



January 15, 2002

Mr. Frank L. Cassidy Jr., Chair
Northwest Power Planning Council
851 SW 6th Avenue, Suite 1100
Portland, OR 97204-1348

Dear Chairman Cassidy:

The fish and wildlife managers of the Columbia Basin Fish and Wildlife Authority (CBFWA) request that the Northwest Power Planning Council (NWPPC) recommend that the Bonneville Power Administration (BPA) fund Project Number 25062, *Growth Rate Modulation in Spring Chinook Salmon Supplementation*. Funding for this project should be made available through the Columbia Plateau Province placeholder.

This ongoing project (formerly Project Number 199202200, *Physiological Assessment and Behavioral Interaction of Wild and Hatchery Juvenile Salmonids*) was submitted in the Columbia Plateau Province under Project Number 25062. Although CBFWA ranked the project as a High Priority and the ISRP ranked the project as Fundable, the project did not receive funding in the rolling review process; apparently due to its new project number. This project is aimed at addressing the problem of very high rates of early maturation in the spring chinook salmon supplementation program at the Cle Ellum hatchery in the Yakima Subbasin. This project has been underway for ten years and is now at a critical point with regard to success of the spring chinook salmon supplementation program. The fish and wildlife managers feel strongly that this project should be funded through the Columbia Plateau Province.

The CBFWA Members recommend approval of this request by the NWPPC. The Members Management Group reviewed the request from NMFS for additional review and the CBFWA Members support the need to evaluate the early maturation phenomenon at the Cle Ellum Hatchery. Funding for this project should be available in the Columbia Plateau placeholder. At the February 7 Quarterly Review, an analysis of available funds within this placeholder should be considered. It is our understanding that several of the projects recommended for funding by the NWPPC will not be initiated, and therefore funds should be available for this high priority project.

Thank you for your consideration of this request.

Sincerely,

Rodney W. Sando, Chair
Columbia Basin Fish & Wildlife Authority

cc: Doug Marker, NWPPC
Sarah McNary and Bob Austin, BPA
CBFWA Members and Fish and Wildlife Managers

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BPA Project Proposal (92-02200)

TITLE: Physiological Assessment and Behavioral Interaction of
Wild and Hatchery Juvenile Salmonids

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DATE OF SUBMISSION: December 18, 2001

PERFORMANCE PERIOD: July 1, 2002 to June 30, 2003

AMOUNT REQUESTED \$358,675

Work statement application for within year funding request

Project #: ~~199200220~~ 199202200

Title: **Physiological assessment and behavioral interaction of wild and hatchery spring chinook salmon.**

Summary

Recommendations of the Columbia River Basin Fish & Wildlife Program (Nov. 14, 2000) for artificial production state: "naturally selected populations should provide the model for successful artificially reared populations, in regard to population structure, mating protocol, behavior, growth, morphology, nutrient cycling, and other biological characteristics." This mirrors guidelines of the NMFS 2000 FCRPS Biological Opinion (9.6.5.3.4, Action 184). We compared the physiology and development of naturally-rearing wild and hatchery-reared spring chinook salmon in the Yakima River Basin, and found substantial differences. The most serious difference was an approximately 50% incidence of early maturation of Cle Elum Hatchery-reared males (1+ year old jacks). This is ten times our estimates of early male maturation in wild spring chinook salmon in the Yakima River. Apparently, the hatchery environment promotes early male maturation. Hundreds of thousands of the early maturing hatchery males may residualize in the basin after release and cause adverse genetic and ecological impacts. The ecological concerns include competition for space and food, food depletion and predation on emerging salmonids and other species. Furthermore, early male maturation translates into a 25% reduction in anadromous adult production. We have found recently in laboratory studies that modulation of growth rate at specific times of the year can reduce the incidence of precocious maturation. Thus, growth rate modulation at Cle Elum Hatchery may reduce early male maturation to levels similar to natural wild fish. This proposal has three central objectives: 1) estimate the incidence of precocious maturation and characterize the related maturational physiology in wild Yakima spring chinook for comparison to the hatchery fish, 2) monitor the incidence of yearling precocious maturation in the hatchery population, and 3) conduct a growth modulation experiment to control precocious maturation in the Yakima hatchery population. Our ultimate goal is to develop rearing protocols to produce fish with morphological, physiological, and life-history attributes similar to naturally reared cohorts.

Scientific Background

Recently, "conservation" hatchery strategies have been employed in an attempt to improve the post release survival of hatchery fish while reducing potential negative genetic and ecological impacts on wild stocks. A conservation hatchery may be defined as a rearing facility to breed and propagate a stock of fish with equivalent genetic resources of the native stock, and with the full ability to return to reproduce naturally in its native habitat (Flagg and Nash 1999). The strategic role of a conservation hatchery is to promote restoration of wild stocks of fish. This requires fish rearing be conducted in a

manner that mimics the natural life history patterns, improves the quality and survival of hatchery-reared juveniles, and lessens the genetic and ecological impacts of hatchery releases on wild stocks.

The Independent Scientific Advisory Board's review of artificial production of anadromous and resident fish in the Columbia River Basin (Brannon et al. 1999), National Marine Fisheries Service Biological Opinion on operation of the Federal Columbia River Power System (NMFS 2000), and the Columbia Basin Fish and Wildlife Program (CBFWP, 2000) all recommend the need to develop rearing protocols that simulate natural growth rate, body size, and life-history composition in hatchery reared fish. This recommendation is due, in part, because previous studies have demonstrated that fish experiencing seasonal growth patterns that more closely approximate that of naturally reared fish have superior smolt development, enhanced downstream migratory activity and greater SAR than fish reared under less natural growth patterns (Dickhoff et al., 1995; Beckman et al. 1998, 1999, 2000). These benefits are obtained while producing a fish of similar size to that of naturally reared fish. Furthermore, recent studies focused on salmonid maturation have shown that size and/or growth rate at specific times of the year may be the most significant factor(s) influencing the incidence of precocious male maturation as well (Hopkins and Unwin 1997, Silverstein et al. 1998, Shearer et al. 2000). Thus, growth rate during specific periods of juvenile development has a significant effect on both maturation and smoltification.

Growth rate and precocious maturation

Many species of male salmonids display phenotypic plasticity in their age of sexual maturation. Two age classes of precocious males exist in spring chinook salmon (*Oncorhynchus tshawytscha*): sub-yearling (0-age precocious parr) and yearling (1+ year-old parr, also commonly referred to as “minijacks”). Gebhards (1960) reported the incidence of 0-age and 1+ age precociously maturing spring chinook in a wild stock from the Lemhi River in Idaho to be very low at 0.9% and 0.2% respectively from 1,020 juveniles examined. More recently, two year-classes of precociously maturing wild spring chinook have also been identified in the Yakima River of Washington (James et al. 1998). Although the incidence of precocious maturation in this and other naturally rearing spring chinook populations is poorly characterized, from the small quantity of data available, the incidence is believed to be relatively low (<5%). In contrast, hatchery populations of spring chinook salmon have been shown to possess proportions as high as 56% precocious yearlings (Foote et al. 1991; Mullan et al. 1992). Furthermore, Shearer and Swanson (2000), using wild progeny Yakima River spring chinook to examine the effect of whole body lipid levels on maturation, produced fish with an incidence of 34 to 45% 1+ precocious male maturation. Thus, the genetic potential for a high incidence of early maturation in Yakima River spring chinook certainly exists.

