An evaluation of two different feeding methods for controlling growth of steelhead reared at a constant water temperature

Summary Report

Brood Years 1996 - 1999

prepared by the

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INTRODUCTION

Summer steelhead at Hagerman National Fish Hatchery (NFH) are reared from eyed-eggs to smolts during a 10 to 11 month growth program in 15^{0}C spring water. Prior to 1999, the target size for fish at distribution was 210 to 218 mm in length (4.5 fish per pound) based on the '*Proposed Recovery Plan for Snake River Salmon'* (Recovery Plan) by the National Marine Fisheries Service (NMFS 1995). The Recovery Plan recommended all steelhead released in the Snake River Basin be between 170 and 220 mm total length. That size range was established to reduce impacts of hatchery steelhead on wild fish. Smaller steelhead have a higher tendency to residualize (Bigelow 1995; Whitesel *et al*.1993; Jonasson *et al*.1994; and Jonasson *et al*.1995) which might lead to competition with the wild fish. Larger steelhead also have a higher likelihood of preying on wild stocks (Parkinson *et al.* 1989). Further data analysis by the Idaho Department of Fish and Game (IDF&G) suggested that the maximum allowable release size should be increased (Rhine *et al.* 1997). Based on this and other information, NMFS modified their recommended steelhead release size range to 180mm - 250mm TL (NMFS 1999).

Conventionally, steelhead at Hagerman NFH are fed continuously throughout the rearing period using a monthly feeding program based on the hatchery constant (HC) method (Piper *et al.* 1982). If steelhead at Hagerman NFH are fed at optimum levels using HC, mean length at distribution generally exceeds the recommended release size range. To meet the size requirement for smolt release, it is necessary to implement a feeding rate less than the optimum. However, feeding a reduced daily ration may exacerbate variation in fish length (Kindschi 1988). Although a mean target size of 180 to 250 mm in length could be obtained, the percentage of fish above and below the target size range may be unacceptable based on recommendations in the Recovery Plan. Intermittent feeding programs have been used to control growth rates for fish and may be preferred to a program that uses a reduction in the daily ration (Smith 1987; Kindschi 1988; Klontz *et al*. 1991). With an intermittent feeding program, fish are fasted for a period of time. After the fasting period, fish are fed full rations for an equivalent period of time.

During the 1995 rearing cycle, Hagerman NFH conducted a pilot study using an intermittent feeding regimen to control the growth rate of steelhead. Steelhead were fasted for 15 days (d) and then fed 30 d rations in the succeeding 15 d period using demand feeders. This program was successful in reducing steelhead growth rate resulting in their size being about one month behind steelhead fed continuously. However, there was some concern that the intermittently fed fish may have been adversely affected by the feeding program.

Our objective was to compare the effects of an intermittent feeding program with a continuous feeding program in relation to fish growth, fish health, smolt emigration rates, and adult return rates. The continuous feeding program was designed to reduce growth by reducing daily rations using the HC method This study began with brood year 1996 (BY96) and was completed with brood year 1999 (BY99). This report summarizes the general results from all four years of the evaluation and includes the final conclusions and recommendations of the Hatchery Evaluation Team. Progress reports for each individual brood year are available for those readers interested in detailed methods or specific data (Idaho FRO 1998, 1999, 2000, 2002). The reports can be obtained by contacting the Hagerman National Fish Hatchery or the Idaho Fishery Resource Office.

The results of this study suggest that intermittent feeding did not have detrimental effects on the health or quality of released smolts. The current feeding practices at the Hagerman NFH incorporate the intermittent feeding management technique with some modification from the 15 d fast/feed cycle.

METHODS

Six raceways with approximately 20,000 fish/raceway were selected for the feeding trial and were divided into two treatment groups of three raceways per group. Both treatment groups were fed using the HC method (Piper *et al.* 1992) using a Delta L calculated to insure that final mean fish length was within the recommended size-at-release range of the Recovery Plan (NMFS 1995). One treatment group was fed continuously (daily) and the other treatment group was fed intermittently where fish were fasted for 15 d and then fed to satiation during the next 15 d period. This fasting/feeding cycle was repeated three times, for a total of three 30 d feeding trials. Rations were administered to all groups using demand feeders. For the group fed intermittently, any food remaining in the demand feeders at the end of the 15 d feeding period was removed, weighed, and subtracted from the total. Other fish culture practices were the same for the two groups. The feeding trial was conducted in the upper deck (first-use water) of the steelhead raceways at Hagerman NFH.

The evaluations started the 1st or 2nd of December each year, except in 1999 when trials were started on November 23rd. Trials ended by the 1st or 2nd of March each year except for 1999 when activities were concluded on February 28. After the conclusion of the trials, all groups were put on a continuous feeding schedule until the smolts were transferred to Sawtooth Fish Hatchery for release. The continuous feeding program during that period was designed to ensure that mean size at release reached the range recommended by the Recovery Plan (NMFS 1995).

In assessing the effects of the treatments, growth, fish health, fin quality, emigration success of smolts after release, and returning adults were evaluated. Length frequency distributions were examined to determine how well the program conformed to the size at release criteria established by NMFS for hatchery steelhead. A number of response variables were monitored during the four year period of the study to evaluate these characteristics. However, not all the variables were monitored every year and in some cases the variables were not monitored using the same procedure every year. Several variables were dropped after the first year and others were added during the second year. Only those variables that were monitored for three of the four years will be included in this summary. Appendix I lists all the variables that were monitored during the course of the study and the brood years that were involved.

RESULTS

Growth

Fish growth was the primary variable targeted for evaluation. However, growth can be expressed in a variety of ways. Therefore, fish length, instantaneous growth and condition factors were selected to help focus the analysis. Length frequency was also examined to determine the effects of feeding method on the range of fish sizes at release time.

Fish Length

Total lengths of steelhead were measured in all the experimental groups: 1) prior to the study to obtain baseline information, 2) at the end of each 30 d trial and 3) and prior to the fish being transferred to Sawtooth Hatchery for acclimation and release (**Figure 1**). At baseline, mean total lengths of the intermittently fed groups were significantly smaller ($P<0.01$) in 1996, were significantly larger ($P<0.01$) in 1997, and were not significantly different ($P>0.05$) in 1998 or 1999 than those of the continuously fed groups. Overall, the intermittently fed groups were significantly smaller ($P<0.01$) than the continuously fed groups at the end of each feeding trial and by the end of the study period. However, there were no significant differences ($P>0.05$) in mean total lengths between the two treatment groups by the end of the grow-out period prior to the fish being transferred to Sawtooth Hatchery. The mean size at release for every group was within the NMFS's recommended size range for release, every year.

