PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Influence Of Marine-Derived Nutrients On Juvenile Salmonid Production

BPA project number: 20061
Contract renewal date (mm/yyyy): ☐ **Multiple actions?**

Business name of agency, institution or organization requesting funding
U. S. Geological Survey, Biological Resources Division

Business acronym (if appropriate) USGS-BRD

Proposal contact person or principal investigator:

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NPPC Program Measure Number(s) which this project addresses
Sections 7.6, 7.6A, 7.6A2, all under 7.6B, 7.6C

FWS/NMFS Biological Opinion Number(s) which this project addresses
None known.

Other planning document references
NMFS Proposed Recovery Plan for Snake River Salmon: Task Nos. 1.1, 1.1b, 1.1b.3, 1.3, 1.3b, 1.4, 1.4a, 1.4b; Wy-Kan-Ush-Mi Wa-Kish-Wit Tribal Anadromous Fish Restoration Plan: Chapters 3 and 5; Return to the River by the Independent Scientific Group: Chapters 5 and 8A.

Short description
Evaluate the influence and efficacy of marine-derived nutrient influx via adult salmonid carcass decomposition on the productivity of selected Columbia River basin tributaries and stream-rearing salmonids.

Target species
Various species of Salmonidae, including but not limited to, spring chinook salmon, coho salmon, and steelhead.

Section 2. Sorting and evaluation

Subbasin
Systemwide

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
9154	Wind River Ecosystem Restoration	Project 9154 has baseline fish and habitat data from potential streams to be used for our research
83319	New fish tag system	We plan to use the new flat-plate PIT-tag detector technology to be developed under project 83319

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Identify and select streams for use in nutrient enhancement research	a	Gather and summarize historical and recent biological data on productivity and anadromous fish runs for third to fifth order tributaries of the Columbia River basin

		b	Using data from task 1a, define the importance of marine-derived nutrients (MDN) to candidate streams and develop criteria for use in selecting streams for research
		c	Select 2-4 streams for nutrient enhancement research
2	Document the productivity of selected streams prior to nutrient enhancement	a	Assess the status of the following stream factors: habitat conditions, marine derived isotopes of C and N in selected flora and fauna, and fish production (e.g., density, biomass, age structure, growth, and physiology)
		b	Collate and analyze data on productivity of selected streams
3	Document the effects of introducing adult salmon carcasses on stream and fish productivity in selected streams	a	Using data from the previous tasks, establish control and treatment streams and/or reaches
		b	Place salmon carcasses or potentially other nutrient sources in selected treatment streams
		c	Monitor the response of stream and fish community productivity in treatment and control streams as outlined in Task 2a

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	10/1999	5/2000		Streams for enhancement work are selected	30.00%
2	6/2000	9/2001		Pre-nutrient enhancement data collected and analyzed; treatment and control streams established	70.00%
3	10/2001	10/2004		Post-nutrient enhancement data collected and analyzed; final write-up and analysis	0.00%
				Total	100.00%

Schedule constraints

Completion date
10/2005

Section 5. Budget

FY99 project budget (BPA obligated):

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel	GS-12@2080 h; GS-11@2080 h; GS-7@1040 h; GS-5@3120 h	%45	140,951
Fringe benefits	@ 28% of personnel for perms and terms; @ 7% for temps	%11	32,635
Supplies, materials, non-expendable property	Electrofishers, field supplies, computer, PIT-tag detectors, laboratory supplies	%9	27,150
Operations & maintenance		%0	0
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		%0	0
NEPA costs		%0	0
Construction-related support		%0	0
PIT tags	# of tags: 4000@ $2.90 ea.	%4	11,600
Travel	Vehicle rentals (2), vehicle mileage, and travel to meetings	%4	11,475
Indirect costs	@ 38%	%27	85,048
Subcontractor	Initial work on stable isotope analysis	%0	1,000
Other		%0	
		TOTAL BPA FY2000 BUDGET REQUEST	$309,859

Cost sharing

Organization	Item or service provided	% total project cost (incl. BPA)	Amount ($)
		%0	
		%0	
		%0	
		%0	
		Total project cost (including BPA portion)	$309,859

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget	$458,672	$375,000	$412,500	$250,000

Section 6. References

Watershed?	Reference
☐	Bilby, R.E., B.R. Fransen, and P.A. Bisson. 1996. Incorporation of nitrogen and carbon from spawning coho salmon into the trophic system of small streams: evidence from stable isotopes. Can. J. Fish. Aquat. Sci. 53:164-173.
☐	Bilby, R. E., B. R. Fransen, P. A. Bisson, and J. K. Walter. 1998. Response of juvenile coho salmon and steelhead to the addition of salmon carcasses to two streams in southwestern

