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SURVIVAL, REPRODUCTIVE CAPACITY, AND MIGRATION OF ADULT *CULEX PIPIENS QUINQUEFASCIATUS SAY*[1]

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ABSTRACT. *Culex pipiens quinquefasciatus* Say normal females, females tagged with ^{32}P, normal males, and chemosterilized males were released on a small island off the Gulf Coast of Florida to study egg-laying patterns, survival and migration. The first egg rafts were found 5 days after the releases were made when many of the females would have been 6 days old. However, the peak of the first oviposition cycle apparently occurred when the females were 8 days old. Only 10.4 rafts for every 100 females released were recovered, indication that about 90 percent of the females emerging on the island did not survive to oviposit. Only a small number of males and females placed 0.5 mile apart came together for mating.

Biological data for many species of insects including such factors as the development times of various stages, egg laying capacity, and survival of immature and adult stages in the laboratory have been available for many years. Recently, emphasis in insect control has been placed on the limitations of single approaches to insect control and the need for maximum integration of all possible methods of control. Management of pest populations implies that we will be able to regulate total populations over time. This approach will require that we thoroughly understand the dynamics of total populations as they exist in nature. A knowledge of such factors as reproductive success of populations from generation to generation or over time with differing environmental conditions and of the extent of migration and its relationship to total populations will be valuable to those interested in pest management.

Thus, although a considerable amount of laboratory data and some field data are available relative to the biology, migratory habits, mating, and host-seeking behaviour of many species of mosquitoes, little is known about the dynamics of total populations as they exist in nature. Weidhaas *et al.* (1971) reported information about the dynamics of a population of *Culex pipiens quinquefasciatus* Say. Also, Hagstrum (1971) studied the survival and dynamics of an isolated population of *Culex tarsalis* Coquillett.

In the present paper, we report the results of preliminary releases of normal adult *C. p. quinquefasciatus,* adults tagged with ^{32}P and chemosterilized adults made to study (1) the egg-laying potential; (2) the survival; and (3) the migration of males in the field.

EXPERIMENTAL LOCATION AND METHODS. We used a small island, Seahorse Key, off the Gulf Coast of Florida near Cedar Key for our experiments. Seahorse Key

[1] This paper reflects the results of research only. Mention of a pesticide in this paper does not constitute a recommendation of this product by the U. S. Department of Agriculture.

is about 1 mile long by ⅛ mile wide and is separated by at least 2 miles of salt water from the mainland and other islands. It is ideal for such studies since it is isolated and since a natural population of *C. p. quinquefasciatus* breeds there. Immature stages have been found in a septic tank and other waterholding containers around the lighthouse and marine laboratory; but all breeding sites occur within a diameter of 130–160 yards. Numerous birds are present to serve as a blood source for the adult females. At the time these releases were made, Patterson *et al.* (1970) were completing a study of the release of chemosterilized male *C. p. quinquefasciatus* which had essentially eliminated the natural population of this mosquito. Since our first release of ^{32}P-labeled females was made during the last 2 weeks of their study, a few sterile egg rafts were still being laid by the small number of laboratory-reared females (about 200 per day) present among their released chemosterilized males. However, the egg rafts from our ^{32}P-labeled females were readily identified and separated from other rafts by their radioactivity.

All the *C. p. quinquefasciatus* adults used in our tests were reared outdoors under a carport at the Insects Affecting Man and Animals Laboratory in Gainesville. From the egg to the pupal stage, they were held in plastic tubs (40-liter capacity) containing 12 liters of water; the larvae were fed a 1:1:1 mixture of liver powder, yeast, and hog supplement. Pupae were separated from larvae by the ice-water technique; then male and female pupae were separated with a pupal separator with a 98–99 percent accuracy. Adult cages were maintained so we would have a continual supply of eggs for rearing.

When ^{32}P-labeled females were needed for release, they were tagged by placing late third- and early fourth-instar larvae in distilled water containing 0.0008 μCi of ^{32}P per ml. These larvae were then fed the regular diet until pupation. The pupae were hand-picked by size for sex and rinsed twice in distilled water to remove external radioactivity. The female pupae were treated with the same chemosterilant as males discussed below. Thereafter, they were handled the same as the other mosquitoes.

The sterile males were obtained by exposing 0- to 24-hour-old male pupae for 4 hours to a 0.7 percent aqueous solution of the chemosterilant thiotepa (the *S*-analog of tepa). (This treatment also sterilized some females that were exposed.) After exposure, the pupae were removed, placed in distilled water for 1 hour, and then put on moist filter paper in trays for transport to the island. Fertile females that mated with the sterile males produced sterile egg rafts; thus, we could identify matings between sterile males and fertile females.

