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DISPERSAL OF *CULEX SALINARIUS* IN SOUTHWESTERN LOUISIANA

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ABSTRACT. The dispersal of post-teneral female *Culex salinarius* was studied near a brackish water breeding source in southwestern Louisiana. An estimated 4,000, 8,000 and 22,000 mosquitoes were marked with fluorescent pigments in 3 mark-release-recapture experiments conducted in 1980 and 1981. Mosquitoes were collected over a 26-hr period following release. Thirteen marked *Cx. salinarius* were recovered in all directions from the release point at distances of up to 2,000 m on the night of release and 1,000 m on the following night. Single specimens of *Aedes vexans* and *Anopheles* sp. were recovered at 1,000 m on the night of release.

INTRODUCTION

Insect dispersal by flight may be divided into 3 categories, migratory, appetitive and consumatory. Kennedy (1975) defined migration as "adaptive travel" involving persistent locomotion in an oriented fashion with a depression of vegetative responses. In the case of mosquitoes, this type of movement usually involves newly emerged adults. Localized movements within the immediate habitat are termed trivial or appetitive and occur as a result of active search for stimuli related to feeding, mating or oviposition (Craig 1918, Matthews and Matthews 1978). These movements usually involve reproductively active members of the population and may include both horizontal and vertical movement. Reception of certain stimuli related to feeding, mating or oviposition leads to consumatory flight which results in the insect approaching its objective (Craig 1918, Tinbergen 1951). The last 2 categories of dispersal are therefore closely related.

This study concerns the appetitive and consumatory flight of *Culex salinarius* Coquillett, a dominant component of the mosquito community in coastal marshes along the U.S. Gulf coast. Information concerning the long distance flight of *Cx.*

salinarius is confined to a single report of the species caught downwind more than 8.0 miles (12.9 km) from the shores of Delaware Bay (MacCreary and Stearns 1937). Vertical movements of this species have also been reported. It was collected by MacCreary (1941) at a height of 103.0 ft (13.4 m), Snow (1955) at 75 ft (22.9 m) and Blakeslee et al (1959) at 20.0 ft (6.1 m). The objective of this study was to determine the horizontal movement of *Cx. salinarius* over short periods of time.

MATERIALS AND METHODS

STUDY AREA. Three mark-release-recapture studies were conducted near a brackish water area in southwestern Louisiana. The study site was centered 9.0 km south of the town of Erath in

