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FIRST-YEAR RESPONSES OF A STREAM AND ITS BROOK TROUT POPULATION TO HINGE-CUTTING OF RIPARIAN BRUSH

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Mark Muir Ultis

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William W. Taylor
Major professor

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FIRST-YEAR RESPONSES OF A STREAM AND ITS BROOK TROUT POPULATION TO HINGE-CUTTING OF RIPARIAN BRUSH

By

Mark Muir Ultis

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ABSTRACT

FIRST-YEAR RESPONSES OF A STREAM AND ITS BROOK TROUT POPULATION TO HINGE-CUTTING OF RIPARIAN BRUSH

By

Mark Muir Ultis

Changes in brook trout (*Salvelinus fontinalis*) abundance and stream channel morphology were investigated after the addition of overhead bank cover in the summer of 1980 by hinge-cutting riparian brush along the Salmon Trout River, Marquette County, Michigan. Within the following year, the trout population declined abruptly over the entire study area (decreases of 21% in numbers, 38% in biomass). However, trout abundance within five treated sections in the study area remained relatively constant (no change in numbers, decrease of 11% in biomass). Changes in stream channel morphology included an 8% decrease in width, 5% increase in depth, 20% increase in water velocity, and 121% increase in overhead bank cover within the treated sections. The study suggests that hinge-cutting of riparian brush may be an economical method of cover creation for streams with suitable bank vegetation.

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INTRODUCTION

Trout habitat management can be divided into four general areas: habitat protection, restoration, enhancement, and maintenance. The first, habitat protection, involves preventing activities which damage streams or their drainage basins. This may entail such practices as fencing streambanks in pastures to decrease damage from grazing, preventing channel modifications such as snagging, clearing, and ditching and controlling sources of pollution, including sedimentation from agriculture and other human activities. Restoration consists largely of repairing the effects of damaging activities which were not prevented. Habitat enhancement is the creation of more suitable habitat than would naturally occur. This may be in relatively undamaged streams leading to a "hyperhabitat," or may be used in stream sections lying near the end of natural suitability for salmonids. Habitat maintenance is the continuing upkeep of previous management endeavors to prevent a return to the prior conditions. This is most critical in cases of hyperhabitat where the stream will eventually return to a less productive state without periodic inputs of energy and materials.

State and federal programs of trout stream improvement had begun by the 1930's (Hubbs et al. 1932), however, little evaluation of the effects on trout populations were possible until accurate methods of estimating trout abundance by electrofishing were developed in the 1950's (White 1975). One method of habitat management, used in both restoration and enhancement, is the construction of current deflectors and bank covers. The primary purposes of these devices are to increase the depth of the channel and to increase the amount of usable bank cover. The importance of increased channel depth to stream salmonids is that more living space is available. An increase in the number of suitable microhabitats in a given stream section may reduce agonistic behavior and allow higher population densities (Chapman 1966; Allen 1969). Many investigators have demonstrated the importance of bank cover in regulation of trout abundance. Trout populations declined following removal of brush cover from a Montana stream (Boussu 1954). Installation of bank covers and deflectors preceded increased trout abundance in several studies (Saunders and Smith 1962; Hale 1969, in White 1973; Hunt 1971; White 1975). The most comprehensive study of the effects of stream habitat improvement was done by Hunt (1971) on Lawrence Creek in Wisconsin. He found that by increasing the amount of available bank cover, the abundance of age II + trout increased dramatically within three years of the alterations. He proposed that the increase was due to greater overwinter survival afforded by the extra cover.

In 1976-77, the relationship between abundance of instream bank cover and abundance of brook trout was studied in two sections of the Salmon Trout River, Marquette County, Michigan (Enk 1977). The study showed that the variation in abundance of trout in 100 m stations was primarily due to variation in the amount of instream cover. It was hypothesized that addition of cover could allow the trout population to expand provided other environmental factors were favorable.

The present study was designed to test the effect of rapid cover creation on trout abundance, and on the physical characteristics of the stream channel in the Salmon Trout River. The method of cover creation chosen was "hinge-cutting" of riparian brush. This involved sawing partially through the stems of streamside brush and folding the tops over into the water. This method is somewhat similar to the use of brush bundles for stream habitat improvement by the Wisconsin Department of Natural Resources but takes less time and effort to construct (R. J. White, pers. comm.). Hinge-cut cover usually comes in close proximity to the stream bed, which is thought to be most desirable as a position choice by trout (Bassett 1978).

Certain manipulations of streamside vegetation are regarded as useful in habitat management for trout (White and Brynildson 1967). Removal of trees and high brush to promote growth of grasses and low brush helps to stabilize banks and provide overhangs. Planting of trees is usually discouraged, except where stream temperatures are unusually high (White and Brynildson 1967). Recently, experiments were carried out to test the effect of complete brush removal on trout abundance and channel form in a number of Wisconsin streams (Hunt 1979). While disruption of fish populations due to stream flow variation confounded the results, it was concluded that removal of brush led to a larger stock of legal sized trout, owing to improved channel conformation.

The hinge-cutting technique of habitat alteration used in the present study is new, hopefully combining the beneficial effects of increasing overhead bank cover, narrowing and deepening of the channel, and removal of shade-producing brush to allow grasses to stabilize the banks. General objectives of this study were:

1) To determine the effect of rapid creation of cover by hinge-cutting riparian brush on the abundance of trout in selected treatment sections on the Salmon Trout River. It was hypothesized that the trout population would increase in response to cover creation, but that there would be a time lag in response such that the slopes of the relationships between trout abundance and cover abundance would decrease in the first years and then gradually increase in later years.

2) To determine the effect of hinge-cutting on channel form, flow, and substrate composition. It was hypothesized that the hinge-cutting would create a narrower, deeper channel, that water velocity would increase, and that fine streambed sediments would be eroded away, leaving more gravel and rubble exposed at the bed surface.

3) To evaluate riparian hinge-cutting as a practical habitat management technique.

STUDY AREA

The Salmon Trout River originates in the southeastern portion of Huron Mountains in Marquette County, Michigan (Figure 1). The stream flows northeastward about 20 km, with a gradient of 1.18 m km^{-1} until it enters Lake Superior (Hendrickson et al. 1973). The total drainage area is 9,790 hectares. The headwaters and central portion of the Salmon Trout flows primarily through northern hardwood forest, while the lower stream is located in a mixed coniferous-hardwood swamp (Enk 1977).

The river is divided by three major waterfall areas which restrict the movement of fish, and by two man-made dams. Lower Dam is within the study area, located about 1 km upstream from Sheet Rock Falls, and was built for flood control and to provide a sediment trap and fishing pond. The stop-logs were removed from this dam in the fall of 1978 to eliminate the impoundment of water in preparation for this study.

Most of the river is located within the boundaries of the Huron Mountain Club, and is isolated from public access, however, local residents and other non-club members are known to fish the Salmon Trout, after trespassing via such routes as hiking trails and logging roads.

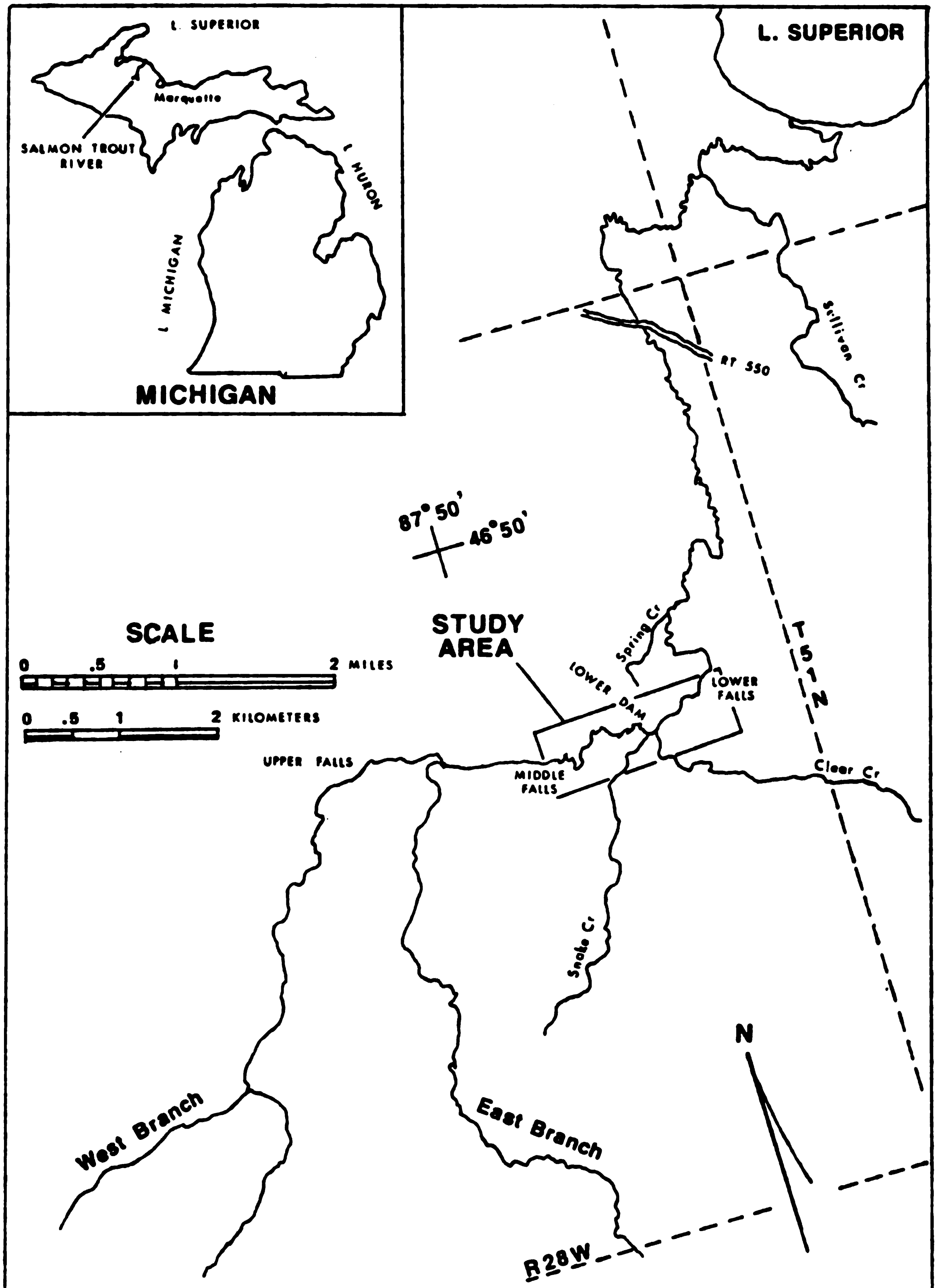


Figure 1. The Salmon Trout River.

Specific Location of Study Area

The study area extended from about 100 m above Sheet Rock Falls (part of the Lower Falls complex) to the base of Middle Falls, a total of 2.872 stream km (Figure 2). This portion of the river lies within sections 13 and 14 of Township 51 North, Range 28 West. The closest town is Big Bay (population: ca. 250), located about 9 km to the east.

