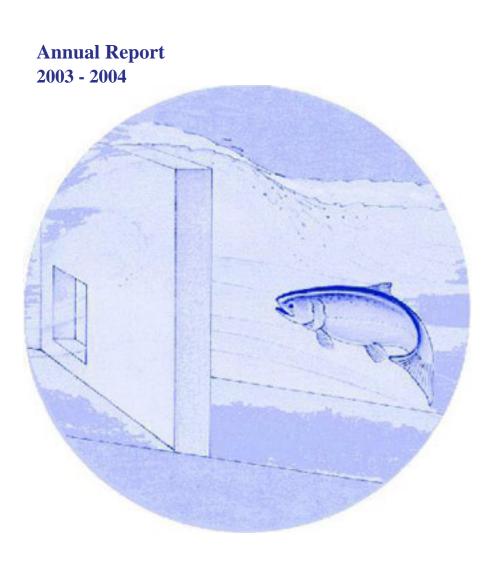# Effects of Domestication on Predation Mortality and Competitive Dominance

Yakima/Klickitat Fisheries Project Monitoring and Evaluation Report 2 of 7

Annual Report
2003 - 2004

This Document should be cited as follows:

Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208

This report covers one of many topics under the Yakima/Klickitat Fisheries Project's Monitoring and Evaluation Program (YKFPME). The YKFPME is funded under two BPA contracts, one for the Yakama Nation and the other for the Washington Department of Fish and Wildlife (Contract number 00013756, Project Number 1995-063-25). A comprehensive summary report for all of the monitoring and evaluation topics will be submitted after all of the topical reports are completed. This approach to reporting enhances the ability of people to get the information they want, enhances timely reporting of results, and provides a condensed synthesis of the whole YKFPME. The current report was completed by the Washington Department of Fish and Wildlife.

The Effects of Domestication on Predation Mortality and Competitive Dominance

Yakima/Klickitat Fisheries Project Monitoring and Evaluation

Annual Report 2003

Prepared by:

Todd N. Pearsons

Anthony L. Fritts

and

Jennifer L. Scott

Washington Department of Fish and Wildlife
600 Capitol Way North
Olympia, Washington 98501-1091

Prepared for:

U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, Oregon 97283-3621

Project Number 1995-063-25
Contract 00013756

May 2004

Executive Summary

Raising fish in hatcheries can cause unintended behavioral, physiological, or morphological changes in chinook salmon due to domestication selection. Domestication selection is defined by Busack and Currens 1995 as "changes in quantity, variety, or combination of alleles within a captive population or between a captive population and its source population in the wild as a result of selection in an artificial environment. Selection in artificial environments could be due to intentional or artificial selection, biased sampling during some stage of culture, or unintentional selection (Busack and Currens 1995). Genetic changes can result in lowered survival in the natural environment (Reisenbichler and Rubin 1999). The goal of supplementation or conservation hatcheries is to produce fish that will integrate into natural populations. Conservation hatcheries attempt to minimize intentional or biased sampling so that the hatchery fish are similar to naturally produced fish. However, the selective pressures in hatcheries are dramatically different than in the wild, which can result in genetic differences between hatchery and wild fish. The selective pressures may be particularly prominent during the freshwater rearing stage where most mortality of wild fish occurs.

The Yakima Fisheries Project is studying the effects of domestication on a variety of adult and juvenile traits of spring chinook salmon (Busack et al. 2003). This report addresses two juvenile traits: predation mortality, and competitive dominance. Other traits will be presented in other project reports. It is anticipated that it will take at least two to five generations to detect measurable responses in many domestication response variables (Busack et al. 2003). This report addresses domestication after one generation of hatchery rearing. Data and findings should be considered preliminary until the results are published in a peer-reviewed journal.

Hatcheries have been used in an attempt to increase the production of Pacific salmonids in the Columbia River system since 1877. While able to achieve better survival from egg to release, it has been noted that hatchery-reared fish do not perform as well as their naturally reared counterparts in the natural environment. We performed an experiment where size-matched fry spawned from first generation hatchery broodstock and from wild broodstock were subjected to rainbow trout (*Oncorhynchus mykiss*) and torrent sculpin (*Cottus rhotheus*) predators in net pens at the Cle Elum Supplementation and Research Facility. Wild origin fish had significantly higher survival (P=0.049) than hatchery origin fish. Prey fish were treated identically, so any differences observed should be due to genetic changes rather than learned behavior. Genetic differences that we detect will be important because in the natural environment these returning wild fish are expected to spawn naturally and produce viable fry. This study will be performed annually for several generations of fish to help monitor the success of supplementation. This data should be considered preliminary until published in a peer-reviewed journal.

Despite our best efforts, raising fish in hatcheries can cause unintended behavioral changes in salmonids due to domestication selection. We tested the null hypothesis that dominance would not be affected by domestication selection after one generation of hatchery culture. Fish that were used in the experiments were offspring of naturally produced spring chinook salmon (wild) and offspring of spring chinook salmon that spent one generation under hatchery culture (hatchery). Both fish had grandparents that were naturally produced in the upper Yakima River.

Fish were mated and reared as part of a common garden experiment. We tested two types of competitive dominance, contest and scramble. Dyadic challenges of size-matched juvenile fish were conducted for one-week trials in 80, 30-gallon aquaria. In the contest trials, we created one highly profitable location in the aquaria. This location provided cover, food, and water velocity. Dominance was assigned to the fish that won two or more of three categories; ate the most pellets within the water column, was in the preferred habitat the most, and initiated the most behavioral contests. In most cases, the fish initiating the most interactions also dominated the most. In the scramble trials, the cover was removed from the tanks and food was introduced in unpredictable locations upon the water surface. Dominance was assigned to the fish that ate the most pellets. There were no significant differences in dominance of hatchery and wild fish in either the contest trials (n=229, Wilcoxon matched pair test, P>0.05) or the scramble trials (n=97, Wilcoxon matched pair test, P>0.05). In addition there were no differences in the frequency of different types of agonistic interactions that were used by hatchery and wild fish, except that wild fish used chasing behaviors more than hatchery fish in contest trials (P<0.05). However, wild fish were generally more aggressive than hatchery fish in both contest and scramble trials (initiated more agonistic interactions). We also found that dominant fish grew more than subordinate fish in both contest and scramble trials. Our results suggest that offspring of first generation hatchery fish that spawn in the Yakima River will have similar dominance rates as wild fish if the timing and size of emergence, and growth rates are similar. These data should be considered preliminary until published in a peer-reviewed journal.

Table of Contents

General Introduction

This report is intended to satisfy two concurrent needs: 1) provide a contract deliverable from the Washington Department of Fish and Wildlife (WDFW) to the Bonneville Power Administration (BPA), with emphasis on identification of salient results of value to ongoing Yakima/Klickitat Fisheries Project (YKFP) planning, and 2) summarize results of research that have broader scientific relevance. This is the first of a series of progress reports that address the effects of hatchery domestication on predation mortality and competitive dominance in the upper Yakima River basin. This progress report summarizes data collected between January 1, 2003 and December 31, 2003.

