391
392

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CONTENTS

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By

W. R. Bridges and Austin K. Andrews
Bureau of Sport Fisheries and Wildlife
Fish-Pesticide Research Laboratory
Denver, Colorado

ABSTRACT

The Swan Creek drainage was treated with DDT at the rate of 1.0 pound per acre as a part of a larger spruce budworm control program. Although the plane didn't spray within one-quarter mile of the stream, a level of 0.01 ppm of DDT was measured in the water samples taken half an hour after the spraying. Tremendous numbers of aquatic insects were killed or seriously affected. Samples of these insects contained progressively larger amounts of DDT, up to 11.0 ppm after 3 hours. Rainbow trout exposed in the stream for various periods up to 96 hours suffered no apparent acute effects, but contained as much as 0.1 ppm of DDT in their tissues.

The U. S. Forest Service conducted a large-scale spruce budworm control program on the Gallatin National Forest in Montana in July 1960. Approximately 60,000 acres of forest land in the Gallatin River drainage were treated with DDT (fig. 1). The Forest Service requested the Fish-Pesticide Research Laboratory, Denver, Colorado, and the Denver Wildlife Research Center to make observations on the effects of the spray on the fish and wildlife resources of the area. This report deals with the work of the Fish-Pesticide Research Laboratory in relation to the spray operation.

The time and personnel available required that our efforts to quantitatively measure the effects of the spray be restricted to a relatively small segment of the total spray area. Swan Creek, a tributary to the Gallatin River, was selected as the study stream.

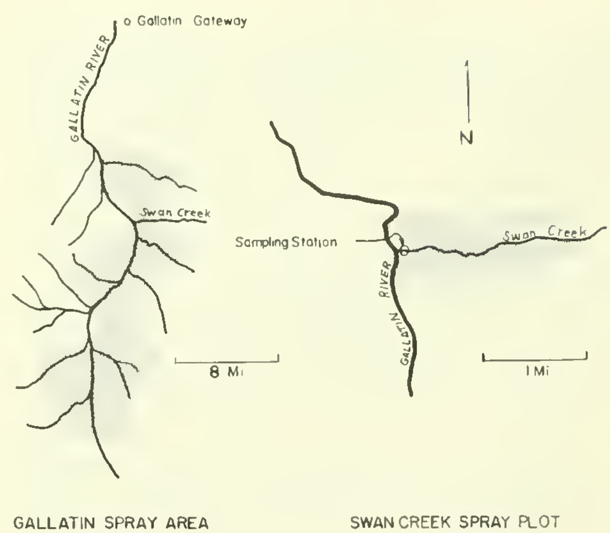

Figure 1.--General DDT spray area and the Swan Creek spray plot, Gallatin National Forest, Montana, 1960. Stippled portions denote areas sprayed.

THE STUDY STREAM

The mouth of Swan Creek is approximately 15 miles south of Gallatin Gateway, Montana (fig. 1). The stream is about 20 miles in length, but only the lower 2 miles were included in the spray plot. Swan Creek flows through a steep, narrow canyon within the boundaries of the spray plot. Near the mouth of the stream the elevation ranges from about 5,700 feet at the valley floor to approximately 6,500 feet at the upper limits of each side of the spray plot. Swan Creek is typical of streams present in the spray area. It is swift and practically devoid of pool areas. The bottom is composed of boulders and coarse rubble. At the time of the spray the stream was high and running at a velocity of 5 feet per second. The estimated flow was 40 cubic feet per second. Water quality determinations were: temperature, 47° F; pH, 8.0; and methyl orange alkalinity, 33 ppm. Invertebrate populations were moderately abundant and anglers' creels contained brook, cutthroat, and rainbow trout.

THE SPRAY OPERATION

Most of the spray plots were treated with DDT at the rate of 1.0 pound per acre. Although some plots along the Gallatin River were treated at the rate of 0.5 pound per acre, the Swan Creek plot received 1.0 pound per acre, sprayed from a Ford tri-motor airplane.

Pilots of planes were instructed not to spray within one-quarter mile of the Gallatin River and its main tributaries. Although pilots carried out the instructions on the Swan Creek plot and on other plots where spray operations were observed, some of the toxicant spray did reach the streams. An observer on the valley floor could see the spray mist start rolling down the sides of the canyon as it was applied. The spray could not be seen on the valley floor, but it could be detected by smell on Swan Creek and on other plots where the canyon sides were steep.

The Swan Creek plot was sprayed on July 3, 1960, between 5:00 AM and 6:00 AM. Two loads of toxicant were required to cover the area sprayed. The plane flew parallel to the stream, and sprayed a strip about 500 feet in width on the upper slopes of each side of the spray plot. The toxicant was not directly applied to the major portion of the spray plot, but drifted down to the lower slopes and to the stream.

Spray cards to measure amounts of toxicant reaching the surface of the water were placed at 8 locations at 400-yard intervals along Swan Creek within the spray plot. The cards indicated that essentially no spray reached the water surface. The results of our study show that in this instance the cards were not a reliable index; the toxicant did contaminate the stream.

EFFECTS OF THE SPRAY ON FISH AND AQUATIC INSECTS

The sampling of Swan Creek was designed to determine the amounts of DDT in water, the acute effects on fish and aquatic insects, and the DDT residues in fish and insects. All samples were collected at one sampling station located near the mouth of Swan Creek (fig. 1). Later our staff chemists conducted analyses for DDT by the paper chromatographic method in our laboratory at Denver.

Amounts of DDT in the water

Two water samples, one surface and one subsurface, were collected from the stream before the spray and at 0.1, 0.5, 1.0, 1.5, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 10.0, 12.0, and 24.0 hours after the spray was applied. Separate analyses revealed no difference in the DDT content between surface and subsurface waters. No DDT was found in the water before the spray. Only a trace, less than 0.002 ppm, was detected 0.1 hour after the spray was applied. The 0.5 and 1.0 hour samples contained 0.01 ppm and 0.002 ppm, respectively. Samples collected after one hour ranged from a trace of DDT to none detected. Most of the DDT in the water was apparently flushed from the Swan Creek area within an hour of the termination of the spray application. This is not surprising when one considers that the stream was flowing approximately 3.4 miles per hour.

Acute effects on aquatic insects

Tremendous numbers of aquatic insects were adversely affected by the DDT spray, as indicated by samples of dead or morbid insects drifting in the stream. A drift sample was obtained by fishing a 40-mesh nylon net 10 inches in diameter for 5 minutes. A mayfly nymph, Baetis, was the only kind of insect collected before the spray; four drift samples contained an average of 6 per sample. After the spray was applied, one drift sample was taken each time water samples were collected. The numbers and kinds of insects contained in each sample are presented in table 1. The greatest number of affected insects were drifting in the stream 1 hour after the spray was applied. The total number dropped sharply after 2 hours and leveled off 7 hours after the spray.

in the drift samples were not separated taxonomically; the analyses reflect the level of toxicant in the whole sample. The results suggest that aquatic insects can concentrate relatively large amounts of DDT in their tissues in a short time. Only a trace of DDT was found in the 0.5 hour sample. The 1.0 and 3.0 hour samples contained 3.4 ppm and 11.0 ppm of DDT, respectively. The 3.0 hour sample also contained 14.2 ppm of the derivative, DDE.