Water Quality and Discharge

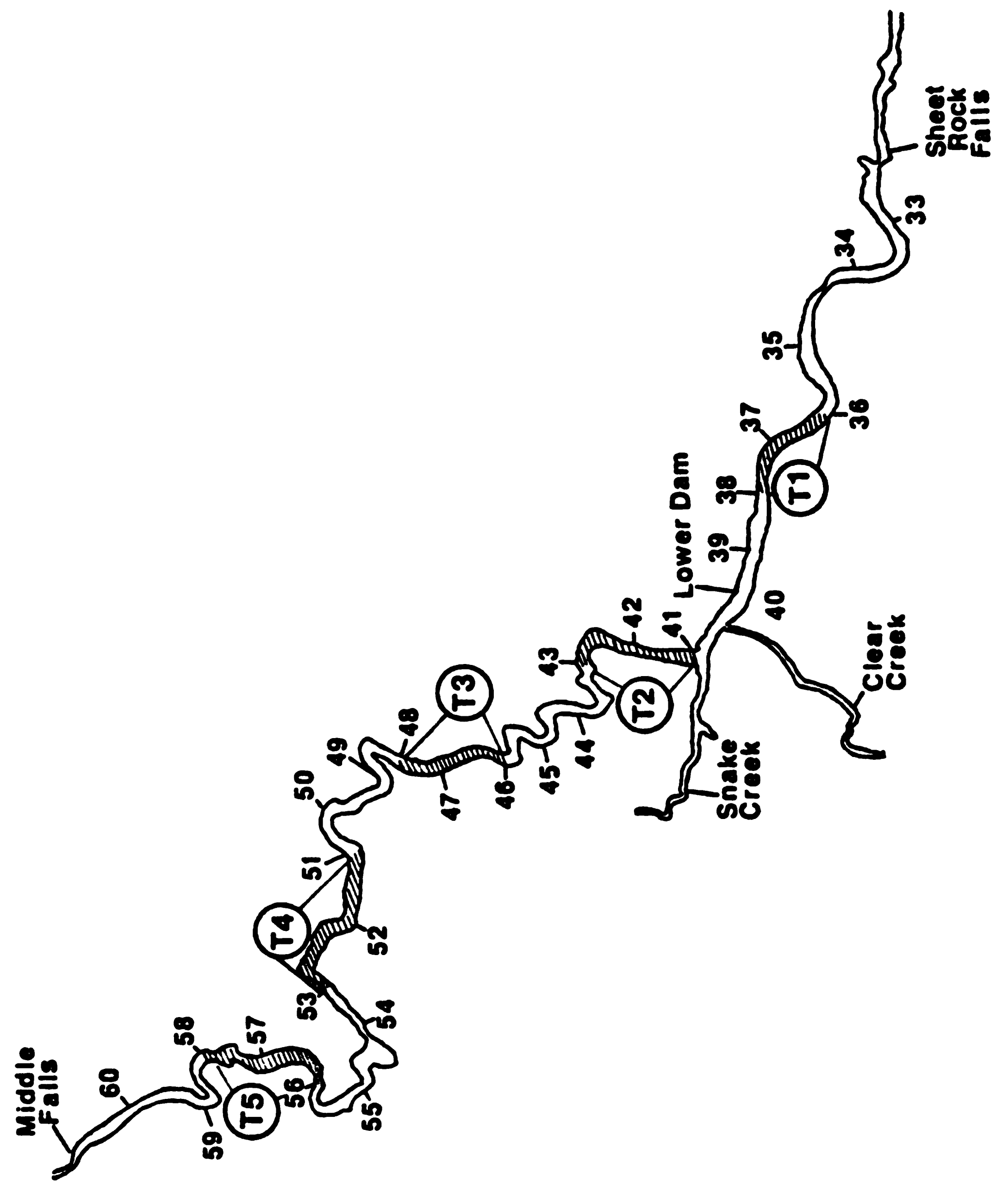
All river basins in the Upper Peninsula were glaciated, however, the glacial deposits were thin or absent in the area of the Salmon Trout. This has contributed to the highly variable streamflow, wide temperature fluctuations, and great floodflows found on the Salmon Trout. Mean discharge reported by Hendrickson et al. (1973) was 53 cfs in section 12, T 51 N, R 28 W. The ratio of 10 percent to 90 percent duration discharge was 1.86.

Hendrickson (1973) also reported that the hardness of the stream was 62 mg/l $CaCO_3$ and the pH about 7.6. The softness of the water is due to outcroppings of crystalline bedrock in the area, which allow little mineralization of runoff entering the river.

Bed Materials

The predominant bed materials vary within the study area. Below Lower Dam, gravel and rubble is abundant, intermixed with sand. Above the dam, sand and silt are predominant up to about station 50. These stations are in a meadow-like area and were formerly impounded

Figure 2. Salmon Trout River study area. Treatment sections are shaded. Control sections are unshaded.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Middle Falls

Figure 2.

by Lower Dam. From station 50 to Middle Falls, the amount of gravel increases and occasional patches of clay are present.

Biota

Aquatic macrophytes are scarce within the study area, presumably due to frequent flooding and sand substrates. Occasional patches of *Potamageton* sp. were present on silt flats below Lower Dam.

Previous work on benthic invertebrates in the Salmon Trout (Smith 1941) found a standing crop of 7.5 cc/m^2 for rubble stream bed and an average of about 6 cc/m^2 for all stream bed types in the unimpounded sections of the current study area. This was low compared to other streams cited by Smith and was also attributed to severe flooding, shifting sand bottom, and poor fertility of the water. In the spring of 1981, a study was undertaken in conjunction with this research to investigate the effects of hinge-cutting on macroinvertebrate abundance and biomass (Dr. R. Merritt, Dept. of Entomology, MSU). Bottom samples in untreated sections revealed a biomass of 12.3 mg dry wt/m^2 in May and 45.6 mg dry wt/m^2 in July. Differences between untreated and experimental sections following hinge-cutting are discussed in the results.

Within the study area, brook trout (*Salvelinus fontinalis*) are the most abundant fish species in both numbers and biomass as determined by electrofishing. Other species present include slimy sculpins (*Cottus cognatus*), creek chubs (*Semotilus atromaculatus*), and dace (*Rhinicthys* sp.). The Huron Mountain Club stocks legal size brook trout (> 200 mm) annually within the study area. Occasionally, rainbow trout (*Salmo gairdneri*) have been stocked.

All stocked brook trout are given fin-clips to differentiate them from wild trout for population estimates (see Table A3 for specific fin-clips). Fishing pressure could be considered light, due to the limited access, and catch and release fly-fishing has been required for club members between Lower Dam and Middle Falls (about 60 percent of the study area) since 1975.

METHODS

Twenty-seven stations, each about 100 m long, were selected for use as experimental and control sections to test the brook trout population response and changes in channel form and flow due to hinge-cutting of riparian brush. The study area corresponds to stations 34-60 as designated by Enk (1977). Five experimental sections, each composed of two stations, were chosen along the study area to provide maximum spacing between treatments (Figure 2). The remaining sections were designated control sections and were either two or three stations in length.

Population Estimates

Mark-and-recapture electrofishing was done in spring and fall to estimate brook trout abundance beginning in the fall of 1979 and continuing through the spring of 1981. Two shocking runs were made for each estimate.

The electrofishing unit consisted of a wood and styrofoam boat which carried a gasoline-powered 100-600-volt DC "generator," formed by an AC alternator with rectification to DC. Three handheld positive electrodes were connected to the generator through spring-loaded retracting reels mounted on the front of the boat. Each electrode was a fiberglass handle with a head of stainless steel rod bent into a diamond-shaped loop about 30 cm long. The cathode was a sheet of galvanized steel covering the bottom of the boat. A live tub for holding captured fish was carried on the boat, and nets within the tub separated fish from different stations.

The electrofishing procedure was composed of one crew member pulling the boat upstream and shocking the mid-channel, while two other men covered the area along each stream bank. Often, all three men would converge on large pieces of cover such as log jams, undercut banks, and brush piles. Fish drawn to the electrodes were netted and transferred to the live tubs. After a number of stations were shocked, the live tub was dropped off, and another crew would process the catch.

During processing, the fish were anesthetized with tricaine methane sulfonate (MS-222), measured for length, weighed, and examined for prior fin-clips. On the first shocking run, all fish captured were given a temporary clip along the bottom of the caudal fin. After processing, the fish were placed in fresh water until revived, then carried back to the downstream end of the station in which they were captured, and released. This enabled the fish to redistribute normally for the recapture run. At least two days were allowed to elapse between shocking runs to enable the fish to recover and redistribute. On the second shocking run, fish were examined for first run marking clips, and recorded as either marked or unmarked. Unmarked fish were measured for length, and weighed, while recaptures were only measured for length. Each shocking run required at least a day and one-half of electrofishing. When processing the fish of the recapture run, the upper tip of the caudal fin was clipped to prevent double-counting of fish that might swim upstream past the shocking team's position overnight.

Shocking dates on the Salmon Trout River are given in Table A2 in the appendices. During the fall shocking periods, young of the year trout captured were given specific permanent fin-clips to facilitate future recognition of the year-classes for growth studies (Table A3).

Calculation of Population Estimates

Trout population estimates were calculated using a modified Petersen method given in Seber (1973):

$$\hat{N} = \frac{(m+1)\ (r+u+1)}{(r+1)} - 1$$

where,

$\hat{N}$ = estimated population

m = number of marked fish

r = number of recaptures

u = number of unmarked fish in second run

When r/r + u > 0.1 the $\hat{N}$ is asymptotically normally distributed, and 95 percent confidence intervals are given by:

$$\hat{N} \pm 1.96\ \sqrt{V}$$

where,

$$V = \frac{(m+1)(r+u+1)(m-r)(u)}{(r+1)^2\ (r+2)}$$

When r/r + u > 0.1 and r/m < 0.1, the Poisson approximation is recommended using r as the entering variable into the tables (Chapman 1948). The upper and lower confidence limits are given by:

$$LC,\ UC = (m)(r+u)(x_{1,2})$$

where,

x_1 = lower limit given by table

x_2 = upper limit given by table

LC, UC = lower and upper confidence limits

Estimates were made for different length groups of trout, due to the size selectivity of electrofishing gear (Cooper and Lagler 1956). Efficiency of capture tends to increase as fish size increases. Separate estimates were made for fish of each 25 mm length interval beginning with $\leq$ 100 mm, continuing up to > 200 mm. Due to great variability of recapture rates for the individual 100-m stations, probably a result of movement of marked fish across station boundaries, population estimates for the entire study were calculated for each size group. These estimates were then prorated back to individual stations by the proportion of marked and unmarked fish ("new fish") captured in that station relative to the total number of marked and unmarked fish in the entire study area. This method of combining the data and then prorating total estimates is more accurate than individual estimates because it allows the use of larger units in the estimations, particularly the number of recaptures, upon which the method is based (Cooper 1952).

Brook trout biomass estimates were calculated by multiplying the average weight of the fish in each station by the estimated population in each size class. Numbers and biomass estimates for each station were converted to stock density (no/km) and standing crop (gm/m) according to actual station lengths.

Habitat Studies

Eighteen discharge measurements were made throughout the summer of 1980 by the transect method, measuring current velocity and water depth every 0.3 m across the stream channel. A staff gauge was installed on the upstream face of Lower Dam to allow quick reference to water levels before habitat measurements. These staff gauge readings were converted to discharge estimates by regression analysis using actual discharge measurements. Habitat measurements were made at baseflow (~0.85 cms) to decrease error caused by water level fluctuations, and because correlations between trout abundance and cover would be most meaningful when cover is at a minimum (Cooper and Wesche 1976).

Pre-alteration measurements of channel width, depth, and current velocity at the thalweg were made at baseflows during June and July, 1980, and post-alteration measurements were made in June, 1981. These measurements were made on transects spaced 10 m apart, beginning at the downstream end of each station. Current velocity was determined using a Swoffer Model 2000 current meter. Substrate type on each transect was determined by visual estimate and recorded as percent composition. Approximate size classes of the substrate types are as follows: Rock, > 8 cm; Gravel, 0.5 - 8 cm; Sand, < 0.5 cm; Silt, any fine organic matter.