Raising fish in hatcheries can cause unintended behavioral, physiological, or morphological changes in chinook salmon due to domestication selection. Domestication selection is defined by Busack and Currens 1995 as, "changes in quantity, variety, or combination of alleles within a captive population or between a captive population and its source population in the wild as a result of selection in an artificial environment." Selection in artificial environments could be due to intentional or artificial selection, biased sampling during some stage of culture, or unintentional selection (Busack and Currens 1995). Genetic changes can result in lowered survival in the natural environment (Reisenbichler and Rubin 1999). The goal of supplementation or conservation hatcheries is to produce fish that will integrate into natural populations. Conservation hatcheries attempt to minimize intentional or biased sampling so that the hatchery fish are similar to naturally produced fish. However, the selective pressures in hatcheries are dramatically different than in the wild, which can result in genetic differences between hatchery and wild fish. The selective pressures may be particularly prominent during the freshwater rearing stage where most mortality of wild fish occurs.

The Yakima Fisheries Project is studying the effects of domestication on a variety of adult and juvenile traits of spring chinook salmon (Busack et al. 2003). The overall experimental design is to compare a variety of traits, across generations, from three lines of Yakima basin chinook, a hatchery control, supplementation line, and a wild control. The hatchery line was derived from wild upper Yakima broodstock and is only allowed to spawn in the hatchery. The supplementation line is upper Yakima stock that spawns in the upper Yakima River. This stock is an integration of wild and hatchery supplementation fish. Starting in 2005, we plan to use a wild control line of fish that will be the offspring of wild broodstock collected in the Naches River system, a tributary to the Yakima River. The Naches River is not stocked with hatchery fish, and there is minimal stray from Upper Yakima supplementation, so we believe that these will serve as a control to compare any genotypic changes in the hatchery and the supplementation line. As generations of fish are tested, we believe we will be able to analyze the data using an analysis of covariance to test the hypothesis that the hatchery line will exhibit greater domestication over generations, the wild line will remain at baseline levels, and the supplementation line will be somewhere in between. In this report, we have used the terms "hatchery" or "supplementation" to refer to upper Yakima fish that are progeny of fish that spent one generation in the hatchery, and "wild" to refer to fish that have had no

exposure to the hatchery other than the matings for this experiment. The terms are relative to the parents that produced the fish for these experiments. All progeny of these fish were mated and reared under the same laboratory conditions.

This report addresses two juvenile traits: predation mortality, and competitive dominance. Other traits will be presented in other project reports. It is anticipated that it will take at least two to five generations to detect measurable responses in many domestication response variables (Busack et al. 2003). This report addresses domestication after one generation of hatchery rearing.

This report is organized into two chapters that represent major topics associated with monitoring hatchery domestication. Chapter 1 reports the results of domestication on predation mortality of juvenile spring chinook salmon. Chapter 2 describes the affects of domestication on competitive dominance of juvenile spring chinook salmon. The chapters in this report are in various stages of development and should be considered preliminary unless they have been published in a peer-reviewed journal. Additional field work and/or analysis is in progress for topics covered in this report. Throughout this report, a premium was placed on presenting data in tables so that other interested parties could have access to the data. Readers are cautioned that any preliminary conclusions are subject to future revision as more data and analytical results become available. Data and findings should be considered preliminary until the results are published in a peer-reviewed journal.

Acknowledgments

References

Busack, C., B. Watson, T. Pearsons, C. Knudsen, S. Phelps, and M. Johnston. 1997. Yakima Fisheries Project Spring Chinook Supplementation Monitoring Plan. Bonneville Power Administration, Portland, Oregon. DOE/BP-64878-1.

Busack, C. S., S. F. Young, A. L. Fritts, J. Loxterman, J. B. Shaklee, S. L. Schroder, C. M. Knudsen, and J. A. Rau. 2003. Genetic Studies in the Yakima River Basin. Annual Report FY 2001-2002 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-00004666-13.

Busack, C. A., and K. P. Currens. 1995. Genetic risks and hazards in hatchery operations: fundamental concepts and issues. American Fisheries Society Symposium 15:71-80.

Reisenbichler, R. R., and S. P. Rubin. 1999. Genetic changes from artificial propagation of Pacific salmon affect the productivity and viability of supplemented populations. ICES Journal of Marine Science 56:459-466.

Chapter 1

The Effects of Domestication on the Relative Vulnerability of Hatchery and Wild Spring Chinook Salmon to Predation

Anthony L. Fritts

Jennifer L. Scott

and

Todd N. Pearsons

Abstract

Hatcheries have been used in an attempt to increase the production of Pacific salmonids in the Columbia River system since 1877. While able to achieve better survival from egg to release, it has been noted that hatchery-reared fish do not perform as well as their naturally reared counterparts in the natural environment. We performed an experiment where size-matched fry spawned from first generation hatchery broodstock and from wild broodstock were subjected to rainbow trout (*Oncorhynchus mykiss*) and torrent sculpin (*Cottus rhotheus*) predators in net pens at the Cle Elum Supplementation and Research Facility. Wild origin fish had significantly higher survival (P=0.049) than hatchery origin fish. Prey fish were treated identically, so any differences observed should be due to genetic changes rather than learned behavior. Genetic differences that we detect will be important because in the natural environment these returning wild fish are expected to spawn naturally and produce viable fry. This study will be performed annually for several generations of fish to help monitor the success of supplementation. This data should be considered preliminary until published in a peer-reviewed journal.

Introduction

Hatcheries have been used in an attempt to increase the production of Pacific salmonids in the Columbia River System since 1877 (Lichatowich 1999). These early hatcheries were not built to increase natural production but to increase commercial catch. More recently, hatcheries have been seen as a way to bolster natural production by increasing survival to smolthood, though it has been noted that hatchery-reared fish do not perform as well as their naturally reared counterparts in the natural environment (Nickelson et al. 1986; Swain and Riddell 1990). Researchers have theorized that the hatchery environment selects for certain behavioral and morphological traits that are not selected for or are repressed in the natural environment (Weber and Fausch 2003; Reisenbichler and Rubin 1999). Many of these differences acquired by hatchery-reared fish are commonly attributed to domestication, which is defined by Busack et al. (2002) as "genetic change in response to the differences between natural and anthropogenic environments".

Research has shown that hatchery fish are not as successful at avoiding predators as their wild counterparts. Alvarez and Nicieza (2003) found that second generation hatchery brown trout (*Salmo trutta*) exhibited less responsiveness to a predator than the offspring of wild brown trout reared in a hatchery and that wild caught brown trout had a higher response level than hatchery-reared wild brown trout. In addition, Yamamoto and Reinhardt (2003) found that farmed masu salmon (*Oncorhynchus masou*) fry, from a population that had been hatchery-reared for a least 30 years, were much more willing to

leave cover and feed under chemically simulated predation risk than were wild-caught masu salmon.

Some studies have found evidence that these differences between hatchery and wild fish may be genetic due to differing selection pressures in the hatchery and natural environments. Berejikian (1995) found that hatchery steelhead (*Oncorhynchus mykiss*) were more vulnerable to predation by sculpins than wild steelhead reared in a hatchery and that domesticated hatchery steelhead that were previously exposed to predators were still more vulnerable to predation than wild naive fry. Johnsson and Abrahams (1991) found that wild laboratory reared juvenile steelhead were less willing to risk exposure to a predator than were juvenile offspring of wild steelhead and domesticated rainbow trout (*Oncorhynchus mykiss*) even though there was no difference in susceptibility to predation.

The mechanisms for a decrease in survival could be physical, behavioral or both. If, for instance, the returning adult hatchery-reared fish began to produce smaller eggs (Heath et al. 2003), then their offspring would be smaller and less able to dart away from a predator (Taylor and McPhail 1985) or have a size refuge from predation (Patten 1977). If fry begin to express less innate antipredator behaviors because of relaxation of selection pressures in the hatchery environment or an increase of selection pressures that are not beneficial in the natural environment, then they will be more likely to be singled out by predators in the natural environment or more likely to take higher risks to obtain food in the presence of a predator (Johnsson and Abrahams 1991).