	Washington, U.S.A. Can. J. Fish. Aquat. Sci. 55: 1909-1918.
☐	Bohlin, T. 1982. The validity of the removal method for small populations -- consequences for electrofishing practice. Institute of Freshwater Research Drottningholm Report 60:15-18.
☐	Cederholm, C. J., D. B. Houston, D. L. Cole, and W. J. Scarlett. 1989. Fate of coho salmon (Oncorhynchus kisutch) carcasses in spawning streams. Canadian Journal of Fisheries and Aquatic Sciences 46: 1347-1355.
☐	Connolly, P.J. 1996. Resident cutthroat trout in the central Coast Range of Oregon: logging effects, habitat associations, and sampling protocols. Doctoral dissertation. Oregon State University, Corvallis.
☐	Dolloff, C.A., D.G. Hankin, and G.H. Reeves. 1993. Basinwide estimates of habitat and fish populations in streams. General Technical Report SE-83. Asheville, North Carolina: U.S. Agriculture, Forest Service, Southeastern Forest Experiment Station
☐	Hankin, D.G., and G.H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences 45:834-844.
☐	Kline, T.C., J. J. Goering, O.A. Mathisen, P.H. Poe, and P.L. Parker. 1990. Recycling of elements transported upstream by runs of Pacific salmon: I. 15N and 13C evidence in Sashing Creek, Southeastern Alaska. Can. J. Fish. Aquat. Sci. 47:136-144.
☐	Larkin, G.A., and P.A. Slaney. 1997. Implications of trends in marine-derived nutrient influx to south coastal British Columbia salmonid production. Fisheries 22:16-24.
☐	Michael, J.H. 1995. Enhancement effects of spawning pink salmon on stream rearing juvenile coho salmon: managing one resource to benefit another. Northwest Sci. 69:228-233.
☐	Richey, J.E., M.A. Perkins, and C.R. Goldman. 1975. Effects of kokanee salmon (Oncorhynchus nerka) decomposition on the ecology of a subalpine stream. J. Fish. Res. Board Can. 32:817-820.
☐	Schuldt, J.A., and A.E. Hershey. 1995. Effect of salmon carcass decomposition on Lake Superior tributary streams. J. N. Am. Benthol. Soc. 14:259-268.
☐	Smith, S.G., J.R. Skalski, W. Schlechte, A. Hoffman, and V. Cassen. 1994. Statistical survival analysis for fish and wildlife tagging studies. SURPH.1 Manual. Center for Quantitative Science, HR-20, Univ. of Washington, Seattle, WA 98195.
☐	White, G.C., D.R. Anderson, K.P. Burnham, and D.L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. No. LA-8787-NERP, UC-11. Los Alamos National Laboratory, Los Alamos, NM.
☐	Zippin, C. 1956. An evaluation of the removal method of estimating animal populations. Biometrics 12:163-189.

PART II - NARRATIVE

Section 7. Abstract

Adult anadromous salmonids (*Oncorhynchus* spp.), through excretion, gamete deposition, and carcass decomposition, transport significant amounts of marine-derived nutrients (MDN) to the freshwater ecosystem. Such nutrient input to streams is a fundamental aspect of salmonid ecology and is important to the productivity of waters in which salmon spawn. However, the decline of salmon populations in the Pacific Northwest has dramatically reduced the availability of carcasses in many tributaries of the Columbia and Snake rivers. Diminished inputs of MDN can depress stream ecosystem productivity and lead to a cascade of deleterious effects such as decreased juvenile salmonid size, reduced overwinter and marine survival, and declines of returning adults. We propose to document the effects and efficacy of nutrient enhancement via carcass decomposition on the productivity of anadromous (and other) fish in selected Columbia River basin tributaries. This research will involve identification and selection of treatment and control streams, collection and analysis of pre-enhancement baseline data on a variety of factors related primarily to fish production, and finally the stocking of carcasses into streams and monitoring and evaluation of the response of fish productivity. Information derived from this project is

fundamental to measures outlined in the FWP regarding coordinated salmon production and habitat. In addition, this information may be critical to the success of restoration and supplementation programs. Our results should add to the growing body of evidence assessing the importance of MDN to salmonid production and will establish a solid foundation towards implementing nutrient enrichment as a long-term management program designed to help reverse the decline of Pacific Northwest salmonid populations.

