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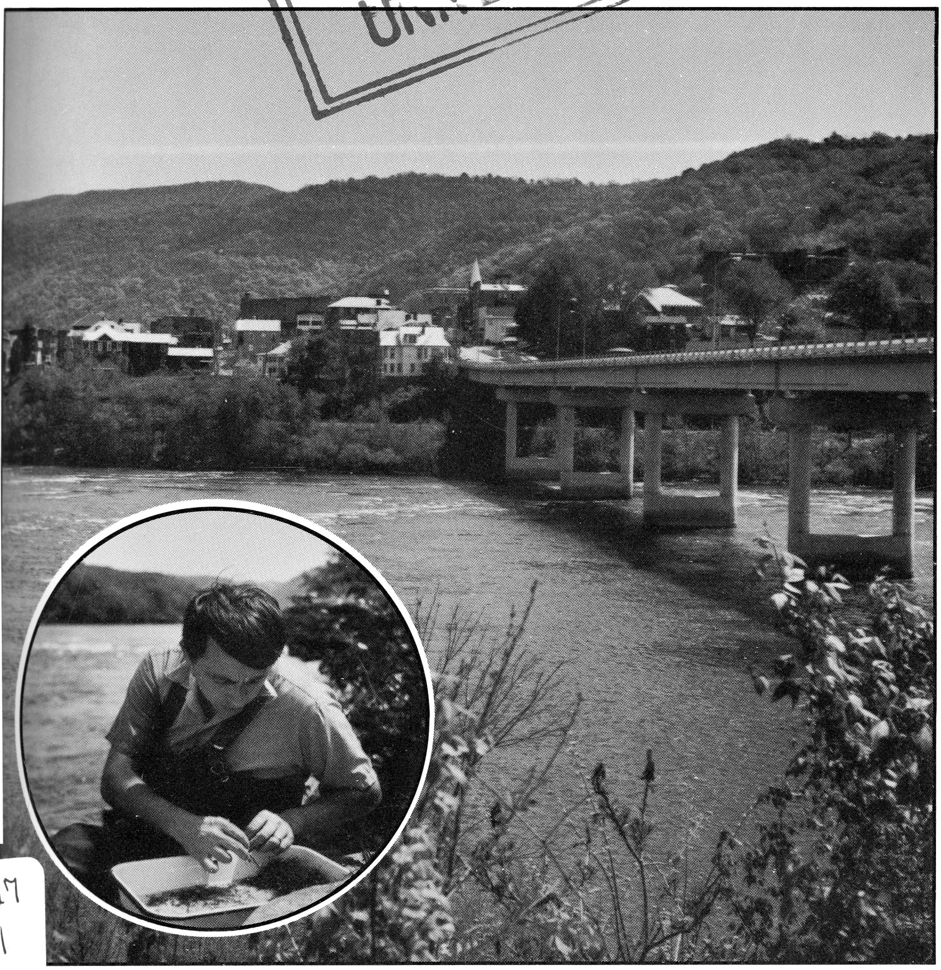

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The Cover—The New River at Hinton, West Virginia.

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Abstract

The black fly, *Simulium (Phosterodoros) jenningsi* Malloch 1914, a pest capable of feeding on human blood, is a severe nuisance in southern West Virginia. It has been studied for four years in eight counties in that region. Primary breeding source of the fly is the Bluestone Dam tailwaters on the New River from Hinton to the town of Meadow Creek—11.3 km downstream. About 7.5 km of this stretch of the river has sufficient velocity to allow larval development, and an estimated 5.2 billion flies emerge daily from this region during emergent periods from May to October. Tables of data and maps are provided to support these conclusions. A protocol for control is presented, utilizing the biological control agent *Bacillus thuringiensis* (Serotype 14), in three treatments at 30-day intervals beginning in mid-April.

The New River Connection to the Black Fly Problem in Southern West Virginia

James W. Amrine, Jr.

Introduction

The black fly problem in southern West Virginia first came to the author's attention in 1976 when Jan D. Hacker, West Virginia Department of Agriculture, described the swarms he observed and collected at Pipestem State Park. His collection consisted of 133 female black flies—all *Simulium (Phosterodoros) jenningsi* Malloch, 1914. Nelson Ferguson, Southern West Virginia Regional Health Council, also reported problems with swarming black flies in Mercer, Raleigh (especially in Beckley), and Summers counties in 1977 and 1978 and invited the author to visit the region to collect samples and to determine the source of the problem. In 1978, Douglas Ritchie, supervisor of Pipestem State Park, pointed out the severe gnat problems which occur at the park every year from May to October and asked the author to survey the region to determine the black fly source. Also in 1978, Paul Salmon of Glade Springs Resort, Daniels, W.Va., described the gnat problem at his facility and asked the author to investigate. Ritchie, Ferguson, and Salmon were using fogging equipment (ULV malathion) in an attempt to control the adult black flies in Beckley, Glade Springs, and at Pipestem. While none reported successful control, each related that citizens approved of the fogging program because "at least something is being done."

The black fly, *Simulium jenningsi* Malloch, 1914, is distributed throughout eastern North America from Ontario to Maine and south to Georgia and Alabama (Snoddy and Noblet, 1976). The larval stages are found only in pollutant-free, warm streams with an average width in excess of 6 meters (Underhill, 1944; Stone and Snoddy, 1969; Snoddy and Noblet, 1976). The adult females are known to feed on a large number of vertebrate hosts, especially cattle, horses, turkeys, and rarely man (Malloch, 1914; Underhill, 1944; Davies *et al.*, 1962; Stone and Snoddy, 1969; Snoddy and Noblet, 1976). In addition to its nuisance and blood-feeding habits, *S. jenningsi* also is a vector of disease organisms. Johnson *et al.* (1938) demonstrated transmission by *S. jenningsi* of the etiological agent of turkey fever, *Leucocytozoon smithi*, to domestic turkeys in Virginia. Eve *et al.* (1972) observed *L. smithi* in the blood of wild turkeys (100% of adult and 77% of immature turkeys) in eastern counties of West Virginia; this indicated active transmission of the parasites by vectors in the region. *S. jenningsi* is the only known vector of *L. smithi* to occur in the area (Amrine, unpublished data). *S. jenningsi* also has been proven to be a vector of *Onchocerca lienalis*, a parasitic worm of cattle in New York State (Cupp, 1982). Since this parasite has been found in cattle in neighboring states, *S. jenningsi* is presumed to be a vector of the parasite in West Virginia as well.

This study began in the summer of 1978 with the objectives of determining the extent of the adult *S. jenningsi* infestation in southern West Virginia, identifying streams serving as major larval breeding sites, observing the reported human blood feeding by *S. jenningsi* (Ferguson related two hospitalizations caused by "gnat" bites), and investigating the possibility of controlling the pest.

Materials and Methods

Adult black flies were collected at several locations throughout the eight-county region (Fayette, Greenbrier, Mercer, Monroe, Nicholas, Raleigh, Summers, and Wyoming). Some adult collections were taken along three radii from the Hinton area to observe changes in black fly populations with increasing distance from the New River: east into Greenbrier County; west into Wyoming County; and north into Nicholas County.

Other adult collections were taken while standing in streams and along shorelines to make comparisons with populations farther from the stream. One series of collections was made at Shanklin's Ferry to determine whether the swarm could be depleted by removing the flies. A 30.48-cm diameter insect net (fine mesh) was used to collect the swarming adults around person's heads. Because the swarm disperses 3 meters from the person after two or three sweeps, each sample consisted of ten sets of three sweeps each, with a duration of 30 seconds immobility between sets. This allowed the swarms to return to the collector's head at the start of each set. The adults were killed by exposure to HCN for 1 to 2 minutes, transferred to a vial of 95% ethanol, and labeled with location and date. The samples were subsequently sorted in the laboratory and specimens were identified to species using the keys to adult Simuliidae by Stone, 1964, and Stone and Snoddy, 1969. Samples were sent to specialists for verification of identification.

Biting black flies fed to repletion were collected in small polyethylene bags containing a piece of moist paper toweling and stored over ice in a cooler until returned to the laboratory. In the lab, blood-fed flies were kept at 25° C in plastic containers with moist paper toweling and, after days, were set up for oviposition. Gravid females ready to oviposit were placed in a small vial with water which was manually shaken to stimulate oviposition.

Streams of all sizes were surveyed in the eight-county region for immature black flies. All substrates in moving water were closely examined for eggs, larvae, and pupae in cocoons. Specimens were either preserved in 95% ethanol or kept alive in polyethylene bags on ice and returned to the laboratory for rearing and examination. Immature stages were identified to species using the keys of Stone, 1964, and Stone and Snoddy, 1969.

Samples of riverweed (*Podostemum ceratophyllum* Michx.), water star grass (*Heteranthera dubia*, [Jacq.] Mac M.), water willow (*Justicia americana* [L.]), pondweed (*Potamogeton* spp.), and filamentous algae (*Cladophora et al.*) were collected and placed in polyethylene bags, stored over ice and returned to the laboratory.

In order to make an estimate of immature black fly densities in the breeding area, the aquatic vegetation was rinsed thoroughly in water, the washings were vacuum filtered through a 100-mesh screen, and the filtered material was preserved in 95% ethanol (at least 4:1 ratio of alcohol to volume of material).

Portions of some aquatic plant samples were subsampled to determine number and species of black fly pupae. All vegetation was dried for 24 hours in a forced-air oven at 40° C and then weighed.

