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PROJECT 4: HATCHERY TROUT EVALUATIONS

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Senior Fisheries Research Biologist

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ANNUAL PERFORMANCE REPORT

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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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ABSTRACT

Nonnative brook trout 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 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 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 increased significantly following stocking with tiger muskellunge. Mean catch rates of brook trout declined from 22.8 per net night to five per net night following tiger musky introductions. For all lakes combined, the mean brook trout length and weight was 246 ± 6 mm (n = 132) and 161 ± 11 g, compared to 212 ± 3 mm and 88 ± 5 g (n = 519) before tiger muskellunge were introduced. 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 we have a limited understanding of the primary factors driving successful tiger muskellunge predation of brook trout. Introducing predatory fish appears to be an effective means to reduce brook trout in a short period, as it requires only a minimal labor investment. However, 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 could be compromised by recolonization from refuge habitats, necessitating 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 were fishless prior to introduction of salmonids by man. So, 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 to declines of downstream fish populations. High elevation streams contain some of the strongest remaining cutthroat and bull trout 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 most downstream habitats by being able to disperse through 80% slopes and over 18 m waterfalls. Brook trout have the ability to outcompete cutthroat trout *Oncorhynchus clarkii* (De Staso and Rahel 1994) and may eventually eliminate some cutthroat trout populations (Kruse et al. 2000). Additionally, brook trout may hybridize or displace bull trout *Salvelinus confluentus*, thereby reducing or eliminating bull trout 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, there is some interest in shifting the size structure of brook trout populations in high mountain lakes to provide higher proportions of quality fish greater than 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 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. 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: Blue, Lower Twin, Katherine, Sugar Bowl, and Upper Camp. Lake trout established self-sustaining populations in all five lakes. By the early 1980s, no response in brook trout populations was noted in two lakes (Sugar Bowl and Upper Camp) while numbers of brook trout were decreased in Blue and Lower Twin lakes and eliminated or nearly so from Katherine Lake (0 fish sampled in 1983; Nelson 1988). He also noted that brook trout lakes that contained brown trout had lower densities of brook trout and 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 to exert significant predation pressure, and due to high densities of brook trout would not be 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 biologist 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 (Schriever and Murphy, *In Press*). 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 and 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, 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 (Schriever and Murphy, *In Press*).

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 now only contains 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 population had decreased by 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, we describe initial efforts to investigate the effectiveness of introducing tiger muskellunge to reduce or eliminate brook trout populations in alpine lakes in Idaho. We 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. We preferentially selected lakes 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 will prevent recolonization by any downstream brook trout populations. Nine lakes were selected throughout central Idaho (Figure 1) as potential study waters for this evaluation.

Potential 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. 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 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 nine alpine lakes selected for this study. 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 again sampled in 2008, approximately 13 months after tiger musky were planted. 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.

Lake habitat and amphibian surveys were conducted at each of the nine lakes at the time fish were sampled in 2008. 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. Conductivity, pH, and surface temperature were measured at the middle of each transect using Hanna hand held conductivity and temperature/pH meters (Model #HI98308, 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 reaches 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 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.

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 in the year following stocking with tiger muskellunge (Table 2). Overall, catch rates of brook trout in 2008 were much lower than before tiger muskellunge were introduced. 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 five per net night overall. Catch-per-unit-effort at several lakes (Black L., Corral L., 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) for a total of 450 brook trout sampled. Even though sampling effort was lower in 2008 compared to pretreatment surveys (in an effort to avoid sacrificing tiger muskellunge), results suggest that brook trout populations have been severely reduced as a result of tiger muskellunge introduction in 2007.

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 would decrease 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.

On average, the mean size of brook trout in 2008 increased slightly compared to 2005/2006 (pre-tiger muskellunge) based on 95% confidence intervals in most locations (Table 3, Figure 2). For all lakes combined, the 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.

The overall size distribution of brook trout noticeably shifted since the 2005/2006 survey data was collected. Small sample sizes at some lakes likely precluded meaningful comparisons of mean length (Black L., Corral L., Grassy Mountain #1, and Shirts L.). The distribution of brook trout sizes indicates an increase in the proportion of larger sized fish, increasing trophy potential at most lakes (Figure 3). In the pretreatment surveys, about 40% of the brook trout sampled were 200 mm (8") or less, compared to only 5% in 2008. Prior to tiger muskellunge, 18% of brook trout equaled or exceeded 254 mm (10"), and of those, only 4% equaled or exceeded 279 mm (11"). During 2008, however, 40% of brook trout equaled or exceeded 254 mm, and 17% equaled or exceeded 279 mm. These data indicate a marked increase in the proportion of larger brook trout in the sample, despite lower overall abundance.

Potential study lakes included a wide variety of physical habitat characteristics and inlet and outlet morphologies (Table 1). 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. 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. 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.

DISCUSSION

Prior to introducing tiger muskellunge, most lakes sampled during 2005 or 2006 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 sampled in 2008 showed substantial declines in CPUE and increased average size of brook trout in the year following stocking with tiger muskellunge. The results indicate that tiger muskellunge were highly effective predators on brook trout in most study locations. Large average size at the time of stocking (>300 mm) and previous experience with live brook trout (in the hatchery) likely contributed to their success. 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 our study design and the conditions found in these lakes. Mean brook trout length likely increased because of lower density (competition), or because the largest individuals would be most likely to avoid 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 we have a limited understanding of the primary factors driving successful brook trout eradication by tiger muskellunge, at least in the first year 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” probability 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 and angling. Tiger musky in Spruce Gulch were the smallest of those captured in 2008, and no tiger muskellunge were caught in Merriam Lake (and only one small specimen was observed during surveys). 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, Figure 3). Despite the smaller size of tiger muskellunge in Spruce Gulch, 12 were captured while sampling, suggesting moderate survival compared to other lakes. This may hold some promise for eliminating more brook trout in the coming year.

Corral Lake showed the largest reduction in CPUE of BKT of all the lakes planted with tiger muskellunge in 2007. 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. Perhaps summer temperatures are more 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.

Upper Hazard Lake showed only a moderate reduction in brook trout catch rates, and a modest increase in mean brook trout length. Even with abundant complex shoreline habitat (in terms of boulders and woody debris), tiger muskellunge only had a moderate impact to brook trout. This is one of the larger lakes in the study (15.8 ha), with an average depth over 7 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. At this point, our 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 in-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 per hectare of 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 one (Platinum Lake), and remained unchanged in the other (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 and with ours, full eradication was not achieved within one year using tiger muskellunge alone. Our 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, we are only able to 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*), we 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 predatory fish appears to be an effective means to reduce brook trout, 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.

RECOMMENDATIONS

1. Sample treated lakes in 2009 to evaluate changes in brook trout populations and longevity of tiger muskellunge.

2. When using tiger muskellunge to control brook trout in mountain lakes, stocking densities of 40 fish/ha appear adequate. Combine tiger muskellunge stocking with electrofishing or chemical treatments to remove brook trout from inlet and outlet streams to reduce recolonization and improve the probability of successful eradication.

3. Evaluate brook trout and tiger muskellunge densities before restocking lakes with other trout. Do not stock rainbow or cutthroat fry into lakes with established brook trout or tiger muskellunge to avoid poor returns of stocked fish. Higher returns might be achieved by waiting to restock treated lakes until after tiger muskellunge and adult brook trout are absent or in very low densities.

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LITERATURE CITED

Adams, S. B., C. A. Frissell, and B. E. Riemann. 2001. Geography of invasion in mountain streams: consequences of headwater lake fish introductions. Ecosystems 296-307.

Anderson, R. 1973. Application of theory and research to management of warmwater fish populations. Transactions of the American Fisheries Society 102:164-171.

Bahls, P. 1992. The status of fish populations and management of high mountain lakes in the western United States. Northwest Science 66:183-193.

Brecka, B. J., M. L. Hooe, and D. H. Wahl. 1995. Comparison of growth, survival, and body composition of muskellunge and tiger muskellunge fed four commercial diets. The Progressive Fish Culturist 57:37-40.

Brimmer, B., K. Andrews, T. Curet, and A. Brimmer. 2002. Regional fisheries management investigations. Project F-73-R-26, Idaho Department of Fish and Game, Boise, Idaho.

Crossman, E. J., and K. Buss. 1965. Hybridization in the family Esocidae. Journal of the Fisheries Research Board of Canada 22:1261-1292.

De Staso III, J., and F. J. Rahel. 1994. Influence of water temperature on interactions between juvenile Colorado River cutthroat trout and brook trout in a laboratory stream. Transactions of the American Fisheries Society 123:289-297.

Donald, D. B., R. S. Anderson, and D. W. Mayhood. 1980. Correlations between brook trout growth and environmental variables for mountain lakes in Alberta. Transactions of the American Fisheries Society 109:603-610.

Donald, D. B., and D. J. Alger. 1989. Evaluation of exploitation as a mean of improving growth in a stunted population of brook trout. North American Journal of Fisheries Management 9:177-183.

Esselman, B., K. Andrews, T. Curet, and A. Brimmer. 2004. Regional fisheries management investigations. Project F-73-R-28, Idaho Department of Fish and Game, Boise, Idaho.

Fraser, J. M. 1989. Establishment of reproducing populations of brook trout after stocking of interstrain hybrids in Precambrian Shield lakes. North American Journal of Fisheries Management 9:352-363.

Gillen, A. L., R. A. Stein, and R. F. Carline. 1981. Predation by pellet-reared tiger muskellunge on minnows and bluegills in experimental systems. Transactions of the American Fisheries Society 110:197-209.

Hall, D. L. 1991. Age validation and aging methods for stunted brook trout. Transactions of the American Fisheries Society 120:644-649.

Kanda, N., R. F. Leary, and F. W. Allendorf. 2002. Evidence of introgressive hybridization between bull trout and brook trout. Transactions of the American Fisheries Society 131:772-782.

Kitano, S., K. Maekawa, S. Nakano, and K. D. Fausch. 1994. Spawning behavior of bull trout in the upper Flathead drainage, Montana, with special reference to hybridization with brook trout. Transactions of the American Fisheries Society 123:988-992.

Knapp, R. A., and K. R. Matthews. 1998. Eradication of nonnative fish by gill netting from a small mountain lake in California. Restoration Ecology 6:207-213.

Kozfkay, J., and M. K. Koenig. 2006. Hatchery trout evaluations. Job Performance Report, Project F-73-R-28, Idaho Department of Fish and Game. Boise, Idaho.

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

Larscheid, J., J. C. Christianson, T. Gengerke, and W. Jorgensen. 1999. Survival, Growht and abundance os pellet-reared and minnow-reared muskellunge stocked in northwestern Iowa. North American Journal of Fisheries Management. 19:230-237.

Murphy, P. D. 2002. The effects of different species of introduced species of introduced salmonids on amphibians in headwater lakes of North-central Idaho. Master's thesis. Idaho State University, Pocatello, Idaho.

Nelson, W. C. 1988. High lake research and management in Colorado, special report. High Lake Research and Management in Colorado. Fort Collins, Colorado.

Parker, B. R., D. W. Schindler, D. B. Donald, and R. S. Anderson. 2001. The effects of stocking and removal of a nonnative salmonid on the plankton of an alpine lake. Ecosystems: 334-345.

Pilliod, D. S. 2001. Ecology and conservation of high-elevation amphibian populations in historically fishless watersheds with introduced trout. PhD dissertation. Idaho State University, Pocatello, Idaho.

Rabe, F. W. 1970. Brook trout populations in Colorado beaver ponds. Hydrobiologia 35:431-448.

Rhodes, T., J. Erhardt, and J. Dupont. 2007. Mountain lakes monitoring and management in north central Idaho Mountains. 2007 Annual Report. Idaho Department of Fish and Game, Boise, Idaho.

Rhodes, T., and J. Dupont. 2009. Mountain lakes monitoring and management in north central Idaho Mountains. 2008 Annual Report. Idaho Department of Fish and Game, Boise, Idaho.

Schriever, E. B., and P. D. Murphy. *In Press.* Utilization of tiger muskellunge for controlling self-sustaining populations of introduced brook trout in mountain lakes. Regional Fisheries Management Investigations. Idaho Department of Fish and Game. Boise, Idaho.

Siler, D. H., and G. B. Beyerle. 1986. Introduction and management of northern muskellunge in Iron Lake, Michigan. *In* Managing muskies. American Fisheries Society, Special Publication 15, Bethesda, Maryland.

