Habitat use of juvenile salmonids in Ophir and East Ophir Creeks, Yakutat, Alaska
by Kellie Su Whitton

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:
Habitat use by juvenile salmonids was examined in Ophir and East Ophir Creek as part of a coho and sockeye salmon restoration effort. Outmigration studies in 1995 indicated winter rearing densities in East Ophir Creek were twice as high as Ophir Creek (43.8 fish/100m^2 vs 19.1 fish/100m^2). I studied juvenile salmonid abundance, habitat availability, habitat use, and physical habitat characteristics in Ophir and East Ophir creeks during the summers of 1996 and 1997 in an attempt to identify limiting factors for Ophir Creek. Glides made up the largest portion of available summer habitat in Ophir Creek (33.8%), compared to sloughs (29.6%) in East Ophir Creek. Additional differences in habitat availability occurred and likely affected the overall smolt production of the two streams. Coho salmon were the most abundant species captured in most East Ophir Creek habitats both years. In Ophir Creek, sockeye salmon were more abundant in 1996 and early summer 1997. Although threespine sticklebacks, slimy Sculpins and Dolly Varden char were captured in both streams, their abundance was low and variable. The proportion of age 1+ coho salmon was higher in most East Ophir Creek habitats during both years. Few age 1+ sockeye salmon were found in either stream, but they were proportionately more abundant in East Ophir Creek. Summer mean water temperatures were warmer in East Ophir Creek in 1995 and 1997 which may be responsible for increased growth rates, improving overwinter survival. Few differences in the other habitat variables were found between streams. Habitat area, volume, and temperature explained the most variation in East Ophir Creek sockeye and coho salmon densities in 1997, while large woody debris (LWD), undercut banks and cover were more important in 1996. Little of the variation in Ophir Creek fish densities was explained by the physical habitat variables although depth or LWD abundance or volume appeared in most habitat models. East Ophir Creek appears to provide better summer and/or winter habitat for older coho and sockeye salmon. Because few of the physical habitat variables explained the differences in smolt production between Ophir and East Ophir Creek in summer, it appears that some other factor such as winter habitat may be limiting smolt production in Ophir Creek.

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Kellie Su Whitton

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Habitat use by juvenile salmonids was examined in Ophir and East Ophir Creek as part of a coho and sockeye salmon restoration effort. Outmigration studies in 1995 indicated winter rearing densities in East Ophir Creek were twice as high as Ophir Creek (43.8 fish/100m^2 vs 19.1 fish/100m^2). I studied juvenile salmonid abundance, habitat availability, habitat use, and physical habitat characteristics in Ophir and East Ophir creeks during the summers of 1996 and 1997 in an attempt to identify limiting factors for Ophir Creek. Glides made up the largest portion of available summer habitat in Ophir Creek (33.8%), compared to sloughs (29.6%) in East Ophir Creek. Additional differences in habitat availability occurred and likely affected the overall smolt production of the two streams. Coho salmon were the most abundant species captured in most East Ophir Creek habitats both years. In Ophir Creek, sockeye salmon were more abundant in 1996 and early summer 1997. Although threespine sticklebacks, slimy sculpins and Dolly Varden char were captured in both streams, their abundance was low and variable. The proportion of age 1+ coho salmon was higher in most East Ophir Creek habitats during both years. Few age 1+ sockeye salmon were found in either stream, but they were proportionately more abundant in East Ophir Creek. Summer mean water temperatures were warmer in East Ophir Creek in 1995 and 1997 which may be responsible for increased growth rates, improving overwinter survival. Few differences in the other habitat variables were found between streams. Habitat area, volume, and temperature explained the most variation in East Ophir Creek sockeye and coho salmon densities in 1997, while large woody debris (LWD), undercut banks and cover were more important in 1996. Little of the variation in Ophir Creek fish densities was explained by the physical habitat variables although depth or LWD abundance or volume appeared in most habitat models. East Ophir Creek appears to provide better summer and/or winter habitat for older coho and sockeye salmon. Because few of the physical habitat variables explained the differences in smolt production between Ophir and East Ophir Creek in summer, it appears that some other factor such as winter habitat may be limiting smolt production in Ophir Creek.

