Habitat and juvenile salmonid populations in streams in logged and unlogged areas of southeastern Alaska

by Peter Joseph Cardinal

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Fish and Wildlife Management
Montana State University

Abstract:
Relationships between fish populations and stream habitat features in logged and unlogged areas on Prince of Wales Island, southeastern Alaska, were studied in 1977 and 1978. Principal components analysis of fifteen habitat features showed that the majority of variation in habitat data (40,3%) was accounted for by fine debris features. Principal component ordination indicated differences in fine debris concentrations between Tye-One-Ohn and Little Toad creeks in logged areas and Three-Tenths Mile Creek in unlogged forest. Measurements of fine and coarse debris were 165-467% greater on Tye-One-Ohn and Little Toad creeks in logged areas than on Three-Tenths Mile Creek in an unlogged area. Debris in the streams in logged areas often extended completely across the stream channel increasing mid-channel cover for fish and creating dams that increased pool area and average depth. Multiple regression analysis indicated that age 1+ coho salmon (Oncorhynchus kisutch) in Tye-One-Ohn Creek preferred submerged coarse debris in mid-channel areas. Age group 2-3+ Dolly Varden (Salvelinus malma) seemed to use pools formed by debris dams and undercut banks when age 1+ coho salmon were not associated with this feature, Riffles with debris were important to age group 0-1+ Dolly Varden in this stream. In Three-Tenths Mile Greek age 1+ coho salmon preferred undercut banks and seemed to make use of debris at stream edges in September. Dolly Varden of both age groups in this stream were primarily associated with debris in July. Undercut banks and features of debris not associated with age 1+ coho salmon in September became important to age groups 2-3+ and 0-1+ Dolly Varden respectively. Age 0 coho salmon used fine debris when it was not associated with age 1+ coho salmon and age group 2-3+ Dolly Varden but were forced to use cover free areas if these age groups were present. Logging debris in Tye-One-Ohn Creek apparently provided fish with suitable habitat over a greater area of the stream and resulted in separation of age groups into distinct habitats. The riparian vegetation along Little Toad Creek appeared to mask the relationships between measured habitat features and fish populations. It may have provided additional cover for age 1+ coho salmon and both age groups of Dolly Varden, It was predicted that removal of the debris associated with logging from the streams in logged areas may have negative impacts on fish populations, particularly on Dolly Varden.

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Date April 28, 1980

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ABSTRACT

Relationships between fish populations and stream habitat features in logged and unlogged areas on Prince of Wales Island, southeastern Alaska, were studied in 1977 and 1978. Principal components analysis of fifteen habitat features showed that the majority of variation in habitat data (40.3%) was accounted for by fine debris features. Principal component ordination indicated differences in fine debris concentrations between Tye-One-Ohn and Little Toad creeks in logged areas and Three-Tenths Mile Creek in unlogged forest. Measurements of fine and coarse debris were 165-467% greater on Tye-One-Ohn and Little Toad creeks in logged areas than on Three-Tenths Mile Creek in an unlogged area. Debris in the streams in logged areas often extended completely across the stream channel increasing mid-channel cover for fish and creating dams that increased pool area and average depth. Multiple regression analysis indicated that age 1+ coho salmon (Oncorhynchus kisutch) in Tye-One-Ohn Creek preferred submerged coarse debris in mid-channel areas. Age group 2-3+ Dolly Varden (Salvelinus malma) seemed to use pools formed by debris dams and undercut banks when age 1+ coho salmon were not associated with this feature. Riffles with debris were important to age group 0-1+ Dolly Varden in this stream. In Three-Tenths Mile Creek age 1+ coho salmon preferred undercut banks and seemed to make use of debris at stream edges in September. Dolly Varden of both age groups in this stream were primarily associated with debris in July. Undercut banks and features of debris not associated with age 1+ coho salmon in September became important to age groups 2-3+ and 0-1+ Dolly Varden respectively. Age 0 coho salmon used fine debris when it was not associated with age 1+ coho salmon and age group 2-3+ Dolly Varden but were forced to use cover free areas if these age groups were present. Logging debris in Tye-One-Ohn Creek apparently provided fish with suitable habitat over a greater area of the stream and resulted in separation of age groups into distinct habitats. The riparian vegetation along Little Toad Creek appeared to mask the relationships between measured habitat features and fish populations. It may have provided additional cover for age 1+ coho salmon and both age groups of Dolly Varden. It was predicted that removal of the debris associated with logging from the streams in logged areas may have negative impacts on fish populations, particularly on Dolly Varden.

