

PROGRESS REPORT

**FACTORS AFFECTING NEARSHORE SURVIVAL AND PRODUCTION
OF JUVENILE SOCKEYE SALMON FROM KVICHAK BAY**

**Phase I:
Important habitat, migration routes
and food resources**

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ABSTRACT

Low returns of sockeye salmon to Bristol Bay in 1997 and 1998, and the failure of the peak sockeye salmon run on the Kvichak River in 2000 has generated great concern for the health and continued viability of the Kvichak River stock of sockeye salmon. These events, in turn, have spurred a renewed interest in determining factors that affect survival of sockeye salmon throughout their life cycle, and particularly the early marine phase of that cycle. In this study we provide detailed information on important habitats utilized by juvenile salmon as they migrate from the Kvichak River into and through Kvichak Bay, define their migratory route through Kvichak Bay, and assess food resources available during that migration. In 2001, during the period of sockeye smolt outmigration (mid May to mid June), juvenile sockeye salmon were sampled along several transects from shore up to 50 km offshore. Abundances of sockeye tended to decrease from shallow, nearshore areas with higher temperatures, higher turbidity, and lower salinities to deeper, offshore areas with colder, more saline, and less turbid waters. Bottom depth, temperature, salinity, Secchi depth, and distance from shore are all strongly confounded, thus their potential effects on the distribution of salmon are difficult to separate. Sockeye abundances were not correlated with total zooplankton density or biomass, however, sockeye were correlated with selected zooplankters, such as the calanoid copepods *Eurytemora* and *Epilabidocera*. *Eurytemora* was the most important prey item, in terms of frequency of occurrence and number eaten. Mysid crustaceans dominated the prey in terms of biomass. There is some evidence that fish nearshore are feeding less than fish offshore in deeper, less turbid water.

BACKGROUND

Very little is known about the biology of sockeye salmon smolt once they pass the sonar fish counters within rivers of origin. The greatest mortality in the ocean is associated with the first few months in the life of smolt and juvenile salmon as they migrate to offshore rearing grounds. The Kvichak River smolt are subjected to substantial mortality from in-river predation before they ever reach Kvichak Bay. Little is known about factors influencing survival of Kvichak River smolt once they reach estuarine waters of Kvichak Bay, a critical time in their life history. If we are to partition those mortality effects that may be most important in determining inter-annual variations in sockeye salmon runs, then we must move from the general to the specific in defining the behavior, habitat, migration routes, and important physical and biological interactions of sockeye salmon within the estuarine waters of Bristol Bay. We must be able to document factors that increase stress or result in direct mortality in smolt and juvenile salmon, as well as document what relationship(s) those stresses may have to subsequent mortality at sea.

This project addresses the following two research priorities of the Pollock Conservation Cooperative Research center:

- Climate regime shifts and interannual variability in the Bering Sea ecosystem and their effects on fish (particularly pollock), marine mammals and birds; and on other components of the ecosystem, including the life history responses of these species; and

- Fishery stock assessments and stock assessment models, including development of improvements to such assessments and models.

OBJECTIVES/HYPOTHESES

In this study we began gathering information to test the following hypothesis:

“The success of smolt migrating from freshwaters to the ocean and transitioning into offshore rearing environments is influenced by both availability of food resources and predation during this migration consistent with major components of the critical size and critical period hypothesis” advanced by Beamish and Mahnken.

In order to fully test this hypothesis is necessary to undertake studies throughout the life cycle of sockeye salmon extending over a period of 5 or more years. It will also be necessary to evaluate factors that influence predation and food resources, as well as the direct effects exerted by the estuarine environment on smolt survival. This particular study will develop detailed baseline data upon which to build such a long-term study with an efficient and cost effective design specifically targeting the Kvichak River sockeye salmon stock. It will also provide more detailed information than presently available on the migration of smolt through Kvichak Bay under a specific set of physical and biological conditions that can be compared to previous work by Straty and others. Specific objectives to be accomplished in this study are:

1. Determine essential estuarine habitat utilized by juvenile sockeye salmon in Kvichak Bay as they migrate to offshore rearing habitat in Bristol Bay and the Bering Sea;
2. Determine major prey items in diet of juvenile sockeye salmon in Kvichak Bay;
3. Assess relative abundance and biomass of major juvenile sockeye salmon prey species in Kvichak Bay.

