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An Annotated Bibliography: Above Barrier Resident Dolly Varden (*Salvelinus malma*) and Related Studies

by Nancy J. Ihlenfeldt

Photo by Bob Karlen, BLM, Fairbanks

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AN ANNOTATED BIBLIOGRAPHY: ABOVE BARRIER RESIDENT DOLLY VARDEN (*SALVELINUS MALMA*) AND RELATED STUDIES

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EXECUTIVE SUMMARY

Dolly Varden (*Salvelinus malma*) exist in two forms – anadromous and resident. Most often the resident form is found upstream of natural barriers (e.g., falls, dams) that prevent upstream movement of the anadromous form. There are many differences between the two forms, such as:

- life history cycle/reproduction (potadromous versus anadromous)
- color (gray/brown versus silver)
- body size (small/stunted [average 135 mm] versus large [average 321 mm])
- length at maturation (average 162 mm versus average 295 mm)
- age at maturation (3-5 years versus 5-6 years)
- fecundity
  egg size (average 3.6 mm in diameter versus average 4.5 mm)
  egg number (average 66 eggs/female versus average 1,888 eggs/female)
- genetic diversity (reduced [4 alleles total] versus more variable [11 or 19 alleles total])

The preferred habitats for resident Dolly Varden are pools, glides, riffles, and cascade/falls, in that order. Preferred spawning areas are the edges of pools in low velocity water with a gravel substrate size of 1-4 cm.

Consecutive year capture studies show resident Dolly Varden do not move much (other than spawning and seasonal movements) within the stream system available as they are often captured in the same area (i.e., survey site) year after year.

Survival and population size is determined by available spawning areas. Most often, per stream population sizes are small. Studies show resident Dolly Varden have evolved characteristics of reduced fecundity, smaller size, young age at maturation, and shorter life span to limit the population size when needed habitats and “home range” are limited. Cover (large woody debris, rocks), overwintering areas, and low-velocity areas are all important factors to the survival of a resident Dolly Varden population.

Aquatic Science Inc. 1998. Kensington Gold Project, Aquatic Resource Surveys 1998. Prepared for Coeur Alaska, Inc. 47 pp.

This report presents the results of the aquatic resource surveys conducted in 1998 for NPDES requirements for the Kensington Gold Project on Sherman (impact stream) and Sweeny (reference) creeks in Southeast Alaska. The study includes: population status, tissue analysis, abundance of spawning salmon, quality of spawning substrate, and determination of any impacts to instream vegetation.

Fish species below barriers on Sherman Creek include Dolly Varden, pink and chum salmon, rainbow and cutthroat trout, and prickly sculpin. Dolly Varden is the only species found above the barrier. Sweeny Creek supports pink and coho salmon in the lower reach with Dolly Varden and rainbow and cutthroat trout occurring throughout the stream. These streams were each divided into 3 (lower, middle and upper) 360 m long sampling sections.

Resident fish survey methods included a diver with snorkel gear and electroshocking (for accuracy of visual counts). While conducting fish surveys, habitat types (i.e., pool, riffle, glide, cascade) were measured in length, width and average depth and recorded. Stream flow rates, water temperatures, and conductivity were also measured.

A total of 71 fish were captured by electroshocking in Sherman and Sweeny Creeks during sampling surveys. This represented 14.6% of the total estimated population in Sherman Creek and 9.0% in Sweeny Creek. [Note: Total number of fish within a stratum were estimated by applying a correction factor to the visual counts based on electroshocking counts; the corrected counts were extrapolated over the total number of units in each habitat type, within a stratum, using equations (5) through (11) in Hankin & Reeves (1988). Standard deviations and 95% confidence intervals for the population estimates were determined for each stratum. Minimum detectable differences between strata were then calculated for each habitat type.] Resident fish (Dolly Varden and trout) counts by habitat type and survey method were documented: the highest densities of Dolly Varden were caught in pool and glide habitats. Rainbow trout showed highest densities in pools and lowest in riffles. Dolly Varden showed the highest densities throughout all survey areas except in lower Sweeny Creek where rainbow trout dominated.

Aquatic Science Inc. 1999. Kensington Gold Project, Aquatic Resource Surveys 1999. Prepared for Coeur Alaska, Inc. 40 pp.

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Resident fish survey methods included a diver with snorkel gear and electroshocking (for accuracy of visual counts). While conducting fish surveys, habitat types (i.e., pool, riffle, glide, cascade) were measured in length, width and average depth and recorded. Stream flow rates, water temperatures, and conductivity were also measured.

A total of 24 Dolly Varden and 7 rainbow trout were captured by electroshocking in Sherman and Sweeny Creeks during sampling surveys. The number of Dolly Varden captured represented 6.8% of the total estimated population in Sherman Creek and 6.4% in Sweeny Creek. The number of rainbow trout captured represented 12.9% of the total estimated population of Sherman Creek and 9.7% of Sweeny Creek. [Note: Total number of fish within a stratum were estimated by applying a correction factor to the visual counts based on electroshocking counts; the corrected counts were extrapolated over the total number of units in each habitat type, within a stratum, using equations (5) through (11) in Hankin & Reeves (1988). Standard deviations and 95% confidence intervals for the population estimates were determined for each stratum. Minimum detectable differences between strata were then calculated for each habitat type.] The highest densities of Dolly Varden were caught in pool and glide habitats, while riffle habitat catches were low. The densities of all salmonids combined were higher in lower Sweeny Creek than in lower Sherman Creek, but were higher in upper Sherman Creek than upper Sweeny Creek.

Aquatic Science Inc. 2000. Kensington Gold Project, Aquatic Resource Surveys 2000. Prepared for Coeur Alaska, Inc. 46 pp.

This report presents the results of the aquatic resource surveys conducted in 1999 for NPDES requirements for the Kensington Gold Project on Sherman (impact stream) and Sweeny (reference) creeks in Southeast Alaska. The study includes: population status, tissue analysis, abundance of spawning salmon, quality of spawning substrate, and determination of any impacts to instream vegetation.

Fish species below barriers on Sherman Creek include Dolly Varden, pink and chum salmon, rainbow and cutthroat trout, and prickly sculpin. Dolly Varden is the only species found above the barrier. Sweeny Creek supports pink and coho salmon in the lower reach with Dolly Varden and rainbow and cutthroat trout occurring throughout the stream. These streams were each divided into 3 (lower, middle and upper) 360 m long sampling sections.

Resident fish survey methods included a diver with snorkel gear and electroshocking (for accuracy of visual counts). While conducting fish surveys, habitat types (i.e., pool, riffle, glide, cascade) were measured in length, width and average depth and recorded. Stream flow rates, water temperatures, and conductivity were also measured.

A total of 34 Dolly Varden and 16 cutthroat trout were captured by electroshocking in Sherman and Sweeny creeks during sampling surveys. The number of Dolly Varden captured represented 14.3% of the total estimated population in Sherman Creek and 10.1% in Sweeny Creek. The number of cutthroat trout captured represented 18.2% of the total estimated population of Sherman Creek and 9.6% of Sweeny Creek. [Note: Total number of fish within a stratum were estimated by applying a correction factor to the visual counts based on electroshocking counts; the corrected counts were extrapolated over the total number of units in each habitat type, within a stratum, using equations (5) through (11) in Hankin & Reeves (1988). Standard deviations and 95% confidence intervals for the population estimates were determined for each stratum. Minimum detectable differences between strata were then calculated for each habitat type.] The densities of Dolly Varden were generally higher in pool and glide habitats in both streams. Sweeny Creek densities increased in pools and glides from middle to upper reaches and in middle reaches, densities in riffles were almost as high as in glides. Dolly Varden and cutthroat trout were present at similar densities in lower Sherman Creek, but Dolly Varden dominated middle and upper Sweeny Creek. No Dolly Varden were found in lower Sweeny Creek where cutthroat trout densities were high. Densities of all salmon combined were higher in Sweeny Creek than in Sherman Creek.

Aquatic Science Inc. 2002. Kensington Gold Project, Aquatic Resource Surveys, December 2002. Prepared for Coeur Alaska, Inc. 37 pp.

This report presents the results of resident fish population estimates conducted in July 2002 for NPDES requirements for the Kensington Gold Project on Sherman (impact stream) and Sweeny (reference) creeks in Southeast Alaska. The study includes population status and benthic macroinvertebrate tissue metal analysis.

Fish species below barriers on Sherman Creek include Dolly Varden, pink and chum salmon, rainbow and cutthroat trout, and prickly sculpin. Dolly Varden is the only species found above the barrier. Sweeny Creek supports pink and coho salmon in the lower reach with Dolly Varden and rainbow and cutthroat trout occurring throughout the stream. These streams were each divided into 3 (lower, middle and upper) 360 m long sampling sections.

Resident fish survey methods included a diver with snorkel gear and electroshocking (for accuracy of visual counts). While conducting fish surveys, habitat types (i.e., pool, riffle, glide, cascade) were measured in length, width and average depth and recorded. Stream flow rates, water temperatures, and conductivity were also measured.

A total of 56 Dolly Varden and 28 cutthroat trout were captured by electroshocking in Sherman and Sweeny creeks during sampling surveys. The number of Dolly Varden captured represented 16.8% of the total estimated population in Sherman Creek and 19.6% in Sweeny Creek. The number of cutthroat trout captured represented 16.6% of the total estimated population of lower Sherman Creek (none present in middle or upper) and 18.8% of Sweeny Creek. [Note: Total number of fish within a stratum were estimated by applying a correction factor to the visual counts based on electroshocking counts; the corrected counts were extrapolated over the total number of units in each habitat type, within a stratum, using equations (5) through (11) in Hankin & Reeves (1988). Standard deviations and 95% confidence intervals for the population estimates were determined for each stratum. Minimum detectable differences between strata were then calculated for each habitat type.] The densities of both fish species tend to be higher in pool or slow riffle habitat, than in fast riffle habitat in both streams. The overall density of combined fish species was twice as high in Sweeny Creek than in Sherman Creek for lower and middle reaches, but upper Sherman Creek had twice the density of upper Sweeny Creek. (Note: Upper Sweeny Creek lost many pool habitat areas. Observers believe the pools filled in after a possible mass-erosion event occurred upstream.)

Aquatic Science Inc. 2003. Kensington Gold Project, Aquatic Resource Surveys, December 2003. Prepared for Coeur Alaska, Inc. 39 pp.

This report presents the results of resident fish population estimates conducted in July 2003 for NPDES requirements for the Kensington Gold Project on Sherman (impact stream) and Sweeny (reference) creeks in Southeast Alaska. The study includes fish population status and benthic macroinvertebrate tissue metal analysis.

Fish species below barriers on Sherman Creek include Dolly Varden, pink and chum salmon, rainbow and cutthroat trout, and prickly sculpin. Dolly Varden is the only species found above the barrier. Sweeny Creek supports pink and coho salmon in the lower reach with Dolly Varden and rainbow and cutthroat trout occurring throughout the stream. These streams were each divided into 3 (lower, middle and upper) 360 m long sampling sections.

