PERFORMANCE/STOCK PRODUCTIVITY IMPACTS OF HATCHERY SUPPLEMENTATION 9005200

SHORT DESCRIPTION:
Evaluate costs and benefits for alternative sources of hatchery broodstocks in supplementation, test for inadvertant domestication in hatchery programs, and determine whether modifications at the hatchery can improve fitness of hatchery fish for spawning and rearing in natural streams.

SPONSOR/CONTRACTOR: BRD
Biological Resources Division, U.S. Geological Survey (formerly NBS)
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SUB-CONTRACTORS:
University of Idaho; University of Washington; U.S. Fish and Wildlife Service; Washington Dept. of Fish and Wildlife

GOALS

GENERAL:
Supports a healthy Columbia basin, Maintains biological diversity, Maintains genetic integrity, Increases run sizes or populations, Adaptive management (research or M&E)

ANADROMOUS FISH:
Research, M&E

NPPC PROGRAM MEASURE:
7.3B.2

RELATION TO MEASURE:
uates the role of broodstock in that failure by comparing the performance of D

OTHER PLANNING DOCUMENTS:
Most plans including supplementation acknowledge the dearth of appropriate information concerning the costs, benefits, and evaluations of supplementation. Although often not explicitly, these plans implicitly call for the type of work undertaken in 90-052.

TARGET STOCK	LIFE STAGE	MGMT CODE (see below)
Spring chinook salmon -- This is a research study to elucidate GENERAL questions to improve the success of supplementation throughout the Columbia River system. The specific work is with Warm Springs River stocks.	Juvenile and adult	This is a research study to examine GENERAL questions to improve the success of supplementation (S).
Steelhead -- This is a research study to elucidate GENERAL questions to improve the success of supplementation throughout the Columbia River system. The specific work is with Clearwater River stocks.	Juvenile and adult	This is a research study to examine GENERAL questions to improve the success of supplementation (S).

BACKGROUND

Subbasin:
N/A. Although the study is conducted in the Clearwater, Deschutes, Little White Salmon, and other proximate drainages, the results apply to or affect all sub-basins throughout the Columbia River system and along the West Coast where supplementation is conducted or proposed.

Project is an office site only

HISTORY:
Cost sharing has occurred with U.S. Fish and Wildlife Service (USFWS) and subsequently with National Biological Service, BRD. These agencies have contributed $25,000-35,000 per year, or approximately 7% of the operating costs. The study also involves extensive cooperation or collaboration with many agencies and facilities including Confederated Tribes of the Warm Springs Reservation, Idaho Department of Fish and Game, Nez Perce Tribe, Oregon Department of Fish and Wildlife, USFWS (Idaho and Lower Columbia River Fisheries Resources Offices; Carson, Little White Salmon, Warm Springs, and Dworshak National Fish Hatcheries), U.S. Forest Service, and Washington Department of Fish and Wildlife.

BIOLOGICAL RESULTS ACHIEVED:
Preliminary results for steelhead show that offspring of hatchery fish have lower fitness for natural rearing and higher fitness for hatchery rearing than do offspring of wild fish, demonstrating that domestication selection largely is responsible for these genetic differences. Our data provide much of the basis for models to predict the long-term consequences of supplementation on the carrying capacity, productivity, and production of naturally spawning populations. We developed a simple model to illustrate these effects, but a more complicated model is required for more general applicability. Preliminary results for spring chinook salmon also showed genetic differences between hatchery and wild fish -- offspring of wild spring chinook salmon survived the same but grew faster in the hatchery than did offspring of hatchery fish; relative survival to returning adult are not yet available. This genetic difference developed in only three generations, and despite development of the hatchery stock from the wild stock, and inclusion of 10->30% wild fish in the brood stock each year.

PROJECT REPORTS AND PAPERS:
Annual report for 1992.
-Reisenbichler, R.R., and G.S. Brown. 1995. Is Genetic Change From Hatchery Rearing of Anadromous Fish Really a Problem? Pages 578-579 in Uses and Effects of Cultured Fishes in Aquatic Ecosystems. American Fisheries Society Symposium 15. Bethesda, MD.

