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Experimental Stream Applications of *B.t.i.* for Human Nuisance Black Fly Management in a Recreational Area

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INTRODUCTION

Biting and swarming black flies are abundant in Maine (Bauer and Granett 1979, Cupp and Gordon 1983) and can cause serious discomfort to humans. This is especially true in recreational areas where their presence may substantially decrease satisfaction in outdoor activities. Black fly ecology and population management strategies have recently been reviewed by Kim and Merritt (1986). The biological insecticide *Bacillus thuringiensis* var. *israelensis* de Barjac (*B.t.i.*) is used to control black flies in other parts of the U.S. and internationally, and its use has been extensively reviewed (Gaugler and Finney 1982, Lacey and Undeen 1986). It is generally considered to be non-toxic to mammals and freshwater organisms other than black flies, mosquitoes and a few other closely related Diptera.

In 1985, 1986 and 1987 a series of experimental applications of *B.t.i.* was made on property owned by the Sugarloaf Mountain Corporation. The 1985 study determined the persistence of *B.t.i.* in stream and river water and the concentration necessary to achieve >90% mortality in black fly larvae. It also indicated that *B.t.i.* had no detectable impact on non-target organisms (Gibbs *et al.* 1987). In 1986 and 1987 the objective was to determine if controlling the black fly larvae in streams within the Sugarloaf property would result in decreasing adult human nuisance flies to an acceptable level. It is these results that we wish to report here.

STUDY AREA

The study was conducted at Sugarloaf Mountain in the Carrabassett Valley of western Maine. The golf course bordering the Carrabassett River was the main target for black fly management, although adjacent residential areas were also of concern. A total of 1,709 ha (6.6 mi^2), ranging in elevation from 360–600 m on the side of Sugarloaf Mountain, constituted the study area (Fig. 1). This area is partially isolated by surrounding Sugarloaf, Crocker, Spaulding and Bigelow Mountains, all with elevations of approximately 1,200 m. The area is well supplied with flowing water ranging from the Carrabassett River with a summer discharge of 1.1–2.8 m^3/sec to small drainage ditches with intermittent flow. All of these streams were surveyed in 1984 and shown to support human nuisance species of larval black flies (K. E. Gibbs and K. R. Hardy, unpublished report to the Sugarloaf Mountain Corporation). Streams were also abundant in regions adjacent to the study area.

METHODS AND MATERIALS

B.t.i. Application Procedures

The formulation of *B.t.i.* used was the aqueous suspension Vectobac® (AS)–14 manufactured by Abbott Laboratories. The application rate of 10 ppm for 5 min and the stream interval between applications were based on the previous work in the area (Gibbs *et al.* 1987). Application was by direct metered introduction into the stream and followed the method of D. P. Molloy, New York Museum and Science Service, New York State Education Department, Albany, New York 12230 (personal communication). *B.t.i.* was applied only when examination of the stream substrate indicated that black fly larvae were present. Location of the treated streams is shown in Fig. 1; total stream length treated and the frequency of application are shown in Table 1.

Effect on Black Fly Larvae

Gibbs *et al.* (1987) determined that the application rate used in this study caused >90% mortality in black fly larvae in 1985. In 1986 and 1987, black fly larval mortality was periodically checked in streams 4-24 h following treatment. As most larvae remain attached to the substrate following death from exposure to *B.t.i.*, percent mortality was calculated by counting numbers of living and dead larvae on natural substrates. When larvae were abundant, a maximum of 100 were examined.

Effect on Adult Black Flies

In 1986, five adult black fly sampling sites were established within the treated area, and two sites in the adjacent untreated area served as controls. One of the treated sites (T1) and one of the control sites (C1) were located close to the Carrabassett River and were used to determine the effect of treatment in the golf course area. The remaining treated sites (T2, T3, T4 and T5) and control site (C2) were compared to assess the effect of treatment in the residential area. On June 3, 1987 four additional control cites (C3, C4, C5 and C6) were added to evaluate the effectiveness of treatment in the residential area. The control and treated sites compared were similar in topography and vegetational cover. The location of the treated sites (T1–T5) is shown in Fig. 1. Control sites were located east of the treated area at the following distances: C1 8 km, C2 6.4 km, C3 4.8 km, C4 3.2 km, C5 1.6 km.