Storck, T W., and D. L. Newman. 1992. Contribution of tiger muskellunge to the sport fishery of a small, centrarchid-dominated impoundment. North American Journal of Fisheries Management 12:213-221.

Szendrey, T.A., and D. H. Wahl. 1996. Size-specific survival and growth of stocked muskellunge: effects of predation and prey availability. North American Journal of Fisheries Management. 16:395-402.

Tipping, J. M. 2001. Movement of tiger muskellunge in Mayfield Reservoir, Wahington. North American Journal of Fisheries Management 21:683-687.

Tomcko, C. M., R. A. Stein, and R. F. Carline. 1984. Predation by tiger muskellunge on bluegill: Effects of predator experience, vegetation, and prey density. Transactions of the American Fisheries Society 113:588-594.

Wahl, D. H. 1999. An ecological context for evaluating the factors influencing muskellunge stocking success. North American Journal of Fisheries Management. 19:238-248.

Wahl, D. H., and R. A. Stein. 1993. Comparative population characteristics of muskellunge (*Esox masquinongy*), northern pike (*E. lucius*), and their hybrid (*E. masquinongy* x *E. lucius*). Canadian Journal of Fisheries and Aquatic Sciences 50:1961-1968.

Walters, C. J., and R. E. Vincent. 1973. Potential productivity of an alpine lake as indicated by removal and reintroduction of fish. Transactions of the American Fisheries Society 102:675-697.

Weithman A. S. and R. O. Anderson. 1977. Survival, growth, and prey of esocidae in experimental systems. Transactions of the American Fisheries Society 106:424-430.

Table 1. Physical description of study waters planted with tiger muskellunge in 2007. Lakes were initially surveyed in 2005 or 2006 prior to introducing tiger muskellunge. Lakes were surveyed again in 2008.

Lake Name	Number planted	Area (ha)	Elevation (m)	Mean depth (m)	Max depth (m)	Mean conductivity (µS/cm)	Mean Temp (C)	Mean pH
Black Lake	420	10.5	2,199	19.7	37.8	31	16.1	7.72
Corral Lake	104	2.6	2,085	4.0	24.0	-	15.9	7
Granite Twin Lakes (Upper)	656	16.1	2,183	7.4	20.4	6.4	13.2	7.72
Grassy Mtn 1	206	5.1	2,263	2.9	6.1	4.8	15.1	6.78
Grassy Mtn 2	225	5.1	2,238	2.6	3.7	5	14.0	6.52
Merriam Lake	107	2.6	2,926	7.5	34.0	20.8	10.0	8.52
Shirts Lake	140	3.5	2,254	7.7	3.0	15.6	13.1	8.3
Spruce Gulch	439	10.9	2,698	4.9	13.0	8.8	15.9	6.84
Upper Hazard Lake	632	15.8	2,264	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
Black Lake	07-00-00-0143	3M	0.0	No	Yes	Yes	Yes	Moderate
Corral Lake	07-00-00-0177	3M	0.9	No	No	No	Yes	Very High
Granite Twin Lakes (Upper)	07-00-00-0193	3M	1.9	No	No	Yes	Yes	High
Grassy Mtn 1	07-00-00-0180	3M	3.0	Yes	No	No	No	Moderate
Grassy Mtn 2	07-00-00-0183	3M	3.0	Yes	Yes	No	No	Moderate
Merriam Lake	07-00-00-1308	7	3.1	No	Yes	Yes	Yes	High
Shirts Lake	09-00-00-0271	3M	1.9	No	No	Yes	Yes	High
Spruce Gulch	07-00-00-1316	7	10.6	No	No	No	Yes	Very High
Upper Hazard Lake	07-00-00-0170	3M	3.1	Yes	Yes	Yes	Yes	Moderate

Table 2. Mean catch-per-unit-effort by gill nets (fish per net night) and angling (fish per hour) sampled from nine mountain lakes before and after tiger muskellunge were introduced in 2007. The total trout caught by each method (n) is shown by lake. Dashed lines indicate where angling was not conducted.

		Before			After		
	Lake Name	**CPUE**	**Gill Net Hours**	**n**	**CPUE**	**Gill Net Hours**	**n**
Gill Nets	Black Lake	13.5	55.5	54	1.0	23.5	2
	Corral	60.0	10.0	60	1.0	31.4	2
	Granite Twin Lakes (upper)	20.0	55.5	80	5.5	31.9	11
	Grassy Mountain #1	28.0	16.5	28	6.0	32.8	12
	Grassy Mountain #2	35.0	17.0	35	0.5	30.9	1
	Merriam Lake	9.3	73.3	37	17.5	24.2	35
	Shirts Lake	14.3	48.0	57	2.0	25.8	4
	Spruce Gulch	15.8	65.5	63	8.0	22.4	16
	Upper Hazard Lake	9.0	81.3	36	4.0	28.3	8
	Mean	22.8	422.5	450	5.1	251.0	91
			Before			After	
	Lake Name	**CPUE**	**Total Angling Hours**	**n**	**CPUE**	**Total Angling Hours**	**n**
Angling	Black Lake	-	0	0	0.05	22	1
	Corral	2.0	2	4	0	5	0
	Granite Twin Lakes (upper)	-	0	0	0.80	5	4
	Grassy Mountain #1	-	0	0	0	2	0
	Grassy Mountain #2	-	0	0	-	0	-
	Merriam Lake	-	0	0	3.33	10.5	35
	Shirts Lake	1.0	65	65	0	6	0
	Spruce Gulch	-	0	0	0	8	0
	Upper Hazard Lake	-	0	0	0.20	5	1
	Mean	1.5	67	69	0.55	63.5	41

Table 3. Mean length (mm), mean weight (g), condition and trophy potential (assessed by the mean of the five longest fish) of brook trout and tiger muskellunge sampled from nine mountain lakes by survey year. Tiger muskellunge were introduced into the listed lakes in 2007. Dashed lines indicate missing values.

Species	Sample Year	Lake Name	Mean length (mm)	n	Mean weight (g)	n	Mean Condition	Longest 5
Brook trout	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 Lakes (upper)	265 (± 13)	15	194 (± 25)	15	1.03	290
		Grassy Mountain #1	283 (± 15)	12	263 (± 34)	12	1.16	303
		Grassy Mountain #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 Lake	246 (± 29)	9	1567 (± 41)	9	1.01	268
		Total	246 (± 6)	132	161 (± 11)	128	1.06	272
Species	**Sample Year**	**Lake Name**	**Mean length (mm)**	**n**	**Mean weight (g)**	**n**	**Mean Condition**	**Longest 5**
Tiger M.	2008	Black Lake	478 (± 31)	26	-	-	-	-
		Corral Lake	572 (± 103)	6	-	-	-	-
		Granite Twin Lakes (upper)	375	1	-	-	-	-
		Grassy Mountain #1	526 (± 114)	2	-	-	-	-
		Grassy Mountain #2	605	1	-	-	-	-
		Merriam Lake	-	-	-	-	-	-
		Shirts Lake	-	-	-	-	-	-
		Spruce Gulch	344 (± 51)	12	-	-	-	-
		Upper Hazard Lake	495	1	-	-	-	-
		Total	460 (± 31)	49	-	-	-	-
Species	**Sample Year**	**Lake Name**	**Mean length (mm)**	**n**	**Mean weight (g)**	**n**	**Mean Condition**	**Longest 5**
Brook trout	2005	Black Lake	203 (± 7)	54	80 (± 7)	54	0.93	244
	2006	Corral Lake	206 (± 12)	64	94 (± 12)	64	1.09	262
	2005	Granite Twin Lakes (upper)	232 (± 12)	80	124 (± 12)	80	0.90	291
	2006	Grassy Mountain #1	209 (± 19)	28	104 (± 24)	28	0.99	278
	2006	Grassy Mountain #2	251 (± 10)	35	161 (± 18)	35	0.98	286
	2005	Merriam Lake	205 (± 14)	37	91 (± 18)	37	0.94	265
	2005	Shirts Lake	196 (± 5)	122	31 (± 7)	122	1.04	231
	2005	Spruce Gulch	207 (± 9)	63	92 (± 11)	63	0.98	260
	2005	Upper Hazard Lake	227 (± 14)	36	113 (± 18)	36	0.90	292
		Total	212 (± 3)	519	88 (± 5)	519	0.97	268

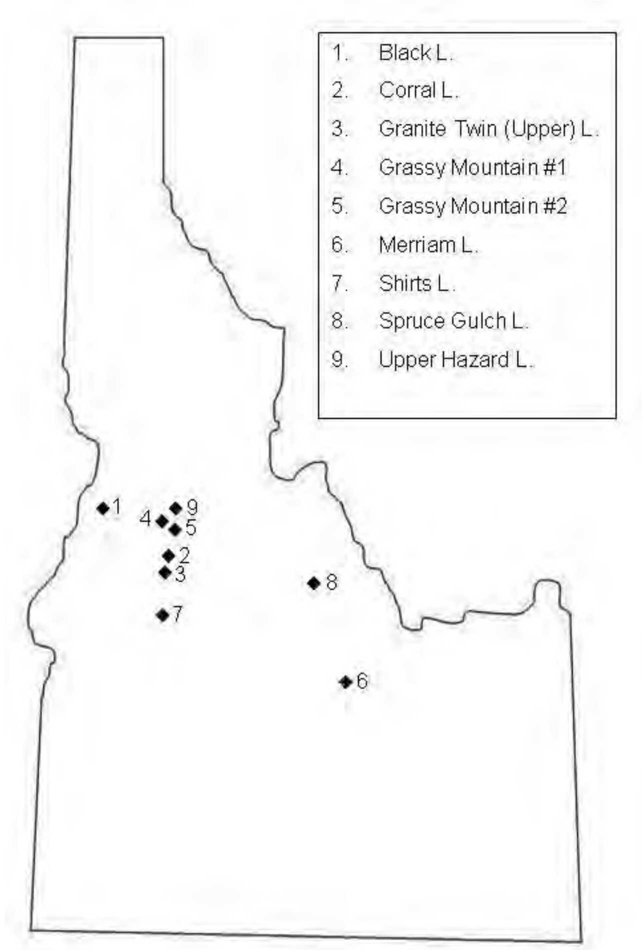

Figure 1. Locations of nine high mountain lakes in Idaho that were chosen for inclusion in a study designed to eliminate brook trout populations by stocking tiger muskellunge. Lakes were initially surveyed in 2005 or 2006 and planted with tiger muskellunge in 2007. Sampling was again conducted in 2008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

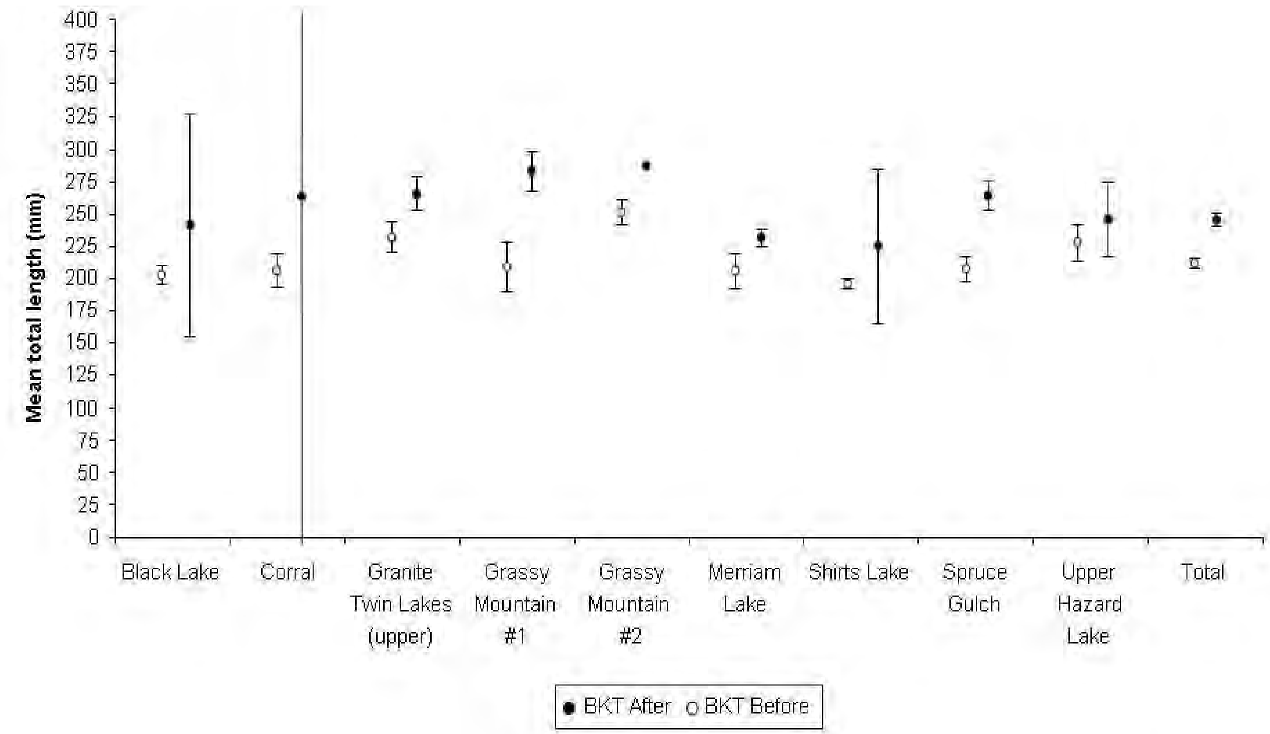

Figure 2. Mean total length of brook trout before and after (2008) tiger muskellunge introduction. Error bars indicated 95% confidence intervals around the mean, where sample sizes allowed. Wide confidence intervals at Corral Lake are a result of low sample size (*n* = 2).