INTRODUCTION

Habitat degradation has been responsible for the reduction and loss of many salmonid fisheries (Cederholm and Reid 1987; Koski 1992; Brown et al. 1994). For example, only 54% of 248 streams in California that previously sustained coho salmon, *Oncorhynchus kisutch*, still contain coho and, of these, only 43% contain wild stock. Loss of stream habitat from human disturbances was the primary factor responsible for the decline of California's anadromous salmonids (Brown et al. 1994). Numerous anthropogenic activities result in habitat degradation including logging, road construction, mining, livestock grazing, agriculture, and urbanization (Koski 1992; Brown et al. 1994; Waters 1995). Even Alaska, which is relatively unimpacted and unpopulated compared to California and the Pacific Northwest, has not escaped the impacts of urbanization and resource extraction. Currently, most of Alaska's anadromous salmonids are at record levels (Holmes and Burkett 1996; Hyatt 1996), but this is not true for all populations. Baker et al. (1996) reported that of 928 southeast Alaska "spawning aggregates", 37 (4%) were declining and 2 (< 1%) showed precipitous declines. The primary causes for declines in Alaska's salmonids are impaired water quality and habitat degradation resulting from urbanization, logging, and mining (Baker et al. 1996).

Ophir Creek, located just south of Yakutat, Alaska, (pop. 800) has not escaped habitat degradation despite its remote location (Figure 1). Several anthropogenic factors may

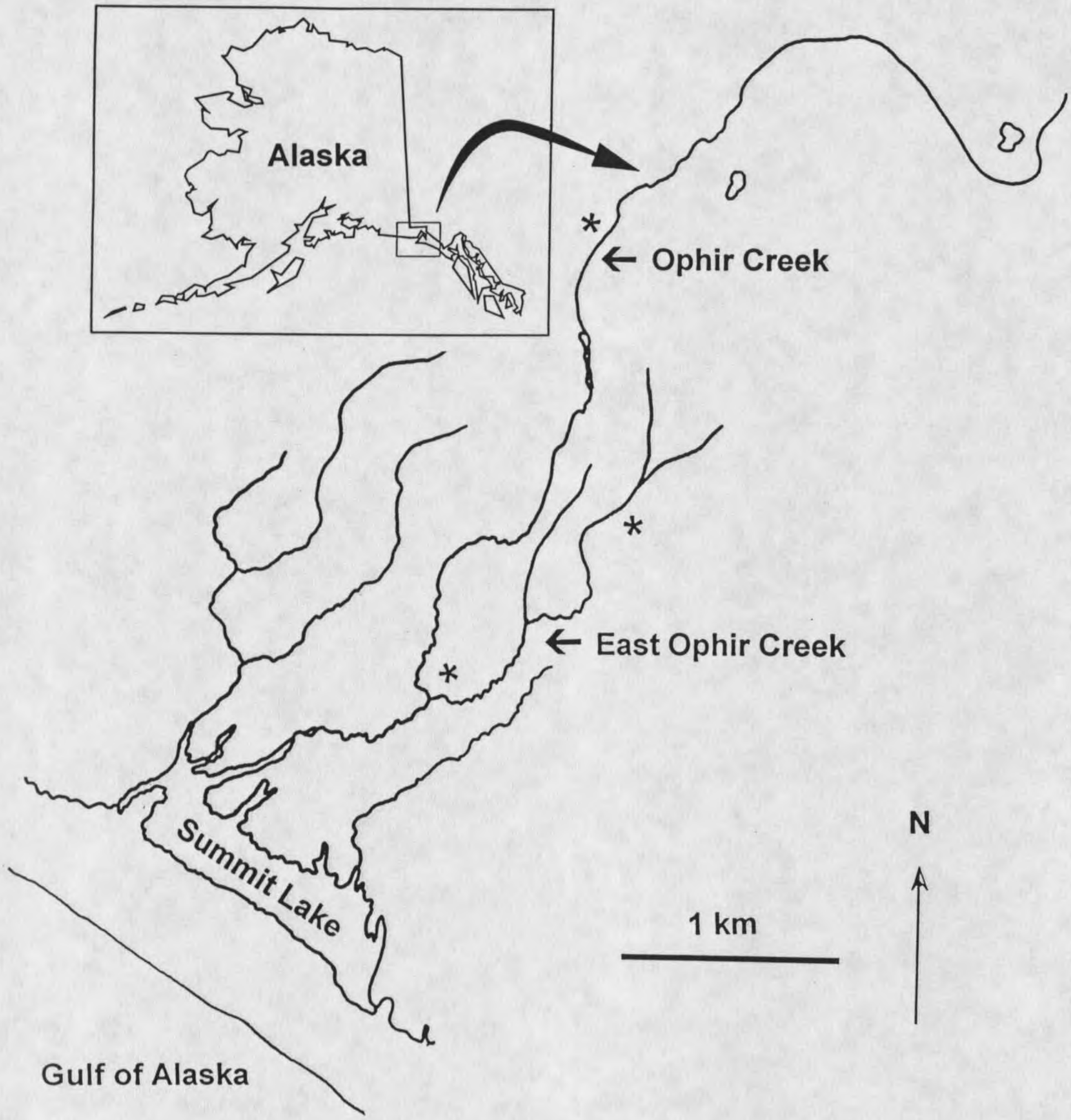

Figure 1. Map of the study area on Ophir and East Ophir creeks. The upper and lower limits of sampling are indicated by asterisks (*).

