nany refinements can be made to increase ts reliability, but as it stands at present t requires less work on the part of the ield personnel than the average per dip ndex, for it eliminates recording a great number of unnecessary negative dips.

Adult Index. We did not use a similar ndex to adult populations on Guadalcanal because of difficulties of sampling, but the same principles may be extended to obtain an adult index utilizing records from liurnal shelters, biting stations, or light raps. The number of mosquitoes collected per unit (hour or man-hour) in each station would correspond to the average per dip in the breeding index and every positive station would correspond to a breeding place. The adult index would be obtained by multiplying the over-all average of mosquitoes per unit in a given area by the total positive stations in that area. No doubt such an index could be refined by standardizing the stations or arbitrarily defining a unit station by some means such as the number of positive minute periods.

FIELD OBSERVATIONS ON LARVAL GROWTH RATES OF IRRIGATED-PASTURE MOSQUITOES IN WESTERN NEBRASKA (DIPTERA, CULICIDAE)

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Introduction. In western Nebraska, our species of mosquitoes, *Aedes dorsalis* Meigen), *Aedes vexans* (Meigen), *Aedes nigromaculis* (Ludlow), and *Culex tarsalis* Coquillett, are commonly found in surface pools on irrigated salt grass pastures and hay meadows in the bottom lands along he North Platte River. In order to understand more clearly the relationship between irrigation and mosquito production, studies were initiated during the 1952 season on the biology of the immature stages of these four species. These tudies were primarily concerned with the ffects of temperature and population densities on growth rates. In addition, observations were made on the succession of mosquito species in the various habitats. The investigations were carried out under actual field conditions, and in practically every habitat studied a mixture of pecies was encountered; however, *A. dorsalis* was by far the most common.

A review of the literature indicates that very little has been published on the biology of these species in the Midwest. The major contributions concerning the four species in other areas are as follows: Rees and Nielsen (1947) published an account on the biology of *Aedes dorsalis* in Utah; Gjullin, *et al.* (1950) on *A. vexans* in the Pacific Northwest; Thurman, *et al.* (1951) and Husbands and Rosay (1952) on *A. nigromaculis* in California; Brookman (1950) and Jenkins (1950) on *Culex tarsalis*.

Methods. Several temporary pool sites in the vicinity of Mitchell, Nebr., were selected for study. These depressions were located in rough pasture areas where the vegetation consisted mainly of salt grass (*Distichilis* sp.) with other native grasses. During the first part of the season, the depressions were filled with water from rainfall or irrigation. Beginning in July, the sites were flooded by means of a gasoline-engine-driven pump. The controlled flooding permitted more accurate determination of the time required for completion of the larval and pupal stages.

Data were obtained from 14 temporary pool sites that were flooded one or more times during the season. Twenty-one floodings were studied: 17 at 24-hour intervals and 4 at 6-hour intervals. The surface areas of the pools ranged from 80 to 500 square feet and the maximum depth of water never exceeded more than about 1 foot.

Samples of the immature stages were collected by random dipping over the entire area of the pools, using a pint-size, white-enamel dipper. Daily population densities were determined by the average number of larvae per dip. The aquatic stages were strained out by pouring the water from each dip through a fine-mesh tea strainer. They were then transferred to alcohol vials by means of a small camel's-hair brush. All samples were examined in the laboratory where the numbers in each stadium were determined and all fourth-instar larvae and pupae were identified to species. The first, second, and third instars were identified only to genus.

RESULTS. During the course of this study, 81,255 fourth-instar larvae were identified. *Aedes dorsalis* was the most common species, accounting for 81 per cent of the total. *A. vexans* made up 6 per cent, *A. nigromaculis,* 7 per cent, and *C. tarsalis,* 6 per cent.