Measurements of overhead bank cover (submerged or at the water surface) in each station were made by determining the length of cover that was at least 9 cm wide and had at least 15 cm of water beneath it. These criteria for usable bank cover were adapted from Wesche (1976) as was done by Enk (1977) in previous work on the Salmon Trout River.

It has subsequently been clarified that Wesche's criteria for cover were somewhat different: at least 9 cm wide and in water at least 15 cm deep (R. J. White, pers. comm. 1984). A special gauge was constructed to facilitate determination of the length of cover (Enk 1977). The gauge was inserted in the water beside potential bank cover and the length of cover which it fit along the stream bank was recorded. Individual sections of cover less than 15 cm long were not recorded, and no attempt was made to measure the width of cover greater than 9 cm wide. Length of overhead cover is more important than area, as trout tend to position themselves near the edges of coverts (Gibson and Keenleyside 1966).

Drift Sampling

Drift samples were taken in a number of stations during August, 1980 to determine if there were differences in macroinvertebrate abundance between control and treatment sections. Drift nets were set for varying amounts of time, ranging from 4 to 24 hours, over either sand or gravel substrate. The nets were set in pairs, one at the lower (downstream) end of a control section, and one at the lower end of the adjoining downstream treatment section. Each site was sampled for a total of 24 hours. Current velocity was measured to estimate the amount of water filtered through the nets. Samples were preserved in 70 percent ethanol, and later identified to order, blotted dry, and weighed to determine biomass of each group represented.

Habitat Alteration

After initial measurements of channel form and flow characteristics were completed, hinge-cutting of riparian brush was begun in the treatment sections. The hinge-cutting involved sawing partially through the stems of the brush, and folding it into the water at a downstream angle. The brush remains in place, held by the strip of wood and bark left uncut. Alders (*Alnus* sp.) were the most prominent streamside vegetation, and grew in thick clumps along most of the bank from stations 41-58. The hinge-cutting was done using small bow saws, and most of the brush which could reach the stream when felled was cut.

Statistical Analysis

Using the estimates for brook trout stock density and standing crop, and the measurements of overhead bank cover, the relationships between these variables were analyzed using simple regression techniques. Correlation coefficients were tested for significance using a t-test given by Gill (1978). The response of the brook trout population to the increased cover provided by the hinge-cutting was analyzed using paired t-tests, comparing stock density and standing crop of the same sections between years, and comparing stock density and standing crop of paired treatment and control sections in the same season and year.

Channel form and flow characteristics are presented as percentage change from before and after habitat alteration. Regression analyses and paired t-tests were performed using the SPSS Version 8.0 statistical package available through the MSU Computer Laboratory.

RESULTS AND DISCUSSION

Trout Population

Over the four electrofishing periods, fall 1979-spring 1981, the population density of brook trout declined slightly between seasons, however, biomass levels stayed fairly constant until spring 1981 when a sharp decline occurred (Tables 1-3, Figure 3). Natural fluctuations in wild trout populations are common, often caused by weak year-classes due to unfavorable climatic conditions (severe floods, drought, ice; White 1975). Recruitment of age-0 trout into the stock over the summer accounts for the larger total numbers present between each spring and the next fall. Trout of 126-175 mm comprised the greatest portion of the total biomass in all seasons (Tables A5-A12).

The sections directly above Lower Dam (T2, C3) had lower stock density and standing crop of brook trout both before and after hinge-cutting, than those sections below the dam and those farther upstream (Tables 1-3). These sections were fairly shallow with relatively large amounts of sand bottom and relatively little cover. In contrast, those stations below the dam were also shallow, but had more cover available in the form of log jams, undercut banks, and instream rubble. The coarser substrate would also be more favorable for aquatic invertebrate production than the shifting sand flats found above the dam (Hynes 1970). Farther upstream

Table 1. Stock density (no/km) and standing crop (g/m) estimates for brook trout (all sizes) in control and treatment sections of the Salmon Trout River over four sampling periods.

Section number	Fall 1979 (no/km)	Fall 1979 (g/m)	Spring 1980 (no/km)	Spring 1980 (g/m)	Fall 1980 (no/km)	Fall 1980 (g/m)	Spring 1981 (no/km)	Spring 1981 (g/m)	% change in numbers spring 1980 to spring 1981	% change in biomass spring 1980 to spring 1981
C1	1044	12.3	446	15.5	1047	21.9	363	7.9	-19	-49
C2	842	10.5	540	17.0	1835	26.1	685	12.8	+27	-25
C3	610	14.5	608	20.5	442	14.0	199	4.3	-67	-79
C4	1030	17.4	570	12.4	436	9.0	217	6.0	-62	-52
C5	1783	23.8	690	17.5	622	12.2	382	7.1	-45	-59
C6	1578	25.9	745	13.6	1302	18.1	650	10.8	-13	-21
Control means	1109	16.8	589	16.3	911	16.7	395	7.9	-33	-52
T1	1390	18.3	325	8.1	1535	22.2	480	8.7	+48	+7
T2	498	7.2	224	2.7	565	12.5	206	4.1	-8	+52
T3	816	15.6	914	24.1	613	18.2	558	15.6	-39	-35
T4	1043	16.9	506	11.7	528	15.0	661	14.5	+31	+24
T5	1658	24.0	650	16.6	1061	21.7	687	11.9	+6	-28
Treatment means	1066	16.2	514	12.3	830	17.7	516	10.9	+0	-11
Grand means	1092	16.6	560	14.7	879	17.1	443	9.1	-21	-38

Table 2. Stock density (no/km) and standing crop (g/m) estimates for brook trout less than 150 mm long in control and treatment sections of the Salmon Trout River over four sampling periods.

Section number	Fall 1979 (no/km)	Fall 1979 (g/m)	Spring 1980 (no/km)	Spring 1980 (g/m)	Fall 1980 (no/km)	Fall 1980 (g/m)	Spring 1981 (no/km)	Spring 1981 (g/m)	% change in numbers spring 1980 to spring 1981	% change in biomass spring 1980 to spring 1981
C1	895	5.3	321	6.4	814	9.0	305	4.1	-5	-36
C2	730	4.6	409	7.3	1592	14.2	615	7.3	+50	0
C3	468	5.2	385	5.6	332	4.6	155	1.8	-60	-68
C4	857	8.3	463	6.6	358	4.3	156	2.7	-66	-59
C5	1566	14.8	525	8.7	500	6.7	312	3.9	-41	-55
C6	1356	14.3	628	8.3	1189	12.8	553	6.9	-12	-17
Control means	943	8.3	443	7.0	759	8.2	331	4.2	-25	-40
T1	1203	8.4	273	4.5	1330	11.6	449	6.7	+64	+49
T2	420	3.5	216	2.9	465	5.2	182	2.7	-16	-7
T3	641	6.7	710	10.2	437	7.0	404	6.8	-43	-33
T4	913	9.7	423	6.5	347	7.0	531	8.5	+26	+31
T5	1424	12.6	488	7.4	905	11.6	604	8.4	+24	+14
Treatment means	908	8.1	416	6.2	668	8.2	433	6.6	+4	+6
Grand means	929	8.2	432	6.6	724	8.2	371	5.1	-14	-23

Table 3. Stock density (no/km) and standing crop (g/m) estimates for brook trout greater than 150 mm long in control and treatment sections of the Salmon Trout River over four sampling periods.

Section number	Fall 1979 (no/km)	Fall 1979 (g/m)	Spring 1980 (no/km)	Spring 1980 (g/m)	Fall 1980 (no/km)	Fall 1980 (g/m)	Spring 1981 (no/km)	Spring 1981 (g/m)	% change in numbers spring 1980 to spring 1981	% change in biomass spring 1980 to spring 1981
C1	149	7.0	124	9.2	232	12.9	58	3.8	-53	-59
C2	112	5.9	131	9.7	243	12.0	70	5.4	-47	-44
C3	142	9.2	223	14.9	110	9.3	44	2.5	-80	-83
C4	173	9.1	107	5.8	78	4.6	61	3.3	-43	-43
C5	216	8.9	165	8.8	122	5.5	69	3.2	-58	-64
C6	222	11.6	117	5.3	113	5.3	98	3.9	-16	-26
Control means	165	8.4	147	9.1	151	8.4	64	3.7	-56	-59
T1	186	9.9	52	3.6	205	10.6	31	2.0	-40	-44
T2	78	3.7	8	0.4	100	7.2	23	1.4	+188	+250
T3	174	8.9	204	13.9	177	11.3	153	8.8	-25	-37
T4	130	7.2	83	5.2	182	9.8	130	6.0	+57	+15
T5	234	11.4	162	9.2	156	10.1	83	3.5	-49	-62
Treatment means	157	8.1	99	6.3	161	9.7	84	4.3	-15	-32
Grand means	162	8.3	128	8.0	155	8.9	72	3.9	-44	-51

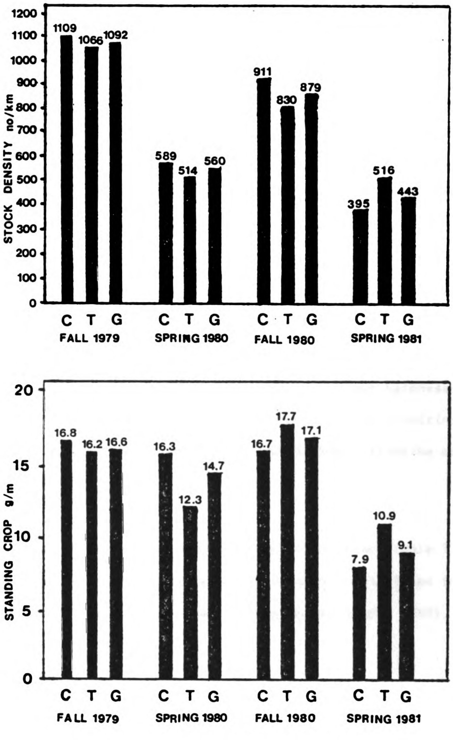

Figure 3. Mean stock density and standing crop estimates for control (C) and treatment (T) sections and grand averages (G) for entire study area over four sampling periods.

(sections C4-C6, T3-T5) depth and substrate size increases, and more cover is available (Tables 4 and 5).

Fall standing crops in the study area are considerably lower than in other Michigan streams that have been studied (Table 6). The other streams are in the northern lower peninsula where flow regimes are more stable than in the upper peninsula, due to sandy soils with high infiltration rates and groundwater recharge, and where the concentration of plant nutrients in the water and in riparian soils is probably greater. Hunt Creek, the only stream listed besides the Salmon Trout River containing exclusively brook trout, had over twice the average fall standing crop of that estimated for the Salmon Trout River. The remainder of the streams had mixed-species populations of trout, and their trout standing crops ranged from about one-and-a-half to over four times that in the Salmon Trout River. More variable flow, lower hardness, greater sparcity of overhead cover, and more severe winter conditions in the Salmon Trout may account for the relatively small standing crop.

Trout Growth

Growth in length and weight of marked year-class fish (Table 7) in the Salmon Trout River were approximately equal to those found for brook trout in lower peninsula streams (Gowing and Alexander 1980).

Habitat

While there was a general decrease in channel width throughout the study area, it was twice as great in the treatment sections as in the controls (Tables 4 and 5). The greater stream width decrease in the

Table 4. Physical characteristics of 10 treatment stations* before (1980) and after (1981) hinge-cutting of riparian brush in the Salmon Trout River, Marquette County, Michigan.