To examine the premise that conditions for development varied at different locations in the New River, samples of *S. jenningsi* cocoons containing pupae from selected locations on the New River were measured for maximum length and height (lateral view, Figure 2). The means of the products of the two measurements for each sample were then compared using Duncan's Multiple Range Test.

Two samples of minnows were collected from the New River from *S. jenningsi* larval beds. Their intestines were removed and dissected, contents identified and counted, to provide information about the occurrence of *S. jenningsi* in minnow diet.

Results

Adults

Eighty-two collections of adult black flies were made by six persons over an eleven-year period in eight counties of southern West Virginia (Table 1). Of a total of 11,743 adult black flies captured, all but 21 were *Simulium jenningsi* (99.82%); the remainder were *S. vittatum*, Zet., *S. decorum* Walker, and *S. parnassum* Malloch. The largest numbers of *S. jenningsi* females were collected within 25 km of the New River in Summers, Raleigh, and Fayette counties (Table 1 and Maps 1 and 2). Collections distant to the New River and in the northern part of the region were considerably smaller (Greenbrier, Nicholas, and Wyoming counties, Table 1). Very few female *S. jenningsi* were attracted to persons in streams or along the shoreline; but within 50 m of the shoreline, numbers increased considerably (Table 1: Summers County, Shanklin's Ferry, Sept. 15, 1981; New River at Indian Creek, May 15, 1980).

The swarming females were collected from mid-May to mid-September and have been reported to be a problem as late as mid-October (Adkinson, 1981).

Table 2 summarizes an attempt to remove all females at one location. A total of 1,528 females were collected in 30 minutes. The numbers of females were reduced significantly only when rain began to fall, and it is of interest that 88 females (only a portion of those flying) were collected in a downpour. If this sample were used in the Hayne method of estimation of population size by "removal trapping," then the swarm consisted of approximately 1,900 females (presuming minimal migration which is probably not the case) (Southwood, 1966).

A total of 76 human-blood-fed female *S. jenningsi* were collected in the study area (Table 3). The females fed on four persons over a seasonal range of May to September. Feeding to repletion required two to five minutes (average of four minutes). Feeding females were relatively insensitive to disturbance and plastic bags or vials could easily be placed over them. Favored biting sites appeared to be the hairline of forehead and temple; the face, especially near the eyes; the ears; the back of the hands; the underside of wrist and arm; and the vicinity of the elbow. Only the head, neck, and arms were exposed during biting collections. The bite wounds continued to bleed for a few minutes after females were removed, indicating an active anticoagulant activity in the saliva. Redness and edema persist for 48 to 72 hours, and scars and itching persist for

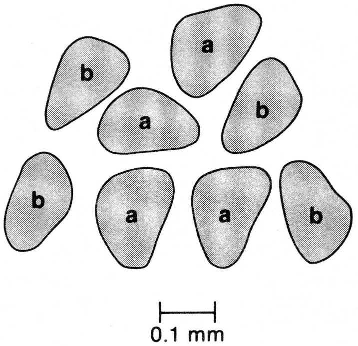


Figure 1. Eggs removed from gravid, female *S. jenningsi* fed on human blood at Hinton, W.Va., 22 July 1981. **a,** eggs from specimen one; **b,** eggs from specimen two. The eggs were mounted in glycerine and variation in shape reflects variable orientation on the slide.

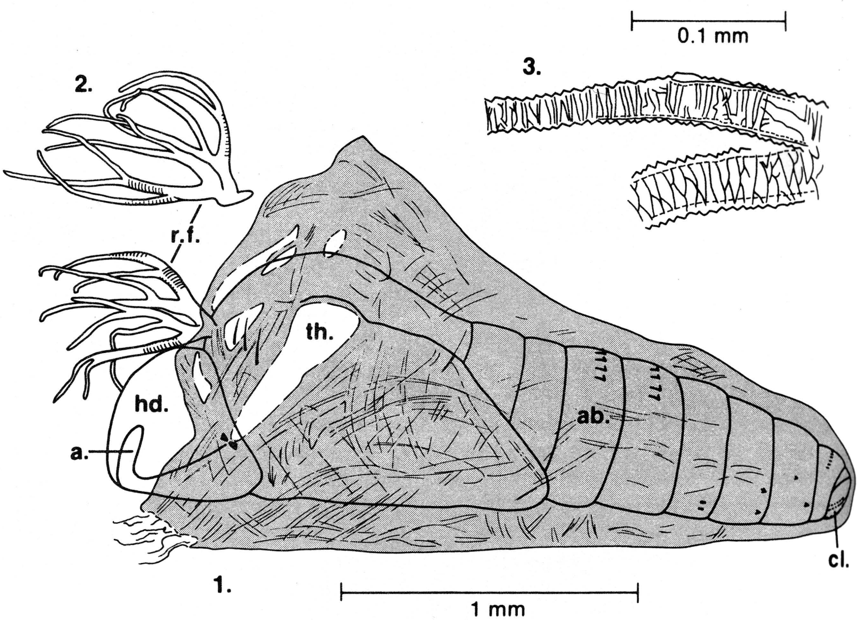
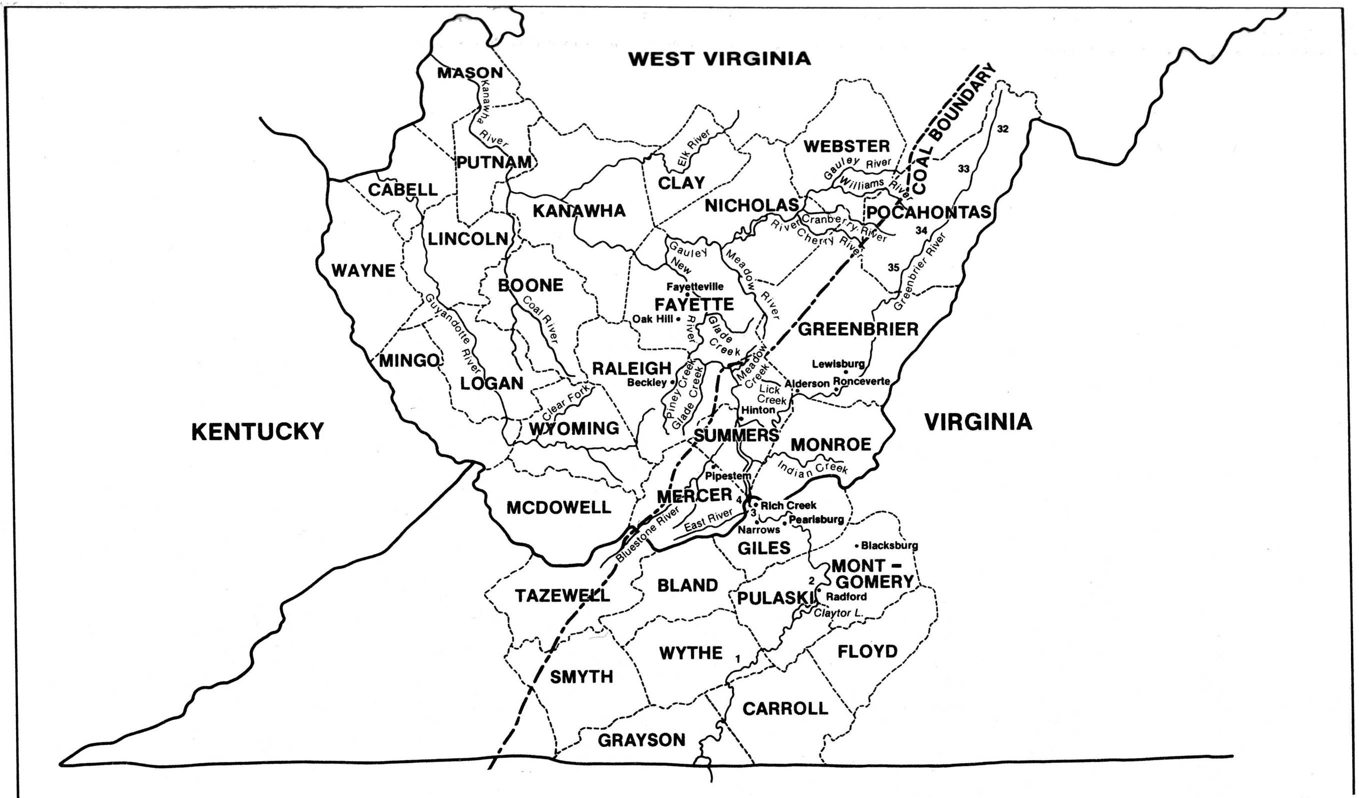
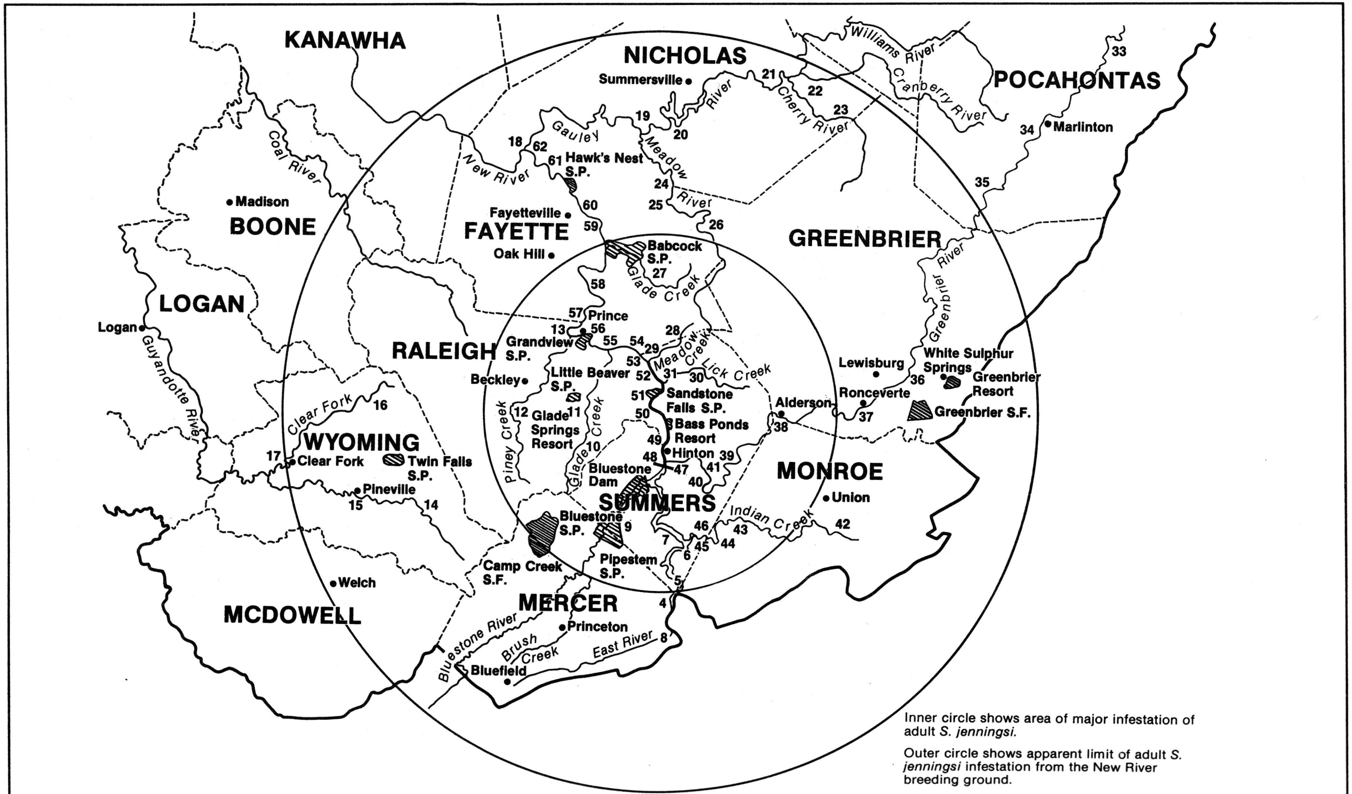


