# IDENTIFICATION OF HABITAT GRADIENTS AND ASSOCIATED LIFE HISTORY CHARACTERISTICS OF JUVENILE COHO SALMON IN THE ANCHOR RIVER DELTA

May 1, 2009

Research Working Plan
For the Anchor River Estuary
Year 1 Feasibility Study

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## Abstract

Estuaries provide a great diversity of habitats and play an important role in the development of many marine and anadromous fishes. Although generally recognized as very productive ecosystems, the diversity of estuarine habitats and the developmental responses that they illicit from animals rearing in these environments are not well understood. Widely differing conditions between estuarine environments could result in fine scale variability in the life history, physiological, and behavioral characteristics of fishes that use them for feeding, migratory corridors, and refuge habitats. This gives rise to the potential for expression of local adaptations and may give insight to differences in the relative vulnerability of adjacent populations to human intervention, climate shifts, and variability in the marine environment. In this project, we propose to investigate the life history characteristics of coho salmon smolts and their use of habitat during estuary rearing in the Anchor River estuary in south-central Alaska. This work plan describes the first year of a proposed three year investigation with the purpose of 1) sampling site selection; 2) identification of environmental gradients (temperature and salinity); and 3) development of base line data of life history characteristics and condition in juvenile coho salmon. This study will allow us to understand the potential for fine scale adaptive variability in life history characteristics resulting from differing rearing environments, providing insight to long-term population resilience of coho salmon populations in a human-impacted environment.

## Introduction

The principles of life history theory describe the expression of traits within organisms as a response to environmental variation that promote individual fitness (Stearns 1976). The study of evolution of life history tactics portrays the suite of responses of an individual as inherited adaptations that allow them to solve an ecological problem (Stearns 1976, Schaffer 2004). Characteristics of an organism, such as size and age at maturation, clutch size, seasonal timing of maturation, and migratory patterns are all aspects of development that can impact the chance of an individual successfully reproducing. Life history tactics can vary across temporal and spatial scales within species and expression of different life history tactics can co-occur in animals originating within the same natal habitats (Olsen and Vøllestad 2001, Rikardsen et al. 2004). It

is the variation in life history tactics that allows for single species resilience to environmental perturbation (Hillborn et al. 2003) and thereby the underlying mechanisms of which are worthy of investigation.

The life cycle of coho salmon in the North Pacific provides opportunity to examine the expression of fine scale adaptations and the magnitude of plasticity related to life history tactics. This species is found in greatest densities using the coastal waters of British Columbia, but have distributions as far north as the Alaska Pennisula in Western Alaska and as far south as the Sacramento River in central California (Pearcy 1992). Coho salmon generally have both a long freshwater rearing phase (1-2 years) and a long ocean rearing phase (1-3 years), although the duration of each phase is variable both among local drainages and across the species distribution (Beamish et al. 1999, Hobday and Boehlert 2001). Estuary use is relatively short, but considered important for coho salmon (McMahon and Holtby 1992, Miller and Sadro 2003). Salmon smolts undergo both physiological changes and behavioral changes during estuary occupancy that have been hypothesized as adaptations that allow them to persist in open ocean environments (McMahon and Holtby 1992). Their diverse use of habitats allows for a wide range of environmental pressures to which developing salmon are exposed and coho salmon, in particular, exhibit a wide range of behavioral and physical adaptations that allow them to persist in their localized environments (Beamish et al. 1997). The mechanisms behind the adaptations of salmon that are expressed are not well understood; particularly aspects of bet-hedging (Stearns and Hendry 2004) and developmental traits which lead to fitness (Thorpe et al. 1998).

Estuary environments contain a variety of habitats for aquatic organisms with wide ranging physical and chemical gradients, resulting in diverse habitat and food availability (Quinn 2005). Because of this, estuaries provide a complement of habitats for the development of juvenile fishes, including feeding, refuge, and, in anadromous fishes, transitional habitat between life stages (Thorpe 1994). Estuaries play an important role in the life cycle of anadromous salmon; providing crucial rearing habitat during a time when physiological transition (Healey 1982, McMahon and Holtby 1992, Beamish et al. 2004). The quality of rearing habitat within estuaries plays a critical role in the survival of developing juvenile fish. Healey (1982) described three characteristics of estuaries that determine their importance in the developmental phase of

juvenile salmonids: duration of occupancy, distance to alternative rearing habitats, and use of alternative rearing habitats. Large estuaries are considered high quality rearing habitat for juvenile coho salmon and fish using these areas have shown higher rates of survival over time than those using small estuaries or moving directly to the open ocean (Beamish et al. 1997). McMahon and Holtby (1992) found that distribution within estuaries was related to the availability of cover and salinity gradients and hypothesized that estuaries that provided greater cover could improve ocean survival by increasing growth and that gradual salinity gradients allowed for optimal osmoregulatory adaptation.