INTRODUCTION

Logging in southeastern Alaska has resulted in the deposition of large quantities of debris and slash in many small streams. Excessive debris has been shown to increase biochemical oxygen demand and decrease surface and intragravel dissolved oxygen (Hall and Lantz 1969, Moring 1975). Debris can fill interstices in gravel and rubble substrates reducing living space for invertebrates (Hynes 1960) and refuges for young salmonids (McCrimmon 1954). Channel instability can result from the movement of debris at high flows (Bishop and Shapley 1963, Helmers 1966). Fish populations have been shown to change in watersheds that have been logged (Narver 1972, Moring and Lantz 1974, Moring 1975). However, few studies have been made to evaluate changes in fish populations as a result of instream debris removal.

Logging operations began on Prince of Wales Island in 1951 when the United States Forest Service (U.S.F.S.) awarded a 50 year timber sale contract to the Ketchikan Pulp Company (now Louisiana Pacific Ketchikan). Prior to 1974, the U.S.F.S. required the company to remove debris only from streams used for spawning. During 1974 they required debris be removed from streams used for rearing, and began a program of debris removal on rearing streams in previously logged areas (Fred Ziegler, personal communication). The U.S.F.S. Pacific Northwest Forest and Range Experiment Station initiated studies in 1977 on fish, aquatic macroinvertebrates,

stream morphology and hydrology in streams on Prince of Wales Island to document the effects of debris removal. The present study was undertaken to provide information prior to debris removal on:

1. Habitat in streams in logged and unlogged areas.
2. Fish population numbers, age composition, biomass and movements.
3. Distribution of fish within habitats in streams in logged and unlogged areas.

Field work was conducted between June and September in 1977 and 1978.

DESCRIPTION OF STUDY AREA

The study area was located on Prince of Wales Island in southeastern Alaska. Records of the U.S. Weather Bureau on Annette Island, 20 miles east of Prince Wales, show precipitation averaged 290.3 cm per year from 1941-1970. Average precipitation for July, August, and September for these years was 13.7, 18.2 and 25.5 cm respectively. In 1977 precipitation was 67, 16, and 43% below normal for July, August, and September respectively. In 1978 precipitation was 66 and 16% below normal for July and August and 16% above normal for September. The annual air temperature averaged 7.6°C from 1941 through 1970.

Prince of Wales Island supported a rain forest composed largely of Sitka spruce (Picea sitchensis) and western hemlock (Tsuga heterophylla). Alaska yellow cedar (Chamaecyparis nootkatensis), mountain hemlock (Tsuga mertensiana), western red cedar (Thuja plicata), red alder (Alnus rubra), and American devils club (Oplapanax horridus), were also present. Logging operations on the island have produced clearcut areas in the forest ranging from several hundred to several thousand hectares in size. Salmonberry (Rubus spectabilis), blueberry (Vaccinium spp), and spruce and hemlock seedlings dominated in clearcut areas.

Three-Tenths Mile, Tye-One-Ohn and Little Toad creeks on the northwestern corner of Prince of Wales Island were selected for

study (Figure 1). All three streams were (1) tributaries to Staney Creek, (2) less than 2m wide, and (3) used as rearing areas by salmonids. The study section on Three-Tenths Mile Creek was 80m in length and lay in unlogged forest between Twin Spur Road and Staney Creek. It contained coho salmon (Oncorhynchus kisutch) and Dolly Varden (Salvelinus malma). The study section on Tye-One-Ohn Creek lay between Road FDR 5400 and Staney Creek. It was 110m in length and was situated in a clearcut created in 1967. Coho salmon, Dolly Varden, coastrange sculpin (Cottus aleuticus), and cutthroat trout (Salmo clarki) were found in this stream. The study section on Little Toad Creek was located between Road FDR 5410 and Road FDR 5414. It was 170m long and lay in a clearcut created in 1971. Coho salmon, Dolly Varden, and cutthroat trout were present in this study section.

