FISHERY RESEARCH

# PROJECT 4: HATCHERY TROUT EVALUATIONS

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# ANNUAL PERFORMANCE REPORT

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**Grant # F-73-R-32**

**Project 4: Hatchery Trout Evaluations**

**Subproject #1: Use of Tiger Muskellunge to Remove Brook Trout From High Mountain Lakes**

**Subproject #2: Sterile Trout Investigations: Performance of Sterile Catchable Rainbow Trout in Lowland Lakes and Reservoirs**

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**ANNUAL PERFORMANCE REPORT**
**SUBPROJECT #1: USE OF TIGER MUSKELLUNGE TO REMOVE BROOK TROUT FROM HIGH MOUNTAIN LAKES**

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## ABSTRACT

Nonnative brook trout *Salvelinus fontinalis* populations in high mountain lakes threaten the persistence of native fish and often offer little fishing opportunity. Elimination of brook trout populations by stocking tiger muskellunge *Esox lucius x masquinongy* may be an efficient means for eliminating some populations, especially in low complexity habitats. Elimination of brook trout populations could contribute to conservation efforts by allowing lakes to be restocked with western salmonids. In 2007, nine alpine lakes containing stunted brook trout were planted with tiger muskellunge (40 fish/ha) with an average length of 317 mm. Lakes were surveyed in summer 2008 and 2009 to compare changes in brook trout size and abundance relative to 2005 or 2006 data. Relative abundance of brook trout varied widely among the nine study lakes but declined substantially in most lakes, while average length and weight increased significantly following stocking with tiger muskellunge. Mean catch rates of brook trout declined from 22.8 per net night before planting tiger muskellunge, to 5.1 and 4.3 per net night in 2008 and 2009, respectively. Prior to tiger muskellunge, mean brook trout length and weight was 212 ± 3 mm ($n$ = 519) and 88 ± 5 g. After stocking, mean brook trout length increased to 246 ± 6 mm ($n$ = 132) in 2008, and to 264 ± 7 mm ($n$ = 138) in 2009. Catch rates of brook trout did not change noticeably in "control" lakes, and size distributions remained largely unchanged. The initial attempt to use habitat characteristics to classify lakes according to the likelihood of eradicating brook trout was generally not an accurate predictor of results. This suggests I have an incomplete understanding of the primary factors driving successful tiger muskellunge predation of brook trout. Brook trout may overcome eradication efforts by recolonizing lakes from refuge habitats and density-dependent recruitment success. I recommend combining tiger muskellunge introductions with other suppression methods in lake tributaries or outlets.

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## INTRODUCTION

During the early 20th century, brook trout *Salvelinus fontinalis* were introduced to high mountain lakes throughout the western United States and Canada, including Idaho. Most introduction efforts ceased by the 1950s, but by this time, brook trout had established self-sustaining populations in many lakes. Although some of these populations have sustained recreationally important fisheries (Donald et al. 1980), the vast majority do not offer quality fishing opportunities. More importantly, some of these populations threaten the persistence of native fish and amphibian populations.

According to Bahls (1992), over 95% of the deep, high mountain lakes in western North American were fishless prior to human introduction of salmonids. Therefore, establishment of salmonids, including brook trout, in high mountain lakes did not likely reduce numbers of native fish substantially within these habitats; however, these introductions have been linked to declines in other native biota such as amphibians (Pilliod 2001; Murphy 2002) and downstream fish populations. High elevation streams contain some of the strongest remaining cutthroat *Oncorhynchus clarkii* and bull trout *Salvelinus confluentus* populations. Headwater lakes within these drainages often contain nonnative trout and may act as source populations for colonization of nonnative fish into downstream habitats (Adams et al. 2001). These authors found that brook trout were capable of invading habitats by their ability to disperse downstream through 80% slopes and over 18 m waterfalls. Brook trout have the ability to outcompete cutthroat trout (De Staso and Rahel 1994) and may eventually eliminate some cutthroat trout populations (Kruse et al. 2000). Additionally, brook trout may hybridize with or displace bull trout, thereby reducing or eliminating some populations (Kitano et al. 1994; Kanda et al. 2002).

Within high mountain lakes, brook trout are capable of spawning in inlet and outlet tributaries, as well as lake margins (Fraser 1989). Due to a combination of abundant spawning habitats, early age at maturity, and few predators, brook trout populations often reach very high densities (Donald and Alger 1989). Since most high mountain lakes are low in productivity, high-density brook trout populations are often prone to stunting (Donald and Alger 1989; Hall 1991; Parker et al. 2001), at which point they become of marginal interest to anglers (Rabe 1970; Donald et al. 1980; Donald and Alger 1989). In this case, fisheries managers may be interested in shifting the size structure of brook trout populations in high mountain lakes to provide higher proportions of quality fish (i.e. those ≥254 mm). In high mountain lakes where complete removal of brook trout is unlikely, investigating techniques to improve the size structure of brook trout populations may be a practical secondary objective.

Biologists have employed several techniques to reduce or eliminate brook trout and other nonnative trout populations from high mountain lakes. Such techniques have included high-intensity gill netting, rotenone application, electrofishing, and introducing piscivorous salmonids. During a brook trout removal effort from a 1.6 ha high mountain lake in the Sierra Nevada mountains in California, three to six gill nets were set per night during the ice-free period for a total effort of 108 net days (Knapp and Matthews 1998). This effort effectively removed the entire population (97 fish) at an estimated cost of $5,600. However, the authors speculated that this technique would not be effective in lakes exceeding 3 ha. With a similar effort, Parker et al. (2001) were able to remove an entire brook trout population (261 fish) from a 2.1 ha lake in Banff National Park, Alberta, Canada. The majority of fish were removed within the first week of netting (54%). Furthermore, within the first year of netting, they suspected that the entire adult population was removed by the time nets were retrieved after ice-off, and only a few juvenile fish were caught thereafter. Walters and Vincent (1973) used rotenone to eliminate brook trout from 1.1 ha Emmaline Lake, Colorado. However, biologists rarely use this method in high lakes due to cost and difficulty of application and subsequent detoxification of outflow, and the negative perception associated with applying chemicals in remote, relatively pristine areas or designated wilderness.

Using piscivorous fish is an attractive alternative for managing brook trout populations in that little effort is needed besides an initial stocking effort and subsequent monitoring. However, results for this technique have been inconsistent. The state of Colorado occasionally stocked lake trout *Salvelinus namaycush* and brown trout *Salmo trutta* in high mountain lakes to control brook trout populations (Nelson 1988). From 1960-1964, experimental plants of lake trout were made in five lakes. Lake trout established self-sustaining populations in all five lakes, and by the early 1980s, no response in brook trout populations was noted in two lakes, while numbers of brook trout were decreased in two others and eliminated or nearly so from the other. Nelson (1988) also noted that brook trout lakes that contained brown trout had lower densities of brook trout and with more brook trout over 250 mm.

Similar attempts have been made in Idaho using Kamloops rainbow trout *O. mykiss*, bull trout, and brown trout. In 1993, Idaho Department of Fish and Game personnel stocked 702 Kamloops rainbow trout in Carlson Lake in an effort to improve the size structure of stunted brook trout (Brimmer et al. 2002). Unfortunately, this attempt was unsuccessful, as the brook trout size structure in the lake was unchanged. Kamloops rainbow trout were stocked at an average weight of 133 g (3.7 per lb) and an approximate length of 200 mm (8"). These fish were likely too small at stocking to exert significant predation pressure, and due to high densities of brook trout, were likely not able to grow large enough to do so. Similar efforts were made in several lakes within Region 4 and the McCall subregion, but to date, none of these efforts has been successful in eliminating or even reducing brook trout densities from their respective lakes (P. Janssen and F. Partridge, IDFG, personal communication).

Tiger muskellunge *Esox lucius X masquinongy* are a cross between a male northern pike *E. lucius* and a female muskellunge *E. masquinongy*. Tiger muskellunge have been stocked in lakes and reservoirs throughout the northern United States to provide trophy angling opportunities (Storck and Newman 1992) and to control prey, rough, and pan-fish populations (Wahl and Stein 1993). Tiger muskellunge are preferred over their parental species due to their superior growth rates, ease of hatchery rearing, and intermediate angling vulnerability (Weithman and Anderson 1977; Brecka et al. 1995), and because they are functionally sterile (Crossman and Buss 1965). Sterility allows biologists to stock tiger muskellunge with little to no threat of creating self-sustaining populations. Tiger muskellunge are highly effective predators on a variety of fish but prefer soft-rayed fusiform prey (Tomcko et al. 1984). When in high densities, muskellunge have been shown to limit densities of prey species such as white suckers *Catastomus commersonii* and black crappie *Pomoxis nigromaculatus* (Siler and Beyerle 1986), showing promise as a means to manage unwanted brook trout populations.

During 1998 and 1999, IDFG personnel began a management case study to determine if tiger muskellunge could eliminate brook trout from Ice Lake and Rainbow Lake, two high mountain lakes in the Clearwater region. Tiger muskellunge were stocked into Ice Lake at a density of 41 fish/ha (E. Schriever and P. Murphy, IDFG, personal communication). To suppress brook trout further, IDFG personnel removed fish from inlet and outlet habitats with backpack electrofishing gear. From 1998 to 2001, catch in a single gill net declined from 17 fish to zero fish per net night. Although some fry were seen in the inlet and outlet, the brook trout population in Ice Lake had been substantially reduced and possibly eliminated with one tiger muskellunge stocking. In Rainbow Lake, tiger muskellunge were stocked during 1999 and 2000 at densities of 6.1 and 33.6 fish/ha, respectively. An initial survey during 1998 indicated that brook trout densities were high (85 fish per net night). By 2001, two years after the initial introduction of tiger muskellunge, brook trout catch decreased to 10 fish per net night. The authors speculated that brook trout would not likely be eliminated from Rainbow Lake with tiger muskellunge predation and backpack electrofishing, due to the size of the inlet and outlet. They anticipated instead that reduced densities would improve the size structure of the remaining brook trout, thereby improving fishery quality (E. Schriever and P. Murphy, IDFG, personal communication).

Tiger muskellunge have also been used by IDFG personnel in Region 7 to improve the size structure of brook trout in Carlson Lake. Carlson Lake once produced trophy size brook trout but recently only contained small stunted fish (Brimmer et al. 2002). Prior to introduction of tiger muskellunge, a population estimate indicated that the lake contained 9,900 brook trout. During 2002, forty-one tiger muskellunge were introduced. By 2003, the brook trout population had decreased by an estimated 8.5% (Esselman et al. 2004). No additional population assessments have been attempted due to high mortality of tiger muskellunge in gill nets but will be attempted in future years.

Although encouraging, the results of the two IDFG management efforts above do not provide the scope necessary to reach firm conclusions regarding the utility of tiger muskellunge for eliminating undesirable brook trout populations. In this progress report, I describe initial efforts to investigate the effectiveness of introducing tiger muskellunge to reduce or eliminate brook trout populations in alpine lakes in Idaho. I compare changes in brook trout populations and relative density following tiger muskellunge introduction.

## RESEARCH GOAL

1. To eliminate or improve the size structure of brook trout populations from high mountain lakes, thereby reducing threats to native species and allowing restocking of lakes with sterile western salmonids to improve recreational angling opportunities.

## OBJECTIVES

1. To determine if tiger muskellunge stocked at densities of 40 fish per hectare into high mountain lakes with stunted brook trout populations can cause recruitment failure and eventual elimination of populations within five years.

2. To determine lake and associated inlet or outlet characteristics that influence success/failure of brook trout eradication efforts with tiger muskellunge.

## METHODS

During 2005, IDFG regional fisheries personnel and U.S. Forest Service personnel provided high mountain lake information that facilitated study site selection. Lakes were preferentially selected that were known to have brook trout populations and were thought to have limited inlet and outlet spawning habitats. To avoid biasing results, steep drainages were preferred, as they most likely possessed barriers that would prevent recolonization by any downstream brook trout populations. Nine lakes throughout central Idaho received plants of tiger muskellunge for this evaluation (Figure 1). Additionally, brook trout densities were monitored at four additional “control” lakes that had established brook trout populations and were in close proximity to the treatment lakes, but did not receive plants of tiger muskellunge.

Study lakes were sampled during 2005 or 2006 to determine relative density, age, and size structure of brook trout populations as well as habitat characteristics. All lakes were surveyed with floating gill nets and angling from August 4 to September 29, 2005, except for Grassy Mountain #1, Grassy Mountain #2, and Corral Lake, which were surveyed in July 2006. The experimental gill nets used had 19, 25, 30, 33, 38, and 48 mm bar mesh panels and were 46 m long by 1.5 m deep. Typically, four gill nets were set in the early afternoon and pulled the following morning. While nets fished, the two- or three-person crew used spin- and fly-fishing gear to collect additional samples. Captured fish were identified to species, measured to the nearest millimeter (total length), and weighed to the nearest gram. Catch-per-unit-effort (CPUE) of brook trout was calculated by lake as the total brook trout caught per total hours netting or angling. CPUE was used as an estimate of relative abundance before and after stocking tiger muskellunge. See Kozfkay and Koenig (2006) for complete descriptions of age structure, size distributions, and mortality estimates.

Tiger muskellunge were reared at Hagerman State Fish Hatchery. Some authors have indicated that tiger muskellunge reared only on pellet diets are less effective predators on live fish and do not survive well after stocking (Gillen et al. 1981). Tiger muskellunge were therefore converted to live brook trout two weeks prior to stocking to make them more effective predators in the wild and increase their survival after stocking. Tiger muskellunge were stocked on June 12, 2007 into the study lakes. At the time of stocking, the mean length of the tiger muskellunge was 317 mm but ranged from 160 to 400 mm. Tiger muskellunge were planted by helicopter using an adjustable-volume fire bucket set at 946 liters (250 gallons). Tiger muskellunge were counted by hand before each flight, and densities in the fire bucket did not exceed two fish/gallon. Stocking density of tiger muskellunge was held constant across lakes at 40 fish/ha for 2,929 total fish planted (Table 1).

Study lakes were sampled in 2008, approximately 13 months after tiger musky were planted, and again in 2009. Fish were sampled using overnight gill net sets and processed according to the methods above. However, only two nets were fished at each lake in an effort to reduce bycatch of tiger muskellunge. Additional samples of brook trout and tiger muskellunge were collected using hook and line techniques using a variety of flies and lures.

Lake habitat and amphibian surveys were conducted at each of the nine lakes at the time fish were sampled in 2008 and 2009. A series of five transects were placed at equal distances perpendicular to the long axis of the lake with the aid of a laser rangefinder. Lake width was measured at each transect using a laser range finder. Depth was measured with a hand-held sonar unit at five equidistant points along each transect. Specific conductivity, pH, and surface temperature were measured at the middle of each transect using Hanna handheld conductivity and temperature/pH meters (Model #HI 98308, DiST 4 and #HI 98127). Lake location and elevation were recorded with the use of a handheld GPS unit. Lake area was calculated with geographic information systems (ArcGIS 9.1). In addition, amphibian surveys were conducted visually by slowly walking the entire perimeter of each lake along the water shore interface and looking near and under woody debris and recording the count, life stage, and species encountered. Basic stream habitat data were collected in inlet and outlets of study reservoirs in an effort to collect information that might help explain eradication success. Measurements were performed over the first 200 m of stream above (inlets) and below (outlets) each lake. Bankfull width was collected every 25 m and the area of suitable trout spawning habitat was estimated using a meter stick. Elevation was measured at the lake level and at the end of each stream reach with a handheld GPS unit. Stream gradient was calculated by dividing the difference in elevation from the start and end of the reach divided by the reach length.

Removal potential (the likelihood that brook trout would be successfully eradicated) at each lake was categorized with a qualitative value based on the following criteria:

- Very High: lakes with no inlet and/or outlet spawning habitat; low habitat complexity within the lake.
- High: lakes contain only limited inlet and/or outlet spawning habitat; lake outlets possess migration barriers.
- Moderate: lakes contain some accessible inlet and/or outlet spawning habitat.
- Low: lakes contain abundant inlet and/or outlet spawning habitat; low gradient outlets with spawning habitat present, connections to lentic habitats with established brook trout present.

## RESULTS

In 2008, sampling of the nine high mountain lakes stocked with tiger muskellunge yielded 132 brook trout and 49 tiger muskellunge, which were the only two species collected (Table 2). The majority of the brook trout sampled were caught at Merriam Lake (n = 70), while catch at all other locations ranged from one to 16 total brook trout. Average catch was 14.6 brook trout per lake, but only 7.8 per lake when Merriam was not included. The lowest catch of brook trout (one) came from Grassy Mountain #2.

In 2009, sampling the nine treatment lakes yielded 138 brook trout and 30 tiger muskellunge. Similar to 2008, Merriam Lake again had the largest number of brook trout sampled (*n* = 63), while no brook trout were captured at Black, Corral, and Granite Twin lakes. Tiger muskellunge were documented in all lakes except Merriam Lake. Corral and Granite Twin lakes had the largest number of tiger muskellunge encountered (*n* = 10), while very few were sampled in most lakes (Table 4). Mean length of tiger muskellunge increased from 460 mm in 2008 to 535 mm in 2009 (Table 4).

Relative abundance of brook trout varied widely among the nine study lakes, but most lakes saw substantial declines in CPUE and increased average size of brook trout during both years following introduction of tiger muskellunge (Table 2). In 2008, gill nets fished for 251 total hours over 18 net nights and caught 91 brook trout. Mean CPUE ranged from one to 18 brook trout per net night, with an average of 5.1 per net night overall. Catch-per-unit-effort at several lakes (Black, Corral, and Grassy Mountain #2) was equal or less than one trout per net night, indicating very low densities. These data show much lower trout densities compared to pretreatment surveys, which averaged 22.8 brook trout per net night (Table 2).

In general, CPUE of brook trout continued to decline in 2009 with some exceptions. Mean catch rates of brook trout were 4.3 per net night, with 301 hours of netting to capture 78 total brook trout. No brook trout were captured in three of the nine lakes, including Black, Corral, and Granite Twin lakes (Table 2). Granite Twin Lake showed a marked decline from 5.5 to zero brook trout from 2008 to 2009, suggesting continued predation by tiger muskellunge, despite no additional stocking. Even though the average gill net catch rate continued to decrease, CPUE actually increased in three other lakes since 2008 (Table 2).

After tiger muskellunge were introduced, angling catch rates of brook trout in 2008 were low overall but heavily reduced in the two lakes where data were comparable (Table 2). In 2008, 63.5 total hours of angling were expended which produced 41 brook trout. However, Merriam Lake accounted for 35 of these trout alone, and angling success was poor at most lakes. Without Merriam Lake, the mean angling CPUE for brook trout decreased from 0.55 trout/hour to 0.15 trout/hr. Before introducing tiger muskellunge, mean catch rates of brook trout were 1.5 trout/hr, based on Corral Lake and Shirts Lake. In 2009, mean angling catch rates increased slightly to 0.60 fish per hour, mainly as a result of increased catches from Grassy Mountain #1 and Upper Hazard lakes (Table 2). As with the gill net surveys, no brook trout were caught angling from three lakes, including Black, Corral, and Granite Twin lakes.

Despite variation in size across lakes, on average, the mean size of brook trout increased slightly compared to 2005/2006 (pre-tiger muskellunge) within one year, based on 95% confidence intervals (Table 3). In 2008, the overall mean brook trout length and weight was 246 ± 6 mm (*n* = 132) and 161 ± 11 g, compared to 212 ± 3 mm (*n* = 519) and 88 ± 5 g before tiger muskellunge were introduced (Table 3). In 2008, the mean brook trout length among lakes ranged from a low of 225 ± 60 mm (Shirts L.) to a high of 287 mm (*n* = 1) in Grassy Mountain #2. Mean weight of brook trout among lakes ranged from a low of 115 ± 118 g in Black Lake to a high of 263 ± 34 g in Grassy Mountain #1. In 2009, mean brook trout size again increased in four out of five lakes where they were caught (since no brook trout were caught in three of the study lakes). Only Upper Hazard showed a small decline in mean length, although not significant based on 95% confidence intervals (Table 3). Brook trout averaged 264 ± 7 mm (*n* = 138) in length, with a mean weight of 181 ± 15 g (*n* = 138).

The overall size distribution of brook trout noticeably shifted after tiger muskellunge were stocked. While small sample sizes at some lakes likely precluded meaningful comparisons of mean length (Black, Corral, Grassy Mountain #2, and Shirts), the distribution of brook trout sizes indicates an increase in the proportion of larger sized fish, increasing average size and trophy potential at most lakes (Figure 2). In the pretreatment surveys, about 40% of the brook trout sampled were ≤200 mm, compared to only 5% in 2008. This remained roughly the same in 2009, when only seven brook trout ≤200 mm were caught (5%), with six of them from Upper Hazard Lake.

Prior to tiger muskellunge, 18% of brook trout were ≥254 mm, and of those, only 4% were ≥279 mm. During 2008, however, 40% of brook trout were ≥254 mm, and 17% were ≥279 mm. In 2009, 64% of brook trout equaled or exceeded 254 mm, with 38% exceeding 279 mm, on average. These data indicate a marked increase in the proportion of larger brook trout in the sample, despite lower overall abundance. Table 3 indicates a noticeable shift towards larger brook trout, as indicated by the increase in trophy potential as determined by the mean of the five longest fish caught.

