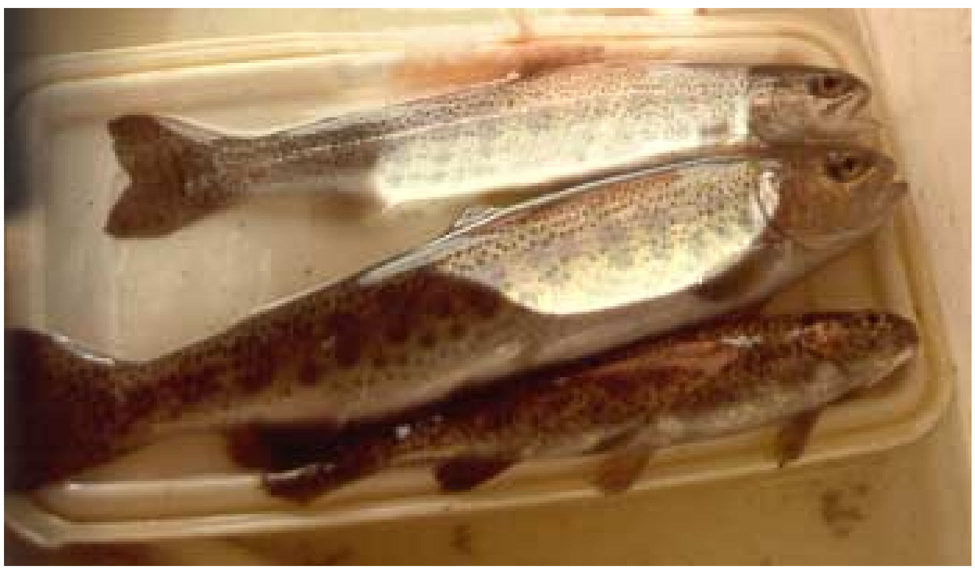
FISHERY RESEARCH

FACTORS AFFECTING PRECOCITY OF HATCHERY-REARED STEELHEAD IN IDAHO

LSRCP Hatchery Evaluation Studies Report



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IDFG Report Number 03-07
February 2003

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Cooperative Agreement
14-110-9-J001

IDFG Report Number 03-07
February 2003

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ABSTRACT

For the first phase of this pilot study, a total of 2,082 juvenile steelhead *Oncorhynchus mykiss* were sampled at Hagerman National, Magic Valley, and Niagara Springs fish hatcheries in March 1999 to determine if precocity was associated with fish stock, the presence of coded-wire tags, fish size, feed regimen, or exposure to security lights. Dworshak B-, Oxbow A-, Pahsimeroi A-, and Sawtooth A-run steelhead from brood year 1998 were used for the study. Precocity of male steelhead at Hagerman National, Magic Valley, and Niagara Springs fish hatcheries was 0.36, 5.25, and 2.13%, respectively. No precocial female steelhead were observed. Only two of the factors studied, coded-wire tags and exposure to security lights, appeared to affect precocity. Steelhead tagged with coded-wire tags had higher rates of precocity than untagged steelhead at all three hatcheries. Steelhead in raceways at Magic Valley Fish Hatchery that were exposed to security lights had higher rates of precocity than steelhead in less lighted raceways; security lights did not appear to affect precocity rates of steelhead at Hagerman National or Niagara Springs fish hatcheries. Nonprecocial males were generally longer, heavier, and had lower mean condition factor than precocial males.

The second phase of the pilot study, conducted during the fall of 1999 and spring of 2000, was designed to identify the particular aspect of coded-wire-tagging that resulted in increased precocity. The three aspects studied were the trauma from the needle, the magnetism of the wire, or a combination. This phase of the study used four groups of 5,000 juvenile A-run steelhead at Magic Valley Fish Hatchery. One group served as a control, a second group received a normal, blank, coded-wire-tag, a third group received a blank coded-wire tag with the magnetism removed, while a fourth group received only a puncture in the nose by the tagging needle, with no tag injected. Only the fourth group, those poked with a needle, showed higher rates of precocity than the control group, and the rates were not much higher. However, all four groups showed rates of precocity that were far higher than any detected during the first phase of the experiment.

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INTRODUCTION

The Idaho Department of Fish and Game (IDFG) and the US Fish and Wildlife Service (USFWS) release approximately eight million summer steelhead *Oncorhynchus mykiss* annually as compensation for hydropower development on the Snake and North Fork Clearwater rivers. The IDFG operates Clearwater, Niagara Springs, and Magic Valley fish hatcheries, and the USFWS operates Hagerman National and Dworshak National fish hatcheries. Steelhead are reared for ten months before being stocked into Idaho waters.

Some hatchery steelhead initiate sexual maturation before stocking. Precocity has been observed only in males. It is assumed that precocial males become stream residents (residualize) following stocking. Prior data collected from precocial steelhead tagged with passive integrated transponder (PIT) tags support this assumption. Personnel from IDFG have PIT tagged 37,047 hatchery steelhead since 1996. A total of 252 of these steelhead were precocial males. Male steelhead that released milt during tagging were classified as precocious. None of the 252 precocial males tagged with PIT tags were interrogated at downstream dams located on the Snake and Columbia rivers.

Residual steelhead may negatively affect native species through competition for food and space, predation (Miller 1958; Bachman 1984; Vincent 1987), and by disseminating diseases (Ratliff 1981). Residual steelhead also reduce the overall effectiveness of hatchery compensation programs by reducing the number of "true smolts" released. In terms of adult steelhead compensation, hatchery-rearing space, fish food, and labor are essentially wasted on this segment of the population.

The purpose of this study was to document current levels of precocity in hatchery steelhead, characterize precocial fish, and identify factors that may affect precocity. Ideally, we hoped this work would provide a better understanding of precocial development in hatchery steelhead and eventually lead to a reduction in the number of precocial steelhead being released.

METHODS

This first phase of the study was conducted in southeast Idaho at Hagerman National, Magic Valley, and Niagara Springs fish hatcheries using brood year 1998 steelhead. Rearing activities at the three hatcheries were not modified for this phase of the study; hatchery inventories were sampled to determine precocity rates of steelhead under normal rearing operations. Factors that could affect precocity were identified at each hatchery, and raceways were selected to examine the effects of each factor independently. Not all factors were applicable for each hatchery. The factors studied at each hatchery were as follows: Hagerman National Fish Hatchery—fish stock, feeding regimen, the effects of coded-wire tags, and light exposure (Table 1); Magic Valley Fish Hatchery—fish stock, the effects of coded-wire tags, and light exposure (Table 2); Niagara Springs Fish Hatchery—fish stock, the effects of coded-wire tags, fish size, and light exposure (Table 3). Raceways that were located in close proximity to security lights were designated "high light exposure"; these were compared to raceways exposed to less direct light, which were designated "low light exposure." The amount of light hitting each raceway was not measured; raceway designations were based on visual observations.