A "human bait" sampling technique was used to assess adult black fly abundance (Service 1987). One researcher remained stationary while another used an insect sweep net to collect flies swarming around the "bait" for a period of 10 min. An attempt was made to use the same person as bait and to make

the collections at the same time (late afternoon) but this was not always possible. These samples represent a "fly/person/10 min density index" of flies swarming about a person engaged in outdoor activity. Flies were removed from the net, preserved in 70 percent ethyl alcohol and returned to the laboratory for identification using the keys of Adler and Kim (1986), Davies *et al.* (1962), Peterson (1970) and Wood *et al.* (1963).

RESULTS

Black Fly Species Present at Sugarloaf

Thirty species of black flies were collected during 1986 and 1987 (Table 2). Five species were collected only as larvae and 11 only as adults. Many of these species consist of sibling species complexes in which species are distinguished on the basis of chromosomal characters. Only a few cytospecies were distinguished.

Black Fly Larval Mortality

Larval mortality of 90%–100% was recorded following treatments (Table 3).

Numbers and Species of Human Nuisance Adults

During 1986 and 1987 substantially fewer black flies were present in the samples from the site on the golf course (T1) than from the comparable control site (C1), especially during the month of June (Fig. 2 and 3). Although in lower numbers, black flies continued to be present in the control and treated sites through July and August. Comparison of the mean numbers in the samples between May and August (Table 4) indicated a reduction of 86.0% in 1986 and 78.5% in 1987.

In 1986, the mean number of flies in the interior treated residential sites (T2-T5) was lower (37.1%) than at the control site (C2) (Fig. 4, Table 4). However, in 1987 numbers were low in both the control (C2-C6) and treated (T2-T5) sites (Fig. 5), but the mean was slightly higher (13.4%) in the treated sites (Table 4) than in the control sites. In these interior sites, the flies were concentrated in the early part of the season, May and June, and were virtually absent during July and August.

Comparison of the numbers of flies in 1986 and 1987 at the two control sites that were sampled continuously throughout the study (C1 and C2) indicated that there were substantially more black flies in 1986 than in 1987 (Fig. 6 and 7).

The relative abundance and seasonal distribution of the species in the adult samples is shown in Tables 5 and 6. *Simulium venustum/verecundum* complex was consistently present at all the sampling sites and represented a high percentage of the black flies in the samples. It was also present throughout the sampling season from May until August. *S. venustum* and *S. verecundum* cannot be easily distinguished in the adult stage. Larvae of *S. verecundum* were rarely collected in the Sugarloaf area, however, so it is assumed that the majority of these adults were *S. venustum*. Adults of *Stegopterna mutata* were also widely distributed and abundant. Species of *Prosimulium*, especially *P. fontanum*, *P. fuscum* and *P. mixtum* were also important components of the adult samples, especially during late May and June. Adults of these species were also present in July, and a small number of *P. fontanum* were collected during the last week of August. Other species were present only occasionally or in low numbers.

DISCUSSION

Sugarloaf has a diverse fauna of black flies. Bauer and Granett (1979) reported 43 species found throughout Maine. Twenty-nine of these species were collected at Sugarloaf. In addition *Simulium vernale*, never before reported from Maine, was collected.

The application rate of 10 ppm for 5 min of *B.t.i.* was adequate as 100% larval mortality was usually obtained. In 1986 and 1987 applications were not initiated early enough in the spring to control early spring pest species. The streams should be carefully monitored for larvae during May and applications initiated immediately. Anecdotal reports indicate that adult black flies were abundant in the study area as early as May 19 in 1987. Earlier applications might be expected to reduce the numbers of adults in June, when they are most abundant. It may be expected that 5-6 applications will be needed rather than the 3-5 applications made during the past two years.

Although adult black flies were most abundant from late May to late June they were also present in sufficient numbers to constitute a nuisance in July and August in the golf course area along the Carrabassett River. They were present only in low numbers in the interior residential areas in August which may reflect the fact that some of the smaller streams temporarily lose flowing water at this time of year.

