Bonneville Power Administration
Fish and Wildlife Program FY99 Proposal

Section 1. General administrative information

Water temperature effects on fall chinook salmon in the Snake and Columbia rivers.

Bonneville project number, if an ongoing project 9078

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

Business acronym (if appropriate) USGS

Proposal contact person or principal investigator:

Name	Dennis W. Rondorf
Mailing Address	5501A Cook-Underwood Rd.
City, ST Zip	Cook, WA 98605
Phone	(509) 538-2299
Fax	(509) 538-2843
Email address	dennis_rondorf@usgs.gov

Subcontractors.

Organization	Mailing Address	City, ST Zip	Contact Name
U.S. Fish and Wildlife Service	Idaho FRO P.O. Box 18	Ahsahka, ID 83520	William Connor
Nez Perce Tribe	P.O. Box 1701	Orofino, ID 83544	Bill Arnsberg

NPPC Program Measure Number(s) which this project addresses.

2.2E.4 AAnalyze the relationship between drawdown limits and fish flow measures≅
5.2B ASummer migrants≅
6.1D ASnake River temperatures≅
7.5B.3 AContinue to fund basic life history studies for Snake River fall chinook.≅

NMFS Biological Opinion Number(s) which this project addresses.

NMFS BO RPA XII.17 AThe COE shall monitor river temperatures and implement, when possible, temperature control measures in the lower Snake River, such as releasing cool water from both Dworshak Dam and the Hells Canyon complex during August and

September.≅

Other planning document references.

Wy Kan Ush Me Wa Kush Wit, the Anadromous Fish Restoration Plan of the Nez Perce, Umatilla, Warm Springs and Yakima tribes recognizes the deleterious effects of high temperatures on salmonids and restoration efforts. This project is consistent with tribal goals of reducing temperature-related mortality and increasing natural production.

The National Marine Fisheries Service=s SRSRP recognizes that one of the factors that managers need to consider in making flow augmentation decisions is AInstream temperature conditions and the degree to which augmentation might affect instream temperatures [and fish] positively.≅ (pp V-2-19,20) This study would be addressed by measure 2.1.d.3 AThe BPA should evaluate juvenile survival in relation to flow augmentation during downstream migration.≅

Subbasin.

Snake River, Clearwater River, Yakima River

Short description.

Determine the effects of water temperature and hydropower operations on the survival and performance of rearing and migrating juvenile fall chinook salmon.

Section 2. Key words

Mark	Programmatic Categories	Mark	Activities	Mark	Project Types
X	Anadromous fish		Construction		Watershed
	Resident fish		O & M		Biodiversity/genetics
	Wildlife		Production		Population dynamics
	Oceans/estuaries	X	Research		Ecosystems
	Climate		Monitoring/eval.	X	Flow/survival
	Other		Resource mgmt		Fish disease
			Planning/admin.		Supplementation
			Enforcement		Wildlife habitat enhancement/restoration
			Acquisitions		

Other keywords.

temperature, fall chinook, summer flows, survival, behavior, performance, heat-stress proteins, Columnaris

Section 3. Relationships to other Bonneville projects

Project #	Project title/description	Nature of relationship

Section 4. Objectives, tasks and schedules

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Determine incubation and emergence timing under an array of fluctuating water temperatures representative of the mainstem Snake River and its tributaries.	A	Assess fall chinook salmon timing and survival from egg fertilization to swim-up under five fluctuating temperature regimes and a control.
		B	Conduct fish health analyses on mortalities and swim-up fry.
		C	Model the relation between survival, swim-up size, water temperature during incubation, cumulative centigrade temperature units to hatch, and fish health using multiple regression analysis.
2	Identify physiological indicators of acute and chronic thermal stress.	A	Examine the feasibility of using stress proteins or heart and liver enzymes to indicate thermal history, heat-related tissue damage, and long-term disposition.
		B	Determine the effects of different thermal exposure histories on seawater entry and survival in fall chinook salmon.
		C	Compare the risks associated with acute temperature and handling stress associated with transportation with those associated with the chronic exposure to sublethal temperatures experienced during in-river migration.
3	Identify performance related changes of juvenile fall chinook	A	Use disease challenges to determine the susceptibility of fall

	salmon exposed to long-term sublethal temperatures.		chinook salmon to *Flexibacter columnaris* under and array of temperatures that would typically be experienced by summer migrants.
		B	Conduct predator avoidance trials to determine the effect of chronic high temperatures on fall chinook salmon predation risk.
		C	Use temperature-sensitive radio tags and telemetry to examine migratory behavior of juvenile fall chinook salmon before and after flow augmentation from Dworshak Reservoir.
4	Determine the effects of temperature on natural production in the Snake and Clearwater rivers, and estimate potential risk of mortality due to exposure to different water temperature regimes characteristic of lower Snake River reservoirs in the summer.	A	Define the role of temperature in determining the difference in natural production between the Snake, Clearwater, and Yakima rivers.
		B	Define alternative scenarios for operating Dworshak Dam to enhance the natural production in the Clearwater River.
		C	Synthesize information obtained from Objectives 2 and 3 to determine if the temperature effects associated with flow augmentation increases the survival of juvenile fall chinook salmon in lower Snake River reservoirs.