Fish used in the first phase of the study were sampled in March 1999 by personnel from IDFG's Fish Health Laboratory. Fish samples were collected from densely populated sections of specified raceways by taking a "grab sample" using a dip net. Generally, 100 fish were collected from each raceway. Sample sizes varied in some raceways at Magic Valley and Hagerman National fish hatcheries due to ongoing studies. Fish were anesthetized in tricaine methanesulfonate (MS-222, pH 7.0). Fish were scanned for PIT tags; PIT-tagged fish were returned to their respective raceway (not applicable for all raceways). The remaining fish were euthanized, measured (FL, mm), weighed (g), sexed, and checked for gonadal development. Fish with enlarged gonads were classified as precocious. Steelhead sampled at Niagara Springs Fish Hatchery in designated "coded-wire-tagged raceways" were scanned for the presence of a coded-wire tag prior to dissection. Steelhead sampled from "coded-wire-tagged raceways" at Magic Valley and Hagerman National fish hatcheries were not scanned for tags; however, about 97% of the fish in these raceways were tagged.

SYSTAT (SYSTAT 1996) was used to analyze all data from the first phase of the study. Data were analyzed by hatchery and by factor (e.g., fish stock). Individual condition factor ($K = \text{weight}/\text{length}^3 \times 100{,}000$) was calculated for each fish. Mean length, weight, and condition factor were estimated for steelhead in each raceway using sample data. Mean length, weight, and condition factor of precocial and nonprecocial male steelhead in each raceway were estimated using sample data. The sex ratio (females:males) was calculated for fish sampled in each raceway and for all fish sampled at each hatchery. The percentage of precocial males at each hatchery, for each stock, and for each raceway was estimated from sample data by dividing the number of precocial males by the total number of males in the sample, multiplied by 100.

The second phase of the study looked at the effects of three different aspects of the coded wire tagging process on precocity. Specifically, the second phase tried to determine whether the presence of the tag, the magnetism of the tag, or the trauma of getting a needle stuck into the nose resulted in increased levels of precocial development. All tagging for this phase of the experiment was performed using a single tagging trailer with an experienced crew and experienced supervisor at Magic Valley Fish Hatchery. Tagging for the study took place on October 7, 1999 before tagging any other fish at the hatchery.

This phase of the study was only conducted at Magic Valley Fish Hatchery using the upper 50-foot section of four of the east bank of raceways. Three of the raceways received treatment groups, while the fourth received a control group. All groups consisted of 5,000 fish taken from the population in the lower section of raceway 3E using a dipnet "grab sample." The fish were crowded down to the bottom end of the raceway before sampling, which should reduce any segregation due to precocity within the raceway.

The coded-wire tagging trailer used in the study consisted of four identical stations. Fish were brought to the trailer by bucket and placed in a central tank that had a large continual flow of fresh water. The fish tagging crew used small dipnets to net fish into one or two of four sinks. Each sink had a continuously circulating, cooled, bath of anesthetic water. The anesthetic used for tagging was MS-222. For proper coded-wire-tagging, it was necessary for the fish to be fairly heavily anesthetized, but no mortality was observed over the week following the tagging operation. Once the fish were adequately anesthetized, the fish tagging crew took the fish from the sink, put their heads up to the head mold on the tagging machine, pressed a button to fire the tagging machine, and dropped the fish into a tube with a constant flow of fresh water to return them to the raceway via a lengthy section of aluminum irrigation pipe. Most fish had recovered from the visible effects of the anesthetic by the time they reached the raceway.

The first of the four groups used in this phase of the study were tagged with blank magnetized wire. The second group was tagged with wire in which the magnetism had been removed. Removing the magnetism is done by the tagging machine, and appeared to be completely successful after the first 100 or so fish per machine. The third group was handled just as they would be for normal tagging, except that the machines had no wire and were, therefore, not doing anything but poking the needle into the snout of the fish. The fourth group was anesthetized for the same length of time as the other three groups, but then was simply counted by hand before being sent to the raceway.

Personnel from the IDFG Fish Health Laboratory performed precocity sampling on April 24, 2000. The sampling was specifically set to occur just before the normal release dates for steelhead from Magic Valley Fish Hatchery. Grab samples of 150 fish were taken from each of the four raceways by the staff of Magic Valley Fish Hatchery. Due to the small area to be sampled and the small number of fish, this probably produced a suitably random sample. It is unlikely that the fish had a chance to segregate by precocity in the short segment of the raceway to which they had been confined.

Sampled fish were euthanized in a strong bath of MS-222 and were dissected by the sampling team. All fish were sexed by examination of the gonads. Male fish with enlarged gonads were classified as precocial. There were no precocial females observed. No scanning for coded wire tags was performed.

RESULTS

Phase 1

Hagerman National Fish Hatchery

On March 2, 1999, 597 Sawtooth A- and Oxbow A-run steelhead were sampled from ten raceways at Hagerman National Fish Hatchery (Table 4). The overall sex ratio was 1.16 females for every 1 male sampled (321:276 females:males). Of the 276 male steelhead sampled, only one fish was precocious (0.36% of the males). No precocial females were observed. The precocial male was of Sawtooth A-run in raceway 50 and measured 155 mm, weighed 39 g, and had a condition factor of 1.05. Mean length, weight, and condition factor of nonprecocial males in raceway 50 (n = 19) were 179 mm, 61 g, and 1.04, respectively. The precocial male observed in raceway 50 was not scanned to verify the presence of a coded-wire tag. Precocial fish were nearly absent in samples collected at Hagerman National Fish Hatchery, and there was little evidence to suggest that fish stock, feeding regimen, coded-wire tagging, or light exposure were affecting precocity levels.

