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EFFECTS OF SILTATION, RESULTING FROM IMPROPER LOGGING, ON THE BOTTOM FAUNA OF A SMALL TROUT STREAM IN THE SOUTHERN APPALACHIANS

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SILTATION, RESULTING FROM IMPROPER-LAND - USE PRACTICES, is regarded as one of the most important factors contributing to a reduction in the acreage of desirable fishing waters in the United States. Although much information of a general nature has been published, there is a lack of quantitative data regarding the effects of siltation on stream values.

One phase of a Dingell-Johnson project, established by the North Caroline Wildlife Resources Commission during the summer of 1952, was to obtain quantitative data regarding the effect of siltation on trout streams in the southern Appalachians. The project was begun on the Coweeta Experimental Forest, located in Macon County, North Carolina, where for 20 years the U. S. Forest Service has been collecting extensive data regarding the effects of various land-use practices on experimental watersheds. The purpose of this report is to present data regarding the effects of siltation on the bottom organisms of Shope Creek, a small trout stream which received the drainage from a 212-acre logged watershed (figure 1).

During 1942, logging was commenced on the 212-acre watershed on the Coweeta Experimental Forest. The periods of activity on the watershed were:

May 1942 - Mar. 1943:	Active logging
Mar. 1943 - Jan. 1945:	No logging
Jan. 1945 - Nov. 1948:	Active logging
Nov. 1948 - Apr. 1953:	No logging
Apr. 1953 - Present:	Active logging

The logging was carried out by local contractors, with no limitation of methods or supervision by the Forest Service. Logs were ground-skidded by teams. Because of steep slopes, the roads and skid trails were built parallel and adjacent to the channel of the drainage stream. The roads were characterized by excessively steep grades alternating with level stretches. No surfacing material and no drains or water cutoffs were used on the roads. With the termination of the original logging in 1948, 2.2 miles of road had been constructed on the 212-acre watershed.

Presented at the Eighth Annual Conference of the Southeastern Association of Game and Fish Commissioners, New Orleans, Louisiana, November 1-3, 1954, to report on one phase of a Dingell-Johnson project undertaken by the U.S. Fish and Wildlife Service, U.S. Forest Service, and North Carolina Wildlife Resources Commission.

Description of Shope Creek

Shope Creek, which received the stream from the logged watershed, flows into Coweeta Creek and thence to the Little Tennessee River. Shope Creek drains a watershed of approximately 1,880 acres and is typical of many smaller trout streams in the southern Appalachians. Average monthly streamflow for a 6-year period ranged from a low of 2.31 c.f.s. during October to 8.32 c.f.s. during February (figure 2). Figure 3 illustrates the frequent occurrence and magnitude of floods occurring in this small trout stream.

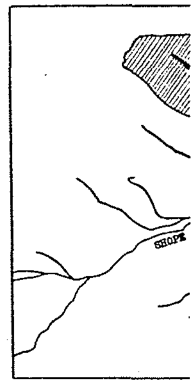
During the period of this study, stream temperatures have ranged from a low of 33.0°F. during December 1952 to a high of 65.5°F. during August 1953. During the fall of 1953, the water had a pH of 6.6 and a methyl orange alkalinity of 8.0 p.p.m.

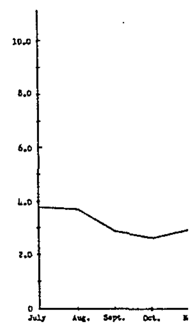
The upper portion of the stream is characterized by steep gradient (900 feet to the mile) with series of cascades and low waterfalls, interspersed with large pools having excellent shelter in the form of large boulders and broken water surface. The bottom is predominantly boulders and rubble with occasional outcrops of granite bedrock. From approximately one-fourth mile above the sampling stations to the lower boundary of the experimental forest, there is a noticeable change in the habitat. The gradient is 224 feet per mile, and the cascades and waterfalls of the upper section are replaced with short riffles and shallow pools. There is no rooted aquatic vegetation in the stream.

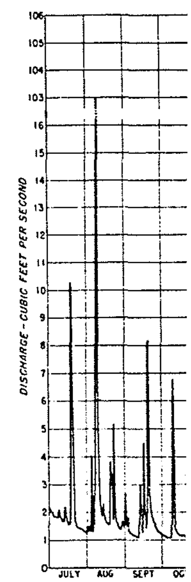
As nearly as can be determined, no trout have been stocked in Shope Creek since 1930, when rainbow trout were introduced by local residents. At present, the upper and lower reaches of the stream contain brook and rainbow trout, respectively, with an intermingling of these two species in the section just above the mouth of the stream from the logged watershed. No fishing has been permitted for the past 4 or 5 years. However, prior to closure, the stream had an excellent reputation among local fishermen.