Figure 2. Cocoon and pupa of *S. jenningsi* showing the lateral openings in the cocoon and detail of the respiratory filament. **1.** Cocoon and male pupa (note short antenna; the antenna of a female pupa extends to the dorsal margin of the compound eye); **2.** respiratory filament from another specimen; **3.** detail of the respiratory filament. **a.,** antenna; **ab.,** abdomen; **cl.,** claspers; **hd.,** head; **r.f.,** respiratory filament; **th.,** thorax. Measurements for Table 7 were maximum cocoon length (anterior margin to posterior tip) and maximum height (dorso-anterior lip of cocoon down to bottom margin). The lateral openings in the cocoon, the presence of 10 filaments in the respiratory organ and the detailed reticulate pattern of the filaments are specific for *S. jenningsi*.



Map 1. The New River and its principal tributaries in West Virginia and Virginia. Map shows locations of stations 1–4 (New River) and 32–35 (Greenbrier River). The "coal boundary" is indicated by dotted line.



Map 2. Location of immature black fly sampling stations on the New River and its tributaries in southern West Virginia. Principal towns, parks, state forests, and resorts are indicated as well as the primary and secondary zones of *Simulium jenningsi* infestation.

Table 1.
Summary of adult black fly collections in southern West Virginia.

Date	Location	County	Number	% *Simulium jenningsi*	Number Males	Remarks	Collector
21 Aug 1977	Corliss	Fayette	28	100.0	0	Representative sample	Keeney
22 Jun 1981	WV Rt. 41, N. Entrance Babcock St. Pk.	Fayette	120	98.3	0	10 sets of 3 sweeps	Amrine
22 Jun 1981	WV Rt. 41, N. Entrance Babcock St. Pk.	Fayette	130	100.0	0	10 sets of 3 sweeps	Amrine
14 Sep 1981	WV Rt. 41, No. Entrance Babcock St. Pk.	Fayette	119	100.0	0	10 sets of 3 sweeps	Amrine
14 Sep 1981	WV Rt. 41, No. Entrance Babcock St. Pk.	Fayette	23	100.0	0	10 sets of 3 sweeps	Amrine
22 Jun 1981	Quinnimont	Fayette	34	100.0	0	10 sets of 3 sweeps	Amrine
24 Jun 1981	Claremont	Fayette	281	96.2	0	10 sets of 3 sweeps	Amrine
9 Jul 1977	Greenbrier St. Forest	Greenbrier	43	100.0	0	Representative sample	Butler
24 Sep 1977	Greenbrier St. Forest	Greenbrier	36	100.0	0	Representative sample	Butler
25 Sep 1977	Greenbrier St. Forest	Greenbrier	20	100.0	15	From black light trap	Butler
29 Jun 1980	WV St. Rt. 12 at Asbury	Greenbrier	13	100.0	0	10 sets of 3 sweeps	Amrine
1 Jun 1970	Lashmeet	Mercer	16	100.0	0	Representative sample	WVDA, Unk
11 May 1980	Athens	Mercer	1	100.0	0	5 sets of 3 sweeps	Graham
15 Jun 1980	Athens	Mercer	2	100.0	0	5 sets of 3 sweeps	Graham
22 Jun 1980	Athens	Mercer	3	100.0	0	5 sets of 3 sweeps	Graham
13 Jul 1980	Athens	Mercer	2	100.0	0	5 sets of 3 sweeps	Graham
21 Jul 1980	Athens	Mercer	17	100.0	0	5 sets of 3 sweeps	Graham
14 Sep 1981	Rt. 122, 6.4 km W. Greenville	Monroe	48	100.0	0	10 sets of 3 sweeps	Amrine
21 Aug 1980	Summersville Dam	Nicholas	42	100.0	0	10 sets of 3 sweeps	Amrine
22 Jun 1981	Summersville Dam	Nicholas	41	100.0	0	10 sets of 3 sweeps	Amrine
22 Jun 1981	Carnifex St. Park	Nicholas	63	96.8	0	10 sets of 3 sweeps	Amrine

(continued)

Table 1. Continued.

Date	Location	County	Number	% *Simulium jenningsi*	Number Males	Remarks	Collector
12 Jun 1980	WV Rt. 3, 2.8 km W. Eccles	Raleigh	24	100.0	1	10 sets of 3 sweeps	Amrine
13 Jun 1980	Glade Springs Resort	Raleigh	178	100.0	1	10 sets of 3 sweeps	Amrine
5 Aug 1980	Glade Springs Resort	Raleigh	153	100.0	1	10 sets of 3 sweeps	Amrine
14 Sep 1981	Glade Springs Resort	Raleigh	165	100.0	0	10 sets of 3 sweeps	Amrine
14 Sep 1981	Glade Springs Resort	Raleigh	164	100.0	0	10 sets of 3 sweeps	Amrine
21 Aug 1980	Grandview State Park	Raleigh	45	100.0	0	10 sets of 3 sweeps	Amrine
13 Jul 1978	Stanaford	Raleigh	250	100.0	0	10 sets of 3 sweeps	Amrine
21 Aug 1980	Glade Creek at Pluto Rd.	Raleigh	245	100.0	0	10 sets of 3 sweeps	Amrine
15 Aug 1975	Pipestem State Park	Summers	18	100.0	0	WVDA sample	Unknown
22 May 1976	Pipestem State Park	Summers	133	100.0	0	WVDA sample	Hacker
22 Jun 1980	Entrance, Pipestem State Park	Summers	28	100.0	0	5 sets of 3 sweeps	Graham
2 Jun 1977	New River, Shanklin's Ferry	Summers	1,274	99.5	0	Continuous sweeping	Amrine
15 Sep 1981	New River, Shanklin's Ferry 50 m fr. R.	Summers	230	100.0	0	10 sets of 3 sweeps	Amrine
15 Sep 1981	New River, Shanklin's Ferry 50 m fr. R.	Summers	363	100.0	0	10 sets of 3 sweeps	Amrine
15 Sep 1981	New River, Shanklin's Ferry 50 m fr. R.	Summers	533	100.0	0	Representative sample	Amrine
15 Sep 1981	New River, Shanklin's Ferry at shoreline	Summers	4	100.0	0	10 sets of 3 sweeps	Amrine
15 Sep 1981	New River, Shanklin's Ferry 1 km fr. R.	Summers	382	100.0	0	10 sets of 3 sweeps	Amrine
15 Sep 1981	New River, Shanklin's Ferry 1 km fr. R.	Summers	280	100.0	0	10 sets of 3 sweeps	Amrine
15 Sep 1981	New River, Shanklin's Ferry 1 km fr. R.	Summers	296	100.0	0	10 sets of 3 sweeps	Amrine
15 Sep 1981	New River, Shanklin's Ferry 1 km fr. R.	Summers	232	100.0	0	10 sets of 3 sweeps	Amrine