Reisenbichler, R.R. 1996a. Effects of supplementation with hatchery fish on carrying capacity and productivity of naturally spawning populations of steelhead. Pages 81-92 in G.E. Johnson, D.A. Neitzel, and W.V. Mavros [eds.] Proceedings from a Workshop on Ecological Carrying Capacity of Salmonids in the Columbia Basin: Measure 7.1A of the Northwest Power Planning Council's 1994 Fish and Wildlife Program, Report 3 of 4. Bonneville Power Administration, Portland, OR.

Reisenbichler, R.R. 1996b. The risks of hatchery supplementation. The Osprey 27: 1-4.

Brown, G.S., and R.R. Reisenbichler. 1996. Evidence for genetic change in behavior and survival of a hatchery population of steelhead, Oncorhynchus mykiss. Poster presented at the Ecological and Evolutionary Ethology of Fishes Conference, Albuquerque, New Mexico., and manuscript
in preparation) for Ethology xx:xx-xx.
Reisenbichler, R.R. 1997. Genetic factors contributing to declines of anadromous salmonids in the Pacific Northwest. Pages 223-244 in D.J. Stouder, P.A. Bisson, and R. J. Naiman [eds.] Pacific Salmon and Their Ecosystems: Status and Future Options. M.G. Duke [assoc. ed]. Chapman & Hall, Inc., New York.
-Reisenbichler, R.R. (in press). Questions and partial answers about supplementation--genetic differences between hatchery and wild fish. In Proceedings of the Columbia River Anadromous Salmonid Rehabilitation Symposium, Richland, WA (June 1995).

ADAPTIVE MANAGEMENT IMPLICATIONS:
Knowledge gained from this project (data and model) is beginning to provide the first explicit basis for incorporating the genetic effects of hatchery programs (even hatcheries using only wild fish for broodstock) in planning and adaptive managment of supplementation programs; and our results illustrate the necessity of making this inclusion for prudent management. The data and model will allow managers to appreciate the time horizon and level of expected changes in carrying capacity and fitness for natural rearing, and to evaluate the likely efficacy of supplementation programs for steelhead, and to compare alternative management strategies. For example, preliminary results suggest that the actual benefit (adult production) from supplementation programs may be only a fraction (e.g., 1/2-1/3) of that expected without considering genetic changes from hatchery rearing (Reisenbichler 1996a&b). Therefore, where hatchery fish could be managed separately from wild fish--avoiding problems from mixed-stock fisheries, competition, predation, interbreeding, etc.--total production might be substantially higher by using the hatchery for a traditional production or harvest augmentation program, rather than for supplementation. Other variables for

consideration are the size of the hatchery production, the proportion of wild fish taken into the hatchery, the proportion of wild fish in the hatchery broodstock, and perhaps the hatchery environment. Our results for steelhead suggest that domestication selection, not relaxed selection, is the primary cause of reduced fitness for natural rearing, therefore (as yet undetermined) modifications of hatchery programs may substantially reduce the loss of fitness for natural rearing, and substantially increase the benefits of supplementation.

PURPOSE AND METHODS

SPECIFIC MEASUREABLE OBJECTIVES:

Genetic data on growth and survival resulting from this study will help project and understand the long-term consequences of supplementing wild populations of salmon and steelhead, and will facilitate planning to achieve maximum efficiency and conservation with supplementation.

Objective I.1.a: Compare the growth and survival of genetically marked offspring from wild steelhead (W) and from Dworshak Hatchery steelhead (H) rearing together in two natural streams in the Clearwater River system, Idaho. Comparisons of HxH and WxW fish will be completed for each of four year-classes. Growth (in length and weight) and survival will be evaluated at the end of each growing season, and at the time of downstream migration.

Objective I.1.b: Compare the growth and survival of genetically marked offspring from wild spring chinook salmon (W) and from Warm Springs Hatchery fish (H) in two natural streams in or near the Deschutes River system, Oregon. Comparisons of HxH and WxW fish will be completed for each of four year-classes. Growth (in length and weight) and survival will be evaluated at the end of each growing season, and at the time of downstream migration.