Station number	Avg. Width (m) pre	post	% change	Avg. Depth (m) pre	post	% change	Avg. Velocity (cm/s) pre	post	% change	Bank Cover (m) pre	post	% change
37	10.6	10.0	-5	.588	.523	-11	26.2	28.7	+9	13.1	25.9	+97
38	10.4	9.40	-10	.575	.545	-5	33.2	42.1	+27	14.2	38.1	+168
42	8.50	7.70	-9	.421	.492	+17	27.7	36.9	+33	2.3	21.5	+834
43	6.98	6.31	-10	.600	.701	+17	24.7	28.7	+16	13.4	80.6	+501
47	6.24	5.91	-5	.671	.762	+14	30.2	37.2	+23	31.9	75.7	+137
48	6.48	5.58	-15	.616	.747	+21	38.1	41.5	+9	18.0	45.9	+155
52	6.93	6.28	-9	.475	.561	+18	33.5	42.1	+26	14.9	56.1	+277
53	7.16	6.97	-3	.671	.665	-1	28.0	31.1	+10	48.8	38.9	-20
57	6.86	6.78	-1	.652	.625	-4	29.0	35.1	+21	30.0	34.3	+14
58	7.90	6.99	-12	.552	.469	-15	33.8	43.9	+29	27.4	54.6	+99
Average	7.80	7.20	-8	.582	.609	+5	30.5	36.7	+20	21.4	47.2	+121

*each station approximately 100 m long. Exact station lengths given in Table 8.

Table 5. Physical characteristics of 15 control stations* before (1980) and after (1981) hinge-cutting of riparian brush in the Salmon Trout River, Marquette County, Michigan.

Station number	Avg. Width (m) pre	Avg. Width (m) post	Avg. Width (m) % change	Avg. Depth (m) pre	Avg. Depth (m) post	Avg. Depth (m) % change	Avg. Velocity (cm/s) pre	Avg. Velocity (cm/s) post	Avg. Velocity (cm/s) % change	Bank Cover (m) pre	Bank Cover (m) post	Bank Cover (m) % change
34	13.0	12.6	-3	.747	.682	-9	20.1	20.7	+3	0.4	2.6	+550
35	12.3	11.2	-9	.533	.524	-1	36.6	41.1	+12	11.8	5.3	-55
36	12.4	12.2	-2	.491	.472	-4	27.7	26.5	-4	26.0	21.3	-18
39	13.6	13.6	0	.387	.310	-20	25.9	40.5	+56	16.0	12.5	-22
40	14.1	14.1	+0	.658	.541	-18	43.6	34.1	-22	15.7	18.1	+15
41	11.0	10.4	-5	.558	.565	+1	21.0	25.0	+19	1.0	3.0	+200
44	6.61	6.26	-5	.756	.742	-2	25.6	30.5	+19	24.4	15.2	-38
45	6.14	5.91	-4	.786	.797	+1	28.0	30.2	+8	28.4	24.5	-14
46	6.10	6.01	-1	.768	.736	-4	23.2	25.6	+10	23.3	17.2	-26
49	6.75	6.26	-7	.771	.629	-18	18.9	25.6	+35	18.6	23.8	+28
50	6.50	6.16	-5	.613	.570	-7	25.3	26.8	+6	21.2	16.3	-23
51	6.75	6.42	-5	.594	.599	+1	24.1	33.8	+40	18.3	11.7	-36
54	7.50	7.34	-2	.536	.457	-15	20.1	29.6	+47	12.0	3.0	-75
55	7.54	6.82	-10	.664	.594	-11	31.1	34.7	+12	22.9	18.9	-17
56	8.53	8.71	+2	.881	.665	-25	17.7	25.3	+43	26.7	13.0	-51
Average	9.25	8.93	-3	.650	.592	-9	25.9	30.0	+16	17.8	13.8	-22

*each station approximately 100 m long. Exact station lengths given in Table 8.

Table 6. Estimates of fall trout standing crop (kg/km) in the Salmon Trout River compared to average fall standing crop in some northern lower peninsula streams.

Stream	Year	Fall standing crop (kg/km)				Reference source*
		Brook	Brown	Rainbow	Total	
Salmon Trout	1979	165	-	-	165	1
	1980	166	-	-	166	1
Mainstream AuSable	1974-77	189	3321	153	3663	2
South Branch AuSable	1974-77	191	1265	-	1456	2
North Branch AuSable	1961-67	736	1616	-	2352	2
Pigeon	1961-64	285	126	-	411	2
Hunt Creek	1959-64	339	-	-	339	2
Williamsburg Creek	1975-76	39	974	5	1018	2

* 1 = This study
2 = Gowing and Alexander (1980)

Table 7. Average lengths (L), weights (W), and standard deviations of marked year-class brook trout in the Salmon Trout River, Marquette County, Michigan. Initial measurements taken on young-of-the-year when given the permanent finclip.

	Fall 1979		Spring 1980		Fall 1980		Spring 1981	
Finclip	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)	L (mm)	W (g)
ALV	86	5	112	18	152	35	154	36
	±3	±1	±8	±4	±13	±12	±11	±9
A	-	-	-	-	87	6	116	16
					±4	±1	±18	±10

treatment sections was due to deposition of silts among the hinge-cuts along the banks. This deposition of silt and sand was evident over the spring floods as some hinge-cuts were becoming buried along their outer margins.

Water depth increased 4.6 percent in the treatments, while decreasing 8.8 percent in the controls (Tables 4 and 5). All stations below Lower Dam decreased in water depth after hinge-cutting. Movement of sand from above the dam into sections below was obvious over the winter after cutting, and much of the sand was caught in the spaces between rocks and led to the decrease in depth. The five treatment stations (42, 43, 47, 48 and 52) closest above Lower Dam were the ones that had increases in depth (14-21 percent), as the stream carved a new channel through the previous pond bed.

Water velocity at the thalweg increased in both treatments and controls, 20 and 15 percent, respectively. The overall narrowing of the stream channel could account for some of the increase in velocity.

Hinge-cutting immediately increased the amount of cover in treatment stations by an average of 400 percent (160-2400 percent), but by a year later, much of the increase had disappeared, with only an average of 120 percent remaining by July, 1981 (Table 8). During the same year, bank cover decreased 18 percent in the controls. The decrease in the controls suggests that 1980-81 was a time of generally decreasing cover and demonstrates the temporary nature of overhead cover in streams which experience frequent high water. For example, a large area of sunken logs in station 40 had supplied a great length of overhead cover in previous studies and in the beginning of this study. These logs were moved to

Table 8. Length of stream bank meeting overhead cover criteria in the Salmon Trout River, Marquette County, Michigan.

Station number	Station length (m)	Length of overhead cover (m)			% change June-Aug. 1980	% change June 1980-June 1981
		June 1980	August 1980	June 1981		
34	105	0.4	--	2.6	--	--
35	110	11.8	--	5.3	--	--
36	95	26.0	--	21.3	--	--
37	100	13.1	91.9	25.9	+602	+98
38	92	14.2	105.5	38.1	+643	+168
39	99	16.0	--	12.5	--	--
40	80	15.7	--	18.1	--	--
41	116	1.0	--	3.0	--	--
42	119	2.3	58.4	21.5	+2439	+835
43	130	13.4	124.1	80.6	+826	+501
44	105	24.4	--	15.2	--	--
45	110	28.4	--	24.5	--	--
46	119	23.3	--	17.2	--	--
47	103	31.9	125.0	75.7	+292	+137
48	98	18.0	114.6	45.9	+537	+155
49	108	18.6	--	23.8	--	--
50	100	21.2	--	16.3	--	--
51	108	18.3	--	11.7	--	--
52	102	14.9	128.6	56.1	+763	+276
53	159	48.8	125.4	38.9	+157	-20
54	81	12.0	--	3.0	--	--
55	116	22.9	--	18.9	--	--
56	90	26.7	--	13.0	--	--
57	130	30.0	93.9	34.3	+213	+14
58	98	27.0	91.9	54.6	+240	+102
59	95	38.5	--	38.5	--	--
60	100	29.9	--	29.9	--	--
Totals for treatments		213.6	1059.3	471.6	+396	+121
Totals for controls		335.1	--	274.8	--	-18

higher ground by spring 1981 flood waters, reducing the amount of available cover, however total overhead cover within the station increased as new lengths were created.

Streambed Material

Following hinge-cutting, treated sections generally underwent significant decreases in amount of streambed sand and concurrent increases in amount of gravel, rock and silt (Table 9). The most important changes in streambed materials after hinge-cutting were in the amount of rock and sand below and above the dam (Table 9). Rock decreased slightly below the dam (C1, C2, T1) while increasing greatly (68-470 percent) in all sections above the dam. Changes in amount of sand were opposite of the changes in rock, with all sections below the dam increasing in sand. The combined effect of opening the dam in fall 1978, with the last stop log removed in spring 1980, and of hinge-cutting was to move sand from above the dam into (and through) the sections below the dam. The density of hinge-cuts was lower below the dam than above, due to higher banks and less streamside brush, so the scouring effect may not have been as great there. Rates of movement of sand into and through the downstream sections was probably still changing at the end of the study, and I expect the amount of sand streambed to decrease in later years.

Silt increased in sections T2-T4 where hinge-cuts were fairly dense. Silt deposited due to slowing of current under felled brush at the stream margins. No trends in silt deposition were detected in the control sections.

Table 9. Substrate composition (%) in control and treatment sections before and after hinge-cutting of riparian brush along the Salmon Trout River, Marquette County, Michigan.

Section number	Rock before	Rock after	Rock % change	Gravel before	Gravel after	Gravel % change	Sand before	Sand after	Sand % change	Silt before	Silt after	Silt % change
						Control Sections						
C1	59.5	53.8	-9.6	12.8	8.2	-36	23.7	32.6	+38	4.1	5.5	+34
C2	53.5	33.9	-37	2.7	2.9	+7.4	34.9	53.4	+53	8.9	9.8	+10
Down-stream averages	56.7	44.1	-22	7.9	5.6	-29	29.1	42.7	+47	6.4	7.6	+19
C3	2.1	6.6	+214	6.4	9.3	+45	81.0	76.5	-5.6	6.0	4.8	-20
C4	1.2	6.8	+467	7.6	6.1	-20	83.6	82.0	-1.9	7.0	4.4	-37
C5	1.9	3.2	+68	15.5	18.0	+16	73.1	66.3	-9.3	7.2	8.0	+11
Upstream averages	1.7	5.6	+222	9.7	11.0	+14	79.4	75.2	-5.3	6.7	5.7	-16
						Treatment Sections						
T1	56.0	41.1	-27	10.5	7.3	-30	16.8	42.3	+152	15.3	9.5	-37
T2	12.3	27.5	+124	2.7	10.1	+274	83.7	48.7	-42	1.4	13.8	+886
T3	0.0	1.5	+∞	4.4	9.0	+105	95.3	76.0	-20	0.0	12.5	+∞
T4	1.1	5.3	+382	16.8	21.7	+29	80.1	62.8	-22	2.0	9.7	+385
T5	5.6	13.1	+134	52.8	53.9	+2.1	32.6	24.7	-24	9.1	8.4	-7.7
Upstream averages	4.9	12.3	+149	19.1	23.7	+24	72.8	52.7	-28	3.1	11.1	+253

I conclude that narrowing of the channel due to hinge-cutting led to scouring of sand, uncovering of rocks and gravel, and deposition of silts along the stream margin. The increases in substrate size in treatment sections can lead to a more diverse invertebrate fauna (Hynes 1970), and increase the amount of suitable spawning areas for trout. Hunt (1971) also found that constricting the streamflow led to considerable scouring away of fine sediments in Lawrence Creek, Wisconsin, a stream with predominantly sand-silt bottom.