Mean, variance, minimum, maximum and ranges of steelhead lengths are reported in **Table 1**. During BY96-97, length frequencies were taken during PIT tagging operations on 26 Feb, 1997 and 25 Feb, 1998 respectively. During BY98-99, length frequencies were collected in April prior to release during mid-April. Hence, the mean lengths and ranges were lower for BY96-97 than BY98-99. Steelhead ranged from 101 – 296 mm over the study period. The length variances for each brood year are depicted in Figure 2. Significant differences ($P<0.05$) in length variances were determined using a one-tailed, two sample F-test for variances. BY97 and BY99 intermittent and continuously fed treatments had significantly different length variances. However, BY97 continuously fed fish had a lower variance than intermittently fed fish and BY99 continuously fed fish had a higher variance than intermittently fed fish.

Instantaneous Growth

Instantaneous growth was evaluated for BY97 - BY99. In all three years, the continuously fed group had significantly higher ($P<0.05$) instantaneous growth rates than the intermittently fed group during the trial period from December through February. However, during the grow-out period the intermittently fed group had a significantly higher ($P<0.05$) instantaneous growth.

Condition Factors

Condition factors were monitored and compared between treatment groups for BY97 - BY99. Condition factors were calculated for individual fish and were used to calculate the mean condition factor of each treatment replicate. Replicate means were then used to determine significant differences ($P<0.05$) between treatments. Comparisons were made prior to the start of the first trial period to establish baseline conditions, at the end of each 30 d trial period, and at the end of the grow-out period just before the fish were transferred to Sawtooth Hatchery.

Feeding method did not have any significant effects ($P>0.05$) on condition factor. The only significant difference observed was for BY97 at the end of the grow-out period where the intermittently fed group had a significantly greater ($P<0.05$) condition factor than the continuously fed group. Otherwise, no significant differences ($P>0.05$) were observed between treatments at any time for any brood year.

Proximate Analysis

Energy content was evaluated by proximate analysis to determine moisture, protein, lipid, and ash content as an indirect measure of growth. Analyses were performed at the Hagerman Fish Culture Experiment Station. Specific techniques and methods were detailed in the individual progress reports for BY96 - BY99 (Idaho FRO 1998, 1999, 2000, 2002).

Samples were collected for analysis before the feeding trial to establish baseline levels. Samples for BY96 and BY97 were collected the end of each 15 d fasting period (once every 30d feeding cycle). Samples for BY98 and BY99 were collected every 15 days (twice every 30 d feeding cycle). Samples were collected at the time of release for BY98 and BY99.

A few inconsistencies between sample years occurred. The baseline samples collected for the BY96 continuously fed group were mistakenly discarded before the assays were completed. All conditions were relatively equal between the intermittently and continuously fed groups prior to the trial beginning, so it would be reasonable to assume that the results of the baseline proximate analyses for both groups would have been the same. However, no statistical comparisons were made for the baseline sampling period that year. Percent moisture content was not monitored for BY97, thus the analysis for this variable was recorded for only three years, BY96, BY98, and BY99. Percent ash was monitored only for BY96 and BY97, so analysis for this variable was not included.

<u>Mean Percent Moisture</u>

The baseline levels of percent body moisture were not significantly different ($P>0.05$) between the intermittently and continuously fed groups for BY98 and BY99. Results for the actual feeding trial period were similar for BY96 and BY99 in that the intermittently fed group exhibited significantly higher ($P<0.05$) levels of percent body moisture than the continuously fed group, indicating a lower rate of growth. However, for BY98, no significant differences ($P>0.05$) were observed between the two groups. At the time of release, the BY98 groups exhibited no significant increase (P>0.05) while the BY99 groups exhibited a significant decrease (P<0.05) in percent body moisture.

Mean Percent Lipid

The baseline levels of percent body lipid were not significantly different (P>0.05) between the intermittently and continuously fed groups. During the feeding trial, BY96 and BY97 exhibited decreasing percent body lipid level with the intermittently fed group being consistently, but not always significantly, lower than the continuously fed group. BY98 exhibited no consistent changes and although lipid levels of both groups were lower at the end of the trial it was not significant (P>0.05). The BY99 groups exhibited opposite trends, with lipid levels in the intermittently fed group decreasing while lipid levels of the continuously fed group increased. At the time of release, neither the BY98 intermittently or continuously fed group exhibited a change in percent body lipids from the end of the feeding trial and only a slight decrease from the beginning of the trial. However, the BY99 intermittently fed group exhibited a significant increase in percent body lipid by the time of release and the continuously fed group had a slight, but not significant decrease (P>0.05).

Mean Percent Protein

The continuously fed group exhibited a variable mean percent protein between years. BY96 and BY97 exhibited no appreciable changes over the course of the study, while BY98 and BY99 exhibited gradual increases by the time of release. With the exception of the BY96, the intermittently fed groups exhibited some variation between feeding cycles having slightly increased from baseline levels at the time of release. Except for BY96, there were no significant differences (P>0.05) between the two treatment groups.

Fish Health

Fish health was monitored all four years. Monthly samples were taken in conjunction with the regular hatchery fish health monitoring to assess bacterial, viral, and parasitic infections. A quantitative fish Health Assessment Index (HAI), (Goede and Barton 1990; Adams *et al.* 1993) was used to determine general fish health and condition before the evaluations began and again prior to fish transport to the Sawtooth Fish Hatchery (FH) for release. However, BY96 was only assessed at the end of the study. Dorsal fin erosion was evaluated using an index of dorsal fin height to fish length.

Monthly Fish Health Monitoring

No bacterial, viral, or parasitic infections were detected in any of the study groups before, during, or after the completion of the feeding trial.

Health Assessment Index (HAI)

The results were not altogether consistent from year to year. BY96 and BY97 had no significant differences (P>0.05) in the HAI values between treatment groups prior to release and BY97 exhibited no significant difference (P>0.05) between the treatment groups prior to the study beginning. For BY98, there was no significant difference (P>0.05) between the treatment groups prior to the trial beginning. However, at the end of the trial, the Intermittently Fed group had a significantly higher HAI value than the Continuously Fed group. For BY99, the Intermittently Fed group had a significantly higher HAI value than the Continuously Fed group prior to the trial beginning, but by the end, there were no significant differences between the groups.

For BY97 and BY98, mean HAI values were lower at the end of the trial period than at the beginning. However, for BY99, just the opposite was observed. Decreased dorsal fin erosion accounted for most of the HAI values in most years and overall, the fish in both treatment groups were in good overall health.

Dorsal Fin Erosion

Dorsal fin erosion was monitored for three years, BY97 - BY99, using the ratio of dorsal fin height (Kindschi 1987) and total fish length as an index. Sampling was conducted at the beginning of the study, at the end of each 15 d feeding cycle, and at the completion of the study. BY97 and BY98 exhibited decreased fin erosion while BY99 had increased fin erosion. There were no significant differences (P>0.05) in dorsal fin erosion between intermittently fed and continuously fed groups during the monitoring period.

Behavior

It was noted during BY96 that steelhead fed intermittently exhibited periods of listlessness during their fast periods. Fish hovered near the bottom of the raceway and on the tailscreens. They also developed a fright response to people who approached the raceway. Continuously fed fish did not exhibit periods of inactivity and did not develop a fright response to people.

