PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Ocean Survival Of Juvenile Salmonids In The Columbia River Plume

BPA project number: 9801400
Contract renewal date (mm/yyyy): 5/1999 ☐ **Multiple actions?**

Business name of agency, institution or organization requesting funding
National Marine Fisheries Service, Northwest Fisheries Science Center

Business acronym (if appropriate) NMFS/NWFSC

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NPPC Program Measure Number(s) which this project addresses
Measure 4.2, 5.0E, 5.0F

FWS/NMFS Biological Opinion Number(s) which this project addresses
NMFS Biological Opinion Sec. VIII. A. 13.

Other planning document references
Proposed Recovery Plan for Snake River Salmon (U.S. Dept. Commerce 1995), Task 2.11a: Investigate the environmental requirements of juvenile salmonids in the estuary and nearshore ocean. Both the ISG (1996) and NRC(1996) noted that ocean conditions and interactions between ocean conditions and juvenile salmonids must be considered when undertaking salmon recovery plans. The relationships between ocean conditions and salmon survival are needed to accurately evaluate freshwater restoration efforts.

Short description
Measure the effects of time of entry, smolt quality, food habits, growth, and health status of juvenile coho and chinook salmon on survival in relation to oceanographic features of the ocean environment associated with the Columbia River plume.

Target species
Stream and ocean-type chinook and coho salmon

Section 2. Sorting and evaluation

Subbasin
Ocean/estuary

Evaluation Process Sort

CBFWA caucus	Special evaluation process	ISRP project type
Mark one or more caucus	If your project fits either of these processes, mark one or both	Mark one or more categories
☒ Anadromous fish ☐ Resident fish ☐ Wildlife	☒ Multi-year (milestone-based evaluation) ☐ Watershed project evaluation	☐ Watershed councils/model watersheds ☐ Information dissemination ☐ Operation & maintenance ☐ New construction ☒ Research & monitoring ☐ Implementation & management ☐ Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

Umbrella / sub-proposal relationships. List umbrella project first.

Project #	Project title/description

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship
9600600	PATH	Study will contribute empirical data on factors influencing estuarine and ocean survival for use in life cycle models
9702600	Marine predators of salmon	Complements partitioning of survival factors

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?
1998	Established a long-term plume monitoring station.	Yes
1998	Collected ocean samples to assess nutrient and zooplankton composition in the Columbia River plume and along the Newport line.	Yes
1998	Collected juvenile stream and ocean-type chinook and coho salmon in and out of the Columbia River plume in June and September, measured, and acquired tissue samples to characterize growth and bioenergetic status.	Yes
1998	Characterize and forecast the spatial and temporal physical variability of the Columbia River plume and vicinity, in support of objectives 2-5	Yes

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Physical characterization of Columbia River plume, estuary, and near-shore environment	a	Integrated numerical modeling and real-time data acquisition of circulation and physical water properties in the Columbia River estuary
		b	Integrated vessel observations and numerical modeling of circulation and physical water properties in the Columbia River plume and nearshore environment
		c	Analysis of variability of present and historical river flow data, and estimation of suspended particulate matter (SPM) using an existing rating curve
2	Biological characterization of Columbia River plume and near-shore environment	a	Measure nutrient concentrations (nitrate, phosphate, silicate), phytoplankton biomass and zooplankton abundance and species composition at monthly intervals in the plume and nearshore environments
		b	Compare results to historical data collected off the central OR and WA coasts and in the plume in 1970s and 1980s (and 1996 and 1997 off Newport) to determine if the plume and adjacent continental shelf waters have changed with respect to nutrient dynamic
		c	Relate variations in seasonal cycles of plankton abundance to interannual variations in date of spring transition, coastal upwelling strength and size of plume, from historical data and for data collected during this proposed study
3	Assess timing of entry as a factor related to salmon survival	a	Collect juvenile salmon in river or at hatchery release sites, measure, and acquire tissue samples for bioenergetic quality assessment
		b	Assess growth characteristics of release groups and smolt quality
		c	Acquire return rates for each release group
		d	Identify relationships among time of entry, smolt condition, and oceanographic conditions in the estuary and nearshore ocean identified in Objectives 1 & 2.
4	Assess salmon growth and health in nearshore ocean habitats off the Columbia River	a	Collect fish, measure, and acquire tissue samples to measure growth rates, bioenergetic status, and pathogen load and prevalence
		b	Assess growth characteristics and bioenergetic status of juvenile coho and ocean and stream-type chinook salmon

		c	Identify relationships among growth, health, and nearshore ocean conditions identified in Objectives 1 & 2, and microhabitats of the ocean in relation to the Columbia River for juvenile coho and ocean- and stream-type chinook salmon
		d	Conduct retrospective analysis of juvenile coho salmon growth during ocean age 1 and 2 using data collected by Fisher and Pearcy (1988) and data collected from this study
		e	Identify relationships among growth and health status between naturally-produced and hatchery-reared juvenile salmon and nearshore ocean conditions identified in Objectives 1 & 2 and microhabitats of the ocean in relation to the Columbia River for j
5	Assess juvenile salmon food habits	a	Collect stomach contents of juvenile salmon in the nearshore ocean off the Columbia River
		b	Perform stomach analysis
		c	Identify relationships between food habits, ocean conditons, and prey fields (identified from Objectives 1 & 2) for juvenile coho and ocean- and stream-type chinook salmon
		d	Identify relationships between food habits of juvenile salmon and microhabitats of the nearshore ocean off the Columbia River
6	Report results	a	Create text, tables, and figures and report results

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	1/2000	10/2004			39.00%
2	4/2000	9/2004	Quantify variation in zooplankton composition of the Columbia River plume		17.00%
3	4/2000	9/2004	Temporal variation in biological condition of outmigrating juvenile salmon prior to estuary/ocean entry		11.00%
4	5/2000	9/2004	Assess temporal and spatial variation in growth and bioenergetic condition of salmon in and out of the plume environment		21.00%
5	5/2000	9/2004	Assess juvenile salmon food habits in relation to variation in physical and biological ocean conditions		7.00%
6	6/2000	10/2004			5.00%
				Total	100.00%

Schedule constraints

ESA Section 7 permit for collection of juvenile salmon in the nearshore ocean. Charter of suitable vessel for collection of juvenile salmon in the nearshore ocean.

Completion date

2010 (10 year study)

Section 5. Budget

FY99 project budget (BPA obligated): $288,000

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel	Includes cost for personnel to run the R/V Sea Otter and 1 FTE equivalent (GS-9)	%11	87,300
Fringe benefits		%4	30,600
Supplies, materials, non-expendable property		%5	40,000
Operations & maintenance		%0	1,500
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		%5	40,000
NEPA costs		%0	
Construction-related support		%0	
PIT tags	# of tags:	%0	
Travel		%1	5,000
Indirect costs		%4	36,600
Subcontractor	Oregon Graduate Institute	%38	315,000
Subcontractor	Oregon State University	%5	40,000
Subcontractor	CIMRS, Hatfield Marine Science Center	%13	110,000
Subcontractor	Surface Trawling Vessel	%13	105,000
Other	Overtime	%2	15,000
		TOTAL BPA FY2000 BUDGET REQUEST	$826,000

Cost sharing

Organization	Item or service provided	% total project cost (incl. BPA)	Amount ($)
NMFS	Labor	%12	112,600
		%0	
		%0	
		%0	
		Total project cost (including BPA portion)	$938,600

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget	$830,000	$830,000	$700,000	$600,000

Section 6. References

Watershed?	Reference
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PART II - NARRATIVE

Section 7. Abstract

Interannual variation in ocean recruitment of salmon is high and thought to be associated with variation in nearshore ocean conditions. The nearshore ocean environment, particularly that associated with the Columbia River plume, is a critical habitat to outmigrating juvenile salmon. Several investigators have suggested that survival during the first year of ocean life is a key to establishing year-class strength. In the case of salmonids originating in the Columbia River Basin, survival success hinges on the complex interaction of smolt quality and the abiotic and biotic ocean conditions at the time of entry and during their first year of ocean existence. We hypothesize that variation in the physical and biological conditions of the nearshore environment, particularly that

associated with the Columbia River plume, affects overall survival of Columbia River stocks. We further hypothesize that primary factors driving the variation in the nearshore environment include (a) food availability and habits and (b) time of entry, smolt quality, and growth and bioenergetic status at the time of entry and during the first growing season in the ocean and (c) predation (a companion study on predation on juvenile salmon is ongoing). We propose to characterize, over a 10-year period, the physical and biological features of the nearshore ocean environment with real-time and modeling projections of the Columbia River plume as it interacts with the coastal circulation regime, and to relate these features, both spatially and temporally, to variation in salmon health, condition, and survival.

Section 8. Project description

a. Technical and/or scientific background

Seasonal and annual fluctuations in mortality of salmon in the marine environment is a significant source of salmonid recruitment variability. Approximately half of all preadult (egg through juvenile stage) salmon mortality occurs in the marine environment (Bradford 1995). Variability in ocean salmon survival is very high, with annual mortality ranging over three orders of magnitude (PSFMC unpublished data 1995). Many abiotic and biotic ocean conditions are highly variable as well, both within and between years, and undoubtedly account for the range of juvenile salmon ocean survival. Long-term regime shifts in climatic processes also affect oceanic structures and can produce abrupt differences in salmon marine survival and returns (Francis and Hare 1994). The latest regime shift occurred in the late 1970s and may be a factor in reduced ocean survival of salmon in the Pacific Northwest (PNW) and increased survival in Alaska (Mantua et al. 1997).

Unlike in the freshwater environment, the physical and biological mechanisms and factors causing marine mortalities of salmon are largely unknown. Predation, inter- and intra-specific competition, food availability, smolt quality and health, and ocean conditions all likely influence survival of salmon in marine environments. Although direct measurements of salmonid mortality in the marine environment are desirable, they are difficult to acquire because of the problems with capturing and following specific salmonid stocks or groups in the ocean. In this proposal we investigate the use of measures of the condition and health of individual salmon (which integrate life history characteristics with ocean conditions) to predict or forecast marine survival of juvenile salmon. If verified, this information would be extremely valuable to salmonid managers to predict and forecast survival potential as a result of "ocean conditions."

Increasing our understanding of estuarine and nearshore ocean environments, and the role they play in salmonid survival, could provide management options to increase adult returns. For example, examination of adult returns from transportation studies conducted at Lower Granite Dam in 1990 showed that adult salmonid returns varied dramatically through the seasons. Smolts transported during the early part of the migration season in 1990 apparently had much lower survival than those transported during the later part for both hatchery and wild fish (Matthews et al. 1992). Progressively enhanced characterization of the space-time variability of the environmental conditions that smolts encounter when they enter the estuary and nearshore ocean and the eventual “good” and “poor” survival of these groups will allow us to identify if or what estuarine and ocean biotic and abiotic conditions are correlated with various ocean survival levels. Managers could potentially use this information to determine optimal times for hatchery releases, alter river flow regimes, 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.