Section 8. Project description

a. Technical and/or scientific background

Historically, the Columbia River Basin supported overwhelming numbers of spawning salmon. Today, however, wild salmon populations in the Pacific Northwest have declined to alarmingly low numbers. In the Columbia River basin, one contributing factor (among several) may be a lack of marine-derived nutrients (MDN)--via salmon carcasses--being transported to tributary streams where adults spawn and juveniles rear. Increasing evidence indicates that the nutrients contained in salmon carcasses can have profound effects on stream productivity and concomitant fish production. For example, several studies have shown that decomposing fish carcasses can increase nitrogen and phosphorus concentrations in streams which, in turn, increase algal biomass and primary and secondary production (Richey et al. 1975; Kline et al. 1990; Schuldt and Hershey 1995; Bilby et al. 1996). Such changes in stream productivity can ultimately lead to substantial increases in fish production (Michael 1995; Bilby et al. 1996; Larkin and Slaney 1997; Bilby et al. 1998). Furthermore, because many streams in the Pacific Northwest have low productivity, only modest inputs of nutrients may be necessary to increase trophic productivity (Schuldt and Hershey 1995; Larkin and Slaney 1997). In short, MDN may be essential for maintaining the productivity of nursery and rearing areas for future generations of salmon (Schuldt and Hershey 1995; Kline et al. 1990; Larkin and Slaney 1997).

Despite the increasing evidence documenting the importance of MDN to stream and fish productivity, several questions remain regarding the utility of nutrient enhancement via carcass introductions. For example, little is known about the importance of spring chinook salmon (*Oncorhynchus tshawytscha*) or steelhead (*O. mykiss*) carcasses to stream community productivity. To date, most work has been done using either coho (*O. kisutch*), pink (*O. gorbuscha*), or sockeye (*O. nerka*) salmon, which may not be valid surrogates for unstudied species. Also, most research to date on MDN in the Pacific Northwest has been done on streams west of the Cascade Mountains. Carcasses have been placed in streams west of the Cascades, but no extensive research on MDN has been conducted on streams east of the Cascades, despite east-side habitat and community differences that could influence the importance of MDN to stream productivity. Few studies have addressed the importance of MDN at the watershed or basin level, thus precluding a detailed knowledge of the utility of nutrient enhancement on a larger scale. Also, more research is needed on the influence of MDN to many aspects of fish production, including growth, population densities and biomass, age structure, physiological health and smoltification, and ultimately survival and adult returns. Finally, little is known about potential disease issues related to the introduction of carcasses into streams. Although we understand the potential importance of MDN to different trophic levels of a stream community, our research will focus on the responses of fish production to MDN because of logistic and budgetary constraints and our belief that fish production responses are probably of primary importance to fishery managers. We hope our proposed research will at least partially address some of the previously mentioned questions regarding the efficacy of nutrient enhancement to increase salmonid production.

Nutrients derived from decomposing carcasses are a fundamental aspect of salmonid and stream ecology and should be an integral component of research and management activities to meet the habitat goals, policies, and objectives of the NPPC Fish and Wildlife Program. Although the importance of nutrient enrichment may vary from stream-to-stream due to a variety of factors, this technique has the potential to be a relatively low-cost, long-term program to help increase salmonid production. Furthermore, the oligotrophic nature of many streams in the basin suggests that nutrient enrichment will likely be a necessary component of proposed or ongoing restoration and supplementation programs.

Given the condition of salmonid habitat and production in the Columbia River basin, the time is now to provide some focus on the potential benefits and risks of nutrient enrichment as a management technique to help reverse the decline of salmonid resources. The states of Washington and Oregon have ongoing efforts at stream nutrient enrichment via carcass introductions, which have received considerable public support and involvement. Ongoing efforts in Canada suggest that direct application of artificial chemical media may be a good substitute, especially if carcasses are scarce or their use is not feasible. Despite the ongoing efforts to add carcasses to streams, scant research has been conducted in the Columbia River basin to address the efficacy of these efforts and to evaluate when and where this technique is most likely to produce the desired effect.

b. Rationale and significance to Regional Programs

This proposed project should be an essential component of Section 7 of the NWPPC Fish and Wildlife Program (FWP), entitled "Coordinated salmon production and habitat". This project clearly seeks to improve and maintain the quality and productivity of salmonid habitat on a watershed basis as stated in Section 7. Furthermore, this project has at its core the use of coordinated, cooperative, and comprehensive efforts by federal, state, tribal, and private parties to undertake activities associated with this work. The FWP states that such efforts are not only needed, but are also the best approach to watershed restoration and habitat improvement projects. This project specifically addresses the habitat goal of the FWP (7.6A), to "protect and improve habitat conditions to ensure compatibility with the biological needs of salmon, steelhead, and other fish and wildlife species". This project addresses the specific objective (7.6A.2) of improving the productivity of salmon and steelhead habitat critical to the recovery of weak and other stocks. We believe this project is highly relevant to *all* the habitat policies of the FWP (7.6B) in that this work will: be cooperative in nature (7.6B.1 and 7.6.B.2), address areas of low to medium productivity (7.6.B.3), maximize the desired result per dollar spent and have a high probability of success (7.6.B.4), and encourage, involve, and promote public involvement and education (7.6.B.6). Finally, from a watershed management perspective, this research should coordinate well with other watershed improvement efforts and seeks to use a natural healing mechanism to help improve habitat quality and restore normative conditions. As previously mentioned, nutrients derived from decomposing salmon carcasses are a fundamental aspect of salmonid and stream ecology.