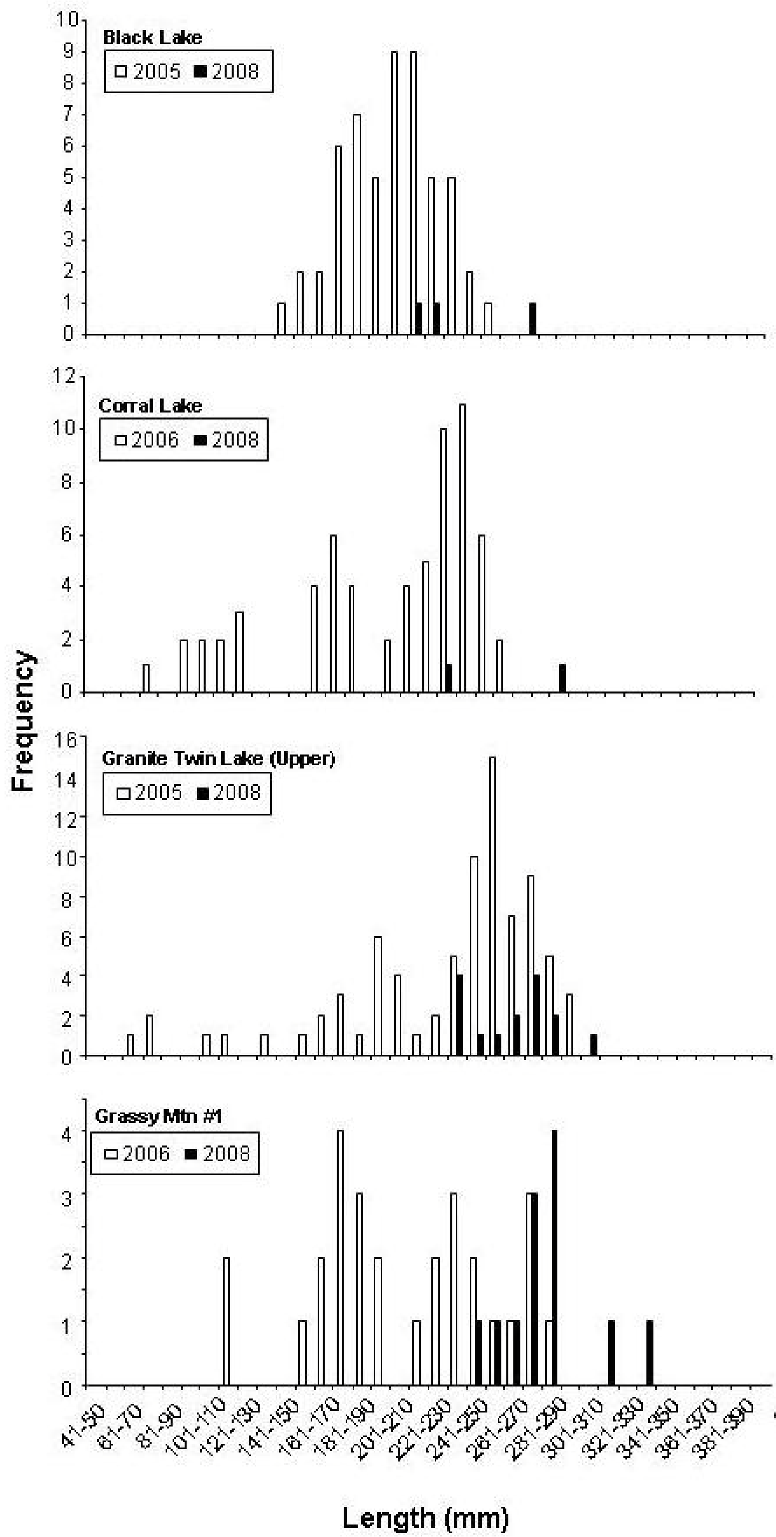

Figure 3. Size distribution (total length, mm) of brook trout captured before (2005 or 2006) and after (2008) introduction of tiger muskellunge. Tiger muskellunge were introduced in 2007.

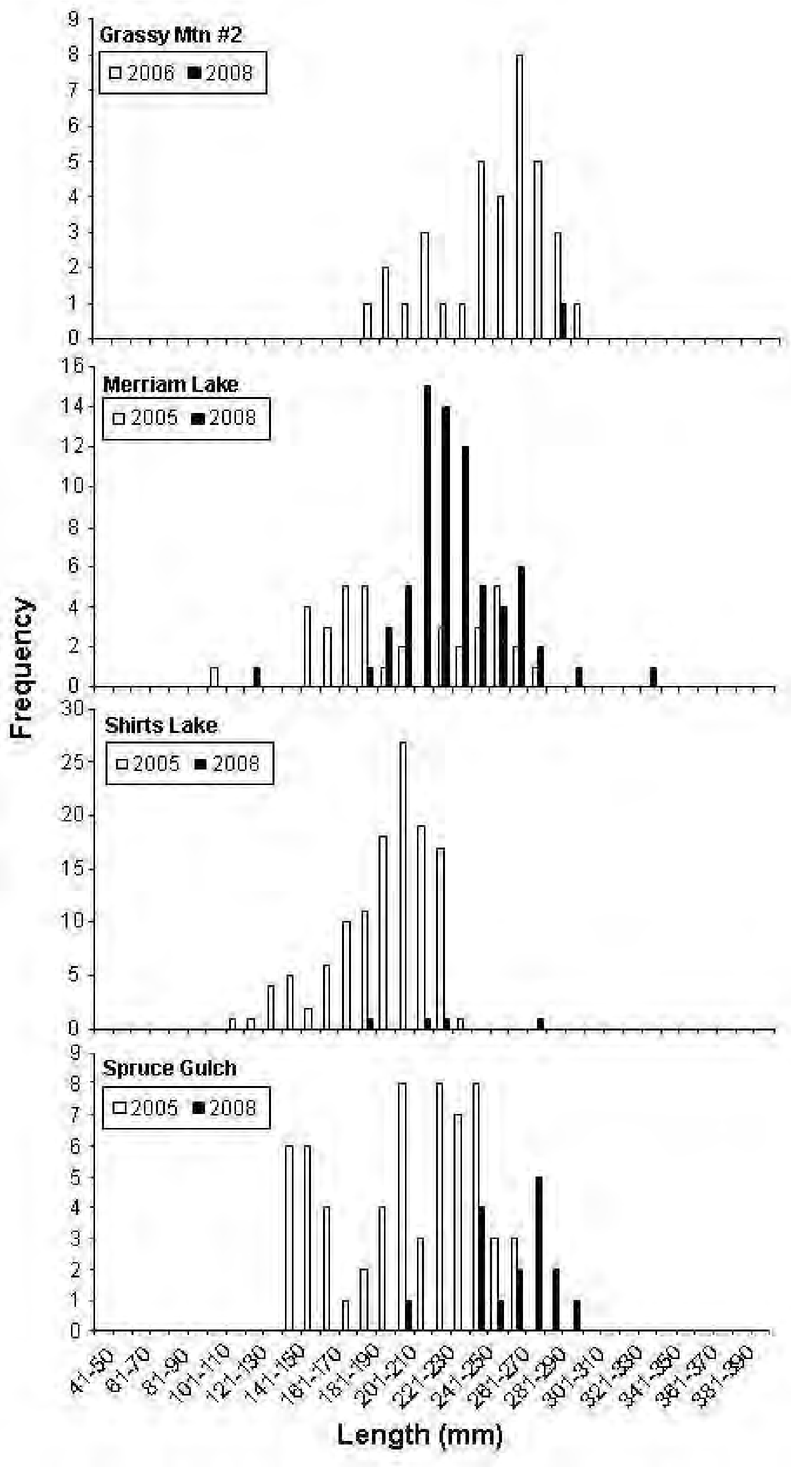

Figure 3. Continued.

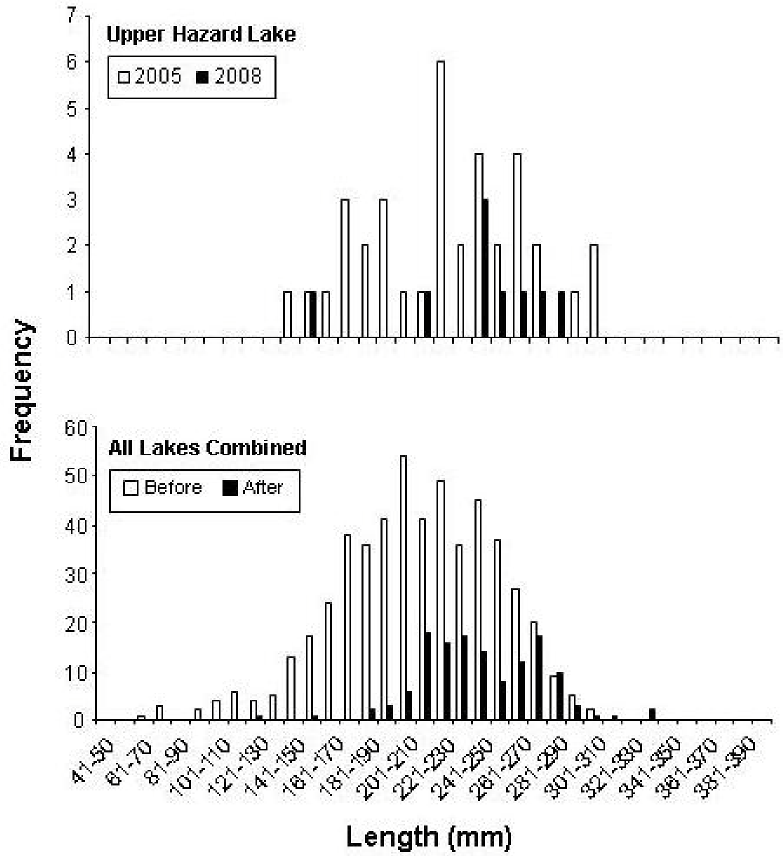

Figure 3. Continued.

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-31 Fishery Research
Project No.:	4	Title:	Hatchery Trout Evaluations
Subproject #2:	Sterile Trout Investigations		
Contract Period:	July 1, 2008 to June 30, 2009		

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. We 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. In fall 2008, a total of 2,270 rainbow trout were captured, including 1,212 recaptured adipose-clip marked rainbow trout. Of the recaptured group, 635 2N and 456 3N rainbow trout were identified, indicating 3N rainbow trout returned to gill nets at 72% of marked 2N rainbow trout, on average. Mean length for 2N and 3N trout were 321 and 317 mm, respectively, showing 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. The number of 2N rainbow trout caught varied across reservoirs, but was significantly higher than the number of 3N rainbow trout caught in nine of 13 reservoirs. Of the marked trout recaptured, 104 did not contain coded wire tags, indicating an overall tag retention rate of approximately 91.3%.