Primary attributes in establishing salmonid recruitment success are mortality of preadult stages and adult reproduction. Mortality of preadult stages is influenced by fish health (growth, diseases, ocean conditions, etc.), life history characteristics (e.g., migrations), predation, and other factors. Fish health is generally highly pliable, integrating various habitat conditions, and it can be used as an indicator of ecosystem health. Growth rate, for example, not only reflects the fish's health and condition, but influences survival and reproductive output (Brandt et al. 1992). The general scientific paradigm is that faster-growing fishes proceed through successive life stages sooner, acquire a greater chance of survival, and higher fecundity at reproduction (Bakun 1996). As such, fish health, growth rate, size, and size at age in the preadult stages represent parameters that can be used to identify the influence of natural and anthropogenic ocean conditions affecting salmonid marine survival.

There are numerous observations linking the health of marine fishes with survival and reproductive potential within the population (Sissenwine 1984, Brandt 1992). Factors affecting these relationships include density-independent (physical) and density-dependent (biological) processes. Environmental effects alter growth, survival, and reproduction, and ultimately population recruitment (Friedland and Haas 1996, Gudjonsson et al. 1995, Unwin 1997, Hinch et al 1995, Fitzhugh et al. 1996, Marschall and Crowder 1995). Fundamental among these observations is the link between the quality (health) of the individuals (based on a bioenergetic assessment) and the "health" of the population (Krohn et al. 1997, Lambert and Denis-Duntil 1997). An additional link focuses on the relationship between growth and mortality rates, which have been shown to scale through allometric (length-weight) relationships (Peterson and Wroblewski 1984, McGurk 1996, Lorenzen 1996). In natural (unfished) populations, growth and mortality rates decrease with increasing size. Factors which slow fish growth extend the period of higher mortality rates and reduced population size. This growth/mortality relationship exists for both within and between species (Fenchel 1974, Banse and Mosher 1980) and includes most marine salmonid species (McGurk 1996, Holtby et al. 1990). Recent observations of decreasing size trends among adult salmonids (Bigler et al. 1996) may account, in part, for lower survival proportions among some species of salmonids currently observed in the Pacific Northwest.

HYPOTHESES

SURVIVAL and GROWTH RATE: The first few weeks-to-months of ocean life is a critical life history phase for recruitment success of salmonids (Pearcy 1992, Unwin 1997, Unwin and Glova 1997, Heath et al. 1997). As such, survival of precocious males or "jack" salmon (one summer in the ocean) correlates closely with eventual adult salmon returns from the same year class (Pearcy 1992, Gudjonsson et al. 1995). We suggest that survival is likely correlated with fish condition; however, the biological mechanisms whereby fish condition (size, growth rate, health, etc.) translate into good ocean survival are unknown**.** Growth rate during migration is evidently more important than actual smolt size **--** Dickhoff et al. (1995) and Beckman et al. (1997) showed that outmigrating juvenile salmon smolts with the highest growth rates at the time of release (and not necessarily the largest smolts) survived better than juveniles exhibiting lower growth rates. Holtby et al. (1990) showed that juvenile coho salmon with higher annual growth rates generally survived better than fish with lower growth rates, and attributed higher growth rates to an ocean environment with favorable conditions (compared to years with poorer conditions). **We hypothesize that growth of juvenile salmon during the first year of ocean residence is related to survival.**

CHANGING RIVER FLOWS: Flow regulation, water withdrawal and climate change have reduced the average and altered the seasonality of Columbia river flows, and sediment discharge, and have changed the estuarine ecosystem (NRC 1996; Sherwood et a. 1990; Simenstad et al. 1990,1992, Weitkamp et al. 1995). Annual spring freshet flows through the Columbia River estuary are ~50% of the traditional levels that flushed the estuary and carried smolts to sea, and total sediment discharge is ~1/3 of 19th Century levels. Decreased spring flows and sediment discharges have also reduced the extent, speed of movement, thickness, and turbidity of the plume that extended far out and south into the Pacific Ocean during the spring and summer (Barnes 1972; Cudaback and Jay 1996, Hickey et al. 1997). This freshwater "plume" likely provided a high turbidity refuge from predation, fronts and eddies where prey became concentrated, and a stable habitat for northern anchovy spawning (Richardson 1981, Bakun 1996). A strong, quickly moving plume also helps juveniles move rapidly offshore through potential heavy estuarine and nearshore predation. The overall impacts on nearshore marine ecosystems of these alterations to the river and the degree to which the development of the Federal Columbia River Power System (FCRPS) and other natural and anthropogenic changes have affected the survival of juvenile and adult salmon are presently unknown.

The Columbia River estuary and plume and adjacent marine waters provide critical habitat that affects health, growth, and survival of outmigrating juvenile salmon and subsequently affects recruitment success. Beamish et al. (1994) found that the plume of the Fraser River affected survival of coho, and chinook salmon, with lower flow years typically supporting higher productivity and salmon survival than high flow years. The mechanisms by which the Columbia River estuary and plume affect juvenile survival have not been quantified, but likely include provision of food, refuge during transport away from coastal predation, and improvement of estuarine conditions for sub-yearling fish. Since the Columbia River estuary and plume have been significantly altered from historical conditions and hatchery stocks may be differently affected than natural stocks, the system's altered state likely contributes to the overall reduction of salmon. The impact of spring river flow and suspended particulate matter (SPM) transport on salmon production in the estuarine and coastal plume environment may be large, as flows in most years may now be sub-optimal for salmon production. **We hypothesize that the health, condition, and survival of Columbia River salmon is better under high May-June river flow and SPM input to the estuary and plume.** We propose to test this hypothesis by determining the importance of estuarine characteristics and the shape, magnitude, speed of movement, and biological characteristics of the Columbia River plume to the survival of out-migrating juvenile salmonids.

OCEAN CONDITIONS: "Ocean conditions" refers to the state of the ocean in terms of bio-physical parameters that affect salmonid survival. However, a mechanistic understanding of relationships between "ocean conditions" and salmon survival is lacking. The challenge to fishery oceanographers is to **define** what it is about the ocean that is good for salmonids in some years and bad in others. Equally important is to understand why, on climate time scales, the ability of the Gulf of Alaska and the California Current ecosystems to produce salmonids is out of phase (Mantua et al., 1997). A hypothesis explaining the food resource side of this issue (Gargett 1997) suggests that water-column stratification or stability controls NE Pacific coastal primary productivity and is one of the key factors in these decadal-scale oscillations. Under this theory, optimum stability windows shift north or south on decadal time scales (the Pacific Decadal Oscillation or PDO). When stratification throughout the region is high, the optimum stability window moves north. Light levels in waters off the US West Coast are high, but nutrients are limiting. Even newly upwelled water may have low nutrient concentrations. When stratification throughout the region is low, the optimum stability window shifts to the south. More nutrient are available and primary productivity increases off the US West Coast. This argument does not include effects of predation or water temperature (aside from the thermal contribution to stability), and major river plume areas like the Columbia and Fraser do not fit simply into this framework – nutrients are never totally exhausted in the estuary outflow (Small et al. 1991).

We suggest that low river inflow is unfavorable for juvenile salmonid survival despite some availability of nutrients from upwelling, because of: a) reduced turbidity in the plume (increasing foraging efficiency of birds and fish predators), b) increased residence time of the fish in the estuary and near the coast where predation is high, c) decreased incidence of fronts with concentrated food resources for juvenile salmonids, and d) reduced overall total secondary productivity based on upwelled and fluvial nutrients. Reduced secondary productivity affects not only salmonid food sources but focuses predation by other fishes and birds on the juvenile salmonids.

Other factors related to interannual fluctuations (e.g., el Niño Southern Oscillation or ENSO effects) that need consideration are ocean and river temperatures. These fluctuations may influence timing of smolt arrival and their condition as they enter the ocean.

Little work has been done to correlate salmonid growth and survival with plume biological and physical conditions. Our work will make significant contributions in this area. Our approach will focus on salmonid growth and condition (a new approach), and to compare growth/condition and ocean survival data to data on ocean food web structure (e.g., nutrient, plankton and neuston abundance) and other biological and physical phenomena. **We hypothesize that the condition of juvenile salmon during the first year of ocean residence is related to ocean conditions and food web structure.** Toward this goal, we propose new measurements as well as a strong retrospective component in which we will assemble phytoplankton, zooplankton, euphausiid, and larval fish data from the 1970s, 1980s, and 1990s which can be used to describe ocean conditions from a food chain perspective. We have zooplankton samples and data from several past ENSO events (1972/73, 1983, 1991/92, and 1997/98) and will be able to compare salmon survival and food web structure from these times as well (Brodeur and Pearcy 1990).

The idea that Columbia River salmonid survival in the coastal ocean should be directly related to river flow is amply supported by experience with anadromous and other fish in San Francisco Bay and in the former Soviet Union (Rosengurt and Haydock 1981, Rosengurt et al. 1987, Rosengurt and Hedgepeth 1989). Moreover, productivity of stocks at most levels of the food chain in San Francisco Bay increase with Sacramento River flow (Kimmerer 1991, Jassby 1992). Jay and Simenstad (1996) have provided a mechanism relating flow diversion in the Skokomish River and estuary (a shallow deltaic system) to declines in salmonid stocks in the system, once the most productive in Hood Canal. In these and numerous other cases, water withdrawal has had adverse effects on fish stocks, including anadromous fishes. The mechanisms vary, but in every case examined in detail the decline in stocks has included a component related to altered or lost oceanic and estuarine habitat. There is every reason, then, based on evidence from other systems, to believe that there is a connection between Columbia River estuarine and plume conditions and salmonid survival. It is this connection that we plan to elucidate.

TIMING OF OCEAN ENTRY: Juvenile salmonids (except for some chinook salmon stocks) have historically entered the ocean after the upwelling season and plankton production has begun, and Columbia River flows are high. If upwelling is weak relative to when salmon arrive at sea, ocean temperatures may be high, turbidity low, plankton biomass low, plume flow either west or north, and feeding conditions poor. Also, the survival of juvenile salmonids at sea may depend on the match/mismatch between the arrival of smolts in the spring and the arrival of predators, notably hake and mackerel. These predators usually arrive in Oregon waters by May. However, their arrival time is probably dependent upon weather patterns and currents. Pearcy (1992) articulated this research need when he asked, "When is the best time (for salmonids) to enter the dangerous ocean environment?". **We hypothesize that survival of juvenile salmon is related to timing of arrival into the estuary and nearshore ocean, and to condition of juveniles and to ocean conditions at the time of arrival.**

b. Rationale and significance to Regional Programs

The century-long decline in abundance of salmon in the Pacific Northwest is the result of the complex interaction of overharvest, habitat loss (e.g., hydropower development - including regulation of river discharges, agricultural development, logging, urbanization, etc.), over-reliance on hatchery production, natural variation in climatic and oceanic conditions, and regulation of river discharges. Over the past 2 decades, the decline has accelerated, leading to sharp reductions in harvest, including complete closure of commercial coho ocean salmonid fisheries off the coasts of Washington and Oregon in 1994, and, as a last resort, listings of selected populations of salmonids under the Endangered Species Act.