have contributed to the degradation and dewatering in the Ophir Creek drainage. The headwaters of Ophir Creek were logged during the 1940-1950's and again in the 1970-1980's. At that time, the headwaters were not designated anadromous fish habitat and buffer zones and other protective measures were not implemented to prevent habitat degradation. Other activities associated with rural community development, including drainage ditches, road building, and gravel pits may have also contributed to the dewatering or habitat degradation of Ophir Creek.

In addition to human-related causes, two natural events that may have contributed to dewatering in Ophir Creek are isostatic rebound (uplift following glacial retreat), and tectonic uplift due to earthquake activity. Limited historical data have documented these events in the Yakutat area (Hicks and Shofnos 1965; Hudson et al. 1982). Although no single factor can account for the loss of perennial flow in Ophir Creek, the combination of both anthropogenic and natural events appear responsible.

Recent declines in spawning adult coho and sockeye, *O. nerka,* salmon have affected historically important sport, commercial, and subsistence fisheries of the Yakutat community. In 1994 a restoration project was initiated in the Ophir Creek drainage to increase the salmon production capability of the stream. Prior to restoration activities, 51% of Ophir Creek and 27% of its tributary, East Ophir Creek, were dewatered during periods of low precipitation in the summer and winter. This dewatering caused high mortality of juvenile salmonids when they were isolated from areas of continuous flow or of eggs due to freezing during winter (Susan Walker, U S Fish and Wildlife Service, personal communication). Adult spawning surveys documented that 80% of adult coho salmon spawned in the portion of Ophir Creek that dewaters. Therefore, the loss of perennial flow in Ophir and East Ophir creeks has reduced the amount of habitat available for spawning adults and has probably reduced the amount of juvenile habitat. This loss of spawning and rearing habitat has probably affected the salmonid production in both streams (Sandercock 1991).

Stream habitat requirements of anadromous salmonids change with life stage (fry, parr, smolt, and adult spawners). Understanding the ecological importance of different habitats for all salmonid species and age classes present is necessary for effective restoration (Bisson et al. 1982; Koski 1992; Nickelson et al. 1992; Rabeni and Jacobson 1993). For restoration to be successful, factors limiting stream salmonid abundance must be identified. This is difficult because information on optimum salmonid densities in different habitat types is lacking (Reeves et al. 1991; Nickelson et al. 1992). For anadromous salmonids, production is usually defined as the number of smolts produced by a stream (Bradford et al. 1997) or the number of returning adult spawners. Many studies make the assumption that all habitat types are capable of producing the same number of smolts. This is unlikely, and estimates of production based on this assumption may not accurately reflect the true production potential of a stream (Nickelson et al. 1992; Bradford et al. 1997).

One goal of the Ophir Creek restoration project was to determine adult and juvenile salmonid habitat use. Habitat use was defined as the density, age, and species composition of fish found in a particular habitat type. Weekly adult spawning surveys conducted since 1995 documented the number of adult spawners and identified important spawning areas for both coho and sockeye salmon in Ophir and East Ophir creeks. Juvenile salmonid rearing habitat had not been studied and was the focus of my research.

Rearing habitat for juvenile anadromous salmonids, rather than spawner abundance, is often the limiting factor in many coastal streams, particularly for species with long freshwater residence (Koski 1992; Meehan and Bjornn 1991; Sandercock 1991; Hartman and Scrivener 1990). Coho and sockeye salmon usually spend from 1 to 3 years in freshwater before migrating downstream to the ocean (Crone and Bond 1976; Wood et al. 1987; Sandercock 1991). Juvenile sockeye salmon usually rear in lakes, but in Ophir and East Ophir creeks, stream-rearing sockeye are common. Although Wood et al. (1987) documented that riverine sockeye in the Stikine and Iskut rivers reared in a variety of river channel and slough habitats, this alternate life history is not well documented. Identifying important rearing areas for juvenile sockeye salmon within Ophir and East Ophir creeks may provide additional information about their habitat requirements in small streams.

Juvenile salmonid habitat requirements change throughout the year and shifts in habitat utilization are common (Swales et al. 1986). In the spring, coho salmon fry tend to concentrate in backwater pools while in the summer they are distributed among all pool types. As winter approaches, coho fry move into deep pools, sloughs, tributaries and side channels (Bustard and Narver 1975; Heifetz et al. 1986; Nickelson et al. 1992).