A voluntary creel census yielded 2,242 returned coded wire tags, with 1,215 2N tags and 989 3N tags, suggesting that 3N rainbow trout returned to anglers at 81% of 2N rainbow trout. While the proportion of 2N fish in the creel varied across locations, most reservoirs showed higher returns of 2N rainbow trout to anglers. While diploid rainbow trout may grow and survive better in chronic warm water conditions, triploid rainbow trout will perform well in good conditions while avoiding genetic impacts to wild stocks or establishing self-sustaining populations. As such, 3N catchable rainbow trout remain a valuable management option for put-take fisheries where adequate habitat exists to support trout.

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INTRODUCTION

Triploid salmonids, created by heat or pressure shock, are functionally sterile and may be a useful tool for managing stocked rainbow trout fisheries. However, triploid (3N) salmonids may suffer lower fertilization rates, increased mortality, or reduced growth from egg through initiation of feeding (Solar et al. 1984; Happe et al. 1988; Guo et al. 1990; Oliva-Teles and Kaushik 1990; Galbreath et al. 1994; McCarthy et al. 1996). Despite these early rearing disadvantages, 3N performance appears to improve with age. Several investigators have reported enhanced hatchery performance in terms of growth and food conversion for age-1 and older triploids (Lincoln and Scott 1984; Bye and Lincoln 1986; Boulanger 1991; Habicht et al. 1994; Sheehan et al. 1999). These performance attributes make sterile salmonids an attractive alternative to traditional diploids for providing and managing angling opportunities.

Genetic changes from selective breeding and domestication of hatchery stocks have resulted in hatchery trout being poorly adapted to survive in natural conditions (Johnson et al. 1995). As such, hatchery trout can pose a risk to wild stocks. The genetic conservation of wild salmonid populations is a management priority for the Idaho Department of Fish and Game (IDFG). Since 2001, IDFG has established a policy to stock only pressure-treated (i.e. triploid) rainbow trout in systems where stocked rainbow trout pose a genetic risk to native trout populations (IDFG 2007a). In this respect, sterile 3N trout provide a valuable tool for conservation and fisheries management. Implementation of the above-noted policy has resulted in the widespread stocking of sterile rainbow trout in waters across Idaho (IDFG 2007b).

Because of increasing fishing pressure in freshwater, fish and game agencies have responded by funding hatchery programs to maintain fishing quality, often consuming large portions of annual fisheries budgets (Johnson et al. 1995). In 1983, rainbow trout made up 77.2% of all catchable-sized trout stocked in the US, with 50 million stocked over 500,000 ha of impoundments (Hartzler 1988). Most of the cost and production capacity of IDFG resident hatcheries is associated with producing catchable-sized triploid rainbow trout. In 2006, the IDFG resident fish hatchery program cost about 2.3 million dollars, with catchable rainbow trout (8-12 inches) accounting for approximately one-half of the total cost (IDFG 2007b). In 2007, resident hatcheries made 1,381 trips and planted approximately 2,115,693 catchable-sized rainbow trout in 340 lakes, rivers or streams (IDFG, *unpublished data*). Of these catchable-sized trout, 1,771,616 (84%) were all-female triploid rainbow trout raised from eggs purchased from Troutlodge Inc. (IDFG, *unpublished data*). Despite the high costs associated with planted fish, post-stocking evaluations to assess performance of catchable trout are rare, despite the large number of water bodies and rainbow trout stocked each year (Hartzler 1988). Previous IDFG evaluations of sterile salmonids have focused on put-grow-take (or fingerling) fisheries in reservoirs (see Teuscher et al. 2003 and Koenig and Ellsworth 2008). Little data currently exists to compare the relative performance of catchable triploid rainbow trout to their diploid counterparts in Idaho lakes and reservoirs.

Sterility can help avoid genetic introgression with wild stocks and may provide a fishery benefit 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 triploid salmonids in natural environments are inconsistent relative to diploid fish (Brock et al. 1994; Simon et al. 1993; Parkinson and Tsumura 1988; Warrillow et al. 1997; Koenig and Ellsworth 2008) and may be species- or strain-dependent (Ihssen et al. 1990). Some studies describing relative survival and return-to-creel of triploid rainbow trout have been performed in streams, ponds, and reservoirs (Simon et al. 1993; Dillon et al. 2000; Teuscher et al. 2003). Although these studies provide a framework for evaluating the performance of 3N salmonids in natural environments, the low number of studies available, limited scope, and contradicting results do not fully address performance of triploid salmonids stocked to benefit anglers.

Given the limited research on triploid rainbow trout performance in natural settings and the contradictory results even among Idaho waters, there remains considerable uncertainty as to whether stocking triploid rainbow trout produces satisfactory fisheries in all Idaho waters. More definitive research results would allow fisheries managers to adjust stocking strategies and evaluate the utility of stocking sterile trout in their regions. The objective of this study was to examine growth, relative survival, and return-to-creel of the most common catchable-sized diploid and triploid rainbow trout stocked in lakes and reservoirs across Idaho.

RESEARCH GOAL

1. To enhance hatchery-supported fisheries while reducing genetic risks to indigenous redband trout and cutthroat trout.

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

We chose 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 4). 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 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 Manger.

METHODS

All-female diploid and triploid rainbow trout eggs were obtained from Troutlodge Inc. (Sumner, WA) and reared at Hagerman State 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. 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 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 4). Trout were transported and stocked by truck from Hagerman State Hatchery. At stocking, the mean length of 2N and 3N marked fish was 252 mm, based on the pound counts at the time of stocking (Table 4). 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.

Sample Collection

Rainbow trout were sampled using a combination of floating gill nets and electrofishing, although the total electrofishing effort was relatively minor. 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 sampled during September and October 2008 (Table 4). However, due to low water conditions, some locations were sampled earlier. Paddock Valley suffered from early drawdown and was sampled in July. Little Camas Reservoir and Thorn Creek Reservoir were also drawn low and were sampled from August 19-21, 2008. 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.

A voluntary creel census was used to collect additional coded wire tags from fish that were caught by anglers. 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 were posted nearby describing the goals of the research program. They invited anglers to participate in the study by depositing snouts of adipose-clipped rainbow trout that they planned on harvesting. 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). Confidence intervals (95%) for mean length and weight were calculated as $\bar{X} \pm t_{\alpha(2),n-1} \bullet SE$ and values from the *t*-distribution with *n*-1 degrees of freedom. Absolute growth (equation 1) was calculated for each fish as the change in length (mm) from the time at stocking, divided by the elapsed time until recapture (days) (Isely and Grabowski 2007). Absolute growth was then averaged across all fish for each group by lake/reservoir. Confidence intervals around mean absolute growth for each group were calculated using α = 0.05 with *n* -1 degrees of freedom according to equation (2).

$$G_{absolute} = \frac{L_2 - L_1}{t_2 - t_1} \tag{1}$$

$$CI = \overline{G_{absolute}} \pm t \bullet (SD / \sqrt{n}) \tag{2}$$

Relative weight (Wr) was calculated as a measure of condition for each marked trout (equation 3) within each lake, using individual fish weights (W) and a length-specific standard weight (Ws) (Pope and Kruse 2007). I used the coefficients for the standard weight equation (equation 4) proposed by Blackwell et al. (2000) for lentic rainbow trout. Mean relative weight (W_r) was calculated for each test group by lake. Confidence intervals around mean relative weight for each group were calculated using α = 0.05 with *n* -1 degrees of freedom according to equation (5) (Pope and Kruse 2007).

$$W_r = (W / W_s) \bullet 100 \quad (3)$$

$$\log_{10}(Ws) = a + b(\log_{10} L) \quad (4)$$

$$CI = \overline{W_r} \pm t \bullet (SD / \sqrt{n}) \quad (5)$$

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 (Figure 5).

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%) (Table 5).

The total marked rainbow trout captured varied across reservoirs, but was highest at Horsethief and Lost Valley reservoirs (Table 5). Mann Lake, Oakley Reservoir, and Paddock Reservoir all had very low numbers of recaptured rainbow trout. According to the tag codes, 635 total 2N and 456 total 3N marked rainbow trout were sampled (Table 5), indicating that 3N rainbow trout returned to gill net at 72% of marked 2N rainbow trout, on average. Overall, 2N rainbow trout were caught in higher numbers in nine of 13 reservoirs. Triploid rainbows were caught in higher numbers in Horsethief and Devil Creek Reservoirs, and were caught in equal numbers at Mann Lake and Oakley Reservoir (Table 5). The overall 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. Diploid trout made up 58 ± 3% of the total marked trout caught, while 3N trout made up only 42 ± 3%. The proportion of 2N rainbow trout caught varied across reservoirs, but was significantly higher than the proportion of 3N rainbow trout caught in seven of 13 reservoirs based on 95% confidence intervals (Table 5, Figure 6).

The voluntary creel census (snout collection boxes) yielded 2,533 snouts, with snouts having been collected from all reservoirs (Table 6). 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 (Figure 10), with the most having been recovered from Horsethief Reservoir (907). 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 at 81% of 2N rainbow trout, on average. While the proportion of 2N tags varied across locations, most reservoirs showed higher returns of 2N tags (Table 6), 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 (Figure 10).

On average, 2N and 3N rainbow trout were of similar length (321 ± 2.6 and 317 ± 2.8 mm, respectively) based on 95% confidence intervals, but 2N trout were heavier than recaptured 3N rainbow trout in both weight and dressed weight (Figure 7). Mean length, weight and dressed weight of test fish varied across reservoirs, with Oakley and Island Park reservoirs having returned the longest fish (Table 6).

Mean absolute growth rates (mm/day) were variable across reservoirs, but similar between 2N and 3N test fish. Overall, 2N rainbow had a mean absolute growth rate (with 95% CI) of 0.53 ± 0.023 (n = 635), while 3N grew at 0.52 ± 0.026 (n = 455). The highest growth rates were observed in Island Park Reservoir (0.87 mm/day), while Mann Lake, Soldier Meadow, and Stone reservoirs showed poor growth (Table 7, Figure 8). Mean relative weight of marked rainbow trout varied across reservoirs (Table 8, Table 9). On average, the relative weight of 2N rainbow trout (86.4 ± 1.1, n = 635) was slightly higher than that of 3N rainbow (82.8 ± 1.3, n = 455). Although overall means differed between 2N and 3N trout, differences in relative weight (based on confidence intervals) were not always significant within all reservoirs (Table 8, Figure 9).

DISCUSSION

Coded wire tags combined with adipose fin clips proved highly successful for tagging rainbow trout for this evaluation. Coded wire tags have been used since the 1960s for fisheries evaluations because of several major advantages. Large numbers of small fish can be tagged with unique marks, with minimal size effects and high tag retention rates (Guy et al. 1996). While mainly used in anadromous salmonid evaluations, CWTs have been successfully used to research rainbow trout (Munro et al. 2003) and lake trout (Elrod and Schneider 1986). Coded wire tags allow small trout (<80 mm) to be marked with little long-term impact on survival or growth after release (Elrod and Schneider 1986; Munro et al. 2003). Based on adipose fin clips, the tag retention of stocked test fish (91.3%) for this evaluation was similar to values reported in other studies (Elrod and Schneider 1986; Hale and Gray 1998; Munro et al. 2003; Vander Haegen et al. 2005). Munro et al. (2003) reported mean CWT retention of 90% for rainbow trout recaptured from five months to three years at large. Elrod and Schneider (1986) combined adipose fin clips with CWT to mark large numbers of juvenile lake trout. Tags were lost in the hatchery at 3%-11%, but only 3.2%-6.3% after fish were stocked. Future hatchery stocking evaluations should consider using coded wire tags as an integral part of the study design.

The voluntary creel census (snout boxes) proved to be highly effective, yielding 2,533 total snouts, of which 2,242 contained tags. This highly cost-effective collection method yielded more than double the number of tags that gill netting produced. The snout boxes were constructed of inexpensive materials and were serviced mainly by volunteers and reservists, lowering the operational cost associated with collecting data. Using snout boxes as a passive means to collect samples also allowed for more samples to be collected throughout the fishing season with very little effort. Additionally, this also allowed snouts to be collected at several different locations at each reservoir, as well as across multiple reservoirs simultaneously throughout the season. The 89% tag retention rate for the returned snouts is close to the overall 91.3% tag retention rate from the gill net samples, suggesting anglers are good at identifying adipose clipped trout, and that few untagged fish were deposited in the snout boxes.

Of the total rainbow trout captured while sampling (2,270) in 2008, about 53% were marked with adipose fin clips. In addition to adipose-clipped catchables, additional unmarked hatchery rainbow trout were planted at several study locations to meet management goals. No other adipose marking programs occurred at our study locations, suggesting hatchery-origin fish make up the majority of rainbow trout present in these lakes and reservoirs. Given the large proportion of marked rainbow trout captured, the data suggest few wild rainbow trout are present, and that carryover from previous stocking events is probably low.