Length Frequency Distributions

Length frequency distributions for all four brood years were constructed in order to determine how well both treatment groups had conformed to the size at release criteria established by NMFS for hatchery steelhead. However, data for constructing the length frequency distributions was not collected consistently all four years at the time fish were transferred from Hagerman NFH to Sawtooth FH, making interpretation and evaluation complicated.

The length frequency distributions for BY96-BY99 are depicted in **Figures 3** to **6**, respectively. Very little observable differences were seen between the Continuously and the Intermittently fed treatments during all four years, demonstrating that the Intermittent feeding method is as effective as the Continuous feeding method, in terms of their effects on length frequency. For BY96, the distribution of the Intermittently fed group was shifted just slightly to the left of the Continuously fed group because of there slightly smaller size. For BY97, the shapes of the distributions were nearly identical, except the Intermittently fed group had a slightly wider distribution than the Continuously fed group. For BY98-BY99, the distributions were nearly identical in shape and location.

In relation to the size at release criteria established by the NMFS for hatchery steelhead, the results are difficult to depict for BY96 and BY97, since actual lengths were not measured at the time the fish were transferred from Hagerman NFH to Sawtooth FH. In the case of BY96, actual length frequency data were collected on March 10 while the fish were transferred to Sawtooth FH on April 3 and 4, 1997, about three weeks difference in time. For BY97, actual length frequency data were collected on March 26 while transfer to Sawtooth FH occurred from March 31 to April 2, 1998, about 5-7 days difference in time. For this reason, growth that occurred during the interim period probably affected the position and shape of the length frequency distribution by the time fish were transferred off station, especially for BY96. For both BY98 and BY99, length frequency data was collected within one to three days prior to transfer to Sawtooth FH, so differences due to growth would probably be negligible.

In order to provide some consistent means of comparing results between years, the mean length at the time of transfer from Hagerman NFH to Sawtooth FH was extrapolated based on the number of fish per pound measured at that time. These means are compared to the mean lengths calculated from the lengths measured to construct length frequency distributions **Table 2**. Differences in mean lengths of the treatment groups varied somewhat between years, but generally were very similar. (A greater degree of variability here is probably due to the fact that the fish were not transferred from Hagerman NFH to Sawtooth on the same dates every year. There was about 12 d difference between the transfer of BY97 and BY99). Given this similarity, it is not unreasonable to assume that the final length frequency distributions for BY96 and BY97 at the time of transfer would not be considerably different that those of BY98 and BY99. The percentage of fish below NMFS's lower limit for size at release (180 mm) ranged from 4 to 7%, while the percent of fish above NMFS's upper limit for size at release (250 mm) ranged from 12 to 16% (**Figures 5 and 6**).

Smolt Emigration and Survival

Passive Integrated Transponder (PIT) tags (Prentice *et al.* 1990) were used to evaluate summer steelhead smolt emigration and survival to Lower Snake River dams. Successful passage of fish through the Snake and Columbia river basins was monitored via the PTAGIS database system (Pacific States Marine Fisheries Commission 1994). Monitoring was conducted at Lower Granite, Little Goose, and Lower Monumental dams on the Snake River and at McNary Dam on the Columbia River. In-river survival to Lower Granite Dam was estimated using the Cormack/Jolly Seber mark-recapture method (Smith *et al.* 1994).

There were no significant differences ($P>0.05$) in either travel time or PIT-tag detection rates between the two treatment groups for all four years. There were also no significant differences ($P>0.05$) in in-river survival between the two treatment groups except for BY99, where the intermittently fed group had a significantly higher rate of survival to Lower Granite Dam than the continuously fed group.

For BY96, there were no significant differences ($P>0.05$) in travel time or PIT-tag detection rates between the two treatment groups. Estimated in-river survival was slightly higher for the continuously fed group, but the difference was not significant. For BY97, there were no significant differences in travel time, PIT-tag detection rates or estimated in-river survival. For BY98, there were no significant differences ($P>0.05$) in travel time, PIT-tag detection rates or estimated in-river survival. For BY99, there were no significant differences ($P>0.05$) between the two treatment groups for either travel time or PIT-tag detection rates. However, the intermittently fed group had a significantly higher ($P<0.05$) estimated in-river survival to Lower Granite Dam than the continuously fed group.

Adult Returns

Adult returns were analyzed by monitoring coded-wire tag (CWT) returns to the basin. All steelhead in both treatment groups received a CWT in October or November for all four years. Tags were coded by raceway so that there were three separate codes for the three continuously fed raceways and three separate codes for the three intermittently fed raceways. Tag return data were obtained from the adult rack returns at Sawtooth FH operated by the IDF&G. Adult return rates were calculated by dividing the number of returning adults for each tag code by the number of tagged fish released and multiplying by 100.

Steelhead adult return rates varied greatly from year to year, averaging 0.08 for BY96 to 0.53 for BY99 (**Table 3**). However, variability in return rates within brood years was very low even across treatments. **Table 4** lists the mean and standard deviations for return rates. The intermittently fed groups consistently had higher mean return rates than the continuously fed groups, but the differences were not significant ($P>0.05$).

DISCUSSION

Summary

The objective of this study was to determine if an intermittent feeding approach could slow the growth of steelhead at the Hagerman NFH without detrimental effects on the health or quality of released smolts. We examined fish growth, fish health, smolt emigration rates, and adult return rates of intermittently and continuously fed fish during BY96-99. The results suggest that an intermittent feeding program did not have detrimental effects on the health or quality of released smolts, while reasonably meeting NMFS's criteria for size at release. The current feeding practices at the Hagerman NFH incorporate the intermittent feeding management technique with some modification from the 15 d fast/feed cycle.

Intermittently fed steelhead consumed fewer total pounds of feed, grew at a slower rate, and ended the trial periods at a smaller size and condition factor than the continuously fed steelhead. However, once the intermittent steelhead were given full rations for their final month before release, they exhibited a higher growth rate and left the station at approximately the same length and condition factor as the continuously fed group. Length variability and range between continuously fed and intermittently fed treatments did not exhibit a consistent pattern throughout the study period. Intermittently fed treatments had a significantly greater variability during BY97 and a lower variability during BY99 than continuously fed treatments. This result is similar to the contradictory findings of previous studies. Kindschi (1988) found that intermittently fed fish had lower length ranges, but Klontz et al. (1991) did not find significant differences in size variations between fish fed continuously and those fed intermittently.

Condition factors for intermittently and continuously fed fish were similar at time of release except for BY97 where intermittently fed fish had a higher condition factor than continuously fed fish. It is our belief that the condition factors were similar due to the period of continuous feeding prior to release). For this study, condition factors were managed for consistency at stocking. However, future intermittent or reduced feeding strategies may consider reduced feeding during the last month prior to release rather than a catch-up month prior to release (Tipping and Byrne 1996).