15 Sep 1981	New River, Shanklin's Ferry 1 km fr. R.	Summers	148	100.0	0	10 sets of 3 sweeps	Amrine
15 Sep 1981	New River, Shanklin's Ferry 1 km fr. R.	Summers	102	100.0	0	10 sets of 3 sweeps	Amrine
15 Sep 1981	New River, Shanklin's Ferry 1 km fr. R.	Summers	88	100.0	0	10 sets of 3 sweeps	Amrine
2 Jun 1977	Rt. 20, 3.2 km N. of Brooks	Summers	81	100.0	0	Representative sample	Amrine
14 Sep 1981	New River, 1 km N. of Indian Creek	Summers	165	100.0	0	10 sets of 3 sweeps	Amrine
15 May 1980	New River, Indian Creek, 17 m in river	Summers	8	100.0	0	10 sets of 3 sweeps	Amrine
15 May 1980	New River, Indian Creek, shoreline	Summers	62	100.0	0	10 sets of 3 sweeps	Amrine
15 May 1980	New River, Indian Creek, shoreline	Summers	47	100.0	0	10 sets of 3 sweeps	Amrine
15 May 1980	New River, Indian Creek, 50 m from shore	Summers	83	100.0	0	10 sets of 3 sweeps	Amrine
15 May 1980	New River, Indian Creek, 50 m from shore	Summers	166	100.0	0	10 sets of 3 sweeps	Amrine
15 May 1980	New River, Indian Creek, 300 m from shore	Summers	209	100.0	0	10 sets of 3 sweeps	Amrine
15 May 1980	New River, Indian Creek, 300 m from shore	Summers	110	100.0	0	10 sets of 3 sweeps	Amrine
15 May 1980	New River, Indian Creek, 300 m from shore	Summers	141	100.0	0	10 sets of 3 sweeps	Amrine
15 May 1980	New River, Indian Creek, 500 m from shore	Summers	389	100.0	0	10 sets of 3 sweeps	Amrine
15 May 1980	New River, Indian Creek, 500 m from shore	Summers	330	100.0	0	10 sets of 3 sweeps	Amrine
15 May 1980	New River, Indian Creek, 800 m from shore	Summers	219	100.0	1	10 sets of 3 sweeps	Amrine
15 May 1980	New River, Indian Creek, 800 m from shore	Summers	252	100.0	0	10 sets of 3 sweeps	Amrine
15 May 1980	New River, Indian Creek, 1.1 km from shore	Summers	330	100.0	0	10 sets of 3 sweeps	Amrine

(continued)

Table 1. Continued.

Date	Location	County	Number	% *Simulium jenningsi*	Number Males	Remarks	Collector
26 Jun 1980	New River, Indian Creek	Summers	84	100.0	0	10 sets of 3 sweeps	Amrine
29 May 1980	Hinton, South Bridge	Summers	33	100.0	0	10 sets of 3 sweeps	Amrine
27 Jun 1980	Hinton, South Bridge	Summers	95	100.0	0	10 sets of 3 sweeps	Amrine
11 May 1980	Hinton, South Bridge, west bank	Summers	12	100.0	0	5 sets of 3 sweeps	Graham
15 May 1980	Indian Creek, Rd. 21/2	Summers	107	100.0	0	10 sets of 3 sweeps	Amrine
26 Jun 1980	Indian Creek, Rd. 21/2	Summers	182	100.0	0	10 sets of 3 sweeps	Amrine
26 Jun 1980	Indian Creek, Rd. 21/2	Summers	242	100.0	0	10 sets of 3 sweeps	Amrine
15 May 1980	Road 21/2, 1.4 km S. Rt. 12	Summers	60	100.0	0	10 sets of 3 sweeps	Amrine
26 Jun 1980	WV Rt. 12, 1.4 km N. jct. Rd. 20/2	Summers	83	100.0	0	10 sets of 3 sweeps	Amrine
5 Aug 1980	WV Rt. 12, 1.4 km N. jct. Rd. 20/2	Summers	38	100.0	0	10 sets of 3 sweeps	Amrine
15 Jun 1980	Entrance, Bluestone St. Park	Summers	26	100.0	0	5 sets of 3 sweeps	Graham
31 Aug 1980	Entrance, Bluestone St. Park	Summers	10	100.0	0	5 sets of 3 sweeps	Graham
21 Jun 1980	Bluestone State Park	Summers	135	100.0	0	Representative sample	Kirchner
15 May 1980	Greenbrier R. at Rd. 14	Summers	110	100.0	0	10 sets of 3 sweeps	Amrine
15 May 1980	Greenbrier R. at Rd. 14	Summers	234	100.0	0	10 sets of 3 sweeps	Amrine
16 May 1980	Sandstone Falls St. Park	Summers	318	100.0	0	10 sets of 3 sweeps	Amrine
16 May 1980	Sandstone Falls St. Park	Summers	792	100.0	0	10 sets of 3 sweeps	Amrine
16 May 1980	Sandstone Falls St. Park	Summers	144	100.0	0	10 sets of 3 sweeps	Amrine
27 Jun 1980	Talcott	Summers	91	100.0	0	10 sets of 3 sweeps	Amrine
14 Jun 1978	Glen Fork	Wyoming	2	100.0	0	Representative sample	Butler
12 Jun 1980	Glen Fork	Wyoming	4	100.0	0	10 sets of 3 sweeps	Amrine
25 Jul 1980	Twin Falls State Park	Wyoming	63	100.0	0	10 sets of 3 sweeps	Amrine
24 June 1981	Twin Falls State Park	Wyoming	7	100.0	0	Representative sample	Hacker

Table 2.
Summary of continuous sampling of female *S. jenningsi* at Shanklin's Ferry on September 15, 1981, over a 30-minute period.

Time of Collection		Number Taken	Remarks
12:00 P.M.		382	partly cloudy
12:05		280	partly cloudy
12:09		296	partly cloudy
12:12		232	fine rain began
12:15		148	steady drizzle
12:20		102	hard rain
12:26		88	downpour
	Total	1,528	

Each collection represents 10 sets of 3 sweeps with a 15" net, and a pause of 30 seconds between sets.

two to three weeks. It appears to be difficult to develop immunity for *S. jenningsi* bites (at least in the author's experience).

The 76 black fly specimens listed in Table 3 are only those collected after having fed to repletion on human blood. However, many more females probed and fed on the subjects during the study. Since ten or more females often fed simultaneously, not all could be captured.

Replete adult females were returned to the laboratory in an attempt to obtain eggs. Despite several attempts to stimulate oviposition in the laboratory, no females deposited eggs. Some females were dissected on the fourth or fifth day after receiving a blood meal, and an average of 118 eggs (range of 112 to 127) were removed from the abdomen. The eggs have a characteristic ovate-triangular shape (Figure 1).

Regional Survey for Immature Black Flies

Tables 4 and 5 and Maps 1 and 2 list the collecting stations for immature black flies in the region. Attention was given to larger streams because of the known breeding site preference by *S. jenningsi* (Stone and Snoddy, 1969; Underhill, 1944); however, many smaller streams were surveyed but are not listed. Immature *S. jenningsi* were not found in streams with an average width under 6 m (20 ft).

Table 4 lists the collecting sites on the New River and its major tributaries, as well as the Guyandotte River and its tributary, Clear Fork. An asterisk indicates those streams where larvae and pupae of *S. jenningsi* were abundant (usually, 1,000's could be found in a 45-minute search), and the symbol # indicates those streams with low numbers (fewer than 500 could be found in a 45-minute search). Sampling stations with neither symbol indicate that *S. jenningsi* could not be found. An average of 45 minutes collecting time was spent per site; most sites were sampled several times at different seasons and in different years. Stations 1 through 4 (New River in Virginia) and 32–35 (upper Greenbrier River) are indicated on Map 1. The remaining station locations are shown on Map 2.

Table 3.
Summary of collection of female *Simulium jenningsi* fed on human blood.

Date	Location	County	Number Blood Fed	Person Fed on
2 Jun 1977	New River, Cedar Branch	Summers	1	Amrine
15 Sep 1981	New River, Shanklin's Ferry	Summers	10	Amrine
31 Aug 1979	Hinton, South Bridge	Summers	2	Amrine
16 May 1980	Hinton, South Bridge	Summers	20	Amrine
27 Jun 1980	Hinton, South Bridge	Summers	12	Amrine
21 Aug 1980	Hinton, South Bridge	Summers	7	Stasny, Amrine
23 Jun 1981	Hinton, South Bridge	Summers	5	Amrine
27 Jul 1981	Hinton, South Bridge	Summers	6	Amrine
16 May 1980	Lick Run at Sandstone	Summers	1	Amrine
16 May 1980	Sandstone Falls State Park	Paleigh	7	Amrine
5 Aug 1980	Glade Springs Resort	Raleigh	3	Salmon, Amrine
26 Jul 1980	Twin Falls State Park	Wyoming	1	Hall
14 Sep 1981	2 km N, Red Sulfur Springs	Monroe	1	Amrine

Table 4.
List of larger streams sampled in southern West Virginia and Virginia for black flies (other than the New River below the Bluestone Dam).