Water Quality

During storm periods, the effect of the stream from the logged watershed (Watershed No. 10) on Shope Creek is illustrated by the turbidity of water samples collected at the mouth of the stream from No. 10, from Shope Creek above the mouth of No. 10, and from Shope Creek below the mouth of No. 10.







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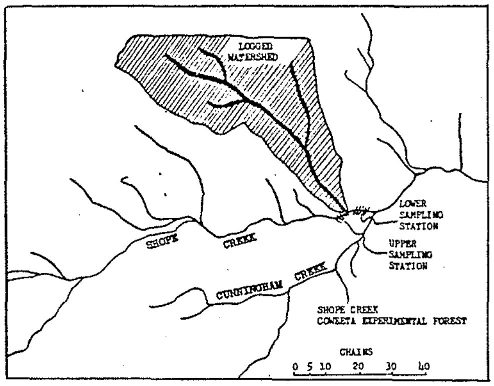

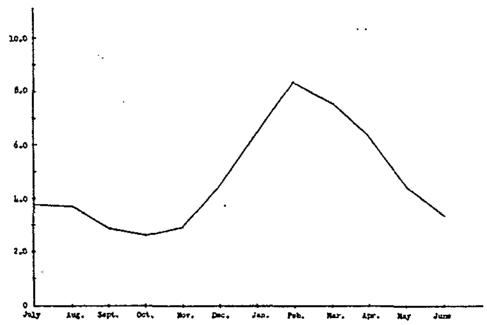

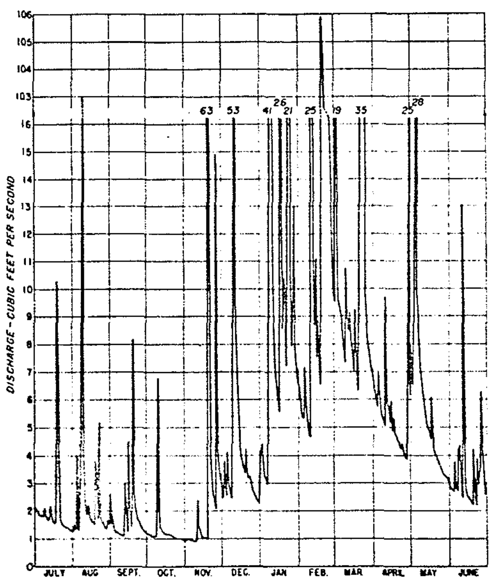

Date	Turbidity (p.p.m.) Stream from Number 10	Shope Creek Above 10	Shope Creek Below 10
Apr. 11, 1947 ---	1,200	25	390
Feb. 20, 1954 ---	1,371	67	261

The roads and skid trails proved to be the major source of turbidity (Lieberman and Hoover 1948). Skidding logs down the steep slopes creates channels which concentrate runoff, resulting in a high rate of erosion. For the 2-year period from April 1951 to March 1953, an average of 5.34 cubic feet of soil per lineal foot of road surface were eroded from the logging road. This would amount to a loss of 2,297 cubic yards of soil for the total 2.2 miles of road system.

During periods of low streamflow, the physical effects of siltation on Shope Creek are noticeably evident. During the low flows of late summer and fall, the bottom of Shope Creek above the mouth of the logged watershed accumulates a thin layer of finely divided organic matter, while below the mouth of the logged watershed the stream bottom in both pools and riffles is covered with a layer of sterile sand and micaceous material which may accumulate to a measured depth of 10 inches.

Bottom Fauna

Because of its relative stability in location, the bottom fauna was selected to obtain a measure of the effects of siltation on the stream community. The limited section of Shope Creek affected by siltation from the logged watershed made a direct evaluation of the fish population impractical. The small stream from the logged watershed is too small to support a resident trout population.

Within limits of space and reproductive capacity, the available food in a stream can certainly be regarded as a factor limiting the production of trout. Leonard (1948) and Henry (1949) have stated that in Michigan trout waters the food supply often is the most important limiting factor in trout production. Allen (1951), working on New Zealand streams, found that the bottom fauna was a limiting factor in the production of brown trout. Tarzwell (1938b) found an apparent relation between the quantities of stream foods present and trout production in streams in the southwestern United States.

(Top to Bottom)

FIGURE 1. -- Map of Shope Creek, Coweeta Experimental Forest, showing the location of logged area and sampling stations.

