Bonneville Power Administration Fish and Wildlife Program FY99 Proposal Form

Identify Marine Fish Predators of Salmon and Estimate Predation Rates

Bonneville project number, if an ongoing project 9702600

Business name of agency, institution or organization requesting funding

National Marine Fisheries Service
Northwest Fisheries Science Center
Fish Ecology Division
2725 Montlake Boulevard, East
Seattle, WA 98112-2097

Business acronym (if appropriate) NMFS/NWFSC

Proposal contact person or principal investigator:

Name	Robert L. Emmett
Mailing Address	NMFS, NWFSC, HMSC
	2030 S Marine Science Drive
City, ST Zip	Newport, OR 97365
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Subcontractors. A commercial mid-water trawling fishing vessel will be obtained by open bidding.

NPPC Program Measure Number(s) which this project addresses. Refer to 1994 Fish and Wildlife Program as amended in 1995; NPPC staff will proof this field and correct if necessary; separate multiple measure numbers with commas.

N/A

NMFS Biological Opinion Number(s) which this project addresses. If the project relates to the Kootenai Sturgeon Biological Opinion, the NMFS Hydrosystem Operations Biological Opinion, or other Endangered Species Act requirements, enter the Action Number and Biological Opinion Title.

Hydrosystem Operations BiOp Sec. VIII.14.

Other planning document references..

Proposed Recovery Plan for Snake River Salmon, Task 2.11a (U.S. Dept. Commerce 1995)

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. The relationships between ocean conditions to salmon survival are needed to accurately evaluate freshwater restoration efforts.

Subbasin. Nearshore Ocean

Short description. Identify, monitor, assess, and quantify the number of juvenile salmonids (some ESA listed stocks) consumed by marine fish predators in marine waters off the Columbia River. Evaluate the relationships between the time of juvenile salmonid ocean entry, ocean environmental conditions, and marine survival of salmonids relative to marine fish predator populations.

Section 2. Key words

Mark	Programmatic Categories	Mark	Activities	Mark	Project
+	Anadromous fish		Construction		Watershed
	Resident fish		O & M		Biodiversity/genetic
	Wildlife		Production	+	Population
X	Oceans/estuaries	X	Research	X	Ecosystems
	Climate		Monitoring/eval.		Flow/survival
	Other		Resource mgmt		Fish disease
			Planning/admin.		Supplementation
			Enforcement		Wildlife habitat en-
			Acquisitions		Ehancement/restora

Other keywords. Anadromous fish, Predation, Ocean Survival, Ecological Interactions, Marine Fishes, Environmental Conditions

Section 3. Relationships to other Bonneville projects:

Project #	Project title/description	Nature of relationship
9600600	PATH	Our study provides critical and empirical data used for modeling survival through the hydrosystem in

		PATH.
New	Ocean survival of salmon	

Section 4. Objectives, tasks and schedules

Objectives and tasks

Obj	Objective	Task	Task
1	Identify, monitor, assess, and quantify the number of juvenile salmonids consumed by marine fish predators in waters off the	a	Collect marine fish predators by mid-water and surface trawling off the mouth of the Columbia River.
	fish predators in waters off the Columbia River.	b	Perform stomach analysis of collected marine fish predators.
2	Evaluate the relationships between the time of juvenile salmonid ocean entry, ocean environmental conditions, and predation rate.	a	Identify the relationship between ocean environmental conditions (salinities, temperatures, season) and the arrival of marine fish predators.
		b	Identify relationships between timing of salmonid ocean entry (from tagged groups), the number of marine fish predators and ocean survival.
3	Document research results	a	Create tables, figures, and text for report.

Objective schedules and costs

Objective #	Start Date mm/yyyy	End Date mm/yyyy	Cost %
1	**04/1999**	**10/1999**	**75%**
2	**04/1999**	**12/1999**	**15%**
3	**10/1999**	**12/2000**	**10%**

Schedule constraints. This project is dependent on contracting a commercial fishing vessel.

Completion date. 2000

Section 5. Budget

FY99 budget by line item
In thousands of dollars.

Item	Note	FY99
Personnel		54.1
Fringe benefits		19.0
Supplies, materials, non-expendable property		1.8
Operations & maintenance	Field Station Utilities and Rents	1.2
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		
PIT tags	# of tags:	
Travel		1.8
Indirect costs	NOAA overhead	22.7
Subcontracts	Mid-water trawling vessel	100.0
Other		
TOTAL		200.6

Outyear costs (In Thousands)

Outyear costs	FY2000	FY01	FY02	FY03
Total budget	200.0			
O&M as % of total	0.6			

Section 6. Abstract

Ocean survival of salmonids from the Columbia River and other Pacific Northwest rivers has declined markedly in the last 15 years. Although specific factors causing reduced survival are poorly understood, predation by large marine fishes (hake and mackerel) is suspected to be a major factor. Of particular note has been the increasing abundance of Pacific mackerel off the Oregon coast in recent years. To better understand the role of large marine fishes as a potential source of mortality of juvenile salmon, we propose to collect these fishes off the mouth of the Columbia River, estimate their abundance, and determine their feeding habits. Fish will be collected by mid-water trawl from April through September using a chartered commercial fishing vessel for 2 days every 2 weeks. A representative sample of these large marine fish will be identified, measured, weighed, and their stomach contents retained for analysis. We expect to collect a minimum of 100-200 stomachs per predator species during each sampling cruise, from which we will estimate the number of salmonids these fish consume. In addition to collecting predators, we will monitor selected oceanographic conditions (salinity, temperature, and chlorophyll *a)* to begin to describe the environmental factors associated with high rates of predation.