Resident fish survey methods included a diver with snorkel gear and electroshocking (for accuracy of visual counts). While conducting fish surveys, habitat types (i.e., pool, riffle, glide, cascade) were measured in length, width and average depth and recorded. Stream flow rates, water temperatures, and conductivity were also measured.

A total of 27 Dolly Varden and 2 cutthroat trout were captured by electroshocking in Sherman Creek and 28 Dolly Varden and 18 cutthroat trout were captured in Sweeny Creek. The number of Dolly Varden captured represented 11.9% of the total estimated population in Sherman Creek and 20.3% in Sweeny Creek. The number of cutthroat trout captured represented 8.0% of the total estimated population of lower Sherman Creek (none present in middle or upper) and 13.4% of Sweeny Creek. [Note: Total number of fish within a stratum were estimated by applying a correction factor to the visual counts based on electroshocking counts; the corrected counts were extrapolated over the total number of units in each habitat type, within a stratum, using equations (5) through (11) in Hankin & Reeves (1988). Standard deviations and 95% confidence intervals for the population estimates were determined for each stratum. Minimum detectable differences between strata were then calculated for each habitat type.] Pool habitats generally showed higher density of fish, with the exception of middle Sherman Creek where riffle habitat density was also high. Cutthroat trout densities were high in lower Sweeny Creek compared with other study areas. The overall density of combined fish species was twice as high in Sweeny Creek than in Sherman Creek for lower and middle reaches, but upper Sherman Creek had twice the density of upper Sweeny Creek. (Note: Upper Sweeny Creek lost many pool habitat areas in 2002. Observers believe the pools filled in after a possible mass-erosion event occurred upstream.)

Blackett, R.F. 1973. Fecundity of resident and anadromous Dolly Varden in SE Alaska. Journal of the Fisheries Research Board of Canada 30:543-548.

In September and October of 1966, 55 resident Dolly Varden were caught in minnow traps (baited with salmon eggs) and collected from above the 12 m falls barrier in Falls Creek. In September and October of 1965, anadromous Dolly Varden were collected by hook and line from Hood Bay (n=66) and Bear Creek (n=59). The minnow traps caught fish up to 250 mm in length. The fish were killed, measured and weighed, and the ovaries were removed and weighed. Five eggs from the anterior, middle and posterior sections of the ovarian tissue were dissected and measured. The eggs from each ovary were counted.

The Dolly Varden from Falls Creek were smaller than the anadromous Dolly Varden and produced fewer eggs. The resident Dolly Varden averaged 66 eggs per female in comparison to 1,888 eggs per anadromous females. The egg size differs as well; resident females had an average egg diameter of 3.6 mm while anadromous females averaged 4.5 mm. Curvilinear regressions between egg number and fish length, and linear regressions between egg number and body and ovary weights show that resident females have fewer eggs per unit of length, approximately the same number of eggs per gram of body weight and more eggs per gram of ovary weight than anadromous females (resident number 4.1 eggs per gram of body weight and anadromous 3.0 eggs). Some (11%) resident Dolly Varden females attain sexual maturity at age 3; the majority (53%) were mature by age 4. The anadromous females were potential spawners at age 5-6.

Otoliths were examined for age determination and showed the oldest fish from Falls Creek was 7 yrs. Seventy-two percent of the anadromous fish were age 6 and 7 and the oldest female was 10 yrs.

The largest mature Dolly Varden from Falls Creek was 207 mm in length, while the smallest mature anadromous Dolly Varden was 295 mm in length. The reproductive potential for resident Dolly Varden is considerably less than that of anadromous Dolly Varden. The author believes this serves as a natural mechanism limiting population size in a restricted freshwater environment and that fish adapt to this environment with small size, early maturity, reduced fecundity and shorter life span.

Bryant, M.D. and M.D. Lukey. 2004. Movement of Dolly Varden and Cutthroat Trout in High Gradient Headwater Streams with Implication for Fish Passage Standards. Progress Report for 2004. USDA Forest Service, Juneau, AK. 15 pp.

This study looks at movement patterns of resident salmonids in a small, high gradient (>5%) stream in southeast Alaska (i.e., Hobo Creek) at different stream stages and times of the year. The objectives were to: (1) develop and test methods and protocols that will detect movement of juvenile salmonids through a range of stream stages in natural streams; (2) identify seasonal movement and habitat use; (3) describe the size and species of fish that move; and (4) determine the relationship between fish movement and stream stage. The study reach is 1,150 m in length with gradients ranging from 2% in the lower sections to 10% in the higher sections. The average channel width is 1.5 m.

Minnow traps (baited) were deployed to capture Dolly Varden and cutthroat trout throughout the study reach in May, July and September. The location of capture, fish length, weight, and tag (PIT) number were recorded. In the 2004 field season, 78 cutthroat trout and 85 Dolly Varden (>65 mm and < 85 mm) were tagged with Destron-Fearing tags and 25 cutthroat trout and 9 Dolly Varden (>105 mm ± 3 mm) were tagged with Texas Instrument tags. The fish that measured between 85 mm and 100 mm were sampled and released. More than 50% of salmonids captured in Hobo Creek are less than 100 mm. The total numbers of fish tagged from start of project in 1999 through 2004 are 378 cutthroat trout and 526 Dolly Varden with the Destron-Fearing tag and 25 cutthroat trout and 9 Dolly Varden with the Texas Instrument tag.

A weir and six antennas were used to detect and document fish movement. More fish movement occurred in spring and fall (transition season when water temperatures are either increasing or decreasing). Both species demonstrated most downstream movement during spring. The only movement detected during winter was downstream and only by a few fish (water temperatures ≤4° C). Higher numbers of cutthroat trout moved upstream in May (spawn) and October (overwinter) and higher numbers of Dolly Varden moved upstream in September and October (spawn). The distance moved between recapture events for both species was generally <100 m (a few moved greater distances, >500 m). More Dolly Varden were captured in the same location where they were marked than cutthroat trout. Dolly Varden and cutthroat trout showed similar movement patterns (a few moved, mostly downstream) at stream stages above 1.0 ft and few fish moved when stream stage was less than 0.25 ft. It appeared all movement ceased when stages were above 2.0 ft.

Cunjak, R.A. 1996. Winter habitat of selected stream fishes and potential impacts from land-use activity. Canadian Journal of Fisheries and Aquatic Sciences 53:(Supplement 1):267-282.

This report reviews habitat characteristics and behavior of selected stream fishes during winter in temperate-boreal ecosystems, with an emphasis on salmonids.

Space (low-velocity areas, instream cover) is the primary factor regulating fish populations in winter. Access to food at near freezing water temperatures is low priority to stream fish, so time spent feeding and defending territories is lessoned or eliminated. If over wintering habitat is limited and fish congregate, substantial winter mortality can occur from predators (e.g., mink, otter). Congregations may be useful as indicators to important wintering areas.

To minimize predation and energy depletion, juvenile chinook and trout prefer sheltering beneath rocks when rock diameter is often directly proportional to their size, some may move 15-30 cm below the substrate surface. Larger-bodied adult fish generally prefer deep pools where depth is assumed to provide cover requirements. Juvenile coho and Dolly Varden are known to over winter in beaver-ponded areas in SE Alaskan streams (Chichagof Island).

Water temperature is a factor and different for each fish species. Most fish tend to prefer 2-4° C to minimize metabolic activity. Change in water temperatures can be detrimental in winter. Point-source groundwater discharge areas in ponds and side channels provide “winter-warm” microhabitats and may serve as winter refuges from ice and variable flows. In Alaska, groundwater may be the most important winter habitat criterion.

Water withdrawal during winter and its direct influence on reducing available habitat (wetted space) probably impacts stream fish populations more than any other winter alteration of streams. The effect is most pronounced in shallow streams and rivers and is exacerbated by ice conditions –the reduction in stream flow (via water withdrawal) creates more ice formation. It also contributes to the loss of near-bank concealment habitat.

Priorities for overwintering fish are: (1) protection from adverse physiochemical conditions (e.g., ice, low oxygen, winter freshets), (2) access to alternate winter habitats (e.g., suitable water depth, instream cover [rocks, LWD, cut banks], floodplain habitat and side-channels, source of aeration, groundwater discharge zones, sub-ice corridors), (3) protection from predators, and (4) access to food. Priorities can vary depending on life stage.

Currens, K.P., K.E. Griswold and G.H. Reeves. 2003. Relations between Dolly Varden populations and between coastal cutthroat trout populations in Prince William Sound, *Exxon Valdez* Oil Spill Restoration Project. Final Report (Rest. Project 98145), USDA Forest Service, Pacific Northwest Research Station, Corvallis, Oregon. 84 pp.

The purpose of the study was to determine the genetic structure of Dolly Varden and coastal cutthroat trout populations in Prince William Sound (PWS) by determining for both Dolly Varden and coastal cutthroat trout: (1) if populations in PWS were a single population or separate subpopulations; (2) whether resident and amphidromous migratory forms in a watershed were a single population or separate populations; and (3) developing a restoration strategy for each species based on results from objectives 1 and 2.

Despite similarities in their life history, Dolly Varden in PWS had different patterns of genetic variation than coastal cutthroat trout.

For Dolly Varden the isolation and allopatric divergence of above-barrier populations was the most important source of genetic differences. Below-barrier Dolly Varden had large amounts of genetic exchange and minor genetic differentiation. Above-barrier Dolly Varden showed reduced genetic diversity. Mitochondrial DNA variation showed pronounced differences between above and below-barrier populations. Data showed no strong geographical patterns of differentiation.

Otolith microchemistry did not show differences in strontium/calcium ratios between populations (above and below barriers); however, it did show patterns consistent with resident or anadromous life histories.

The report concluded that Dolly Varden most likely colonized PWS from a northern glacial refuge and probably had longer to evolve differences among populations because they were almost certainly among the first colonizers of recently deglaciated streams.

For coastal cutthroat trout the results showed that all populations in PWS belonged to a single mitochondrial DNA clade with nearly all individuals possessing the same haplotype. Genetically, above and below-barrier coastal cutthroat trout showed no significant differences. Results did not support dispersal of coastal cutthroat trout across large, open water of PWS – they noted coastal cutthroat trout tend to move along shorelines and estuaries.

The report concluded that coastal cutthroat trout most likely colonized PWS from a southern glacial refuge.

Dean, Jack (semi-retired Fisheries Biologist). July 22, 2002. Memo to Bill Stockwell (Cooper Landing Fish and Game Advisory Committee) regarding Cooper Lake Arctic char. 9 pp.