The proximate analysis results were similar between the intermittently and continuously fed groups immediately prior to release after the period of continuous feeding. However, lipid levels of the intermittently fed group were consistently the same or lower throughout the study and moisture levels were the same or significantly higher than continuously fed groups. This suggested that the dietary restriction in the intermittently fed groups was sufficient to reduce body fat reserves during some brood years. However, most of these lipid / fat reserves were recovered during the month prior to release when feeding resumed at continuous levels. Percent protein did not exhibit significant trends at the time of release. The results of the proximate analysis and lipid concentrations suggest that body fat levels of the fish could be manipulated at times by using an intermittent feeding strategy. The ability to manipulate body fat could be used to mimic the body fat composition of wild smolts. Other wild anadromous fish have been shown to have lower muscle lipid levels than their hatchery counterparts derived from the same parent population (McDonald et al. 1998).

The general health of steelhead as measured by the quantitative HAI, did not appear to be adversely affected by either feeding method. Differences in HAI values were not significant at the start or end of the trials. No bacterial, viral, or parasitic infections were detected in either treatment group before, during, or after completion of the feeding for BY96-99. Additionally, no differences in dorsal fin indexes were found between intermittently and continuously fed fish. This result was similar to Kindschi (1988) and Klontz et al. (1991) who also did not find differences in dorsal fin erosion between feeding regimes.

Fish fed using the Intermittent feeding method have similar length frequency distributions as those fed using the Continuous feeding method in terms of meeting the NMFS's criteria for size at release. Mean size at the time of transfer of smolts from Hagerman National NFH to Sawtooth FH was consistently at or below the mid-point (215 mm) of the NMFS's size range (180 to 250 mm) for hatchery steelhead smolts, exceeding it only once by 1 mm for BY99.

Despite every effort to keep growth within the acceptable limits for the range of size at release, the upper and lower limits were exceeded all four years, especially the upper limit. This is not surprising considering the warmer spring water used for production at Hagerman NFH.

Smolt emigration as measured by travel time and survival to downstream dams was unaffected between feeding methods. Adult returns were also unaffected by feeding regime. The similarity of smolt emigration and adult returns between treatment groups suggest that intermittently fed steelhead were equally successful as the continuously fed steelhead during this four year study. The result could be expected because the steelhead smolts left the hatchery at nearly the same condition factor, length, and health condition. The differences in feeding practices during the rearing period did not have an effect on the ultimate adult return rates. Hence, intermittent feeding programs may be beneficial for reducing growth without affecting returns.

An additional benefit to intermittent feeding was realized during feeding and cleaning activities. During intermediate feeding, half of the raceways were fed for 15 d and the other half were fed the subsequent 15 d. During the fast period, there was no build-up of waste that needed to be cleaned from the raceways. Thus, Hagerman NFH realized some savings in time and human resources, but these savings were not quantified. A time and labor savings was also noted by Kindschi (1988) and Klontz et al. (1991). This economic benefit may be important to the decision of implementing an intermittent feeding program.

During the study, the majority of Hagerman NFH raceways in steelhead production were fed intermittently. During every 15 d fast period, approximately half of those raceways were off feed. It was noted that solids in the effluent water were reduced when only half of the raceways were being fed. We suspect that lower solids in the effluent water was likely the result of less raceways receiving feed per day even though the amount of feed for the entire system was similar. Each raceway of fish would likely suspend a similar amount of solids that would not settle in the quiescent zone regardless of the quantity of feed delivered. Hence, reducing the number of raceways being fed during a day reduced the solids effluent into the receiving waters.

Although intermittently fed steelhead were nearly identically in quantifiable measures, they did exhibit behavior differences during the fast cycles. Periods of quiescence and listlessness were observed and fish dropped out of the water column and hovered near the bottom of the raceway and on the tailscreens. The intermittently fed fish also developed a fright response toward anyone that approached the raceway. This was similar to observations reported by Smith (1987) who observed steelhead entering a “non-feeding mode” during extended fasting periods. The continuously fed fish did not exhibit quiescent periods of inactivity or develop a fright response. This fright response may have also affected feed conversion rates for intermittently fed fish. Feed conversion rates calculated in BY98 and 99 were higher for intermittently fed fish than continuously fed fish. This was similar to Kindschi’s (1988) findings that fish fasted for 4 weeks and fed 4 weeks had the poorest food conversion and Smith (1987) who reported that efficiency declined during longer than 4 d fast cycles. The poorer food conversions could be attributed to wasted feed during the satiation feeding period (overfeeding) or uneaten feed from the fright response exhibited during feed distribution activities on the raceway walls.

The objective of this study was to determine if an intermittent feeding approach could reduce the growth of Hagerman NFH steelhead without detrimental effects on fish health or quality of released smolts. From the four years of data collected, we can conclude that the intermittent feeding strategy used was successful at reducing fish growth without detrimental effects. Quantifiable fish health factors remained the same, and smolt emigration and adult return rates were unaffected by the feeding regime. Additionally, a labor savings was realized with intermittent feeding. However, extended periods of listlessness, a fright response to people, and poorer feed conversion ratios offset some of the benefits of the intermittent feeding strategy.

Managers attempting to implement an intermittent feeding program would benefit from additional biological and economic research. Future research should address the optimal feeding and fasting periods, quantify labor savings, and examine the cost/benefit ratio of reduced labor costs and poorer feed conversions. Additional research is needed to determine if intermittent feeding during the last month of rearing could capture some of the benefit of increased emigration rates of lower condition factor fish as in Tipping and Byrne (1996).

Current Practices

The intermittent feeding program was successful at reducing steelhead growth without detrimental effects to fish growth, health, and quality. The program also had the added benefit of increased savings in time and human resources. However, the Hagerman hatchery staff decided to modify the intermittent feeding protocol to a less extreme fasting period for steelhead rearing because of the extended periods of listlessness and the poorer feed conversion ratios. Since steelhead returns were unaffected by feeding strategy, the Hagerman hatchery staff felt that they could further manipulate the feeding strategy without any detrimental affects to steelhead return rates. The current feeding strategy uses a staggered approach where fish in half the total raceways are feed on day one and day three each seven day period (1-3/7). The remaining half of the raceways are feed the same schedule one day later in the seven day period.

During early rearing, steelhead are grown to a minimum of 100 mm at near satiation feeding according to recommendations by Klontz et al. (1991). Steelhead are fed with demand feeders once they have reached 100 mm and are accepting 2.5 mm extruded feed. Reduced rations are administered from November through March after fish are split into final rearing raceways to meet target release goals. At this time, 1,3/7 intermittent feed schedule is used to reduce feeding, cleaning, and fish stress caused by walking on the raceway walls.

In the 1,3/7 intermittent feed schedule, weekly steelhead reduced rations are calculated using a HC with the appropriate daily growth rate required to reach the target release length at the projected release date. One week worth of feed is split into a four-day ration and a three-day ration. The four-day ration is administered on Monday in demand feeders and is generally consumed during the 24-hour period following feeding. The three-day ration is administered on Thursday and again is generally consumed during the 24-hour period following feeding. Hence, the steelhead are fed on Monday, fasted for two days (Tuesday and Wednesday), feed again on Thursday, and fasted for three days (Friday, Saturday, and Sunday) resulting in a 1,3/7 intermittent feed schedule. Appendix II outlines the intermittent feeding schedule at the Hagerman NFH.