Objective schedules and costs

Objective #	Start Date mm/yyyy	End Date mm/yyyy	Cost %
1	10/1999	10/2001	20
2	10/1999	10/2003	30
3	10/1999	10/2003	30
4	10/1999	10/2003	20

Schedule constraints.

Completion date.
2003

Section 5. Budget

FY99 budget by line item

Item	**Note**	**FY99**
Personnel		$150,000
Fringe benefits		$50,000
Supplies, materials, non-expendable property		$30,000
Operations & maintenance		
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		
PIT tags	# of tags:	
Travel		$12,000
Indirect costs	Administrative overhead	$98,000
Subcontracts	Cooperator: USFWS and NPT	$350,000
Other	Vehicle and boat operation	$10,000
TOTAL		$700,000

Outyear costs

Outyear costs	**FY2000**	**FY01**	**FY02**	**FY03**
Total budget	$700,000	$700,000	$600,000	$500,000
O&M as % of total	$0	$0	$0	$0

Section 6. Abstract

The goal of this project is to define the short and long-term effects of temperature on juvenile fall chinook salmon. One of the primary objectives of the Fish and Wildlife Program is to increase juvenile survival and rebuild diminished stocks. Temperature influences survival to a large degree, but its effects are usually indirect, difficult to measure, and poorly understood as a mechanism of survival. Incubation and survival to emergence under different temperature regimes will be examined in laboratory experiments to evaluate the operation of Dworshak Dam on naturally produced fall chinook salmon in the Clearwater River. Indicators of chronic thermal stress will be used to evaluate temperature effects on fish physiology. Laboratory and field data will be collected on fish health, predation, and migratory behavior to examine how temperature may compromise fish performance and survival. Finally, this information will be

integrated to predict the risks to fall chinook salmon under different temperature and in-river versus transportation scenarios that managers will be able to use to manage the hydropower system.

Section 7. Project description

a. Technical and/or scientific background.

Hydromanagement has changed thermal regimes in the Snake and Columbia river basin from that historically encountered. In the Snake River, the Hells Canyon Complex of dams has delayed emergence of naturally produced fall chinook salmon, as has the construction of Dworshak Dam on the North Fork Clearwater River. The timing of the fall chinook salmon life cycle and success of fall chinook salmon production in the Clearwater River may be limited by cold temperatures, but in the Yakima River and lower Snake rivers high temperatures may be limiting the success of fall chinook populations. As a result of hydro development, smolts migrate seaward later in the summer at a time when flows are low and water temperatures approach the upper incipient lethal. Returning adult fall chinook salmon have faced thermal blocks in the lower Snake River, and this phenomenon probably also exists in places like the Yakima River.   High water temperatures in the lower Yakima River and cold temperatures in the Clearwater River may be limiting natural production in those systems. Considering the life history of fall chinook salmon along with the environmental conditions that exist during their freshwater life cycle, they are one of the most thermally challenged salmonid in the basin.

The aforementioned statements are not surprising since temperature is an important driver of many salmonid processes. Temperature affects swimming performance (Brett 1967), growth and energetics (Elliott 1982), movement behavior (Bjornn 1971), physiological development (Ewing et al. 1979), and disease susceptibility (Fryer and Pilcher 1974) to name but a few. It is assumed, and probably rightly so, that high temperatures are bad for coldwater adapted fish such as salmonids, but few studies exist that quantify the long-term effects of chronic high temperatures on juvenile salmon performance and survival. Little Goose Reservoir surface temperatures can reach 24^{N}C in the top meter of the water column in late summer. Brett (1952) found that the upper incipient lethal temperature for chinook salmon juveniles is 24^{N}C. Since typical late summer temperatures in lower Snake River reservoirs range from 19 to 22^{N}C, juvenile migrants are at risk of temperature-related mortality factors such as disease, predation, and metabolic constraints. Evidence for such risk is evident in the 1994 subyearling chinook salmon kill at McNary Dam. About 100,000 fish presumably died from thermal shock and probably *Flexibacter columnaris* infection. The USGS collected 125 subyearling chinook salmon at John Day Dam ten days after the fish kill, and after five days of holding, all but seven had died of *Flexibacter columnaris* infection (USGS unpublished data).   *Flexibacter columnaris* infection has been shown to be a significant pathogen to chinook salmon (Holt et al. 1975; Becker and Fujihara 1978). Finally, studies have shown that late migrants have poorer survival and return fewer adults than earlier migrants (Connor et al. 1998; Muir et al. 1998; Giorgi et al. 1994; Tiffan et al.

