FISHERY RESEARCH

ASSESSMENT OF NATIVE SALMONIDS ABOVE HELLS CANYON DAM, IDAHO

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Assessment of Native Salmonids Above Hells Canyon Dam, Idaho

Project Progress Report

2005 Annual Report

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ABSTRACT

The introduction of nonnative species across the West has placed many native populations at risk, but existing methods for controlling nonnative species are usually time-consuming, expensive per unit of treatment, harmful to nontarget species, and often unsuccessful. With two designs, we used different combinations of mature brook trout (single male, a male/female pair, and no fish) as treatments in hoop nets to test differences in catch between treatment and stream locations. We also recorded the amount of time expended in the field and calculated the monetary costs for this removal effort for comparisons to other removal studies. We captured 1,227 brook trout in three study streams. We were unable, however, to detect a difference in the number of brook trout captured attributable to treatments. The calculated cost of the hoop netting effort in 2005 was $7,500, which is comparable to other methods. We were successful in capturing brook trout using hoop nets but did not show any increase in catch with the treatments we tested; however, this method may still be useful, especially if other methods prove undesirable.

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INTRODUCTION

Brook trout have become widely distributed and appear to have replaced many native trout populations in areas they were introduced, including the historical range of Yellowstone cutthroat trout (Behnke 1992). Thurow et al. (1997) reported that brook trout were present in 50% of the interior Columbia River basin watersheds. In an Idaho study within the historical distribution of Yellowstone cutthroat trout, 48% of the sites sampled contained Yellowstone cutthroat trout, 25% contained brook trout, and 18% contained both species (Meyer et al. 2006a). Likewise, Kruse et al. (2000) found that brook trout were present in 26% of all streams sampled and 46% of the streams that contained trout in Wyoming waters. The widespread presence of brook trout and co-occurrence with Yellowstone cutthroat trout is a concern, and managers are looking for ways to control brook trout in their efforts to recover native fish populations.

Existing methods of fish removal have inherent problems that make their use undesirable in certain circumstances. Chemical treatment and electroshocking are currently the most effective methods to remove undesired fish in streams; however, both can be objectionable for several reasons. Chemical toxicants are nondiscriminate in nature and will kill most aquatic species that contact the chemical. The use of chemicals can also be dangerous to workers if undue exposure occurs. Chemicals are difficult to apply thoroughly and often require additional effort to make sure that the distribution is complete (Gresswell 1991). In a social aspect, chemical use is oftentimes not publicly accepted and the administrative procedures to get permission for their use can be complicated (Bettoli and Maceina 1996; Finlayson et al. 2005). Different problems exist for electrofishing. For example, the equipment is oftentimes unable to remove fish from deep pools and heavy cover effectively, and fish commonly fail to be recruited because of size or habitat preferences (Reynolds 1996; Thompson and Rahel 1996; Kulp and Moore 2000).

Experiments performed in 2004 successfully captured brook trout using hoop nets seeded with mature brook trout. Overall, we captured the most brook trout in nets seeded with a mature male/female pair and the fewest with a single male. However, these findings contradicted Young et al. (2003) who found more brook trout were captured in nets seeded with a male. In addition, we discovered that a possible net location interaction was influencing our conclusions in 2004. Although the block design incorporated as a study design answered many questions, some issues about the interaction effects between net location and treatment presented new questions. Addressing these matters, we will perform two independent experiments to determine if one treatment is responsible for capturing more brook trout and test potential interactions. One experiment will entail nets set in multiple streams, and the other experiment will incorporate a three-way repeated measures design in a single stream. We are also reducing the number of treatments to three: 1) a male/female pair, 2) a single male, and 3) none (no fish) instead of five. The two dropped treatments (the single female and three male treatments) captured approximately the same number of brook trout as the related treatments and were therefore redundant. Removing the two treatments will allow greater focus on the treatments that provided the most promising results, address the issue of disagreement with Young et al. (2003), and increase our sample sizes for those treatments.

The two different trapping strategies, one to trap in multiple streams and the other a three-way repeated measures design, will further test differences of effects from treatments and directly identify whether a net location interaction effect exists. These strategies will provide clear results, which will allow us to address the efficacy of using hoop nets seeded with mature brook trout to capture their conspecifics for removal.

The cost-benefit factor is important in optimizing the utility of practically any type of project to ensure that the results are worth the costs involved (Willis and Murphy 1996). Cost evaluation is an important aspect of fish removal projects but is not often reported in a standard manner. The amount of time and money necessary to complete projects removing fish comparing chemicals, electrofishing, and hoop netting would provide an important insight into the effectiveness and success of all three methods . One example of a chemical removal project, Gresswell (1991), acknowledges an entire agency office and 35 volunteers were required in the treatment of Arnica Creek in order to remove brook trout but did report total hours expended. Similarly, Thompson and Rahel (1996) reported that a two-person crew required 62 h to complete three pass depletions on a 1,300 m reach, 114 h on a 2,800 m reach, and 206 h on a 3,600 m reach, or an average of 9.9 worker hours/100 m on several small streams and total removal was not achieved. On a small stream in Great Smoky Mountain National Park, it took a three-person crew 682 h to treat 858 m of stream, or 159 worker-hours/100 m to remove rainbow trout successfully (Kulp and Moore 2000). Meyer et al. (2006b) estimated 2,100 worker hours over a 3-year period were spent removing brook trout from 7,800 m in Pikes Fork (27 worker-hours/100 m) at a cost of over $61,000. Brook trout are also going to be removed from East Threemile Creek using electrofishing equipment as part of another project providing an opportunity to calculate costs of a removal project from the beginning and allow a direct comparison of costs and success between one method and hoop netting in the same stream. We will record the effort expended and calculate the costs of using hoop nets seeded with adult brook trout for comparison between this method and others.

OBJECTIVES

1. Determine the effects of treatment and net location on the number of brook trout captured in hoop nets seeded with three combinations of mature brook trout.

2. Compare the monetary costs of using hoop nets to remove brook trout with costs of other methods.

STUDY AREA

We performed fish removal experiments in three small streams located in northeastern Idaho near the town of Spencer. The streams were East Threemile Creek (ETC), West Rattlesnake Creek (WRC), and East Rattlesnake Creek (ERC; Figure 1). Brook trout are the only fish species present in ETC while brook trout and Yellowstone cutthroat trout are present in both WRC and ERC. All three streams have approximately the same length of fish bearing stream (3-6 km), average width (1.5-3.0 m), and elevation range (1950-2400 m), and they all flow from north to south with limited or no connectivity to other systems. It was necessary to install a weir in ETC to block the study section from emigration of brook trout from a large beaver dam complex below the site; the other two streams naturally disappear into the ground at their lowest extent. All streams are located in the “Sinks” drainages of Idaho, whose streams typically disappear into the surface material of the Snake River plain approximately 50-60 km before reaching the Snake River. Brook trout in ETC have access to the entire watered section of the stream upstream from the weir, while the other two have waterfalls that limit their upstream distribution. All calculated stream lengths account for those barriers. As part of a separate study, brook trout were also removed using electrofishing equipment from ETC before the netting experiment began.

METHODS

Abundance Estimates

In order to estimate the proportion of the brook population removed by hoop nets, we used estimates of trout abundance for ETC, WRC, and ERC that were collected during the summers of 2004 and 2005. Estimates in WRC and ERC were conducted in 2004 as part of a regional sampling program and were repeated in 2005 for this study. By using two consecutive years of data, we were able to account for possible population changes from factors other than treatment effects and compare population numbers before and after brook trout removal using hoop nets in 2004 in ETC. Population estimates were conducted at 12 sites on ETC, nine sites on WRC, and seven sites on ERC for all trout present via multiple-pass electrofishing using Smith-Root backpack electrofishers (Model 15-D). We completed population estimates and density calculations as described in Meyer and Lamansky (2005). We also calculated the percent of brook trout removed for fish ≥100 mm and <100 mm by dividing the number captured in hoop nets by the estimated abundance of both groups in the three streams.

Experimental Design

In order to answer the remaining questions from the previous year, we designed two different experiments. The first design (Experiment 1) entailed using 30 nets placed in three different streams (ETC, WRC, and ERC) to test differences in the number of brook trout captured in hoop nets seeded with the three treatments and to identify the effect from different streams on the number captured. The second design (Experiment 2) was more complex and involved using 30 nets in a single stream (a different section of WRC) where treatments were moved between nets to more directly test if the treatment or the location of the net was responsible for the number of fish captured.

Several aspects of both experiments were identical beginning with identifying hoop net locations before netting. Prior to the start of the experiment, netting sites were identified in the field using the criteria that the site was long enough to contain a net, deep enough to cover the throat, and had moving water. All sites were associated with pools. Either we placed nets at the head or tail-out of the pool depending on which was most suitable. The hoop nets used were the same as those described in Meyer and Lamansky (2005). As net treatments, we used the following mature brook trout: 1) a single male, 2) a male/female pair, and 3) none (an empty net). We captured treatment fish from their respective streams by electrofishing outside the immediate netting area. Gender was identified and treatment fish were placed in nets also using the methods described in Meyer and Lamansky (2005). Every effort was taken to replace treatment fish every three days; however, this was not always feasible because of the lack of suitable fish. Treatment fish in WRC and ERC were changed on average every 3-6 days (±3 days). Conversely, the replacement of treatment fish in ETC was not possible in that time frame because of low catch rates. In no cases were the fish used as treatments moved between streams. When a new treatment fish was placed in a net, we recorded net location, treatment, and date the fish was captured. After netting ceased, fish captured in nets and subsequently used as treatment fish were retained for evaluation in the laboratory to identify gender and properly assign the actual date of capture.

Experiment 1: Multiple–stream removals

The first design incorporates using 30 nets in 30 net locations identified in each study stream (ETC, WRC, and ERC). We randomly assigned ten of each of the three net treatments to locations in each stream. Hoop nets and treatments were installed in WRC, ERC on September 10, 2005, hoop nets in ETC on September 11, and treatments on September 12, 2005. Nets were removed from ETC on October 5 because of low catch rates and from WRC and ERC on October 12, 2005. Personnel checked each net every day. Brook trout captured in hoop nets were anesthetized and frozen for later analysis. In the laboratory, we measured the fish for total length (±1 mm) and mass (±0.01 g). Gender was identified and fish were designated as mature male, mature female, immature male, or immature female. Males were considered mature if gonads were large and milky white and immature if gonads were small and threadlike. Females were considered mature when ovaries contained large, well-developed eggs and immature if ovaries were thin and granular with no developed eggs (Strange 1996). When other species were encountered in nets (Yellowstone cutthroat trout), we recorded the number and net location of capture and released them above the capture net. All Yellowstone cutthroat trout were fin clipped (adipose) to identify recaptures. Net capture data was analyzed using a two-way analysis of variance to test for differences in mean captures by net treatment and stream. We considered the experimental unit as an individual net and the response variable as the total number of fish captured during the netting period. We analyzed capture data for mature males, mature females, immature males, and immature females separately because obvious differences in capture regarding gender were apparent. Capture data were transformed using $\log_e(x + 1)$ in order to equalize the variance across treatments. Statistical analyses were conducted using SAS software (version 9.1, SAS Institute 2005).

