PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Ecology Of Marine Predatory Fishes: Influence On Salmonid Ocean Survival

BPA project number: 9702600
Contract renewal date (mm/yyyy): 4/1999 ☐ **Multiple actions?**

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

Business acronym (if appropriate)

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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 (1995) noted that ocean conditions and interactions between marine fish species populations and juvenile salmonids must be considered when undertaking salmon recovery plans. Besides being the habitat where salmonids spend most of their lives, the relationships between ocean conditions to salmon survival are needed to accurately evaluate freshwater restoration efforts.

Short description
This study will identify and document the relationships between the distribution, abundance, and food habits of marine fish predators and forage fishes off the Columbia River and salmonid ocean survival.

Target species
Predatory marine fishes and forage fishes associated with salmonids. Salmonids of interest include spring/summer chinook salmon, coho salmon, and steelhead.

Section 2. Sorting and evaluation

Subbasin

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
9801400	Ocean Survival Of Juvenile Salmonids In The Columbia River Plume

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.

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?
1998	Collected marine fish predators and their stomachs	Yes
1998	Collected stomach contents of potential juvenile salmon marine fish predators to to assess salmon predation rates and preferred prey species	Yes
1998	Measured ocenaographic conditions during sample collection	Yes

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Identify the timing of arrival and abundance of marine fish predators, forage fish, and other prey species off the Columbia River.	a	Collect marine fish predators and forage fish by surface trawling every 10 days off the mouth of the Columbia River.
		b	Identify, count, and measure predatory and forage fishes.
		c	Describe the temporal dynamics of the predator and prey fish community off the Columbia River in relation to the historical and current characteristics of the timing and magnitude of the juvenile salmon outmigration event
2	Identify food habits of predatory marine fishes.	a	Collect stomach from predatory fishes for prey analyses
		b	Identify stomach contents, including number and species of juvenile salmon consumed.
		c	Calculate salmonid consumption rates by marine fish predators
		d	Describe the temporal and dynamic nature of the trophic links between potential juvenile salmon marine fish predators and the available prey field
3	Measure selected oceanographic conditions in the nearshore ocean off the Columbia River	a	Perform CTD casts, Chlorophyll a measurements, and surface temperatures at each sampling station.
4	Relate predator and forage fish distribution and abundance to oceanographic conditions and ocean survival of juvenile salmonids.	a	Describe the current and historical relationship between marine fish predator and prey field communities off the Columbia River during the spring and early summer period
		b	Identify the current relationship between changing ocean conditions off the Columbia River during the spring and early summer and the marine fish predator and prey field community
		c	Identify the relationship between marine fish (predators and prey) ecology, changing ocean conditions, and ocean survival of juvenile salmonids
		d	Relate the temporal and dynamic nature of the oceanographic condition and marine fish ecology off the Columbia River to regular (weekly) estimates of salmon ocean survival using timing of tagged groups
5	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	4/1999	6/1999	Collect predatory and forage fishes.	Maintain a database of fish catches.	50%
2	4/1999	11/1999	Identify food habits of predatory marine fishes.	Figures showing fish feeding habits.	30%
3	4/1999	6/1999	Measure oceanographic conditions while on cruise.	Figures of ocean physical conditions.	5.00%
4	7/1999	1/2000	Relate predator and forage fish distribution and abundance to oceanographic conditions and ocean survival of juvenile salmonids.	Figures relating ocean physical conditions, fish community structure, and salmon predation rates and survival	10%
5	7/1999	1/2005	Empirical evidence of the impact marine fish predation on juvenile salmon ocean survival	Peer-reviewed publication	5%
				Total	100.00%

Schedule constraints
Sampling is dependent on obtaining ESA permits and availability of commercial fishing vessels for charter.

Completion date
2005 (5 year study)

Section 5. Budget

FY99 project budget (BPA obligated): $200,000

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel		%27	54,000
Fringe benefits		%10	19,000
Supplies, materials, non-expendable property	Surface Trawl Net	%10	20,000
Operations & maintenance	Field Station Utilities and Rents	%1	2,000
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		%0	
NEPA costs		%0	
Construction-related support		%0	
PIT tags	# of tags:	%0	
Travel		%2	3,000
Indirect costs		%11	22,000
Subcontractor	Contracted fishing vessel	%40	80,000
Other		%0	