Manuscript in preparation), and this phenomenon may be temperature related.

The Plan for Analyzing and Testing Hypotheses (PATH) for spring chinook salmon has found that various fish passage and stock-recruitment models cannot account for all of the mortality that must take place to explain observed smolt to adult survival. Delayed mortality has been identified as an important source of mortality for spring chinook salmon. Delayed mortality may also be important to fall chinook salmon trying to cope with high summer water temperatures. Because temperature effects on fish mortality are often indirect, they are often difficult to quantify. At a recent EPA-sponsored temperature workshop on the Columbia River basin (November 10-11, 1997, Portland, Oregon), the term Aswimming dead≅ was coined by C.C. Coutant to describe fish that have receive sublethal exposures to high temperatures that will likely die a death that will never be observed or have its causes directly elucidated. This may be especially true for late migrating fall chinook salmon in the Snake River that are exposed to 19-22C temperatures for weeks during their migration.

One of the goals of the NPPC Fish and Wildlife Program is to increase the survival of juvenile through the lower Snake River, and flow augmentation is one measure aimed at attaining that goal. Flow augmentation using releases from Brownlee Reservoir (Measure 5.2B.1) increases flow through the lower Snake River, but increases water temperature at the same time. Connor et al. (1998) speculated that the increase in water temperatures in 1996 due to Brownlee releases may have contributed to decreased survival of natural fall chinook salmon in that year. Muir et al. (1998) showed that the survival of hatchery subyearling fall chinook salmon was positively related to flow and negatively related to temperature. Since flow and temperature are also correlated with each other, determining which variable is most important to subyearling survival is difficult. The Program will need to resolve this issue to make flow augmentation recommendations that make the most biological sense.

An alternative to Brownlee releases is to release water from Dworshak Reservoir (Measure 5.2B.2). This action is controversial with recreational users of Dworshak Reservoir because of draw down consequences. Releases from Dworshak to increase summer flows has moderated high temperatures in the lower Snake River reservoirs, thus enhancing survival and migration conditions for juvenile fall chinook salmon in the reservoirs. In contrast, the cool water releases may also have deleterious effects on naturally spawned juvenile fall chinook salmon from the Clearwater River by reducing growth and delaying migration. Inasmuch as the lower Snake and Clearwater rivers are regulated rivers, managers are faced each year with making decisions on how to balance the need for flow and moderating temperatures through the lower Snake River reservoirs with the possible deleterious cool water temperature effects on the Clearwater River fall chinook salmon. The program needs specific information on the effects of relatively low and relatively high water temperatures on incubation, emergence timing, physiological and behavior performance, and survival of juvenile fall chinook salmon in the Snake and Columbia River basin.

b. **Proposal objectives**.

The objectives of this study are to:
1) Determine incubation and emergence timing under an array of fluctuating water temperatures representative of the mainstem Snake River and its tributaries.
2) Identify physiological indicators of acute and chronic heat stress.
3) Identify performance related changes of juvenile fall chinook salmon exposed to long-term sublethal temperatures.
4) Determine the effects of temperature on timing and success of natural production in the Snake and Clearwater rivers, and estimate potential risk of mortality due to exposure to different water temperature regimes characteristic of lower Snake River reservoirs in the summer.

The following **null** hypotheses and assumptions are numbered to correspond to the objectives listed above.
1) Hypothesis: Temperature has no effect on egg incubation and emergence timing in the Snake River and its tributaries.

2) Hypothesis: Heat stress in fall chinook salmon does not elicit a physiological response.
Assumptions: 1) A physiological indicator of temperature-induced stress can be found and will be cost effective. 2) The mid to late summer temperatures experience by juvenile fall chinook salmon migrating through lower Snake River reservoirs will elicit a response in the selected physiological indicator.

3) Hypothesis: Long-term exposure to sublethal temperatures does not affect the performance of juvenile fall chinook salmon.
Assumptions: 1) *Flexibacter columnaris* can be consistently cultured and maintained for disease challenges. 2) Lyons Ferry Hatchery fall chinook salmon are suitable surrogates for naturally produced fish.

4) Hypothesis: Temperature does not affect the timing and success of natural production, and does not influence survival in the lower Snake River.
Assumptions: 1) The benefits, or lack there of, of temperature and flow can be separated when evaluating flow augmentation provided from Dworshak Reservoir.

c. Rationale and significance to Regional Programs.

The NPPC has identified temperature as a potential limiting factor to Snake River fall chinook salmon in Program Measure 7.5B.3. Since temperature affects both adult and juvenile fish, the Fish and Wildlife Program has included measures to moderate temperature effects, both directly and indirectly, in the Snake River. Measure 6.1D ASnake River Temperatures≅ addresses the need to moderate high water temperatures in the lower Snake River for returning adult fall chinook salmon by releasing cool water from Dworshak Reservoir. These releases are also intended to improve in-river conditions for summer migrants under Measure 5.2B ASummer Migrants≅. The biological objective of these releases is stated in Measure 5.2 as, ATo improve conditions for salmonid production by increasing flow and water velocities, decreasing downstream migration time for anadromous fish and decreasing the quantity of habitat for predatory and competing fish species.≅ Increasing summer flows by releasing water from Brownlee (Measure 5.2B.1) or Dworshak (Measure 5.2B.2) will probably benefit fish by decreasing travel times, but depending on which reservoir is used, may have negative thermal effects on Snake or Clearwater river fall chinook salmon.