A comprehensive program to rebuild anadromous salmon runs must focus on all life history stages and all opportunities to increase salmonid survival. However, efforts to date have largely been limited to the freshwater life stages, with attempts to rehabilitate and mitigate for losses occurring primarily in the riverine environment. A broad approach to reestablish the sustainability of salmon stocks by focusing on the entire salmonid life cycle is needed (NRC 1996). In particular, research into the transition period of juvenile salmonids from freshwater to seawater is clearly warranted. If the marine environment affects recruitment success in a predictable manner (relative to specific measurable variables), then measuring, predicting, and reducing salmonid losses in the marine environment may be possible. This information would strongly complement freshwater-related salmonid restoration efforts by providing measures of project success using adult return data that would not be confounded by fluctuations in marine mortality.

Understanding interactions between physical and biological attributes in the marine environment and long-term trends in coastal salmon production will assist with the development of effective tools (e.g., models) for forecasting salmonid survival. Such tools are essential for rational harvest management. Many fisheries managers believe that salmon populations can not be rebuilt by just improving freshwater habitats and/or improved hatchery practices. Estuarine and nearshore ocean research is critical to developing information to effectively manage Pacific salmon populations (Emmett and Schiewe 1997).

All proposed freshwater habitat rehabilitation and restoration efforts will operate within the context of uncertainty associated with environmental variability and environmental change. The NRC (1996) report stated that variations in ocean conditions powerfully influence salmon abundance. Since at the present time ocean conditions in the Pacific Northwest region are thought to be poor, the perceived low ocean survival might explain, at least in part, the limited success to date of habitat restoration efforts. We are just now beginning to understand what happens to salmon during the major part of their lives—the years spent at sea; new insights already demonstrate that variations in salmon abundance are linked to phenomena on spatial and temporal scales that biologists and managers have not previously taken into account (the entire North Pacific Basin on decadal time scales). Given that the current declines in productivity of the California Current and related declines in chinook and coho stocks may be part of a natural cycle, the declines may reverse themselves. Thus salmon might return without human interventions. Will we have sufficient understanding in place that will allow managers to decide the extent to which sound management practices should be credited or whether salmon fortunes were due to a reversal in natural climate cycles?

Finally, it should be noted that if improvements to habitat do not result in immediate improvements in stock size, we must be able to demonstrate if ocean conditions are part of the problem.

c. Relationships to other projects

This study will complement ongoing studies evaluating the influence of the nearshore ocean environment in and around the Columbia River on health and survival of juvenile salmon, one funded by BPA, several others funded from an initiative within NMFS/NOAA. One study (BPA Supported) will work to identify the contribution of predation to early ocean mortality and recruitment success of juvenile salmon. Two other studies, funded by an ESA-funded inititiative seeks to understand the contribution of disease and the availability of alternate prey (anchovies primarily) as factors affecting survival of juvenile salmon in estuaries and the nearshore ocean environment of the Pacific Northwest. These studies, when taken in total, will provide one of the most comprehensive evaluations of the influence of trophic interactions (predator, prey, disease) on the growth, health, and survival of juvenile salmon in relation to the abiotic and biotic structure of the ocean. Information from this study will be applicable to PATH by providing critical data for life cycle models and evaluation from an ecosystem perspective for evaluating effects of mitigation activities in freshwater dedicated to recovery efforts. Information generated from this study could also be used to help parameterize the newly developed NerkaSim model (Rand et al. 1997), a computer program used to simulate and visualize the life history of Pacific salmon in a dynamic environment. Because the model executes a spatially explicit, individual based Pacific salmon model based on the sockeye salmon energetics, parameterizing the model with growth and mortality characteristics specifically for chinook and coho salmon during their first year of ocean life would help to develop its application for use on the Columbia River relevant to all the major species from this system.

The following projects will provide information on passage times of pit-tagged groups of salmonids as they pass Bonneville Dam or information when a estuarine release group reaches the ocean (Clatsop Economic Development Committee releases). These data will permit us to identify when a particular group of fish entered the ocean and thus identify the relationship between time of ocean entry, oceanographic conditions, fish health, and salmonid ocean survival.
BPA projects include: 96-020 (Comparing survival rates study of hatchery produced chinook salmon), 94-034 (Assessing summer/fall chinook restoration in the Snake River Basin), 91-029 (Identification of spawning, rearing, and migration of fall chinook salmon in the Columbia River Basin), 93-290 (Survival estimate of juvenile salmonid through dams and reservoirs), Nutritional states of salmon and steelhead in the Columbia River Basin - Dr. Marshall Adams PI, Clatsop Economic Development Committee : Coded-wire tagged release groups, and the Corps of Engineers Projects (Transportation Evaluation Study)

Our proposed research will benefit from research and monitoring being funded by the U.S. GLOBEC program (NSF and NOAA funding) and the PNCERS program (NOAA funding). GLOBEC (Global Ocean Ecosystem Dynamics) has just initiated their northeast Pacific research program. One of the funded projects involves monitoring physical ocean conditions and plankton abundances off Newport, Coos Bay and northern California and comparing present conditions to those observed in the 1970s. Funding level is approx. $500K per year. Cruises are made five times per year and stations from 1 to 100 mile to sea are sampled. These cruises will provide data on hydrography, water clarity, nutrients, chlorophyll and zooplankton at stations inside the plume, within the plume and offshore of the plume. Two current meter moorings have been deployed on the continental shelf off Newport and Coos Bay as well. One of us (Peterson) is a co-PI on that project. In addition, Peterson serves on the Northeast Pacific GLOBEC Research Coordination Committee. The purpose of that committee is to help coordinate ALL northeast Pacific oceanographic research and monitoring efforts.

The U.S. GLOBEC program will soon release an Announcement of Opportunity for oceanographic process studies to be conduced in the region of Oregon and northern California. One aspect of that announcement that is germaine is that GLOBEC is about to begin a major study of the distribution, abundance, growth, feeding and survival of juvenile salmonids in the coastal zone extending from approximately Coos Bay south to Eureka. The salmon work will be carried out over a four year period (1999-2003) at the same time as our work off the Columbia and will be supported by satellite observations, hydrographic measurements and numerical modelling studies of circulation patterns. Thus, over a four year window, BPA and GLOBEC together will be gathering data on salmonid ecology from Gray's Harbor to Eureka. Since GLOBEC scientists are focused on similar questions as our BPA project, the synergy of the two projects is quite high allowing a unique opportunity to compare and validate findings from the BPA plume study.

The PNCERS program (Pacific Northwest Coastal Ecosystem Region Study includes physical and biological monitoring cruises and current meter moorings off Coos Bay and Willapa Bay. Much of the PNCERS efforts are focused on very nearshore processes, thus the moorings and cruises off Willapa Bay will have the greatest application to our proposed work. The lead PI on the Washington state work is Barbara Hickey, who maintains close ties with the GLOBEC project.

Two other projects that are related to our proposed research include annual coastwide trawl surveys conducted by the National Marine Fisheries Service of stocks of Pacific whiting (in July) and groundfish (Dover sole, sablefish and thornyheads; in autumn). During those cruise CTD profiles are made and currents are measured with ship-board ADCP. These cruises produce an annual snapshot of sea surface salinity which will give us fairly synoptic maps of the shape and extent of the plume. The other project is a survey of anchovy and sardine eggs/larvae carried out by R. Emmett (NMFS) with ESA funding. His survey grid extends from 1 to 100 miles from shore and from Willapa Bay south to Cape Blanco (south of Coos Bay). He too does CTD measurements and can produce snapshots of the shape and extent of the plume. These data are readily available to us.

d. **Project history** (for ongoing projects)

Sampling of juvenile salmon and associated oceanographic measurements in and out of the Columbia River plume were conducted in the spring-summer of 1998 as the scaled down version of BPA project #9063. Because the ocean conditions and salmon survival were likely to be strongly influenced by the 1997 el Nino, a concerted effort was made to assemble the necessary gear and contract a trawling vessel to conduct the work. A Nordic 264 surface trawl (dimensions of 20 x 30 x 175m; Net Systems, Inc.) was purchased and the R/V *Sea Eagle* was contracted to conduct the surveys. Surveys along 8 transects from Newport, OR to La Push, WA were conducted during June and in September 1998. Approximately 240 juvenile ocean and stream-type chinook and coho salmon were sampled during each 10-day survey period. The majority of juvenile salmon were ocean-type chinook, but significant numbers of each target species were acquired during each cruise. Fork lengths and scales were obained on the vessel, and the fish frozen and transported to a land base, to obtain total and tissue weights and and tissue samples for bioenergetics, genetic assessment of stock composition, growth, stomach contents, parasite load, and CWT's. A majority (>70%) of the juvenile salmon were captured in the Columbia River plume and south, and few salmon were caught further than 10km off shore. In addition, few salmon were captured in surface waters that exceed 13-14° C. The associated fish community was coincidentally sampled. Over 25 different fish species were captured during each survey and included herring, anchovy, sardines, hake, Pacifc and Jack makerel, sharks, barracuda, rockfish, shad, and squid. Size ranges for important prey and predator species were also recorded. We feel that quantity and composition of our catches indicate that we are effectively sampling the surface ocean waters. Cruise reports are currently being assembled and relevant analyses are being conducted.

Further, in support of the project objective to characterize the physical features of the plume, we have established and partially instrumented a long-term plume monitoring station, located at about 100m depth, south of the Columbia River mouth. In addition, we have extended the Columbia River modeling system by implementing and initiating tests of the 3D baroclinic model of the Eastern North Pacific that will provide ocean conditions for the plume and near-shore model and have continued verification of the Columbia River modeling system by conducting in the estuary a pilot drifter experiment to evaluate the ability of the models to simulate transport processes.

We have concluded that we are able to effectively sample juvenile salmon and make associated oceanographic measurements in and out of the Columbia River plume environment and that further support of the study to address the proposed hypotheses is warrented. Support for the first year to initiate the study is $288,000.

e. **Proposal objectives**

1. Over a projected 5 to 10-yr period we will characterize and enhance (through integrated numerical modeling, real-time and time-delayed data from moored instruments, remote sensing, and vessel observations) the understanding of:

   a) the tidal, seasonal, and inter-annual variability of the circulation, hydraulic residence times, and physical properties of the Columbia River below Bonneville Dam,
   b) the extent and physical properties of the Columbia River plume and its variability at tidal, seasonal and inter-annual scales, and
   c) the physical properties of the nearshore ocean environment outside (north and south) the plume.

