Juvenile Salmon Migration Mapping:

A Pilot Study in Roscoe Inlet

Prepared by:
Chris Williamson

GIS mapping by:
Carl Humchitt

RAINCOAST
CONSERVATION FOUNDATION

Background

While aspects of life history strategies of Pacific salmon have been studied intensively, most of the research has been stimulated by the desire to increase the commercial catch efficiency of returning adults, hence focusing on this stage in their life cycle. In fact, significant gaps in basic spatial and temporal distributions of juvenile salmon in the marine environment still remain A search of the peer-reviewed publications available on this topic reveals only a handful of studies have been conducted and most are limited to a small spatial scale. With continued declines coast wide in salmon stocks, detailed research on juvenile salmon will aid in conservation efforts by expanding our knowledge of salmon biology and specifically identifying habitats necessary for successful migration. This Raincoast study addresses factors that contribute to habitat use and selection as well as specific routes used by migrating juvenile salmon within Roscoe Inlet, British Columbia (BC).

On the coast of BC, the many inlets, islands and passages provide a diverse and complex selection of potential habitats for juvenile salmon. Once they leave their natal streams, the near-shore migration of juvenile salmon through these inlets and islands onwards to the open ocean environment is not only a critical time for feeding and rapid growth but can also be a stressful and vulnerable portion of their life cycle when mortality rates can exceed 65% (Parker 1965). Of the five salmon species on the coast of BC, pink and chum salmon are particularly at risk because they migrate to sea shortly after hatching and will weigh less than half of a gram and be under 3 cm in length. The other salmon species select to remain in fresh water up to several years and will enter the ocean at a much larger size, increasing their odds of survival at sea (Quinn 2005).

With increased development along coastal areas, there is great concern that increasing industrial activity is negatively impacting juvenile salmon during their outward migration. Of these impacts, salmon farming has recently drawn a great deal of attention and criticism because of the documented connection between salmon farms and elevated parasitic sea lice infections in juvenile salmon (Morton et al. 2004, Krkosek et al. 2005). In the Broughton Archipelago, BC, this infestation has been linked to the near complete collapse of several major pink salmon runs (Pers.Comm. Alexandra Morton). Additional impacts from industrial development in these near-shore environments, including logging and mining, further threaten these fish.

Studying the migration habits of salmon has long been one of the greatest challenges to scientists. The vastness of the ocean coupled with the great variation inherent in salmon behavior and the environment in which they live, has left many questions unanswered. Generally, there is a consensus that once juvenile salmon leave near-shore waters, they migrate north, parallel to the North American continent, towards the Alaskan panhandle, remaining within 40 km from shore (Hartt and Dell 1986; also see Figure 1). Yet little research has been done on the migratory habits of juvenile salmon in near-shore environments (Hartt and Dell 1986). In fact, only one published account of pink and chum salmon migration routes exists; and it only focuses on the Bella Coola River stock (Healey 1967).

Such basic information including use of specific bays and channels, residence time in certain habitat types, and environmental cues used to aid in the migration have yet to be answered. Providing answers to these questions is necessary for successful marine and land use planning processes since industrial activities alter these habitats and may interfere with successful migration. For example, in the Broughton Archipelago, where large scale salmon farming is practiced, a major hindrance in the conservation movement to get salmon farms relocated out of critical migration routes is the lack of scientific data documenting these migration routes. Fortunately the area where this study is conducted is free of salmon farms and will provide baseline data prior to any planned industrial activity that may be planned in the future.