Releasing water from Brownlee Reservoir has little cooling effect on the lower Snake River and may negate the benefits of increased water velocity if high summer water temperatures place fish at risk of temperature-related mortality. Releases from Dworshak Reservoir may have a cooling effect on lower Snake River reservoirs, which may benefit Snake River fall chinook salmon by increasing flows and reducing temperatures. However, cool-water releases may negatively impact naturally produced fall chinook salmon in the Clearwater River by delaying emergence and growth. Program Measure 2.2E.4 calls for, Aanalyzing the relationship between drawdown [to provide flows] limits and fish flow measures set for resident and anadromous fish in this program, including the water budget.≅ It is clear that the Fish and Wildlife Program needs information on the effects of management actions, such as flow augmentation, of juvenile salmonids. We believe that information on temperature effects on fall chinook salmon is lacking and poorly understood.

The rationale for the areas of research outlined in this proposal stem from the need to quantify temperature effects, and not merely conclude that, Ahigh temperatures are bad.≅ We are most concerned about the effects of seasonal low and high water temperatures on the incubation and timing of emergence, and summer seaward migration of juvenile fall chinook salmon. Prior to the construction of the Hells Canyon Complex of dams, Snake River fall chinook salmon emerged and migrated seaward earlier than in recent years because spawning occurred primarily upstream of the Hells Canyon Reach where mainstem temperatures were warmer. In the Clearwater River a combination cool natural flows delay emergence and water releases from Dworshak Dam reduce growth of juvenile fall chinook produced in the Clearwater River. This project will directly address temperature effects on the early life history of fall chinook salmon in the Snake and Clearwater rivers to better define the effects of Dworshak Dam releases as called for in Measure 2.2E.4.

The delay for Snake River fall chinook salmon in reaching the migratory threshold is further exacerbated by the need to migrate through the lower Snake River reservoirs during summer. Water temperatures in the top 1 m of the water column in August can reach 24^{N}C, the upper incipient lethal temperature for fall chinook salmon. It is currently unknown what sublethal effects high temperatures have on performance and long-term survival. Our objectives and tasks will address these questions by looking at specific areas of performance both singularly and collectively to quantify delayed mortality due to chronic exposure to the high temperature experienced in lower Snake River reservoirs.

One novel approach to obtaining specific information on thermal exposure histories is to use temperature-sensitive radio tags, and new technologies to identify heat-stress proteins. The USGS has considerable experience and expertise in radio telemetry, and technological advances have enabled us to radio tag fall chinook salmon migrants as small as 110 mm. This technology will allow us to collect unprecedented thermal and behavioral data on fish in the natural environments. The use of heat-stress proteins and organ enzymes may be a good integration tool over periods of chronic thermal stress (Sanders 1993; Iwama 1995)

d. Project history

This project will be a new start in FY1999.

e. Methods.

The scope of this work will cover the freshwater portion of the juvenile fall chinook salmon lifecycle from egg incubation to seaward migration. The work will be conducted to make products applicable to fall chinook salmon throughout the basin, but will focus research in the Snake, Clearwater, and Yakima rivers. These rivers have been chosen because the temperature regime of each has been altered by hydro management. Additionally, these rivers are worthy of comparison because the Snake and Clearwater rivers have the potential for some temperature control whereas the Yakima River has little opportunity for temperature control. These rivers are also unique in that the Yakima and lower Snake rivers present high temperature challenges to juvenile and adult fall chinook salmon, whereas in the Clearwater River, cold temperatures may be limiting growth and production.

The approach will be to conduct laboratory experiments and collect field data that can be used to directly relate temperature effects to fish performance and survivability. By doing this, performance and survival can be modeled under different temperature scenarios, either singularly or collectively, to predict the long-term risk associated with chronic exposure to temperatures near the upper incipient lethal. A multiple-year approach is necessary to include variability between years.

Objective 1. Determine incubation and emergence timing under an array of fluctuating water temperatures representative of the mainstem Snake River and its tributaries.