   In the first year, we will focus on initial verification of existing numerical models and on developing the methodology for field sampling guided by numerical models and remote sensing data. In subsequent years, the balance will shift toward using appropriately data-constrained models to describe the oceanographic features of the Columbia River estuary, plume, and near-shore environment, and their space-time variability, as needed to support the objectives below.

2. Over a projected 5- to 10-year period, describe the nutrient dynamics and the biological oceanographic features of the Columbia River plume environment and compare to the nearshore ocean environment outside (north and south) of the plume during the principal outmigration and growing season (May-September).

3. Over a projected 5-year period, determine the relationship among time of entry of outmigrating juvenile salmon, quality and health of juveniles, survival, and the oceanographic conditions using known date of ocean entry of tagged (PIT and coded-wire) groups of Columbia River salmonids.

4. Over a projected 5- to 10-year period, identify the influence of the Columbia River plume habitat on the survival potential of juvenile salmon, by measuring differences in growth and health (bioenergetics and disease status) of juvenile chinook and coho salmon inside and outside (north and south) of the plume during the first year (spring through fall) of ocean life. Relate differences in health, quality, and growth of juvenile salmon to abiotic and biotic oceanographic features inside and outside of the plume.

   In the first year, we will focus on identifying growth characteristics of juvenile coho and ocean- and stream-type chinook salmon in the nearshore ocean and on developing the methodology for field sampling. In subsequent years, we will expand to include sampling of representative stocks of juvenile salmon in estuaries to capture the variation in growth and health of fish heading into the Pacific Nothwest ocean ecosystem and to increase the months for sampling to gain better temporal resolution within years.

5. Over a projected 3- to 5-year period, describe the food habits of juvenile salmon inside and outside of the Columbia River plume and relate to the physical and biological oceanography of the Columbia River plume environment and the nearshore ocean environment outside (north and south) of the plume.

This study will:

- provide integrated modeling and descriptions of the physical and biological features of the Columbia River estuary, plume, and nearshore ocean environment; and

- provide fisheries managers and agencies with information to adjust release times to match oceanographic conditions in the nearshore ocean environment under prevailing operational conditions favorable to survival; and

- provide fisheries managers and agencies with growth rate estimates and bioenergetic evaluation of juvenile salmon in relation to oceanographic characteristics of the Columbia River plume under prevailing operational and environmental conditions; and

- begin to assess the relative roles of ocean and estuarine variability and freshwater-side anthropogenic activity on salmon survival.

f. Methods

It is not possible to understand the dynamics of ocean conditions and salmon survival without a strong research program which involves process research, physical and bio-optical modeling of ocean circulation and Columbia River plume dynamics, and monitoring of physical and biological conditions in the Lower Columbia River and coastal ocean.

Objectives 1 & 2 -Physical and biological oceanography of the nearshore ocean, including the Columbia River plume

Scope - Describe the oceanographic features such as the shape, extent, and direction of the plume relative to winds, flows, and upwelling events; turbidity; phytoplankton biomass and variations in salmonid prey fields (zooplankton and ichthyoplankton) of the Columbia River plume environment and compare to the nearshore ocean environment outside (north and south) of the plume during the principal outmigration and growing season (May-September).

Approach - Sampling of juvenile salmon will be conducted in the Columbia River plume and adjacent ocean vicinity in discrete cruises. Oceanographic parameters will be measured in the same and during additional cruises, and will be used to characterize the ocean structure that most strongly associates with the survival success at time of entry and food and growth characteristics of juvenile salmon in the first year of ocean life. Oceanographic parameters will include sea temperature and salinity along with estimates of phytoplankton and zooplankton biomass. Characterization of the extent and magnitude of the plume in the ocean during each year's growing season will also be augmented through detailed numerical modeling and analysis of NOAA satellite images (both ocean color data from SeaWiFs and sea surface temperature from AVHRR) . A systematic retrospective analysis of river discharges, detailed numerical modeling of current and historical conditions, and remote sensing imagery will be jointly used to characterize seasonal and inter-annual variations in plume size/shape in relation to ocean, river, and atmospheric conditions.

Detailed Methodology - Twice a year (June and August/September) we will conduct two-vessel "salmon cruises" to measure oceanographic variables (both vessels) and collect juvenile salmonids (one vessel, henceforth "interdisciplinary vessel") along 8 transect lines along the Oregon-Washington coast sampled in 1998 with a focus on three transectlines: off Grays Harbor, WA; off Newport, OR; and a complex transect along the main axis of the Columbia River estuary starting just north of Tongue Point and plume. The transects lines are consistent with lines previously described by Fisher and Pearcy (1988). In addition, single-vessel "monthly cruises" (April, May, and July) sampling only oceanographic properties will be conducted along the same Grays Harbor and Newport transects, and along a simpler transect off the Columbia River estuary. The transect lines were chosen to contrast environments outside the plume (either Grays Harbor or Newport, depending on prevailing conditions), along the estuary and plume axis, and in the far-field of the plume (either Newport or Grays Harbor, depending on prevailing conditions). Specific choices of Grays Harbor and Newport are also designed to capitalize on synergisms between this and ongoing GLOBEC and PNCRS field programs (see Section 8). Sampling along the major axis of the Columbia River plume is important to distinguish between conditions inside and outside (as delineated by the 29 ppt salinity) the plume near-field.

The axis and extent of the Columbia River plume will vary with prevailing ocean, river, and atmospheric conditions, thus significantly complicating the logistics of the survey. The physical oceanography vessel will sample faster at a much higher (to be determined) spatial resolution. Combination of these observations with progressively more reliable modeling and with remote sensing will be essential to identify the plume axis and other areas of interest, and thus to guide the design of the salmonid sampling.

Due to its logistical complexity, we will only attempt sampling along the plume axis during the salmon cruises. During the monthly cruises, sampling in the Columbia River line will be performed in 5 fixed stations, starting just upstream from Tongue Point and extending to the continental slope. For the interdisciplinary vessel (during the salmon cruises) and for the monthly cruises the Grays Harbor line will consist of 5 fixed stations beginning at a nearshore station in 20-m water depth out to the continental slope (approx. 30 miles from shore), and the Newport line of 7 fixed stations located 1, 5, 10, 15, 20, 25 and, 30 miles from shore. The Newport stations coincide with the sampling regime conducted by Peterson (personal communication) allowing us to utilize a more extensive database for potential retrospective analyses.

The interdisciplinary vessel will measure surface temperature and salinity underway to help the track location and strength of the plume. At fixed stations, we will make a CTD cast from the surface to the bottom (conductivity-tempertaure-depth) with a Seabird-19 CTD. We will also measure turbidity with a transmissometer and with a secchi disk. Water samples for later analysis of nutrients (nitrate, phosphate, and silicates) and chlorophyll (a measure of phytoplankton biomass) will be taken at the surface as well as depths of 5, 10, 15, 20, 30 and 50 m. Zooplankton will be sampled with a 1/2m 202-micron-mesh net hauled vertically over the upper 50 m of the water and with 70-cm Bongo nets towed over the upper 100 m of the water column. In addition, neustonic zooplankton and ichthyoplankton will be sampled with a neuston net (at the sea surface). These plankton net tows will allow us to characterize the prey field of juvenile salmonids and will permit a determination of whether or not salmonids feed selectively. Our focus will be on the larger copepods, euphausiids, and larval/small juvenile fishes that are known salmonid prey.

During the period when we are sampling for juvenile salmonids, we will augment the resolution of the physical oceanography of the nearshore ocean environment with the following observations from the physical oceanography vessel:

- Temperature , salinity, turbidity, and depth will be measured underway, in a "continuous" three-dimensional pattern with instruments mounted in a towable underwater vehicle with two-way communications. Characteristics of the towable underwater vehicle are under analysis. Our instrument of choice in years 2-5 is a Sealogger CTD SBE 25, with fluorescence, optical backscatter sensor (OBS), and Wetlabs AC3 fluorometer (chlorophyll, phaeophyton and transmissivity). In the first year we will use an existing OS 200 CTD with an OBS and AC3.
- Profiles of velocity and acoustic backscatter (a rough surrogate for suspended sediments) will be measured underway with an existing vessel-mounted ADCP.
- Wind speed and air temperature will be measured underway with an existing Coastal Leasing MicroWind.
- Vessel position will be continuously recorded with an existing Trimble Navigation DGPS.

During the monthly cruises when we are not sampling for juvenile salmonids, the sampling of physical and biological features of the ocean will be the same as for the interdisciplinary vessel during the salmon surveys, except that no fish samples will be collected.

All field work will be coupled with CORIE, a nowcast-forecast system that the Center for Coastal and Land-Margin Research (CCALMR) is developing for the physical oceanography of the Lower Columbia River, extending from Bonneville Dam to the plume (Baptista et al. 1998). CORIE is designed to tightly integrate numerical modeling, real-time observations, data management, and scientific visualization, toward the characterization and prediction of complex circulation and mixing processes in a system encompassing the lower river, the estuary, and the nearshore environment of the Columbia River. The CORIE infrastructure consists of:

- A real-time data acquisition system, including an array of 14 permanent and a variable number of temporary stations, and one mobile station. Of the permanent stations, 13 are located in the estuary and (motivated by this project) one in the plume. We currently monitor, in various combinations at each station: temperature, conductivity, depth, currents, acoustic backscatter, wind speed and direction, air temperature, and atmospheric pressure. Deployment of chemical and biological sensors is under consideration.
- A range of circulation models, currently extending from Bonneville Dam to the close coastal vicinity of the Columbia Riverestuary. All models are based on finite element codes that solve the shallow water equations on unstructured grids. Codes (Luettich and Westerink 1995, Beck and Baptista 1997, Lynch et al. 1996) differ on the dimensionality (2D -Luettich and Westerink 1995, Beck and Baptista 1997- or 3D -Lynch et al. 1996) and on whether they include wetting and drying (Luettich and Westerink 1995, Beck and Baptista 1997) and baroclinic (Lynch et al. 1996) effects. Hindcast model runs, extending for selected 1-month or 2-day periods, are being used to systematically benchmark all models, individually and in their contrasting features. Exploratory nowcast-forecast runs are being performed daily with one model (Luettich and Westerink 1995), and will eventually be extended to at least one other model (Lynch et al. 1996). This project motivated the on-going extension of the modeling domain to the zone of influence of the Columbia River plume and the Eastern North Pacific. The

Eastern North Pacific model is based on a finite difference code (POM, Blumberg and Mellor 1987), and its role is to provide ocean boundary condions for the plume plume.

