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Sand Sediments in a Michigan Trout Stream
Part II.
Effects of Reducing Sand Bedload on a Trout Population

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and
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SAND SEDIMENTS IN A MICHIGAN TROUT STREAM

PART II. EFFECTS OF REDUCING SAND BEDLOAD ON A TROUT POPULATION[1]

Gaylord R. Alexander and Edward A. Hansen[2]

Abstract

A sediment basin excavated in a Michigan trout stream reduced sand bedload sediment by 86% (from 56 ppm down to 8 ppm). Following the reduction in bedload, trout numbers increased significantly. Small or young trout increased about 40% throughout the treated area. Larger and older trout increased in the portion of the treated area that had an erodible sand bed. Although production increased 28%, growth rate of trout changed little. Both brown and rainbow trout populations responded similarly to the bedload reduction. However, statistical tests were more conclusive for brown trout than for rainbow trout due to lower year-to-year variation of the brown trout population. The results suggest that in-stream sediment basins are an effective means for removing sand bedload and that even small amounts of moving sand bedload sediments can have a major impact on a trout population.

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Introduction

Biologists and anglers have believed for a long time that stream sediments are detrimental to fish. Studies have shown that sustained concentrations of suspended inorganic sediments over 270 ppm adversely affect trout (Herbert and Merkings 1961, Herbert et al. 1961, and Herbert and Richards 1962). Production of juvenile coho salmon in experimental stream channels has been demonstrated to increase with less sedimentation (Crouse et al. 1981). Suspended sediments from a gas-oil drilling accident ranging between 10 and 5,000 ppm for over a year period reduced trout biomass (Alexander and Hansen 1977). Sediment from agricultural land that increased suspended sediment concentration from about 20 to 300 ppm along a 15-mile length of Montana trout stream was associated with a decrease in trout numbers (Peters 1967); however, these sediment effects were confounded with large changes in stream discharge and water temperature.

There is considerable documentation of the effects of mismanagement of the upland on increased sediment load and consequently on stream substrate following floods (Allen 1951, Elwood and Waters 1969), highway construction (King and Ball 1964), and logging (Tebo 1955). Cordone and Kelly (1961) cite many studies showing reduced fish populations in sections of streams receiving much sediment from mining operations. Most of these studies have a common drawback in that no measurements of the sediment load were made either during normal conditions or while the increases were occurring. These studies document cases where apparent large increases in sediment loads led to increased deposition of sediment on the streambed and a deterioration of trout habitat. The results suggest a definite relationship between stream sediments, fish habitat, and fish populations. However, application of these results to other streams is limited due to the general lack of sediment data and to the confounding of sediment changes with other variables such as stream discharge, fish cover and water temperature.

All of these studies dealt with either the influence of large but generally unquantified sediment increases, or with measured changes in suspended sediment on trout populations. Little work has been done to evaluate the impact of bedload sediments on either trout or on trout habitat, particularly at concentrations often present in undisturbed trout streams. Excessive sand bedload can cause streambed aggradation which destroys cover by filling pools. It can also bury or plug desirable gravel substrate used by trout for spawning and can effect egg and alevin survival (Cooper 1965). Further, sand substrate, particularly moving sand bedload, is the poorest substrate for habitation and production of invertebrate food organisms (Pennak and Van Gerpen 1947, Usinger 1968, Hynes 1970).

The objective of this study was to measure the response of a trout population to reduced sand bedload resulting from excavating an in-stream sediment basin.

Methods

The study area, study design and results of the sediment basin on stream bedload and channel morphometry are described in Part I of this paper. Control and treated as used here are identical to that in Part I. The pre-treatment period was from 1972-1974. The 1975-1980 treatment consisted of excavation and operation of the sediment basin. The treatment resulted in a sustained 86% reduction in moving the sand bedload.

The trout population of Poplar Creek was composed of brown trout (*Salmo trutta*), rainbow trout (*Salmo gairdneri*), and a few brook trout (*Salvelinus fontinalis*). The standing stock of trout was about average at the outset of the study (Gowing and Alexander 1980).