Methods: Temperature regimes will be chosen based on historical data from the Snake River basin. There will be six replicates of each temperature regime. One hundred eggs will be placed in each jar, which will correspond to a particular regime, and monitored daily to assess survival through stages of development. Mortalities and swim-up fry will receive health scans that will include virology and histology assessments. Methodologies will follow established U.S. Fish and Wildlife Service fish health protocols. Fish health screening will be carried out by Kathy Clemens from the Dworshak Fish Health Center. Data will be compiled and multiple regression analysis will be used to model the relation between survival, swim-up size, water temperature during incubation, cumulative centigrade temperature units to hatch, and fish health. This statistical approach will allow prediction of survival and emergence timing based on different temperature scenarios representative of releases from Dworshak Dam. This information will be input into a basin-wide temperature model being developed by the Enviromental Protection Agency to model changes in early life history of fall chinook salmon under different hydromanagement scenarios. The completion and usefulness of this model is a critical uncertainty associated with this objective that will be partially beyond the control of this project.

<u>Objective 2</u>. Identify physiological indicators of acute and chronic heat stress.
Methods: *Phase 1* XReview the literature and compile a list of candidate physiological indicators of heat stress. Develop a laboratory assay to measure the indicator of interest. Conduct laboratory experiments to determine at what temperatures and exposure times fish produce the heat stress indicator. Vary temperatures and exposure times so that different amounts of the indicator or tissue damage is obtained. Measure long-term survival by inducing heat stress and tissue damage and then holding fish for extended period (e.g. 6 mos.). Periodically measure delayed mortality and conduct histology examinations. Collect samples at Little Goose and John Day dams to assess thermal histories of in-river migrants. Use a bioenergetics approach as a tool to measure the effects of stress and temperature on fish metabolic rates and enzyme kinetics. Respiration has direct effects on growth, which may limit other areas such as smoltification, migration, and survival. The methods for this would include exposing fish to varying temperatures and stressors, such as handling and disease, then measuring oxygen consumption in a respirometer, or measuring metabolic enzyme activities. The energy expended in respiration would then be input in a bioenergetics model to predict growth given varying levels of metabolic cost.

The probability for success for this Phase is high because temperature is a driver of enzyme activities and most all other physiological processes in fish. Non-lethal techniques will be sought where appropriate because of ESA concerns. The products produced will be a measure of delayed mortality due to exposures to sublethal temperatures that produce a heat stress response, such as organ tissue damage.

Phase 2 XExpose laboratory fish to sublethal temperatures varying in magnitude and duration that are representative of summer reservoir conditions. Transfer fish to seawater and measure delayed mortality for a period of two months. Collect growth and physiological information, such as gill ATPase, periodically. At the end of two months, and for all mortalities prior to that time, complete physiological and histological profiles of experimental fish. The product produced will be the effect of sublethal temperature exposure on subsequent seawater entry and growth. Past studies have shown that late migrants have poor survival and return fewer adults than earlier migrants. Temperature effects on seawater entry and survival may play a role in this phenomenon.

Phase 3 XUse a physiological indicator to measure the degree of heat stress in groups of 20 hatchery subyearling fall chinook salmon sampled weekly from July through August prior to transportation from Lower Granite Dam. These fish will serve as starting points with which to compare subsequent fish. Sample groups of 20 fish at time of release below Bonneville Dam after transportation, and groups collected at Bonneville Dam to represent in-river migrants. Use analysis of variance to compare the degree of heat stress of groups after transportation with groups sampled at Bonneville Dam after in-river migration. It is hypothesized that in-river migrants may be exposed longer to higher temperatures and be at greater risk of mortality than transported fish.

<u>Objective 3.</u> Identify performance-related changes in juvenile fall chinook salmon exposed to long-term sublethal temperatures.

Methods: Susceptibility to disease is one area of performance that is greatly influenced by temperature. *Flexibacter columnaris* may be a major pathogen to fall chinook salmon migrating during the summer. We will expose fish to various sublethal temperatures for different amounts of time in the presence of *Flexibacter columnaris* in laboratory experiments. Use two-way analysis of variance to test for differences between time to infection and death given different treatments of temperature and exposure. One of the critical uncertainties surrounding this task will be our ability to consistently culture *Flexibacter columnaris* for experimental trials. The technology currently exists, but maintaining consistency has been a problem. The anticipated product from this work will be disease susceptibility versus temperature curves that will be used to determine risk of mortality under different temperatures and levels of infection.

Vulnerability to predation has been cited as a cause of mortality of fish migrating through reservoirs. Temperature not only determines predator consumption rates but may place prey at greater risk if they have been physiologically compromised. We will expose juvenile fall chinook salmon to different temperature regimes then expose 15 treatment and 15 control fish simultaneously to 8 Northern squawfish in a 7 m x 1.5 m x 1.5 m fluvial raceway. Each trial will last 3 h or until 50% of salmon have been consumed. Results will be analyzed using Chi-square analysis to compare the number of treatment and control fish eaten to a random distribution. This experiment will be replicated 12 times obtain a measure of variability.