Table 1.--Numbers of aquatic insects per drift sample from Swan Creek after aerial spray of DDT

Aquatic Insects	Time elapsed after spray application, in hours													
	0.1	0.5	1.0	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	10.0	12.0	24.0
Plecoptera nymphs														
Acroneuria	0	0	0	0	0	0	23	0	0	0	0	0	0	0
Arcynopteryx	0	10	50	0	5	0	0	0	0	0	0	0	1	0
Hastaperla	0	1,126	225	55	300	117	0	0	0	0	0	0	0	0
Isogenus	183	0	0	0	0	0	8	17	21	2	7	0	0	1
Paraperla	69	574	175	395	175	47	11	19	1	1	3	1	0	2
Ephemeroptera nymphs														
Baetis	234	1,798	16,925	8,005	8,150	2,335	652	283	136	44	42	24	92	54
Ephemerella	0	88	50	525	100	29	6	10	4	6	3	1	6	6
Iron	6	97	50	1,180	275	175	315	103	33	15	0	10	55	17
Paraleptophlebia	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Stenonema	91	151	475	525	450	2,043	754	502	155	53	19	37	98	23
Trichoptera larvae														
Hydropsyche	0	27	95	395	75	41	16	6	2	0	0	0	3	4
Rhyacophila	10	54	375	525	550	146	80	30	37	[illegible]	6	4	4	4
Agapetus	77	178	825	920	710	292	101	70	41	9	13	4	5	10
Coleoptera adults														
Amphizoa	1	0	0	80	0	5	3	0	1	0	0	0	0	0
Diptera larvae														
Blepharoceridae	0	0	0	0	5	0	2	2	1	1	0	2	0	0
Rhagionidae	0	0	0	0	0	0	0	0	1	0	0	0	0	2
Simuliidae	45	107	125	395	425	729	239	244	93	35	9	12	8	4
Chironomidae	14	35	75	130	100	70	50	43	23	5	5	6	9	12
Tipulidae	0	0	25	0	0	0	1	1	0	0	1	0	2	1
Total	735	4,245	19,470	13,130	11,320	6,029	2,263	1,330	549	192	100	101	203	150

Figure 2 shows, graphically, the time-frequency occurrence of drift-sample insects of each of the four orders that were most common. The largest collection of affected insects of each order occurred at a different time: Plecoptera, 1/2 hour; Ephemeroptera, 1 hour; Trichoptera, 1-1/2 hours; and Diptera, 3 hours after the spraying. This situation probably reflects varying degrees of susceptibility to the toxicant rather than differences in distribution of insects in the stream, since the stream was flowing at a rate that would have carried insects from the uppermost spray area to the mouth in less than an hour and since its ecological features were relatively uniform within the spray plot.

DDT residues in aquatic insects

Drift samples collected 0.5, 1.0, and 3.0 hours after the spray was applied were frozen for chemical analysis. Insects contained

Acute effects on fish

Live-cars containing 4-5 inch rainbow trout from the Bozeman National Fish Hatchery were placed in the stream 1 day before the spray. Initially, 90 fish were exposed. Samples, each containing 15 fish, were taken from the live-cars for residue analysis 6, 12, 24, 48, 72, and 96 hours after the spray. No mortality occurred in the live-cars and the fish did not exhibit any unusual reactions. Apparently, the resident fish population did not suffer acute effects, since observations of the stream did not reveal any dead or morbid fish.

DDT residues in fish

As indicated above, fish from the live-cars were collected for chemical analysis after varying periods of exposure in Swan Creek. The results of the residue analysis of fish tissues appear in table 2. All measurable amounts of

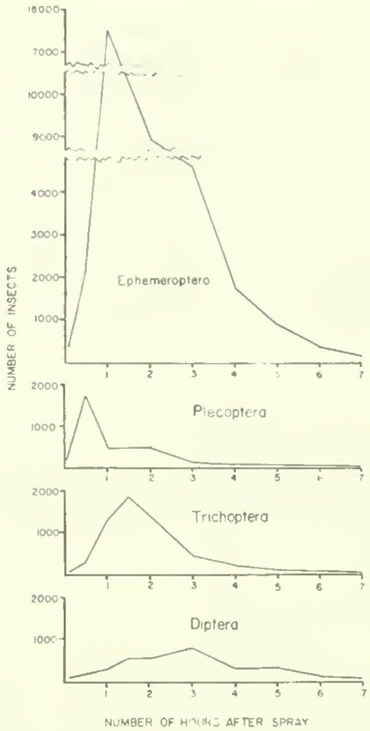

Figure 2.--Numbers of aquatic insects per drift sample from Swan Creek after DDT spray, by taxonomic order.

DDT found in fish were the same, i. e., 0.1 ppm. Fish with full stomachs were analyzed separately from those with empty stomachs and there appeared to be no difference in DDT content between the two groups. This suggests that the accumulation of DDT in fish was not necessarily related to feeding on exposed insects.

In addidion, 20 rainbow trout previously placed in a polyethylene container were offered insects that had been collected from Swan Creek 3 to 6 hours after the spray was applied. The fish had an opportunity to feed on affected insects for 20 hours. Then the fish were removed from the container and frozen for chemical analysis. They contained 0.1 ppm of DDT, the same as the measurable amounts found in the fish exposed in Swan Creek, indicating that ingested dead or morbid insects alone may provide the DDT accumulated in fish tissues.

SUMMARY

Portions of Swan Creek received at least 0.01 ppm of DDT, although the plane did not spray within one-quarter mile of the creek.

Measurable amounts of DDT were not present in Swan Creek after 1 hour.

There were no apparent acute effects on fish.

Rainbow trout accumulated up to 0.1 ppm of DDT after short exposure to low concentrations of the toxicant in water, whether or not their stomachs contained stream insects at the time of sampling.

Rainbow trout acquired a tissue concentration of 0.1 ppm of DDT by feeding on insects that had been exposed to low concentrations of DDT for 3 to 6 hours.

Large numbers of aquatic insects were adversely affected by the relatively low concentration of DDT found in the water.

Aquatic insects apparently concentrate DDT very rapidly. Insects exposed to low concentrations for 3 hours averaged 11.0 ppm of DDT and 14.2 ppm of DDE.