- A sophisticated data archival, management and distribution system, with real-time and archival access through the web (http://www.ccalmr.ogi.edu/CORIE) to script-generated graphical displays and actual data. While access to actual data is currently internal to CCALMR, our proposed research will provide the impetus to extend the distribution to our collaborators, thus allowing for a limited but important assessment of the logistical difficulties associated with broad public distribution.

It is important to stress that CORIE is a system designed to have models progressively learn from available moored and vessel data. Over the 5- to 10-year project, with a degree of realism that will increase over time:

a) By providing detailed spatial and temporal descriptions of the estuary, plume, and near-shore environments during the cruise periods (in hindcast and forecast modes, as appropriate), CORIE will assist the design of the salmon cruises and will support the interpretation of all cruises.
b) By providing a characterization of the plume extent and primary physical properties for the project- and selected prior-years, CORIE will help relate seasonal and inter-annual variations in river discharge with plume characteristics. Coupled with a systematic retrospective review of river discharge variation, this will enable us to place our observations in a broader temporal/historical context.
c) By providing reliable estimates of the statistics, and of spatial, seasonal and interannual variability of estuarine parameters (e.g., temperature, salinity, and hydraulic residence times), CORIE will help relate to environmental data the initial size, growth, and health characteristics of salmon that are entering the ocean environment from the Columbia River.

River flow observations are available on a daily basis at The Dalles (1878 to date) and Beaver (since 1991). Time dependent SPM input will be estimated using daily river flow and an established rating curved based on historical observations (Sherwood et al. 1990; Simenstad et al. 1992). Analysis of river flow and SPM input fluctuations (1878 to present) will be carried out using the continuous wavelet transform analyses methods described in Jay and Flinchem (1997 a,b). *This approach will reveal the evolving seasonality of flow and SPM input under the influence of flow regulation, water withdrawal, ENSO processes, the Pacific decadal oscillations, and long-term climate changes*.

Objective 3 - Timing of entry of juvenile salmon into the nearshore ocean as a factor affecting survival

Scope -Determine the relationship among time of entry of outmigrating juvenile salmon, quality and health of juveniles, survival, and the oceanographic conditions (e.g., date of spring transition, strength of upwelling, zooplankton biomass and production) that produce highest salmonid ocean survival using known date of ocean entry of tagged (PIT and coded-wire) groups of Columbia River salmonids, carried out with data collected during this proposed study.

Approach - Tagged juvenile salmon with known dates of entry throughout the release period from April through July in the Columbia River will be periodically sampled for health and condition. Return survival rates will be monitored and correlated with the physical and biological conditions of the ocean, as described in Objectives 1 & 2 above, and fish health described in Objective 4 below.

Detailed Methodology - The release of several tagged stocks and species of fish (coho and chinook), some of which are transported, from the Columbia River will be monitored. A number of stocks of fish from the Columbia River are being tagged and released at a known location at a specific time (below Bonneville Dam). The migrational timing of juvenile salmon through the estuary and to the ocean is being monitored by an ongoing study by Oregon State University using miniature radio tags. We will know the specific ocean entry dates of these release groups. We will also calculate time of ocean entry for Clatsop Economic Development Committee coded-wire groups (which are released into the lower Columbia River estuary) by day of release with estimates of passage obtained from recent research (pers. comm., Dick Ledgerwood, NMFS, Pt. Adams Biological Field Station, Hammond, OR) beginning from May through July. Approximately 30 juvenile salmon will be subsampled for each group of fish being monitored on a biweekly schedule and analyzed for their bioenergetic status and size and growth characterisitics as described in the growth measurements section in the Methods section for Objective 4 (below). The relationship between the timing of juvenile salmonid entry into marine waters, ocean bio-physical conditions, and eventual adult survival will be determined by evaluating the known date on entry of PIT- and coded wire tagged groups of salmonids with measured ocean bio-environmental conditions. The PIT-tagged groups will be from ongoing survival studies and transportation studies. Actual dates of marine entry for these groups will be obtained by using river flow and known time of passage at Bonneville Dam. We will include other groups of fish if we have estimates of adult return and can estimate time of ocean entry. The important factors that explain ocean survival (response variable) will be identified by loading explanatory variables (season, number of predators, upwelling, temperature, fish condition, etc.) using a multivariable regression model.

Objective 4 - Salmon growth and health in different microhabitats of the nearshore ocean off the Columbia River

Scope - We hypothesize that there are significant differences in the growth (characterized as size or growth rates) and health (bioenergetic and disease status) of juvenile salmon captured in and around the Columbia River plume compared to juveniles captured well outside of the plume environment. Our intent is to measure growth and health of naturally-produced and hatchery juvenile chinook and coho salmon from the summer and fall period inside and well outside (north and south) of the Columbia River plume during their first year of ocean existence. If differences are observed, we will identify relationships between growth and health of juveniles with physical and biological features of the nearshore environment inside and outside the Columbia River plume derived from information generated in Objective 1 & 2.

Approach - Juvenile coho and ocean and stream-type chinook salmon will be sampled along transects from inside the Columbia River plume in the nearshore ocean environment and outside the plume north and south of the Columbia River. Samples will be obtained from juveniles during May, representing the early phase of the growing season when Pearcy (1992) hypothesized that mortality was extensive, during June, representing the early to middle phase of the growing season for juvenile salmon, and during August to early September, representing the end of the principal growth period. The three sampling periods are proposed because we are uncertain when, during the growth season, differences will be evident. All the sampling periods will provide an increased opportunity to identify differences in growth and health of juvenile salmon as well as to validate difference by providing the opportunity to repeat the findings. Additionally, using three sampling periods will provide an opportunity to capture the three targeted species sometime during the growth season, since the observed peak period of entry of juvenile coho and stream- and ocean-type chinook salmon into the nearshore ocean environment are not identical nor are their continued residences in the nearshore environment assurred. Coho and stream-type chinook appear to enter the ocean from late April through June, whereas ocean-type chinook enter the ocean typically from June through September. As a result, ocean-type chinook may not generally be available during the May and June sampling period, but would be expected during the September sampling period. Similarly, whereas juvenile coho and ocean-type chinook may reside in the nearshore environment for a extended period of time, stream-type chinook typically move quickly out of the nearshore environment and likely will not be obtained during the September sampling period.

Growth differences will be evaluated by comparing size (weight and length) and growth rates (with the use of scales and/or otoliths) for fish sampled from inside and well outside the Columbia River plume. Growth rates generated from scale measurements will also be used to assess if slower growing individuals make up a reduced proportion of juvenile chinook and coho salmon population as age increases during the first year of ocean life for juveniles captured in the plume compared to juveniles captured outside of the plume. We expect that if the plume environment offers some generalized advantage, that a larger portion of slower growing fish will survive in a more favorable environment than in a more hostile environment (Parker 1971). Although it is expected that we will not know the source of most of the fish (except for any coded wire tagged or PIT-tagged fish) in our samples, lack of this information does not invalidate the approach used in the study. We will, however, compare the results retrospectively with growth estimates of coho salmon sampled in 1981-85 obtained by Fisher and Pearcy (1988). Although they did not report information based on a spatial basis, they do have concurrent information on surface salinities during their sampling off the Oregon and Washington coast. Information on growth during the first ocean year for ocean- or stream-type chinook, however, is not available for retrospective analysis.

We will also assess the impact of the selected characterisitics of the environment (representing features that would affect the quality of the environment from the perspective of salmon) on the bioenergetic health of juvenile salmon inside and near or well outside of the Columbia River plume as a complementary measure of the effect of the nearshore environment on the growth and health of juvenile salmon. We propose to assess the development of energy reserves by assessing lipid, glycogen, and water content of liver and muscle of wild and hatchery juvenile chinook and coho salmon from the summer and fall period inside and outside (north and south) of the Columbia River plume. Differences in bioenergetic health will be evaluated by comparing lipid, glycogen, and water content of liver and muscle of juvenile chinook and coho salmon during both sampling periods for juveniles sampled inside and outside (north and south) of the Columbia River plume. It is expected that we will also document the accumulation of energy reserves during the growth season (comparing energy reserves of fish in September compared to fish sampled in June) that will benefit survival of juveniles during the winter when food availability is lower.

As an additional measure of health, we will determine the prevalence and intensity of selected salmonid pathogens. *Renibacterium salmoninarum*, the causative agent of Bacterial Kidney Disease (BKD), Erythrocytic Inclusion Body Syndrome virus, and the parasites: *Ceratomyxa shasta* and *Nanophyetus salmincola;* are common in juvenile salmon of the Columbia River basin and have the capacity to be highly pathogenic. Their prevalence has been best measured in the Columbia River and other river systems of the Pacific Northwest, and their potential impact on salmon smolt survival has been documented (Milleman and Knapp, 1970; Piacentini 1989; Bartholomew et al, 1992; Sanders et al., 1992; Elliot et al., 1997; Arkoosh et al., 1998). We have recently found a negative relationship between pathogen intensity and/or prevalence with weight in juvenile salmon from selected Oregon estuaries (Jacobson et al., 1998). One earlier study demonstrated that a percentage of juvenile salmon in the ocean had overt signs of BKD suggesting that pathogens do indeed have the potential to influence survival in the ocean (Banner et al., 1986). However, the paucity of information on the effects of these pathogens on the health of ocean fish has contributed greatly to the challenge of understanding their effects on salmonid survival at the population level. In the current study we have the unique opportunity to measure the prevalence and intensity of these four pathogens in ocean juveniles that have in fact survived the migration to the estuary, smoltification, and ocean entry, and can correlate this information with size, growth rate and bioenergetic health of juvenile salmon inside and outside of the plume.

Differences in size, growth rate, and bioenergetic and pathogen health of naturally-produced and hatchery juvenile chinook and coho salmon inside and outside the Columbia River plume will also be assessed. Although a greater proportion of hatchery fish are expected to be adipose clipped, it is unclear what proportion of natural produced fish will be obtained in our samples, and whether all hatchery chinook and coho salmon will be tagged. In case all hatchery fish are not tagged, fish not tagged (adipose clipped) will be determined to be a hatchery or naturally produced fish using otolith structure as described by Zhang et al. (1995). Naturally produced fish typically have more erratic and closely spaced rings during their freshwater growth phase compared to hatchery fish which are more evenly and wider spaced. Differences in size, growth rate, and bioenergetic health of naturally produced juveniles will be compared to similar characteristics in hatchery produced juveniles for salmon sampled inside or well outside the Columbia River plume.

If differences are observed, we will identify relationships between growth and health of juveniles with physical and biological features of the nearshore environment inside and outside the Columbia River plume derived from information generated in Objective 1 using correlative techniques.