The link between migratory performance of juvenile fall chinook salmon and temperature will be examined using temperature-sensitive radio tags and telemetry. Obtain subyearling fall chinook salmon from Lyons Ferry Hatchery to use as surrogates for wild fish. Make three weekly releases of 30 fish each in the Clearwater River at Dworshak National Fish Hatchery in early June before summer flow augmentation begins. Make three weekly releases of 30 fish each at the beginning of flow augmentation. Coordinate releases with supplementation releases made by the Nez Perce Tribe. Use mobile tracking and fixed sites to describe thermal history and migratory behavior. Use analysis of variance to compare travel rates and preferred temperatures occupied by tagged fish of the different release groups. This information will be used to determine if the cooling effect of Dworshak releases has a positive effect on juvenile fall chinook salmon travel times.

<u>Objective 4.</u> Determine the effects of temperature on natural production in the Snake and Clearwater rivers, and estimate potential risk of mortality due to exposure to different water temperature regimes characteristic of lower Snake River reservoirs in the summer.
Methods: Compile redd count data, temperature records, and estimates of juvenile production from the Snake, Clearwater, and Yakima rivers. Compare timing and success of fall chinook salmon production in the Clearwater River, which may be limited by cold temperatures, to that of the Yakima River, which may be limited by warm temperatures, and the Snake River, which is intermediate. The product will be a measure of temperature-related production potential that will be useful for supplementation efforts or reintroductions of fall chinook salmon elsewhere in the basin.

Synthesize information gained from Objectives 1-3 to define alternative scenarios for operating Dworshak Dam. Consult with Dworshak National Fish Hatchery on temperature criteria for hatchery operation. One product may be the definition of the timing and volume of water that could be released during the winter to provide a warming effect for the lower Clearwater River during egg incubation and emergence. This management action may advance emergence so that naturally produced fall chinook salmon will migrate seaward earlier under more hospitable conditions, which may increase their survival and return of adults to the Clearwater River.

Synthesize physiological and performance-related risks from temperatures that approach the upper incipient lethal to develop a multivariate model that will quantify delayed mortality from temperature. If temperature is a source of delayed mortality, either directly or indirectly, then flow augmentation using Dworshak releases may have a significant effect on increasing survival of late-summer migrants. The product would be information that managers can use to better define the timing and magnitude of releases to increase survival.

Fish holding and care: These procedures will be true for all laboratory experiments conducted by this project. Circular 800 L holding tanks, which measures 122 cm in diameter by 69 cm deep, will be used to hold fish. No more than 100 fish will held at one time in the tank. Holding tanks will be supplied with heated well water that has been passed through a cracking column to remove excess nitrogen. Flow rate into the tank will be 13.3 L/min, which will result in one complete water change per hour. Acclimation to desired temperatures will proceed at 1^{N}C per day. Dissolved oxygen will be measured daily. Fish will be fed twice daily and tanks cleaned daily. All fish will be juvenile fall chinook salmon obtained from the Little White
Salmon National Fish Hatcher or Lyons Ferry State Fish Hatchery, Washington.

f. Facilities and equipment.

The Columbia River Research Laboratory is equipped with all of the resources necessary to carry out this project. Each person employed by this project has a computer and the necessary software to complete data reduction, storage, and complex statistical analyses. In addition, we have a computer network system and the latest software at the lab. USGS and USFWS have fish holding facilities suitable to meet project objectives. Laboratories are supplied with well water or river water, and have an aeration system to provide air to each holding tank, complete photoperiod and temperature control, and we have a full-time wet lab supervisor who oversees and maintains the facility. As for field activities, this project has all the boats, vehicles, and capital equipment necessary collect data for field related tasks. Our radio telemetry activities use state of the art miniature radio tags and digital receivers.

Our project cooperators (USFWS and NPT) are also equipped with the necessary office space, equipment, boats, vehicles, and personnel to accomplish project objectives.

g. References.

Becker, C.D., and M.P. Fujihara. 1978. The bacterial pathogen *Flexibacter columnaris* and its epizootiology among Columbia River fish. Monograph No. 2. American

Fisheries Society, Washington D.C.

Bjornn, T.C. 1971. Trout and salmon movements in two Idaho streams as related to temperature, food, stream flow, cover, and population density. Transactions of the American Fisheries Society 100:423-438.

Brett, J.R. 1952. Temperature tolerance in young Pacific salmon, genus Oncorhynchus. Journal of the Fisheries Research Board of Canada 9:265-322.

Brett, J. R. 1967. Swimming performance of sockeye salmon (Oncorhynchus nerka) in relation to fatigue time and temperature. Journal of the Fisheries Research Board of Canada 24:1731-1741.

Connor, W.P, H.L. Burge, R. Waitt, and T. Andersen. 1998. Early life history and survival of Snake River natural subyearling fall chinook salmon in 1996. Chapter 1 *in* J.G. Williams, and T.C. Bjornn, editors. Fall chinook salmon survival and supplementation studies in the Snake River and lower Snake River reservoirs, 1996. Draft Annual Report, 1996. DOE/BP 93-029. Bonneville Power Administration, Portland, Oregon.