Experiment 2: Repeated Measures Experiment

The second experiment was designed as an independent study to allow direct testing of treatment and location effects and any potential interactions between the two factors. This experiment was conducted approximately 1 km upstream from the uppermost net from Experiment 1 and was separated by a high gradient section of stream that most likely limited brook trout movement (J. Lamansky, unpublished data). This second experiment employed the rotation of net treatments between net locations and was performed using 30 net locations. We divided 30 hoop nets into 10 groups of three and randomly assigned the three treatments to the three nets in a group. In other words, there were 10 groups (labeled A-J), each group contained three nets, and within those three nets were three randomly assigned treatments (labeled 1-3). Each treatment remained in its original net for a period of 24 hours; after that time treatments were rotated to the next upstream net within the group. The treatment in the topmost net was moved to the bottom net in the group. Thus, each treatment resided in each net in a group for 24 hours over a three-day period. This was repeated five times for a total of 15 days. The hoop nets and treatments were installed on September 26 using the same methods described earlier and removed on October 12, 2005. Nets were checked daily by personnel; any fish captured were placed in individual bags and labeled with the net group, net number, treatment, and date. Treatments were rotated as the nets were being checked. We attempted to check nets and move treatments at the same time every day so each net treatment remained in a location for 24 hours (±2 hours). On average, it took 2.5 h/day to check all 30 nets with a range of 2–3.5 h, depending on the number of fish captured and replacement of treatment fish. To move treatments, we placed a tube (with the fish inside) into a bucket filled approximately halfway with water and walked them between nets. The tubes were labeled with the treatment, and the datasheets were customized daily to assure the correct treatment was in the correct net on any given day.

Net capture data for this design was analyzed using a three-way repeated measures analysis of variance. The three factors used in the analysis of variance model were net group, net treatment, and location, with time period (3 days) as the repeated measure. The experimental unit was an individual net with a unique treatment in a location within a group over a 24 h period. The response variable was the number of brook trout captured in an experimental unit. We only analyzed mature and immature brook trout instead of separating it further by gender because of inadequate numbers to perform the tests properly. Capture data for this design were also transformed in the same manner as the previous experiment.

Electrofishing Removal

In order to evaluate the effectiveness and compare costs of electrofishing efforts to remove brook trout and measure the effects of hoop netting in 2004 on the population, brook trout were removed from ETC using electrofishing equipment. We included ETC in the hoop netting experiment because of its proximity and availability as a study stream. This allowed us to test the efficacy of using hoop nets to remove brook trout after intensive electroshocking and, therefore, a relatively low density of fish.

We removed brook trout from ETC using Smith-Root backpack electro-fishers (Model 15-D) during two, single pass electrofishing treatments applied during the summer of 2005, approximately one month apart. The first removal treatment was applied July 21-24, the other August 29-31. The stream was divided into two relatively equal length sections, and on both occasions, two crews of two individuals made a single electrofishing pass on one section, or approximately half the stream. One crew began shocking at the weir and continued in an upstream fashion until they reached the point of beginning of the second crew, which began electrofishing on the upstream side of the first road crossing, approximately three km upstream of the weir. All fish removed electrofishing were frozen and later analyzed in the laboratory in the same manner as those captured with hoop nets described earlier.

Cost Comparisons

We calculated the estimated hours per 100 m of stream spent to complete removals and separately calculated the estimated costs in dollars (U.S.) associated with brook trout removal using hoop nets in each year and the electrofishing removal in 2005. We also made similar calculations for other studies using different removal methods for comparison. We recorded the number of people and the number of hours spent installing and checking hoop nets. The number of hours was multiplied by $12 (an average hourly wage) to arrive at a total expense for labor. Likewise, we recorded the number of days spent in the field and multiplied that by the current per diem rate for the State of Idaho ($30) to arrive at an estimated cost of keeping people in the field. These numbers were added together to arrive at a total dollar cost for the respective removal method. Amounts spent on sampling equipment were ignored because the value changes with time and use, becoming less the more the equipment is used. Likewise, travel expenses (vehicles and travel times) were also ignored because any differences would be mainly accountable to the distances of removal sites from camp or duty stations, not anything inherent in the removal method. Calculating cost in this manner, instead of just hours/100 m of stream, is probably more reflective of the actual price of these projects because it includes the cost of keeping workers in the field for the days required to complete a removal project.

RESULTS

Abundance Estimates

Comparing the abundance of brook trout between years based on our electrofished sample reaches, abundance was generally similar for fish ≥100 mm between 2004 and 2005; however, a striking drop in the abundance of brook trout <100 mm was observed. We estimated 2,027 (±410) brook trout ≥100 mm resided in ETC in 2004 and 1,617 (±556) in 2005. This is in contrast to brook trout <100 mm where we estimated 1,950 (±697) in 2004, but only 124 (±77) in 2005. The same trends were observed in both WRC and ERC where we estimated 2,515 (±1,204) and 1,031 (±408) brook trout ≥100 mm in 2004, and 1,587 (±963) and 1,304 (±444) in 2005, respectively. However, the estimates for brook trout <100 mm decreased from 3,309 (±1,948) in WRC and 2,061 (±68) in ERC to only 256 (±185) and 150 (±68), respectively.

Hoop Net Removals

Experiment 1

Hoop netting with Experiment 1 captured 1,227 brook trout. Of those fish, 604 were mature males, 194 were mature females, and 429 were immature. Within the immature brook trout, 188 were male and 241 were female. We removed 1,141 brook trout ≥100 mm, 783 from WRC, 301 from ERC, and 57 from ETC. We only captured 86 brook trout <100 mm total, reflecting the low number from abundance estimates. The greatest number of brook trout <100 mm were from WRC (47), followed by ERC (36), and ETC (3).

When comparing the removals of mature brook trout between the three streams, we removed 830 from WRC, 304 from ERC, and 93 from ETC (Table 1). Comparing the three treatments, overall the male/female pair treatment was responsible for capturing the most brook trout (454), followed closely by the no fish treatment (442), and the single male with the fewest (331; Table 2). Breaking down the totals by gender, the male/female pair was responsible for capturing the most mature males and females with 262 and 74, respectively (Table 2A and B). Nets with no fish captured the second most mature males (176) and females (67), and the single male captured the fewest with 166 and 53, respectively (Table 2A and B). Hoop nets with no fish seeded in them captured the most immature brook trout (199), followed by the male/female pair (118) and the single male (112; Table 2C).

Although the male/female treatment nets captured the largest total number of brook trout, when brook trout capture rates were compared across nets treatments, there was no significant difference in the number of brook trout captured in hoop nets (ANOVA, $F_{df\ 2}$ = 1.43, P = 0.247; Figure 2). In contrast, a significant proportion of the variability of brook trout capture rates were accounted for by between stream differences (ANOVA, $F_{df\ 2}$ = 29.97, P <0.0001; Figure 3). Forty-seven percent of the variability in capture rates was accounted for by differences between streams. As in past studies, there were differences in the number of mature male versus mature female brook trout captured across hoop net treatments (ANOVA, F_{df2} = 49.31 , P <0.0001; Figure 4). On average, almost twice as many mature males were captured as females.

Unlike Meyer and Lamansky (2005), when comparing the capture rates of mature males no significant difference could be attributed to net treatment (Table 3). This was also true in models for mature females and immature females (Table 3). There was, however, an interaction effect with stream and net treatment for immature males (ANOVA, F_{df6} = 2.59, P = 0.025). This only accounted for 8.5% of the variation in the model and is a reflection of the higher numbers of fish captured in WRC in general. Not surprisingly, stream differences were significant for all models and explained a large proportion of the variability in capture rates (41.5-51.1%; Table 3); an expected outcome provided the degree of separation between the numbers of captures between streams.

Experiment 2

In Experiment 2, we removed 181 brook trout. Of the 181 fish, we captured 90 mature males, 27 mature females, 30 immature males, and 34 immature females, approximately the same ratios of gender as netting with Experiment 1 in WRC. Again, the male/female pair captured the most mature males (36) compared to the no fish and single male treatments (27 each). All three treatments captured nine mature females. Comparing immature brook trout, the single male treatment caught 33 fish followed by the male/female pair (28) and the no fish treatment (23). Of the 181 brook trout, 171 were ≥100 mm and 10 were <100 mm. Statistical analysis of this experiment revealed no main or interaction effects of treatment or location for mature or immature brook trout. There was an effect of time for mature (F_4 = 10.13, P <0.0001: Figure 5) and immature (F_4 = 3.59, P = 0.008) brook trout; however, no interactions between time and any of the other variables was detected.

The percent of brook trout removed from each stream using hoop nets for fish ≥100 mm and <100 mm also varied. Including capture numbers from both designs in WRC, 60.1% of the estimated numbers of brook trout in WRC ≥100 mm were removed. Hoop nets removed 23.1% of the brook trout ≥100 mm in ERC. The percent removed from ETC could not be calculated, because we removed more brook trout electrofishing (2,769) than we estimated (1,587) were present originally.

Electrofishing Removals

During electrofishing removals in ETC, 2,771 brook trout were removed. During the first treatment in July, we collected 1,440, and during the second treatment in August, we removed 1,331. We recorded gender from a subsample of individuals from both the July (n = 336) and August (n = 203) treatments to measure sex ratio. Sex ratio was virtually 1:1 in both July (54% male, 46% female), and August (48% male, 52% female).

Cost Comparisons

Overall, 395 worker hours were spent trapping with hoop nets in the fall of 2004. It took 95 worker hours to install the nets and seed them with brook trout, and 280 hrs were spent checking and maintaining the nets during the study period (1 person, 8 hr/day, 35 days).

Another 20 worker hours were spent removing the nets when the field project finished. We calculate it took 6.3 hours/100 m, and after multiplying hours by $12 and $30 for wage and per diem, we estimate it cost $5,790 to remove brook trout from ETC using hoop nets in 2004.

