Exxon Valdez Oil Spill
Restoration Project Annual Report

Tributary Restoration and Development Project: Port Dick Creek, Lower Cook Inlet, Alaska

Restoration Project 97139A2
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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Study History: The Port Dick Creek Tributary Spawning Habitat Restoration Project was initiated under the restoration surveys in FY91 and FY92 (Restoration Study Number 105) which resulted in the selection of Port Dick Creek for further instream restoration work. A tributary restoration feasibility analysis was initiated at this site in 1991 and was continued through the spring of 1993. The tributary restoration project was initially approved for continued funding in FY94 and FY95, however, spending was placed on hold pending further review and discussion at the supplemental workshop held in Anchorage in January 1995. A Detailed Project Description "Proposed Spawning Channel Construction Project Port Dick Creek, Lower Cook Inlet" (Restoration Project 95139), was written, and the project was subsequently approved by the Trustee Council in May 1995. In June 1996, two tributaries to Port Dick Creek were excavated which created an additional 2,500 m^2 of spawning habitat. A three-year evaluation project was initiated in FY97 to assess project success by determining fry production and streambed stability. This is the second annual report to be submitted.

Abstract:. Restoration surveys on the outer coast of the Kenai Peninsula resulted in the identification and feasibility analysis for the restoration of pink and chum salmon spawning habitat within a tributary system of Port Dick Creek. Port Dick Creek is located approximately 25 miles southeast of Homer on the Kenai Peninsula. The primary project goal involves the restoration of the native Port Dick Creek pink salmon, *Onchorynchus gorbusca*, and chum salmon, *Onchorynchus keta,* stocks through instream habitat restoration in two intermittent tributaries (former spawning channels) of Port Dick Creek. Feasibility studies conducted from 1991 through 1995 warranted excavation (in June 1996) of approximately 3,000 m^3 of material in two tributaries to create additional stable spawning habitat. In July and August 1996, 572 pink and 300 chum salmon voluntarily colonized the two tributaries and spawned, depositing a potential 767,000 eggs. The following spring 324,889 (or 346 fry/ m^2) were enumerated emigrating from both tributaries. Adult pink and chum salmon entered both tributaries to spawn for the second time in July and August 1997.

Key Words: Alluvial, chum salmon, *Exxon Valdez* oil spill, groundwater, habitat, instream, *Oncorhynchus gorbuscha, Oncorhynchus keta*, pink salmon, Port Dick, restoration, sedimentation, spawning channel.

Project Data: *Description of data* - Data collected to support the spawning tributary design includes water level and temperature data. *Format* - text files. *Custodian*: Mark Dickson, 3298 Douglas Place, Homer, Alaska 99603-8027, E-Mail; MarkD@fishgame.state.ak.us). *Availability*: upon request.

Citation:

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INTRODUCTION

In 1991, the Alaska Department of Fish and Game, (ADF&G) Commercial Fisheries Management and Development Division (CFM&D), conducted restoration surveys on the outer coast of the Kenai Peninsula to identify pink salmon *Onchorynchus gorbusca* and chum salmon *Onchorynchus keta* spawning systems that would benefit from instream habitat restoration. Port Dick Head End Creek, located within Kachemak Bay State Wilderness Park approximately 25 miles southeast of Homer (Figure 1) was chosen because 1) it is considered one of the more important wild pink and chum salmon production streams in the Lower Cook Inlet area; 2) the 1964 earthquake caused an uplift of material that virtually eliminated the available spawning habitat that was in existence prior to the earthquake (Val McLay, personnal communication); and 3) the total return of chum salmon to Port Dick Creek has declined in recent years. The total return of the wild Port Dick Bay chum salmon has averaged only 5,000 fish for the nine year period, 1988-1997, compared to the previous 15 year period (1974-1987) of 31,000 fish (Figure 2). The minimum spawning escapement goal at Port Dick Creek for chum salmon, has been met only twice since 1988 ADF&G (1996). The primary species targeted is the native chum salmon of Port Dick Creek, however, pink salmon will also benefit from the instream restoration project.

The goal of the restoration project is to reverse the decline in chum and pink salmon stock abundance and provide for a harvestable surplus as a mitigative measure to address the results of the *Exxon Valdez* Oil Spill (EVOS). If stable prime spawning habitat could be restored within the two Port Dick Creek tributaries, standard mean egg to fry survival rates of up to 16.9% and 22.8% could be expected for chum and pink salmon, respectively according to Lister et al. (1980).

The two intermittent but largely subterranean tributaries of the Port Dick Creek Watershed that were selected for restoration as shown in Figure 3, and designated as the Primary and Secondary Tributaries. The larger Primary Tributary intersects Port Dick Creek near the high tide line and receives its surface water flow from a small lake of less than 4 ha. at an elevation of 300 m. Prior to the 1964 earthquake, the Primary Tributary had a stable surface water system which successfully produced salmon (Val McLay, personal communications). The lower 150 m of the Primary Tributary was affected by uplift from the earthquake, causing a dry streambed of rock and cobble during times of average to low discharge. The nearby Secondary Tributary (Figure 3) had an intermittent surface water flow due to fluctuations in its groundwater source. Previous to restoration there was no evidence of salmon spawning within the Secondary Tributary; however, it provided an opportunity to create additional spawning habitat within the Port Dick Creek drainage. Feasibility studies conducted from 1991 through 1995 were designed to determine the suitability of excavating the tributaries to increase spawning habitat. The studies revealed that during the winter months surface water withdrew 10-80 cm below streambed level in the Primary Tributary and 10-30 cm in the Secondary Tributary (Dudiak et al., 1996). The tributaries were carefully designed from the collected data to withstand two extremes, low and high water events with a goal of sustaining long term salmon habitat.

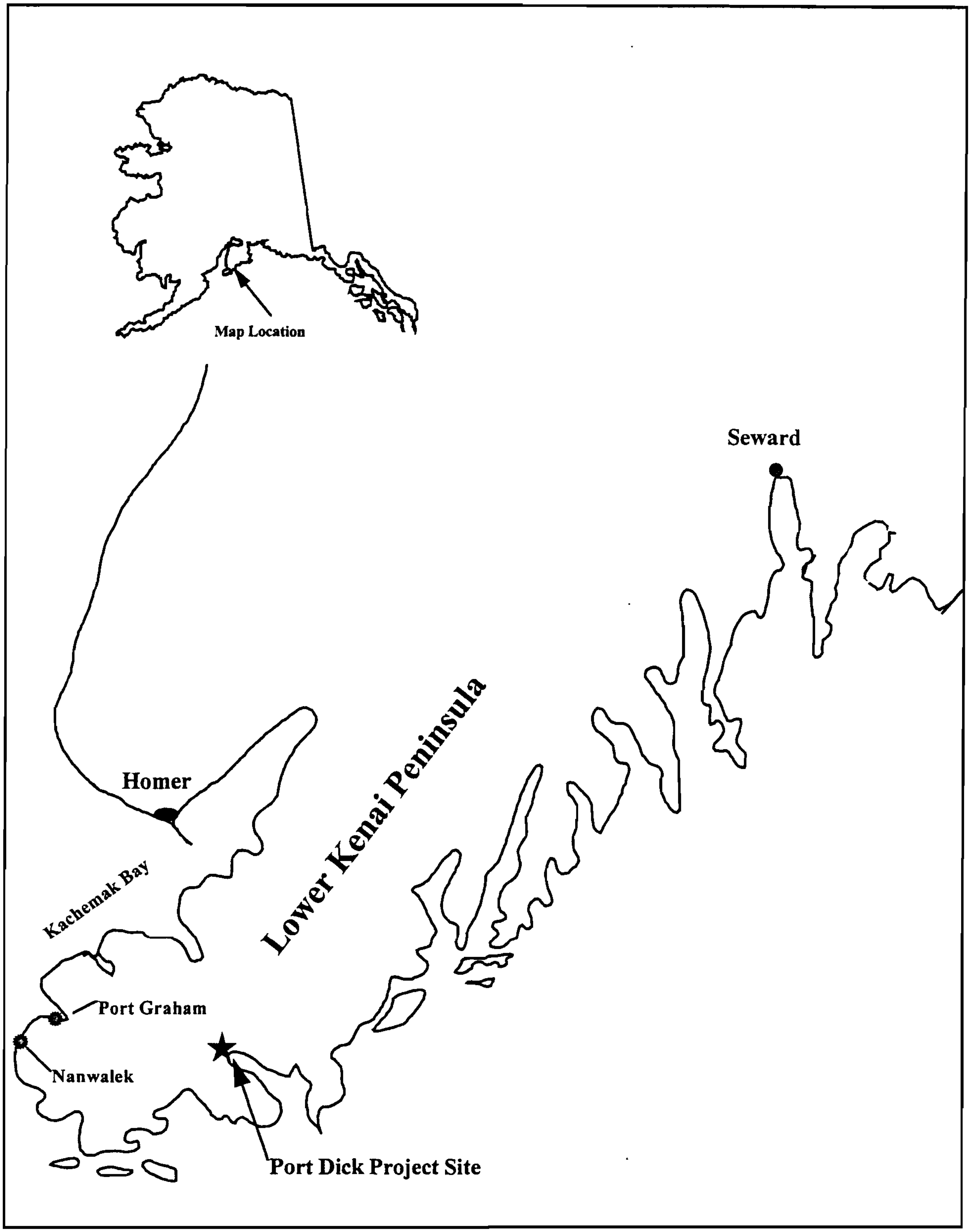


Figure 1 . Map of the outer gulf coast of the Kenai Peniunsula showing the location Port Dick Project site.