To lower the solids discharge from the facility and meet the National Pollutant Discharge Elimination System (NPDES) requirements, only half of the production raceways are fed the 1,3/7 intermittent feed schedule on Monday. On Tuesdays, the unfed half starts a 1,3/7 intermittent feed schedule that consists of feeding on Tuesday, fasting for two days (Wednesday and Thursday), feeding again on Friday, and fasting for three days (Saturday, Sunday, and Monday). Hence, at any given feeding, only 33 of the 66 production raceways at Hagerman NFH are administered feed during the intermittent feeding period from November through March.

Feeding rates are automatically adjusted weekly for feed conversion and expected temperature-dependent daily length increase using feed spreadsheets. Raceways are sampled inventoried monthly and the HC is adjusted for actual fish growth for a given month. The continuous monitoring ensures that we will meet our target release goals.

Raceway cleaning is also coordinated with the feeding schedule to lower TSS discharge and meet NPDES requirements. The steelhead fed on the Monday 1,3/7 intermittent feed schedule are cleaned on Wednesday and Saturday. The steelhead fed on the Tuesday 1,3/7 intermittent feed schedule are cleaned on Thursday and Sunday. Appendix III outlines the intermittent feeding schedule and cleaning schedule.

The modified intermittent feeding strategy at the Hagerman NFH is successful at reducing fish growth without detrimental effects to fish growth, health, and quality. The current strategy also reduces the listlessness, fright response, and the poorer feed conversion ratios of the 15 d feed and 15 fast intermittent feeding protocol. By carefully administering our intermittent feeding and cleaning protocol, we are able to produce smolts within the recommended size range, minimize fish health problems, meet NPDES requirements, and meet our returning adult mitigation goals.

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TABLES AND FIGURES

Table 1. Mean, variance, minimum, maximum, and range of lengths (mm) of steelhead on intermittently and continuously fed diets at the Hagerman NFH, Broodyears (BY) 1996-1999. BY96-97 lengths were measured in February during PIT tagging operations and BY98-99 lengths were measured in April just prior to the time of release.

	BY96		BY97		BY98		BY99	
	Intermittent	Continuous	Intermittent	Continuous	Intermittent	Continuous	Intermittent	Continuous
Mean	170	186	174	183	213	215	213	214
Variance	377	402	425	380	489	461	652	844
Minimum	118	118	109	108	126	164	128	101
Maximum	223	248	237	247	263	281	275	296
Range	105	130	128	139	137	117	147	195

Table 2. Comparison of mean lengths of the Treatment and Control groups of steelhead based on actual lengths measured for constructing length frequency distributions with mean lengths extrapolated from data collected for estimating the number of fish per pound at the time steelhead were transferred from Hagerman NFH to Sawtooth FH.

Brood Year	Date		Mean Length (mm)	
			Treatment	Control
96	March 10, 1997	(length data)	192	204
	April 3, 1997	(fish per pound data)	207	212
97	March 26, 1998	(length data)	210	211
	March 31 to April 2, 1998	(fish per pound data)	211	207
98	April 6, 1999	(length data)	213	215
	April 7 to 9, 1999	(fish per pound data)	208	208
99	April 12, 2000	(length data)	213	214
	April 13 to 14, 2000	(fish per pound data)	212	216

Table 3. Number and return rate of coded-wire tagged steelhead for intermittent and continuous feeding trials at Hagerman National Fish Hatchery, BY96-BY99.

Brood Year	Treatment	Rearing Container	Tag Code	Number Released	Number of Returns	Return Rate
1996	Intermittent	Rwy 43	10-51-51	20,498	23	.108
		Rwy 44	10-51-52	20,268	12	.058
		Rwy 45	10-51-53	20,038	20	.097
	Continuous	Rwy 49	10-51-57	20,507	16	.076
		Rwy 50	10-51-58	19,792	17	.084
		Rwy 51	10-51-59	19,619	15	.075
1997	Intermittent	Rwy 41	10-44-47	18,337	32	.156
		Rwy 42	10-45-48	17,839	36	.183
		Rwy 43	10-45-49	20,409	25	.118
	Continuous	Rwy 50 and 51[1]	10-45-50 10-46-08	19,891 19,208	16 29	.074 .146
		Rwy 52	10-46-09	20,927	22	.097
1998	Intermittent	Rwy 50	10-52-59	19,171	48	.223
		Rwy 52	10-52-60	19,426	58	.27
		Rwy 54	10-52-63	19,678	41	.189
	Continuous	Rwy 49	10-52-57	18,973	50	.235
		Rwy 51	10-52-58	18,786	56	.263
		Rwy 53	10-52-61	17,807	28	.129
1999	Intermittent	Rwy 42	10-55-21	19,303	129	.613
		Rwy 44	10-55-23	18,149	129	.614
		Rwy 45	10-55-24	20,166	102	.484
	Continuous	Rwy 40	10-55-19	19,437	113	.538
		Rwy 41	10-55-20	19,993	91	.433
		Rwy 43	10-55-22	19,561	101	.481

[1] Steelhead with tag codes 10-45-50 and 10-46-08 were inadvertently mixed in raceways 50 & 51.

Table 4. Mean and standard deviation of adult return rates by brood year for intermittent and continuous feeding trials at Hagerman National Fish Hatchery, BY96-BY99.

	1996		1997		1998		1999	
Treatment Group	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Intermittently Fed	0.088	0.026	0.152	0.032	0.227	0.040	0.570	0.075
Continuously Fed	0.078	0.005	0.105	0.037	0.209	0.071	0.484	0.053