Objective I.2: Compare the growth and survival of genetically marked offspring from local wild fish (W) and from hatchery fish (H) in hatchery ponds at Dworshak, Clearwater, and Warm Springs hatcheries. Comparisons of HxH and WxW fish will be completed for each of four year-classes. The two groups of fish will be reared together (i.e., in the same ponds). Growth (in length and weight) and relative survival will be evaluated immediately before the juvenile fish are released from the hatchery as smolts. Steelhead will be reared at Dworshak and Clearwater hatcheries; spring chinook salmon will be reared at Warm Springs National Fish Hatchery.

Objective I.3 : Compare the reproductive success (the number of offspring produced) of genetically marked adult offspring from wild steelhead (WxW) and from hatchery steelhead (HxH) spawning in Silver Creek, South Fork Clearwater River system. The comparison is to be made for each of four year-classes.

Objective I.4 : Test for selection on the genetic marks by comparing the growth and survival of juvenile fish with the different genotypes rearing together in natural streams and in hatcheries. The test fish will be the offspring of hatchery fish. The tests will be repeated for up to four year-classes, depending on preliminary results from the first two year-classes.

CRITICAL UNCERTAINTIES:

We assume that the genetic marks are selectively neutral, that differences observed between experimental groups result from genetic differences not maternal effects, and that incubation at different temperatures doesn't differentially effect subsequent growth or survival of experimental fish. Results from other studies suggest that the first two assumptions are valid; however, we have included ancillary tests in our study to evaluate each of these assumptions for our particular circumstances.

BIOLOGICAL NEED:

Some persons have identified supplementation as a tool of major importance for restoring the salmonid fisheries of the Columbia and Snake river systems. Other persons have identified supplementation as a major force compromising the sustainability and persistence of the endemic, naturally spawning (wild) stocks of salmonids. Much of the disagreement and confusion (and therefore lack of progress) with supplementation stems from our lack of solid information concerning the effects of supplementation, particularly the long-term or genetic effects on sustainability of wild populations. The purpose of study 90-052 is to provide such information to help in current planning and future adaptive management, including the identification of important additional hypotheses to be tested. Even just the preliminary data from study 90-052, considered in conjunction with data from three previous studies, provide a minimally sufficient data set for predicting the long-term consequences of supplementing steelhead and provide a greatly improved basis for planning supplementation programs (Reisenbichler 1996a&b).

The data from this study will allow more complete consideration and analysis of questions such: Is it more prudent to supplement or to simply augment harvest in any given situation? What is the optimal capacity for a supplementation hatchery? What is the optimal hatchery:wild ratio on the spawning grounds? Can modifications of hatchery environments reduce the deleterious genetic differences between hatchery and wild fish? ...

As implied above, all of the data to test for and evaluate genetic differences in growth or survival between hatchery and wild salmonids come from steelhead. Chinook salmon have different habitat requirements and other life-history characteristics than do steelhead, so the genetic effects of hatchery rearing on fitness for natural rearing may be different than for steelhead. Our study will be the first to develop this important information for chinook salmon. Indeed our preliminary results suggest, among several competing hypotheses, that spring chinook salmon exhibit a substantially different response to hatchery rearing than do steelhead--relaxed selection, rather than domestication selection may be the dominant evolutionary factor operating in the hatchery environment. If this hypothesis stands after additional results are available for the 1992- and future year-classes, then unlike for steelhead, little potential may exist for altering hatchery environments to ameliorate the loss of genetic fitness for natural rearing.

HYPOTHESIS TO BE TESTED:

Hypothesis I.1.1. Survival in natural streams, from release to the end of each growing season and to downstream migration, does not differ among juveniles resulting from matings of HxH and WxW fish.
Hypothesis I.1.2. Growth in natural streams, from release to the end of each growing season and to downstream migration, does not differ among juveniles resulting from matings of HxH and WxW fish.
Hypothesis I.2.1. Survival in the hatchery, from fertilization to the standard time of release at each station and to returning adult, does not differ among fish resulting from matings of HxH and WxW adults.
Hypothesis I.2.2. Growth in the hatchery, from fertilization to the standard time of release at each station and to returning adults, does not differ among fish resulting from matings of HxH and WxW adults.
Hypothesis I.3.1. Reproductive success to swim-up fry is the same for offspring of HxH fish and WxW fish.
Hypothesis I.3.2. Survival from swim-up fry to fingerling in late August and from swim-up fry to smolt is the same for offspring of HxH fish and WxW fish.
Hypothesis I.3.3. Growth to late August is the same for offspring of HxH fish and WxW fish.
Hypothesis I.3.4. Size of smolts and timing of downstream (smolt) migration in the spring is the same for offspring of HxH fish and WxW fish.
Hypothesis I.4.1. Survival of juvenile fish from release to the end of the first summer (chinook salmon) or second summer (steelhead) in natural streams is independent of their genetic mark.
Hypothesis I.4.2. Growth of juvenile fish to the end of the first summer (chinook salmon) or second summer (steelhead) in natural streams is independent of their genetic mark.
Hypothesis I.4.3. Survival of juvenile fish in the hatchery and in a natural stream from fertilization to the time of release or migration as smolts is independent of their genetic mark.
Hypothesis I.4.4. Growth of juvenile fish in the hatchery and in a natural stream to the time of release or migration as smolts is independent of their genetic mark.