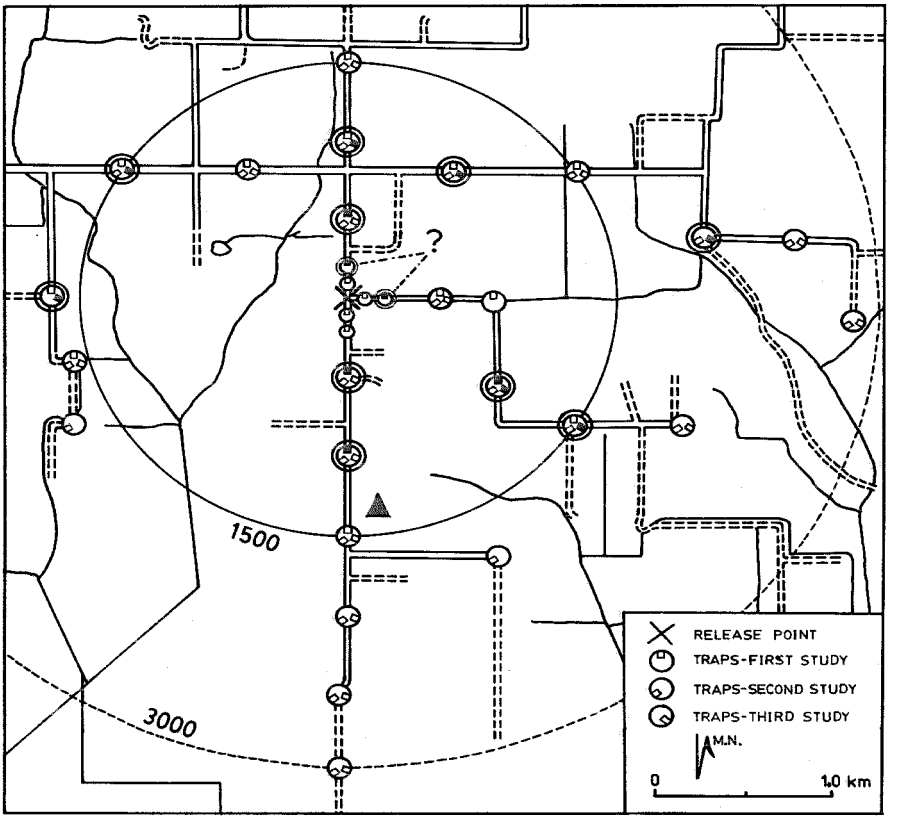

Fig. 1. Study Area. Located at 29° 52′ 30″ N; 92° 01′ 50″ W. Circles indicate trap locations. Boxes within circles indicate for which study each location was used. Successful recapture locations for each study are indicated by a double ring and appropriately blackened box. The question mark indicates uncertainty of recapture direction at 200 m in first study. Triangle indicates location of New Jersey trap in first study.

Vermilion Parish (Fig. 1). The area south of the release point is composed of pasture and extensive brackish water marsh while land to the north is used in rice and soybean cultivation. The release point was chosen so that we could use the roads in the area to place traps in all directions from the point. We had previously determined that *Cx. salinarius* occurs throughout the entire study area.

TRAP DESIGN. Methods of capture, marking, holding, release and recapture of adult mosquitoes followed closely those of Quarterman et al. (1955), Bailey et al. (1962) and Bailey et al. (1965). These studies differ primarily in the type of traps used for recapture. Huffaker and Back (1943) determined that traps which used both carbon dioxide and light obtained the largest catches of *Cx. salinarius*.

For financial reasons, a modification of the basic cylindrical trap design, used by previous workers, was developed for use in the present study. The trap was constructed from a gallon size tin can from which the top and bottom were removed and replaced with screen cones. A battery operated light source (Fig. 2) was attached to one side. The light source unit consisted of a piece of 0.25 inch (6.35 mm) plywood on which 3 thin gauge metal pieces (0.79 mm) were attached with 0.5 inch no. 8 metal screws (3.3 × 13.0 mm). These metal plates held 2 size C flashlight batteries and a bulb (Fig. 2C). Slots were cut in each metal piece to receive the battery terminals (Fig. 2B). The strip of metal cut from those slots contacting the negative end of each battery was rolled downward to form a coil. The metal strip was removed from slots contacting the positive end of each battery.

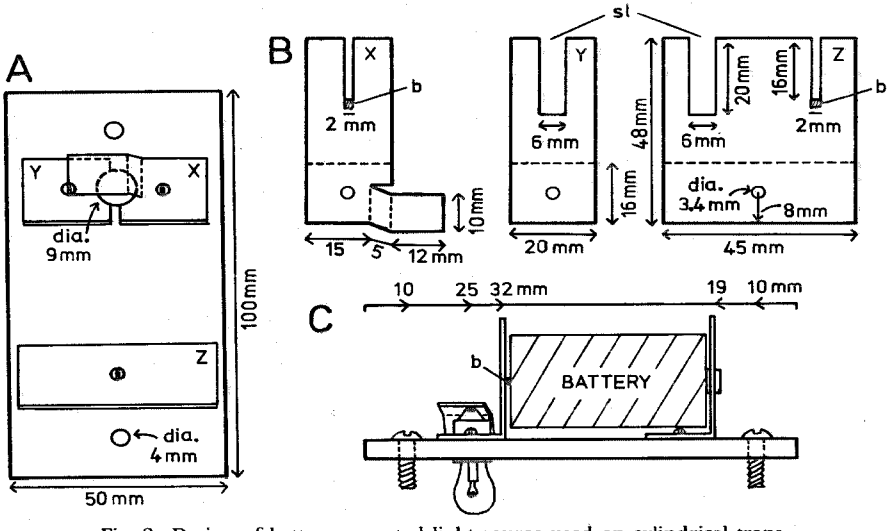

Fig. 2. Design of battery operated light source used on cylindrical traps.
A— plywood base showing position of holes and metal pieces.
B— design patterns of metal pieces.
C—side view of completed unit.
b- metal coil; sl- slot.

The light unit was secured to the outside of the can using two 0.5 inch #10 stove bolts (3.9 × 13.0 mm) with the light bulb protruding through a hole cut halfway down the side of the can. Screen cones were fitted into both ends of the can and held in place by no. 64 rubber bands. A 10 mm diameter hole was cut at the apex of each cone. A 60 cm length of no. 12 nylon twine was used to suspend the trap.