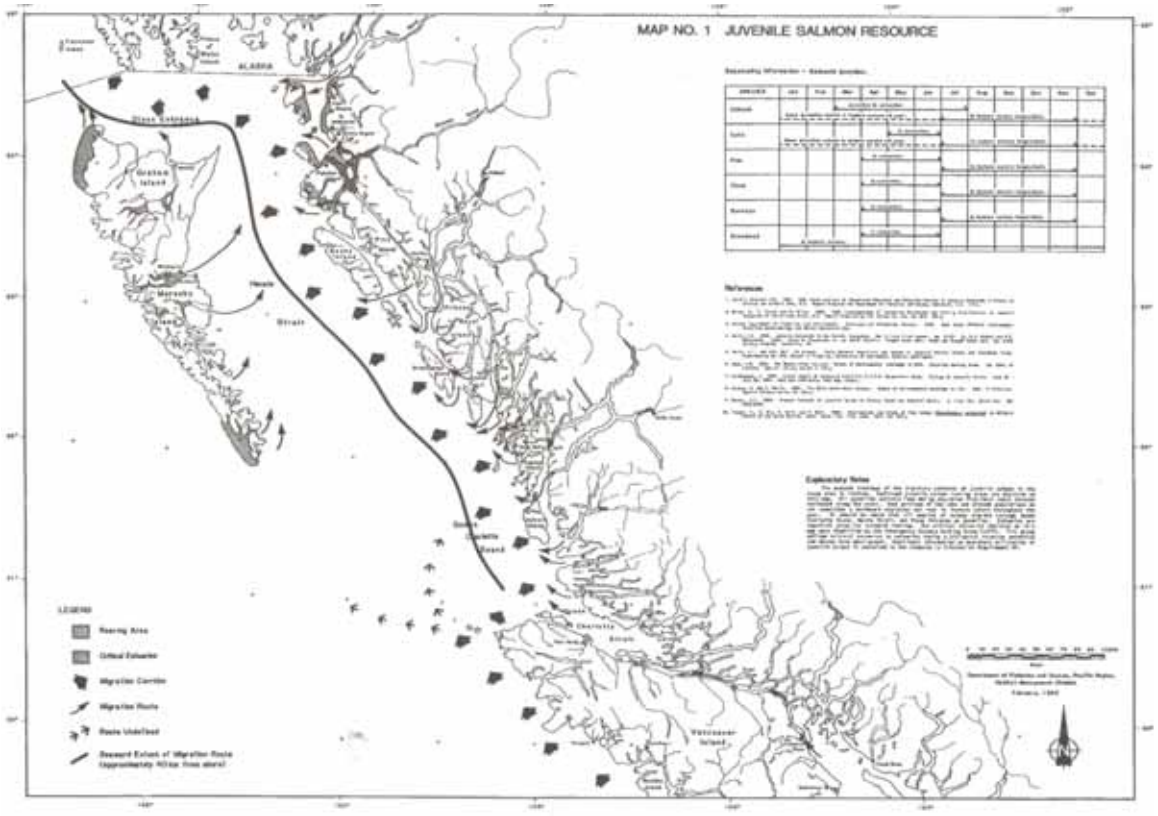


Figure 1. Large scale, coastal migration routes of juvenile salmon along British Columbia. Source: Department of Fisheries and Oceans

Project Outline

The purpose of this pilot study was to investigate whether it is feasible to undertake a large-scale juvenile salmon migration mapping project on the central coast. Objectives included determining movement patterns and distribution of juvenile salmon as well as physical and biological influences on migration. Some specific questions addressed in this study as outlined in the Smolt Migration Feasibility Study (Temple and Peet 2004) include:

- When are peak abundances for juvenile salmon in near-shore habitats and how does this vary among species:
- What factors can be used to predict juvenile movement?
- Are there differences in abundance and species composition between bays and channels?
- How long are different species spending in near-shore habitats?

Site Description

This study was conducted in Roscoe Inlet, on the central coast of British Columbia (Figure 2). Streams flowing into this inlet support pink, chum, coho, and sockeye salmon, as well as Dolly Varden and steelhead/rainbow trout (Jacobs 2001). Roscoe Inlet was specifically chosen because of the significant pink and chum runs as well as having equal representation of both, bays and channel sites for sampling. Of 15 streams in Roscoe Inlet, 10 are documented as fish bearing. In 2000, of these 10 fish bearing streams, 8 of them contained coho, 6 had chum, and 5 held pink salmon while 5 of the 10 streams had trout (Jacobs 2001). In the inlet there are 3 major salmon producing systems, Roscoe, Quartcha and Clatse Creek supporting primarily chum and pink salmon along with small populations of coho (Table 1). The inlet is characterized by protected bays representing a diversity of habitats from eelgrass and mud flats to steep rock drop-offs and deep water. Between these bays are deep channels generally void of any habitat features other than steep, rocky shoreline.

Salmon species	Roscoe Creek	Quartcha Creek	Clatse Creek
Coho	1,000	495	N/A
Pink	1,600	4,000	14,900
Chum	35,000	4,600	4,400

Table 1. 10 year average (1990-2000) of number of returning salmon to spawn (escapement) in each of the salmon producing creeks in Roscoe Inlet. Data collected from the BC Provincial FISS database, (http://srmapps.gov.bc.ca/apps/fidq/main.do)

Experimental design

Six sampling locations were chosen in 3 of each of the two habitat types: bay and channel. These locations were chosen because they are evenly spaced along the length of the inlet providing an adequate spatial sampling distribution. At each location, 3 sampling sites were randomly chosen. In the bay locations, each site was adjacent to the shore, while in the channel locations two of the sites were on opposing shores and the third site was located mid-channel (Figure 2). Sampling sites were marked on shore with flagging tape in addition to GPS marking of the location. Dr. Michael Healey (University of British Columbia) was consulted on the experimental design of the project and provided recommendations and suggestions regarding sampling procedure.