Fall trout population estimates were made annually from 1972 to 1980 for the control section, treated 1 (T-1) and treated 2 (T-2) sections by electrofishing. Estimates, stratified by 1-inch size groups, were calculated by the Petersen mark-and-recapture method as described by Shetter (1957). Representative samples of trout scales were used to convert estimates by length groups to estimates by age groups. Mortality rates were computed from sequential estimates of age groups. The average length by age group was determined following the procedure described by Alexander and Ryckman (1976). Growth rates were computed from sequential estimates of the average size of trout by age group. Estimation of trout production (elaboration of flesh) followed the procedure of Ricker (1975). Since a temporal change occurred in both the treated and control trout populations, we used a ratio analysis (Shetter and Alexander 1962) to test for significant changes attributable to a reduction in bedload sediment. These ratios were calculated by dividing the population size in a particular treated section by the population size in the control section for each year. Then the average population ratios for the pre-treatment years were compared to average ratios for the treatment years using analysis of variance. Trout growth was tested using the ratio approach together with regression analysis. The 95% level was used for statistical significance in all tests.

Results

Trout Population Changes

The average trout population in the treatment zone increased considerably following reduction of bedload sediment (Table 1). Total numbers of trout in the treatment zone increased 29% whereas a 5% decrease was noted in the control zone. The population increased primarily during the first two years following construction of the sediment basin, then stabilized. Changes were most rapid for young fish with both species responding similarly. Increases in numbers of older fish differed between the sub-treatment areas.

The increases in trout 1.0-6.9 inches in length (total length) were similar in T-1 and T-2 but T-1 had a much greater increase in trout 7.0 inches and longer (Table 1). A change was also noted for the trout population of the control area between the pre-treatment and treatment periods. Trout 1.0-6.9 inches in length decreased, but trout 7.0 inches and longer increased; in fact, the increase was comparable to that noted for the T-2 area.

The brown trout population increased significantly in the T-1 section for all length groups. Increases ranged from 34% to 39% for the various length groups (Table 2). In the T-2 section small brown trout (1.0-6.9 inches) also showed a significant increase. However, 7.0-9.9 inch, and 10.0 inches and longer fish had non-significant changes of +7% and -2% respectively. Combining the data from T-1 and T-2, which probably gives the best overall measure of sediment treatment effects on brown trout showed that significant increases occurred for all length groups, ranging from 16% to 45%.

The response of rainbow trout to decreased bedload sediment was generally the same as that of brown trout. But, because of the greater year-to-year variability in rainbow trout numbers most changes were not statistically significant (Table 3). Rainbow trout in the T-1 section increased 36% to 136% depending on the size group. The increase in rainbow trout 10.0 inches and longer was significant. Rainbow trout numbers in the T-2 area increased for 1.0- to 6.9-inch fish and for fish 10.0 inches and longer. Fish 7.0-9.9 inches in length showed a decrease. Only the increase of rainbow trout 10.0 inches and longer was significant. The combined rainbow data from T-1 and T-2 showed increases for all size groups of rainbows but again only those 10.0 inches and longer were significant.

Combining all trout species showed significant increases in T-1 for all size groups with increases ranging from 34% to 39% depending on size group (Table 4). The treatment response in the T-2 section showed a significant increase for 1.0- to 6.9-inch fish but little change in trout over 7.0 inches in length. Again combining all trout species from T-1 and T-2 sections there was a significant increase of 43% in numbers of small trout. Increases were also noted for fish 7.0-9.9 inches and 10.0 inches and longer, but these were not significant.

Numbers of trout increased after sediment reduction for all age groups of brown trout and rainbow trout except age-III fish in some cases (Tables 5 and 6). However, most increases were not statistically significant. Significant increases in brown trout occurred in the T-1 section for I and IV year old trout and in T-2 section for 0, I, and V year old trout (Table 5). The combined T-1 and T-2 data sets showed only age-0 and I brown trout had significantly larger numbers after sediment reduction. Numbers of age-0 rainbow trout increased significantly for T-1, and T-2 separately and combined (Table 6). Changes were not significant for any other rainbow trout age group.