TOTAL BPA FY2000 BUDGET REQUEST	$200,000

Cost sharing

Organization	Item or service provided	% total project cost (incl. BPA)	Amount ($)
NMFS	Salaries	%20	50,000
		%0	
		%0	
		%0	
Total project cost (including BPA portion)			$250,000

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget	$180,000	$180,000	$180,000	$180,000

Section 6. References

Watershed?	Reference
☐	Ashton, H. J., V. Haist, and D. M. Ware. 1985. Observations on abundance and diet of Pacific mackerel (Scomber japonicus) caught off the west coast of Vancouver Island, September 1984. Can. Tech. Rep. Fish. Aquat. Sci., No. 1394, 11 p.
☐	Bailey, K. M, R. C. Francis, and P. R. Stevens. 1982. The life history and fishery of Pacific whiting, Merluccius productus. CalCOFI. Rep. 23:81-98.
☐	Brodeur, R. D., and D. M. Ware. 1992. Interannual and interdecadal changes in zooplankton biomass in the subarctic Pacific Ocean. Fish. Oceanogr. 1:32-38.
☐	Brodeur, R. D., and W. G. Pearcy. 1986. Distribution and relative abundance of pelagic nonsalmonid nekton off Oregon and Washington, 1979-84. NOAA Tech. Rept. NMFS 46, 85 p.
☐	Brodeur, R. D., H. V. Lorz, and W. G. Pearcy. 1987. Food habits and dietary variability of pelagic nekton off Oregon and Washington, 1979-1984. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 57, 32 p.
☐	Brodeur, R. D., and W. G. Pearcy. 1992. Effects of environmental variablility on trophic interactions and food web structure in a pelagic upwelling ecosystem. Mar. Ecol. Prog. Ser. 84:101-119.
☐	Brodeur, R. D., B. W. Frost, S. R. Hare, R. C. Francis, and W. J. Ingraham, Jr. 1996. Interannual variations in zooplankton biomass in the Gulf of Alaska and covariation with California Current zooplankton. Calif. Coop. Oceanic Fish. Invest. Rep. 37:8
☐	Dorn, M. W. 1996. Status of the coastal Pacific whiting resource in 1996. In Appendix Volume I to the Status of the Pacific Coast Groundfish Fishery Through 1996 and Recommended Acceptable Biological Catches for 1997. Available from Pacific Fishery Ma
☐	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
☐	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.
☐	Francis, R. C., and S. R. Hare. 1994. Decadal-scale regime shifts in the large marine ecosystems of the northeast Pacific: a case for historical science. Fish. Oceanogr. 3:279-291.
☐	Francis, R. C., S. R. Hare, A. B. Hollowed, and W. S. Wooster. 1998. Effects of

	interdecadal climate variablility on the oceanic ecosystem of the northeast Pacific. Fish. Oceanog. 7(1):1-21.
☐	Hare, S. R., N. J. Mantua, and R. C. Francis. In Press. Inverse production regimes: Alaska and West Coast Pacific salmon. Fisheries.
☒	ISG (Independent Scientific Group). 1996. Reurn to the river: restoration of salmonid fishes in the Columbia River ecosystem. Northwest Power Planning Council. Rep. 96-6, Portland, OR.
☐	Livingston, P. A., and M. S. Alton. 1982. Stomach contents of Pacific whiting, Merluccius productus, off Washington and Oregon, April-July. U.S. Dept. Commer., NOAA, Tech Memo. NMFS-F/NWC32, 36 p.
☐	Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis. 1997. A Pacific – interdecadal climate oscillation with impacts on salmon production. Bull. Amer. Meteor. Soc. 78:1069-1079.
☐	Matthews, G. M., S. Achord, J. R. Harmon, O. W. Johnson, D. M. Marsh, B. P. Sandford, N. N. Paasch, K. W. McIntryre, and K. L. Thomas. 1992. Evaluation of transportation of juvenile salmonids and related research on the Columbia and Snake Rivers, 1990.
☐	MBC applied Environmental Sciences. 1987. Ecology of important fisheries species offshore California. OCS Study, (Rep. To Minerals Management Serv., U.S. Dept. Int., Contract No. MMS 14-12-0001-30294). 251 p.
☐	National Research Council (NRC). 1996. Upstream: Salmon and Society in the Pacific Northwest. Committee on Protection and Management of Pacific Northwest Anadromous Salmonids, Board on Environmenatal Studies and Toxicology, Commission on Life Sciences.
☐	Pearcy, W. G. 1988. Factors affecting survival of coho salmon off Oregon and Washington. Pages 67-73, In W. J. McNeal (editor), Salmon Production, Management, and Allocation. Oregon State Univ. Press, Corvallis, OR.
☐	Pearcy, W. G. 1992. Ocean ecology of North Pacific salmonids. Wash. Sea Grant, Univ. Washington Press, Seattle. 179 p.
☒	Polovina, J. J., G. T. Mitchum, and G. T. Evans. 1995. Decadal and basin-scale variation in mixed layer depth and the impact on biological production in the Central and North Pacific, 1960-88. Deep Sea Res. 42:1701-1716.
☐	Roemmich, D., and J. McGowan. 1995. Climatic warming and decline of zooplankon in the California Current. Science 267:1324-1326.
☐	Ware, D. M., and G. A. McFarlane. 1995. Climate-induced changes in Pacific hake (Merluccius productus) abundance and pelagic community interactions in the Vancouver Island upwelling system. In R. J. Beamish (editor), Climate change and northern fish po