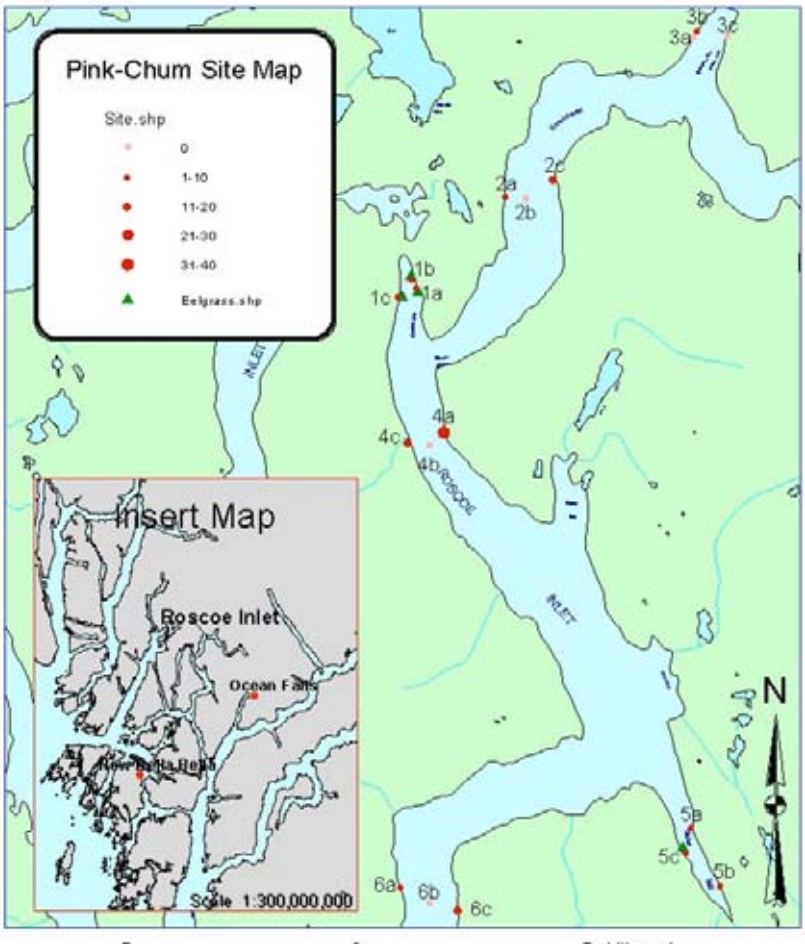


Figure 2. Sampling sites in Roscoe Inlet, central coast British Columbia. Sites 1,3 and 5 are “Bay” sites while 2,4 and 6 are “Channel” sites.

Fish were sampled at each location approximately once per week beginning April 8, 2005 and continuing until May 18, 2005. These dates roughly coincided with the beginning and the end of the migration by pink and chum salmon in Roscoe Inlet (personal observation). Using a 150 x 5 ft. (5 mm mesh size) beach seine, fish were captured at each site from the exact location every time without selecting specific schools of fish.

This technique was used in an effort to avoid bias towards artificially selecting schools. To deploy the seine net, an assistant on shore held one end while a boat with the other end attached, slowly created an arch away from the shore and then returned to shore approximately 30 meters away. The two ends of the net were then pulled together and 30 fish were randomly selected using a small dipnet for further analysis of length, weight, and species composition. Abundance and species composition of remaining fish were estimated then released

Measured Variables

In an effort to correlate habitat with fish abundance, abiotic variables (dissolved oxygen, salinity, temperature) were measured 1.0, 2.5, 5.0, 7.5, and 10 meters below the ocean surface. In addition, turbidity was measured at each site using a Secchi disc, to provide an indication of phyto and zooplankton densities in the water column. An effort was made to take zooplankton samples at each site, once per week, with three vertical tows from 10 meters depth combined to create one sample. Unfortunately, the samples were consistently filled with debris and zooplankton were rarely observed. Thus collections were stopped part way through the study.

Outcomes

The sampling design proved to be efficient and effective for collecting juvenile salmon and abiotic variables potentially influencing their migration. The research crew, comprised of 3 people, was able to sample 6 sites per day when the weather was cooperative. The goal of sampling each site weekly was met with a total of 7 collections made per site. Of the 12,494 fish captured during the study, approximately 86% were chum with the remaining 14% comprised mostly of pink and coho salmon, and herring. Occasionally other species were captured including greenling juveniles, Dolly Varden, and sand lance. The dominance of chum in our samples corresponds with the average proportion of spawners reported for the various systems. During our collections it was noted that pink and chum salmon migrate together in schools and rarely was a single species school observed.

The timing of the migration in Roscoe Inlet began at the beginning of April and ended near the middle of May. While there were likely small schools moving through both before and after this time, the majority of the migration was during this window. At the beginning of the study, fish were quite small (~3 cm) but doubled length by May 18th (Figure 3). Rapid growth is common in this early stage of life and generally results from feeding in productive estuaries and bays (Macdonald et al. 1987). This result also illustrates that fish are not necessarily moving quickly out of Roscoe Inlet but are instead feeding and growing within the protected inlet for extended periods of time. All captured fish were observed within 1 meter of the surface of the water; a behavior common in juvenile pink and chum salmon (personal observation).