In June of 1996, approximately 3,000 m^3 of material were excavated from both tributaries producing a stable surface water flow creating approximately 2,500 m^2 of long term spawning habitat.

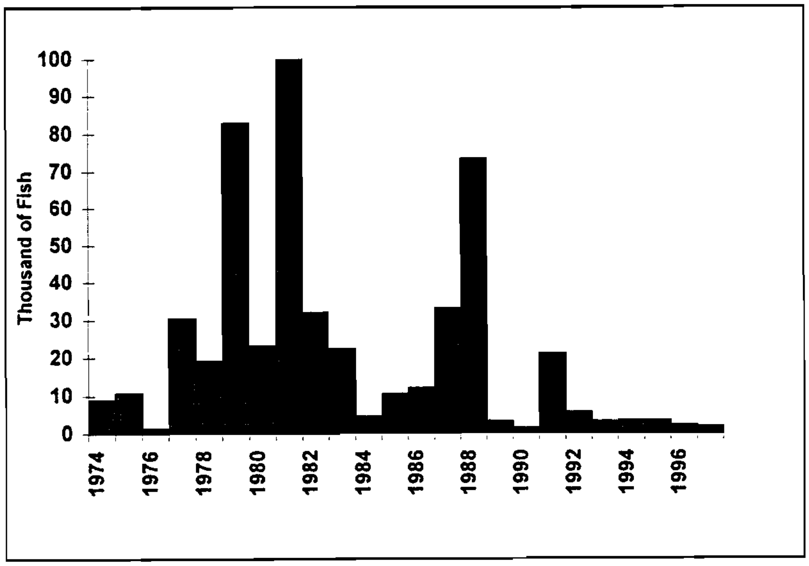
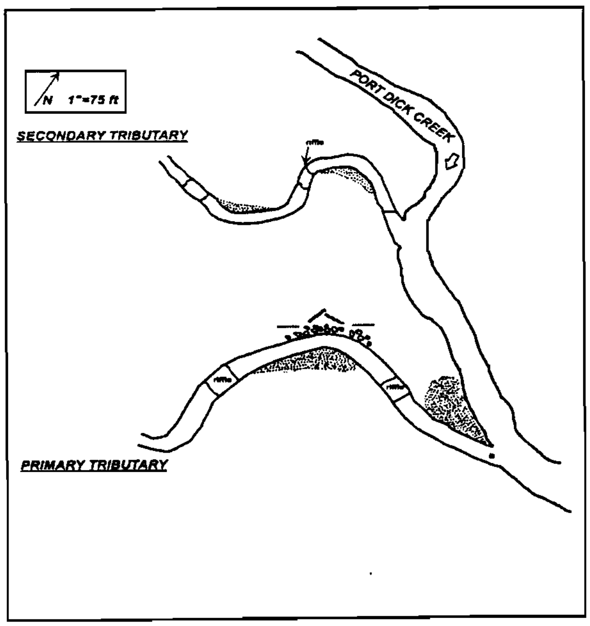


Figure 2. Total return (catch & escapement) of Port Dick Creek Chum salmon, 1974-1997.

In July and August 1996, an estimated 572 pink and 300 chum salmon colonized both tributaries and spawned, depositing an estimated 767,000 pink and chum salmon eggs. The following spring ADF&G field staff enumerated a total of 312,860 pink and chum fry from both tributaries producing an estimated egg to fry survival rate as high as 40.8 % or 346 fry/m^2. For comparison, Lister et al. (1980) calculated an egg to fry survival rate of 16.3% for chum salmon on seven groundwater-fed spawning channels in British Columbia. Mean length at emergence for chum (39.2 mm) and pink fry (33.9 mm) falls within the size range expected for chum and pink fry throughout their Pacific range as discussed in Groot & Margolis (1991).



The tributaries were designed from data collected during the feasibility analysis to withstand two extremes, low and high water events, with a goal to sustain spawning channel stability. Phase two of the project also includes long term monitoring and evaluation of the physical stability of the tributaries by evaluating sediment and bedload transport as well as the stability of riffles and streambanks in the project site area.

This is the third year of a five year project funded by the EVOS Trustee Council. A five year feasibility study, 1991-1995, was jointly funded by ADF&G and the EVOS Trustee Council.

Figure 2. Total return (catch & escapement) of Port Dick Chum salmon, 1974-1997.

OBJECTIVES

The initial objectives of creating the Primary and Secondary Tributary spawning habitat was accomplished in June 1996. Current objectives include a program to determine project success by estimating egg to fry survivals and fry production (fry produced/m^2) and sedimentologic stability as related to these tributaries. Work performed during FY97 was intended to accomplish the following parameters:

1. Continue to estimate spawning success in the restored tributaries through egg to fry survivals and fry production, and estimate adult production as a result of the increased spawning habitat.
2. Continue to evaluate the success of the restored tributaries through sediment transport parameters on a bimonthly basis.
3. Prepare annual Port Dick Detailed Project Descriptions and annual reports. Prepare long term monitoring results for peer review and evaluation in preparation for publication.
4. Monitor and evaluate water/tributary parameters including sediment transport parameters approximately six times per year.

METHODS

Study Area

Port Dick Creek is located on the Outer Gulf Coast of the Kenai Peninsula on the exposed coastline of the Gulf of Alaska (Figure 1). The area is characterized and influenced by the warming affect of the maritime currents of the North Gulf Coast, and annual rainfall can exceed 60 inches ADNR (1994). The predominate vegetation type is Sitka Spruce and Western Hemlock forest and is considered climax. Sitka Spruce commonly reach a diameter of 24 inches. The creek corridor is narrow (less than 250 m) with adjacent slopes in excess of 30%. Port Dick Creek is a fresh water creek with the headwaters originating 2 miles to the west of tide water.

Project Evaluation

Successful instream habitat restoration and research requires cautious planning and competent scientific evaluation. It is essential that all such projects be thoroughly documented and objectively evaluated so that we can learn from project performance to improve future efforts Kondorf et al. (1996). Two project components exist with the Port Dick Project to measure success; the fishery survival evaluation and the physical stability evaluation component. For the fishery component, determination of egg to fry survivals, fry production and size at emergence fry, as well as physical parameter evaluation (temperature, salinity and water velocity), address the suitability of the restored spawning habitat to produce salmon fry. Bonnel (1991), found that fry production (fry produced per unit area), rather than egg to fry survival, may be a more suitable method to measure project success and longevity because of complicating factors influencing variability in estimating egg to fry survival. These factors include uncertainty in spawner counts, degree of egg retention, variations in fecundity, predation and problems associated with fry trapping.

One of the main factors to consider with respect to egg to fry survival at this site, however, is the long term stability of the spawning habitat. This is being evaluated using several techniques including tracer gravel, scour chains and surveyed streambed transects. These studies use the physical parameter data also needed for the biological evaluation, in particular hourly stream stage records of flood events.

Spawning success

The spawning escapement for each tributary was determined from periodic ground (foot) surveys by a 2-person CFM&D ground survey crew as part of the annual program to enumerate spawning escapements in Lower Cook Inlet (LCI) streams. To standardize the escapement, ground survey data from both tributaries were generated into daily escapement estimates using stream life data (number of days) live and dead count, the number of surveys and the time between surveys Yuen (1993). Accumulated pink and chum salmon escapements are then estimated from:

$$\frac{\sum_{i=1}^{n} \frac{(x_i + x_{i-1})}{2} (d_i - d_{i-1})}{17.5}$$

where n = number of surveys, d_i = Julian calendar date of survey i, and x_i = number of live pink or chum salmon observed in the study stream during the survey i. A stream life value of 17.5 days was chosen to use in estimating pink and chum spawner abundance based on work by Helle (1964).

The total potential egg deposition for both tributaries was then estimated as the number of fish spawned multiplied by the potential fecundity.

To enumerate seaward migrating fry, intertidal fry traps were installed at the down stream end of each tributary (Figures 4 and 5). At the Primary Tributary, migrating fry entered the trap through a 1.5 m square tunnel entrance that funnels to a cylindrical entrance at the trap. Meshed wings extended from each side of the tunnel entrance to the north and south shores of the tributary and effectively fished 100% of the tributary width (Figure 4). The trap is rectangular in shape, 1.0 m x 0.85 m x 0.80 m (L x W x H), with the up-stream end as a funnel shaped entrance. Baffles were installed to divert current and provide resting areas for captured fry.

