EMERGENCE AND REPRODUCTIVE BEHAVIOR OF *GLYPTOTENDIPES LOBIFERUS* (DIPTERA: CHIRONOMIDAE)

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ABSTRACT. Field surveys utilizing black light and adhesive traps made during the summers of 1969 and 1970 to determine emergence patterns of adult *Glyptotendipes lobiferus* (Say) from the Holyoke canal system indicated that emergence peaks may occur irregularly from mid-April through mid-September.

Emergence patterns, swarming, mating and oviposition data of the species are reported for the first time. A positive phototaxis of emerging pharate adults is reported for the first time in the Chironomidae. Swarming at dusk and dawn was initiated by natural light intensities of 6 to 9 foot candles. Mating occurred in flight in the dawn swarms and averaged 6 seconds. Solitary pairs mated after dark. Mating occurred near the water surface upon female emergence and lasted 1 second or less. Oviposition involved extrusion of a dense egg mass 3 to 5 mm long onto the hind legs, followed by a flight during which the egg mass was deposited in the water. In the laboratory egg masses were observed to swell and resulted in a gelatinous mass about 13.5 mm long. Length of the egg stage at 22°–25° F. and length of life of mated females at this temperature was 3 days.

INTRODUCTION

The group of insects known as the chironomid midges (Chironomidae=Tendipedidae[1]) Order Diptera, are usually rather inconspicuous and innocuous. Although they do not attack man or animals, mass emergences may create an intolerable nuisance when they alight on the body or enter homes, industries and restaurants. Many other aquatic insects such as chaoborid midges, mayflies, and caddisflies may become troublesome on occasion, but chironomids are the most frequently cited nuisance organisms.

The works of Grodhaus (1963) and Oliver (1971) give general and detailed information on the biology of chironomids as well as extensive bibliographies. Eggs are usually laid in water in gelatinous strings or globs. The larval period, consisting of 4 instars underwater, is both the longest period of the life cycle and most resistant to winter conditions, particularly the 4th instar (Grodhaus, 1963; Hilsenhoff, 1966). Depending on the species, the larvae may be burrowing, clinging, crawling or, as in the case of *G. lobiferus,* tube dwelling in behavior. Adaptations to the surfaces of diverse substrata are known and locomotion by swimming is well-developed. Larval food includes particulate debris and phytoplankton. Water-borne food is drawn into a larval-constructed net spun over the end of the tube as the insect undulates its body within. The short, sedentary pupal stage undergoes development within a tube-like case prior to rising to the water surface in preparation for emergence.

Because chironomids are found in many different habitats such as eutrophic lakes, polluted streams and estuaries and include so many different species, the development of effective control methods must be suited to the biology of each species. Methods employed against mosquitos frequently have failed or have not been practical for economic reasons. Often, the larval breeding areas are bodies of water which serve as sources of drinking water or for an industrial use. Radical changes of the physical environment or the use of insecticides in such waters might create a hazard to humans and other organisms or render the water supply useless for industrial processes through chemical contamination.

Summer nuisance outbreaks of flying insects in the city of Holyoke have been especially intense in certain years, particularly in those areas bordering the Holyoke

[1] The nomenclature used herein is based on the work of Sublette and Sublette (1965).

Canal system. This canal system in particular, and the adjacent river as well, serves as a breeding area for the immature stages of many aquatic insects. The canal totaling 4½ miles in length, vary in width from 80 to 140 feet, and in depth from 6 to 30 feet. Water enters the system from the Connecticut River through a main gate just above the Holyoke Dam and moves through three levels, finally re-entering the river at various points through 5 overflow stations. Total capability of the system is 10,000 cubic feet per second, but it is normally operated below this rating.

Although mayflies, caddisflies and many dipterous insects are known to be fairly numerous in the summer season, the midge, (*Glyptotendipes lobiferus* (Say))[2] appears to be the most significant nuisance species. Huge numbers of this species may emerge rather suddenly during hot weather, at times making human passage between buildings and near the canals comfortable only by holding a handkerchief over the mouth and nose. Paper industries located near the canals are severely hampered in their operations due to the inevitable entrance of the midges into their buildings. Not only do workers complain of the mosquito-like midges alighting on their bodies, but when midges fall into paper-processing machines, great quantities of quality paper are down-graded by the brown stain of crushed insect bodies.

For a number of years, control of the midge has been attempted through screening of buildings and insecticide treatment of the canal walls during the summer drainage when canal repairs were being made. These procedures have been employed with virtually no reference to midge biology and seasonal distribution, and with no quantitative assessment of the value of the insecticide treatments. Screening and closure of buildings is difficult to enforce in hot weather because of inadequate ventilation for workers. Necessary loading and traffic operations in and around buildings compound the problem of building closure. Thus, reduction of the midge nuisance has been limited and insecticidal control effects have been questionable.

The purpose of this study was to investigate midge summer emergence patterns and reproductive behavior preparatory to revising methods of control.

SAMPLING PROCEDURES

LIGHT TRAP DESCRIPTION AND METHOD OF USE. Commercial black light traps (Onamia Manufacturing Co., Onamia, Minnesota) were modified by attaching a large (15 in x 18 in) heavy duty plastic bag in place of the standard burlap bag, beneath the intake fan of each trap. Plastic bags permitted much more effective collection of the midge catch than did the burlap in that specimens were more visible, fewer specimens were damaged, and more accurate counts were obtained.

A corner of the plastic bag was opened and the catch transferred to a smaller plastic sack, using the air blast from the fan to drive insects through the opening. The opening was then securely closed by fastening with a wire clip. The plastic sack was also secured with a wire clip and the catch transported to the laboratory for counting. The location of light traps follows:

Canal Traps—1. In front of the Valley Paper Company on a frame 5 feet above the canal penstock opening (Figure 1).