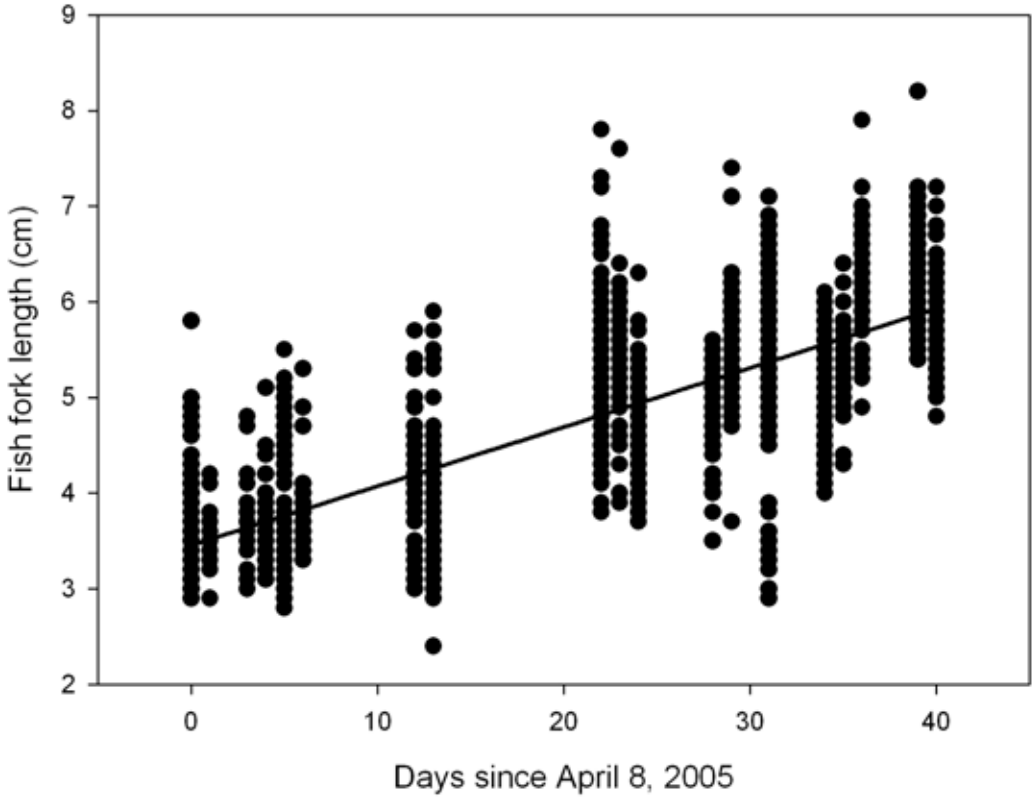


Figure 3. Pink and chum salmon fork length (cm) as a function of time in Roscoe Inlet

While we originally assumed that higher densities of fish would be found in the bays and estuaries, we instead found that fish densities were up to 30 times greater in the channel sites than in bays (Figure 4). While it may appear illogical for fish to be spending more time in the channels, where there is little food available and strong tidal currents to deal with, a contributing factor may be that trade-offs between the benefits of feeding and the need to avoid predators does not permit fish to spend much time in estuaries and bays (Quinn 2005). A significant number of juvenile coho were regularly caught in Quartcha Bay and occasionally in both Clatse and Boukind Bays. Juvenile coho are known to predate heavily on juvenile pink and chum salmon (Parker 1968, Hargreaves and LeBrasseur 1986) and the presence of coho salmon may have influenced the low densities of pink and chum at these sites.