Stream Name	Location
1. New River*	8 km S. Laswell, Va. (above Claytor L.)
2. New River	Radford, Va. (below Claytor L.)
3. New River	Rich Creek, Va.
4. New River	1 mi. N. U.S. Rt. 460, Va.
5. New River#	Shanklin's Ferry (several locations)
6. New River#	Mouth of Indian Creek
7. New River	Crump's Bottom (impounded)
8. East River	Rt. 460 near WV State Line
9. Bluestone R.#	Pipestem St. Pk.
10. Glade Creek	Pluto Rd., Raleigh Co.
11. Glade Creek	Glade Springs Resort
12. Piney Creek	Beckley
13. Piney Creek	New River
14. Guyandotte R.	Mullens
15. Guyandotte R.	Pineville
16. Clear Fork R.	Oceana
17. Clear Fork R.	Near Clear Fork
18. Gauley R.	Gauley Bridge
19. Gauley R.	Peters Creek
20. Gauley R.	Summersville Dam
21. Gauley R.#	Rt. 20, S. of Craigsville
22. Cherry R.#	Cranberry Confluence
23. Cherry R.#	Richwood
24. Meadow R.#	Anglins Creek
25. Meadow R.	Nallen
26. Meadow R.	Russellville
27. Glade Cr.	Babcock St. Pk.
28. Meadow Cr.	3 km NE of town, Meadow Creek
29. Meadow Cr.	Town of Meadow Creek
30. Lick Cr.	Green Sulfur Springs
31. Lick Cr.	3, 2, and .5 km N. Sandstone
32. Greenbrier R.	Durbin
33. Greenbrier R.*	Cass
34. Greenbrier R.#	Marlinton
35. Greenbrier R.#	Seebert
36. Greenbrier R.#	Caldwell
37. Greenbrier R.#	Ronceverte
38. Greenbrier R.#	Alderson
39. Greenbrier R.#	Talcott
40. Greenbrier R.#,*	Summers Co., Rd. 14
41. Greenbrier R.#,*	Several locations near Hinton
42. Indian Creek	Covered Bridge

(continued)

Table 4. Continued.

Stream Name	Location
43. Indian Creek#	Red Sulphur Springs
44. Indian Creek#	5 km below Red Sulphur Springs
45. Indian Creek*	Summers Co., Rd. 21/2
46. Indian Creek*	New River

S. jenningsi immatures were found in moderate to high numbers.
S. jenningsi immatures in low numbers; the presence of both symbols indicates a change in abundance from year to year.

In the upper New River, *S. jenningsi* immatures were plentiful above Claytor Lake, Virginia. However, no *S. jenningsi* were found at Stations 2-4, from Claytor Lake to Rich Creek, Virginia. Immatures were found in some seasons and in some years at Stations 5 and 6. The larvae and pupae were numerous at Stations 5 and 6 in April, 1979 and 1980, but disappeared after mid-May in both years when stream discharge returned to normal levels (4,000-7,000 cfs). In 1981, small numbers of *S. jenningsi* persisted throughout the season at Stations 5 and 6.

In the Greenbrier River, numbers of immatures were generally low except near Cass. In 1979 and 1980, no *S. jenningsi* were found in the lower Greenbrier River (Stations 37-41) after mid-May. In some cases, very small larvae were found in July and August, indicating that eggs were hatching but larvae could not complete development. However, in 1981, moderate to heavy larval numbers were observed at Stations 40 and 41. The reason for the increase over previous years is not known. In summer months the Greenbrier River is reduced to a small stream in a large channel with numerous rocks, boulders and gravel beds; the stream becomes very warm and would appear to be very susceptible to low oxygen problems.

The Bluestone River was found to produce small numbers of *S. jenningsi*: no location produced more than 100 immatures during a 45-minute search. Lower Indian Creek (Stations 45 and 46) produced moderate to heavy numbers of immature *S. jenningsi*, but only in mid-summer to fall. No immatures were found in Indian Creek in April or May when large numbers of *S. jenningsi* larvae were developing in other streams. Apparently, diapausing eggs are not laid in Indian Creek. The upper Gauley River and the Cherry River in Nicholas and Webster counties were found to produce low numbers of *Simulium jenningsi*.

Despite repeated examinations at different seasons over a period of four years, none of the other large streams in the vicinity of Hinton and Beckley were found to be producing immature *S. jenningsi*.

The only other stream producing black flies in the subgenus *Phosterodoros* (whose females are difficult to differentiate but whose pupae and mature larvae are very distinctive) in the region was the Meadow River in the vicinity of Nallen, Nicholas County. The dominant species was *Simulium (Phosterodoros) nyssa* (60.9%), followed by *S. tuberosum* (27.5%), *S. (P.) fibrinflatum* (11.1%), *S. (P.) jenningsi* (0.3%) and *S. vittatum* (0.1%) (based on 952 pupae). Numbers of the first two species were moderate, and it is very difficult to distinguish *S. nyssa* from *S. jenningsi* females. However, this limited, small breeding source rules out *S. nyssa* as being more than a local trace of the nuisance black fly problem in southern West Virginia.

Characteristics of the New River at Hinton

The Bluestone Dam was completed on June 12, 1952, with storage beginning in 1949. The dam is equipped with 21 lift gates on the spillway and 16 sluice gates through the spillway and has a total capacity for storing 631,000 acre-feet (778 hm^3). The dam is 54.9 m (180 feet) high and 642.2 m (2,048 feet) long (U.S. Army Corps of Engineers, 1949). The discharge from the dam fluctuates widely, both daily and hourly; in general, Sunday and Monday have the lowest discharge because the Claytor Lake Power Plant stops power generation on weekends and changes in discharge from Claytor Lake reach the Bluestone Reservoir after 24 hours (Chesne, 1980). The fluctuation especially affects water depth and current and, undoubtedly some mortality of sessile aquatics such as black fly pupae occurs on emergent vegetation at stream margins; black fly larvae in deeper waters are forced to drift at low discharge because the velocity becomes insufficient to allow filtering of food by the headfans.

The New River at Hinton drains an area of 16,206 km^2 (6,257 mi^2), and has an average discharge of 225.9 m^3/s (7,977 ft^3/s) (U.S. Geological Survey, 1980). The river below the dam drops from an elevation of 414.6 m (1,360 feet) at Hinton to 377.9 m (1,240 feet) at Meadow Creek, for an average drop of 3.2 m (10.6 feet) per km. The river width varies from a minimum of 124.8 m (409.6 feet) to a maximum of 416.1 m (1,365.3 feet) at Sandstone Falls. Using aerial photos,[1] the width of the Bluestone Dam as a reference, and taking 19 measurements between the dam and the town of Sandstone, the average river width was calculated to be 245.1 m (804 feet). The average depth is estimated to be 91 cm (36 in), and the bottom is mostly bedrock down to Sandstone Falls. The same photos clearly showed the extensive riffle areas in contrast to short stretches of quiet water, and the length of the stream with a velocity high enough to support sizable populations of *S. jenningsi* (0.7 ft/sec) was estimated to be 7.5 kilometers (out of a total of 11.3 km) from the dam to the town of Meadow Creek. Most of the land area in the counties bordering the New River consists of a plateau ranging from 731.5 m to 1,219 m (2,400 to 4,000 feet) elevation.

Immature Black Flies Collected from the New River— Hinton to Gauley Bridge

Table 5 lists the sampling stations, distance downstream in km, and relative numbers of immature *S. jenningsi* collected in the New River below the Bluestone Dam (Map 2). The 11-km stretch from the dam to just south of the town of Meadow Creek was found to produce immense numbers of *S. jenningsi* larvae and pupae. One 36-square-inch sample of *Podostemum ceratophyllum* Michx. (dry weight, 3.2 grams) from the river at the south bridge in Hinton, collected August 1, 1979, contained 8,908 larvae (2,784 larvae per gram dry weight). In the vicinity of the town of Meadow Creek, the numbers of immatures dropped to a low level (Station 53)—(only a few hundred specimens could be found in 45 minutes). From there on downstream, the populations of

[1]Frames 101, 157, 171 and 219, roll 2, product code 13, project VBPI; obtained from Eros Data Center, Sioux Falls, SD, 57198.

Table 5.
Location of sampling stations on the New River, downstream from the Bluestone Dam, and the relative abundance of immature *Simulium jenningsi*.

Location	km below dam	*S. jenningsi* abundance
47. South Bridge, Hinton	0.5	high*
48. Greenbrier channel, Opposite Shopping Center	0.9	high
49. ½ km. N. of North Bridge, Hinton	2.1	high
50. Falls at Camp Brookside	5.1	high
51. Sandstone Falls S. P.	8.4	high
52. RR Crossing, S. of Meadow Creek	11.1	high
53. 1 km. N. Meadow Creek	12.7	low
54. Fayette-Summers County Line	13.2	low
55. "Backus"	16.4	low
56. Prince	21.3	low
57. McKendree P.H.A.	26.0	low
58. Stone Cliff	31.0	low
59. Sewell (Babcock State Park)	37.6	none
60. Fayette Station (New River Bridge)	43.2	none
61. Hawk's Nest State Park	47.1	none
62. Gauley Bridge	52.5	Trace

*High numbers indicate that 1,000's of immatures could be found in a 45-minute search; low numbers mean that 500 or fewer immatures were found in a 45-minute search.

S. jenningsi were relatively low. Numbers of larvae continued to drop in the river until none could be found at Stations 59–61 and only a trace at Station 62.

The first coal preparation plant observed on the New River (going downstream from Hinton) is located at Meadow Creek. Map 1 indicates the relative position of the "coal boundary" in West Virginia and Virginia: to the west of this line occur geological deposits of coal; to the east of this line, rock strata are free of coal. Numerous strip mines appear in the northern half of the Meadow Creek Quadrangle (7.5 minute series, West Virginia Geological Survey) and appear in each quadrangle (Prince, Thurmond) from this point downriver.