On average, triploid rainbow trout did not grow or survive as well as 2N rainbow trout over the period of this evaluation (one fishing season). Disparities in returns from 2N and 3N rainbow trout varied across reservoirs, but 2N trout provided higher returns in most locations (Table 5, Table 6). Triploid rainbow trout were caught at 72% and 81% of 2N rainbow trout to gill nets and angling, respectively. Relative proportions of 2N and 3N rainbow trout collected were similar between the voluntary creel census and active sampling with gill nets (Table 5, Table 6). These data suggest similar susceptibility to angling of 2N and 3N rainbow trout used in this study. Therefore, the disparities in returns are more likely a result of lower 3N survival than from differential harvest rates. Gill net surveys only provided a snapshot sample in the fall, while the voluntary creel census 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 seem to appear early in the fishing season (Figure 11). Simon et al. (1993) reported similar finding, with lower survival of 3N rainbow trout rainbow trout shortly after planting.

While triploid 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. Habitat conditions varied across the study reservoirs and likely affected survival and returns of the marked trout. Many of the study sites are irrigation reservoirs that are subject to drawdowns, often to very low levels. The disparity in catch between 2N and 3N rainbows was usually greatest in reservoirs that experienced low water conditions by the time sampling occurred (Figure 6). Little Camas, Paddock, Roseworth, Stone, and Thorn Creek reservoirs were drawn down by the 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) are commonly implicated in the poor survival and returns of stocked trout, especially 3N rainbow trout (Simon et al. 1993; Wiley et al. 1993; Ojolick et al. 1995; Dillon and Alexander 1996). Previous research has shown triploid rainbow trout have higher mortality than diploid 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 diploids during the same period. These authors speculated that lowered hemoglobin-oxygen loading ratios in triploid 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. This proposed mechanism may explain increased mortality and reduced growth rates of triploid rainbow trout during stressful environmental periods. Triploids had higher mortality rates occurring earlier in the study, with 50% cumulative mortality occurring 20 days earlier than for diploids. Earlier mortality or 3N trout could reduce return-to-creel by reducing the time that trout are available for anglers. Simon et al. (1993) reported similar results in three South Dakota ponds, where catch data indicated lower survival of triploid rainbow trout compared to their 2N counterparts. The authors found triploid rainbow trout had lower weight, length, and relative weight than 2N rainbow trout at 45 months of age. Their data indicated lower survival rates probably began shortly after stocking, suggesting that triploid rainbows may be a poor choice for even short-term fishing opportunities.

Although not formally evaluated here, performance differences in 2N and 3N rainbow trout appeared to be less pronounced at sites with higher pool elevations and trout-dominated fish communities (Table 5, Table 6). Fish communities of Horsethief, Lost Valley, and Devils Creek reservoirs consist almost exclusively of trout. Sites that contained higher species diversity appeared to have greater disparity in returns of 2N and 3N trout. Island Park, Stone, and Paddock reservoirs have a higher diversity of species including Utah chub *Gila atraria*, largescale sucker *Catostomus macrocheilus*, Utah sucker *Catostomus ardens,* black crappie *Pomoxis nigromaculatus*, largemouth bass *Micropterus salmoides,* smallmouth bass *Micropterus dolomieui*, common carp *Cyprinus carpio*, and yellow perch *Perca flavescens*. Other authors have made similar observations in other stocking evaluations. Wiley et al. 1993 noted similar observations after evaluating trout stocking programs in Wyoming. They found low survival of stocked trout was common in 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) found higher returns and improved growth of planted rainbow trout in reservoirs with few competing species and when water levels remained high. Higher reservoir levels and simple fish assemblages probably combine to maximize survival of stocked trout by increasing and prolonging available trout habitat and reducing competition for available food sources.

Several authors have reported growth advantages of triploid salmonids over their diploid counterparts. In our study, 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 and dressed weight (Figure 7). This was also apparent in the fact that growth rates were mostly similar (a metric based on length), but diploids had significantly higher relative weight in seven of the 13 reservoirs (Figure 9). Similarly, Ojolick et al. (1995) found growth patterns of diploid rainbow trout had higher girth, while triploid rainbow trout tended to grow longer and leaner with lower condition factor. Teuscher et al. (2003) reported similar findings in Daniels and Treasureton reservoirs, where 3N rainbow trout did not show any growth advantages over 2N rainbow at two or three years of age. We might anticipate 3N rainbow dressed weights to be greater as the 2N group approaches sexual maturity over time. However, in put-take fisheries with little winter carryover, any long-term growth advantages of 3N rainbow trout may be of little benefit to the anglers.

Teuscher et al. (2003) argued that the benefits of stocking sterile fingerling trout, such as larger sizes and increased longevity, do not begin until the species reaches the normal age of sexual maturity. However, my 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 limited. In fact, most catchable trout are caught as quickly as 7-10 days after stocking (Butler and Borgeson 1965), while up to 83% are harvested in the first year (Wiley et al. 1993). On average, triploid rainbow trout did not grow or survive as well as 2N rainbow trout over the period of this evaluation (one fishing season). High exploitation rates (although rarely achieved) combined with lower survival (and return to creel) during the fishing season could reduce benefits to anglers of any long-term growth advantages of 3N rainbow trout. Sampling in 2009 will determine differences in growth or survival that might develop in the second year after stocking. However, in lakes with good conditions, 3N rainbow trout will perform well while preventing genetic impacts to wild stocks or establishing self-sustaining populations. Stocking strategies for catchable trout are highly site-specific, where successful stocking criteria change from one location to another (Hartzler 1988). Fisheries managers must decide whether benefits of triploid catchable rainbow trout outweigh the potential for reduced survival and return-to-creel on an individual lake basis.

RECOMMENDATIONS

1. Evaluate current stocking strategies using triploid catchable rainbow trout in lakes and reservoirs. Consider stocking diploid catchables in reservoirs where impacts to native salmonids are unlikely.

2. Evaluate the present hatchery system to determine if rearing triploid and diploid catchable rainbow trout would be feasible. Triploid catchable rainbow trout would be necessary in some locations, and would have to be reared separately from diploid trout in the same hatcheries.

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LITERATURE CITED

Blackwell, B. G., M. L. Brown, and D. W. Willis. 2000. Relative weight (Wr) Status and current use in fisheries assessment and management. Reviews in Fisheries Science 8:1-44.

Blanc, J.M., H. Poisson, and F. Vallee. 1992. Survival, growth and sexual maturation of the triploid hybrid between rainbow trout and arctic char. Aquatic Living Resources 5:14-21.

Boulanger, Y. 1991. Performance comparison of all female diploid and triploid brook trout. Canadian Technical Report in Fisheries and Aquatic Sciences 1789:111-121.

Brock, I. V., P. A. Hansen, D. N. McBride, and A. C. Havens. 1994. Culture and performance of triploid rainbow trout in Alaska. Transactions of the North American Wildlife and Natural Resource Conference 59:263-273.

Butler, R. L., and D. P. Borgeson. 1965. California “catchable” trout fisheries. California Department of Fish and Game, Fish Bulletin 127.

Bye, I. V., and R. F. Lincoln. 1986. Commercial methods for the control of sexual maturation in rainbow trout *Salmo gairdneri* Richardson. Aquaculture. 57:299-309/

Dillon, J. C., and C. B. Alexander. 1996. Hatchery trout evaluations. Job Performance Report, Project F-73-R-18, Idaho Department of Fish and Game. Boise, Idaho

Dillon, J. C., D. J. Schill, and D. M. Teuscher. 2000. Relative return to creel of triploid and diploid rainbow trout stocked in eighteen Idaho streams. North American Journal of Fisheries Management 20:1-9.

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

Fleiss, J. L., B. Levin, and M.C. Paik. 2003. Statistical methods for rates and proportions, 3rd edition. A John Wiley and Sons, Inc., Hoboken, New Jersey.

Galbreath, P. F., W. St. Jean, V. Anderson, and G. H. Thorgaard. 1994. Freshwater performance of all-female diploid and triploid Atlantic salmon. Aquaculture 128:41-49.

Guo, X., W. K. Hershberger, and J. M. Meyers. 1990. Growth and survival of intrastrain and interstrain rainbow trout Oncorhynchus mykiss triploids. Journal of the World Aquaculture Society. 21:250-256.

Guy, C.S., H. L. Blankenship, and L. A. Nielsen. 1996. Tagging and marking. Pages 353-383 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd Edition. American Fisheries Society, Bethesda, Maryland.

Habicht, C., J. E. Seeb, R. B. Gates, I. R. Brock, and C. A. Olito. 1994. Triploid coho salmon outperform diploid and triploid hybrids between coho salmon and Chinook salmon during their first year. Canadian Journal of Fisheries and Aquatic Sciences 51:31-37.

Hale. R. S., and J. H. Gray. 1998. Retention and detectioin of coded wire tags and elastomer tags in trout. North American Journal of Fisheries Management 18:197-201.

Happe, A., E. Quillet, and B. Chevassus. 1988. Early life history of triploid rainbow trout *Salmo gairdneri* Richardson. Aquaculture 71:107-118.

Hartzler, J. R. 1988. Catchable trout fisheries: the need for assessment. Fisheries 13:2.

IDFG (Idaho Department of Fish and Game). 2007a. Fisheries Management Plan 2007-20012. Idaho Department of Fish and Game. Boise.

IDFG (Idaho Department of Fish and Game). 2007b. Resident fish hatcheries 2006 annual report. Idaho Department of Fish and Game, Annual Report 07-04, Boise.

Ihssen, P. E., L. R. McKay, I. McMillan, and R. B. Phillips. 1990. Ploidy manipulation and gynogenesis in fishes: cytogenetic and fisheries applications. Transactions of the American Fisheries Society 119:698-717.

Isely J. J., and T. B. Grabowski. 2007. Age and growth. Pages 187-228 *in* C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Johnson, D. M., R. J. Behnke, D. A. Harpman, and R. G. Walsh. 1995. Economic benefits and costs of stocking catchable rainbow trout: a synthesis of economic analysis in Colorado. North American Journal of Fisheries Management 15:26-32.

Johnston, N. T., E. A. Parkinson, and K. Tsumura. 1993. Longevity and growth of hormone-sterilized kokanee. North American Journal of Fisheries Management 13:284-290.

Koenig, M., and K. Ellsworth. 2008. Hatchery trout evaluations. Job Performance Report, Project F-73-R-30, Idaho Department of Fish and Game. Boise, Idaho

Lincoln, R. F., and A. P. Scott. 1984. Sexual maturation in triploid rainbow trout *Salmo gairdneri* Richardson. Journal of Fish Biology 25:385-392.

McCarthy, I. D., C. G. Carter, D. F. Houlihan, R. Johnstone, and A. I. Mitchell. 1996. The performance of all-female diploid and triploid Atlantic salmon smolts on transfer together to sea water. Journal of Fish Biology. 48:545-548.

Munro, A. R., T. E. McMahon, S.A. Leathe, and G. Liknes. 2003. Evaluation of batch marking small rainbow trout with coded wire tags. North American Journal of Fisheries Management 26:600-604.

Myers, J.M., and W.K. Hershberger. 1991. Early growth and survival of heat shocked and tetraploid-deprived triploid rainbow trout (*Oncorhynchus mykiss*). Aquaculture 96:97-107.

Ojolick, E. J., R. Cusack, T. J. Benfey, and S. R. Kerr. 1995. Survival and growth of all-female diploid and triploid rainbow trout reared at chronic high temperature. Aquaculture 131:177-187.

Oliva-Teles, A., and S. J. Kaushik. 1990. Growth and nutrient utilization by 0+ and 1+ triploid rainbow trout, *Oncorhynchus mykiss*. Journal of Fish Biology. 37:125-133.

Parkinson, E. A., and K. Tsumura. 1988. Growth and survival of hormone-sterilized coho *Oncorhynchus kisutch* and kokanee salmon *O. nerka* in a lacustrine environment. Canadian Journal of Fisheries and Aquatic Sciences 45:1490-1494.

Pope, K. L., and C. G. Kruse. 2007. Condition. Pages 423-471 *in* Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Sheehan, R. J., S. P. Shasteen, A. V. Suresh, A. R. Kapuscinski, and J. E. Seeb. 1999. Better growth in all-female diploid and triploid rainbow trout. Transactions of the American Fisheries Society 128:491-498.