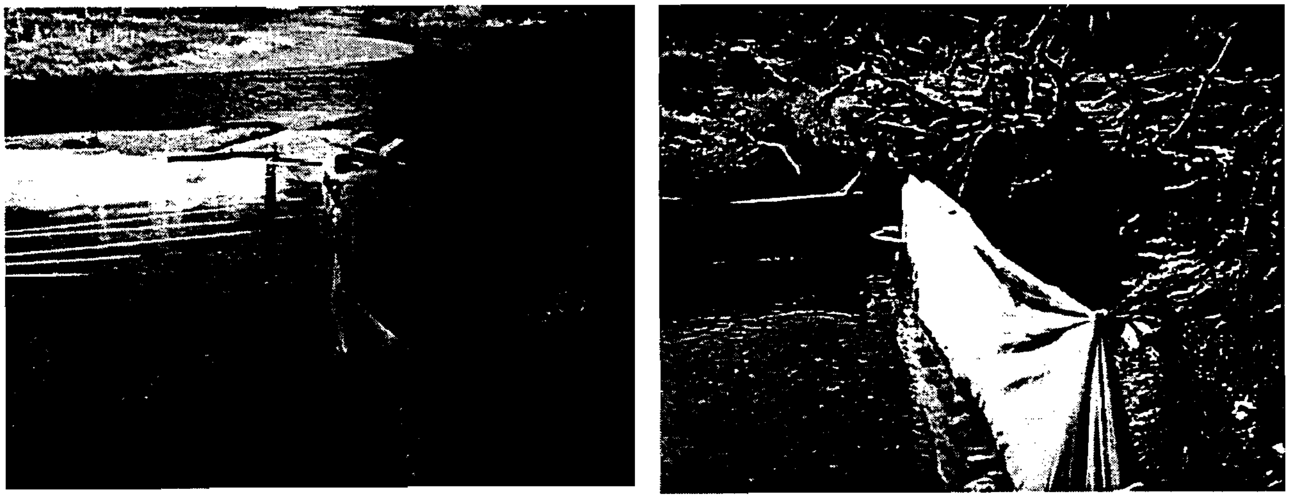


Figure 4. Picture of the fry trap used to capture pink and chum salmon fry that emigrated the primary (left) and the Secondary Tributary (right), Port Dick Creek, Alaska.

The area fished in the Primary Tributary is located at the higher high tide line, and at low tide, is 11.0 m wide and approximately 1.0 m deep (Figure 5). During the higher tides (> 10.5' as recorded in the Cordova, Alaska District Tide Table) the Primary Tributary is affected and the width increases to more than 20 m and the depth increases to 2.0 m. The fry trap was designed to float with the rise and fall of the water level. The fyke wing on the north side of the fry trap

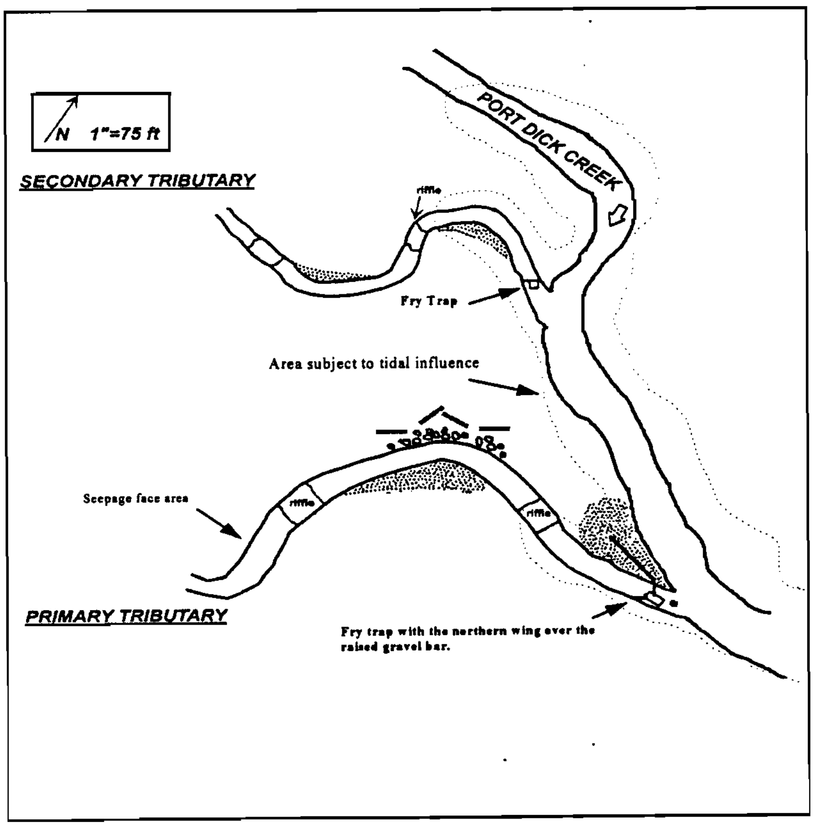


Figure 5. Diagram of the Primary and Secondary tributaries with the location of the fry traps and the area subject to tidal influence.

extended over a raised gravel bar that is adjacent to the tributary and is submerged during higher tides (Figure 5).

In the Secondary Tributary, the shallow water depth (< 0.5 m at the trap site), the slower water current, and the lesser tidal affect allowed a much simpler trap system to be used. A screened box with the opening upstream was positioned in mid-stream. A nylon curtain (6.4 mm mesh) was attached to opposite sides of the box and extended to the north and south banks of the tributary and fished 100% of the width (Figures 4 and 5). The box was checked several times per day and trapped fry were identified to species, enumerated, and recorded in the fyke net log.

All fry that entered the traps were enumerated. When the numbers of fry were manageable (e.g. < 4,000), they were identified to species, counted with hand held tally counters, and recorded in the fyke net log. When numbers of emigrating fry were too great to be counted by hand (e.g. > 4,000), a subsampling and bio-massing procedure was used. Then, all fry entering the trap were weighed to the nearest 0.1 kg using a hanging scale. Twenty fish per day were subsampled to determine average weight (to the nearest 1.0 g in a tared container using an Ohaus CT 600 portable electronic scale) length, and species composition. To maintain accurate species composition during peak emigration, several hundred additional fish were counted throughout the 24 hour period. To calculate the total number of fish for a given 24 hour period, the total weight of the catch was proportioned by the ratio of pink to chum fry and divided by the average weight of each specie. Egg to fry survival was then calculated as the number of fry trapped divided by the potential fecundity.

Physical Parameter Evaluation

Four types of sensors were installed following excavation of the tributaries in June, 1996: water temperature, level, velocity and conductivity. Figure 6 shows the general measurement locations and field arrangement of the equipment. Project methods are to continue to measure spawning channel bed-load sediment transport that will address the long term stability of the spawning habitat created through the restoration project.