Observations made during larval collections showed a preference for aquatic plant substrates by the immature *S. jenningsi*. Aquatic plants on which larvae were collected were waterwillow, *Justicia americana* (L.); river weed, *Podostemum ceratophyllum* Michx.; water star grass, *Heteranthera dubia* (Jacq.) Mac M.; pondweeds, *Potamogeton* spp.; and filamentous algae, (*Cladophora* et al.).

Justicia stems sprout from beds in shallow parts of the river in April and can then serve as a substrate for larvae until plants die off with the approach of cold weather in October and November. Beds of *Justicia* are found only in shallow regions and along stream margins. They become a significant larval substrate only near the margins of beds where individual plants have been bent over by the current, allowing leaves to be covered by flowing water. Emergent *Justicia* provide little area for substrate; only the stem and a few leaf bases are utilized by larvae.

Podostemum is the most important larval substrate in spring and early summer. It is the dominant aquatic plant in the New River, comprising up to 98 percent of the total biomass in areas of swift current (Mitchell, 1973). Both larvae and pupae attach to the numerous 10–15 cm long filamentous leaves and stems which blanket large areas of the river bottom, especially in shallow regions with bedrock and high velocity. During July, many of the *Podostemum* leaves abcise and decay, and only the stems and flowers are present for larval attachment, greatly reducing its importance as a substrate in mid-summer. New, delicate leaves appear in September, and the plant again becomes a significant substrate in late September and early October. However, larval and pupal populations are on the decline at that time. Water star grass, *heteranthera dubia*, becomes an important larval substrate in mid-June and remains the most reliable substrate from which to sample immatures until late September, when leaves are shed. *Potamogeton* is an important substrate in some areas, such as just below the Bluestone Dam for a few hundred meters. Filamentous algae support low numbers of immatures, presumably because of their deciduous nature.

Immatures also attach to stones, clams, trash, and other forms of debris in the stream. In spring and early summer, relatively few larvae and pupae are found on stones, presumably because a layer of diatoms and algae prevents attachment of adhesive silk pads by the larvae. In mid-summer and fall, more larvae are found on stone and bedrock.

Simulium jenningsi larvae first appear in February or March, and pupation occurs in early April. Larval development, through 7 instars, requires 4 to 5 weeks, and the pupal stage lasts 4 to 5 days. The first emerging adults have been found in early April. Development of the insect is then continuous until September. Eggs laid in August or September enter diapause and will not hatch until the following February or March. A large sample of *S. jenningsi* larvae collected on October 7, 1981, contained no larvae smaller than third instar, indicating that no eggs hatched after mid- to late-September.

During the spring, summer and early fall, first instar larvae (recognized by the presence of a sclerotized egg-burster on the tentorium) can be found evenly distributed across the width and along the length of the river, indicating an even dispersal of eggs. However, despite diligent searches for eggs, only four have been collected in nature—three from silt collected from aquatic vegetation and one from the stomach of a minnow (*Notropis photogenis*).

One sample of *Heteranthera dubia* was collected at Station 48 in water 134.6 cm (4′ 5″) deep with an approximate velocity of 20 cm/sec (0.6 ft/sec); a total of 61 pupae (17 emerged) and 0 larvae were collected from 1 gram, dry weight. This sample represents the greatest depth and lowest velocity for which immature *S. jenningsi* were collected. The velocity had apparently been somewhat higher a few days earlier (greater discharge), and when it dropped below 30 cm/sec (1 ft/sec), the larvae drifted to a more suitable site.

Pupae of *S. jenningsi* have been collected from various plant substrates at several locations in the New River (Table 6). The highest densities were found below the Bluestone Dam at Hinton, with one sample of *Heteranthera dubia* having the unusually large average of 828.4 pupae per gram dry weight. *S. jenningsi* pupae also were collected from rocks, pieces of metal, plastic, and other man-made debris and from clam shells (living and dead). The average density of pupae on nonvegetative substrates was 1.66 per cm^2, (one gram dry weight of *Heteranthera dubia* has an area of 412 cm^2; 828.4 pupae per gram dry weight equals 2.01 pupae per cm^2).

A total of 10,925 black fly pupae were examined from the New River from the months April through November, 1978–1981. Of this number, 92.67 percent were *Simulium jenningsi*, 7.1 percent were *S. vittatum*, and 0.3 percent were *S. tuberosum*. The number of eclosed pupae was counted per sample, and the overall average was 43.5 percent. The average percent eclosed by month was: May, 18.1; June, 45.2; July, 49.9; August, 38.8; September, 40.2 and October, 43.9 (comparisons were not made for April or November). The pupal stage lasted four to five days (at 25° C) and the above eclosion data indicated that empty cocoons did not remain attached to the substrate much longer than 4 to 5 days (otherwise, the percent eclosed would have been much higher). The peak period of adult emergence occurred in mid-July, which agrees with the findings of Underhill, (1944).

In October, 1981, the *Simulium jenningsi* population in the New River at Hinton drastically declined (Table 6). Only a small fraction of the September population was present in the New River channel, whereas numbers remained unchanged in the Greenbrier Channel (Station 48) and at Sandstone Falls and south of Meadow Creek. The suspected cause of this drastic reduction is the seasonal inversion of water layers in the reservoir which takes place in late September (Chesne, 1981). The bottom layer with low oxygen, possibly containing noxious materials, surfaced and its passage downstream appeared to have eliminated the pest for several kilometers (recovery began to appear at Station 50). The numbers of *S. vittatum* larvae and pupae remained unchanged, supporting its known ability to tolerate low oxygen and other adverse conditions.

The size of *S. jenningsi* cocoons varied among locations on the New River (Table 7). The cocoons from the South Bridge (Station 47) in Hinton were considered standard size. Cocoons from the Greenbrier Channel (Station 48) were 14.2 percent smaller, and cocoons from McKendree P.H.A. (Station 57) and Stone Cliff (Station 58) were 26.5 and 33.3 percent smaller respectively. Samples from other locations in the New River within 11 km of the Bluestone Dam did not vary significantly from those at Station 47.

In 1979, 1980, and 1981, no immature *S. jenningsi* were collected from a narrow, 20 m (60 ft.) zone along the right margin[2] of the New River at the railroad switching station just south of Hinton. This location is approximately 1 km below the Hinton sewage treatment plant. Apparently, effluent from this plant is sufficiently toxic to eliminate *S. jenningsi* from the zone. The same *S. jenningsi*-free zone was observed north of Bass Ponds Resort in 1980 and 1981. The zone extends approximately 25 meters (75 ft) into the river at this point. Numbers of immature *S. jenningsi* rise to normal levels a few meters farther in the stream (30–35 m). This observation reinforces past observations of the sensitivity of immature *S. jenningsi* to pollutants (Underhill 1944; Stone and Snoddy, 1969). It is concluded that conditions are not optimal for

[2]Facing downstream.

Table 6.
Number of *S. jenningsi* pupae per gram dry weight of vegetation collected at several locations on the New River.

Station Number	Date	No. pupae	Vegetation
5	18 Aug 1981	28.3	*Heteranthera*
5	15 Aug 1981	5.0	*Heteranthera*
6	21 Jul 1980	0.04	*Justicia*
6	17 Aug 1981	16.1	*Heteranthera*
47	1 Aug 1979	309.7	*Justicia*
47	1 Aug 1979	149.0	*Podostemum*
47	4 Aug 1980	134.4	*Potamogeton*
47	21 Jul 1981	544.0	*Potamogeton*
47	21 Jul 1981	155.5	*Podostemum*
47	21 Jul 1981	580.0	dead leaves (Aspen)
47	14 Sep 1981	828.4	*Heteranthera*
47	6 Oct 1981	10.2*	*Heteranthera*
48 (Greenbrier Channel)	22 Jul 1981	23.4	*Justicia*
48 (New River)	17 Aug 1981	247.2	*Heteranthera*
49	22 Jul 1981	386.2	*Heteranthera*
50	22 Jul 1981	410.6	*Heteranthera*
51	22 Jul 1981	95.6	*Heteranthera*
51	7 Oct 1981	65.2	*Heteranthera*
52	6 Oct 1981	198.0	*Heteranthera*
53	22 Jul 1981	0.7	*Heteranthera*
53	6 Oct 1981	15.9	*Heteranthera*
56	14 Sep 1981	70.0†	*Heteranthera*
57	22 Jun 1981	0.5	dead leaves
58	24 Jun 1981	0.5	dead leaves

*Following temperature inversion in the Bluestone Reservoir.
†Along West Bank, influenced by flow of clean water from Glade Creek.

maximum growth in the Greenbrier Channel at Hinton and in the segment of the New River north of Meadow Creek.

Examination of the intestinal contents of selected minnows (Tables 7 and 8) from the New River (Tables 8 and 9) indicates, at least for the species studied, that immature *S. jenningsi* were a minor part of their diet. The minnow, *Notropis* sp., collected in May contained no simuliids. The major components of its diet were glochidia (immature clams), ostracods and chironomids (with a total of 12 different items collected from the intestine). The intestinal contents of *Notropis photogenis* (Silver Shiner—identified, courtesy of Mr. Cincotta, West Virginia Department of Natural Resources) consisted of 9.9 percent simuliids, 40.2 percent chironomids and 19.9 percent mayflies as major diet items. Sixteen different items were found in the diet of this minnow.

Table 7.
Comparison of *S. jenningsi* cocoon sizes (length × height in mm) collected at various locations in the New River below the Bluestone Dam.