Over the past three years we have conducted research to characterize the physiological development of the first three brood years (BY 97, 98, 99) of hatchery produced spring chinook salmon at the Cle Elum Supplementation and Research Facility. Fish were sampled in the hatchery at Cle Elum, at remote acclimation sites at Clark Flat and Jack Creek, and at downstream dams (Roza, Prosser, John Day Dam) during outmigration. One of the most significant observations from the analysis to date is the

apparently high incidence of 1+ precocious males in the hatchery population. At the Clark Flat acclimation site in the spring prior to and during volitional outmigration, approximately 12-75% (depending on date) of the fish examined showed advanced testicular development characteristic of 1+ age precocious maturation (Fig. 1).

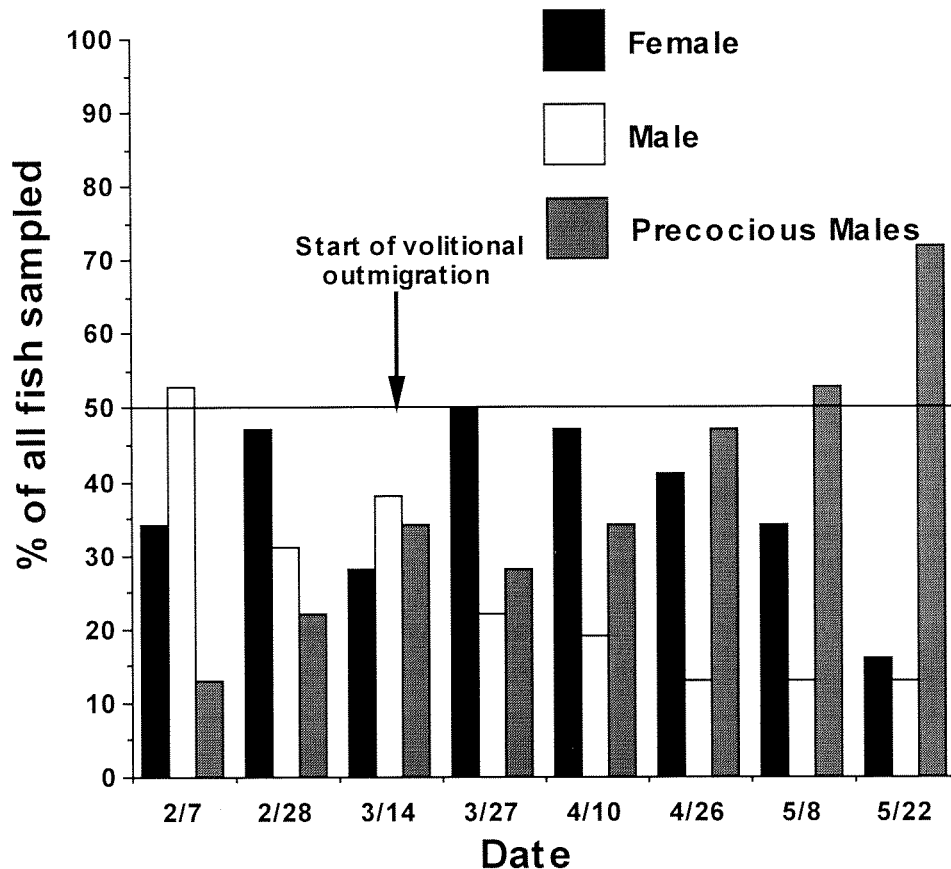


Figure 1. Gender and maturational state of Yakima hatchery spring chinook sampled at the Clark Flat acclimation site before and after the start of volitional outmigration; N = 32 fish per date.

These visual observations were later confirmed through histological analysis and measurement of plasma sex steroid levels. It should be noted that as more fish emigrated from the acclimation site throughout the spring, precocious males made up a greater proportion of fish sampled suggesting that the true smolts were migrating out while many of the precocious males remained in the raceway. Furthermore, during the routine pathological screening of brood year 1999 fish conducted in March 2001, prior to volitional outmigration, we examined 360 fish at each of three remote acclimation sites (Easton, Jack Creek and Clark Flat) in an effort to obtain a more accurate estimate for incidence of precocious maturation. Similar to earlier findings, approximately 50% of the males were precociously maturing (Fig. 2).

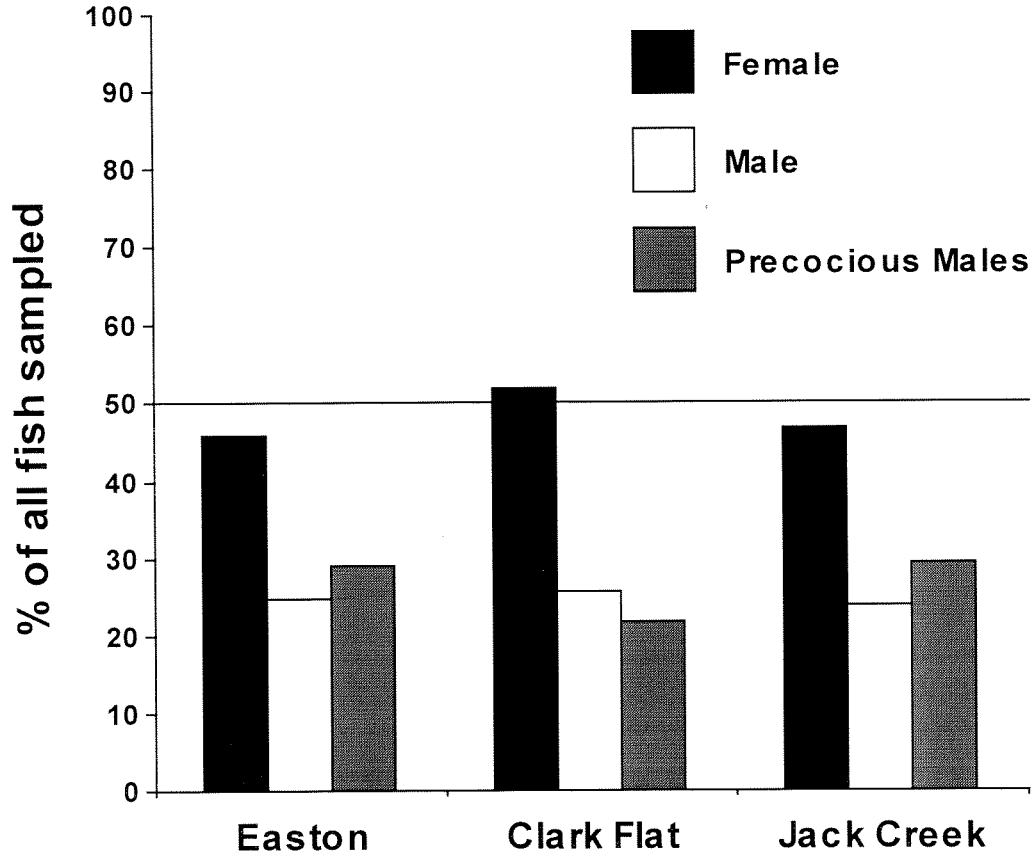


Figure 2. Gender and maturational state of Yakima hatchery spring chinook sampled March, 2001 at Easton, Clark Flat and Jack Creek remote acclimation sites prior to volitional outmigration. N = 60 fish per raceway for a total of 360 fish per site.