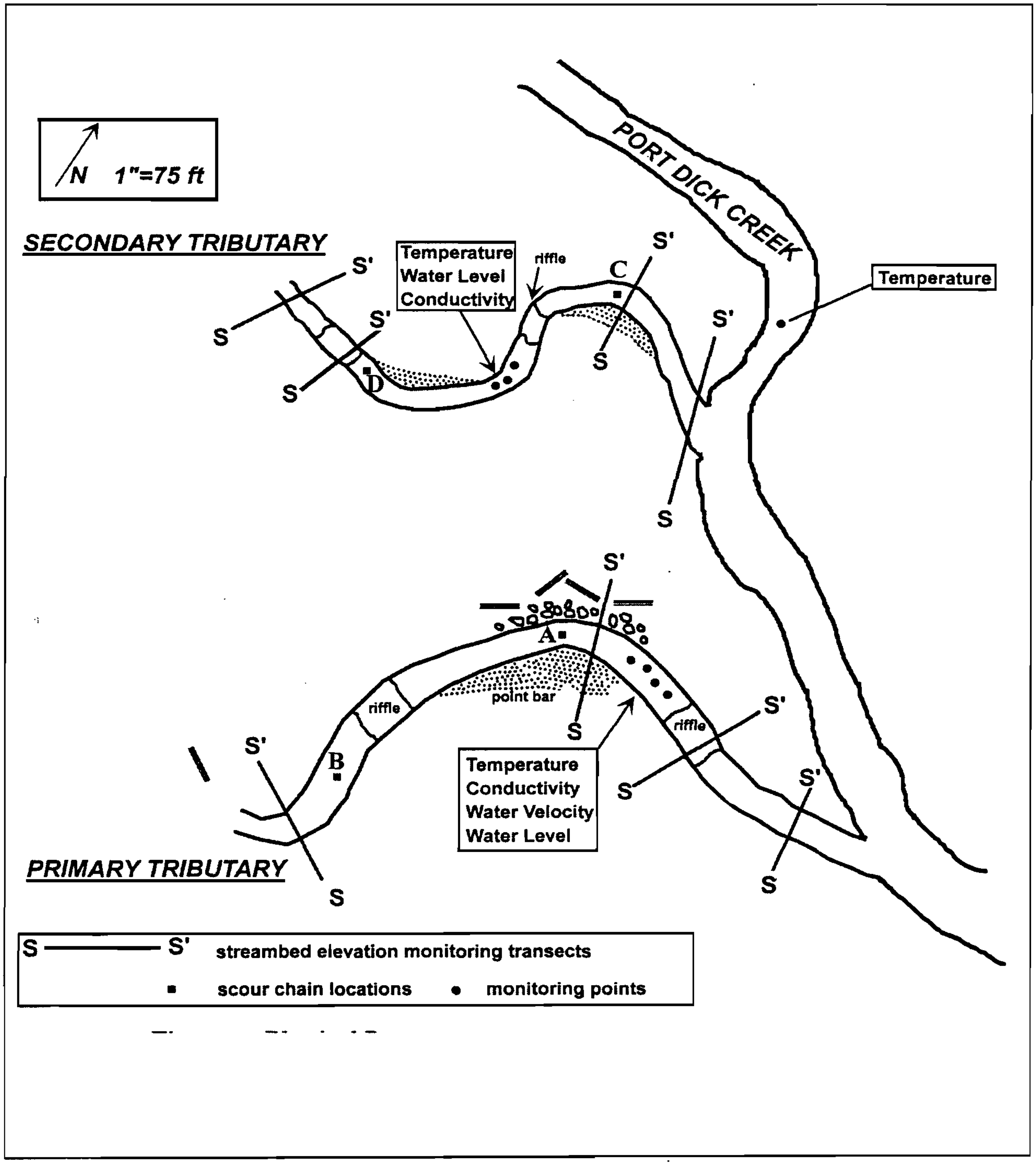


Figure 6. Physical parameter monitoring locations at the Primary and Secondary Tributary, Port Dick Creek.

The changing channel geometry after construction and sensitivity of salmon eggs to stream stage necessitated monitoring of water levels after the spawning channel was constructed. Stream stage is also used to determine the timing of flood events for interpreting the sediment transport data. Stream stage is measured using water level pressure transducers with a precision of 0.01 ft of water within the pressure range expected at the site. The transducers measure pressure relative to atmospheric pressure in standpipes mounted into the streambank and connected to the streambed (one for each tributary).

Surface water temperature is measured to an accuracy < 0.4 C at least every hour, in both tributaries. In 1997 identical thermistors were added within the spawning gravel as well to better determine temperature effects directly on salmon eggs during incubation.

When comparing results of the present study to previous studies it is useful to have similar accuracy. Temperature effects on salmon cited in the literature (e.g. Pauley, 1988; Wangaard, 1983) correlate egg to fry survival rates to temperature using similar accuracy. The temperature probes are secured within the top 10 cm of substrate to facilitate comparisons of temperature to egg to fry survival rates and to protect the sensors. An additional temperature monitoring point in Port Dick Creek is used to provide a comparison to the known chum and wild pink salmon runs in that reach as shown in Figure 6.

Water velocity measurements are taken to estimate discharge in both tributaries, as well as estimate the near-bed water velocity for sediment transport purposes. The water velocity measurement station is now intended for use in obtaining near-bed water velocities in flooding conditions.

The effects of tides on the tributaries are partly gauged by one conductivity sensor in each of the tributaries. Since sea water has a conductivity of approximately 40 to 50 msiemens, which requires an electrode spacing much greater than conductivity sensors for fresh water. The conductivity meter used is calibrated from fresh water to full strength sea water, however the electrode spacing is designed for discerning salinity changes in the spawning channel. Both conductivity sensors are temperature compensated.

The physical parameter data is collected using datalogging equipment which easily retains measurements every hour for 2 months. A solar panel was added in 1997 to increase the battery life due to additional sensors and a projected more intensive monitoring schedule in FY98. That is, several rapid sampling intervals will be monitored in FY98 to obtain more information on tidal and flood events, which will help augment the data collected for more detailed sediment transport analyses.

Streambed Stability

Stream stability is affected by channel morphology and channel material (Myers et al., 1992), both factors of which were changed during spawning channel excavation. Four methods typically used in detailed sediment transport studies of gravel-bedded streams are being used to monitor long term stream stability for this project. The methods include measurement and comparison of changes in surveyed stream transects, use of tracer cobbles and gravel, measurement of changes in scour chain positions and measurements of surface water energy slope.

The eight stream transects shown in Figure 6 are surveyed periodically for both streambed elevation change and water discharge measurements. The streambed elevations are made using a Total Station surveying instrument and prism rod. Each measured point is recorded in both position and elevation with a vertical precision of approximately 0.01 feet. The elevations of the cross sections are made in reference to seven surveyed monuments, all of which are referenced to bedrock. The transects are taken along a surveyors tape stretched above the streambed to aid in the surveying. The number of measurements for each cross section generally ranges from 20 to 40 measurements.

The elevation and position of each point along a cross section is compared to previous cross sections to determine a sediment budget and to monitor the spawning bed surface area.

Near-bed water velocity is a parameter that is periodically monitored using an on-line water velocity probe. The bed shear velocity, a parameter important in gravel-bedded stream sediment transport models, may be estimated using near bed velocity (Wilcock, 1996).

Bedload sampling has the advantage of directly sampling the rate of bedload transport along the streambed for a given measured discharge, however the Helley-Smith method is not easily implemented given the timing of flood events that coincide with inclement weather at this remote site. Sufficient discharge must be available for transport, particularly a problem for gravel transport which has longer residence times than finer sediment. Therefore a third water level monitoring station was added to help determine when gravel transport events would be occurring, and to monitor their duration. This station will be online in April, 1998, and will help in the implementation of bedload sampling 'traps' to replace the Helley-Smith method.

Finally, tracer gravel and cobbles are being used to determine rates of gravel transport, which is of particular concern for the post excavation phase of the spawning channels. Port Dick Creek Tributary gravel and cobbles were constructed into tracer material. Some of the gravel used is in the range useful for salmon spawning grounds. The cobbles and gravel were marked using holes drilled in the material and each filled with a unique numbered copper disc and epoxy (the tracers must be unobtrusive, yet easy to find). The shape of the tracer material was as rounded as possible in order to reduce shape-induced uncertainties in the course of their movement (Cavazza, 1981).

The weight and orthogonal axes of each tracer were measured. The tracers were then carefully replaced with other gravel into the streambed at different tracer strip source locations. In addition to the effects of any resulting bed armor disturbance on transport, it is also known that gravel sized bedload at a one location may not be entrained in the same flood event where bedload is entrained at an adjacent location.

Therefore it is typically important that a lot of tracers be used to lessen these effects. There are four tracer strip locations, and each tracer source area originally contained 170 tracers. The tracers are being relocated periodically with a metal detector to determine the amount of movement from the source area for the specific tracer material during periods of high discharge.

Significant movement of the tracers seem to occur only during significant flood events. Each tracer will be re-weighed periodically throughout the long-term monitoring, and re-deployed to the source area if found near the mouth of either tributary.

Use of scour chains is the final method for addressing streambed stability. Scour chains are an inexpensive method for determining the thickness of bed mobility (depth of scour and depth of fill) following high discharge events. The scour chains consist of vertically oriented and weighted stainless steel link chain (1 inch links). The chain locations are shown in Figure _, and were re-located in the field and unburied on 7/4/97. The length of horizontal chain and depth to the chain were recorded, and the chain was reoriented for measurements of the 1998 high discharge events. This allows the evaluation of scour (flood) events such as the depth of bedload scour and/or depth of subsequent sediment burial. Such maximum-event data helps determine the mobility of sediment during high discharge (Gordon et al., 1992).

Sediment Transport Analyses

The measured sediment transport parameters will then be used in surface water models to help answer questions concerning the long term streambed stability, the short term ability for the channel to maintain its water depth and to determine what changes in the channel geometry could be made to improve the streambed stability. In addition, comparison studies are being made with other gravel-bedded stream studies in the literature.

One parameter that is becoming better defined at the Port Dick site is the 'flushing flow' or critical discharge necessary for significant bedload transport in these gravel-bedded streams (e.g. Kondolf, 1996). Other basic parameters that are useful in surface water modeling and that can be derived from the onsite data are shear stress, sedimentologic characteristics, stream width, stream depth profile and variations in discharge.

Models that use these parameters for gravel-bedded streams are continually being refined, researched and published. For example, Bridge et al. (1992) recently published a basic sediment transport model for gravel-bedded streams that includes the critical discharge parameter, Hassan and Church proposed a model for gravel movement using tracer data (1991) and a model for the mixing of bedload downgradient from a source area (1994). Whiting and Dietrich (1993) and Dietrich and Whiting (1989) have worked with models that include meanders in gravel bedded rivers, an important component at this site. In addition there are valuable published data sets for comparison studies available for gravel bedded flow, for example from laboratory flume studies (e.g. Pizzuto, 1990).

