WILD SMOLT BEHAVIOR/PHYSIOLOGY (ESA) 9202200

SHORT DESCRIPTION:
Using our findings on the physiological development of wild spring chinook salmon as a template, we are testing the physiological aspects of wild fish that may be used to improve migration behavior and smolt-to-adult survival of hatchery-reared salmonids.

SPONSOR/CONTRACTOR: NMFS
National Marine Fisheries Service
Walt Dickoff, Physiologist
2725 Montlake Boulevard East, Seattle, WA 98112-2097
206/860-3234 wdickhoffsci.nwfsc.noaa.gov

SUB-CONTRACTORS:
Oregon State University, Cooperative Fishery Research Unit, U.S. Geological Survey

GOALS

GENERAL:
Increases run sizes or populations, Adaptive management (research or M&E)

ANADROMOUS FISH:
Production, Research, M&E

NPPC PROGRAM MEASURE:
7.2D.1, 7.2D.3, 7.2D.5

RELATION TO MEASURE:
This project examines physiological aspects of development and smoltification of wild juvenile salmon that may be used to improve smolt quality and smolt-to-adult survival of hatchery-reared fish. The main focus is exmining the use of rapid growth rate during smoltification to enhance smolt survival.

OTHER PLANNING DOCUMENTS:
NMFS Snake River Salmon Recovery Plan items 4.3a, 4.4a, 4.4c

TARGET STOCK	LIFE STAGE	MGMT CODE (see below)
Steelhead trout	Juvenile	A
Coho salmon	Juvenile	A
Chinook salmon	Juvenile	A

BACKGROUND

Subbasin:
Deschutes River, Yakima River, Columbia River Estuary (Young's Bay)

Project is an office site only

HISTORY:
This project is an outgrowth and obvious next step of a previous study entitled "Smolt quality assessment of hatchery-reared spring chinook salmon in the Columbia River Basin." High quality salmon smolts are defined as fish that migrate rapidly downstream and survive to adulthood. Our original study of hatchery-reared spring chinook salmon indicated that differences in smolt quality as assessed by physiological and morphological indices accounted for differences in smolt survival to adulthood. High growth rates of hatchery smolts during the 40 to 60 days before release correlated with adult survival. Results suggested that manipulation of growth rate of hatchery fish prior to their release may improve their survival to adulthood. The present project verified these findings relating high growth rates of wild spring chinook salmon during smoltification in the first detailed, systematic study of the physiology and morphology of wild chinook salmon. The hypothesis that high growth rate of smolts leads to downstream migratory behavior was confirmed. Physiological development of wild juvenile chinook salmon may serve as model for hatchery rearing. Producing a more wild-like hatchery fish may improve their survival. The role of growth rate in stimulating smoltification of chinook salmon is being tested on a production scale at Young=s Bay terminal fishery project. Laboratory studies are being conducted to determine which of the characteristics of wild smolts must be created in hatchery fish

to achieve high smolt quality.

BIOLOGICAL RESULTS ACHIEVED:

A technique of enhanced spring growth rate has been developed that should improve smolt quality (migration and smolt-to-adult survival) in production, supplementation and conservation hatcheries. Hatchery managers are aware of some of this project's results to date and have implemented tests of the studies recommendations; for example, at Spring Creek NFH, production-scale testing of growth rate effect on smolt quality is underway. Results from these production-scale hatchery tests are not yet available. The physiology of wild spring chinook salmon has been characterized and is providing a template for additional improvement in smolt quality.

PROJECT REPORTS AND PAPERS:

One BPA report is completed, two manuscripts have been submitted to Canadian Journal of Fisheries and Aquatic Sciences, two other manuscripts are in preparation:

1) Beckman, B.R., D.A. Larsen, B. Lee-Pawlak, and W.W. Dickhoff. Physiolgical assessment and behavioral interaction of wild and hatchery juvenile salmonids: The relationship of fish size and growth to smoltification in spring chinook salmon. BPA Report, October 1996.

2) Beckman, B.R., D.A. Larsen, and W.W. Dickhoff. The relationship of fish size and growth to smoltification in spring chinook salmon. I. Migratory tendencies. (submitted)

3) Beckman, B.R., W. W. Dickhoff, D. A. Larsen, S. Moriyama, and B. Lee-Pawlak. The relationship of fish size and growth to smoltification in spring chinook salmon. II. Plasma insulin-like growth factor-I and other physiological measures. (submitted)

ADAPTIVE MANAGEMENT IMPLICATIONS:

Knowledge of how to produce higher quality and more wild-type smolts that migrate downstream rapidly, show high survival to adulthood, and minimize negative impacts on naturally-produced smolts should be broadly applicable to management objectives. For example, hatchery production of higher quality smolts with high survival to adulthood would result in either a larger number of adult salmon produced or allow similar numbers of hatchery adults produced from a smaller number of hatchery-reared fish. Wild type hatchery smolts may be smaller than the traditional large hatchery smolts. A reduced size difference between wild and hatchery-reared smolts would remove a size advantage for hatchery smolts in agonistic hatchery-wild fish interactions. Increasing downstream migratory tendency and rate in hatchery fish would reduce hatchery-wild fish interactions. Hatchery fish would move downstream more purposefully and at a higher rate, reducing the opportunity for wild-hatchery encounters. More rapidly migrating smolts would reduce the requirement for increased river flow and dam drawdown.