Table 2.--DDT residues in fish exposed in Swan Creek

Exposure time in hours	DDT content	
	Full stomach	Empty stomach
0	none detected	none detected
6	trace	trace
12	0.1 ppm	trace
24	trace	0.1 ppm
48	--	0.1 ppm
72	0.1 ppm	trace
96	--	trace

EFFECTS OF DDT SPRAY ON STREAM BOTTOM ORGANISMS IN TWO MOUNTAIN STREAMS IN GEORGIA

By

Paul J. Frey
Bureau of Sport Fisheries and Wildlife
Fish-Pesticide Research Laboratory
Gulf Breeze, Florida

ABSTRACT

DDT was sprayed at 0.5 pound per acre for elm spanworm control in two drainages in north Georgia in both 1959 and 1960. In one drainage, precautions were taken to avoid the stream, and no significant mortality to aquatic organisms resulted. In the other drainage, DDT reached the stream in a normal spray operation, and serious depletion of aquatic invertebrates resulted. Recovery of bottom organisms was rapid, and total numbers of invertebrates were up to pre-treatment levels after four months.

The elm spanworm, Ennomus subsignarius (Hbn.), became established in the Chattahoochee National Forest in the early 1950's. In the late 1950's the infestation spread from high isolated points to lower levels and in a general northeasterly direction. Protection of the forest in two important recreational areas necessitated the use of control measures by the Forest Service in 1959 and 1960. The two heavily infested areas were treated by helicopter with one-half pound of DDT per gallon of oil per acre. This paper reports a study by the Bureau of Sport Fisheries and Wildlife on the effects of these treatments on the stream-bottom organisms in two small streams.

DESCRIPTION OF THE STUDY STREAMS

The two study streams (fig. 1), one in the Conasauga Lake area near Chatsworth, Georgia, and the other originating on Brasstown Bald near Blairsville, Georgia, are typical of high mountain streams in this region. The treated section of the Conasauga Lake stream is one-half mile long and falls approximately 200 feet enroute. The stream originates from small springs which have a flow of approximately 50 gpm. From this point the volume increases rapidly and reaches a volume of approximately

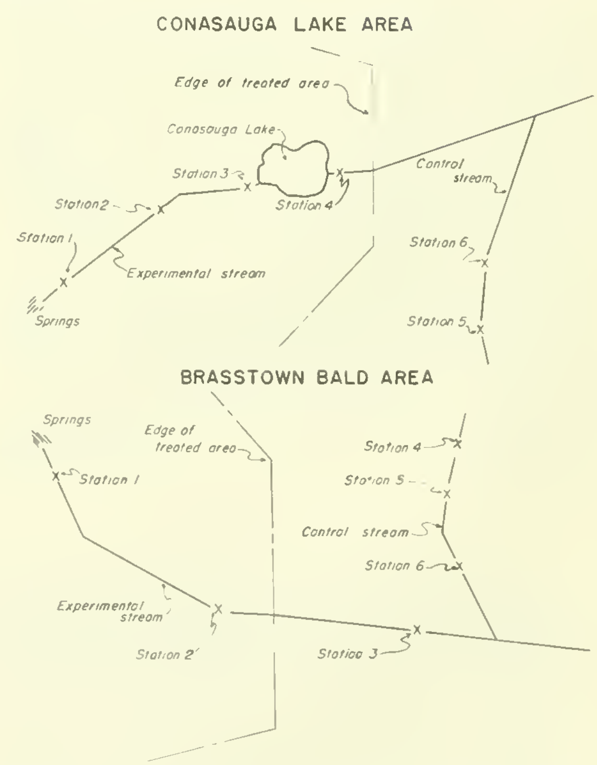

Figure 1.--Diagrammatic drawing of control and experimental streams showing positions of sampling stations, and the relationships between experimental and control streams.

750 gpm where it empties into Conasauga Lake. The treated section of the Brasstown Bald stream is three-fourths of a mile long and falls approximately 900 feet enroute. The small spring from which this stream originates flows at about 25 gpm from which point the volume increases to approximately 1,350 gpm where the stream leaves the sprayed area. Both streams fall and cascade over mica schist boulders and are bordered with heavy growths of laurel, rhododendron, small hemlock, basswood and sassafras.

The streams differ from each other mostly in that the Conasauga Lake stream empties into Conasauga Lake within the spray area, while the Brasstown Bald stream empties into a larger stream several miles from the experimental area.

TREATMENT OF THE STUDY STREAMS

The DDT was applied to the Conasauga Lake stream on May 15, 1959, and May 24, 1960, and to the Brasstown Bald stream on May 22, 1959, and May 26, 1960. First, the helicopter laid narrow swaths parallel to the creek until a strip about 100 feet wide was treated on each side of the stream. These strips served as a buffer zone to prevent insecticide from reaching the stream during the remainder of the spraying operation. The entire treatment of the stream was completed in approximately fifteen minutes. Both streams were treated in similar manner, except that special care was taken to keep the insecticide out of the Conasauga Lake stream; no care was taken to keep it out of the Brasstown Bald stream.

METHODS OF STUDY

Prior to the DDT treatment, four bottom samples were taken at each collection station with a Surber square-foot sampler. Three stations (1, 2, and 3) were established on the Conasauga Lake stream above its point of entry into the lake, and one (4) in the stream below the dam. No stations were established in the lake. At the same time, two stations (5 and 6) were established and sampled in a control stream. These control stations were comparable to the experimental stream stations 1 and 2 but no comparable stations could be found for stations 3 and 4 which lay immediately above and below the lake.

Two stations (1 and 2) were established in the Brasstown Bald stream within the treated area. An additional station was located approximately one-half mile below the perimeter of the spray area. Three stations (4, 5, and 6) were established in a control stream. Bottom samples from these control stations were comparable to prespray samples from stations 1, 2, and 3 in the experimental stream.

Collecting of drift samples was accomplished by placing a Surber sampler in the stream for periods of five minutes. The nature of these streams was such that one could screen approximately 90 percent of the water flowing in the stream. Drift sampling was initiated one-half hour after the spraying was begun, and samples were taken at one-half hour intervals for the first hour and then at hourly intervals until dark. After that, they were taken at irregular intervals up to 72 hours after treatment. All specimens were placed in containers with 10 percent formalin, taken to the laboratory, sorted into taxonomic groups, and tabulated.

The amount of insecticide which reached the creek surface was determined by the use of 4 1/2- by 5-inch oil-sensitive cards. The variety of cover conditions suggested classifying the cover into three groups: (1) low canopy, in which the laurel, rhododendron, hemlock, etc. formed an almost solid canopy from immediately above the water surface to a height of 10 - 15 feet, (2) high canopy, in which the canopy was from 20 - 50 feet from the water surface, and (3) open, in which the sky was visible from the creek. Three spray cards were placed under each cover type.

Interpretation of the cards was made by the author and Mr. Dale Vandenburg, U. S. Forest Service, the forest entomologist working on the project.

