PRELIMINARY RESEARCH PROPOSAL (COE) (FY07)

TITLE:	Evaluation of the relationship among time of ocean entry, physical, and biological characteristics of the estuary and plume environment, and adult return rates
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PROJECT DURATION:	Multi-year
SUBMISSION DATE:	July 2006

PROJECT SUMMARY

This study will examine the relationship among time of juvenile salmon ocean entry, physical and biological characteristics of the estuary and nearshore ocean plume environment, and smolt-to-adult return rates (SARs) for yearling Chinook salmon reared by the Clatsop Economic Development Committee Fisheries Project (CEDC) in the Columbia River estuary. Smolt-to-adult-return rates for serially released groups of coded-wire-tagged (CWT) yearling Chinook salmon made between 2002 and 2006 will be integrated with information collected from ongoing studies funded by the Bonneville Power Administration (BPA) and others characterizing the physical and biological conditions of the estuary and plume environment. Enhancing our understanding of the linkages between survival during ocean entry and the physical and biological estuarine and ocean conditions smolts encounter may provide a basis to increase SARs through manipulation of transportation tactics and hatchery release dates.

From 2002 through 2006, 6 groups of about 25,000 coded-wire-tagged spring Chinook salmon were released into Blind Slough at 10 day intervals between 6 April and 30 May each year. Adults from those releases began returning to Blind Slough in the spring of 2004 and will be complete in 2009. During 2007, we will continue monitoring adult returns of study fish to sport and commercial fisheries and begin exploring relationships among physical and biological conditions in the nearshore ocean and SARs

Relevance

Expanded research, monitoring, and evaluation efforts aimed at estuarine and nearshore ocean survival relationships are called for in each of the Columbia River salmon restoration plans (Northwest Power Planning Council Strategy for Salmon, National Marine Fisheries Service 2000 Biological Opinion on the operation of the Federal Columbia River Power System,

Governor's 2000 Plan, and the Tribal Restoration Plan). Furthermore, Williams et al. (2005) concluded that observed differential delayed mortality (*D*) between transported and inriver migrating smolts could largely be due to differences in timing of ocean entry, and this was a critical factor in determining the efficacy of smolt transportation. Increasing our understanding of variations in estuarine and nearshore ocean habitats, and the role they play in salmonid survival, could provide management options to increase adult returns.

Methodology

To determine what biological/physical estuarine and ocean factors affect survival of juvenile salmonids entering the Columbia River estuary and associated nearshore ocean environment, 6 groups of about 25,000 coded-wire-tagged yearling Chinook salmon from the CEDC in the lower Columbia River were coded-wire-tagged and released every 10 days from early-April through the end of May each year from 2002 through 2006 (Table 1). Smolts were sampled each year prior to release to determine their level of physiological development and health using standard assays. Size at release was kept as constant as possible between releases to eliminate this variable's effect on survival.

The conditions within the estuary and nearshore environment that smolts experience, both biotic and abiotic, were closely monitored primarily by utilizing data from existing Columbia River estuary and plume studies.

Adult returns from serial releases (every 10 days) will be evaluated and correlated with the biotic and abiotic conditions smolts encountered in the Columbia River estuary and nearshore ocean environment. Adult return rates of PIT-tagged fish passing Bonneville Dam or transported and released below Bonneville Dam will also be compared to the CEDC fish with similar time of ocean entry.

PROJECT DESCRIPTION

Background

The effects of short and long-term fluctuations in oceanographic and climatic conditions on survival of salmon has received increased attention in the Pacific Northwest as salmon runs have declined (Emmett and Schiewe 1997, NRC 1996, Williams et al. 2000). Growth and survival of salmonids in their first days and months at sea appear to be critical in determining overall salmonid year class strength. This is based on the relationship between returns of jack salmon with numbers of adults returning from the same brood class in later years, and between ocean purse seine catches of juvenile salmonids in June and subsequent jack and adult returns (Pearcy 1992).

The Columbia River estuary has been significantly altered by human development (Sherwood et. al. 1990, Weitkamp 1994). Seasonal flow patterns have been altered by dam construction and salmonid habitat has changed as a result of dredging, diking, and urbanization. Exotic species introductions and shifts within salmon species, including the development of large scale hatchery programs, has radically changed the species mix in the Columbia River estuary. Furthermore, ocean conditions appear to vary significantly both spatially and temporally at a variety of scales (Beamish et al. 1999, Francis et al. 1998, Mantua et al. 1997, Welch et al. 2000). The Columbia River estuary and nearby ocean are very dynamic environments. Coastal winds, upwelling, currents, sea surface temperatures, and other physical conditions such as plume structure can change very quickly (Garcia Berdeal et al. 2002). Large changes in biological conditions (such as forage fish abundance and predatory fish abundance) in the plume (Emmett and Brodeur 2000; Emmett et al. 2001; Emmett 2006) (Figure 1) and the estuary (R. L. Emmett, NOAA Fisheries, personal communication) have been observed between

and within years. The relative importance of these factors to juvenile salmon survival is not well understood.