PROCEDURE. Adult mosquitoes were collected not more than 48 hr prior to the planned time of release with 2 battery operated CDC miniature light traps from the brackish water marsh located 4,000 m south of the release point shown in Fig. 1. Small blocks of dry ice were hung just above each trap. The captured mosquitoes were transported to Lafayette, LA, in a 1 m^3 wood-framed cage covered with wet muslin cloth.

At the same time adults were being collected for the first study, 2 cylindrical traps were operated to test their effectiveness. The mosquitoes captured in these traps were used to estimate the percentages of each mosquito species present in the total catch. These percentages were later used to estimate the number of marked *Cx. salinarius* that were released. The percentages of each mosquito species collected for the second and third studies were estimated from the mosquitoes killed by the fan of the CDC trap during collection. This method of estimate may not be accurate because of possible differences in the percentage of each species killed by the fan.

Powdered fluorescent pigments, manufactured by the DAYGLO Color Corporation, Cleveland, OH, were used to mark the captured adults. A Blaze Orange pigment, (A-15-N), was used in the first study. A Rocket Red pigment, (A-13-N), was used in the second and third studies. Both pigments have a particle size range of 4-6μ. The pigment was blown onto the mosquitoes through the screen of the holding cage using a powder blower (Model 119) manufactured by the DeVilbiss Company, Somerset, PA. The mosquitoes were marked on the night before release to allow for any mortality caused by the pigment or the marking technique.

After marking, the holding cage was covered with wet muslin cloth and placed in a cool area of a lab to maintain high humidity. An estimate of the number of mosquitoes alive in the cage, prior to release, was obtained by counting the individuals resting on a horizontal strip of known area on one side of the cage. The mean of 2 separate counts was used to estimate the total number on the 4 sides and the top of the cage. Mosquitoes were not fed during the holding period.

Traps were placed in concentric circles around the release point at easily accessible locations. Since there are no roads southwest of the release point no traps were located in that direction. In the first study 22 traps were used within a 1500 m radius around the release point. In addition, a standard New Jersey light trap was placed 1,400 m south of the release point. In the second and third studies 23 traps and 22 traps respectively were used within a 3000 m radius around the release point.

All traps were suspended 1.5 m above the ground from wooden poles placed 2 m from the edge of the road. A 3 cm^3 block of dry ice, loosely wrapped in newspaper, was placed in each trap.

The marked mosquitoes were released just after sunset as suggested by Provost (1957). Measurements of air temperature, relative humidity, wind speed and direction were made every 30 min beginning at the time of release. Air temperature and relative humidity were measured with a Taylor sling psychrometer. Wind speed, in mps, and direction were determined with a hand-held WinDial wind speed indicator with compass (Model 919) manufactured by the Airguide Instrument Company.

The traps were operated for 1.5 hr after release. Upon recovery, a large plastic bag was used to enclose each trap and any mosquitoes resting on the outside surface. In the lab, both bag and trap

were placed in a freezer for 5–10 min to kill the insects.

Trapping resumed on the following morning beginning 1 hr prior to and ending ½ hr after sunrise. A third trapping period took place the night after release for the first and third studies. Specimens were examined under a dissecting scope. Marked specimens were distinguishable without the use of an ultraviolet light.

RESULTS

FIRST STUDY. Mosquitoes were collected for the first study on 7 and 8 May 1980. Collections from 2 cylindrical traps yielded 739 mosquitoes (501 and 238). We felt these numbers indicated that the traps could be used for recapture studies. Using the percentage of each species in the cylindrical traps, it was estimated that of the 4,000 mosquitoes alive in the holding cage at the time of release approximately 3,800 were *Cx. salinarius* (95%), 130 were *Aedes vexans* (Meigen) (3%) and 70 were *Anopheles* sp. (2%).

Release of marked mosquitoes took place on 8 May 1980. Weather parameters for each trapping period are shown in Table 1. The sky was clear during all trapping periods and there was no moon present. There was a change in wind direction during the first trapping period.