We recognize that there are several ongoing efforts that are introducing carcasses to streams throughout the Pacific Northwest, and we see no need to simply propose to expand these efforts in the Columbia River basin. We do see a need for a comprehensive and systematic research effort to evaluate the utility and efficiency of this management technique. Results from our proposed project will help guide future efforts by helping to define when and where the addition of carcasses or other nutrient enrichment media will have the highest chance of success and will have the lowest chance of producing adverse effects.

Although the importance of marine-derived nutrients to stream and salmonid productivity may be self-evident to those familiar with general principles of aquatic and salmonid ecology, we offer the following quote from Larkin and Slaney (1997) as timely advice for justifying nutrient enhancement work in the Columbia basin: "Without a broad-based, integrated strategy of renewal by intensifying research on nutrient-salmon interdependence, habitat protection efforts, extensive restoration and mitigation of impacted fish habitat, and risk-averse fisheries exploitation, we are confronted with unsustainability and continued decline of weaker stocks of coastal wild anadromous salmonids...". Furthermore, the recent and upcoming symposia and workshops on MDN (e.g., the Western Division of the American Fisheries Society special symposium on MDN in Anchorage during October 1998) and the extensive media coverage and community support that nutrient enrichment of streams via carcasses has received illustrates the importance of this concept to the region's lay and scientific communities. Clearly, the time is now for research on MDN to become an integral part of Columbia River basin anadromous salmonid management.

c. Relationships to other projects

The existence of data from past and ongoing projects will influence our choice of study sites. We will forge cooperative working relationships with private, state, tribal, and federal entities to maximize the efficiency of our efforts. For example, we have a high degree of interest in the fish monitoring data from the Wind River Ecosystem Restoration project (no. 9154). Use of this type of long term data set will help us decipher treatment effects against the background of natural variation.

d. Project history (for ongoing projects)

(Replace this text with your response in paragraph form)

e. Proposal objectives

Objective 1. Identify and select streams for use in nutrient enhancement research.

(This objective involves no rigorous hypothesis testing)

Products: criteria for site selection; list of study sites.

Objective 2. Document the productivity of selected streams prior to nutrient enhancement. Factors to be examined could include, but would not be limited to, such factors as estimating nutrient cycling (i.e., status of marine-derived isotopes of C and N), and fish growth, biomass, densities, and selected aspects of fish physiology and health.

(This objective also involves no rigorous hypothesis testing, but serves to collect baseline data prior to nutrient enhancement)

Products: annual progress report or publication on the trophic status of our study sites.

Objective 3. Document the effects of introducing adult salmonid carcasses on stream and fish productivity in selected streams.

Null hypothesis: "There is no difference in quantity of marine-derived isotopes of C and N in selected flora and fauna between streams stocked with carcasses and those without".

Null hypothesis: "There is no difference in selected aspects of fish production and physiology between streams stocked with carcasses and those without".

Null hypothesis: "There are no deleterious aspects of introducing carcasses to streams such as disease or deterioration of water quality".

Products: final report of research and research publications dealing with the efficacy of nutrient enhancement to help restore the productivity of salmon populations.

f. Methods

Objective 1. Identify and select streams for use in nutrient enhancement research.

To address objective 1, a list of candidate study streams will be developed using historical information, data from ongoing projects in the Columbia River basin, and through contacts with state, tribal, and federal fishery biologists. A list of criteria will be developed to assess the adequacy of candidate streams for our proposed research. Criteria for stream selection will encompass a variety of factors including, but not limited to, accessibility, availability of historical data, fish species composition (both resident and anadromous), surrounding watershed characteristics (e.g., geology, climate, and land use practices), stream gradient, discharge patterns, stream-channel complexity, the status of any ongoing salmonid reintroduction or rehabilitation efforts, and any socio-political concerns. A primary criterion for stream selection will be that adult salmonid returns are currently nonexistent or minimal but were historically present. Also, the streams should support some juvenile anadromous salmonid production because of either ongoing reintroduction efforts or natural spawning. Streams that appear promising based on our criteria will be visited in the field prior to final selection. After assessing the adequacy of streams using the set of criteria and field examinations, we will select from two to four streams for use in our study. The number of streams selected will depend on logistical and budgetary constraints.