S. venustum was the single most important pest species in the area. It was present at all sites and throughout most of the sampling season. This species is reported to have several generations per year (Cupp and Gordon 1983). *Stegopterna mutata* was also important in the adult samples and present

throughout the season. Both of these species are important pests of humans, domestic animals, and wild animals. *Prosimulium fontanum*, *P. fuscum*, and *P. mixtum* were abundant and widespread early in the season. These species are also reported as nuisances to humans, domestic animals, and wild animals. Larvae of *Simulium venustum* were widely distributed in the Carrabassett River and the tributaries, but larvae of *Stegopterna mutata* and *Prosimulium fontanum*, *P. fuscum* and *P. mixtum* were found mainly in the smaller streams. Although *Simulium tuberosum* was the most abundant species of larvae in the river and streams it was not an important human nuisance species at Sugarloaf Mountain. This supports the observation of Burger (1987) in New Hampshire that this species is not a human nuisance in the northeast. *Prosimulium magnum*, *P. multidentatum*, *P. mysticum*, *P. pleurale*, *P. rhizophorum* and *P. vernale* were present only occasionally and usually in small numbers. Only *P. rhizophorum* is reported to be a pest of humans. *Simulium decorum*, *S. fibrinflatum*, *S. jenningsi*, *S. parnassum*, and *S. vittatum* have all been reported to be human nuisance species in the northeast but were never reported as being abundant at Sugarloaf. *S. aureum*, *S. exisum*, *S. impar*, *S. quebecense* and *S. johannseni* were present in the samples in low numbers and are reported to attack birds and wild animals but not humans. *S. baffinense* is an unusual black fly in that the adults do not feed and have no functional mouthparts.

The differences in abundance of adults between 1986 and 1987 at the two control sites indicate that annual variation attributable to naturally occurring factors can be substantial. Although reasons for this variation cannot be identified with certainty, it is suggested that the extreme flood conditions that occurred on April 1, 1987 may be at least partly responsible. Although black flies are well adapted to withstand normal high water associated with spring run-off, the flooding on April 1 was extreme and resulted in substantial displacement of the substrate.

Comparison of numbers of black flies at the treated and control sites demonstrated that substantial reductions of adults can be expected as a result of larval treatment with *B.t.i.* This is especially true in the area of the golf course and during years when the flies are abundant. This is supported by anecdotal evidence by persons using the golf course who reported that black flies were less abundant there than in adjacent areas and did not constitute an intolerable nuisance. The occurrence of the larvae of many of the important nuisance species in the smaller streams supports the need to continue to include these streams in the treatment schedule.

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TABLES

Table 1. Lengths of streams treated and numbers of treatments per season in 1986 and 1987.

	1986		1987	
	Stretch of Stream Treated (in Meters)	No. of Treatments	Stretch of Stream Treated (in Meters)	No. of Treatments
Brackett Brook	3862	5	3218	5
Carrabassett River	6436	4	4827	5
No Name Stream 1	4827	4	1448	4
No Name Stream 2			804	3
No Name Stream 3			1448	3
No Name Stream 4	2414	4	2091	4

Table 2. Black fly species collected at Sugarloaf.

Prosimulium
fontanum Syme & Davies
fuscum Syme & Davies
**gibsoni* (Twinn)
magnum Dyar & Shannon
mixtum Syme & Davies
***multidentatum* (Twinn)
***mysticum* Peterson
***pleurale* Malloch
***rhizophorum* Stone & Jamback
***vernale* Shewell
Greniera
***denaria* (Davies, Peterson & Wood)
Stegopterna
mutata (Malloch)
Simulium
**aestivum* Davies, Peterson & Wood
aureum cytospecies A
***baffinense* Twinn
corbis Twinn
***decorum* Walker
***excisum* Davies, Peterson & Wood
***fibrinflatum* Twinn
**gouldingi* Stone
***impar* Davies, Peterson & Wood
jenningsi Malloch
**latipes* (Meigen)
parnassum Malloch
**pictipes* Hagen
quebecense Twinn
tuberosum cytospecies CDE
tuberosum cytospecies FG
venustum Say
verecundum Stone & Jamnback
vittatum Zett.

*Collected only as larvae.
**Collected only as adults.

Table 3. Larval black fly mortality following *B.t.i.* treatments.