Date	New River Location	km Below Bluestone Dam	Number Observations	Mean of Length Times Height	County	Percent Reduction
23 Jun 81	S. Bridge, Hinton	0.50	32	3.913 a*	Summers	0.0
15 Jul 81	S. Bridge, Hinton	0.50	50	3.663 b	Summers	6.4
23 Jun 81	Greenbrier Channel	0.95	32	3.358 c	Summers	14.2
23 Jun 81	Camp Brookside	5.10	33	3.833 ab	Summers	2.0
22 Jun 81	Mckendree PHA	26.00	8**	2.876 d	Fayette	26.51
24 Jun 81	Stone Cliff	31.00	15**	2.611 d	Fayette	33.3

*Considered standard size.

**All that could be found in 45 minutes. Means with the same letter are not significantly different (Duncan's Multiple Range Test, 95 percent probability).

Table 8.
Itemized occurrence of intestinal contents of immature minnows (Cyprinidae: prob. *Notropis*) collected in the New River at Hinton, West Virginia, on May 16, 1980.

	Specimen Number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	Mean %
1. Glochidia	1 (33.0)		12 (80.0)	8 (72.7)	3 (60.0)	4 (57.1)	3 (42.8)	4 (57.1)	4 (80.0)		15 (75.0)	18 (85.7)	4 (26.7)	76 (57.1)	51.5

2. Ostracods	1 (33.3)			2 (18.2)			1 (14.3)				3 (15.0)		9 (60.0)	16 (12.0)	10.8
3. Chironomidae		1 (6.2)	1 (6.2)		1 (20.0)	2 (28.6)	1 (14.3)					1 (4.8)	1 (6.7)	8 (6.0)	6.7
4. Undet. Insects (not Simuliidae)							1 (14.3)	1 (14.3)						2 (1.5)	2.2
5. Simuliidae															0.0
6. Fish				1 (9.1)							1 (5.0)	1 (4.8)		3 (2.2)	1.5
7. Annelida			1 (6.7)											1 (0.1)	0.5
8. Parasites	1 (33.0)	12 (75.0)	1 (6.7)											14 (10.5)	8.8
9. Algae		1 (6.2)				1 (14.3)	1 (14.3)							3 (2.2)	2.7
10. Seeds		1 (6.2)						1 (14.3)						2 (1.5)	1.6
11. Stone		1 (6.2)												1 (0.1)	0.6
12. Unknown					1 (20.0)			1 (14.3)	1 (20.0)	1 (100.0)	1 (5.0)	1 (4.8)	1 (6.7)	7 (5.3)	13.1
Total	3	16	15	11	5	7	7	7	5	1	20	21	15	133	100.0

Numbers in columns represent number observed; numbers in parentheses represent percent for that column.

Table 9.
Itemized occurrence of intestinal contents of immature minnows *Notropis photogenis* (Cyprinidae), collected in the New River at Hinton, West Virginia, on August 17, 1981.

Item	1	2	3	4	5	6	7	8	9	10	11	12	Total	Mean %
1. Simuliidae	1 (4.2)		3 (17.6)		1 (7.1)	3 (14.3)	2 (9.0)	1 (8.3)	9 (37.5)	1 (5.5)		6 (15.4)	27 (12.4)	9.9
2. Chironomidae	14 (58.3)	5 (50.0)	3 (17.6)		3 (21.4)	13 (62.0)	10 (45.4)	3 (25.0)	6 (25.0)	10 (55.5)	7 (50.0)	28 (71.8)	102 (47.0)	40.2
3. Ephemeroptera			6 (35.3)		7 (50.0)	4 (19.0)	6 (27.3)	2 (16.7)	6 (25.0)	4 (22.2)	5 (35.7)	3 (7.7)	43 (19.8)	19.9
4. Plecoptera	5 (20.8)	1 (10.0)		1 (50.0)									7 (3.2)	6.8
5. Trichoptera	2 (8.4)	1 (10.0)	1 (5.9)		1 (7.1)		2 (9.0)	1 (8.3)	3 (12.5)			1 (2.6)	12 (5.5)	5.4
6. Odonata		1 (10.0)											1 (0.5)	0.9
7. Lepidoptera	1 (4.2)												1 (0.5)	0.3
8. Fish		1 (10.0)	3 (17.6)		1 (7.1)						1 (7.1)		6 (2.8)	3.5
9. Cladocera										1 (5.5)	1 (7.1)		2 (0.9)	1.0
10. Algae		1 (10.0)					1 (4.5)	2 (16.7)					4 (1.8)	2.6

11. Seeds							1 (4.5)						1 (0.5)	0.4
12. Nematodes					1 (7.1)								1 (0.5)	0.6
13. Dytiscidae												1 (2.6)	1 (0.5)	0.2
14. Parasites								1 (8.3)		1 (5.5)			2 (0.9)	1.1
15. Cyclorrhapha										1 (5.5)			1 (0.5)	0.4
16. Unknown	1 (4.2)		1 (5.9)	1 (50.0)		1 (4.8)		2 (16.7)					6 (2.8)	6.8
Total	24	10	17	2	14	21	22	12	24	18	14	39	217	100.0

Numbers in columns represent numbers observed; numbers in parentheses represent percent for that column.

The identification of *S. jenningsi* from collections on the New River were verified by the following specialists: Dr. Bobby V. Peterson and Dr. D. M. Wood,[3] Dr. E. W. Cupp,[4] Dr. E. L. Snoddy,[5] and Dr. I. M. McDaniel.[6] All of the above agreed that the mature larvae and pupae are *Simulium (Phosterodoros) jenningsi*. The adult females were identified to *S. (Ph.) jenningsi* subgroup; but since all mature larvae and pupae in the subgenus *Phosterodoros* collected from the New River were *S. jenningsi*, the other subgroup species are ruled out (*S. nyssa*, *S. penobscoti*, etc.).

Discussion

The species of black fly responsible for causing severe nuisance to and biting of the citizens of southern West Virginia is *Simulium (Phosterodoros) jenningsi* Malloch. Of all the adult black flies collected in the eight-county region over a ten-year period, 99.8 percent were *S. jenningsi*. The greatest number of adults were collected near the New River in Summers, Raleigh, and Fayette counties, strongly indicating that the river is the source. The adults were apparently capable of dispersing 55.4 km (34.4 miles) from the breeding site (the New River at Hinton) as indicated by the collection of this species from the Wyoming County Youth Camp at Glen Fork in two different years. None of the streams in Wyoming County produce *S. jenningsi*; the nearest breeding sites of *S. jenningsi* are the New River at Hinton, 55.4 km (34.4 miles), and the Bluestone River in Mercer County (28.3 miles). This conclusion also is supported by the collections of adults at Summersville Dam in Nicholas County. The nearest known breeding sites from that location are the New River at Meadow Creek, 45.4 km (28.3 miles), and the upper Gauley River at State Route 20, 26.5 km (16.5 miles), which produces only low numbers of the insect and can probably be ruled out as the source. Dispersal of *S. jenningsi* for 55 km (34 miles) is not unreasonable, as many species of black flies have been observed to fly considerable distances from their breeding source (Fredeen 1969; Underhill 1944).

The major breeding source of *S. jenningsi* in southern West Virginia is the New River, from the Bluestone Dam to the town of Meadow Creek. The greatest number of immature *S. jenningsi* were found in this stretch of the New River (Table 6). Much smaller numbers of *S. jenningsi* developed in the New River at Shanklin's Ferry and at the mouth of Indian Creek and downstream from the town of Meadow Creek. Small numbers were also found in the Bluestone River and the upper Gauley River at State Route 20. Moderate numbers of immature *S. jenningsi* were found in the lower Greenbrier River (Summers County) and in the lower reaches of Indian Creek (west of Summers County Road 21/2). Interestingly, moderate numbers of *S. jenningsi* were found in the Greenbrier River only in 1981, but none were found in the preceding two years except early in the season (April–May) when stream discharge was high. No other breeding sites for *S. jenningsi* occurred in southern West Virginia.

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[5]Water Quality and Ecology Branch, Tennessee Valley Authority, Mussel Shoals AL 35660.

[6]Maine Agricultural Experiment Station, 303 Deering Hall, University of Maine.

The conclusion that the New River at Hinton is the major source of black flies in southern West Virginia is supported by the research on the faunal diversity of the New River by Klarburg (1977). Three of his 22 sampling stations (18, 19, 20) were located below the Bluestone Dam at Hinton and in 1971 produced the highest numbers of Simuliidae that he collected in his study. He also found over 129 genera of aquatic organisms, mostly insects, indicating that at least 500 different species probably occurred in the river.

About 98 percent of the adult *S. jenningsi* causing the nuisance in southern West Virginia breed in this 11-km stretch of the New River. The numbers being produced there are enormous. Based on a low productivity of 120 pupae per gram dry weight of the riverweed, *Podostemum*, an average biomass of 30.5 grams/m^2 (Mitchell, 1973), an average width of 245.1 meters, and a productive river length of 7.5 km, the number of pupae occurring at any one time is estimated at 6.73×10^9. Since an average of 43.5 percent of pupae are eclosed at any one time, then 3.80×10^9 pupae occur on *Podostemum* at any given time, resulting in the production of an average of 3.8 billion flies every four days, or 950 million flies emerging daily from pupae attached to *Podostemum*. If one takes into account the pupae found on non-vegetative substrate at an average of 1.66 per cm^2, then an average river width of 245.1 meters times 7.5 km length produces 3.05×10^{10} pupae. Deducting 43.5 percent for those eclosed means a rough average of 17.2 billion flies are produced from non-vegetative substrate every four days, or 4.3 billion flies emerging daily. An estimated total of 5.25 billion flies are produced from this 11-km stretch of the New River daily during the developmental season, thus producing the severe nuisance and biting problems observed during the past several years in southern West Virginia.