PART II - NARRATIVE

Section 7. Abstract

Ocean survival of salmonids from the Columbia and other Northwest rivers has declined markedly in the last 20 years. While the events causing this poor salmon survival are empirically unknown, predation by large marine fishes (e.g., hake and mackerel) is suspected to be a principal source of mortality. Although it is unclear whether ocean mortality of salmon is abrupt or evenly distributed over the entire marine lifestage, there is evidence that the time period shortly after ocean entry is a critical period. Factors potentially affecting marine survival of Columbia River salmon include specific timing of ocean entry and distribution and abundance of marine fish predators and forage fishes in the nearshore marine habitat adjacent to the Columbia River. We hypothesize that the marine fish community off the mouth of the Columbia River has changed since the 1980s and is structured by physical oceanographic characteristics. We further hypothesize that the distribution and abundance of the nearshore marine predator and forage fish community directly or indirectly affects the amount of predation on juvenile salmonids. We propose to characterize, over a 5-year period, the temporal and dynamic nature of the marine fish community off the Columbia River during the spring-summer transition (peak salmonid migration period) and relate dynamics

in this marine fish community with salmonid survival. A primary focus will be identification of the strength of trophic linkages between forage and fish predator species, and the influence of these relationships on predation rates on juvenile salmon. To identify if large marine fishes are a major source of salmon smolt mortality, we will collect predatory and forage fishes off the mouth of the Columbia River, estimate their abundance, and determine predatory fish feeding habits**.** Sampling will be conducted from late April to June when juvenile salmon begin outmigration into the nearshore ocean environment. A representative sample of these large marine fish predators will be identified, measured, weighed, and their stomach contents retained for analysis. We will also assess ocean water conditions (salinity, temperature, and chlorophyll *a*). These data will be used to estimate the relationship between the marine fish community structure and juvenile salmon consumption rates in the nearshore ocean adjacent to the Columbia River and begin to describe the environmental factors that influence this predation.

Section 8. Project description

a. Technical and/or scientific background

For the past 20 years, runs of Northwest salmonids have been in decline, with some salmon returns presently less than what is necessary to maintain run sizes. To rebuild and maintain salmon runs, resource agencies have spent considerable funds ameliorating negative anthropogenic influences by restoring freshwater habitats, improving dam passage, releasing hatchery produced salmon, and other activities. However, these measures have met with limited success. There is increasing information that ocean survival plays a significant role in determining eventual adult salmon returns. Moreover, the Pacific Ocean off the Northwest appears to undergo cyclic “regimes” shifts every 20-30 years in its ability to produce salmonids (Francis and Hare 1994; Mantua et al. 1997; Francis et al. 1998). In the present cycle, which began in 1977, ocean salmonid survival and thus salmon populations are high in Alaska but low in the Pacific Northwest (Hare et al. In Press). While salmonid ocean survival appears to be related to the ocean’s primary and secondary production (Brodeur and Ware 1992; Polovina et al. 1995; Roemmich and McGowan 1995; Brodeur et al. 1996), the actual mechanisms controlling ocean salmonid survival are undetermined.

Research indicates that ocean survival of salmonids is evidently determined very early during their ocean residency, with predation thought to be a major influence on salmonid ocean survival rates (Fisher and Pearcy 1988; Pearcy 1988, 1992). Supporting this conclusion was Pearcy’s (1988) discovery that average ocean purse seine catches of coho salmon (*Oncorhynchus kisutch*) in June correlated closely with coho salmon jack counts (and thus adult run size) in the fall. This indicates that most ocean mortality occurs during early ocean entry (April and May). Matthews et al. (1992) also found early ocean survival for juvenile Columbia River spring/summer chinook salmon (*Oncorhynchus tshawytscha*) migrating in 1990 to be very poor, especially for hatchery fish.

