Volume 18 Study D-I-B

STATE OF ALASKA

Jay S. Hammond, Governor

Annual Performance Report for

ECOLOGY OF REARING FISH

by

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RESEARCH PROJECT SEGMENT

State: ALASKA Name: Sport Fish Investigations of Alaska

Project No.: F-9-9

Study No.: D-I Study Title: A STUDY OF LAND USE ACTIVITIES AND THEIR RELATIONSHIP TO THE SPORT FISH RESOURCES IN ALASKA

Job No.: D-I-B Job Title: Ecology of Rearing Fish

Period Covered: July 1, 1976 to June 30, 1977

ABSTRACT

The job, Ecology of Rearing Fish, conducts research on the various effects of land use practices on juvenile Dolly Varden, Salvelinus malma (Walbaum), and coho salmon, Oncorhynchus kisutch (Walbaum), and the small stream environment. Emphasis of the study is placed on the removal of logging slash and its effect on stream ecosystems, the comparison of winter survival of juvenile Dolly Varden and coho in spring-fed and runoff streams, and the effects of forest canopy removal on winter temperatures and ice conditions in small salmonid rearing streams.

Hand removal of logging slash from a heavily littered tributary stream resulted in a 50% decrease in the population of juvenile Dolly Varden. This sharp decrease in population size was also accompanied by a loss of approximately 17% of the stream surface area, due to removal of debris dams, and a change in the character of the streambed. Before cleaning, approximately 85% of the streambed was littered with fine particulate debris, branches and logs. After cleaning, only 37% of the stream bed was covered with introduced material. An increase in exposed gravel substrate from 18% to 50% also occurred.

Comparison of winter mortality of juvenile salmonids in a spring-fed, runoff tributary showed that populations of juvenile Dolly Varden suffered about 31% mortality in the spring-fed stream over the months of November to June, while juvenile Dolly Varden and coho populations decreased approximately 51% and 86% respectively, in a small surface-water stream. Higher mortality in the runoff stream is attributed to loss of wintering area when discharge and stream volume decrease leaving isolated pools that freeze during cold weather.

Preliminary findings on the effects of canopy removal indicate that removal of the forest canopy by clear cut logging methods reduces ground water temperatures and thus affects thermal regimes of small spring-fed streams. We speculate that this cooling may be caused by increased precipitation entering the groundwater system after the timber canopy has been removed.

BACKGROUND

Surveys of 21 logged watersheds in Southeast Alaska during the 1971-1972 field season indicated that a number of issues regarding the impact of logging on the aquatic environment had not been totally addressed. The surveys (Reed and Elliott, 1972) showed that many streams in Southeast Alaska had been altered by heavy accumulation of organic debris and slash from clearcutting operations. In most cases the debris accumulations were large enough to warrant removal in order to restore the stream to its original condition.

Another issue that warranted investigation was the value of small streams, especially spring-fed streams, to winter survival of juvenile salmonids. Past research at Hood Bay Creek, Alaska, suggests that young Dolly Varden, Salvelinus malma (Walbaum), and coho salmon, Oncorhynchus kisutch (Walbaum), migrate upstream to warmer, spring-fed tributaries to overwinter (Blackett, 1968). Temperature monitoring of the spring-fed streams in Hood Bay, revealed stable temperatures of 5.0° to 6.1°C during the winter, while the main stream developed heavy ice formations (Armstrong and Elliott, 1972).

The effects of canopy removal on the winter stream environment is also poorly understood. Green (1950) indicates that lower temperatures are experienced during the winter in exposed streams, which may result in detrimental ice conditions and delay development of incubating salmon eggs.

To further investigate the effects of debris removal, winter temperature regimes, and canopy removal on juvenile salmonid populations, the Sport Fish Division created the Job D-I-B, Ecology of Rearing Fish, under the auspices of the Land Use Study. One year's preliminary work was conducted at Kadashan Creek, where methods of making population estimates were investigated (Elliott and Reed, 1973). The study was then moved to Starrigavan Creek near Sitka, where several small streams were selected and weired for future studies.