2. In front of the Brown Company's Albion mill in the same manner as 1. (Figure 1).

River Trap—Located behind the Valley Paper Company on a frame 5 ft above the ground adjacent to County Bridge which spans the Connecticut River below the Holyoke Dam. This trap was located approximately 225 ft from Canal Trap 1 and behind the 5 story Valley Paper Company Building. (Figure 1).

The traps were operated continuously during the sampling periods except for infre-

[2] Specimens were kindly identified by Dr. Hugo Jamnback, Entomologist, New York State Science Service, State University of New York, Albany, New York.

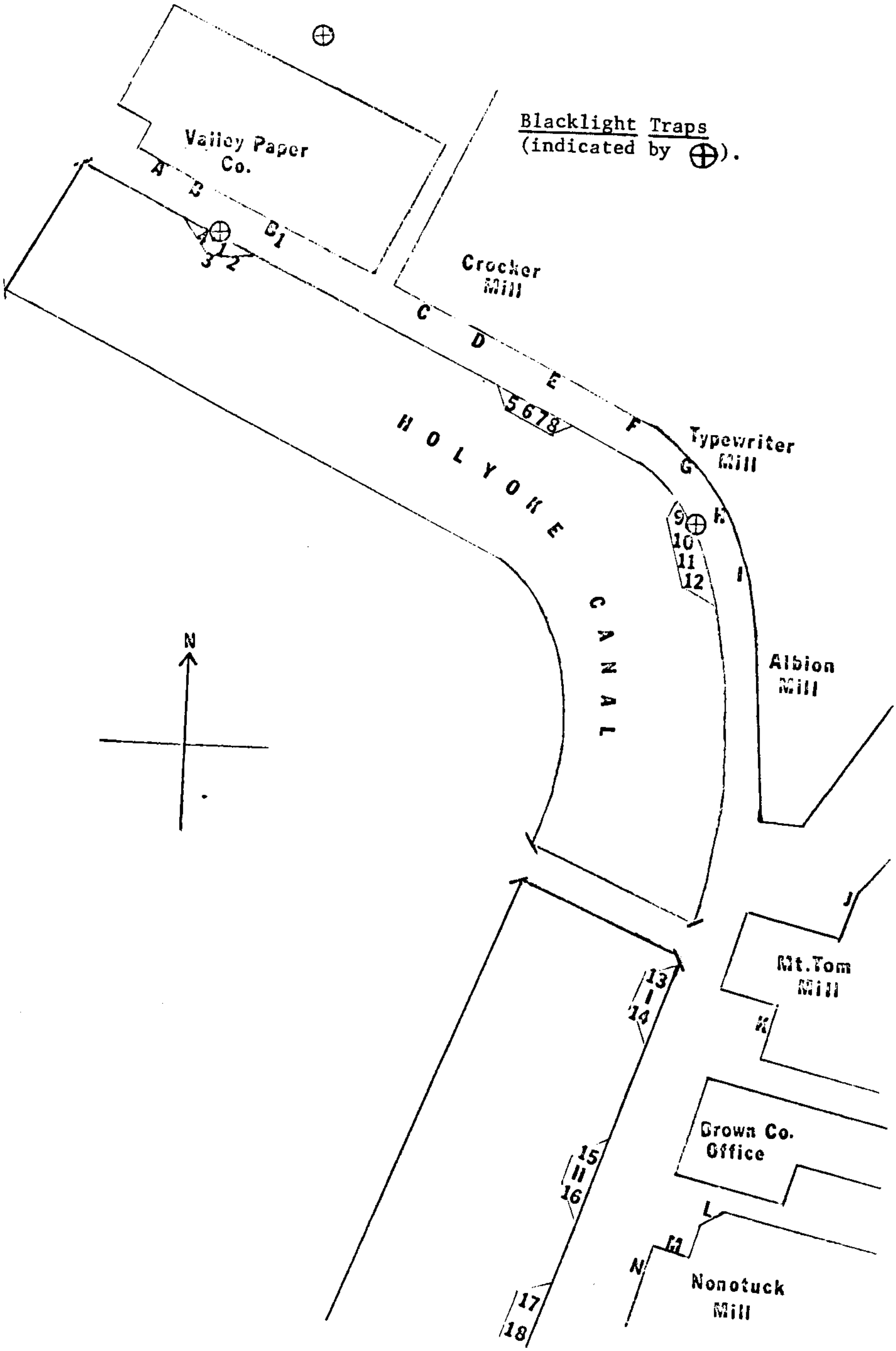

Fig. 1. Holyoke Study Area. Shows location of: *Adult Midge Adhesive Traps* (Nos. 1 through 18 plus I and II located on canal ice fenders and traps A through N located on mill window screens).

quent cleaning and repair during daylight hours after the catch had been removed.

In the laboratory the total catch of insects per each trap was removed from the plastic sack to a white enamel pan. The catch was spread evenly in the pan and insects of other species larger than 1 cm were removed. (Size range of midges was 0.8 to 0.9 cm based on 100 measured specimens.) A 1-oz. capacity measure filled level full (not packed) with a portion of the catch was found to contain 500 specimens (actually 500+25, a 5% error, based on 10 fillings). The number of measures of catch X 500 was used, therefore, as the total catch per unit time.