In addition to seasonal shifts, habitat requirements for juvenile anadromous salmonids also change for different life stages (Bugert et al. 1991; Sandercock 1991). As coho increase in size, they prefer deeper pools with more cover (Bugert et al. 1991). Sampling in a variety of different habitats may help identify which are important for each life stage, and sampling multiple times within a season may determine whether shifts in preferred habitats occur as fish increase in size. A complete understanding of these changing habitat requirements for all species present is necessary for determining the potential production of a stream.

If spawning is sufficient to fully seed a stream, the number of smolts produced is related to the stream's carrying capacity for juvenile salmonids which is a function of its physical structure or habitat quality. A high quality habitat is one that provides all of the components necessary for the growth and survival of juvenile salmonids (i.e. food, space, and cover). Gradient, depth, velocity, substrate, large woody debris, and other forms of cover provide the necessary complex of physical structures or hydrologic forces that create the diversity of habitats important for all salmonids (Koski 1992). Low-gradient streams found in old-growth forests are the most productive habitats for anadromous salmonids because of the habitat complexity resulting from large woody debris (Koski 1992). Studies have found coho salmon densities were positively related to the amount of large woody debris and other forms of cover (Bustard and Narver 1975; McMahon and Holtby 1992). The habitat complexity provided by large woody debris may reduce aggressive interactions through increased visual isolation, allowing an increase in rearing densities (Dolloff 1986; Taylor 1991; Fausch 1993). Coho salmon, which are very territorial, are often limited by the availability of suitable territories (Larkin 1977). Streams that provide complex habitat and sufficient quantities of food should support higher numbers of coho salmon (Scrivener and Andersen 1984; Sandercock 1991).

In addition to physical factors, biological factors such as predation and competition may affect the rearing potential of many salmonid streams (Bugert et al. 1991; Taylor 1991; Koski 1992). Threespine sticklebacks, *Gasterosteus aculeatus*, slimy sculpins, *Cottus cognatus*, and Dolly Varden char, *Salvelinus malma*, are found in both Ophir and East Ophir creeks, and their presence may affect the seasonal habitat distribution of coho and sockeye salmon. Competition between threespine sticklebacks and sockeye and coho salmon has been documented (O'Neill and Hyatt 1987; Swales et al. 1988; Burgner 1991). Competitive interactions between species may reduce the rearing capacity of a given habitat because dominant species, through aggressive encounters, may influence the distribution and habitat use by a less dominate species or conspecific (Hartman 1965; Taylor 1991). Predation may also reduce rearing densities if cover is limited.

Large numbers of juvenile salmonids inhabiting streams with limited rearing habitat move downstream to other areas (Cederholm and Reid 1987). This migration occurs because fish are unable to find or defend a territory (Mason and Chapman 1965; Ruggles 1966; Sandercock 1991). Using averages reported by Sandercock (1991) for coho salmon fecundity (4510 eggs/female for southeast Alaska), survival during incubation (15-27%), and assuming a 1:1 sex ratio for spawning adults (approximately 2885 females in 1994), Ophir Creek should produce approximately 1.9 - 3.5 million fry. In 1994, spawning surveys conducted in Ophir Creek documented that 80% of adult coho spawned in areas that dewatered; therefore, 80% of the potential production (1.5 - 2.8 million) may have been lost and only 390,000 - 702,000 fry would emerge. Comparing the estimated emergence with the actual number of coho fry that migrated out of Ophir Creek in 1995

(273,121), it appeared that a large number of fry may be leaving the stream. The juvenile fish weirs only monitored outmigration for 2 months (April 12 - June 16) so this number may have underestimated the actual number of coho fry that left the stream. This suggests that juvenile rearing habitat in Ophir and East Ophir creeks may be limited.

Outmigration data from 1995 also suggested that there were differences in rearing potential between Ophir and East Ophir creeks. Although Ophir Creek has approximately twice the total habitat area of East Ophir creek, it only accounted for 55% of the total parr and smolt counted at both weirs. In fact, the estimated density of fish (parr and smolt) rearing in East Ophir Creek (43.8 fish/100 m^2) during the winter was more than twice as high as that for Ophir Creek (19.1 fish/100 m^2) (Harke and Lucey 1995a, unpublished report). The reasons for differences in rearing densities could not be explained without additional information.

The objectives of this study were to (1) determine and quantify the availability of different juvenile rearing habitats in both streams; (2) quantify differences in habitat use by coho and sockeye salmon; (3) document the presence of other species within these habitats and streams; and (4) determine whether there are differences in physical habitat variables that may explain why rearing densities are higher in East Ophir Creek.