The first year at the Starrigavan site was devoted to the study of seasonal movement patterns of juvenile fish and established that many juvenile coho and Dolly Varden seek tributaries during the fall months (Elliott and Reed, 1974). Determination of seasonal population dynamics during 1973, 1974, and 1975 was conducted to provide baseline data for studies of overwinter survival and debris removal (Elliott and Dinneford, 1976).

RECOMMENDATIONS

Research

1. Determine the effects of logging debris removal on juvenile salmonid populations in small streams by:

   a. Conducting systematic population estimates in Spring Pond Creek to monitor changes in population size and structure after debris removal.

   b. Determine biomass, standing crop, species diversity, and distribution of macrobenthos after debris removal.

   c. Continue to monitor transport of fine debris from the system.

2. Determine the importance of spring-fed tributaries to the overwinter survival of rearing fish by:

   a. Monitoring seasonal population trends of juvenile fish in spring-fed and non-spring fed tributary streams.

3. Determine methods for future research on the effects of canopy removal in temperature and ice conditions of small streams during the winter months by:

   a. Investigate methods of remote thermal sensing in cooperation with the Geophysical Institute, University of Alaska, to establish baseline data for canopy removal studies.

   b. Continue literature search on monitoring methods that can be used to determine the effects of canopy removal on groundwater temperature, frost depth, ice development, and ice penetration.

4. Determine the distribution, abundance, and species diversity of macrobenthos and its relationship to rearing fish populations by:

   a. Collection and identification of aquatic insects.

   b. Obtaining biomass, standing crop, and distribution of species.

   c. The above will be correlated with estimates of fish abundance and biomass to determine if a correlation exists.

5. Determine the feasibility of conducting a study on the effects of Molybdenum open pit mining on juvenile salmonid populations and macrobenthos by:

   a. Conduct foot and float surveys to determine the distribution and relative abundance of juvenile salmonids in the Keta, Wilson, and Blossom rivers.

b. Examine sites near mouth of rivers for the feasibility of weir construction.

c. Collect macrobenthos from the rivers to determine basic species composition and distribution in relation to possible heavy metal and pH changes.

Management

Results of experiments on debris removal show that a relationship exists between juvenile Dolly Varden populations and deposits of logging slash. Removal of logging slash resulted in an immediate 50% decrease in population size, suggesting that slash deposits may be beneficial as cover to juvenile Dolly Varden. We do not make the assumption that the population reached artificially high levels after debris introduction, but do feel that removal has stressed the post logging population, causing an immediate decline.

From surveys of logged areas in 1971, we estimated that there are approximately 500 miles of debris damaged tributary streams in Southeast. The U.S. Forest Service has expressed an interest in locating these streams and removing as much of this material as possible.

Experiments involving habitat alteration can require up to four years post treatment monitoring to adequately assess changes in populations, (Hunt, 1976). Consequently, results from the Spring Pond Creek studies are considered tentative at this time. However, until more data is available on the effects of debris removal on small stream salmonid populations, we recommend that removal projects be postponed at least for the interim.

OBJECTIVES

1. To determine the effects of logging debris removal on fish populations in small streams.

2. To determine the importance of spring-fed tributaries for the over-winter survival of rearing fish.

3. To determine methods of future research on the effects of canopy removal on temperature and ice conditions of small streams during the winter months.

4. To determine the distribution, abundance and species diversity of the macrobenthos and its relationship to rearing fish populations.

TECHNIQUES USED

Spring-Fed Tributary Study

To determine if spring-fed streams provide a better wintering environment than run-off streams, small migrant weirs were placed on Spring Pond Creek (spring-fed) and Skunk Cabbage Creek (run-off) to count migrating juveniles that move into the streams each fall to overwinter. Population estimates are made in the fall and spring on each stream using Chapman's modification of the Peterson estimate:

Adjusted Peterson Estimate

$$N = \frac{(m + 1)(c + 1)}{(R + 1)}$$

$$N \pm Z\alpha \frac{(m + 1)^2(c + 1)(c - R)}{(R + 1)^2(R + 2)}$$

where N = estimated population
M = Number of fish marked
C = Total number of fish captured
R = Number of marked fish in C

Results of Peterson estimates obtained in the fall months are compared to population levels the succeeding spring to determine if any changes occurred in population level during the winter months. Juvenile Dolly Varden and coho in Spring Pond Creek and Skunk Cabbage Creek were also given permanent fin clips in the fall of 1975, and attempts were made to recapture these marked fish in early June of 1976.