Finally, outmigrating Yakima hatchery chinook were also collected at Roza, Prosser and John Day dams (Fig. 3). Precocious males were captured downstream on some dates, however, at a much lower frequency (5-25%) than observed at the acclimation sites. In contrast to the acclimation sites, the largest proportion of outmigrating fish captured at the dams were females. These data suggest that the majority of these precocious males do not migrate downstream, but remain in the headwaters.

Precocious maturation represents a natural life-history strategy for the Yakima and other spring chinook populations, but the hatchery environment may be magnifying this developmental pathway beyond natural levels. Alterations in the normal life-history composition of salmon populations are undesirable in conservation as well as production hatcheries. An uncharacteristically high incidence of precocious male maturation results in loss of potential returning anadromous adults, biasing of male/female sex ratios, and negative genetic and ecological impacts on wild populations and other native species. These impacts may include increased straying, predation, and competition with native fish species and other stocks for limited resources and habitat.

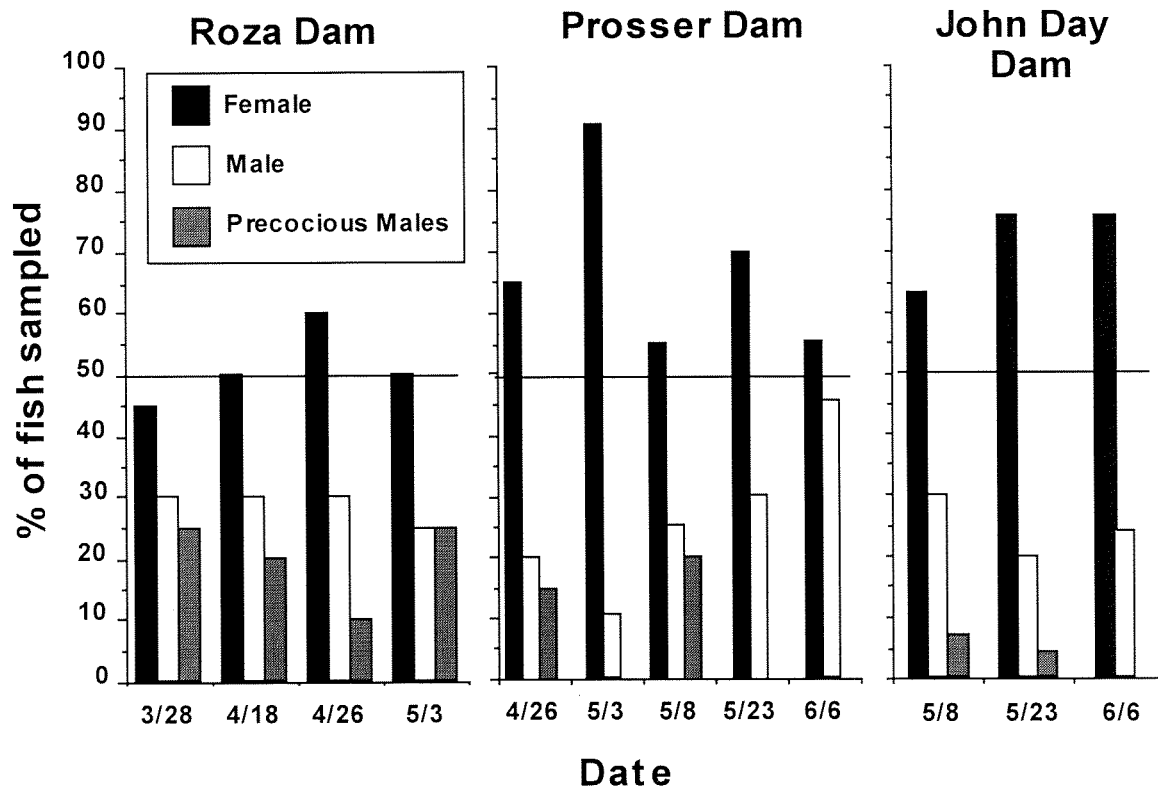


Figure 3. Gender and maturational state of Yakima hatchery spring chinook sampled during spring outmigration at Roza and Prosser Dams on the Yakima River, and John Day Dam on the Columbia River. N = 20-60 fish per date.

Age of maturation in salmon is influenced by genetic, biotic, and abiotic factors (Power 1986). While the level of energy stores (whole body lipid) has been shown to influence the incidence of sexual maturation in Atlantic (Rowe et al. 1991) and Pacific salmon (Silverstein et al. 1998, Shearer and Swanson 2000) size and/or growth rate at specific times of the year may be an even more significant factor(s) influencing male maturation (Hopkins and Unwin 1997, Silverstein et al. 1998, Shearer et al. 2000). Studies in spring chinook have shown that male maturation at age 1+ is physiologically initiated in the fall, approximately 10 months prior to autumn maturation (Silverstein et al. 1998; Shearer and Swanson, 2000; Shearer et al. 2000). Initiation occurs over a relatively broad and poorly characterized period extending from November to February of the year prior to spawning (Shearer et al. 2000). Only recently, with these laboratory based studies, have the analytical tools for early detection of advanced gonadal development been applied to understanding initiation of precocious maturation in salmon. These early stages of gonad development occur at the time that normal male and female fish are initiating the parr-smolt transformation. External characteristics of maturation (olive pigmentation, deep body shape, and dark fin margins) as well as very large white gonads typical of the later stages of maturation may not be evident until mid-summer prior to autumn spawning. These more obvious signs of early maturity often escape

detection since most spring chinook hatcheries release fish in March and April. This fact may explain why this issue has historically received only modest attention.

Studies primarily in Atlantic salmon (*Salmo salar*) have suggested that the spring period, proceeding autumn spawning, is a permissive period. If growth and energy stores are adequate, maturation progresses in fish that have initiated the process in the previous autumn. In fact, reduced feeding during the spring will reduce, but not prevent, the incidence of maturation in Atlantic (Rowe and Thorpe 1990, Herbinger and Friars 1992) and chinook salmon (Hopkins and Unwin, 1997). However, as mentioned above, high growth rate during smoltification has been correlated with improved smolt quality, downstream migration and smolt-to-adult return of spring chinook salmon (Beckman et al. 1998, 1999; Dickhoff et al. 1995, 1997). Thus, reducing growth during the spring may be a double-edged sword; while it may retard early maturation in the precocious fish it may also be detrimental to successful smoltification of non-precociously maturing fish. The best strategy for preventing precocious male maturation may be prevention of initiation in the autumn one year prior to spawning. The aim of this study is to better understand how to rear fish in the hatchery environment so they will display similar rates of precocious maturation as their wild congeners and, in those fish which do not precociously mature, superior smolt quality. Superior quality smolts will rapidly undergo smoltification and emigration from headwater streams to the ocean with minimal residualization and impact on other resident fish.