Trout Population - Bank Cover Relationships

Correlations between trout abundance and cover density were significant for most population parameters prior to hinge-cutting, the exceptions being those stations below Lower Dam (Tables 10 and 11). After hinge-cutting in the summer of 1980, correlations declined for all stations combined and for those stations above Lower Dam. This was the anticipated immediate result as cover ratings increased abruptly, while the trout population had insufficient time to adjust to the changes.

Enk (1977) had also found that stations below Lower Dam had poor correlations between trout abundance and cover. One possible explanation for the weak correlations is the method used to quantify usable cover. This study was concerned with bank cover that had 15 cm or more of water beneath it, which may have been relatively rare and applicable only to larger fish, and overlooked the rather small-sized but perhaps numerous bits of cover provided by instream rubble. The stream sections below Lower Dam are wide and predominantly riffles, so any estimate

Table 10. Correlation coefficients (r) and coefficients of determination (r^2) for trout standing crop (Y) and cover density (x) in the Salmon Trout River.

Standing crop (g/m)	Fall 1979		Spring 1980		Fall 1980		Spring 1981	
	r	r^2	r	r^2	r	r^2	r	r^2
All sizes- all stations	.718**	.515	.453*	.205	.210	.044	.465**	.216
All sizes- above dam	.756**	.571	.577**	.333	.413	.171	.744**	.554
All sizes- below dam	.117	.014	.035	.001	.725	.526	.094	.009
≤150mm- all stations	.683**	.466	.632**	.399	.319	.102	.433*	.188
≤150- above dam	.704**	.495	.692**	.478	.544*	.296	.642**	.413
≤150mm- below dam	.187	.035	.545	.297	.727	.528	.362	.131
>150mm- all stations	.610**	.372	.259	.067	.057	.003	.406*	.164
>150mm- above dam	.622**	.438	.401	.161	.167	.028	.678**	.460
>150mm- below dam	.043	.002	.245	.060	.570	.325	.242	.059

*indicates significance at 5% level
**indicates significance at 1% level

Table 11. Correlation coefficients (r) and coefficients of determination (r^2) for trout population density (Y) and cover density (x) in the Salmon Trout River.

Stock density (no/km)	Fall 1979		Spring 1980		Fall 1980		Spring 1981	
	r	r^2	r	r^2	r	r^2	r	r^2
All sizes-all stations	.576**	.332	.668**	.447	.144	.021	.391*	.153
All sizes-above dam	.611**	.373	.723**	.522	.418	.175	.637**	.405
All sizes-below dam	.558	.311	.272	.074	.662	.438	.232	.054
≤150mm-all stations	.546**	.298	.664**	.441	.147	.022	.336	.113
≤150mm-above dam	.580**	.336	.687**	.472	.398	.158	.573**	.329
≤150mm-below dam	.567	.321	.428	.183	.617	.381	.284	.080
>150mm-all stations	.581**	.337	.412*	.170	.089	.008	.541**	.292
>150mm-above dam	.659**	.434	.516*	.267	.244	.059	.676**	.457
>150mm-below dam	.339	.115	.204	.042	.758*	.574	.274	.075

* indicates significance at the 5% level
**indicates significance at the 1% level

of the amount of usable cover was probably underestimated by measuring only large-sized bank cover. Above Lower Dam up to station 58, the stream is narrower with primarily sand bottom. Little cover is provided by instream rubble, leading to better estimates of usable cover by the methods employed.

In the fall of 1980 correlations for stations below Lower Dam were stronger as cover ratings had increased quickly (Tables 10 and 11), possibly compensating for the previous underestimation of usable cover. However, in the spring of 1981 the correlations had dropped to approximately the same levels as the spring of 1980. Sand scoured out of stations above Lower Dam filled in spaces between rocks which may have provided some cover. The loss of this cover may have contributed to the population decline in that part of the study area in the spring of 1981.

The slopes of the trout abundance - cover density regression lines, which would be the predicted increases in trout numbers or biomass with the addition of one meter of overhead cover within the observed cover-density range, decreased steadily from a high of 3.3 fish and 65.2 gm in the fall of 1979, to 0.6 fish and 14.4 gm in the spring of 1981 (Figures 4-7). An abrupt drop following hinge-cutting would be expected as the study area would be "cover-saturated." As the hinge-cut areas are thinned of excess cover, and the trout population expands to utilize the available living space, the slopes will begin to rise.

Comparison of Trout Populations between Treatments and Controls

Control sections showed no significant differences in trout populations between the fall of 1979 and the fall of 1980, but they had

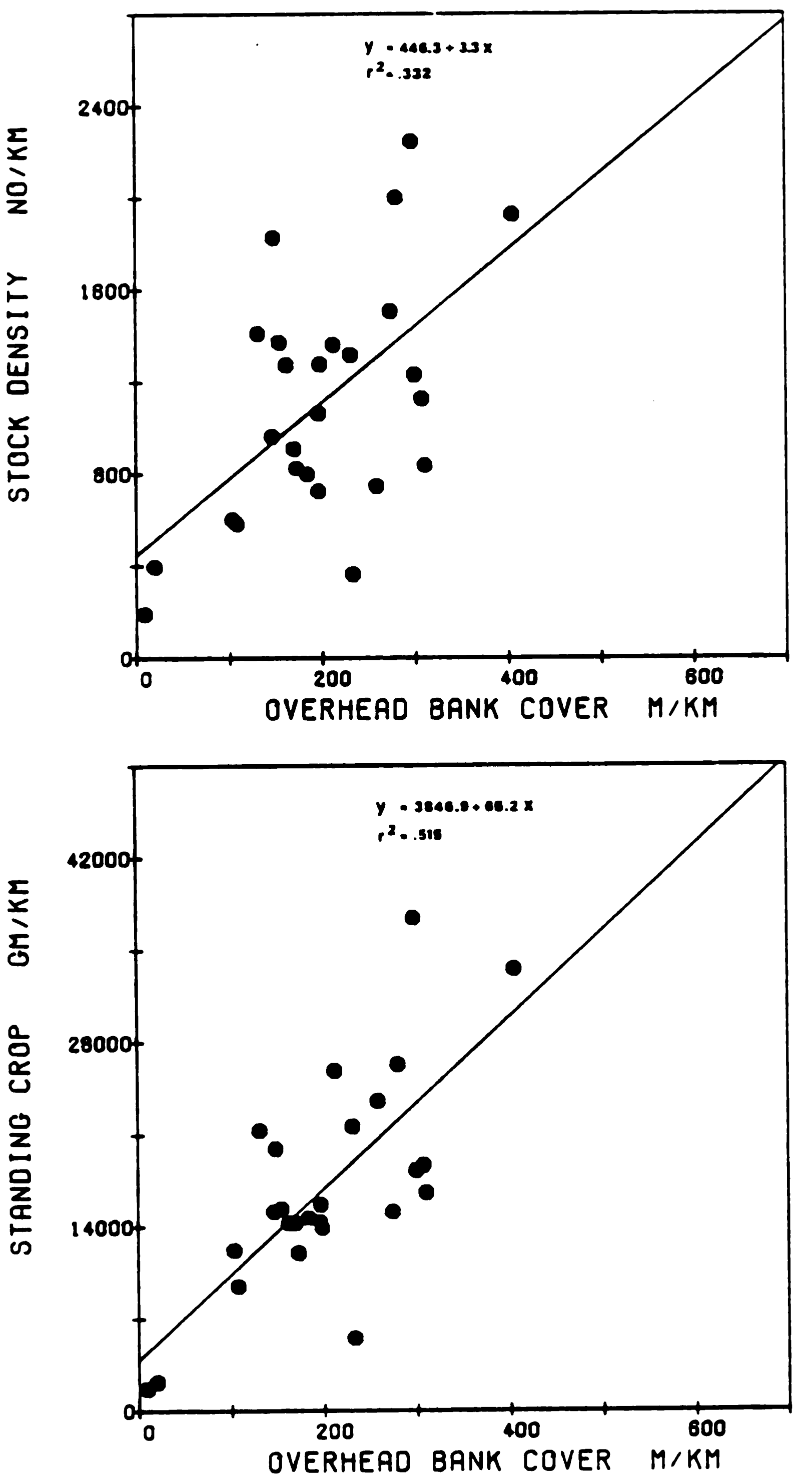

Figure 4. Relationship between stock density and standing crop with length of bank cover, September 1979.

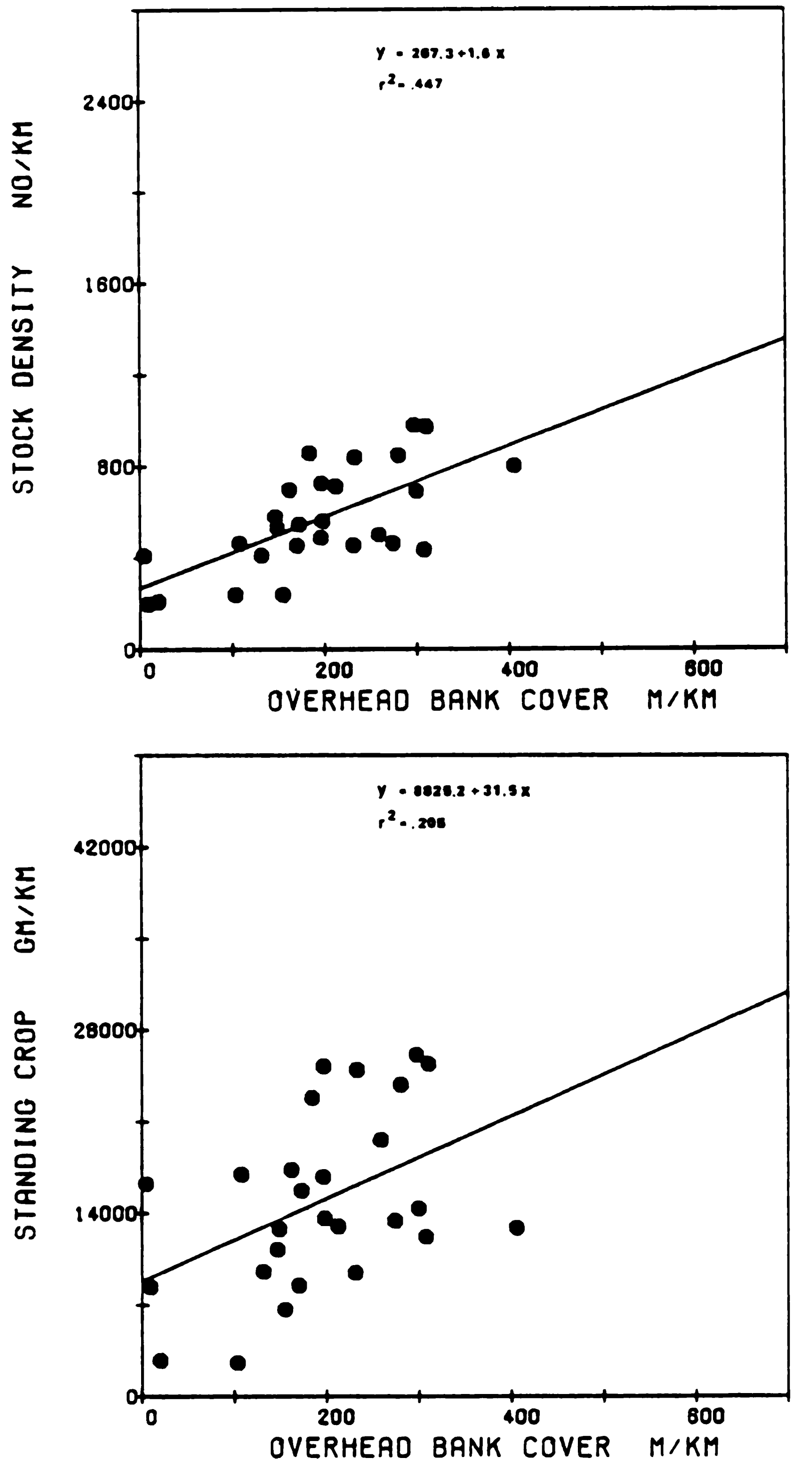

Figure 5. Relationship between stock density and standing crop with length of bank cover, June 1980.