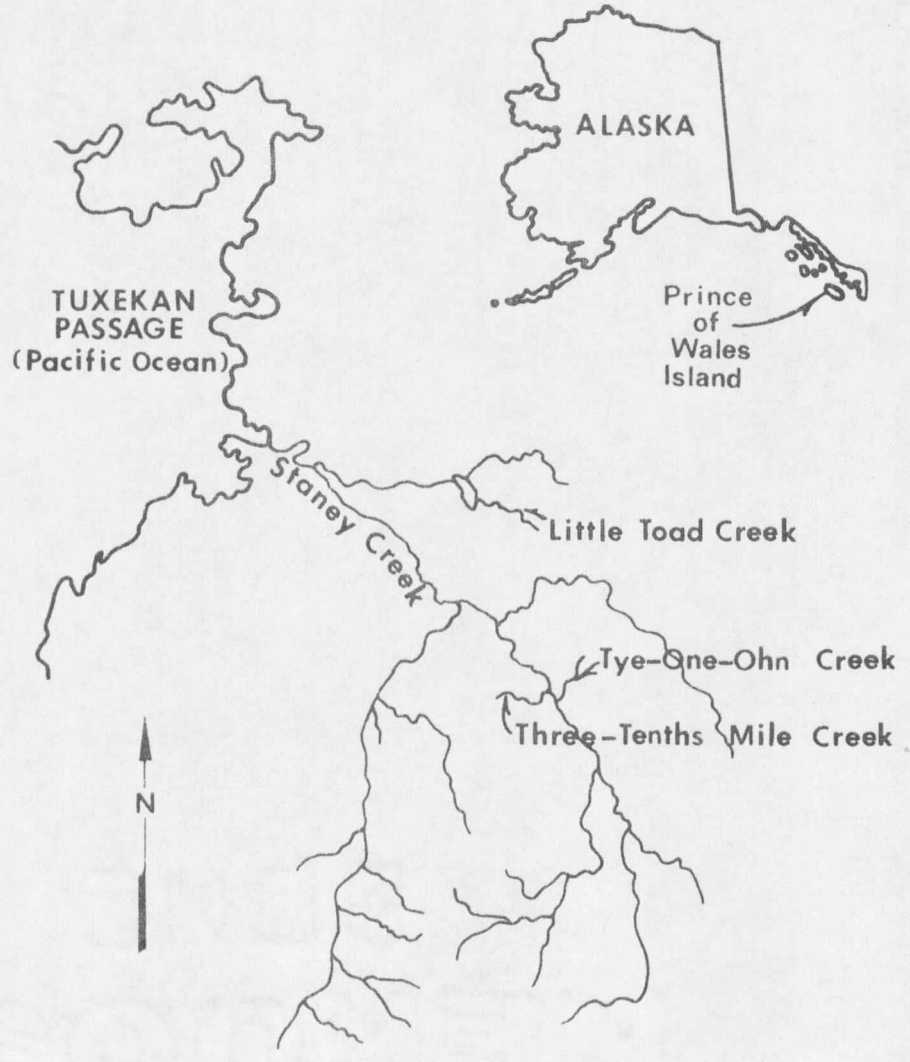

Figure 1. Map showing the location of the study streams in the Staney Creek drainage on Prince of Wales Island.

METHODS

Sampling Stations

Eleven stations of 10m length were established on Tye-One-Ohn Creek and used during 1977 and 1978. Eleven stations of 20m length were established on Little Toad Creek in 1977. In 1978 four of these were retained, three were shortened by 10m, and four were shortened by 5m. Eight stations of 10m length were established on Three-Tenths Mile Creek in 1978. All stations on a given stream comprised the study section. Stations were selected to provide a range of habitats on all streams.

Measurement of Habitat

Each station was mapped in 1978 to show undercut banks, riffles, pools, areas with fine debris (1cm to 10cm in diameter), and individual pieces of coarse debris (greater than 10cm in diameter and 30cm in length). Shallow, fast moving portions of the stream were mapped as riffles and areas that appeared to have slower currents and greater depth were recorded as pools. Mapping was done with a steel tape and compass on a 1:48 scale.

Six to eight line transects were established perpendicular to the stream channel at each station. Intervals between the transects were equal and dependant on the length of the station. Depth was measured to the nearest 0.5cm at 15cm intervals along

each transect. Fine debris was sampled by the line intersect method of Froelich et al. (1972). Individual pieces of fine debris were counted along the entire wetted portion of each transect and classified as submerged or elevated.

The following habitat features were derived from measurements taken at each station.

1. Fine debris as percent of surface area (submerged and elevated).
2. Submerged fine debris as percent of surface area.
3. Elevated fine debris as percent of surface area.
4. Density of fine debris (submerged and elevated).
5. Density of submerged fine debris.
6. Density of elevated fine debris.
7. Coarse debris as percent of surface area (submerged and elevated).
8. Density of coarse debris (submerged and elevated).
9. Density of submerged coarse debris.
10. Stream gradient
11. Pools as percent of surface area.
12. Average depth.
13. Water surface area.
14. Undercut bank as percent of surface area.
15. Length of undercut bank as percent of total bank.