Magic Valley Fish Hatchery

On March 30, 1999, 597 Dworshak B- and Pahsimeroi A-run steelhead were sampled from ten raceways at Magic Valley Fish Hatchery (Table 4). The overall sex ratio was 1.36 females for every one male sampled (519:381 females:males). Of the 381 male steelhead sampled, 20 fish were precocious (5.25% of the males). No precocial females were observed. Precocial fish were observed in seven of ten raceways sampled. Mean length, weight, and condition factor of precocial males (n = 19, one fish was dropped from analyses due to suspect data) were 206 mm, 100 g, and 1.10, respectively. Mean length, weight, and condition factor of nonprecocial males collected from the same raceways (n = 296) were 223 mm, 113 g, and 1.0, respectively.

Comparing precocity rates between fish stocks, 6.0% (12 fish) of the Pahsimeroi A-run males and 4.4% (8 fish) of the Dworshak B-run males were precocial. The higher precocial rates in Pahsimeroi A-run steelhead may be due to light exposure rather than stock differences. Two of the four raceways that contained Pahsimeroi A-run steelhead raceways were designated high light exposure raceways, whereas none of the six raceways stocked with Dworshak B-stock steelhead were considered high light exposure raceways.

Pahsimeroi A-run steelhead in raceways West 16A and West 16B, the two raceways with the greatest exposure to security lights, had the highest precocial rates of the ten raceways—10.42 and 8.51%, respectively (Table 4). However, Pahsimeroi A-run steelhead in raceway West 11A were not exposed to security lights, and the precocial rate of male steelhead was 7.14%.

Coded-wire-tagged steelhead in raceways West 11A, West 16B, and East 13A were compared to untagged steelhead in raceways West 10A, West 16A, and East 14A, respectively (Table 5). For each comparison, precocity was higher in male steelhead tagged with coded-wire tags. Overall, 7.7% of tagged males were precocial as compared to 3.2% of untagged males (Table 5). Note that steelhead at Magic Valley Fish Hatchery were not scanned for coded-wire tags prior to dissection, since about 98% of the fish were tagged.

Niagara Springs Fish Hatchery

On March 29, 1999, 585 Oxbow A- and Pahsimeroi A-run steelhead were sampled from six different raceways at Niagara Springs Fish Hatchery (Table 4). The overall sex ratio was 1.49 females for every one male sampled (350:235 females:males). Of the 235 male steelhead sampled, five fish were precocious (2.13% of the males). No precocial females were observed. Precocial males were observed in three of the six raceways sampled. Mean length, weight, and condition factor of precocial males (n = 5) were 219 mm, 126 g, and 1.17, respectively. Mean length, weight, and condition factor of nonprecocial males collected from the same raceways (n = 109) were 203 mm, 93 g, and 1.06, respectively.

Comparing precocity rates between fish stocks, 3.6% (4 fish) of Oxbow A-run males and 0.8% (1 fish) of Pahsimeroi A-run males were precocious. Three of the four precocial Oxbow A-run males were observed in raceway 4A. Raceway 4A had the highest percentage of precocial males (8.1% of the males) of the six raceways.

We sampled Pahsimeroi A-run steelhead from raceways 16 and 18 and Oxbow A-run steelhead from raceways 4A and 4B to determine if coded-wire tags affected precocity. Tagged steelhead were in raceways 16 and 4A (all fish were scanned for coded-wire tags prior to dissection). No precocial steelhead were observed in either raceway 16 or raceway 18. Three precocial steelhead were observed in raceway 4A, and one precocial steelhead was observed in raceway 4B. All three precocial fish from raceway 4A were tagged with coded-wire tags.

Steelhead in raceway 4B were compared to steelhead in raceway 7 to determine if precocity was related to fish size; steelhead in raceway 4B were longer than steelhead in raceway 7 (mean = 210 mm [n = 99] versus 199 mm [n = 99], respectively). However, if females were excluded from the analyses, mean lengths for males in raceways 4B and 7 were almost identical (204 mm [n = 35] versus 203 mm [n = 40], respectively). One precocial male (253 mm) was observed in raceway 4B and no precocial males were observed in raceway 7.

Pahsimeroi A-run steelhead from raceways 18 and 10 were compared to determine if security lights affected precocity. Steelhead in raceway 18 had greater exposure to security lights. No precocial steelhead were observed in raceway 18, and one precocial steelhead was collected from raceway 10.

Phase 2

The results of the second phase of the study showed that coded-wire tagging did not appear to be influencing precocial development. However, the data strongly suggests that some factor surrounding fish marking is affecting precocial development. Since the control group had the second highest precocity rate and had rates of precocity higher than either of the groups that received coded-wire tags, the data clearly shows that coded-wire tagging does not increase precocity (Figure 1). The highest precocity was observed in the treatment group, where the fish were poked in the snout with the tagging needle but were not actually tagged. This suggests that differences between the four groups were due more to inherent variability within the population than any causative factor.

Notably, all four groups showed extraordinarily high precocity. In fact, the average precocity for the four treatments was 13.9%, which is considerably higher than any of the samples taken from any of the hatcheries during the first phase of this study. Unfortunately, no adequate sample was taken from the rest of the steelhead at Magic Valley Fish Hatchery for brood year 1999 for comparison. These data suggests that something in the marking process was resulting in increased precocity, but there is little indication as to what this factor might be.

DISCUSSION

For the first phase of this study, we summarized sampling statistics, by factor, across all hatcheries and found that only two of the factors studied, coded-wire tags and exposure to security lights, appeared to affect precocity (Table 5). The effect of coded-wire tags was consistent among hatcheries: precocity was higher in tagged fish. Precocity was not related to exposure to security lights at Hagerman National or Niagara Springs fish hatcheries, but it was at Magic Valley Fish Hatchery. Raceways at Magic Valley Fish Hatchery that had greater exposure to security lights contained a higher percentage of precocial male steelhead.

Over all hatcheries, 5.24% of male steelhead tagged with coded-wire tags were precocial as compared to 1.93% of untagged males (Table 5). In five out of six comparisons, precocity was higher in tagged males than untagged males. We cannot explain the apparent connection between coded-wire tags and precocity. One weakness of the first phase of the study was that we failed to verify that each steelhead sampled from designated “coded-wire tagged raceways” at Hagerman National and Magic Valley fish hatcheries was tagged. Although most of the fish in the sampled raceways were tagged, it is possible that our samples contained untagged fish. Moreover, some fish may have lost their tag. Tag loss for steelhead at these hatcheries generally averages around 5%.

