *Culex quinquefasciatus* was abundant during the latter part of the season in both urban and rural areas. It ranked third in the urban and sixth in the rural light trap collections. Western equine encephalitis virus was isolated from 3 out of 15 pools of *C. tarsalis*, and from 1 out of 17 pools of *C. quinquefasciatus*.

Aedes nigromaculis ranked first in the total number of female mosquitoes taken in light traps. It also ranked first in the rural and third in the urban biting collections. *Aedes vexans* ranked fifth in the total number of females taken in the light traps, but it ranked first in the urban and second in the rural biting collections. The abundance and widespread distribution of *C. tarsalis*, *C. quinquefasciatus*, *A. nigromaculis*, and *A. vexans*, and the presence of encephalitis virus constitute a significant public health problem in the Texas High Plains.

Playa lakes on native grazing land accounted for approximately three-fourths of the mosquito production in the study areas. Surface pools and roadside ditches and borrow pits were also important sources of mosquitoes. Waste and residual irrigation water accounted for 87 percent of the total mosquito production at Plainview, and 45 percent at Hereford. Practically all of the remaining production was caused by surface runoff from local rains.

Throughout the High Plains area, much of the water that collects in the playas is lost through evaporation and transpiration. This loss of water is vitally important to the economy of the region, because the underground reservoir is being lowered by pumpage for irrigation at a much greater rate than it is being replenished. Various methods of making beneficial use of the water that is now lost from the playas have been suggested, and several are being tested at the present time. These and other water conservation measures should be evaluated from agricultural and mosquito control viewpoints. In this area, as in others, such viewpoints are likely to be served by the same methods. Where mosquito production cannot be eliminated by water conservation measures, chemical control will be necessary.

Mosquito production associated with municipal sewage disposal is not as widespread as that caused by irrigation waste water and surface runoff; however, this is a special problem for which both temporary and permanent control measures are needed.

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