Examination of the growth profiles of wild and hatchery spring chinook from the Yakima River support the contention that seasonal growth patterns in the hatchery environment may be conducive to high rates of precocious maturation. The growth profiles between naturally rearing Yakima spring chinook (Beckman et al. 2000) and that of the first three brood years of spring chinook at the Cle Elum hatchery (Larsen et al. unpublished) are different (Fig. 4). Wild Yakima River fish typically show high growth in the summer following emergence and reduced growth in the fall as temperature decreases. In contrast, despite some variation in absolute size between brood years, Yakima hatchery fish have very low growth in the summer following emergence and very high growth in the fall. Based on studies noted above (Hopkins and Unwin 1997, Silverstein et al. 1997, Shearer et al. 2000) we hypothesize that the high autumn growth rate of the Yakima hatchery fish provides the energetic signal to initiate maturation in a significant proportion of the male fish. We propose that by altering growth rate during the critical summer-fall period, through manipulation of feed rate, to more closely approximate growth of wild Yakima River fish, the incidence of precocious maturation may be reduced to a level more similar to that of the wild stock (see Methods Fig. 5). Furthermore, by maximizing growth rate in the following spring, as seen in wild Yakima River spring chinook, we believe these fish will display enhanced smolt development and rapid downstream migration as well.

The Yakima River, Cle Elum supplementation and research facility presents the best available venue for examining the effects of growth rate modulation on

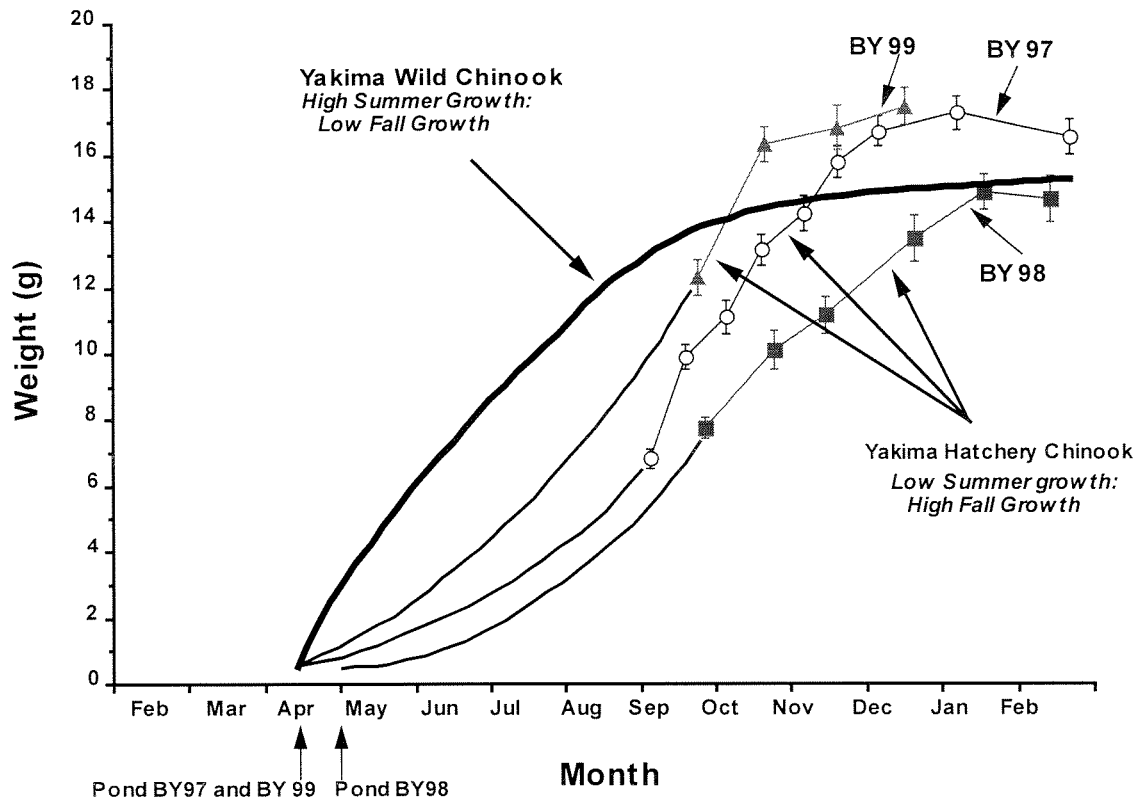


Figure 4. Growth profiles of brood year 97, 98, 99 Yakima hatchery spring chinook (Larsen et al. unpublished) and Yakima wild spring chinook from Beckman et al. (2000).

developmental decisions in spring chinook salmon in a conservation hatchery. Hatchery operations at this facility represent the most extensive test, to date, of conservation hatchery principals. In addition, a significant body of research concerning the physiology of wild and now hatchery spring chinook from the Yakima River exists. This proposal has three central objectives: 1) to estimate the incidence of precocious maturation and characterize the related developmental physiology in wild Yakima spring chinook for comparison to the hatchery fish, 2) monitor the incidence of yearling precocious maturation in the hatchery population, and 3) conduct a growth modulation experiment to control precocious maturation and optimize smolt development in the Yakima hatchery population. The ultimate goal of this research is to develop rearing protocols that will allow for production of fish in conservation and production hatcheries which have similar morphological, physiological, and life-history attributes as their naturally reared cohorts.

Rationale and Significance to Regional Programs

This proposed research directly addresses objectives put forth in documents regarding hatchery reform by the Northwest Power Planning Council Fish and Wildlife Program (CBFWP, 2000), Independent Scientific Advisory Board (Brannon et al, 1999), National Marine Fisheries Service (NMFS, 2001) and others. Each of these documents recommends that major strategic and procedural changes be made in overall hatchery programs within the Columbia River Basin. It is suggested that hatcheries utilize native brood stocks and release juveniles that resemble and perform similarly to their naturally

reared cohorts. In addition, these documents strongly recommend thorough monitoring and evaluation of these new programs. The NWPPC Fish and Wildlife Program Artificial Production Review specifically states in section 4e "Naturally selected populations should provide the model for successful artificially reared populations, in regard to population structure, mating protocol, behavior, growth, morphology, nutrient cycling, and other biological characters". The ISAB Review of artificial production of anadromous and resident fish in the Columbia River basin specifically states in Guideline D4. "To mimic natural populations, anadromous hatchery production strategies should target natural population parameters in size and timing among emigrating anadromous juveniles to synchronize with environmental selective forces shaping natural population structure ". The NMFS Biological Opinion on operation of the federal Columbia River Power System, Reasonable and Prudent Alternatives Action Item 9.6.4.2 specifically recommends to: "Minimize predation and other negative interactions between hatchery and natural fish, for example, by producing fish similar in size, behavior, life history characteristics to the naturally produced fish in the same waters" and "Design hatchery facilities to mimic natural incubation and rearing conditions". Furthermore, this document recommends under Action Item 9.6.5.3.4 "to monitor the size, age, health, and smolt quality (growth), as well as release locations, timing, and life stages of hatchery fish.