A final subject that is of interest to the site is studying the influence of small and large drop structures and their effect on gravel sediment transport. These topics often appear in the context of bridge construction, since bridges frequently must be founded on erodible material. The scour of a gravel-bedded river is different at the location of a drop structure, so a variety of studies (e.g. Laursen et al., 1984) indicate the stable sediment size at sloping sills and erosion depth directly below drop structures.

Elements of more specific papers on drop structures will also be useful in deriving models that describe sediment transport at drop structures (e.g. Humpherys, 1986; Fiuzat, 1987; Christodoulou, 1985). A related topic is streambank stability analyses (e.g. Chang, 1990). These topics are useful to keep in mind should future channel changes be deemed necessary.

RESULTS

Project Evaluation,

Initial Spawning

Only 2,200 chum and 23,200 pink salmon returned to the Port Dick Creek system in 1996, well below or just achieving the minimum spawning escapement goal of 4,000 and 20,000 fish respectively ADF&G (1996). Initial colonization into the restored tributaries was volitional with an estimated 292 chums and 422 pinks colonizing the Primary Tributary, and 8 chums and 149 pink salmon colonizing the Secondary Tributary. Water levels within the tributaries were lower than anticipated due to unusually low precipitation in southcentral Alaska in 1996. As a result, access to spawning habitat above the first riffle (in both tributaries) was restricted. In an effort to distribute the spawners throughout more of the restored spawning habitat, approximately 50 chums were netted and lifted over the first riffle in the Primary Tributary, and approximately 100 pink salmon were lifted over the first riffle in the Secondary Tributary. In 1997, precipitation and stream levels were again low however, fish were able to access spawning habitat above the first riffle by utilizing the higher tides. The 1997 spawning escapement (estimated with 17.5 day stream life) was recorded at 324 chum and 146 pink salmon for the Primary Tributary and 65 chum and 44 pink salmon for the Secondary Tributary, a 10% increase for chum and 67% decrease for pink salmon.

Spawning in the Primary Tributary was concentrated between Port Dick Creek and the first riffle during 1996 (Figure 3). Spawning in the Secondary Tributary was concentrated above the first riffle by the spawners that were moved there by the field crew.

To calculate total potential egg deposition for each tributary, the number of females was assumed at 50% of the total estimated number of spawners, and the fecundity was determined to be 2,295 for chum salmon Lister et al. (1980) and 1,600 eggs for pink salmon ADF&G (1979) table 1.

Table 1. Summary of initial colonization and egg to fry success from the Primary and Secondary tributaries, Port Dick Creek, Alaska, 1996. The number of spawners (from which number of females is derived) is estimated with a conservative 17.5 day stream life. Inadequate ground survey data for chum salmon precluded spawner abundance estimates for the Secondary Tributary.

Tributary	# of Females	Fecundity	% Egg Retention	Total Potential Deposition	Emergence	% Survival
Primary						
Pink Salmon	211	1,600	5.1	320,382	146,936	43.5
Chum Salmon	141	2,295	5.1	307,092	131,519	42.8
Secondary						
Pink Salmon	75	1,600	5.1	119,200	34,405	30.2
Grand Total (both tribs)	427			767,000	312,860	40.8

Spawning densities (females/m^2) were calculated for each tributary and expressed in relation to area actually available for spawning. In the Primary Tributary, the upper 30 m is developed into a seepage face (an area where instream structures are incorporated to diffuse flood energy and prevent streambed movement, Figure 5). As a result, approximately 300 m^2 is not available for spawning. In the Secondary Tributary, the entire 150 m length (or 800 m^2) are available for spawning resulting in a combined total spawning area of 2,000 m^2. Spawning densities are expressed collectively (pink and chum salmon) with the Primary Tributary density calculated at 0.4 females/m^2 and the Secondary at <0.1 female/m^2.

Spawning success, Primary Tributary

A 2-person crew set up camp and installed the fry traps on 3 April, 1997, at both tributaries and enumeration began on 6 April. Operation of the fry trap in the Primary Tributary proved difficult at times due to high water events. High water with debris would obstruct the meshed fyke wings, increasing water flow through the trap, jeopardizing the fry and the trap and/or forcing the fyke wings to collapse. Still, we were successful fishing the primary fry trap 56 out of 63 days. The trap was removed from the water during periods of high water on 25 April through 29 April and 11 May through 13 May. The higher spring tides and/or high water events (freshets) partially submerged the fyke wings on 6, 10, 22 and 23 May (Figure 6). Daily migrant fry numbers were interpolated when the fyke net was not fishing for 24 hours or more. There was no attempt to estimate the numbers of fry that may not have been enumerated when the fyke wings were only partially submerged.

The first notable output of chum fry occurred on 24 April, with an accompanying high tide of 13.2' and concurrent increased stream flow. The highest daily output was recorded on 21 May at 7,559 fry with a 12.9' tide (Figure 6). The first conspicuous output of pink fry occurred 11 days later on 5 May, associated with temperature spikes from tides greater than 10.5' with the peak daily output occurring on 16 May at 7,903 fry (Figure 7). The later initial output of pink fry, relative to chum fry emergence, would correlate with later spawning by adult pink salmon and subsequent egg and embryo development.

The emigration pattern developed as expected for pink and chum salmon in southcentral Alaska with respect to the accumulation of temperature units (TU) and the seasonal trend of increasing stream temperatures. T.U.'s are defined as a degree(s) of heat above 0° C. Salmon egg and embryo development is dependent on a minimum accumulation of T.U.'s and emergence usually occurs between 850 - 950 T.U.'s Carlander (1969).

An estimated 146,936 pink and 131,519 chum fry (278,455 total) were enumerated through the Primary Tributary fry trap for the emigration period ending on 8 June (Table 1). The fry trap system in the Primary Tributary was placed downstream far as possible without the stronger current of Port Dick Creek interfering. However, this left an estimated 132 m^2 of spawning habitat downstream of the fyke net (Figures 3 and 4). Spawning activity was noted within this area by the field staff. Given a production of 346 fry/m^2, as measured for the Primary Tributary, an additional 45,672 additional pink and chum fry may have emerged uncounted downstream of the fry trap.

Egg to fry survival rates of 42.8% for chum and 45.9% for pink salmon (Primary Tributary) were calculated using a conservative stream life value of 17.5 days Helle et al. (1964). Although ADF&G management biologists have used this stream life value since at least 1969 to estimate pink and chum spawner abundance, recent work has shown this value to be highly variable. We examine the variability of survivals further in the discussion.

Length at emergence was determined from 218 chum and 196 pink fry captured from the Primary Tributary. Mean lengths were measured at 39.5 mm for chum and 33.7 mm for pink fry.

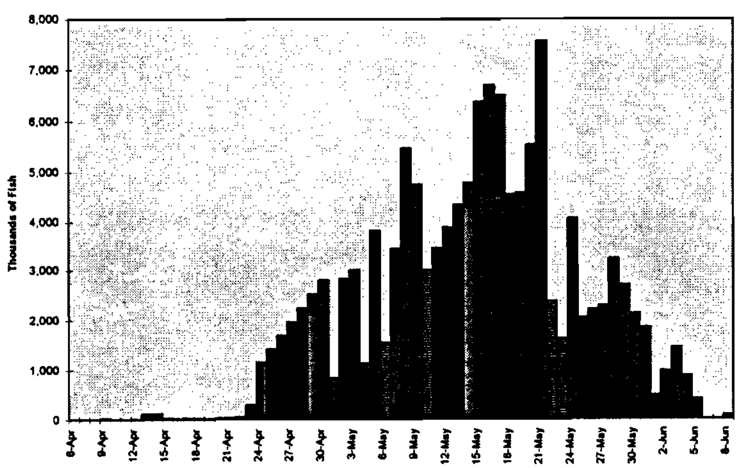


Figure 6. Results of the chum salmon fry emergence from the Primary Tributary at Port Dick Creek, Alaska. The dark bars are periods when the fry trap was not fishing and numbers interpolated; striped bars are periods when the wings were partially submerged and partial counts obtained.

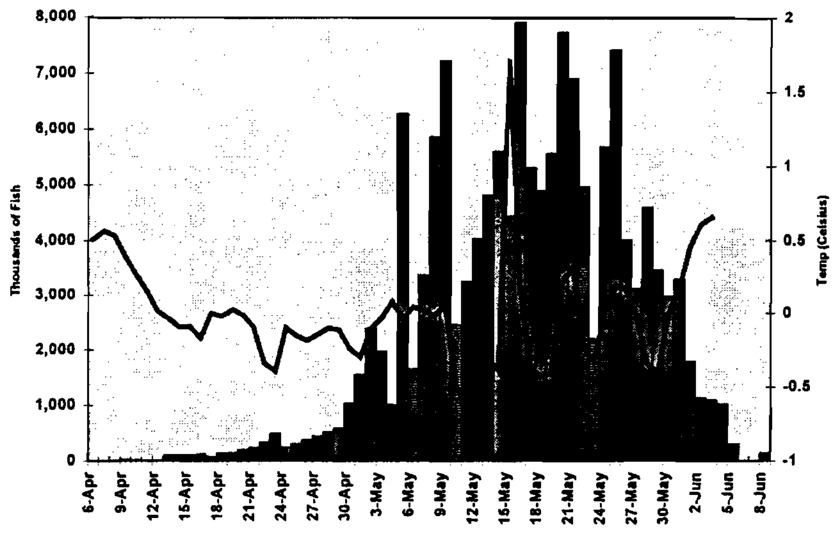


Figure 7. Results of pink salmon fry emigration from the Primary Tributary, Port Dick Creek, Alaska. Dark bars are periods when the fyke net was not fishing and numbers interpolated; striped bars are periods when the fyke wings were partially submerged. The line graph represents increases in water temperature (spikes from the seasonal trend) produced by tides 10.5' or greater.