In contrast to lakes that received plants of tiger muskellunge, the four “control” lakes that were not planted saw little change in brook trout populations. Length-frequency histograms indicate little change in the overall size distribution of brook trout length (Figure 3) between 2006 and 2009. Average size was not significantly different between years (Table 5), and catch rates (both angling and gill nets) of brook trout remained consistent (Table 6) across years.

Potential study lakes included a wide variety of physical habitat characteristics and inlet and outlet morphologies (Table 1). However, I did not see any consistent patterns of success in relation to perceived potential for elimination. Spruce Gulch and Corral lakes were considered to have “very high” probability for elimination. These lakes had little or no inlet/outlet spawning habitat, limited tributary habitat with barriers nearby, and low complexity lake habitat. At this point in the study, brook trout were heavily reduced in Corral Lake, but are still readily present in Spruce Gulch Lake. The potential for elimination at Granite Twin, Merriam, and Shirts lakes was thought to be “high.” These lakes had only limited spawning habitat in inlet tributaries and possessed migration barriers in outlet tributaries. While brook trout were reduced in Granite Twin and Shirts lakes, CPUE actually increased in Merriam Lake. The brook trout population in Black Lake, Upper Hazard, Grassy Mountain #1, and Grassy Mountain #2 lakes were considered to have “moderate” elimination potential because of easily accessible spawning habitat and tributary refuge habitat where brook trout might escape predation from tiger muskellunge. Brook trout were heavily reduced in Black Lake, yet were still present in Upper Hazard, Grassy Mountain #1, and Grassy Mountain #2 lakes.

## DISCUSSION

Prior to introducing tiger muskellunge, most lakes in this study generally contained small brook trout. On average, only a small proportion (18%) of the trout sampled were over 254 mm (10”). Brook trout populations were characterized by an abundance of younger year classes and slow growth rates, especially after age-4 (Kozfkay and Koenig 2006). Thus, these populations were likely of limited interest to anglers and presented an opportunity for improvement. Removal of these stunted brook trout populations could help conserve native species and may improve recreational fishing opportunities if the lakes are restocked with native salmonids.

Most lakes planted with tiger muskellunge showed substantial declines in CPUE and increased average size of brook trout in the years following stocking with tiger muskellunge. Conversely, “control” lakes that did not receive tiger muskellunge showed little or no change in relative abundance or average size of brook trout. Even though sampling effort was lower in 2008 and 2009 compared to pretreatment surveys (in an effort to avoid sacrificing tiger muskellunge), results suggest that brook trout populations were severely reduced following tiger muskellunge introductions in 2007. Tiger muskellunge were highly effective predators on brook trout in most study locations. The effectiveness of the tiger muskellunge was probably improved by their large average size at the time of stocking (>300 mm) and previous experience with live brook trout (in the hatchery). In general, esocids survive better and have higher foraging success when reared on a diet of live fish, and are stocked at larger sizes (>250 mm) in the spring, with high densities of suitable prey (Storck and Newman 1992; Szendrey and Wahl 1996; Larscheid et al. 1999; Wahl 1999). This corresponds well with the design of this study and the conditions found in these lakes.

While catch rates declined, average brook trout length increased following tiger muskellunge stocking. Mean brook trout lengths likely increased because of lower density (i.e. reduced competition), or because the largest individuals escaped predation through avoidance or exceeding the gape limitation of the tiger muskellunge. Anderson (1973) suggested that large piscivores could improve the size structure of prey populations by reducing prey densities and triggering compensatory increases in growth. Similarly, Donald and Alger (1989) reported increases in mean weight for all age classes of brook trout in a subalpine lake when subjected to only 20% exploitation. Reductions in brook trout were undoubtedly facilitated by the stocking density of 40 tiger muskellunge per hectare, well beyond the 25 fish/ha considered "high" by Storck and Newman (1992).

The initial attempt to classify lakes by the likelihood of eradicating brook trout was generally not an accurate predictor of results. This suggests I have an incomplete understanding of the primary factors driving successful brook trout eradication by tiger muskellunge, at least two years after stocking. For example, Merriam and Shirts lakes were thought to have "high" probability of eradication, when in fact these lakes showed the least success of all. Black Lake was considered to have only "moderate" probably of success, but results suggest much greater impact to brook trout than first anticipated. Only at Corral Lake did results mirror those anticipated by classifying probability of eradication as "very high."

Eradication appeared to be limited in Merriam and Spruce Gulch lakes. Unlike any other lakes in this study, Merriam Lake actually saw a marked increase in CPUE for both gill nets in 2008, followed by similar catch rates in 2009. Merriam Lake sits at the highest elevation of the study lakes and had the lowest average temperature. Conditions here may have been unfavorable for tiger muskellunge, and predation pressure on brook trout may have been light. Regardless of poor tiger muskellunge survival in Merriam Lake, mean brook trout length still increased and smaller size classes were heavily reduced (Figure 2). Brook trout catch rates in Spruce Gulch declined by about half of pre-tiger muskellunge rates in 2008, but remained similar in 2009. Tiger musky in Spruce Gulch were the smallest captured in 2008, and no tiger muskellunge were caught in Merriam Lake (and only one small specimen was observed during surveys, with none in 2009). Despite the smaller size of tiger muskellunge in Spruce Gulch, 12 were captured in 2008 and five in 2009, suggesting moderate survival compared to other lakes. There may have be some promise for eliminating more brook trout in the coming years, although their continued small size may limit their effectiveness.

Brook trout declined in some lakes more quickly than in others, and declines continued from 2008 to 2009. In 2008, Corral Lake showed the largest reduction in CPUE of BKT of all the lakes planted with tiger muskellunge. The lake habitat appears ideal for lie-in-wait predators like tiger muskellunge. Corral Lake is shallow, with abundant submerged woody debris and emergent aquatic vegetation. It is a small lake with the lowest elevation of those planted and summer water temperatures that may be suited for tiger muskellunge growth, as reflected by the large average size of the tiger muskellunge collected there (Table 3). Faster growing tiger muskellunge would be able to eat progressively larger prey, thereby reducing the fraction of the brook trout population that would otherwise exceed the gape limitation. By 2009, no brook trout were captured in three lakes: Black Lake, Corral Lake, and Granite Twin lakes. Although no brook trout were sampled, young brook trout were seen in Corral and Granite Twin lakes, and were likely still present in the outlet of Black Lake.

Upper Hazard Lake showed only a moderate reduction in brook trout catch rates and a modest increase in mean brook trout length in both survey years. Even with abundant complex shoreline habitat (in terms of boulders and woody debris), tiger muskellunge only had a minor impact to brook trout. This is one of the larger lakes in the study (15.8 ha), with an average depth over 7 m and a maximum recorded depth of 21.4 m, suggesting a large amount of pelagic habitat. Tipping (2001) found tiger muskellunge preferred shallow water macrophytes (3-5 m deep) in summer and fall. He speculated that this habitat preference likely reduced their opportunity to prey on salmonids, which are generally pelagic. This tendency for salmonids to occupy pelagic zones while tiger musky remain mainly littoral might help explain the lower success of eradication efforts larger lakes like Upper Hazard, despite abundant littoral cover for concealment. This pattern might also apply to Merriam Lake, which despite its smaller surface area, has higher average and maximum depths, corresponding to its steep shorelines and limited littoral habitat.

Despite heavy predation by tiger muskellunge, complete eradication was not achieved in any lakes at this time, as at least some brook trout were captured in all lakes. Although no brook trout were sampled, young brook trout were seen in Corral and Granite Twin lakes, and were likely still present in the outlet of Black Lake. At this point, these results are similar to those reported from previous IDFG studies to manage brook trout in Lower Rainbow Lake and Ice Lake in the Clearwater River drainage (Schriever and Murphy, *In Press*). These lakes were stocked with tiger muskellunge in 1999 and affected brook trout with mixed results. Lower Rainbow Lake (4.5 ha) was initially stocked with a low density of tiger muskellunge, then restocked again with a higher density (40.7 fish/ha) a year later. Brook trout densities decreased while mean length increased following treatment, but eradication was never achieved. Failure to remove brook trout was likely a result of lower tiger muskellunge stocking density, abundant complex lake habitat, and extensive inlet and outlet habitat that reduced the effectiveness of tiger muskellunge to consume brook trout. Brook trout were successfully removed from Ice Lake, which is a very small lake (0.54 ha) and was stocked with a high density of tiger muskellunge (40.7 fish/ha surface area). Stocked in 1999, tiger musky were observed until 2001, but no brook trout were observed in 2002. Small lake size, minimal inlet/outlet habitat, and low complexity lake habitat likely helped to remove brook trout. Within both mountain lakes, tiger muskellunge introductions were coupled with electrofishing removal of brook trout from lake inlets and outlets. Together, these significantly changed the composition of the brook trout population and decreased overall brook trout abundance in these two lakes (Schriever and Murphy, *In Press*).

More recently, Rhodes et al. (2007) reported similar findings in four additional lakes in the Clearwater drainage treated with tiger muskellunge in 2006. Fly, Heather, Platinum and Running lakes range in size from 1.0 ha to 8.4 ha and were stocked with tiger muskellunge at similar densities (40 fish/ha). Their results indicated similar shifts in mean brook trout size, with an overall average increase of 76 mm in length, while catch-per-unit-effort also declined in three of the four lakes simultaneously. Survey results from 2008 showed mean brook trout length again increased, but only in two of the four lakes (Fly and Running lakes), while it decreased in Platinum Lake and remained unchanged in Heather Lake (Rhodes and Dupont 2009). CPUE also decreased in all lakes except Platinum, suggesting that tiger muskellunge continued to reduce brook trout numbers two years after planting. However, as with previous studies, full eradication was not achieved using tiger muskellunge alone. This study differs in that no electrofishing removal was conducted to improve eradication efforts. Additionally, tiger muskellunge were stocked on only one occasion across a higher number of lakes. The lakes used in this study were of larger sizes with deeper mean depths, on average, with several lakes over 10 ha in surface area.

At this point in the study, one can only discuss the short-term success of tiger muskellunge to reduce brook trout in mountain lakes. Short-term success is likely dependent on lake morphology and size (shallow, small lakes), while long-term success may likely be a function of brook trout recruitment through reproduction or immigration from inlet/outlet refugia and spawning. The population dynamics and species interactions between tiger muskellunge and brook trout in alpine lakes are poorly understood. Long-term success of eradicating brook trout may hinge on whether tiger muskellunge can live long enough to continue limiting brook trout. If tiger muskellunge exhaust their food resources quickly, they may starve and die off before completely removing brook trout. As with Schriever and Murphy (*In Press*), I also noted that brook trout were present in inlet and outlet streams, away from typical tiger muskellunge habitat. Without further effort to remove brook trout that persist in refuge habitats such as inlet or outlet streams, lakes could be recolonized shortly after tiger musky have disappeared (Schriever and Murphy *In Press*). Completely eradicating brook trout using tiger muskellunge may require several stockings to maintain adequate predatory pressure to collapse a brook trout population. Additionally, brook trout that escape predation may represent the largest individuals, and would therefore have the highest fecundity to repopulate a mountain lake. In the absence of predatory tiger muskellunge, brook trout may rebound quickly, so multiple suppression methods should be combined for the best chance of success.

Introducing tiger muskellunge appears to be an effective means to reduce brook trout densities in alpine lakes, as it requires only a minimal labor investment. After an initial stocking effort, only cursory sampling efforts are needed to document population responses in small, shallow lakes. Tiger muskellunge may live for several years, thereby removing brook trout for extended periods. In larger, more complex lakes, additional effort may be needed to eliminate brook trout not accessible to tiger muskellunge. Such fish might include those inhabiting outlet and inlet tributaries or near seep springs, unless they are forced to move to the main lake during winter. Both electrofishing and chemical treatment could prove useful in such scenarios.

This study is currently at an important stage, where decisions about using other treatment options should be made. If left untreated, brook trout populations in these lakes are likely to rebound quickly from the few large remaining adults or young brook trout already spawned. Table 7 lists some of the key attributes of each lake that may help guide future treatment options, and whether further treatments should be considered. Current conditions in some lakes (such as Corral Lake) suggest other treatments could be highly successful for eradicating brook trout completely, while conditions in other lakes suggest further efforts are likely futile or too difficult (such as Merriam Lake). Smaller lakes with simple inlet and outlet habitat and few numbers of juvenile fish should be a priority, since they offer great benefit at little effort. Larger lakes with little change in brook trout populations and complex habitats would not be worth the effort necessary for successful eradication.

## RECOMMENDATIONS

1. Sample treated lakes in 2010 to evaluate changes in brook trout populations and longevity of tiger muskellunge. Sampling in 2010 will also indicate any continued presence of young brook trout.

2. Treat inlets and outlets of four lakes (see Table 6) in fall 2010 to eradicate sources of brook trout in inlets and outlets. Treatments that could be applied to lakes, inlets, and outlets might include rotenone, electrofishing, or high-intensity gill netting to target any remaining fish.

    a. Corral Lake, Black Lake, Shirts Lake, and Granite Twin Lake should be prioritized for additional treatments, especially inlet and outlets applications.

    b. Grassy Mountain #1 and Grassy Mountain #2 may benefit from inlet and outlet treatments, unless adult brook trout are eliminated in 2010 by tiger muskellunge (which is unlikely). A combination of tributary treatments and restocking may result in an acceptable non-brook trout fishery.

c. Merriam, Spruce Gulch, and Upper Hazard lakes should not be given additional treatments because of the remaining adult brook trout population.

3. Corral Lake, Black Lake, Shirts Lake, and Granite Twin Lake could be restocked in fall 2010 with alternate salmonids such as rainbow or cutthroat trout.

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**TABLES**

Table 1. Physical description of study waters planted with tiger muskellunge in 2007.

| Lake name | Number planted | Area (ha) | Elevation (m) | Mean depth (m) | Max depth (m) | Mean spec. cond. (µS/cm) | Mean temp (C) | Mean pH |
|---|---|---|---|---|---|---|---|---|
| Black Lake | 420 | 10.5 | 2199 | 19.7 | 37.8 | 31 | 16.1 | 7.72 |
| Corral Lake | 104 | 2.6 | 2085 | 4 | 24 | - | 15.9 | 7 |
| Granite Twin | 656 | 16.1 | 2183 | 7.4 | 20.4 | 6.4 | 13.2 | 7.72 |
| Grassy Mtn 1 | 206 | 5.1 | 2263 | 2.9 | 6.1 | 4.8 | 15.1 | 6.78 |
| Grassy Mtn 2 | 225 | 5.1 | 2238 | 2.6 | 3.7 | 5 | 14 | 6.52 |
| Merriam Lake | 107 | 2.6 | 2926 | 7.5 | 34 | 20.8 | 10 | 8.52 |
| Shirts Lake | 140 | 3.5 | 2254 | 7.7 | 3 | 15.6 | 13.1 | 8.3 |
| Spruce Gulch | 439 | 10.9 | 2698 | 4.9 | 13 | 8.8 | 15.9 | 6.84 |
| Upper Hazard | 632 | 15.8 | 2264 | 7.6 | 21.4 | 3 | 13.8 | 8.24 |

| Lake name | IDFG catalog | Region | Distance from road (km) | Part of chain? | Inlet spawning habitat? | Outlet spawning habitat? | Outlet barrier w/in 1 km? | Elimination potential | Apparent success |
|---|---|---|---|---|---|---|---|---|---|
| Black Lake | 07-00-00-0143 | 3M | 0 | No | Yes | Yes | Yes | Moderate | Yes |
| Corral Lake | 07-00-00-0177 | 3M | 0.9 | No | No | No | Yes | Very High | Yes |
| Granite Twin | 07-00-00-0193 | 3M | 1.9 | No | No | Yes | Yes | High | Yes |
| Grassy Mtn 1 | 07-00-00-0180 | 3M | 3 | Yes | No | No | No | Moderate | No |
| Grassy Mtn 2 | 07-00-00-0183 | 3M | 3 | Yes | Yes | No | No | Moderate | No |
| Merriam Lake | 07-00-00-1308 | 7 | 3.1 | No | Yes | Yes | Yes | High | No |
| Shirts Lake | 09-00-00-0271 | 3M | 1.9 | No | No | Yes | Yes | High | No |
| Spruce Gulch | 07-00-00-1316 | 7 | 10.6 | No | No | No | Yes | Very High | No |
| Upper Hazard | 07-00-00-0170 | 3M | 3.1 | Yes | Yes | Yes | Yes | Moderate | No |

Table 2. Mean catch-per-unit-effort of brook trout caught with gill nets (fish per net night) and angling (fish per hour) in nine mountain lakes before stocking tiger muskellunge, and for two years after stocking tiger muskellunge in 2007. The total trout caught by each method (n) is shown by lake. Dashed lines indicate where angling was not conducted.

| | 2005-06 | | | 2008 | | | 2009 | | |
|---|---|---|---|---|---|---|---|---|---|
| **Lake Name** | **CPUE** | **Hours** | **n** | **CPUE** | **Hours** | **n** | **CPUE** | **Hours** | **n** |
| **Gill Nets** | | | | | | | | | |
| Black Lake | 13.5 | 55.5 | 54 | 1.0 | 23.5 | 2 | 0 | 58 | 0 |
| Corral Lake | 60.0 | 10.0 | 60 | 1.0 | 31.4 | 2 | 0 | 29 | 0 |
| Granite Twin | 20.0 | 55.5 | 80 | 5.5 | 31.9 | 11 | 0 | 27 | 0 |
| Grassy Mtn 1 | 28.0 | 16.5 | 28 | 6.0 | 32.8 | 12 | 6.5 | 33 | 13 |
| Grassy Mtn 2 | 35.0 | 17.0 | 35 | 0.5 | 30.9 | 1 | 4.5 | 40 | 9 |
| Merriam Lake | 9.3 | 73.3 | 37 | 17.5 | 24.2 | 35 | 16.0 | 31 | 32 |
| Shirts Lake | 14.3 | 48.0 | 57 | 2.0 | 25.8 | 4 | 0.5 | 23 | 1 |
| Spruce Gulch | 15.8 | 65.5 | 63 | 8.0 | 22.4 | 16 | 6.5 | 26 | 13 |
| Upper Hazard | 9.0 | 81.3 | 36 | 4.0 | 28.3 | 8 | 5.0 | 35 | 10 |
| *Total* | 22.8 | 422.5 | 450 | 5.1 | 251.0 | 91 | 4.3 | 301 | 78 |

| | 2005-06 | | | 2008 | | | 2009 | | |
|---|---|---|---|---|---|---|---|---|---|
| **Lake Name** | **CPUE** | **Hours** | **n** | **CPUE** | **Hours** | **n** | **CPUE** | **Hours** | **n** |
| **Angling** | | | | | | | | | |
| Black Lake | - | 0 | 0 | 0.05 | 22 | 1 | 0 | 17.5 | 0 |
| Corral Lake | 2.0 | 2 | 4 | 0 | 5 | 0 | 0 | 4.4 | 0 |
| Granite Twin | - | 0 | 0 | 0.80 | 5 | 4 | 0 | 8.5 | 0 |
| Grassy Mtn 1 | - | 0 | 0 | 0 | 2 | 0 | 1.1 | 7 | 8 |
| Grassy Mtn 2 | - | 0 | 0 | - | 0 | - | 0.2 | 5.5 | 1 |
| Merriam Lake | - | 0 | 0 | 3.33 | 10.5 | 35 | 2.6 | 12 | 31 |
| Shirts Lake | 4.3 | 15 | 65 | 0 | 6 | 0 | 0.2 | 5 | 1 |
| Spruce Gulch | - | 0 | 0 | 0 | 8 | 0 | 0.3 | 4 | 1 |
| Upper Hazard | - | 0 | 0 | 0.20 | 5 | 1 | 1.1 | 16 | 17 |
| *Total* | 6.3 | 17 | 69 | 0.55 | 63.5 | 41 | 0.6 | 79.9 | 59 |

Table 3. Mean length (mm) and mean weight (g) (with 95% confidence intervals), condition and trophy potential (assessed by the mean of the five longest fish) of brook trout sampled from nine mountain lakes arranged by survey year. Tiger muskellunge were introduced into the listed lakes in 2007. Asterisks indicate where fewer than five brook trout were captured.