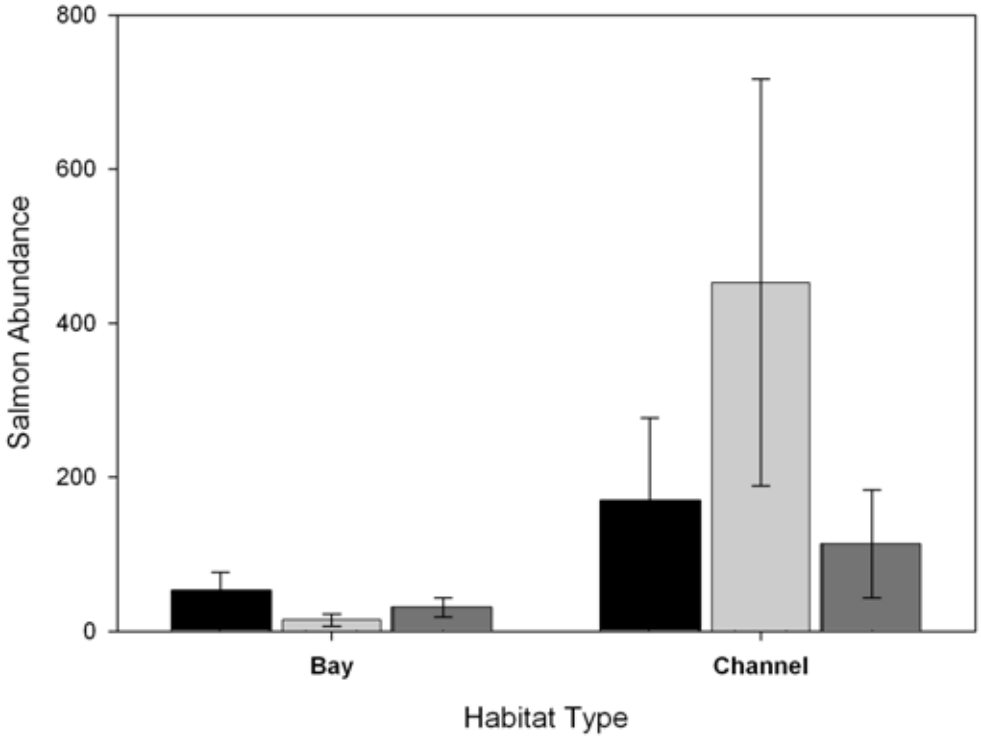


Figure 4. Average combined juvenile pink and chum salmon abundance between 3 Bay and 3 Channel sites within Roscoe Inlet

Because of the physiological changes salmon must undergo when moving into ocean environments, the transition from freshwater to salt can be stressful and is usually done gradually over several weeks rather than abruptly (Iwata and Komatsu 1984). Therefore, salinity levels have been hypothesized to be a driving force in habitat selection by juvenile salmon during the early marine phase of their migration (Thorpe 1994). Generally, estuaries provide a large salinity gradient that is conducive to juvenile salmon going through this transformation (Quinn 2005).

In Roscoe Inlet the bays provided a significantly lower salinity habitat than the channels (Figure 6). The numerous creeks and rivers, heavy with winter runoff, combined with the reduced tidal and wind action, provide a spatial and temporal salinity gradient ideal for juvenile salmon initially making the fresh- to salt water transition. While we did not find any correlation between salinity and salmon density, it is clear that salinity does play an important role in the timing of sea entry and may assist migrating salmon to orient away from the bays to the stronger salinity levels in the channels (McInerney 1964).

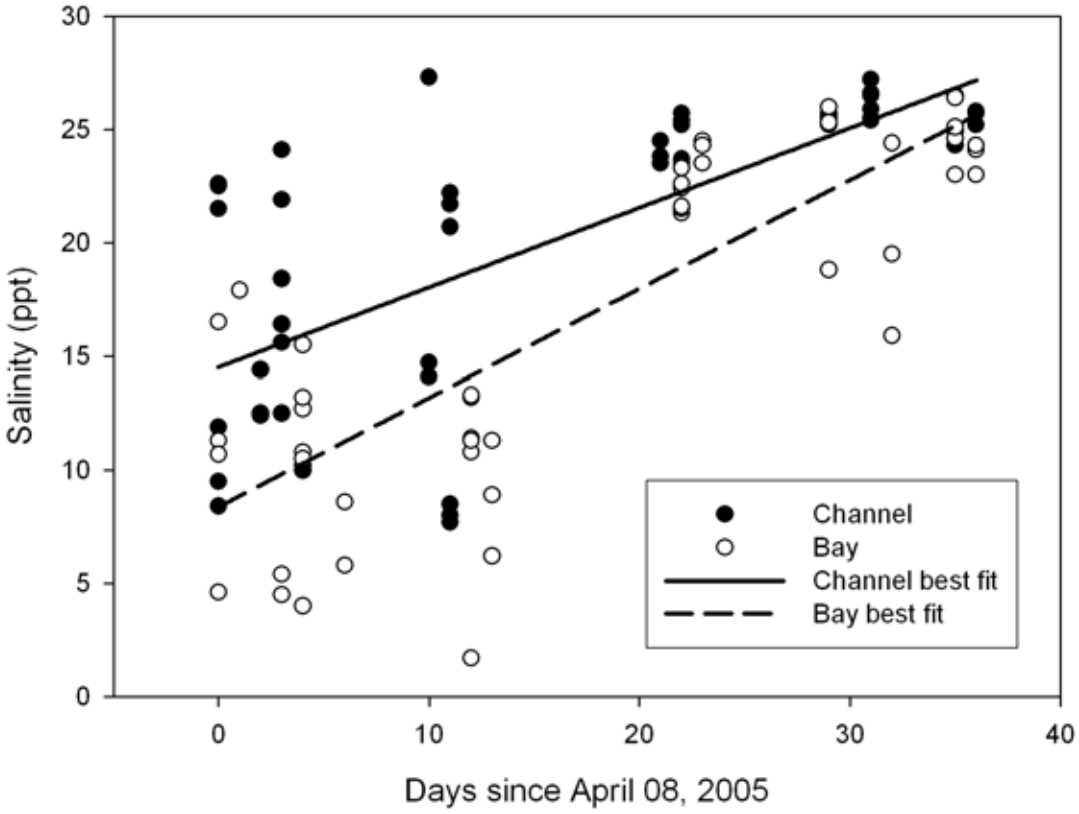


Figure 6. Salinity (parts per thousand) levels in bay and channel sites in Roscoe Inlet from April 8-May 18, 2005. Channel sites had significantly higher salinities than bay sites throughout the study period.