While scientists have observed the declining ocean survival of Northwest salmonids, they have also noticed large numbers of marine fish predators, particularly Pacific hake, (*Merluccius productus)*, Pacific mackerel, (*Scomber japonicus)*, and jack mackerel (*Trachurus symmetricus*) becoming more abundant, arriving earlier, and staying longer in coastal waters. For example, in 1977, mackerel were rarely captured during NMFS's triennial trawl surveys off Oregon; by 1995, mackerel were abundant and commonly caught at many stations (raw data provided by Mark Wilkins, NMFS, Seattle, WA). During a six-year ocean purse seine study off the Northwest, Brodeur and Pearcy (1986) identified a shift in the June fish community, from a community dominated by forage fish and squid from 1979-1982, to one being dominated by predators (Pacific mackerel, jack mackerel, and dogfish shark) from 1983-1984. These piscivorous fishes may be a significant cause of juvenile salmon mortalities. For example, an investigation in British Columbia, found that Pacific mackerel consumed nearly all the salmon smolts released from a nearby hatchery (Brent Hargreaves, Canadian Fish and Oceans, Pacific Biological Station, Nanaimo, B.C. Canada V9R 5K6, Pers. commun., March 1996), resulting in few returns from that brood-year release.

Although feeding characterisitics of common Pacific Northwest predatory fishes vary geopgraphically, temporally, and with repect to their life stage, the mitigating factors driving their feeding strategies are not known. For example, Pacific mackerel captured off Oregon in the early 1980s fed primarily on euphausiids (Brodeur et. al. 1987; Brodeur and Pearcy 1992). In California, however, they feed primarily on larval and juvenile fishes and secondarily on squid and euphausiids (MBC 1987). Food habit information from California indicated that Pacific mackerel are often voracious feeders of fishes - particularly northern anchovy. A preliminary examination of Pacific mackerel feeding habits off Vancouver Island, British Columbia in 1984 revealed that salmonids were eaten, although Pacific herring (*Clupea pallasi*) were the primary prey (Ashton et al. 1985). Juvenile jack mackerel**,** another Northwest predatory fish, have been found to feed heavily on squid (*Loligo opalescens*) and northern anchovy (*Engraulis mordax*) whereas adults eat fishes (lantern fishes and northern anchovy) squid, pelagic crustaceans (euphausiids and copepods) and pteropods (MBC 1987). Another example of a predatory fish with a varying diet is Pacific hake off the Northwest. They feed primarily on euphausiids, shrimp, and fishes, with fishes (primarily northern anchovy) being more important to larger individuals (Livingston and Alton 1982). Seventy percent of the diet of larger hake (>55 cm total length) was composed of fish (Bailey et al. 1982). The extent of predation by these fishes on juvenile salmonids is unknown, but given the temporal, geographic, and size related variation in their feeding habits, their potential impact could be extensive.

Marine predatory fishes could simply impact juvenile salmon populations because of their large population size. The Pacific hake population presently represent the largest single species fishery on the West Coast. Over 5 billion Pacific hake were expected to migrate into Northwest waters during the spring/summer of 1997 (Dorn 1996). The biological demands of this population undoubtedly has a large impact on coastal marine food webs and biological communities in Northwestern coastal waters (Ware and McFarlane 1995). If each hake consumed only one salmonid they would decimate

Northwest salmonid runs. Research off British Columbia indicates that the recent increases in the numbers of Pacific hake and mackerel in these waters has increased predation rates and decreased abundance of Pacific herring (Ware and McFarlane 1995). We hypothesize that the timing of movement, food habits, and abundance of the seasonal migrant fish marine predators into Oregon and Washington coastal waters will have significant effects on the biological community for which juvenile salmonid ocean survival is dependent. We further hypothesize that the distribution and abundance of the nearshore marine predator and forage fish community affects the amount of predation on juvenile salmonids by marine predatory fish.