FIGURE 2. -- Mean monthly streamflow (c.f.s.) of Shope Creek for the 6-year period, 1937-42.

FIGURE 3. -- Peak daily streamflow (c.f.s.) of Shope Creek for the period, July 1952 to June 1953.

(Drawings courtesy of the author)

In trout streams of western North Carolina the food of trout is obtained from three sources: the bottom fauna, terrestrial insects, and fish. Analysis of 241 rainbow trout stomachs collected from streams of western North Carolina during 1952 and 1953 indicate that, from January to June, 83 percent of the diet is obtained from the bottom fauna. From June to December, 42 percent of the food of rainbow trout is obtained from the bottom fauna. Terrestrial insects are of major importance during the summer and fall months. Of the 241 trout stomachs examined, only 1 specimen contained fish remains and 3 had eaten salamanders.

From October 1952 to June 1953, 108 square-foot bottom samples were collected at monthly intervals from Shope Creek immediately above and below the mouth of the stream draining the logged watershed. The standing crop of bottom organisms was at all times very low, with a high average of 49.0 organisms per square foot occurring at the untreated station on November 13 (table 1). The highest average volume occurred in the samples of January 14 at the untreated station. The high volume occurring on January 14 resulted from an abundance of large cranefly larvae, *Tipula* sp., and the stonefly nymph, *Pteronarcys scotti*. The frequent occurrence of floods (figure 3) is undoubtedly an important factor contributing to the low quantities of bottom fauna produced in this small trout stream.

From October 1952 to February 1953, the upper station had a significantly larger numerical standing crop of bottom organisms than did the lower station, which was subjected to the siltation from the logged watershed (tables 2 and 3). The volume of bottom organisms was greater in the control section on all but two sampling dates, April 23 and May 21, 1953 (table 1).

A major flood that occurred on February 21, 1953, increased the flow in Shope Creek from 6.7 c.f.s. to 105.8 c.f.s. in a 24-hour period (figure 3). The flood completely resorted bottom materials and flushed the deposited sediments downstream, exposing the original rubble and gravel bottom. On February 26, 1953, the numbers of bottom organisms at the lower station had been reduced 73.2 percent, as compared with the January level, while the numbers at the untreated station had been reduced 22.2 percent (table 1).

High water levels plus frequent rains February to May (figure 3) prevented a reaccumulation of silt in the lower section of Shope Creek. On April 2, April 23, and May 21, that section of stream produced slightly greater standing crops of bottom organisms than did the control section. The difference was not significant ($F=0.208$ d.f.= 1 and 30), and was the result of an increase in the numbers of mayfly nymphs in the treated section of stream (table 1). The inexplicable superiority of mayflies in the treated section of stream may have been the result of reduced competition and improvement in habitat, both caused by the February flood.

When samples were collected in June 1953, silt and sand again had begun to accumulate in the treated section of the stream, and the control section again produced a greater average standing crop of bottom organisms (table 1). The difference was not statistically significant ($t=1.42$ d.f.=10).

Before the reduction in the quantity of stream bottom organisms, from October through February, can be attributed to the effects of siltation, it is necessary to assume that there was no difference between the two sampled stations prior to logging. The study was commenced quite some time after logging took place, and it is therefore impossible to test this basic assumption. However, the fact that the sampled areas are on immediately adjacent and similar sections of the same stream, as well as the comparable quantities of bottom fauna produced during the spring months, when silt did not accumulate in the treated section of the stream, lends support to the assumption that there were no pretreatment differences between the two stations sampled.

With the exception of the difference in mayflies during the spring months, as noted above, there were no appreciable qualitative differences between the two stations sampled (table 1).

Discussion

The period during which the standing crop of organisms in the treated section of Shope Creek was significantly lower than in the control section coincided with the period of maximum accumulation of inorganic silt and sand. Inorganic silt and sand have poor ability to support a fauna. Tarzwell (1938a) found that mineral silt bottoms were poor in food. Murray (1938) stated that, in Indiana streams, sand by itself is likely to be barren of life.

In addition to its poor ability to support a fauna, the shifting sand created an unstable habitat, and organisms inhabiting it were particularly vulnerable to decimation by flood waters. The flood during February removed the accumulated sediments and resulted in a drastic reduction in the number and volume of bottom organisms in the treated section of stream. During the high flows and frequent rains from February to May, the rate of dilution by clear water from the main fork of Shope Creek prevented the reaccumulation of sediment in the treated section of stream. A fauna which resulted was quantitatively comparable to that found in the control section. It is doubtful that the rapid recovery after the flood -- undoubtedly by means of the drift of organisms from the control section -- could occur if all of the Shope Creek watershed were subject to the effects of siltation.