| **Lake Name** | **Mean length (mm)** | **n** | **Mean weight (g)** | **n** | **Mean Condition** | **Longest 5** |
|---|---|---|---|---|---|---|
| | | | **2005-2006** | | | |
| Black Lake | 203 (± 7) | 54 | 80 (± 7) | 54 | 0.93 | 244 |
| Corral Lake | 206 (± 12) | 64 | 94 (± 12) | 64 | 1.09 | 262 |
| Granite Twin | 232 (± 12) | 80 | 124 (± 12) | 80 | 0.90 | 291 |
| Grassy Mtn 1 | 209 (± 19) | 28 | 104 (± 24) | 28 | 0.99 | 278 |
| Grassy Mtn 2 | 251 (± 10) | 35 | 161 (± 18) | 35 | 0.98 | 286 |
| Merriam Lake | 205 (± 14) | 37 | 91 (± 18) | 37 | 0.94 | 265 |
| Shirts Lake | 196 (± 5) | 122 | 31 (± 7) | 122 | 1.04 | 231 |
| Spruce Gulch | 207 (± 9) | 63 | 92 (± 11) | 63 | 0.98 | 260 |
| Upper Hazard | 227 (± 14) | 36 | 113 (± 18) | 36 | 0.90 | 292 |
| *Total* | 212 (± 3) | 519 | 88 (± 5) | 519 | 0.97 | 268 |
| **Lake Name** | **Mean length (mm)** | **n** | **Mean weight (g)** | **n** | **Mean Condition** | **Longest 5** |
| | | | **2008** | | | |
| Black Lake | 241 (± 87) | 3 | 115 (± 118) | 3 | 0.80 | 241* |
| Corral Lake | 263 (± 400) | 2 | 170 (± 762) | 2 | 0.89 | 263* |
| Granite Twin | 265 (± 13) | 15 | 194 (± 25) | 15 | 1.03 | 290 |
| Grassy Mtn 1 | 283 (± 15) | 12 | 263 (± 34) | 12 | 1.16 | 303 |
| Grassy Mtn 2 | 287 | 1 | 210 | 1 | 0.89 | 287* |
| Merriam Lake | 232 (± 7) | 70 | 124 (± 9) | 66 | 1.04 | 288 |
| Shirts Lake | 225 (± 60) | 4 | 128 (± 100) | 4 | 1.08 | 225* |
| Spruce Gulch | 264 (± 11) | 16 | 223 (± 29) | 16 | 1.19 | 283 |
| Upper Hazard | 246 (± 29) | 9 | 1567 (± 41) | 9 | 1.01 | 268 |
| *Total* | 246 (± 6) | 132 | 161 (± 11) | 128 | 1.06 | 272 |
| **Lake Name** | **Mean length (mm)** | **n** | **Mean weight (g)** | **n** | **Mean Condition** | **Longest 5** |
| | | | **2009** | | | |
| Black Lake | - | 0 | - | 0 | - | - |
| Corral Lake | - | 0 | - | 0 | - | - |
| Granite Twin | - | 0 | - | 0 | - | - |
| Grassy Mtn 1 | 299 (± 8) | 21 | 243 (± 22) | 21 | 0.90 | 324 |
| Grassy Mtn 2 | 286 (± 46) | 10 | 244 (± 64) | 10 | 0.95 | 317 |
| Merriam Lake | 251 (± 4) | 63 | 138 (± 8) | 63 | 0.88 | 280 |
| Shirts Lake | 273 (± 121) | 2 | 188 (± 158) | 2 | 0.93 | 273* |
| Spruce Gulch | 309 (± 12) | 14 | 337 (± 51) | 14 | 1.12 | 326 |
| Upper Hazard | 235 (± 23) | 28 | 130 (± 27) | 28 | 0.88 | 296 |
| *Total* | 264 (± 7) | 138 | 181 (± 15) | 138 | 0.91 | 334 |

Table 4. Mean length (mm) with 95% confidence intervals (where possible) and count of tiger muskellunge by survey method for two years after planting. Tiger muskellunge were introduced into the listed lakes in 2007. Dashed lines indicate where survey data were not collected.

| Lake Name | Mean length (mm) | n | Gill Net | Angling | Visual |
|---|---|---|---|---|---|
| | | **2008** | | | |
| Black Lake | 478 (± 31) | 26 | 1 | 25 | - |
| Corral Lake | 572 (±103) | 6 | 0 | 6 | - |
| Granite Twin | 375 | 1 | 1 | 0 | - |
| Grassy Mtn 1 | 526 (± 114) | 2 | 2 | 0 | - |
| Grassy Mtn 2 | 605 | 1 | 1 | 0 | - |
| Merriam Lake | - | 0 | 0 | 0 | 1 |
| Shirts Lake | - | 0 | 0 | 0 | - |
| Spruce Gulch | 344 (± 51) | 12 | 1 | 11 | - |
| Upper Hazard | 495 | 1 | 1 | 0 | - |
| *Total* | 460 (± 31) | 49 | 7 | 42 | 1 |
| | | **2009** | | | |
| Black Lake | 540 (± 58) | 10 | 2 | 7 | 1 |
| Corral Lake | 494 (± 136) | 10 | 0 | 4 | 6 |
| Granite Twin | 580 (± 108) | 6 | 0 | 2 | 4 |
| Grassy Mtn 1 | 431 | 1 | 0 | 0 | 1 |
| Grassy Mtn 2 | 0 | 1 | 0 | 0 | 0 |
| Merriam Lake | 0 | 0 | 0 | 0 | 0 |
| Shirts Lake | 643 | 1 | 1 | 0 | 7 |
| Spruce Gulch | 370 | 1 | 1 | 0 | 4 |
| Upper Hazard | 0 | 1 | 1 | 0 | 0 |
| *Total* | 535 (± 41) | 41 | 5 | 13 | 23 |

Table 5. Mean length (mm) and mean weight (g) (with 95% confidence intervals), condition and trophy potential (assessed by the mean of the five longest fish) of brook trout sampled from four "control" mountain lakes. These lakes were in the same drainage as most of the treated lakes.

| Lake Name | Mean length (mm) | n | Mean weight (g) | n | Mean Condition | Longest 5 |
|---|---|---|---|---|---|---|
| | | | **2005** | | | |
| Hard Creek Lake | 226 (± 19) | 44 | 140 (± 38) | 44 | 0.98 | 340 |
| | | | **2006** | | | |
| Black Lake #2 | 192 (± 29) | 25 | 100 (± 33) | 25 | 1.01 | 270 |
| Hard Creek Lake | 217 (± 18) | 31 | 110 (± 24) | 31 | 0.96 | 287 |
| Lloyds Lake | 220 (± 15) | 30 | 120 (± 23) | 30 | 1.04 | 281 |
| Rainbow Lake | 185 (± 18) | 30 | 66 (± 17) | 30 | 0.97 | 260 |
| *Total* | 210 (± 56) | 160 | 111 (± 88) | 160 | 0.99 | 287 |
| | | | **2009** | | | |
| Black Lake #2 | 236 (± 16) | 31 | 131 (± 19) | 31 | 0.95 | 294 |
| Hard Creek Lake | 233 (± 11) | 72 | 130 (± 20) | 46 | 0.93 | 315 |
| Lloyds Lake | 233 (± 13) | 45 | 140 (± 21) | 45 | 1.00 | 296 |
| Rainbow Lake | 213 (± 14) | 22 | 78 (± 14) | 22 | 0.78 | 253 |
| *Total* | 231 (± 44) | 170 | 125 (± 65) | 144 | 0.93 | 290 |

Table 6. Mean catch-per-unit-effort by gill nets (fish per net night) and angling (fish per hour) sampled from four “control” mountain lakes by sample year. These lakes were in the same drainage as most of the treated lakes. Dashed lines indicate where angling was not conducted.

| Lake Name | CPUE Gill Nets | Net-Nights | n | CPUE Angling | n | Angling Hours |
|---|---|---|---|---|---|---|
| | | **2005** | | | | |
| Hard Creek Lake | 22 | 2 | 44 | - | - | |
| | | **2006** | | | | |
| Black Lake #2 | 11 | 1 | 11 | 7.0 | 14 | 2 |
| Hard Creek Lake | 31 | 1 | 31 | - | - | - |
| Lloyds Lake | 30 | 1 | 30 | - | - | - |
| Rainbow Lake | 30 | 1 | 30 | - | - | - |
| *Total* | *25.5* | *4* | *102* | *7.0* | *14* | *2* |
| | | **2009** | | | | |
| Black Lake #2 | 9.0 | 2 | 18 | 6.5 | 13 | 2 |
| Hard Creek Lake | 23.0 | 2 | 46 | 5.1 | 26 | 5.05 |
| Lloyds Lake | 21.5 | 2 | 43 | 1.3 | 6 | 4.5 |
| Rainbow Lake | 7.5 | 2 | 15 | 1.9 | 7 | 3.75 |
| *Total* | *15.3* | *8* | *122* | *3.4* | *52* | *15.3* |

Table 7. Summary details to help consider future management options for continued suppression of brook trout (BKT) and the future direction for mountain lakes stocked with tiger muskellunge (TM).

| Lake | Area (ha) | Part of Chain? | Refugia | Barrier w/in 1km? | Initial BKT Num | Final BKT Num | TM Remaining | YOY Present 2009 | Changed BKT Size | Treatment Potential | Potential Treatment | Treatment Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Black Lake | 10.5 | No | Inlet/Outlet/ Shoreline | Yes | 54 | 0 | 10 | no | - | inlet/outlet good targets<br>very deep, large lake | Yes | 3 |
| Corral Lake | 2.6 | No | Inlet | Yes | 60 | 0 | 10 | fry in inlet | - | easy inlet/outlet treatments<br>maybe whole lake? | Yes | 1 |
| Granite Twin Lakes | 16.1 | No | Inlet | Yes | 80 | 0 | 6 | dozens along shore | - | easy inlet treatment | Yes | 2 |
| Grassy Mt Lake #1 | 5.1 | Yes | Outlet | No | 28 | 13 | 1 | 1 fry | + 90 mm | easy outlet treatment<br>but can TM kill all adult BKT? | Yes | - |
| Grassy Mt Lake #2 | 5.1 | Yes | Inlet/Outlet | No | 35 | 9 | 1 | lots in inlet/outlet | + 35 mm | easy inlet treatment<br>easy outlet treatment<br>but can TM kill all adult BKT? | Yes | - |
| Merriam Lake | 2.6 | No | Inlet/Outlet | Yes | 37 | 32 | 0 | lots in inlet | + 46 mm | too many adult BKT<br>no TM left | No | - |
| Shirts Lake | 3.5 | No | Inlet/Outlet/ Shoreline | Yes | 57 | 1 | 8 | 100s on shore | + 77 mm | easy outlet treatment<br>lots of small inlets<br>few adult BKT, some TM left | Yes | 4 |
| Spruce Gulch Lake | 10.9 | No | Shoreline | Yes | 63 | 13 | 5 | no | + 102 mm | too many adult BKT | No | - |
| Upper Hazard Lake | 15.8 | Yes | Inlet/Outlet/ Shoreline | Yes | 36 | 10 | 1 | 100's on shore | + 8 mm | too many adult BKT | No | - |

**FIGURES**

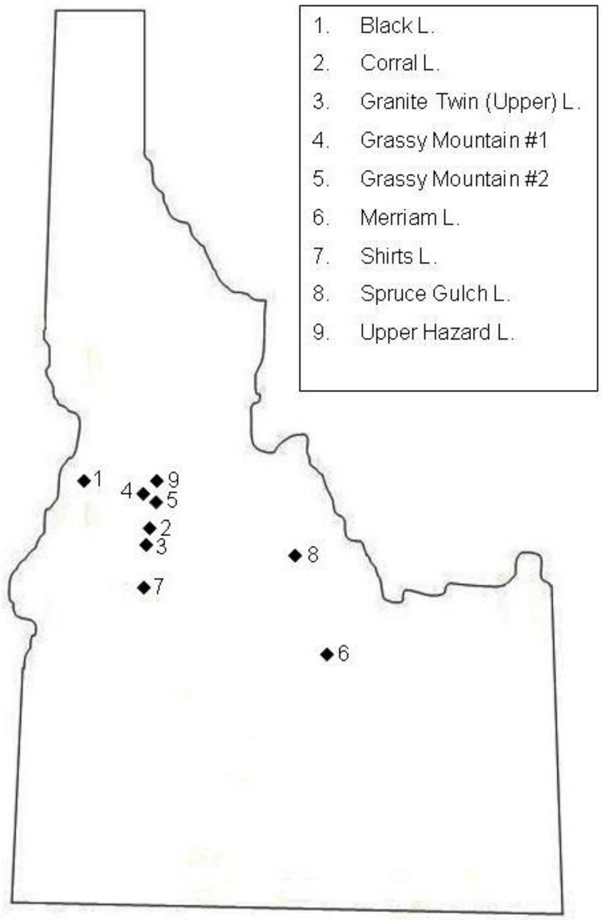



Figure 1. Locations of nine high mountain lakes in Idaho that were chosen for inclusion in a study designed to eliminate brook trout populations by stocking tiger muskellunge. Lakes were initially surveyed in 2005 or 2006 and planted with tiger muskellunge in 2007. Sampling was again conducted in 2008 to investigate subsequent changes to brook trout populations.

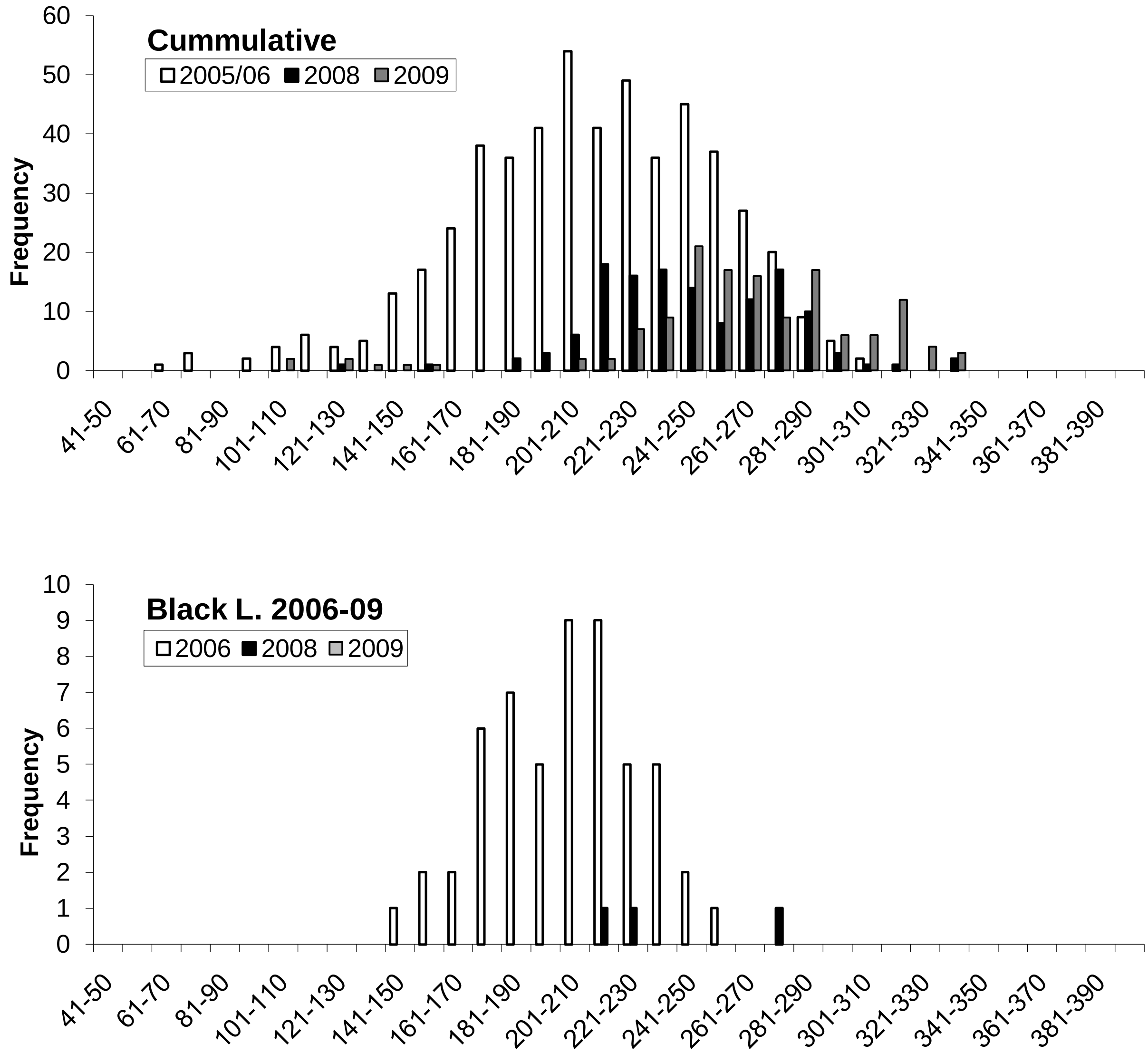
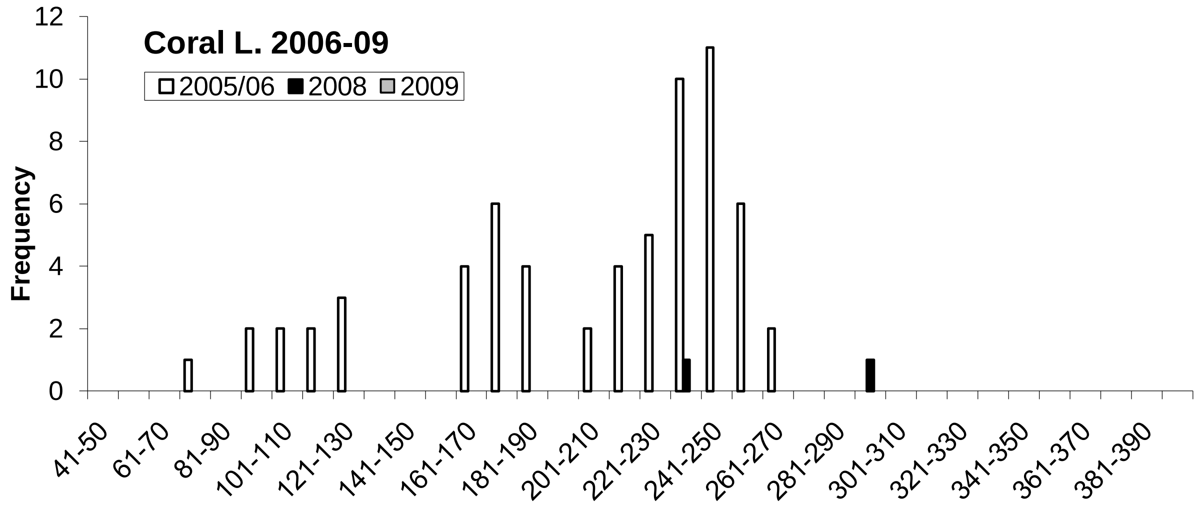
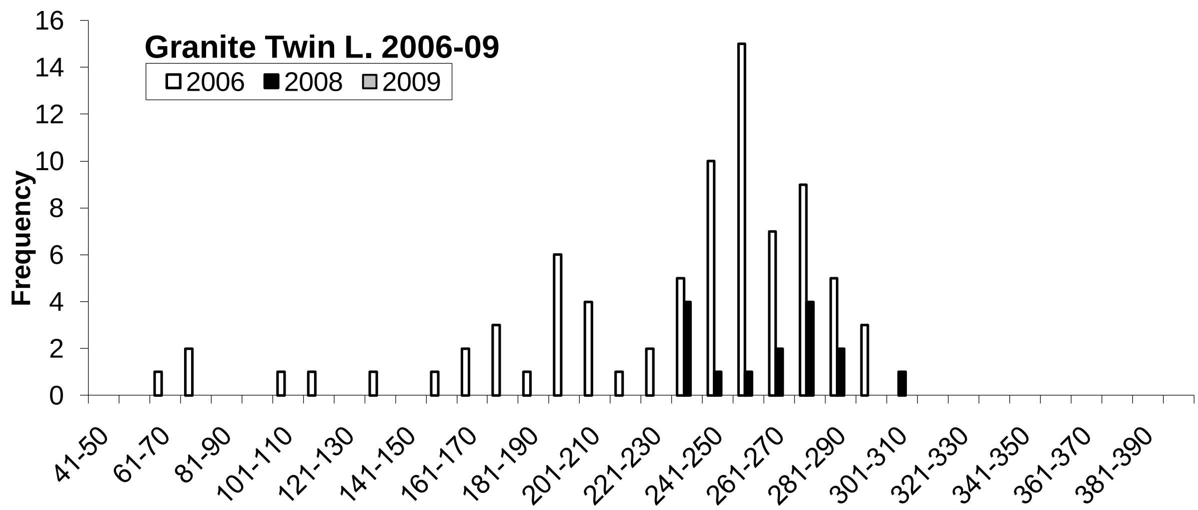



Figure 2. Size distribution (total length, mm) of brook trout captured before (2005 or 2006) and after (2008) introduction of tiger muskellunge. Tiger muskellunge were introduced in 2007.