Section 7. Project description

a. Technical and/or scientific background.

Recent returns of Pacific Northwest salmonids have been very low, with some populations consistently falling below replacement levels. At the same time, there is growing evidence that ocean survival plays a large role in determining eventual adult salmon returns and that over the past 15 years, ocean survival has declined substantially. Research also indicates that ocean survival of salmonids is largely determined early during their ocean residency, with predation thought to be a major influence on ocean survival rates (Fisher and Pearcy 1988, Pearcy 1992).

While scientists have documented the declining ocean survival of salmonids, they have also noticed large numbers of marine fish predators, particularly Pacific hake, *Merluccius productus,* and Pacific mackerel*, Scomber japonicus,* becoming more abundant, arriving earlier, and staying longer in coastal waters. In 1977, mackerel were rarely captured during NMFS's triennial trawl surveys off Oregon; however, by 1995, mackerel were abundant and commonly caught at many sampling stations (Pers. Commun., Mark Wilkins, NMFS, Seattle, WA). That these piscivorous fishes may be causing significant mortalities among salmon was documented in British Columbia, where it was found that Pacific mackerel consumed nearly all the salmon smolts released from a coastal hatchery (Pers. Commun., Brent Hargreaves, Canadian Fish and Oceans, Pacific Biological Station, Nanaimo, B.C. Canada V9R 5K6, March 1996), resulting in few returns from that brood-year release.

Several previous studies have focused on the food habits of large piscivorous fishes off the Pacific Coast, but no such studies have been conducted in recent years. For example, Pacific mackerel captured off Oregon in the 1980s fed primarily on euphausiids (Brodeur et. al. 1987, Brodeur and Pearcy 1992). In California, this same species feeds primarily on larval and juvenile fishes and secondarily on squid and euphausiids (MBC 1987). Food habit information from California indicated they are voracious feeders on 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 were the primary prey (Ashton et al. 1985).

Juvenile jack mackerel have been found to feed heavily on squid, *Loligo opalescens,* and northern anchovy. Adults of this species prey on several forage fishes (lantern fishes and northern anchovy), squid, pelagic crustaceans (euphausiids and copepods) and pteropods (MBC 1987).

Pacific hake off the Washington and Oregon coasts feed primarily on euphusiids, 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).

There is no detailed information on the present feeding habits of piscivorous fishes off the mouth of the Columbia River during the salmonid smolt outmigration. By

estimating the abundance of selected predators in the vicinity of the mouth of the Columbia River and by quantifying predation rates on juvenile salmonids, we will provide fisheries managers with the first estimate of the role predation plays in recruitment success. In a related study, we are investigating how predation is mediated by the abundance of alternative prey (i.e., northern anchovy, an ongoing NMFS study) and mediated by physical oceanographic conditions (upwelling, Columbia River flows, etc.). If large piscivorous marine fishes are significant salmonid predators, fishery managers will be able to incorporate these findings into their management plans, with the potential to increase ocean survival of many salmonid stocks. For example, if we discover that marine fish predators are significant predators, these fishes could be targeted for harvest by either sport or commercial fisheries. Other possible management options include releasing hatchery fishes when predators are not abundant (i.e., before or after they have left the area), or releasing hatchery fishes when alternative prey are abundant (i.e., when piscivorous fishes are foraging on prey other than salmonids). This research program will assist with the goal of managing Columbia River salmonids in an ecosystem context. It will also begin to measure salmon ocean mortalities so that the success of freshwater salmonid restoration efforts can be accurately measured. For example, if a restoration project (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 to an unsuccessful restoration project. Finally, this study can be integrated with west coast GLOBEC studies and NOAA's Pacific Northwest Coastal Ecosystem Regional Study (PNCERS).

b. Proposal objectives

Objective 1

Monitor, assess, and quantify the number of juvenile salmonids (some ESA listed stocks) consumed by marine fish predators in marine waters off the Columbia River.