Objective 2. Document the productivity of selected streams prior to nutrient enhancement.

Our preferred experimental design to address objective 2 will require the use of paired treatment and control streams with similar biological, geomorphological, and physicochemical features. As a secondary design, we could use upstream (control) and downstream (treatment) study reaches within the same stream separated by natural barriers. The aims of this objective are to thoroughly assess the following characteristics of our study streams: (1) the status of selected habitat variables; (2) the stable isotope ratios of ^{13}C and ^{15}N in selected flora and fauna; and (3) numerous variables associated with fish production. The theoretical idea underlying this objective is to document the structure and function of our streams *before* we introduce carcasses.

To characterize the habitat of our research streams, we will conduct intensive habitat surveys of the entire stream length. Data obtained from habitat surveys will include habitat types (e.g., pools, glides, and riffles), stream gradient, amount of large woody debris, pool frequency, amount of fish cover, stream substrate types, channel type, hillslope condition and vegetation, riparian condition and vegetation, and affecting anthropogenic and natural disturbances. We will use GIS or other mapping tools to determine size of watershed and topographical descriptors such as elevation, geology, and hillslope gradients. We will place thermographs at multiple locations to record annual and diel temperature profiles within each stream and will also collect basic information on water chemistry, such as dissolved oxygen levels, pH, and total alkalinity.

Stable isotope ratios in selected flora and fauna will be assessed using methods similar to those described by Kline et al. (1990) and Bilby et al. (1996). Briefly, samples of riparian vegetation, aquatic vegetation (i.e., periphyton), aquatic macroinvertebrates, and fish and other fauna (e.g., salamanders) will be collected from selected locations at each stream for isotope analysis. In the field, riparian foilage will be removed using forceps and placed in plastic bags. Epilithic organic matter will be scraped from aquatic substrates, collected in steel pans, and stored in glass vials with stream water. Aquatic invertebrates will be collected by disturbing the streambed upstream of a Surber sampler and placing the contents in a plastic bag with stream water. Fish, both anadromous and resident (and perhaps amphibians), will be collected by electrofishing, sacrificed, and placed in plastic bags with distilled water. All samples collected from the field will be kept on ice until transported back to our laboratory. At our laboratory, all samples will be frozen at –20°C until they can be processed for isotope analysis. For analysis, samples will be thawed, freeze dried, ground to a fine powder using a laboratory mill, and stored over silica gel dessicant in sealed vials. Invertebrates will be sorted by trophic categories (e.g., grazers, shredders, collector-gatherers, and predators). We will use from 25-100 mg of sample for analysis, depending on taxa, and will pool samples if necessary. The powdered samples will be sent to an outside contractor to conduct the isotope ratio analyses. The analyses basically involve combusting the samples to generate CO_2 and N_2 gases and measuring the isotope ratios in the evolved gases with mass spectrometry. We will attempt to obtain a sample size of 10 for each taxa or group examined at three different locations (e.g., upper, middle, and lower sections) on each stream and will compare values between treatment and control streams using two-sample *t*-tests or their non-parametric analogs.

We will estimate species composition, density, biomass, size, and growth rates of fish in control and treatment streams. We will use the habitat unit information from our habitat surveys (described above) and a stratified systematic approach modified from Hankin and Reeves (1988) to estimate fish population attributes. Fish density and biomass will be estimated for an entire stream using snorkeling. We will snorkel a systematic sample of habitat units within the strata of habitat types (e.g., 1-in-5 pools; 1-in-10 riffles, etc.) to identify and count fish by species and age groups. We will calibrate our snorkel estimates primarily by electrofishing using a ratio method following guidelines of Dolloff et al. (1993). Besides calibrating our snorkel estimates, electrofishing will be used in selected habitat units to assess species composition, fish condition and food habits (described below), and to obtain more detailed information on length, weight, and age. For electrofishing, habitat units chosen for sampling will be blocked off with nets to insure no movement into or out of the unit during sampling. A backpack electrofisher will be used to conduct two or more passes under the removal-depletion methodology (Zippin 1956; Bohlin et al. 1982; White et al. 1982). The field guides of Connolly (1996) will be used to insure that a pre-determined level of precision for the population estimate is achieved (generally, coefficient of variation no greater than 25%) within each sampling unit for each salmonid species and age group (expected: 2-3 age groups). These methods have been chosen to specifically insure maximum conservancy in the number of units sampled by electrofishing and in the number of electrofishing passes conducted, which lessen the chance that individual fish will be exposed to potentially harmful effects of electroshocking.