There was less year-to-year variability in brown trout populations than in rainbow trout populations which resulted in more significant changes in brown trout following treatment. Because of rainbow trout, the combined data for all species also had broader confidence limits than brown trout alone.

Trout Growth Changes

Changes in trout growth following bedload sediment reduction were tested by combining T-1 and T-2 data and using the T/C ratio approach. We found slight but non-significant changes in growth of both brown and rainbow trout (Table 7). Within each species the older fish were slightly larger and younger fish slightly smaller following sediment reduction.

Trout Survival Changes

Trout survival rates increased in T-1 and T-2 for young fish (egg-to-age-0 and age-0-to-age-I life stages) following bedload reduction. An increase in brown trout survival was also noted for age-I to age-II fish in the T-1 section. Survival rates of older fish changed little. We did not determine whether the increased survival between egg to age 0 was due to better egg-to-fry or fry-to-age-0 survival.

Trout Production Changes

We calculated trout production to determine possible benefits from bedload reduction. Trout production was enhanced considerably (Table 8). Brown trout production increased 41% in T-1 and 22% in T-2. Rainbow trout production rose 15% in T-1 and 8% in T-2. Total trout production increased about 35% in T-1 and 20% in T-2. Total trout production in the control section remained nearly constant during the entire study period.

Discussion

The significant increase in the number of trout despite a lack of a major change in channel morphometry between treated and control, suggests that the most beneficial effect was from reduction of sand from the streambed and not from channel deepening. However, we believe that additional improvement would have occurred for large trout if the channel had an erodible bed and had deepened over more of the treated sections.

It was apparent that the reduction in sand bedload greatly enhanced the habitat for small trout (fry to age I) in both T-1 and T-2. We hypothesize that this improvement was due to a change in micro-habitat. The stream bottom became rougher because of less sand embeddedness (extent to which predominant, larger size particles are covered by finer sediments (Sandine 1974)). Thus, uncovered gravel, cobble, sticks, and other obstacles provided more cover for small fish. This rougher bottom would also reduce visual contact between trout and thus reduce territorial competition. Furthermore, roughness creates greater diversity of water velocities adjacent to the stream bottom, resulting in more areas of very low velocity for resting and energy conservation by trout. Bjornn et al. (1977) speculated that fine sediment embeddedness reduced protective cover for juvenile salmonids. Our data support this hypothesis.

An improved substrate for egg incubation could have resulted in greater hatch of the deposited eggs. However, survival and numbers of age-I trout, as well as age-0 trout, increased the first year following sediment reduction. These initial increases were not related to any increased hatching success. Thus, we believe that improved habitat for eggs was not as important as improved habitat for small fish.

Food conditions probably improved because of better streambed substrate. However, this was not clearly evident in T-2 where neither the population numbers nor growth changed. In contrast, in T-1 there was a substantial increase in 7.0 inch and longer trout after sediment reduction and they showed no decrease in growth. This increase in production indicates either greater food production or more efficient foraging for food. Also, since there was no evidence of improved growth rates, it follows that increased production resulted from increased survival.

We should caution that although the increased numbers of trout implies greater survival rates, they could also result from less migration. Possibly with better habitat the "carrying capacity" increased and fewer trout migrated. We had no estimate of trout migration from the experimental area thus we cannot quantify its impact on survival rates and standing crop. Further, no estimate of the trout removed by recreational angling was made. However, we believe the increase in trout numbers as measured by fall standing crop is conservative because with larger standing crops and greater production there would be a tendency for more trout to be removed by anglers and more to migrate.

In this study the rainbow trout population had greater variability than did the brown trout population. We believe that this is probably true in general, but evidence is sparse. Stauffer (1979) noted that rainbow trout exhibit alternate strong and weak year classes in some streams. This factor along with a greater migratory tendency (Rounsefell 1958) could have contributed to greater variation. Alternate year class abundance was not evident in the population of rainbow trout at Poplar Creek, however.