Comparing the estimated costs between the electrofishing removal in ETC and the hoop netting of the three streams in 2005 shows that electrofishing was more cost effective. Approximately 300 worker hours (4 people, 12 h/day) over an eight-day period were expended electrofishing ETC in 2005. Multiplying accordingly by $12 and $30 for wage and per diem, respectively, it cost approximately $3,600 in wages and $840 for per diem totaling $4,560. With hoop netting, it took 80 man/hours to install nets (4 people, 9 h/day, 2 days) and 350 worker hours (2 people, 5 h/day, 35 days) to operate the hoop nets in three different streams (including ETC). Again, multiplying for wage and per diem, the estimated cost for the hoop netting effort was $7,500. Electrofishing resulted in capturing almost three times more brook trout than hoop netting with approximately 2,800 brook trout removed from ETC electrofishing and only about 1,100 with hoop nets in the three streams.

Yellowstone Cutthroat Trout

We encountered Yellowstone cutthroat trout (YCT) on many occasions during abundance estimates and hoop netting. In WRC and ERC where abundance estimates were available for both years, we noted a decrease in abundance between 2004 and 2005. In 2004, we estimated an abundance of 176 (±65) YCT ≥100 mm in WRC, but in 2005 it decreased to 73 (±31). The same occurred in ERC where the estimated abundance decreased from 420 (±180) to 237 (±69) between the two years. Abundance estimates of YCT <100 mm for both streams also decreased from 131 (±121) to 46 (±61) in WRC and 143 (±79) to 10 (±12) in ERC between 2004 and 2005. Overall, 36 Yellowstone cutthroat trout were captured in hoop nets during the sample period: 23 in WRC, and 13 in ERC.

DISCUSSION

We designed two experiments to test if an effect from treatment, location, stream, or their interactions were detectable. We found that if nets were placed in stream locations using the simple criteria outlined in this study for net placement, that no treatment effect could be detected. This does not mean there was no effect only that it was probably very small, and when nets were placed in locations as in this study, any effect due to treatment is lost. This was evident in the fact that we were able to detect differences in 2004 (Meyer and Lamansky 2005) where nets were placed using less strict criteria and the observation that some nets captured more fish than others regardless of the treatment. Further experiments were designed to more directly clarify this issue; however, we were unable to detect treatment effects most likely because the ability to detect treatment effects was overcome by the net location. The objective of this study was to determine if catch rates of brook trout were higher in hoop nets seeded with a certain combination of mature brook trout seeded into hoop nets, not to maximize removal. Thus, the fact that approximately 2,500 brook trout were removed using hoop nets in two years is encouraging. It is possible that a considerably greater number of fish could be captured and removed, provided that nets are set to maximize removal by 1) increasing the number of nets in a stream that could be checked by one person in a day (approximately 90; Lamansky, unpublished data); 2) deploying the leads to either entirely block the stream or help guide fish into the mouth; and 3) placing the nets in the most suitable locations.

It appears that factors other than pheromonal attraction are the reason brook trout were susceptible to capture in hoop nets, although it is most likely related to spawning behavior. First, brook trout are known to move considerably (Adams et al. 2000; Peterson and Fausch 2003) and the most likely reason more males were captured is because they were actively searching for mates and, therefore, more susceptible to capture. Secondly, we observed that total catch in the nets declined as time progressed, which may be due to several reasons, the first being there were fewer fish present in the stream from continuous removal and secondly that any attraction that would cause movement ceased. However, the most likely reason was decreased movement activity or the subsequent downstream movement of fish as water temperatures decreased with time. We observed that the daily capture of fish in hoop nets generally declined as temperature decreased (correlation coefficient: $r = 0.67$, $n = 33$, $p < 0.0001$ in WRC and $r = 0.61$, $n = 33$, $p = 0.0002$ in ERC; Figure 6). In addition, if fish were moving downstream, they would be less susceptible to capture because the nets were set with the mouths open facing downstream.

During the hoop netting effort in 2005, we observed approximately the same patterns of brook trout removal as the previous year (Meyer and Lamansky 2005). We captured approximately the same proportion of males and females (3 to 1), and removed approximately the same percentage of brook trout from the populations in our study streams (16-50%, average 30%). Although we were not able to distinguish statistically any differences between treatments, the male/female pair treatment was still responsible for capturing the most brook trout and the single male captured the fewest (Figure 4). We also found that empty nets (the no fish treatment) again captured the second most brook trout. Overall, this is interesting because it happened in both years and suggests, however small the treatment effect, there may still be an attraction to the male/female pair and/or possibly a repulsion effect of the single male.

These findings, along with those from Meyer and Lamansky (2005), remain in contradiction with what Young et al. (2003) described where they captured significantly more mature males in nets seeded with males. One explanation is that they may not have sampled the entire spawning period and some aspect of the attracting nature of mature fish changed with time. Moore and Scott (1991) described a situation where testosterone production stopped almost completely 14 days prior to female ovulation in Atlantic salmon. Therefore, if brook trout respond similarly, Young et al. (2003) may have missed the period when fish were susceptible to attraction. However, none of the work we conducted suggests that nets seeded with mature males capture more brook trout than other treatments during any time period. Indeed, it would more clearly point to a repulsive effect, although any explanation at this point would be speculative.

We observed a surprisingly large decrease in the number of brook trout <100 mm between 2004 and 2005. Had we not measured abundance across years, the conclusions regarding ETC would probably have been that the removal of 658 mature fish in 2004 was responsible for the decline of fish <100 mm in 2005. It appears, however, that another environmental occurrence was the cause. We observed (Lamansky, unpublished data) that there appeared to be high levels of bedload movement over the winter of 2004-5, which may have contributed to this decline because of higher mortality to eggs or fry in the substrate. If this is indeed true, the reason for the higher abundance in previous years was probably due to the low snowpack in years preceding the study and the level of mortality observed was probably the norm, not the exception, although we did not conduct mortality estimates to calculate actual mortality rates. One study looking at the population dynamics of brook trout in an Idaho stream suggested the population probably experienced at least 90% natural mortality annually (Meyer et al. 2006b). Subsequent mortality to brook trout in egg or fry form is probably substantial during runoff and may actually be beneficial in naturally regulating brook trout populations.

Although numbers of Yellowstone cutthroat trout also declined during this period, the decline was not to the degree of brook trout. Likewise, exposure of Yellowstone cutthroat trout to mortality during runoff is unlikely because they spawn later in the spring after peak flows have occurred and eggs or fry are not susceptible to high flow.

Another unexpected result was the degree to which we apparently underestimated the abundance of brook trout in ETC. Electrofishing abundance estimates are known to be biased low (Riley and Fausch 1992; Peterson et al. 2004). However, underestimating the abundance almost two-fold is worrisome. One explanation other than the previously noted biases is that when the first electrofishing removal was made, the stream had not yet reached base flow, reducing sampling efficiency. Another explanation is that brook trout were moving into the study section through the weir. However, during routine checks of the weir no holes or other problems were observed between installation and removal. In addition, the riparian habitat on ETC was complex with heavy brush, beaver activity, and undercut banks, which made electrofishing difficult for both estimates and removals (Thompson and Rahel 1996; Kulp and Moore 2000). We believe the bias of abundance estimates are less in the other two streams because the habitat was not nearly as complex as in ETC. Evaluation of the proportion of brook trout captured with hoop netting after electrofishing removal in ETC is not possible because of the magnitude of the underestimation of abundance.

Underestimating abundance may also be problematic in the ability to predict what percentage of brook trout could be removed using hoop nets. We calculated that 49.3% of the estimated abundance in WRC was removed (Experiment 1). If we used approximately 60 more nets and captured the same number of fish/net, we would have removed almost the entire population of brook trout ≥100 mm (783 in 30 nets, 783*3 = 2,349) presuming maximum brook trout abundance (2,550) was present in WRC. However, if the abundance is greatly underestimated, the ability to state confidently what proportions removed is lost. As mentioned previously, we believe the abundance estimates were not underestimated to such a degree in the other two streams as ETC. Still, the proportion of brook trout we removed should be considered a maximum.

Although we calculated the monetary cost to remove brook using hoop nets in the three streams was almost double ($7,500) compared to the electrofishing effort in ETC ($4,650), comparing these costs directly is problematic because effort per stream is different and hoop netting did not attempt to maximize removal. We removed brook trout from three streams with hoop nets, so if the total cost is divided by three, it cost approximately $2,025 per stream, about half of electrofishing. In addition, we were not maximizing removals because of study constraints. If, for example, we used 90 nets in one stream with leads deployed and operated them for 35 days, the cost would have been very comparable to electrofishing (1 person, 8 h/day, 35 days) at $3,750, and increasing the number of fish captured. This is not to say that electrofishing may be more cost effective, only that comparison with hoop netting costs in these experiments should be made with the understanding of the study design limitations. Comparisons to other fish removal studies are difficult for the same reasons. Because of the difficulties comparing methods, studies using hoop nets to maximize removals should be considered.

CONCLUSION

During hoop netting over two years, with three different experimental designs, we could not detect a substantial effect in tests to verify if using hoop nets seeded with mature brook trout increased the capture of brook trout. However, the use of hoop nets themselves to remove brook trout may be worthwhile. The development of a passive method to remove fish that would avoid the social or biological issues of chemicals or electrofishing and be less expensive while providing a good deal of success would be extremely helpful in restoring many native species of fish. We removed between 23-50% of the estimated abundance of brook trout present in the study streams without using the nets in a manner that would maximize removal. Therefore, studies to evaluate using hoop nets that maximize removal deserve further study.

RECOMMENDATION

1. Although this and our previous work (Meyer et al. 2006b) may remove portions of unwanted populations of fish, it is relatively obvious that electrofishing and hoop netting may not achieve complete removals of undesired fish species. Different methods, such as chemical treatments (using rotenone and/or antimycin A), should be explored to find an alternative removal strategy that completely removes undesired species to meet management objectives.

2. If active methods (i.e. electrofishing or chemicals) are undesirable options due to physical or social concerns, assiduous use of hoop nets may provide long-term suppression of brook trout populations with lower labor intensity than some other methods.

ACKNOWLEDGMENTS

Ernest Keeley, Kevin Meyer, and Michael K. Young provided guidance throughout this project. Many others including Ron Roberts, Daniel Ball, Dan Henbest, Silvia Copeland, Steve Seiler, and Trapper Bradshaw provided help collecting data. Funding was provided by the Bonneville Power Administration.

LITERATURE CITED

Adams, S. B., C. A. Frissell, and B. E. Rieman. 2000. Movements of nonnative brook trout in relation to stream channel slope. Transactions of the American Fisheries Society 129:623-638.