There is presently no detailed, or recent data, on the feeding habits of pisciverous fishes off the mouth of the Columbia River during the salmonid smolt outmigration period (spring). By assessing the dynamics of the marine fish predators and forage fish community during the juvenile salmon outmigration period, and monitoring the food habits of the dominant marine fish predators (by analyzing stomach contents), we will identify if predation is a large direct or indirect source of marine mortality of juvenile salmonids entering the ocean from the Columbia River. We will also identify how this predation is mediated by alternative prey abundance (abundance of northern anchovy, or sardines, from this and an ongoing NMFS study) and physical oceanographic conditions (temperatures, salinities, etc.).

b. Rationale and significance to Regional Programs

Although freshwater survival for salmonid in the Columbia River Basin may have increased as a result of regional programs, salmonid ocean survival of Columbia River and other Northwest stocks has been very poor the last few years, with no indications of improvement. Given the recent increased number of mackerel (two species) and hake residing off Oregon and Washington, we believe that predation by these species (and possibly others) may be causing poor ocean salmonid survival. Furthermore, the once abundant northern anchovy (*Engraulis mordax*) appears to have decreased significantly in recent years (Emmett et al. 1997) exacerbating predation by not providing an alternative prey for these marine predatory fishes.

If large pisciverous marine fishes are significant salmonid predators, fishery managers will be able to incorporate these finding into their management plans, and hopefully increase ocean survival of many salmonid stocks. For example, hake and mackerel are migratory species; hatchery salmonids could be released before and after the period hake and mackerel reside off the Columbia River. Alternatively, these fishes could be targeted for harvest by either sport or commercial fisheries. Other possible management options available include releasing hatchery fishes when other alternative prey are abundant (i.e., when pisciverous fishes are foraging on prey different than salmonids).

Incorporating measures of ocean survival (as indicated by increased or decreased adult salmon returns) may enhance appropriate evaluations of freshwater restoration projects. For example, evaluations of restoration projects that do not appear to be functioning (e.g. no increase in salmonid returns) may actually be influenced by poor ocean survival, which overshadowed project benefits. Finally, only effective ocean studies will verify if poor ocean conditions (in the broadest sense) are actually contributing to the continued decline, or non-increase, in regional salmonid abundances.

This research program will assist with the goal of managing Columbia River salmonid in an ecosystem context. It will also begin to assess the processes and mechanisms that affect salmon ocean mortalities so that the success of freshwater salmonid restoration efforts can be accurately partitioned. For example, if a restoration project salmonids (e.g., stream restoration) produces juvenile salmonids that arrive to the ocean during times of high predation pressure, the eventual poor adult returns to that restoration project can be attributed to ocean predation, not an unsuccessful restoration project.

c. Relationships to other projects

This project complements BPA study Project 9063, Ocean Survival of Salmonids Relative to Migrational Timing, Fish Health, and Oceanographic Conditions. Project 9063 is focused primarily on the health (growth, physiology, feeding habits, etc.) of migrating salmonids relative to oceanographic conditions (river flows, upwelling, zooplankton densities, etc.). Large pisciverous predator/prey relationships are not being studied. Project 9063 has a seasonal sampling scheme and will relate salmonid ocean survival primarily to salmonid health and physical oceanographic conditions, in the Columbia River plume (wide study area). Our study will conduct intense sampling during spring in a limited study area. The project we propose will also relate salmonid ocean survival primarily to biological conditions (number of predators, forage fishes, predator feeding habits) off the mouth of the Columbia River. However, both projects will be using similar fish collection gear type (surface trawl) and methods, so all data collections will be comparable and shared between projects.

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, predator abundance and distribution, 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. the Global Ocean Ecosystem Dynamics (GLOBEC) program (NSF and NOAA funding) and the Pacific Northwest Coastal Ecosystem Region Study (PNCERS) program (NOAA funding). GLOBEC 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. The PNCERS program includes physical and biological monitoring cruises and current meter moorings off Coos Bay and Willapa Bay. Being adjacent to our study area, the Willapa Bay data may provide useful information for our analysis.

Three 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 hake (in July), the triennial groundfish survey, which was conducted this past fall, and a study of northern anchovy and sardine spawning biomass. These surveys provide valuable information on population trends in many of the marine fishes of interest (mackerel, anchovy, and sardines), and these data are readily available to us.

d. Project history (for ongoing projects)