This proposed research is specifically addressed in the Yakima Subbasin Summary (Berg et al. 2001). The document explicitly states under the Present Subbasin Management, Statement of Fish and Wildlife Needs: "continued monitoring of the physiological development of Yakima hatchery spring chinook salmon to further evaluate and improve the ability of conservation hatcheries to produce high quality smolts with morphological, physiological, behavioral, and life-history attributes similar to wild fish". The document also stresses the need for "future studies to be conducted to more accurately determine the incidence of precocious male maturation in both wild and hatchery chinook" and "to develop rearing strategies for controlling precocious male maturation in the hatchery population".

The Yakima Supplementation Project is currently the most extensive blueprint for conservation hatchery strategies. Native broodstock are utilized to produce hatchery-reared fish that volitionally outmigrate from acclimation ponds in the upper reaches of the Yakima Basin. We've estimated that approximately 50% of the male spring chinook released are undergoing age 1+ precocious maturation and are likely to residualize within the basin rather than outmigrate to the ocean as smolts. Previous physiological studies have demonstrated that growth rate at specific times of the year significantly affects developmental decisions in salmonids. Energetically enriched artificial feeds and altered water temperature regimes, produced by the use of ground water, make it probable that almost all hatchery programs will rear fish that have seasonal growth patterns that differ from that of naturally produced fish. The data gathered by analysis of the Yakima Supplementation program will be relevant to every hatchery program basin wide that seeks to produce fish that are similar to naturally reared fish. Specifically, results from these studies may result in the recommendation for specific seasonal growth profiles for conservation hatcheries rearing any population or species of salmonid.

Relationships to other projects

The Yakima Supplementation Project (BPA Project #'s199506325) is the most extensive test, to date, of the principles of conservation hatcheries. This proposed research has an integral role in the monitoring and evaluation of this project. Over the past several years we have characterized the physiological development of wild (Beckman et al. 2000) and conventional (OCT) and semi-natural (SNT) hatchery reared (Larsen et al. unpublished) spring chinook from the Yakima River (Project # 92002200). We work in close collaboration with biologists from the WDFW, USFWS, and Yakama Nation that make up the monitoring and implementation team for this project. From these studies, we have a unique and comprehensive database on the physiological development of juvenile salmonids in this basin. Data from these studies have allowed us to compare and contrast wild and hatchery fish and identify differences between them. We have estimated that approximately 50% of the male spring chinook released from the Yakima hatchery are undergoing age 1+ precocious maturation. Unnaturally high rates of precocious maturation are undesirable in both conservation and conventional hatchery programs due to loss of returning anadromous adults, biasing of the sex ratios, and negative genetic and ecological impacts. Because of the potential implications of these findings, we have received extensive encouragement and support from all collaborators to pursue the work proposed in this work statement. This proposed work aims to better quantify precocious maturation in both hatchery and wild spring chinook and to conduct pilot growth modulation experiments to control precocious maturation in the hatchery environment. At the Yakima Supplementation and Research facility we have received support for installation of the experimental rearing vessels required to carry out these experiments. Biologists who make up the Monitoring and Implementation Team of the Yakima Project are eagerly awaiting the findings from these studies to direct their next 5 year operational plan for rearing of fish in this project. Information from the proposed research will benefit development and implementation of conservation hatchery strategies for state, Federal and Tribal programs, including those for the Yakama Nation and Nez Perce Nation tribal conservation hatchery projects. The problem of early male maturation is not limited to the Cle Elum Hatchery; a study of chinook salmon returning to the Umatilla River also revealed a 50% rate of early male maturation of hatchery fish (Zimmerman and Stonecypher, 2001). The ultimate goal of this research is to develop rearing protocols for use in all conservation hatcheries that will allow for production of fish that have similar morphological, physiological, and life-history attributes as their naturally reared cohorts.

Project History

The original goals of the project were to: 1) characterize the physiology and behavior of wild spring chinook salmon, 2) compare the wild with hatchery chinook salmon, and 3) make recommendations regarding hatchery fish husbandry to improve hatchery fish performance. The project began in 1992 with the characterization of physiology and migratory behavior of wild spring chinook salmon in the Yakima river Basin. This first goal of the project was completed and published (Beckman et al. 2000). Work on the second goal began with the first brood year (1997) of spring chinook salmon reared at the Cle Elum Hatchery when it began operation. The physiology and development of fish at the hatchery, acclimation sites, and during migration continued through broodyears 1998

and 1999. Samples from the last year of the study are still being analyzed, and a manuscript describing the results is in preparation. The major finding of this work is that the hatchery fish differ significantly from wild spring chinook salmon, of particular concern is the exceptionally high incidence of early male maturation at the hatchery. The third goal of the original project is not yet completed. Recommendations regarding hatchery fish husbandry techniques for controlling early male maturation cannot be made because they depend on results of the work outlined in this statement.

Milestones in the project history:

- 1997** Described the underlying physiological connection between growth rate and development of smolts: Dickhoff, et al, 1997. The role of growth in the endocrine regulation of salmon smoltification. *Fish Physiol. Biochem.* 17:231-236.
- 1998** Found that high growth rate of smolts promotes rapid downstream migration Beckman, et al. 1998. Relation of fish size and growth rate to migration of spring chinook salmon smolts. *N. American J. Fish. Management* 18:537-546.
- 1998** Demonstrated that manipulating growth rate of salmon juveniles affects the season of smolting. Beckman and Dickhoff. 1998. Plasticity of smolting in spring chinook salmon: relation to growth and insulin-like growth factor-I. *J. Fish Biol.* 53:808-826.
- 1999** Described the effects of growth rate and body fat levels on early maturation of male salmon: Silverstein et al. 1998. The effects of growth and fatness on sexual development of chinook salmon parr. *Can. J. Fish. Aquat. Sci.* 55:2376-2382.
- 1999** Found significant correlation between growth rate of juvenile salmon during smoltification and smolt-to-adult survival. Indicating that hatcheries should promote high growth rate during smolting: Beckman, et al. 1999. *Trans. Am. Fish. Soc.* 128:112
- 2000** Characterized the growth and physiology of wild juvenile spring chinook salmon rearing in the Yakima River: Beckman, et al 2000. *Trans. Am. Fish. Soc.* 129:727-753.
- 2000** Provided a review of ecological and behavioral impacts of hatchery fish on abundance of wild salmon populations: Flagg, et al. NOAA Technical Memorandum NMFS-NWFSC-41.
- 2001** Examined the effects of low temperature and fasting during the winter on metabolic, endocrine and smolt physiology of hatchery reared salmon. Larsen et al. 2001 *N. Am. J. of Aqua* 63;1-10.; Larsen et al. 2001. *Gen. Comp. Endocrinol.* 123:308-323.
- 2001** Confirmed the high incidence (50%) of early maturing (one-year old) male spring chinook salmon in Cle Elum hatchery production.