EFFECTS OF TREATMENT

Measurements of deposition of DDT on the water surface of the two streams are shown in table 1. In the Conasauga Lake area, where care was taken to keep away from the stream,

Table 1:--DDT reaching the water surface, pounds per acre

	Canopy, type and percent coverage			Weighted
Conasauga Lake	Open, 10%	High, 40%	Low, 50%	Average
1959	0.2	0.015	0.005	0.029
1960	trace	trace	trace	trace
Brasstown Bald	Open, 30%	High, 30%	Low, 40%	
1959	0.4	0.1	0.03	0.16
1960	0.2	0.05	0.45	0.09

0.029 pound per acre of DDT reached the water in 1959; in 1960, only a trace penetrated to the water surface. This decrease from the 1959 concentration may have been partly due to a more advanced growth of vegetation.

In the Brasstown Bald area, spray cards indicated that 0.16 pound per acre of DDT reached the surface in 1959 and 0.09 pound per acre in 1960. Increased density of foliage in 1960 may have affected the deposition here, too, although reductions were measured in the open areas as well as the vegetated plots.

Drift samples (tables 2 and 3) indicated very little increase in numbers of dead and dying invertebrates drifting downstream after the spray in the Conasauga Lake creek in 1959 and 1960. Drift samples in the creek at Brasstown Bald, on the other hand, indicated large increases in affected stoneflies, mayflies, noterids, and limnephilids from pre-spray to post-spray times in 1959 (fig. 2). Smaller increases were noted in 1960. Increases in numbers of affected terrestrials were relatively higher in 1960 than in 1959. Both 1959 and 1960 drift samples showed that different groups of aquatic organisms were affected by the DDT to different degrees. Those that were affected showed signs of distress within the first hour. The greatest number of dead or dying insects were collected one-half hour after the application at Brasstown Bald, and by the fourth hour after spray time the numbers had decreased 85 percent in 1959. Few insects appeared in the drift sample after 24 hours.

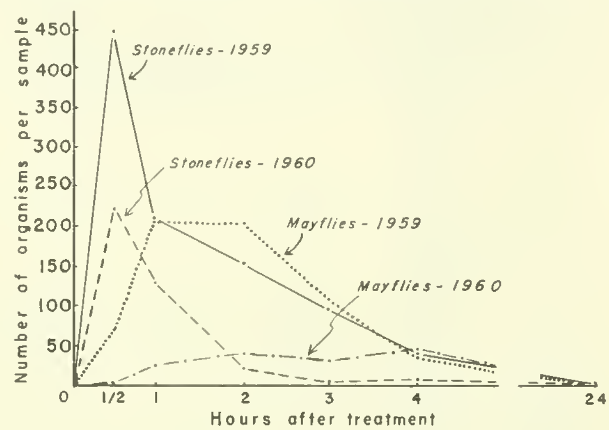

Figure 2.--Number of mayflies and stoneflies taken in five-minute drift samples in a stream on Brasstown Bald.

Table 2:--Numbers of organisms taken in five-minute drift samples from a stream near Conasauga Lake

Name		Pre-treatment		Hours after treatment 1/2		1		2		3		4		24		72	
		'59	'60	'59	'60	'59	'60	'59	'60	'59	'60	'59	'60	'59	'60	'59	'60
Stonefly	Peltoperla	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Stonefly	Alloperla	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Mayfly	Ephemerella	0	5	0	3	0	2	0	3	1	0	0	0	0	1	0	0
Mayfly	Paraleptophlebia	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Caddisfly	Limnephilidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Midge	Chironomidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Water strider	Gerridae	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Water beetle	Noteridae	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Total individuals		2	5	0	7	1	2	0	4	2	1	0	0	1	1	0	0
Group frequency		2	1	0	3	1	1	0	2	2	1	0	0	1	1	0	0

Table 3.--Number of organisms taken in five-minute drift samples from a stream on Brasstown Bald.

		Pre-treatment		Hours after treatment ½		1		2		3		4		24		48		72	
		'59	'60	'59	'60	'59	'60	'59	'60	'59	'60	'59	'60	'59	'60	'59	'60	'59	'60
Aquatics																			
Stonefly	Peltoperla	1	0	94	24	90	22	78	7	40	3	10	6	0	0	0	0	0	0
Stonefly	Acroneuria	0	2	152	87	51	28	28	2	22	0	17	2	1	0	0	0	0	0
Stonefly	Alloperla	0	1	200	100	70	42	50	3	31	3	13	3	2	0	1	0	0	0
Stonefly	Nemoura	0	0	0	7	0	36	0	8	0	2	0	3	0	1	0	1	0	1
Mayfly	Ephemerella	0	1	50	4	94	11	97	15	61	3	1	9	0	0	0	0	0	0
Mayfly	Cloeon	0	0	15	0	101	12	92	0	42	2	20	4	0	0	0	0	0	0
Mayfly	Stenonema	0	0	0	4	1	0	6	23	5	24	12	32	0	3	0	2	1	1
Mayfly	Iron	0	0	5	0	7	1	6	3	4	1	1	0	0	0	0	0	0	0
Midge	Chironomidae	0	0	7	0	12	0	16	0	0	0	0	0	0	0	0	0	0	0
Caddisfly	Hydropsychidae	0	0	0	0	3	1	2	0	4	0	3	0	1	0	0	0	0	0
Caddisfly	Limnephilidae	0	0	15	89	7	17	9	0	6	5	5	0	0	0	0	0	0	0
Caddisfly	Rhyacophilidae	0	0	0	2	6	5	2	5	0	4	0	0	0	1	0	0	0	0
Caddisfly	Philotomatidae	0	0	0	2	0	0	0	0	0	1	0	0	0	1	0	0	0	0
Water beetle	Noteridae	0	0	12	0	9	0	0	0	1	0	0	0	0	0	0	0	0	0
Snail	Helisoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Salamander	Desmognathus	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Total individuals		1	4	550	319	451	176	386	66	216	48	82	59	4	6	1	3	3	2
Group frequency		1	3	9	9	12	11	11	8	10	10	9	7	3	4	1	2	2	2
Terrestrials																			
Flies	Diptera	0	1	19	17	10	8	0	9	0	3	2	3	5	0	15	0	1	0
Ants	Hymenoptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Leafhopper	Homoptera	0	0	0	0	0	0	0	0	0	0	3	0	0	0	4	0	0	0
Spiders	Arachnida	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
Beetles	Coleoptera	0	0	7	10	6	11	0	7	0	3	1	0	0	0	0	0	0	0
Wasps	Hymenoptera	0	0	7	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Spanworm	Ennomus	0	0	0	2	0	5	0	7	0	5	0	2	0	1	0	0	0	0
Larvae	Diptera	0	0	0	0	0	2	0	0	0	0	8	0	0	0	0	0	0	0
Larvae	Lepidoptera	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Total individuals		0	1	33	29	30	26	0	23	0	11	14	6	6	1	20	0	1	0
Group frequency		0	1	3	3	4	4	0	3	0	3	4	3	2	1	3	0	1	0

Measurements of aquatic populations on stream bottoms are summarized in tables 4, 5, 6, 7, and 8. Table 4 indicates that in the creek at Conasauga Lake in 1959 the organisms per square foot were reduced in numbers less in the treated section than in the control sections, except in the case of midges and blackflies. Both midges and blackflies were quite prevalent in Station 4, which lies below the dam. It is possible that this particular area received a heavier dose of DDT than the remainder of the stream; however, Gjullin, et al (1949) found that blackflies were highly susceptible to DDT. The larval forms were partially paralyzed by the insecticide. As a result, they lost their ability to hold to the substrate and were carried downstream by the current. Table 5, covering 1960, showed that reductions in numbers were greater in the treated areas than in the untreated, but that the reductions were only moderate in extent. Midges were not as seriously affected in 1960 as in 1959.