A summary of the number of days required for the *Aedes* species to reach fourth-instar and pupal stage is shown in table 1. At average air temperatures between 68.2° F. and 76.9° F., *A. dorsalis*

TABLE 1.—Time required for *Aedes dorsalis, A. vexans,* and *A. nigromaculis* to reach the fourth instar and pupal stage, May 16 through September 18, 1952, Scotts Bluff County, Nebraska

Pool number	Date flooded	Avg. air temperature ° F.*	No. of days required to reach IV-instar			No. of days required to reach pupal stage		
			Aedes dorsalis	*Aedes vexans*	*Aedes nigromaculis*	*Aedes dorsalis*	*Aedes vexans*	*Aedes nigromaculis*
1–1 **	May 16 ***	53.7	8	8	9	12		12
2	June 12	73.5	5	5	4	7		6
3	June 21	69.1	4	4	5	8	7	
4	June 21	68.2	4	5	4	8	7	7
1–2	June 24	70.5	5	6	5	7		7
5–1	June 24	70.5	5	5	5	7	7	6
5–2	July 22	76.9	4	3	3	5	5	5
7–1	July 22	76.9	4	3	3	5	5	5
5–3	Aug. 1	73.2	4	3		6	5	
8	Aug. 1	73.2	4	3	3	6	5	5
9–1	Aug. 4	70.0	4	3	3	6	6	5
7–2 ****	Aug. 6	68.9	3¾	3	4¼	6¾	5¾	6
10	Aug. 7	69.4	4	4	4	7	7	6
9–2	Aug. 12	69.6	3	4	3			5
11	Aug. 18	73.6	4		3	6		5
9–3 ****	Aug. 19	73.1	3¼	3¼	3	5	4½	4
13 ****	Aug. 19	73.4	3¼			7		
5–4 ****	Aug. 21	72.2	3¼	3	4¼	5	4¾	4¾
14	Aug. 21	72.8	6	6	5		7	6
9–4	Sept. 15	58.8	7	8	8	12	12	11
5–5	Sept. 18	60.2	7	7	8	11	9	9

* From daily maximum-minimum air temperatures recorded 5 miles east of Mitchell.
** Substation numbers indicate number of times pool was flooded.
*** Approximate date flooded.
**** 6-hour check.

required 3¼ to 6 days to develop to the fourth-instar and 5 to 8 days to the pupal stage; *A. vexans,* 3 to 6 days to the fourth-instar and 4½ to 7 to the pupal stage; and *A. nigromaculis,* 3 to 5 days to the fourth-instar and 4 to 7 to the pupal stage. At average air temperatures between 53.7° F. and 60.2° F., 7 to 8 days were required for *A. dorsalis* and *A. vexans* to reach the fourth-instar and 9 to 12 days to reach the pupal stage. *A. nigromaculis* required 8 to 9 days to reach the fourth-instar and 9 to 12 days to attain the pupal stage at the same temperatures. A comparison of the larval growth rates of *A. dorsalis, A. vexans,* and *A. nigromaculis* for various periods and different temperatures during the season is presented in figure 1.

The growth rates of *Aedes* larvae in two pools (No. 5–3 and 7–1) supporting widely differing larval population levels are shown in figure 2. Growth-rate patterns of the early instars were similar in both pools even though the daily population density was considerably higher in pool No. 7–1. In the pool with the higher larval density a greater percentage of the larvae spent more time in the fourth instar.