Migration of juvenile salmon through Roscoe Inlet was both temporally and spatially variable. As previously mentioned, a larger proportion of salmon were caught in the channels than in the bays and the timing of the migration was variable within and between these habitat types. It appears that the migration did not happen as one group but instead was spread out over several weeks with a distinct ending near the middle of May (Figure 7,8). Moreover it is clear that the entire length of shoreline habitat in Roscoe Inlet is important for the migration of juvenile salmon. No salmon were caught in the middle of the channel, which supports previous observations (pers. comm. Corey Peet) in confined inlets but contradicts the findings of Healey (1967), where pink salmon would actively migrate away from shore and only come close to shore to feed.

The timing of individual runs can vary dramatically and while the source for the variation is not fully understood, the various peaks in catch densities suggest that various runs of pink and chum salmon within Roscoe Inlet enter the salt water at different times (Figure 7,8). Without being able to tag fish from specific stocks, it is difficult to be certain of this theory but previous research in other systems has shown this to be the case (Groot 1965).

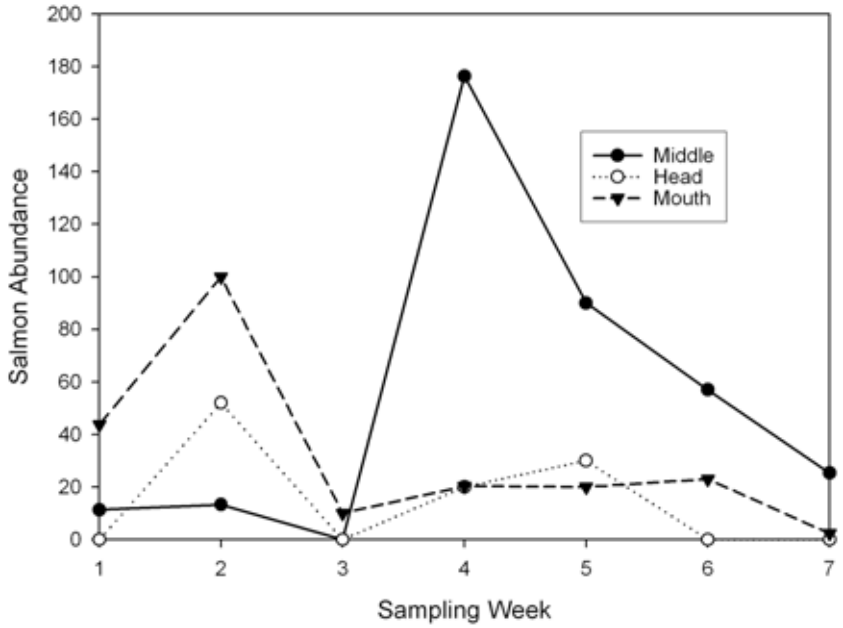


Figure 7. Average (n=3) salmon densities at various **Bay** locations in Roscoe Inlet through time. "Head", "Middle", and "Mouth" refer to approximate positions in the inlet.