Comparison of the data on drift samples and bottom samples shows that the noterids were the most heavily affected of all the larvae present, but they constitute such a small part of the invertebrate population that their loss may not be serious from the fish standpoint. The stoneflies and mayflies, on the other hand, made up about 70 percent of the population and 75 percent of the drift samples. Although the mayflies outnumbered the stoneflies in the population, more stoneflies appeared in the drift samples (fig. 2). This is in contrast to the report by Hoffmann and Surber (1949) indicating that mayflies were more susceptible to DDT.

Table 4.--Number of organisms per square foot of bottom, before and seventy-two hours after treatment in May, 1959.

		Experimental Stream								Control Stream			
		Station 1		Station 2		Station 3		Station 4		Station 5		Station 6	
		Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Planaria	Turbellaria	0	0	0	0	0	0	.5	0	0	0	0	0
Earthworm	Annelida	0	0	1.0	.8	2.0	.8	0	0	1.0	0	0	1.0
Crayfish	Cambarus	1.5	.5	.5	.8	.8	.5	0	0	1.0	1.0	1.0	1.5
Stonefly	Peltoperla	0	1.0	0	0	9.0	6.5	0	0	.3	.8	2.0	1.0
Stonefly	Alloperla	0	0	1.8	2.5	1.3	4.3	0	0	0	0	2.0	1.5
Stonefly	Acroneuria	1.5	0	0	0	1.3	0	0	0	1.3	0	1.5	1.5
Stonefly	Isoperla	4.0	3.5	2.0	1.3	0	2.3	0	0	2.3	2.0	1.3	1.0
Mayfly	Ephemerella	0	0	2.5	2.5	0	0	0	0	0	0	1.0	.8
Mayfly	Cloeon	0	0	0	0	1.5	0	0	0	0	0	1.0	2.5
Mayfly	Stenonema	3.0	3.8	4.8	2.8	5.0	0	.5	0	3.0	0	3.8	1.3
Mayfly	Paraleptophlebia	0	0	0	0	0	0	9.5	4.5	0	0	0	0
Dragonfly	Aeschnidae	0	3.0	0	.8	0	.3	0	0	0	.8	0	.5
Helgramite	Corydalidae	0	0	0	0	0	0	1.5	2.0	0	0	0	0
Caddisfly	Hydropsychidae	0	2.0	2.8	1.0	.8	2.5	0	0	1.5	.8	.8	1.0
Caddisfly	Limnephilidae	0	2.0	.3	.5	.5	.3	0	0	0	0	.8	.5
Caddisfly	Rhyacophilidae	0	0	0	1.0	0	.8	2.5	0	0	0	0	0
Water Beetle	Noteridae	1.0	1.5	1.3	.8	1.0	.8	0	0	1.0	1.0	1.0	.5
Midge	Chironomidae	5.0	0	0	0	0	0	75.0	4.0	9.0	.3	3.8	0
Horsefly	Tabanidae	0	0	1.8	0	1.5	0	.5	0	0	0	1.8	1.5
Blackfly	Simuliidae	0	0	0	.5	0	0	20.0	2.5	0	0	0	0
Fingernail clam	Sphaeridae	0	0	0	0	0	0	3.5	1.5	0	0	0	0
Salamander	Desmognathus	.5	.5	.3	.5	.3	0	.5	0	.3	1.0	.5	.5
Total Individuals		16.5	17.8	19.1	15.8	25.0	19.1	114.0	14.5	20.7	7.7	22.3	16.6
Group Frequency		7	9	11	13	12	10	10	5	10	8	14	15

Table 5.--Number of organisms per square foot of bottom, before and seventy-two hours after treatment in May, 1960.

		Experimental Stream						Control Stream			
		Station 1		Station 2		Station 3		Station 5		Station 6	
		Before	After	Before	After	Before	After	Before	After	Before	After
Earthworm	Annelida	0	0	0	0	0	0	0	0	1.0	.5
Crayfish	Cambarus	.5	1.5	1.5	.5	1.0	1.0	1.0	.5	.5	.5
Alderfly	Megaloptera	1.5	0	0	0	0	0	0	0	0	1.0
Stonefly	Peltoperla	10.5	9.0	0	0	0	0	0	0	6.0	4.5
Stonefly	Alloperla	7.0	6.5	2.5	2.0	0	.5	3.5	2.0	4.0	4.5
Stonefly	Acroneuria	6.0	6.5	3.5	3.0	0	0	5.5	3.5	2.0	3.0
Stonefly	Nemoura	15.0	16.0	18.0	14.5	26.0	20.5	11.5	14.0	9.5	12.0
Mayfly	Cloeon	4.5	3.0	0	0	0	0	1.0	3.5	.5	.5
Mayfly	Ephemerella	8.0	6.5	10.5	10.0	12.0	9.5	6.5	7.0	9.0	8.0
Mayfly	Stenonema	15.5	10.0	17.5	15.0	19.5	20.0	11.0	14.0	14.5	9.0
Dragonfly	Aeschnidae	1.5	.5	1.0	0	0	0	.5	0	0	1.0
Caddisfly	Hydropsychidae	0	0	1.0	1.5	1.5	.5	.5	0	1.0	1.0
Caddisfly	Rhyacophilidae	4.0	2.5	1.0	2.0	0	.5	.5	.5	3.0	.5
Caddisfly	Limnephilidae	3.5	4.0	2.0	.5	4.0	3.0	.5	1.5	0	0
Water Beetle	Noteridae	1.0	1.0	3.0	1.5	1.5	.5	2.5	2.0	1.5	.5
Midge	Chironomidae	7.0	6.0	8.5	5.0	6.0	6.0	8.5	9.0	2.0	5.5
Horsefly	Tabanidae	1.0	.5	1.5	0	1.5	.5	0	0	.5	0
Salamander	Desmognathus	1.0	.5	1.5	1.0	1.5	2.0	.5	.5	1.0	.5
Total	Individuals	87.5	74.0	73.0	56.5	74.5	64.5	53.5	58.0	56.0	52.5
Group	frequency	16	15	14	12	10	12	14	12	15	16

Table 6.--Number of organisms per square foot of bottom in the Brasstown Bald experimental stream, before and after treatment in May, 1959.