Site	Date	# Dead	# Alive	% Mortality
Carrabassett River	6/10/86	102	0	100
		100	0	100
	5/26/87	123	0	100
		59	0	100
	6/3/87	100	0	100
	6/24/87	42	2	95.5
No Name Stream 1	5/29/86	69	4	94.5
	7/5/86	112	4	96.6
	8/14/86	35	2	94.6
	5/25/87	61	0	100
No Name Stream 2	6/3/87	100	0	100
		100	0	100
No Name Stream 3	6/3/87	100	0	100
No Name Stream 4	5/30/86	92	2	97.9
	7/29/86	72	0	100
Brackett Brook	5/30/86	13	1	92.9
	7/2/86	71	1	98.6
	7/8/86	107	0	100
	8/6/86	103	0	100
	6/24/87	100	0	100

Table 4. Seasonal mean numbers of adult black flies per sample and percent difference between control and treated areas.

	Golf Course		Residential Area	
	Treated	Control	Treated	Control
1986	8.6	61.6	10.3	16.4
% difference	−86.0		−37.1	
1987	6.3	29.4	8.2	7.1
% difference	−78.5		+13.4	

Table 5. Relative abundance of species of adult black flies collected at the sampling sites in 1986 and 1987. Numbers represent a percent of the total.

	Control				Treated			
	Golf Course		Res. Area		Golf Course		Res. Area	
	1986	1987	1986	1987	1986	1987	1986	1987
Prosimulium								
fontanum	3.0	6.8	2.7	17.6	13.3	26.0	9.0	24.9
fuscum	0.6	1.8	0.9	5.8	3.5	11.5	10.1	9.3
magnum	0.1							0.2
mixtum	4.7	0.3	11.7		28.5	1.4	32.5	1.6
multidentatum				1.9		2.8	0.9	0.2
mysticum		0.3						0.1
pleurale						4.2		4.2
rhizophorum		0.6		3.9		2.8		1.2
vernale	0.2				0.8			
Greniera								
denaria		3.0						
Stegopterna								
mutata	11.3	7.7	2.4	35.2	10.7	18.8	11.1	21.3
Simulium								
aureum	5.9	2.4	1.4	3.9	1.6			0.3
baffinense	0.2							
corbis	0.9	4.0			3.5	1.4	2.0	6.4
decorum		1.5				1.4		1.0
excisum	0.1							
fibrinflatum	0.9	1.8					0.4	0.3
impar	0.1						0.1	
jenningsi	1.8	0.9		1.9			0.1	0.1
johannseni								0.3
parnassum	1.8	3.7	0.4		5.3	2.8	1.3	3.6
quebecense	0.6	1.8	0.9					0.1
tuberosum	1.6		1.4		3.5		4.0	
venustum/ verecundum	53.3	22.2	76.6	29.4	30.3	28.9	26.2	24.6
vittatum	11.8	0.6	0.4		0.8		1.8	0.5

Table 6. Seasonal distribution of adult black flies in the Sugarloaf study area from the third week of May to the fourth week of August.

	May		June				July				August			
Prosimulium														
fontanum	X	X	X	X	X	X	X	X	X					X
fuscum	X	X	X	X	X	X								
magnum	X													
mixtum	X	X	X	X	X	X	X	X	X					
multidentatum	X	X		X										
mysticum		X												
pleurale		X	X											
rhizophorum		X	X				X							
vernale		X												
Greniera														
denaria							X							
Stegopterna														
mutata	X	X	X	X	X	X	X	X	X					
Simulium														
aureum	X	X	X	X	X	X	X	X	X	X				X
baffinense		X		X										
corbis	X	X	X				X	X		X		X		
decorum	X	X	X			X								
excisum							X							
fibrinflatum						X	X	X	X	X		X		
impar			X				X							
jenningsi					X	X	X				X	X		
johannseni	X													
parnassum							X		X	X	X	X		X
quebecense		X		X			X							
tuberosum		X	X	X		X	X	X	X	X				
venustum/ verecundum	X	X	X	X	X	X	X	X	X	X		X		X
vittatum	X			X	X	X	X	X	X		X			