Increasing our understanding of variations in estuarine and nearshore ocean environments, and the role these variations play in salmonid survival, could provide management options to increase adult returns. For example, examination of adult returns from transportation studies conducted at Snake River dams have shown that returns vary dramatically within and between years (Williams et al. 2005, Muir et al. *In press*) (Figure 2). Yearling Chinook salmon transported by barge from Snake River dams arrive to the release point below Bonneville Dam in about 1.5 days while those that migrate through the 5 to 7 remaining dams take from 3 to 4 weeks early in the migration season, to less than 2 weeks by the end of May (Muir et al. *In press*) (Figure 3). Thus, smolts marked on the same day, but either transported or returned to the river likely encounter much different physical and biological conditions within the estuary and nearshore ocean upon their arrival.

Past studies have documented little juvenile salmonid mortality during transport, and recent studies using juvenile radio tags have indicated rapid migration and high survival to the Columbia River estuary after release (Schreck and Stahl 1998). Studies of smolt survival during downstream migration through Snake and Columbia River reservoirs and dams have shown little variation in survival within or between years (Muir et al. 2001, Williams et al. 2001). Therefore, changes in direct survival during migration through freshwater does not appear to explain observed changes in SARs for groups of fish within or between years. Characterizing the conditions that smolts encounter in the estuary and nearshore ocean, along with SARs on a temporal basis, should allow us to identify which estuarine or ocean biological/physical conditions are correlated with high or low levels of salmon ocean survival. Managers can

potentially use this information to determine optimal times for hatchery releases, or whether to transport smolts from collector dams or allow them to migrate naturally to synchronize their arrival to the estuary and nearshore ocean during optimal conditions.

Environmental conditions that might vary in the estuary and nearshore ocean and affect salmonid survival include the abundance of predators (birds, fish, and marine mammals), alternative prey for those predators (northern anchovy, Pacific herring, Pacific sardine, and euphausiids), and salmonid prey (which allows smolts to grow rapidly, reducing their vulnerability to predators). An example of the utility of this type of information was the observation by Canadian researchers of intense mackerel predation on the West Coast of Vancouver Island in 1992 and 1993 (presentation by B. Hargreaves, Canadian Department of Fisheries and Oceans, Newport, OR, March 22, 1997). If those researchers had not been working in the area, the poor adult salmonid returns in 1994 and 1995 might have led to expensive, but ineffective mitigative efforts to increase returns. Another example of the value of ocean studies is that of Willette et al. (1999) who found that mortality of pink salmon (*O. gorbuscha*) was negatively correlated with the duration of the spring copepod bloom in Prince William Sound, with predators switching their diet from copepods to alternative prey, including pink salmon, as copepod biomass declined.

Relationship to Other Research

This study will depend on information provided by several ongoing studies, including studies characterizing the physical and biological characteristics of the estuary and ocean plume (NOAA and Oregon Graduate Institute) and the COE funded studies of transportation. In addition, this study will provide valuable information to the CEDC program to assess potential release strategies to maximize SARs to the terminal gill net fishery.

Objectives

This research proposal describes a study to examine the relationship among time of salmonid ocean entry, physical and biological characteristics of the Columbia River estuary and nearshore plume environment, and SARs for yearling Chinook salmon. The objectives will be to

1) estimate SARs of serially-released, yearling Chinook salmon through the spring migration period for releases made in 2002 through 2006,

2) characterize variations in the physical and biological conditions in the Columbia River estuary and nearshore ocean environment during those time periods,

3) correlate SARs with environmental conditions, and

4) identify potential indicators (biotic, abiotic, or a combination of both) of salmonid marine survival that could be used to improve management actions.

Methods

Groups of about 25,000 Willamette Hatchery Stock spring Chinook salmon were used for the releases each year between 2002 and 2006. We are now waiting for the adults to return, with the last adults returning in 2009. During 2007 adults from releases made in 2004 and 2005 will return.

Beginning in 2005, scale samples were taken from smolts of various lengths (n=300) at the time of release to determine the relationship between scale diameter and fish length. Scales from returning adults in 2005, 2006, and future years will be collected and measured to back-calculate size at release as juveniles.