Behnke, R. J. 1992. Native trout of western North America. American Fisheries Society Monograph 6.

Bettoli, P. W., and M. J. Maceina. 1996. Sampling with toxicants. Pages 303-333 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques. American Fisheries Society. Bethesda, Maryland.

Finlayson, B. J., R. A. Schnick, R. L. Cailteux, L. DeMong, W. D. Horton, W. McClay, C. W. Thompson, and G. J. Tichacek. 2005. Rotenone use in fisheries management: administrative and technical guidelines manual. American Fisheries Society, Bethesda, Maryland.

Gresswell, R. E. 1991. Use of antimycin for removal of brook trout from a tributary of Yellowstone Lake. North American Journal of Fisheries Management 11:83-90.

Kruse, C. G., W. A. Hubert, and F. J. Rahel. 2000. Status of Yellowstone cutthroat trout in Wyoming waters. North American Journal of Fisheries Management 20:693-705.

Kulp, M. A., and S. E. Moore. 2000. Multiple electrofishing removals as a management tool for restoration of southern Appalachian brook trout, Great Smoky Mountains National Park. North American Journal of Fisheries Management 20:940-946.

Meyer, K. A., and J. A. Lamansky, Jr. 2005. Assessment of native salmonids above Hells Canyon Dam, Idaho: Part #2: The capture of brook trout using hoop nets seeded with mature conspecifics as attractants. Annual Progress Report 05-41. Boise, Idaho.

Meyer, K. A., D. J. Schill, J. A. Lamansky Jr., M. R. Campbell, and C. C. Cegelski. 2006a. Status of Yellowstone cutthroat trout in Idaho. Transactions of the American Fisheries Society 135:1329-1347

Meyer, K. A., J. A. Lamansky, Jr., and D. J. Schill. 2006b. Evaluation of an unsuccessful brook trout electrofishing removal project in a small Rocky Mountain stream. North American Journal of Fisheries Management.

Moore, A., and A. P. Scott. 1991. Testosterone is a potent odorant in precocious male Atlantic salmon (*Salmo salar* L.) parr. Philosophical Transactions of the Royal Society of London B 332:241-244.

Peterson, J. T., R. F. Thurow, and J. W. Guzevich. 2004. An evaluation of multiple pass electrofishing for estimating the abundance of stream-dwelling salmonids. Transactions of the American Fisheries Society 133:462-475.

Peterson, D. P., and K. D. Fausch. 2003. Testing population-level mechanisms of invasion by a mobile vertebrate: a simple conceptual framework for salmonids in streams. Biological Invasions 5:239-259.

Reynolds, J. B. 1996. Electrofishing. Pages 221-253 *in* L. A. Nielson and D. J. Johnson editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Riley, S. C., and K. D. Fausch. 1992. Underestimation of trout abundance size by maximum likelihood removal estimates in small streams. North American Journal of Fisheries Management 12:768-776.

SAS. 2005. SAS Version 9.1. SAS, Cary, North Carolina.

Strange, R. J. 1996. Field examination of fishes. Pages 433-446 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Thompson, P. D., and F. J. Rahel. 1996. Evaluation of depletion-removal electrofishing of brook trout in small Rocky Mountain streams. North American Journal of Fisheries Management 16:332-339.

Thurow, R. F., D. C. Lee, and B. E. Rieman. 1997. Distribution and status of seven native salmonids in the interior Columbia River Basin and portions of the Klamath River and Great Basins. North American Journal of Fisheries Management 17:1094-1110.

Willis, D. W., and B. R. Murphy. 1996. Planning for sampling. Pages 1-15 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Young, M. K., B. K. Micek, and M. Rathburn. 2003. Probable pheromonal attraction of sexually mature brook trout to mature male conspecifics. North American Journal of Fisheries Management 23:276-282.

Table 1. The total number of brook trout captured in hoop nets seeded with three different treatments in East Threemile, West Fork Rattlesnake, and East Fork Rattlesnake creeks from September 10 to October 12, 2005.

	Stream			
Treatment	East Threemile Creek	West Fork Rattlesnake Creek	East Fork Rattlesnake Creek	Total
Male/Female Pair	36	293	125	454
None	29	312	101	442
Single Male	28	225	78	331
Total	93	830	304	

Table 2. The total number of mature males (A), mature females (B), and immature (C) brook trout captured in hoop nets seeded with three different treatments in East Threemile, West Fork Rattlesnake, and East Fork Rattlesnake, from September 10 to October 12, 2005.

A	Mature Males			
	Stream			
Treatment	East Threemile Creek	West Fork Rattlesnake Creek	East Fork Rattlesnake Creek	Total
Male/Female Pair	18	164	80	262
None	17	109	50	176
Single Male	12	118	36	166
Total	47	391	166	

B	Mature Females			
	Stream			
Treatment	East Threemile Creek	West Fork Rattlesnake Creek	East Fork Rattlesnake Creek	Total
Male/Female Pair	2	51	21	74
None	0	51	16	67
Single Male	1	40	12	53
Total	3	142	49	

C	Immature			
	Stream			
Treatment	East Threemile Creek	West Fork Rattlesnake Creek	East Fork Rattlesnake Creek	Total
Male/Female Pair	16	78	24	118
None	12	152	35	199
Single Male	15	67	30	112
Total	43	297	89	

Table 3. Two-way analysis of variance results for mature males, mature females, immature males, and immature females for the variables stream and treatment used in the model to test differences in means of brook trout captured in experiment 1 in East Threemile, West Fork Rattlesnake, and East Fork Rattlesnake from September 10 to October 12, 2005.

Sex	Variable	df	F-value	P-value	r^2
Mature	Stream	3	40.11	<0.0001	0.51
	Treatment	2	0.52	0.597	0.0044
Mature Females	Stream	3	28.33	<0.0001	0.42
	Treatment	2	0.69	0.505	0.0068
Immature Males	Stream	3	25.85	<0.0001	0.43
	Treatment	2	7.75	0.0009*	0.085
	Stream*Treatment	6	2.59	0.025*	0.085
Immature Females	Stream	3	18.68	<0.0001	0.42
	Treatment	2	0.06	0.937	0.0009

* indicates significance

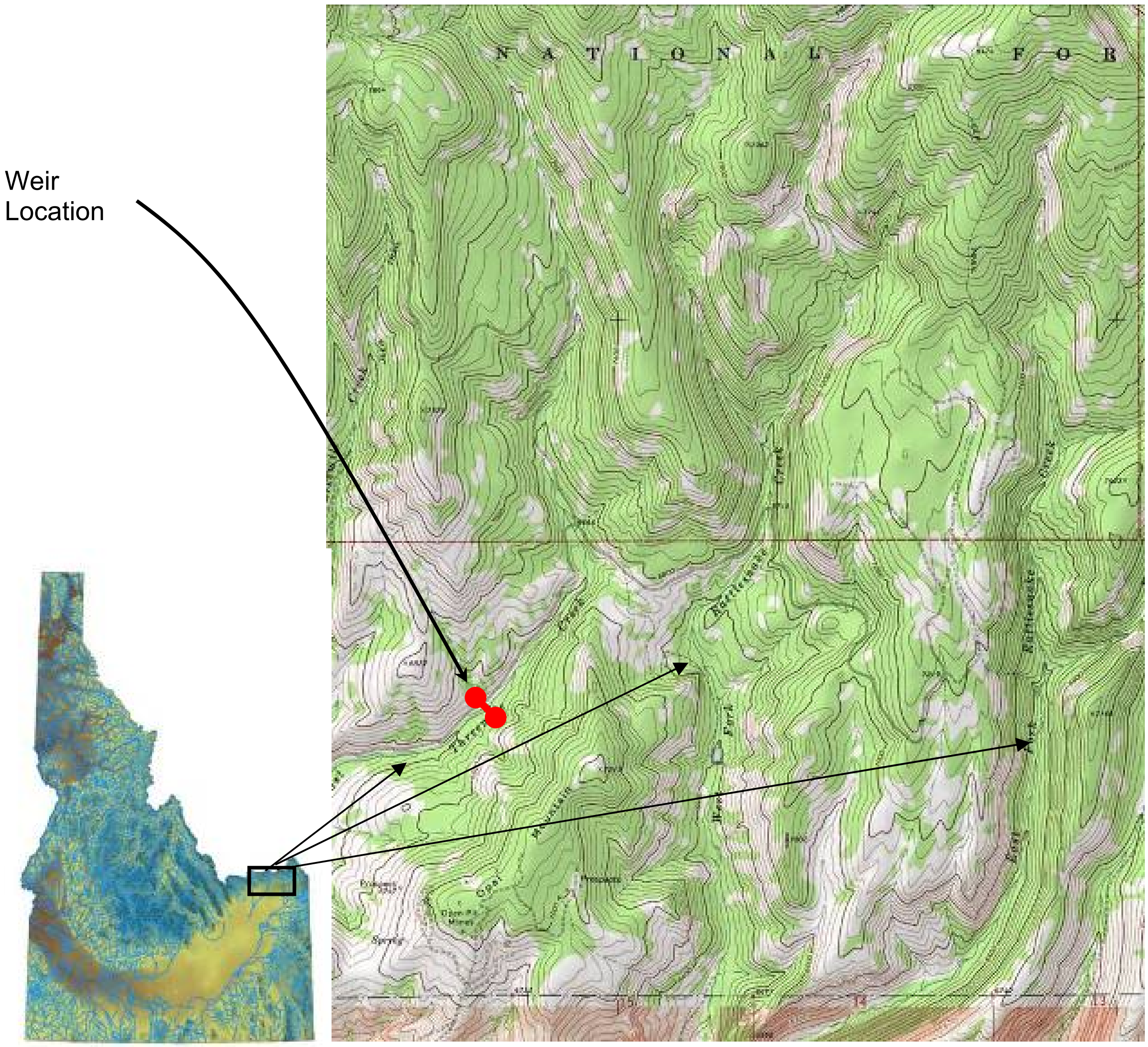

Figure 1. A map of the study sections on East Threemile Creek (UTM 412845E 4915895N), West Fork Rattlesnake Creek (UTM 414301E 4913966N), and East Fork Rattlesnake Creek (415942E 4914162N) in Northeast Idaho where brook trout were removed using seeded hoop nets in 2005. UTM coordinates (Zone 12, NAD27) were recorded at the lower end of the sampling areas in all streams.