There is relatively little research on domestication of Chinook salmon (*Oncorhynchus tshawytscha*). To date, other research on domestication has dealt with the more traditional hatcheries that, for the most part, use hatchery fish for broodstock. The Cle Elum Supplementation and Research Facility (CESRF) is an intentionally integrated hatchery program where returning hatchery and naturally produced fish are allowed to spawn together in the natural environment. This integrated concept is designed to limit the consequences of domestication by allowing returning hatchery-reared fish to undergo natural selection to the greatest extent feasible.

This chapter will report on the first year of the predator avoidance portion of our domestication studies.

Methods

Our fry were hatched in isolettes that were used for experimental crosses to gather data on other aspects of the domestication work (see Knudsen et al. 2003 for more detail on isolettes and crosses). We selected approximately 12,000 fry of each origin, hatchery by hatchery (hatchery) and wild by wild (wild), which was approximately half of the total fish contained in the isolettes. We opted to select isolettes in a way that ensured that nearly all adult broodstock used for the experimental isolette crosses were represented in our sample at least once (33 wild females, 25 wild males, 32 hatchery females and 15 hatchery males; 58 wild families and 59 hatchery families). All surviving fish in each isolette that was selected were used, even if there were very few. This ensured that our sample of experimental fish represented the true reproductive effort expressed by each

6

parental cross. These fish were transferred into two 1,710-liter polyethylene conical-bottomed circular tanks on April 17, 2003.

All work was conducted in a 3 meter (m) by 30 m concrete raceway at the CESRF. Eight 1/8-inch nylon mesh net pens measuring 3 m long by 2.4 m wide by 1.5 m high were placed in the raceway to contain each group of trials. Net pens were totally enclosed with a zippered top. Each net pen included one 0.8 m and one 1.3 m diameter floating hoop covered with black plastic to provide overhead cover and a 1.2 m tall plastic evergreen tree to provide instream cover.

Predators were collected from area streams by backpack electrofishing. Each net pen received three rainbow trout and three torrent sculpin (*Cottus rhotheus*). These predators remained in the net pens for the duration of the experiment.

Trials were conducted on the weeks of May 19, May 26, June 9, and June 16, 2003. Each weekly trial started on Monday with the introduction of 100 hatchery and 100 wild size-matched fry. Before introduction into the net pens, all fry were anesthetized in a solution of Tricaine Methanesulfonate, measured to the nearest millimeter fork length (mm FL), and given either an upper caudal (UC) mark or lower caudal (LC) mark by incising a small amount of fin tissue from the tip of the fin. These marks were alternated between net pens and origins to eliminate any possible introduced biases between clip types. All data was entered directly onto a microcomputer and after all fry were measured and marked, students t-tests were used to make sure that there was no significant difference between the sizes of the two stocks in each net pen. If there was no significant difference found, then the fry were allowed to recover before being introduced into the net pens. Each weekly trial was terminated on Friday and all surviving prey were removed, enumerated, measured to the nearest mm FL, interrogated for marks and any bite marks that would indicate escape from a predator.

Each net pen was fed lightly Tuesday thru Thursday to ensure that weakening due to hunger did not influence survival. Feeding also introduces a situation where the fry must choose whether to increase their exposure to predation in order to feed.

The raceway and net pens were cleaned between each trial by lowering the water level, sweeping out silty debris, and rinsing off the net pens.

We used ANOVA to test whether the sizes of the predators we used were similar between net pens. We used the G-test, a goodness of fit procedure, to test that the sizes of our fish had the same distribution at stocking and to test for any size differences between the survivors. We also used the G-test to test whether there were differences in the size distributions between stocking and removal. We used the Wilcoxon matched pairs test to test whether there was differences in the number of fry consumed between the two stock origins.

During the week of June 23 we stocked each net pen with 100 naïve fry and 100 experienced fry, which were the survivors from previous trials. There were four net pens with 200 hatchery fish and four net pens with 200 wild fish. We did these trials in an attempt to evaluate if there was any difference in the ability of the two crosses to learn to avoid predators relative to each other. Each net pen was treated as a replicate so that we had four replicates for each origin to perform the Wilcoxon matched pairs test with the null hypothesis that there was no difference between survival of naïve and experienced fish within each net pen.

Results

The sizes of all predators in all net pens were similar (Table 1). The sizes of predators in each net pen did not vary significantly (ANOVA; $F = 0.085$, $N = 48$, $P = 0.999$).

Table 1. Lengths of rainbow trout (RBT) and torrent sculpin (TSC) in each net pen at the time of stocking. Lengths are mm FL for rainbow trout and mm total length (TL) for torrent sculpin. Mean lengths of RBT and TSC are given for each net pen.

	RBT	RBT	RBT	Mean	TSC	TSC	TSC	Mean
Net pen 1	238	205	212	218.3	130	110	112	117.3
Net pen 2	198	230	194	207.3	96	103	139	112.7
Net pen 3	236	191	184	203.7	102	100	125	109.0
Net pen 4	188	205	206	199.7	105	103	111	106.3
Net pen 5	225	190	192	202.3	140	95	106	113.7
Net pen 6	200	229	190	206.3	100	92	107	99.7
Net pen 7	182	218	180	193.3	143	105	114	120.7
Net pen 8	252	225	178	218.3	140	122	106	122.7

We found no significant difference between the means (t-test, $P>0.05$) or size distributions (G-test, $P>0.05$) between the hatchery and wild fry that were introduced into the net pens. We also found no significant difference in the size distributions between the hatchery and wild fry that survived predation (G-test, $P>0.05$). There was also no significant difference in the size distributions between stocking and removal (G-test, $P>0.05$). The means of the two origins of fish at introduction never varied by more than 0.4 mm within a net pen (Table 2).

Table 2. Mean fork lengths of the hatchery (H) and wild (W) fry upon stocking and removal in each net pen.

		May 19		May 26		June 9		June 16	
		H	W	H	W	H	W	H	W
Net pen 1	In			42.7	42.9	45.0	45.0	45.7	45.9
	Out			42.8	43.2	46.0	46.3	47.4	46.8
Net pen 2	In			42.3	42.6	45.3	44.9	46.1	45.9
	Out			42.4	42.8	45.6	44.7	47.4	47.1
Net pen 3	In	41.3	41.4	42.4	42.3	45.4	45.4	47.0	46.8
	Out	41.9	41.3	43.2	41.9	48.2	48.6	46.6	46.3
Net pen 4	In	40.7	40.8	42.9	42.9	45.2	45.1	45.9	45.9
	Out	40.9	42.2	43.1	43.1	45.5	45.3	47.3	47.0
Net pen 5	In	40.7	41.1	42.7	43.0	44.9	44.7	46.7	46.5
	Out	40.9	41.8	43.0	42.4	44.7	44.8	48.2	48.0
Net pen 6	In	41.5	41.2	42.4	42.2	45.0	45.0	46.3	46.3
	Out	41.9	41.2	42.7	42.6	45.2	45.2	46.8	46.3
Net pen 7	In			43.3	43.7	45.5	45.3	46.5	46.5
	Out			43.2	43.9	46.1	46.1	46.8	47.6
Net pen 8	In			42.2	42.3	45.1	45.1	46.8	46.6
	Out			43.3	42.7	46.0	46.1	47.4	47.1

For all trials combined, hatchery fish survival averaged 57.0%, or 57 out of 100 introduced fish, and wild survival averaged 60.1%. Hatchery fish survived better in ten of the 28 trials, wild fish had higher survival in 16 of the 28 trials, and survival was equal in two of the trials (Table 3).