Environmental conditions within the estuary and nearshore ocean environment, both biotic and abiotic, are being characterized during each salmonid release time primarily by utilizing data from existing Columbia River estuary and plume studies. Existing studies monitored physical conditions including water temperature, salinity, and current at various depths using anchored buoys in the Columbia River estuary and plume (Oregon Graduate Institute Study). The population of salmonid predators (Pacific hake, Pacific mackerel, jack mackerel) along with the abundance of alternative prey for those predators and for salmonids (northern anchovy, Pacific herring, and Pacific sardine), was evaluated by surface trawling in the Columbia River plume at about 10 day intervals, with predator stomach contents collected during this study analyzed to determine if they were eating salmonid smolts (ongoing NOAA Predator/Prey Study funded by BPA). Populations estimates of birds and their diets are available from ongoing research in the Columbia River estuary (University of Oregon Study funded by BPA).

Adult returns from serial releases (when complete) will be evaluated and correlated with the biotic and abiotic conditions smolts encountered in the Columbia River estuary and nearshore ocean environment. Adult returns will be monitored at about a 50% sample rate in the lower Columbia River terminal area gillnet fishery by ODFW. In addition, adult return rates of PIT-tagged fish passing Bonneville Dam or transported and released below Bonneville Dam will also be compared to the CEDC fish with similar time of ocean entry.

Statistical Analyses

When adult returns are complete, we will conduct a statistical analysis similar to that of Logerwell et al. (2003) who were able to build a generalized additive model (GAM) of ocean physical variables that accounted for 75% of the variation in annual coho salmon marine survival. Initial analysis of explanatory variables versus SAR will be conducted (using linear and nonlinear regression) and then a full model incorporating important variables will be built using a GAM. We will first build and test a model using data from initial returns (our 2002 releases and 1999-2002 PIT-tagged Snake River transported fish) and make predictions about survival of 2003 releases. Once final SAR data from 2003 are available, we will incorporate these data into the model and test the model against future returns. We will continue to fine tune the model throughout the study period as more adults return. Correlations among explanatory variables will be checked; a variable will not be added to the model if it is too highly correlated with another variable already in the model.

Limitations and Expected Difficulties

The degree of success of this project will be primarily contingent upon three factors

1) sufficient SARs from marked released groups, and

2) collection of sufficient information on physical and biological conditions in the estuary and plume from other studies.

Correlating meaningful biotic and abiotic indicators with salmonid smolt survival is a challenging task because of the complexity, variation, and difficulty in sampling the marine environment.

Biological Effects

Conducting this study will not adversely effect ESA-listed stocks and will not require any ESA permitting.

Technology Transfer

Information acquired during the proposed work will be transferred to the fisheries community by presentations at meetings and workshops, by personal contact, by annual and final reports to the U.S. Army Corps of Engineers, and through scientific publications.

KEY PERSONNEL AND DUTIES

William Muir and Robert Emmett	Principal Investigators
Steven Smith, Richard Zabel, and Benjamin Sandford	Statisticians

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Table 1. Release dates, mean fork length (mm), percent mortality while acclimating, and numbers of PIT-tagged yearling Chinook salmon released from Blind Slough in the Columbia River estuary, 2002 through 2006.

Release date	Fork length (s.e.)	Percent mortality	Number released
2002			
10 April	140 (0.9)	0.38	24,887
19 April	139 (0.9)	0.77	23,871
30 April	139 (0.8)	0.36	24,164
10 May	145 (0.9)	0.21	24,441
20 May	142 (0.8)	0.18	23,536
30 May	150 (0.7)	0.48	24,403
2003			
9 April	136 (0.8)	1.63	18,508
18 April	139 (0.6)	5.05	22,353
28 April	139 (0.7)	4.69	21,236
7 May	138 (0.8)	7.11	20,801
16 May	140 (0.7)	2.24	20,158
27 May	142 (0.7)	1.22	20,319
2004			
7 Apr	143 (0.8)	0.43	16,168
16 Apr	152 (0.7)	0.37	27,359
26 Apr	147 (0.8)	3.10	27,644
6 May	150 (0.7)	0.83	27,482
17 May	155 (0.7)	8.63	24,488
20 May	---	12.60	23,508
2005			
6 Apr	140 (0.6)	0.64	25,646
15 Apr	142 (0.6)	0.71	25,344
25 Apr	140 (0.6)	1.28	25,182
4 May	146 (0.6)	2.98	24,747

Table 1. Continued.