PURPOSE AND METHODS

SPECIFIC MEASUREABLE OBJECTIVES:

1. Enhance smolt quality - Confirm relation between growth rate and smolt quality
   A. Compare temperature and ration manipulation to affect smolt quality
   B. Estimate range of critical growth rates and timing necessary for high smolt quality
   C. Scale up to hatchery production studies; improve smolt-to-adult survival and cost-effectiveness of terminal fisheries project (Young=s Bay project).
2. Enhance downstream migration - Confirm relation between growth rate and downstream migratory tendency and rate.
   A. Controlled laboratory experiments to isolate effects of growth rate on migration.
   B. Scale up to in-stream survival and migration studies in the Columbia River Basin.

BIOLOGICAL NEED:

Smolt to adult survival of hatchery reared fish is generally lower than that of wild fish. This is due, in part, to poorer quality of hatchery compared to wild smolts. Improved quality of hatchery smolts should improve their survival.

HYPOTHESIS TO BE TESTED:

1. Physiological and behavioral characteristics of naturally reared chinook salmon can be identified, and used to develop hatchery practices to rear fish with a more wild phenotype.
2. Hatchery-produced smolts having a more wild phenotype will have minimal negative impact on wild fish and survive to adults at a higher rate than traditional hatchery fish.

3. Growth rate during smoltification is more important than size at release from hatcheries for high smolt-to-adult survival.

METHODS:

A variety of study approaches are used.
Wild fish were collected from the Yakima River Basin, sampled and analyzed for physiological and morphological features. Sample analysis included body size, gill ATPase activity, blood hormone levels, total body lipid, liver glycogen and stomach fullness. Data are being analyzed to determine possible salient features that may be biological ly significant as differences between wild and hatchery reared fish.
Methods for manipulating juvenile salmon growth rates will be developed and compared for their effects on smolt physiology and behavior (migration). Migration behavior is being analyzed in an artificial stream. Migration behavior and in-stream survival of fish with differing growth rates will be analyzed in future work.
Standard statistical methods will be used as appropriate (Zar 1984). These include both parametric and nonparametric analyses; ANOVA, multiple range testing (Fisher PLSD), linear and nonlinear regression, and chi-square.
Chinook salmon will be used primarily, although some behavioral and physiological testing will use coho salmon in addition. For wild fish sampling in the Yakima River Basin, approximately 300 juvenile chinook salmon were collected. Thousands of chinook and coho salmon will be examined in our Seattle hatchery. These will come from Puget Sound stocks. Chinook salmon in the terminal fisheries project at Young=s Bay are being used for physiological tests (gill ATPase, blood hormone, and body fat level) and behavioral tests (seawater preference). Coho salmon are used in some studies because their life-history characteristics are less variable, e.g., no fall smolting and no precocious (zero-age) male maturation, which interfere with studies of smolting in the spring. Also, the endocrine profiles of coho salmon are more uniform within experimental groups (no multiple springtime peaks in blood hormone levels, in contrast to chinook salmon).

PLANNED ACTIVITIES

SCHEDULE:

Planning Phase **Start** 1996 **End** 2002 **Subcontractor**

Task Activity will be continuous during the year. Conduct experiments examining effect of growth rate on salmon physiology and behavior. Conduct experiments evaluating methods to manipulate growth rate in hatchery.

Implementation Phase **Start** 1996 **End** 2002 **Subcontractor**

Task Activity will be continuous during the year. Begin experiments in laboratory and Young's Bay.

PROJECT COMPLETION DATE:

2000

CONSTRAINTS OR FACTORS THAT MAY CAUSE SCHEDULE OR BUDGET CHANGES:

Reduction in support of related project Columbia River Terminal Fishery Project will require redirecting efforts to other production facilties within the Columbia River Basin.

OUTCOMES, MONITORING AND EVALUATION

SUMMARY OF EXPECTED OUTCOMES

Expected performance of target population or quality change in land area affected:

Improved smolt to adult survival of hatchery reared fish by improving smolt quality will increase the efficiency of hatchery production. Improving smolt quality and migration rates will reduce negative impact of hatchery fish on wild fish, reduce straying rates, and maintain adult contribution with lower numbers of hatchery fish released.

Present utilization and convservation potential of target population or area:

Most immediately, this research may improve the adult contribution and efficiency of the Young=s Bay terminal fishery.

Long term expected utilization and conservation potential for target population or habitat:

The findings of these studies could be applied to all salmonids in all basins.