Table 2 summarizes the collection data for each trapping period. A standard New Jersey light trap was in operation during the third trapping period (see Fig. 1). Among the mosquitoes collected, during the first trapping period, 6 female *Cx. salinarius,* and 1 female each of *Ae. vexans* and *Anopheles* sp. had been marked. These recoveries represent 0.2% of the total number of marked mosquitoes released. Marked specimens of *Cx. salinarius* were recovered at 500 m north and south and 1,000 m south and southeast (Fig. 1). The contents of 2 traps placed 200 m north and east (indicated by ? in Fig. 1) were mislabeled upon recovery and as a result it is uncertain in which trap the sixth specimen of *Cx. salinarius* was recovered. A single marked specimen each of *Ae. vexans* and *Anopheles* sp. was recovered at 1,000 m south.

SECOND STUDY. Mosquitoes were collected for the second study on 18 June 1980. A sample of 593 dead mosquitoes from the CDC traps was identified and used to estimate the percent of each species captured. From these data it was estimated that of the 8,000 mosquitoes alive in the holding cage at the time of release, approximately 3,600 were *Cx. salinarius* (45%), 3,040 were *Psorophora columbiae* (Dyar and Knab) (38%), 1,360 were *Anopheles* sp. (17%), and 15 were *Ps. ciliata* (Fabr.) (0.2%).

Release took place on 19 June 1980. Weather parameters are shown in Table 1. The sky was clear during each trapping

Table 1. Summary of weather parameters during each trapping period for 3 mark-release-recapture studies.

Date and time	Wind direction	Wind speed (mps)	Temperature (°C)	Relative humidity (%)
1980				
9 May (p.m.)	ENE-SE	0.0	21.9–24.7	57.0–60.5
10 May (a.m.)	SE	1.0	21.4	79.0
10 May (p.m.)	SE	1.0	23.9	70.0–72.5
18 June (p.m.)	SE	1.0	28.9–29.4	68.0–71.5
19 June (a.m.)	SE	0.0–1.0	26.4	71.8
1981				
7 May (p.m.)	N-E	0.0	25.5	—
8 May (a.m.)	SE	0.0	13.3	—
8 May (p.m.)	SE	1.0	25	—

Table 2. Summary of collection data for each trapping period for all 3 mark-release-recapture studies.

Date and time	Species	Total no. collected	Marked specimens collected		
			No.	Distance	Direction
1980					
9 May (p.m.)	*Cx. salinarius*	45 ♀	1 ♀	1,000 m	S
			1 ♀	1,000 m	SE
			2 ♀	500 m	N
			1 ♀	500 m	S
			1 ♀	200 m[1]	
	Ae. vexans	2 ♀	1 ♀	1,000 m	S
	Anopheles sp.	2 ♀	1 ♀	1,000 m	S
10 May (a.m.)	*Cx. salinarius*	103 ♀		No recoveries	
10 May (p.m.)	*Cx. salinarius*	331 ♀			
		84 ♀, 1 ♂[2]		No recoveries	
	Ae. vexans	9 ♀			
1980					
18 June (p.m.)	*Cx. salinarius*	40 ♀		No recoveries	
	Ps. columbiae	18 ♀, 3 ♂			
19 June (a.m.)	*Cx. salinarius*	16 ♀		No recoveries	
	Ps. columbiae	10 ♀, 1 ♂			
1981					
7 May (p.m.)	*Cx. salinarius*	201 ♀	1 ♀	1,000 m	SE
			1 ♀	1,500 m	NW
			1 ♀	1,500 m	SE
			1 ♀	1,600 m	W
			1 ♀	2,000 m	ENE
8 May (a.m.)	*Cx. salinarius*	7 ♀		No recoveries	
	Ae. sollicitans	1 ♀			
8 May (p.m.)	*Cx. salinarius*	506 ♀	1 ♂	1,000 m	N
			1 ♀	1,000 m	NNE
	Ae. sollicitans	17 ♀			
	Anopheles sp.	2 ♀			

[1] Mislabeled collection from either N or E.
[2] Collected from standard New Jersey light trap.

period, however, a severe thunderstorm passed to the north of the study area at about 2300 on 19 June. There was a 3/4 moon in the western sky at about 30° above the horizon during the first trapping period. No marked mosquitoes were recovered.

THIRD STUDY. Mosquitoes were collected for the third study on 6 May 1981. A sample of 431 dead mosquitoes from the CDC traps was used to estimate the percent of each species of mosquito captured. From these data it was estimated that of the 22,000 mosquitoes alive in the holding cage at the time of release, approximately 18,260 were *Cx. salinarius* (83%), 1,980 were *Anopheles* sp. (9%), 1,652 were *Aedes sollicitans* (Walker) (7.5%) and 40 were *Ps. ciliata* (0.2%).