The number of midges in a total catch was obtained by counting the number of midges per measure (or per 500 insects) times the total number of measures. This method was selected after counting 10 measures of the same catch. For this each measure of 500 insects was spread in the white pan and counted. Results indicated a maximum variation of 10% between measures. In the first part of the sampling period mold developed in some catches held more than 2 days after collection and prevented accurate use of this counting procedure. Subsequently, all counts were made within 2 days of collection and any catches contaminated with mold were omitted from the study.

ADHESIVE TRAPS. Adhesive traps were prepared by cutting ¼ in. unfinished plywood into 6 in. squares and painting one surface with Stikem Special (Michel & Pelton Co., Emeryville, California) in a layer ⅛ inch deep. These traps were placed to provide an index of the number of midges per 6 in. square per 24 hr. From these data, seasonal distribution and peaks of emergence were calculated and compared with data obtained from black light traps.

Two banks of traps were set in the study area (Figure 1). One set of 20 traps was nailed to wood surfaces 6 in. to 24 in. above the water surface (water fluctuations in this area prevented establishment of a standard distance; however, except at times noted—August 9 and 16, water level was maintained within these 2 distances). The actual sites selected for position were the 6 ice fenders located within the study area (Figure 1). Beginning at the north end of the area, ice fender No. 1 held 4 traps (traps 1 to 4). This pattern was repeated on the next 2 fenders (traps 5 to 8 and 9 to 12). Fenders Nos. 4 and 5 held 3 traps each and fender No. 6 held 2 traps. None of the traps above on any fender was closer than 4 ft nor greater than 12 ft from any other trap. The ice fenders are spaced approximately 350 ft apart.

Another bank of 15 traps (A through N) was set on the screens of the mill windows which were located 30 ft from the edge of the canal (except for 2 traps (J and K) located approximately 60 ft from the canal). All of the traps on the windows were 6 to 10 ft above the ground or 9 ft above the water surface. These traps were held in place on the 18 mesh/in. screening by means of a wire hook which was forced through the holes of the screen. The purpose of the traps was to obtain an estimate of the number of adults alighting on the screens per 24 hour period.

Every 24 hours, or other period noted, counts and records of trapped midges were made. All insects on each trap were removed by means of a small metal spatula and discarded. When numbers per trap exceeded 200, only ¼ to ½ of the trap was counted and cleaned. Numbers were recorded as number per 6 in. square after multiplication by 4 or 2. Each time a trap was read, an inspection was made of the sticky surface and either existing Stikem was redistributed or more was added to obtain the ⅛ inch coating. Damaged or weathered traps were replaced.

METHOD OF SAMPLING SWARMS. Dusk swarms of midges were sampled by means of a transparent plastic cup 4.8 cm in diameter and 4.4 cm deep. The cup was held in the palm of the hand and swept briskly through the swarm at the 6 ft level above the ground. At the end of the sweep the other hand was clamped over the opening prior to cessation of the sweeping motion. Counting and sexing the catch was made by direct observation through the transparent sides of the cup with the aid of a flashlight. Withdrawal of the hand from the open end and slight shaking freed any midges caught and the device was ready for the next sweep.

EMERGENCE TRAPS. Emergence traps were constructed of pine and 18 mesh aluminum window screen. A 4-sided cone of screen 2 ft high was attached to a pine frame, having a basal opening 2 x 2 ft so that 4 square ft of water surface would be sampled. At the small end of the cone a pine block 4 x 4 in. was attached. The device was floated large end down in canal waters and removed periodically for examination of resting adults to determine numbers. After recording the counts all midges were removed and the sampler reset for the next determination.

In studies measuring the influence of light on emergence, a 75 watt incandescent light was suspended immediately beneath the 4 x 4 in. pine block. Measurement of foot-candles of light striking the water surface was accomplished by holding the trap 3 in. off the water surface and slipping the sensing element of a light meter between the trap and the water surface to a point where it intersected with the center of the trap. Preliminary test readings averaged 26 foot-candles illumination. The trap was then floated on the water. Samples were collected at one minute intervals. After recording the number emerged, the trap was cleared of all insects and again floated, but this time with the light off. Subsequently, alternate samples were taken in the light and in the dark.

MISCELLANEOUS SAMPLING PROCEDURES. METHOD OF MEASURING WIND VELOCITY, LIGHT INTENSITY, RELATIVE HUMIDITY AND TEMPERATURE. Wind velocity was estimated using the Beaufort Wind Scale modified for use on land. A Canadian hemlock tree 10 ft in height adjacent to the study site was observed for twig and branch movement and the wind speeds estimated from this movement.

Light intensity was measured with a Weston Illumination Meter—Model 756 with quartz filter (Weston Electrical Instrument Corporation, Newark, N.J.). This instrument measures intensity in foot-candles, or lumens per square foot evenly distributed. Readings were taken at the same site and same position every time. Method of use involved turning on the instrument and allowing at least a 1-min. warm-up. With sensing element held parallel to the surface of the ground at a height of 6 ft, at least 3 readings were made in the low range. Other readings at times of adult emergence were made while holding the sensing element parallel to the water surface at a height of 3 inches.

Relative humidity was measured by a sling psychrometer (Bacharach Co., Pittsburgh, Pa.). Again, 3 readings were taken. Raw data were converted to percent relative humidity using a nomogram.

Temperature readings were made with an armored thermometer (—30°F to +120°F in 1 degree divisions, Taylor Instruments, Asheville, N.C.). Air temperatures were taken at breast height (5 ft above ground) and canal water temperatures at a depth of 6 in. below the surface.