Simon, D. C., C. G. Scalet, and J. C. Dillon. 1993. Field performance of triploid and diploid rainbow trout in South Dakota ponds. North American Journal of Fisheries Management 13:134-140.

Solar, I. I., E. M. Donaldson, and G. A. Hunter. 1984. Induction of triploid and diploid rainbow trout in South Dakota ponds. North American Journal of Fisheries Management 13:134-140.

Teuscher, D. M., D. J. Schill, D. J. Megargle, and J. C. Dillon. 2003. Relative survival and growth of triploid and diploid rainbow trout in two Idaho reservoirs. North American Journal of Fisheries Management 23:983-988.

Thorgaard, G. H. 1986. Ploidy manipulation and performance. Aquaculture 57:57-64.

Vander Haegen, G. E., H. L. Blankenship, A. Hoffman, and D. A. Thompson. 2005. The effects of adipose fin clipping and coded wire tagging on the survival and growth of spring Chinook salmon. North American Journal of Fisheries Management 25:1161-1170.

Warrillow, J. A., D. C. Josephson, W. D. Youngs, and C. C. Krueger. 1997. Differences in sexual maturity and fall emigration between diploid and triploid brook trout *Salvelinus fontinalis* in an Adirondack lake. Canadian Journal of Fisheries and Aquatic Sciences 54:1808-1812.

Wiley, R. W., R. A. Whaley, J. B. Satake, and M. Fowden. 1993. Assessment of stocking hatchery trout: a Wyoming perspective. North American Journal of Fisheries Management 12:160-170.

Table 4. 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**	**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**	**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 5. Counts of total rainbow trout and coded wire tags recaptured from rainbow trout stocked in spring 2008 and recaptured in fall 2008 using gill nets and electrofishing, by reservoir. Tag codes indicate whether marked rainbow were diploid (2N) or triploid (3N).

Lake Name	**Total RBT**	**Total ad-clips**	**Total w/ tags**	**Percent tagged**	**No sample**	**Lost in lab**	**2N**	**3N**	**% 2N**	**% 3N**
Devil Creek Res	189	84	71	85%	2		33	36	48%	52%
Horsethief Res	263	239	218	91%		1	98	118	45%	55%
Island Park Reservoir	203	82	77	94%		2	46	30	61%	39%
Little Camas Res	262	143	132	92%		1	85	46	65%	35%
Lost Valley Res	264	264	245	93%	2	5	144	94	61%	39%
Mann Lake	39	14	12	86%			6	6	50%	50%
Oakley Res	60	18	11	61%		1	5	5	50%	50%
Paddock Res	11	11	11	100%			10	1	91%	9%
Roseworth Res	336	20	18	90%			16	2	89%	11%
Soldier Meadow Res	369	73	67	92%			35	33	51%	49%
Stone Res	106	105	99	94%		2	70	27	72%	28%
Thorn Creek Res	53	53	50	94%			30	20	60%	40%
Waha Lake	115	106	97	92%		2	57	38	60%	40%
Grand Total	*2270*	*1212*	*1108*	*91%*	*4*	*13*	*635*	*456*	*58%*	*42%*

Table 6. Counts of total snouts and coded wire tags returned by voluntary creel census using “snout collection boxes” during the 2008 fishing season by reservoir. Tag codes indicated whether marked rainbow were diploid (2N) or triploid (3N).

Lake Name	**Total Snouts**	**Percent Tagged**	**Total w/ Tags**	**Lost in Lab**	**2N**	**3N**	**% 2N**	**% 3N**
Devil Creek Res	111	80%	89	3	47	39	55%	45%
Horsethief Res	972	93%	907	11	442	454	49%	51%
Island Park Res	102	82%	84	0	56	28	67%	33%
Little Camas Res	97	93%	90	0	46	44	51%	49%
Lost Valley Res	140	99%	138	2	66	70	49%	51%
Mann Lake	152	76%	115	3	57	55	51%	49%
Oakley Res	136	68%	93	2	65	26	71%	29%
Paddock Res	9	100%	9	0	5	4	56%	44%
Roseworth Res	142	89%	126	0	82	44	65%	35%
Soldier Meadow Res	106	95%	101	7	59	35	63%	37%
Stone Res	157	78%	122	0	81	41	66%	34%
Thorn Creek Res	233	86%	200	0	111	89	56%	45%
Waha Lake	176	95%	168	10	98	60	62%	38%
Grand Total	*2533*	*89%*	*2242*	*38*	*1215*	*989*	*55%*	*45%*

Table 7. Mean total length (mm), weight (g), dressed weight (g), associated sample sizes and associated 95% confidence intervals (CI) of diploid (2N) and triploid (3N) marked rainbow trout stocked in spring 2008 and recaptured in fall 2008.

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

Table 8. Mean absolute growth G_{abs}(mm/day) by location for diploid (2N) and triploid (3N) marked rainbow trout stocked in spring 2008 and recaptured in fall 2008, by reservoir.

			2N			3N		
Lake Name	**Stock date**	**Sample date**	**Mean G_{abs}**	**n**	**SD**	**Mean G_{abs}**	**n**	**SD**
Devil Creek Res	4/1/2008	9/24/08	0.570	33	0.116	0.49	36	0.099
Horsethief Res	4/7/2008	9/8/08	0.485	98	0.158	0.45	118	0.198
Island Park Res	4/8/2008	9/25/08	0.871	46	0.168	0.86	30	0.186
Little Camas Res	4/28/2008	8/19/08	0.791	85	0.128	0.71	45	0.166
Lost Valley Res	4/29/2008	9/9/08	0.833	144	0.154	0.75	94	0.142
Mann Lake	4/30/2008	10/6/08	0.071	6	0.257	0.22	6	0.063
Oakley Res	5/1/2008	10/16/08	0.829	5	0.093	0.78	5	0.081
Paddock Res	5/14 - 6/4/08	7/7/08	0.699	10	0.114	0.80	1	0
Roseworth Res	5/16/2008	10/14/08	0.505	16	0.089	0.44	2	0.037
Soldier Meadow	5/20/2008	10/8/08	0.149	35	0.128	0.15	33	0.192
Stone Res	5/20/2008	10/1/08	0.194	70	0.146	0.24	27	0.094
Thorn Creek Res	5/29/2008	8/21/08	0.645	30	0.168	0.75	20	0.168
Waha Lake	6/2 - 6/3/08	10/7/08	0.215	57	0.149	0.18	38	0.157

Table 9. Mean relative weight (W_r) by location for diploid (2N) and triploid (3N) marked rainbow trout stocked in spring 2008 and recaptured in fall 2008, by reservoir.

			2N			3N		
Lake name	**Stock date**	**Sample date**	**Mean W_r**	**n**	**SD**	**Mean W_r**	**n**	**SD**
Devil Creek Res	4/1/2008	9/24/08	90.5	33	6.46	88.3	36	5.24
Horsethief Res	4/7/2008	9/8/08	89.3	98	6.49	84.7	118	17.36
Island Park Res	4/8/2008	9/25/08	92.2	46	6.96	88.5	30	6.32
Little Camas Res	4/28/2008	8/19/08	88.2	85	6.50	83.3	46	9.88
Lost Valley Res	4/29/2008	9/9/08	96.3	144	6.43	91.9	94	6.41
Mann Lake	4/30/2008	10/6/08	97.8	6	79.75	61.5	6	8.89
Oakley Res	5/1/2008	10/16/08	91.2	5	7.01	86.9	5	5.99
Paddock Res	5/14 - 6/4/08	7/7/08	83.9	10	2.31	76.6	1	0.00
Roseworth Res	5/16/2008	10/14/08	76.5	16	5.42	71.5	2	1.52
Soldier Meadow	5/20/2008	10/8/08	71.9	35	4.35	70.0	33	5.19
Stone Res	5/20/2008	10/1/08	69.9	70	18.78	63.5	27	10.45
Thorn Creek Res	5/29/2008	8/21/08	95.1	30	7.10	88.5	20	4.96
Waha Lake	6/2 - 6/3/08	10/7/08	73.1	57	4.46	69.3	38	5.36

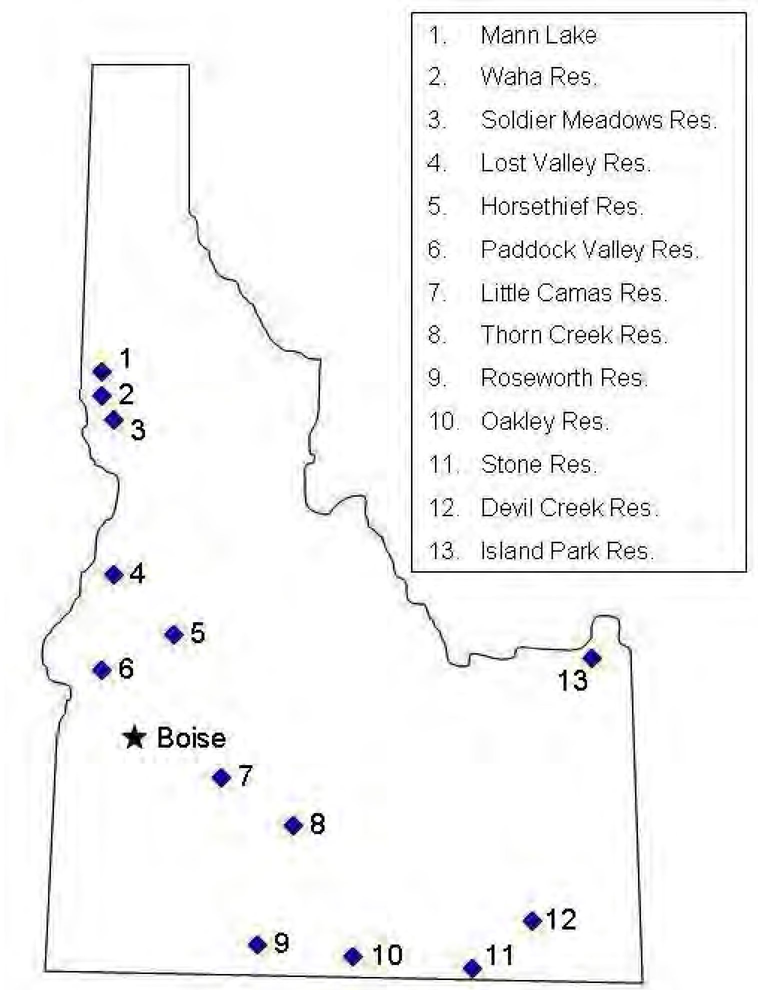


Figure 4. Lakes and reservoirs stocked with marked diploid and triploid catchable rainbow trout in 2008.

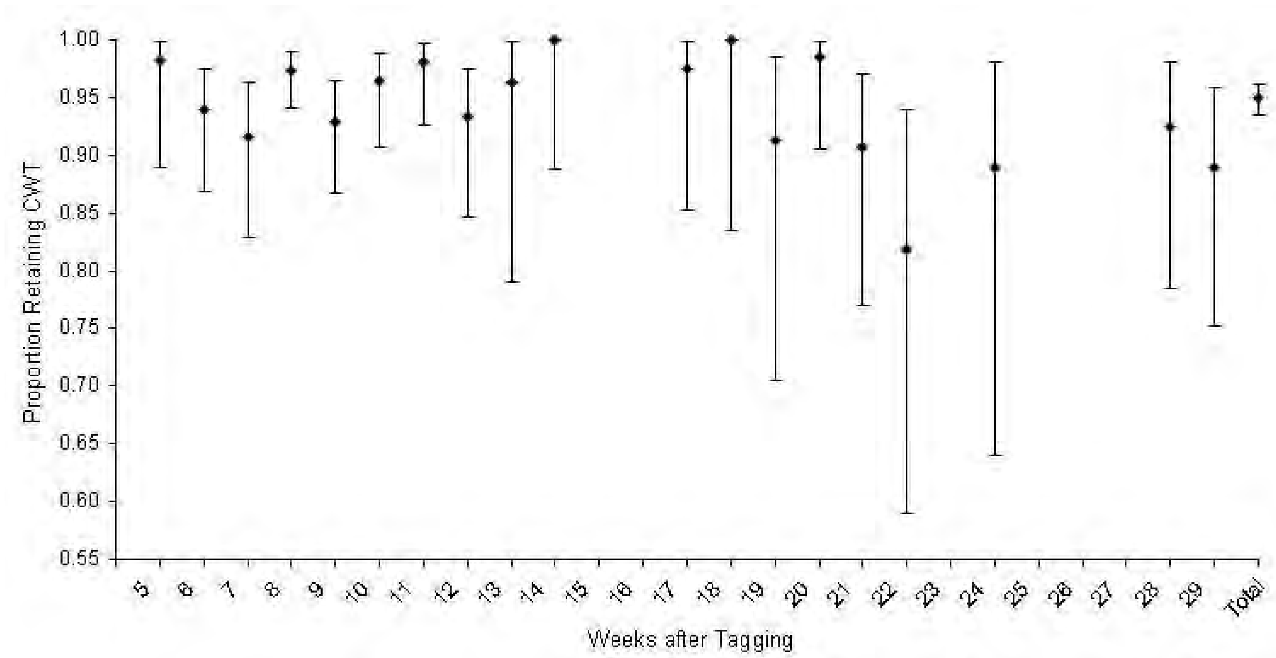


Figure 5. Proportion of marked trout within Hagerman State Hatchery retaining coded wire tags by week after tagging. Data based on examination of incidental mortalities. Error bars indicate 95% confidence intervals for proportions (Fleiss et al. 2003). "Total" indicates the proportion containing coded wire tags across all weeks combined.