Table 3. Numbers of hatchery (H) and wild (W) fry surviving predator net pen trials at the end of each week.

	May 19		May 26		June 9		June 16	
	H	W	H	W	H	W	H	W
Net pen 1			30	38	50	49	47	54
Net pen 2			36	44	56	68	56	59
Net pen 3	41	43	42	58	50	42	59	51
Net pen 4	48	45	62	59	64	70	65	68
Net pen 5	37	53	31	49	22	26	51	49
Net pen 6	79	79	84	82	82	89	80	78
Net pen 7			66	67	79	74	71	66
Net pen 8			72	82	75	75	61	69

We found no significant difference in survival between the two crosses in each net pen (Table 4). Because one of the trials ended in equal survival in net pen eight leaving only two samples to test, we were unable to use the Wilcoxon test. Employing a paired two-sample t-test, we found no significant difference in net pen eight (T = 1.96, N = 3, P = 0.188). We used the mean survival of each cross in each net pen to run a Wilcoxon test for the overall survival, which was significant (Z = 1.96, N = 8, P = 0.049).

Table 4. Results of Wilcoxon matched pairs test for each net pen.

Net pen number	Test result
Net pen 1	Z = 1.07, N = 3, P = 0.285
Net pen 2	Z = 1.60, N = 3, P = 0.109
Net pen 3	Z = 0.00, N = 4, P = 1.000
Net pen 4	Z = 0.37, N = 4, P = 0.715
Net pen 5	Z = 1.10, N = 4, P = 0.273
Net pen 6	Z = 0.00, N = 4, P = 1.000
Net pen 7	Z = 1.07, N = 3, P = 0.285
Net pen 8	NA due to ties

Experienced hatchery fry survived better in all trials while experienced wild fry survived better in only two of the four trials (Table 5). Mean survivals were similar for wild fry while hatchery experienced fry had higher survival relative to naïve hatchery fry (Table 6). Analysis using the Wilcoxon matched pairs test indicated that experienced hatchery fry survived at a higher rate (Z = 1.83, N = 4, P = 0.07), but not significantly higher. Survival of experienced wild fry was no different than their naïve counterparts (Z = 0.00, N = 4, P = 1.00).

Table 5. Numbers of fry surviving in each net pen and the difference in survival (experienced minus naïve) during the week of June 23, 2003.

	Naïve	Experienced	Survival difference (exp. – naïve)
Wild	65	55	-10
Wild	76	34	-42
Wild	40	60	20
Wild	48	71	23
Hatchery	45	78	33
Hatchery	66	79	13
Hatchery	54	80	26
Hatchery	39	64	25

Table 6. Mean survival for naïve and experienced fry during the week of June 23, 2003.

	Naïve	Experienced
Wild	57.25	55.00
Hatchery	51.00	75.25

Discussion

Our test for the overall difference in survival indicates that these first generation hatchery fish exhibited a decrease in survival relative to the wild fish as a result of domestication (P = 0.049). This test was performed on a small sample (N = 8). Additional years of this study are needed to conclude whether or not there is a real difference in susceptibility to predation.

Because we used prey fish that were treated identically, any differences we observe should be due to genetic differences and not learned behavior. This means that any differences that we find may be important in the natural environment because these returning hatchery-reared offspring of wild fish are expected to spawn and produce viable fry.

If we begin to see differences in survival it will be important to know what mechanisms are bringing about the difference. The fish may exhibit different behaviors that make them more or less attractive or available to predators (Johnsson and Abrahams 1991; Healey and Reinhardt 1995) or some fish may not be as physically capable to escape a predator attempting to capture them. We intended to do some observations in large observation tanks to look for any behavioral differences between the two lines of fish when exposed to a predator but were unable to get the tanks completed in time. We plan to do these observations in 2004.

Even though domesticated hatchery fish may exhibit lower survival in the natural environment due to predation, some could argue that other genetic changes such as earlier emergence and faster growth could make up for their increased vulnerability to predation by giving them a size advantage over wild fish. Our size data would counter that assertion because we found no significant differences between the size distributions of prey at the beginning and end of each trial, indicating that there was no size related survival advantage; although if we had used a wider range of sizes in each trial, we may have been able to detect a difference in size related mortality.

We were unable to perform statistical tests on all the trials independently because we used the same predators throughout the trials, which would be pseudo-replication (Hurlbert 1984). Predators in a certain net pen could key in on some difference in the fry causing there to be similar results for all trials in that net pen. We had to test the means of the replicates of each net pen against each other to avoid pseudo-replication. For 2004, we plan on using new predators as often as possible to increase our replication.

The naïve versus experienced trials yielded some results that were counter to what we thought we would have seen. We thought that we would find higher survivals of experienced fish in both hatchery and wild populations or only slight differences. The two net pens that had a higher survival of wild naïve fry (Table 5) could be anomalous and a larger sample size is needed to be certain of what is happening. Even if we believe that experienced hatchery fish are indeed surviving better than their naïve counterparts, the processes for the higher survival are hard to decipher. There is no way of knowing if the higher survival is due to learning to avoid predators or if these survivors were more physically capable of avoiding predators in the first place, therefore surviving their first trial while the less fit individuals were cropped out of the population. If we are able to perform behavioral observations in 2004, we hope to learn what role behavior may be playing in their survival.

During 2004, we plan to perform mixed trials where experienced hatchery and naïve wild fish are stocked together. This should allow us to ascertain if surviving hatchery fish from previous trials are able to overcome any behavioral or physical deficits and outperform inexperienced wild fish. We would then be able to track this performance over generations to see if the hatchery fish are able to continue to perform better after an initial culling from predators.

In 2004, we will stop the predator trials before more than 50% are eaten because we believe that once the most vulnerable fry are eaten, predators will concentrate on the less vulnerable prey. This would result in the equalization of relative predation vulnerability and a dependency situation. We are therefore proposing to cut back our predators to two rainbow trout and two sculpins per net pen to ensure that we do not have more than 50% of prey consumed in each trial. For the 28 trials, the mean consumption was 41% (range, 18-61%) of all fish per pen. If we assumed that all predators in a net pen were eating an equal number of fry, then the reduction of one predator per species should still give us an average consumption of 27% (range, 12-41%). We believe that this would still allow us to get meaningful results while making it much easier to get enough predators each week.

Acknowledgements

References

Alvarez, D., and A. G. Nicieza. 2003. Predator avoidance in wild and hatchery-reared brown trout: the role of experience and domestication. Journal of Fish Biology 63:1565-1577.

Berejikian, B. A. 1995. The effects of hatchery and wild ancestry and experience on the relative ability of steelhead trout fry (*Oncorhynchus mykiss*) to avoid a benthic predator. Canadian Journal of Fisheries and Aquatic Sciences 52:2476-2482.

Busack, C. A., S. L. Schroder, and C. M. Knudsen. 2002. Domestication research/monitoring design. Pages 10-44 *in* Busack, C., S. L. Schroder, J. B. Shaklee, S. F. Young, and C. M. Knudsen, and J. Rau. Yakima/Klickitat Fisheries Project Genetic Studies. Bonneville Power Administration Annual Report, 2000-2001, Portland, Oregon.