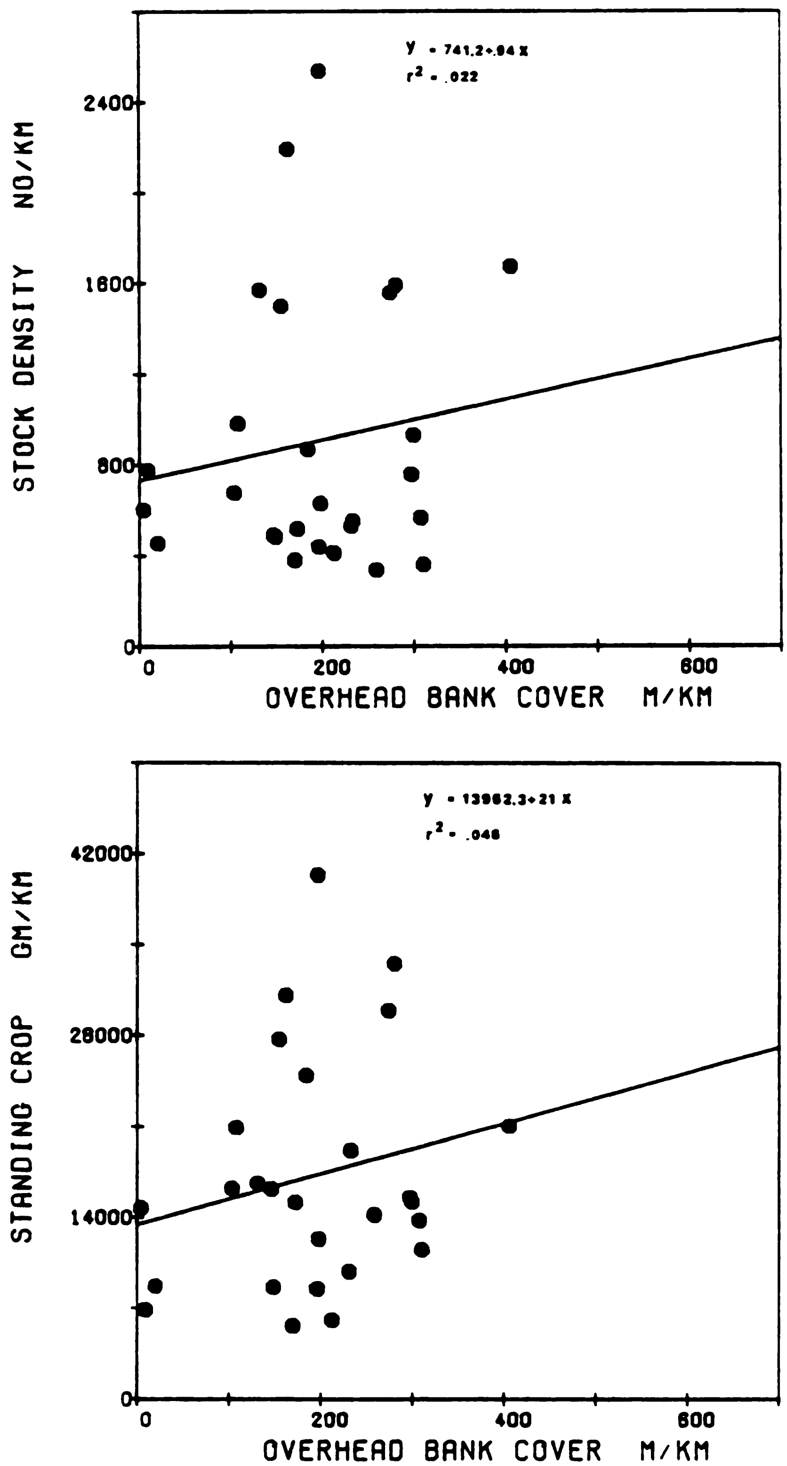

Figure 6. Relationship between stock density and standing crop with length of bank cover, September 1980.

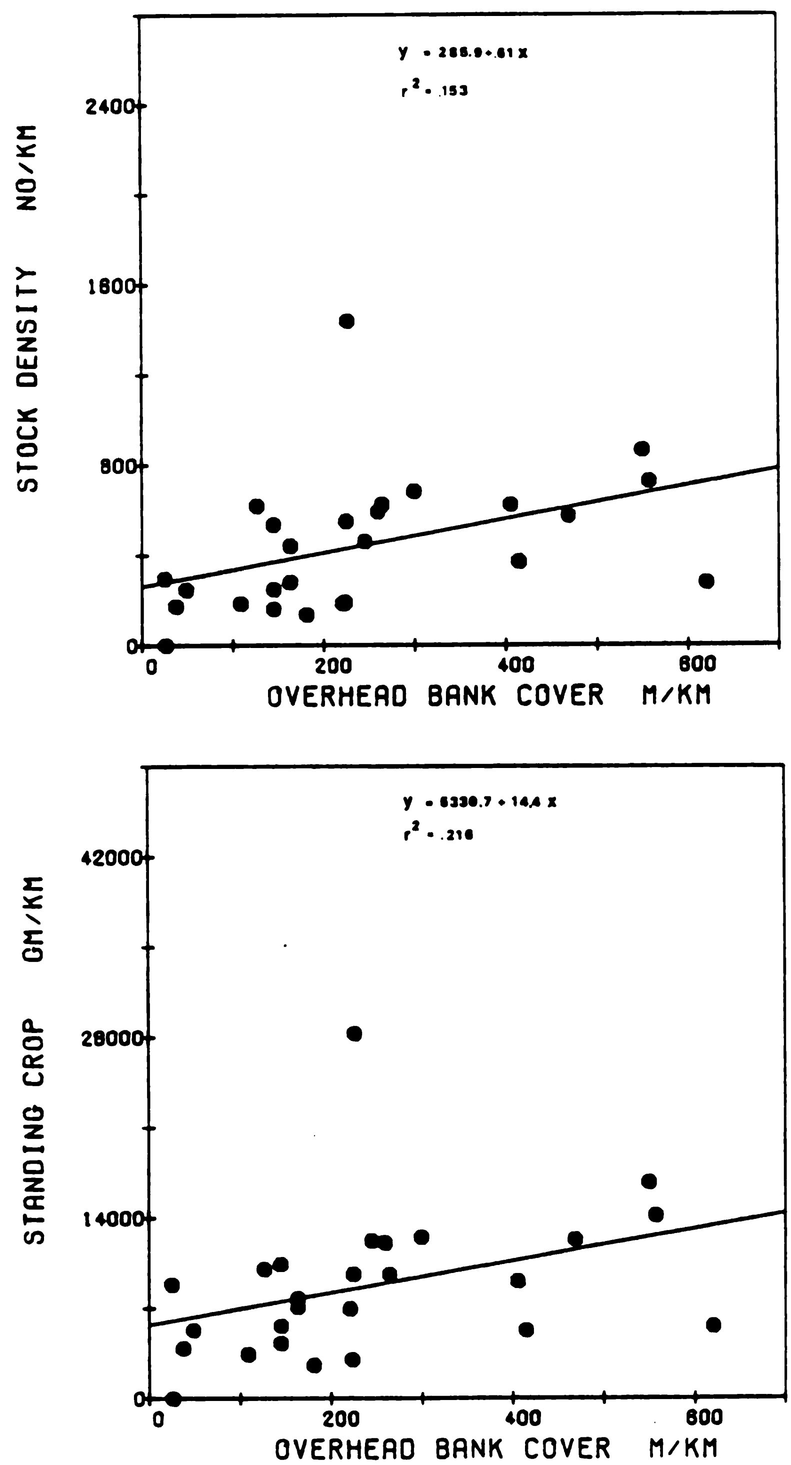

Figure 7. Relationship between stock density and standing crop with length of bank cover, May 1981.

significantly fewer trout in the spring of 1981 than in the spring of 1980 for all parameters with the exception of stock density of fish less than 150 mm long (Table 12). This was not the pattern for the treatment sections, as no significant differences were present between the spring of 1980 and the spring of 1981. Therefore, the decline in the trout population experienced between the fall of 1980 and the spring of 1981 was primarily within the control sections, while population levels within the treatment sections remained about the same. This may have been due to improvements in "space-refuge factors" (increased depth, more hiding cover, and increase food supply) within the treatment sections (Hunt 1969).

In comparing trout abundance between paired control and treatment sections, the only significant differences were found in the spring of 1980 when control sections had more fish greater than 150 mm in length than did their paired treatments (Table 13). After hinge-cutting no significant differences were detectable.

Invertebrate Drift

Total invertebrate drift rates (mg wet wt./1/day) were in all paired comparisons, higher in the control section than in its immediate downstream treatment section (Table 14). A possible explanation for this could be that the newly uncovered hard streambed materials and the dense lacework of hinge-cut brush in the water along stream edges of treatment sections may have provided increased substrate for attachment of invertebrates, and that there was less movement out of such sections and a greater net rate of attachment or "settlement" of drifting

Table 12. Directions and significance levels of changes in trout abundance from fall to fall and spring to spring within control and treatment sections, based upon t-tests.

Trout population variable	Fall 1979 - Fall 1980 Control sections	Fall 1979 - Fall 1980 Treatment sections	Spring 1980 - Spring 1981 Control sections	Spring 1980 - Spring 1981 Treatment sections
Stock density (fish/km)				
≤ 150 mm	ns	1979>1980 ($p < .2$)	ns	ns
> 150 mm	ns	ns	1980>1981 ($p < .02$)	ns
all sizes	ns	ns	1980>1981 ($p < .15$)	ns
Standing crop (g/m)				
≤ 150 mm	ns	ns	1980>1981 ($p < .05$)	ns
> 150 mm	ns	1980>1979 ($p < .15$)	1980>1981 ($p < .05$)	ns
all sizes	ns	ns	1980>1981 ($p < .02$)	ns

Table 13. Differences in trout population statistics between paired control and treatment sections, based on t-tests.

Trout population variable	Fall 1979	Spring 1980	Fall 1980	Spring 1981
Stock density (fish/km)				
≤ 150 mm	ns	ns	ns	ns
> 150 mm	ns	controls > treatments ($P < .1$)	ns	ns
all sizes	ns	ns	ns	ns
Standing crop (g/m)				
≤ 150 mm	ns	ns	ns	ns
> 150 mm	ns	controls > treatments ($P < .2$)	ns	ns
all sizes	ns	ns	ns	ns

Table 14. Invertebrate drift rates at the downstream ends of each treatment (T) section compared to the immediate upstream control (C) section over two substrate types.