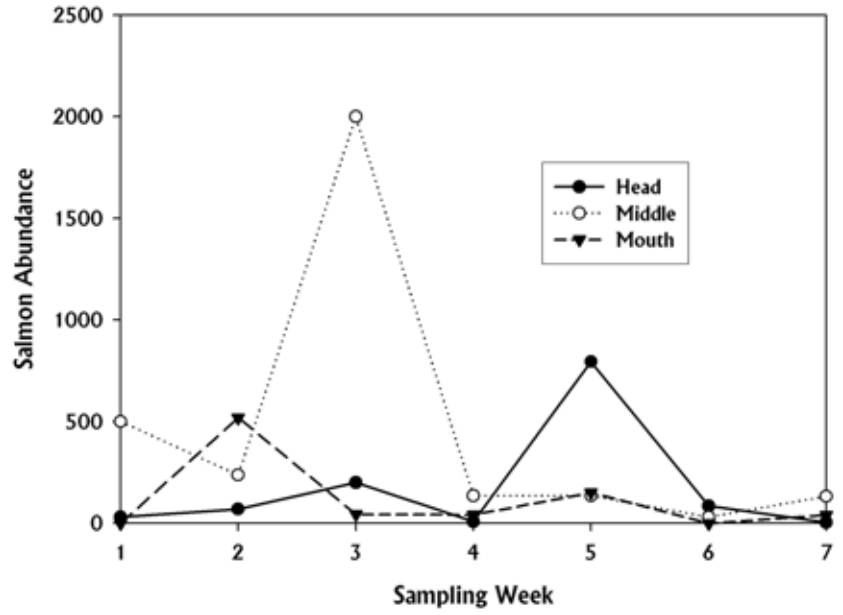


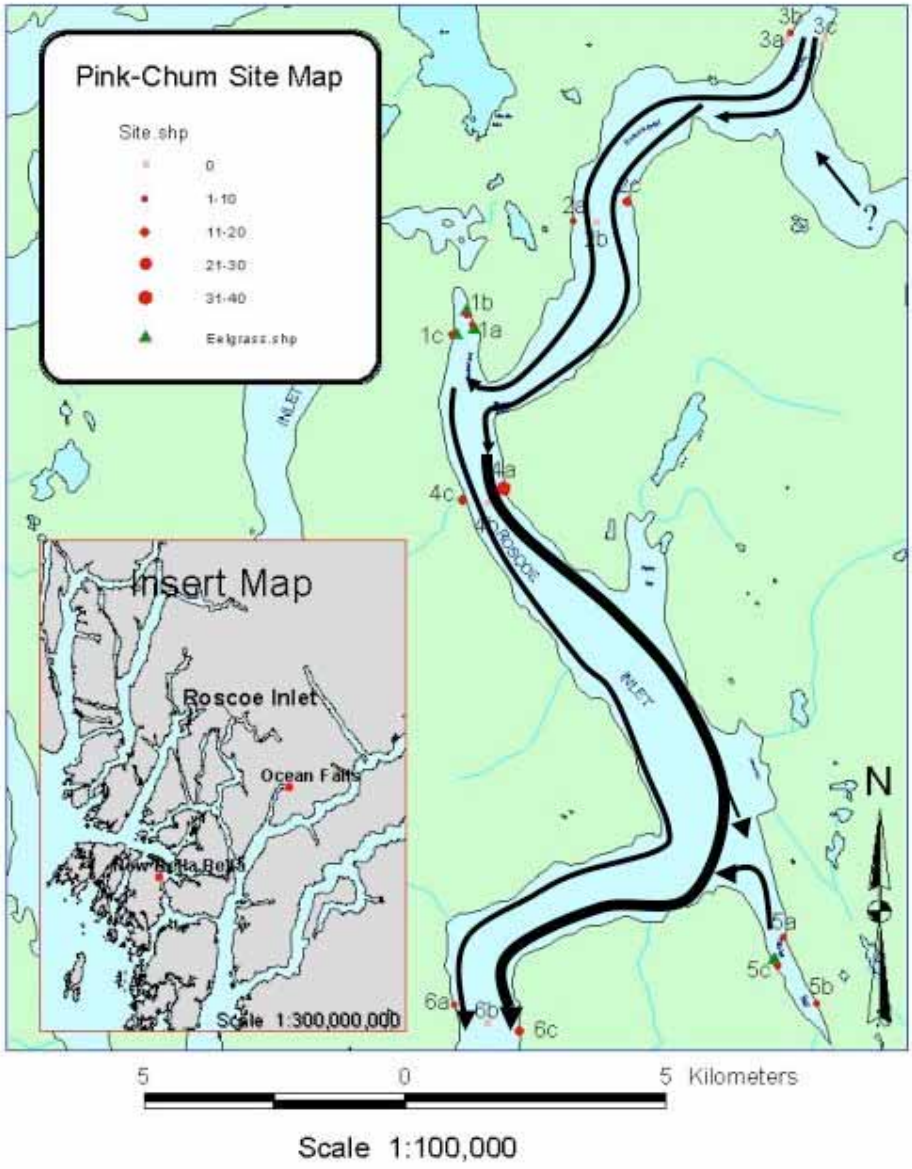
Figure 8. Average (n=3) salmon densities at various **Channel** locations in Roscoe Inlet through time. "Head", "Middle", and "Mouth" refer to approximate positions in the inlet.

Study Conclusions and Future Goals

The migration of juvenile salmon through Roscoe Inlet occurs during a distinct time window from the beginning of April until mid-May. This migration period may vary annually and should be given consideration in development plans that may affect the migration. Rapid growth occurs during residence in Roscoe Inlet and all habitat types except for mid-channel are utilized. It appears that chum and pink salmon migrate together but schools are temporally and spatially segregated throughout Roscoe Inlet. Virtually all sites had salmon present at some point during the study illustrating the importance of both channels and bays as habitat for migrating salmon. However there does seem to be a preference by salmon to use channels rather than bays in Roscoe Inlet. The migration routes through Roscoe Inlet run parallel to the shoreline on both sides of the inlet with fish from tributary streams joining the route (Figure 9). A fundamental "next step" in the study of juvenile migration is to identify where they migrate after leaving the protected inlet. Once out of Roscoe Inlet, options for habitat selection are greater as are choices for migration routes.

It is our opinion that this pilot study was tremendously successful and the methods developed here give an excellent foundation for a larger study in the central coast. With funding support from the Gordon and Betty Moore Foundation, we are planning to expand this project significantly with the cooperation of Heiltsuk Fisheries Co-management. We will map migration routes within Heiltsuk traditional territory and identify variables that contribute to selection of habitats by juvenile salmon. This information will be critical in helping guide the Marine Use Plan currently being developed by the Heiltsuk First Nation. In addition, the techniques and results will be instrumental in helping guide other studies. In fact, biologists studying pink and chum salmon in the Broughton Archipelago are developing protocols to map migration routes in the area and we have been able to collaborate, providing information and suggestions on experimental design. We are also in discussions with organizers of the Pacific Oceans Shelf Tracking (POST) project to determine the feasibility of deploying an acoustic array in the central coast to determine if any juvenile fish from southern waters are using the inside passage for their northern migration.