This project was initially scheduled to begin late 1997. However, no commercial fishing vessel bid on the work proposal in 1997. A contract with a commercial trawl vessel was obtained in early 1998. Beginning at the end of April 1988, we sampled for two nights every two weeks. Initial sampling consisted of assessing the efficacy of various large commercial trawling gear with different configurations (doors, weights, etc.) and speeds. In late June we used a rope trawl and foam filled doors utilized by Project 9063 (a Nordic 264 surface trawl) which proved to be the most effective gear type for collecting large marine fishes near the surface. In 1998 we conducted a total of 9 cruises and 72 hauls off the Columbia River, ranging from Grays Harbor to the north to Cape Falcon to the south, finishing in late August. Over 34,000 fishes were captured, from 27 different species, and includes over 10,000 Pacific hake, 700 Pacific mackerel, and 300 jack mackerel. We collected approximately 2,000 stomachs during these surveys. Some juvenile salmon were observed in some of the stoamch samples, but a proper assessment will require more detailed analyses. Stomachs content analyses are presently being prioritized for analysis, which will be conducted this winter. A major focus will be compiling information of food habits of marine fish predators from samples in areas off the Columbia River commensurate with where juvenile salmon were predominately found. We are presently working on a research report.

e. Proposal objectives

There are four overall objectives:

1) Identify the temporal dynamics and abundance of marine fish predators and forage fishes in the nearshore ocean off the Columbia River during the juvenile salmon outmigration period
By regularly sampling in marine waters adjacent to the Columbia River we will identify the characterisitics of fish community which salmonid smolts are interacting with during the peak smolt migration period (end of April through June) and whether that community is static or dynamic.

2) Identify the food habits of predatory marine fishes
We will describe the temporal and dynamic nature of the trophic links between potential juvenile salmon marine fish predators and the available prey field. Stomach analysis of large marine pisciverous fishes will reveal if these predators are eating salmonids (some possibly endangered stocks), and at what rate.

3) Measure selected oceanographic conditions in the nearshore ocean off the Columbia River
Distribution and abundance of marine fishes are affected by physical oceanographic conditions (temperatures, salinities, etc.). Measurements of these physical conditions (by CTD etc.) will provide information on these possible controlling factors.

4) **Relate predator and forage fish distribution and abundance to oceanographic conditions and ocean survival of juvenile salmonids historically and to the present**
Elements in this objective are designed to utilize the information generated from Objectives 1-3 to address 4 principle questions: a) describe the current and historical relationship between marine fish predator and prey field communities off the Columbia River during the spring and early summer period, b) identify the relationship between changing ocean conditions off the Columbia River during the spring and early summer and the marine fish predator and prey field community, c) identify the relationship between marine fish (predators and prey) ecology, changing ocean conditions, and ocean survival of juvenile salmonids, and d) relate the temporal and dynamic nature of the oceanographic condition and marine fish ecology off the Columbia River to regular (weekly) estimates of salmon ocean survival using timing of tagged groups.

f. Methods

Large marine fish predators (primarily Pacific hake, Pacific mackerel, and jack mackerel) and other associated fishes, will be collected by surface trawling primarily during nighttime, but also daylight, with a contracted commercial mid-water trawler. We will sample at designated stations along 2 designated transect lines north and south of the entrance to the Columbia River. Approximately 6 stations will be sampled along each transect, with the first station being as close to shore as possible and the furthest approximately 30 km from shore. Recent research indicates juvenile salmonids reside primarily within this area (Robert Emmett, Personal Observation). However, if salmonids are common at 30 km, samplings further offshore will be conducted. Sampling will be conducted every 10 days from late April through early July 1998, for a total of 20 sampling days (10 sampling cruises). Sampling effort is focused on spring because salmonid ocean survival appears to be, in part, determined during this period. Furthermore, this is the period when the of largest number of smolts are entering the ocean and predator/prey interactions are most likely be observed.

From each trawl, all potential salmonid predators and forage fish species will be identified, enumerated, and measured. A subsample (20 specimen) of each species will be iced, transported to the laboratory, and measured and later weighed to determine accurate length/weight relationships. From each trawl, up to 30 stomachs of each potential marine fish predator will be removed and preserved. A random subsample of stomachs will be taken when large catches occur. We expect to collect approximately 100-200 predator fish stomachs/species each 2 week period. A stratified sampling design will be used to select stomachs for initial content identification. Although all stomachs could be analyzed, a design will be chosen to provide an efficient means to appropriately rank and subsample the stomach contents such that prey selectivity and compositon can be elucidated. For example, if predator size influences a predators ability to feed on fish, we will focus most our effort on larger size classes. We anticipate that not all stoamchs will need to be evaluated. Stomach contents will be identified to lowest practical taxa (usually species), counted and weighed. Any fish prey (including salmonids) found in predator stomachs will be measured (length and width) and compared to predator length to identify any possible size thresholds or size-selectivity. Any salmonids found (either while sampling or in stomachs) will be checked for coded-wire tag or other evidence of hatchery origins.