RESULTS AND DISCUSSION

SURVEY OF ADULTS. Numbers of adult midges present at sites near the Valley Paper Company in the Holyoke study area and near the adjacent Connecticut River were measured by 2 black light traps during the period 10 June to 1 September in the summer of 1969. Results of this survey are summarized in Figure 2. In both areas numbers were highest in mid-June and mid-July with a final and smaller peak in late August. Numbers were consistently higher in the Valley Paper Company trap after July 1, 1969, suggesting the importance of the canal as a source of adults in mid and late summer.

During the period 28 April to 6 September, 1970, the 2 black light traps were again operated in the same areas. An additional trap was operated in the Brown

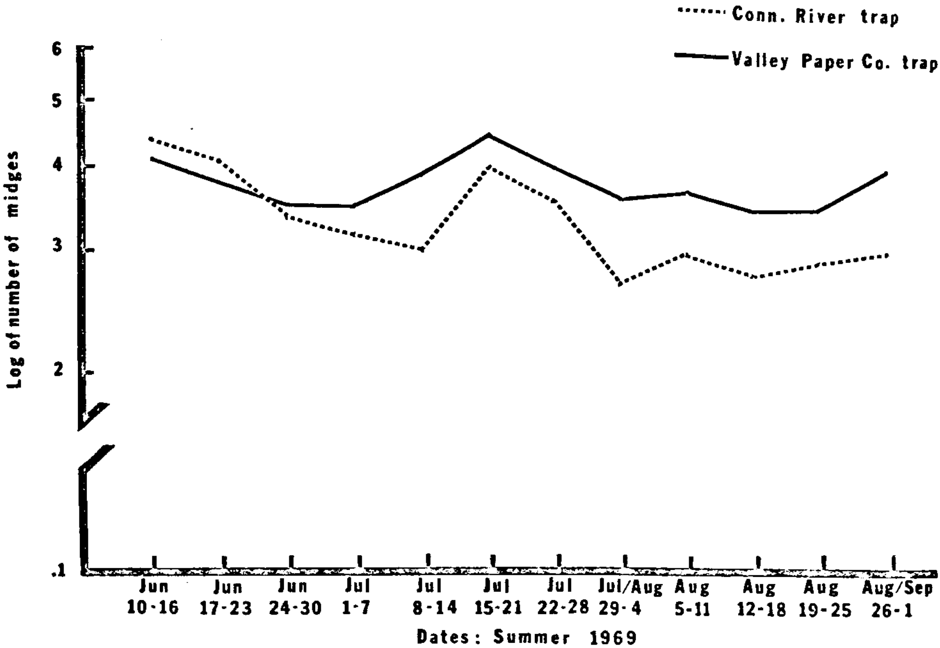

Fig. 2. Number of midges collected during the summer of 1969 at the Conn. River and Valley Paper Co. black light trap stations. Recorded as log of whole numbers caught per week.

Company area adjacent to the Holyoke study area from 27 May to 11 August, 1970. The results of 1970 are found in Figure 3. Again, the numbers caught were higher in the canal traps than in the river trap during the times of maximum emergence after the first week of July.

During both summers the numbers caught near the river and near the canal appeared to fluctuate equally with respect to each other. The reasons for these fluctuations are unknown, but the data suggest that the factors promoting population increases are common to both river and canal habitats. Therefore, control methods concentrated only in canal areas would, at best, provide only partial relief from the adult midge nuisance.

A comparison of number peaks in the two seasons reveals little similarity. The 1969 data show a higher peak in mid-June, then a gradual decrease and another peak in mid-July. The 1970 data show a small June peak, a sudden decrease in late June and a gradual increase through July, and a final, extended high peak throughout the month of August. This last peak created extreme nuisance conditions in the Holyoke study area.

The reasons for these differences between the 2 years are unknown. Hilsenhoff (1966) records a variation in yearly life histories of *C. plumosus* in Wisconsin. Reiss (1968) reported similar July and August emergence peaks and Darby (1962) recorded a similar year-to-year variation in emergence numbers. Data collected over a number of years would be essential in order to arrive at any accurate generalizations. The value of the light trap technique was in indicating when nuisance levels of adults might be expected and in pin-pointing the Connecticut River as a likely source of midge reinfestation.

Data obtained from adhesive traps (Figure 4 and Table 1) show a decided

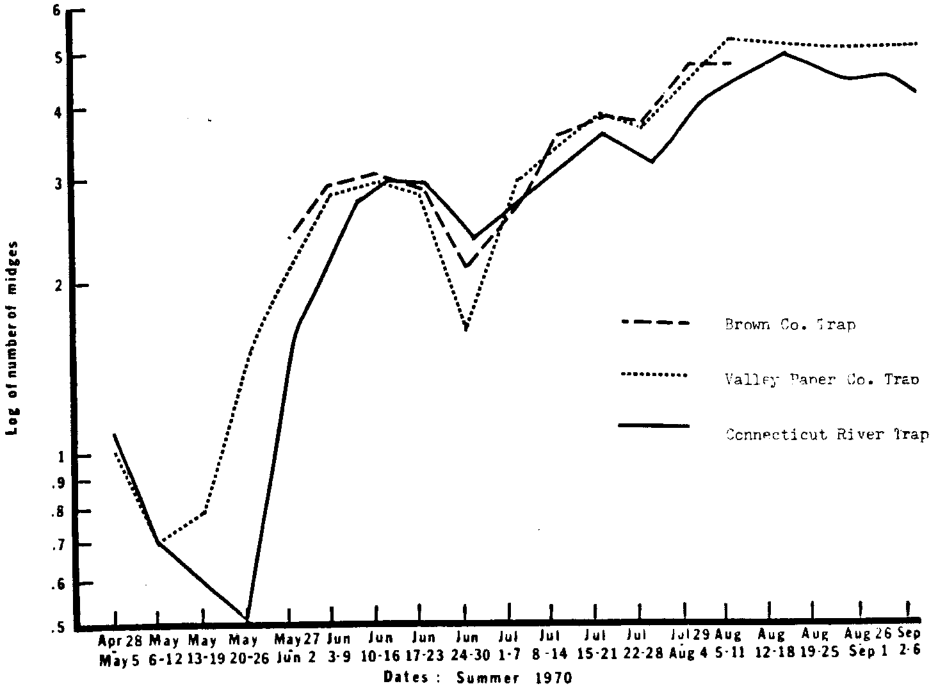

Fig. 3. Numbers of midges collected during the summer of 1970 at three black light trap stations. Recorded as log of whole numbers caught per week.