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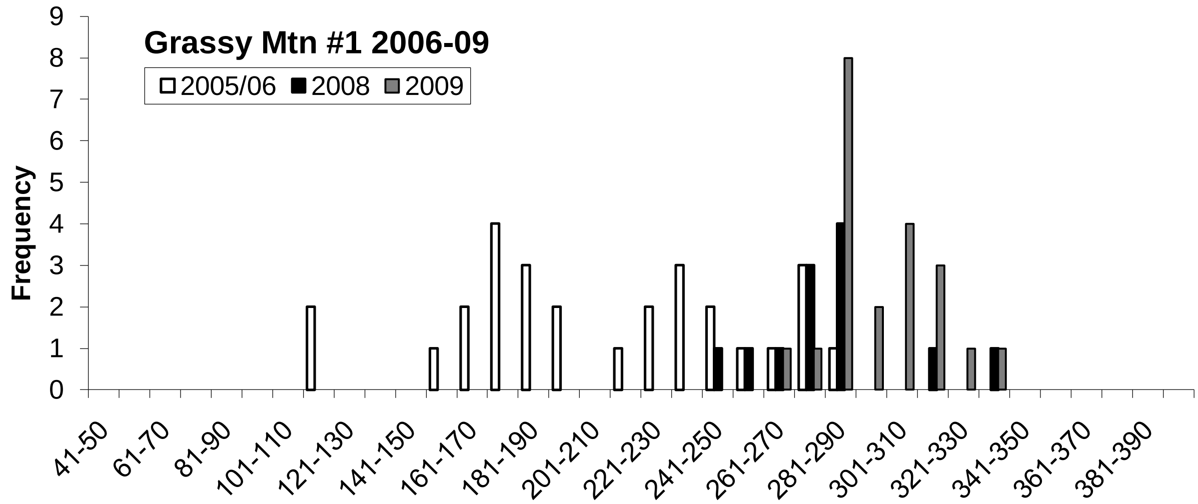


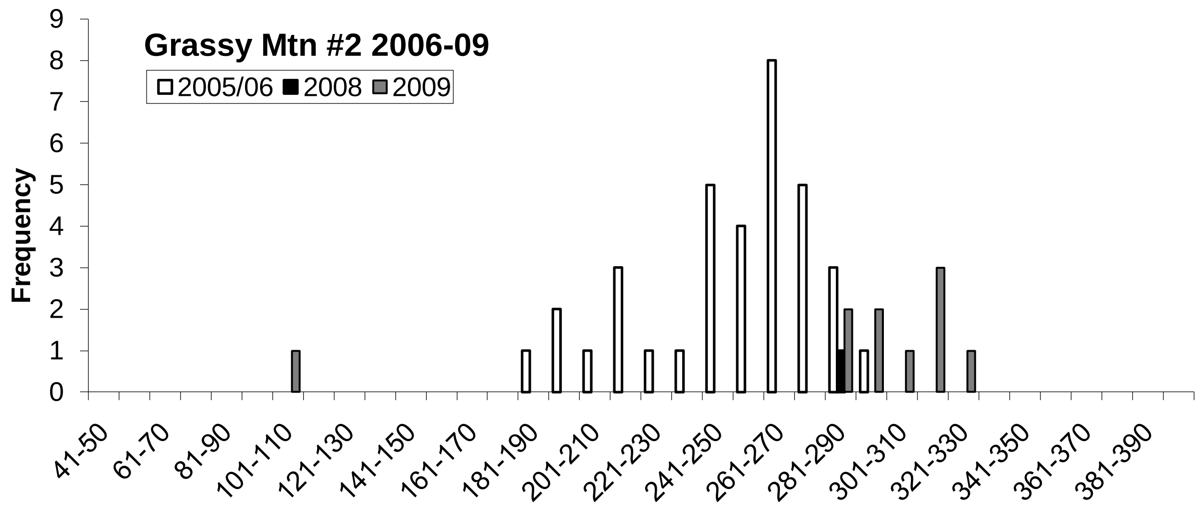


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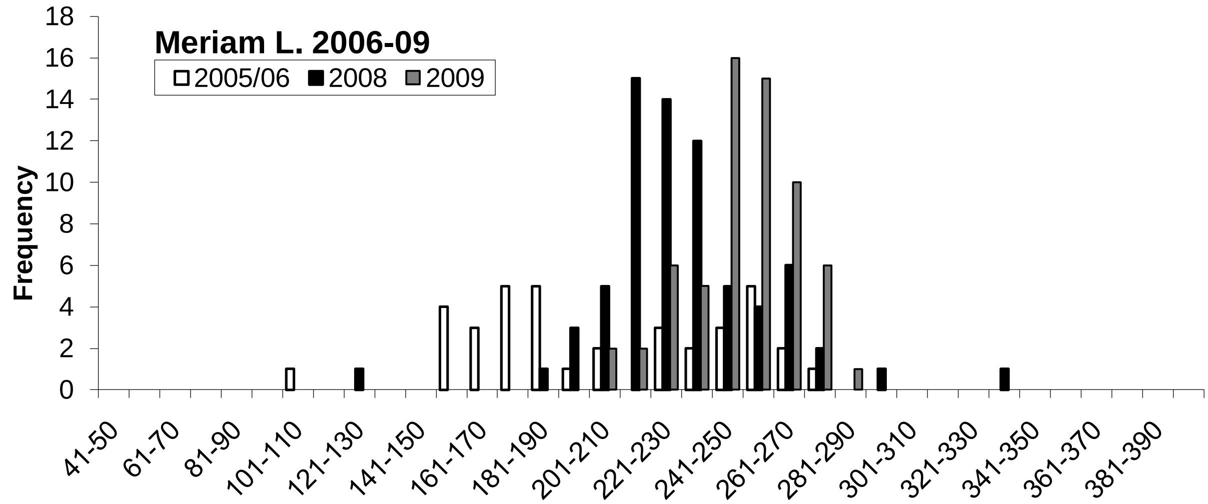


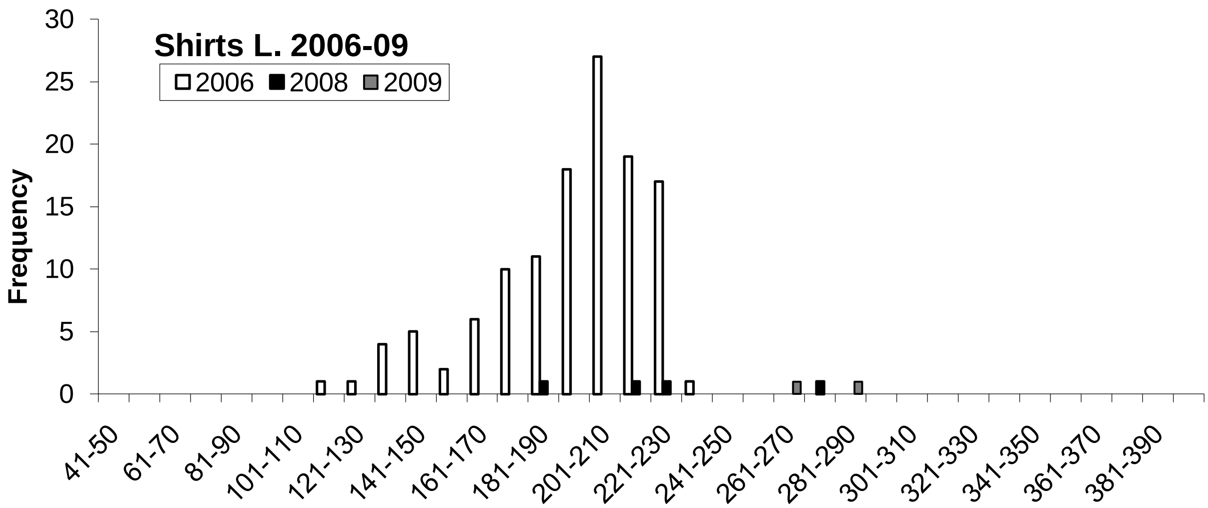


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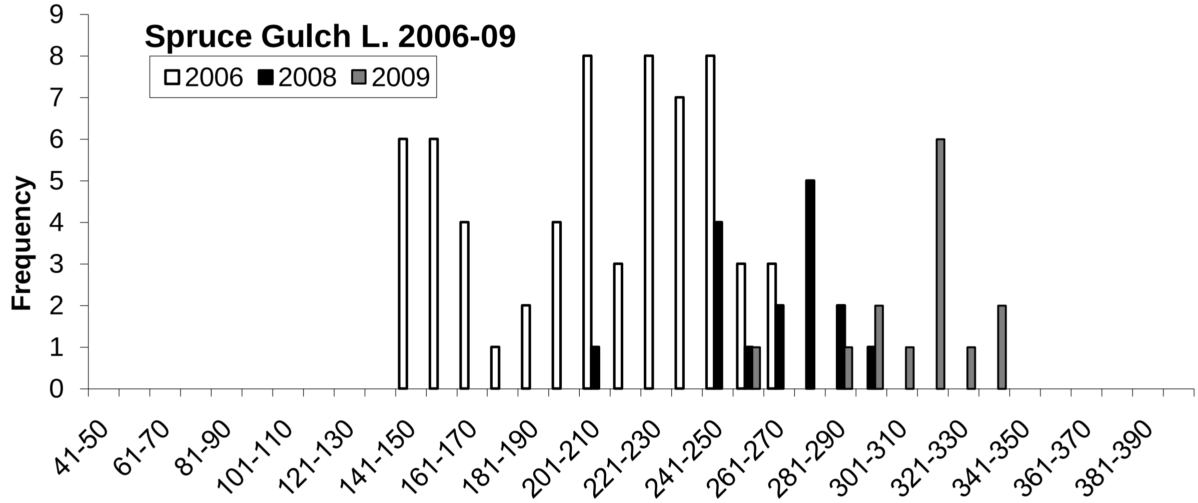


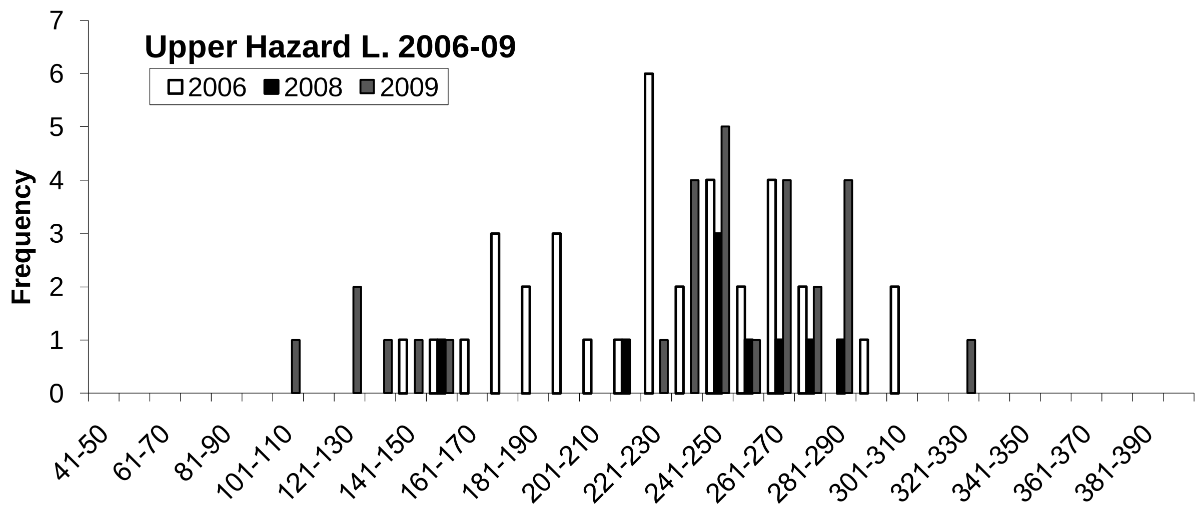


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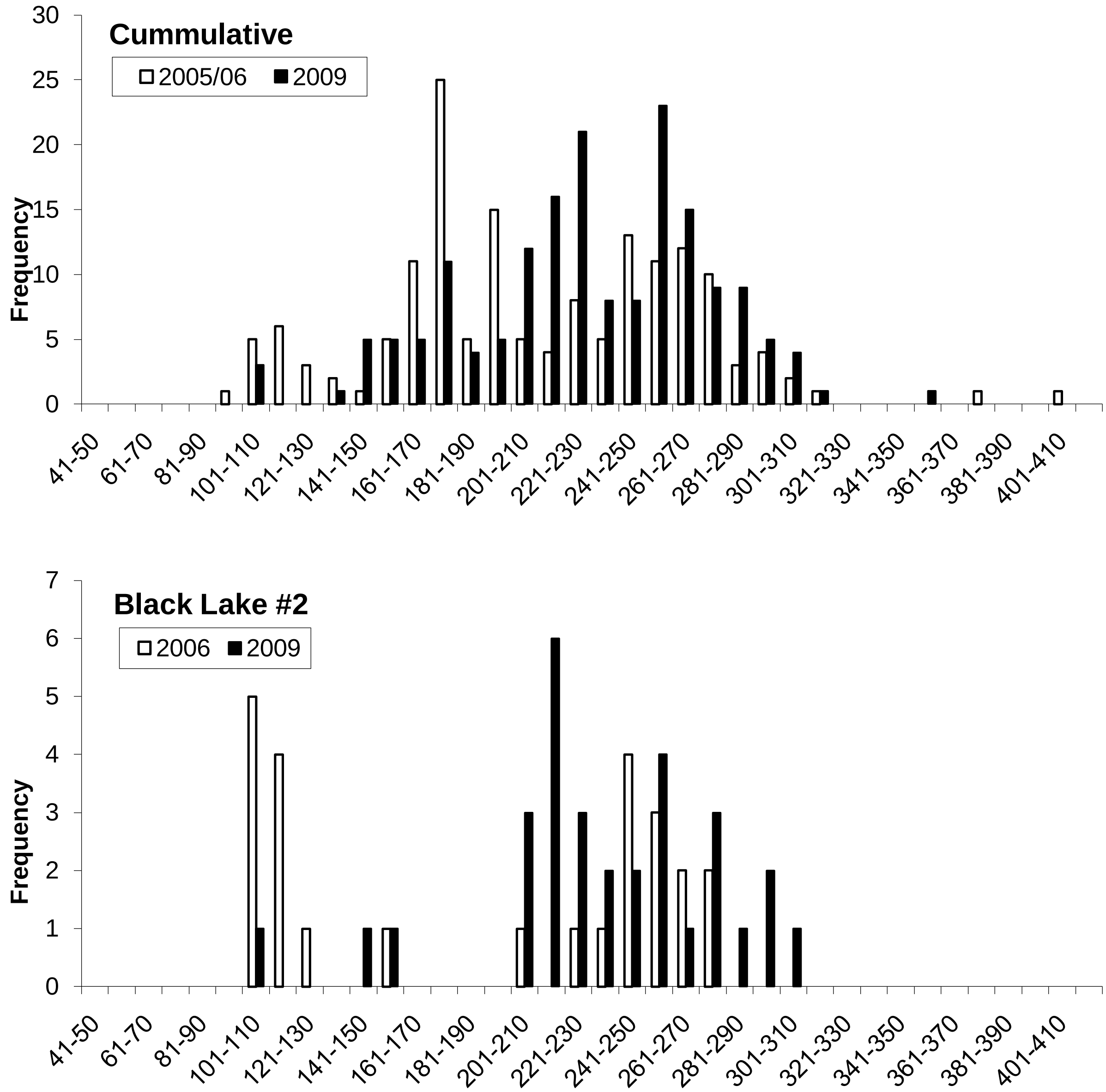
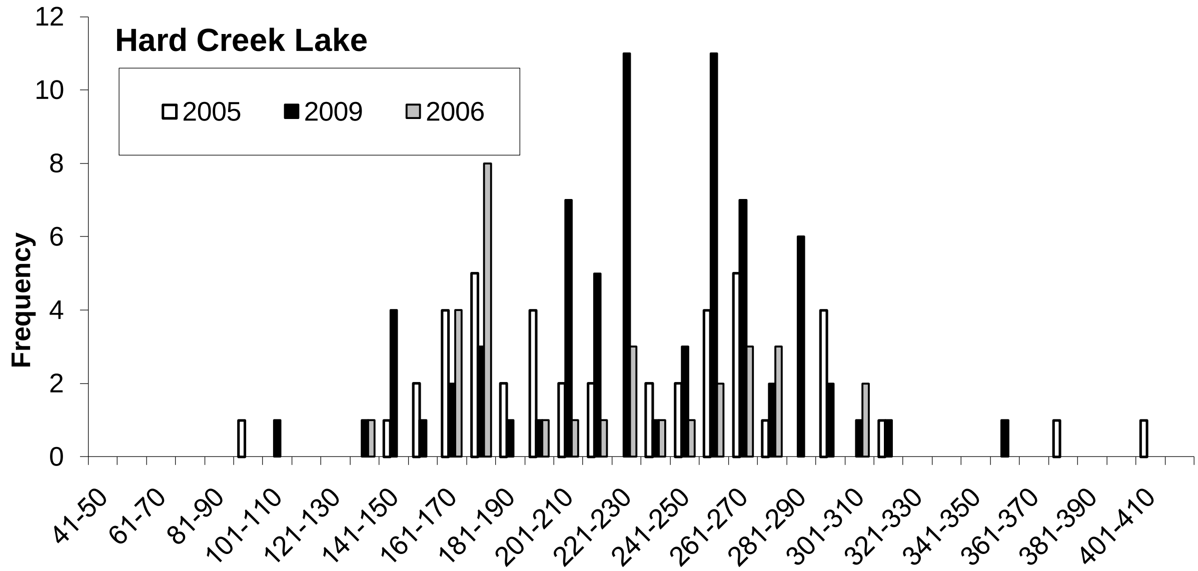
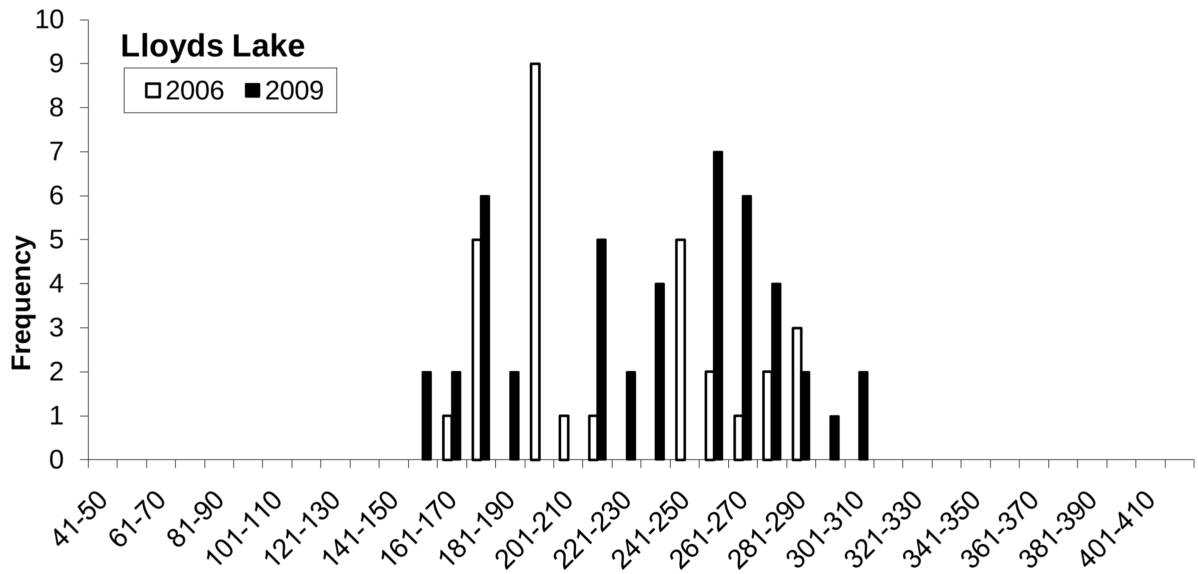



Figure 3. Size distribution (total length, mm) of brook trout in “control lakes” captured before (2005 or 2006) and after (2008) introduction of tiger muskellunge.

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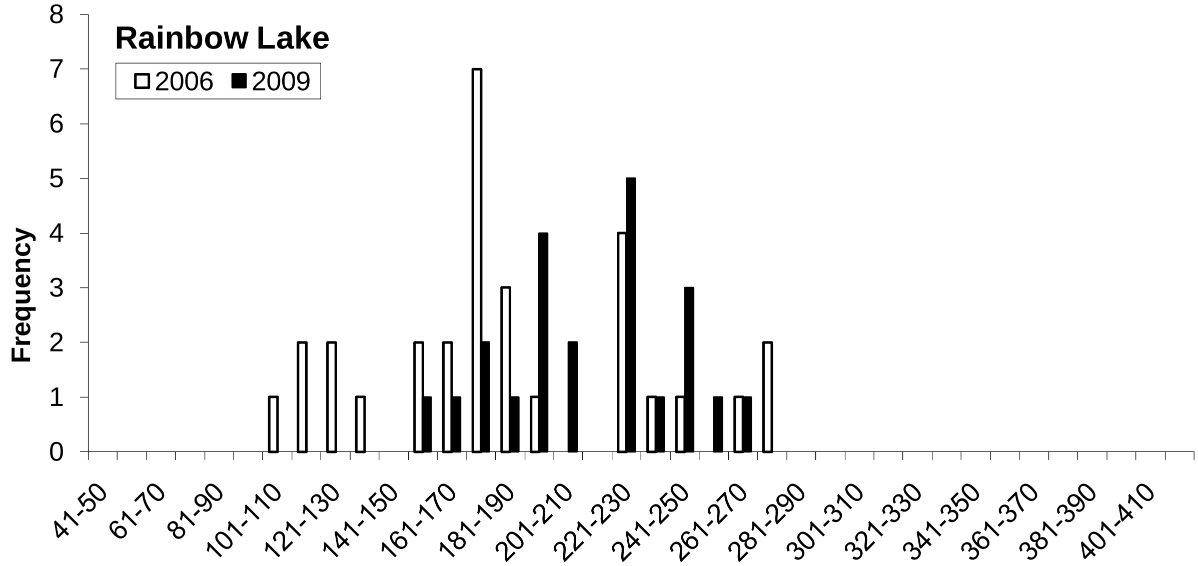


Figure 3. Continued.