The low fertility and frequent occurrence of floods in western North Carolina trout streams results in a low production of stream bottom organisms under the very best conditions. Therefore, because of the dependence of trout on stream-produced organisms, any outside factor, such as siltation, which reduces the normally low quantities of stream organisms will ultimately have a deleterious effect on the trout population.

It is apparent from the Coweeta studies that poorly planned road systems and the promiscuous use of smaller stream channels as skid trails result in a

TABLE 1.—Numbers and volume of bottom organisms collected from riffles in Shope Creek from October 1952 to June 1953 at stations above and below the mouth of a tributary stream draining a logged watershed

October 16		November 13		December 17		January 14		February 26	
Above	Below	Above	Below	Above	Below	Above	Below	Above	Below

TABLE 1.--Numbers and volume of bottom organisms collected from riffles in Shope Creek from October 1952 to June 1953 at stations above and below the mouth of a tributary stream draining a logged watershed

	October 16		November 13		December 17		January 14		February 26	
	Above	Below	Above	Below	Above	Below	Above	Below	Above	Below
Number of samples	3	3	3	3	6	6	6	6	6	6
Total number of organisms	116	74	147	78	226	137	234	164	182	44
Number per square foot	38.7	24.7	49.0	26.0	37.5	22.8	39.0	27.3	30.3	7.3
Standard deviation	9.29	13.0	12.1	14.7	13.6	6.80	15.4	16.9	22.3	3.19
Total volume (cc)[1]	0.70	0.15	0.70	0.20	3.20	0.50	5.70	2.40	2.65	trace
Volume per square foot	0.23	0.05	0.23	0.07	0.53	0.08	0.95	0.40	0.44	trace
Diptera	27	4	57	33	65	55	90	70	76	13
Trichoptera	18	12	7	5	25	20	19	9	10	4
Plecoptera	25	9	49	-----	57	24	50	18	9	6
Ephemeroptera	30	23	22	29	53	23	54	51	36	16
Odonata	1	-----	-----	-----	2	-----	2	1	1	-----
Coleoptera	11	25	12	11	23	15	19	15	21	5
Oligochaeta	4	1	-----	-----	-----	-----	-----	-----	-----	-----

	April 2		April 23		May 21		June 12	
	Above	Below	Above	Below	Above	Below	Above	Below
Number of samples	6	6	6	6	6	6	6	6
Total number of organisms	259	283	239	249	180	196	256	202
Number per square foot	43.2	47.2	39.8	41.5	30.0	32.7	42.7	33.7
Standard deviation	17.6	17.6	19.3	26.6	9.27	15.2	11.3	10.7
Total volume (cc)[1]	5.20	3.75	2.50	2.70	1.35	2.60	3.80	1.20
Volume per square foot	0.87	0.63	0.42	0.45	0.23	0.43	0.63	0.20
Diptera	41	33	32	24	25	16	9	10
Trichoptera	13	11	8	5	4	11	18	16
Plecoptera	41	29	24	20	17	31	75	21
Ephemeroptera	148	190	160	189	106	130	112	127
Odonata	-----	1	-----	-----	-----	-----	2	-----
Coleoptera	15	17	12	10	25	5	29	24
Oligochaeta	-----	-----	1	1	2	2	4	1
Crayfish	1	1	1	-----	1	1	3	1
Salamanders	-----	1	-----	-----	-----	-----	-----	-----

1/ Does not include salamanders and crayfish.

TABLE 2.--Analysis of variance on the basis of total numbers of organisms in October and November 1952

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Between stations--------	1	1,027	1,027	1/6.62
Between months----------	1	102	102	------
Interaction-------------	1	62	62	------
Error-------------------	8	1,239	155	------

1/ Significant at 5-percent level.

TABLE 3.--Analysis of variance on the basis of total numbers of organisms in December 1952 and January and February 1953

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Between stations--------	1	2,434	2,434	1/15.02
Between months----------	2	1,372	686	4.23
Interaction-------------	2	207	104	------
Error-------------------	29	4,706	162	------

1/ Significant at 1-percent level.

high rate of erosion and consequent siltation of the stream channel. Steep grades, lack of allowance for proper drainage, and the proximity of roads to stream channels are particularly conducive to siltation. Also, it is the opinion of many foresters that properly constructed roads, in addition to conserving water values, will, in the long run, pay the logging operator by reducing road maintenance work. Where important fishery values are involved, it is imperative that skid trails and road systems be carefully located and constructed.