Healey, M. C., and U. Reinhardt. 1995. Predator avoidance in naïve and experienced juvenile chinook salmon and coho salmon. Canadian Journal of Fisheries and Aquatic Sciences 52:614-622.

Heath, D. D., J. W. Heath, C. A. Bryden, R. M. Johnson, and C. W. Fox. 2003. Rapid evolution of egg size in captive salmon. Science 299:1738-1740.

Hurlbert, S. H. 1984. Psuedoreplication and the design of ecological field experiments. Ecological Monographs 54:187-211.

Johnsson, J. I., and M. V. Abrahams. 1991. Interbreeding with domestic strain increases foraging under threat of predation in juvenile steelhead trout (*Oncorhynchus mykiss*): an experimental study. Canadian Journal of Fisheries and Aquatic Sciences 48:243-247.

Knudsen, C. M., S. L. Schroder, T. N. Pearsons, J. A. Rau, A. L. Fritts, and C. R. Strom. 2003. Monitoring phenotypic and demographic traits of upper Yakima River hatchery and wild spring chinook: gametic and juvenile traits. Pages 38-62 *in* C. Knudsen. Reproductive ecology of Yakima River hatchery and wild spring chinook. Bonneville Power Administration, Annual Report 2001-2002, Portland, Oregon.

Lichatowich, J. A. 1999. Salmon without rivers. Island Press, Washington, DC.

Nickelson, T. E., M. F. Solazzi, and S. L. Johnson. 1986. Use of hatchery coho salmon (*Oncorhynchus kisutch*) presmolts to rebuild wild populations in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 43:2443-2449.

Patten, B. G. 1977. Body size and learned avoidance as factors affecting predation on coho salmon (*Oncorhynchus kisutch*) fry by torrent sculpin (*Cottus rhotheus*). Fishery Bulletin 75:457-459.

Reisenbichler, R. R., and S. P. Rubin. 1999. Genetic changes from artificial propagation of Pacific salmon affect the productivity and viability of supplemented populations. ICES Journal of Marine Science 56:459-466.

Swain, D. P., and B. E. Riddell. 1990. Variation in agonistic behavior between newly emerged juveniles from hatchery and wild populations of coho salmon, *Oncorhynchus kisutch*. Canadian Journal of Fisheries and Aquatic Sciences 47:566-571.

Taylor, E. B., and J. D. McPhail. 1985. Burst swimming and size-related predation of newly emerged coho salmon *Oncorhynchus kisutch*. Transactions of the American Fisheries Society 114:546-551.

Weber, E. D., and K. D. Fausch. 2003. Interactions between hatchery and wild salmonids in streams: differences in biology and evidence for competition. Canadian Journal of Fisheries and Aquatic Sciences 60:1018-1036.

Yamamoto, T., and U. G. Reinhardt. 2003. Dominance and predator avoidance in domesticated and wild masu salmon *Oncorhynchus masou*. Fisheries Science 69:88-94.

Chapter 2

The Effects of Domestication on Competitive Dominance of Juvenile Spring Chinook Salmon

Todd N. Pearsons

Anthony L. Fritts

and

Jennifer L. Scott

Abstract

Despite our best efforts, raising fish in hatcheries can cause unintended behavioral changes in salmonids due to domestication selection. We tested the null hypothesis that dominance would not be affected by domestication selection after one generation of hatchery culture. Fish that were used in the experiments were offspring of naturally produced spring chinook salmon (wild) and offspring of spring chinook salmon that spent one generation under hatchery culture (hatchery). Both fish had grandparents that were naturally produced in the upper Yakima River. Fish were mated and reared as part of a common garden experiment. We tested two types of competitive dominance, contest and scramble. Dyadic challenges of size-matched juvenile fish were conducted for one-week trials in 80, 30-gallon aquaria. In the contest trials, we created one highly profitable location in the aquaria. This location provided cover, food, and water velocity. Dominance was assigned to the fish that ate the most pellets within the water column, was in the preferred habitat the most, and initiated and dominated the most behavioral contests. In the scramble trials, the cover was removed from the tanks and food was introduced in unpredictable locations upon the water surface. Dominance was assigned to the fish that ate the most pellets. There were no significant differences in dominance of hatchery and wild fish in either the contest trials (n=229, Wilcoxon matched pair test, P>0.05) or the scramble trials (n=97, Wilcoxon matched pair test, P>0.05). In addition there were no differences in the frequency of different types of agonistic interactions that were used by hatchery and wild fish, except that wild fish used chasing behaviors more than hatchery fish in contest trials (P<0.05). However, wild fish were generally more aggressive than hatchery fish in both contest and scramble trials (initiated more agonistic interactions). We also found that dominant fish grew more than subordinate fish in both contest and scramble trials. Our results suggest that offspring of first generation hatchery fish that spawn in the Yakima River will have similar dominance rates as wild fish if the timing and size of emergence, and growth rates are similar. These data should be considered preliminary until published in a peer-reviewed journal.

Introduction

Despite our best efforts, raising fish in hatcheries can cause unintended behavioral changes in salmonids due to domestication selection. Domestication selection is defined by Busack and Currens 1995 as "changes in quantity, variety, or combination of alleles within a captive population or between a captive population and its source population in the wild as a result of selection in an artificial environment. Selection in artificial environments could be due to intentional or artificial selection, biased sampling during some stage of culture, or unintentional selection (Busack and Currens 1995). The goal of supplementation or conservation hatcheries is to produce fish that will integrate into natural populations. Conservation hatcheries attempt to minimize intentional or biased sampling so that the hatchery fish are similar to naturally produced fish. However, the selective pressures in hatcheries are dramatically different than in the wild, which can result in genetic differences between hatchery and wild fish. The selective pressures may be particularly prominent during the freshwater rearing stage where most mortality of wild fish occurs.

During freshwater rearing, salmonids in hatcheries and rivers use very different methods to acquire food. River environments are very heterogenous (e.g., patchy) with respect to food and habitat quality. Salmonids rearing in streams primarily feed on drifting invertebrates as they maintain energetically profitable stream locations (Fausch 1984). Dominant fish secure the most food and grow the fastest (Metcalfe 1986). These fish use a variety of agonistic interactions, such as nips, butts, chases, and threats to defend territories that have predictably high levels of food (Chapman 1962; Grant and Kramer 1990; McMichael et al. 1999). This type of interference interaction is referred to as contest competition. In contrast, salmonids in hatchery raceways live in homogenous environments where positions are equally viable. Fish in hatcheries frequently use shoaling or schooling behaviors and acquire food from the water surface. Thus, agonistic interactions prior to food interactions is wasted energy but with little immediate consequences in hatchery environments where food is plentiful. Fish that are in the right place at the right time and that swim rapidly towards the food are the most successful. This type of interaction is referred to as scramble competition.

Domestication selection has been shown to alter the aggressiveness and dominance of hatchery fish. Domestication has been implicated as increasing and decreasing aggressive and schooling behavior in fish (Ruzzante 1994). Berejikian et al. (1996) found that offspring of wild steelhead trout were more aggressive and dominant (87.5%) than size matched offspring of parents that had been in hatchery culture for 4 to 7 generations. However, when hatchery fry had a 3.0-4.5% size advantage, they dominated wild fish in 68% of encounters. Swain and Riddell (1990) found that domesticated coho were more aggressive than those of natural origin from nearby streams. Hatchery reared chinook salmon dominated smaller wild chinook salmon and altered wild fish behavior (Peery and Bjornn 1996). Farrell (2003) found that wild spring chinook salmon from the Yakima Basin were competitively dominant to descendents of first generation local origin hatchery fish in contest competition trials.