<u>Detailed Methodology</u> - Sampling of oceanographic variables and juvenile salmonids will be conducted along transect lines as described in the Detailed Methodology Section for Objectives 1 & 2. Fish will be collected with a Nordic 264 (Net systems, Inc.) trawl rigged to sample the upper layers of the water column (see Project History describing our successful ability to capture juvenile salmon with this gear). Since juvenile ocean-type chinook salmon appear to inhabit the coastal regions in very shallow water (< 20 m) compared to coho and stream-type chinook salmon (Fisher and Pearcy 1995), we will sample for these fish at shallow depth contours near the mouth of the Columbia to ensure sampling of appropriate microhabitats which appear to favor the targeted salmon life histories.

From each sampling site along each transect, during each sampling period, juvenile ocean-type (fall) chinook, stream-type (spring-summer) chinook, and coho salmon will be targeted for growth and health measurements. Because the sampling design embraces a decidedly random approach, the number of targeted juveniles along each transect can not be specified, although an effort will be made to insure that sufficient juveniles from both inside and outside the plume are obtained . Our initial view of optimal sampling requirements to gauge changing growth characteristics of the salmon populations in each of the sampling areas in and out of the Columbia River plume will target 600 juveniles for each salmon species under the study. We, however, do not have sufficient information to gauge necessary sample size requirements to assess differences among groups for the physiological and biological measuremnts we are proposing, as described below. Based on our sampling in 1998, a total of 500 juvenile salmon were sampled, thus the desired numbers of each species appear optimistic. However, 1998 is considered a lean year for juvenile salmon survival because of the el Nino conditions, and future years are expected to offer greater opportunities to sample juvenile salmon. The information generated from this study will provide some of the first opportunities to gauge variation in these parameters with respect to groups in the ocean.

Growth and Health Meaurements:
For each fish sampled, fork length (to the nearest mm) and weight (to the nearest 0.1 g) will be taken. Hepatic tissue will be excised and weighed (to the nearest 0.01 g) along with the somatic weight of fish (eviscerated fish weight to the nearest 0.1 g). If conditions do not allow measurement of weight on the sampling platform, fish will be bagged individually, frozen, and returned to the laboratory for weight determinations. Scale and otolith samples will also be taken from all sampled fish to measure growth rates and to identify wild and hatchery salmon in the sampling groups, according to the methods outlined by Fisher and Pearcy (1988), Zhang et al. (1995), and Bernard and Myers (1996). Scales will be the primary means to assess growth rate and identify hatchery and wild fish, when tags (adipose clip) do not uniquely characterize a hatchery fish. Reading of rings on otoliths will serve as a backup means to assess growth rate if scales fail to provide enough detail in the growth characteristics of each fish or to provide verification of wild/hatchery status as described by Zhang et al. (1995). If >100 fish per sampling transect are obtained, a subsample of 60 fish selected randomly will be evaluated for growth rates using the last 5 ocean circuli to obtain representative growth rates. In the current project, acetate impressions of scales and grinding of otoliths (when appropriate) will be made. Scale and otolith circuli spacing and number (widely accepted surrogate measures of growth) will be measured along an axis approximately 20° ventral to the long axis using an image analysis (Optimus Bioscan) system coupled with an appropriately mounted camera on a dedicated dissecting microscope (Fisher and Pearcy 1988). Ocean-related growth for each of the sampled groups, in total, will be evaluated along with the overall growth of the wild and hatchery-derived juvenile salmon for each species studied. Differences in length and weight and growth rates among fish from the three transects from the initial ocean growth period in June/July, and final sampling period at the end of the principal growth season in September, will be used to evaluate the potential influence of the plume habitat on estimated growth rates for fish in the various ocean habitats sampled. Absolute length at the time of capture may be used as a control for differences in growth rates of cohorts within each population when using scale or otolith data to evaluate growth rates.

Assessment of the bioenergetic health of juvenile salmon during the initial ocean growing season will entail measurement of the representative energy storage components of lipid, carbohydrate, and protein in addition to water content of juvenile salmon hepatic and muscle tissue. Hepatic tissue excised, as described above, will be stored in individual capsules, frozen in liquid nitrogen, and stored at -80° C until analyzed. Similarly, a portion of the white and red muscle tissue, taken from the body, dorsal to the anterior line and anterior to the dorsal fin, will be excised, placed in individual capsules, frozen in liquid nitrogen, and stored at -80° C until analyzed. If 100 fish per sampling transect are obtained, a random sampling from 60 juvenile salmon of each species studied from each site and from each sampling period will be subject to tissue analysis. For each tissue, analyses of water, lipid, and protein content will be performed after homogenization of the tissues. Water content will be determined by drying tissue samples to constant weight at 105°C. Triglycerides (the primary form of lipid stored for energy conversion in fish) and glycogen (the primary storage form of carbohydrates for energy conversion) will be measured as described for fish by Casillas and Ames (1986). Energy content in each tissue will be calculated by applying appropriate energy equivalents for lipid and carbohydrate as described for salmon (Groot et al. 1995). The relative importance of lipid and carbohydrate content in the muscle and liver to juvenile salmon from each of the habitats (transects) sampled will be assessed by comparing their relative contribution to their total energy reserves for juvenile salmon for each species studied from the initial ocean growth period in June/July, and final sampling period at the end of the principal growth season in September. Differences in rate of accumulation of energy reserves will be determined from differences in energy reserves calculated for fish sampled in September compared to fish sampled in June from each of the sampling transects.

The intensity and/or prevalence of four pathogens: Erythrocytic Inclusion Body Syndrome virus (EIBSV); *R. salmoninarum*; *C. shasta*; *N. salmincola*; will be measured in coho and chinook salmon. A blood smear will be taken from the caudal vein immediately after capture for the detection of EIBSV. For detection of the 3 remaining pathogens, fish will be opened aseptically in the laboratory after thawing. A portion of the posterior intestine will be placed in 1 ml of lysis buffer for susbsequent analysis of *C. shasta* using the polymerase chain reaction (PCR) for amplification of DNA. Kidneys will be removed and placed in whirlpak bags for the microscopic examination of *N. salmincola* and immediate isolation of DNA for PCR amplification of *R. salmoninarum* (Chase and Pascho, in press). All PCR products will be analyzed by agarose gel eletrophoresis. Blood smears will be stained following the procedure of Picentini et al. (1989) and examined for EIBSV inclusions.

Objective 5 - Salmon food habits in different microhabitats of the nearshore ocean off the Columbia River

Scope - Describe the food habits of juvenile salmon inside and outside of the Columbia River plume and relate to the physical and biological oceanography of the Columbia River plume environment and the nearshore ocean environment outside (north and south) of the plume.

Approach - Stomach contents of juvenile salmon sampled from the nearshore ocean will be obtained from fish, as described above. Stomach contents will be analyzed to the lowest taxa possible from samples up to 60 fish for each transect and for each sampling period. Differences in stomach contents among species of juvenile salmon in relation to oceanographic features of the nearshore ocean and growth and condition of the different species evaluated will be assessed.

Detailed Methodology - Stomach contents of juvenile salmon sampled in Objective 4, described above, will be preserved using standard techniques. Stomach content analysis will follow standard methods as used by Peterson et al. (1982) and Brodeur and Pearcy (1990) in their studies of food habits of juvenile salmonids in the coastal waters off Oregon and Washington. We note here that the new aspect of our proposed work is that we will have information on prey fields to complement our stomach content work so that we will be able to look at prey selectivity by salmonids. Besides identifying specific feeding habits (i.e., what items are being eaten), we will document stomach fullness, and percent empty and determine relationships between feeding habits, stomach fullness, and growth and bioenergetic status.

g. Facilities and equipment

A contracted commercial surface or mid-water fishing vessel will be used to collect juvenile salmon and some of the oceanographic measurements. The RV *Sea Otter* of the NWFSC, located at Hammond,OR will be used to supplement oceanographic measurements during the study. Growth rate measurements will be performed both at Oregon State University and at the NWFSC. Bioenergetic status measurements will be conducted at the NWFSC. Fish stomach analysis will be conducted at the NWFSC Hatfield Marine Science Center facility. All the facilities have the requisite scientific support material and space to conduct the necessary analyses and computer capabilities to conduct the proposed study.

h. Budget

Personnel costs represent funds to support staffing of the R/V Sea Otter which requires 24hr operations during the oceanographic and salmon cruises and for 1FTE equivalent (GS-9) to be used in the varied field sampling to be conducted. Supplies are for expendables to support sampling efforts and to assess growth and health of juvenile salmon. Equipment needs includes a coaxial cable for instrumentation support for physical oceanographic measurements and a replacement 264 Nordic trawl net. Travel costs includes trips for personnel between Seattle, Pt Adams field station, and the Hatfield Marine Science Center for meetings and scientific support of operations. Subcontractor costs include support for a trawling vessel to conduct salmon sampling at $3,500 per day for a total of 30 days operations, and support for the Oregon Graduate Institute and Oregon State University. The Oregon Graduate Institute sub-contract will be for the characterization and forecast (through an integrated combination of modeling, long-term fixed-station observations and short-term surveys) of plume location and of the spatial and temporal variability of the circulation and water properties in the estuary, plume and nearshore ocean environment. Forecasts will be used to increase the efficiency of the design and implementation of the biological surveys, while characterization of variability will provide the necessary detailed physical context for the interpretation of the biological data. The Oregon State University sub-contract will be for the CIMRS program to conduct zooplankton and fish health analyses. The CIMRS program is a cooperative effort between the National Marine Fisheries Service and Oregon State University to support studies that are of mutual interests and allow expeditious transfer of funds to support students and staff to perform specific tasks. The Other category includes overtime costs to support operations of staff during field ocean and land-based operations to acquire the necessary samples in the allotted time.

Section 9. Key personnel

Michael Schiewe	Research Fisheries Biologist	Principal Investigator
Edmundo Casillas	Research Fisheries Biologist	Co-PI - Growth and bioenergetics
Antonio Baptista	Professor	Co-PI - Estuary and plume dynamics
David A. Jay	Associate Professor	Co-PI - Physical Oceanography
William G. Pearcy	Professor Emeritus	Co-PI - Fisheries Oceanography
William Peterson	Research Oceanographer	Co-PI - Biological oceanography
Joseph P. Fisher	Senior Faculty Research Assistant	Growth
Robert L. Emmett	Research Fisheries Biologist	Timing of Ocean Entry
Kym C. Jacobson	Zoologist	Health and disease

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Education:

Humboldt State College	B.S.	Fisheries	1968
University of Washington	M.S.	Fisheries	1976
University of Washington	Ph.D.	Fisheries	1980

Professional Experience:

1997- Present	Director, Fish Ecology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, Seattle, WA.
1992- Present	Affiliate Associate Professor, College of Ocean and Fishery Sciences, University of Washington
1991-1997	Director, Coastal Zone and Estuarine Studies Division, Northwest Fisheries Science Center, National Marine Fisheries Service, Seattle, WA.
1988-1991	Program Manager, Habitat Investigations Program, Coastal Zone and Estuarine Studies Division, Northwest Fisheries Science Center, National Marine Fisheries Service, WA.
1981-1992	Affiliate Assistant Professor, College of Ocean and Fishery Sciences, University of Washington
1971-1988	Fisheries Research Biologist, Environmental Conservation Division, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, Seattle, WA.