Mr. Dean goes over previous references to Dolly Varden in Cooper Lake (Chugach Electric Association dam) and other lakes in Southcentral Alaska. He states that Dolly Varden and Arctic char are closely related species and only specifically identified by internal characteristics in the gill raker and pyloric caeca counts.

Char in Cooper Lake have been visually observed and lab tested and were determined to be Arctic char (e.g., external characteristics are forked tail, a few spots larger than the pupil of the eye and a narrow caudal peduncle – internal gill raker and pyloric caeca counts).

Older reports refer to the char in Cooper Lake as Dolly Varden for nearly half a century but never report this species using the lakes tributary streams for spawning (i.e., Dolly Varden spawn in streams in the fall). There was no evidence of biologists counting pyloric or gill rakers of Cooper Lake char until 1999.

Cooper Lake has the highest char CPUE and yet the smallest average size of any Arctic char lake surveyed and documented in Southcentral Alaska. Why this difference? The water levels fluctuate and reduce bottom fauna production. Other lakes are smaller and may be spawning limited so larger char may be cannibalistic, because there is not an adequate supply of freshwater shrimp. Char in Cooper Lake show the poorest condition of all lakes surveyed, especially for the larger fish in the population (8-13.5 in). Arctic char in Cooper Lake apparently do not start eating fish until a threshold size is attained - mean fork length of 12.7 in (range of 10.2-14.9 in).

Mr. Dean believes the Arctic char population in Cooper Lake is not over-fished, is dominated by small, probably dwarf char, and that water level fluctuations from hydroelectric power use periodically impacts the spawning success of the normal-sized char.

Dwarf char were found spawning in an area 200 yds south of the intake structure, off the mouth of a small stream, in about 10-15 ft of water. Mr. Dean suspects normal-sized char are spawning in a different area, depth, and possibly at a different time.

Cooper Lake Arctic char have also been confused with lake trout as some of the larger fish are gray in color. There are 2 color phases of the normal sized Arctic char - normal color and gray color phase.

Flory, E.A. 1999. Fish and fish habitats of the Falls Creek area. A report to Gustavus Electric Company. 45 pp.

Fish habitat data was collected from Falls Creek near Gustavus in Southeast Alaska. A total of 7,010 m of stream was studied, looking closely at pools, riffles, glides, cascades, or gentle riffles. Fish trapping and observation methods used were electroshocking, minnow traps baited with roe and soaked for ≤ 1-2 hrs and ≥ 4 hrs, and a diver with snorkel gear. The stream was divided into 8 reaches of similar habitat and channel type with 4 reaches below the proposed zone of water extraction and 4 reaches above. The first reach was the only portion of the stream that supported anadromous fish (pink, chum, and coho salmon, with coast range sculpin, Dolly Varden and cutthroat trout). A "lower falls" structure (between Reach 1 and Reach 2) blocks upstream movement of fish. Resident populations of Dolly Varden reside above the lower falls. The most extensive area of continuous good quality habitat is located well upstream of the proposed penstock intake site (Reach 4).

636 Dolly Varden were caught and measured, 20 of these fish were dissected:

- dissection revealed differences in the size of sexually mature fish between sites;
- sites further upstream tended to have fish maturing at smaller sizes than downstream;
- otoliths suggests variation in growth rates between sites;
- differences in length-frequency patterns, mean fish lengths and sizes of mature fish between reaches 2, 4 & 7 suggest the existence of separate populations at these sites;
- mean length = 11.10 cm to 13.47 cm between reaches 2 to 8.
- size of mature fish in Reach 2 were 19.2 cm = 7 years
- size of mature fish in Reach 7 were 14.3 cm = 7 years

Flory, E.A. 2000. Resident Dolly Varden, anadromous fish species and benthic invertebrates of the Falls Creek area, 2000. A report prepared for Gustavus Electric Company. 67 pp.

This report covers the February to November 2000 field studies in Falls Creek near Gustavus in Southeast Alaska. Fish surveys for distribution, relative abundance and condition were conducted February 16-19 (over-wintering surveys) and August 3-6 and October (spawning activity). Snorkel surveys and minnow traps baited with roe were used for fish observation/collection. Invertebrates were collected May 28-31 at 4 sites. Falls Creek was divided into 8 reaches of similar habitat and channel type with 4 reaches below the proposed zone of water extraction and 4 reaches above. Dolly Varden are the only fish species present upstream of the “lower falls” (between reaches 1 and 2).

The traps were soaked overnight at reaches 2, 4 & 7. The total number of Dolly Varden caught was 41, 29 and 43 respectively. All marked fish caught were captured in the same location as when caught and clipped in 1999. The continuous range of size classes caught indicates year-round population of Dolly Varden in these reaches. The greatest numbers of Dolly Varden were caught in sites characterized by extensive pool habitat with large woody debris (LWD).

Fish in Reach 7 are typified by shorter body length than fish downstream. Reach 7 is about ½ the width of the reaches downstream, but has a greater proportion of suitable spawning habitat that may result in greater recruitment, producing a higher fish density, that causes slower growth rates and smaller size fish (i.e., energy going into spawning).

High condition of fish in Reach 4 implies they are not food-limited. Low density of fish in this reach suggests population control by some other factor such as limited spawning or over-wintering habitat.

Spawning population age ranged from 4 to 7 years (occasionally 3 & 8 yrs) and length from 13.6 cm to 20 cm. Fish were in spawning colors on October 3-4 and 25-26, and probably spawned in late October to mid-November. Suitable spawning habitat is defined as 1-4 cm gravel size that is free from scouring and maintains sufficient water flow throughout the incubation period (if the gravel is too small there is not enough oxygen, and if it is too large the female cannot manipulate it).

Nothing is known about recruitment of resident Dolly Varden in this stream system. Only 2 fry were observed in the stream (one in Reach 3 and one in Reach 7). However, the author believes this implies successful recruitment occurs in both reaches. The fry were found in 1-2 in of water and zero velocity, demonstrating that they prefer shallow, edge habitats that may be impacted by dewatering during hydropower operation.

This study finds that Dolly Varden prefer low velocities of 0 to 1.4 ft/sec.

Gillikin, D. 2000. Cutthroat trout and Dolly Varden rehabilitation in Western Prince William Sound. *Exxon Valdez* Oil Spill Restoration Project Final (Restoration Project 98043B). U.S. Forest Service, Glacier Ranger District, Girdwood, Alaska. 20 pp.

This study monitored habitat improvement projects from 1995 through 1998 to evaluate their effects on cutthroat trout and Dolly Varden abundance. In 1995, 63 habitat improvement structures were installed in Prince William Sound at 4 different project locations.

Observations showed cutthroat trout abundance significantly increased overall at one structure location site, but not at any other. Total Dolly Varden abundance increased during 1995-1998 but no significant use at structure or non-structure sites was observed at any site.

Stream enhancements such as cross-logs and particularly boulder clusters seemed to benefit trout more than other types of improvements monitored. The only other structure type installed was tree tops.

Competition with juvenile coho salmon was believed to limit trout production.

Note: The report never stated exactly how structures were placed and the type of habitat created from the structures (e.g., scour pool, riffles, etc.).

Gowan, C., M.K. Young, K.D. Fausch and S.C. Riley. 1994. Restricted movement in resident stream salmonids: a paradigm lost? Canadian Journal of Fisheries and Aquatic Sciences 51:2626-2637.

Gerking (1959) proposed a theory that guided much of the research on stream fish populations for the next 30 years, "adult stream fish are sedentary, often spending their entire lives within a single pool or stream reach no longer than 20 m." Gowan et. al look at studies on the subject of Restricted Movement Paradigm (RMP) and show how they believe it is incorrect.

The recognized movements of resident stream salmonids are listed below – some types of movement are acknowledged as specialized behaviors that interrupt "normal" sedentary behavior:

1. passive fry dispersal with flow
2. active fry dispersal, possibly mediated by social dominance effects
3. limited fry dispersal in closely juxtaposed habitats
4. specialized patterns of fry and juvenile dispersal in unique habitats
5. movements related to ontogenetic shifts in microhabitat use, possibly to increase rate of food intake or avoid competition by habitat segregation
6. diel (24-hr period involving a day and a night) movements from feeding to resting positions
7. movements related to fish having different microhabitat preferences at different water temperatures
8. seasonal movements between summer and winter habitat locations
9. potadromous spawning movements predominantly upstream over relatively long distances
10. potadromous spawning movements in all directions over relatively short distances (when spawning and rearing habitats are interspersed)
11. homing movements following displacement.

It may be difficult to measure the mobile population, but that does not mean it is biologically unimportant. Conclusions drawn about fish movement depend on the spatial and temporal scale studied.

Other studies showed: (1) instream movement was extensive, even beneath ice during winter, (2) individual fish move up to 50-300 m (depending on size), (3) the causes of movement – when or why are unknown, (4) frequency of movement varies with the stream type (movement more common in variable or harsh systems).

Griswold, K.E. 1996. Genetic and meristic relationships of coastal cutthroat trout (*Oncorhynchus clarki*) residing above and below barriers in two coastal basins. M.S. Thesis. Oregon State University, Corvallis.

Trout were collected from two basins separated by a great distance: Elk River, Oregon and Vixen Inlet, Alaska. Forms found above and below geologic barriers to anadromous adults were compared. Elk River fish were collected in September and October 1992 – sample sizes ranged from 24 to 36 individuals. Vixen Inlet fish were collected in July 1992 and 1993 – sample sizes ranged from 33 to 54 individuals.

Starch gel electrophoresis was used to obtain genotype data to describe the amount of genetic variation within and among populations.

The results suggest that a wide range of genetic variation exists within and among populations of coastal cutthroat trout at a basin scale. These different patterns may result from a combination of evolutionary history and local environmental conditions.

In Alaska, smaller genetic and meristic differences were detected, but the pattern of differences did not appear to correspond with geographic features. Data suggests there may be some gene flow among the groups in Vixen Inlet, or alternatively, the colonization of Vixen Inlet by coastal cutthroat trout has occurred relatively recently and there has been no opportunity for the groups to diverge. In Alaska, it appears that the genetic diversity is distributed largely among individuals throughout the basin.

*The author believes above barrier populations are important to below barrier populations due to their potential to add genetic diversity.

Hankin, D.G., and G.H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences 45:834-844.

Visual methods (diving) and electrofishing were used to determine fish abundance and total habitat type in small streams. The stream was divided into lower, middle, and upper reaches and then into pool, riffle, glide, or side channel habitat unit types. Each habitat unit was measured and total unit type was recorded. Sampling was conducted on Cummins Creek, a third-order stream located on the central Oregon coast. Cummins Creek supports juvenile anadromous salmonids (i.e., steelhead trout [*Salmo gairdneri*) and coho salmon [*Oncorhynchus kisutch*]) in the lower reach that was studied. The stream width ranged from 2 to 16 m, water depth from 0.1 to 1.3 m, and the stream gradient averaged 2.5%.