		Station 1					Station 2					Station 3				
		Before	72 hrs. after	1 mo. after	2 mo. after	4 mo. after	Before	72 hrs. after	1 mo. after	2 mo. after	4 mo. after	Before	72 hrs. after	1 mo. after	2 mo. after	4 mo. after
Earthworm	Annelida	0	0	0	0	1.0	0	0	0	0	4.0	0	0	1.0	.5	3.0
Crayfish	Cambarus	0	1.0	.3	0	1.0	1.0	0	.3	0	1.0	1.5	.5	.3	0	1.5
Water mite	Hydracarina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stonefly	Pteronarcys	0	0	0	0	0	0	0	0	0	0	.5	.5	0	.3	2.0
Stonefly	Peltoperla	1.3	.8	.5	1.5	3.0	7.8	3.3	.5	1.5	16.5	16.5	3.5	.5	1.5	15.0
Stonefly	Acroneuria	2.0	.8	0	0	2.0	26.0	1.3	0	.8	10.0	7.0	6.0	0	1.0	9.5
Stonefly	Alloperla	1.3	.3	0	1.3	1.5	5.3	0	0	.3	3.5	4.5	0	0	.8	4.0
Stonefly	Nemoura	0	0	2.3	3.5	0	0	0	.5	2.5	0	0	0	1.5	0	0
Stonefly	Isoperla	0	0	1.5	0	0	0	0	1.3	1.5	0	0	0	1.5	2.0	1.5
Mayfly	Ephemerella	0	0	0	1.3	0	0	.8	.3	5.5	0	0	3.5	0	3.5	0
Mayfly	Cloeon	.3	0	0	0	1.0	0	0	0	0	6.5	1.0	0	0	0	4.5
Mayfly	Isonychia	0	0	0	0	0	2.5	0	0	0	0	4.5	0	0	0	0
Mayfly	Paraleptophlebia	1.7	0	.3	0	0	2.5	0	0	0	0	5.5	1.0	0	0	0
Mayfly	Stenonema	2.7	.8	0	0	5.0	4.0	1.5	0	.5	10.5	1.0	1.0	0	1.0	5.0
Mayfly	Iron	0	0	.3	0	.5	0	0	.8	.5	1.0	0	0	1.0	3.0	1.0
Cranefly	Tipulidae	0	0	0	.5	0	.8	.3	0	.3	0	1.5	1.0	0	.3	2.0
Dragonfly	Aeschnidae	0	.3	.3	.3	1.0	.5	0	.5	0	1.0	3.0	4.5	1.0	.5	3.0
Caddisfly	Hydropsychidae	1.7	0	0	0	1.5	.3	.3	0	0	3.0	4.0	3.0	0	1.8	3.0
Caddisfly	Limnephilidae	1.0	.3	0	0	1.0	2.0	0	0	1.0	1.5	0	2.5	0	0	0
Caddisfly	Rhyacophilidae	0	0	0	0	0	0	.5	0	0	0	0	0	0	0	0
Caddisfly	Philotomatidae	0	0	0	0	0	0	0	0	1.0	0	0	0	0	.3	0
Caddisfly	Brachycentridae	0	0	0	0	0	0	0	.5	0	0	0	0	.3	0	0
Water Beetle	Noteridae	0	0	0	0	0	.5	0	0	.5	0	1.5	0	0	.3	0
Water Beetle	Dryopidae	0	0	0	0	0	0	0	.8	0	0	0	0	0	1.5	1.0
Midge	Chironomidae	1.3	0	0	0	2.0	11.0	0	0	0	3.0	3.5	0	0	0	6.0
Blackfly	Simuliidae	0	0	0	0	0	2.0	0	0	.5	2.0	1.5	0	0	0	5.5
Horsefly	Tabanidae	1.7	0	0	0	1.0	0	0	0	0	1.5	0	0	0	0	1.5
Snipefly	Rhagionidae	0	0	0	0	0	0	0	0	0	0	0	0	2.3	1.5	0
Salamander	Desmognathus	.3	1.0	0	.5	1.0	0	0	0	0	1.0	.5	2.5	.3	0	0
Total	individuals	15.3	5.3	5.5	8.9	22.5	66.2	8.0	5.5	16.4	66.0	57.5	29.5	9.7	19.8	69.0
Group	frequency	11	8	7	7	14	14	7	9	13	15	17	12	10	16	17

Table 7.--Number of organisms per square foot of bottom in the Brasstown Bald control section, before and after treatment in May, 1959, at stations 1, 2, and 3 in the experimental stream.

		Station 4					Station 5					Station 6				
		Before	72 hrs. after	1 mo. after	2 mo. after	4 mo. after	Before	72 hrs. after	1 mo. after	2 mo. after	4 mo. after	Before	72 hrs. after	1 mo. after	2 mo. after	4 mo. after
Earthworm	Annelida	0	0	0	0	1.0	1.0	1.0	5.0	.5	3.5	1.0	1.0	1.0	1.5	5.0
Crayfish	Cambarus	.3	.5	.3	0	.5	.3	1.5	.5	.5	1.0	1.3	1.0	.8	1.0	.5
Stonefly	Pteronarcys	0	0	0	0	0	0	0	0	0	0	.8	.3	.3	.3	1.0
Stonefly	Peltoperla	1.0	1.0	.3	1.3	2.5	2.6	2.0	1.3	4.5	17.0	15.2	12.0	4.5	5.8	16.0
Stonefly	Acroneuria	2.3	2.0	0	.3	1.5	6.0	4.0	0	3.0	5.0	3.0	1.3	1.3	2.0	7.5
Stonefly	Alloperla	2.0	1.0	.3	1.0	2.0	2.0	1.5	1.5	1.3	2.0	3.8	2.8	.8	1.0	3.0
Stonefly	Nemoura	0	0	2.5	3.5	0	.8	1.0	0	.5	0	0	0	0	0	0
Stonefly	Isoperla	0	0	1.3	.8	0	0	0	2.3	0	0	0	0	1.3	1.0	0
Mayfly	Ephemerella	0	0	0	1.0	0	0	0	0	0	1.5	1.3	2.5	3.0	2.5	0
Mayfly	Cloeon	0	.3	0	0	1.0	1.0	0	0	0	1.0	0	0	0	0	0
Mayfly	Paraleptophlebia	2.0	1.3	.5	0	0	10.0	4.0	5.0	0	0	6.0	2.0	2.0	3.5	0
Mayfly	Stenonema	2.3	2.0	0	0	4.0	2.7	3.0	.5	1.3	17.5	2.0	1.5	1.0	1.8	11.0
Mayfly	Iron	0	0	.5	0	.5	0	0	1.0	0	.5	0	0	1.0	1.0	2.5
Cranefly	Tipulidae	0	1.0	0	.3	0	0	0	.3	.3	0	1.0	1.3	.8	1.0	1.0
Dragonfly	Aeschnidae	1.5	2.0	.3	.5	1.0	0	0	.3	.8	1.0	4.0	3.5	2.0	1.0	3.5
Dragonfly	Libellulidae	0	0	0	0	0	1.3	2.5	0	1.0	0	0	0	0	1.0	0
Caddisfly	Hydropsychidae	2.0	2.0	0	0	1.0	3.3	3.5	0	.8	2.0	5.0	4.5	0	2.3	4.5
Caddisfly	Limnephilidae	.8	1.0	0	0	.5	1.3	2.5	0	0	.5	0	0	0	0	0
Caddisfly	Rhyacophilidae	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0
Caddisfly	Philotomatidae	0	0	0	0	0	0	0	0	1.0	0	0	0	0	0	0
Caddisfly	Brachycentridae	0	0	0	0	0	0	0	0	0	0	0	0	0	.8	0
Water Beetle	Noteridae	0	0	0	0	0	.3	.3	0	0	0	1.8	1.5	1.0	1.5	1.0
Water Beetle	Dryopidae	0	0	0	0	0	0	0	1.3	.3	.5	0	0	0	2.0	1.0
Midge	Chironomidae	3.0	0	0	0	1.0	5.0	.3	0	0	3.0	5.3	5.0	.3	0	5.0
Blackfly	Simuliidae	0	0	0	0	0	1.3	1.3	0	0	1.0	2.8	0	0	0	4.5
Horsefly	Tabanidae	0	.3	0	0	0	0	1.0	0	0	1.0	0	0	0	0	2.0
Snipefly	Rhagionidae	0	0	0	0	0	0	0	0	.3	0	0	0	3.0	1.5	0
Salamander	Desmognathus	.8	.5	0	.3	1.0	1.0	1.0	.8	.3	.5	.5	.5	.5	.5	.5
Total individuals		17.8	14.9	6.5	10.0	17.5	41.2	30.4	19.8	16.9	58.5	55.3	40.7	24.8	33.8	59.5
Group frequency		11	13	8	9	13	17	16	12	15	17	16	15	17	20	17