Contribution toward long-term goal:
Improve chances of success of production, supplementation, and conservation hatcheries.

Information products:
The project should allow for improved management of production hatcheries, improved recovery of natural producing stocks by improving supplementation hatcheries, reduced hatchery and wild fish interactions to improve health of wild stocks through reduced competition with hatchery fish.

Coordination outcomes:
Activities:
1992-93 sampling sites and methods for determining smolt development of juvenile spring chinook salmon were established.
1993-94 juvenile chinook salmon were systematically sampled from different regions of the Yakima River and analyzed in the laboratory.
1994-95 sampling and analysis will continue in order to examine year-to-year variation in chinook salmon development.
1995-1996 completed analysis of wild salmon development and physiology and initiated production scale tests of using growth rate modification to improve hatchery effectiveness.

Products:
Wild spring chinook salmon in the Yakima River Basin show highly seasonal changes in physiology, growth, metabolism, and development. The summer after emergence of fry is associated with high feeding and growth rate and accumulation of stored energy in the form of liver glycogen and total body lipid. Growth rate and energy stores decline in the autumn and winter to extremely low levels. Prior to smoltification in the spring, growth rate and energy reserves increase dramatically. Smolts captured during their migration show high levels of development based on physiological smolt indices whereas their body length (125mm) is relatively small compared to hatchery-reared spring chinook salmon. The extreme seasonal fluctuations in physiology of wild juvenile salmon contrasts with the relatively modest changes seen in hatchery-reared fish.
In laboratory-reared spring chinook salmon, comparison of smolt size versus growth rate indicates that high growth rates produce higher quality smolts as determined by physiological indices and downstream migratory tendency. The effect of body size on the quality of smolts produced was much less than the effect of growth rate for the range of sizes tested. These results suggest that hatchery managers should aim for high growth rates of smolts during the 40 to 60 days prior to their release. Target size at release is less important for improving smolt quality. These studies need to be extended to large-scale tests at production hatcheries.
Production of high quality smolts that migrate rapidly downstream and survive to adulthood at high rates will improve hatchery efficiency. Producing rapidly migrating smolts of similar size as wild smolts should minimize negative impacts of hatchery fish on wild fish, minimize residualism of juveniles and reduce the incidence of straying.

MONITORING APPROACH
Progress reports at seminars, workshops, scientific meetings; processed reports and publications in the peer-reviewed literature. Success of the terminal fisheries studies will be assessed by rates of adult salmon contribution.

Data analysis and evaluation:
Standard statistical methods will be used as appropriate (Zar 1984). These include both parametric and nonparametric analyses; ANOVA, multiple range testing (Fisher PLSD), linear and nonlinear regression, and chi-square.

Information feed back to management decisions:
Progress reports of the research findings at seminars, workshops, scientific meetings; processed reports and publications in the peer-reviewed literature.

EVALUATION
Publication of findings, acceptance of findings by the scientific community. Improved rates of adult returns and efficiency of hatcheries.

Incorporating new information regarding uncertainties:
The project is critically reviewed internally and externally by scientists and administrators.

Increasing public awareness of F&W activities:
All publications and presentations acknowledge the region=s (BPA) efforts and support.

RELATIONSHIPS

RELATED BPA PROJECT	RELATIONSHIP
9305600 Assessment of Captive Broodstock Technology	Collaboration on effects of growth rate on smolt quality and precocious sexual maturation.
9306000 Columbia River Terminal Fisheries Research Project	Production scale testing of smolt quality criteria.

RELATED NON-BPA PROJECT	RELATIONSHIP
Regulation of salmonid growth/ U.S. Department of Agriculture	Collaborative work on indices of growth and smolt quality.

OPPORTUNITIES FOR COOPERATION:
Researchers are cooperating and sharing equipment in these studies. Collaboration with other BPA projects (9306000; Columbia River Terminal Fisheries), for example, involves use of tagged fish and facilities that we are using to test production scale releases of smolts. The collaborative research should benefit both projects and be cost-effective.

COSTS AND FTE

1997 Planned: $350,000

FUTURE FUNDING NEEDS:

FY	$ NEED	% PLAN	% IMPLEMENT	% O AND M
1998	$447,000		100%	
1999	$469,000		100%	
2000	$493,000		100%	

PAST OBLIGATIONS (incl. 1997 if done):

FY	OBLIGATED
1992	$296,395
1994	$366,276
1995	$369,704
1996	$370,850
TOTAL:	$1,403,225

Note: Data are past obligations, or amounts committed by year, not amounts billed. Does not include data for related projects.

OTHER NON-FINANCIAL SUPPORTERS:
National Marine Fisheries Service, University of Washington, Clatsop County Economic Development Council.

1997 OVERHEAD PERCENT: 45.6% of total direct labor costs

HOW DOES PERCENTAGE APPLY TO DIRECT COSTS:
45.6% of total direct labor costs

CONTRACTOR FTE: Four

SUBCONTRACTOR FTE: 1