Dominance among salmonids has been demonstrated to be most consistently associated with fish size (Abbott et al. 1995, Berejikian et al. 1996, McMichael et al. 1999), but prior residence, prior winning experience, genetics, aggressiveness, and hatchery rearing also influence dominance (Huntingford et al. 1990, Berejikian et al. 1996, Rhodes and Quinn 1998). Differences in aggression are related to metabolic rate (Metcalfe et al. 1995), genetics (Taylor and Larkin 1986; Rosenau and McPhail 1987), and rearing experience (Berejikian et al. 1996; Rhodes and Quinn 1998).

The goals of this study were to determine if there are differences in dominance between offspring of wild and first generation hatchery upper Yakima basin spring chinook salmon under 1) contest and 2) scramble competition, and 3) determine if differences in dominance are related to differences in aggression. If domestication does not occur, we would expect offspring of hatchery and wild fish to have equivalent levels of aggression and dominance. If domestication does occur, we would expect offspring of hatchery fish to be the dominant in scramble competition, and offspring of wild fish to be dominant in contest competition. Alternatively, the more aggressive fish may be the most dominant in both types of competition. In addition, we would expect that these differences would be accentuated with time.

Methods

Fish used in this experiment were either juvenile offspring of wild spring chinook salmon (wild) or offspring of fish that spent one generation in the hatchery (hatchery). The fish that spent one generation in the hatchery were offspring of wild spring chinook salmon that were collected at Roza Dam as part of the Yakima Fisheries Project Supplementation Program. The only difference between the two types of fish was that one type spent one generation in the hatchery.

The fish that spent one generation in the hatchery were treated using state-of-the-art fish culture practices. Hatchery and wild fish are collected in proportion to their abundance and timing at Roza Dam. Adult fish that were taken to the hatchery were spawned, eggs incubated, and juveniles reared in one of two types of raceways under similar densities (e.g., approximately 40,000 fish/raceway). The two types of rearing environments differed in their degree of "naturalness". The "optimal conventional treatment" (OCT) is a combination of the conventional factors that have been demonstrated to produce good results from other hatcheries. This includes low rearing density, optimal flow conditions, and desirable food distributions. The second of the two treatments, "semi-natural treatment" (SNT), uses the same strategies as the OCT but adds some factors that are present in natural streams. These factors include overhead cover (floating mats), instream cover (christmas trees), natural coloration (painted raceways), and underwater feeding.

Fish that were used for this experiment were collected at Roza Dam, held in ponds, spawned, incubated, and reared at the Cle Elum Supplementation and Research Facility. Hatchery and wild fish were collected in proportion to the run throughout the season at Roza Dam. Naturally produced fish were spawned with naturally produced fish to produce "wild" fish, and hatchery fish were spawned with hatchery fish to produce

"hatchery" fish. A factorial mating scheme was used to spawn both groups of fish. After spawning, fertilized eggs were disinfected and placed into isolettes within incubation trays. Dead eggs and monstrosities were removed. The fish used for experimentation were taken from isolettes that were used for experimental crosses to gather data on other aspects of the domestication work (see Knudsen et al. 2003 for more detail on isolettes and crosses). We selected approximately 12,000 fish of each origin, hatchery by hatchery (H x H) and wild by wild (W x W), which was approximately half of the total fish contained in the isolettes. We opted to select isolettes in a way that ensured that nearly all adult broodstock used for the experimental isolette crosses were represented in our sample at least once (33 wild females, 25 wild males, 32 hatchery females and 15 hatchery males; 58 wild families and 59 hatchery families). All surviving fish in each isolette that was selected were used, even if there were very few. This ensured that our sample of experimental fish represented the true reproductive effort expressed by each cross. These fish were transferred into two 450-gallon polyethylene conical-bottomed circular tanks on April 17, 2003 and fed starter feed until large enough to feed on Bio-moist pellets.

Experiments were conducted in 80, 30 gallon glass aquaria (91.4 cm (36") long, 30.5 cm (12") wide, 40.6 cm (16") deep inside dimensions) at the Cle Elum Hatchery. Two types of dominance experiments were conducted. The first experiment was designed to assess dominance under contest competition and the second experiment was designed to assess dominance under scramble competition. In both experiments, fish length (mm FL) and weight (g) were recorded, size matched to within 1 mm, and the adipose fin was either completely incised or slit so that the fin remained intact. This allowed us to identify the origin of each fish during observations and the slit fin was intended to put the "unmarked" fish under similar handling procedures as the marked fish. Marks were alternated between aquaria and origin to eliminate any behavioral difference due to marking stress. Fish were allowed to recover from anesthetization and then stocked into aquaria. Both fish were introduced at the same time to prevent any prior residence advantage. Observations were done on the seventh day in the test arena. Fish were fed a total of 10 pellets during each acclimation day, except for the sixth day when fish were not fed. Fish were fed through a feeding tube in contest experiments and from the surface in scramble experiments.

Contest competition

The arenas were configured to provide one highly preferred location that is close to an underwater food source, provides cover, and has desirable water velocities. A blind was constructed out of camouflage netting to prevent fish from seeing the observer. One hatchery and one wild spring chinook salmon was placed in each chamber. One of the fish was marked with a small adipose fin clip and the other with a slit adipose fin to identify its origin. These marks were alternated among trials and origins. Fish were acclimated for six days in each of the arenas. This time length was determined by comparing behavioral responses and dominance from pairs of fish that were held for different lengths of time during previous experiments (Pearsons et al. 2001). After six days the behavioral responses and dominance did not generally change. After

acclimation, food acquisition, agonistic interactions, and habitat location was measured on day seven.

Food pellets ground into a slurry were introduced through a tube with running water to alert fish that food was available. Once both fish had keyed into the food source, then one food pellet was added at approximately one-minute intervals. The number of food items acquired by each fish was recorded. Agonistic interactions were recorded throughout the duration of the trial. We recorded which fish initiated an interaction and whether they dominated. Dominance was assigned to the fish that defended a position or removed another fish from a preferred position. Type of interaction was recorded as: nip (contact with mouth open), butt (contact with mouth closed), chase (no contact, swimming after another fish at least 1 body length), threat (no contact; for example fin flares, opercle flares, swimming side by side), crowd (no clear threat but physical presence moved the other fish away)

The location of each fish was recorded once every minute. The location was expressed as which fish, if any, was in the most desirable spot. The most desirable spot was defined as the fish that was closest to the source of food, flow, and cover. This was generally in the middle of the tank, from 1-10 inches off the bottom, and from the end of the pipe to 12 inches in front of the pipe. If both fish were in this zone, then the fish closest to the pipe was assessed to be dominant. Total observation time for each arena was approximately 20-25 (not including slurry time) minutes up to a total of 20 pellets were consumed. Dominance was attributed to the fish that won at least two of three categories; acquired the most food, initiated the most behavioral contests, and occupied the preferred location the most. If fish did not consume at least 10 pellets or if fish did not interact with each other, then they were not included in the analysis. Relative coloration was also recorded. This was expressed as which fish was darker than the other (darker parr marks and body coloration). Fish size, growth, and rearing history were examined to determine how they influence dominance.