With several pristine freshwater systems holding strong runs of chum and pink salmon, Roscoe Inlet deserves strict protection against development of any kind. The Heiltsuk First Nation recently released a Land Use Plan for their traditional territory and in the plan Roscoe Inlet is designated as protected and there are no plans for development. We applaud this effort and encourage government agencies to recognize this designation. Unfortunately, the watershed that surrounds Clatse Lake and feeds Clatse Creek has recently been clear-cut and an extensive road built. The consequences of this logging on the stream ecosystem have yet to be determined but similar practices elsewhere have resulted in increased run-off and silt loading, often scouring and/or suffocating spawning beds. It is highly recommended that this situation be monitored and, if necessary and possible, restoration efforts be made.



Source:
Chris Williamson, Salmon Biologist
Raincoast Conservation Society

Prepared by:
Carl R. Hunnicutt, Haïlbuk GPS/GIS Technician

Figure 8. Proposed migration routes of juvenile pink and chum salmon through Roscoe Inlet based on capture densities at 6 sampling locations. Size of circle at each site represents percentage of all fish caught during study. Line thickness represents importance of migration route extrapolated from sampling.

Acknowledgments

Raincoast Conservation is grateful for the financial contributions from the Gordon and Betty Moore Foundation that made this project possible. Chris Wilson, Jordan Wilson and Julie Carpenter assisted in the field collections and their help is greatly appreciated. Dean Wyatt of Knight Inlet Lodge kindly donated the boat used in the study. Carl Humchitt completed the GIS mapping for the project. Lastly we would like to thank the Heiltsuk people for allowing us to conduct this research in their traditional territory.

Literature Cited

Groot, C. 1965. On the orientation of young sockeye salmon (*Oncorhynchus nerka*) during their seaward migration out of lakes. Behaviour 14:1-198

Hargreaves, N.B., and R.J. LeBrasseur. 1985. Species selective predation on juvenile pink (*Oncorhynchus gorbuscha*) and chum salmon (*O. keta*) by coho salmon (*O. kisutch*). Can. J. Fish. Aquat. Sci. 42: 659-668

Hartt, A.C., and M.B. Dell. 1986. Early oceanic migrations and growth of juvenile Pacific salmon and steelhead trout. Int. N. Pac. Fish. Comm. Bull. 46:1-105

Healey, M.C. 1967. Orientation of pink salmon (*Oncorhynchus gorbuscha*) during early marine migration from Bella Coola river system. J. Fish. Res. Board. Can. 24: 2321-2338

Iwata, M., and S. Komatsu. 1984. Importance of estuarine residence for adaptation of chum salmon (*Oncorhynchus keta*) fry to seawater. Can. J. Fish. Aquat. Sci. 41: 744-749

Jacobs, M. 2001. The Heiltsuk Stream Inventory 2000 Summary Report. Prepared for the Heiltsuk Tribal Council.

Krkosek, M., M.A. Lewis, and J.P. Volpe. 2005. Transmission dynamics of parasitic sea lice from farm to wild salmon. Proc. Royal Society B. 272: 689-696

Macdonald, J.S., I.K. Birtwell, and G.M. Kruzynski. 1987. Food and habitat utilization by juvenile salmonids in the Campbell River estuary. Can. J. Fish. Aquat. Sci. 44:1233-1246

McInerney, J.E. 1964. Salinity preference: an orientation mechanism in salmon migration. J. Fish. Res. Board. Can. 21: 995-1018

Morton, A., R. Routledge, C. Peet, and A. Ladwig. 2004. Sea lice (*Lepeoptheirus salmonis*) infection rates on juvenile pink (Oncorhynchus gorbuscha) and chum (*O. keta*) salmon in the nearshore marine environment of British Columbia, Canada. Can. J. Fish. Aquat. Sci. 61: 147-157

Parker, R.R. 1965. Estimation of sea mortality rates for the 1961 brood-year pink salmon of the Bella Coola area, British Columbia. J. Fish. Res. Board Can. 22: 1523-1554

Parker, R.R. 1968. Marine mortality schedules of pink salmon of the Bella Coola River, Central British Columbia. J. Fish. Res. Board Can. 25: 757-794

Quinn, T.P. 2005. The behavior and ecology of Pacific salmon and trout. American

Fisheries Society and UBC Press

Temple, N. and C. Peet. 2005. Juvenile salmon migration mapping: A feasibility study. Raincoast Conservation Society

Thorpe, J.E. 1994. Salmonid fishes and the estuarine environment. Estuaries 17:76-93