13 May	147 (0.6)	6.73	23,051
23 May	147 (0.6)	6.66	23,115
2006			
6 Apr	133 (0.5)	0.21	28,099
17 Apr	136 (0.5)	0.32	27,440
27 Apr	139 (0.5)	0.12	27,459
5 May	142 (0.5)	0.21	27,831
16 May	144 (0.6)	0.22	27,493
24 May	141 (0.5)	0.27	25,851

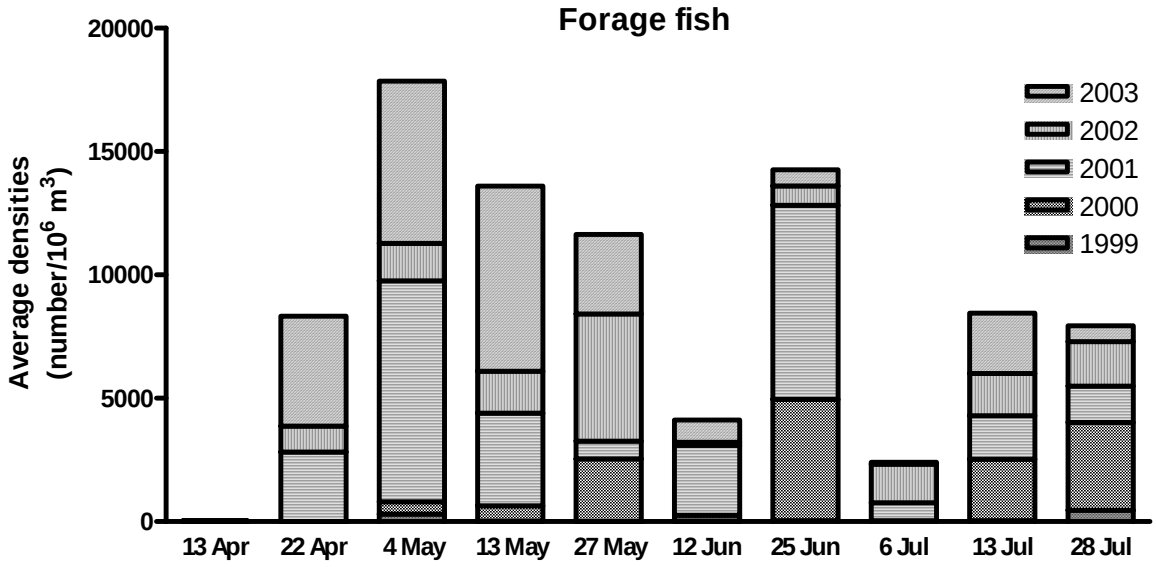

Figure 1. Abundance of forage fish off the mouth of the Columbia River 1999-2003.