Visual methods proved extremely effective for estimation of habitat areas and allowed the construction of detailed maps of the locations and sizes of all habitat units. The authors emphasize that it requires a single experienced diver (observer) be responsible for all visual estimates and bookkeeping.

Patterns of distribution and abundance of habitat units and fish numbers suggest that attempts to assess fish abundance based on so-called “representative reaches” are unlikely to provide good estimates of true fish abundance. They found substantial changes in size and composition of habitat units and in fish species composition and abundance along the length of this stream. Many more fish were found in downstream pools than in middle and upstream pools.

Hastings, Kim. 2005. Long-Term Persistence of Isolated Fish Populations in the Alexander Archipelago - Chapter 4. Long-Term Persistence of Small Isolated Fish Populations. Pages 76-112. USFWS Juneau.

This report examined the conditions under which small, isolated populations (i.e., above bedrock waterfalls) of coastal cutthroat trout (*Oncorhynchus clarki clarki*) and Dolly Varden (*Salvelinus malma*) appeared to persist or fail and looked for conditions (quality of habitat) that appeared to support or limit population persistence. All sites observed were undisturbed streams in Southeastern Alaska. Suitable habitat was defined as any stream channel with <25% gradient that was originally connected to saltwater (prior to the Holocene uplift). Streams with access to lakes were excluded from the study. The length of above-barrier habitat sites surveyed varied from 200 m to 50,100 m.

One hundred twenty four streams were assessed for fish presence/absence. Sixty six of the streams were field-verified by the author, first by electroshocking, and if no fish were found, then 25 minnow traps baited with salmon eggs were set. The Tongass National Forest personnel gave data for the remaining 58 streams. No fish were found in 29 of the 124 streams assessed. Coastal cutthroat trout were found in 54 of the 124 streams and Dolly Varden in 74. Both species were found in 33 of the 124 streams, with 21 streams supporting only coastal cutthroat trout and 41 supporting only Dolly Varden. The smallest streams had only Dolly Varden present and the largest streams (>10 km) nearly always (>50% of the time) had both species present. Coastal cutthroat trout and Dolly Varden were the only two species found above waterfalls in streams that did not have access to lakes.

Data showed there was a 90% likelihood that populations of coastal cutthroat trout or Dolly Varden would be present when there was more than 5.5 km of linear habitat available. There was less than a 50% likelihood of finding either species present if there was less than 1.5 km of linear habitat available.

The density of coastal cutthroat trout and Dolly Varden was estimated in 24 streams annually for 6 years. The density was estimated by 3-pass removal sampling using baited minnow traps and expressed linearly as fish/m. Adult coastal cutthroat trout density ranged from 0.01 to 1.29 fish/m over 53 sampling occasions in 11 streams that supported both species and from 0.19 to 0.82 fish/m over 23 sampling occasions in 4 streams with only coastal cutthroat trout present. Adult Dolly Varden density ranged from 0.02 to 1.10 fish/m over 50 sampling occasions in the 11 streams that supported both species. Where Dolly Varden were the only species present, densities ranged from 0.34 to 5.42 fish/m in 9 streams over 29 sampling occasions. The author found strong evidence that Dolly Varden densities are suppressed when stream habitat is shared with coastal cutthroat trout. Several cited documents stated a general pattern that *Oncorhynchus* tends to out-compete sympatric *Salvelinus* when both are native.

Adult stream-resident coastal cutthroat trout and Dolly Varden in Southeast Alaska are typically about 80 – 120 mm in length and do not exceed about 205 mm. The author cited many studies that found coastal cutthroat trout in similar settings rarely live longer than 4 years. However, this study found a small amount of anecdotal evidence that stream-resident coastal cutthroat trout in Southeast Alaska may live for 6 years or more and that Dolly Varden may live for at least 10 years.

The author estimated that most populations in her study have been isolated for 8,000 to 12,000 years.

Heggenes, J., T.G. Northcote, and A. Peter. 1991. Seasonal habitat selection and preferences by cutthroat trout (*Oncorhynchus clarki*) in a small coastal stream. Canadian Journal of Fisheries and Aquatic Sciences 48:1364-1370.

The purpose of the study was to investigate habitat use by cutthroat trout of different lengths and in a less competitive (numerically dominant to other salmonids) situation. The study area was Musqueam Creek, a small stream in British Columbia. The stream was divided into 175 segments by making transects every 3 m along the creek. The study looked at (1) water depth use, (2) water velocity use, (3) substrate use, and (4) cover use by cutthroat trout 9-32 cm long during a winter and summer season.

Throughout the study (January 1 through August 31, 1998), 754 observations of habitat use by cutthroat trout were made. Fish were sampled at 2-week intervals with an electroshocker. The position of fish >9 cm was recorded. Significant regressions between fish length and habitat use were found for water depth and total amount of cover. With increasing fish length, the trout preferred deeper stream areas. Fish selected habitats with significantly lower amounts of cover in the winter than in summer. There was no significant difference in cover type used, but instream cover was used more frequently than overhead cover.

Seasonal habitat use showed with winter water temperatures <6.3°C, trout inhabited somewhat more shallow stream areas (abandoned pool areas) but moved towards deeper stream areas with increasing water temperatures in spring (8.1-10°C) and occupied the deepest stream areas during summer with temperatures >10.9°C.

Areas with higher (>20 cm/s) mean water velocities were not frequently used; trout preferred slower-flowing areas, provided there was suitable cover. A variety of substrate sizes were used, provided the preferred water depth and cover was available. No particularly strong preferences for any of the available substrate sizes were found.

Habitat use significantly differed from measured habitat availability. For instance, water depth of 25 cm (5% of total available habitat) was used by 17% of fish, whereas water depth of 5 cm (33% of total available habitat) was used by 8% of fish.

Data suggest that habitat selection is a result of complex behavior, that is possibly influenced by environmental factors other than the ones measured in this study. However, the author suggests all the habitat variables measured in this study appear to influence habitat selection, with water depth being the most important factor (particularly for the larger fish) influencing cutthroat trout in this small stream.

Hilderbrand, R.H. 2003. The roles of carrying capacity, immigration, and population synchrony on persistence of stream-resident cutthroat trout. Biological Conservation 110:257-266.

Hilderbrand created a Matrix model to explore the dynamics of isolated populations or populations connected by immigration. Cutthroat trout populations have declined substantially and many existing populations are isolated. Hilderbrand looked at the following factors that can help reduce the risk of extinction:

1. carrying capacity
2. survival of subadults that become reproductively mature the next year
3. survival of young-of-the-year fish
4. immigration

Results highlight the importance of maintaining adequate space or increasing habitat capacity for isolated populations and the importance of connectivity and large population cores if remnant populations are to be maintained. Populations connected to others through immigration can persist at carrying capacities much lower than those of isolated populations, provided immigrants actually reproduce.

Time to extinction of isolated populations showed that most extinctions do not occur for several decades. Even for the smallest carrying capacity simulated (K=100) where over 90% of populations went extinct, 50% of extinctions did not happen before 40 years. Extinctions dramatically declined with modest increases in carrying capacity of the smallest populations (until at a population size near the 95% persistence threshold).

It is imperative that isolated populations are protected against further reductions in habitat length or habitat quality and equally critical that larger populations do not become fragmented and isolated (must maintain the largest possible population size for isolated populations). Increasing habitat quality or amount can substantially increase the abundance of fish.

Hino, T., K. Maekawa, and J.B. Reynolds. 1990. Alternative male mating behaviors in landlocked Dolly Varden (*Salvelinus malma*) in Southcentral Alaska. Journal of Ethology 8:13-20.

This study describes male mating behavior in a monomorphic Dolly Varden population in the Tiekel River (September 15-28, 1987). During the breeding season, Dolly Varden migrate from main streams or ponds into small tributaries to spawn, but breeding behavior is poorly known. The inter-individual difference in mating behavior and the success of males depends on dominance ranks related to age and/or body size. The authors suggest a possible evolutionary mechanism of alternative mating behaviors in this population.

The primary male (PM) (or Pair Male) is always the biggest and always paired with females during spawning. The satellite males (SM1, SM2, etc.) would hang close to the egg nest and "streak" to deposit sperm. SMs could be successful maters (release sperm) when the PM was chasing another SM away from the nest, usually the dominant SM1. So the SM1 was not as successful as say SM2 or SM3.

Males migrate to spawning areas earlier than females. Dominance hierarchy is already clearly formed between males – no fights for PM status occurred (PMs were >250mm and 5 yrs). Late in the spawning period, when the number of females increase, and the early PMs are spent, the SM move in and become the PM.

Hodges, K., and K. Buckley. 1995. Rocky Creek cutthroat trout habitat enhancement. *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 94043B2). U.S. Forest Service, Cordova, Alaska. 30 pp.

Habitat enhancement work was performed in 1994 and monitoring was conducted in 1995 in Rocky Creek in Prince William Sound. Eighteen instream structures (logs and boulders) were built in two small tributaries of the creek to create spawning and rearing habitats. The structures were designed to scour pools, create backwaters, trap spawning gravel above the structures and create spawning areas in the tail-outs of the pools. With only a few exceptions, the structures created the intended habitat conditions and monitoring showed an increase in pools and spawning areas. Trout were observed spawning at one of the structures, and pink and coho salmon were observed spawning at some structures in September. Researchers thought more time was needed for the total effect of the structures to be complete and the streams to level out.

First year trout use the backwaters and edges of pools for rearing and the deeper areas of the pools for over-wintering habitat. Trout compete with juvenile coho salmon for habitat, which most often forces trout into less desirable habitat. Cutthroat trout populations in Prince William Sound are naturally small and variable and especially sensitive to the effects of catastrophic events.

(Note: This document included an appendix with all the instream structures diagramed and the effect [e.g., pools created] of the structure on the stream bed or bank was described in detail.)

Kline, E. R. (Kline Environmental Research LLC). 2001. Kensington Project, June 2000 Slate Creek basin survey data report. Prepared for Coeur Alaska, Inc. 36 pp (plus appendices).

Couer Alaska, Inc. investigated the feasibility of disposing the tailings generated from the Kensington Gold Mine into Lower Slate Lake. Surveys were conducted to (1) assess the distribution of fish species within the basin, (2) analyze the diet of Dolly Varden in Lower Slate Lake, (3) survey habitats in Lower Slate Lake and Mid-Lake East Fork Slate Creek, (4) collect baseline data on stream invertebrates and metals in sediment and fish, and (5) collect sediment for habitability testing.

Lower Slate Lake is 4 mi southeast of Kensington Gold Mine in Southeast Alaska, is 51 ft deep at the deepest section and has one outlet and 5 inlets. A dam would be constructed to maintain a permanent water cover as the tailings fill and raise the lake bottom. Dolly Varden is the only fish species of game fish present in the Slate Lake system.