Collection of larval samples at 6 a.m.,

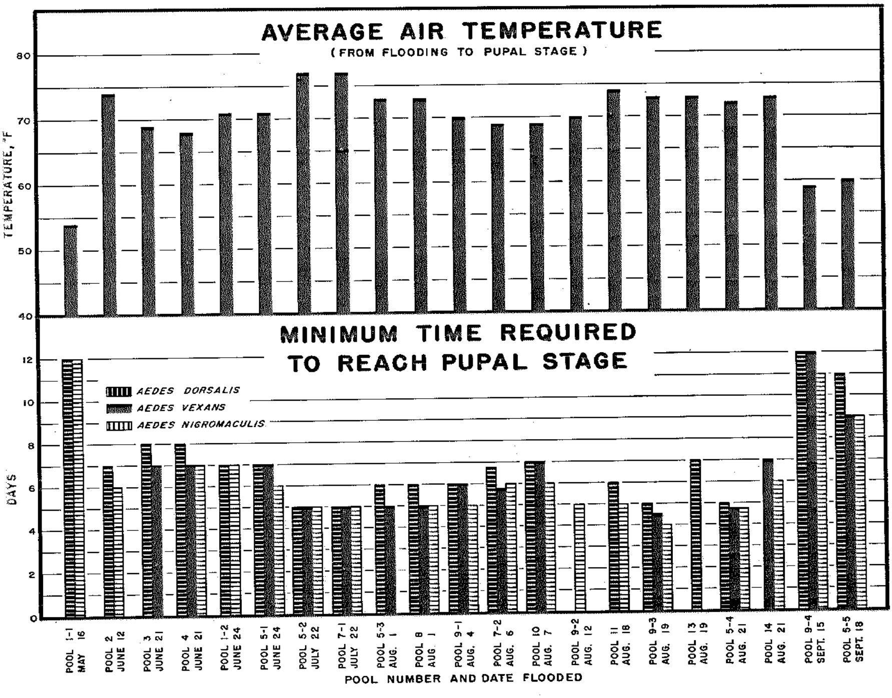


Figure 1. Relationship between average air temperatue and minimum number of days required for *Aedes dorsalis*, *A.vexans*, and *A.nigromaculis* to reach the pupal stage in surface pools flooded at irregular intervals. May – September, 1952. Scotts Bluff County, Nebraska.

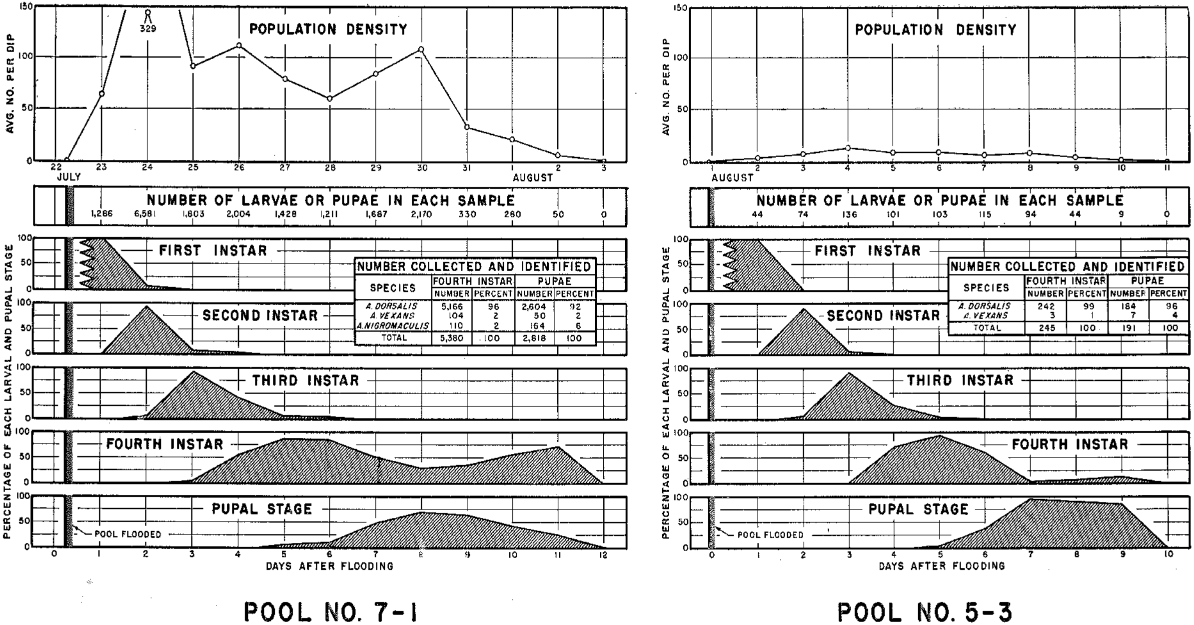


Figure 2. The rates of development of *Aedes* larvae and pupae in surface pools with high and low population densities. Near Morrill, Nebraska, July-August, 1952.