Coded-wire tags are generally assumed benign in terms of affecting fish health and behavior (Buckley and Blankenship 1990). Quinn and Groot (1983) reported that coded-wire tags (magnetized or not magnetized) had little effect on the orientation of juvenile chum salmon *O. keta* migrating through Nootka Sound to the North Pacific Ocean. Thrower and Smoker (1984) and Elrod and Schneider (1986) reported that coded-wire tags, and the application of coded-wire tags, had no major effects on pink salmon *O. gorbuscha* and lake trout *Salvelinus namaycush*, respectively. Barnes (1994) reported that coded-wire tags had no significant impact on feed conversion, growth, or condition factor of rainbow trout *O. mykiss*. Fletcher et al. (1987) reported that cheek muscle tissue of largemouth bass *Micropterus salmoides* that received the coded-wire tag healed normally with no apparent histologic damage.

Although most researchers found coded-wire tags to be benign in fish, Morrison and Zajac (1987) reported that 41% of chum salmon fry tagged with half-length coded-wire tags had damaged olfactory nerves. In each case, they found that the damaged nerve corresponded with tag placement. Habicht et al. (1998) reported that coded-wire tag placement in pink salmon fry can affect adult homing ability. Hasler and Scholz (1983) reviewed the importance of olfactory function in parr-smolt transformation, imprinting, and homing behavior in salmonids. Damage to the olfactory bulb, or olfactory nerves, could interfere with specific morphological, physiological, and behavioral transitions. Damage to olfactory nerves from tagging would be more likely to occur in smaller fish. Steelhead used in this study were tagged when they were approximately 187 mm in total length (5 fish/pound). Coded-wire-tagging would be less likely to damage olfactory nerves in fish of this size (Lee Blankenship, Washington State Department of Fisheries, personal communication).

Since the first phase of this study suggested that coded-wire tagging of steelhead was increasing the rate of precocity, the second phase of the study was conducted to attempt to identify which aspect of coded-wire tagging caused this increase. However, since the tagged steelhead actually had lower rates of precocity than the control group, there appears to be another factor, other than the tags themselves, which caused the increased precocity seen in the first phase of the study.

One critical flaw in the second phase of the study was the control group. The control group was handled the same way as the tagged groups, except that it was not tagged or poked with a needle. However, all fish used in the second phase had been previously adipose fin clipped several weeks earlier. This is standard practice at Magic Valley Fish Hatchery, where the hatchery staff hires a clipping crew to get the adipose fin clipping done well before the tagging crew arrives. This means that all of the fish used in the second phase, both control and treatment, were handled and anesthetized twice in a span of only a month or two. In fact, since this dual handling occurred for all tagged fish at Magic Valley Fish Hatchery, and Magic Valley Fish Hatchery showed the strongest correlation between coded-wire tagging and precocity, it may very well have been that the handling, not the tagging, was the cause of the increased precocity. The second phase of the study was not designed to address that question at all. However, it should be noted that all four groups used in the second phase of the study had rates of precocity higher than any group measured during the first phase.

We did not evaluate tag placement on precocial fish during either phase of the study. Histologic examinations, or radiographs, of tagged precocial fish may have helped to explain the apparent relationship between coded-wire tags and precocity during the first phase of the study, though the second phase of the study suggests that this may not be a profitable line of further inquiry. However, other obscure factors may be involved. For example, the US Fish and Wildlife Service Fisheries Research Office is currently investigating how spawn timing of adult steelhead affects precocity of their progeny at Dworshak National Fish Hatchery (Ray Jones, personal communication). Preliminary findings suggest that progeny of adults that were spawned early in the run have higher rates of precocity than progeny of adults spawned later in the run.

We also did not check for the presence of coded wire tags during the second phase of the study. We assumed that 100% of the sampled fish from the two tagged treatment groups actually were tagged. This assumption was certainly incorrect for the nonmagnetized group, though it may be reasonable for the magnetized group. While it is possible that there were a large number of untagged fish sampled, and while this may mean that precocity among the actual tagged fish was higher than reported, it is highly unlikely to have altered the figures for the magnetized group beyond the least significant digit, and that is not enough to alter the conclusions. Retention checks performed on the next raceway tagged by the crew used for the second phase showed a tag loss of less than 1%, which suggests that they did a good job on the study fish as well. Tag retention for the nonmagnetized group was severely compromised by the problems inherent in using nonmagnetized wire. The tagging machines have several quality control features that are dependent upon the magnetism. By using nonmagnetized wire, these quality control features are disabled. A minimum of 200 fish were definitely not tagged in this group, and the actual number of untagged fish may be as high as 20% or the total group. Furthermore, accurate detection of nonmagnetized wire can require X-ray equipment. Due to these problems, use of nonmagnetized coded wire tags is strongly discouraged.

Approximately 9.5% of the male steelhead in brightly illuminated raceways at Magic Valley Fish Hatchery were precocial as compared to 3.5% of the males in less lighted raceways (Table 5). Our results concur with Moore et al. (1998) who reported that steelhead reared at Magic Valley Fish Hatchery in raceways exposed to security lights had higher rates of precocity. However, the effect of light exposure was not consistent among hatcheries; security lights did not increase the levels of precocity at Hagerman National or Niagara Springs fish hatcheries. The difference could be attributed to the dissimilarity between the lights and/or the proximity of the lights to the raceways (i.e., juxtaposition of raceways to lights). High-pressure sodium lights were used at all three hatcheries, but the wattage varied among hatcheries: Magic Valley—250 watt bulbs (26,100 lumens), Hagerman National—70 watt bulbs (5,500 lumens), and Niagara Springs—400 watt bulbs (45,000 lumens). We cannot explain why the lights at Niagara Springs, which were the most powerful of the three hatcheries, did not affect precocity. Certainly, factors such as the proximity of the lights, the height of the light poles, the amount of surface area affected, the angle of the light, the amount of light hitting the surface of the water, and the direction of water flow in relation to the security light are all variables worthy of investigation. It is important for the reader to understand that "high light exposure" as used in this study was not a consistent treatment applied to all hatcheries, but rather a relative designation given to specific raceways at each hatchery. To compare light exposure among hatcheries, the factors mentioned above would need to be quantified and documented.