This study demonstrated that sediment basins are an effective technique for producing major reductions in moving sand bedload. Reduction of sand bedload sediment, even at very low concentrations, can enhance both brown and rainbow trout populations. From our experience, a sediment basin can be excavated in a day or two and maintained with two to three excavations a year on streams with sediment loads similar to Poplar Creek. We believe that sediment basins can be a cost effective method for improving trout populations in many Michigan streams. This technique should be used as an addition to a stream improvement program and not as a substitute for the prevention and control of soil erosion.

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Table 1. Average numbers of trout by length group in the fall for treated and control areas of Poplar Creek, pre-treatment 1972-1974 and treatment 1975-1980.

Treatment Area 1

Year	Species	Length group (inches) 1.0-6.9	7.0-9.9	10.0+	Total
1972-74	Brown	730	87	50	867
	Rainbow	524	28	1	553
	Brook	7	1	0	8
Totals		1,261	116	51	1,428
1975-80	Brown	897	154	81	1,132
	Rainbow	688	47	2	737
	Brook	9	1	0	10
Totals		1,594	202	83	1,879

Treatment Area 2

Year	Species	Length group (inches) 1.0-6.9	7.0-9.9	10.0+	Total
1972-74	Brown	693	101	57	851
	Rainbow	366	29	1	396
	Brook	2	0	0	2
Totals		1,061	130	58	1,249
1975-80	Brown	888	141	66	1,095
	Rainbow	449	29	1	479
	Brook	6	0	0	6
Totals		1,343	170	67	1,580

Control Area

Year	Species	Length group (inches) 1.0-6.9	7.0-9.9	10.0+	Total
1972-74	Brown	1,948	283	99	2,330
	Rainbow	585	49	2	636
	Brook	7	1	0	8
Totals		2,540	333	101	2,974
1975-80	Brown	1,741	361	116	2,218
	Rainbow	554	50	1	605
	Brook	3	0	0	3
Totals		2,298	411	117	2,826

Table 2. Ratios of treated-to-control area (T1/C, T2/C, T1 and T2/C) for brown trout populations before and during treatment. Ratios are listed by length group with 95% confidence limits. Changes in trout numbers between the pre-treatment (1972-1974) and treatment (1975-1980) periods are shown in percent.

Treatment Area 1

Year	Length group (inches) 1.0-6.9	7.0-9.9	10.0+
1972-74	0.374 ±0.080	0.316 ±0.080	0.507 ±0.080
1975-80	0.521 ±0.048	0.424 ±0.048	0.692 ±0.048
Percent change	+39.30 ±18.81	+34.18*[a] ±22.07	+39.69* ±13.81

Treatment Area 2

Year	Length group (inches) 1.0-6.9	7.0-9.9	10.0+
1972-74	0.353 ±0.078	0.363 ±0.078	0.574 ±0.078
1975-80	0.536 ±0.047	0.390 ±0.047	0.564 ±0.047
Percent change	±51.84 ±19.97	±7.44 ±18.26	-1.74 ±11.53

Treatment Areas 1 and 2 combined

Year	Length group (inches) 1.0-6.9	7.0-9.9	10.0+
1972-74	0.728 ±0.140	0.679 ±0.140	1.081 ±1.140
1975-80	1.057 ±0.084	0.814 ±0.084	1.256 ±0.084
Percent change	+45.19* ±17.06	+19.88* ±17.60	+16.19* ±11.02

[a] Asterisk denotes significant differences at the 95% level.

Table 3. Ratios of treated-to-control area (T1/C, T2/C, T1 and T2/C) for rainbow trout populations before and during treatment. Ratios are listed by length group with 95% confidence limits. Changes in trout numbers between the pre-treatment (1972-1974) and treatment (1975-1980) periods are shown in percent.