The large range of habitats and variable conditions make estuaries logistically challenging areas in which to conduct ecological or behavioral research. Therefore, few studies have looked at the mechanisms behind behavior patterns related to estuary occupancy (Quinn 2005). Improvements in technology have allowed researchers to begin to address the questions of fine scale adaptations of fish in the estuary and early marine environment through acoustic tagging and tracking studies (Miller and Sadro 2003, Thorstad et al. 2007, Chittenden et al. 2008). We propose to take a comparative approach to examine juvenile salmon size, condition, habitat use, and movement patterns in two physically different, but proximate estuary rearing environments. This approach will allow us to ascertain the characteristics that are adaptive to the specific estuary environment from those that are regional traits of the species. Additionally, we can infer some evolutionary significance for development of traits related to population size and condition of the animals.

## Justification

Conservation of diversity within a population and developing management approaches that maximize the diversity expressed within a species are critical components to resource management (Ford 2004). The concept of Ecologically Significant Units (ESU) was introduced as one solution to describing and defining diversity expressed within a species into conservation units (Ryder 1986). The ESU was defined as a unit below the species level that still expressed the majority of diversity within the species. Considering this, we propose to evaluate the factors that contribute to diversity in life history expressed among and between two populations of coho salmon that rear in physically different estuary environments.

This project also addresses management needs of understanding the value of estuary habitats to production and survival of salmon. Estuary rearing habitats are considered to be important for increasing ocean survival of coho salmon (Healey 1982). Increasing pressure for land and water resource development and fishery resource use will require managers to consider what approaches provide the best benefit to all users. Understanding how, when, and what aspects of estuary habitats are important to persistence of salmon populations will help managers evaluate the use of limited resources.

We propose to test several hypotheses based on the current understanding of how environmental conditions correlate to life history by examining relationships between juvenile coho salmon size and condition and their use of estuary and early marine habitat. The estuaries of the Fox and Anchor rivers of south-central Alaska differ in size and diversity of estuarine habitats available for estuary immigrating smolts. Comparing developmental trait related to the use of these two physically different estuaries within a close geographic region can help us clearly differentiate patterns that are related to estuary rearing habitats. This will allow us to thoroughly examine the importance of estuaries in early life history development of coho salmon.

Our study addresses the ecological problem of how local adaptations during estuary and early marine rearing can contribute to population resilience. The overarching question for this study is: do differences in estuary conditions correspond to differences in juvenile salmon outmigration processes that reflect potential for local adaptation and plasticity among populations?

## Study Site

The Anchor River abruptly transitions into the marine environment, with an approximate estuary length of 0.8 km (measured from mean high water tide line to mouth of estuary). Coho salmon have been enumerated on the Anchor River as they return to spawn, with a four year average of 10,765 fish counted through sonar to mid-September (Alaska Department of Fish and Game 2008). Enumeration data for juvenile coho salmon was not available for the Anchor River watershed. Increasingly, land development and recreational use are affecting the entire Anchor River watershed. This watershed maintains salmon fisheries important to recreational and subsistence harvests. The work proposed for this project will not only provide important

baseline data, but will also increase our understanding of the scope of coho salmon life history variability, thus benefitting decision makers in Kachemak Bay and throughout Alaska.