Elliott, J.M. 1982. The effects of temperature and ration size on the growth and energetics of salmonids in captivity. Comparative Biochemistry and Physiology 73 B(1):81-91.

Ewing, R.D., S.L. Johnson, H.J. Pribble, and J.A. Lichatowich. 1979. Temperature and photoperiod effects on gill (Na+K)-ATPase activities in chinook salmon (Oncorhynchus tshawytscha). Journal of the Fisheries Research Board of Canada 36:1347-1353.

Fryer, J.L., and K.S. Pilcher. 1974. Effects of temperature on diseases of salmonid fishes. EPA-660/3-73-020 to Office of Research and Development, EPA, by Western Fish Toxicology Laboratory, EPA, Corvalis, OR. 114pp.

Giorgi, A.E., D.R. Miller, and B.P. Sandford. 1994. Migratory characteristics of juvenile ocean-type chinook salmon, Oncorhynchus tshawytscha, in John Day Reservoir in the Columbia River. Fishery Bulletin 92:872-879.

Holt, R.A., J.E. Sanders, J.L. Zinn, J.L. Fryer, and K.S. Pilcher. 1975. Relation of water temperature to *Flexibacter columnaris* infection in steelhead trout (*Salmo gairdneri*), coho (*Oncorhynchus kisutch*), and chinook (*O. tshawytscha*) salmon. Journal of the Fisheries Research Board of Canada 32:1553-1559.

Iwama, G.K. 1995. Detecting stess in fish. Bulletin of the Aquaculture Association of Canada 95-2:50-53.

Muir, W.D., and six coauthors. 1998. Passage survival of hatchery subyearling fall chinook salmon to Lower Granite, Little Goose, and Lower Monumental dams, 1996. Chapter 2 *in* J.G. Williams, and T.C. Bjornn, editors. Fall chinook salmon survival and supplementation studies in the Snake River and lower Snake River reservoirs, 1996. Draft Annual Report, 1996. DOE/BP 93-029. Bonneville Power Administration, Portland, Oregon.

Sanders, B.M. 1993. Stress proteins in aquatic organisms: an environmental perspective. Critical Reviews in Toxicology 23:49-75.

Tiffan, K.F., D.W. Rondorf, and P.G. Wagner. Manuscript in prepartion. Physiological development and migratory behavior of subyearling fall chinook salmon in the Columbia River. For submission to the North American Journal of Fisheries Management.

Section 8. Relationships to other projects

This project is a cooperative effort between the Biological Resources Division of the U.S. Geological Survey, the U.S. Fish and Wildlife Service, and the Nez Perce Tribe of Idaho. Cooperation was sought because of the expertise and the varied resources of the agencies involved. All three agencies have extensive experience studying Snake River fall chinook salmon ecology and life history, and have produced much of the current information on fall chinook salmon. This arrangement will be one of cost-savings as BRD has the necessary laboratory facilities for experiments, while USFWS and NPT are located where field activities will take place.

This project will require an ESA and state fish collection permits.

Section 9. Key personnel

Project Manager:
Dennis W. Rondorf
Research Fisheries Biologist, 1 FTE

EDUCATION:
M.S. Oceanography and Limnology, University of Wisconsin, Madison, 1981
B.S. Wildlife Management, University of Minnesota, St. Paul, 1972

CURRENT EMPLOYMENT AND RESPONSIBILITIES:
D.W. Rondorf serves as a Fishery Research Biologist and Section Leader for the Anadromous Fish Ecology section at the Columbia River Research Laboratory, Biological Resources Division, U.S. Geological Survey, Cook, Washington. Current areas of research include the behavior and ecology of Snake River wild and hathery fall chinook salmon, the distribution of smolts and relation to gas supersaturation in the main stem Columbia River, and behavior of smolts to evaluate a prototype surface collector at Lower Granite Dam, Washington. In recent years, D.W. Rondorf has lead research teams using radio telemetry, geographic information systems (GIS), global positioning systems

(GPS), remotely operated underwater vehicles (ROV), hydroacoustic fish stock assessment systems, and acoustic Doppler current profilers (ADCP) as research tools. Between 1979 and 1997, D.W. Rondorf was employed by the research division of the U.S. Fish and Wildlife Service and the National Biological Service to conduct research on juvenile salmon in the Columbia River basin.

Adams, N.S., D.W. Rondorf, S.D. Evans, J.E. Kelley, and R.W. Perry. 1998. Effects of surgically and gastrically implanted radio transmitters on swimming performance and predator avoidance of juvenile chinook salmon. (*In Press*) Canadian Journal of Fisheries and Aquatic Sciences.

Adams, N.S., D.W. Rondorf, S.D. Evans, and J. E. Kelley. 1998. Effects of surgically and gastrically implanted radio transmitters on growth and feeding behavior of juvenile chinook salmon. Transactions of the American Fisheries Society 127:128-136.