Overwinter survival using this method was calculated using Bailey's Method (Ricker, 1975):

$$S = \frac{M_2 (R_{13})}{M_1 (R_{23} + 1)}$$

Survival formula - Baileys method

S = estimated survival from time 1 to time 2
M_1 = Number of fish marked at time 1
M_2 = Number of fish marked at time 2
R_{13} = Recapture of M_1 fish at time 3
R_{23} = Recapture of M_2 fish at time 3

Winter mortality and magnitude of juvenile migrations into both streams was compared to determine which type of stream is most beneficial to juvenile populations.

Debris Removal Study

To determine the effects of logging debris removal on juvenile coho and Dolly Varden populations, two streams, Spring Pond Creek and Control Creek, both heavily littered with slash were selected for study. Logging debris was left in Control Creek, where juvenile populations served as a comparison for debris removal activities on Spring Pond Creek.

Periodic population estimates were conducted throughout the summer season during 1973 through 1976 on Spring Pond Creek, and 1975 through 1976 on Control Creek to establish baseline data prior to debris removal in Spring Pond Creek. Each creek was blocked with a migrant fish weir to prevent movement into or out of the creeks while estimates were being conducted.

Removal of logging debris was initiated during July 1976 using chainsaws and chainsaw winches to remove large debris such as logs and large limbs. Small material was removed by hand and with garden rakes. All material that had been placed in the creek during logging was removed.

To evaluate the thoroughness of debris removal, stream bed types were mapped using a grid system before and after debris removal. This yielded a series of sample points where the streambed was catagorized as being: large debris (>1 cm), fine debris (<1 cm), logs, or exposed gravel.

Since large debris often formed impoundments, the surface area was measured before and after debris removal to determine if removal decreased the stream surface area.

Analysis of macrobenthos population was also conducted at the study site. Invertebrates are collected from the substrate with a surber sampler (0.093 m^2 - 280 micron mesh) and drift sampler (0.093 m^2 - 280 micron mesh) to determine benthos populations in debris littered and non-littered areas before and after debris removal. Specimens were frozen in water and shipped to Juneau where they were counted and the ash-free dry weight calculated.

Canopy Removal Study

Temperature data collected at Spring Pond Creek in 1973 through 1976 was tested by analysis of variance. Yearly means were different at the 0.01 level of significance.

FINDINGS

Spring Fed Tributaries and Their Importance

Juvenile Inmigration:

Each fall juvenile Dolly Varden and coho leave the mainstream of Starrigavan watershed during September and October and migrate into small tributaries

to overwinter. In the initial years of this study, inmigration of juveniles numbered approximately 200 for Spring Pond Creek, a small (700 m^2) spring-fed stream, and Skunk Cabbage Creek (runoff stream, 1,140 m^2). Since 1973, annual inmigration of juveniles into the study streams have declined, and in 1976 the streams again received negligable runs. Annual weir counts (net inmigration) are as follows:

	Spring Pond Creek		Skunk Cabbage Creek	
	Dolly Varden	Coho	Dolly Varden	Coho
1973	187	24	NA	NA
1974	171	47	256	91
1975	52	59	128	140
1976	55	5	27	27

There are several possible explanations for the declining numbers of upstream migrants. Depredations by Mustelids could have caused the loss, but no evidence of predation was observed this fall. It is possible that fish refuse to enter the upstream migrant trap, though this is contrary to the good catches obtained in 1973. Another possibility, is that overall productivity of the watershed has declined since 1973, causing a decrease in the winter use of tributaries by mainstream Dolly Varden populations.