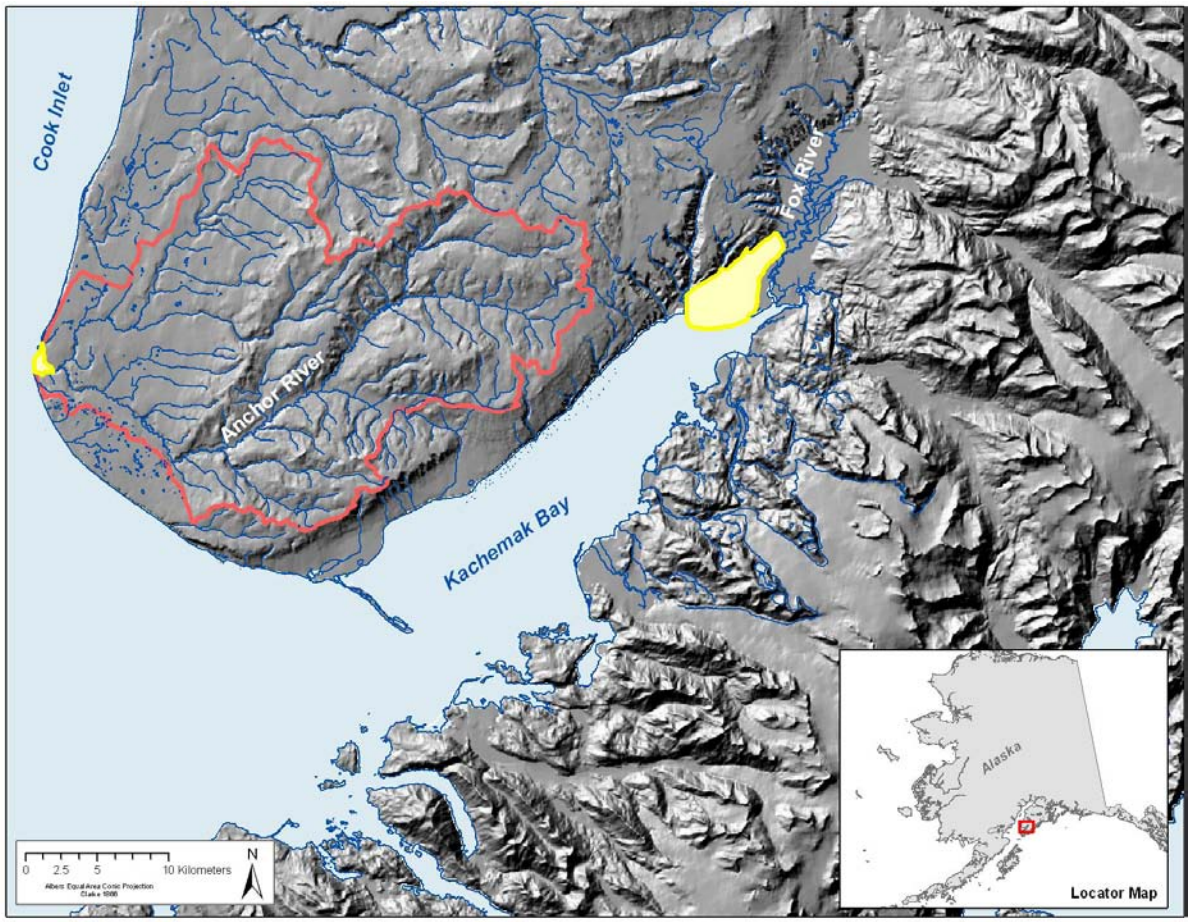


**Figure 1. Map of the lower Kenai Peninsula illustrating estuaries in Kachemak bay, the Fox and Anchor River estuaries are identified for comparison (GIS data from KBRR and NOAA 2001).**

**Figure 2. Aerial view of the Anchor River delta with five habitat types to be sampled**

# Objectives

This plan describes the first year of work designed to complement that proposed by Walker et al. (2009) for the Fox River Flats and develop baseline data for a comparative study between the Fox and Anchor River estuaries. The goals of the first year of sampling are threefold: 1) to define environmental gradients in salinity, temperature, and depth; 2) identify long term sampling sites along the five habitat units described under Walker et al. (2009); and 3) develop baseline data for the size and relative distribution of juvenile coho salmon within the Anchor River delta and tidal flat. This involves describing:

a. Estuarine environmental gradients in salinity, temperature, and depths;

b. Life history characteristics of juvenile salmon using estuaries, including variability and central tendency of fish condition, age, and the interrelationship of the two with the timing of outmigration;
c. Distribution of smolts within the estuarine environment and use of habitat types within and adjacent to the estuary;

# Methods

## *Objectives 1 and 2: Define environmental gradients across various estuary habitats and determine sampling sites.*

Existing bathymetric mapping and ecological characterization has been completed in Kachemak Bay (NOAA 2001) and fairly detailed maps exist of the estuary habitats in the Anchor River (Baird 2008). We will validate existing GIS data to incorporate changes that may have occurred between the sampling years as well as collect data to enhance what currently exists.

### Site selection

Twenty sites in each estuary have been selected in channel habitats using the relationship to the main river and spaced longitudinally along salinity gradients within each channel (Walker et al. 2009). Five channel types will be sampled: 1) main river channel; 2) side channel of the river; 3) tributaries to the main channel; 4) tributaries to the side channel; and 5) tributaries not related to the river. Four salinity gradients will be sampled at high tide within each channel habitat type: 1) freshwater (salinity range 0-0.4); 2) oligohaline (0.5-3); 3) mesohaline (3.1 to 18); and 4) polyhaline (18.1-30). During the first year feasibility study, sites will be sampled three times from June to mid-July in the in the Anchor River estuary.

