ertainly the physiology of egg production 1 the two species appears to be quite dif- :rent. Figure 2 shows a specimen of *ledes communis,* recently emerged, with orsal longitudinal flight muscles, larval nuscles and extensive "fat body." Figure shows another specimen of *Aedes com- zunis* with eggs almost completely de- eloped. The dorsal longitudinal flight nuscles are present. Of particular in- :rest is the reduction of the "fat body" nd the absence of larval muscles which ave long since histolysed. The "fat ody" of *Aedes hexodontus* also becomes educed with age; however no egg production takes place without blood. In the blood-sucking species we must still continue to consider blood meals as the most probable source of protein for egg development.

References

HOCKING, B., et al. 1950. Observations on the bionomics of some northern mosquito species (Culicidae; Diptera). Can. J. Res., D, 28:58–80.

———, 1952. Autolysis of flight muscles in a mosquito. Nature, 169:1101

———, 1954. Personal communication.

ROUBAUD, E., 1932. Des phénomènes d'histolyse larvaire postnymphale et d'alimentation imaginal autotrope chez le moustique commun, *Culex pipiens.* C. R. Acad. Sci. Paris, 194(4): 389–391.

SIMPLE LARVAL AND ADULT MOSQUITO INDEXES FOR ROUTINE MOSQUITO CONTROL OPERATIONS

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Few of the numerous methods used at resent to obtain an index of larval or dult mosquito populations in routine nosquito control operations are satisfac- ory or reliable. While engaged in ento- nological phases of mosquito control perations in the Solomon Islands in 943–1945 I used a simple index which ppeared to be quite reliable and required minimum of work for the field person- nel. Recently this method has been tried n a limited scale in California with satis- actory results. Therefore it seems advis- ble to bring it to the attention of persons ngaged in mosquito control operations.

It is a well known fact that mosquito opulations, both adult and immature tages, are not dispersed at random but ccur in concentrations over a wide and ariable area. The difficulty with most nethods of estimating mosquito popula- ions, such as the popular "average per lip" index for larval populations and the "mosquitoes per hour" or per man-hour for adult populations, is that only one of these variables is taken into account. In developing our simple index we therefore attempted to include both factors of density and extent or spread of the population. Essentially the method consists of standardizing the unit areas to be sampled, measuring the density for each unit area and combining this information into an index. No originality is claimed for this idea but it appears that it has not been widely applied to developing an index suitable for mosquito control operations.

BREEDING INDEX (BI). The breeding index as developed by us is particularly adapted to anopheline breeding in situations where the larval breeding places consist of small, temporary pools as well as streams and other permanent bodies of water, and where there is a considerable fluctuation in the number and extent of breeding sites. With slight modifications it can be adapted to culicine breeding as well as to different types of breeding sites.

The information necessary to determine the breeding index is obtained by field checkers using the standard dipping technique. To minimize individual variations in dipping, each man is assigned to an area for an entire season. The field checkers are trained to estimate water surface areas. A specific number of dips is taken per unit surface. In our case we took 20 dips for every 100 square feet of effective breeding surface, disregarding open, deep, standing water or open, flowing water which by experience we knew did not serve as breeding sites. The field checkers are provided with a standard form on which separate entries are made for every situation checked. Such a situation consists of a single body of water or a series of pools, puddles, etc., in a restricted area which is conveniently checked as a unit. For each situation a brief identification and description is made, followed by entries for the total number of dips taken, the number of positive dips (containing larvae or pupae or both) and the total number of larvae and pupae dipped. A representative sample of mosquitoes is also taken for every situation for laboratory identification. In checking, no record is made of negative dips until the first positive dip is obtained, then a record is kept of positive dips as well as of all dips taken. After the first positive dip, the full number of dips required by the size of the area checked is taken. For situations where no positive dips are obtained no entries are made other than a record that they were checked.

In the headquarters laboratory the larvae and pupae in each sample are identified to species as needed or desired. For each situation the number of breeding places and the average per dip are determined and from them the breeding index is compiled. The breeding index can be determined, if desired, for each subdivision of the area under control, for each species and for each week with very little additional work.