parallel with midge number peaks and troughs shown in the black light survey. Clearly those midges attempting to enter the mills are from the adjacent canal perhaps augmented by adult immigrants from the Connecticut River.

MIDGE BIOLOGY AND BEHAVIOR.

1. *Description of Emergence.* Data pertaining to adult midge emergence were collected during the summers of 1970 and 1971. Tables 2, 3 and 4 summarize these findings. Adult emergence rarely occurred between the hours of 6:30 a.m. and 7:30 p.m. on the dates recorded. Emergence was most common during the time from 7:30 p.m. to about 10:00 p.m. After 10:00 p.m. emergence appeared to decrease although quantitative data stipulating this were not obtained. These findings are similar to those of Frommer and Rauch (1971) and Nielsen (1959, 1962b) who worked with other genera and species of

Table 1. Mean number of adult midges collected on six inch square adhesive traps located on mill window screens and on ice fenders above canal water surface. Summer 1970.

	Mill Window Traps	Ice Fender Traps
Dates	Mean No. midges trapped	Mean No. midges trapped
June 19–25	6	15
June 26	3	6
July 2–3–9	5	7
July 10–16	13	26
July 17–23	29	99
July 24–30	21	39
July 31	360	599
Aug 6–7–13	1,038	2,253
Aug 14–20	688	1,333
Aug 21–27	403	877
Aug 28	448	1,288
Sept 6–7–12	129	346

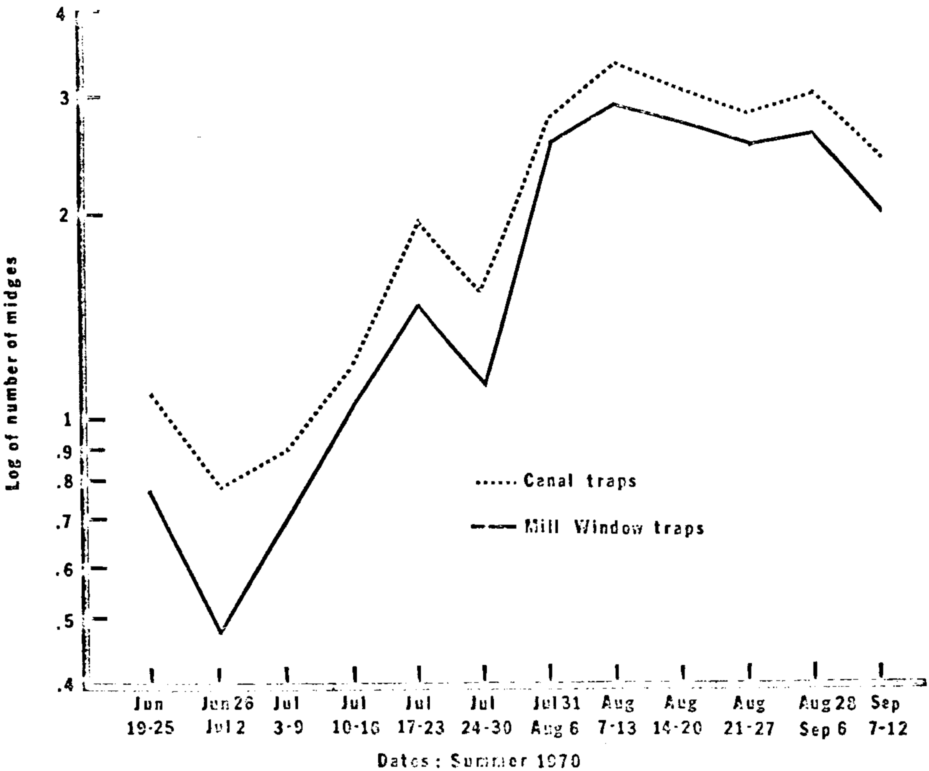

Fig. 4. Numbers of midges collected during the summer of 1970 in six inch square adhesive traps located on mill window screens or attached to ice fenders near canal water surface. Recorded as log of numbers of weekly mean catches.

Table 2. Number of adults emerging at various time intervals as determined by catches in emergence traps. 1970 and 1971.

Date	Time	Time Interval (minutes)	Light Intensity (foot candles)	Number Adults Emerged
25 Aug 70	6:30am– 8:30am	120	>200	4
25 Aug 70	8:30am– 5:00pm	510	>200	3
19 Aug 70	10:00am–11:00am	60	>200	0
19 Aug 70	11:00am– 7:30pm	510	>200	5
19 Aug 70	7:30pm– 7:40pm	10	>8	*6
19 Aug 70	7:45pm– 7:55pm	10	>8	*3
8 Aug 71	7:55am– 8:05pm	10	10	**2
19 Aug 70	8:05pm– 8:15pm	10	<8	*22
19 Aug 70	8:22pm– 8:32pm	10	0	109
19 Aug 70	9:25pm– 9:35pm	10	0	*40

* = average of 2 samples.
** = average of 10 samples.
All others = single sample.