FIGURES

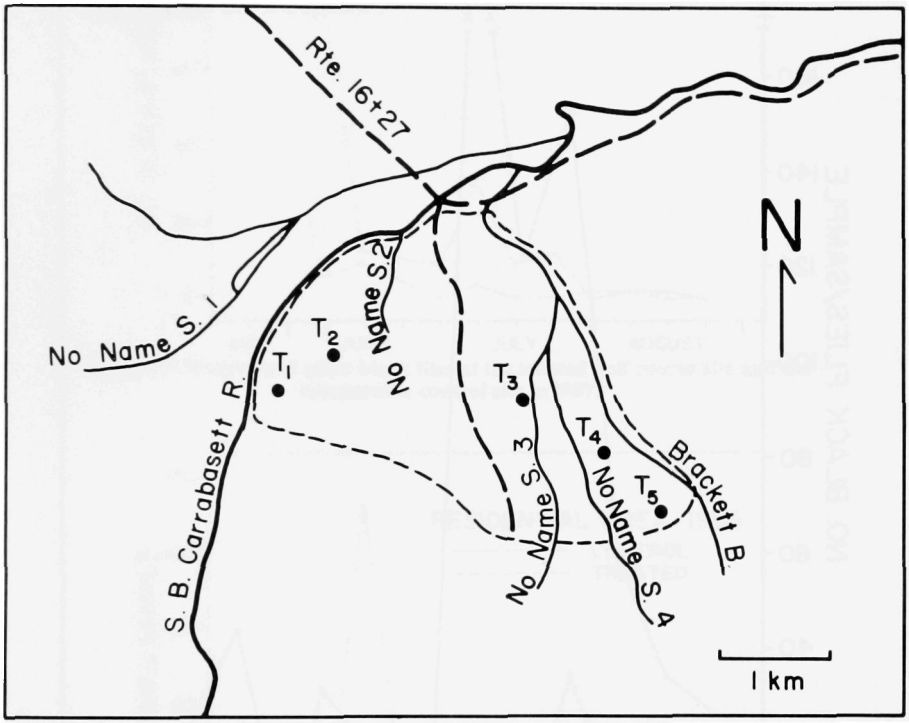

Figure 1. Study area, adult sampling sites and streams treated at Sugarloaf, Maine.