STUDY AREA

Ophir Creek is a major tributary in the Lost River-Tawah Creek watershed, and is located 0.65 km southeast of Yakutat, Alaska (Figure 1). The creek is approximately 6.85 km long, and East Ophir, the only major tributary, is 2.1 km long. Both are small, low gradient, (< 1.0 %) groundwater-fed streams consisting mostly of pool, glide and slough habitat. The 2,740 ha watershed is located in a glacial outwash plain bounded by relic glacial moraines. Ophir creek originates in several kettle ponds located in the glacial moraines and then flows southeast into eutrophic Summit Lake (28 ha). East Ophir Creek flows into Ophir Creek approximately 500 m upstream of the confluence with Summit Lake. Prior to glacial retreat, flow within Ophir Creek was maintained primarily by glacial melt; however, today most flow is derived from precipitation. The mean discharge for 1992-1996 was 0.413 m^3/s. Yakutat receives an average of 370 cm of precipitation per year and the mean annual temperature is 3.9 °C. Summer (May - August) mean temperatures range from 6.4 -11 °C.

The lower reaches of both streams have not been clearcut and flow through old-growth forests of western hemlock, *Tsuga heterophylla*, and sitka spruce, *Picea sitchensis*. The understory, a mixture of alder, *Alnus* spp., willow, *Salix* spp., salmonberry, *Rubus, spectabilis*, blueberry, *Vaccinium* spp., and devil's club, *Opopanax horridum*, grows along the banks of both streams and provides overhanging cover during the summer.

In Ophir Creek, the study area included the 3,050 m upstream of its confluence with East Ophir Creek. The area upstream of this section went completely dry during the summer of 1996, and only 625 m at the upper end of the excluded section contained water during 1997. The area below the confluence contained fish from both streams and was excluded from the study. In East Ophir Creek, the study area was the 1250 m upstream from the confluence with Ophir Creek (Figure 1). The area upstream of this point was completely dry during both summers. Stream flow in the East Ophir Creek study area was discontinuous for short periods of time during both summers.

METHODS

Habitat Classification and Sample Site Selection

To assess the importance of different habitats to juvenile salmonids, I classified Ophir and East Ophir Creek into five habitat types (glides, riffles, side channels, sloughs, and pools) in May 1996. The habitat classifications used were based on a modification of the classification system developed by Bisson et al. (1982) (Table 1). Pools were further subdivided into midchannel scour (Nickelson et al. 1992), lateral scour, and backwater. Several habitat types included in the Bisson classification system were not found in Ophir or East Ophir creeks and are not described here. Two additional habitat types sloughs and side channels, were added.

Following habitat classification, I measured the area of each habitat unit in both streams to determine the total area of each habitat type. For the purposes of this study, a habitat unit was defined as one pool, riffle, glide, slough or side channel. The area of each habitat unit was calculated from the length, measured parallel to the direction of flow, and the average of three width measurements taken at 1/4, 1/2, and 3/4 along the length of the site. Because water levels within the streams changed relative to recent precipitation events, bankful width (bank to bank including undercut) rather than wetted width was used to determine area. Therefore, for total stream area estimates, the measured area of a habitat type was the potential area and not the actual area covered by

Table 1. Habitat types encountered in Ophir and East Ophir creeks, Alaska (modified from Bisson et al. 1982)

Habitat Type	Description
Glide (GLD)	Areas with a smooth surface appearance and little turbulence. Depth is fairly uniform throughout the site.
Riffle (RIF)	Shallow low-gradient areas with moderately fast flow and surface turbulence.
Side Channel (SCH)	Secondary channels branching off the main channel; may be isolated or discontinuous during the summer.
Slough (SLO)	Wide deep pond-like areas on the main channel characterized by the aquatic macrophyte, mare's tail, *Hippuris vulgaris*
Pools	
Midchannel Scour (MCP)	Primary scour area is in the center of the channel. Often formed by the scouring action of the current when there is a channel constriction.
Lateral Scour (LSP)	Primary scour area is on either side of the channel. Scour is often formed because the flow is deflected by a partial channel obstruction.
Backwater (BWP)	Pools found along channel margins often caused by eddies behind main channel obstructions. Characterized by low velocities and fine sediments.

water at any point in time. However, wetted area was used to determine fish densities while sampling in selected sites. Small riffle-like transition zones between habitats were not classified as riffles because most were less than 3 m long. Reliable fish abundance estimates would be difficult in these habitats because of low numbers and shallow water. Instead, to account for fish in these areas, transition zones were divided at the break point (mid-point) and the two sections added to the adjacent habitat units.