Treatment Area 1

Year	Length group (inches) 1.0-6.9	7.0-9.9	10.0+
1972-74	0.897 ±0.519	0.698 ±0.519	0.917 ±0.519
1975-80	1.317 ±0.310	0.947 ±0.310	2.167 ±0.310
Percent change	+46.82 ±51.47	+35.67 ±64.76	+136.31*[a] ±66.38

Treatment Area 2

Year	Length group (inches) 1.0-6.9	7.0-9.9	10.0+
1972-74	0.620 ±0.490	0.720 ±0.490	0.417 ±0.490
1975-80	0.870 ±0.293	0.592 ±0.293	1.167 ±0.293
Percent change	+40.32 ±69.43	-15.67 ±59.34	+179.86* ±160.62

Treatment Areas 1 and 2 combined

Year	Length group (inches) 1.0-6.9	7.0-9.9	10.0+
1972-74	1.517 ±0.132	1.401 ±0.132	1.333 ±0.132
1975-80	2.186 ±0.107	1.539 ±0.107	3.033 ±0.107
Percent change	+44.10 ±51.19	+9.85 ±53.04	+127.53* ±74.88

[a] Asterisk denotes significant differences at the 95% level.

Table 4. Ratios of treated-to-control area (T1/C, T2/C, T1 and T2/C) for trout populations for all species combined before and during treatment. Ratios are listed by length group with 95% confidence limits. Changes in trout numbers between the pre-treatment (1972-1974) and treatment (1975-1980) periods are shown in percent.

Treatment Area 1

Year	Length group (inches)		
	1.0-6.9	7.0-9.9	10.0+
1972-74	0.511 ±0.089	0.366 ±0.089	0.508 ±0.089
1975-80	0.705 ±0.053	0.491 ±0.053	0.705 ±0.053
Percent change	+37.96*[a] ±15.33	+34.15* ±21.27	+38.79* ±15.44

Treatment Area 2

Year	Length group (inches)		
	1.0-6.9	7.0-9.9	10.0+
1972-74	0.416 ±0.081	0.406 ±0.081	0.568 ±0.081
1975-80	0.610 ±0.048	0.415 ±0.048	0.568 ±0.048
Percent change	+46.63* ±17.27	+2.22 ±16.81	0 ±0

Treatment Areas 1 and 2 combined

Year	Length group (inches)		
	1.0-6.9	7.0-9.9	10.0+
1972-74	0.927 ±0.149	0.772 ±0.149	1.076 ±0.149
1975-80	1.321 ±0.077	0.906 ±0.077	1.273 ±0.077
Percent change	+42.56* ±23.75	+17.30 ±27.50	+18.29 ±19.75

[a] Asterisk denotes significant differences at the 95% level.

Table 5. Ratios of treated-to-control area (T1/C, T2/C, T1 and T2/C) for brown trout populations by age group with 95% confidence limits. Changes in trout numbers between the pre-treatment (1972-1974) and treatment (1975-1980) periods are shown in percent.

Treatment Area 1

Year	Age group 0	I	II	III	IV	V
1972-74	0.457 ±0.106	0.255 ±0.106	0.245 ±0.106	0.344 ±0.106	0.376 ±0.106	1.333 ±0.106
1975-80	0.568 ±0.064	0.456 ±0.064	0.390 ±0.064	0.455 ±0.064	0.572 ±0.064	1.333 ±0.064
Percent change	+28.36 ±33.63	+78.84*[a] ±67.69	+59.30 +66.73	+32.15 ±44.85	+52.01* ±42.64	0.000 ±0.000

Treatment Area 2

Year	Age group 0	I	II	III	IV	V
1972-74	0.435 ±0.106	0.243 ±0.106	0.294 ±0.106	0.420 ±0.106	0.310 ±0.106	0.667 ±0.106
1975-80	0.638 ±0.064	0.422 ±0.064	0.366 ±0.064	0.365 ±0.064	0.359 ±0.064	0.917 ±0.064
Percent change	+45.78* ±36.41	+73.54* ±69.85	+24.26 ±51.90	-13.08 ±36.08	+15.90 ±48.87	+37.50 ±23.37

Treatment Areas 1 and 2 combined

Year	Age group 0	I	II	III	IV	V
1972-74	0.891 ±0.151	0.498 ±0.151	0.539 ±0.151	0.764 ±0.151	0.686 ±0.151	2.000 ±0.151
1975-80	1.220 ±0.090	0.877 ±0.090	0.756 ±0.090	0.820 ±0.090	0.931 ±0.090	2.250 ±0.090
Percent change	+36.85* ±36.02	+76.25* ±72.84	+40.17 ±60.04	+7.30 ±40.31	+35.70 ±46.67	+12.50 ±15.45

[a] Asterisk denotes significant differences at the 95% level.