Summary

1. From 1942 to 1948, a 212-acre watershed on the Coweeta Experimental Forest, Macon County, North Carolina, was logged by a local contractor. Roads and skid trails were built parallel and adjacent to the stream channel. No surfacing material and no drains were used.

2. The physical and chemical characteristics of Shope Creek, a small trout stream which receives the stream from the logged watershed, are described.

3. During storm periods the turbidity of Shope Creek was appreciably increased by the highly turbid waters from the logged area. The accumulation of sand and silt in Shope Creek below the mouth of the stream from the logged watershed is described.

4. Roads and skid trails proved to be the major source of turbidity. From April 1951 to March 1953, an average of 5.34 cubic feet of soil per lineal foot of road surface was eroded from the logging road.

5. From October 1952 to June 1953, 108 square-foot bottom samples were collected at monthly intervals in Shope Creek at stations above and below the mouth of the stream from the logged watershed.

6. From October 1952 through January 1953, the period of maximum accumulation of sediment in the affected section of Shope Creek, there was a significantly lower standing crop of bottom organisms at the station below the mouth of the logged watershed.

7. A flood on February 21, 1953, removed the accumulation of sand and silt in Shope Creek below the mouth of the logged watershed and reduced the bottom fauna at the lower station to 7.3 organisms per square foot, as compared with 25.5 organisms per square foot at the upper station, which had not been subject to siltation from the logged watershed.

8. The February flood exposed an excellent bottom of rubble and gravel at the lower station; from February through May spring rains and high streamflow prevented the reaccumulation of sand and silt at the lower station on Shope Creek. During this period there was no significant difference in the standing crop of bottom fauna at the control and treated stations. During June, when silt had begun to reaccumulate, the control section again produced a larger standing crop of bottom organisms. The difference was not statistically significant.

Acknowledgments

Facilities of the U.S. Forest Service station at Coweeta Hydrologic Laboratory have been utilized freely in the conduct of this study. The cooperation and advice of Mr. E.A. Johnson and Dr. T. C. Nelson, technicians at Coweeta, have been particularly helpful.

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STREAM LIFE AND THE POLLUTION ENVIRONMENT*

Alfred F. Bartsch
and
William Marcus Ingram

Increased field investigations over the past 10 years, directed toward the abatement of pollution, have prompted this pictorial presentation to show the impact of pollution upon the stream environment and in turn upon the stream life, or biota. The illustrations were developed initially for use in training sanitary engineers and supporting scientists at the U. S. Public Health Service's Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio.

To show schematically the effects of pollution on biota, raw domestic sewage has been chosen as the pollutant. With such a waste, the lowering of dissolved oxygen and formation of sludge deposits are the most commonly seen of the environmental alterations that damage aquatic biota. Fish and the organisms they feed on may be replaced by a dominating horde of animals such as mosquito wrigglers, bloodworms, sludge worms, rattailed maggots and leeches. Black-colored gelatinous algae may cover the sludge and, as both rot, foul odors emerge from the water and paint on nearby houses may be discolored. Such an assemblage of abnormal stream life urges communities not to condone or ignore pollution, but to abate it without delay. This biotic picture emphasizes that pollution is just as effective as drought in reducing the utility of a valuable water resource. They help to make clear that pollution abatement is a vital key to the over-all problem of augmenting and conserving waters of this land.

No two streams are ever exactly alike. In their individualism streams differ from each other in the details of response to the indignity of pollution. In the following paragraphs, and in the charts they describe, the hypothetical stream is made to conform exactly to theory, showing precisely how an idealized stream and its biota should react in a perfect system. In reality, of course, no stream will be exactly like this although the principles shown can be applied with judgment to actual problems that may be encountered.

ASSUMED CONDITIONS

The stage for discussion is set in Figure 1. The horizontal axis represents the direction and distance of flow of the stream from left to right. Time and distance of flow downstream are shown in days and also in miles. The vertical scale of quantity - or more accurately, concentration - expressed in parts per million, applies to dissolved oxygen and biochemical oxygen demand at distances upstream and downstream from the origin of the sewage discharge, which is identified as point zero. Here, raw domestic sewage from a sewered community of 40,000 people flows to the stream. The volume flow in the stream is 100 cubic feet per second, complete mixing is assumed, and the water temperature is 25°C. Under these conditions the dissolved oxygen (D.O.) sag curve reaches a low point after two and one-quarter days of flow and then

*Originally published with colored illustrations. Editorial changes have been made to make this text conform with the halftone illustrations.