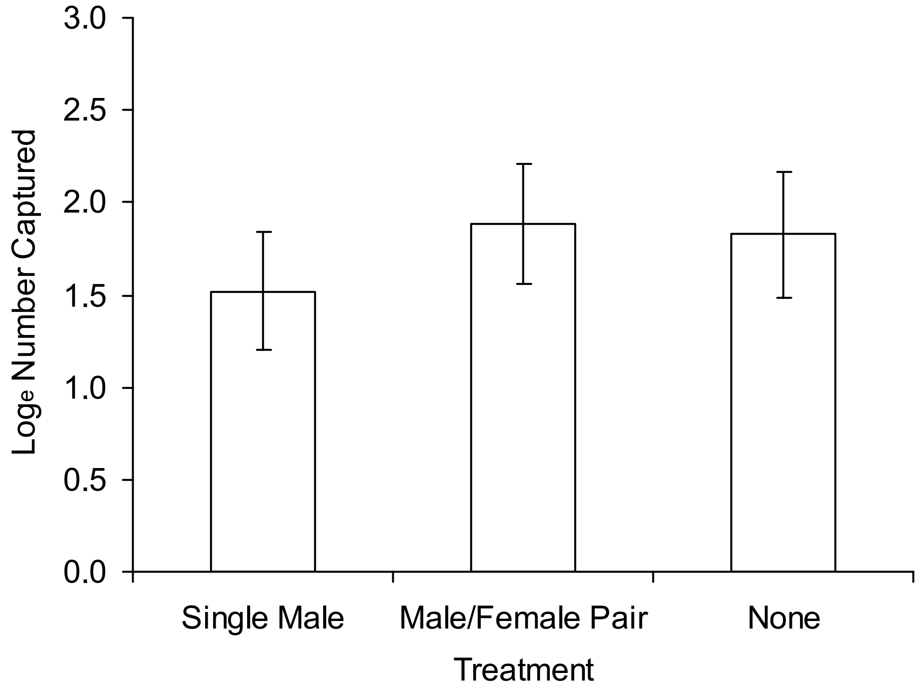

Figure 2. The mean (±95% C.I.) number of mature brook trout captured in hoop nets seeded with three treatments for the study streams sampled from September 10 to October 12, 2005.

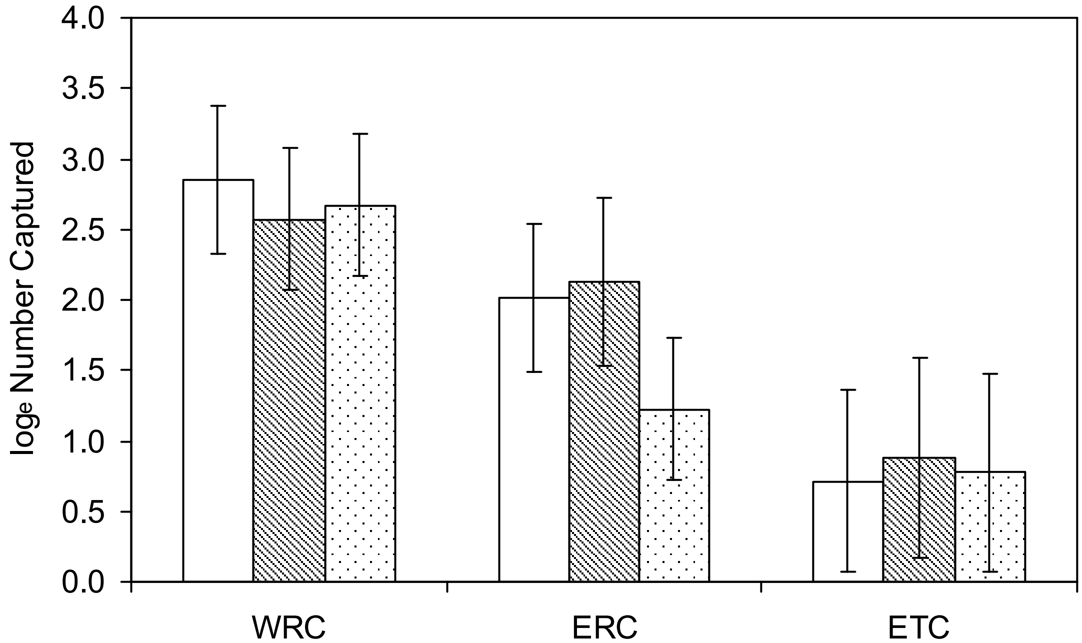

Figure 3. The mean (±95% C.I.) number of mature brook trout captured in each study stream according to treatment. WRC = West Fork Rattlesnake Creek, ERC = East Fork Rattlesnake Creek, and ETM = East Threemile Creek. Open bars = male/female pair treatment, hatched bars = no fish treatment, and dotted bars = single male treatment.

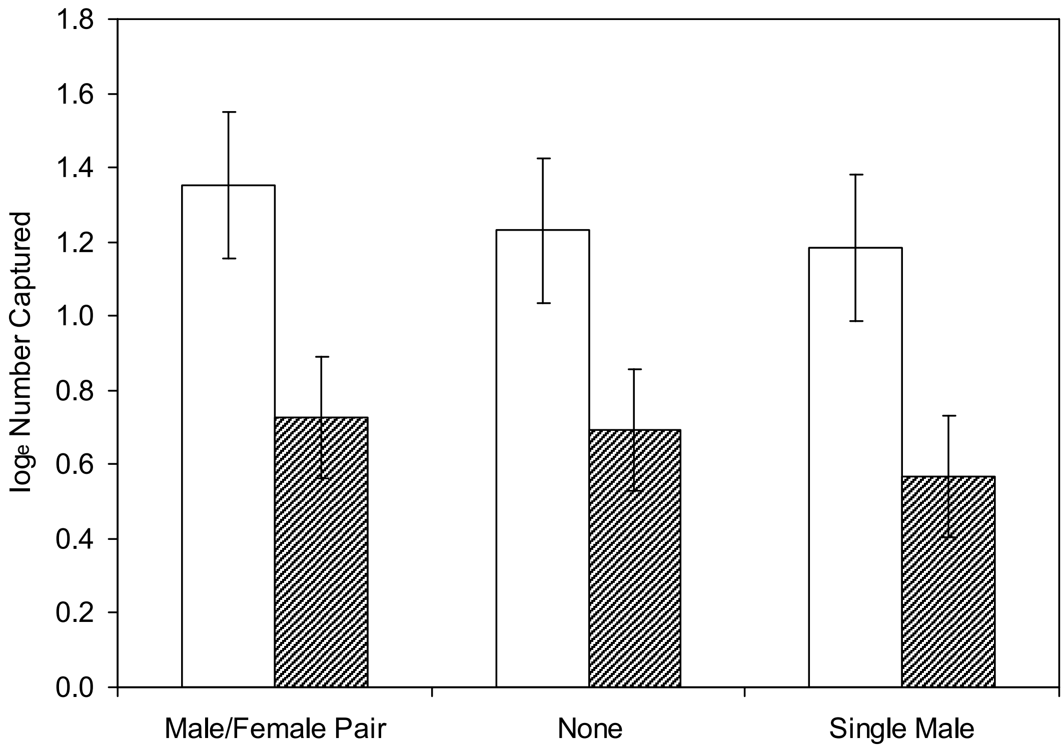

Figure 4. The mean (±95% C.I.) number of mature brook trout by gender captured in hoop nets seeded with three treatments from Experiment 1 for the study streams sampled from September 10 to October 12, 2005. Open bars are males and hatched bars are females.

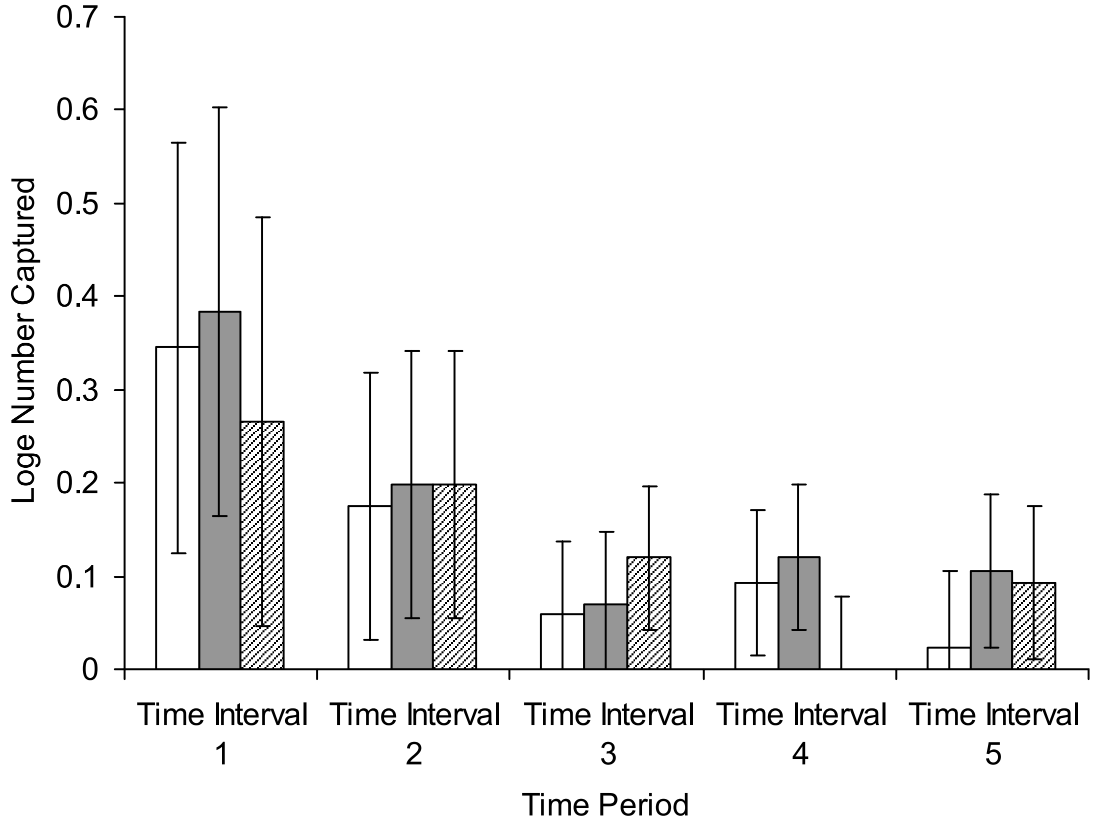

Figure 5. The mean (±95% CI) number of mature brook trout captured in hoop nets seeded with three treatments from Experiment 2 for the study streams during the five time intervals sampled from September 27 to October 12, 2005. Differences between time intervals were significant. Open bars = male/female pair treatment, solid bars = no fish treatment, and hatched bars = single male treatment.