The pupae were transported to the island in trays lined with moistened filter paper and placed in chilled styrofoam boxes. Cedar Key is 60 miles by car from Gainesville, and Seahorse Key is 2.5 miles by boat from Cedar Key. When the trays arrived at Seahorse Key, they were placed under the marine laboratory building, and water was added to half fill the trays. By this time, some adults had emerged, and these adults flew from the trays and rested under the building; emergence of the remaining adults was completed by the following day. Therefore, on the day of release, some mosquitoes were 0 to 12 hours old while others were yet to emerge and were not 0 to 24-hour-old adults until the following day.

We made two releases on Seahorse Key. The first involved the release of ^{32}P-labeled females which were also sterilized. As mentioned, this release was made at the end of an experiment requiring the release of chemosterilized males. After the release of these females, we determined the number of ^{32}P-tagged egg rafts that we could recover from our ovitraps on the island. (During this release, natural oviposition sites were present on the island.)

The second release involved the release of a specific number of fertile males and females and sterile males when all known oviposition sites were covered or destroyed. The objectives were: (1) to determine the number of egg rafts per given number of females when no naturally-occurring oviposition sites were available; (2) to compare the number of egg rafts laid in ovitraps when natural oviposition sites were absent with the number laid in ovitraps when natural oviposition sites were present (first release); and (3) to determine whether any mating occurred between sterile males and fertile females released one-half mile apart.

In the first release, 200 females per day tagged with ^{32}P were released at a single location in the center of the island for 14 days from August 5 through August 18, 1969. Chemosterilized males from the sterile male release were still present to mate with these females. Egg rafts were collected daily from the ovitraps for 37 days. Rafts from the released females were identified by radioactive content assayed with a liquid scintillation counter which had about 95 percent efficiency for ^{32}P.

In the second release which extended over a 15-day period, 17,500 fertile males and 17,500 fertile females were released at a single point in the center of the island, and 175,000 sterile males were released at one end of the island, a distance of 0.5 mile from the site where the fertile males and females were released. Thus, the averages per day were 1,167, 1,167, and 11,667, respectively. Collections of egg rafts were made daily from the ovitraps from September 2 through September 27. The females in this second release were not tagged with ^{32}P. Since the natural breeding sites had been covered or destroyed since September 7, since the release of chemosterilized males from June into August had essentially eliminated the natural population, and since no radioactive egg rafts were collected after September 6, we considered that all rafts collected after September 6 came from the fertile females that we had released.

A total of 12 ovitraps was located in the central portion of the island, and an additional 3 were located at other sites on the island. The ovitraps were plastic tubs (40-liter capacity) containing 12 liters of water and 5 g of a 1:1:1 mixture of liver powder, dried brewer's yeast, and hog supplement ground to a fine powder. The medium was changed weekly.

RESULTS. The data obtained from the two releases are given in Table 1. In the first experiment, 2,800 females were released over 14 days, but a total of only 151 radioactive egg rafts was recovered over a period of 37 days, that is, 5.4 rafts for each 100 females released. The radioactive rafts had an average of 111 counts per minute (range 10–246) compared with an average of 772 counts per minute on the day of emergence of females kept in the laboratory.

The first raft was recovered August 10, 5 days after releases were started when

TABLE 1.—Data on egg raft collections from Seahorse Key following 2-week releases of females of *C. p. quinquefasciatus* tagged with ^{32}p (Test I) or of sterile and normal males and normal females at a 10:1:1 ratio (Test II).[a]

Days after start of releases	Avg. No. of rafts collected/100 females in Test I	Avg. No. of rafts collected/100 females in Test II	Percent sterility of egg rafts collected in Test II
5–6	1.5	0	....
7–8	7.0	0.45	25.0
9–10	3.0	3.3	4.5
11–12	1.5	4.0	2.0
13–14	4.0[b]	5.9[b]	6.5
15–16	2.25	13.7	10.0
17–18	10.5	16.7	10.0
19–20	2.0	9.3	5.0
21–22	3.75	9.7	8.0
23–24	1.0	13.3	6.0
25–26	0.75	9.2[c]	3.0
27–28	0	....	....
29–30	0.25	....	....
30–31	0	....	....
32–33	0.25	....	....
37	0	....	....

[a] Two hundred tagged females released/day from August 5 to August 18, 1972. Sterile males were released 0.5 mile from normal males and females from September 2 to September 16, 1972.
[b] Releases terminated.
[c] No collection made on day 26.

many of the mosquitoes released the first day would have been 6 days old. The first peak abundance of egg rafts occurred August 12, 7 days after releases were started when many females would have been 8 days old. Thus, the preoviposition time for a majority of the females in the field at the conditions prevailing on Seahorse Key was about 8 days but ranged from 6 to more than 8 days. We could not determine preoviposition times beyond 8 days. The number of rafts collected per day was extremely variable as would be expected. However, 90 percent of the rafts laid were collected 7 to 22 days after the releases started so the daily average during this period was 8.5 per day. Then from 23 to 37 days after the start of the releases, we never collected more than 2 rafts per day, and the average was only 0.8 per day. The noticeable reduction in number of egg rafts that occurred after 22 days, 9 days after the releases were stopped, tends to confirm the 8 days preoviposition time mentioned previously and indicates that a large majority of the rafts deposited were from the first egg cycle. The last radioactive raft was collected 19 days after the releases were terminated and 32 days after they were begun.