Sediment samples were taken at 4 m and 15 m water depths at 3 locations each from Lower Slate Lake. Three Dolly Varden were taken for fish tissue metal analysis and three more were taken from Lower Slate Lake for gut content analysis. The samples represented small, medium and large fish relative to those captured to that point. Gut content results showed that two of the larger fish contained only three-spine stickleback and the smallest fish contained only benthic invertebrates (chironomid worms and pill clams). The rank order of relative abundance of gut contents was reversed from rank order found in grab samples from 4 m. No oligochaete worms were found in gut samples which was the second most abundant taxa found in the 4 m grab samples. No planktonic organisms were seen.

Six Dolly Varden were taken from Upper Slate Lake, 3 for fish tissue metal analysis and 3 for gut content analysis.

The Dolly Varden captured in streams were 4 to 9 times smaller (by weight) on average than those captured in the lakes. Dolly Varden captured in the lakes were dark olive in color compared to the more silver Dolly Varden captured in the streams.

A total of 33 Dolly Varden were tagged in Lower Slate Creek; too few to estimate the population size (due to lack of success using hoop nets to capture fish). The author believed the Dolly Varden populations were low in the Slate Creek lakes.

Kline, E.R. (Earthworks Technology, Inc.). 2002. Kensington Project, August - September 2001 Slate Lakes basin survey data report. Prepared for Coeur Alaska, Inc. 32 pp (plus appendices).

The survey objectives of this report were: (1) estimate population size and assess the distribution of Dolly Varden in Lower Slate Lake (20 acres with maximum depth of 51 ft) and adjoining streams, (2) survey habitat in East Fork Slate Creek above the upper barrier to anadromous fish, (3) collect baseline data in Lower Slate Lake, Upper Slate Lake, and Mid-Lake East Fork Slate Creek. Dolly Varden is the only fish species of game fish present in this Southeast Alaska system.

This survey (August to September 2001) was designed to augment and verify data from previous surveys. In Lower Slate Lake, fish were captured with rod and reel, minnow traps baited with salmon eggs (492 hrs), and hoop nets (228 hrs). Fish were sampled in the streams using an electroshocker. The minnow traps were most successful during this survey (set on the bottom at <10 m depth) and the hoop nets were largely ineffective. The stream surveys showed that most of the Dolly Varden were captured in pools, followed by glides and then riffles -- showing a preference for slower water.

Dolly Varden (n = 9) were taken for laboratory analysis: 3 from Lower Slate Lake for fish tissue metals analysis, 3 from Lower Slate Lake for gut content, and 3 from Upper Slate Lake for fish tissue metals analysis. Gut contents contained mayflies, caddis flies and round worms, taxa found in the stream samples but not in the lake invertebrate samples. Dolly Varden either fed in streams or in the Lower Slate Lake at the mouth of Mid-Lake East Fork Slate Creek on prey as it drifted into the lake (data from 2000 were insufficient to determine where sacrificed Dolly Varden were feeding).

Lower Slate Lake sediment was sampled for invertebrate abundance and identities from 3 locations each at 4 m and 15 m water depths using a Ponar grab sampler. Six additional samples were collected from the same sites (in the same manner) and sampled for metals, organic content, specific gravity, and grain size.

An oblique plankton tow was conducted ranging from the deepest portions of Lower Slate Lake to the surface and was analyzed for invertebrates (species list and relative abundance).

Stream habitat was quantified in East Fork Slate Creek and sediment was sampled for metals/mercury and stream benthos for taxonomic analysis.

Dolly Varden population estimates for fish measuring ≥75 mm was 996 (±292) in Lower Slate Lake and the near-lake reaches of East Fork Creek and Mid-Lake East Fork Slate Creek during this survey. There was no evidence of relocation between lake systems. (Note: Dolly Varden <75 mm were not tagged.)

Kline, E.R. (Kline Environmental Research, LLC). 2003. Kensington Project: Analysis of Dolly Varden Tissue Chemistry Data from Upper and Lower Slate Lakes. 28 pp.

The objectives of this study were to: (1) summarize and compare 2000 and 2001 tissue chemistry data from Upper Slate Lake and Lower Slate Lake, (2) determine statistical consideration for possible Dolly Varden tissue monitoring proposals, and (3) compare Slate Lake Dolly Varden tissue chemistry to U.S. national values and studies.

Twelve Dolly Varden were collected: 3 each from Upper Slate Lake and Lower Slate Lake in early June 2000 and 3 each from Upper Slate Lake and Lower Slate Lake in late August 2001. Fish were frozen whole and delivered to a lab for whole tissue metal and selenium analysis (21 elements).

Analysis of variance was used to compare the tissue concentration for each of the 21 elements between lakes for each year separately (n = 3) in the previous two data reports (Kline 2001, Earthworks 2002). For this report, additional statistical analyses were conducted on 8 elements (i.e., As, Cd, Cr, Cu, Pb, Hg, Se, Zn). These elements were chosen because they are the only elements of the 21 that have triggered fish consumption advisories in the U.S. Tissue data are highly variable and do not allow generalizations to be drawn when comparing the lakes. In addition, the data indicated that required sample size for statistically rigorous surveys would require sample sizes larger than available in the existing lake population of Dolly Varden. Depending on the element, sample sizes ranging from 25 to 800 fish per lake are required for detecting an appreciable difference (20%).

Tissue residues are near or below regional or U.S. averages for salmonids or fish in general. Selenium is near a laboratory derived effects threshold suggesting Slate Lake Dolly Varden may be stressed due to accumulated selenium in their tissues or the laboratory study is overstated and not applicable.

Konopacky Environmental. 1992. Baseline monitoring studies of fish and fish habitat in Sherman and Sweeny Creeks, located near the Kensington Mine, Alaska during 1991. Annual Report – 1991, Volume 2 of 2. 110 pp.

The objective of this study was to conduct monitoring studies on Sherman and Sweeny creeks (near the proposed Kensington Mine project) that could be repeated and produce baseline data or measurements, relative to each study, and be statistically compared to data from later years. The seven monitoring studies were: (1) aquatic habitat characteristics; (2) water temperature; (3) benthic macroinvertebrates; (4) freshwater habitat use by salmonids; (5) potential stream diversion impacts to resident fish/habitat; (6) composition of spawning substrate; and (7) spawning migrations of adult salmon.

Sherman Creek supports rainbow trout, Dolly Varden, prickly sculpin, and pink salmon downstream of the first barrier. Upstream of the barrier are Dolly Varden and prickly sculpin. Sweeny Creek supports Dolly Varden, cutthroat trout, prickly sculpin and pink and coho salmon downstream of the first barrier. Dolly Varden and cutthroat trout are found in the middle reaches of the stream.

Various aspects of the 7 monitoring studies were conducted on 18 reaches or “strata” on both creeks and their major tributaries. Sherman Creek (and 3 tributaries) was divided into 13 strata, while Sweeny Creek (and 2 tributaries) was divided into 5 strata for the 1991 monitoring studies. Strata 1 and 2 of each creek was the lower (from the mouth up) 360 m long reach (strata 1) and the 1,100 m long reach immediately above reach 1 (strata 2). Fish were observed by a diver with snorkel gear and then electrofished for verification.

The study for strata 1 and 2 of each creek defined: (1) total surface area of the major habitat types, (2) total number of pieces of large woody debris per 30 m reach of stream, and (3) the prevalent substrate particle size class. Habitat was defined as riffle, glide, pool or cascade/falls. Sherman Creek’s most numerous habitat type was cascade/falls and Sweeny Creek’s was riffles.

Water temperatures in Sweeny Creek were near optimum for resident and anadromous fish. Sherman Creek temperatures were below optimum but still in the preferred range (Dolly Varden prefer 10° to 12.8° C while rainbow trout prefer 10° to 14.4° C).

Strata 1 of Sherman Creek showed highest population estimates of Dolly Varden and rainbow trout in pool habitats; lowest in riffle then glide habitats. Strata 2 showed the highest population estimate for Dolly Varden in pool habitats (no rainbow trout found in this reach); lowest in glide habitats. Strata 1 of Sweeny Creek showed highest population estimates for Dolly Varden and cutthroat trout in riffle habitats; lowest in glide habitats. Strata 2 showed highest population estimates for Dolly Varden and cutthroat trout in riffle habitats; lowest in glide habitats.

Konopacky Environmental. 1993. Ongoing and completed monitoring studies of fish and fish habitat in Sherman and Sweeny Creeks, located near the Kensington Mine, Alaska, during 1992. Annual Report – 1992, Volume 2 of 2. 56 pp.

The objective of this study was to conduct monitoring studies on Sherman and Sweeny creeks (near the proposed Kensington Mine project) that could be repeated and produce baseline data or measurements, relative to each study, and be statistically compared to data from later years. The selection of the preferred EIS Alternative F gave way to additional objectives for the 1992 study: define (1) total surface area of the major habitat types, and (2) the number of Dolly Varden in the various habitat types within strata 5 through 9 on Sherman, Ophir, Ivanhoe and No-Name creeks.

All habitat in each strata was defined (e.g., riffle, pool, glide, or cascade/falls) and measured (length, width, and thalweg depth). Large woody debris was counted and documented and substrate material was classified into size groups.

Sherman Creek supports rainbow trout, Dolly Varden, prickly sculpin, and pink salmon downstream of the first barrier. Upstream of the barrier there are Dolly Varden and prickly sculpin. Sweeny Creek (many barriers along the stream) supports Dolly Varden, cutthroat trout, prickly sculpin and pink and coho salmon downstream of the first barrier. Dolly Varden and cutthroat trout are found in the middle reaches of the stream.

Fish were observed and counted by a diver with snorkel gear and then electrofished for verification. (Note: No-Name Creek was too narrow and shallow for the diver to sample as he did in the other strata – fish were counted in every third 50 m reach of the stream.)

Water temperatures in Sweeny Creek were near optimum for resident and anadromous fish. Sherman Creek temperatures were below optimum but still in the preferred range (Dolly Varden prefer 10° to 12.8° C while rainbow trout prefer 10° to 14.4° C).

Across all habitat types in the strata studied, the highest mean counts of fish per habitat unit (6.00 fish) were in glide habitat within strata 6 (confluence of Ophir and Ivanhoe creeks) and in riffle habitat within strata 7 (Ophir Creek). The lowest mean counts per habitat unit (0.00 fish) were in pool habitat in strata 8 (Ivanhoe Creek).

Konopacky Environmental. 1996. Supplemental baseline studies of aquatic habitat and salmonid populations in the Slate and Johnson creek systems, located near Berner's Bay, Southeast Alaska, during summer-fall 1995. Annual Report – 1995, Volume 2 of 2 (042-0/049-0). Prepared for Coeur-Alaska, Inc. 100 pp.