A sample report on the anopheline breeding in the Lunga District of Guadalcanal for the month of April, 1945 is illustrated here (fig. 1). The actual method of determining the breeding index can be best understood by inspection of this form and the explanation of abbreviations which follow:

BP: Breeding Place. A "breeding place" is defined, for the purpose of obtaining the breeding index, as any situation in which from 1 to 20 positive dips are obtained. If no positive dips are obtained the situation is disregarded. If in any given situation (a single body of water or a series of pools, puddles, etc. in a restricted area) more than 20 positive dips are obtained, then the number of breeding places recorded is one for each 20 positive dips or fraction thereof. If a more refined index is desired fractional breeding places may be determined as follows: $BP = \frac{\text{total positive dips}}{20}$.

TLP: Total Number of Larvae and Pupae. The total number of larvae and pupae found in any given situation is recorded, regardless of the number of breeding places.

ND: Number of Dips. The number of dips taken in any given situation is standardized to correspond to the surface area of the water present—say 20 dips per 100 sq. ft. of water surface. In dipping no record is kept of negative dips until the first positive dip is obtained, following which all dips taken are recorded. For example, in a series of small pools with a surface area of approximately 200 sq. ft., roughly 40 dips are taken without a single larva. This situation is disregarded as a breeding place and no record is kept. In another situation with approximately the same water surface, after 5 negative dips a positive dip is obtained. The first 5 dips are disregarded, and the full 40 dips are taken for this situation and the number of positive dips recorded to determine the number of "breeding places."

APD: Average per Dip. The average number of larvae and pupae per dip is determined by dividing the total number

- Anopheline breeding for the month of April 1945 -

SPECIES	A	31 Mar - 6 Apr					7 Apr - 13 Apr					14 Apr - 20 Apr					21 Apr - 27 Apr					Entire Period				
		BP	TLP	ND	APD	BI	BP	TLP	ND	APD	BI	BP	TLP	ND	APD	BI	BP	TLP	ND	APD	BI	BP	TLP	ND	APD	BI
	I																									
ANOPHELES	II	7	48	135	0.36	2.52	3	22	60	0.37	1.11	2	32	40	0.80	1.60	1	9	20	0.45	0.45	13	111	255	0.44	5.72
FARAUTI	III	*31	698	620	1.13	35.03	*24	337	480	0.70	16.80	*2	34	40	0.85	1.70	15	140	300	0.47	7.05	*72	1209	1440	0.84	60.48
LAVERAN	IV	9	126	180	0.70	6.30	10	56	118	0.47	4.70	*6	33	65	0.51	3.06	*4	15	28	0.54	2.16	*29	230	391	0.59	17.11
	E	*47	872	935	0.93	43.71	*37	415	658	0.63	23.31	*10	99	145	0.68	6.80	*20	164	348	0.47	9.40	*114	1550	2086	0.74	84.36
	I																									
ANOPHELES	II											1	9	20	0.45	0.45						1	9	20	0.45	0.45
PUNCTULATUS	III																									
DOENITZ	IV																									
	E											1	9	20	0.45	0.45						1	9	20	0.45	0.45
	I																									
ANOPHELES	II																									
SOLOMONIS	III											*1	12	20	0.60	0.60						*1	12	20	0.60	0.60
B. K. & R.	IV																									
	E											*1	12	20	0.60	0.60						*1	12	20	0.60	0.60
	I																									
ANOPHELES	II																									
LUNGAE	III	*4	30	80	0.38	1.52	*9	26	180	0.14	1.26	*3	20	60	0.33	1.00						*16	76	320	0.24	3.84
B. & S.	IV						1	1	10	0.10	0.10	*1	3	5	0.60	0.60	*1	2	6	0.33	0.33	*3	6	21	0.29	0.87
	E	*4	30	80	0.38	1.52	*10	27	190	0.14	1.40	*4	23	65	0.35	1.40	*1	2	6	0.33	0.33	*19	82	341	0.24	4.56
	I																									
TOTAL	II	7	48	135	0.36	2.52	3	22	60	0.37	1.11	3	41	60	0.68	2.04	1	9	20	0.45	0.45	14	120	275	0.44	6.16
ANOPHELES	III	31	728	620	1.17	36.27	24	363	480	0.76	18.24	4	66	80	0.83	3.32	15	140	300	0.47	7.05	74	1297	1480	0.88	65.12
	IV	9	126	180	0.70	6.30	11	57	128	0.45	4.95	6	36	65	0.55	3.30	4	17	28	0.61	2.44	30	236	401	0.59	17.70
	E	47	902	935	0.96	45.12	38	442	668	0.66	25.08	13	143	205	0.70	9.10	20	166	348	0.48	9.60	118	1653	2156	0.77	90.86
	I																									
BIRONELLA	II	2	3	20	0.15	0.30											1	8	20	0.40	0.40	3	11	40	0.28	0.84
HOLLANDI	III	1	13	20	0.65	0.65						2	10	40	0.48	0.96	1	12	20	0.60	0.60	4	44	80	0.55	2.20
TAYLOR	IV																									
	E	3	16	40	0.40	1.20						2	19	40	0.48	0.96	2	20	40	0.50	1.00	7	55	120	0.46	3.22