In the second experiment, 1,889 egg rafts were collected from 9 to 25 days after releases started (September 9 through September 27); however, we discontinued collections after 25 days because of stormy weather so we did not recover all egg rafts that might have been laid although we felt that we had collected the majority. Thus, when all natural oviposition sites were covered or destroyed, the recovery averaged about 10.4 rafts for every 100 females released—just twice the number recovered per 100 females when natural oviposition sites were present. In this release, the first egg raft was collected 7 days after the releases were initiated. An average of 7 percent of the rafts collected during the second release were sterile, indicating that some sterile males and fertile females came together for mating over a distance of one-half mile.

Discussion. The release of known numbers of tagged or untagged mosquitoes permitted us to study certain aspects of the biology of *C. p. quinquefasciatus.* Of course, in the field, variations in ecological or environmental conditions tend to make the results obtained on a daily basis quite variable. However, the averaging of such data over days should produce useful data though the results vary from time to time and in different ecological situations. For example, environmental conditions more or less favorable to the survival of adult females could result in a greater or lower number of egg rafts collected per female.

Also, the accuracy of the information obtained from releases of tagged insects depends on the assumption that the method of tagging has no deleterious effect on the insects released. We made this assumption on the basis of previous reports: Dame *et al.* (1964) reported that the field mating activity of male *Anopheles quadrimaculatus* Say was not affected by chemosterilization. Weidhaas and Schmidt (1963) and Smittle *et al.* (1968) found that the chemosterilant, apholate, did not affect mating competitiveness of male *Aedes aegypti* (L.) or *C. p. quinquefasciatus.* Patterson *et al.* (1968) found that radioactive male *C. p. quinquefasciatus* were competitive with untreated males. Smittle and Patterson (1970) found that females placed in distilled water containing 0.25 μCi/ml (over 300X the concentration used in the present study) for 48 hours produced egg rafts containing an average of 155 eggs and that 92.3 percent of these eggs hatched.

The fact that we collected twice as many rafts per 100 females after we covered or destroyed natural oviposition sites indicates that our ovitraps collected about 50 percent of the rafts deposited on the island when natural oviposition sites were present. This figure could vary from time to time, but we feel that the 2-week averages give a fairly accurate picture of the percentage of rafts collected by ovitraps on the island. The fact that 15 ovitraps located in close proximity to the breeding sites, 12 within a diameter of 130–160 yards, collected 50 percent of the rafts indicates that: (1) ovitraps can be effective survey tools for this species of mosquito and that (2) ovitraps do not collect a sufficiently high percentage of rafts to be used by themselves for population reduction unless their attractiveness to gravid females is increased by some means. Weidhaas *et al.* (1971) showed that a reduction of at least 90 percent in reproductive success was necessary to maintain a reduction in density of this population.

The recovery of only 10.4 rafts for every 100 females released is a measure of the survival of the females released on the island since we can consider this figure as representing almost total recovery of rafts. A large majority of the egg rafts recovered were demonstrably rafts from the first oviposition cycle. Therefore, we can conclude that about 90 percent of the females emerging into the population did not become involved in egg laying and that the survival of a majority of the females in the field was relatively low. Nevertheless, the number of eggs produced per female at a single oviposition is sufficiently large to provide stable populations or populations that increase at 5- to 8-fold rates if survival of the immature stages is 0.1, 0.5, or 0.8, respectively (Weidhaas *et al.*, 1971), even without any change or increase in the survival of adult females. The egg-laying of females of this species under the field conditions is thus very similar to that of the model presented for an isolated population of *C. tarsalis* by Hagstrum (1971).

Our action in releasing sterile males in one location and normal virgin males and females at another location meant that the sterile males and fertile females would have to come together for mating over a distance of 0.5 mile. Since only 7 percent sterility was found in the egg rafts collected from these females, only a small number of sterile males, probably less than 0.5 percent and fertile females came together for mating over this distance. Lindquist *et al.* (1967) made the following comment in their study of the dispersal of ^{32}P-labeled *Culex p. fatigans* in Burma: "the fact that males travelled in good numbers as far as 0.20 miles (320 meters) or more is encouraging if experimental work is initiated on the possible control of *C. p. fatigans* by the release of sterile males." Also, Patterson *et al.* (1970) showed that a population could be eliminated when the males had to disperse as much as 160 yards. These data indicate that any releases of sterile male *C. p. quinquefasciatus* for population control may be limited to distances of less than 0.5 mile and possibly as low as 0.05 to 0.2 mile.

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