Table 3. Time of the first emergence of midge adults on six separate days in the summer of 1970.

Date	Time-pm	*Illumination (foot candles)	Water Temp.°F.
7 Aug	8:15	38	79
10 Aug	8:15	14	78
11 Aug	8:10	14	79
12 Aug	8:15	32	79
13 Aug	8:10	28	79
19 Aug	7:40	36	79

Mean = 27 foot candles

* Measured at a height of 3 inches above surface of canal waters.

Chironomidae. First emergence occurred when natural light reached a mean intensity of 27 foot-candles based on 6 separate days' samples (see Table 3). At this intensity, pupae begin to arrive at the water surface by means of thrashing motions with the paddle-shaped posterior abdomen. Upon breaking the surface film, the notum split and the fully-formed adult emerged in a mean time of 8.6 seconds. The range was 4 to 17 sec. for a total of 75 observations on 3 different days. After freeing itself from the pupal skin, the adult flew away immediately or rested on the water surface for a short time. The cast pupal skin remained buoyant to be swept away by the surface currents.

A comparison of numbers emerging in total darkness and under the influence of 26 foot candles of artificial light revealed a positive phototaxis by unemerged adults (see Table 4). Data collected on 3 separate evenings indicated that from 4 to 7 times as many adults entered emergence traps in the light as in the dark. This is the first known report of such behavior in the Chironomidae.

2. *Description of swarming.* Swarming occurred twice daily at dawn and dusk. Observations were made of a number of physical factors which might affect swarming behavior (Table 5). The most consistent factor of those measured which could be correlated with this activity was the mean number of foot candles of light at which time organized swarming took place. For dawn swarms this was 9.3 foot-candles and for dusk swarms it was 6.2 foot-candles. This strongly suggests that the triggering device which initiated swarming was light intensity. Nielsen and Greve (1950) reported that 7 Lux (0.65 foot-candles) illumination initiated and dispersed a mixed swarm of *Aedes cantans* and *Chironomus plumosus*. They also reported that humidity was of minor importance and that low temperatures may

Table 4. Number of adult midges which emerged* per minute in artificial light or in darkness as determined by catches in emergence traps, 1970 and 1971.

	21 August 1970 8:45–9:48 pm		8 August 1971 8:45–9:20 pm		13 August 1971 9:05–10:00 pm	
	Dark 0 f.c.	Artificial Light 26 f.c.	Dark 0 f.c.	Artificial Light 26 f.c.	Dark 0 f.c.	Artificial Light 26 f.c.
	63	156	2	18	25	105
	57	142	3	15	31	137
	18	107	3	23	38	106
	15	49	4	16	20	98
	10	44	6	15	33	111
	13	29	5	11	27	121
Total	76	527	23	98	174	678
Mean	12.7	87.9	3.9	16.3	29.0	113.0

* Although quantitative data were not recorded for the degree of attraction to light in the trap, highest numbers of pharate adults congregated in the center of light beam just prior to emergence from the pupal skin.

Table 5. Physical factors recorded at time of organized swarming of midges.

Date	Time	Wind Speed mph	Temp. °F	Relative humidity per cent	Light intensity in foot-candles
Dusk Swarms:					
8-04-70	8:35pm	none	72	65	6
8-05-70	8:15pm	8-12	72	74	5-6
8-07-70	8:20pm	none	73	77	6-7
8-08-70	8:20pm	none	72	81	6
8-10-70	8:15pm	none	78	51	5-6
8-11-70	8:10pm	5-8	72	57	6-7
8-12-70	8:08pm	none	78	70	6
8-13-70	8:13pm	none	80	64	4-5
8-19-70	8:00pm	13-18	77	50	5-6
9-10-70	7:25pm	812	74	90	10
					Mean light intensity = 6. f.c.
Dawn Swarms:					
8-09-70	5:30am	2-3	62	90	6
8-12-70	5:45am	0-2	64	90	20
8-13-70	5:35am	none	66	86	7
8-14-70	5:40am	none	65	95	6-7
8-18-71	5:42am	none	65	86	7
					Mean light intensity = 9.3 f.c.

delay swarming. No swarming occurred below 50°F.

Dusk swarms: Swarming began with short flights of males in small groups of 4 or 5 or even singly. These flights were typical of later swarming in that the insect flew in a "box" pattern covering an air space of perhaps 1 ft, forward, to the rear, up and down, and often diagonally across the box. Syrjamaki (1965) described this activity as "pre-swarming." Light intensity during these flights was recorded at 140-50 foot-candles.

Small groups clumped together in an irregular hovering pattern which returned to the box pattern periodically. As light intensity diminished, an irregular pattern developed during which activity was increased by members of the swarm which often increased to 25-50 members. This pattern was characterized by a lack of direction and rapid flying.

At a mean light intensity of 6.2 foot-candles the swarm, now grown to many members by the joining of many small swarms or, in some cases, remaining as a small swarm, began an "organized" pattern. This pattern was characterized by all members flying forward and backward in essentially one direction, but changing altitude and position in the swarm. Some members flew in opposite or oblique directions, but the appearance of the swarm was that the vast majority were facing in the same direction. Slowly, altitude was gained and the swarm often rose to 50 ft or more off the ground. Massive swarms of thousands often oriented themselves above trees, buildings, or other structures. These great swarms usually resembled columns of smoke against the setting sun and could be heard by an observer standing beneath the swarm. Not all swarms rose. Some remained 6 to 25 ft above the ground orienting on objects such as bridges, autos, and humans. It was not unusual to have a swarm of several hundred midges orient at head height to several ft above the head of the observer. These "low" swarms would regroup despite collecting efforts of the investigator. On several occasions swarms developed above the raised tailgate of a station wagon. If the auto was then moved at a speed of 10 mph to a site 50 feet away, the entire swarm moved to the new site and continued orienting above the tailgate. Downes (1969) described this phenomenon well as "the swarm seems indeed to be merely a special case dominated by a relatively rare but strongly preferred feature of the landscape," (p. 278).