For the size range of fish studied, we did not find any evidence that growing fish to a larger size will increase precocity. These data suggest that precocial males were not the largest fish in the raceway, but rather they were average in size or smaller. Precocial males were observed at all three hatcheries in 11 different raceways. In nine out of 11 raceways, the mean length of precocial males was less than the mean length of nonprecocial males in the same raceway (Table 6). The mean weight of precocial males was less than the mean weight of nonprecocial males in eight of the 11 raceways (comparing precocial versus nonprecocial males collected from the same raceway). Mean condition factor was higher for precocial males in all 11 raceways.

Precocity rates of male steelhead were low at all three hatcheries during the first phase of the study: Hagerman National—0.36%, Magic Valley—5.25%, and Niagara Springs—2.13%. Note that these rates are for male steelhead only. If females are included in the calculations, the rates are more than halved: Hagerman National—0.17%, Magic Valley—2.22%, and Niagara Springs—0.85%. Overall, only 2.91% of the male steelhead that we sampled were precocious (26 out of 892 males).

Fewer precocial males were observed at Hagerman National Fish Hatchery than at the other two hatcheries. One notable nonconformity in these data was the time of sampling. Fish were sampled on March 2 at Hagerman National Fish Hatchery but not until the end of March at the other two hatcheries. The time of sampling may have affected our results (i.e., we may have underestimated precocity at Hagerman National Fish Hatchery). We are unaware of any literature addressing the temporal aspects of precocial development in steelhead. Personnel at Magic Valley Fish Hatchery have reported seeing precocial males as early as January or February (Dave May, IDFG, personal communications). Additionally, it is also important to know when steelhead no longer change into precocial fish, that is, if there is a date when all steelhead compelled to become precocious exhibit enlarged gonads. By defining the time period when juvenile steelhead make the transition from parr to sexually mature, we can ensure that representative data, in terms of data used to describe precocity, are collected.

One of the final observations that must be discussed concerning the second phase of the study was the very high rate of precocity observed. It is regrettable that no samples were taken from the non-study steelhead at the same time as the study fish were sampled. There is evidence, however, that precocity rates were elevated for some Magic Valley Fish Hatchery brood year 1999 steelhead. Newman (2002) reported precocity rates at Squaw Pond that were in the same range as those reported here. The steelhead used in the Squaw Pond study were the same stock, though not the same group, as those used in the second phase of this study. The Squaw Pond samples were taken much later than the samples taken for this study, which may have elevated the precocity rates seen in the Squaw Pond fish somewhat, but the Squaw Pond samples were still higher than normal.

ACKNOWLEDGMENTS

We would like to thank the personnel at Hagerman National, Magic Valley, and Niagara Springs fish hatcheries for their assistance and cooperation. We would also like to thank the US Fish and Wildlife Service-Lower Snake River Compensation Plan Office for providing financial support for this research.

Table 1. Steelhead raceways at Hagerman National Fish Hatchery that were sampled to identify factors associated with precocity. All raceways were on the fast/feed regimen except raceways 49, 51, and 53.

Raceway	Stock	Coded-wire Tag	Factors	Comparisons
49, 51, 53	Sawtooth A	yes	continuous feed regimen	raceways 50, 52, 54
50, 52, 54	Sawtooth A	yes	fast/feed regimen fish stock comparison coded-wire tag	raceways 49, 51, 53 raceway 92 raceway 69
55	Sawtooth A	no	high night light exposure fish stock comparison	raceway 69 raceway 91
69	Sawtooth A	no	low night light exposure no coded-wire tag	raceway 55 raceways 50, 52, 54
91	Oxbow A	no	no coded-wire tag fish stock comparison	raceway 92 raceway 55
92	Oxbow A	yes	coded-wire tag fish stock comparison	raceways 91 raceways 50, 52, 54

Table 2. Steelhead raceways at Magic Valley Fish Hatchery that were sampled to identify factors associated with precocity.

Raceway	Stock	Coded-wire Tag	Factors	Comparisons
East 13A	Dworshak B	yes	coded-wire tag fish stock comparison	raceway East 14A raceway West 11A
East 14A	Dworshak B	no	no coded-wire tag fish stock comparison	raceway East 13A raceway West 10A
West 11A	Pahsimeroi A	yes	coded-wire tag low night light exposure fish stock comparison	raceway West 10A raceway West 16B raceway East 13A
West 10A	Pahsimeroi A	no	no coded-wire tag low night light exposure fish stock comparison	raceway West 11A raceway West 16A raceway East 14A
West 16A	Pahsimeroi A	no	no coded-wire tag high night light exposure	raceway West 16B raceway West 10A
West 16B	Pahsimeroi A	yes	coded-wire tag high night light exposure	raceway West 16A raceway West 11A
East 15A	Dworshak B	no	Squaw Creek Pond Study	baseline data
East 15B	Dworshak B	no	Squaw Creek Pond Study	baseline data
East 16A	Dworshak B	no	Squaw Creek Pond Study	baseline data
East 16B	Dworshak B	no	Squaw Creek Pond Study	baseline data

Table 3. Steelhead raceways at Niagara Springs Fish Hatchery that were sampled to identify factors associated with precocity.

Raceway	Stock	Coded-wire Tag	Factors	Comparisons
4A	Oxbow A	yes	coded-wire tag fish stock comparison	raceway 4B raceway 16
4B	Oxbow A	no	no code-wire tag large size	raceway 4A raceway 7
7	Oxbow A	no	small size fish stock comparison	raceway 4B raceway 10
16	Pahsimeroi A	yes	fish stock comparison	raceway 4A
18	Pahsimeroi A	no	high night light exposure	raceway 10
10	Pahsimeroi A	no	low night light exposure fish stock comparison	raceway 18 raceway 7

Table 4. Morphological characteristics of juvenile steelhead, brood year 1998, at Hagerman National, Magic Valley, and Niagara Springs fish hatcheries. Steelhead were sampled in March 1999 to identify factors associated with precocity.