Spawning Success, Secondary Tributary

The fry trap in the Secondary Tributary was used continuously throughout fry emigration, except for 10 May (1997), when it was removed to repair flood damage. A total of 34,405 pink and 12,029 chum fry (46,356 total) were counted from 6 April to 8 June, resulting in an egg to fry survival of 30.2 % for pink salmon (Figure 8). Survival rates for chum salmon were not calculated due to inadequate spawner abundance survey data .

The emigration pattern developed comparable to the Primary Tributary with respect to the seasonal temperature trend and peak fry output. Fry production (pink and chum is very low at 58 fry/m^2, undoubtedly a result of the extremely low spawner density of <0.1 female/m^2. Observations by the field crew in August 1996, reveal that adult salmon were reluctant to move across a shallow sill and into the tributary. The shallow water is presumed to be the result of low precipitation during the salmon return in 1996

Length at emergence is similar to that of the Primary Tributary at 38.9 mm for chum and 34.2 mm for pink fry.

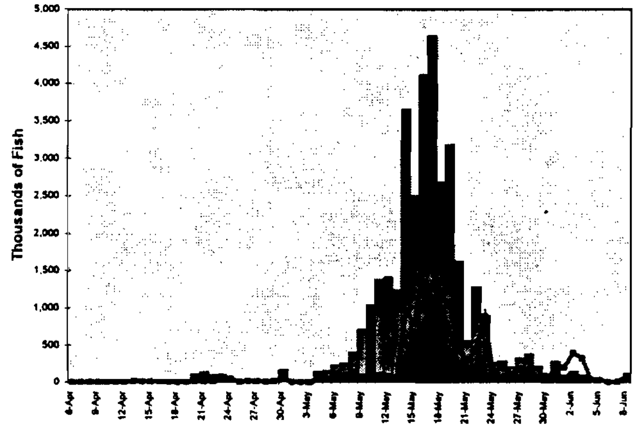


Figure 8. Results of fry emergence from the Secondary Tributary. The bars represent pink fry and the line graph represents chum fry. The dark bar represents interpolated data.

Stream Stability Evaluation

In evaluating the stream stability data it is important to keep in mind that most of the stream stability data have constraints as to when the data can be collected in the field. For example, there is only a limited amount of time in the summer each year when the tracers can be recovered between spawning activity and the presence of developing salmon eggs. Figure 9 shows the tracer movement in the Primary Tributary detected up to 7/5/97. The movement of tracer gravel was along the deepest part of each tributary (the thalweg) as would be expected, despite the tracer locations within the source areas. Figure 9 shows that there is significant gravel transport above the site compared to the mouth of the Primary Tributary. Figure 9 also shows a rough trend in downstream fining of the tracers as might be expected.

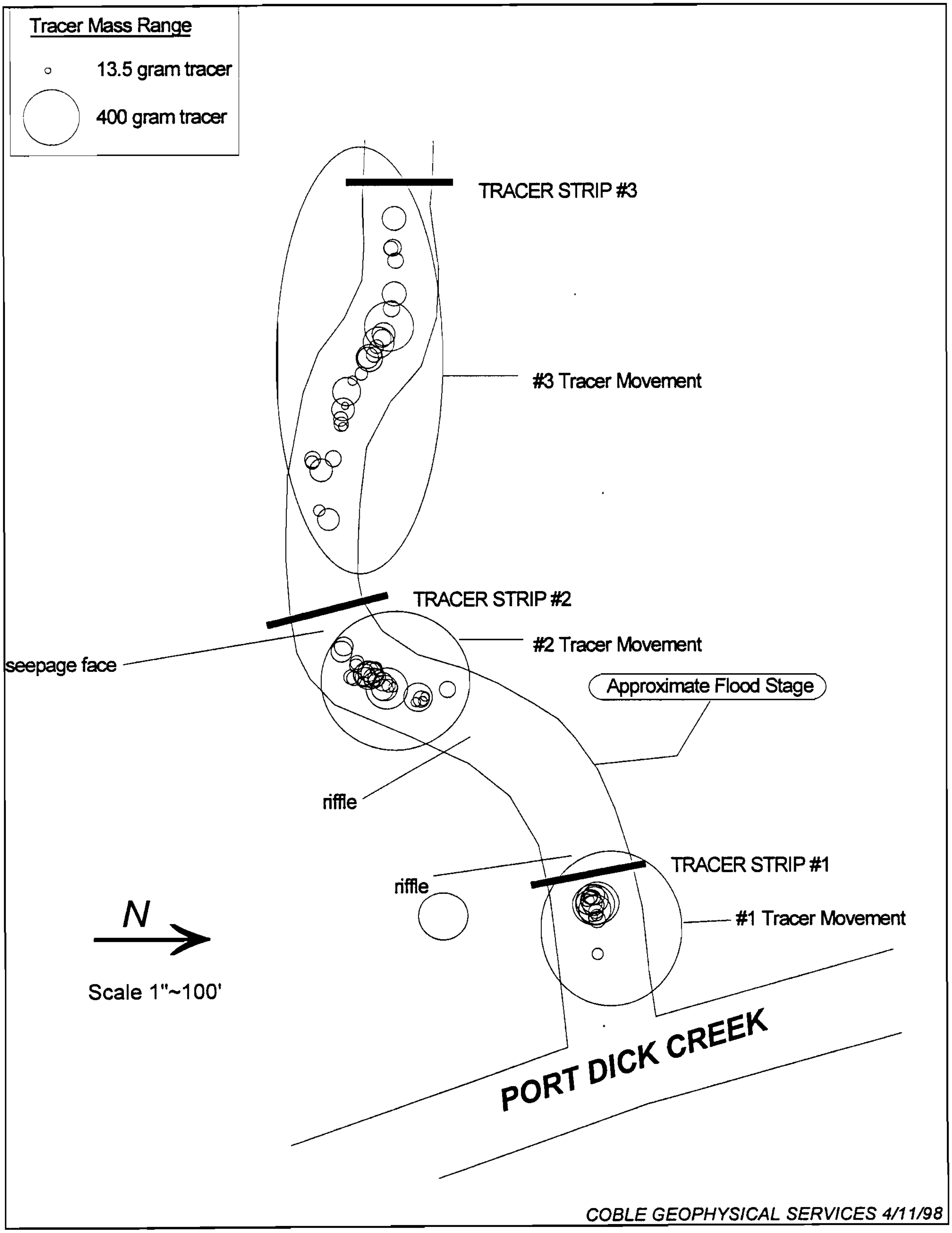


Figure 9. Tracer Gravel Movement in the Primary Tributary up to 7/27/97.

The tracers from source area #3 clearly moved further than tracers from the other source areas which may indicate a greater overall upgradient sediment transport rate, though it is important to be cautious when interpreting tracer results for the reasons mentioned previously. The tracer movement probably occurs only during the peaks of selected flood events in this watershed, one of which is shown in Figure 10.

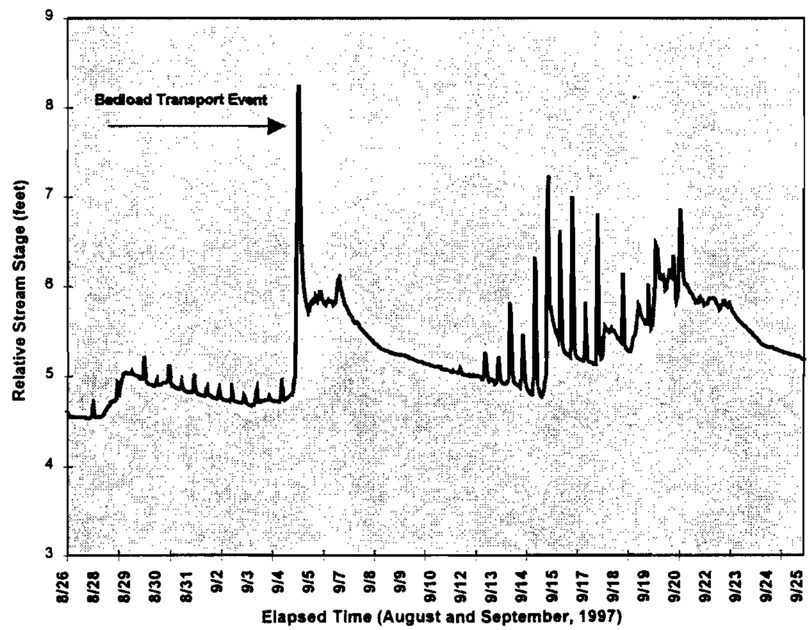


Figure 10. Graph showing probable bedload transport events and stream stage.