All captured fish will be lightly anesthetized in tricaine methanesulfonate (MS-222), weighed and measured, and returned back to the stream. We will sacrifice a small subsample of fish to obtain tissues for an assessment of fish health. Tissues to be sampled will include liver, muscle, and gills. Physiological factors to be examined will include liver glycogen levels, the activity of certain enzymes associated with intermediary metabolism, and gill Na^+, K^+-ATPase levels in salmonids. If appropriate and feasible, we will provide sacrificed fish to the Lower Columbia Fish Health Center (USFWS) for a complete disease profile as part of an ongoing wild fish health survey. For another subsample of our fish, we will assess their food habits to determine the relative importance of autochthonous and allochthonous food sources in their diets. This will also allow us to examine potential pathways for marine-derived nutrient uptake (i.e., directly through consumption of eggs and carcass flesh, or indirectly through the ingestion of aquatic invertebrates) by fish in the treatment streams after carcass introduction. Stomach contents will be obtained from a subsample (by species and age group) of collected fishes. A pilot study and literature review on the feeding habits of fishes in our study streams will be used to determine when fishes should be sampled for maximum gut fullness. We will use a non-lethal gastric lavage procedure for obtaining stomach contents. Food habits data will be expressed as the ratio of dry weight of food consumed (food items will be categorized into one of several major groups) per wet gram of predator following the methods of Bilby et al. (1998).

In addition to the *in situ* population attributes just described, we will document survival and movement of anadromous fish in treatment and control streams using a combination of PIT tags and smolt traps. We will PIT tag juvenile salmonids greater than 60 mm and place traps and/or detector devices to interrogate PIT-tagged fish during their outmigration. By FY2001, we hope that flat-plate PIT-tag detector devices will be available to stretch across a stream's entire width for enhanced monitoring of timing of fish movement through the stream. Depending on location of our research streams, we will use the PIT tag interrogation systems at dams to obtain data needed for survival estimates and, by using the sort-by-code system at certain dams, will assess fish size and condition during periods of outmigration. We will use screw-type smolt traps as a second method to assess movement characteristics and fish size and condition. Our first choice will be to use data from traps already in place around the basin, which would help decrease FY 2001 funding needs. If existing traps are not available, we will place traps in an appropriate location near the downstream ends of our research streams. We will operate these traps as long as water conditions allow, with an emphasis on having them in place during anticipated periods of emigration for the species under study. We will estimate the efficiency of these traps by releasing marked fish above the trap sites at selected intervals during the period of trap operation. These intervals of time will be determined by numbers of fish passing and changes in flow conditions. Data from PIT tag sort-by-code interrogations and/or smolt traps will be used to assess changes in fish size and condition and migration timing and age between fish from treatment and control streams. Data from PIT tag interrogations will also be used to estimate survival of treatment and control fish during their downstream migration using methods outlined in Smith et al. (1994).

Objective 3. Document the effects of introducing adult salmonid carcasses on stream and fish productivity in selected streams.

To examine the effects of marine-derived nutrients (MDN) on stream and fish productivity, we will introduce carcasses of adult salmonids into our treatment streams. Carcass introductions will comply with any existing state and federal requirements or guidelines regarding disease issues, water quality standards, and other concerns (e.g., Washington State Department of Fish and Wildlife Protocols and Guidelines for distributing salmonid carcasses to enhance stream productivity in Washington State). Depending on present and past records, we anticipate using carcasses of either adult spring chinook salmon *O. tshawytscha*, coho salmon *O. kisutch*, or steelhead *O. mykiss* for placement into treatment streams. Unlike many previous nutrient enrichment studies that investigated relatively short stream reaches, we are proposing to examine the effects of carcass introductions along an entire stream gradient. Densities of introduced carcasses will approximate historical spawner escapements for the study streams. If escapement data are unavailable for the treatment streams, carcass loadings will be based on spawner densities from similar streams in the region. The seasonal timing of carcass introduction and the distribution of carcasses along the stream gradient will be chosen to reflect possible past nutrient contributions from naturally spawning fish.

Adult salmon carcasses will be obtained from state, federal, or tribal hatcheries, preferably from within the same drainage as the treatment streams. We will comply with all agency requirements for interbasin transfer of carcasses, if necessary. Carcasses may have to be frozen in order to assure an adequate seasonal supply. If possible we will attempt to mimic naturally occurring sex ratios of introduced carcasses. We will also try to distribute some intact (unspawned) female salmon carcasses, since Bilby et al. (1998) found that salmon eggs are consumed preferentially to salmon flesh by juvenile salmonids when available. Salmon carcasses will be weighed and measured for length before distribution. Many streams may have lost the ability to retain carcasses (Cederholm et al. 1989) due to loss of channel complexity resulting from human disturbances. For this reason we may have to tether or anchor carcasses in place to assure their retention within the study stream. After carcass introductions, we will repeat the methods discussed for objective 2 to assess the effects of MDN on nutrient cycling and the fish population attributes described above. All of the factors we have described in objective 2, including MDN levels in the flora and fauna, population densities, size and condition, physiological factors, movements, and survival will be compared between fish from treatment streams and those from control streams.