METHODS/ANALYSES

Survey Timing: We conducted a field survey between May 28 and June 13, prior to the start of the commercial sockeye salmon fishing season. No sampling occurred on 6 days, mainly because of poor weather. The survey was to correspond with the peak outmigration period for Kvichak River smolt and after the point when 50% of the smolt have historically passed the sonar counter at Igiugig. At that time Kvichak River smolt should have comprised the bulk of the smolt migrating through Kvichak Bay. Planned intertidal beach seine and fyke net sampling was excluded after initial attempts failed because of strong currents and high surf.

Trawl Transects: A total of 14 transects were established for trawling. Cruise transects are shown in Figure 1. All sampling occurred from the 12m F/V *Namorada*.

Smolt were sampled along each transect line using a Kodiak surface trawl. The trawl was 6.1 m wide, 3.1 m deep, and 13 m long; stretched mesh at the mouth was 76 mm tapering to 3 mm at the cod end. The mouth of the net was held open with spreader bars. The trawl was fished between two boats on the surface. The cod end of the trawl was rigged with a purse line to

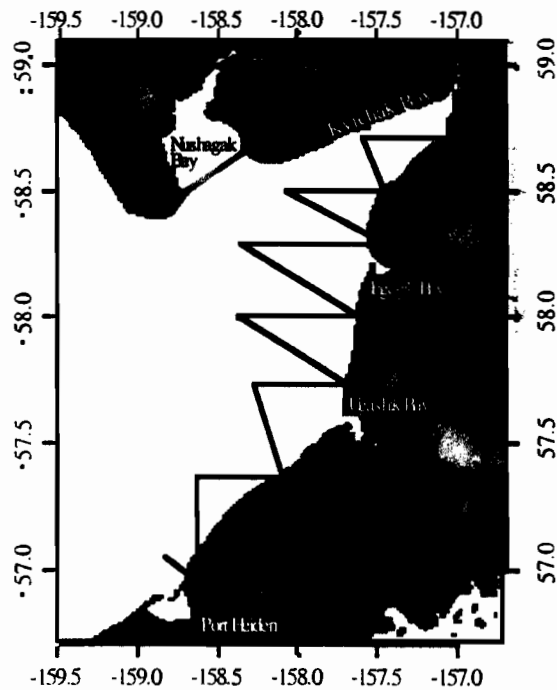


Figure 1. Transects established to sample juvenile sockeye salmon, 2001.

facilitate the recovery of samples without having to retrieve the trawl during each set. This modification minimized the need to keep setting and retrieving trawl during the survey. The tow speed was approximately 2 knots for a duration of approximately 10 minutes to facilitate good quality fish samples and retention of scales. Trawl sampling on each transect line was generally one trawl per 5 km of transect line. A GPS was used to record the start and finish of every trawl sample along each transect line. Time of day, local weather conditions, sea state and date were also recorded for each sample.

At the end of each tow, a profile of temperature, salinity and turbidity within the top 5 m of the water column was made using calibrated electronic meters. Data were collected at the surface, 3-m and 5-m depths, or the bottom if water depth is less than 5 m. Surface current speed and direction was also measured at the end of each trawl. From each trawl sample, up to 100 sockeye salmon smolt were collected, measured, weighed to the nearest 0.1g, labeled and preserved in 10% formalin. All remaining fish captured in each tow was identified, enumerated and released. If large numbers of fish were captured then subsampling of the catch was used to minimize mortality from the trawling program.

Zooplankton: Zooplankton was sampled along each trawl transect line with a 50 cm diameter plankton net, constructed with 0.5-1 mm mesh. Three vertical plankton hauls were made at most stations, from 3 m depths to the surface. The three replicates were composited. Locations of samples were coordinated so that samples were collected across the zone of high concentration of outmigrating smolt. All plankton samples were preserved immediately after collection with buffered formalin containing a vital dye; labeled with date, time and transect leg; and placed in nonbreakable containers. Plankton samples will be transferred to alcohol preservative upon arrival in the laboratory.