BREEDING INDEX SUMMARY

		Weeks 1	2	3	4	All
A	I. Lunga Delta					
R	II. Lunga to Matanikau	2.52	1.11	2.04	0.45	6.16
E	III. Matanikau to Bonegi	36.27	18.24	3.32	7.05	65.12
A	IV. Bonegi to Umasami	6.30	4.95	3.30	2.44	17.70
S	E. Entire District	45.12	25.08	9.10	9.60	90.86

LEGEND

*One or more breeding places repeated under another species

A - Areas
APD - Average number of larvae and pupae per dip, TLP:ND
BI - Breeding index, APD x BP
BP - Number of breeding places, Based on 20 or less positive dips
ND - Total number of dips
TLP - Total number of larvae and pupae

of larvae and pupae (TLP) found in a situation by the total number of dips (ND) taken. In the above example, let us say 400 larvae and pupae were taken. Therefore, the average per dip would be $\frac{400}{40} = 10.00$.

BI: Breeding Index. The breeding index for any given situation or area is obtained by multiplying the number of breeding places (BP) by the average per dip (APD). In the above situation, let us assume that out of the 40 dips taken 25 were positive. This gives us 2 breeding places (BP). The average per dip (APD) for the entire situation was 10.00. (Note that it is not determined separately for each "breeding place.") The *breeding index* would therefore be $2 \times 10.00 = 20.00$.

This breeding index was used for 10 months on Guadalcanal in routine malaria control activities and proved to be a much more accurate, sensitive and time-saving method of comparing populations of immature mosquitoes than the conventional average per dip, which takes into account only the density of the population but not its extent.

It will be noted that, while there is practically no correlation between the average per dip (APD) and the breeding index (BI) as obtained by our method, there is more agreement of the latter with the total number of larvae and pupae (TLP). Therefore it would appear that the total number of larvae and pupae taken can be used directly for comparison of populations for a given area for different checking periods. It could easily be developed into an index but from our records it does not seem to be as reliable as our breeding index. On the other hand it is certainly a much more valuable figure than the average per dip index and could be used in routine mosquito control operations if an effort is made to standardize the unit area sampled and the number of dips taken in each unit. This would probably mean more reliance on the field personnel and more work for them.

Using the same principles a very simple breeding index may be determined for survey work or for checking purposes when the personnel and the time available are more limited. Every breeding site (body or container of water) may be considered separately and any convenient number of dips taken. The more dips taken the more reliable the index, but a fairly accurate comparative index may be obtained, even if only a few dips are taken, as long as the dips are made in several parts of the body of water checked. The same procedure is followed in the field as above but the following information is recorded by the checker for every breeding site:

SA—surface area of body of water serving as effective breeding site; in square feet.

ND—total number of dips taken, disregarding all negative dips prior to the first positive dip.

PD—positive dips obtained.

TLP—total number of larvae and pupae.

The breeding index for every site is then computed as follows:

$$BI = \frac{SA \times PD \times TLP}{ND \times ND \times 10 \text{ (or } 100)}$$

If the average per dip (APD) is computed separately then the breeding index is obtained as follows:

$$BI = \frac{SA \times PD \times APD}{ND \times 10 \text{ (or } 100)}$$

In either case the choice of the factor 10 or 100 in the denominator depends on the intensity of breeding. It is included merely to produce an index figure that can be easily handled. Of course once the choice is made, the same figure must be used throughout the area and the season.

The breeding index for an area is then obtained by summation of the indexes for all the individual breeding sites within the area.

It is obvious that many factors affect the breeding index and that it has many limitations. It appears nevertheless that it is much more reliable than any of the other methods now in general use. Undoubtedly 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 umber 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 ame 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 952 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.