12 m., 6 p.m., and 12 p.m. permitted a more accurate determination of the time required for completion of each stage. The growth-rate patterns of *Aedes* larval instars and pupae for one pool inspected at 6-hour intervals are shown in figure 3. This pool was flooded from 10:30 to 11:00 a.m. on August 21, and hatching had occurred by 1 p.m. Nearly all the larvae changed to second instars between 6 p.m. and 12 p.m. on August 22. The time spent in the second stadium was shorter than that in the others. Fourth-instar larvae of *A. dorsalis* were first collected at 6 p.m. on August 24 and the first pupae at 12 m. on August 26. The minimum time observed for completion of the larval stage of *A. dorsalis* was 5 days. Adult emergence occurred on August 27 and 28, as indicated by the low percentage of pupae. By August 29 most of the fourth-instar larvae had changed to pupae.

In three of the pools studied at 6-hour intervals, a difference was noted in the rates of development of *A. dorsalis*, *A. nigromaculis*, and *A. vexans* (only *A. dor-*

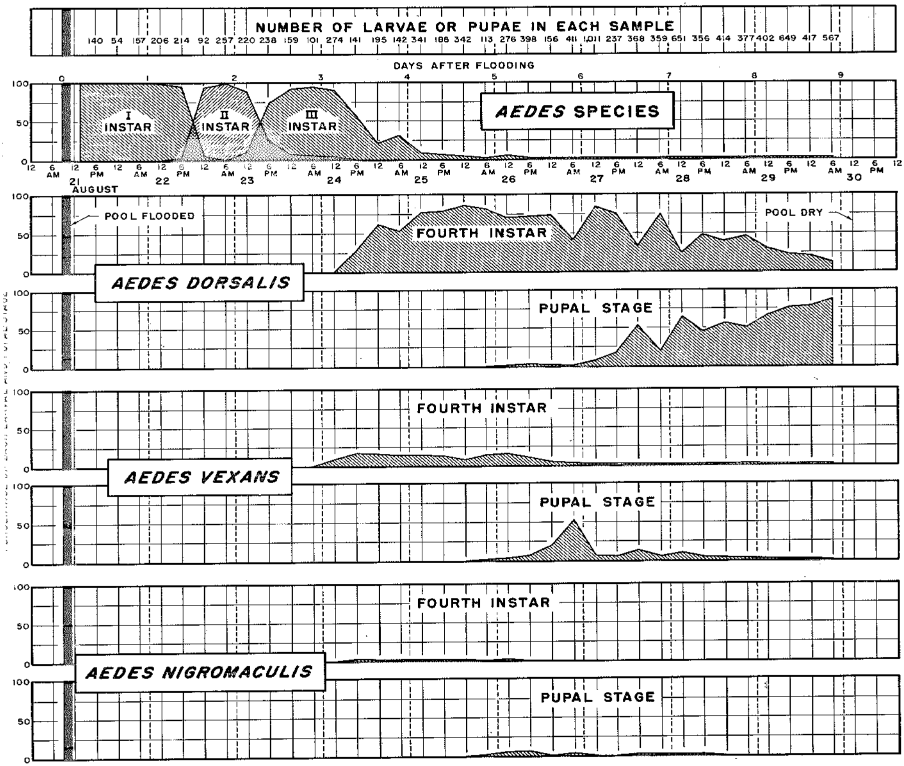
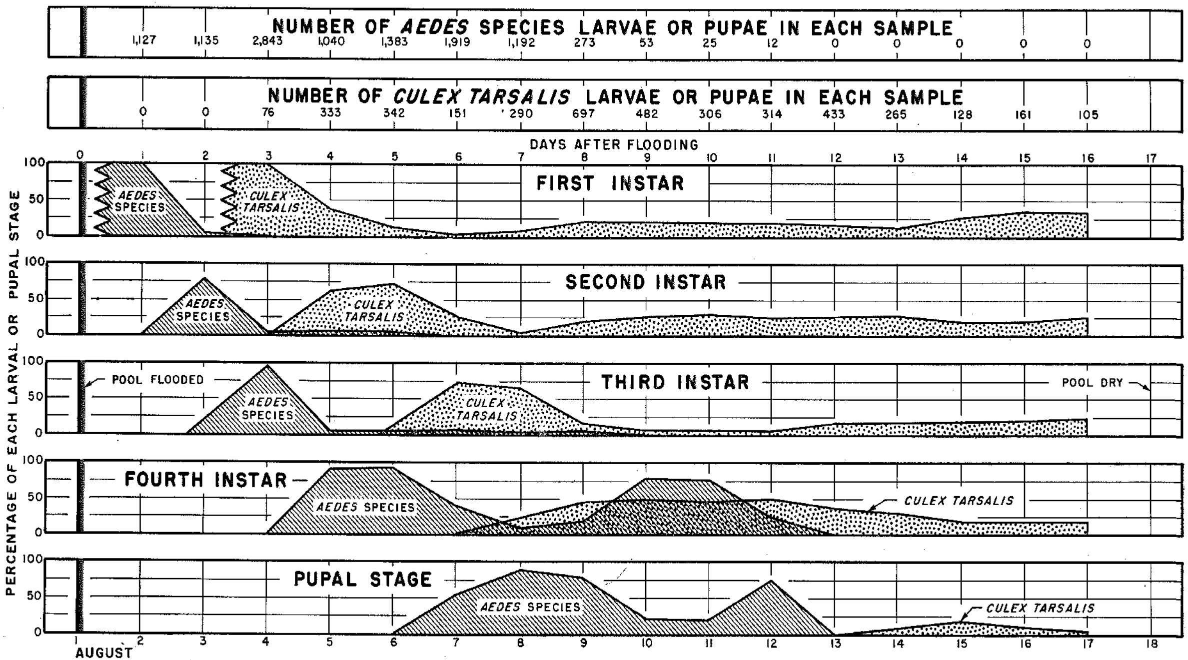