It is important to evaluate the energy slope of such floods when interpreting the tracer gravel data, so an additional water monitoring station was recently added to the Primary Tributary to enable this analysis. The Secondary channel tracers also moved later in 1997, at a maximum distance of 15 meters.

The movement of bed load is complex, intermittent and yet very important to understanding of the stability problems this project poses. The different sized gravel is being used for comparisons to size-selective tracer studies such as Ashworth et al. (1989). Bridge et al. (1992) show why tracer densities and tracer dimensions are important for studying the results of tracer transport, so the lengths of the orthogonal gravel axes were measured for completeness, which could turn out to be a useful parameter in the long term. Hassan et al. (1991) have also had success using tracer gravel in gravel-bedded streams to calculate gravel transport rates which will be useful in the discussion of construction techniques for future spawning channel projects in gravel-bedded streams.

Measuring the variation of parameters across a section of a stream channels can also be a very useful way to monitor streambed stability. Numerous studies have used this technique successfully, e.g. Jacobsen, 1995 in AGU Monograph 89. Dietrich and Whiting (1989) concluded in their work with gravel-bedded rivers that monitored stream cross sections were very useful for the study of gravel transport.

The streambed elevation changes from the surveyed cross sections are continually changing, although generally within a few centimeters of their post-excavation levels. There have been some exceptions as recently discussed by Coble et al., 1998, however these data are preliminary and may primarily be due to localized bank erosion. Such deposition is of interest to the project, even if it is localized, since it forms part of the bedload sediment transport. The surveyed cross sections help monitor the 'sediment waves' as they migrate through the system. The monitored cross sections are primarily useful for the long term objectives of this project.

The scour chains were relocated and unburied on 7/4/97 using both the total station and a submersed metal detector. The scour chain positions are shown in Figure 6. The Primary Tributary scour chain 'B' as shown in Figure 6 showed no indication of scour or deposition as of 7/4/97. This scour chain would be mostly affected by any movement in the boulder and log riffles of the seepage face area. Scour chain 'A' was found oriented downstream and covered by a lobe of sediment approximately 23 cm. in depth. It is suspected that this sediment also came primarily from localized bank slough, however in this case there was also a significant amount of scouring as the scour chain was found oriented downstream. The re-buried chain 'A' will be evaluated again in July, 1998 to help determine the sediment budget in that reach of the Primary Tributary.

Both scour chains 'C' and 'D' in the Secondary channel showed no signs of re-alignment as of 7/4/97, however both were covered with a small amount of bedload sediment. The scour chain at the head of the Secondary Tributary was covered with less than 3 cm of fine sediment and leaf litter, while the scour chain closer to the mouth of the Secondary Tributary was covered with approximately 10 cm. of gravel bedload. The burial near the mouth was probably due to local stream bank erosion and bank sloughing. The fall floods in 1997 following these data seem to have carried significant bedload, however, so some changes in the scour chain data will be of interest when the biologists allow their exposing again in July, 1998.

Discussion

This is the first reporting period for which salmon production (emergent fry) are reported from the recently restored spawning habitat. The two primary objectives of this project are to determine salmon production using egg to fry survival and fry production, as well as to determine the long term spawning channel stability. Both objectives require relatively long term data sets. From the biologic perspective, a complete life cycle of chum salmon is 3-4 years, a minimum period for determining salmon production from the tributaries. A relatively long data set is also required from the standpoint of gravel transport in gravel-bedded stream systems. The data in this report has been discussed with these considerations in mind.

Project Evaluation Through Spawning Success

Evaluation of spawning success is limited to overall survivability and is compared to similar natural, surface-fed gravel-bedded streams that the tributaries were engineered and restored to mimic. In-depth research into individual variables that can effect egg to fry survivability, such as gravel size, intra-gravel water flow, oxygen levels and water temperature is outside the extent of this project. Therefore, evaluation of spawning success is intended to illustrate that the results achieved at Port Dick Creek fall within the parameters expected in natural salmon streams or similar instream spawning habitat projects.

Colonization

In 1996 the first year spawning occurred, an estimated 572 pink and 292 chum salmon colonized and spawned in the tributaries. Spawner density (pink and chum) at the Primary Tributary was recorded at 0.4 females/m^2 with a production of 346 fry/m^2, and <0.1 female/m^2 at the Secondary Tributary with a production of 58 fry/m^2. Results published in the literature suggest that optimal spawning density is not yet realized at Port Dick. McNeil (1969) found optimal fry production for pink and chum salmon at 500 fry/m^2 with spawning densities of approximately 1.0 female/m^2 at Sashin Creek in southeast Alaska. Adult returns to the Port Dick Creek system have been declining since the early 1980's and may be contributing to the less than optimal spawning densities. Minimum spawning escapements have been achieved only twice for chum salmon since 1988 and reached an all time low of 1,926 fish in 1997 ADF&G (1997). The minimum spawning escapement goal for pink salmon has been met five of the last ten years ADF&G (1997).

Estimated chum salmon spawner abundance (both tributaries) increased 10% in 1997, while pink salmon abundance declined 65%; from 572 in 1996 to 190 fish in 1997, although pink salmon escapement abundance within the Port Dick Creek system increased slightly ADF&G (1997). Two conditions exist in 1997 that may have contributed to a decrease in estimated spawner abundance, particularly in the Secondary Tributary. First, precipitation levels in southcentral Alaska were lower than normal for the second consecutive year creating a shallow water riffle area at the entrance to the Secondary Tributary. Observations by the ground survey crew during the pink salmon return indicates that fish were reluctant to move across a shallow riffle area at the entrance to the Secondary Tributary. Perhaps a more significant factor estimating the spawner abundance in 1997 is that only two ground surveys were conducted during the pink salmon return and did not include counts on or near the recorded traditional peak for the pink salmon return at Port Dick Creek. This could lead to an inability of the area-under-the-curve method to capture the spawner abundance curve according to Hill (1997).

We believe that to achieve optimal spawning densities within the tributaries, increased spawner abundance will depend on production that the added spawning habitat produces; particularly if our original hypothesis (FY96 Detailed Project Description, *EVOS* T.C.) is correct in assuming that spawning habitat within the main stem of Pot Dick Creek has been taken out of production because of flooding and freeze-out events. In addition, lower than normal precipitation levels throughout southcentral Alaska for the first two years after tributary restoration (1996 and 1997), has affected water levels and limited access to the Secondary Tributary and restricted spawning habitat above the first riffle in both tributaries. It is anticipated that with increased water levels access will improve and spawning abundance will increase.

Increased adult chum salmon production is expected in 2000 when the first age 0.3-fish (the dominate age class) return from the 1997 fry emigration. For pink salmon, 1998 will be the first year that increased production may occur as a result of the restoration project.

Fry Output Patterns

Daily and seasonal timing of fry output occurred within parameters expected for pink and chum salmon in southcentral Alaska. Divergence (output spikes) from the seasonal emigration trend is shown to be associated with water temperature spikes (associated with tides > 10.5' or greater), increased turbidity, and stream flows.

Water temperature spikes associated with tidal intrusions of 10.5' or higher in the Primary Tributary is suspected of increasing daily fry output (Figure 7). This output pattern fits with work completed by Coburn and McCart (1967). They could manipulate fry output from incubator trays by increasing or decreasing water temperatures; few fry left when temperatures were low, and large numbers left when the temperature was increased. Long term work by ADF&G staff at a pink and chum salmon hatchery near Homer, Alaska, have shown that fry output from incubator trays is influenced by increased water temperatures from the saltwater intrusion. There, the high tides would infiltrate instream intake-pipes and raise water temperatures in the hatchery by 4.0^{0}C-9.0^{0}C, elevating fry output (Dave Waite, personal communications.) . Increased turbidity associated with increased water velocity caused by rain or snow melt, is also shown to correlate with increased daily fry output. Further work by Coburn and McCart (1967), has shown that increased turbidity associated with increasing stream flows at Kleanza Creek, British Columbia, caused large numbers of pink salmon fry to leave even when water temperatures were falling.

Length at emergence was determined from 218 chum and 196 pink fry captured from the Primary Tributary. Mean lengths were found at 39.5 mm for chum and 33.7 mm for pink fry. These lengths fall within the size expected for pink and chum fry within their Pacific range (Groot & Margolis, 1991).

Egg to Fry Survival

To calculate egg to fry survival, the value of three pre-spawning variables (i.e. stream life, degree of egg retention, and variations in fecundity) were needed in order to generate estimates of spawner abundance. Since those values were not known nor were they measured, we used values published in the literature.