g. Facilities and equipment

We anticipate that all of the work for this project will be based from our Columbia River Research facility. Our laboratory, which has a long history of conducting research throughout the basin, has a fully equipped wet laboratory as well as several dry laboratories for conducting physiological assays. Our laboratory is also well equipped with most of the state of the art equipment necessary to conduct a wide array of field work. We are fully capable of working in a variety of field situations, from large reservoirs to small streams. Our office is well supplied with the modern equipment and analysis software necessary to complete this research. In short, our laboratory already has much of the equipment and technology necessary to complete this research, which we believe will result in substantially lower costs.

h. Budget

Personnel costs are based on the number of people and the level of expertise needed to complete the tasks. These personnel include 12 months of project leader time, 12 months of a project biologist, and several 6-month field positions. Rates charged are based on standardized USGS wage scales. Fringe benefits are a product of standard percentages charged for insurance and medical and retirement plans by the USGS. Supplies include sampling gear (including electrofishers and drysuits) and office supplies (including 1 computer). We will not have O&M, Capital, or NEPA costs. We have proposed to purchase 4,000 PIT tags and two PIT-tag detectors. Travel includes costs that were derived using GSA's standardized per mile vehicle costs and rental rates. Travel also includes the cost of two individuals for attending one regional meeting or workshops each fiscal year. Indirect Costs are a product of our agency's standard of 38% charged for overhead. Subcontractor costs include fees associated with lab analyses of stable isotopes of carbon and nitrogen.

Section 9. Key personnel

The names, titles, hours, and duties of key personnel are:

Matthew G. Mesa, Research Fishery Biologist, 1,040 h. Duties: project oversight, analysis of physiological and stable isotope data, write up of reports or publications.

Patrick J. Connolly, Research Fishery Biologist, 1,040 h. Duties: project oversight, field work coordinator, analysis of field data, and write up of reports or publications.

Craig A. Barfoot, Research Fishery Biologist, 2,080 h. Duties: field team leader and coordinator, analysis of field data, and write up of reports or publications.

The resumes of these key personnel follow.

Resume for: Matthew G. Mesa

Experience

1991-Present	Research Fishery Biologist, U.S. Geological Survey, Biological Resources Division, Columbia River Research Laboratory, Cook, WA Current responsibilities: Team leader on research projects addressing the effects of thermal stress on juvenile salmonids and evaluating the swimming performance and physiology of Pacific lamprey
1989-1991	Fishery Biologist, U.S. Fish and Wildlife Service, Seattle-NFRC, Columbia River Field Station, Cook, WA
1986-1989	Fishery Biologist/CEA Appointee, Seattle-NFRC, Oregon Cooperative Fisheries Research Unit, Oregon State University, Corvallis, OR
1984-1986	Fishery Biologist, U.S. Fish and Wildlife Service, Seattle-NFRC, Columbia River Field Station, Cook, WA

Education:	School	Degree and Date Received
	California Polytechnic State Univ. at San Luis Obispo	B.S., Nat. Res. Mgt., 1984
	Oregon State Univ.	M.S., Fisheries Science, 1989
	Oregon State Univ.	Ph.D, 1999 (anticipated)

Expertise: My areas of expertise include predator-prey interactions in fishes, fish behavior and performance, and general and stress physiology of fishes

Publications and Reports (five most relevant)

Mesa, M.G. and C.B. Schreck. 1989. Electrofishing mark-recapture and depletion methodologies evoke behavioral and physiological changes in cutthroat trout. Transactions of the American Fisheries Society 118:644-658.

Mesa, M.G. 1991. Variation in feeding, aggression, and position choice between hatchery and wild cutthroat trout in an artificial stream. Transactions of the American Fisheries Society 120:723-727.

Mesa, M.G. 1994. Effects of multiple acute stressors on the predator avoidance ability and physiology of juvenile chinook salmon. Transactions of the American Fisheries Society 123:786-793.

Mesa, M.G., T.P. Poe, D.M. Gadomski, and J.H. Petersen. 1994. Are all prey created equal? A review and synthesis of differential predation on prey in substandard condition. Journal of Fish Biology 45 (Supplement A):81-96.