Release took place on 7 May 1981. Weather parameters are shown in Table 1. The sky was clear during all trapping periods and there was no moon present. There was a change in wind direction between the first and second trapping periods.

Five female specimens of *Cx. salinarius* were recovered during the first trapping period and 2 female *Cx. salinarius* were recovered during the third trapping pe-

riod. These recoveries represent 0.03% of the total number of marked mosquitoes released. Marked specimens were recovered at distances of 1000 m north, north-northeast and southeast; 1500 m northwest and southeast; 1600 m west; and 2000 m east-northeast (Fig. 1).

DISCUSSION

The use of freshly captured adult female mosquitoes, which were attracted to simulated host stimuli in the form of carbon dioxide, suggests that we were studying movements related to appetitive and consumatory activity rather than migratory behavior.

The recapture of *Cx. salinarius* in all directions from the release point suggests equal dispersal as shown by Bailey et al. (1965) for *Culex tarsalis* Coquillett. These authors found that *Cx. tarsalis* flew upwind at wind velocities between 2.0 and 4.0 mph (0.9–1.8 mps) and that at wind velocities less than 2.0 mph dispersal was in all directions.

On the basis of the data collected in this study, females of *Cx. salinarius* can travel at least 2.0 km in 1.5 hr. If this distance was traveled several nights in a single direction this species could fly considerable distances. Horsfall (1954) mentioned such a pattern of movement for which he used the term "creeping spread." Observations made by MacCreary and Stearns (1937) on distances flown by *Cx. salinarius* in excess of 8.0 mi cannot be compared to the present data since the length of time for those flights was not determined.

In general the results obtained in these studies are consistent with results reported for other species of mosquitoes. *Culex tarsalis* was recovered upwind at a distance of 2.75 mi (4.4 km) and downwind as much as 15.75 mi (25.3 km) (Bailey et al. 1965). Reeves et al. (1948) reported flights of *Cx. stigmatosoma* Dyar (= *Cx. peus* Speiser) at 1.0 mi (1.6 km) and *Culiseta incidens* (Thomson) at 0.6 mi (0.96 km). Quarterman et al. (1955) reported downwind dispersal of *Ps. columbiae* as far as 6.0 mi (9.65 km) and *Ps. discolor* (Coquillett) as far as 1.5 mi (2.4 km). Some of these flights were made over periods of several days. These studies suggest that appetitive dispersal activity is usually characterized by short distance flight.

Migratory flight probably covers longer distances. The status of migratory flight in most species is unknown. Provost (1953) suggests that some species of mosquitoes do not exhibit a migratory period. Whether or not members of the genus *Culex* show migratory behavior is uncertain. Bailey et al. (1965) believe that *Cx. tarsalis* does not undergo a migratory stage.

While there seem to be conflicting reports on times of flight activity by *Cx. salinarius* (Murphey and Darsie 1962, Carroll and Bourg 1977, Slaff and Crans 1981), all studies agree that the peak of activity is immediately after sunset. It is not surprising that all of our recaptures of marked specimens were made during the early evening trapping period.

The morning trapping period was designed to take advantage of a possible dawn activity peak suggested by Carroll and Bourg (1977). It is impossible to establish from our data if this peak exists. It should be noted that the low temperature on the morning of 8 May 1981 would have depressed any tendency toward a presunrise flight that may exist in the population.

It is interesting to note that the marking agents used in these studies were easily recognized on any marked specimen without the use of ultraviolet light. However, the amount of pigment adhering to specimens of *Cx. salinarius* was observably small. Particles were observed on the thorax, abdomen, antennae and wings. The orange pigment seemed to be retained better since recaptured specimens marked with the red pigment were only lightly marked. Since the application technique was the same for both pigments it would seem that the orange pigment was the better choice.

ACKNOWLEDGMENTS

Financial support for this work was provided by the Department of Biology and the Graduate Student Organization of the University of Southwestern Louisiana. We would like to thank the following persons for their help with the field work: Sam Riche, Ricky Faulk, A. J. Broussard, Milton Lantier, Bonnie Broussard and Steven Faulk of the Vermilion Parish Mosquito Control; and Mary N. LaSalle, T. Dale Bishop, Shirley A. Bishop and J. Dirk Kavanagh. We also thank the DAYGLO Color Corporation and Jerome D. Madden.

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