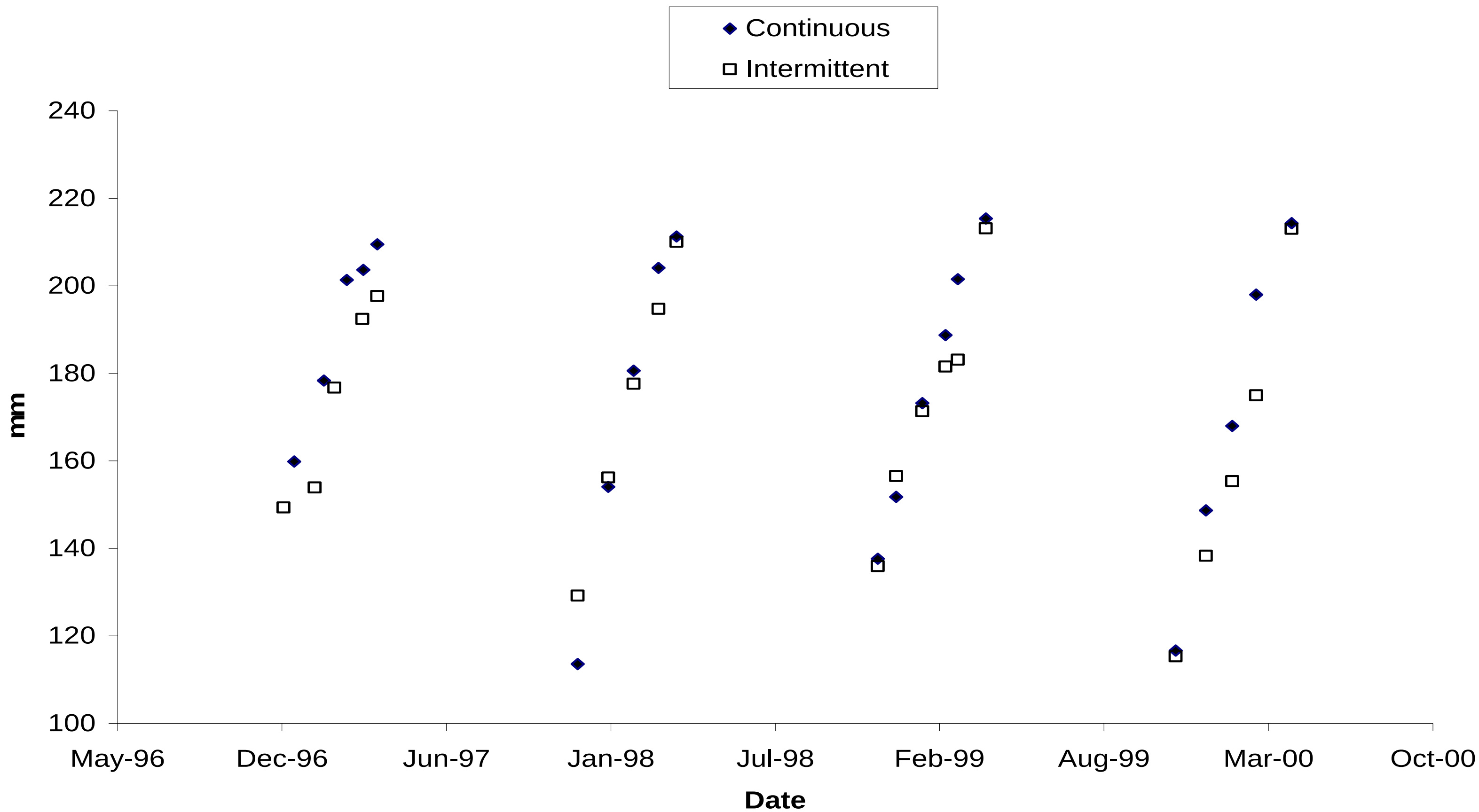

Figure 1. Mean total lengths of steelhead fed continuously and intermittently at the Hagerman National Fish Hatchery, brood years 1996-1999.

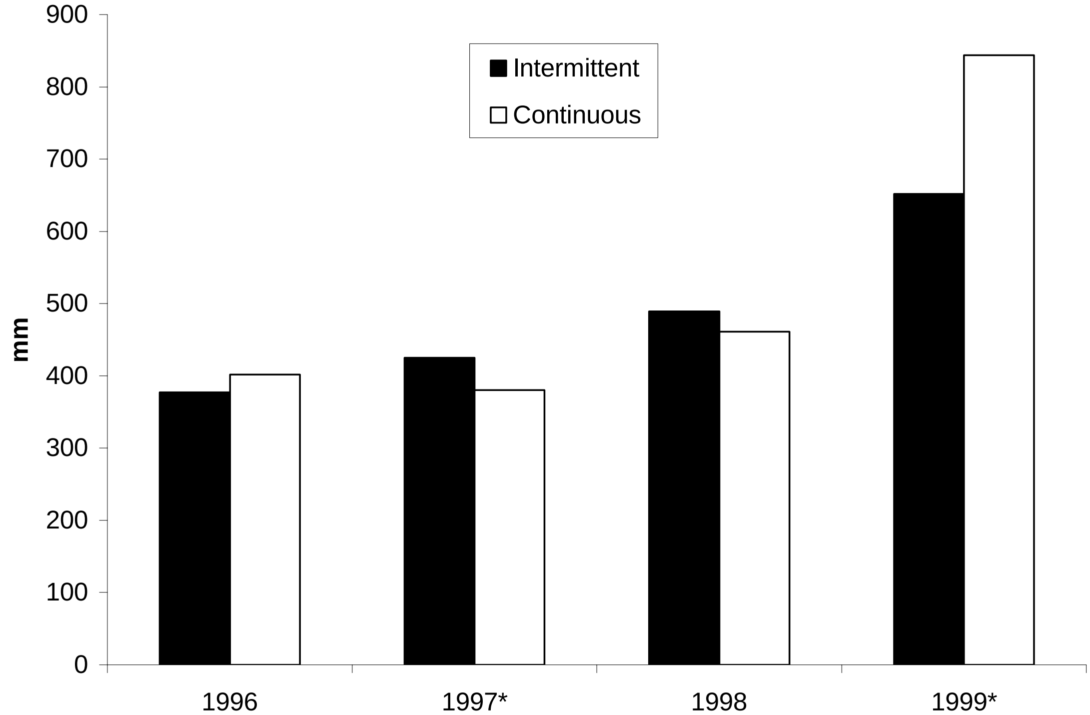

Figure 2. Length variances of intermittently and continuously fed steelhead at Hagerman NFH, BY96-99. Brood years followed by an * indicate periods when intermittently and continuously fed length variances were significantly different ($P<0.05$).