SUMMARY OF RESULTS

Biological and physical data:

A total of 104 stations were sampled with a surface trawl

- 2,260 sockeye smolts were collected at 54 of the stations, ranging from 1 to 534 Sockeye per station. Highest abundances just south of the mouth of the Cinder River. Generally, abundances were highest in Kvichak Bay and close to shore (< 10km) between Egegik Bay and Port Heiden.
- 71 coho smolts were collected at 21 stations, ranging from 1 to 16 coho per station. Highest abundance station also had highest number of sockeye. Generally, coho were caught in Nushagak and Kvichak Bay.
- 1 chum smolt was collected.

Other biological variables include:

- Size and weight of salmon smolts (32 stations for sockeye).
- zooplankton abundances, wet weight, and species composition (52 stations) stomach contents (20 stations).

The average size and weight of sockeye smolts did not increase significantly over time (as indicated by a correlation of 0.04 between julian day and sockeye abundances), although average smolt size was largest on the last day of sampling. Size and weight of sockeye smolts increased from the inner to the outer bay.

Total zooplankton abundances and weights were highest in Kvichak Bay, along the shore, and in the southern part of the sampling region.

Environmental variables available at all (or most) stations include:

- Bottom depth
- Temperatures at 1m, 3m, and 5 m
- Salinities at 1m, 3m, and 5 m
- Secchi depth
- Distance from shore

The following variables are “nuisance” variables that may have an impact on catches but are not otherwise of primary interest:

- Current direction at time of sampling (available at 93 stations)
- Current speed at time of sampling (93 stations)
- Direction of sampling (heading)
- Time of sampling (hour)
- Sampling day (julian day)

Key Correlations among biological and environmental variables:

- Sockeye abundance was not significantly correlated with total zooplankton density or total zooplankton wet weight biomass ($r = 0.13$ and -0.01 , respectively), while coho abundance was positively correlated with both (density: $r = 0.37$, $p = 0.007$; weight: $r = 0.20$, $p = 0.160$).
- Both sockeye and coho abundances had significant negative correlations with bottom depth, salinity (not significant for sockeye: $r = -0.05$), Secchi depth, and distance from shore. Both were positively and significantly correlated with temperature. That is, abundances of sockeye and coho tended to decrease from shallow, nearshore areas with higher temperatures, higher turbidity, and lower salinities to deeper, offshore areas with colder, more saline, and less turbid waters.
- Bottom depth, temperature, salinity, Secchi depth, and distance from shore are all strongly confounded, thus their potential effects on the distribution of salmon are difficult to separate. Generally, bottom depth, salinity, and Secchi depth increase in the offshore direction and from the inner to the outer bay, while temperatures decrease.
- Sockeye abundances were most strongly correlated with depth and distance from shore, suggesting that smolts tend to stay in shallow, nearshore areas following outmigration, regardless of salinity ($r = -0.05$) or prey availability (see above).
- While prey availability (total zooplankton density and wet weight) was not correlated at a local scale with sockeye abundances, prey was similarly distributed at a larger scale: There was a general tendency for zooplankton abundances to decrease with depth and distance from shore ($r = -0.54$ and $r = -0.50$ between zooplankton density and bottom depth and between zooplankton density and distance from shore, respectively).
- Moderately strong (positive) correlation between average sockeye fork length (FL) at a station and Secchi depth ($r=0.35$, $p=0.012$), i.e. larger individuals were more abundant in less turbid waters, while highest abundances in general occurred in the more turbid, shallow, nearshore waters. Possibly reflects active, offshore migration of larger individuals into less turbid waters.
- Similarly, moderately strong (positive) correlation between average sockeye fork length (FL) and salinity ($r = 0.29$, $p = 0.042$), i.e. larger individuals were more abundant in more saline waters, again possibly reflecting active, offshore migration of larger individuals.
- Based on average numerical abundance of the copepod *Eurytemora* (67.4 individuals / stomach), the helmet crab *Telmessus cheiragonus* (5.37) and invertebrate eggs (3.28) were the three most common prey items.
- Based on their average weight in zooplankton samples, the mysids *Thysanoessa raschii*, *Xenacanthomysis pseudomacropsis*, and Mysidacea, and *Telmessus cheiragonus*, may be more important than *Eurytemora* in terms of weight, in spite of the large numerical abundance of *Eurytemora*.