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EFFECTS OF SALMON SPAWNING ACTIVITY ON MACROINVERTEBRATES IN A SMALL MICHIGAN STREAM

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ABSTRACT

Density and composition of macroinvertebrate populations were examined prior to and during the migration and spawning of coho and chinook salmon in a small stream in Michigan. Data gathered from bottom samples indicated that disruption of substrate in the experimental area resulted in a significant decrease in the numbers and species of the macroinvertebrate community. This reduction of invertebrates can create a severe stress on native trout populations.

As salmon migrate upstream, severe disturbances in the stream substrate occur due to vigorous swimming movement and redd-digging activity. The benthic population is reduced by this disruption, which destroys the habitats provided by the deposited silt and sand and the existing macrophytic growth. A mean salmon redd area of 2.8 m^2 was reported by Burner (1951) for the Toutle River, a tributary of the Columbia River, and Hildebrand (1971) estimated that as much as 20,773 m^2 of substrate area was disrupted by 7,000 spawning female salmon in Michigan's Platte River. The loss of benthic macroinvertebrates in such large areas may be temporarily catastrophic and results in a substantial decrease in the food supply available to native salmonids.

Pacific coho salmon (*Onchorynchus kisutch* Walbaum) were planted by the Michigan Department of Natural Resources in three Michigan streams during 1966. The stocking project was adopted in an effort to reduce extremely large populations of the alewife (*Alosa pseudoharengus* Wilson) in the Great Lakes, while providing a valuable sport fish resource. Two years after the release, strays of returning adult salmon spawners were entering most trout streams of northern Lake Michigan and southern Lake Superior, causing disruption of the benthic macroinvertebrate communities in these streams.

One such stream, Cedar Creek, was chosen for study in order that the actual effects of the spawning disturbance might be quantified. The benthic population was sampled and examined before and after the spawning period and changes have been evaluated to determine the severity of the damage. In addition, community diversity and similarity within the study area have been calculated.

STUDY AREA

Cedar Creek is located 6.4 km north of Traverse City in Elmwood Township, Leelanau County, Michigan (T.28N,R.11W,S.28). It is a relatively short stream, flowing easterly from Cedar Lake into the west arm of Grand Traverse Bay. The substrate of 40% gravel, 40% sand, and 20% silt is reported as being optimal for salmon spawning (Shapovalov and Taft, 1954). The stream averages 5.3 m in width, 0.39 m in depth and maintains a stable flow throughout the year. It supports a diverse population of macroinvertebrates and trout (brown, rainbow and brook trout). Vegetation surrounding the stream is heavy, with cedar and lowland hardwoods dominant.

The study area begins 30 m from the stream mouth and extends 121 m upstream to a small dam. Within this area, four sub-sections, each 15 m in length, were designated for study purposes. The downstream sub-sections, 3 and 4, displayed an average current of

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15 cm sec^{-1}, a velocity which allows for deposition of silt and sand which support macrophytes. *Potamogeton, Myriophllum,* and *Ceratophyllum* cover 65% of the substrate in these sub-sections. Upstream, in sub-sections 1 and 2, velocity increases to over 60 cm sec^{-1}. The substrate in this area is composed of large gravel and some sand with very little macrophytic growth.

METHODS

The entire study area was divided lengthwise in order to create control (C) and experimental (E) sections. The experimental section was easily accessible to adult migrating salmon. The control section, however, was enclosed with 3.5 cm wire mesh. This fence allowed native fish species to pass freely between the experimental and control sections while preventing anadromous fish from entering the control section.

Two sampling periods were chosen: the first in August, 1976, prior to the salmon run, and the second in November, 1976, five weeks after the run had started. Sampling sites were determined by a coordinate system within each sub-section, selected from a table of random numbers. The modified Hess sampler of 0.052 m^2 was used to take triplicate bottom samples from each sub-section (Waters and Knapp, 1961).

All aquatic macroinvertebrates from the samples were hand picked, enumerated and identified to the lowest practical levels (Hilsenhoff, 1975). The Shannon-Weaver function (Lloyd, et al., 1968), community similarity coefficients and the single-tail F-test (Campbell, 1967) were determined for each sample. These tests were used to compare control and experimental populations before and after the salmon run. The control populations before and after the run were also compared in order to verify the absence of change in this section during the sampling periods.

RESULTS

The first mature female salmon entered the stream on 12 October, 1976 and large concentrations remained throughout November. An informal survey conducted on 22 October indicated approximately 420 salmon in the study area. It was estimated that one half of these were spawning females which could potentially disrupt 600 m^2 of substrate. Since the total study area was only 557 m^2, virtually all of the substrate was overturned, causing complete elimination of periphytic growth. Redds were observed throughout the stream bed in the experimental section, with depths as great as 40 cm and areas as large as 2.6 m^2. The disruption was most noticeable in the upstream sub-sections, E-1 and E-2.