Physical oceanographic data (temperature, salinity, chlorophyll *a*) will also be collected. Information on time of ocean entry of specific groups of juvenile salmonids will be obtained from ongoing studies in the Columbia River (PIT-tagging, barging release, and coded-wire tagging studies).

Number of salmonids being consumed will be calculated by multiplying the percentage of the diet composed by salmonids in marine fish predators by estimates of the predator densities (within the study area). Predator and forage fish densities will be estimated as mean number/m^3 (mean number of predators per volume of water trawled).

Ancillary physical oceanographic information, such as upwelling indices, will be obtained from the Pacific Fisheries Environmental Group, Monterey, CA; Columbia River flows from the U.S. Army Corps of Engineers; and Columbia River buoy data from NOAA. The relationship between salmonid ocean survival and biological and environmental oceanographic conditions will be identified by regression analysis (multiple or linear) of ocean salmonid survival (percent adult returns) on environmental variables.

g. Facilities and equipment

A contracted commercial surface or mid-water fishing vessel will be used to collect marine fishes and some of the oceanographic measurements. Fishing gear and samples will be stored primarily at the NMFS Point Adams Biological Field Station. Fish food habit analysis will be performed at Point Adams and at the NMFS/NWFSC facility at the Hatfield Marine Science Center. 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 chartered vessel during the sampling cruises and for 1 FTE equivalent (GS-9) to assist with field sampling and laboratory analysis. Supplies are for primarily for surface trawl net (264 Nordic rope trawl) and expendables for food habit analysis equipment (vials, formaldehyde, etc.). 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 $4,000 per day for a total of 20 days of operation (10 surveys). The indirect category includes overhead 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

Robert L. Emmett	Research Fishery Biologist	Principal Investigator
Paul J Bentley	Research Fishery Biologist	Lab Analysis and Field Collections
Susan A. Hinton	Biologist	Lab Analysis and Field Collections

Robert L. Emmett
National Marine Fisheries Service
Hatfield Marine Science Center
2030 SE Marine Science Drive
Newport, OR 97365
1-541-867-0109

Education:

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

Professional Experience:

10/77 to present: Research Biologist 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.
Developed a GIS of west coast salmonid spawning escapement and hatchery production.
Developed data base for living marine resources of west coast estuaries.
Principal investigator of numerous benthic invertebrate and fishery surveys in the Columbia River, its estuary and offshore waters.

Honors and Awards:

US Presidential Award 1994.

Committees and Society Memberships:

Past President of Pacific Estuarine Research Society
Estuarine Research Federation
NOAA representative South Slough National Estuarine Research Reserve Management Commission
NOAA representative Western Regional Panel of Aquatic Nuisance Species

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.

Emmett, R. 1997. Estuarine survival of salmonids: The importance of interspecific and intraspecific predation and competition, p. 147-158. In R. L. Emmett and M. H. Schiewe (editors), Estuarine and ocean survival of northeastern Pacific salmon: Proceedings of the workshop, March 20-22, 1996, Newport, Oregon. NOAA Tech. Memo. NMF-NWFSC-29.

Emmett, R., and E. Dawley. 1997. Estuarine life history of salmonids: Potential insights from tagging studies, p. 8-10. In G. W. Boehlert (editor), Application of acoustic and archival tags to assess estuarine, nearshore, and offshore habitat utilization and movements of salmonids. NOAA Tech. Memo. NMFS-SWFSC-236.

Emmett, R. L., D. Miller, and T. Blahm. 1986. Food of juvenile chinook, *Oncorhynchus tshawytscha*, and coho, *O. kisutch*, salmon in the coastal waters of Oregon and Washington, May-June, July, and August-September 1980. Cal. Fish and Game. 72(1):38-46.

Emmett, R. L., S. L. Stone, S. A. Hinton, and M. E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in west coast estuaries. Volume II: Species life history summaries. ELMR Rep. No. 8, NOAA/NOS Strategic Environmental Assessments Division, Rockville, MD. 329 p.

Paul J. Bentley
Fisheries Biologist
National Marine Fisheries Service
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Hammond, OR 97121-0155
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Education:

B.S. in Fisheries and Aquatic Sciences (1987), Purdue University, West Lafayette, IN.