Figure 3. Rates of development of *Aedes dorsalis*, *A. vexans*, and *A. nigromaculis* as determined by collections made at 6-hour intervals in a surface pool (No. 5-4) near Morrill, Nebraska, August 21–30, 1952.



NUMBER COLLECTED AND IDENTIFIED				
SPECIES	FOURTH INSTAR		PUPAE	
	NUMBER	PERCENT	NUMBER	PERCENT
A. DORSALIS	3,116	97	2,295	96
A. VEXANS	35	2	78	3
A. NIGROMACULIS	5	1	14	1
TOTAL *AEDES*	3,156	100	2,387	100
C. TARSALIS	1,252	100	54	100

Figure 4. A comparison of development patterns of *Aedes* species and *Culex tarsalis* as determined by collections made at 24-hour intervals in a surface pool (No. 8) near Morrill, Nebraska, August 1-18, 1952.

alis was collected in the fourth pool). The average time for completion of the larval stage was 6 days for *A. dorsalis* and 5 days for *A. vexans* and *A. nigromaculis* at average air temperatures ranging from 68.9° to 73.4° F. The minimum number of days required for each of these species to reach the fourth-instar and pupal stage in the four pools is shown in table 1.

The brood patterns of *Culex tarsalis*, the only *Culex* present in the habitats studied, were not so well defined as those of the *Aedes* (fig. 4). The eggs of *C. tarsalis* were laid on the water surface and hatching occurred in 2 or 3 days. Because new egg rafts continued to appear in the pool, *C. tarsalis* larvae from different hatchings were intermingled. *Aedes* larvae appeared shortly after flooding and no further aedine hatching occurred unless there was a rise in water level in the pools. *C. tarsalis* larvae gradually increased in numbers as a result of periodic oviposition. In several pools the mosquito fauna changed completely to *C. tarsalis* after the *Aedes* emerged.

Most of the pools dried up before *Culex tarsalis* reached the pupal stage. In the few that retained water long enough for completion of the larval stage, the fourth-instar stage was reached in an average of 7 days after flooding, and pupae appeared in an average of 10½ days, at average air temperatures ranging from 70° to 77° F.