In two reaches ("strata") of the Slate Creek (South Creek [strata 4] and Upper North Fork Slate Creek [strata 5]) and Johnson Creek (lower [strata 1] and upper [strata 2]) systems, habitat/fish studies were conducted that included: (1) total surface area of the major habitat types, (2) total number of large woody debris pieces per 100 m reach of stream, and (3) dominant substrate particle size class. Other studies conducted during the summer and fall of 1995 for all strata included: (1) defining and measuring aquatic habitat, (2) benthic macroinvertebrates composition, (3) salmonid population counts, (4) substrate composition, and (5) weekly/biweekly counts of spawning salmon.

Aquatic habitat was defined as riffle, pool, glide, cascade/falls, or beaver dam pond. The length, width and depth of all habitat units were measured and summed per habitat type. Large woody debris was counted and recorded per reach. Prevalent stream substrate was sized and classed. Fish were observed by a diver with snorkel gear and electrofished for verification.

The Slate Creek system supports rearing and spawning habitat for pink and coho salmon, Dolly Varden, cutthroat trout, rainbow trout and prickly sculpin downstream of the first fish barrier. Upstream of the barrier there are Dolly Varden and three-spine stickleback. The Johnson Creek system contains spawning and rearing habitat for pink, coho and chum salmon, Dolly Varden, cutthroat trout and prickly sculpin downstream of the first fish barriers. Dolly Varden are the only species found upstream of the barrier.

The results for the Slate Creek system showed South Creek with an average gradient of 4.6%, and habitat available for fish use as 36% riffle and 64% pool. The total estimated population of Dolly Varden was 38±65, with 38±65 observed in pool habitat and 0 fish in riffle habitat. The Dolly Varden were primarily present near Upper Slate Lake in the study reach. No cutthroat trout or juvenile coho salmon were observed. All four primary functional groups of aquatic insects (i.e., collectors, scrapers, shredders, and predators) were present at this site.

Upper North Fork Slate Creek had an average gradient of 3.3%, and habitat available for fish use was 64% riffle, 26% pool and 10% glide habitat. The total estimated population of Dolly Varden was 124±55, with 37±28 observed in riffle habitat, 24±29 in glide habitat and 63±38 observed in pool habitat. Dolly Varden were distributed throughout the Upper North Fork study reach. No cutthroat trout or juvenile coho salmon were observed. All four primary functional groups of aquatic insects (i.e., collectors, scrapers, shredders, and predators) were present at this site.

The Johnson Creek system showed Lower Johnson Creek with an average gradient of 2.8%, and habitat available for fish use as 54% riffle, 43% pool, 1% glide and 2%

cascade/falls habitat. The total estimated population of Dolly Varden was 230±300 with 63±58 observed in riffle habitat, 167±264 in pool habitat, and 0 in cascade/falls and glide habitats. Dolly Varden were primarily present in the upstream portion of this reach. Cutthroat trout total estimated population was 53±32 with 20±18 in riffle habitat, 33±23 in pool habitat, and 0 in glide and cascade/falls habitats. Cutthroat trout were primarily present in the downstream portion of this reach. The total estimated population for juvenile coho salmon was 8,168±7,494 with 0 present in cascade/falls habitat, 1,632±1,247 in riffle habitat, 63±0 in glide habitat, and 6,473±6,630 in pool habitat. Juvenile coho salmon were primarily present in the downstream portion of this reach.

Upper Johnson Creek showed an average gradient of 5.6%, and habitat available for fish use as 5% riffle, 4% glide, 14% pool, 53% cascade/falls and 24% beaver dam pond habitat. The total estimated population for Dolly Varden was 514±132 with 201±81 in cascade/falls habitat, 0 in riffle and beaver dam pond habitat, 21±6 in glide habitat, and 292±78 in pool habitat. No cutthroat trout or juvenile coho salmon were observed or captured in the Upper Johnson Creek study reach.

Heptageniidae (Order Ephemeroptera, mayflies) made up 71% of the benthic macroinvertebrates that were identified; no other family represented more than 10% of the total. All four primary functional groups of aquatic insects (i.e., collectors, scrapers, shredders, and predators) were present at these two sites.

Latterell, J.J., R.J. Naiman, B.R. Fransen, and P.A. Bisson. 2003. Physical constraints on trout (*Oncorhynchus spp*.) distribution in the Cascade Mountains: A comparison of logged and unlogged streams. Canadian Journal of Fisheries and Aquatic Sciences 60:1007-1017.

This study examined 58 streams with the following objectives: (1) to identify the physical constraints and stream characteristics at the upstream limits of trout distribution, and (2) determine whether forest management activities have altered constraints on trout distribution and, consequently, the historic upstream boundaries of trout distribution.

The upstream limit of trout distribution was frequently associated with (1) a sharp increase in channel gradient (i.e., trout were consistently absent from channels where gradient exceeded 22%), (2) declines in pool abundance in both logged and unlogged sites, and (3) channel constrictions or subsurface flows (more frequently in logged sites than unlogged).

Trout presence declined with decreased wetted channel width in logged areas, but not in unlogged areas. In unlogged sites, substrates were significantly coarser in upstream reaches, but correlated with channel gradient.

NOTE: “Habitat-based models” were created to predict fish presence or absence in different stream reaches per the habitat descriptions; the model proved better than chance alone.

Leder, E. 2001. Genetic affinities and population differentiation among Dolly Varden of the Falls Creek area. A draft report to National Park Service Glacier Bay National Park and Preserve and Gustavus Electric Company. 11 pp.

This report investigates isolated Dolly Varden populations in Kahtaheena Creek which drains into Icy Passage within Glacier Bay National Park, Alaska. A 40 ft high waterfall (lower falls) located about 0.5 miles above the mouth of the stream is a barrier to fish migration. A 60 ft high waterfall (upper falls) is located 3.4 miles upstream of the mouth creating another barrier to what is presumably two separate char populations. The author tried to (1) determine timing of divergence of the isolated populations from anadromous form, and (2) determine stock distinctiveness of the lower and upper isolated, stunted populations.

In late summer 1999, a genetic analysis was conducted on fish caught from the Log Jam site (i.e., between the lower and upper falls) and Big Woods site (i.e., above the upper falls) and from two anadromous populations (i.e., Salmon River near Gustavus and Indian River near Sitka).

From the samples taken at the Log Jam site, the fish ranged in size from 9.9 to 15.5 cm and were aged at 3 to 5 years via otolith readings. From the samples taken at the Big Woods site, the fish ranged in size from 10.4 to 18.1 cm and were aged at 3 to 7 years.

Results showed resident populations are genetically distinct from the current anadromous populations. Resident populations were nearly homozygous for three loci and had very few alleles for the other two loci. Anadromous populations were much more variable. Resident populations had only 4 alleles total compared to 11 or 19 alleles in the anadromous populations (which could be evidence of bottleneck). Allele 232 was in 20% of the Log Jam sample and 0% in the Big Woods sample which suggests reproductive isolation. The author believes the lack of genetic diversity in resident populations probably arose from a few fish.

Lum, J.L., J.D. Jones, and S.G. Taylor. 2001. Dolly Varden and cutthroat trout populations in Auke Lake, Southeast Alaska, during 2000. Fishery Data Series No. 01-33. ADF&G Division of Sport Fish. 35pp.

The Auke Creek weir near Juneau operates to count migrating sea-run Dolly Varden, cutthroat trout and other species of Pacific salmon (note: the same gear is used to count both immigration and emigration, so only one migration route can be documented at a time). Dolly Varden emigration has been declining since 1995. The 2000 run was very low. Weir counts showed:

Dolly Varden emigration:

- first fish captured March 20 and the last fish caught June 27
- average fork length was 259 mm (ranging from 60-460 mm)
- larger fish emigrated earlier
- total number emigrated was 5,254

Dolly Varden immigration:

- lowest count since 1997
- first fish captured June 29 (probably would have been earlier but upstream migration was blocked until the trap was reversed) and the last fish caught was on November 7 (when the weir was removed).
- total number immigrated was 3,665

Cutthroat trout emigration:

- declining since 1996
- first fish captured March 20 and last fish caught June 29 (when weir converted to upstream migrant trap and no additional emigration allowed).
- lowest immigration since recording began in 1997
- fork length ranged from 166 mm-444 mm
- total number emigrated was 250

Cutthroat trout immigration:

- first fish captured September 19 and ended November 7
- total number immigrated was 105

Data showed that summertime populations of cutthroat trout in the lake include fish that are considered resident and fish that are migratory at some point in their life. It is very difficult to distinguish sea-run from resident cutthroat trout in a lake that is accessible to upstream migrants, as some sea-run fish appear to become temporary lake residents and some apparent "residents" become sea-run.

Maekawa, K. and S. Nakano. 2002. Latitudinal trends in adult body size of Dolly Varden, with special reference to the food availability hypothesis. Population Ecology (2002) 44:17-22.

The food availability hypothesis (FAH) predicts that the relative productivity of ocean and freshwater habitats changes with latitude. It also predicts that anadromous life cycles will evolve when ocean productivity is greater than freshwater habitats, or vice versa.

Some populations of Dolly Varden are prevented anadromy due to a physical barrier (e.g., falls); other populations live a "fluvial" life history where individuals appear to "choose" not to migrate. Instead, they remain in river habitats to complete their life cycle because the conditions are more favorable. If the gain in fitness is greater from migrating to the ocean than from staying in freshwater, then anadromy can evolve. The most important fitness components are survivorship, body size (with regards to fecundity) and growth rate (with regards to age at maturation).

Most species of *Salvelinus* maintain alternative fluvial and anadromous life histories either across populations or across individuals within a population (believed to be relatively primitive). In some species of more advanced genera, such as *Oncorhynchus,* all individuals migrate to the ocean to continue life history stages.

Both *Salvelinus malma* and *S. leucomacnis* anadromous populations exist in the northern part of their distribution range and fluvial populations exist in the southern range. At around 44° N, however, both anadromous and fluvial females in populations of Dolly Varden coexist in the same streams.

Body size at maturity in females of anadromous populations is much larger than that of resident populations in most northern populations; the difference decreases with latitude.

Mean growth rate in resident Dolly Varden at low latitudes is considerably higher than that in resident Dolly Varden at high latitudes – also reflecting a difference in stream productivity.

Martin, D.C. 1988. Aquatic habitat of the Tiekel River, Southcentral Alaska, and its utilization by resident Dolly Varden (*Salvelinus malma*). Ms. Thesis. University of Alaska Fairbanks, Fairbanks, Alaska USA. 180 pages.

One goal of this study was to determine which habitats were the most important to resident Dolly Varden (*Salvelinus malma*) in the Tiekel River. Dolly Varden in the Tiekel River are of the southern stream-resident form, described as smaller fish (average length of 150 mm), earlier to mature, lower fecundity, and shorter lived (high mortality rates after age 4) than the anadromous form. (Note: Armstrong and Morrow [1980] described 7 different life forms of Dolly Varden: [1] northern anadromous, [2] northern lake resident, [3] northern stream resident, [4] northern spring resident, [5] southern anadromous, [6] southern stream resident, and [7] southern stream-lake resident.)