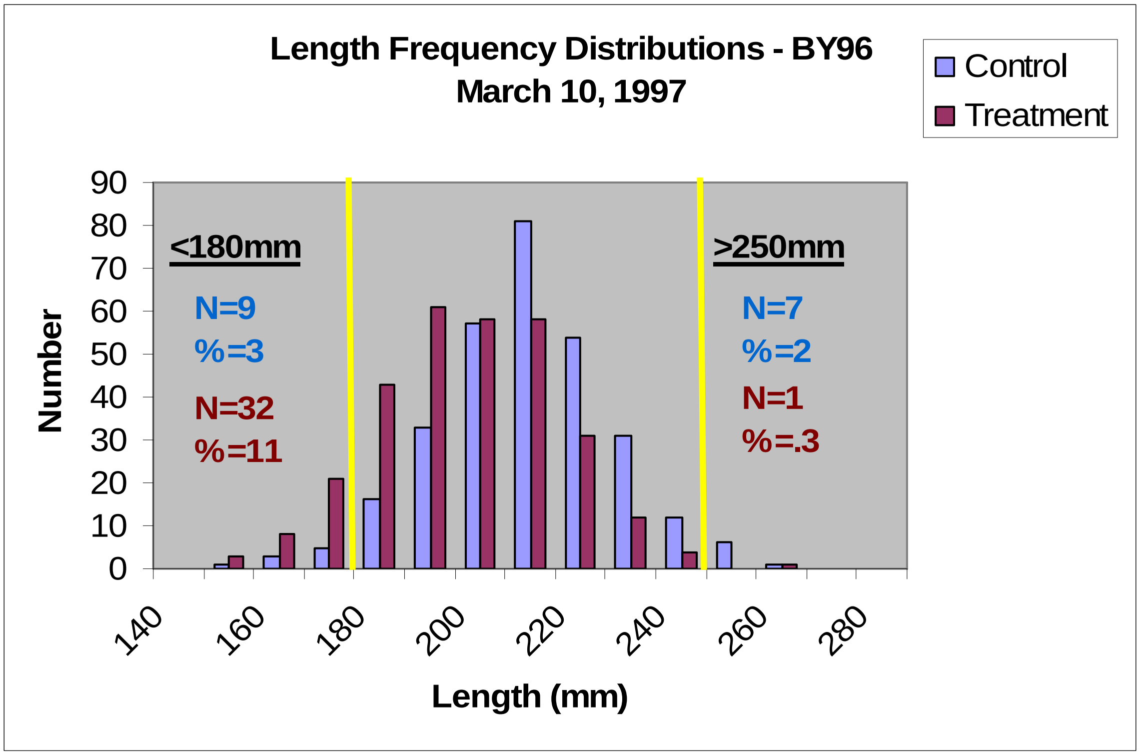

Figure 3. Length frequency distributions of the Continuously (Control) and Intermittently (Treatment) BY96 summer steelhead at Hagerman NFH on March 10, 1997.

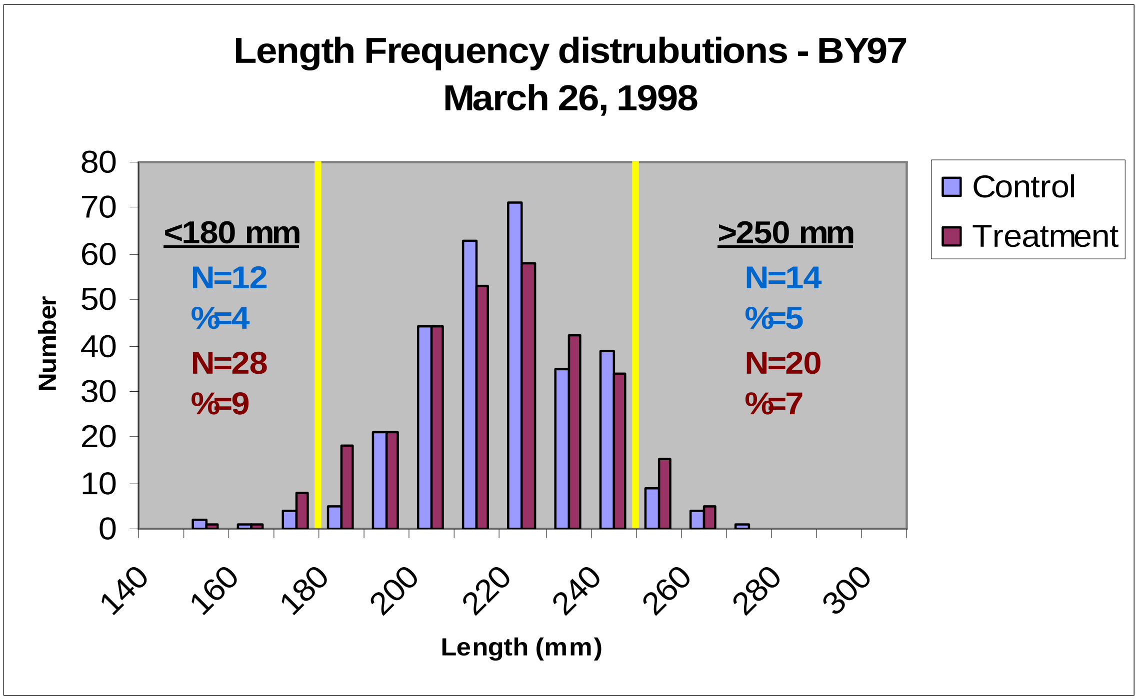

Figure 4. Length frequency distributions of the Continuously (Control) and Intermittently (Treatment) BY97 summer steelhead at Hagerman NFH on March 26, 1998.

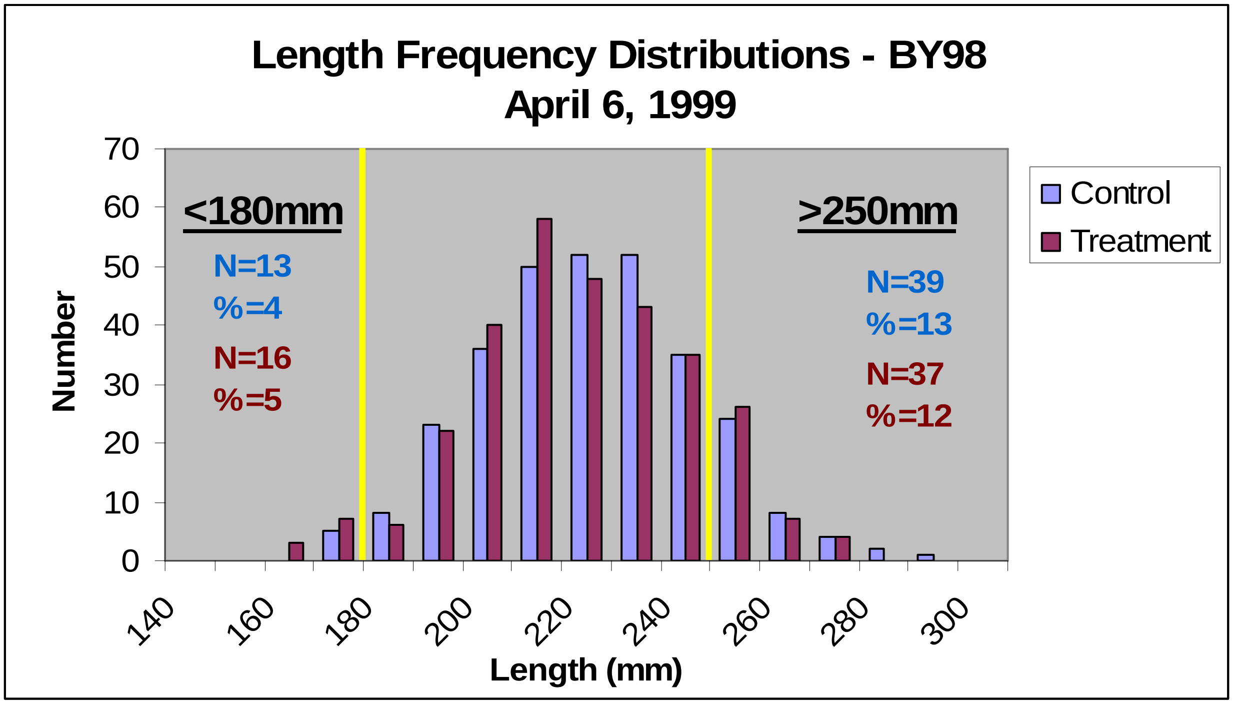

Figure 5. Length frequency distributions of the Continuously (Control) and Intermittently (Treatment) BY98 summer steelhead at Hagerman NFH on April 6, 1999.