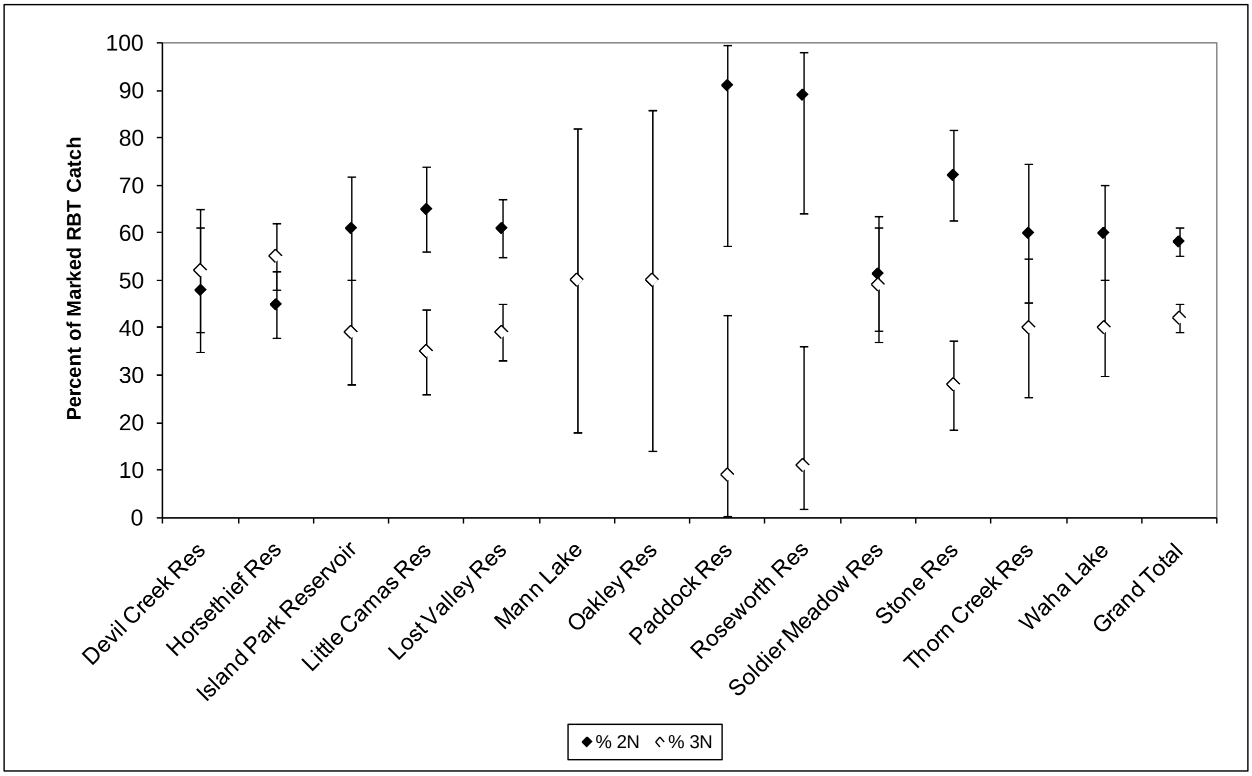


Figure 6. Percent of diploid (2N) and triploid (3N) rainbow trout of the total catch of marked rainbow trout sampled in fall 2008 by reservoir. Error bars represent 95% confidence intervals (Fleiss et al. 2003).

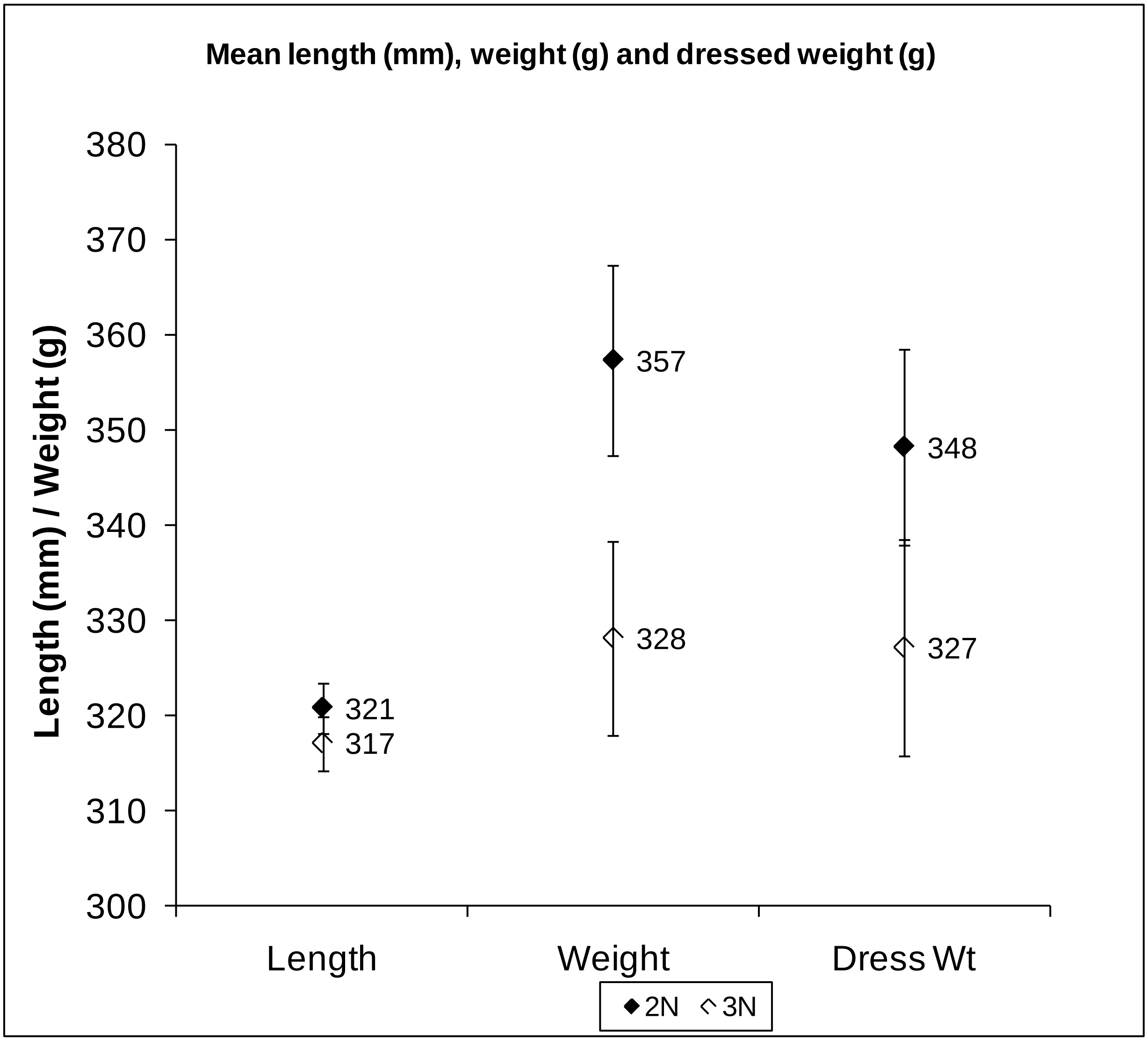


Figure 7. Mean length (mm) and mean weight (g) of diploid (2N) and triploid (3N) catchable rainbow trout stocked in spring 2008 and sampled in fall 2008. Error bars represent 95% confidence intervals around the mean.

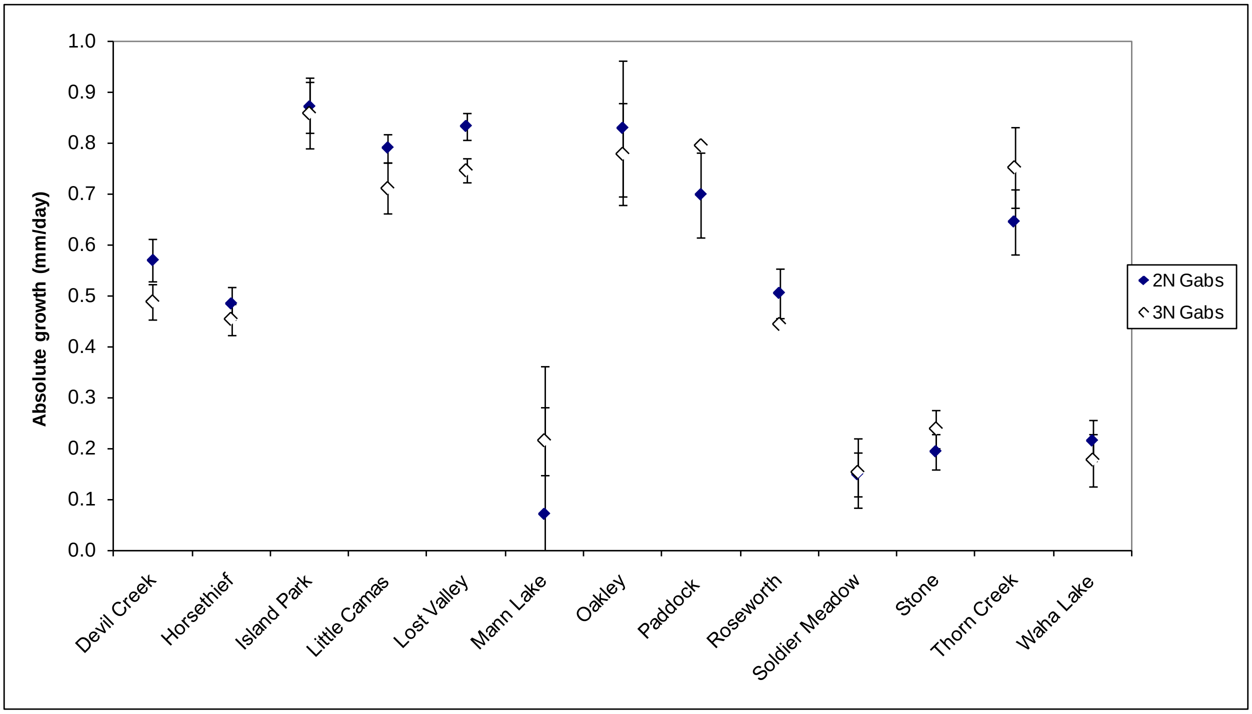


Figure 8. Mean absolute growth (mm/day) for diploid (2N) and triploid (3N) catchable rainbow trout sampled stocked in spring 2008 and sampled in fall 2008 by reservoir. Error bars represent 95% confidence intervals around the mean. Values without error bars had sample sizes too low to calculate confidence intervals.