Table 8.--Number of organisms per square foot of bottom in experimental and control sections of Brasstown Bald, before and seventy-two hours after treatment in May, 1960.

		Experimental stream						Control stream					
		Station 1		Station 2		Station 3		Station 4		Station 5		Station 6	
		Before	72 hr after	Before	72 hr after	Before	72 hr after	Before	72 hr after	Before	72 hr after	Before	72 hr after
Earthworm	Annelidae	0	1.0	0	0	0	0	0	0	0	0	0	0
Crayfish	Cambarus	1.0	2.5	.5	2.5	1.5	.5	1.0	1.0	1.0	1.5	.5	1.0
Stonefly	Peltoperla	8.5	1.0	6.5	8.5	1.5	16.5	7.0	6.0	5.5	6.0	8.0	6.0
Stonefly	Acroneuria	10.0	13.5	10.5	12.5	6.0	5.0	9.0	11.0	8.5	6.5	14.0	15.5
Stonefly	Alloperla	18.5	13.5	14.0	13.0	7.0	5.0	10.5	9.5	9.0	9.0	11.0	9.0
Stonefly	Nemoura	10.0	5.0	15.5	8.5	12.5	5.0	7.0	5.0	5.5	6.5	6.0	8.0
Mayfly	Ephemerella	15.0	18.0	12.0	9.0	12.5	15.5	16.0	18.0	12.5	13.0	15.0	15.5
Mayfly	Cloeon	0	1.0	0	0	0	10.0	0	0	0	0	0	.5
Mayfly	Paraleptophlebia	0	0	1.0	0	7.0	6.0	0	0	0	0	1.5	2.0
Mayfly	Stenonema	16.5	4.5	12.0	2.5	40.0	54.0	10.0	11.5	17.0	14.5	19.0	20.0
Mayfly	Iron	1.0	0	0	0	5.5	5.0	0	0	0	0	0	0
Cranefly	Tipulidae	0	0	0	0	2.0	.5	0	0	.5	.5	0	.5
Dragonfly	Aeschnidae	.5	.5	.5	.5	.5	.5	1.0	.5	0	1.0	.5	2.0
Caddisfly	Hydropsychidae	.5	.5	0	1.0	4.5	2.5	1.5	1.0	.5	2.0	3.0	2.0
Caddisfly	Philotomatidae	0	0	.5	.5	2.0	.5	.5	0	2.0	2.5	0	.5
Caddisfly	Rhyacophilidae	2.0	0	3.0	0	0	0	0	2.0	.5	.5	0	0
Caddisfly	Brachycentridae	0	0	0	0	1.0	0	0	0	0	0	0	0
Water Beetle	Noteridae	0	0	2.0	5.0	0	0	2.0	3.0	.5	0	2.5	3.0
Midge	Chironomidae	3.5	2.5	7.5	8.5	6.0	8.0	4.0	3.0	4.5	5.0	7.0	6.0
Snipefly	Rhagionidae	0	0	0	0	4.0	2.5	0	0	0	0	0	1.0
Blackfly	Simuliidae	0	0	0	0	0	2.0	.5	0	0	0	2.0	0
Salamander	Desmognathus	.5	.5	.5	.5	.5	0	1.0	0	.5	.5	1.0	.5
Total individuals		87.5	69.0	86.0	72.5	114.0	139.0	71.0	71.5	68.0	69.0	91.0	93.0
Group frequency		13	13	14	13	17	17	14	12	14	14	14	17

In the Brasstown Bald stream in 1959, reductions in numbers of bottom invertebrates were significant in the treated area, as seen in table 6, but were not serious in the control section (table 7). Stoneflies, mayflies and dipterans were affected in the treated stream; some of them recovered moderately well after 4 months. Reduction in the control stream was mainly among midges, stoneflies and mayflies; recovery in these groups after 4 months was satisfactory within the limits of accuracy of the collection methods. Station 3 on the experimental stream was established approximately one-half mile below the spray area to determine whether the kill extended any distance below the spray area. Observations by Hoffmann and Surber (1949) and Surber and Friddle (1947) indicated that the kill due to the accumulative effect is greater immediately below the spray area and carries quite some distance downstream. In this study, however, the kill was less pronounced, as can be seen from Station 3 (table 6). This is probably due to the rapid increase in water volume in streams of this nature.

In the same stream in 1960 (table 7) the mayflies, stoneflies and caddisflies were moderately reduced in the treated stream after 72 hours, while invertebrates in the control stream were, in general, not reduced in number.

DISCUSSION

Seldom would one find an area more difficult to treat than the sharply pointed peaks and deep ravines with adverse wind currents that were encountered in these areas. Yet, in the Conasauga Lake area, the special care taken to keep spray from entering the creek was successful. Such small amounts of DDT entered the stream that there was no significant loss of aquatic organisms. This suggests that with greater care in the application of insecticides, kills of aquatic organisms may be minimized.