**ANNUAL PERFORMANCE REPORT**
**SUBPROJECT #2: STERILE TROUT INVESTIGATIONS: PERFORMANCE OF STERILE CATCHABLE RAINBOW TROUT IN LOWLAND LAKES AND RESERVOIRS**

State of: Idaho | Grant No.: F-73-R-32 Fishery Research

Project No.: 4 | Title: Hatchery Trout Evaluations

Subproject #2: Sterile Trout Investigations

Contract Period: July 1, 2009 to June 30, 2010

## ABSTRACT

Increased growth, improved survival, and genetic protection of wild stocks have been suggested as benefits of stocking triploid (i.e. sterile) salmonids for recreational fisheries. Catchable-sized rainbow trout are stocked in over 500 water bodies annually across Idaho and are a critical component for maintaining sportfishing opportunities. I examined the relative survival, growth, and return-to-creel of diploid (2N) and triploid (3N) all-female catchable rainbow trout *Oncorhynchus mykiss* across 13 lakes and reservoirs stocked in spring 2008. While the proportion of 2N fish in the creel varied across locations, most reservoirs showed higher returns of 2N rainbow trout to anglers. Gill net catch of 2N and 3N trout were significantly different in the first year after stocking (2008) but not in the second year (2009). Sampling in fall 2008 yielded 2,270 total rainbow trout, of which 635 2N and 456 3N were marked test fish. This indicated 3N rainbow trout returned to gill nets at 72% of marked 2N rainbow trout, on average. Carryover of marked rainbow trout from 2008 into 2009 was low or zero in most reservoirs. Gill net sampling in spring and fall of 2009 yielded a combined 2,351 total rainbow trout, which included 152 2N and 145 3N marked rainbow trout. This indicated 3N rainbow trout returned to gill nets at 95% of 2N rainbow trout in the second year after planting, on average. Snout collection boxes showed significant differences in angler catch of 2N and 3N trout in 2008, but not in 2009. In 2008, anglers returned 2,242 tags, with 1,215 2N tags and 989 3N tags, suggesting that 3N rainbow trout returned to anglers at 81% of 2N rainbow trout, on average. Snout collection boxes in 2009 yielded 90 2N tags and 64 3N tags. This suggested 3N rainbow trout returned to anglers at 71% of 2N rainbow trout in the second year after planting, on average. Triploid rainbow trout did not show any growth advantages over 2N rainbow trout. While mean length between the groups was similar, 2N fish were significantly heavier in weight in fall 2008 and spring 2009 samples. Triploid trout appeared to return at rates more similar to 2N trout in reservoirs with less drawdown and simple fish communities. While diploid rainbow trout may grow and survive better in chronic warm water conditions, triploid rainbow trout will perform well under good habitat conditions while avoiding genetic impacts to wild stocks or establishing self-sustaining populations.

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## INTRODUCTION

In order to meet demands on recreational trout fisheries, many fish and game agencies have funded hatchery programs to maintain fishing quality, often consuming large portions of annual fisheries budgets (Hartzler 1988; Johnson et al. 1995). In 1983, rainbow trout *Oncorhynchus mykiss* made up 77% of all catchable-sized trout stocked in the U.S., with 50 million stocked over 500,000 ha of impoundments (Hartzler 1988). Stocking practices in the U.S. have trended towards stocking fewer, larger individuals that are immediately available to anglers, with catchables now the most commonly stocked size of rainbow trout (Halverson 2008). In fact, Halverson (2008) reported that while rainbow trout made up only 5% of fish stocked in the U.S. by numbers, they made up 50% of fish stocked by weight in 2004. A large portion of the cost and production capacity of Idaho Department of Fish and Game (IDFG) resident hatcheries is associated with producing catchable-sized triploid (3N) rainbow trout. In 2008, IDFG hatcheries raised and stocked approximately 2.4 million catchable trout across more than 500 water bodies, requiring approximately one-half of the annual resident hatchery system budget (IDFG 2008). Since 2001, IDFG has established a policy to stock only sterile (i.e. triploid) rainbow trout in systems where stocked rainbow trout pose a genetic risk to native trout populations (IDFG 2001). Triploid salmonids, created by heat or pressure shock, are functionally sterile. In this respect, 3N trout provide a valuable tool for conservation while managing for recreational trout fisheries.

In addition to protecting native stocks from genetic introgression, sterile fish could theoretically provide fishery benefits such as increased growth (Thorgaard 1986; Boulanger 1991; Teuscher et al. 2003) or longevity (Parkinson and Tsumura 1988; Johnston et al. 1993; Warrillow et al. 1997). Although well studied in laboratory and aquaculture settings, survival, longevity, and growth of 3N salmonids in natural environments are inconsistent relative to 2N fish (Parkinson and Tsumura 1988; Simon et al. 1993; Brock et al. 1994; Warrillow et al. 1997; Teuscher et al. 2003) and may be species dependent (Ihssen et al. 1990).

Previous IDFG evaluations of sterile salmonids have examined relative survival and return-to-creel of 3N rainbow trout, including catchables in streams (Dillon et al. 2000), fingerlings in highland reservoirs (Teuscher et al. 2003), and fingerlings in high alpine lakes (Koenig and Ellsworth 2008). Dillon et al. (2000) found no difference in return-to-creel rates of 3N and 2N catchable rainbow trout stocked together in 18 Idaho streams. Mean time to harvest was not different for sterile fish, as most trout in the study were caught in less than 30 days. Teuscher et al. (2003) evaluated all-female 3N and 2N fingerling rainbow trout in two productive Idaho highland reservoirs. Overall, the total electrofishing catch of triploids over several years was higher than for diploids, but 3N trout did not show any advantage in length or weight over 2N trout. In high alpine lakes, mixed-sex 2N rainbow trout returned to gill nets at almost twice the rate as mixed-sex 3N trout, 3 and 4 years after stocking (Koenig et al., in press). However, catch of the all-female 3N group was significantly higher than both mixed-sex groups 3 and 4 years after stocking (Koenig et al., in press). As with other evaluations, no significant differences in length or weight were found between 2N and 3N test groups. Although these studies evaluated the performance of 3N salmonids in natural environments, the low number of studies available, limited scope and contradictory results do not fully elucidate the performance of 3N salmonids stocked to benefit anglers, especially in the context of put-and-take fisheries. Despite the high costs associated with catchable-sized trout, post-stocking evaluations to assess performance of catchables are rare, despite the large number of water bodies and rainbow trout stocked each year (Hartzler 1988; IDFG 2008).

## RESEARCH GOAL

1. To enhance hatchery-supported fisheries while reducing genetic risks to indigenous *O. mykiss* and *O. clarkii*.

## OBJECTIVE

1. Determine if growth, relative survival, and return-to-creel of triploid catchable rainbow trout is comparable to that of diploid catchable rainbow trout in stocked lakes and reservoirs lakes.

## STUDY SITE

The study was conducted in 13 lakes and reservoirs across Idaho representing the range of sizes, habitats, and elevations of lakes typically stocked with catchable rainbow trout by IDFG (Table 8). Study lakes were selected from those having a history of catchable rainbow trout stocking and were scheduled to receive plants in the given study year from Hagerman State Fish Hatchery (Figure 4). Stocked lakes had an average elevation of 1,388 m but ranged in elevation from 547 m to 1,922 m. Most lakes had a surface area between 35 and 482 ha, except for Island Park Reservoir (2,947 ha). Other than Horsethief Reservoir (which remains near full pool for most of the year), these reservoirs are used for irrigation purposes and are subject to drawdown, which can be substantial in some years.

All study lakes were managed under the “general” trout regulation of six fish per day with no length restrictions. Test fish were not stocked in drainages where conflicts with native or wild trout populations were likely, based on the recommendations of the regional fisheries mangers.

## METHODS

All-female diploid and triploid rainbow trout eggs were obtained from Troutlodge Inc. (Sumner, Washington) and reared at Hagerman State Fish Hatchery until the time of stocking. Ploidy level of test groups was determined using blood samples and flow cytometry by Dr. Jeff Hinshaw at North Carolina State University. At the time blood samples were collected, diploid and triploid trout averaged 84 mm and 78 mm in total length, respectively. The triploid induction rate was estimated at 100% (n = 49), while results from the diploid group indicated 100% diploid (n = 50).

### Marking and Stocking

Diploid (hereafter 2N) and triploid (hereafter 3N) groups were marked with both adipose fin clips and coded wire tags (CWT). Stocked rainbow trout were marked with adipose fin clips to distinguish them when collected in the field, while coded wire tags were used to identify ploidy level. Experimental groups were marked from October 1, 2007 to October 9, 2007 at Hagerman State Fish Hatchery. A total of 110,485 diploid and 109,885 triploid rainbow trout were tagged. Most trout (65%) were marked using the Northwest Marine Technologies (NMT) AutoFish system in a mobile tagging trailer, while the remainder were hand-tagged using scissors and Mark IV Automatic Tag Injectors (NMT). At the time of tagging, the 3N and 2N groups were 92 mm (n = 110,113, CV = 13.7) and 102 mm (n = 75,260, CV = 14.7) in total length, respectively.

Retention of coded wire tags was monitored over the in-hatchery rearing phase by collecting and examining incidental mortalities weekly. Collected mortalities were examined for CWTs using a V-Detector (NMT) antenna. If detected, tags were then dissected with the aid of the V-Detector and tag codes read using a compound microscope. Percent tag retention was defined as the proportion of collected adipose-clipped mortalities containing CWTs, multiplied by 100. Confidence intervals (95%) around the proportion marked were calculated according to equations for small, medium, and large proportions presented in Fleiss et al. (2003).

Reservoirs were stocked between April 1 and June 3, 2008, depending on water conditions and access availability. The total numbers of marked trout planted varied among study locations, but each reservoir received approximately equal numbers of 2N and 3N test fish (Table 8). Trout were transported and stocked by truck from Hagerman State Fish Hatchery. At stocking, the mean length of 2N and 3N marked fish was 251 mm and 252 mm, respectively (Table 8). A combined total of 169,806 marked catchable-sized rainbow trout were planted across the 13 locations for this study, consisting of 84,523 2N and 85,283 3N fish. Overall, this corresponds to 2N and 3N trout making up 50.2% and 49.8% of the total marked trout planted, respectively. An additional 62,733 unmarked catchable rainbow trout were also planted in these reservoirs during 2008 to meet fish stocking objectives. On average, marked catchables for this study comprised 73% of the total catchable rainbow planted (before sampling began in fall 2008), but actually made up 100% of the catchable rainbows planted in nine of the 13 reservoirs (Appendix A).

## Sample Collection

Rainbow trout were sampled using a combination of floating gill nets and electrofishing, although the total electrofishing effort was relatively minor and only used in the first sampling season. Floating gill nets measured 46 m long by 2 m deep and were comprised of six panels of 19, 25, and 32 mm stretch mesh monofilament. Sampling effort varied between sites depending on lake size and catch rates. Gill nets were set at sunset and fished overnight for a minimum of 8 hours. During each sampling event, five to 15 gill nets were fished at each reservoir from one to three nights, depending on catch rates. Gill nets were set in a variety of locations to include both pelagic and littoral zones, but locations were not standardized across reservoirs. Sampling typically yielded enough recaptured fish so that most reservoirs were only sampled on one occasion. Electrofishing was conducted at night in the littoral zone using a Smith-Root electrofishing boat (Island Park, Horsethief, and Lost Valley reservoirs only). Pulsed direct current was produced by a 5,000 watt generator and frequency was set at 60 or 120 pulses per second with an output of 4-5 amps. Electrofishing was only used in a few locations because boat launch ramps were often unavailable (because of low water) at the time of sampling.

Most sites were first sampled during September and October 2008 (Table 4). However, due to low water conditions, some locations were sampled earlier. Paddock Valley Reservoir was subjected to early drawdown and therefore was sampled in July. Little Camas Reservoir and Thorn Creek Reservoir were also drawn low and were sampled from August 19-21, 2008. Reservoirs were again sampled in spring (April-May) 2009 and in fall (September-October) 2009. Some reservoirs were not sampled after very low catches of marked fish or reservoir conditions suggested further sampling would be futile. All rainbow trout captured were examined for adipose fin clips and separated. Adipose-clipped rainbow trout were then measured (total length) to the nearest millimeter and weighed to the nearest gram. Dressed weight was collected on a subsample of the marked rainbow after removing entrails, gonads, and gills, but leaving the pectoral fins and kidney intact. Heads of marked fish were then removed behind the gills, stored in individually labeled bags, and frozen for later tag recovery. Recovered heads were scanned for coded wire tags using a V-Detector (NMT). If detected, tags were then dissected with the aid of the V-Detector antenna and read using a compound microscope.

In addition to gill netting, samples caught by anglers were collected using “snout collection boxes” in 2008 and 2009. Snouts of adipose-clipped rainbow trout were collected passively using “snout collection boxes” installed mainly at boat ramps or other locations such as docks and intersections of access roads around study locations. Signs posted nearby described the goals of the research program and invited anglers to participate in the study by depositing snouts of adipose-clipped rainbow trout that they planned to harvest. Snout collection boxes were constructed from Rubbermaid Action Packers™ with locking lids. A 3” diameter hole was cut through the lid and covered with a flexible rubber sheeting to allow samples to be deposited, but otherwise keep the boxes free of other material. Boxes were filled halfway with a mixture of rock salt and borax to acts as desiccant and preservative. Snout boxes and the associated signs were installed on or before the day of stocking. Boxes were checked from weekly to monthly, depending on anticipated fishing pressure. Snouts recovered were bagged, labeled with the collection date, and stored in a freezer until tags could be dissected using the methods described above. Snout boxes were dismantled in the fall during September and October, usually around the time that gill net surveys were conducted. Coded wire tags were recovered by the traditional dissection method as described above.

## Data Analysis

Confidence intervals (CI) for the proportion of 2N and 3N rainbow trout caught were calculated according to equations for small, medium, and large proportions presented in Fleiss et al. (2003). Mean length, weight, and dressed weight for marked fish were compared using confidence intervals (95%) calculated with $\bar{X} \pm t_{\alpha(2),n-1} \bullet SE$ and values from the *t*-distribution with *n*-1 degrees of freedom. Overall differences in catch of marked fish were compared using the Wilcoxon paired-sample test with $\alpha$ = 0.05 (Zar 1999). Comparisons were made by year, with separate analyses for gill net and angler-caught data.

Relationships between relative abundance of triploid marked trout and other biological and habitat parameters were examined using analysis of variance (ANOVA). Reservoirs were categorized according to the numbers of fish species present and the percent of pool volume remaining at the time of the fall 2008 sampling. Reservoirs were categorized as having species count of “low” (2 or less), “medium” (three to four), and “high” (five or greater). The total number of other fish caught (not including rainbow trout) was categorized as “low” (<200), “medium” (200-325), or “high” (325 or more). Species counts were based on bycatch in gill nets and did not represent all those present in each location. The percent of pool volume remaining was categorized as “low” (30% or less), “medium” (30-59%), and “high” (60-100%). Only sampling occasions where at least one trout from each of the 2N and 3N groups was caught were included in the analysis. The percent 3N trout (of the total marked trout captured) was compared to environmental variable using mixed-model ANOVA (to accommodate unbalanced sample design) with repeated measures to account for multiple samples in each reservoir over time. In conjunction to the ANOVA, Tukey’s Multiple Comparisons were used to compare the treatment means at each level. For these analyses, alpha was set to 0.1.

## RESULTS

In-hatchery retention of CWTs varied with time after tagging but did not show any consistent pattern. Tag retention (±95% CI) was generally high, ranging from 82% to 100%, with an overall average of 95% ± 1% (n = 1,181) across the entire rearing period.

Within the first year planted, 2N trout returned to gill nets significantly higher than 3N trout ($P$ = 0.032, $n$ = 13) on average. Overall, 2N rainbow trout were caught in higher numbers in nine of 13 reservoirs (Table 9, Appendix A). The mean catch-per-unit-effort (± 95% CI) for 2N and 3N trout was 0.43 ± 0.24 and 0.30 ± 0.18 fish per hour, respectively. According to the tag codes, 635 total 2N and 456 total 3N marked rainbow trout were sampled, indicating that 3N rainbow trout returned to gill net at 72% of marked 2N rainbow trout, on average (Table 9). The total marked rainbow trout captured varied across reservoirs, but was highest at Horsethief and Lost Valley reservoirs (Table 9). Mann Lake, Oakley Reservoir, and Paddock Reservoir all had very low numbers of recaptured rainbow trout. Total sampling effort in fall 2008 consisted of 2,031 hours of gill netting and 3.5 hours of electrofishing. Sampling yielded a combined total 2,270 rainbow trout across all reservoirs. Of these rainbow trout captured, 1,212 (53%) were marked with adipose fin clips. Of the adipose fin clipped trout, 104 did not contain coded wire tags, suggesting an overall CWT retention rate of 91.3%. Tag retention seemed to be variable across reservoirs, with Oakley Reservoir having the lowest (61%) and Paddock Valley Reservoir having the highest (100%) (Appendix A).

Within the first year planted (2008), angler-caught tag returns of 2N trout were significantly higher than for 3N trout ($P$ = 0.015, $n$ = 13), on average. The snout collection boxes yielded 2,533 snouts, with snouts having been collected from all reservoirs (Table 9). Of the snouts returned, 2,242 contained CWTs, indicating an 89% tag retention rate (assuming only adipose-clipped rainbow trout snouts were deposited, which is unlikely). The number of snouts returned was highly variable across reservoirs, with the most having been recovered from Horsethief Reservoir (Table 9). Overall, 2N rainbows trout made up 55 ± 2% or 1,215 of returned tags, while 3N made up 45 ± 2% or 989 returned tags. This indicates that 3N rainbow trout returned to anglers at 81% of 2N rainbow trout during 2008, on average. When angler-caught tags were compared by month, paired differences were also significant ($P$ = 0.043, $n$ = 7), and differences in angler catch rates were apparent almost immediately after planting but decreased over time (Figure 5). While the proportion of 2N tags varied across locations, most reservoirs showed higher returns of 2N tags (Table 9), while some were roughly equal (Horsethief Reservoir, Little Camas Reservoir, and Mann Lake). Tags were returned throughout the fishing season, although more tags were returned earlier in June or July (Appendix B, C).

Sampling in spring 2009 included 10 of 13 reservoirs with 2,212 total hours of gill netting. A total of 939 rainbow trout were captured, including 303 adipose-clipped rainbows, of which 262 contained tags (Appendix D). This suggested an overall CWT retention rate of 86%. Catch of marked fish was again highly variable and much lower than in the previous fall, with most marked rainbow trout caught at Lost Valley Reservoir. No marked trout were caught at Little Camas and Thorn Creek reservoirs, suggesting poor overwinter survival, likely due to low water levels (Appendix D). The mean catch-per-unit-effort (± 95% CI) for 2N and 3N trout was 0.09 ± 0.01 and 0.08 ± 0.09 fish per hour, respectively. Tag codes indicated 138 2N and 117 3N rainbow trout were caught in spring 2009. Six of the 13 reservoirs were sampled again in fall 2009, with 1,458 total hours of gill netting. Catch rates of marked fish were low, yielding 1,392 rainbow trout, including 67 adipose-clipped, of which 42 were tagged. This suggested an overall CWT retention rate of 63%, much lower than the 91% retention in the previous fall or the 86% retention from spring of the same year. The vast majority of marked trout were recaptured at

Lost Valley Reservoir (38 of 42), with no marked fish being recaptured in four of the six reservoirs sampled (Appendix E), suggesting most holdover fish were caught in the spring, with few fish surviving through the second summer. Spring and fall samples for 2009 were combined to compare gill net catch of each group. From these data, paired comparisons of gill net returns were not significantly different between 2N and 3N rainbow trout ($P > 0.5$, $n = 8$).

Angler-caught returns of marked fish were less variable across reservoirs in 2009. The voluntary creel yielded 470 snouts, with snouts having been collected from seven of the reservoirs surveyed (Table 9). Of the snouts returned, 160 contained tags (34%). As with the gill net data, Lost Valley Reservoir provided the majority of returned tags. Overall, 2N trout made up 58 ± 8% (90) of tags recovered, while 3N comprised 42 ± 8% (64), suggesting 3N rainbow trout returned to anglers at only 71% of 2N trout. However, the paired differences in number of 2N and 3N tags returned by anglers were not statistically significant ($P > 0.15$, $n = 7$).

Mean length, weight, and dressed weight of test fish varied across reservoirs, with Oakley and Island Park reservoirs having returned the longest fish (Appendix F, G, H). In fall 2008, 2N and 3N rainbow trout were of similar length (321 ± 3 mm and 317 ± 3 mm, respectively) based on 95% confidence intervals, but 2N trout were heavier than recaptured 3N rainbow trout in both weight and dressed weight (Figure 6). Marked 2N and 3N trout increased in length in the following year (340 ± 8 mm and 329 ± 8 mm, respectively), but statistical differences between test groups were not apparent (Figure 6). However, 2N trout were significantly heavier in spring 2009, but this difference narrowed by fall 2009 (Figure 6), possibly a result of large confidence intervals associated with few recaptured fish. Similarly, mean dressed weight of 2N trout was greater on average in fall 2008 and spring 2009, but differences were less apparent by fall 2009 when few fish were recaptured (Figure 6).