Mesa, M.G., T.P. Poe, A.G. Maule, and C.B. Schreck. 1998. Vulnerability to predation and physiological stress responses in juvenile chinook salmon experimentally infected with *Renibacterium salmoninarum.* Canadian Journal of Fisheries and Aquatic Sciences 55:1599-1606.

Resume for: Patrick J. Connolly

Experience

1997-Present	Research Fishery Biologist, U.S. Geological Survey, Biological Resources Division, Columbia River Research Laboratory, Cook, WA. Current responsibilities: Team leader on a research project to determine survival of summer steelhead over their first winter in the Wind River subbasin (WA).
1994-1997	Consultant to Wind River Restoration Team, WA.
1990-1996	Research Assistant, Oregon State University, Corvallis.
1988-1991	Fish Biologist--Subbasin Planner, Oregon Dept. Fish & Wildlife, Corvallis.
1987-1988	Fish Biologist--Research, Oregon Dept. Fish & Wildlife, Columbia River Research, Clackamas, OR.
1985-1987	Fish Biologist, Beak Consultants Inc., Portland, OR.
1984-1985	Fishery Biologist, U.S. Fish and Wildlife Service, National Fisheries Research Center, Columbia River Field Station, Cook, WA.
1983	Fish Habitat Surveyor, Idaho Transportation Dept., Coeur d'Alene, ID.

Education: School	Degree and Date Received
Oregon State Univ., Corvallis	Ph.D. Fisheries Science, 1996
Univ. of Idaho, Moscow	M.S. Zoology, 1983
Centre College of Kentucky, Danville	B.S. Biology, 1977

Expertise: The primary areas of my expertise include stream fish ecology and population dynamics. I have contributed to numerous studies involving anadromous and resident salmonids as well as non-salmonids of the Pacific Northwest.

Publications and Reports (five most relevant)

Connolly, P.J. and J.D. Hall. In press. Biomass of coastal cutthroat trout in unlogged and previously clearcut basins in the central coast range of Oregon. Trans. Am. Fish. Soc.

Connolly, P.J. 1997. Influence of stream characteristics and age-class interactions on populations of coastal cutthroat trout. Pages 173-174 *in* J.D. Hall, P.A. Bisson, and R.E. Gresswell, editors. Sea-run cutthroat trout: biology, management, and future conservation. Oregon Chapter, Am. Fish. Soc., Corvallis.

Connolly, P.J. 1996. Resident cutthroat trout in the central Coast Range of Oregon: logging effects, habitat associations, and sampling protocols. Doctoral thesis, Oregon State University, Corvallis.

Connolly, P.J. 1995. Wind River steelhead restoration project: with special emphasis on the Trout Creek Basin. Prepared for: Col. River Res. Lab., NBS, Cook, WA.

Connolly, P.J. et al. 1992. Fish management plan for the Middle Fork Willamette Subbasin. Oregon Dept. Fish and Wildlife, Portland.

Resume for: Craig A. Barfoot

Experience

1992-Present Research Fishery Biologist, U.S. Geological Survey, Biological Resources Division, Columbia River Research Laboratory, Cook, WA

Current responsibilities: I am a team leader for a study evaluating the effects of lower Snake River hydrosystem changes on predation-related juvenile salmonid mortality. Field data are being collected on food habits and habitat use of northern pikeminnow and smallmouth bass within the free-flowing lower Snake River and the Hanford reach of the Columbia River.

1990-1992 Research assistant, Montana State University

Education:

School	Degree and Date Received
University of South Dakota	B.S. Biology 1989
Montana State University	M.S. Fish and Wildlife Mgmt. 1993

Expertise: Fish Assemblage Structure, Larval Fish Ecology, Stream Ecology

Publications:

Gadomski, D.M., and C.A. Barfoot. 1998. Diel and distributional abundance patterns of fish embryos and larvae in the lower Columbia and Deschutes rivers. Environmental Biology of Fishes. 51: 353-368.

Wertheimer, R.H., and C.A. Barfoot. In press. Validation of daily increments in otoliths of northern squawfish larvae. California Fish and Game.

Barfoot, C.A., D.M. Gadomski, and R.H. Wertheimer. In press. Growth and mortality of age-0 northern squawfish, Ptychocheilus oregonensis, rearing in shoreline habitats of a Columbia River Reservoir. Environmental Biology of Fishes.

Section 10. Information/technology transfer

For all research activities associated with this project, we fully intend to have findings published in peer-reviewed journal articles and agency reports. An integral part of this project involves public education and outreach. In areas where carcass introductions might take place, we plan on conducting seminars for all interested parties to fully inform the public of the goals, objectives, and potential benefits of this type of work. We anticipate this project could generate considerable media interest, and will work to convey the importance of this research and management technique to the restoration of Columbia River basin salmonids.

Congratulations!