DISCUSSION. Knowledge of the time required for completion of the immature stages of irrigated pasture mosquitoes is important for effective prevention and control of the severe mosquito problems in many sections of the North Platte Valley. Extensive salt grass pastures and hay meadows are irrigated 3 or 4 times during the summer. Because of irregular topography, the fields are irrigated by wild flooding and when enough water is applied to cover the high spots, excessive ponding occurs in the low places. Owing to tight soils, water often stands in the depressions from 1 to 2 weeks, thereby permitting both *Aedes* and *Culex* to complete their aquatic stages. A succession of species occurs with each irrigation, beginning with *Aedes* and ending with *Culex*. Irrigation schedules for individual farms vary so that mosquito production is almost continuous throughout the summer.

Mosquito production occurring on the pastures could be prevented if irrigation and drainage practices that would remove residual irrigation water from the fields and adjacent areas within 5 days after the water is applied were uniformly adopted by the farmers. From the standpoint of chemical control, the rapid growth rate of the larval stadia of *Aedes* limits the time available for application of larvicides to surface water collections. Since the first three instars are more susceptible to larvicides, these materials should be applied within 3 days after the pastures are flooded.

SUMMARY. Data on mosquito larval development were obtained from 14 temporary pool sites in salt grass pastures in western Nebraska, 1952. The larval growth rates of mosquitoes in the pools studied varied with the temperature, growth periods becoming shorter as the average air temperature increased. The minimum time for *Aedes dorsalis* to complete the larval stage was 5 days, *A. vexans* 4½ days, and *A. nigromaculis* 4 days at average air temperatures between 72° and 77° F. In two pools, where the larval populations differed greatly, the development rates of the first three instars were about the same; however, in the pool where higher larval populations prevailed, a greater percentage of the larvae remained in the fourth instar for a longer period.

Culex tarsalis reached the fourth instar in an average of 7 days after flooding, and the pupal stage in 10½ days at average air temperatures between 70° and 77° F. After the pools were flooded, *C. tarsalis* larvae usually appeared in 2 or 3 days and the population density gradually increased as a result of periodic oviposition.

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MERMITHID NEMATODE PARASITES IN MOSQUITOES [1]

D. W. JENKINS [2] AND A. S. WEST [3]

In the arctic and subarctic regions where mosquitoes are very abundant but the larvae are widely dispersed and not concentrated, chemical control methods have generally given results of limited value. In these areas natural control methods using parasites or predators would be most valuable if made practical.

Mermithid-type nematodes were discovered emerging from mosquito larvae at Churchill, Manitoba and Coral Harbor, Southhampton Island, Northwest Territories by the authors during the summer of 1950. Additional collections were made by West the following summer at Churchill.

Nematode infested fourth-instar mosquito larvae appeared to have the thorax, or abdomen, or both, whitish and swollen. Most frequently the nematodes were observe to be coiled inside of the thorax just below the integument. They were also coiled evenly in the first and second abdominal segments. Occasionally specimens were observed irregularly coiled in the thorax, irregularly coiled in the thorax and abdomen, or entirely within the abdomen, doubled back several times. Infested mosquito larvae were usually slower moving and frequently were covered with a dense mass of epizootic protozoans (*Vorticella*-type) and algae. Such growth was also commonly found on larvae uninfested by nematodes, but it occurred in smaller quantities.

Larvae of *Aedes communis* (DeGeer) were the most frequently infested. In two pools at Churchill in 1950 up to 100 per cent of the late developing larvae were infested and died. No larvae of *A. excrucians* (Walker) in these same pools were observed to be infested. Parasitization was most severe during the latter part of the larval season in early July. Nematodes in *A. communis* larvae were collected on 18 June, and from 5 to 18 July, 1950, and from 19 June to 4 July, 1951. An infested larva of *A. nearcticus* Dyar was collected at Coral Harbor, Southhampton Island on 3 July, 1950. An infested larva of *A. nigripes* Zett. was collected at Churchill in June, 1951.

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