### Habitat measurement

Temperature will be monitored at the twenty sites using moored loggers collecting readings at two hour increments (Onset Stowaway Tidbit, MicroDAQ.com). Point readings for conductivity and temperature will be taken along each channel from confluence fresh water input to determine salinity zones (YSI Inc.,Yellow Springs, OH). Once zones are determined, detailed profiles will be obtained at three points within each salinity zone using a SeaBird Electronics SBE-19*plus* Seacat CTD (conductivity, temperature, depth) sensor. Additionally, data will be collected for

each site including availability of vegetation types and structure for cover, and daily weather patterns.

## *Objective 2: Determination of patterns in fish size, age, and condition*

### Fish capture

Sampling for the year one feasibility study will occur as described in Walker et al. (2009). After salinity zones are determined in each of the five habitat types at high tide (main channel, side channel, tributary channels –main and side, tidal channel), each salinity zone will be sampled with the most appropriate gear for the channel depth and velocity (fyke net or beach seine).

Beach seines will be used in wider, river channel habitats and modified fyke nets will be used to sample fish in smaller tidal channels and marshes. The fyke nets are placed near the mouth of small tidal channel at high tide sampling fish as they move out of the channel on the receding tide. Beach seines will deployed by anchoring one end along the shoreline while the other end of the seine is set from the boat. The seine will be deployed parallel to shore and once the net is set, it will be hauled to the beach by lines attached to each end of the seine.

### Fish handling and processing

All fish captured throughout the study will be enumerated and identified to species. All juvenile coho salmon will be mildly anesthetized in 70 mg/L methane tricane sulfonate, MS-222 (Bailey et al. 1998, Chittenden et al. 2008) and measured (fork length, nearest mm), weighed (nearest 0.1 g), and several scales will be removed from the body slightly posterior to the dorsal fin and dorsal of the lateral line (INPFC 1963) for later ageing in the laboratory. Three coho salmon (not to exceed 10% of the catch at each site representing small, medium, large sizes) will be euthanized using 140 mg/L MS-222. These fish will be designated unique identifiers to site, date, and size, and will then be frozen for laboratory analysis to determine energy density.

### Data Handling, Processing, and Reporting

This is the first year feasibility study conducted as part of a cooperative project including Kachemak Bay Research Reserve, NOAA Fisheries, and the University of Alaska Fairbanks. Data handling and processing is being conducted under a PhD graduate student project supervised by Drs. Amanda Rosenberger and Nicola Hillgruber and supported by the NOAA

National Estuarine Research Reserve Sytem. The work and data analyses for the full project is described under the student research proposal (Hoem 2009). Annual and semi-annual project reports are required for the project under the NOAA NERRS program and UAF. Additionally, annual reports will be submitted summarizing results for each field session to ADF&G as required for scientific collection permitting.

## Project Timeline

The full project, under which this work plan defines the first year, will encompass four years with field work occurring over three years.

### *Year One*

*Spring-summer 2009*: Feasibility study, work in Anchor River estuary (for schedule, see Table 1). This includes determination of sampling sites and habitat characteristics, baseline data collection for temperature and salinity gradients, fish size and condition.

Table 1. Sampling Schedule for Feasibility Year One

| Date | Location |
|---|---|
| June 14-15, 17-18, 2009 | Anchor River Delta |
| June 29-30, July1-2, 2009 | Anchor River Delta |
| July 13-14, 16-17, 2009 | Anchor River Delta |

*Late summer-early winter 2009* (August-December): proximate composition analysis in laboratory, report preparation and submission

### Responsibilities

Tammy Hoem (UAF).

Graduate student assigned to project. Develops study design, leads data collection, conducts laboratory analysis, completes all analyses and reporting. Cooperates with all entities involved including presenting progress reports and findings at team and public meetings.

Amanda Rosenberger (UAF).

Oversees graduate student activities, provides assistance for development of study design and analytical procedures, reviews reports and products, provides guidance to graduate student and technical team.

Nicola Hillgruber (UAF).

Oversees graduate student activities, provides assistance for development of study design and analytical procedures, reviews reports and products, provides guidance to graduate student and technical team.

Coowe Walker (KBRR) and Steve Baird (KBRR).

Assists with data collection in the field as well as data entry and quality control of all relevant data as required.

Michelle Gutsch (UAF).

Will assist with data collection in the field as well as data entry and quality control of all relevant data.

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