Winter Mortality in Spring-fed and Runoff Tributaries:

Winter mortality of juvenile Dolly Varden and coho in Spring Pond Creek and Skunk Cabbage Creek were compared using two methods: by comparing Peterson Estimates taken in the fall and spring and by using Baileys method. Mortality rates calculated by these two methods are as follows:

	Spring Pond Creek		Skunk Cabbage Creek		
	Dolly Varden	Coho	Dolly Varden	Coho	Pt*
Peterson	.343	ND	.632	.764	.694
Baileys Method	.314	ND	.511	.866	.672

* Population total (Dolly Varden and coho)

Two methods compare closely, both show that juvenile populations in Skunk Cabbage Creek suffer higher rates of mortality than populations in Spring Pond Creek. We feel that the high losses of juveniles in Skunk Cabbage Creek is due primarily to loss of rearing area during the winter,

as most of the stream dries up except for isolated pools. Pools also develop heavy ice covers, with water temperatures close to 0°C (32°F).

Debris Removal Study

Five parameters were examined prior to and after debris removal: changes in rearing fish populations, changes in streambed type, changes in total surface area of the stream, and change in macroinvertebrate populations and feeding habits of juvenile fish.

Population estimates of juvenile Dolly Varden in Spring Pond Creek are complicated by growth of young fish to sizes most easily captured by minnow traps (Elliott and Reed, 1973). This results in a steady increase in population size during the months of June through October. Active growth is suspended in the fall and estimates of populations tend to stabilize at that level. Consequently, changes in population levels due to debris removal are best determined by using the October estimates, as they reflect more stable conditions in the population. Population estimates of juvenile Dolly Varden in Spring Pond Creek since 1973, and the resulting population after debris removal in 1976, are compared to estimates taken in Control Creek, a debris littered stream that was not cleaned. Results of the estimates before and after cleanup are as follows:

	Spring Pond Creek			Control Creek		
	Dolly Varden	Coho	Pt**	Dolly Varden	Coho	Pt**
1973	1,051	75	1,134	ND	ND	ND
1974	1,070	47	1,104	ND	ND	ND
1975	1,251	ND	1,251	474	586	1,054
1976*	594	ND	594	870	222	1,095

* Debris removal conducted in July, 1976.
** Population Total (Dolly Varden and coho)

Catchable populations of Dolly Varden in the fall had a mean of 1,163 (Sd = 77.6), prior to debris removal. After removal, the population decreased by about 50% and remained at approximately 600 fish during the months of November through January. Populations of fish in Control Creek did not change relative to 1975.

Stream surface area in Spring Pond Creek (measured at low water) also changed after debris removal. Prior to removal, the surface area was measured at 874 m^2. Removal of debris reduced the amount of slash-caused impoundments and decreased the stream surface area to 726 m^2. This is a reduction of about 148 m^2 or 17% of the original area.

Mapping of streambed types before and after debris removal, showed that hand removal of the debris had changed the character of the substrate (Figure 1). Before removal, 85% of the stream sample points were littered with introduced debris, mostly large material such as branches, logs, and wood fragments. After cleaning, only 30% of the sample points were covered with debris, primarily decaying needles and fine organic oozes. Changes in water velocity, and channel direction removed much of the fine debris and exposed greater amounts of gravel substrate. Prior to removal, 15% of the sample points were exposed gravel. After cleaning, about 55% of the sample points were exposed gravel.

The loss of surface area above (17% of the stream area) does not account for the 50% decrease in population that was observed. Slash, to some degree, may serve as cover for juvenile Dolly Varden. Debris removal reduced the carrying capacity by eliminating stream features that served as shelter for the population.

We expected that a large number of fish would outmigrate from Spring Pond Creek if the carrying capacity was lowered. However, very few fish (54) left the stream after debris removal. Of the outmigrants, 24 left Spring Pond Creek within five days of debris removal. The fate of the remaining fish is unknown; no dead fish were observed. We feel that removal of slash resulted in increased social stress that may have involved higher degrees of agonistic behavior, predation and possibly disease.

Other aspects of the effects of debris removal involved changes in macrobenthos populations and community structure and therefore altered food habits of juvenile Dolly Varden. Approximately 120 invertebrate and stomach samples were taken in Spring Pond Creek in 1976 for analysis. However, due to difficulties in acquiring trained personnel to analyze this material, only a few of the samples were prepared in time for this writing. The material will be ready for reporting for next year's Report of Performance.

Canopy Removal Study

Since 1973, temperatures of Spring Pond Creek, a small spring-fed stream have been dropping steadily, (Table 1). Mean temperature during the period of September to October has declined by 1.4°C (34.5°) from 1973 to 1976. The annual mean temperatures were tested with analysis of variance and found to be different at the 0.01 level of significance.