Objectives

The ultimate goals of this proposed research are determine what is the natural level of precocious male maturation in Yakima spring chinook and to determine whether unnatural growth rates in the hatchery environment induce an artificially high incidence of age 1+ precocious male maturation in the conservation hatchery stock of Yakima spring chinook. Based on this information, hatchery protocols may be altered to result in a more natural growth pattern and, associated with that, a more natural distribution of life-history types in fish released from the hatchery. These protocols may have universal utility at all conservation hatcheries. This may increase production of anadromous adults, normalize sex ratios between returning anadromous fish, and reduce potentially negative genetic and ecological impacts. Each of these goals is explicitly called for in the Yakima Subbasin Summary and the recent biological recommendations of the ISAB, CBFWP, and NMFS as noted above.

Work Statement Tasks

Task 1: Estimate incidence of precocious maturation and developmental physiology in wild Yakima River spring chinook salmon

The purpose of this task is to assess the incidence of precocious maturation and describe the associated physiological changes of naturally rearing Yakima River spring chinook. Monitoring of fish from three brood years (BY 2001, 2002, and 2003) is proposed to determine interannual variability between and among wild and hatchery fish each brood year. Wild fish will be collected by electroshock technique in the fall (Aug.-Oct) and winter (Nov.-Dec.) from the rip-rap bank near the town of Cle Elum (this technique was very successful for collecting fish in Beckman et al. (2000)), from the Roza Dam smolt trap during their mid-winter redistribution migration (dependent on YN trap operation activity) from December to March, and at the Prosser Dam smolt bypass facility during outmigration in the spring from March to May. Approximately 20 fish every three weeks will be collected in the fall at Cle Elum. Approximately 300 fish (100/sample) will be collected at Roza Dam from December to March. Approximately 300 fish (100/sample) will be collected at Prosser Dam from March to May. The large sample size is necessary to obtain an accurate estimate for incidence of precocious maturation in the wild population and because approximately 50% of the fish collected will be females.

The wild fish sampled at Cle Elum for comparison to hatchery fish will be sacrificed for determination of length, weight, sexual development (by visual examination), plasma levels of insulin-like growth factor-I (a growth regulating hormone) by method of Shimizu et al. (2000), and whole body lipid (a metric of energetic stores) by the method of AOAC (1975). The fish sampled at Roza and Prosser Dam will be sacrificed for determination of length, weight, gonadal development, and plasma 11-ketotestosterone (for determination of precocious maturation) by the method of Schultz (1984).

Fish #'s

Cle Elum 20 fish X 6 dates	= 120 fish/year
Roza 100 fish/date X 3	= 300 wild fish/year
Chandler 100 fish/date X 3	= <u>300</u> wild fish/year
Total	= 720 wild fish/year

WDFW and ESA permitting will be obtained for sample collection as required. Data from this task will be used for comparison with that of hatchery reared fish and analyzed by analysis of variance (ANOVA), the factors being time and treatment (hatchery vs wild). Results from this task will be reported in peer reviewed publications. The expectation from this task is that naturally rearing Yakima spring chinook will differ from the normal hatchery production spring chinook. Naturally reared fish will have high summer growth and low fall growth, and lower whole body lipid levels and a lower incidence of precocious maturation than the hatchery fish.

Task 2: Estimate Incidence of age 1+ precocious male maturation in the Yakima Hatchery population.

The purpose of task 2 is to accurately assess the incidence of 1+ precocious male maturation for three brood years (BY 2001, 2002, 2003) of Yakima hatchery spring chinook released from the Easton, Jack Creek, and Clark Flat acclimation sites. In cooperation with Ray Brunson (USFW pathologist) we will kill 60 fish/raceway for length, weight, visual assessment of gonadal development, and plasma 11-ketotestosterone levels. Samples will be collected in March of each year during the routine pathogen screening prior to the opening of the gates for volitional release.

Fish #'s

60 fish/raceway X 6 raceways X 50% males = approximately 180 males screened/site
Total # fish = 1080 fish/year or approximately 540 male fish analyzed/year

Data from this task will be used for direct comparison with that of the naturally reared fish from objective 1. The Results from this task will be reported in peer reviewed publications. The expectation from this task is that the hatchery fish will differ from the wild fish. The hatchery-reared fish will have an incidence of age 1+ precocious male maturation of approximately 50% at each acclimation site under the current production rearing protocol. If new production scale rearing protocols are initiated based on this proposed research, this analysis will be used to monitor the results of these changes.

Task 3: Experimental control of precocious maturation through growth rate modulation in a conservation hatchery.

The purpose of task 3 is to conduct an experiment (in 1.4m diameter outdoor tanks) to examine the effect of growth rate modulation on the incidence of age 1+ precocious male maturation in Yakima hatchery spring chinook. This experiment will test the following null hypothesis:

H0: Growth modulation has no effect on physiological development or incidence of precocious male maturation of conservation hatchery spring chinook.

This experiment will be conducted at the Cle Elum Supplementation and Research Hatchery because of the unique water temperature available for rearing compared to other sites. Growth rate in fish is directly dependent on water temperature. The unique seasonal thermograph created through use of both well and surface water supplies at this site would be very difficult to reproduce at another site. For this reason, experimental fish will be reared on the same water source used in the production raceways. Experiments will be conducted over three years (BY 2001, 2002, 2003) employing an adaptive management strategy as the outcome of each annual iteration is examined. Depending on the results of the BY 2001 experiment, production scale studies may be conducted in subsequent years (BY 2002, etc.).

BY 2001: The first experiment will examine the effect of alteration in growth rate in summer and fall (the period just before and during maturational initiation) on the incidence of 1+ male maturation in Yakima River hatchery spring chinook. Four treatment groups with different growth trajectories in a 2X2 factorial design will be employed as shown in Figure 5.

Large Hatchery Fish pattern	High summer growth / High fall growth (HH) Reared to match the growth profile of a large production hatchery stock
Cle Elum Hatchery Fish pattern	Low summer growth / High fall growth (LH) Reared to match the growth profile of the current production stock of Cle Elum (OCT) fish (Larsen et al. unpublished).
Large Wild Fish pattern (LW)	High summer growth / Low fall growth (HL) Reared to mimic the growth profile of wild fish (Beckman et al. 2000) with high growth in the summer, through increased feeding, followed by low growth, through feed restriction, in fall.
Small Wild Fish pattern (SW)	Low summer growth / Low fall growth (LL) Reared to match current production stock of Cle Elum (OCT) fish in summer followed by low growth, through feed restriction, in fall.

At the production ponding date of April 15th, 2002 fish will be randomly selected from the production stock and assigned to one of the four treatments. Following ponding replicates will immediately be reared according to treatment groups in quadruplicate. Ration manipulation will be used to modulate growth rate. Fish will be fed the same brand of feed as the production stock. Computer software currently in use at the hatchery for production ration calculations will be used to calculate feed rates depending on target size and water temperature. In feed restriction experiments such as this, dominance/subordinate behavioral interactions can occur, resulting in an undesirable bi-

modal size distribution. To minimize bi-modal size problems, feed restriction will be imposed by limiting the number of days a treatment group is fed each week rather than the amount of food each day. This technique allows for more equal distribution of food among all fish regardless of their position in the dominance hierarchy.