Table 6. Ratios of treated-to-control area (T1/C, T2/C, T1 and T2/C) for rainbow trout populations by age group with 95% confidence limits. Changes in trout numbers between the pre-treatment (1972-1974) and treatment (1975-1980) periods are shown in percent.

Treatment Area 1

Year	Age group 0	I	II	III	IV
1972-74	0.951 ±0.168	0.808 ±0.168	0.728 ±0.168	0.703 ±0.168	0.000 ±0.168
1975-80	1.609 ±0.100	0.931 ±0.100	0.817 ±0.100	0.795 ±0.100	0.792 ±0.100
Percent change	+69.22*[a] ±27.82	+15.22 ±29.56	+12.23 ±37.76	+13.04 ±33.94	

Treatment Area 2

Year	Age group 0	I	II	III	IV
1972-74	0.712 ±0.168	0.410 ±0.168	0.560 ±0.168	0.695 ±0.168	0.111 ±0.168
1975-80	1.076 ±0.100	0.508 ±0.100	0.577 ±0.100	0.506 ±0.100	0.667 ±0.100
Percent change	+51.23* ±35.51	+23.69 ±58.72	+3.13 ±42.46	-27.15 ±34.81	+500.090 ±785.870

Treatment Area 1 and 2 combined

Year	Age group 0	I	II	III	IV
1972-74	1.662 ±0.238	1.219 ±0.238	1.288 ±0.238	1.398 ±0.238	0.111 ±0.238
1975-80	2.685 ±0.142	1.439 ±0.142	1.394 ±0.142	1.301 ±0.142	1.458 ±0.142
Percent change	+61.51* ±32.66	+18.07 ±40.22	+8.27 ±37.74	-6.94 ±34.74	+1212.69 ±4360.69

[a] Asterisk denotes significant differences at the 95% level.

Table 7. Ratios (T1 and T2/C) of growth by age group of brown and rainbow trout with 95% confidence limits.

	Brown		Rainbow	
Age group	Pre-treatment	Treatment	Pre-treatment	Treatment
0	1.134 ± 0.042	1.069 ± 0.027	1.153 ± 0.085	1.037 ± 0.029
I	1.087 ± 0.022	1.061 ± 0.015	1.119 ± 0.058	1.059 ± 0.018
II	1.062 ± 0.024	1.057 ± 0.016	1.098 ± 0.080	1.073 ± 0.025
III	1.047 ± 0.039	1.054 ± 0.020	1.084 ± 0.102	1.082 ± 0.033
IV	1.036 ± 0.034	1.052 ± 0.024	1.074 ± 0.119	1.089 ± 0.039
V	1.029 ± 0.038	1.051 ± 0.027	1.067 ± 0.132	1.094 ± 0.044

Table 8. Average production (pounds) of brown trout, rainbow trout, and total trout for treated and control areas of Poplar Creek; pre-treatment (1972-1974) and treatment (1975-1980) periods. Change in production between the pre-treatment and treatment is show in percent.

	Areas		
Year	T1	T2	Control
1972-74			
Brown	74.9	78.3	183.6
Rainbow	19.9	13.1	23.2
Totals	94.8	91.4	206.8
1975-80			
Brown	105.6	95.5	190.1
Rainbow	22.9	14.1	20.2
Totals	128.5	109.6	210.3
Percent Change			
Brown	+41.0	+22.0	+3.5
Rainbow	+15.1	+7.6	-12.9
Totals	+35.5	+19.9	+1.7

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