Figure 3 points up an important reaction of the depleted aquatic invertebrate population. In all cases the population dropped between the pre-treatment and post-treatment sampling; however, the treated areas dropped considerably more. The general decrease in the population was probably due to emergence, as was shown by Anderson and Hooper (1956) and Ball and Hayne (1952) in studies of seasonal fluctuation of bottom fauna. Both of these studies indicated a decrease in bottom fauna population starting soon after the disappearance of the ice cover and proceeding until July. At that time the population density began to increase. The greater decrease witnessed in the treated area in the present study was undoubtedly due to the effect of the DDT which entered the stream. Immediately after treatment large numbers of stoneflies and lesser numbers of mayflies and caddisflies appeared in drift samples. One hour after treatment, mayflies appeared in the greatest numbers while stoneflies and caddisflies decreased and midges increased slightly. Two hours after treatment, midge numbers were still increasing while all other forms were decreasing in number. It is interesting to note

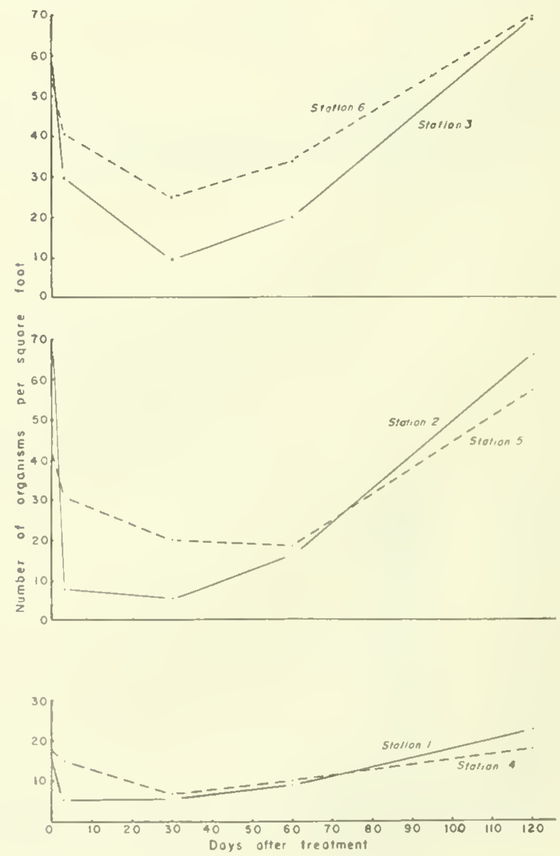

Figure 3.--Numbers of aquatic invertebrates sampled in the experimental and control streams on Brasstown Bald in 1959.

the similarities between the frequency and time of occurrence of the various forms in the 1959 and 1960 drift samples. At the end of four hours, very few organisms were appearing in the drift samples.

The first post-spray bottom samples were taken seventy-two hours after treatment. At this time the number of organisms in the drift samples was back to pre-treatment levels. These bottom samples indicated that the populations in the experimental stream on Brasstown Bald had undergone a serious decline. Webb (1959) in Canada, Cope and Park (1957) in Montana, Hoffmann and Drooz (1953) in Pennsylvania, and Hoffmann and Surber (1945) in West Virginia all recognize this severe immediate reduction. Most workers seem to agree that the caddisfly is one of the aquatic insects most seriously affected by DDT. Caddisflies were scarce in this particular stream, but the fact that they were severely affected is evident by their appearance in relatively large numbers in the drift samples and their consequent reduction in bottom samples following the treatment. Although the families Hydropsychidae and Limnephilidae appeared in about equal numbers in the pre-treatment samples, the limnephilids appeared in much higher numbers in the drift samples; this may imply that the burden of cases (the hydropsychids are free living) made them more susceptible to DDT poisoning.

At the end of one month, population levels in both the control and experimental streams had declined still further; the declines in the experimental stream were greater than those in the control stream. If some of this decline was caused by emergence, then it is possible that those immature forms which survived the DDT poisoning did not suffer severe chronic effects from the insecticide, and thus could complete their life cycle and emerge. It is also possible that some of the loss was due to a delayed effect of the DDT. The data from the bottom samples indicate that none of the forms present in these streams were immune to DDT at the concentration reached in the Brasstown Bald stream. However, only the Tendipedidae, Tabanidae and Noteridae were entirely absent from later samples.

During the second month after treatment, population levels in both streams began a gradual increase, with the treated stream increasing at a more rapid pace than the untreated. This increase could come from several sources. The fact that many of the forms present were mature nymphs would suggest the possibility of an upstream migration from the unaffected lower reaches of the stream. Roos (1957) mentioned studies of positive rheotaxis and upstream migrations as factors in invertebrate distribution and Muller (1954) proposed a "Colonization Cycle". In this cycle the mature aquatic insects migrated upstream to deposit eggs and then the resulting immature forms floated downstream. Both of these could be responsible for the general increase shown.

The last set of samples, taken four months after treatment, indicate a complete recovery of the bottom fauna at all stations, in terms of total numbers of organisms.

Larrimore, et al (1959) state that the rate of reinvasion of a stream habitat depends on (1) extent of the area affected, (2) source of the new organisms, (3) degree of damage and the recovery of habitat, (4) water levels, and (5) season of the year. The rapid reinvasion of the aquatic insects in this study was favored by each of these factors: (1) only a small section of the stream was treated; thus, there could be an upstream migration of insects; (2) there were several streams in close proximity of the treated stream which could act as hatcheries or reserves for the treated area; (3) most of the aquatic forms were not completely eliminated from the stream; thus, they themselves could help repopulate the stream; (4) no detrimental change in water level occurred; and (5) the stream was treated at that time of the year when only a short time would elapse before mature forms would be laying their eggs for the new brood. This date coincides closely with those shown in studies by Anderson and Hooper (1956) and Ball and Hayne (1952).

SUMMARY

The watersheds of sections of two small mountain streams in Georgia were treated with 0.5 pound per acre of DDT in a one-gallon oil solution in both 1959 and 1960. In the Conasauga

Lake area, care was taken to keep the DDT out of the stream. As a result not enough DDT entered the stream, either year, to cause an appreciable kill of aquatic organisms.

The Brasstown Bald area, on the other hand, was treated without special precaution and a sufficient amount of DDT entered the creek in 1959 to cause a serious depletion of the bottom organisms. The three sampling stations on this stream showed reductions of 65 percent, 80 percent, and 40 percent in total number of bottom organisms. Mortality reduction was exaggerated by emergence. Drift samples indicated that the bottom organisms were affected almost immediately by the DDT, with the greatest number of organisms appearing in drift samples one-half hour after treatment. Thereafter, the numbers decreased at each sampling and had diminished 85 percent at the end of four hours. Although all forms of aquatic insects were affected by the DDT, only the Chironomidae, Tabanidae, and Noteridae appeared to be completely eliminated. Populations in this stream declined for one month after treatment, and then began a gradual increase. At the end of four months bottom samples indicated a complete recovery at all stations, in terms of total numbers of organisms.

In 1960 the vegetation was somewhat advanced and this may have prevented some DDT from entering the stream.

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