The macroinvertebrate data compiled in Table 1 are expressed as the mean value of three samples. During the study, a total of 55 invertebrate genera representing eight orders were identified. The major portion of these belonged to the family Chironomidae (Diptera). Sub-section 4, which had a sand-silt substrate, produced the greatest number of species and individuals.

The spawning activity affected the entire benthic community, resulting in an overall reduction of individuals, particularly in sub-sections E-1 and E-2 (Table 1). The mean number of organisms in E-1 and E-2 fell below two individuals in November. The comparable control sub-sections (C-1 and C-2) showed a mean of 207 individuals during the same sampling period. A similar decrease in the mean number of taxa was also found, with the control section averaging 16.5 taxa and the experimental section 1.5. Since the greatest spawning activity occurred in sub-sections E-1 and E-2, the reduction in mean number and taxa was most severe.

The Shannon-Weaver Index was applied to samples taken in both sampling periods and the calculated index values appear in Table 2. August samples showed relatively constant diversity values throughout both the control and experimental sections, ranging from a low value of 2.10 (C-4) to a high value of 2.95 (E-2). In November, diversity index values dropped in sub-sections E-1 and E-2, the area of greatest spawning activity. Diversity in the control section showed little variance between August and November. Sub-sections E-3 and E-4 showed a slight increase in diversity between August and November. These sub-sections tended to support benthos composed primarily of midges. Since the

TABLE 1. Macroinvertebrate Composition of Study Area.

Section	Sub-Section	Month	No. Taxa	No. Organisms	No. Diptera
Control	1	August	17	206	103
	2		19	95	76
	3		16	131	110
	4		18	314	288
Control	1	November	17	216	159
	2		20	198	165
	3		13	190	175
	4		20	526	475
Experimental	1	August	15	216	48
	2		18	105	50
	3		17	133	114
	4		21	162	142
Experimental	1	November	1	1	0
	2		2	1	1
	3		12	110	108
	4		18	428	420

TABLE 2. Shannon-Weaver Index of Diversity.

Section	Sub-Section	Mean Diversity (Aug.)	Mean Diversity (Nov.)
Control	1	2.86	2.47
	2	2.80	3.00
	3	2.39	2.70
	4	2.10	2.90
Experimental	1	2.70	0.20
	2	2.95	0.00
	3	2.29	2.90
	4	2.40	1.97

Chironomidae are active within the sediment, the spawning and swimming activities had little effect.

The community similarity (Jaccard, 1928) showed that, before spawning, the benthos in the control and experimental sections displayed similarity coefficients near unity (Table 3). This coefficient dropped after spawning occurred, indicating a significant change in the communities. Furthermore, testing the similarity of each sub-section before and after the spawning period showed a distinct difference in the experimental populations, while similarity remained near unity in the control section.

In order to verify the significance of this change, the single-tailed F-test was applied. For both collection periods, the F-test indicated no significant difference between the total number of organisms and taxa for all subsections, except for E-1 and E-2. These areas showed a statistically significant loss of macroinvertebrates coincident with a very high number of spawning salmon.

DISCUSSION

As a result of the salmon spawning, some areas of the experimental section underwent a significant decrease in the total number of benthic macroinvertebrates, total number of

TABLE 3. Community Similarity

Sub-Sections	Coefficient of Community Similarity
August, 1976 (before run)	
C-1 vs. E-1	0.96
C-2 vs. E-2	0.99
C-3 vs. E-3	0.97
C-4 vs. E-4	0.96
November, 1976 (after run)	
C-1 vs. E.1	0.64
C-2 vs. E-2	0.53
C-3 vs. E-3	0.80
C-4 vs. E-4	0.89
Before Run vs. After Run	
C-1 vs. C-1	0.98
C-2 vs. C-2	0.93
C-3 vs. C-3	0.96
C-4 vs. C-4	0.99
E-1 vs. E-1	0.10
E-2 vs. E-2	0.58
E-3 vs. E-3	0.64
E-4 vs. E-4	0.67

macroinvertebrate taxa, and community diversity. This decrease is directly attributable to the vigorous swimming behavior and redd-digging activity of the spawning salmon. The importance of this decrease in terms of the entire stream cannot be ascertained from this phase of study. Further work is required to determine the long-term effects on the stream ecosystem. Continuation of the spawning activity will cause further reduction and loss of representative organisms can be experienced over time, resulting in an unstable community. This loss of important food chain members would have its greatest impact on the next trophic level, the native trout, since they depend on the benthic community as a major food source.

The rate of recolonization by drift and adult reproduction must be considered when assessing the stream once it has become denuded of macroinvertebrates. Hildebrand (1971) observed that five months was insufficient to completely recolonize a portion of the Platte River during the Fall of 1967. If indeed this process requires a longer time period, the food supply will remain below normal levels during the peak growing and feeding periods of trout. Taube (1975) reports that the reduction of benthic organisms is responsible for reduced reproduction in brown trout although no noticeable effect on older trout can be seen. If reproduction is slowed and the trend is for survival of older trout, a change in the population structure is imminent.

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