Observations showed that Dolly Varden were wintering in the larger, deeper parts of the lower, main river where large sections of the stream remain ice-free throughout the winter, or in beaver ponded areas adjacent to the Tiekel River. These fish reinhabit the shallower, upstream sections and side-feeder streams of the Tiekel River each year. By late June, Dolly Varden were abundant in the entire study area and were found in the small pool areas created by large boulders, at the edge of dropoffs, and near large debris piles (i.e., submerged root wads and whole trees). Most of the smaller feeder streams contained Dolly Varden as far upstream as the last accessible pool. Dolly Varden used deep water, turbidity, turbulent water and large woody debris as cover throughout the summer. Spawning occurred in late September in many of the smaller feeder streams and rarely in the main channel of the river. The author observed as many as 200 fish crowding over 2 or 3 redds in some of the more popular spawning areas. Young-of-the-year fish first appeared in mid-July; the author believed they emerged from the substrate at this time.

Important habitat variables and the preferred condition for young-of-the-year Dolly Varden were: (1) water velocity [strong preference for 0 velocity], (2) dominant substrate type [sand and silt], (3) water depth [9-17 cm], and (4) cover presence and type [submerged forest debris].

Habitat variables assessed and the preferred condition for adult Dolly Varden were: (1) size of stream [10-20 cm wide], (2) mean water velocity [9.7-10.6 cm/sec], (3) percent pools [6.5-14%], (4) dominant substrate type [pebble, then boulder and cobble], (5) turbidity [0.0-3.5 NTU], (6) percent embeddedness of substrate [12-18%], (7) maximum depth [1.65 ft and greater], and (8) stream gradient [strong preference for slope between 0.5-1%; preference dropped off dramatically at 3% slope]. Strong evidence suggests (from this report and others cited) that pool area and cover availability are the most important habitat factors for adult Dolly Varden.

Observed habitat variables required for spawning Dolly Varden were: (1) water velocity [range of 4-17 cm/sec, with optimum at 7.5-10 cm/sec], (2) water depth [optimum was 0.26 ft-0.5 ft], (3) dominant substrate [gravel and sand, with gravel being optimum], (4) cover type and presence [non-cover areas preferred, with submerged forest debris areas used as well].

Dolly Varden were observed using beaver ponded areas adjacent to the Tiekel River. Some of these ponds were actively used as overwintering areas and had fish of all sizes in them during the summer months if water temperatures were favorable and access was not too difficult. Chlorophyll a concentrations (optimum 4.26 – 7.95 ug/l) and August water temperatures (preferred 8.9° – 10.3° C) were important factors to pond use.

Armstrong, R.H., and J.E. Morrow. 1980. The Dolly Varden charr. Pages 99-140. in Balon, E.K. (ed.). Charrs: Salmonid Fishes of the Genus *Salvelinus*. Dr. W. Junk b.v., Publishers. The Hague, Netherlands.

Northcote, T.G. 1992. Migration and residency in stream salmonids – some ecological considerations and evolutionary consequences. Nordic Journal of Freshwater Research 67:5-17.

This author studies many reports and considers the "movement" of resident and migratory fish (e.g., when, where, why and how). His research found that territory size shows a strong positive regression to body size for several species of stream dwelling salmonids. Body size can also determine whether fish stay in stream habitat or migrate downstream; smaller, weaker fish move to other areas when food limits are low.

The restricted movement of stream resident trout was studied on 3 progressively smaller systems: the longest stream showed some brown trout moved downstream over 300 m; those in a smaller stream did not go further than 200 m downstream; 1/3 of those in a very small creek were recaptured within 1 m of their previous site, and 63% of the recaptured fish had not moved more than 10 m. A slight skew for a downstream direction was found for the distribution of movement with less movement in the winter and low water temperatures and more movement in spring and summer at high flows and water temperatures. After analyzing the pattern of movement by stream resident trout, data suggests a large static fraction and a small, mobile fraction of individuals within the population. The mobile fish could represent explorers and colonizers of new areas and habitats.

Strong genetic control for residency seems to be particularly well developed in populations that live in habitats where emigration could be detrimental (headwater streams, reaches above waterfalls, or other barriers).

The location of suitable spawning areas seems to initiate the most extensive movement in resident salmonid populations, but even here the distances traveled may only be a few hundred meters and sometimes much less. For small streams, cutthroat trout populations feeding and reproductive habitats may be the same.

Energetically, it can be expensive to change residence sites; the movement up or downstream, physiological adaptations to new habitats, predators or parasites and diseases must be contended with. At home, movement costs should be small and the range of predators, parasites and diseases reduced.

Osborn, J.G., C.J. Cederhold, and E.O. Salo. 1981. Final Report. The effects of logging on cutthroat trout (*Salmo clarki*) in small headwater streams. Univ. of WA College of Fisheries, Fisheries Research Institute. FRI-UW-8113. 89 pp.

This study monitored five streams for the effects of logging (one unlogged stream for a control and four previously logged streams in various stages of recovery) on resident nonanadromous cutthroat trout populations in the headwater area of Clearwater River in Jefferson County, WA. Salmonids require specific stream habitat for cover and shelter, overwintering protection, and stable stream environment, and much is associated with forest debris (e.g., boles, limbs, branches, root wads). The most common cause of debris alteration is the felling and yarding of trees during logging operations.

Fish surveys were conducted with an electroshocker from July 1978 through October 1979. The fish that were caught were anesthetized with MS-222, measured, weighed, marked (clipped dorsal lobe of caudal fin) and then placed in water to recover. The surveys were conducted again 24 hours later (no fish marked on 2nd pass). No noticeable differences were seen in population size, fish biomass or density, or movement over the course of the study in the streams monitored.

Measurements were taken of accumulated logging debris (e.g., twigs, small branches, large branches, logs) within each stream's study section. Stream character measurements were taken to document any morphometric changes during the study: stream widths, depths along the thalweg, riffle areas, discharge and average stream gradients were measured. Pool data included lengths, widths and depths of all pools in the study section. Water temperatures were monitored on a daily basis throughout the study.

The control stream showed no noticeable difference in the volume of forest debris available – virtually unchanged. The experimental stream (i.e., most recently logged) changed considerably over time as the available "bank potential" and "potential" debris decreased noticeably, resulting in an unstable stream system with a loss of winter habitat (e.g., log jams, upturned roots, pools). Stream temperatures also changed noticeably.

Logging appeared to have subtle effects on the population of trout during this study in the experimental stream. However, comparable studies show the same results immediately after logging, followed by a sharp decline of fish population in future years, due to high overwintering mortality. The controlling factor of a sustained increase in production is the availability of habitat (i.e., forest debris), which is essential to cutthroat trout for cover and the creation of overwintering habitat and to the stream's stability. Logging practices deplete the stream bank and the adjacent area of this material. The results of this study indicate that current logging practices are potentially damaging to streams, depending on its location, substrate, etc. Logging may have already permanently damaged many miles of small headwater streams, but recovery is possible. Headwater streams are important spawning and rearing areas for resident cutthroat trout.

Reed, R.D. and S.T. Elliott. 1973. Effects of logging on Dolly Varden. ADF&G Division of Sport Fish. Job R-IV-B, Project F-9-4.

This study surveyed 22 logged watersheds throughout Southeast Alaska. The surveys showed stream/habitat damage due to improper culvert placement and removal, improper clearance of debris and logs from the stream bed, and damage done during equipment crossings. Thick detritus (e.g., needles, twigs, bark and slash) left in streams results in low water velocities, resulting in decreased dissolved oxygen levels, resulting in low aquatic insect populations. The detritus fills in the space between the gravels and destroys insect habitat, resulting in a decrease in aquatic insect species diversity in the altered stream sections. The monthly catch per trap analysis results showed no significant trends in Dolly Varden population sizes.

An annotated bibliography on the effects of logging on fish was compiled with over 90 citations.

Rosenfeld, J.S., S. Macdonald, D. Foster, S. Amrhein, B. Bales, T. Williams, F. Race, and T. Livingstone. 2002. Importance of small streams as rearing habitat for coastal cutthroat trout. North American Journal of Fisheries Management 22:177-187.

This study looked at the total stream length in different channel-width classes in high and low-gradient streams located on the west coast of Vancouver Island, British Columbia to document the relative importance of channels of different widths to juvenile cutthroat trout. Fish presence was determined by visual observation and/or sampling with baited minnow traps during summer and winter.

After gathering their data, authors compared it to published papers regarding relationships between cutthroat trout density and channel width and used the information to (1) estimate the distribution of juvenile cutthroat trout populations across streams of different sizes, (2) assess how topographic relief affects the abundance of small-stream rearing habitat for cutthroat trout, and (3) determine the degree to which fish-bearing streams are underrepresented on 1:50,000 and 1:20,000 topographic maps. This information can be used to roughly estimate the distribution of rearing habitat for cutthroat trout when funds or means are limited and sampling can not be conducted.

The distribution of stream length in different channel-width classes differed noticeably between high gradient streams and the lower gradient streams. The majority of stream habitat area is in channels >3 m wide, whereas the majority of stream length is in channels <3 m wide.

A high proportion of (fish bearing) streams was absent on topographic maps, particularly in low-gradient areas. This can lead to problems for stream protection during development (forestry, urbanization) since streams that are not identified will not be addressed during development planning. There is no substitute for field surveys to document location and extent of streams prior to development.

The distribution of juvenile cutthroat trout population by channel width class appears to more closely approximate the linear length of stream channel than it does the habitat area over the range of channel widths (<9 m) included in this study. Linear stream length is the best predictor of fish production.

This study documents the disproportionately large contribution of small streams as potential rearing habitat for cutthroat trout in coastal drainages and emphasizes the need for riparian regulation and land-use management practices that will adequately protect small streams.

Schelske, M., K. Hodges, and D. Schmid. 1998. *Exxon Valdez* oil spill restoration project Final Report. Prince William Sound cutthroat trout, Dolly Varden char inventory (Restoration Project 97302) USDA Forest Service, Cordova Ranger District. 12 pp.

This was a one-year project (1996 – 1997). The research was hampered by a lack of basic information on Dolly Varden and cutthroat trout distribution in the area. Researchers found these fish were more widespread in the area than first believed. Researchers talked with fisherman and residents to find streams occupied by Dolly Varden and trout. They found 29 lakes and streams which had undocumented populations of these and other anadromous fish. New populations identified included: 23 Dolly Varden, 21 cutthroat trout, 14 coho, 2 sockeye, 1 chum, 6 resident Dolly Varden, and 6 resident cutthroat trout populations. Fish found upstream of 6 ft barriers were considered resident; all others were considered anadromous.

A more complete and accurate inventory is needed for future purposes (comprehensive protection or management plan).