Raceway Number	Fish Stock	Coded-Wire Tag	Factor Studied	n	Mean Fork Length	Mean Weight	Mean Cond	Sex Ratio F	: M	Number Precocial Males	Percent of Males Precocial	Comparison Raceways
Hagerman National—Sampled 3/2/99												
49, 51, 53	Sawtooth A	Yes	continuous feed regimen	98	193	83	1.12	53	45	0	0.00%	50, 52, 54
50, 52, 54	Sawtooth A	Yes	fast/feed regimen fish stock comparison coded-wire tag	99	175	56	1.02	46	53	1	1.89%	49, 51, 53 92 69
55	Sawtooth A	No	exposed to high light fish stock comparison	100	171	55	1.07	60	40	0	0.00%	69 91
69	Sawtooth A	No	exposed to low light no coded-wire tag	100	177	60	1.05	53	47	0	0.00%	55 50, 52, 54
91	Oxbow A	No	no coded-wire tag fish stock comparison	100	186	73	1.1	50	50	0	0.00%	92 55
92	Oxbow A	Yes	coded-wire tag fish stock comparison	100	184	67	1.06	59	41	0	0.00%	91 50, 52, 54
		Total Fish Sampled		**597**	**181**	**66**	**1.07**	**321**	**276**	**1**	**0.36%**	
Magic Valley—Sampled 3/30/99												
East 13A	Dworshak B	Yes	coded-wire tag fish stock comparison	98	218	106	1.01	71	27	1	3.70%	East 14A West 11A
East 14A	Dworshak B	No	no coded-wire tag fish stock comparison	100	211	97	1.01	65	35	0	0.00%	East 13A West 10A
West 11A	Pahsimeroi A	Yes	coded-wire tag exposed to low light fish stock comparison	98	219	110	1.02	56	42	3	7.14%	West 10A West 16B East 13A

Table 4. Continued.

Raceway Number	Fish Stock	Coded-Wire Tag	Factor Studied	n	Mean Fork Length	Mean Weight	Mean Cond	Sex Ratio F	: M	Number Precocial Males	Percent of Males Precocial	Comparison Raceways
West 10A	Pahsimeroi A	No	no coded-wire tag exposed to low light fish stock comparison	110	222	114	1.02	65	45	0	0.00%	West 11A West 16A East 14A
West 16A	Pahsimeroi A	No	no coded-wire tag exposed to high light	99	228	121	0.99	52	47	4	8.51%	West 16B West 10A
West 16B	Pahsimeroi A	Yes	coded-wire tag exposed to high light	100	226	120	1.01	52	48	5	10.42%	West 16A West 11A
East 15A	Dworshak B	No	Squaw Cr. Pond Study	75	229	120	0.98	44	31	0	0.00%	none
East 15B	Dworshak B	No	Squaw Cr. Pond Study	72	218	103	0.97	36	36	3[a]	8.33%	none
East 16A	Dworshak B	No	Squaw Cr. Pond Study	73	226	118	1	43	30	2	6.67%	none
East 16B	Dworshak B	No	Squaw Cr. Pond Study	75	220	105	0.98	35	40	2	5.00%	none
		Total Fish Sampled		**900**	**221**	**112**	**1**	**519**	**381**	**20**	**5.25%**	
Niagara Springs—Sampled 3/29/99												
4A	Oxbow A	Yes	coded-wire tag fish stock comparison	96	218	115	1.05	59	37	3	8.11%	4B 16
4B	Oxbow A	No	no coded-wire tag large size	99	210	99	1.03	64	35	1	2.86%	4A 7
7	Oxbow A	No	small size fish stock comparison	99	199	96	1.17	59	40	0	0.00%	4B 10
16	Pahsimeroi A	Yes	fish stock comparison	98	210	106	1.12	63	35	0	0.00%	4A
18	Pahsimeroi A	No	exposed to high light	96	205	101	1.14	50	46	0	0.00%	10
10	Pahsimeroi A	No	exposed to low light fish stock comparison	97	192	80	1.1	55	42	1	2.38%	18 7
		Total Fish Sampled		**585**	**206**	**100**	**1.1**	**350**	**235**	**5**	**2.13%**	

* one precocial fish was dropped from analyses due to suspect data

Table 5. Factors used to analyze precocity of steelhead at Hagerman National (HNFH), Magic Valley (MVFH), and Niagara Springs (NSFH) fish hatcheries in March 1999. Dworshak (DWOR) B-, Oxbow (OXB) A-, Pahsimeroi (PAH) A-, and Sawtooth (SAW) A-run steelhead from the 1998 brood were used for the study. Length (mm), weight (g), and condition factor (K) statistics were calculated for all fish sampled from specified raceways.

Hatchery	Fish Stock	Raceway	Coded-Wire Tag	n	Mean Fork Length	Mean Weight	Mean Condition	Sex Ratio M	: F	Number Precocial Males	Percent of Males Precocial	Factor
Coded-wire Tag Comparisons												
HNFH	SAWT	69	no	100	177	60	1.05	53	47	0	0.00%	not tagged
HNFH	SAWT	50,52,54	yes	99	175	56	1.02	46	53	1	1.89%	tagged
HNFH	OXB	91	no	100	186	73	1.1	50	50	0	0.00%	not tagged
HNFH	OXB	92	yes	100	184	67	1.06	59	41	0	0.00%	tagged
MVFH	PAH	W10A	no	110	222	114	1.02	65	45	0	0.00%	not tagged
MVFH	PAH	W11A	yes	98	219	110	1.02	56	42	3	7.14%	tagged
MVFH	PAH	W16A	no	99	228	121	0.99	52	47	4	8.51%	not tagged
MVFH	PAH	W16B	yes	100	226	120	1.01	52	48	5	10.42%	tagged
MVFH	DWOR	E14A	no	100	211	97	1.01	65	35	0	0.00%	not tagged
MVFH	DWOR	E13A	yes	98	218	106	1.01	71	27	1	3.70%	tagged
NSFH	OXB	4B	no	99	210	99	1.03	64	35	1	2.86%	not tagged
NSFH	OXB	4A	yes	96	218	115	1.05	59	37	3	8.11%	tagged
	Summary											
HNFH			**no**	**200**				**103**	**97**	**0**	**0.00%**	
HNFH			**yes**	**199**				**105**	**94**	**1**	**1.06%**	
MVFH			**no**	**309**				**182**	**127**	**4**	**3.15%**	
MVFH			**yes**	**296**				**179**	**117**	**9**	**7.69%**	
All Hatcheries			**no**	**608**				**349**	**259**	**5**	**1.93%**	
All Hatcheries			**yes**	**591**				**343**	**248**	**13**	**5.24%**	

Table 5. (Continued).