Initially 10 sites of each habitat type (if available) were selected in each stream using systematic sampling with a random start, but logistics prevented sampling of all selected sites (Table 2). Systematic sampling ensured sites were selected throughout the entire length of both streams rather than being concentrated in one area, thus providing more representative measurements of stream characteristics than simple random sampling (Scheaffer 1990). If a selected habitat site proved too difficult to sample effectively (i.e. excessive amounts of large woody debris and substrate composition which reduced maneuverability), then the nearest downstream site of that habitat type was sampled.

Table 2. Number of sampling sites for each habitat type found in Ophir and East Ophir creeks in 1996 and 1997. In 1997 sample periods one (May 27 - July15) and two (July 16 - August 20) are designated S#1 and S#2. BWP = backwater pools; GLD = glides; LSP = lateral scour pools; MCP = midchannel scour pools; RIF = riffles; SCH = sidechannels; SLO = sloughs.

	1996		1997			
Habitat Type	Ophir Creek	East Ophir Creek	Ophir Creek S #1	Ophir Creek S#2	East Ophir Creek S#1	East Ophir Creek S#2
BWP	2	1	2	2	2	2
GLD	7	7	9	9	8	7
LSP	2	1	2	2	1	1
MCP	6	6	6	6	7	7
RIF	5	0	4	3	0	0
SCH	4	2	3	4	1	1
SLO	1	2	0	1	3	3
Total	27	19	27	27	22	21

Side channel habitat was one exception because side channels were often overgrown with willow and alder making effective sampling with available equipment impossible in most areas. Therefore, side channel sites were a subsample of the available sites that could be adequately accessed. Although this nonrandom selection of sample sites may have biased results, selecting accessible sites was better than eliminating this habitat type, which has been documented as important winter rearing habitat for coho salmon (Bustard and Narver 1975).

Fish Abundance and Sampling

In 1996, all sites were sampled (fish abundance and physical habitat variables) once during the summer (July 15 - August 22). Minnow traps and a seine were tested in a few sites in May and June to determine which sample gear was more effective for capturing all fish species. In 1997, all sites were sampled twice during the summer. May 27 - July 15 was designated sample period one, and July 16 - August 20 sample period two. I waited at least 1 month before resampling any site. Sampling in 1997 was modified in both Ophir and East Ophir creeks. Two sites were added (one glide and one riffle) to Ophir Creek to increase sample sizes and to replace a riffle eliminated by shifting gravel, and one midchannel scour pool was removed because it could not be relocated in 1997. Five new sites (two glides, one midchannel pool, one backwater pool, and one slough) were added to East Ophir Creek in 1997, and two were removed. Four sites were added to increase sample sizes, one glide was added to replace a site that could not be effectively sampled in 1996, and one side channel site could not be relocated in 1997.

Site selection for daily sampling was nonrandom because of time limitations. Access to both streams was limited, particularly East Ophir Creek; therefore, sites that could be accessed through similar access points were sampled together. To maximize sampling efficiency, sampling was usually limited to one stream on any given day and sites located in the same general area were sampled on the same day. When two or more sites were close to each other, sampling began at the site furthest downstream to prevent activities in upstream sites from affecting downstream sites.

Prior to sampling, both the upstream and downstream ends of each sample site were blocked off with seines to prevent movement of fish in and out of the site (Johnson et al. 1994). Any additional side channels or adjacent habitat sites that connected to the sample site were also blocked. This was necessary to meet the assumption of no immigration and emigration for a closed population estimate.

During 1996 all fish species within all sites were captured using a beach seine (5.4 m long, 1.5 m deep, 6 mm mesh, with a pole at each end) pulled upstream against the current. If extra personnel were available, they released snags and if necessary, flushed fish from areas inaccessible to the seiners. In 1997, a beach seine was used to capture all species in all habitats except sloughs. Minnow traps were used to capture coho salmon in slough habitats because seining was not effective in 1996 and because aquatic vegetation prevented seining in the new slough added to East Ophir Creek in 1997. Estimates from different sample gears are not directly comparable; therefore, minnow traps were used to capture coho salmon in all sloughs.

In 1996, the removal method was the primary method used to estimate coho and sockeye salmon abundance in all sites (Zippen 1958). Although mark-recapture is considered more accurate for estimating populations of juvenile salmonids in small streams (Peterson and Cederholm 1984; Rodgers et al. 1992), removal estimation was selected because it was less time intensive. Each site was seined two to four times until a reduction occurred. The reduction level was not predefined and often depended on the site and logistics. However, most sites that were only seined twice had estimated capture probabilities greater than 66%. To verify removal estimates, a Peterson mark-recapture estimate of coho salmon ≥40 mm was made in nine Ophir Creek and four East Ophir Creek sites. For these 13 sites, coho salmon captured during the removal estimates were held, marked with an upper or lower caudal fin clip, and released after all fish had been identified and counted. One hour after release, fish were recaptured and coho salmon examined for fin clips. The 1 h recapture interval was selected because Peterson and Cederholm (1984) found little difference in mark-recapture population estimates of fish recaptured after 1 h and fish recaptured after 24 h. Abundance estimates were only calculated for coho and sockeye salmon because they were the primary species of interest, and the numbers of Dolly Varden char, slimy sculpin and threespine stickleback were often too low (< 30) to accurately estimate abundance (Riley and Fausch 1995).