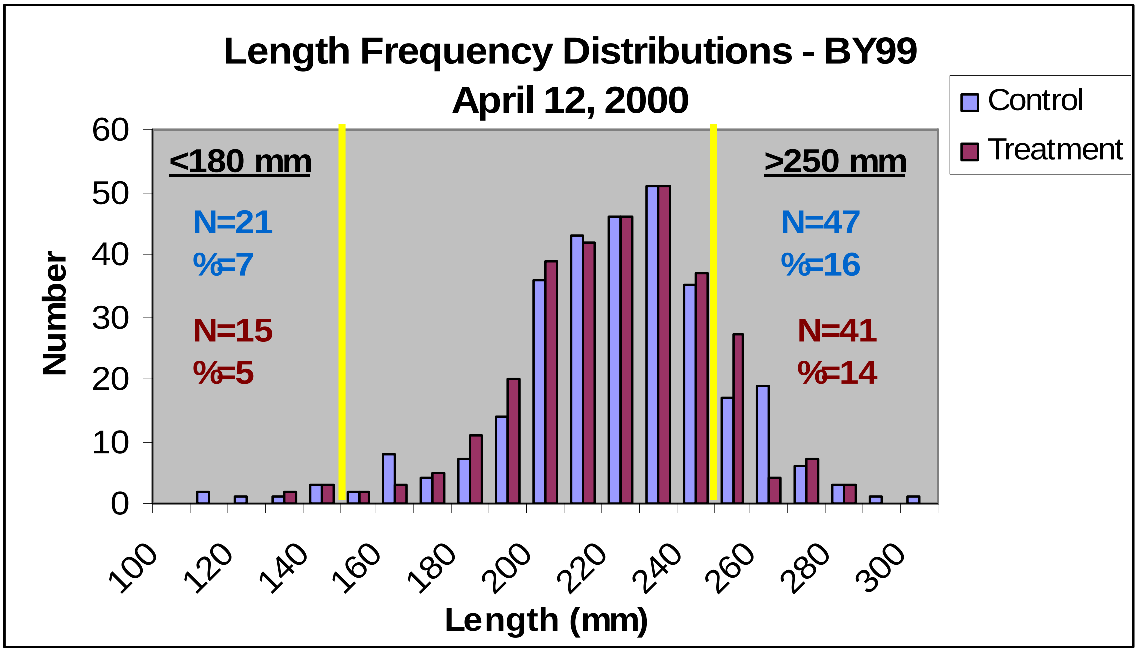

Figure 6. Length frequency distributions of the Continuously (Control) and Intermittently (Treatment) BY99 summer steelhead at Hagerman NFH on April 12, 2000.

APPENDICES

Appendix I. Response variables that were monitored during the four-year evaluation of Intermittent vs. Continuous feeding to control growth in summer steelhead at Hagerman NFH, 1996-1999.

Response Variables	Brood Year			
	1996	1997	1998	1999
Growth				
Mean Length	x	x	x	x
Mean Weight	x	-	-	x
Feed Consumed	-	x	x	x
Liver Somatic Index Growth	x	-	-	-
Instantaneous Growth	-	x	x	x
Condition Factor	-	x	x	x
Plasma Protein	x	-	x	-
Proximate Analysis				
Mean Percent Moisture	x	-	x	x
Mean Percent Lipid	x	x	x	x
Mean Percent Protein	x	x	x	x
Mean Percent Ash	x	x	-	-
Fish Health Examinations				
Viral	x	x	x	x
Bacterial	x	x	x	x
Dorsal Fin Ray Erosion	x	x	x	x
Health Assessment Index	x	x	x	x
Dorsal Fin Index	-	x	x	x
Thermal Stress Index	x	-	-	-
Length Frequency Distributions	x	x	x	x
Smolt Emigration				
Travel Time	x	x	x	x
Smolt Survival / Detection Rates	x	x	x	x
Adult Returns	x	x	x	x

Appendix II. Example of feeding protocol using demand feeders for steelhead smolt production from 120 - 215mm for the Hagerman National Fish Hatchery, 2005.

Steelhead Raceway Feed Chart - Hagerman National Fish Hatchery

Raceway	Feed Size	Mon	Tue	Wed	Thur	Fri	Sat	Sun	Week Total (lbs)
37	4.5mm	400			300				700
38	4.5mm	400			300				700
39	4.5mm	400			300				700
40	4.5mm	400			300				700
41	4.5mm	400			300				700
42	4.5mm	400			300				700
43	4.5mm	400			300				700
44	4.5mm	400			300				700
45	4.5mm	400			300				700
46	4.5mm	400			300				700
47	4.5mm	400			300				700
48	4.5mm		400			300			700
49	4.5mm		400			300			700
50	4.5mm		400			300			700
51	4.5mm		400			300			700
52	4.5mm		400			300			700
53	4.5mm		400			300			700
54	4.5mm		400			300			700
55	4.5mm		400			300			700
56	4.5mm		400			300			700
57	4.5mm		400			300			700
58	4.5mm		400			300			700

Appendix III. Example of feeding and cleaning protocol using demand feeders for steelhead smolt production from 120 - 215mm for the Hagerman National Fish Hatchery, 2005.

Steelhead Raceway Feed Chart - Hagerman National Fish Hatchery									
Raceway	Feed Size	Mon	Tue	Wed	Thur	Fri	Sat	Sun	Week Total (lbs)
37	4.5mm	400	F[1]	F/C[2]	300	F	F/C	F	700
38	4.5mm	400	F	F/C	300	F	F/C	F	700
39	4.5mm	400	F	F/C	300	F	F/C	F	700
40	4.5mm	400	F	F/C	300	F	F/C	F	700
41	4.5mm	400	F	F/C	300	F	F/C	F	700
42	4.5mm	400	F	F/C	300	F	F/C	F	700
43	4.5mm	400	F	F/C	300	F	F/C	F	700
44	4.5mm	400	F	F/C	300	F	F/C	F	700
45	4.5mm	400	F	F/C	300	F	F/C	F	700
46	4.5mm	400	F	F/C	300	F	F/C	F	700
47	4.5mm	400	F	F/C	300	F	F/C	F	700
48	4.5mm	F	400	F	F/C	300	F	F/C	700
49	4.5mm	F	400	F	F/C	300	F	F/C	700
50	4.5mm	F	400	F	F/C	300	F	F/C	700
51	4.5mm	F	400	F	F/C	300	F	F/C	700
52	4.5mm	F	400	F	F/C	300	F	F/C	700
53	4.5mm	F	400	F	F/C	300	F	F/C	700
54	4.5mm	F	400	F	F/C	300	F	F/C	700
55	4.5mm	F	400	F	F/C	300	F	F/C	700
56	4.5mm	F	400	F	F/C	300	F	F/C	700
57	4.5mm	F	400	F	F/C	300	F	F/C	700
58	4.5mm	F	400	F	F/C	300	F	F/C	700

[1] = F = fasting days

[2] = F/C = fasting and cleaning days