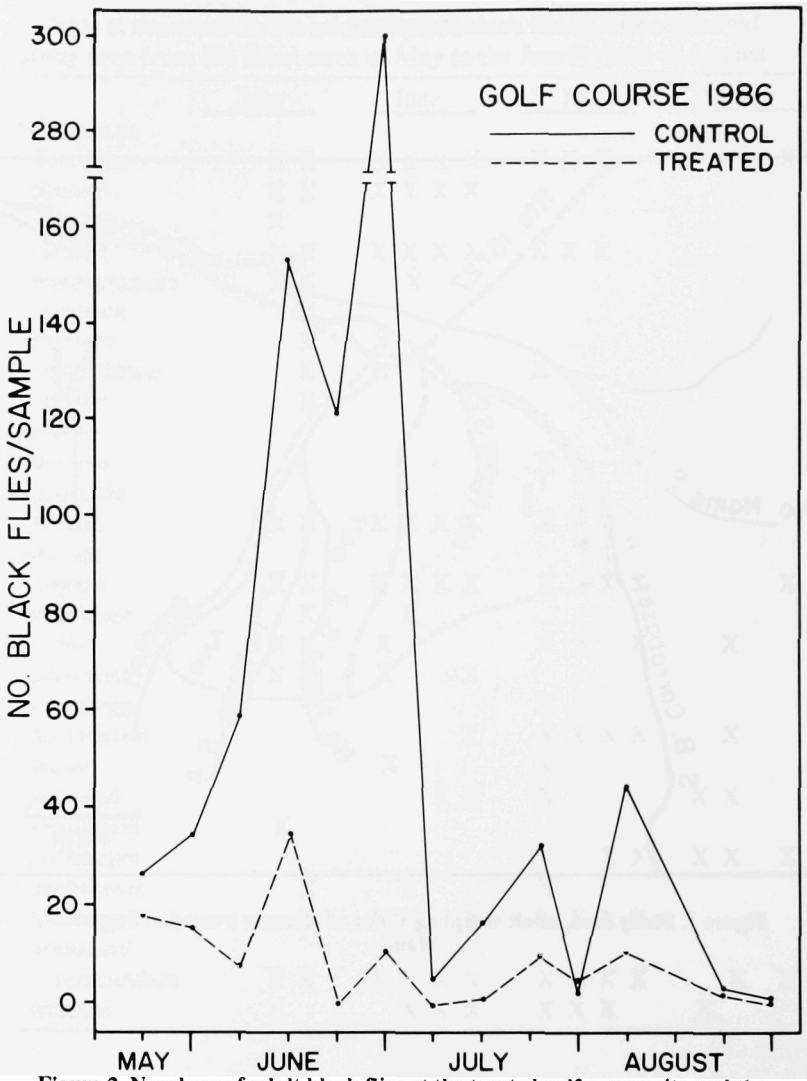

Figure 2. Numbers of adult black flies at the treated golf course site and the comparable control site in 1986.

Figure 3. Numbers of adult black flies at the treated golf course site and the comparable control site in 1987.

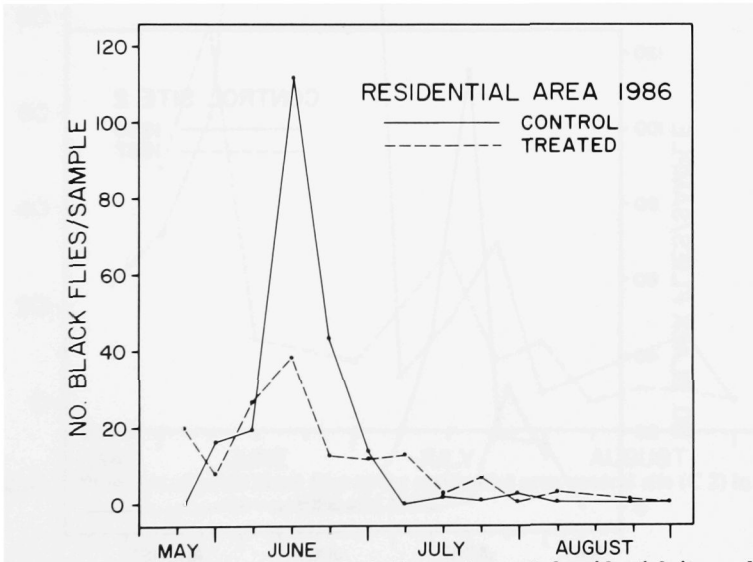

Figure 4. Mean numbers of adult black flies at the treated residential sites and the comparable control site in 1986.

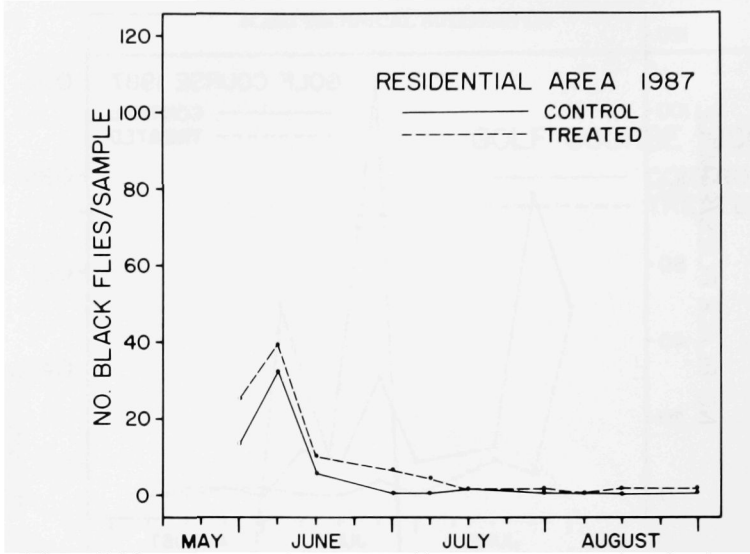

Figure 5. Mean numbers of adult black flies at the treated residential sites and the comparable control sites in 1987.