ALTERNATIVE APPROACHES:

N/A

JUSTIFICATION FOR PLANNING:

N/A

METHODS:

The experimental design uses genetic marks so that experimental groups of fish can be released as eyed embryos or swim-up fry (not easily marked by other means) to rear together in the same stream or hatchery pond. Genetic marks also enable tests of reproductive success where the experimental fish result from natural spawning of (genetically marked) hatchery and wild adults in the same stream (hence, no opportunity to handle the offspring and apply a physical mark). Mixing experimental fish and introducing them to the streams as eyed-embryos or swim-up fry avoids or severely restricts the influences of the hatchery environment that might confound our comparisons between groups of fish. When experimental organisms share a common environment for their entire life, any differences between them illustrate genetic differences (or maternal effects).
Genotypes at the dipeptidase locus serve as the genetic marks for steelhead, and at the superoxide dismutase locus for spring

chinook salmon. Each year, wild adult fish are captured, and a small sample of muscle tissue is extracted from each adult. The genotype is determined from each tissue sample with horizontal starch-gel electrophoresis, and all fish are released except those homozygous for the common allele, keeping 25 males and 25 females. Adult hatchery fish are captured at the respective hatchery, and are similarly screened for the appropriate (alternate) genotypes. At least 25 of each sex are retained for the study. Adults with the appropriate genotypes are held until mature, at which time they are spawned in 2x2 crosses, if possible, to ensure substantial genotypic variation (Objectives 1.1 & 1.2), or they are radio-tagged and released into the study stream to spawn naturally (Objective 1.3). Each study stream receives at least 20,000 fry for Objective I.1, representing all families from each experimental group; each hatchery pond (Objective I.2) receives at least 3300 from each experimental group.

We test to ensure that the experimental crosses have the correct genotypes by holding 5 to 10 embryos from each mating, rearing them to hatching or button-up, then sacrificing them and verifying the genotypes. We test for possible maternal effects confounding comparisons of HxH and WxW fish by making HxW crosses using only hatchery females and wild males--if differences between HxH and WxW fish are due to maternal effects rather than genetic effects, the performance of HxW fish should be indistinguishable from that of HxH fish; otherwise, genetic differences are indicated. Egg size is measured volumetrically or by subsampling individual eggs. Mean egg size is determined for hatchery fish and for wild fish.

Samples of approximately 250 experimental fish are collected from each study stream by electrofishing or seining in late summer each year, and as fall or spring outmigrants in downstream migrant traps. Differences in abundance are tested by chi-square or log-likelihood analysis. Differences in size (growth) are tested with one-way ANOVA. Statistical sensitivity analysis suggested that we should be able to detect true differences between groups of less than 25% with a 5% chance of Type I error and a 20% chance of Type II error.

PLANNED ACTIVITIES

SCHEDULE:

Planning Phase **Start** Jan 90 **End** Jun 91 **Subcontractor** N/A (funded by USFWS)

Task Conceptualize problem, develop experimental design, contact cooperating agencies and personnel, write study proposal.

Implementation Phase **Start** Jun 91 **End** Oct 01 **Subcontractor** In part

Task Conduct experiments. (The original study plan approved for this study gives a detailed schedule for each of the 24 primary tasks.)

O&M Phase **Start** Dec 92 **End** Dec 02 **Subcontractor** In part

Task Finish data analysis and write final report and publications.