The reason for the steady drop in ground water temperature is not known at this time. We speculate that the original conifer canopy intercepted precipitation (personal communication, Bartos) and eliminated much of it through transpiration. After canopy removal, all precipation entered the groundwater system, causing a cooling effect on ground water streams.

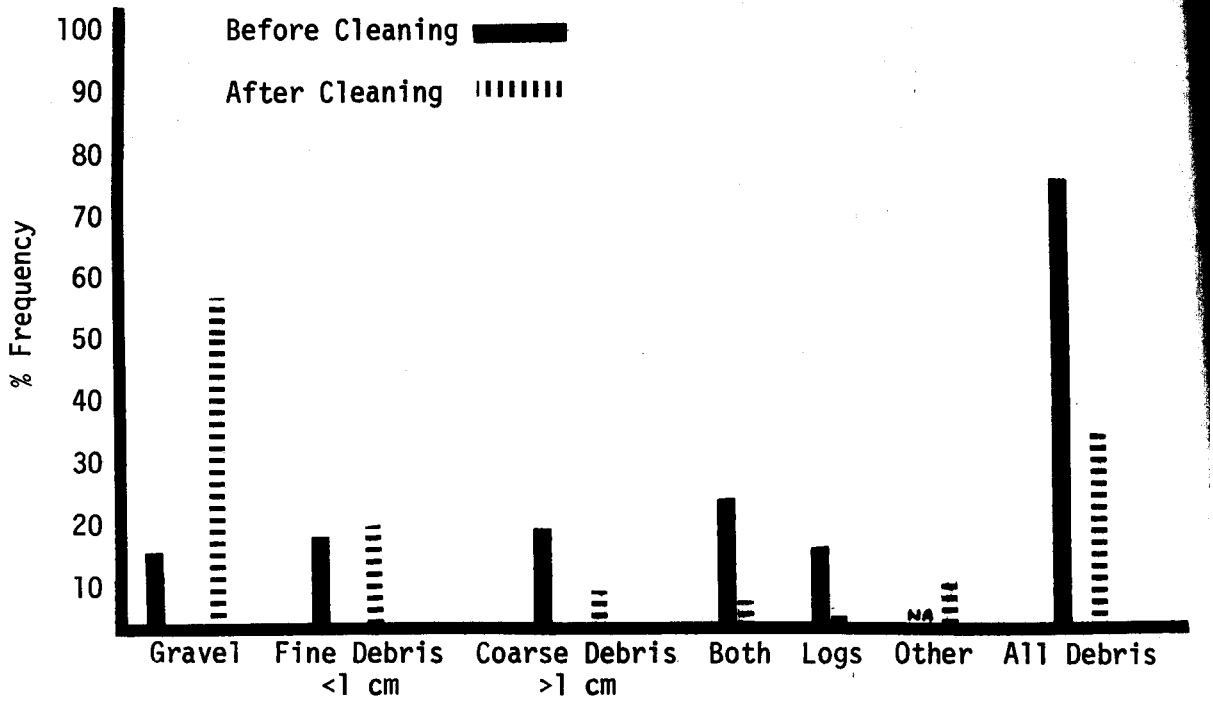

Figure 1. Percent Frequency of Streambed Types Before and After Debris Removal, Spring Pond Creek, 1976.

Table 1. Water Temperature (C°) of Spring Pond Creek from mid-September to November 1, 1973, 1974, 1975 and 1976.

Date	1973	1974	1975	1976
09/15-09/20	9.4	9.5	8.2	9.1
09/21-09/25	9.3	9.2	8.3	8.7
09/26-09/30	9.4	8.8	7.8	7.3
10/01-10/05	9.2	8.0	8.0	7.4
10/06-10/10	8.8	7.7	7.5	7.5
10/11-10/15	8.6	7.2	7.7	6.7
10/16-10/20	8.2	7.3	7.0	6.6
10/21-10/25	8.0	7.2	7.0	6.9
10/26-10/30	7.7	6.9	6.2	6.0
$\bar{X}$ Temperature	8.7	7.9	7.5	7.3

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