Catch of 3N fish was related to reservoir volume (percent pool remaining) in the fall after planting ($p = 0.057$, $df = 10$). A higher proportion of 3N rainbow trout were caught in reservoirs with more water (higher percent full) that those with low pools (Figure 3). Triploid numbers declined with lower reservoir levels, but differences between medium and low percent full were not statistically significant (Table 10). These results suggest performance of 3N trout is more comparable to that of 2N trout in reservoirs where water levels might remain closer to full pool throughout the season.

On average, gill net catch of 3N trout was more similar to that of 2N trout in reservoirs where non-trout bycatch was low (Figure 7). In reservoirs with “low” bycatch, 3N fish made up 44 ± 11% of the marked trout captured on average, while making up only 32 ± 14% in reservoirs with “high” bycatch. The 3N returns were not statistically different from 2N by level of bycatch (Table 10). However, graphically it appears that the disparity in returns between 2N and 3N rainbow trout generally increases as the number of other fishes increased (Figure 7).

Comparing the proportion of 3N rainbow caught relative to the number of other species present yielded similar results. On average, 3N rainbow trout made up 45 ± 11% of the marked trout captured when the number of other species present was two or less (“low”), but only 30 ± 11% when five or more species were present (“high”). Despite the trend (Figure 3), differences in 3N catch between “low”, “medium,” and “high” numbers of other species were not statistically significant (Table 10).

## DISCUSSION

While 3N salmonids often perform similar or better than diploids in aquaculture settings (Habicht et al. 1994; Sheehan et al. 1999), performance in natural environments after stocking can be variable (Simon et al. 1993; Dillon et al. 2000; Teuscher et al. 2003). Brock et al. (1994) found the cumulative catch of 3N rainbow trout (age-1 and age-2) to be 39% lower than 2N trout in six Alaska lakes. Similarly, 3N rainbow trout in this study did not survive as well as 2N rainbow trout over the period of two fishing seasons. Disparities in returns from 2N and 3N rainbow trout varied across reservoirs, but 2N trout provided higher returns in most locations. Moreover, relative proportions of 2N and 3N rainbow trout collected were similar between the snout return boxes and active sampling with gill nets, suggesting the disparities in returns are likely a result of lower 3N survival rather than from differential angler harvest resulting from differences in catchability. Gill net surveys only provided a snapshot sample, while the snout return boxes provided return-to-angler data across much of the fishing season, allowing comparison of returns over time. In some locations such as Devils Creek, Island Park, Oakley, Roseworth, Soldier Meadow, Stone, and Thorn Creek reservoirs, differences in return-to-anglers between 2N and 3N appeared early in the fishing season (Figure 1). Simon et al. (1993) reported similar findings, with lower survival of 3N rainbow trout rainbow trout becoming apparent shortly after planting. Considering the relatively brief window of time that catchable trout are available for harvest (Johnson et al. 1995), differences in survival of 2N and 3N trout soon after planting would directly translate to changes in angler success for put-take fisheries typical of this study.

One possible reason for using 3N trout in sport fisheries is the potential for faster growth rates and larger ultimate size (Brock et al. 1994). Several authors have reported growth advantages of 3N salmonids over their 2N counterparts (Thorgaard 1986; Ihssen 1990; Boulanger 1991; Galbreath et al. 1994; Sheehan et al. 1999). However, these studies were conducted with treatments reared separately in hatchery environments, and any growth advantage of 3N fish seems only to materialize at larger sizes (500—700 g) after the species has passed the normal size of sexual maturity. Growth advantages of 3N salmonids tend to reverse or disappear when reared in sympatry or in natural environments with 2N conspecifics or when examined at earlier life stages (Simon et al. 1993; Brock et al. 1994; Galbreath et al. 1994). In this study, 3N rainbow trout did not show any growth advantages over 2N rainbow trout. While mean length between the groups was similar, 2N fish were significantly heavier in weight and dressed weight in the first two sampling events, and 3N trout did not catch up in weight until fall 2009 (Figure 3). Similarly, Ojolick et al. (1995) found growth patterns of 2N rainbow trout had higher girth, while 3N rainbow trout tended to grow longer and leaner with lower condition factor. Teuscher et al. (2003) reported similar findings in Daniels and Treasureton reservoirs in Idaho, where 3N rainbow trout did not show any growth advantages over 2N rainbow up to four years of age. One expected dressed weights of 3N rainbow trout to surpass those of 2N trout after sexual maturity (Boulanger 1991). However, in put-take fisheries with little carryover, any long-term growth advantages of 3N rainbow trout may be of little benefit to the anglers given the short life expectancy of a catchable trout.

Habitat conditions varied across the study reservoirs and affected survival and returns of stocked trout. While returns of 3N rainbow trout were on average lower than those of 2N trout, results indicate that performance differences were less pronounced at sites with less reservoir drawdown. The disparity in catch between 2N and 3N rainbows was usually greatest in reservoirs that experienced low water conditions in the fall when the first sampling occurred. Many of the study sites are irrigation reservoirs that are subject to drawdowns after mid-June when spring runoff end and irrigation season begins. Little Camas, Paddock, Roseworth, Stone, and Thorn Creek reservoirs were drawn down by fall of 2008, with Little Camas and Stone reservoirs becoming so low that these fisheries were opened to public salvage. These reservoirs likely experienced high summer water temperatures and low dissolved oxygen levels.

Low reservoir levels from drought and drawdown (and the associated stressful habitat conditions and limited food supplies for salmonids) are commonly implicated in the poor survival and returns of stocked trout (Wiley et al. 1993; Dillon and Alexander 1996). Triploid salmonids are especially affected by poor water quality such as low dissolved oxygen (Simon et al. 1993) and elevated water temperatures (Ojolick et al. 1995), and perform poorly under chronic environmental stress (Maxime 2008; Piferrer et al. 2009). Research has shown 3N rainbow trout have higher mortality than 2N controls at water temperatures above 17°C (Myers and Hershberger 1991; Blanc et al. 1992). Ojolick et al. (1995) reported 65% of 3N rainbow trout died within three weeks while reared at 21°C compared to only 39% of 2N trout during the same period. These authors speculated that lowered hemoglobin:oxygen loading ratios in 3N trout reduce their maximum blood oxygen capacity. During periods of warm water when metabolic rates increase, this could limit their ability to supply oxygen to tissues during periods of higher oxygen demand. Ojolick et al. (1995) concluded that triploids had higher mortality rates occurring earlier in the study, with 50% cumulative mortality occurring 20 days earlier than for diploids. Earlier mortality of 3N trout could subsequently reduce return-to-creel by reducing the duration that trout are available to anglers. Simon et al. (1993) reported such findings in three South Dakota ponds, where catch data indicated 3N rainbow trout had lower weight, length, and relative weight than 2N rainbow trout at 45 months of age. They found that lower survival rates began shortly after stocking (a finding echoed in this study), suggesting that 3N rainbow trout may be a poor choice for even short-term fishing opportunities in waters with poor habitat conditions.

Although results were not statistically significant given the sample size, sites that contained higher species diversity appeared to have greater disparity in returns of 2N and 3N trout. The fish communities of Horsethief, Lost Valley, and Devils Creek reservoirs consisted almost exclusively of trout, and triploids made up on average 72%, 48%, and 59% of the marked trout sampled, respectively. In contrast, Island Park, Stone, and Paddock reservoirs had a higher diversity of species including Utah chub *Gila atraria*, largescale sucker *Catostomus macrocheilus*, Utah sucker *Catostomus ardens,* black crappie *Pomoxis nigromaculatus*, largemouth bass, smallmouth bass *Micropterus dolomieui*, common carp *Cyprinus carpio*, and yellow perch *Perca flavescens*. In these locations, triploids made up 22%, 28%, and 9% of the marked trout sampled, respectively. Wiley et al. (1993) found low survival of stocked trout was common in Wyoming lakes where established populations of holdover hatchery or wild trout were present, or in locations where competing nongame and predatory species were present. Returns to anglers of planted trout were always better when lakes contained few competing nongame and predatory species, regardless of fishing pressure. Dillon and Alexander (1996) reported higher returns and improved growth of planted rainbow trout in reservoirs with few competing species and where water levels remained high. Poor competitive ability of triploid fishes has been demonstrated for Atlantic salmon (Galbreath et al. 1994) and saugeye (Czesny 2000) which could exacerbate low return-to-creel rates of triploid rainbow trout in locations with diverse species assemblages.

Several authors have suggested that benefits of sterile trout, such as increased growth rates, larger ultimate sizes and increased longevity, do not begin until the species reaches the normal age of sexual maturity (Ihssen et al. 1990; Sheehan et al. 1999; Teuscher et al. 2003). However, these results suggest these advantages may never be realized in many put-take fisheries, especially in reservoirs subject to drawdown, high summer temperatures, or intense fishing pressure where carryover may be even more limited. In fact, most catchable trout are caught as quickly as 7-10 days after stocking in streams (Butler and Borgeson 1965; Johnson et al. 1995) and within two months (with more than 83% harvested in the first year) in lakes and reservoirs (Wiley et al. 1993). On average, 3N rainbow trout did not grow or survive as well as 2N rainbow trout over the period of this evaluation (two fishing seasons). High exploitation rates (although rarely achieved), combined with lower survival (and return to creel) during the fishing season could negate any long-term benefits associated with triploidy. However, in lakes with good habitat conditions, 3N rainbow trout may perform well while preventing genetic impacts to wild stocks or establishing self-sustaining populations. Stocking strategies for managing catchable trout are highly site-specific (Hartzler 1988). Fisheries managers should decide on an individual lake basis whether protection of wild stocks outweigh the potential for reduced survival and return-to-creel of 3N trout. Fortunately in Idaho, most reservoirs with lower quality habitat and mixed species assemblages (where 3N trout would perform poorly) also tend to have few native salmonid populations, thus stocking 2N trout poses little genetic risk. In reservoirs dominated by trout that maintain good water quality and are less subject to drawdown, native salmonids are more frequently found nearby, and continuing to use 3N trout in these locations will protect native genotypes.

## RECOMMENDATIONS

1. Evaluate current rainbow trout stocking practices in lakes and reservoirs in relation to wild trout distribution. Determine if risks to wild populations outweigh the potential reduced survival and lower return-to-creel of triploid rainbow trout. Consider stocking diploid catchables in drawdown reservoirs where impacts to native salmonids are unlikely.

2. Future hatchery trout evaluations in reservoirs should collect comprehensive habitat data to monitor how habitat changes might affect returns over the course of a typical fishing season.

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**TABLES**

Table 8. Location, date and quantities of marked trout planted during 2008 in 13 Idaho lakes and reservoirs to assess relative performance of diploid (2N) and triploid (3N) catchable-sized rainbow trout.

| Lake Name | Lake Size (ha) | Elevation (m) | Stock Date | Sample Date |
|---|---|---|---|---|
| Devil Creek Res. | 35 | 1571 | 4/29/2008 | 9/24/08 |
| Horsethief Res. | 101 | 1541 | 5/14 - 6/4/08 | 9/8/08 |
| Island Park Res. | 2947 | 1922 | 6/2 - 6/3/08 | 9/25/08 |
| Little Camas Res. | 391 | 1502 | 4/30/2008 | 8/19/08 |
| Lost Valley Res. | 211 | 1454 | 5/29/2008 | 9/9/08 |
| Mann Lake | 55 | 547 | 5/1/2008 | 10/6/08 |
| Oakley Res. | 407 | 1435 | 4/7/2008 | 10/16/08 |
| Paddock Res. | 482 | 979 | 4/1/2008 | 7/7/08 |
| Roseworth Res. | 393 | 1594 | 4/8/2008 | 10/14/08 |
| Soldier's Mdw. Res. | 45 | 1388 | 5/20/2008 | 10/8/08 |
| Stone Res. | 50 | 1402 | 4/28/2008 | 10/1/08 |
| Thorn Creek Res. | 45 | 1679 | 5/16/2008 | 8/21/08 |
| Waha Res. | 38 | 1034 | 5/20/2008 | 10/7/08 |
| **Lake Name** | **Total 2N Stocked** | **2N Fish/lb** | **2N Length (mm)** | **2N Density (ha)** |
| Devil Creek Res. | 5,405 | 2.30 | 257 | 156.4 |
| Horsethief Res. | 15,126 | 2.27 | 258 | 150.2 |
| Island Park Res. | 16,800 | 2.35 | 255 | 5.7 |
| Little Camas Res. | 3,776 | 2.36 | 255 | 9.7 |
| Lost Valley Res. | 7,590 | 2.30 | 257 | 35.9 |
| Mann Lake | 5,063 | 2.47 | 251 | 91.8 |
| Oakley Res. | 4,995 | 2.70 | 244 | 12.3 |
| Paddock Res. | 4,988 | 2.85 | 239 | 10.4 |
| Roseworth Res. | 4,995 | 2.70 | 244 | 12.7 |
| Soldier's Mdw. Res. | 4,700 | 2.35 | 255 | 103.5 |
| Stone Res. | 5,040 | 2.40 | 253 | 100.4 |
| Thorn Creek Res. | 2,520 | 2.40 | 253 | 56.5 |
| Waha Res. | 3,525 | 2.35 | 255 | 92.5 |
| **Lake Name** | **Total 3N Stocked** | **3N Fish/lb** | **3N Length (mm)** | **3N Density (ha)** |
| Devil Creek Res. | 5,355 | 2.10 | 265 | 154.9 |
| Horsethief Res. | 15,593 | 2.25 | 259 | 154.8 |
| Island Park Res. | 17,465 | 2.45 | 255 | 5.9 |
| Little Camas Res. | 3,885 | 2.22 | 260 | 9.9 |
| Lost Valley Res. | 7,557 | 2.29 | 257 | 35.7 |
| Mann Lake | 5,040 | 2.40 | 253 | 91.4 |
| Oakley Res. | 4,950 | 2.75 | 242 | 12.2 |
| Paddock Res. | 4,930 | 2.90 | 238 | 10.2 |
| Roseworth Res. | 4,950 | 2.75 | 242 | 12.6 |
| Soldier's Mdw. Res. | 4,540 | 2.27 | 258 | 100.0 |
| Stone Res. | 5,040 | 2.80 | 241 | 100.4 |
| Thorn Creek Res. | 2,573 | 2.45 | 252 | 57.7 |
| Waha Res. | 3,405 | 2.27 | 258 | 89.4 |

Table 9. Total counts of diploid (2N) and triploid (3N) rainbow trout tags recaptured by method and year. Trout were stocked in spring 2008 and recaptured in fall 2008, spring 2009, and fall 2009. “Marked at stocking” refers to the percent of the total catchable rainbow trout stocked in 2008 that that were marked for this study. “Marked at capture” refers to the percent marked of the total rainbow trout captured at the time of sampling.

| | | | Gill nets | | | | | | Voluntary creel | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Fall 2008 | | Spring 2009 | | Fall 2009 | | 2008 | | 2009 | |
| Lake name | Marked at stocking | Marked at capture | 2N | 3N | 2N | 3N | 2N | 3N | 2N | 3N | 2N | 3N |
| Devil Creek Reservoir | 67% | 44% | 33 | 36 | 3 | 1 | 0 | 1 | 47 | 39 | 6 | 1 |
| Horsethief Reservoir | 100% | 91% | 98 | 118 | 10 | 16 | 0 | 2 | 442 | 454 | 11 | 14 |
| Island Park Reservoir | 100% | 40% | 46 | 30 | 17 | 6 | 1 | 0 | 56 | 28 | 16 | 14 |
| Little Camas Reservoir | 100% | 55% | 85 | 46 | 0 | 0 | - | - | 46 | 44 | - | - |
| Lost Valley Reservoir | 100% | 100% | 144 | 94 | 31 | 20 | 13 | 25 | 66 | 70 | 31 | 18 |
| Mann Lake | 37% | 36% | 6 | 6 | - | - | - | - | 57 | 55 | - | |
| Oakley Reservoir | 66% | 30% | 5 | 5 | 2 | 0 | - | - | 65 | 26 | 2 | 1 |
| Paddock Reservoir | 100% | 100% | 10 | 1 | - | - | - | - | 5 | 4 | - | - |
| Roseworth Reservoir | 22% | 6% | 16 | 2 | 0 | 1 | - | - | 82 | 44 | 0 | 0 |
| Soldier Meadow Reservoir | 100% | 20% | 35 | 33 | 13 | 11 | 0 | 0 | 59 | 35 | 11 | 9 |
| Stone Reservoir | 100% | 99% | 70 | 27 | - | - | - | - | 81 | 41 | - | - |
| Thorn Creek Reservoir | 100% | 100% | 30 | 20 | 0 | 0 | - | - | 111 | 89 | - | - |
| Waha Lake | 100% | 92% | 57 | 38 | 62 | 62 | 0 | 0 | 98 | 60 | 13 | 7 |
| *Grand Total* | | | *635* | *456* | *138* | *117* | *14* | *28* | *1215* | *989* | *90* | *64* |
| *Total Percent* | | | 58% | 42% | 54% | 46% | 33% | 67% | 55% | 45% | 58% | 42% |

Table 10. Parameter estimates for one-way ANOVA analysis of three factors versus the percent of 3N marked rainbow trout captured in gill nets. “Total bycatch” is the number of other fish caught (not including rainbow trout) categorized as “low” (≤200), “medium” (201-325) or “high” (≥326). “Number of species” refers to the number of other species found present categorized as “low” (one or two), “medium” (three to four), and “high” (five or more). “Reservoir level” refers to the proportion of pool volume remaining in the fall categorized as “low” (0-30%), “medium” (31-60%), and “high” (61-100%). Levels of each factor that share the same letter group are not statistically different based on Tukey’s multiple comparisons (α = 0.1).

| Factor | p - val. | F | df | Level | Estimate | SE | Letter group |
|---|---|---|---|---|---|---|---|
| Total bycatch | 0.54 | 0.64 | 2, 10 | Low | 0.44 | 0.07 | A |
| | | | | Med | 0.38 | 0.07 | A |
| | | | | High | 0.32 | 0.08 | A |
| Number of species | 0.28 | 1.44 | 2, 11 | Low | 0.45 | 0.66 | A |
| | | | | Med | 0.42 | 0.05 | A |
| | | | | High | 0.3 | 0.07 | A |
| Reservoir level | 0.06 | 3.85 | 2, 12 | Low | 0.32 | 0.06 | A |
| | | | | Med | 0.36 | 0.05 | AB |
| | | | | High | 0.50 | 0.04 | B |

**FIGURES**

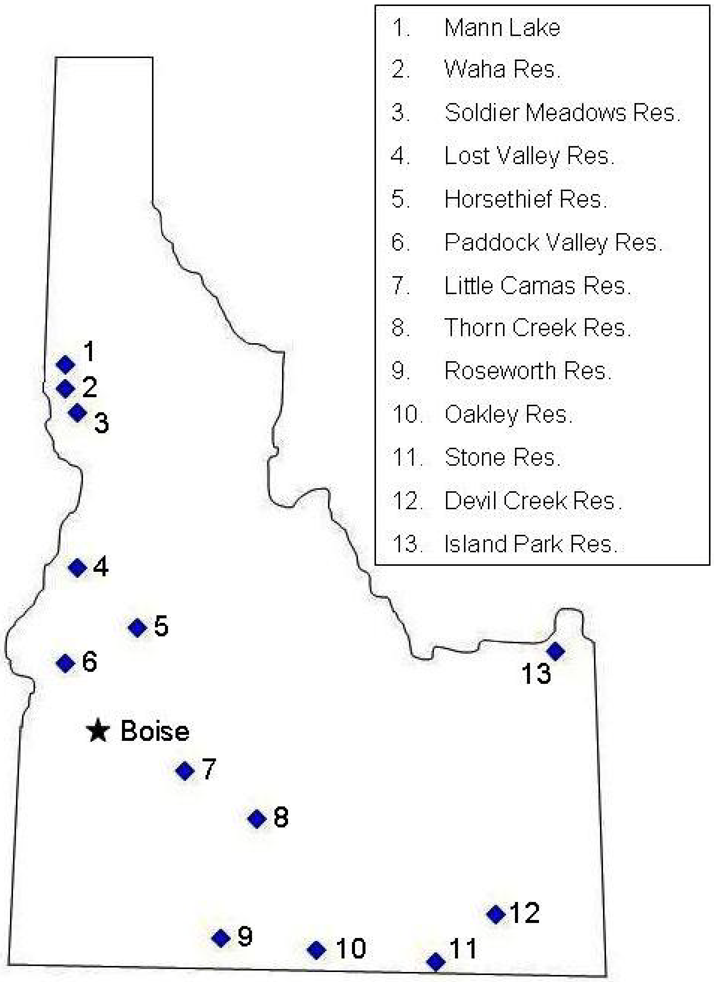



Figure 4. Lakes and reservoirs stocked with marked diploid and triploid catchable rainbow trout in 2008.