Research Interests: Marine, estuarine, and freshwater ecology of salmon; pathogenesis of infectious and non-infectious fish diseases and effect of contaminants on fish health

Publications: over 50; selected recent examples

Emmett, R. E. and M.H. Schiewe (editors). 1997. Ocean and Estuarine Survival of Northeast Pacific Salmon: Proceedings of a Workshop. NOAA Technical Memorandum NMFS-NWFSC 29, 313 p.

Schiewe, M.H., T.A. Flagg, and B.A. Berejikian. 1997. The use of captive broodstocks for gene conservation of salmon in the western United States. Bull. Nat. Res. Inst. Aquacult., Suppl. 3: 29-34.

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Academic Training and Honors

1978 Engenheiro Civil, Academia Militar, Lisboa, Portugal

1984 Master of Science in Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA (Thesis title: Eulerian-Lagrangian Analysis of Pollutant Transport in Coastal Waters. Advisors: Prof. K.D. Stolzenbach and Dr. E. Eric Adams)

1986 Especialista em Hidráulica Maritima (Specialist in Maritime Hydraulics), Laboratório Nacional de Engenharia Civil-LNEC, Lisboa, Portugal

1987 Doctor of Philosophy in Civil Engineering, Massachusetts Institute of Technology Thesis title: Solution of Advection-dominated Transport by Eulerian-Lagrangian Methods Based on the Backwards Method of Characteristics. Advisors: Prof. K.D. Stolzenbach and Dr. E. Eric Adams)

Professional Experience

s. 1998 Professor, Department of Environmental Science and Engineering, OGI

s. 1991 Director, Center for Coastal and Land-Margin Research, OGI

1987/98 Assistant Professor then Associate Professor, Department of Environmental Science and Engineering, OGI

1979/87 Researcher, Estuaries Division, Hydraulics Department, Laboratório Nacional de Engenharia Civil (LNEC), Portugal: Assistant Researcher (79/86); Research Officer (86/87)

1979/80 Visiting Engineer, Laboratoire National d'Hydraulique, Chatou, France

Professional Affiliations and Activities

Affiliations: The Tsunami Society (s. 1993); Ordem dos Engenheiros, Portugal (s. 1993); American Society of Civil Engineers, ASCE (s. 1992); American Geophysical Union, AGU (s. 1986); Associação Portuguesa dos Recursos Hídricos (s. 1978)

Editorial Boards: Science of Tsunami Hazards (s. 1995)

Organizer - Scientific Meetings: Land-Margin Ecosystem and Processes topical session, Eastern Pacific Ocean Conference (EPOC), Timberline, OR (1996); 2nd Convection-Diffusion Forum, an activity of the VII Int. Conf. on Computational Methods in Water Resources, Boston, MA, USA (1988).

Scientific Advisory Committee - Conferences: 3rd Int. Conf. on Estuarine and Coastal Modeling, Chicago, IL, USA (1993); Int. Conf. on Computer Modeling of Seas and Coastal Regions, Southampton, England (1992); 2nd Int. Conf. on Estuarine and Coastal Modeling, Tampa Bay, FL, USA (1991)

Keynote Addresses: Int. Conf. on Education Practice and Promotion of Computational Methods in Engineering Using Small Computers, Macau (1995); Water Congress, Lisboa, Portugal (1994); Int. Conf. on the Pearl Harbor River Estuary, Macau (1992); Int. Conf. on Computer Modeling of Seas and Coastal Regions, Southampton, England (1992)

Some Representative Publications

Oliveira A. and A.M. Baptista. On the role of tracking on Eulerian-Lagrangian solutions of the transport equation, Advances in Water Resources (in press).

Fortunato A., A.M. Baptista and R. Luettich. Tidal dynamics in the mouth of the Tagus Estuary (Portugal), Continental Shelf Research (in press).

Oliveira A. and A.M. Baptista, 1997. Diagnostic modeling of residence times in estuaries, Water Resources Research, 33(8):1935-1946.

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Education

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University of Washington, Seattle	- M.S. (Fisheries Biology)	1974
University of California, Santa Barbara	- B.A. (Environmental Biology)	1972

Positions

Supervisory Fish Research Biologist, National Marine Fisheries Service 1991-present
Member of the Editorial Board for Aquatic Toxicology 1985-1991
Affiliate Assistant Professor, Laboratory Medicine, Univ. of Wash. 1982-1986
Research Associate, Laboratory Medicine, Univ. of Wash. 1980-1982
Fishery Research Biologist, National Marine Fisheries Service 1980-1991
Senior Postdoctoral Fellow, Laboratory Medicine, Univ. of Wash. 1978-1980

Research Interests

Fish physiology, comparative aquatic biomedicine, salmon toxicology and biology

Publications - 61

Casillas, E., M.S. Myers, L.D. Rhodes, and B.B. McCain. 1985. Serum chemistry of diseased English sole (*Parophrys vetulus*) from polluted areas of Puget Sound, Washington. J. Fish Diseases. 8:437-449.
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Arkoosh, M., E. Casillas, E. Clemons, A. Kagley, R.E.Olson, P. Reno, and J.E. Stein (In press). Effect of pollution on fish disease: potential population impacts. J. Aquat. Anim. Health.

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EDUCATION

B.Sc. Fishery Biology	University of Massachusetts	1977
M.Sc. Biology	University of Oregon	1982

WORK EXPERIENCE AND RESEARCH ACCOMPLISHMENTS

10/77 to present: National Marine Fisheries Service
Principal investigator for ongoing study of the relationship between baitfish populations off the Oregon/Washington coast and juvenile salmon ocean survival. Help develop a GIS of west coast salmonid spawning escapement and hatchery production; developed data base for living marine resources of west coast estuaries; conducted benthic invertebrate and fishery surveys in various estuarine and marine habitats, identified the food habits of fishes in the Columbia River and its estuary and offshore waters.

HONORS AND AWARDS

US Presidential Award 1994.

COMMITTEES AND SOCIETY MEMBERSHIPS

President of Pacific Estuarine Research Society
Estuarine Research Federation South Slough National Estuarine Research Reserve Management Commission

SELECTED PUBLICATIONS

Emmett, R. L., P. J. Bentley, and M. H. Schiewe. 1997. Abundance and distribution of northern anchovy eggs and larvae (*Engraulis mordax*) off the Oregon coast, Mid-1970s and 1994 and 1995. P. 505-508, In Forage Fishes in Marine Ecosystems, Proceedings International Symposium on the Role of Forage Fishes in Marine Ecosystems. Univ. Alaska Sea Grant College Program Report No. 97-01, University of Alaska, Fairbanks, AK.

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Education:

B.A., Biology, 1975, Macalester College, St. Paul, Minnesota 55101
M.S., Biological Oceanography, 1979, Oregon State university, Corvallis, Oregon 97331

Professional Experience:

Senior Faculty Research Assistant, College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, Or 1991 - present.

Faculty Research Assistant, College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, Oregon: April 1981 - 1990

Fisheries Technician, Oregon Department of Fish and Wildlife, Corvallis Research Laboratory, Corvallis, Oregon 1980 - 1981

Selected Publications:

Fisher, J.P. and W.G. Pearcy. 1983. Reproduction, growth and feeding of the mesopelagic fish Tactostoma macropus (Melanostomiatidae). Mar. Biol. 74:257-267.
Fisher, J.P. and W.G. Pearcy. 1987. Movements of coho, Oncorhynchus kisutch, and chinook, O. tshawytscha, salmon tagged at sea off Oregon, Washington, and Vancouver Island during the summers 1982-85. Fish. Bull., U.S. 85:819-826.
Fisher, J.P. and W.G. Pearcy. 1988. Growth of juvenile coho salmon (Oncorhynchus kisutch) in the ocean off Oregon and Washington, USA, in years of differing coastal upwelling. Can. J. Fish. Aquat. Sci. 45:1036-1044.
Pearcy, W.G. and J.P. Fisher. 1988. Migrations of coho salmon, Oncorhynchus kisutch, during their first summer in the ocean. Fish. Bull., U.S. 86:173-195.
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Pearcy, W.G., J.P. Fisher and M.M. Yoklavich. 1993. Biology of the Pacific pomfret (Brama japonica) in the North Pacific Ocean. Can. J. Fish. Aquat. Sci. 50:2608-2625.
Fisher, J.P. and W.G. Pearcy. 1995. Distribution, migration, and growth of juvenile chinook salmon, (Oncorhynchus tshawytscha), off Oregon and Washington. U.S. Fish. Bull. 93:274-289.
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Pearcy, W.G., J.P. Fisher, Anma, G. and Meguro, T. 1996. Species associations of epipelagic nekton of the North Pacific Ocean, 1978-1993. Fish. Oceanogr. 5:1-20.

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EDUCATION:
Ph.D. Biology, Wake Forest University, North Carolina, 1991
M.S. Biology, Wake Forest University, North Carolina, 1987
B.S. Zoology, University of Nevada,1985
B.A. French, University of Nevada, 1984

PROFESSIONAL EXPERIENCE:
1997-Present: Zoologist, NOAA/NMFS/NWFSC, Fish Ecology Division, Newport, Oregon
1996-1997: NRC Associateship Award Recipient, NOAA/NMFS/NWFSC, Environmental Conservation Division, Newport, Oregon
1993-1996: Postdoctoral Scientist, Seattle Biomedical Research Institute & Department of Pathobiology, University of Washington
1991-1993: Postdoctoral Research Fellow, Departments of Immunology and Neurology
Mayo Clinic/Foundation, Rochester, Minnesota
1988-1991: Research Assistant, Department of Biology; Biology & French Tutor, Departments of Biology and Athletics, Wake Forest University
1985-1988: Teaching Assistant, Department of Biology, Wake Forest University

RESEARCH INTERESTS: Ecology of infectious diseases, community ecology, host-parasite interactions

SELECTED PUBLICATIONS:
Esch, G.W., D.J. Marcogliese, T.M. Goater and **K.C. Jacobson**. 1989. Aspects of the evolution and ecology of helminth parasites in turtles: a review. In: The life history and ecology of the slider turtle, *Trachemys scripta* (J.W. Gibbons, ed.). Smithsonian Institution Press, p. 299-307.