Samples of the composition of the dusk swarms were taken by sweeping at the 6–7 ft height. Only *G. lobiferus* males were taken, and the mean number of specimens per sweep was 5.14. Takes ranged from 2 to 12 males per sweep for a total of 50 observations on 5 different days. Nielsen and Greve (1950) reported mixed swarms of *Chironomus plumosus* and *Aedes cantans* and Chiang (1963) working with Cecidomyiidae reported that *Anarete johnsonii* (Felt) and a closely related species swarmed simultaneously. Downes (1969), however, suggested that such mixing is rare. Males were the only sex in these swarms. Gibson (1945) attributed this masculinity to the fact that any females which originally may have been present had mated and flown off. Although swarms flew in such tight formation that occasional contact occurred, no attempts at copulation between males were observed. Contact appeared to generate an avoidance reaction and both males rapidly flew to separate areas of the swarm. Downes (1969) stated that the culiciformes do not exhibit darting behavior between males in swarms, but this study suggests that such behavior does exist and that contact somehow releases the male from the pattern.

Dawn swarms. Dawn swarming followed a similar pattern sequence to the dusk swarming, but was of shorter duration in the initial patterns. A mean light intensity of 9.3 foot-candles stimulated swarming and an organized pattern was achieved almost immediately. At 50–60 foot-candles swarms were 25 ft above the ground. Mating occurred at 60 to 180 foot-candles. Swarms became disorganized at 260–270 foot-candles. At a light intensity of 380 foot candles the swarms had dispersed. On one occasion swarms dispersed at 180 foot candles. Dawn swarms were not sampled for composition.

3. *Description of Mating.* Observations of mating in swarms were made at dawn only. Darkness precluded observation during the evening swarming. Mating occurred at light intensities of between 60 and 180 foot-candles and the swarms observed were at a height of 10 to 20 ft. Accurate observation of mating above this height was impossible. Most members of the swarm flew in the organized pattern as previously described. Mating occurred when a female entered the swarm from below and was seized by a male. Coupling involved the attachment of the male claspers to the female's posterior abdominal segments in some fashion yet to be described. Coupled pairs slowly descended from the swarm, maintaining a horizontal plane in flight. The only site of attachment was the tips of the abdomen, the remainder of each body assuming what appeared to be a normal flight position, each member facing in an opposite direction. Mean time for copulation was 6.7 sec. and pairs separated at a mean height of 11.51 feet above the ground. Ranges were 3 to 12 sec. for copulation and 3 to 20 ft height at separation based on 45 observations. Downes (1969), in reviewing the data of others, stated that mating often occurs within a few seconds and that separation occurs prior to reaching the ground.

After separation, females flew away from the swarm, presumably to resting sites. Males reentered the swarm. It was not possible to observe whether these males mated again because of the intense activity in the swarms.

Mating also occurred between newly emerged virgin females and low-flying males after dark. On 5 different evenings between 9 and 10 p.m. this type of mating was observed by means of flashlight illumination. Virgin females, standing on the water surface or not yet free of the pupal skin were approached from behind and mounted by males flying alone in an undirected fashion some 6 to 12 inches above the canal waters. Nielsen (1959) reported that males mount from behind in *G. paripes* at rest. Attachment of abdominal tips was achieved rapidly, the female often becoming airborne upon contact with the male. Airborne pairs descended, often landing on the water surface before separating. These matings often occurred in 1 sec. or less. After separation, males attempted to copulate with other females. Females were not observed in a second copulation.

A number of the coupled pairs were collected from the water surface and returned to the laboratory for observation. These results, the first observed for *G. lobiferus*, are summarized in Table 6 and indicate the following:

1. Females may be fertilized by males immediately after emergence.

2. Fertile eggs may be laid within 24 hr after mating.

3. These eggs may hatch at the end of 3 days. Thus, within 4 days after emergence, progeny of this species of midge may be reestablished in the tube environment under water. This suggests that control procedures directed against both the egg and adult stage must be carefully timed and of sufficient frequency to ensure contact within successive life cycles.

Females are shorter lived than males. In these studies, females lived an average of 2.8 days after emergence, while males lived an average of 4.1 days after copulation. Fellton (1940) recorded males as living 9 days from time of emergence. No attempt was made in this study to determine the age of males at mating.

4. *Description of oviposition.* All observations in this study were made after dark under flashlight illumination between the hours of 9 and 10 p.m. on 5 different nights. Females ready to oviposit usually took up a position on a moist vertical or near-vertical surface near the water surface. No females were observed selecting dry surfaces. The oviposition attitude began with a waggling and rotary movement of the posterior abdomen. The metathoracic legs were raised and the abdomen was stroked by the tibiae, the weight of the body shifting onto the meso- and prothoracic legs. Eggs were extruded as a curved dense mass 3 to 5 mm long (mean of 10 samples was 3.6 mm) onto the posterior surfaces of the metathoracic tibiae which were now held horizontally just below the female opening and, in this position, served as a receiving platform. Fischer (1969) described a similar pattern of egg extrusion for *C. nuditarsis* Str. After egg deposition, the female made a post-oviposition flight. Eggs were usually released during this flight either by dipping the metathoracic legs in the water, as recorded

Table 6. Mating data, egg laying and hatching data and longevity of selected midge pairs. 1971.