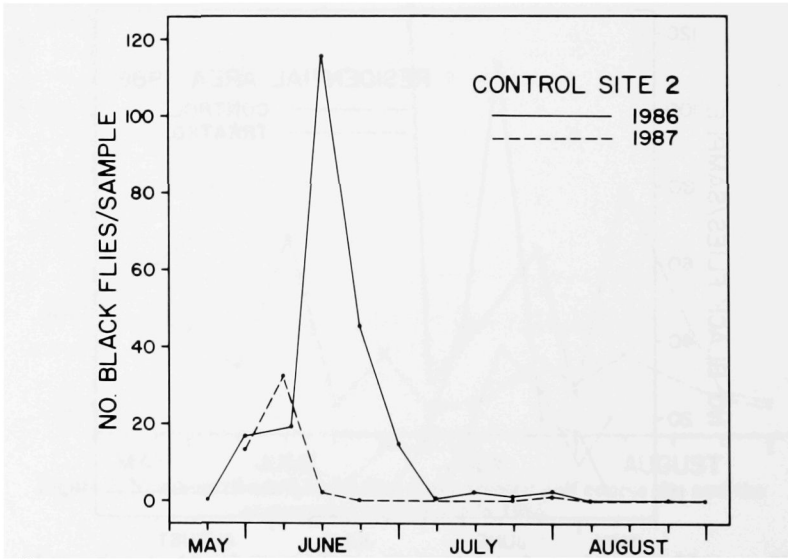

Figure 6. Numbers of adult black flies at the golf course control site (C 1) in 1986 and 1987.

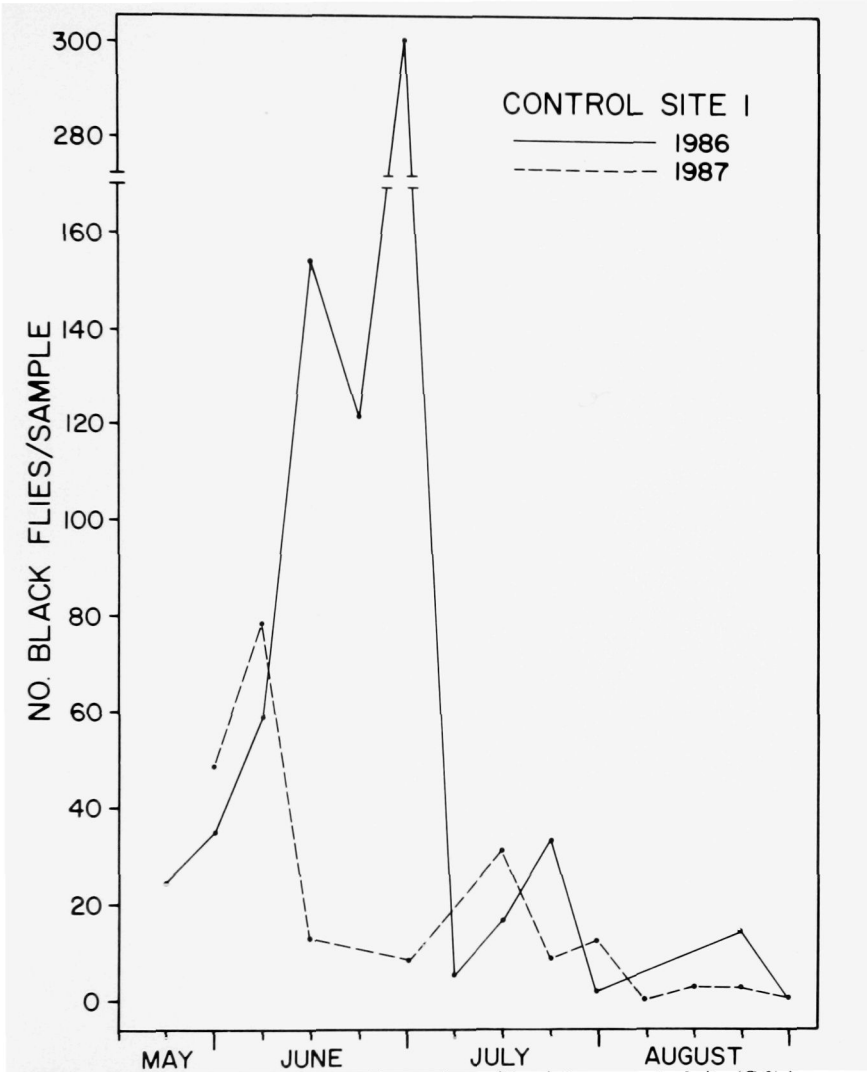

Figure 7. Numbers of adult black flies at the residential area control site (C 2) in 1986 and 1987.