Assessment of the effects on these species from the *Exxon Valdez* oil spill was not determined.

Sea-Run Fisheries. 2004. Final Report – Evaluation of potential impacts of the Power Creek Hydroelectric Project intake on resident Dolly Varden char. Prepared for Cordova Electric Cooperative. 21 pp.

This report documents supplemental monitoring of fish at the Power Creek hydroelectric project during calendar years 2001-2003. Fish use and behavior in the vicinity of the intake area was studied and determined: (1) relative abundance (i.e., CPUE) of Dolly Varden in the vicinity of the project intake as compared to lower velocity, more typical habitat found upstream; (2) whether intake-area Dolly Varden are subject to injury or mortality as a result of project operations.

The study area was divided into two areas: (1) the "intake area," ~100 yards upstream and downstream of the intake and forebay; and (2) the "upstream area," reaches upstream of the influence of the project in the typically lower gradient habitats of Surprise Valley.

Baited minnow traps were the primary sampling method. Nineteen were set in the "intake area" at favorable habitats (i.e., cover and water velocity) and to achieve a broad distribution of trapping effort. One trap was set at the "upstream area" (i.e., pool habitat with lots of debris). Trapping initiated in October and November 2001 after the power plant started operating. The next season, traps were deployed as soon as snow and avalanche conditions permitted access. Sampling was conducted June through November as opportunities occurred. Caudal fin clips were used to mark initial capture area and provide recapture information. Stream discharge and water temperatures were taken when sampling occurred.

An underwater video was taken during the intake screen sampling using a lens that offered an ~39 ft depth of field and infra-red for low light capability. No fish were caught during screen sample deployment (58 hours) and no fish were observed in the video.

The minnow traps fished for 38 days over 9 sample events. A total of 101 fish were captured at the "intake sites" of which 49 were recaptures; 252 fish were caught at the "upstream site" of which 74 were recaptures. Recapture of marked fish was higher at the "intake" sites than at the "upstream" site. As the water temperatures dropped below 2°C, catch rates declined to 0. Fish ranged in size from 45 mm to 160 mm (very few fish in the lower end of the 40 to 60 mm size class and the largest fish [>120 mm] were most abundant during mid-summer).

Fish were successfully caught/trapped adjacent to the waters edge where depth, boulders and woody debris provided cover and reduced velocity. Some trap locations consistently caught fish while others never caught any fish.

Five fish were captured downstream of the diversion structure prior to Project operation. Once the facility was operating, no fish were captured below the diversion structure.

Assumptions were made that Dolly Varden would not "prefer" the intake area habitat available because of its moderately steep (8%) gradient, coarse gravels and boulders, high water velocities, and long distances to peripheral habitats. Results of this study show this may be true.

Dolly Varden in these particular circumstances exhibit a preference for small, localized habitats and do not travel great distances as part of their day-to-day foraging activities.

Sempeski, P. and P. Gaudin. 1995. Size-related changes in diel distribution of young grayling (*Thymallus thymallus*). Canadian Journal of Fisheries and Aquatic Sciences. 52:1842-1848.

This paper looks at the diel habitat use of grayling (*Thymallus thymallus*) early life stages, and to point out the dynamic aspect of size-related differences in day and night habitat use by young grayling in habitats for which the day use has already been described, but for which night use is still unknown. The studies were conducted on the River Pollon, a small tributary of the River Ain (France). Fish observations were made from the top of the bank; all fish encountered were documented.

In the daytime, fish were observed in deeper water than at night and never observed in depths <5 cm (even fish in the smallest size-class). Those larger than 20 mm were never found in <10 cm of water. Conversely, shallow depths were intensively used at night. Seventy percent of the 15-20 mm long individuals were found in depths <5 cm and 70% of the 20-30 mm long fish were observed in depths <10 cm. Modes of preferred depths increased with fish size. The majority of the 50-60 cm and >60 cm fish that were observed in depths from 40-60 cm in the daytime were still found in depths <40 cm at night.

The general pattern of habitat use by young grayling can be characterized by (1) a general tendency to shift towards the channel (i.e., deeper water) with increasing size, and (2) a diel migration between feeding and resting habitats, that can be interpreted as a succession of four phases:

1. Size-class 15-20 mm appear to be most linked to dead zones (i.e., area along the riverbank, small bays created by bank curves).
2. Size-class 20 to 35-40 mm represent a second homogeneous group also linked to dead zones but to a lesser extent. Also, especially during the daytime, this size class took position close to the bottom and tended to use the transition zone (i.e., between dead zone and main current of river).
3. Individuals larger than 35-40 mm (fish that have reached parr stage and are able to live in the channel) still use dead zones mainly at night and an increasing proportion of individuals was observed in the channel.
4. All but a few fish >60 mm have left the dead zones during the daytime. Nightime distribution also differed from the other size-classes.

Water temperatures ranged from 10-15° C during the study period.

Tabor, R.A., and R.M. Piaskowski. 2002. Nearshore habitat use by juvenile Chinook salmon in lentic systems of the Lake Washington basin, Annual Report, 2001. U.S. Fish and Wildlife Service, Western Wash. Office, Div. of Fish and Watershed Assessment. 57 pp.

Observations were made by a diver with snorkel gear or by walking on top of the bank to determine nearshore habitat use of juvenile chinook salmon in Lake Washington, Lake Sammamish, and the Ship Canal in WA. Both day and night surveys were conducted.

Juvenile chinook salmon preferred sand and gravel substrates in winter and spring and rarely used boulders. A low percentage were found along the shoreline with armored banks; most that were found along armored banks were adjacent to bulkheads. Few were observed along riprap.

During the daytime, fish were active and mostly in small schools (2-100 fish), often with a group of sockeye salmon. During nighttime, fish were spread out from each other, inactive (motionless) and close to the bottom.

During the day, all chinook were within 3 m of an overhead structure such as a dock, walking bridge, or overhanging vegetation. At night, juvenile chinook salmon did not prefer to be under overhead structures, but preferred deeper, open water. Daytime use of woody debris/overhanging vegetation was much more apparent for juvenile coho than juvenile chinook. In February and March, 52% of juvenile chinook were directly under an overhead structure, but in April and May none were observed using overhead structures. Nearshore habitat was not extensively used during the day or night after mid-May.

Most chinook preferred 0.4 m deep water in spring (March – April). Approximately 1/2 preferred 0.7 m depth in May to early June, and deeper water as time and size increased.

Reaction to predators was to move closer to shore and seek refuge in the woody debris.

Van Alen, B.W. 1983. Feasibility of salmon enhancement programs in the Indian Lake system, Southeastern AK, with emphasis on population characteristics of resident Dolly Varden char, *Salvelinus malma* (Walbaum). Info. Leaflet No. 215. ADF&G.

This document looks at rearing coho fry from the hatchery in a landlocked lake and at the existing resident Dolly Varden in that lake (other fish in the system were kokanee, three-spined stickleback and coast range sculpin). A total of 1,843 Dolly Varden were killed in August throughout the Indian Lake system to document age, growth, sex, maturity and diet determinations. Researchers only checked the nets every 4-5 days, so many fish were partially decomposed.

From the sample of 1,843 Dolly Varden:
- 1,802 were examined for age determinations - oldest were 14 yrs, youngest were 1 yr
- 1,736 were examined for weight – weights ranged from 2 to 1,864 grams
- 1,843 were examined for lengths – lengths ranged from 58 mm to 556 mm
- 1,453 were examined for gonad condition

Younger and smaller char were found in rivers and littoral zones of lakes, while the larger and older char were found in the lakes at all depths. Most of the fish were caught in the littoral zone of the lakes (DO was low near bottom of lake). Most char reside near the bottom and at all depths. There appeared to be considerable movement of char between lakes and rivers in the system. Few char reside in the pelagic zone.

The data showed significant differences in growth rates of the char from each lake and stream. Males have the fastest growth rate. Age:length relationship for males was significantly different than females 4 years and older; ages 1, 2, and 3 showed no significant difference.

Length:weight relationship for male and female showed no significant differences.

Females spawn annually between 6 and 9 years of age, males apparently spawn every 2 years. The ratio of males to females was 1:1. This system showed char mature as young as age 2, most at age 5 or 6, and all mature by age 7. Females mature faster than males (67% of females mature at age 5 while only 42% of males are mature). The author speculated that determining maturity in August is too early in the year and that some were not classified correctly, which may account for the difference in the age of maturation.

The females contained 2 sizes of eggs: <2 mm and >2 mm in diameter, the same numbers of both and approximately 200 total.

Benthic invertebrate analysis showed Chironomidae was the most common stomach content rather than Diptera, Tricoptera and Coleoptra. Char at age 8 are large enough to prey on sticklebacks, cottids, kokanee and young char ≤200 mm long.

Young, K.A., S.G. Hinch, and T.G. Northcote. 1999. Status of resident coastal cutthroat trout and their habitat 25 years after riparian logging. North American Journal of Fisheries Management 19:901-911.

In 1973 two sections of East Creek, a small headwater stream located in the University of British Columbia's Malcom Knapp Research Forest, were subjected to 2 types of stream side logging. Section A was clearcut to the stream bank (banks damaged by heavy equipment) and all wood and logging debris was left in place for several weeks, then pushed into piles in the summer (1973), and burned in spring (1974). This created scarification. Section B was clearcut to the stream bank in spring (1973), all wood and debris was left in the stream and on the hill slopes, and then burned in spring (1974). Section C was left undisturbed to serve as a reference section. Waterfalls downstream from the study site prevent upstream migration of fish, so resident coastal cutthroat trout is the only fish species present.

A survey reach was established near the outflow of each treatment section. Each section was monitored and evaluated for stream habitat assessment, fish population estimates and temperature monitoring. Monitoring was conducted intermittently for 25 years.

The monitoring studies showed movement of trout between sections is limited by culverts and steep gradients. Each section was considered a "population." Population assessments were made between mid-July and mid-September each year. For the first several years trout density was much lower in Section A than the others.

There was a low percentage of year-one fish immediately after logging and for the next two years. Pre-emergence mortality was thought to be due to temperature increase and sediment introduction. There were high water temperatures in Section A and Section B for the first several years. Despite the lethal maximum temperatures in 1973 and 1974, fish remained in the survey reach at low densities, probably due to groundwater input sources that provided thermal refugia. Ten years after logging, trout densities were similar in all sections and age-class distributions were similar.

Trees were planted in Section A and B and habitat structures were placed in-stream in Section A. In 1997, trout density in Section A was approximately twice that of sections B and C. Section C had slightly fewer large fish than A and B. Trout recovery in Section A was probably due to reintroduction of large woody debris into the stream channel.

Section B and C fish density and age-class distribution was similar throughout the study. The researchers thought Section B would be higher because of a likely increase in primary productivity.

The authors emphasized that large woody debris is very important in protecting trout populations.