In 1997, a removal estimate was used to determine coho and sockeye salmon abundance in all sample sites. A mark-recapture estimate was only used to verify estimates of coho salmon captured with minnow traps in slough habitats. Changes in sampling protocol between years were made because seine removal estimates were not effective for coho salmon in slough habitats, and because the 1996 mark-recapture estimates in 13 sites were only applicable to coho salmon ≥ 40 mm; therefore, they could not be used for smaller coho or any sockeye salmon. In 1997 most sites were seined three to five times. Sites that were only seined twice had capture probabilities > 83%, or were not seined again because of logistical problems (i.e. high mortality or high water caused block nets to fail).

For the removal estimate of coho salmon in slough habitats in 1997, minnow traps were baited and set approximately 3 m apart for three or four 2 h intervals. Each 2 h capture event was equivalent to one removal. Minnow traps (3 mm and 6 mm mesh) were baited with salmon roe treated with iodine and placed inside perforated film containers to prevent consumption, which might affect weight measurements. Minnow traps with 6 mm mesh are size selective for fish 51 mm and larger, so a mark-recapture estimate was used to verify removal estimates (Bloom 1976; Swales 1987). All fish captured during the removal estimate were marked with either an upper or lower caudal fin clip and released at the end of sampling. During release, fish were distributed throughout the site rather than released in one area. The recapture event was conducted the following day. Traps were set for three or four 1.5 h intervals until the number of fish captured was similar to the number originally marked, ensuring a reasonable estimate.

In both 1996 and 1997, all fish species captured in one seine haul or minnow trap period were separated into buckets or live carr for identification and counting. A subsample of coho and sockeye salmon was anesthetized with tricane methanesulfonate (MS-222), weighed to the nearest 0.1 g and measured (fork length) to the nearest 1 mm. If Dolly Varden were present, they were also measured. The predefined minimum number of fish measured in 1996, was 30 of each species while in 1997 the minimum was 50. However, for both years, if the total number of either species captured in a sample site was less than the minimum, all fish were measured. To verify the size overlap in age classes, a scale sample was taken from a subsample of coho and sockeye salmon > 45 mm. Scale sampling was not random because the goal was to obtain at least 10 fish in every 5 mm interval. However, I attempted to sample scales from all sites within each stream. Scale samples were pressed between two pieces of acetate until age analysis could be conducted. The anesthetized fish were then allowed to recover in fresh water and eventually released back into the capture site.

Physical Habitat Variables

Several physical habitat variables were measured to quantify differences between habitat types and between the two study streams. These included habitat depth, area, temperature, substrate composition, abundance and volume of large woody debris (LWD), area of undercut banks, and area of cover provided by both aquatic and riparian vegetation. These physical variables were measured at the same sites sampled for fish abundance so that comparisons between fish density and specific habitat variables could be made. Temperature (°C) was measured with a hand-held thermometer each time a site was sampled. In addition, in July 1997 three Onset thermographs (accuracy ±0.2 °C) deployed in each stream recorded water temperatures every 2 h and 23 min. In both streams, one thermograph was deployed in a slough habitat and one in a main channel site. The third thermograph in Ophir Creek was deployed outside of the study area, while in East Ophir Creek the third thermograph was deployed in another slough habitat. Additional water temperature data for 1994 to 1997 were obtained from thermographs deployed by other agencies. Data from 1996-1997 were collected with Hobo temperature loggers which recorded water temperature every 2 h. Deploy locations for the Hobo thermographs were unknown. Data from 1994-1995 were collected with Endeco thermographs deployed in a similar East Ophir Creek location, and near the Ophir Creek slough. Temperature data were summarized as daily maximum, minimum, and mean for comparisons.

Substrate composition was determined using a modified pebble count technique (Wolman 1954; Kondolf and Li 1992). One person randomly selected 50 substrate samples while criss-crossing the sample site. To eliminate selection bias, samples were selected without looking, from a point directly in front of the sampler's foot. The frequency of a particular substrate size was determined by the percentage of time it was included in the pebble count. Using a modified Wentworth Scale, substrate was classified into seven categories based on the estimated diameter (Table 3). Initially, observers measured substrate diameters, but eventually sizes were estimated visually. Substrate composition was summarized as mean substrate size.