Scramble competition

Methods for scramble competition were the same as those for contest competition except for the following differences. The configuration of arenas was the same except that the cover was removed. In addition, food was introduced onto the surface of the water. Food was tossed into one of five locations every minute. The locations were the four corners and the center of the aquaria. These locations were rotated such that no position in the tank was superior to another. Dominance was assessed to the fish that ate the most pellets.

Analysis

Paired comparisons of dominance and agonism were made for each replicate using either a two-tailed Wilcoxon matched pair or paired sign test. A statistically significant test indicates that dominance was caused by hatchery rearing. Paired comparisons of growth and interaction rate were compared using a two tailed paired t-

20

test. Differences were considered significant if P values were less than 0.05. Statistical tests were performed using the software program Statistica.

Results

Contest competition

Overall dominance was not significantly different between hatchery and wild fish, but wild fish initiated and dominated more agonistic interactions than hatchery fish (Table 1). Food acquisition and habitat occupation were not significantly different between hatchery and wild fish in contest competition trials (Table 1). Dominance was assessed in 229 out of 256 trials. Twenty-seven trials had to be eliminated because one of the fish escaped, died, or they did not meet the criteria for an acceptable trial. The fish were the same length in all but 15 of the trials, and of the 15 trials they were 1 mm different. Four of the five types of interactions and interaction rate that hatchery and wild fish initiated were also not significantly different (Tables 2). However, wild fish used chases more often than hatchery fish (Table 2). There was no difference in the growth of hatchery and wild fish, but dominant fish grew more than subordinate fish (Table 3). The darker colored fish were significantly more dominant than lighter fish, regardless of origin (Table 4).

Table 1. Food acquisition, habitat occupation, agonism initiation, agonism dominance and overall dominance in 229 contest competition trials. P values are from two tailed matched Wilcoxon tests. The test for total dominance was a matched comparison of the sums of percentages.

Origin	% Food	% Habitat	% Initiations	% Dominated Interactions	% Total Dominance
Wild	54%	54%	55%	56%	54%
Hatchery	46%	46%	45%	44%	46%
P	0.103	0.249	0.036	0.049	0.081

Table 2. Frequencies of interaction types initiated by hatchery and wild fish in 229 contest competition trials. Number of total interactions and interaction rate (average interactions per minute for all tanks) are also presented. P-values for interaction types are from two-tailed paired Wilcoxon tests and for interaction rate a paired t-test.

Origin	Crowd	Threat	Chase	Butt	Nip	Total Interactions	Interaction Rate (+/- SD)
Wild	5%	48%	22%	13%	12%	3275	0.63 (0.62)
Hatchery	5%	51%	18%	14%	11%	2910	0.57 (0.66)
P	0.896	0.377	0.028	0.556	0.772		0.380

Table 3. Growth and frequency of dominance of fastest growing wild and hatchery fish in 227 contest competition trials (2 fish did not have lengths and weights upon removal). % dominance is the percentage of trials that wild or hatchery fish was dominant when it also grew the most (length or weight). P-values are for paired t-tests (growth) and paired sign tests (% dominance) for fish regardless of origin.

Origin	Average Growth mm (S. D.) Length	Average Growth Mg (S.D.) Weight	% Dominant when Grew the Most (Length)	% Dominant when Grew the Most (Weight)
Wild	0.44 (1.24)	94.70 (279.32)	75%	80%
Hatchery	0.59 (1.33)	57.72 (290.37)	82%	80%
P	0.133	0.223	<<0.001	<<0.001

Table 4. Dominance of lighter and darker colored fish in 135 contest competition trials (42 had no color assignment and 52 had equal colors that are not included here). P-value is from a paired sign test evaluating if there was a difference between fish of different color and dominance.

	Lighter and Dominant	Darker and Dominant	Total
Total Number	32 (18 H, 14 W)	103 (43 H, 60 W)	135
Sign test p-value			<<<0.001

Scramble competition

Total Dominance, food acquisition, agonism initiation, and agonism dominance was not significantly different between hatchery and wild fish in scramble competition trials (Table 5). Dominance was assessed in 97 out of 112 trials. Fifteen trials had to be

eliminated because one of the fish escaped or they did not meet the criteria for an acceptable trial. The fish were the same length in all but 21 of the trials, and of the 21 trials they were 1 mm different. The types of interactions and interaction rate that hatchery and wild fish initiated were also not significantly different (Tables 6). The growth of hatchery fish was significantly greater than wild fish and the dominant fish was the one that grew the most, regardless of origin (Table 7). There were more lighter colored fish that were dominant than darker fish but the difference was not significantly different (Table 8).

Table 5. Dominance, food acquisition, agonism initiation, and agonism dominance in 97 scramble competition trials. Mixed scramble competition total dominance determined by % food eaten only. Wilcoxon matched pairs test were used to produce P values.

Origin	% Food	% Initiations	% Dominated Interactions	% Total Dominance
Wild	48%	57%	54%	45%
Hatchery	52%	43%	46%	47%
				7% Equal
P	0.568	0.056	0.445	0.855

Table 6. Frequencies of interactions initiated by hatchery and wild fish in 97 scramble competition trials. Total interactions and interaction rate (average interactions per minute for all tanks) are also presented. Wilcoxon matched pairs tests were used for interaction types and a paired t-test was used for interaction rate.

Origin	Crowd	Threat	Chase	Butt	Nip	Total Interactions	Interaction Rate (+/- SD)
Wild	12%	46%	19%	8%	14%	1239	0.60 (0.65)
Hatchery	6%	48%	18%	13%	15%	944	0.46 (0.66)
P	0.451	0.793	0.966	0.126	0.351		0.203

Table 7. Growth and frequency of dominance of fastest growing wild and hatchery fish in 97 scramble competition trials. % dominance is the percentage of trials that wild or hatchery fish was dominant when it also grew the most (length or weight). P-values are for paired t-tests (growth) and paired sign tests (% dominance) for fish regardless of origin.

Origin	Average Growth mm (S. D.) Length	Average Growth Mg (S.D.) Weight	% Dominant when Grew the Most (Length)	% Dominant when Grew the Most (Weight)
Wild	0.37 (0.86)	48.85 (513.12)	39%	48%
Hatchery	0.77 (0.80)	285.35 (456.74)	80%	78%
P	0.0008	0.0009	0.049	0.015

Table 8. Dominance of lighter colored fish in 36 scramble competition trials. Trials in which there was equal dominance (n=7) or where color difference could not be discerned (n=51) were not analyzed. A sign test was used to test for differences.

	Lighter and Dominant	Darker and Dominant	Total
Total Number	24	12	36
	7 SH, 17 SN	8 SH, 4 SN	
P			0.067

Discussion

Preliminary results of our study indicate that one generation of hatchery exposure did not affect total dominance in either contest or scramble competition. However, wild fish were generally more aggressive than hatchery fish in both contest and scramble trials (initiated more agonistic interactions). We also found that dominant fish grew more than subordinate fish in both contest and scramble trials. A similar study that used similar fish and facilities in the Yakima River found that wild fish were more dominant than hatchery fish (Farrell 2003). At this time, we cannot reconcile the differences between the two studies. Our study and Farrell 2003 are somewhat unique in that the hatchery and wild population were founded from the same source, the hatchery population was in the hatchery for only a single generation, and that hatchery protocols were directed at producing fish that minimized divergence from wild fish. Other studies have demonstrated differences in aggression or dominance, but these studies have used fish that have come from different sources, have been under hatchery culture for many generations, and/or have come from hatcheries whose protocols are not intended to produce fish that reproduce well in natural systems (Berejikian et al. 1996).