Pair #	Date female emerged	Date female mated	Date eggs laid	Date eggs began to hatch	Date pair died Female	Date pair died Male
1	13 Aug 9:30pm	13 Aug 9:30pm	14 Aug	17 Aug	15 Aug	16 Aug
2	13 Aug 9:30pm	13 Aug 9:30pm	14 Aug	17 Aug	16 Aug	18 Aug
3	14 Aug 9:35pm	14 Aug 9:35pm	15 Aug	18 Aug	17 Aug	19 Aug
4	14 Aug 9:35pm	14 Aug 9:35pm	15 Aug	18 Aug	17 Aug	18 Aug
5	15 Aug 9:35pm	15 Aug 9:40pm	16 Aug	19 Aug	18 Aug	20 Aug

by Grodhaus (1963), or by simply dropping the egg mass. Nielsen (1962a) observed that *G. paripes* females dipped the tip of the abdomen in water while in flight to lay eggs. This behavior is probably the equivalent of dipping the legs. Egg masses were found in large numbers on damp rocks and wood as well as on light trap and adhesive trap surfaces up to 8 feet away from any moist surface. Eggs also were deposited in collecting vessels and cages where no water existed. No females were collected bearing eggs on the tibiae after the post-oviposition flight. The mean time required for egg laying was 6.09 min. The range was 5.08 to 7.13 mins. for the 11 females observed.

Computation of the sizes of egg masses and the time periods required for masses to reach maximum size were made. Females in the egg extrusion attitude were collected in culture jars containing a small amount of water. These females did not attempt to fly and could easily be scooped into the jar.

Egg masses enlarge by taking in water when deposited on a moist surface. A size range of 11 to 20 mm may be reached in 23 to 38 minutes as determined by 10 observations of masses in the study area. The mean size of enlarged masses was 13.5 mm and the mean length of time to reach maximum size was 30.4 min. In the enlarged state the eggs were enclosed by a sticky gelatinous matrix described previously by various authors. The number of eggs per mass averaged 1500 based on actual counts of 5 egg masses. Newly laid egg masses sink in water, but may attach readily to any floating or submerged structure by means of a long, slender suspensory stalk or the gelatinous matrix. The stalk may stretch to 18 inches or more. These data generally support the findings of Morrow, *et al.* (1968) and Sturgess and Goulding (1969) for other genera and species of Chironomidae.

SUMMARY AND CONCLUSIONS

Adult midge surveys based on black light trap data for 2 summers indicated that nuisance levels of midges may be expected from early June through mid-September with peak numbers most likely during July and August. The survey also pointed out that the Holyoke canals are the main source of adult midges creating summer nuisances for adjacent paper mills. Factors promoting midge abundance, however, appear to be present in both the canal environment and in the Connecticut River which flows nearby. The possibility cannot be excluded that adult and immature midge immigrations from the river into the canal may reestablish midge populations and amplify the nuisance.

Numbers of midges alighting on mill window screens appear to be in direct relation to the numbers emerging from the canals. Midge flight occurs at both dawn and dusk and adults are strongly attracted to light after dark. Adults in the preemergence stage are also strongly attracted to light at least during the period from sunset to 11 p.m. Therefore, reduction of exterior mill illumination and proper screening of all mill portals would contribute to lessening the nuisance effects of the adult midges.

Data obtained concerning the biology and behavior of *G. lobiferus* corroborate and enlarge upon information gathered by other investigators (Fellton 1940, Nielsen 1959, 1962, Grodhaus 1963, Sturgess and Goulding 1969, Downes 1969, Oliver 1971) on other genera and species of Chironomidae. New information obtained for *G. lobiferus* includes:

1. Adult emergence occurs mainly from sunset to 10 p.m.
2. The process of adult extrication from the pupal skin and initial flight is a rapid one occurring in a mean time of 8.6 sec.
3. Adults are attracted to a light intensity of 26 foot-candles even when still enclosed in the pupal skin. After emergence, attraction to both black and yellow light is pronounced.
4. Swarming occurs daily at dusk and dawn. Dusk swarms consist entirely of males except when a female enters the

swarm for mating. Swarming appears to be triggered by light intensity. After initial grouping phases near the ground, the males reach an organized swarm at a mean light intensity of 6.2–9.3 foot-candles and usually rise to a height of 50 or more ft above the ground in a dense cloud.

5. Mating may occur in the dawn swarm and lasts about 6 sec. Mating may also occur after dark as virgin females emerge from the pupal skins. This post-emergence mating may last only 1 sec., and viable eggs have been deposited by females the day after mating.

6. Oviposition by females was observed after dark and occurred in a mean time of 6 min. from onset of oviposition attitude to postoviposition flight.

7. Egg masses are usually deposited on a moist surface or in water and average 3.6 mm in length when extruded by the female. After approximately 30 minutes of enlargement by uptake of water they reach a mean length of 13.5 mm.

8. The eggs hatch in 3 days at a laboratory temperature of 72–76°F.

9. Ovipositing females die 2 to 3 days after mating; males die 3 to 5 days after mating.

These data suggest that chemical control measures against midge adults should be carefully planned to take into account daily activity patterns as well as seasonal population fluctuations to ensure maximum contact of chemicals at times when the midge is most vulnerable. Control of lighting patterns in and around buildings after dark so that emerging adults would not be attracted into the mill areas would help in reducing the nuisance.

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