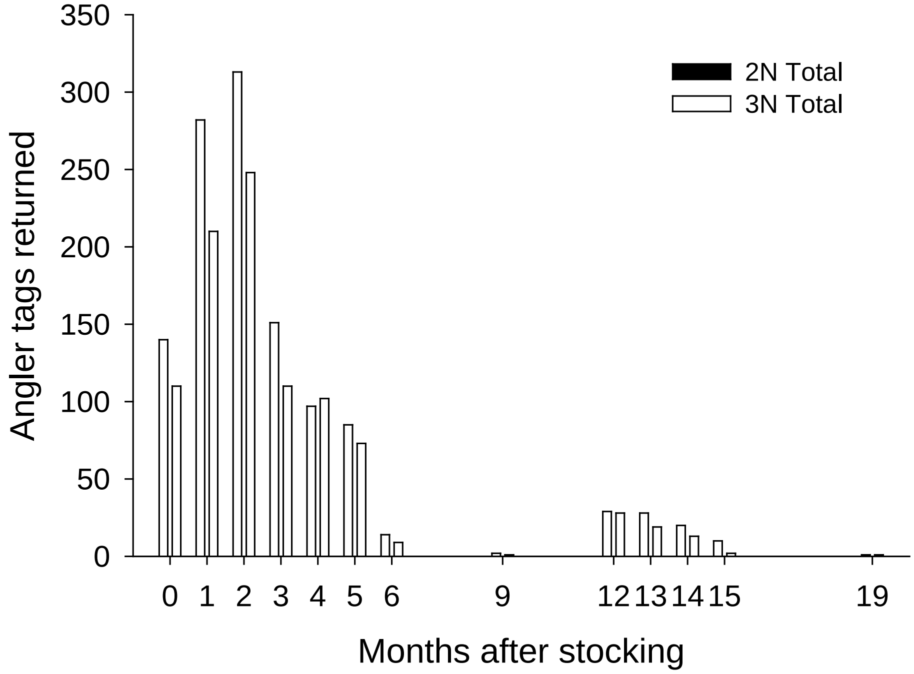



Figure 5. Lakes and reservoirs stocked with marked diploid and triploid catchable rainbow trout in 2008.

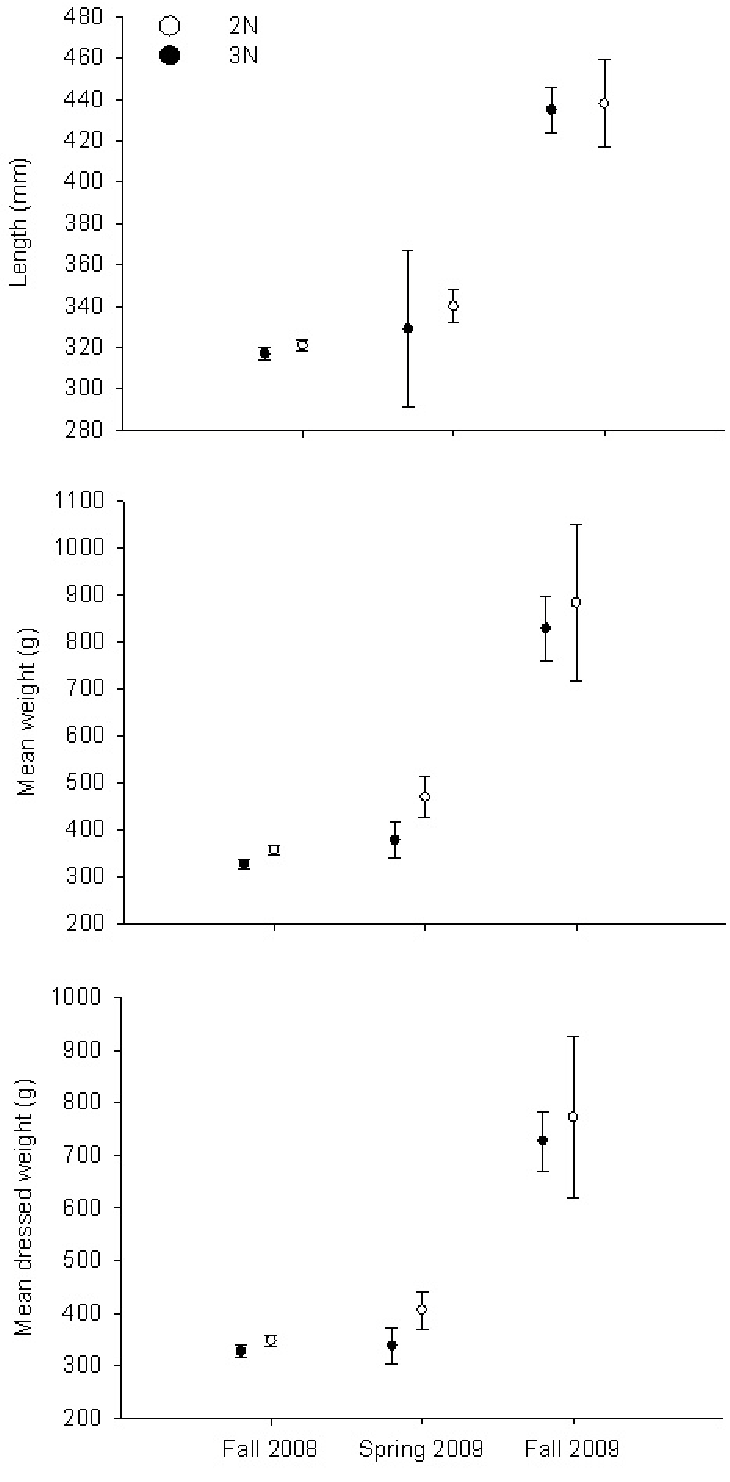



Figure 6. Mean length (mm), mean weight (g), and mean dressed weight of diploid (2N) and triploid (3N) rainbow trout combined across all reservoirs by sampling season. Error bars indicate 95% confidence intervals.

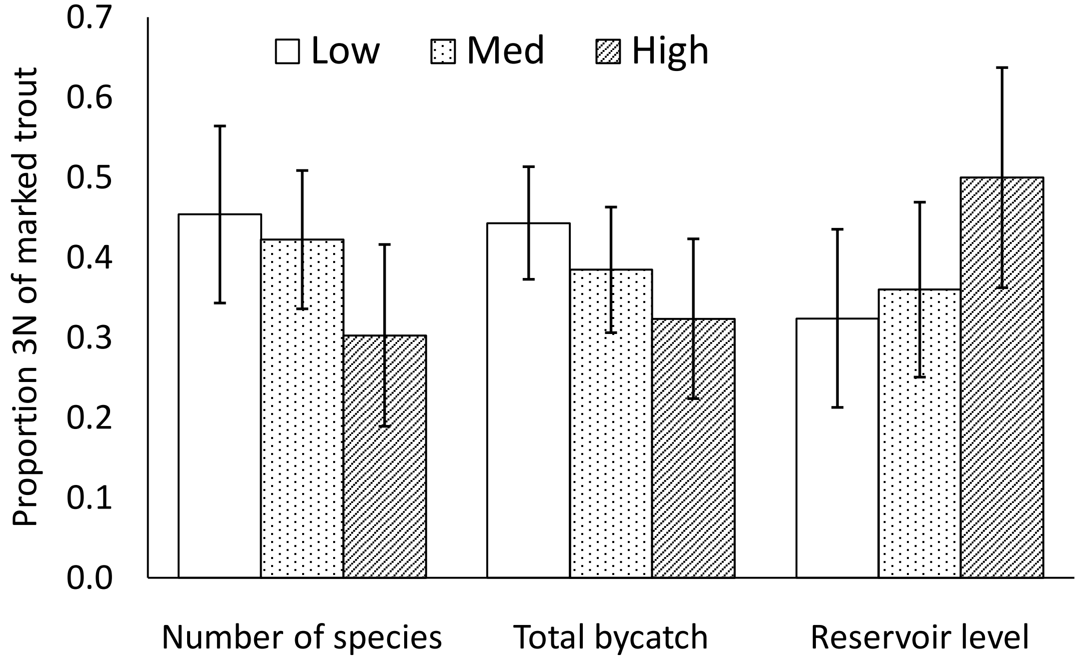
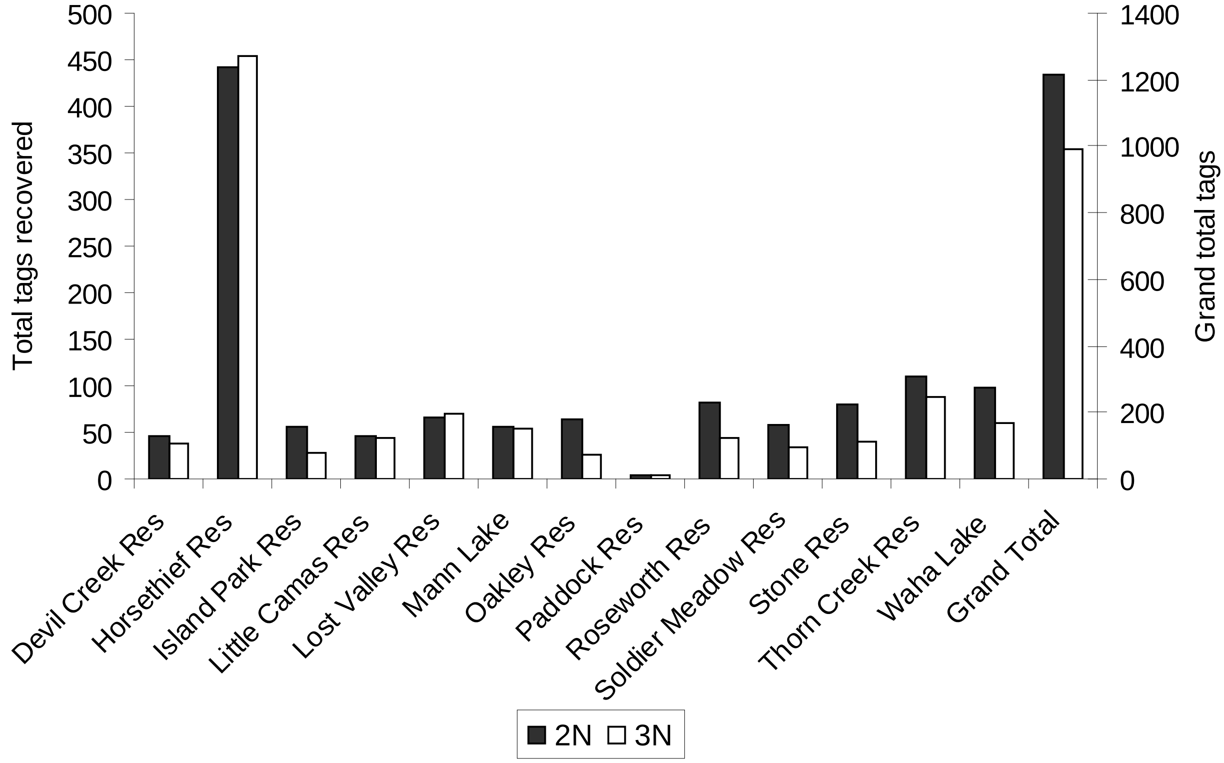



Figure 7. Treatment means for the proportion triploid of marked rainbow trout relative to three explanatory variables: species category, reservoir level, and total bycatch. Means were generated by repeated measures ANOVA and include all three sampling event (fall 2008, spring 2009, fall 2009). Error bars indicate 90% confidence intervals.

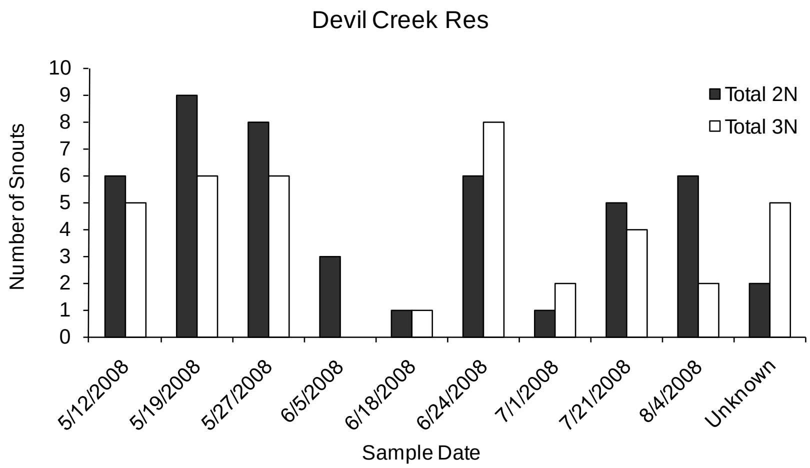
**APPENDICES**

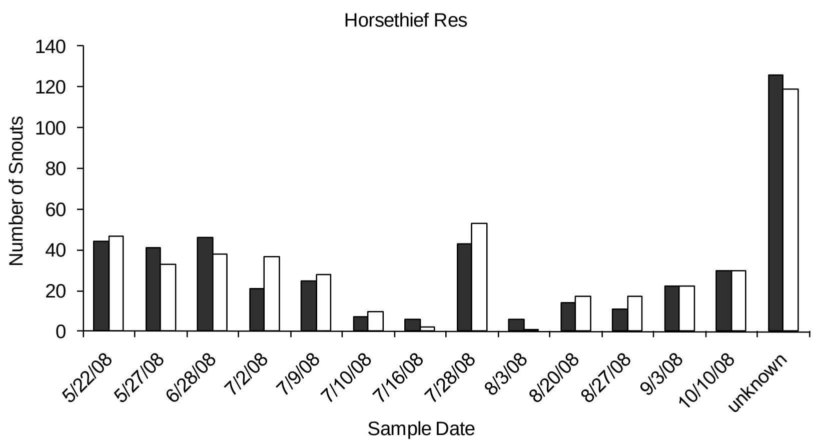
Appendix A. Counts of diploid (2N) and triploid (3N) rainbow trout and coded wire tags recaptured in fall 2008 from rainbow trout stocked in spring 2008 using gill nets and electrofishing, by reservoir. Reservoirs marked with stars indicate locations that received fingerling plants of unmarked rainbow trout, which could affect the proportion of marked rainbow trout caught.

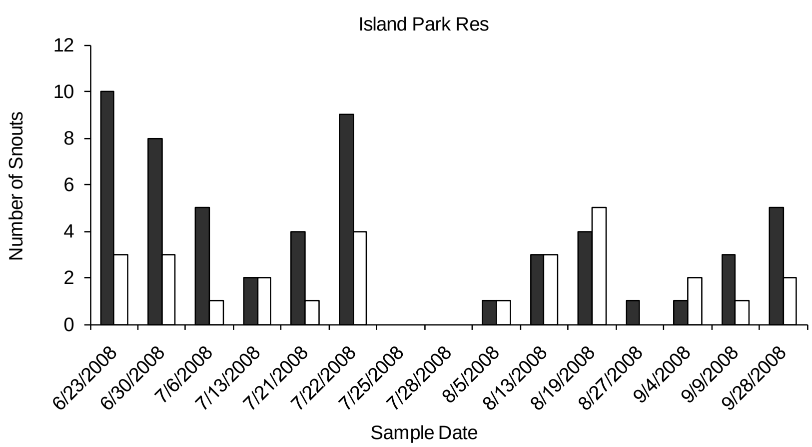
| Lake Name | Total RBT | Total ad-clips | Total w/ tags | Percent tagged | No sample | Lost in lab | 2N | 3N | % 2N | % 3N | % Stocking Marked | % Capt. Marked |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Devil Creek Res | 189 | 84 | 71 | 85% | 2 | | 33 | 36 | 48% | 52% | 67% | 44% |
| Horsethief Res* | 263 | 239 | 218 | 91% | | 1 | 98 | 118 | 45% | 55% | 100% | 91% |
| Island Park Res* | 203 | 82 | 77 | 94% | | 2 | 46 | 30 | 61% | 39% | 100% | 40% |
| Little Camas Res | 262 | 143 | 132 | 92% | | 1 | 85 | 46 | 65% | 35% | 100% | 55% |
| Lost Valley Res | 264 | 264 | 245 | 93% | 2 | 5 | 144 | 94 | 61% | 39% | 100% | 100% |
| Mann Lake* | 39 | 14 | 12 | 86% | | | 6 | 6 | 50% | 50% | 37% | 36% |
| Oakley Res* | 60 | 18 | 11 | 61% | | 1 | 5 | 5 | 50% | 50% | 66% | 30% |
| Paddock Res | 11 | 11 | 11 | 100% | | | 10 | 1 | 91% | 9% | 100% | 100% |
| Roseworth Res* | 336 | 20 | 18 | 90% | | | 16 | 2 | 89% | 11% | 22% | 6% |
| Soldier Meadow Res* | 369 | 73 | 67 | 92% | | | 35 | 33 | 51% | 49% | 100% | 20% |
| Stone Res | 106 | 105 | 99 | 94% | | 2 | 70 | 27 | 72% | 28% | 100% | 99% |
| Thorn Creek Res | 53 | 53 | 50 | 94% | | | 30 | 20 | 60% | 40% | 100% | 100% |
| Waha Lake | 115 | 106 | 97 | 92% | | 2 | 57 | 38 | 60% | 40% | 100% | 92% |
| *Grand Total* | *2,270* | *1,212* | *1,108* | *91%* | *4* | *13* | *635* | *456* | *58%* | *42%* | *73%* | *53%* |



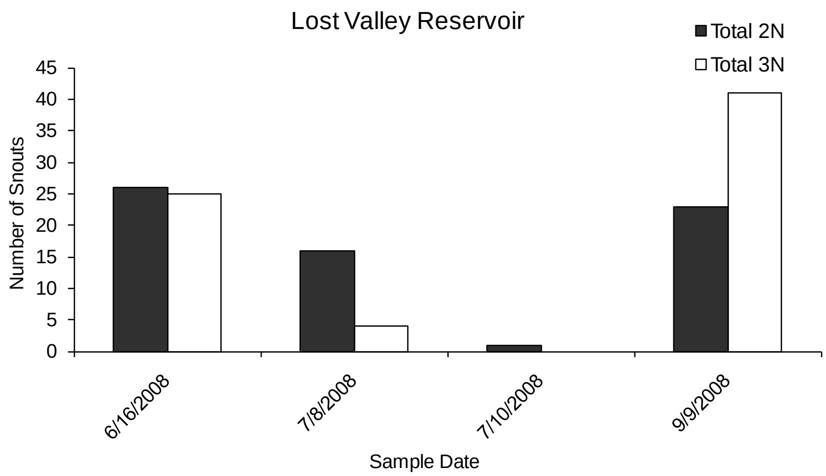

Appendix B. Total diploid (2N) and triploid (3N) coded wire tags returned by anglers using “snout collection boxes” by reservoir during 2008.

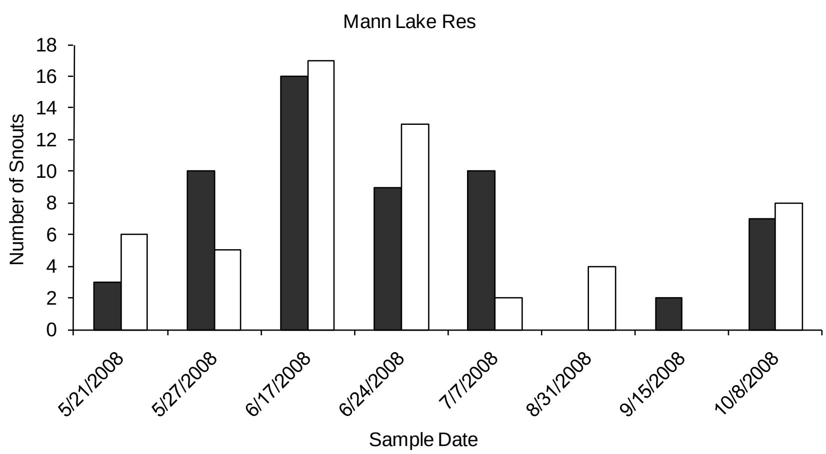


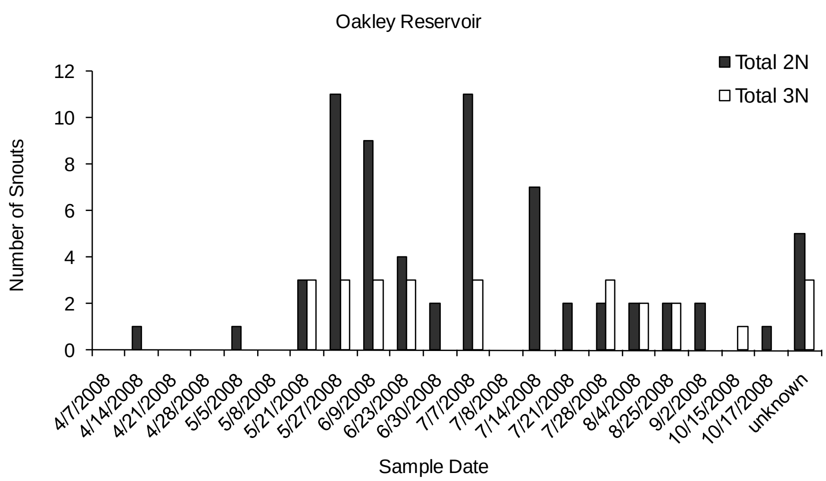



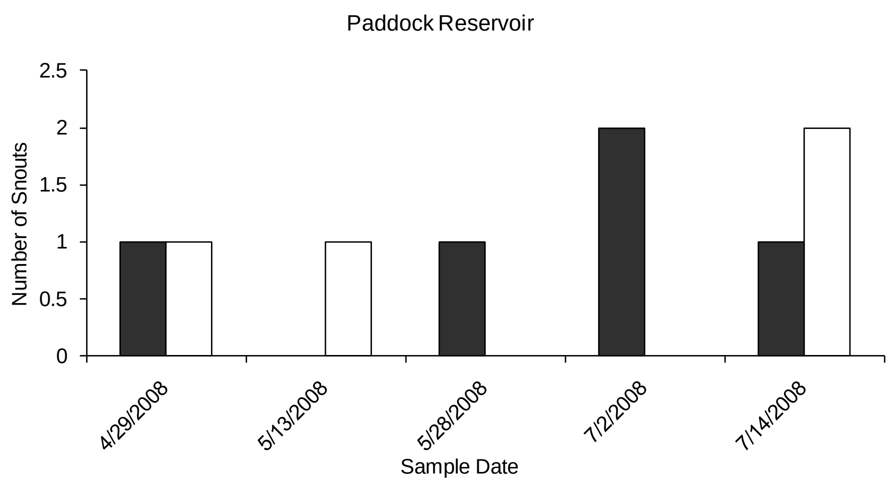

Appendix C. Counts of diploid (2N) and triploid (3N) coded wire tags returned by anglers using "snout collection boxes" by collection date during 2008.