Our results suggest that offspring of first generation hatchery fish that spawn in the Yakima River will have similar dominance rates as wild fish if the timing and size of emergence, and growth rates are similar. However, if emergence time, size at emergence, or growth rates diverges between offspring of hatchery and wild parents, then biological factors could influence dominance patterns. In the scramble trials, hatchery fish grew more than wild fish even though dominance was not significantly different. This suggests that hatchery fish may have a greater capacity to grow than wild fish. Farrell 2003 found that hatchery fish grew faster than the wild fish even when the amount of food delivered was the same. This resulted in hatchery fish being larger than wild fish. Berejikian et al. 1996 found that an approximate size advantage of 3.0-4.5% could provide hatchery steelhead fry a dominance advantage even when size matched fish were competitively inferior to wild fish. It is likely, that divergences in phenotypic or genotypic characteristics that affect size differences in offspring of hatchery and wild fish has the potential to influence dominance relationships more than genetic differences in dominance (e.g., differences in dominance of size matched fish as tested in this

experiment). Therefore, it is important to monitor factors that influence size differences of juvenile hatchery and wild fish.

For hatcheries that use wild endemic broodstock and best hatchery practices, differences in aggressiveness and dominance between hatchery and wild fish may be more strongly influenced by hatchery rearing and relative size than the genetic effects of behavioral domestication. We found no difference in dominance in this study, but we did find differences in dominance when we tested spring chinook salmon smolts that were reared in the hatchery and those that were reared in the Yakima River. Larger fish generally dominated smaller fish, but the size difference didn't have to be as large for hatchery fish to dominate as wild fish (Pearsons et al. Unpublished data). In short, hatchery fish were dominant over wild fish in contest competition trials unless wild fish were sufficiently larger than hatchery fish. In a study of coho salmon, Rhodes and Quinn 1998 reported similar findings.

This is the first year of a long-term evaluation of the effects of hatchery domestication on dominance and aggression of spring chinook salmon. In 2004, we will replicate this study. We will make the following improvements to our study in 2004:

- size matching will be exact,
- cover will be more realistic,
- daily recording of individual food intake during acclimation,
- conduct single fish trials to determine food acquisition, growth, and habitat preference, in the absence of competition (feed the same amount as in two fish trials), and
- sex of the fish will be determined at the end of each trial.

If time is available we will also test whether dominance relationships observed in aquaria are the same as in the field. This might be accomplished by taking known dominant and subordinate fish from aquaria and placing them in the experimental spawning channel or in an enclosure in the field. Observations would then be made using snorkeling and the dominance of the fish assessed using methods described in this study. In 2005, we anticipate having the addition of offspring from our wild control line that are collected from the Naches Basin.

Acknowledgments

References

Abbott, J. C., R. L. Dunbrack, and C. D. Orr. 1985. The interaction of size and experience in dominance relationships of juvenile steelhead trout (*Salmo Gairdneri*). Behaviour 92:241-253.

Busack, C. A., and K. P. Currens. 1995. Genetic risks and hazards in hatchery operations: fundamental concepts and issues. American Fisheries Society Symposium 15:71-80.

Berejikian, B. A., S. B. Mathews, and T. P. Quinn. 1996. Effects of hatchery and wild ancestry and rearing environments on the development of agonistic behavior in steelhead trout (*Oncorhynchus mykiss*) fry. Canadian Journal of Fisheries and Aquatic Sciences 53: 2004-2014.

Chapman, D. W. 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. Journal of the Fisheries Research Board of Canada. 19:1047-1081.

Grant, J. W. A., and Kramer, D. L. 1990. Territory size as a predictor of the upper limit to population density of juvenile salmonids in streams. Canadian Journal of Fisheries and Aquatic Sciences. 47:1724-1737.

Farrell, M. H. 2003. Growth, dominance and precocity in juveniles of first generation hatchery and wild chinook salmon (*Oncorhynchus tshawytscha*) [Master's thesis]. Ellensburg, WA: Central Washington University. 57 pp.

Fausch, K. D. 1984. Profitable stream positions for salmonids: relating specific growth rate to net energy gain. Canadian Journal of Zoology 62:441-451.

Huntingford, F. A., N. B. Metcalfe, J. E. Thorpe, W. D. Graham, and C. E. Adams. 1990. Social dominance and body size in Atlantic salmon parr, *Salmo salar L.* Journal of Fish Biology 36:877-881.

Maynard, D. J., T. A. Flagg, and C. V. W. Mahnken. 1995. A review of seminatural culture strategies for enhancing postrelease survival of anadromous salmonids. American Fisheries Society Symposium 15:307-314.

McMichael, G. A., T. N. Pearsons, and S. A. Leider. 1999. Behavioral interactions among hatchery-reared steelhead smolts and wild Oncorhynchus mykiss in natural streams. North American Journal of Fisheries Management 19:948-956.

McMichael, G. A., T. N. Pearsons, and S. A. Leider. 1999. Behavioral interactions among hatchery-reared steelhead smolts and wild *Oncorhynchus mykiss* in natural streams. North American Journal of Fisheries Management 19:948-956.

Metcalfe, N. B. 1986. Intraspecific variation in competitive ability and food intake in

salmonids: consequences for energy budgets and growth rates. Journal of Fish Biology (1986) 28:525-531.

Metcalfe, N. B., Tayler, A. C., and Thorpe, J. E. 1995. Metabolic rate, social status and life-history strategies in Atlantic salmon. Animal Behavior 49:431-436.

Pearsons, T. N., A. L. Fritts, K. D. Ham, G. A. McMichael, E. L. Bartrand, G. M. Temple, and C. W. Hopley. 2001. Yakima River Species Interactions Studies. Annual Report FY 1999 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-64878-7.

Peery, C. A., and T. C. Bjornn. 1996. Small-scale investigations into chinook salmon supplementation strategies and techniques: 1992-1994. Technical Report 96-3. Idaho Cooperative Fish and Wildlife Research Unit.

Phinney, D. D., S. B. Mathews, and T. N. Pearsons. 2000. Development of a bird predation index. Annual Report FY 1998 submitted to Bonneville Power Administration, Portland, Oregon.

Rhodes, J. S., and T. P. Quinn. 1998. Factors affecting the outcome of territorial contests between hatchery and naturally reared coho salmon parr in the laboratory. Journal of Fish Biology 53:1220-1230.

Rosenau, M. L., and J. D., McPhail. 1987. Inherited differences in agonistic behavior between two populations of coho salmon. Transactions of the American Fisheries Society 116:646-654.

Ruzzante, D. E. 1994. Domestication effects on aggressive and schooling behavior in fish. Aquaculture 120:1-24.

Riddell, B.E., and Swain, D. P. 1991. Competition between hatchery and wild coho salmon (Oncorhynchus kisutch): genetic variation for agonistic behaviour in newly-emerged wild fry. Aquaculture 98:161-172.

Swain, D. P., and B. E. Riddell. 1990. Genetic variation in agonistic behavior of juveniles between hatchery and wild stocks of coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 47:566-573.

Taylor, E. B., and P. A. Larkin. 1986. Current response and agonistic behavior in newly emerged fry of chinook salmon, Oncorhynchus tshawytscha, from ocean- and stream-type populations. Canadian Journal of Fisheries and Aquatic Sciences 43:565-573.

White, R. J., J. R. Karr, and W. Nehlsen. 1995. Better roles for fish stocking in aquatic resource management. American Fisheries Society Symposium 15:527-547.