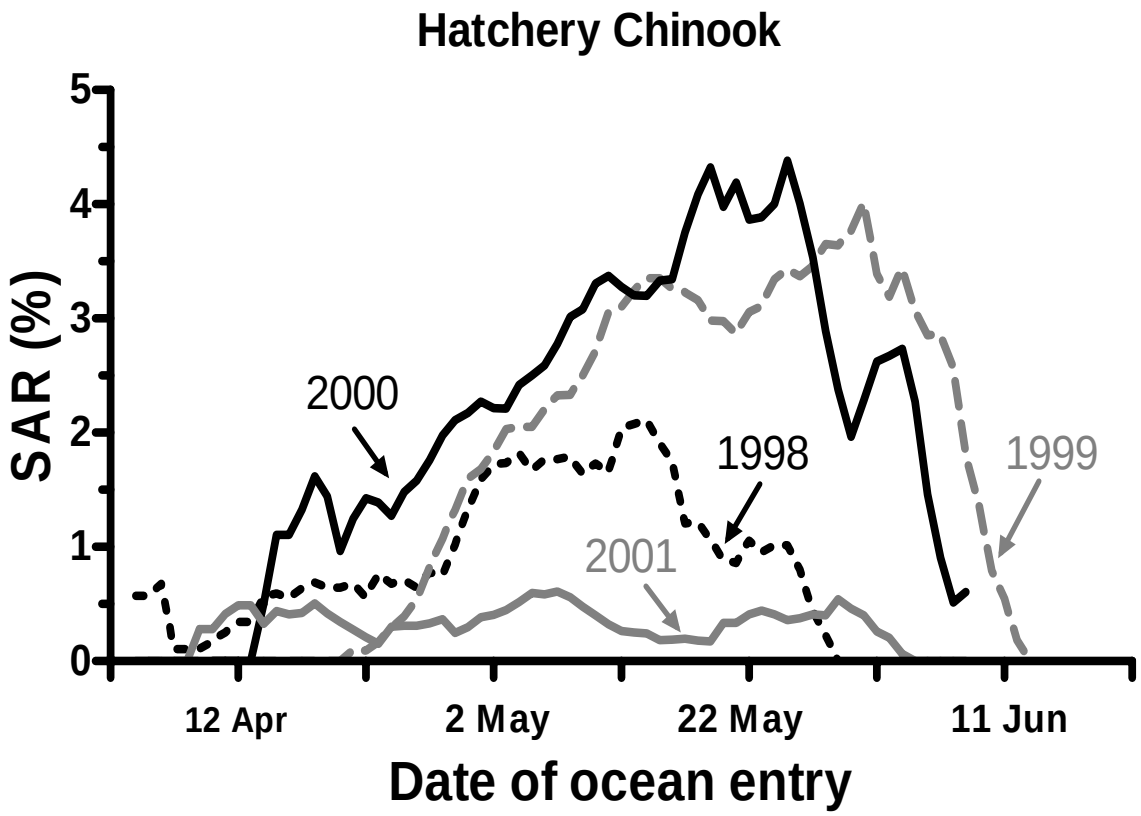

Figure 2. Temporal change in SARs (5-day running average) of PIT-tagged hatchery Snake River spring-summer Chinook salmon transported from Lower Granite Dam or Little Goose Dam, 1998-2001.

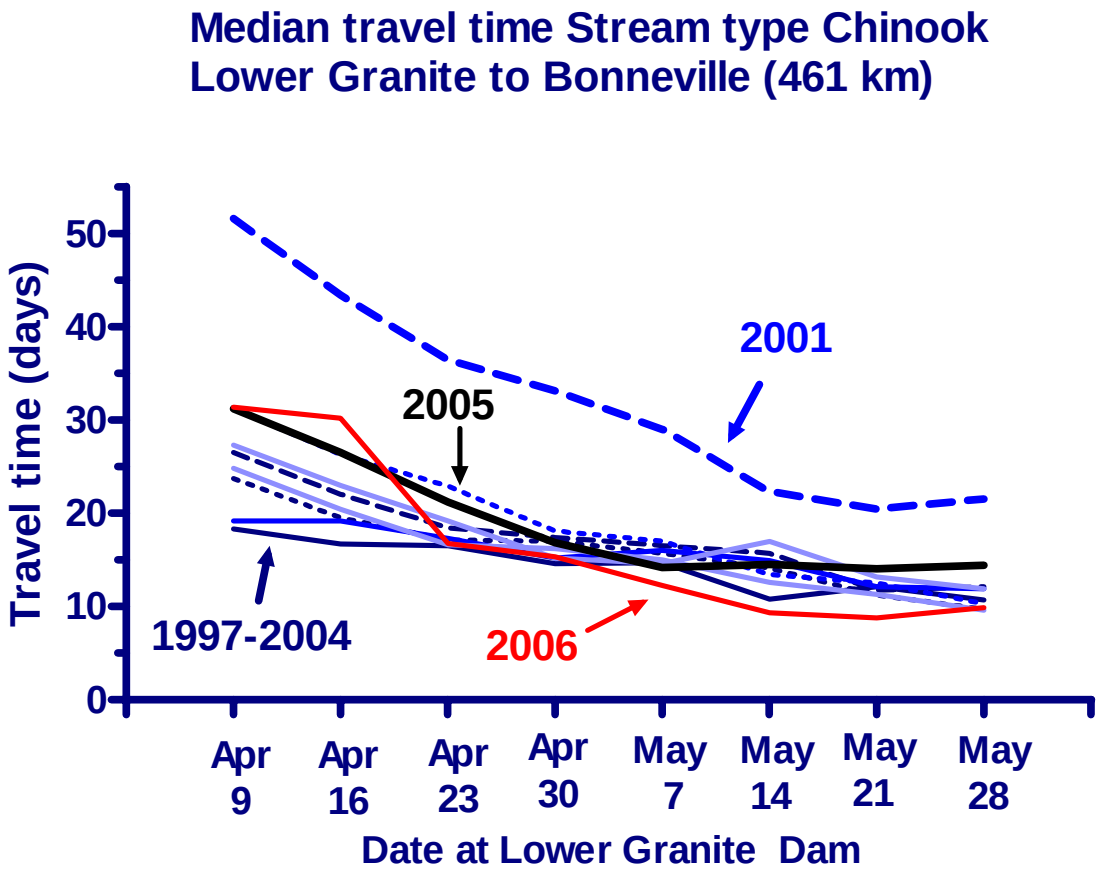

Figure 3. Median travel time (days) between Lower Granite and Bonneville Dams for PIT-tagged yearling Chinook salmon, 1997-2006.