PROJECT COMPLETION DATE:
2002

CONSTRAINTS OR FACTORS THAT MAY CAUSE SCHEDULE OR BUDGET CHANGES:
Very low returns of adult fish or retraction of consent by other agencies could preclude significant portions of the study.

OUTCOMES, MONITORING AND EVALUATION

SUMMARY OF EXPECTED OUTCOMES

Expected performance of target population or quality change in land area affected:
Knowledge from this project should lead to decisions about supplementation which increase the efficiency of supplementation programs, increase the protection of the genetic diversity and adaptedness of anadromous salmonids, and increase or maintain productivity for natural rearing. This research project should benefit all populations under or considered for supplementation with hatchery fish. These benefits should continue to accrue indefinitely into the future, with a substantial benefit to fish populations throughout the Columbia River system within ten years.

Present utilization and convservation potential of target population or area:

N/A--This is a research project

Assumed historic status of utilization and conservation potential:
N/A--This is a research project

Long term expected utilization and conservation potential for target population or habitat:
This project should aid in conserving biodiversity and fisheries in the form of natural spawning populations of salmon and steelhead, and their productivity, through improved planning and operation of supplementation programs.

Contribution toward long-term goal:
Improve natural/hatchery productivity through better understanding of the costs, benefits, and options for supplementation programs.

Indirect biological or environmental changes:
N/A

Physical products:
N/A--This is a research project

Environmental attributes affected by the project:
N/A

Changes assumed or expected for affected environmental attributes:
N/A

Measure of attribute changes:
N/A

Assessment of effects on project outcomes of critical uncertainty:
N/A

Information products:
The products are various oral presentations, reports, and peer-reviewed publications describing and interpreting our experimental results. These products should be very useful in planning enhancement strategies, and implementation or evaluation of supplementation programs.

Coordination outcomes:
N/A--This is a research project

MONITORING APPROACH
Peer review of reports and publications.

Provisions to monitor population status or habitat quality:
N/A--This is a research project

Data analysis and evaluation:
Standard statistical procedures will be used to analyze the data, as outlined in the study proposal. Peer review has evaluated the planned methods, and will evaluate the actual methods, results, and conclusions.

Information feed back to management decisions:
Information will feed back to management decisions through peer-reviewed publications and oral presentations of results and implications.

Critical uncertainties affecting project's outcomes:
Critical uncertainties (possibility of very low adult returns) cannot be resolved. Very important corollary research needs are: (1) Develop a computer-based model (an elaboration of Reisenbichler's [1996a & b] model), based on the results from this (90-052) and comparable studies, to predict the effects of supplementation on carrying capacity, production, and productivity of the affected fish populations. The model must accommodate variation in parameters such as maximum proportion of wild fish taken into the hatchery each generation, and recovery rate for fitness for natural rearing. (2) Research to evaluate the rate at whic h offspring of hatchery fish recover fitness for natural rearing.

EVALUATION
Peer review should be employed to judge the project's performance. Factors to be evaluated should include soundness of the study, level of (responsible) imagination employed to interpret the results, and relevance to important management issues.

Incorporating new information regarding uncertainties:
Through consultations with the project officer.

Increasing public awareness of F&W activities:
Preliminary results from this study have already been revealed in newspaper and newsletter articles. Continued disemmination of our results through popular media, oral presentations, BPA reports, and peer-reviewed publications will illustrate to the public the reion's efforts to responsibly protect and manage the fishery resource.

RELATIONSHIPS

RELATED BPA PROJECT	RELATIONSHIP
9005500 Steelhead supplementation studies in Idaho rivers is to describe life history features of wild steelhead populations in Idaho.	The weir that we designed and built under Project 90-052 for Fish Creek, Clearwater River system, is now being used for Project 90-055. The weir and the data that we collected with it during the first two years of this study are proving to be a cornerstone for Project 90-055. Idaho Fish and Game personnel consider 90-052 as the desirable, sister study to 89-098 and 90-055.
8909800 Salmon supplementation studies in Idaho rivers)--Project 89-098 evaluates the success of ongoing supplementation programs for chinook salmon.	Because long-term effects, although potentially very serious, may not be discernable for eight or nine generations (30+ years; after Reisenbichler 1996a&b), project 89-098 will be focussed on the short-term effects for the first several decades. Study 90-052 complements 89-098 by dealing with an additional species (steelhead), by evaluating genetic differences between hatchery and wild fish which allow extrapolation to both the short-term and long-term consequences of supplementation, and by testing for the feasibility of modifying hatchery programs to reduce genetic problems associated with supplementation.
8909600 A genetic monitoring and evaluation program for supplemented populations of salmon and steelhead in the Snake River basin)--Project 89-096 monitors the frequencies of (nearly) selectively neutral alleles (allozymes), in part, to estimate the repr	89-096 (A genetic monitoring and evaluation program for supplemented populations of salmon and steelhead in the Snake River basin)--Project 89-096 monitors the frequencies of (nearly) selectively neutral alleles (allozymes), in part, to estimate the repr