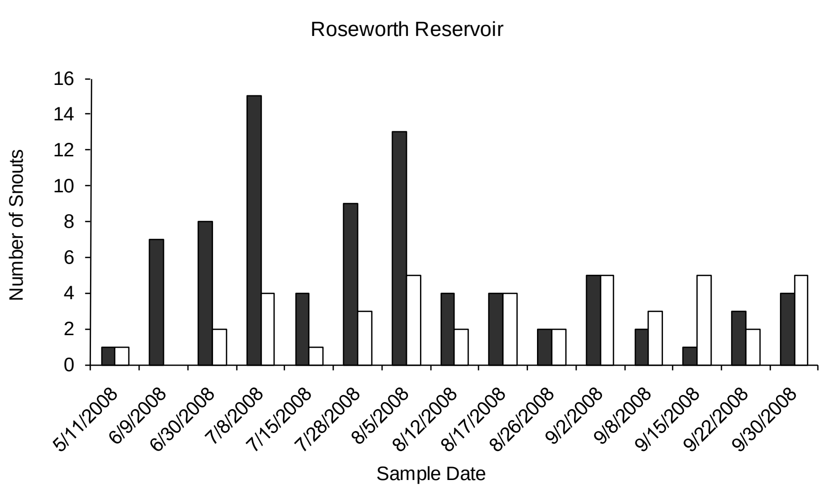



Appendix C. Continued.

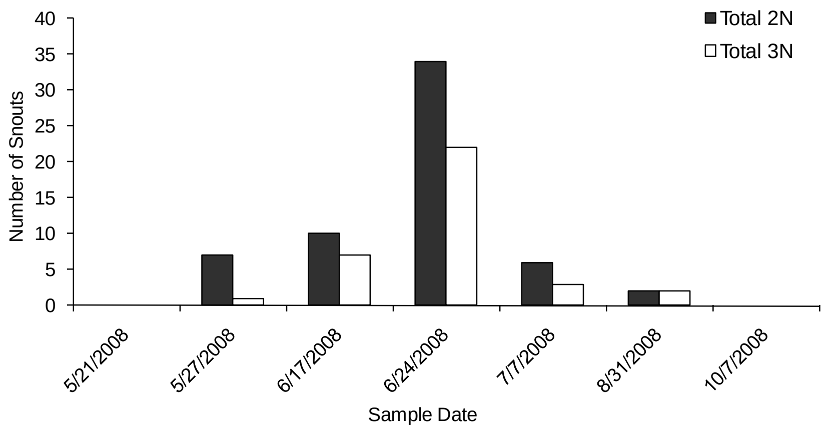


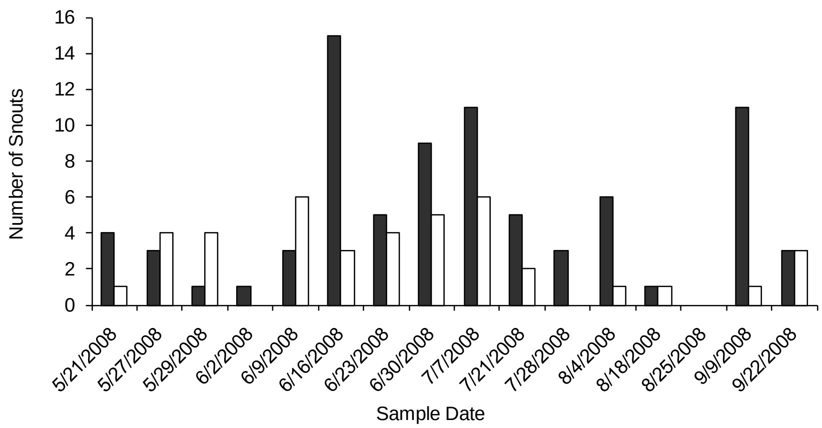




Appendix C. Continued.

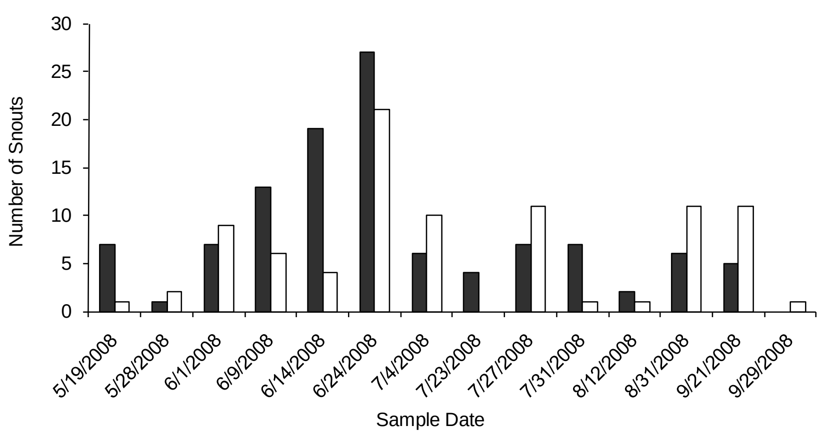
Soldier Meadow Reservoir



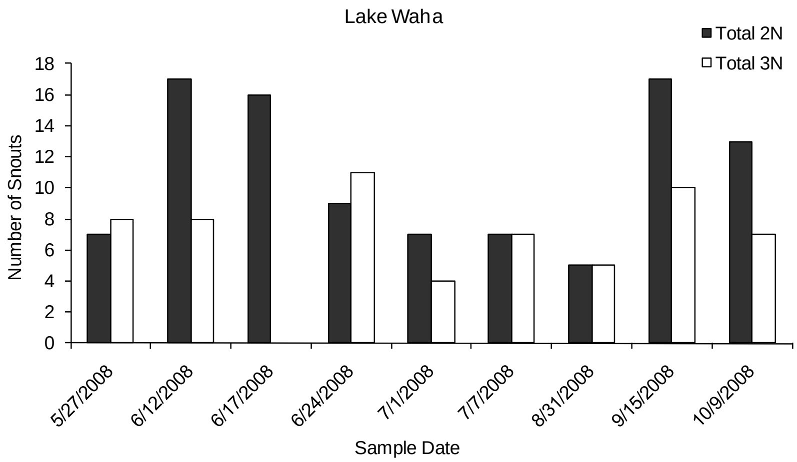

Stone Reservoir




Thorn Creek Reservoir




Appendix C. Continued.




Appendix C. Continued.

Appendix D. Counts of diploid (2N) and triploid (3N) rainbow trout and coded wire tags recaptured in spring 2009 from rainbow trout stocked in spring 2008 using gill nets by reservoir.

| Lake Name | Total RBT | Total ad-clips | Total w/ tags | Percent tagged | No sample | Lost in lab | 2N | 3N | % 2N | % 3N |
|---|---|---|---|---|---|---|---|---|---|---|
| Devil Creek Res | 191 | 11 | 5 | 45% | | 1 | 3 | 1 | 75% | 25% |
| Horsethief Res | 101 | 38 | 27 | 71% | | 1 | 10 | 16 | 38% | 62% |
| Island Park Res | 242 | 26 | 23 | 88% | | 0 | 17 | 6 | 74% | 26% |
| Little Camas Res | 1 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| Lost Valley Res | 62 | 62 | 53 | 85% | | 2 | 31 | 20 | 61% | 39% |
| Mann Lake | — | — | — | — | | — | — | — | — | — |
| Oakley Res | 28 | 5 | 2 | 40% | | 0 | 2 | 0 | 100% | 0% |
| Paddock Res | — | — | — | — | | — | — | — | — | — |
| Roseworth Res | 69 | 2 | 1 | 50% | | 0 | 0 | 1 | 0% | 100% |
| Soldier Meadow Res | 91 | 25 | 24 | 96% | | 0 | 13 | 11 | 54% | 46% |
| Stone Res | — | — | — | — | | — | — | — | — | — |
| Thorn Creek Res | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| Waha Lake | 174 | 134 | 127 | 95% | | 3 | 62 | 62 | 50% | 50% |
| *Grand Total* | *959* | *303* | *262* | *86%* | | *7* | *138* | *117* | *54%* | *46%* |

Appendix E. Counts of diploid (2N) and triploid (3N) rainbow trout and coded wire tags recaptured in fall 2009 from rainbow trout stocked in spring 2008 using gill nets by reservoir.

| **Lake Name** | **Total RBT** | **Total ad-clips** | **Total w/ tags** | **Percent tagged** | **No sample** | **Lost in lab** | **2N** | **3N** | **% 2N** | **% 3N** |
|---|---|---|---|---|---|---|---|---|---|---|
| Devil Creek Res | 132 | 4 | 1 | 25% | | 0 | 0 | 1 | 0 | 100% |
| Horsethief Res | 291 | 5 | 2 | 40% | | 0 | 0 | 2 | 0 | 100% |
| Island Park Res | 61 | 3 | 1 | 33% | | 0 | 1 | 0 | 100% | 0 |
| Little Camas Res | — | — | — | — | — | — | — | — | — | — |
| Lost Valley Res | 415 | 51 | 38 | 75% | | 0 | 13 | 25 | 34% | 66% |
| Mann Lake | — | — | — | — | — | — | — | — | — | — |
| Oakley Res | — | — | — | — | — | — | — | — | — | — |
| Paddock Res | — | — | — | — | — | — | — | — | — | — |
| Roseworth Res | — | — | — | — | — | — | — | — | — | — |
| Soldier Meadow Res | 419 | 2 | 0 | 0% | | 0 | 0 | 0 | 0 | 0 |
| Stone Res | — | — | — | — | — | — | — | — | — | — |
| Thorn Creek Res | — | — | — | — | — | — | — | — | — | — |
| Waha Lake | 74 | 2 | 0 | 0% | 0 | 0 | 0 | 0 | 0 | 0 |
| *Grand Total* | *1,392* | *67* | *42* | *63%* | *0* | *0* | *14* | *28* | *33%* | *67%* |

Appendix F. Mean length (mm), mean weight (g) and mean dressed weight (g) and associated 95% confidence intervals of diploid (2N) and triploid (3N) catchable rainbow planted in spring 2008 and recaptured in fall 2008. Dashed lines indicate where no sampling occurred.

| Lake Name | 2N Length (mm) | n | ±CI (mm) | 3N Length (mm) | n | ±CI (mm) |
|---|---|---|---|---|---|---|
| Devil Creek Res | 341 | 33 | 6 | 337 | 36 | 5 |
| Horsethief Res | 311 | 98 | 3 | 308 | 118 | 4 |
| Island Park Res | 353 | 46 | 6 | 348 | 30 | 8 |
| Little Camas Res | 343 | 85 | 3 | 340 | 46 | 6 |
| Lost Valley Res | 343 | 144 | 3 | 334 | 94 | 3 |
| Mann Lake | 262 | 6 | 43 | 287 | 6 | 10 |
| Oakley Res | 403 | 5 | 22 | 392 | 5 | 19 |
| Paddock Res | 307 | 10 | 8 | 315 | 1 | |
| Roseworth Res | 339 | 16 | 9 | 326 | 2 | 64 |
| Soldier Meadow Res | 276 | 35 | 6 | 280 | 33 | 10 |
| Stone Res | 284 | 70 | 5 | 278 | 27 | 6 |
| Thorn Creek Res | 316 | 30 | 6 | 325 | 20 | 8 |
| Waha Lake | 285 | 57 | 6 | 283 | 38 | 7 |
| **Lake Name** | **2N Weight (g)** | **n** | **±CI (g)** | **3N Weight (g)** | **n** | **±CI (g)** |
| Devil Creek Res | 431 | 33 | 22 | 405 | 36 | 16 |
| Horsethief Res | 322 | 98 | 11 | 298 | 118 | 11 |
| Island Park Res | 489 | 46 | 27 | 450 | 30 | 30 |
| Little Camas Res | 426 | 85 | 12 | 387 | 45 | 16 |
| Lost Valley Res | 464 | 144 | 11 | 410 | 94 | 10 |
| Mann Lake | 174 | 6 | 34 | 176 | 6 | 39 |
| Oakley Res | 711 | 5 | 102 | 620 | 5 | 52 |
| Paddock Res | 291 | 10 | 25 | 286 | 1 | |
| Roseworth Res | 357 | 16 | 25 | 296 | 2 | 229 |
| Soldier Meadow Res | 184 | 35 | 14 | 186 | 33 | 18 |
| Stone Res | 190 | 70 | 10 | 165 | 27 | 16 |
| Thorn Creek Res | 359 | 30 | 18 | 364 | 20 | 28 |
| Waha Lake | 206 | 57 | 13 | 191 | 38 | 15 |
| **Lake Name** | **2N Dressed Wt (g)** | **n** | **±CI (g)** | **3N Dressed Wt (g)** | **n** | **±CI (g)** |
| Devil Creek Res | 375 | 33 | 19 | 365 | 36 | 15 |
| Horsethief Res | 272 | 35 | 14 | 264 | 52 | 13 |
| Island Park Res | 426 | 45 | 21 | 402 | 28 | 29 |
| Little Camas Res | 363 | 58 | 14 | 354 | 30 | 17 |
| Lost Valley Res | 393 | 55 | 14 | 354 | 38 | 20 |
| Mann Lake | — | — | — | — | — | — |
| Oakley Res | 601 | 5 | 94 | 541 | 5 | 45 |
| Paddock Res | — | — | — | — | — | — |
| Roseworth Res | 321 | 16 | 24 | 266 | 2 | 356 |
| Soldier Meadow Res | — | — | — | — | — | — |
| Stone Res | — | — | — | — | — | — |
| Thorn Creek Res | 304 | 30 | 16 | 311 | 20 | 22 |
| Waha Lake | 186 | 28 | 16 | 173 | 17 | 21 |

Appendix G. Mean length (mm), mean weight (g) and mean dressed weight (g) and associated 95% confidence intervals of diploid (2N) and triploid (3N) catchable rainbow planted in spring 2008 and recaptured in spring 2009. Dashed lines indicate where no sampling occurred.

| Lake Name | 2N Length (mm) | n | ±CI (mm) | 3N Length (mm) | n | ±CI (mm) |
|---|---|---|---|---|---|---|
| Devil Creek Res | 390 | 3 | 23 | 380 | 1 | |
| Horsethief Res | 345 | 10 | 8 | 343 | 16 | 5 |
| Island Park Res | 389 | 17 | 10 | 390 | 6 | 17 |
| Little Camas Res | | 0 | | | 0 | |
| Lost Valley Res | 396 | 31 | 6 | 401 | 20 | 9 |
| Mann Lake | — | — | | — | — | |
| Oakley Res | 442 | 2 | 172 | | 0 | |
| Paddock Res | — | — | | — | — | |
| Roseworth Res | | 0 | | 333 | 1 | |
| Soldier Meadow Res | 281 | 13 | 12 | 297 | 11 | 17 |
| Stone Res | — | — | | — | — | |
| Thorn Creek Res | | 0 | | | 0 | |
| Waha Lake | 305 | 62 | 6 | 301 | 62 | 6 |

| Lake Name | 2N Weight (g) | n | ±CI (g) | 3N Weight (g) | n | ±CI (g) |
|---|---|---|---|---|---|---|
| Devil Creek Res | 651 | 3 | 65 | 618 | 1 | |
| Horsethief Res | 427 | 10 | 43 | 389 | 16 | 20 |
| Island Park Res | 702 | 17 | 44 | 637 | 6 | 94 |
| Little Camas Res | | 0 | | | 0 | |
| Lost Valley Res | 796 | 31 | 36 | 744 | 20 | 49 |
| Mann Lake | — | — | | — | — | |
| Oakley Res | 925 | 2 | 1257 | | 0 | |
| Paddock Res | — | — | | — | — | |
| Roseworth Res | | 0 | | 346 | 1 | |
| Soldier Meadow Res | 178 | 13 | 26 | 202 | 11 | 51 |
| Stone Res | — | — | | — | — | |
| Thorn Creek Res | | 0 | | | 0 | |
| Waha Lake | 178 | 13 | 19 | 260 | 62 | 16 |

| Lake Name | 2N Dressed Wt (g) | n | ±CI (g) | 3N Dressed Wt (g) | n | ±CI (g) |
|---|---|---|---|---|---|---|
| Devil Creek Res | 577 | 3 | 68 | 546 | 1 | |
| Horsethief Res | 365 | 10 | 24 | 346 | 16 | 16 |
| Island Park Res | 548 | 17 | 33 | 520 | 6 | 83 |
| Little Camas Res | | 0 | | | 0 | |
| Lost Valley Res | 629 | 31 | 32 | 620 | 20 | 40 |
| Mann Lake | — | — | | — | — | |
| Oakley Res | 777 | 2 | 1511 | | 0 | |
| Paddock Res | — | — | | — | — | |
| Roseworth Res | | 0 | | 308 | 1 | |
| Soldier Meadow Res | 148 | 13 | 21 | 180 | 11 | 45 |
| Stone Res | — | — | | — | — | |
| Thorn Creek Res | | 0 | | | 0 | |
| Waha Lake | 248 | 43 | 20 | 220 | 45 | 19 |

Appendix H. Mean length (mm), mean weight (g) and mean dressed weight (g) and associated 95% confidence intervals of diploid (2N) and triploid (3N) catchable rainbow planted in spring 2008 and recaptured in spring 2009.

| Lake Name | 2N Length (mm) | n | ±CI (mm) | 3N Length (mm) | n | ±CI (mm) |
|---|---|---|---|---|---|---|
| Devil Creek Res | | 0 | | 411 | 1 | |
| Horsethief Res | | 0 | | 368 | 2 | 11 |
| Island Park Res | 491 | 1 | | | 0 | |
| Little Camas Res | — | — | | — | — | |
| Lost Valley Res | 434 | 13 | 16 | 442 | 25 | 9 |
| Mann Lake | — | — | | — | — | |
| Oakley Res | — | — | | — | — | |
| Paddock Res | — | — | | — | — | |
| Roseworth Res | — | — | | — | — | |
| Soldier Meadow Res | | 0 | | | 0 | |
| Stone Res | — | — | | — | — | |
| Thorn Creek Res | — | — | | — | — | |
| Waha Lake | | 0 | | | 0 | |
| **Lake Name** | **2N Weight (g)** | **n** | **±CI (g)** | **3N Weight (g)** | **n** | **±CI (g)** |
| Devil Creek Res | | 0 | | 712 | 1 | |
| Horsethief Res | | 0 | | 447 | 2 | 56 |
| Island Park Res | 1512 | 1 | | | 0 | |
| Little Camas Res | — | — | | — | — | |
| Lost Valley Res | 834 | 13 | 96 | 864.48 | 25 | 60 |
| Mann Lake | — | — | | — | — | |
| Oakley Res | — | — | | — | — | |
| Paddock Res | — | — | | — | — | |
| Roseworth Res | — | — | | — | — | |
| Soldier Meadow Res | | 0 | | | 0 | |
| Stone Res | — | — | | — | — | |
| Thorn Creek Res | — | — | | — | — | |
| Waha Lake | | 0 | | | 0 | |
| **Lake Name** | **2N Dressed Wt (g)** | **n** | **±CI (g)** | **3N Dressed Wt (g)** | **n** | **±CI (g)** |
| Devil Creek Res | | 0 | | 596 | 1 | |
| Horsethief Res | | 0 | | 395 | 2 | 65 |
| Island Park Res | 1354 | 1 | | | 0 | |
| Little Camas Res | — | — | | — | — | |
| Lost Valley Res | 727 | 13 | 84 | 759 | 25 | 48 |
| Mann Lake | — | — | | — | — | |
| Oakley Res | — | — | | — | — | |
| Paddock Res | — | — | | — | — | |
| Roseworth Res | — | — | | — | — | |
| Soldier Meadow Res | | 0 | | | 0 | |
| Stone Res | — | — | | — | — | |
| Thorn Creek Res | — | — | | — | — | |
| Waha Lake | | 0 | | | 0 | |

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