Approximately monthly, an estimate of the length and weight of fish from each treatment and two representative production raceways will be conducted to compare growth profiles. 60 fish per production raceway and 30 fish per replicate tank will be measured for length and weight each month. These data may be used to modify rations of experimental fish throughout the course of the experiment in order to modulate growth according to treatment.

Throughout the experimental period (summer-fall) fish from each treatment and the representative production raceways will be sacrificed to monitor for fall smoltification (gill Na^+/K^+ ATPase according to McCormick, 1993) and energetic status (plasma insulin-like growth factor-I, whole body lipid level). Beckman and Dickhoff, (1998) demonstrated that under high summer growth conditions, Yakima spring chinook may undergo fall smoltification. The following physiological parameters will be measured from July 2002 until January 2003: weight, length, appearance, visual gonadal development, plasma insulin-like growth factor-I, whole body lipid (6 times in fall), and gill Na^+/K^+ ATPase (August to November).

In May-June 2003, all remaining fish from each treatment will be killed and analyzed to determine the incidence of 1+ precocious male maturation. Using data from studies similar to the one proposed here (Silverstein et al. 1997, Shearer and Swanson, 2000, Shearer et al. 2000) a Power Analysis was conducted to determine the number of fish and replicates required to optimize detection of difference in percent maturation between treatments. These data indicate that using 4 replicates/treatment for a total of 16 tanks with a final (n) of 300 fish/tank (approximately 150 males) will provide sufficient statistical power. We propose to stock each tank with approximately 500-600 fish to accommodate physiological monitoring (approximately 200 fish will be sampled throughout the study), losses due to mortality, and determination of the rate of maturation at the end of the experiment in early summer. At the end of the experiment in early June 2003 all remaining fish (approximately 300/tank) will be killed and visually assessed for gender and incidence of male maturation.

Total # of fish needed

4 treatments x 4 replicates/treatment x 600 fish/replicate = 9600 fish in experiment

Fish sample #'s

Physiology samples

4 Treatments x 4 replicates x 6 fish/replicate = 96 fish/date x 8 dates = 768 fish

2 production raceways x 8 fish/raceway = 16 fish/date x 8 dates = 128 fish

Maturation samples (at the end of experiment)

4 Treatments x 4 replicates x 150 male fish/replicate = 2400 fish

Total = 3296 fish

The data from this task will be analyzed by ANOVA comparing physiological parameters and incidence of precocious male maturation among different treatments and

wild fish over time. Results from this task will be used to develop rearing protocols for use in the Yakima and other conservation hatcheries to produce fish with similar morphological, physiological and life-stage composition as their naturally reared congeners. Results will be reported in peer reviewed publications. The expectation from task 3 is that the hatchery fish reared on the more natural growth regimes (HL and LL) will have precocious male maturation rates similar to that of naturally reared fish from task 1. The fish reared on the conventional or Cle Elum production regimes (HH and LH) will have precocious male maturation rates similar to that of the current production stock of Yakima hatchery fish (approximately 50% or greater).

Sampling Time Line for all Tasks

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
pond																
Task #1																
Wild fish physiology						x	x	x	x		x	x		x	x	x
Task #2																
Incidence of maturity																x
Task #3																
Growth Modulation Experiment																
Physiology Samples						x	x	x	xx	xx	x					
Maturation Samples																x

Facilities and Equipment

The fish rearing for Task 3 will be conducted in a series of sixteen 2 m diameter circular tanks to be installed near the production raceways at the Cle Elum Supplementation and Research Hatchery. Tanks will be plumbed to draw water from the production raceway water supply and effluent treatment system. Hatchery personnel will assist in rearing of experimental animals according to our prescribed protocol. The hatchery monitoring and implementation team members of the Yakima Supplementation Project fully support this hatchery modification. Costs for tank installation and supplies have been included in the planning and design budget.

Laboratory and data analysis and base of operations is the Northwest Fisheries Science Center of the National Marine Fisheries Service in Seattle, which is well equipped to conduct the proposed studies. We have analytical balances, centrifuges, a gamma and beta counter, ELISA plate readers, spectrophotometers, and chemical and radiation safety hoods. We have a van that is equipped with sampling gear, centrifuges, and electric generator for field sampling on the Yakima River. No additional equipment is requested.

Budget Justification

Funding is requested to support the project manager, NMFS biologist Dr. Donald Larsen, for 24 pay periods and NMFS biologist Dr. Brian Beckman for 14 pay periods. Support of travel is requested for field sampling trips and attending scientific meetings within the Pacific Northwest to report progress and results. Supplies include laboratory reagents, glassware, chemicals for laboratory analyses. A subcontract to the University of Washington is to support two laboratory technicians (Kathy Cooper and Brad Gadberry) who will assist in field sampling and perform laboratory analyses.

References

- AOAC (Association of Official Analytical Chemists). (1975). Official methods of analysis, 12th edition. AOAC, Washington, D.C.
- Beckman, B.R. and Dickhoff, W.W. (1998). Plasticity of smoltification in spring chinook salmon (*Oncorhynchus tshawytscha*): Relation to growth and insulin-like growth factor-I. J. Fish Biology 53: 808-826.
- Beckman, B.R., D.A. Larsen, B. Lee-Pawlak and W.W. Dickhoff. (1998). The Relation of fish size and growth rate to migration of spring chinook salmon smolts. North American Journal of Fisheries Management. 18:537-546.
- Beckman, B.R., Dickhoff, W.W., Zaugg, W.S., Sharpe, C., Hirtzel, S., Schrock, R., Larsen, D.A., Ewing, R.D., Palmisano, A., Schreck, C.B., and Mahnken C.V.W. 1999. Growth, smoltification, and smolt-to-adult return of spring chinook salmon (*Oncorhynchus tshawytscha*) from hatcheries on the Deschutes River, Oregon. Transactions of the American Fisheries Society 128:1125-1150.
- Beckman, B.R., Larsen, D.A., Sharpe, C., Lee-Pawlak, B., Schreck, C.B., and Dickhoff, W.W. (2000). Physiological status of naturally reared juvenile spring chinook salmon in the Yakima River: Seasonal dynamics and changes associated with smolting. Trans. of the Am. Fish. Soc. 129:727-753.
- Berg, L et al. (2001) Yakima Subbasin Summary for the Northwest Power Planning Council. (<http://www.cbfw.org/files/province/plateau/010302YakimaDraft.pdf>).
- Brannon, E.L. and nine authors (1999). Review of Artificial Production of Anadromous and Resident Fish in the Columbia River Basin, Part I: A Scientific Basis for Columbia River Production Program, Northwest Power Planning Council, 139pp. (<http://www.nwcouncil.org/library/1999/99-4.htm>).
- Columbia River Basin Fish and Wildlife Program. (2000). (www.nwppc.org/2000-19_toc.htm).
- Dickhoff, W.W., Beckman, B. R., Larsen, D. A., Mahnken, C. V. W., Schreck, C. B., Sharpe, C, and Zaugg, W. S. (1995). Quality assessment of hatchery-reared spring chinook salmon smolts in the Columbia River Basin. 292-302. In H. L. Schramm and R. G. Piper eds. Uses and Effects of Cultured Fishes in Aquatic Ecosystems. Bethesda, Maryland, American Fisheries Society.
- Dickhoff, W.W., Beckman, B.R., Larsen, D.A., Duan, C., and Moriyama, S. (1997). The role of growth in the endocrine regulation of salmon smoltification. Fish Physiol. Biochem. 17:231-236.
- Flagg, T.A. and Nash, C.E. (editors). (1999). A conceptual framework for conservation hatchery strategies for Pacific salmonids. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-38, 48 p.