Depth and area were measured each time a habitat site was sampled because of changing water levels. Depth was measured at three points (1/4, 1/2, 3/4) across the stream at every 3 m interval (Thedinga et al. 1993) unless the sample site was < 10 m in length, where depth was measured at 2 m intervals. For statistical analysis, depth was summarized as mean, maximum, minimum, and variance. Area was calculated from the length and the average of three wetted width measurements of the sample site. Habitat volume was calculated using the habitat area and mean depth

In each sample site, large woody debris (LWD), undercut banks, and aquatic and

Table 3. Criteria used to classify substrate sizes in Ophir and East Ophir creeks, based on a modified Wentworth Scale (Neilson and Johnson 1993; Allan 1995).

Substrate Category	Diameter Range
Small Boulders	25.5 cm to 1m
Large Cobbles	12.7 to 25.4 cm
Small Cobbles	6.3 to 12.7 cm
Coarse Gravel	2.5 to 6.3 cm
Gravel	4 mm to 2.5 cm
Very Fine Gravel and Sand	1 to 4 mm
Organic Muck or Silt	<1 mm

riparian vegetation were quantified to determine available cover. Large woody debris was counted and classified in each habitat site (Table 4). If the woody debris extended out of the stream channel, only that portion within the stream banks was measured. The volume (length x area of a circular cross section) of each piece of LWD was calculated using the mean length and diameter for each category. For length categories < 3 m and >7 m and diameter categories < 10 cm and >40 cm the values used to define those categories (3, 7, 10 and 40) were used to calculate LWD volume.

The amount of cover provided by undercut banks was determined by measuring the length of undercut on both banks and the depth of the undercut at several (10 or more) points along the bank. Cover provided by aquatic and riparian vegetation was determined by measuring the length and width of the vegetation to determine what proportion of the habitat area was covered by vegetation. Vegetative cover was limited during sample period one in 1997; therefore, it was not included in the multiple regression model.

Table 4. Categories used for classifying large woody debris in Ophir and East Ophir creeks. The values listed in parentheses were used to calculate volumes unless the actual measurements were available.

Diameter Categories	Length Categories
<10 cm (10)	<3 m (3)
10 - 20 cm (15)	3 - 5 m (4)
20 - 30 cm (25)	5 - 7 m (6)
30 - 40 cm (35)	>7 m (7)
>40 cm (40)	
Root Wad - recorded by size using the same categories.	

Data Analysis

Removal estimates were calculated using the computer program Capture (White et al. 1982) and Peterson mark-recapture estimates were calculated with a Bayesian based software program (Gazey and Staley 1986). Coho and sockeye salmon densities were calculated using the estimated abundance and wetted habitat area. However, if < 30 fish were captured density estimates were based on the total number captured, because Riley and Fausch (1995) reported the removal estimator performed poorly with small sample sizes. Most statistical analyses were performed using SAS statistical software (SAS Institute 1988). Prior to analysis, a Wilk-Shapiro normality test was used to test all data sets for normality. Coho and sockeye salmon densities were not normally distributed because some sites had densities that were very low or zero; therefore, estimates were squareroot transformed prior to analysis. Two-way ANOVA's were used to test for differences in coho and sockeye salmon densities between streams and sample periods, and one-way ANOVA's were used make comparisons between different habitats within each streams. Coho salmon densities in slough habitats in 1997 were not included in the analysis because estimates from minnow traps were not directly comparable to seine estimates. Coho salmon densities in slough habitats were summarized by sample gear (minnow traps and seine) and the method used for estimating abundance (removal and mark-recapture) because small sample sizes prevented statistical comparison between streams. If the ANOVA's indicated significant differences, a Tukey's multiple comparison test was used to compare coho and sockeye salmon densities between different habitat types within each stream. ANOVA contrasts were used to determine whether coho and sockeye salmon densities in similar habitats types were different between streams and periods. ANOVA contrasts allow for comparisons of only similar habitats rather than pairwise comparisons of all habitat types. A Kolmogorov-Smirnov test was used to compare coho and sockeye salmon fork length distributions between streams and among habitat types (Sokal and Rohlf 1981).

Statistical comparisons of physical habitat variables measured at each sample site were made using the same methods used for comparing coho and sockeye salmon densities. However, small sample sizes and nonnormality prevented extensive statistical comparisons between streams and habitat types, but when possible they were included. Often, nonnormality occurred because the values for some habitat variables were zero in many sites. Prior to statistical comparison, abundance and volume of LWD, area of undercut banks, and area of cover (aquatic and riparian) were standardized by habitat area. Variables that were not normally distributed were transformed (squareroot, log10,