RELATED NON-BPA PROJECT	RELATIONSHIP

Other existing or planned studies, funded by various agencies, are similar to 89-098 -- e.g., Supplementation programs in the Grande Ronde River system.	Study 90-052 complements these studies in the same ways that it complements 89-098 or 90-055. Study 90-052 is the only one among these studies that elucides long-term effects by specifically evaluating genetic differences between hatchery and wild fish, and excludes confounding with behavioral, physiological, or other direct effects of the hatchery programs.
Kalama River studies, funded by NMFS.	Both the Kalama Study and ours (90-052) test for differences in fitness between hatchery and wild steelhead, but the two studies use hatchery fish that have been subjected to domestication selection for different numbers of generations, and from different races of steelhead (coastal, winter-run for the Kalama; inland, summer-run for us). It is necessary to pool data from these two studies and from previous work to develop a believable description for the rate of domestication in steelhead from hatchery rearing. Other differences between the two studies are that our's provides (1) a comparison of hatchery and wild fish both originating in the same river system, (2) a comparison of hatchery and wild spring chinook salmon, and (3) direct tests of domestication selection (i.e., comparisons in the hatchery as well as in streams).

OPPORTUNITIES FOR COOPERATION:

Various forms of cooperation, collaboration, or assistance from the Confederated Tribes of the Warm Springs Reservation, Idaho Department of Fish and Game, Nez Perce Tribe, Oregon Department of Fish and Wildlife, U.S. Fish and Wildlife Service, U.S. Forest Service, and Washington Department of Fish and Wildlife have helped or been integral to the success of this project. Relations with each of these entities are good, and should remain so. Lack of enough returning adults to allow full implementation with a year-class can reduce the costs for that year, and if BPA and NPPC choose, increase the duration of the study.

COSTS AND FTE

1997 Planned: $444,000

FUTURE FUNDING NEEDS:

FY	$ NEED	% PLAN	% IMPLEMENT	% O AND M
1998	$450,000	0%	85%	15%
1999	$450,000	0%	85%	15%
2000	$400,000	0%	80%	20%
2001	$300,000	0%	50%	50%
2002	$300,000	0%	20%	80%

PAST OBLIGATIONS (incl. 1997 if done):

FY	OBLIGATED
1991	$699,417
1992	$24,067
1993	$283,000
1994	$282,292
1995	$300,000
1996	$300,000

TOTAL: $1,888,776

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

FY	OTHER FUNDING SOURCE	AMOUNT	IN-KIND VALUE
1998	BRD	$27,000	0
1999	BRD	$27,000	0
2000	BRD	$27,000	0
2001	BRD	$30,000	0
2002	BRD	$30,000	0

OTHER NON-FINANCIAL SUPPORTERS:
Confederated Tribes of the Warm Springs Reservation; Idaho Department of Fish and Game; Native Fish Society; Nez Perce Tribe; Oregon Department of Fish and Wildlife; Washington Department of Fish and Wildlife; U.S. Fish and Wildlife Service; U.S. Forest Service

LONGER TERM COSTS: N/A--the project ends in 2002.

1997 OVERHEAD PERCENT: 33%

HOW DOES PERCENTAGE APPLY TO DIRECT COSTS:
Total direct project costs

CONTRACTOR FTE: 6

SUBCONTRACTOR FTE: 3

SUPPLEMENTAL ANADROMOUS FISH EVALUATION FACTORS:
This is a study to elucidate basinwide hatchery/natural fish interactions, focused on genetic interactions.