Section compared	Substrate type	Date (1980)	Drift rate (mg wet wt/l/day) Ephemeroptera C	Ephemeroptera T	Trichoptera C	Trichoptera T	Plecoptera C	Plecoptera T	Other C	Other T	Total C	Total T
C2 vs T1	sand-rock	8-16	.188	.179	.468	.499	.051	.000	1.949	1.841	2.656	2.519
	rock	8-16	.006	.012	.050	.078	.000	.066	.752	.243	0.808	0.399
C3 vs T2	sand	8-16	.132	.087	.334	.398	.585	.031	1.489	.780	2.540	1.296
	rock-gravel	8-17	--	.025	--	.030	--	.007	--	.006	--	0.122
	rock	8-17	.018	--	.118	--	.012	--	.277	--	0.425	--
C4 vs T3	sand	8-18	.006	.007	.060	.026	.001	.003	.004	.048	0.107	0.084
	sand-gravel	8-18	.011	<.001	.039	.016	.049	.003	.208	.052	0.307	0.071
C5 vs T4	sand	8-21	.002	.002	.096	.060	.044	.001	.105	.048	0.247	0.111
	gravel-sand	8-21	<.001	--	.010	--	.050	--	.071	--	0.131	--
	gravel	8-21	--	<.001	--	.019	--	.000	--	.021	--	0.040
C6 vs T5	sand	8-21	--	.000	--	<.001	--	.001	--	.010	--	0.011
	sand-gravel	8-22	.022	.005	.031	.045	.001	.007	.031	.005	0.085	0.062
	rock-gravel	8-22	.011	--	.042	--	.030	--	.169	--	0.252	--
Means			.040	.032	.125	.117	.082	.012	.506	.305	0.756	0.471

invertebrates into treatment sections than in the control sections which lacked such abundance of attachment sites for invertebrates. Also, the brush and leaves in the water in treatment sections were probably a large source of food, "enticing" invertebrates not to drift out.

Salmonids are primarily drift feeders (White 1967, in Hunt 1969), so availability of food for trout was probably better in the control sections at the time of drift sampling. It has been suggested that the level of incoming drift food is a factor in determining a stream sections' trout carrying capacity (Mason and Chapman 1965; Peterson 1966, in Waters 1969).

Dr. R. Merritt (Dept. of Entomology, MSU) studied samples of hinge-cut twigs, leaf packs, and bottom sediments on two dates (May 16-17, 1981 and July 29-30, 1981) from stations 38 and 47 to investigate the effects of the hinge-cutting on macroinvertebrate abundance and biomass. He found that bottom samples immediately adjacent to or under hinge-cuttings had a higher biomass of aquatic invertebrates (May: 162.8 mg dry wt/ft^2; July: 1180.5 mg dry wt/ft^2) than comparable sites in control sections (May: 132.0 mg dry wt/ft^2; July: 490.7 mg dry wt/ft^2). Merritt suggested that the differences in biomass might be due to the scouring effect of the hinge-cuts, which increase current speed and, subsequently substrate size. Merritt concluded that the practice of hinge-cutting created a greater variety of habitats for macroinvertebrate colonization, by providing twig surface area for attachment, trapping leaf litter which provides additional sites, and changing bottom sediments by scouring.

Implications for Management

Due to the short duration of this study, complete evaluation of hinge-cutting as an effective management tool was not possible. Several years are required after habitat enhancement for trout populations to adjust ecologically to improved conditions. White (1975) states that at least one year is needed before the onset of a positive population response and Hunt (1976) found that at least five years are needed for full response of brook trout to habitat improvement. However, such changes in channel form and flow as preceded increased trout abundance in Lawrence Creek, Wisconsin (Hunt 1971), occurred due to hinge-cutting within the treatment sections of the Salmon Trout River.

In Lawrence Creek, the amounts of pool area and overhead bank cover were the key environmental factors determining trout survival before installation of bank covers and deflectors, and following habitat modification, channel depth, pool area, and protective cover all increased. Resultant population responses included reduced emigration, a decrease in overwinter mortality, and a stockpiling of age-I+ trout (Hunt 1971). Hinge-cutting has produced an initial narrowing and deepening of the channel, and has provided additional overhead cover. These characteristics have been found to reduce unfavorable effects of low flows (White 1975). There is also evidence of reduced mortality or emigration from treated sections, as hinge-cut areas did not experience a significant decline in trout abundance between the springs of 1980 and 1981, as was found in the control sections. Increased water velocities produced by constricting the flow have scoured sand and silt off gravel, now available for trout spawning, and would conceivably also have increased the abundance of macroinvertebrates.

The preferred trout feeding microhabitat includes an area of low current velocity near to a principal line of drift, all with adjacent overhead cover (Jenkins 1969). The denser areas of hinge-cuts provide these characteristics by constricting the flow and concentrating the drift food supply. Hinge-cut brush can provide visual isolation among the branches, and a higher current velocity in the channel. Both features can ultimately serve to decrease agonistic behavior, and allow more trout to occupy a given area.

Hunt (1979) reported on removal of woody brush from stream sections in Wisconsin, and hypothesized that favorable changes in channel morphometry (similar to those I have found with hinge-cutting) would result due to proliferation of aquatic macrophytes, and establishment of grassy turf banks. Growth of grasses and sedges help stabilize the banks, prevents erosion, and forms undercuts which provide hiding cover (White and Brynildson 1967). Hunt's (1979) study was complicated by decreased stream discharges, which were believed to be the primary reason that standing crops of brook trout failed to increase following brush removal. Year-round discharge estimates for the Salmon Trout were not made, so correlations with trout standing crop are not possible.

While the trout population had little time to react to any beneficial environmental changes brought on by hinge-cutting, macroinvertebrates quickly colonized the submerged brush. The prevalent species were filter-feeding caddisflies of the genera Hydropsyche and Brachycentrus. Merritt (Dept. of Entomology, MSU) also demonstrated a greater abundance of benthic invertebrates in hinge sediments than in comparable control sites. The blend of an easily available food supply and protective cover should provide an attractive position choice for stream salmonids.

There is obvious advantage of hinge-cutting over conventional bank covers and deflectors in ease of construction and economy. Virtually no materials need be purchased and transported to the stream, and labor is greatly reduced. Each treatment section was completely hinge-cut by a two-man crew within a single work day. In actual management, only those areas along streams should be hinge-cut which have suitable quantities and type of riparian brush and are located in stretches with inadequate overhead cover or in erosion susceptible zones.

Disadvantages of hinge-cutting include unnatural appearance, especially initially and when applied over long sections of stream. However, some of the felled brush gradually becomes covered with sediments, and grasses and sedges invade (or can be planted) to conceal cuttings on the bank. Fishing can be both enhanced and hindered by hinge-cutting. Large amounts of brush in the stream increase the likelihood of snagged and lost lures. However, fly-casting is made easier with the streamside brush knocked down, and hinge-cuts provide centralized areas on which fishing effort can be focused. Huron Mountain Club members had mixed reactions to the fishability of the treatment sections. Again, applied use of hinge-cutting would likely not involve the full lengths of both banks, so the aesthetics and access for fishing would not need to be altered drastically in actual practice.

Conclusions

Hinge-cutting of riparian brush is a simple technique for manipulating stream channel form and flow to benefit trout. The method may be particularly suited to streams in steep terrain, where the force of floods may limit the use of conventional bank covers. Loss of hinge-cut covers would not be costly.

Hinge-cutting provides overhead cover from predators and shelter from adverse currents, increases the availability of food organisms, and promotes bank stabilization. The suitability and effectiveness of the method of habitat modification is dependent upon physical and biological characteristics of each proposed treatment area. Proper site selection will enhance the desired physical changes, while holding aesthetic losses to a minimum.

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APPENDIX

Table Al. Discharge estimates (cms) at station 40 (Lower Dam) on the Salmon Trout River during the summer of 1980.

Date	Discharge (cms)	Date	Discharge (cms)	Date	Discharge (cms)
6 - 27	0.76[a]	7 - 16	0.81	8 - 4	--[p]
28	0.76	17	--	5	1.10
29	--[p]	18	--	6	0.78
30	1.04[a]	19	--	7	0.75
7 - 1	--[p]	20	--	8	0.74[a]
2	0.86[a]	21	--	9	0.72
3	0.81	22	0.81	10	--[p]
4	0.77	23	0.78	11	1.31
5	--[p]	24	0.78	12	1.02[a]
6	0.87[a]	25	0.77	13	1.26[p]
7	1.33[p]	26	0.76	14	1.78
8	1.06[a]	27	0.76	15	1.16
9	0.86	28	0.75	16	0.93
10	0.78	29	0.76	17	0.86
11	0.77	30	0.72	18	0.83[p]
12	--	31	0.74	19	0.86
13	0.71	8 - 1	0.72	20	1.02
14	--[p]	2	0.71	21	0.89
15	0.99[a]	3	0.70	22	0.80
				23	0.77

[a]actual discharge measurement

[p]precipitation

Table A2. Shocking dates for brook trout population estimates in the Salmon Trout River, Marquette County, Michigan.

Electrofishing period	Date
Fall 1979	September 22-24, 1979
Spring 1980	June 8-13, 1980
Fall 1980	September 14-17, 1980
Spring 1981	May 16-19, 1981

Table A3. Finclip record for wild young-of-the-year brook trout and for stocked hatchery brook trout in the Salmon Trout River, Marquette County, Michigan.

Year	Wild Trout: Finclip	Wild Trout: Date
1975	A (below Lower Falls)	June-July 1976
	ARV (above falls)	
1976	LV	Fall 1976
1977	RV	Fall 1977
1978	none	not shocked
1979	ALV	Fall 1979
1980	A	Fall 1980
	Hatchery Trout	
1976	LP	
1977	RP (possible some A clips)	
1978	--	
1979	2V	
1980	LP	

Key: A - adipose; RV - right ventral; LV - left ventral; RP - right pectoral; LP - left pectoral; 2V - both ventrals

Table A4. Recapture efficiency (%) of brook trout by size class for four shocking periods on the Salmon Trout River, Marquette County, Michigan.

Size class	Shocking period			
	Fall 1979	Spring 1980	Fall 1980	Spring 1981
$\leq$ 100 mm	18%	33%	12%	9%
101–125 mm	32%	45%	19%	23%
126–150 mm	34%	55%	30%	29%
151–175 mm	35%	57%	23%	42%
176–200 mm	32%	53%	39%	35%
$\geq$ 201 mm	38%	47%	41%	14%

Table A5. Brook trout population estimates by station in the Salmon Trout River, September 1979.

Station number	Total length size class (mm)						Total
	≤100	101-125	126-150	151-175	176-200	>200	
34	-	-	-	-	-	-	-
35	44	5	2	10	2	1	64
36	113	9	4	12	5	0	143
37	113	2	5	10	11	1	141
38	90	14	7	9	5	1	126
39	90	14	7	9	5	1	126
40	57	7	7	8	5	1	85
41	19	0	2	0	0	1	22
42	41	4	0	2	0	0	47
43	28	9	23	12	3	3	78
44	19	4	11	3	0	1	38
45	35	11	9	8	11	8	82
46	38	13	18	10	4	3	86
47	38	13	18	10	4	3	86
48	31	16	13	15	0	3	78
49	47	15	14	10	2	1	89
50	76	9	25	13	8	5	136
51	65	3	15	8	4	3	98
52	65	3	15	8	4	3	98
53	104	16	41	13	2	3	179
54	92	17	25	13	0	1	148
55	92	17	25	13	0	1	148
56	85	29	56	27	5	0	202
57	91	7	52	13	5	3	171

Table A5. (cont'd.)