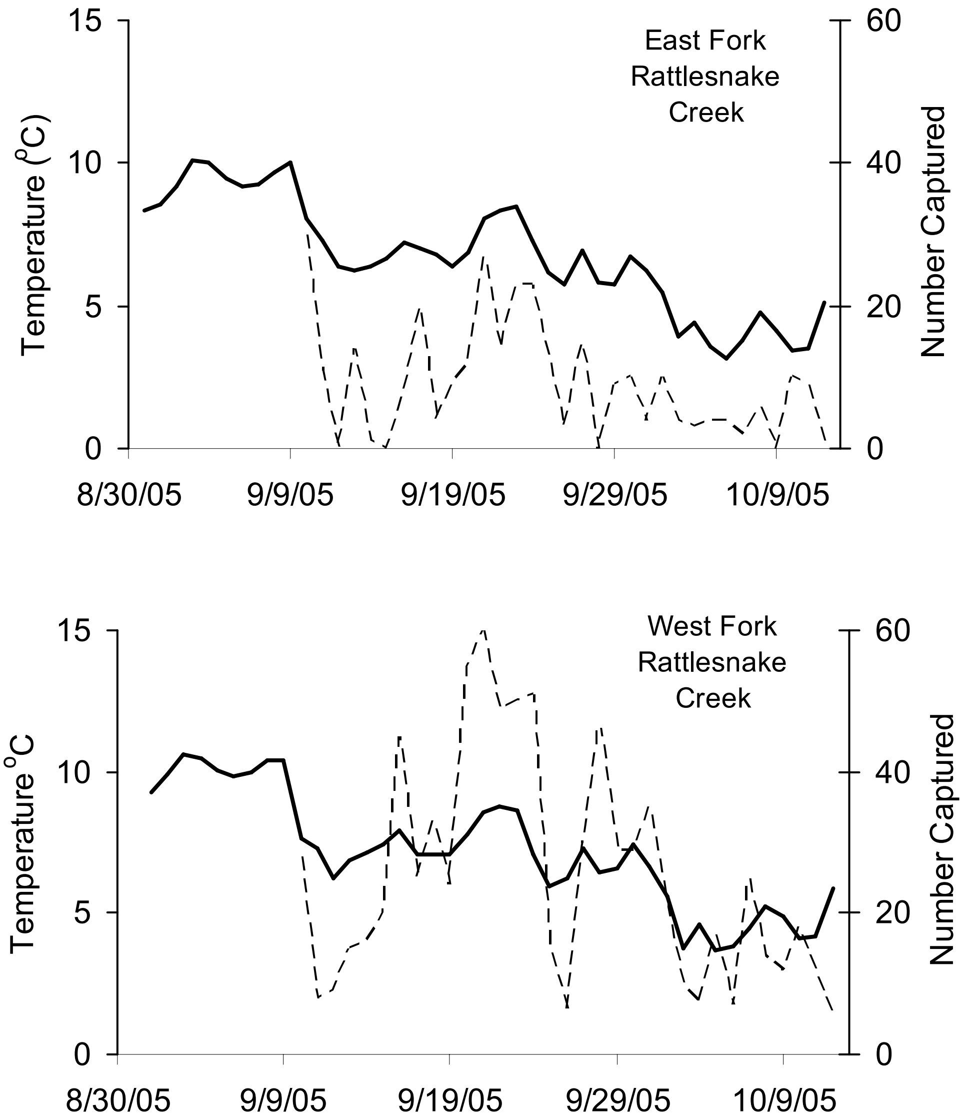

Figure 6. Daily mean temperatures (°C) and total number of brook trout captured daily in hoop nets in the two study streams in 2005. Solid lines are temperature; dashed lines are numbers of brook trout captured.

PART #2: STATUS OF MOUNTAIN WHITEFISH IN THE UPPER SNAKE RIVER BASIN, IDAHO

ABSTRACT

Mountain whitefish *Prosopium williamsoni* are one of four native salmonids in the upper Snake River basin, but their current status relative to the status of these other salmonids is unknown. In this study, we electrofished almost 2,500 study sites to assess the distribution and abundance of mountain whitefish (in streams only) throughout the upper Snake River basin in Idaho (and portions of adjacent states). In addition, we sacrificed mountain whitefish at 14 locations to determine population demographic characteristics such as age, growth, mortality, maturity, and sex ratio. Mountain whitefish were found in 104 (4.6%) of the 2,269 sites surveyed. A total of 1,234 mountain whitefish were sacrificed for age, growth, fecundity, longevity, maturity, and mortality estimates, which will be presented in the 2006 annual report. Fieldwork is nearly finished but continues in 2006. Our results will help determine mountain whitefish status in Idaho and help set management priorities for their management and future conservation.

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INTRODUCTION

Like most other native salmonids in the western United States, the mountain whitefish *Prosopium williamsoni* has, over the past century or more, experienced declines in abundance and distribution in large portions of its historical range. Declines have been ascribed to a number of factors, but most notably are habitat alterations and fragmentation due to water storage and diversion. The extent of the decline is unknown because, to our knowledge, no broadscale assessment of the distribution or abundance of mountain whitefish has ever been made in Idaho or elsewhere. It is unlikely that declines are of similar magnitude as for other native salmonids because they typically reside in mainstem rivers that have been extensively altered by water diversion and storage. They have nevertheless persisted in a variety of habitats in most areas in Idaho where they were historically found. However, to ascertain more definitively the status of mountain whitefish in the upper Snake River basin (USRB), a primary objective of this study was to estimate overall distribution and abundance of mountain whitefish in the USRB in Idaho (and portions of adjacent states; see below) and to estimate abundance within major river drainages. We also sought to identify subpopulations of mountain whitefish within major river drainages and estimate abundance within subpopulations where possible.

While estimation of population size and similar demographic parameters are probably more important than genetic issues when evaluating population persistence (Lande 1988), assessment of genetic risks stemming from small population size is also desirable. Genetic risks to small populations are related to inbreeding and/or declines in heterozygosity, which is a function of the census population size (N_{census}). However, it is not the absolute number of individuals in a population that is relevant to the amount of genetic variation in the population, but rather the effective population size (N_e; Wright 1931). The importance of N_e has led to the development and general acceptance of the “50/500” rule (Franklin 1980; Soule 1980), which states that an N_e of at least 50 is needed to avoid inbreeding depression in the short term, while at least 500 is needed to avoid serious genetic drift and maintain genetic variation in the long term.

Unfortunately, N_e is difficult to estimate, especially when relying on demographic data. However, precise estimates of this parameter for management purposes are not always crucial. Approximations can provide managers with useful information regarding the relative degree of genetic loss likely to take place and seem especially helpful in prioritizing conservation efforts across multiple populations (Harris and Allendorf 1989). Rieman and Allendorf (2001) approximated N_e by using a generalized age-structure simulation model to relate N_e to adult spawning numbers under a variety of bull trout life history characteristics (some of which closely match mountain whitefish) and suggested the most realistic estimates of N_e were between 0.5 and 1.0 times the mean number of adults spawning annually. Previously we developed a method of estimating the number of spawners in a population by developing models that predict, from easily measurable stream attributes, the size at which Yellowstone cutthroat trout mature at any given stream location (Meyer et al. 2003a). A second study objective was to build similar maturity models for mountain whitefish, and in conjunction with the abundance and size structure data we gathered in this study, approximate mountain whitefish N_e within as many subpopulations as possible. Because we needed to sacrifice mountain whitefish to develop maturity models, and because little information was available for mountain whitefish growth, mortality, sex ratio, fecundity, and other demographic parameters, we used the sacrificed fish to collect these data as well. Because data collection was not entirely completed, this report focuses on the methods used and areas sampled to date. A complete summary of this study will follow in 2006.

OBJECTIVES

1. Determine the distribution and abundance of mountain whitefish in the USRB within river drainages and subpopulations;

2. Approximate N_e by estimating the number of mountain whitefish spawners in the USRB within river drainages and sub-populations;

3. Determine mountain whitefish age and length at sexual maturity across their historical range in Idaho;

4. Determine mountain whitefish fecundity, longevity, sex ratio, and other demographic parameters;

5. Develop a model to predict mountain whitefish length at maturity based on easily obtained physical stream attributes.

STUDY AREA

The Snake River flows through southern Idaho from east to west, flowing 1,674 km from the headwaters in Yellowstone National Park to its confluence with the Columbia River. The USRB is defined herein as that portion of the Snake River drainage from Hell's Canyon Dam upstream to the headwaters of all tributaries, except (1) Pine Creek, Burnt River, Powder River, and Malheur River in Oregon, and (2) the South Fork of the Snake River drainage above its confluence with the Salt River at the Idaho-Wyoming border. Stream surveys were conducted mostly in Idaho but also within the state boundaries of Oregon, Nevada, Utah, and Wyoming where portions of river drainages lay outside the state of Idaho. Discharge in most of the streams in this portion of the USRB is heavily influenced by snowmelt and peaks between April and June. However, streamflow in the Snake River and in a number of major tributaries is highly regulated for agricultural and hydroelectric uses by dams and diversions. Elevation within the basin ranges from over 4,000 m at mountain peaks to 466 m at Hells Canyon Dam. The climate is semiarid with an average precipitation of about 25 cm.

The historical range of mountain whitefish in the USRB included the entire drainage (Behnke 2002), excluding the Big Lost and Little Lost rivers (B. Gamett, USFS, personal communication) and possibly the Portneuf and Blackfoot rivers (Thurow et al. 1988). Redband trout *Oncorhynchus mykiss*, bull trout *Salvelinus confluentus*, and Yellowstone cutthroat trout *O. clarkii bouvieri* are also native, as are a number of nongame species. Nonnative trout, including rainbow trout *O. mykiss*, brook trout *Salvelinus fontinalis*, and brown trout *Salmo trutta* have been introduced throughout the basin and have widely established self-sustaining populations.

METHODS

Mountain Whitefish Distribution and Abundance

Data collection occurred between 1999 and 2005. We selected study sites using a standard 1:100,000 hydrography layer throughout the study area. We randomly selected study streams using two different protocols, except where random selection was not possible due to access restrictions or river conditions that precluded sampling. The density of sites (i.e. the sample size) across the study area was based on: (1) time constraints, considering the vastness of the study area; (2) other recent (i.e. within the last eight years) existing data which we used to the extent possible; and (3) the limited distribution of mountain whitefish in some areas, where less sampling was needed to characterize status. When study sites occurred on private property, access was routinely obtained from landowners and was denied less than 1% of the time; roughly 25% and 75% of the sites occurred on private and public land, respectively. Table 1 summarizes these study sites.