Hatchery	Fish Stock	Raceway	Coded-Wire Tag	n	Mean Fork Length	Mean Weight	Mean Condition	Sex Ratio M	: F	Number Precocial Males	Percent of Males Precocial	Factor
Night Light Comparisons												
HNFH	SAWT	55	no	100	171	55	1.07	60	40	0	0.00%	high light
HNFH	SAWT	69	no	100	177	60	1.05	53	47	0	0.00%	low light
MVFH	PAH	W16A	no	99	228	121	0.99	52	47	4	8.51%	high light
MVFH	PAH	W10A	no	110	222	114	1.02	65	45	0	0.00%	low light
MVFH	PAH	W16B	yes	100	226	120	1.01	52	48	5	10.42%	high light
MVFH	PAH	W11A	yes	98	219	110	1.02	56	42	3	7.14%	low light
NSFH	PAH	18	no	96	205	101	1.14	50	46	0	0.00%	high light
NSFH	PAH	10	no	97	192	80	1.1	55	42	1	2.38%	low light
	Summary											
MVFH			**High Light**	**199**				**104**	**95**	**9**	**9.47%**	
MVFH			**Low Light**	**208**				**121**	**87**	**3**	**3.45%**	
All Hatcheries			**High Light**	**395**				**214**	**181**	**9**	**4.97%**	
All Hatcheries			**Low Light**	**405**				**229**	**176**	**4**	**2.27%**	
Fish Size Comparison												
NSFH	OXB	4B	no	99	210	99	1.03	64	35	1	2.86%	large
NSFH	OXB	7	no	99	199	96	1.17	59	40	0	0.00%	small
Feeding Regimen Comparison												
HNFH	SAWT	50,52,54	yes	99	175	56	1.02	46	53	1	1.89%	fast/feed
HNFH	SAWT	49,51,53	yes	98	193	83	1.12	53	45	0	0.00%	continuous

Table 5. (Continued.)

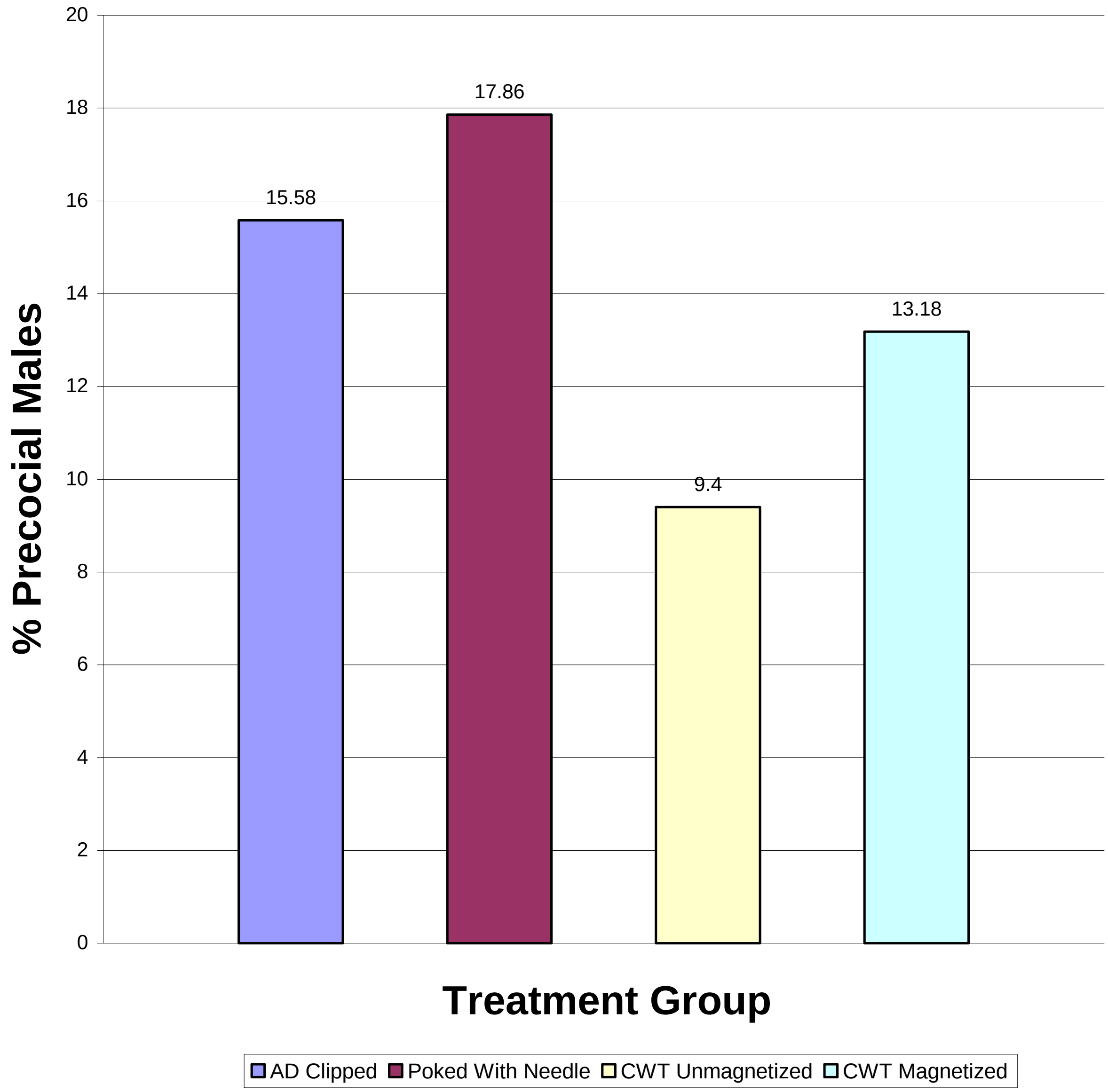
Hatchery	Fish Stock	Raceway	Coded-Wire Tag	n	Mean Fork Length	Mean Weight	Mean Condition	Sex Ratio M	: F	Number Precocial Males	Percent of Males Precocial	Factor
Fish Stock Comparisons												
HNFH	SAWT	55	no	100	171	55	1.07	60	40	0	0.00%	SAWT
HNFH	OXB	91	no	100	186	73	1.1	50	50	0	0.00%	OXB
HNFH	SAWT	50,52,54	yes	99	175	56	1.02	46	53	1	1.89%	SAWT
HNFH	OXB	92	yes	100	184	67	1.06	59	41	0	0.00%	OXB
MVFH	DWOR	E13A	yes	98	218	106	1.01	71	27	1	3.70%	DWOR
MVFH	PAH	W11A	yes	98	219	110	1.02	56	42	3	7.14%	PAH
MVFH	DWOR	E14A	no	100	211	97	1.01	65	35	0	0.00%	DWOR
MVFH	PAH	W10A	no	110	222	114	1.02	65	45	0	0.00%	PAH
NSFH	PAH	10	no	97	192	80	1.1	55	42	1	2.38%	PAH
NSFH	OXB	7	no	99	199	96	1.17	59	40	0	0.00%	OXB
NSFH	PAH	16	yes	98	210	106	1.12	63	35	0	0.00%	PAH
NSFH	OXB	4A	yes	96	218	115	1.05	59	37	3	8.11%	OXB
Summary												
	SAWT			**199**				**106**	**93**	**1**	**1.08%**	
	OXB			**395**				**227**	**168**	**3**	**1.79%**	
	DWOR			**198**				**136**	**62**	**1**	**1.61%**	
	PAH			**403**				**239**	**164**	**4**	**2.44%**	