Ordinarily, immature black flies have clumped distributions in streams—they are found in large numbers only at riffles or on some few substrates at key locations. However, this 11.3-km stretch of the New River has a remarkably uniform broad width and shallow depth with high water velocity. *S. jenningsi* immatures were observed to be remarkably uniformly distributed over the entire bottom of this stream, except for a few locations noted above.

The astronomical numbers of flies being produced in the New River explains why adult fogging programs used in the region have been ineffective in controlling the problem. The use of malathion fog undoubtedly killed thousands of adult *S. jenningsi*, but the enormous numbers flying and migrating through the region replaced those killed in a matter of minutes or a few hours. The futility of adult fogging for black fly control has been well documented in the literature (Smith, 1973; Frommer, 1980).

Pollution is probably the reason that other parts of the New River and other streams do not significantly serve as breeding sites for the flies. The New River in Virginia receives agricultural, industrial and sewage discharge from towns and arable land. The major cities and towns contributing effluent are Pulaski, Dublin, Radford, Blacksburg, Pearisburg, Narrows, and Rich Creek. Although secondary sewage treatment may be used in several towns, the resulting effluent still depresses oxygen levels to some degree. The Glen Lyn power plant (at Rich Creek) raises the temperature of the New River on the left bank to 34° C, much higher than the normal 26 to 28° C summer temperatures. Fish kills on this segment of the New River have been recorded (Reed, 1981)—possibly as a result of industrial effluents released into the river. It is well known that *S. jenningsi* cannot tolerate pollution (Stone and Snoddy, 1969;

Underhill, 1944) and the presence of this species in a stream is a good indicator of high water quality. Conversely, its absence in a large stream (especially where adults are numerous) indicates less than optimal water quality.

The Bluestone Reservoir is an ideal system for removal or modification of pollution effects. It is presumed that eutrofication occurs in the reservoir, and that water passing through the 16 gates of the Bluestone Dam is loaded with algae and other planktonic items but virtually free of the suspected pollution problems found in the upper New River. This clean water, supercharged with nutrients, undoubtedly explains why the New River at Hinton is the best warm-water fishing stream in West Virginia (Miles, 1980) and why it also produces the largest populations of *S. jenningsi* the author has ever seen.

It is presumed that this pestiferous population began to develop in 1949, when the storage began in the newly constructed Bluestone Dam. As the reservoir filled and eutrofication (and detoxification?) began to occur, the tailwaters presumably became suitable for an immense population of *S. jenningsi*. One factor that may have caused a great increase in numbers of *S. jenningsi* is the obstruction of the 16 trash racks which began in 1965. This was a result of citizen disapproval of moving dead trees and assorted debris by derrick from the trash racks to the front face of the dam (Chesne, 1980). As the trash racks became clogged, the water became top flow through the sluice gates rather than bottom flow as originally designed (U.S. Army Corps of Engineers, 1949). It is well known that the top surface of a lake or reservoir is rich in planktonic material on which black flies and other filter-feeders obtain nutrition. Also, this stratum of water would have higher O_2 levels than water flowing from the bottom. A major part of the *S. jenningsi* pest problem may possibly be corrected by cleaning the trash racks and returning the dam to bottom flow as designed.

The reduction in the number of *S. jenningsi* observed at the town of Meadow Creek may be related to the presence of a coal preparation plant at that location (the first such plant to be found on the New River). The large quantities of fine coal dust which end up in the river may account for the reduced populations. The fine dust can be observed incorporated in the silken cocoons spun by the larvae. Unlike clams, which can sort particulates into nutritional and non-nutritional fractions (Barnes, 1980), black fly larvae must ingest all particulate matter collected by the head fans. If a significant proportion of particulate matter is silt, or in this case, fine coal dust, then larval nutrition is greatly reduced. There may also be a toxic factor involved as the larvae attempt to digest the fine coal dust. The reduction in numbers of immature *S. jenningsi* from Meadow Creek to Stone Cliff and their absence from the New River at Sewell and Fayette Station is probably related to the occurrence of a number of coal preparation plants on the New River and its tributaries, as well as the seepage of pollutants from the numerous active and abandoned coal strip mines in the region.

The potential for control of *S. jenningsi* in the New River is excellent. Simultaneous application of a larvacidal material at the stilling basin of the Bluestone Dam and to the Greenbrier River (at Talcott, for example) would potentially eliminate large numbers of larvae from the breeding sites. In the past, the chemical insecticides DDT, methoxychlor, and temephos have been used to kill black fly larvae. However, DDT and methoxychlor (chlorinated hydrocarbons) are toxic to a large number of organisms (including fish). They are extremely persistent in natural ecosystems, and have been reported to cause disturbances to some organisms, especially fish and birds. Although non-persistent, temephos still has lethal activity against a number of organisms and has reduced populations of some non-target organisms in field trials in Africa (Lacey, 1982). In addition, *Simulium* in Africa has developed resistance to temephos (Lacey, et al., 1982 a). To date, only *Bacillus thuringiensis* (S14) is registered with the U.S. Environmental Protection Agency for control of black fly larvae in streams and rivers.

Recently, *Bacillus thuringiensis*, serotype 14 (BT S14) has been developed as a very effective larvacide against mosquitoes and black flies (Molloy, 1982). It was registered by the EPA and West Virginia Department of Agriculture for mosquito control in 1981 and for black fly control in 1982. This environmentally sound biological control agent is a variant of *Bacillus thuringiensis* which has been used for more than 20 years to control lepidopterous pests of gardens, farms and forests. It is so safe for vertebrate consumption that no tolerance limitations are required for several serotypes of *B. thuringiensis* on fresh vegetables, grains and other foodstuffs. Like other serotypes of *Bacillus thuringiensis*, BT S14 has a very narrow spectrum of activity, in this case affecting only nematocerous Diptera, especially black flies, mosquitoes and some species of midges.

Bacillus thuringiensis S14 is the safest and most environmentally sound commercial material available for controlling black fly larvae (Gaugler and Finney, 1982). The fact that the crystal inclusion is activated only in the presence of a high gut pH, a large reduction-oxidation potential, and specific enzymes renders it completely safe for all animals and plants except those very few insects that possess the required intestinal conditions. Numerous scientific reports have verified that it is inactive against all non-target organisms except for some midges (Nematocera) (Gaugler and Finney, 1982).

BT S14 has been used in the laboratory and field to control many species of black flies (Gaugler and Finney, 1982). It is effective at rates as low at 0.5 mg per liter of flowing water (0.5 ppm), making it competitive with chemical insecticides. It was used in the fall of 1981 in the Susquehanna River at Harrisburg, Pennsylvania, to attempt to control nuisance populations of *S. jenningsi* (Jones, 1982). A single application of BT S14 to the Marahoue River, Ivory Coast, controlled *Simulium damnosum* for 26 km (16 miles) (Lacey, et al., 1982b).

Treatment of the North River, Hampshire County, West Virginia, with BT S14 in 1980, using 0.5 ppm for 30 minutes, obtained 80 percent control for 1 km, despite many impoundments and sluggish flow (Amrine, 1982).

To control immature *S. jenningsi* in southern West Virginia, three applications of BT S14 should be made. The Greenbrier River at Talcott and the stilling basin at the Bluestone Dam should be simultaneously treated at the rate of 0.5 ppm BT S14 for a minimum of 15 minutes at 30-day intervals with treatments in mid-April, mid-May, and mid-June. It is estimated that the cost of the three treatments would be approximately $9,000: $6,000 for the BT S14 (average discharge of 6,000 cfs, price of $12.80 per pound), and $3,000 for labor and other costs. The environmental impact of this treatment would be minimal in comparison to using other possible larvacides.

Aside from reducing the black fly population, and possibly reducing some midge populations (no lotic species have been found susceptible to date), *no faunal element of the New River should be affected* (Gaugler and Finney, 1982).

For initial treatments of the New River, applications should be made at increasing fractions (starting at 0.05 ppm) of the recommended rate to safely verify anticipated absence of impact on the non-target fauna and to determine the most economic rate of application of BT S14 that reduces the population of *S. jenningsi* to a tolerable level, rather than attempting complete eradication.

Summary

The pestiferous black fly, *S. jenningsi*, is a severe nuisance in several counties of southern West Virginia and breeds in an 11-km stretch of the New River from the Bluestone Dam to the town of Meadow Creek. Over-wintering eggs hatch in March, adults first appear in mid-April, and development is continuous until about mid-September when no further hatching of eggs occurs (although larval development and adult eclosion continues until November).

The adult black flies emerge from the New River in enormous numbers (5.2 billion daily) and are able to disperse 35 miles from the river. The adults are strong fliers and apparently can fly several miles per day. A small proportion of the females feed on humans, causing swelling and severe discomfort which has resulted in three documented hospital treatments in the past four years.

Attempted control by adult fogging was ineffective. The only currently known effective means of control is larvaciding, using three applications at 30-day intervals beginning in mid-April. The most promising and presently safest commercially available larvacide is *Bacillus thuringiensis* S14, which is highly effective at 0.5 ppm for 15 minutes. Control evaluations should begin with a 0.05 ppm application (1/10th recommended rate) to verify anticipated non-effect on non-target organisms and to determine economically effective rates.

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