At each study site, unless the site was dry (n = 635 study sites), fish were captured using electrofishing gear. Sampling occurred during low to moderate flow conditions (usually late June to early October) to facilitate fish capture and help to standardize sampling conditions. Fish were identified, enumerated, measured to the nearest millimeter (total length, TL) and gram, and released.

Sampling in small streams (i.e. less than about 8 m wide) was conducted by depletion electrofishing, using one or more backpack electrofishers (Smith-Root Model 15-D) with pulsed DC. Block nets were installed at the upper and lower ends of the sites to meet the population estimate modeling assumption that the fish populations were closed. Depletion sites were typically (69% of the time) between 80 and 120 m in length (depending on habitat types and ability to place block nets) and averaged 96 m (range 20-200 m). Maximum-likelihood abundance and variance estimates were calculated with the MicroFish software package (Van Deventer and Platts 1989). When all whitefish were captured on the first pass, we estimated abundance to be the total catch. Because electrofishing is known to be size selective (Reynolds 1996), whitefish were separated into two length categories, <100 mm TL and ≥100 mm TL; abundance estimates were made separately for these two size groups.

At sites too large to perform backpack electrofishing, mark-recapture electrofishing was conducted where possible with a canoe- or boat-mounted unit (Coffelt Model Mark-XXII) and DC (if possible) or pulsed DC. Recapture runs were made two to seven days after marking fish, and we assumed there was no movement of marked or unmarked whitefish into or out of the study site. Site length was much longer than for depletion sites (typically 300–12,000 m), reducing the likelihood of fish movement. Log-likelihood estimates of whitefish abundance were made using the Mark Recapture for Windows software package (Montana Fish, Wildlife and Parks 1997). Estimates were made for each 100 mm size class and summed to produce an estimate of total number of whitefish present. However, we could not estimate whitefish <100 mm at the mark-recapture sites due to low capture efficiencies of small fish. Where electrofishing was not possible, snorkeling was conducted following the protocol of Thurow (1994) to count all whitefish present. Total counts of mountain whitefish were used as minimal abundance estimates with no correction for any sightability bias.

For a more detailed description of methodology of abundance estimations, see Meyer et al. (2006). In short, we will be estimating total mountain whitefish abundance separately for each river drainage using the stratified random sampling formulas from Scheaffer et al. (1996). We will first sum the total length of stream for each stream order (or stratum) using the ArcView® geographic information system (GIS), and divide this total by 100 meters of stream (our typical study site length) to calculate the number of sampling units (N_i) in each stratum (L). Our abundance estimates will be standardized to density per 100 linear meters of stream. We will calculate a mean abundance ($\bar{y}_i$) within each stream order (stratum) and an associated variance. For total population size (N_{census}), we will use the formula:

$$N_{census} = \sum_{i=1}^{L} N_i \overline{y_i}$$

and for variance of N_{census} we used the formula:

$$\widehat{V}(N_{census}) = \sum_{i=1}^{L} N_i{}^2 \left(\frac{N_i - n_i}{N_i} \right) \left(\frac{s_i{}^2}{n_i} \right)$$

where s_i^2 is the variance of the observations in stratum *i* and n_i is the sample size within stratum *i*. All sample sites, including dry and fishless sites, were included in these estimates.

Within each river drainage, we will determine the number of presumably unconnected mountain whitefish subpopulations based on (1) our sampling and that of others, and (2) personal observations and local biologists' knowledge. We will estimate individual subpopulation abundance by the same methods and formulas as above. Because of small sample sizes within some stream orders, variance estimate will often not be possible or will be unreliable for subpopulation estimates; thus, we will not calculate confidence intervals.

Mountain Whitefish Population Dynamics

Using backpack- and boat-mounted electrofishing units, 1,234 mountain whitefish were collected to date from 14 streams in 2005. Two additional study streams will be sampled in 2006. Sample streams and the study sites within the streams were selected arbitrarily, but we purposefully distributed study sites across a broad geographic area in southern Idaho that contained a wide variety of stream conditions (Table 2). The length of stream electrofished at a site varied depending on the amount of effort needed to capture an adequate number of fish, but generally was from 200-1,000 m long. Because mountain whitefish spawn in the late fall, fish were collected in late summer to early fall to facilitate maturity confirmation. Captured fish were transported directly to a freezer for storage.

Several physical and physiochemical stream attributes were measured to assess their effect on mountain whitefish maturity (Table 2). Selection of the stream characteristics we measured was based on their ecological importance, on previous research into factors related to fish growth as well as age and length at maturity, and on their ease of collection. We generally focused on variables we felt reflected stream size (e.g., stream order, width, drainage area) or fish growing conditions (e.g., elevation, water temperature, stream aspect, conductivity). At each collection site, we determined elevation from U.S. Geological Survey (USGS) 1:24,000 topographic maps using UTM coordinates obtained at the lower end of the reach electrofished. Stream order (Strahler 1964) was determined from both USGS 1:24,000 and Bureau of Land Management 1:100,000 topographic maps. We suspected that stream order from the 1:24,000 scale would more precisely reflect stream size and flow patterns. However, because stream order between these map scales is correlated across southern Idaho streams (r = 0.60, n = 2,255, K. Meyer unpublished data), we used data from the 1:100,000 scale for the remaining analysis because the Idaho Department of Fish & Game (IDFG) GIS coverage for stream hydrology is at that scale. Gradient was determined using the software package Topo! Version 2.7.3 for Windows (National Geographic Society), stream length (m) was traced between the two contour lines that bounded the study site (average traced distance was 1575 m), and gradient was calculated as the elevational increment between the contours divided by the traced distance. Conductivity was measured with a calibrated handheld conductivity meter accurate to ±2%. Stream width was calculated from the average of 10 readings through the reach that was electrofished, except for large rivers (i.e. >15 m in width), where width was determined using a rangefinder accurate to ±1 m. Drainage area was calculated using digitized USGS topographic maps and the ArcView Version 3.1 software package (Environmental Systems Research Institute, Redlands, California). Mean aspect was measured along a line from the upstream extent of perennial stream on 1:24,000 topographic maps to the study site as the number of degrees from true north (oriented in either an easterly or a westerly direction); thus, 180° was the maximum value for aspect. We deployed electronic temperature recorders at each site that recorded hourly water temperature throughout the summer months (Jun-Aug), from which summer average daily minimum, daily mean, and daily maximum water temperature was calculated.

Sacrificed fish were thawed in the laboratory and measured for total length (nearest mm) and weight (nearest g). Sagittal otoliths were removed and stored dry in vials, and scales were removed and spread on strips of paper which were then stored in envelopes. Age was determined primarily by viewing whole otoliths, dry or submersed in saline, with a dissecting microscope using reflected or transmitted light. The same two readers aged all fish. For all fish whose age was determined to be ≥age-6, or for any fish whose age did not agree between readers, otoliths were placed in epoxy and sliced with a Bronwill crosscutting saw, and then viewed with a binocular microscope for a second reading by the same readers to reconcile age. All fish were considered one year old when they reached their first January. Average agreement between readers for our 14 study sites was 74% (range 56-91%). Scales were not used for aging because we achieved good agreement with otoliths and no fish went unresolved for age, and because scale aging is difficult (Lentsch and Griffith 1987; Downs 1995) and usually less reliable than otoliths.

Gender and maturity were determined by laboratory examination of the gonads. Males were classified as immature if testes were opaque and threadlike and mature if they were large and milky white. Females were classified as immature if the ovaries were small, granular and translucent and mature if they contained large, well-developed eggs that filled much of the abdominal cavity (Strange 1996). Eggs were counted from 272 mature females across all sites, and curvilinear (i.e. power function) regression equations were developed to predict fecundity (F) from fish length (TL). To test for differences in regression slope between study sites, we log transformed the length and fecundity data to create a linear relationship, then used 95% confidence intervals (CIs) around the difference between the regression coefficient estimates ($ß_1$ - $ß_2$) (Zar 1996); nonoverlapping CIs indicated a significant difference. Because testing for a difference between y-intercepts (α_1-α_2) is inappropriate (Zar 1996), we used *t*-tests to compare regression elevation estimates. To evaluate sex ratio at each site, we calculated 95% CIs around the percentage of the population that was female, following Fleiss (1981); CIs not overlapping 50% indicated a statistically significant departure from a 50:50 ratio.

For ecological perspective, we wished to characterize the variation in length and age at maturity across the study sites. For length at maturity, we did this by estimating the length at which the probability of being mature was 0.5 (termed ML50), using one of two methods. If there was no overlap between the largest immature and smallest mature fish, we selected the midpoint between the length of these two fish as ML50. If there was overlap, we related fish length to maturity using logistic regression, using a binary dependent variable (0 = immature, 1 = mature), and selected ML50 as the fish length at which the probability of being mature was equal to 0.5. Separate estimates were developed for males and females, since males tended to mature at a smaller size than females, and because size at maturity selection forces are different between sexes (Roff 1992). If there was overlap between immature and mature fish, and a suitable logistic regression could not be fit to the data for a site, no estimate was made at that site.

These guidelines were not appropriate for age at maturity characterization because in most instances, there was no age overlap in immature and mature fish for males or females, and where there was overlap, suitable logistic regression models generally could not be developed. Instead, we simply reported the oldest immature and youngest mature fish for each site.

We assessed the relationship between length and age at maturity and the stream attributes we measured with logistic regression. Our ultimate goal was to use this information to model maturity across the range of mountain whitefish in Idaho. Because length frequency information is available from hundreds of locations but age structure information is available for only a few streams, we were most interested in developing length at maturity models. However, we compared the strength of the length at maturity models to age at maturity models to assess whether environmental variables influenced one differently or more strongly than the other. Before performing logistic regression analysis, we removed from consideration any combination of independent variables with bivariate correlations greater than 0.70 (Tabachnick and Fidell 1989). If two independent variables were highly correlated, we removed the variable for which data was more difficult to obtain.

Each fish was considered a sample unit. As above, a binary dependent variable was used for maturity. All independent variables were continuous. Only first order interactions were tested for significance. Of the 1,234 mountain whitefish that were collected, gender could be determined for all age-1 and older fish. The Hosmer and Lemeshow goodness-of-fit statistic (Hosmer and Lemeshow 1989) was used to determine whether a particular logistic regression model adequately fit the data; those models not satisfying the goodness-of-fit test were discarded. We then used Akaike's information criteria (AIC) and McFadden's Rho^2 to assess the best logistic regression models. AIC is an extension of the maximum likelihood principle with a bias correction term that penalizes for added parameters in the model (Akaike 1973); models with lower AIC values are better. McFadden's Rho^2 is a transformation of the likelihood-ratio statistic and mimics an r^2 value (SYSTAT 1998), though scores tend to be much lower; values between 0.20 and 0.40 are considered very satisfactory (Hensher and Johnson 1981).