Jacobson, K.C., R.C. Fletcher and R.E. Kuhn. 1992. Resistance to complement-mediated lysis and differential binding of parasite-specific IgG to trypomastigotes of a Brazil strain of *Trypanosoma cruzi*. Parasite Immunol. 14, 1-12.

Jacobson, K.C., R. Washburn and R.E. Kuhn. 1992. Binding of complement to trypomastigotes of a Brazil strain of *Trypanosoma cruzi*: evidence for heterogeneity within the strain. J. of Parasitol. 78(4), 697-705.

Aho, J.M., M. Mulvey, **K.C. Jacobson** and G.W. Esch. 1992. Genetic differentiation among congeneric acanthocephalans in the yellow-bellied slider turtle. J. Parasitol 78(6), 974-981.

Jacobson, K.C., J. de Oliveira Ferreira, M. de Fatima Ferreira da Cruz, J. Thurman, C. Schmidt, and R. Howard. 1998. A study of antibody and T cell recognition of *Plasmodium falciparum* rhoptry-associated protein 1 (RAP-1) and RAP-2 recombinant proteins and peptides in migrants and residents of the state of Rondonia, Brazil. Am J. of Trop Med Hyg 59:208-216.

Howard, R. F, **K. C. Jacobson**, E. Rickel and J. Thurman. 1998. Analysis of inhibitory epitopes in the *Plasmodium falciparum* rhoptry protein RAP-1 including identification of a second inhibitory epitope. Infect Immun. 66(1):380-386.

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ACADEMIC TRAINING AND HONORS

Ph.D. in Physical Oceanography 1987, Department of Oceanography, University of Washington. Thesis advisor: J. D. Smith; title: Residual circulation in shallow, stratified estuaries.

M.S. in Marine Environmental Studies 1974, SUNY at Stony Brook, Stony Brook, New York.

B.A. (*cum laude*) in Chemical Physics 1970, Pomona College, Claremont, California.

PROFESSIONAL EXPERIENCE

1995 to date, Associate Professor; Oregon Graduate Institute, Department of Environmental Science and Engineering, and Center for Coastal and Land Margin Ecosystem Research

1993 to 1995, Research Associate Professor; Geophysics Program, University of Washington.

1993 to date, Adjunct Research Associate Professor; Physics Department, University of Washington.

1991 to 1995, adjunct faculty member; Oregon Graduate Institute Center for Coastal and Land Margin Ecosystem Research.

1987 to 1993, Research Assistant Professor; Geophysics Program, University of Washington.

PROFESSIONAL AFFILIATIONS AND ACTIVITIES

Associate Editor, *Estuaries*, 1993-1995

Coordinating Committee, NSF Land Margin Ecosystem Research Program 1991-date

San Francisco Bay Estuary Study, Salinity Standards Committee, 1991-92.

Member Coordinating Committee SCOPE Conference on Estuarine Synthesis 1994-date

Consultant in estuarine and fluvial ecosystem process, 1979-date

Chair “Harbors and Approaches Working Group”, National Research Council Conference on Coastal Oceanography and Littoral Warfare, San Diego, CA, 1993.

Memberships: American Association for the Advancement of Science, American Geophysical Union, The Oceanography Society, Estuarine and Coastal Science Association, Estuarine Research Federation.

SOME REPRESENTATIVE PUBLICATIONS

Hickey, B. M., L. J. Pietrafesa, D. A. Jay and W. C. Boicourt, 1997, The Columbia River plume study: subtidal variability in the velocity and salinity field, in press, *J. of Geophys. Res.*

Jay, D. A. and Flinchem, E. P., 1997, Interaction of fluctuating river flow with a barotropic tide: A test of wavelet tidal analysis methods, *J. Geophys. Res.* **102**: 5705-5720.

Jay, D. A. and Flinchem, E. P., 1997, A comparison of methods for analysis of tidal records containing multi-scale non-tidal background energy, in press *Contin. Shelf Res.*

Cudaback, C. N. and D. A. Jay, 1996. Buoyant plume formation at the mouth of the Columbia River -- an example of internal hydraulic control?, *Buoyancy Effects on Coastal and Estuarine Dynamics*, AGU Coastal and Estuarine Studies **53**: 139-154.

Jay, D. A. and J. D. Musiak, 1996, Internal Tidal Asymmetry in Channel Flows: Origins and Consequences. C. Pattiaratchi (ed.), *Mixing Processes in Estuaries and Coastal Seas*, an American Geophysical Union *Coastal and Estuarine Sciences Monograph*, pp. 219-258.

Jay, D. A. and J. D. Musiak, 1994, Particle trapping in estuarine turbidity maxima, *J. Geophys. Res.* **99**: 20,446-61.

LMER Coordinating Committee (W. Boynton, J. T. Hollibaugh, D. Jay, M. Kemp, J. Kremer, C. Simenstad, S. V. Smith, I. Valiela), 1992, Understanding changes in coastal environments: the Land Margin Ecosystems Research Program, *EOS* **73**: 481-485.

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EDUCATION:

Iowa State University B.S., Zoology 1951
Iowa State University M.S., Zoology 1952
Yale University Ph.D., Marine Zoology 1960

EXPERIENCE:

Oregon State University Professor 1970-Present
(COAS) Associate Professor 1965-70
(COAS) Assistant Professor 1960-65

CURRENT RESEARCH:

Fishery Oceanography, Ocean Ecology of Salmon

MOST SIGNIFICANT SERVICE, PROFESSIONAL ACTIVITIES AND ACCOMPLISHMENTS

Director, Cooperative Institute for Marine Resources Studies (1983-1985)
Invited Lecturer on Recruitment Fishery Oceanography, Univ. Washington (1990)
Editorial Board, Fisheries Oceanography (1992-1997)
Member PICES Working Group 6 on Subarctic Pacific Ocean (1993-95)
Invited Participant - Pacific Salmon & their Ecosystem, Seattle, WA (Jan. 1994)
Invited Participant - Saving Pacific Salmon, Seattle, WA (April 1994)
American Fisheries Society-Oscar E. Sette, Outstanding Marine Fishery Biologist Award (1996)
Scientific Steering Committee--U.S. GLOBEC
American Institute of Fishery Research Biologists, Outstanding Achievement Award (1998)
Member, Independent Multidisciplinary Science Team for Oregon Salmon P (1998-2002)

RECENT PUBLICATIONS

Pearcy, W. G. 1997. The sea-run and the sea. pp.29-34 In: J.D. Hall, P.A. Bisson and R.E. Gresswell (eds.) Symposium on Sea-Run Cutthroat Trout, Biology, Management, and Future Conservation. Oregon Chapter, American Fisheries Society, Corvallis, OR

Pearcy, W.G. 1996. Salmon production in changing ocean domains. pp. 331-352 In: D.J. Stouder, P.A. Bisson, R.J. Naiman (eds.) Pacific Salmon and Their Ecosystems. Chapman and Hall.

Pearcy, W.G., J.P. Fisher, G. Anma and T. Meguro. 1996. Species associations of epipelagic nekton of the North Pacific Ocean, 1978-1993. Fisheries Oceanography 5:1-20.

Jamir, T.V., A. Huyer, W. Pearcy and J. Fisher. 1995. Influence of environmental factors on the marine survival of Oregon hatchery coho (Oncorhynchus kisutch). 1994 Northeast Pacific Chinook and Coho Workshop, pp 115-138.

Fisher, J.P. and W.G. Pearcy. 1995. Distribution, migrations and growth of juvenile chinook salmon off Oregon and Washington, U.S.A. Fish. Bull. 93: 274-289.

Sinclair, E., T. Loughlin and W. Pearcy. 1994. Prey selection by northern fur seals (Callorhinus ursinus) in the eastern Bering Sea. Fish. Bull. 92: 132-156.

Pearcy, W.G., J.P. Fisher and M.M. Yoklavich. 1993. Biology of the Pacific pomfret (Brama japonica) in the North Pacific Ocean. Can. J. Fish. Aquat. Sci. 50: 2608-2625.

Pearcy, W.G. 1992. Ocean Ecology of North Pacific Salmonids. Books in Recruitment Fishery Oceanography. Washington Sea Grant Program. University of Washington, Seattle, 176p.

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Education

1960 B.A. Biology and Chemistry, Pacific Lutheran Univ
1969 M.S. Oceanography, Univ. of Hawaii
1980 Ph.D. Oceanography, Oregon State

Professional Experience

Oceanographer, NOAA/NMFS, Newport, OR	1995-present
Member, Graduate Faculty of OSU/Oceanic and Atmospheric Sciences	1996-present
Program Manager, U.S. GLOBEC/NOAA and NSF, Washington, DC	1992-1995
Supervisory Physical Scientist, NOAA/National Ocean Service, Monterey, CA	1990-1992
Senior Research Officer/Research Fellow, University of Cape Town	1987-1990
Assistant Professor, State Univ. of New York at Stony Brook	1980-1987
Research Assistant, Oregon State University	1972-1979

(Visiting Scientist: Univ. of Concepcion, Chile, Jan/Feb 1986; Danish Institute for Marine Research, Summer 1988, 1989; Univ. of Cape Town, Sept 1994)

PUBLICATIONS: (most relevant examples):

Peterson, W.T. and C.B.Miller. 1975. Year-to-year variations in the planktology of the Oregon upwelling zone. Fish. Bull. U.S. 73:642-653

Peterson, W.T. and C.B.Miller. 1977. Seasonal cycle of zooplankton abundance and species composition along the central Oregon coast. Fish. Bull. U.S. 75:717-724

Peterson, W.T., C.B. Miller and A. Hutchinson. 1979. Zonation and maintenance of copepod populations in the Oregon upwelling zone. Deep-Sea Res. 26A:467-494

Peterson, W.T., R.D.Brodeur and W.G.Pearcy. 1982. Food habits of juvenile salmon in the Oregon coastal zone, June 1979. Fish. Bull. 80:841-851.

Peterson, W.T. 1996. The food environment of juvenile salmonids: year-to-year variations in zooplankton abundance over the inner-middle shelf off Central Oregon -- 1979-1978. In R.Emmett and M. Schiewe (eds.) Estuarine and Ocean Survival of Northeastern Pacific Salmon, NOAA Tech. Memo. NMFS-NWFSC-29, 313.

Peterson, W.T. 1998. Life cycles of copepods in upwelling zones. 6th International Copepod Symposium. J. Mar. Systems (in press)

Gomez-Gutierrez, J. and W.T. Peterson. 1998. Egg production rates of eight copepod species during the summer of 1997 off Newport, Oregon, USA. J. Plankton Res. 15: 313-326.

Section 10. Information/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 Bonneville Power Administration, and through scientific publications. We will also disseminate information through the WEB describing the plume in the nearshore ocean and relevant productivity and fisheries issues.

Congratulations!