Measurements of undercut bank, coarse debris, fine debris, and stream surface areas were made from station maps with a planimeter. Stream gradients were determined with a stadia rod and hand level. Volume of fine debris per unit area (V) was calculated by:

$$V = \frac{\pi^2 d^2}{8L}$$

where d= count of intersections of all pieces in diameter class times mean diameter (2.42 cm), and L = length of transect line (Froelich et al. 1972). Pieces of coarse debris were measured individually

and submerged pieces were counted. Specific weight of organic material was assumed to be 0.5 (Swanson et al. 1977) and density of debris was described as kg/m^2 water.

Fish Populations

Fish populations were censused on Little Toad Creek during July 13-27 and August 10-24 and on Tye-One-Creek during August 10-24 and September 9-21, 1977. In 1978 fish populations were censused during July 10-21 and September 1-4 on all streams. Fish were captured in minnow traps baited with salmon eggs placed at three trap sites per station on Three-Tenths Mile and Tye-One-Ohn creeks. Traps were used at three or four sites per station on Little Toad Creek. Traps were spaced as evenly apart as depth and channel characteristics permitted. Captured fish were anesthetized with MS 222 (Tricane Methanesulfonate), measured to the nearest mm (Total length) and marked with a station-specific combination of caudal and/or anal fin punches which were identifiable for up to two weeks.

Estimates of fish numbers on each study section of Tye-One-Ohn and Little Toad creeks in 1977 and July 1978 were made using the Chapman modification of the Schnabel formula (Ricker 1975). Estimates on the study section of Three-Tenths Mile Creek during July and on the study sections of all streams in September, 1978

were made with the Chapman modification of the Peterson formula (Ricker 1975). Confidence limits for Schnabel and Peterson estimates were obtained following the procedures of Ricker (1975). Population densities were estimated by dividing population estimates by stream volumes.

The lengths and weights of 20-25 live coho salmon and 20-25 living Dolly Varden were obtained at the end of each census period in 1978 to determine size-age and length-weight relationships. The ages of these fish were determined from examination of otoliths following the procedures of Williams and Bedford (1973). Size ranges were determined for each age or age group and these were compared to length-frequency distributions. The Fire 1 computer program (Hesse 1977) was used to sort length-frequencies from the population census data.

Biomass estimates on each stream were calculated using the population estimates and predicted weights from the length-weight relationships calculated by the Fire 1 computer program. The estimates of densities and biomass of each species for stations within each study section were obtained by proportioning the estimates from a given section to its individual stations based on the percentage of fish marked at each station during the censuses.

Fish Movement

Fish movements were monitored by one way box traps. Two one way box traps were located upstream and downstream from the study sections on Tye-One-Ohn and Little Toad creeks. The numbers, species, and direction of movement of fish captured at these sites were recorded. Traps were checked daily between July 17 and September 21 in 1977 and between May 12 and August 16 in 1978.

Statistical Analyses

Principal component (PC) analysis (Nie et al. 1975) was used to identify linear combinations of habitat features which described levels of variation in the habitat data from the three study streams. The first combination of habitat features (PC-1) explained the greatest amount of variation in the habitat data. Each subsequent PC was the combination of habitat features that explained the greatest amount of the variation that was not accounted for by preceeding components. Each PC was independant of the others. Within each PC habitat features having a correlation coefficient of 0.8 or more with other features were identified.

A stepwise multiple regression procedure (Nie et al. 1975) was used to determine the variation in fish population estimates attributable to specific habitat features or combinations of features in each stream. Population densities for each age group of

coho salmon and Dolly Varden at each station served as dependant variables. Measurements of habitat features at each station having low (0.8 or less) correlation to other habitat features were used as independent variables. The use of low-correlated habitat features from each PC allowed a reduction in the number of variables considered in the same regression and reduced bias due to multicollinearity (Nie et al. 1975). The amount of variation in fish population estimates attributable to habitat features was described by the statistic $R^{2'}$. This statistic was the coefficient of determination (R^2) adjusted for the number of independant variables and the number of cases (stations per stream) in the analysis (Nie et al. 1975). It was a more conservative estimate of the variation explained than was R^2, especially when the number of cases was small. All statistical analyses were performed with the Sigma 7 computer at Montana State University.