To estimate spawner abundance, periodic ground (foot) survey data was converted into spawner abundance estimates using a FORTRAN program that took into account stream life (number of days), time between surveys, live and dead count, and number of surveys (Yuen, 1993).

Estimates of the length of stream life vary between regions and systems as well as being influenced by water temperature according to Perrin et al. (1990). Based on considerable work with pink and chum stocks in Prince William Sound, Helle et al. (1964) derived a conservative stream life of 17.5 days for pink and chum salmon. The Lower Cook Inlet CFM&D staff has used this value to estimate pink and chum salmon spawner abundance for at least 28 years and we chose this Figure to include in the estimation of spawner abundance for this project ADF&G (1969).

Fecundity is the second variable for estimating egg to fry survival. Estimates vary considerably between regions and systems and even size of fish. Fecundities for pink salmon range from 1,223 to 2,038 eggs per female and 2,200 to 3,450 eggs for aged-0.3 chum, the dominate age class of Port Dick Chums as discussed in Groot and Margolis (1991). Further work by Lister et al. (1980) supports a conservative fecundity of 2,295 eggs per female for chums of similar size. We chose conservative fecundities of 1,600 eggs for pink salmon (supported by fecundities measured at a nearby pink salmon hatchery facility at Tutka Bay) and 2,295 eggs for chum salmon.

Egg retention is the third variable estimating egg to fry survival. Again, actual egg retention was not measured at Port Dick Creek and is beyond the scope of this project. However, we chose to use a conservative egg retention factor of 5.1% to estimate pink salmon survivals. Egg retention rates of 2.7% - 5.1% were found for pink salmon on Olsen Creek in Prince William Sound Helle et al. (1964). Higher retention rates of up to 41.5% were found; however, they were associated with overcrowding and competition for redd areas and were not considered for this evaluation.

Overall egg to fry survivals (calculated using a 17.5 day stream life, 5.1% egg retention and fecundities of 2,295 and 1,600 for chum and pink respectively) were calculated at 38.8%. To compare, Lister et al. (1980) calculated a 16.3% egg to fry survival from seven groundwater-fed spawning channel systems in southern British Columbia which is twice the survival calculated for natural streams. For further comparison, Heard, W. R. (1978) found that survivals for pink salmon in natural streams ranged from 0.2% to 22.8% while Lister et al. (1980) found that the egg to fry survival for chum salmon in natural streams ranged from 1.3% to 16.9%.

Because the accuracy of the value of the three pre-spawning variables (i.e. stream life, degree of egg retention, and variations in fecundity) is highly variable, survivals were also calculated using liberal values (e.g. 8.5 day stream life, 2.7 % egg retention and fecundities of 2,038 and 3,450 for pink and chum salmon respectively). Overall survival would then calculate to 11.8 %. Table 3 includes the conservative and liberal survival estimates based on the above variables and does not include environmental variables that could affect survivals.

Table 2. Table of egg to fry survivals generated from conservative (17.5 day) stream life Helle (1964) and liberal (8.5 day) stream life Perrin et al. (1990); fecundity (Groot and Margolis 1991; and Lister et al. 1980) and egg retention Helle et al. (1964). The number of females was assumed at 50% of the estimated escapement which was generated with high and low stream life. Survival estimates for chum salmon from the Secondary Tributary were omitted due to inadequate adult spawner survey data.

Primary Trib.	**# of Females**		**Fecundity**	**% Egg Retention**	**Total Potential Deposition**	**Emergence**	**% Survival**
Pink Salmon	low	211	1,600	5.1	320,382	146,936	45.9
	high	595	2,038	2.7	1,179869	146,936	12.5
Chum Salmon	low	141	2,295	5.1	307,091	131,519	42.8
	high	291	3,450	2.7	976,843	131,519	13.5
Secondary Trib.							
Pink Salmon	low	75	1,600	5.1	113,880	34,405	30.2
	high	187	2.038	2.7	370,816	34,405	9.3
Mean Egg to Fry Survival (17.5 day stream life)							39.6
Mean Egg to Fry Survival (8.5 day stream life)							11.8

Another measure of project success through fishery survival is fry production. Fry produced per unit area, rather than egg to fry survival, may be a more suitable method to measure project success and longevity because of complicating factors influencing variability in estimating egg to fry survival (Bonnel, 1991). These factors include uncertainty in spawner counts, degree of egg retention, variations in fecundity, predation and problems associated with fry trapping. The fry production for pink and chum salmon from both tributaries is calculated to be approximately 350 fry/m^2. This compares with observations by McNeil (1969), on Sashin Creek, a stable surface-fed stream in southeast Alaska. There after 25 years of observations, optimal fry production was found at 500 fry/m2 at 1.0 female per m^2. We calculated spawner density at 0.4 females/m^2 (Primary Tributary) and <0.1 female per/m^2 for the Secondary or a combined total of 0.25 females/m^2. At Sashin Creek, fry production declined to approximately 100 fry/m^2 when densities increased to 2.2 females/m^2.

Physical Factors Affecting Survivability

Several physical factors can affect development and/or emergence (survival) of pink and chum salmon fry including, but not limited to temperature, stream flow, turbidity, and salinity. Physical differences exist between the tributaries which may have produced or contributed to differences in survivals. Survivals were slightly higher for pink salmon, 43.5%, in the Primary Tributary, versus 42.8% for chum salmon (calculated with a 17.5 day stream life). In the Secondary Tributary, survivals were estimated at 30.2 % for pink salmon. Survivals were not calculated for chum salmon due to due inadequate adult spawner survey data.

The first and most obvious difference is the source water which in the Secondary Tributary is groundwater fed consequently, water in that tributary is shallower and velocity slower. Water velocity in the Primary Tributary is frequently twice that of the Secondary Tributary. For example, on 29 September, 1997, the water velocity in the Primary Tributary measured 0.34 m/s versus 0.16 m/s in the Secondary Tributary. Water velocity was measured at mid channel in both tributaries. Groot and Margolis (1991) have shown that chum salmon prefer between 0.2 and 0.8 m/s for spawning (80%), although spawning has been observed in water velocities between 0 and 1.67 m/s. The preferred spawning velocities for pink salmon range from 0.30 to 1.4 m/s, with an average water velocity over the redds of 0.70 m/s (Groot and Margolis, 1991). Pink salmon prefer more intragravel oxygen than Chum salmon, which is consistent with a higher velocity preference, whereas Chum salmon prefer spawning grounds with upwelling water, i.e. gaining streams.

Water temperatures in the Secondary Tributary fell to below freezing at the streambed level on 30 December through 15 February (1997), likely the result of the slower, shallower water. Although temperature thermistors were not installed at egg burial depth, redd freeze-out may have occurred and affected survivals. By contrast, in the Primary Tributary temperatures at the streambed level fell to 0^{0} C only once at the monitored location.

Another factor that may have lowered survival rates in the Secondary Tributary is the presence of silt that was disturbed during excavation in June 1996. It was expected that due to the slower current additional time would be required for channel flow to remove silt disturbed by excavation. The higher average water velocity in the Primary Tributary and high water events (freshets) cleansed the tributary of fines after excavation, whereas the Secondary Tributary will depend on infrequent high water events to clean the streambed of the fines. The literature is abundant with research documenting the effects of silt on salmonid egg and embryo development.

Physical Factors Affecting Streambed Stability

Sediment and bedload transport in gravel-bedded rivers has received far less attention in the published literature compared to stream channels of finer grained sediments, probably due in part to the long term data collection required to establish and verify models of such systems. The sediment transport objectives for this project range from determining the effect of high discharge events on the sediment transport and bed armor of natural gravel-bedded streams and rivers (e.g. Ikeda et al., 1990) to numerical modeling of long term spawning channel stability. Discerning the effects of altering a gravel-bedded stream channel on sediment transport and deposition is a side benefit of this study useful for future spawning habitat rehabilitation projects.

In addition to the long term data being collected already, the streambed stability aspect of the project has identified the need for more data directly pertaining to the onset of sediment transport. The sediment transport analysis will benefit from the addition of online measurements of surface water energy slope in the Primary Tributary as mentioned previously. This data will be calibrated to surface water slope measurements at other locations in the tributaries for a more comprehensive data set concerning surface water dynamics. In addition, more near-bed velocity measurements during peak flow events will be monitored. These data will be used to support the sediment transport modeling and stream stability analyses.

CONCLUSIONS

Enough data has been collected to date such that a relationship between egg to fry survival rates and the hydrologic and sedimentologic data is beginning to be made as shown in this report. The sediment transport data continues to be collected with some adjustments to the data collected as detailed in the report. As a result, this project has proceeded towards a workable data set for the sediment transport modeling and research priorities, such as determining an effective discharge for both tributaries and addressing long term streambed stability. Assuming optimal spawning densities of 1.0 female/m^2 and 1,605 m^2 of spawning habitat (Primary and Secondary tributaries) and a production of 500 fry/m^2, an estimated 802,500 pink and chum fry could be produced annually.

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