RESULTS

A total of 2,269 study sites were sampled across 40,158 km of stream in 21 river drainages in the USRB (Table 4). Of these sites, mountain whitefish were captured at only 104 (4.6%) sites. Mountain whitefish were encountered most often in the Payette River, Boise River, and Palisades/Salt drainages. Mountain whitefish were apparently absent from a number of river drainages, most notably the Owyhee River (238 sites surveyed), Sinks (209 sites), Raft River (99 sites), Goose Creek (97 sites), Willow Creek (94 sites), Portneuf River (87 sites), and Salmon Falls Creek (76 sites) drainages. Mountain whitefish were rarely caught in small tributary streams and instead were usually only found in larger, mainstem rivers. Six hundred thirty-five study sites (30%) were dry or contained too little water to contain fish.

A total of 1,234 fish were sacrificed from 14 study sites in the USRB (Table 5). At these study sites, mean (range) elevation, conductivity, gradient, and width were 1,449 m (700-1,985 m), 316µS/cm (51–835µS/cm), 0.29% (0.03-0.86%, and 42.3 m (5.3–96.4 m), respectively.

DISCUSSION

When finalized, this study will be, to our knowledge, the most broadscale status assessment ever conducted for mountain whitefish. Our preliminary summaries indicate that, unlike most other native salmonids in the USRB, mountain whitefish are rarely found in smaller streams, but instead are located almost exclusively in larger mainstem rivers, where they appear to be relatively abundant. How much this distribution and abundance has changed from historical levels will be difficult if not impossible to assess, but because of their mainstem distribution, mountain whitefish have almost certainly experienced more impact from habitat fragmentation resulting from hydropower production and irrigation storage and diversion facilities than most other salmonids in the USRB.

The completion of this study will build on previous work that has focused on basic life history characteristics of mountain whitefish (Pettit and Wallace 1975; Thompson and Davies 1976). In addition, it is hoped that the factors that influence these characteristics will be better explained. Mountain whitefish have received little to no attention in the fisheries and conservation communities, other than as indicator species for overall ecosystem health (e.g., Cash et al. 2000). This study should help elucidate many facets of mountain whitefish status, biology, and management in the USRB.

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LITERATURE CITED

Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. Pages 267-281 *in* B. N. Petran and F. Csaki, editors. International symposium on information theory, 2nd edition. Akademiai Iadi, Budapest, Hungary.

Behnke, R. J. 2002. Trout and salmon of North America. The Free Press, New York.

Cash, K. J., W. N. Gibbons, K. R. Munkittrick, S. B. Brown, and J. Carey. 2000. Fish health in the Peace, Athabasca and Slave river systems. Journal of Aquatic Ecosystem Stress and Recovery 8:77-86.

Downs, C. C. 1995. Age determination, growth, fecundity, age at sexual maturity, and longevity for isolated, headwater populations of westslope cutthroat trout. Master's Thesis, Montana State University, Bozeman, Montana.

Fleiss, J. L. 1981. Statistical methods for rates and proportions. John Wiley and Sons, Inc. New York, New York.

Franklin, I. R. 1980. Evolutionary change in small populations. Pages 135-150 *in* M. E. Soule and B. A. Wilcox, editors. Conservation Biology: an evolutionary-ecological perspective. Sinauer Associates, Sunderland, Massachusetts.

Harris, R. B., and F. W. Allendorf. 1989. Genetically effective population size of large mammals: an assessment of estimators. Conservation Biology 3:181-191.

Hensher, D., and L. W. Johnson. 1981. Applied discrete choice modeling. Croom Helm. London, England.

Hosmer, D. W., and S. Lemeshow. 1989. Applied logistic regression. John Wiley & Sons, Inc. New York, New York.

Lande, R. 1988. Genetics and demography in biological conservation. Science 241:1455-1460.

Lentsch, L. D., and J. S. Griffith. 1987. Lack of first-year annuli on scales: frequency of occurrence and predictability in trout of the western United States. Pages 177-188 *in* R. C. Summerfelt and G. E. Gresswell, editors. Age and growth of fish. Iowa State University Press, Ames, Iowa.

Meyer, K. A., D. J. Schill, and J. A. Lamansky. 2006. Status of Yellowstone cutthroat trout in Idaho. Transactions of the American Fisheries Society 135:1329-1347.

Meyer, K. A., D. J. Schill, F. S. Elle, and J. A. Lamansky. 2003a. Reproductive demographics and factors that influence length at sexual maturity of Yellowstone cutthroat trout in Idaho. Transactions of the American Fisheries Society 132:183-195.

Montana Fish, Wildlife and Parks. 1997. Mark Recapture for Windows, Version 5.0. Bozeman, Montana.

Pettit, S. W., and R. L. Wallace. 1975. Age, Growth, and Movement of Mountain Whitefish, Prosopium williamsoni (Girard), in the North Fork Clearwater River, Idaho. Transactions of the American Fisheries Society 104:68–76.

Reynolds, J. B. 1996. Electrofishing. Pages 221-254 *in* B. Murphy and D. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Rieman, B. E., and F. W. Allendorf. 2001. Effective population size and genetic conservation criteria for bull trout. North American Journal of Fisheries Management 21:756-764.

Roff, D. A. 1992. The evolution of life histories: theory and analysis. Chapman & Hall, Inc., New York, New York.

Scheaffer, R. L., W. Mendenhall, and L. Ott. 1996. Elementary survey sampling, fifth edition. Duxbury Press. Belmont, California.

Soule, M. E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 135-150 *in* M. E. Soule and B. A. Wilcox, editors. Conservation Biology: an evolutionary-ecological perspective. Sinauer Associates, Sunderland, Massachusetts.

Strahler, A. N. 1964. Quantitative geomorphology of drainage basins and channel networks. Pages 39-76 *in* V. T. Chow, editor. Handbook of applied hydrology. McGraw-Hill, New York, New York.

Strange, R. J. 1996. Field examination of fishes. Pages 433-446 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

SYSTAT. 1998. SYSTAT 8.0 Statistics. SPSS Inc., Chicago, Illinois.

Tabachnick, B. G., and L. S. Fidell. 1989. Using multivariate statistics, second edition. Harper Collins, New York, New York.

Thompson, G. E., and R. W. Davies. 1976. Observations on the age, growth, reproduction, and feeding of mountain whitefish (*Prosopium williamsoni*) in the Sheep River, Alberta. Transactions of the American Fisheries Society 105:208-219.

Thurow, R. F. 1994. Underwater methods for study of salmonids in the intermountain west. U.S. Forest Service General Technical Report, INT-GTR-307. Logan, Utah.

Thurow, R. F., C. E. Corsi, and V. K. Moore. 1988. Status, ecology, and management of Yellowstone cutthroat trout in the upper Snake River drainage, Idaho. American Fisheries Society Symposium 4:25-36.

Van Deventer, J., and W. S. Platts. 1989. Microcomputer software system for generating population statistics from electrofishing data - user's guide for MicroFish 3.0. U.S. Forest Service General Technical Report INT-254.

Wright, S. 1931. Evolution in Mendelian populations. Genetics 16:97-159.

Zar, J. H. 1996. Biostatistical analysis. Third edition. Prentice Hall, Inc., Upper Saddle River, New Jersey.

Table 1. Summary of mountain whitefish status assessment study sites from 21 river drainages in the upper Snake River basin (USRB) in Idaho.

River drainages	Total kilometers in USRB	Number of sites sampled	Sites containing MWF	Dry or nearly dry sites
Weiser River	1,805	83	2	12
Payette River	4,200	249	38	13
Boise River	5,327	167	28	12
Owyhee River	7,309	238	0	138
Salmon Falls Creek	1,625	76	0	33
Big Wood River	3,242	112	5	65
Bruneau River	2,714	122	10	47
Rock Creek	700	18	0	11
Dry/Marsh/Rock	798	31	0	21
Goose Creek	1,137	97	0	30
Raft River	1,346	99	0	30
Bannock Creek	445	7	0	2
Portneuf River	1,467	87	0	10
Blackfoot River	1,017	83	1	14
Willow Creek	673	94	0	25
South Fork Snake River	1,122	95	3	27
Palisades/Salt River	713	55	8	6
Teton River	1,177	92	3	25
Henry's Fork Snake River	1,828	90	4	16
Sinks drainages	1,513	209	0	43
Snake River mainstem and tributaries	10,115	165	2	55
Total	40,158	2,269	104	635

Table 2. Summary of mountain whitefish population dynamics study sites in the upper Snake River basin in Idaho.

Site Location	Date	UTM coordinates East	North	Zone	Elevation (m)	Conductivity (µS/cm)	Gradient (%)	Mean width (m)	Number of fish sampled
Snake River (Menan)	9/28/2005	418778	4845382	12	1,460	333	0.25	84.8	120
Snake River (Blackfoot)	9/30/2005	391056	4786226	12	1,368	328	0.10	70.5	93
Henrys Fork (Warm River)	9/19/2005	473014	4883874	12	1,604	143	0.29	62.3	107
S. Fork Snake (Twin Bridges)	9/27/2005	440507	4834936	12	1,515	365	0.16	42.8	97
S. Fork Snake (Palisades Dam)	9/29/2005	483104	4798938	12	1,640	327	0.14	96.4	80
Teton River (Hog Hollow)	10/17/2005	451132	4864709	12	1,522	350	0.18	32.2	113
Teton River (Buxton Bridge)	10/18/2005	484921	4840977	12	1,825	350	0.07	25.0	96
Stump Creek	10/13/2005	493958	4737673	12	1,887	835	0.42	6.9	69
Crow Creek	10/11/2005	489676	4715833	12	1,985	502	0.86	5.3	75
S. Fork Boise (Featherville)	9/1/2005	665159	4828902	11	1,618	113	0.61	25.2	104
Boise River (Boise)	10/31/2005	566658	4827288	11	830	90	0.16	36.1	79
Boise River (Notus)	11/9/2005	516423	4840758	11	700	459	0.12	32.9	64
Payette River (Emmett)	8/2/2005	543654	4861406	11	722	51	0.03	48.2	75
Big Wood River (Hailey)	11/3/2005	714026	4829359	11	1,616	172	0.64	23.3	62

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