Station	Total length size class (mm)						
number	≤ 100	101-125	126-150	151-175	176-200	>200	Total
58	126	11	29	23	3	4	196
59	101	18	38	15	3	8	183
60	57	13	36	15	2	0	123
Totals	1757	279	497	289	93	58	2973
95% CI	1367-2139	212-344	408-580	232-346	66-120	41-73	2326-3602

Table A6. Brook trout biomass (gm) estimates by station in the Salmon Trout River, September 1979.

Station	Total length size class (mm)						
number	≤100	101-125	126-150	151-175	176-200	<200	Total
34	-	-	-	-	-	-	-
35	290	53	46	420	140	92	1041
36	463	111	96	480	285	0	1435
37	791	24	125	410	781	0	2131
38	340	164	176	396	293	43	1412
39	340	164	176	396	293	43	1412
40	274	89	133	344	230	95	1255
41	38	0	46	0	0	111	195
42	156	48	0	58	0	0	262
43	140	117	437	480	165	246	1585
44	48	60	264	105	0	101	578
45	238	163	207	256	693	1032	2589
46	205	150	432	400	284	235	1706
47	205	150	432	400	284	235	1706
48	102	173	299	585	0	279	1438
49	226	170	336	360	104	99	1295
50	433	103	600	455	464	530	2585
51	323	20	377	285	252	285	1542
52	323	20	377	285	252	285	1542
53	832	216	902	494	122	414	2970
54	412	185	539	475	0	53	1664
55	412	185	539	475	0	53	1664
56	391	392	1176	1080	330	0	3369

Table A6. (cont'd.)

Station number	Total length size class (mm)						Total
	≤100	101-125	126-150	151-175	176-200	<200	
57	364	97	1144	481	340	384	2810
58	491	132	638	828	183	308	2580
59	535	238	836	570	168	840	3187
60	222	159	792	525	128	0	1826
Total	8594	3383	11125	11043	5871	5763	45779
95% CI	6686-10462	2571-4171	9133-12983	8865-13221	4167-7575	4074-7253	35496-55665

Table A7. Brook trout population estimates by station in the Salmon Trout River, June 1980.

Station	Total length size class (mm)						
number	≤100	101-125	126-150	151-175	176-200	>200	Total
34	2	13	11	4	7	6	43
35	0	20	17	3	3	8	51
36	2	16	18	3	3	2	44
37	6	20	9	3	0	3	41
38	4	7	7	1	0	3	22
39	8	29	21	4	5	2	69
40	6	21	14	3	8	6	58
41	2	7	6	3	3	2	23
42	12	8	4	1	0	0	25
43	16	13	1	1	0	0	31
44	26	18	20	11	7	6	88
45	8	10	6	17	12	2	55
46	12	13	14	3	11	5	58
47	28	26	24	13	3	6	100
48	26	29	10	9	5	5	84
49	14	15	11	9	8	2	59
50	20	29	13	5	4	0	71
51	18	11	14	5	1	0	49
52	14	28	9	3	3	2	59
53	6	29	20	5	3	6	69
54	6	20	6	7	4	0	43
55	18	21	14	9	1	2	65
56	12	37	16	17	4	2	88
57	12	28	6	9	4	0	59

Table A7. (cont'd.)

Station number	Total length size class (mm)						Total
	≤100	101-125	126-150	151-175	176-200	>200	
58	10	31	20	15	4	3	83
59	18	39	10	9	0	0	76
60	10	29	16	7	7	0	69
Totals	316	567	337	178	110	73	1582
95% CI	231-395	484-642	291 383	152-206	89-131	45-97	1292-1854

Table A8. Brook trout biomass (gm) estimates by station in the Salmon Trout River, June 1980.

Station	Total length size class (mm)						
number	≤100	101-125	126-150	151-175	176-200	>200	Total
34	14	192	263	155	466	617	1707
35	0	254	447	147	186	832	1866
36	16	208	556	116	189	190	1275
37	48	296	231	108	0	270	953
38	28	79	197	40	0	267	611
39	72	403	548	157	364	170	1714
40	60	315	349	134	582	578	2018
41	14	118	165	165	230	280	972
42	74	83	108	60	0	0	325
43	114	160	22	48	0	0	334
44	179	191	506	516	512	716	2620
45	62	135	144	826	817	174	2158
46	96	182	349	126	732	514	1999
47	224	374	610	566	203	641	2618
48	244	365	236	369	330	692	2236
49	112	225	267	413	502	180	1699
50	166	371	281	188	295	0	1301
51	128	164	347	209	66	0	914
52	98	381	218	102	179	168	1146
53	54	432	498	243	177	536	1940
54	54	292	162	305	223	0	1036
55	182	328	393	405	60	210	1578
56	120	540	418	699	264	308	2349
57	80	378	143	390	237	0	1228

Table A8. (cont'd.)

Station number	Total length size class (mm)						Total
	≤100	101-125	126-150	151-175	176-200	>200	
58	64	431	502	653	264	423	2337
59	137	523	209	354	0	0	1223
60	60	319	360	294	403	0	1436
Totals	2500	7739	8529	7778	7281	7766	41593
95% CI	1828-3125	6606-8763	7365-9693	6642-9002	5891-8671	4787-10319	33119-49573

Table A9. Brook trout population estimates by station in the Salmon Trout River, September 1980.

Station number	Total length size class (mm)						Total
	≤100	101-125	126-150	151-175	176-200	>200	
34	33	12	3	8	1	6	63
35	48	19	16	14	5	6	108
36	77	17	23	24	4	3	148
37	113	21	8	14	1	0	157
38	66	33	15	20	1	3	138
39	139	26	15	22	4	1	217
40	135	19	16	26	4	3	203
41	80	2	3	2	0	3	90
42	22	10	11	8	3	0	54
43	40	24	10	0	5	9	88
44	7	19	15	8	6	3	58
45	11	2	13	4	3	4	37
46	26	7	11	4	1	3	52
47	11	7	11	4	0	4	37
48	15	19	24	20	6	1	85
49	11	19	11	8	3	4	56
50	22	6	8	4	0	1	41
51	22	6	8	4	0	1	41
52	11	7	11	14	4	3	50
53	26	19	20	20	4	1	90
54	15	7	11	6	0	0	39
55	40	0	21	8	1	3	73
56	26	5	20	16	1	0	68
57	29	10	16	14	0	0	69

Table A9. (cont'd.)

Station number	Total length size class (mm)						Total
	≤100	101-125	126-150	151-175	176-200	>200	
58	66	31	39	14	0	6	156
59	91	24	33	10	0	1	159
60	40	19	23	10	0	1	93
Total	1222	400	415	306	57	70	2470
95% CI	828-1614	276-526	350-484	222-394	44-72	51-93	1771-3183

Table A10. Brook trout biomass (gm) estimates by station in the Salmon Trout River, September 1980.

Station	Total length size class (mm)						
number	≤100	101-125	126-150	151-175	176-200	>200	Total
34	257	158	90	310	65	666	1546
35	288	205	366	603	295	546	2303
36	547	216	589	979	243	270	2844
37	588	218	206	578	73	0	1663
38	370	406	419	900	78	377	2550
39	1112	367	389	913	232	66	3079
40	891	226	478	1071	276	287	3229
41	320	40	66	102	0	270	798
42	128	115	249	364	80	0	1036
43	256	350	215	0	314	974	2109
44	39	274	332	350	398	620	2013
45	99	28	300	142	231	763	1563
46	130	98	230	198	62	293	1011
47	63	103	250	186	0	587	1189
48	86	302	583	924	443	107	2445
49	61	245	289	328	246	468	1637
50	104	99	189	173	0	45	610
51	104	99	189	173	0	45	610
52	55	86	295	587	268	359	1650
53	221	253	488	810	292	127	2191
54	75	86	286	252	0	0	699
55	208	0	519	312	55	355	1429
56	156	85	500	581	79	0	1401
57	223	128	390	536	0	0	1277

Table A10. (cont'd.)

Station number	Total length size class (mm)						Total
	≤100	101-125	126-150	151-175	176-200	>200	
58	409	412	893	598	0	977	3289
59	437	346	729	366	0	123	2001
60	136	274	561	392	0	158	1521
Total	7363	5219	10090	12926	3830	8463	47693
95% CI	4989-9725	3601-6863	8510-11768	9378-16643	2956-4838	6166-11244	35600-61081

Table All. Brook trout population estimates by station in the Salmon Trout River, May 1981.

Station	Total length size class (mm)						
number	≤100	101-125	126-150	151-175	176-200	>200	Total
34	11	10	2	3	3	2	31
35	11	10	0	3	3	0	27
36	11	24	13	1	3	0	52
37	16	26	13	1	1	2	59
38	11	17	4	1	1	0	34
39	32	19	4	3	1	2	61
40	65	36	2	4	3	5	115
41	0	0	0	0	0	0	0
42	0	7	9	0	0	0	16
43	16	10	4	4	0	2	36
44	16	2	2	1	3	2	26
45	16	0	4	1	0	0	21
46	0	7	4	8	0	0	19
47	11	7	17	10	6	5	56
48	11	24	11	7	3	0	56
49	0	5	9	4	0	2	20
50	11	2	6	6	3	0	28
51	5	5	6	4	0	0	20
52	27	24	22	9	6	0	88
53	11	7	37	16	0	2	73
54	0	5	6	3	0	0	14
55	27	17	0	4	1	2	51
56	22	5	11	7	3	0	48
57	27	34	13	6	1	0	81

Table A11. (cont'd.)

Station number	Total length size class (mm)						Total
	≤100	101-125	126-150	151-175	176-200	>200	
58	16	22	22	10	1	0	71
59	27	14	9	9	0	0	59
60	22	14	22	7	3	0	68
Total	422	353	252	132	45	26	1230
95% CI	87-756	237-467	169-335	108-168	28-66	4-50	633-1842

Table A12. Brook trout biomass (gm) estimates by station in the Salmon Trout River, May 1981.

Station number	Total length size class (mm)						Total
	≤100	101-125	126-150	151-175	176-200	>200	
34	94	118	62	120	183	350	927
35	88	178	0	117	200	0	583
36	83	286	321	36	189	0	915
37	117	387	364	42	58	236	1204
38	88	243	98	0	56	0	485
39	250	258	94	116	66	208	992
40	481	742	48	163	200	630	2264
41	0	0	0	0	0	0	0
42	0	82	223	0	0	0	305
43	128	133	96	167	0	202	726
44	48	40	60	43	207	192	590
45	181	0	98	52	0	0	331
46	0	89	76	344	0	0	509
47	88	110	485	443	345	480	1951
48	22	372	290	315	204	0	1203
49	0	93	203	176	0	280	752
50	88	24	204	275	183	0	774
51	50	60	124	133	0	0	367
52	216	305	515	335	338	0	1709
53	83	86	910	606	0	252	1937
54	0	58	148	108	0	0	314
55	216	216	0	126	64	200	822
56	161	63	264	270	179	0	937
57	243	425	293	239	50	0	1250

Table A12. (cont'd.)

Station number	Total length size class (mm)						Total
	≤100	101-125	126-150	151-175	176-200	>200	
58	112	273	523	411	59	0	1378
59	157	157	221	328	0	0	863
60	161	179	484	258	168	0	1250
Total	3155	4977	6204	5223	2749	3030	25338
95% CI	650-5652	3341-6584	4164-8247	4273-6647	1710-4032	466-5827	14601-36989