Objective 2

Evaluate the relationships between the time of juvenile salmonid ocean entry, ocean environmental conditions, marine survival of salmonids, and marine fish predator populations.

c. Rationale and significance to Regional Programs. Although freshwater survival for salmonids in the Columbia River Basin may have increased as a result of regional programs, ocean salmonid survival for 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 the proposed study identifies these fishes as significant predators of migrating juvenile salmonids, measures can be taken to reduce this predation. For example, since hake and mackerel are migratory species, hatchery salmonids could be released before and after the period hake and mackerel reside off the Columbia River.

d. Project history: This project was initially scheduled to begin in late 1997. However, no commercial fishing vessel bid on the work proposal. We have recently announced a revised work proposal to the commercial fishing fleet and expect to have a vessel under contract by April 1998. Field work will be conducted every 2 weeks from April to August. A final report is scheduled for December 1998.

e. Methods. Large marine fish predators (primarily Pacific hake, Pacific mackerel, and jack mackerel, *Trachurus symmetricus*) will be collected by midwater and surface trawling during daylight and night hours, with a chartered commercial fishing vessel. Sampling will be conducted along designated transects off the mouth of the Columbia River. When sonar or echo-sounders detect marine predator fish schools, fishing gear will be deployed. Sampling will be conducted over 2 days every 2 weeks from April through September 1999, for a total of 24 sampling days. Potential salmonid predators will be identified, measured, and weighed and stomachs removed and preserved. A subsample will be taken when large catches occur. We expect to collect approximately 100-200 predator fish stomachs/species each 2 week period. Stomach contents will be identified to lowest practical taxa (usually species), counted, and weighed. 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 of salmonids in marine fish predators by estimates of the predator population size.

The relationship between ocean survival and biological and physical oceanographic conditions will be investigated using regression analysis (multiple or linear) of ocean salmonid survival (percent adult returns) on environmental variables. Upwelling data 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. This study will identify if large marine fish predators off the mouth of the Columbia River are significant sources of juvenile salmonid mortality and how this predation is influenced by physical and biological oceanographic conditions.

f. Facilities and equipment. A chartered commercial fishing vessel capable of fishing a mid-water and surface trawl will be used to collect both fish predators (hake, mackerel, etc.) and oceanographic measurements. Fish stomach analysis will be conducted at the NMFS Point Adams Biological Field Station at Hammond, OR and/or NMFS Hatfield Marine Science Center facility, Newport, OR. Both facilities have the necessary computers and microscopes to perform the laboratory and data analyses.

g. References.

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. 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., 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.

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 vs 1994 and 1995, p. 505-508. *In* Forage Fishes in Marine Ecosystems. Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems. Alaska Sea Grant College Prog. Rept. 97-01. Univ. Alaska, Fairbanks.

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.

ISG (Independent Scientific Group). 1996. Return 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.

MBC Applied Environmental Sciences. 1987. Ecology of important fisheries species offshore California. OCS Study, (Rep. To Minerals Management Serv., U.S. Dept. Int., Contract MMS 14-12-0001-30294. 251 p.

NRC (National Research Council). 1996. Upstream: Salmon and society in the Pacific Northwest. National Academy Press, Wash. D.C.

Pearcy, W. G. 1992. Ocean ecology of North Pacific salmonids. Wash. Sea Grant, Univ. Washington Press, Seattle. 179 p.

U.S. Department of Commerce. 1995. Proposed recovery plan for Snake River salmon. U.S. Dept. Commerce, National Oceanic Atmospheric Administration, NMFS. Washington, D.C. various pagination.

Section 8. Relationships to other projects

This proposal integrates well with and is a companion to the proposed project: **Salmonid ocean survival relative to migrational timing, fish health, and oceanographic conditions**.

Section 9. Key personnel

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

Principal Investigator

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

EDUCATION

A) B.Sc. Fisheries Biology (1977)
University of Massachusetts
Amherst, MA

B) M.Sc. Biology (1982)
University of Oregon
Eugene, OR

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.

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.

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.

Field Collections and Laboratory Analysis

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Fisheries Biologist
National Marine Fisheries Service
Point Adams Biological Field Station
520 Heceta Place (P.O. Box 155)
Hammond, OR 97121-0155
Telephone: (503) 861-1853

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 Report Z, 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 90-077. Annual Report to Bonneville Power Administration, Portland, OR.

Dawley, E. M., R. D. Ledgerwood, L. G. Gilbreath, P. J. Bentley, 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. 1992. Effectiveness of predator removal for protecting juvenile fall chinook salmon released from Bonneville Hatchery, 1991. (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).

Field Collections and Laboratory Analysis

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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
1) 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.
2) Senior author of nine biological research reports.
3) Senior author of two NOAA-NMFS Technical Memoranda.

WORK EXPERIENCE - ***10/88 to present***
1) Serves aboard NMFS, Point Adams Biological Field Station, research vessels and assists with all aspects of biological and physical data collections on research projects.
2) Refine and maintain data files, including: recording, computer entry and verification, performing statistical analysis using computers, and assembling tables, charts, and appendices for reports.
3) 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).
4) Monitor and verify the quality of work by private contractors who are processing benthic invertebrate samples.
5) 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., 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.

Hinton, S. A., 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.

Section 10. Information/technology transfer

Report will be available at the end of the each year of study. Final results of this study will be published in a peer reviewed journal.