Current Research:

Assessing the relationships between forage fish abundance and survival of Oregon juvenile salmonids in the near ocean environment.

Employment:

September 1992 to present: Fisheries biologist, National Marine Fisheries Service, Hammond, OR.

Selected Publications:

Bentley, P. J., R. L. Emmett, N. C. Lo, and H. G. Moser. 1996. Egg production of Pacific Sardine (*Sardinops sagax*) off Oregon in 1994. Calif. Coop. Oceanic. Fish. Invest. Rep. 37:193-200.

Reports:

Monk, B. H., W. D. Muir, P. J. Bentley. 1992. Feasibility of various techniques for removal of northern squawfish at Bonneville Dam, Columbia River. In preparation Report Z in A. A. Nigro, editor, Developing a predation index and evaluating ways to reduce salmonid losses to predation in the Columbia River Basin. Oregon Department of Fish and Wildlife, Contract Number 90-077. Annual Report to Bonneville Power Administration, Portland, OR.

Dawley, E. M., R. D. Ledgerwood, L. G. Gilbreath, P. J. Bentley, and M. H. Schiewe. 1992. Direct measure of mortality, injury, and stress among juvenile salmonids using the bypass system at Bonneville Dam Second Powerhouse, 1991. In preparation. Report to the U.S. Army Corps of Engineers, Contract E96910013. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097

Ledgerwood, R. D., E. M. Dawley, P. J. Bentley, L. G. Gilbreath, T. P. Poe, H. L. Hansen, and D. L. Ward. In Prep. Effectiveness of predator removal for protecting juvenile fall chinook salmon released from Bonneville Hatchery, 1991. In preparation. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097).

Ledgerwood, R. D., E. M. Dawley, L. G. Gilbreath, P. J. Bentley, B. P. Sanford, and M. H. Schiewe. 1991. Relative survival of subyearling chinook salmon which have passed through the turbines or bypass system of Bonneville Dam Second Powerhouse, 1990. Report to U.S. Army Corps of Engineers, Contract E86900104, 90 p. (Available from Northwest Fisheries Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097).

Susan A. Hinton
Biologist
National Marine Fisheries Service
Point Adams Biological Field Station
520 Heceta Place (P.O. Box 155)
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503-861-1818

Education:

A.S. Oceanographic Technology (5/84)—Clatsop Community College

Honors and Awards:

NMFS Outstanding Job Performance Award – 1990, 91, 92, 93, 94, 95 and 96

Research Accomplishments:

Project leader for a study of the long-term changes in fish and benthic invertebrate communities at Miller Sands, Columbia River estuary and Trestle Bay Enhancement Project, Columbia River Estuary.
Senior author of nine biological research reports.
Senior author of two NOAA-NMFS, Technical Memoranda.

Work Experience:

10/88 to present Research Biologist – NMFS, Pt. Adams Biological Field Station.
Serves aboard research vessels and assists with all aspects of biological and physical data collections on research projects.
Refine and maintain data files, including: recording, computer entry and verification, performing statistical analysis using computers, and assembling tables, charts, and appendices for reports.
Process benthic invertebrate and fish samples from various marine, estuarine, and freshwater habitats. This involves sorting, counting and identifying organisms to the lowest practical taxonomic level (usually genus or species).
Monitor and verify the quality of work by private contractors who are processing benthic invertebrate samples.
Edit and write research reports and publications.

Selected Reports and Publications:

Hinton, S. A., and R. L. Emmett. 1996. Benthic infauna and sediment characteristics offshore from the Columbia River, August 1994. Report to U.S. Army Corps of Engineers, Contract E96930048, 43 p.

Hinton, S. A., and G. T. McCabe, Jr., and R. L. Emmett. 1995. In-water restoration between Miller Sands and Pillar Rock Island, Columbia River: Environmental surveys, 1992-93. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-23, 47 p.

Hinton, S. A., R. L. Emmett, and G. T. McCabe, Jr. 1992. Benthic invertebrates, demersal fishes, and sediment characteristics at and adjacent to ocean dredge material disposal site F, offshore from the Columbia River, June 1989 and 1990. Final Rep. to U.S. Army Corps of Engineers, Portland District, Portland, OR. 22 p. plus appendices.

Section 10. Information/technology transfer

A research report will be written at the end of the each study year. Final results of this study will be published in a peer reviewed journal and presented at least one scientific meeting or workshop**.** We will also disseminate information through the NMFS/NWFSC WEB site when possible.

Congratulations!