Parsley, M.J., D.W. Rondorf, and M.E. Hanks. 1998. Remote sensing of fish and their habitats. Proceedings of instream and environmental flows symposium-technology and policy issues. (*In Press*) North American Lake Management Society and others, Denver, Colorado.

Adams, N.S., D.W. Rondorf, E.E. Kofoot, M.J. Banach, and M.A. Tuell. 1997. Migrational characteristics of juvenile chinook salmon and steelhead in the forebay of Lower Granite Dam relative to the 1996 surface bypass collector tests. U. S. Army Corps of Engineers, Walla Walla, Washington.

Principal Investigators:
William P. Connor
Fisheries Biologist, 1 FTE

Education:
Master of ScienceX1988; Montana State University; degree in Fish and Wildlife Management
Bachelor of ScienceX1984; West Virginia University; degree in Fish and Wildlife Management
Employment:
1991 to PresentXFishery Biologist for the U.S. Fish and Wildlife Service. Conducting research on fall chinook salmon in the Snake and Clearwater rivers.

1987 to 1991XFishery Research Biologist for the Nez Perce Tribe of Idaho. Conducted fall chinook salmon research in the Clearwater River.

Current Responsibilities:
Principle investigator for the U.S. Fish and Wildlife Service who are cooperators on this project. Responsible for oversight of Snake River fall chinook salmon redd surveys, juvenile seining and PIT tagging efforts, supplementation/survival releases and analysis, and emergence and outmigration forecasting.

Expertise:
William Connor has over 10 years as a fishery biologist focusing on Snake River fall chinook salmon research. He has been involved with all Snake River fall chinook salmon research conducted upstream of Lower Granite Dam since 1987. His research efforts provided fishery managers with new empirical information on Snake River fall chinook salmon redd surveys, spawning habitat availability, spawning habitat quality, early life history, travel time analyses, juvenile run timing predictions, survival, supplementation, and summer flow augmentation.

Work Products:
XSeveral journal manuscripts are in preparation including one accepted for publication in the North American Journal of Fisheries Management.

Connor, W. P., H. L. Burge, and D. H. Bennett. In Preparation. Detection of PIT-tagged subyearling chinook salmon at a Snake River dam: Implications for summer flow augmentation. North American Journal of Fisheries Management. Expected to be published in the spring issue 1998.

XCoauthored nine BPA annual reports
XPresented eight different papers at formal meetings with attendance > 100 persons

Principle Investigator:
Bill D. Arnsberg

Fishery Biologist, 1 FTE

Education:

University of Idaho, Moscow, ID. 1987-1990. M.S. coursework in Fisheries Science. Thesis entitled: Food Availability and Diet of Fish in Little Payette Lake Before and After Rotenone Treatment.

University of Missouri, Columbia, MO. 1982-1984. B.S. Degree in Fisheries and Wildlife Management.

Employment:

Nez Perce Tribe, Lapwai, ID. 1989-Present. Fisheries Research Project Leader. Researcher and primary author of the Mainstem Clearwater River Study: Assessment for Salmonid Spawning, Incubation, and Rearing, BPA Project 88-15. Project Leader for two years on Salmon Supplementation Studies in Idaho Rivers, BPA Project 8909802. Currently Project Leader for Assessing Summer and Fall Chinook Salmon Restoration in the Snake River Basin (BPA Project 9403400).

Idaho Department of Fish and Game, McCall, ID. 4/86-9/88. Fisheries Research Technician.

Publications:

Muir, W.D., S.G. Smith, E.E. Hockersmith, M.B. Eppard, W.P. Connor, and B.D. Arnsberg. REVIEW DRAFT. 1998. Passage survival of hatchery subyearling fall chinook salmon to Lower Granite, Little Goose, and Lower Monumental Dams, 1996. Prepared for Bonneville Power Administration.

Arnsberg, B.D and D.P. Statler. 1995. Assessing summer and fall chinook salmon restoration in the upper Clearwater River and principal tributaries. Annual Report 1994 prepared for the U.S. Department of Energy, Bonneville Power Administration, Contract No. DE-BI79-87BI12872, Project No. 94-034.).

Arnsberg, B.D., W.P. Connor, and E. Connor. 1992. Mainstem Clearwater River study: assessment for salmonid spawning, incubation, and rearing. Project 88-15. Final Report to Bonneville Power Administration, Portland, OR.

Connor, W.P., B.D. Arnsberg, and E. Connor. 1990. Mainstem Clearwater River study: assessment for salmonid spawning, incubation, and rearing. Project 88-15. Annual Report to Bonneville Power Administration, Portland, OR.

Anderson, D., D. Scully, J.H. Griswold, and B. Arnsberg. 1987. Idaho Department of Fish and Game Federal Aid in Fish Restoration, Job Performance Report, Project F-71-R-11.

Section 10. Information/technology transfer

Information obtained will be disseminated in annual technical project reports, peer review publications, presentations to workgroups, and at professional meetings.