- Footte, C., Clarke, W.C., and Blackburn, J. (1991). Inhibition of smolting in precocious male chinook salmon, *Oncorhynchus tshawytscha*. Can. J. Zool. 69:1848-1852.
- Gebhards, S.V. (1960). Biological notes on precocious male chinook salmon parr in the salmon river drainage, Idaho. Prog. Fish Cult. 22, 121-123.
- Herbinger, C.M. and Friars, G.W. (1992). Effects of winter temperature and feeding regime on the rate of early maturation in Atlantic salmon (*Salmo salar*) male parr. Aquaculture 101:147-162.
- Hopkins, C.L. and Unwin, M.J. (1997). The effect of restricted springtime feeding on growth and maturation of freshwater-reared chinook salmon, *Oncorhynchus tshawytscha* (Walbaum). Aqua. Res. 28:545-549.
- James, B.B., Pearsons, T.N., McMichael, G.A. (1998). Washington Department of Fish and Wildlife, Spring Chinook Salmon Interactions Indices and Residual/Precocial Monitoring in the Upper Yakima Basin, Annual Report, Report to Bonneville Power Administration, Contract No. 1995B164878, Project No. 9506409. (<http://www.efw.bpa.gov/cgi-bin/efw/FW/publications.cgi>)
- McCormick, S.D. (1993). Methods for nonlethal gill biopsy and measurement of Na⁺/K⁺-ATPase activity. Can. J. Fish. Aquat. Sci. 50:656-658.
- Mullan, J.W., Rockhold, A., and Chrisman, C.R. (1992). Life histories and precocity of chinook salmon in the Mid-Columbia River. Prog. Fish. Cult. 54:25-28.
- National Marine Fisheries Service. (2000). Biological Opinion, Endangered Species Act Section 7 Consultation of the Federal Columbia River Power System, Hatchery and Research, Monitoring, and Evaluation Reasonable and Prudent Alternative (RPA). (www.nwr.noaa.gov/1hydroweb/hydroweb/docs/Final/2000Biop.html).
- Power, G. (1986). Physical influences on age at maturity of Atlantic salmon (*Salmo salar*): a synthesis of ideas and questions. In Meegurg, D.J. (Ed.). Salmonid age at maturity. Can. Spec. Publ. Fish. Aquat. Sci. 89:91-101.
- Rowe, D.K., and Thorpe, J.E. (1990). Suppression of maturation in male Atlantic salmon (*Salmo salar* L.) parr by reduction in feeding and growth during spring months. Aquaculture 86:291-313.
- Rowe, D.K., Thorpe, J.E., Shanks, A.M. (1991). The role of fat stores in the maturation in male Atlantic salmon (*Salmo salar*) parr. Can. J. Fish. Aquat. Sci. 48:405-413.
- Schulz, R.W. (1984). Serum levels of 11-oxotestosterone in male and 17 β -estradiol in female rainbow trout (*Salmo gairdneri*) during the first reproductive cycle. Gen. Comp. Endocrinol. 56:111-120.
- Shearer, K.D., and Swanson, P. (2000). The effect of whole body lipid on early sexual maturation of 1+ age male chinook salmon (*Oncorhynchus tshawytscha*). Aquaculture 190:343-367.
- Shearer, K.D., Swanson, P., Campbell, B., Beckman, B.R., Parkins, P., and Dickey, J.T. (2000). The effects of growth and low fat diet on the incidence of early sexual maturation in male spring chinook salmon (*Oncorhynchus tshawytscha*) Bonneville Power Administration Report.
- Shimizu, M., Swanson, P., Fukada, H., Hara, A., and Dickhoff, W.W. (2000). Comparison of extraction methods and assay validation for salmon insulin-like growth factor-I using commercially available components. Gen. Comp. Endocrinol. 119:26-36.

- Silverstein, J.T., Shearer, K.D., Dickhoff, W.W., and E.M. Plisetskaya. (1998). Effects of growth and fatness on sexual development of chinook *salmon* (*Oncorhynchus tshawytscha*) parr. Can. J. Aquat. Sci. 55:2376-2382.
- Zimmerman, C.E. and Stonecypher, W. (2001). Precocial maturation and migration in yearling hatchery chinook salmon, Umatilla River, Oregon. Northwest Fish Culture Conference. Dec. 4-5, 2001. Portland OR.

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Growth modulation budget July 1, 2002 - June 30, 2003

1. Personnel	pay periods	Hourly	Cost
Permanent			
Fish biologist, GS 13-1	14	\$31.97	35,806
Fish biologist, GS 12-3	24	\$28.68	55,066
	Total perm		90,872
	Total personnel		90,872
2. Fringe Benefits			
Leave surcharge (19.0% Perm.&Temp. Base)			17,266
			0
Overtime, Shift Dif., Hazard Pay			0
Security Clearance			50
TOTAL DIRECT LABOR			108,188
Employee Cont. (24.0%)			25,953
TOTAL PERSONNEL COSTS			134,140
3. Travel			
Mileage 11,000 mi @ \$0.19/mi			2,090
GSA vehicle charge, 12 mo @ \$239/mo.			2,868
Per diem 3 persons/33 days ea @ \$66/day			6,534
	Subtotal travel		11,492
5. Nonexpendable Property			
Fish tanks (6ft by 3 ft fiberglass) 16 tanks X \$597 ea			0
shipping (\$30/tank)16 tanks X 30 = \$480			
	Subtotal equipment		0
6. Supplies			
Misc sampling			18,347
Maint. & service supplies NMFS equip			4,408
	Subtotal supplies		22,755
Subcontract: University of Washington			124,623
TOTAL DIRECT COSTS			293,010

8. Support Costs	
SLUC (9.5% TDL/Perm.)	10,273
NOAA (51.2% TDL)	55,392
Unemployment Comp.	0
 TOTAL SUPPORT COSTS	 65,665
 9. YEAR TOTAL	 358,675

Budget - University of Washington - July 1, 2002 - June 30, 2003

Salaries:

Professional Staff:

Fish Biologist I (12 mo@\$3,356/mo)	40,272
Fish Biologist I (12 mos@\$3,183/mo)	38,196

Total salaries	78,468
Benefits (24.2% of prof staff)	18,989
Publications, slides	250
Supplies (chemical reagents, glassware)	1,200
Total direct costs	98,907
Indirect costs (26% of TDC)	25,716
Total project costs	124,623