Table 6. Statistics of precocial and nonprecocial male steelhead, brood year 1998, collected from Hagerman National, Niagara Springs, and Magic Valley fish hatcheries in March 1999. Precocial males were compared to non-precocial males in the same raceway. Means for fork length (mm), weight (g), and condition factor (K) are shown.

Group	Hatchery	Stock	Raceway	n	Fork Length	Weight	Condition Factor
Precocial	Hagerman	Sawtooth A	50	1	155.00	39.00	1.05
Nonprecocial	Hagerman	Sawtooth A	50	19	179.21	60.79	
Precocial	Niagara	Pahsimeroi A	10	1	193.00	83.30	1.16
Nonprecocial	Niagara	Pahsimeroi A	10	41	189.88	77.89	1.10
Precocial	Niagara	Oxbow A	4A	3	217.33	119.63	1.16
Nonprecocial	Niagara	Oxbow A	4A	34	219.15	115.37	1.04
Precocial	Niagara	Oxbow A	4B	1	253.00	187.00	1.16
Nonprecocial	Niagara	Oxbow A	4B	34	202.00	87.39	1.03
Precocial	Magic	Dworshak B	E13A	1	179.00	63.00	1.10
Nonprecocial	Magic	Dworshak B	E13A	26	216.50	104.92	1.00
Precocial	Magic	Dworshak B	E15B	2[a]	202.00	89.00	1.07
Nonprecocial	Magic	Dworshak B	E15B	34	217.47	101.64	0.97
Precocial	Magic	Dworshak B	E16A	2	190.50	76.00	1.08
Nonprecocial	Magic	Dworshak B	E16A	28	226.86	119.43	1.00
Precocial	Magic	Dworshak B	E16B	2	209.50	92.50	0.99
Nonprecocial	Magic	Dworshak B	E16B	38	220.66	106.71	0.98
Precocial	Magic	Pahsimeroi A	W11A	3	204.33	98.67	1.13
Nonprecocial	Magic	Pahsimeroi A	W11A	39	216.79	108.15	1.02
Precocial	Magic	Pahsimeroi A	W16A	4	217.50	121.25	1.16
Nonprecocial	Magic	Pahsimeroi A	W16A	43	230.00	123.64	0.99
Precocial	Magic	Pahsimeroi A	W16B	5	211.20	108.40	1.10
Nonprecocial	Magic	Pahsimeroi A	W16B	43	231.30	127.51	1.01

[a] One precocial male was dropped from analyses.

Figure 1. Percent precocity of male steelhead sampled at Magic Valley Fish Hatchery on April 24, 2000. A total of 599 fish were sampled, with 150 sampled in each of the first three groups and 149 sampled in the fourth group. The first group represents the control group, while the other three groups are the three different treatments.



LITERATURE CITED

Bachman, R. A. 1984. Foraging behavior of free ranging wild and hatchery brown trout in a stream. Transactions of the American Fisheries Society 113:1-32.

Barnes, M. E. 1994. Effects of coded-wire tags on feed conversion in rainbow trout. The Progressive Fish-Culturist 56:291-292.

Buckley, R. M., and H. L. Blankenship. 1990. Internal tags and marks. Fish-Marking Techniques, American Fisheries Society Symposium 7:173-182.

Elrod, J. H., and C. P. Schneider. 1986. Evaluation of coded-wire tags for marking lake trout. North American Journal of Fisheries Management 6:264-271.

Fletcher, D. H., F. Hall, and P. K. Bergman. 1987. Retention of coded-wire tags implanted into cheek musculature of largemouth bass. North American Journal of Fisheries Management 7:436-439.

Habicht, C., S. Sharr, D. Evans, and J. E. Seeb. 1998. Coded-wire tag placement affects homing ability of pink salmon. Transactions of the American Fisheries Society 127:652-657.

Hasler, A. D., and A. T. Scholz. 1983. Olfactory imprinting and homing in salmon. Zoophysiology. Springer-Verlag, Berlin Heidelberg New York Tokyo.

Miller, R. B. 1958. The role of competition in the mortality of hatchery trout. Journal of the Fisheries Research Board of Canada 15:27-45.

Moore, B., D. May, K. Hills, and M. Olson. 1998. Magic Valley Hatchery 1996 brood year report. Idaho Department of Fish and Game, Boise, Idaho.

Morrison, J., and D. Zajac. 1987. Histologic effect of coded-wire tagging in chum salmon. North American Journal of Fisheries Management 7:439-441.

Newman, R. L. 2002. Steelhead Volitional Release Experiment Squaw Creek Pond, Idaho. 2000 Project Progress Report. Idaho Department of Fish and Game, Idaho.

Quinn, T. P., and C. Groot. 1983. Orientation of chum salmon *Oncorhynchus keta* after internal and external magnetic field alteration. Canadian Journal of Fisheries and Aquatic Sciences 40:1598-1606.

Ratliff, D. E. 1981. Ceratomyxa shasta: epizootiology in chinook salmon of central Oregon. Transactions of the American Fisheries Society 110:507-513.

SYSTAT 6.0 for Windows: statistics. 1996. SPSS Inc., Chicago, Illinois.

Thrower, F. P., and W. W. Smoker. 1984. First adult return of pink salmon tagged as emergents with binary-coded wires. Transactions of the American Fisheries Society 113:803-804.

Vincent, E. R. 1987. Effects of stocking catchable-sized hatchery rainbow trout on two wild trout species in the Madison River and Odell Creek, Montana. North American Journal of Fisheries Management 7:91-105.

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