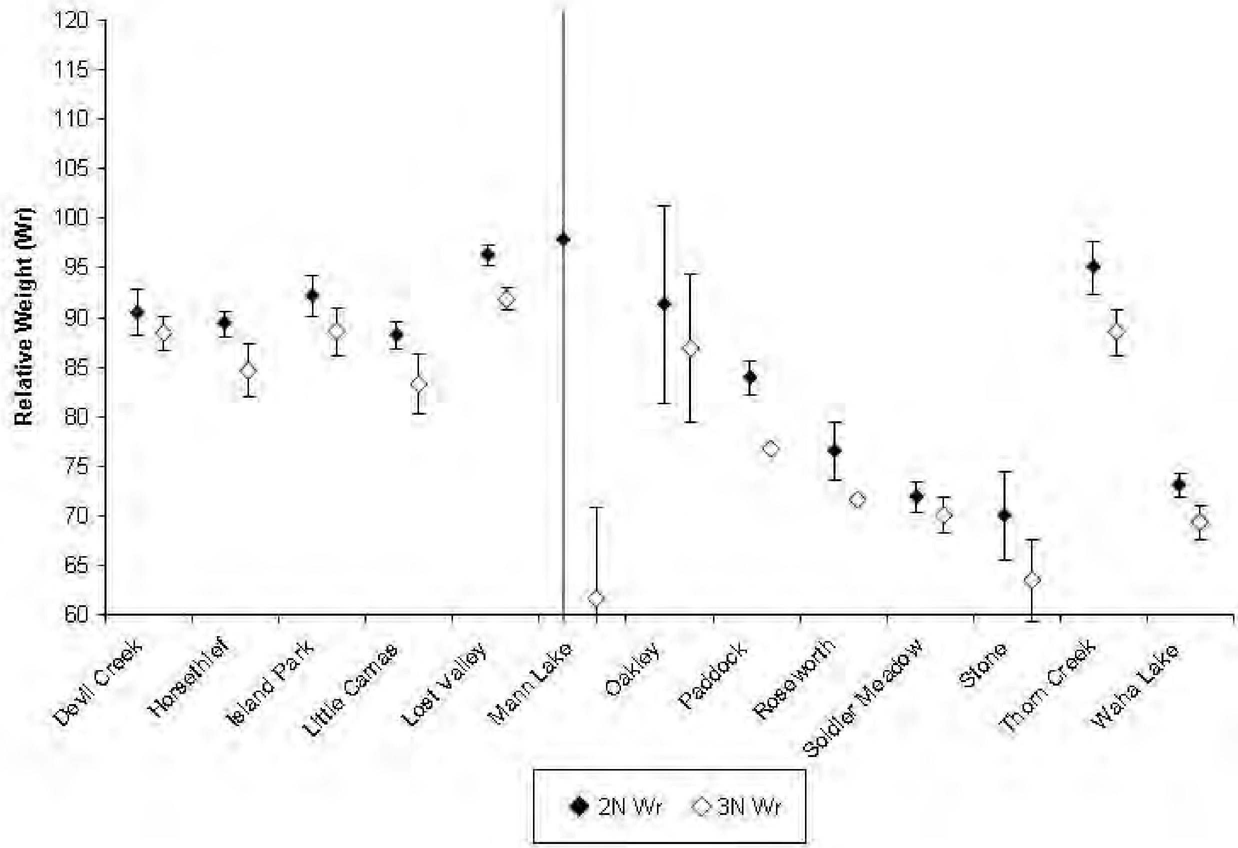


Figure 9. Mean relative weight (W_r) for diploid (2N) and triploid (3N) catchable rainbow trout stocked in spring 2008 and sampled in fall 2008 by reservoir. Error bars represent 95% confidence intervals around the mean. Values without error bars had sample sizes too low to calculate confidence intervals.

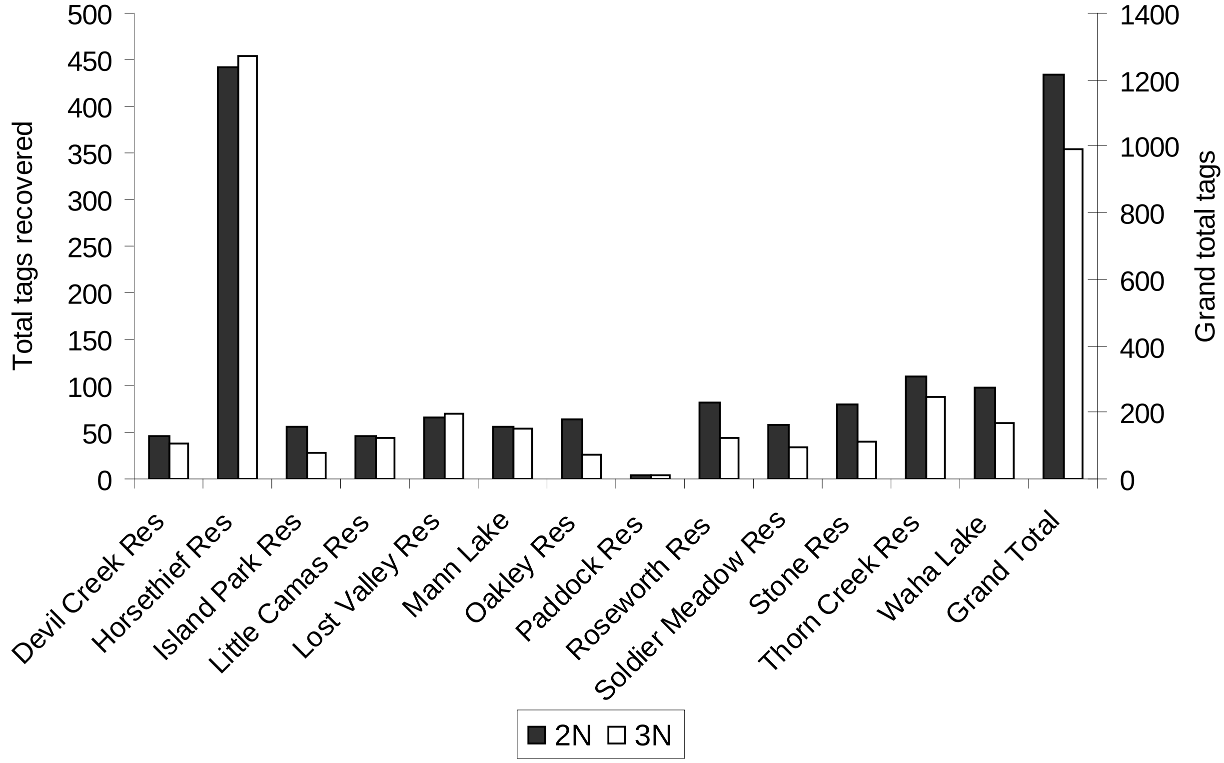
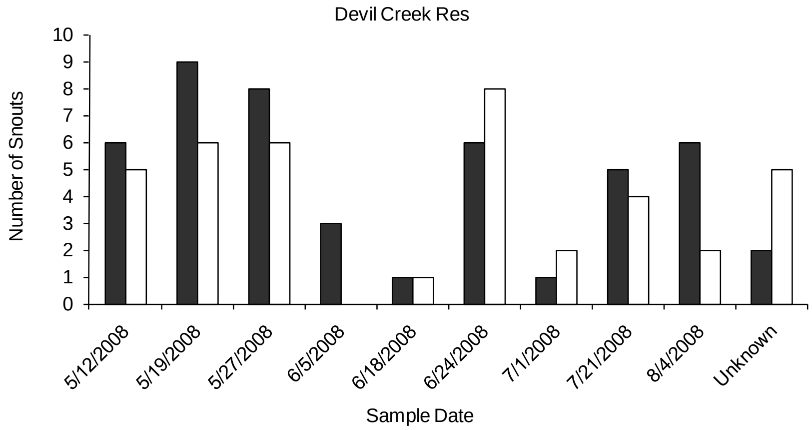
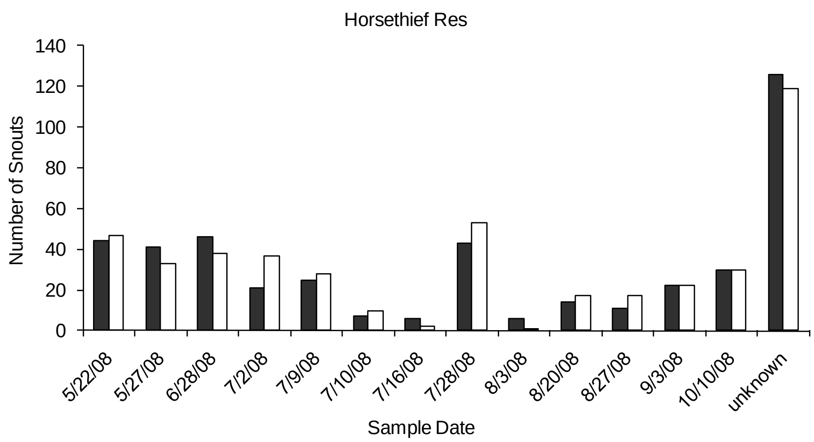


Figure 10. Total diploid (2N) and triploid (3N) coded wire tags returned by anglers using "snout collection boxes" by reservoir during 2008.





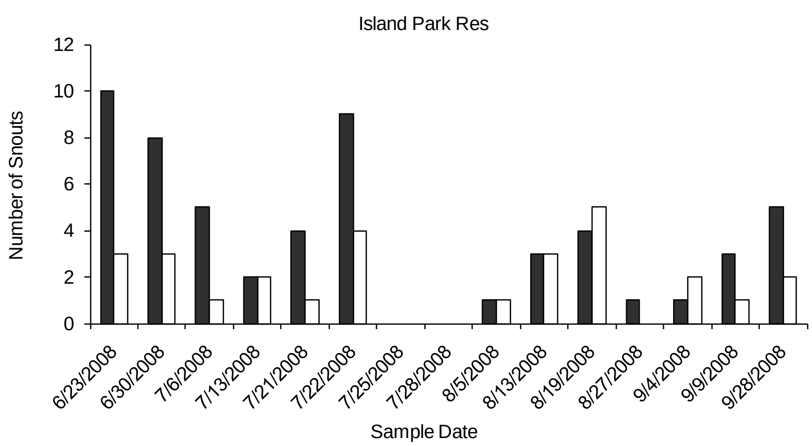
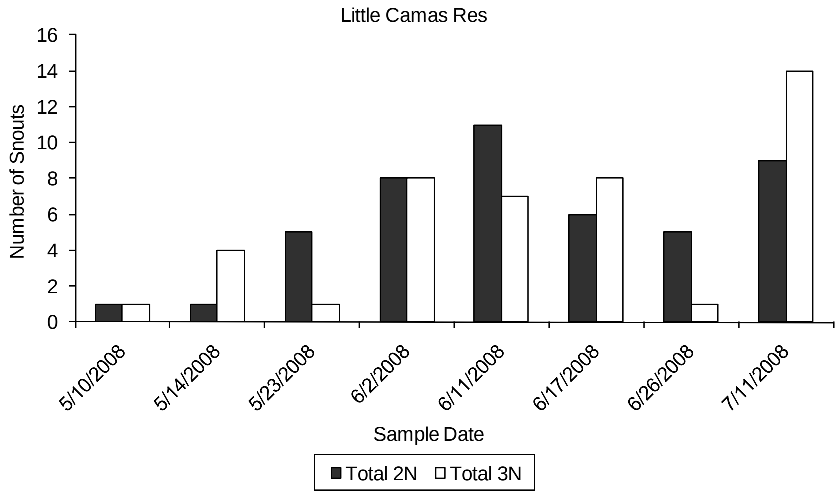
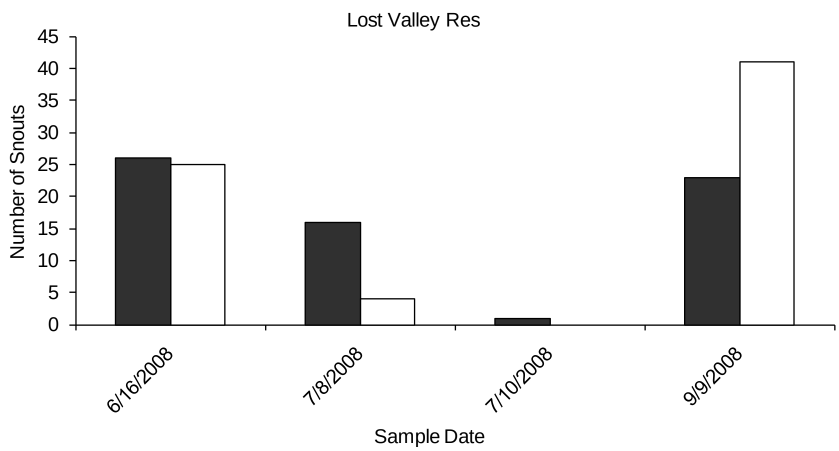
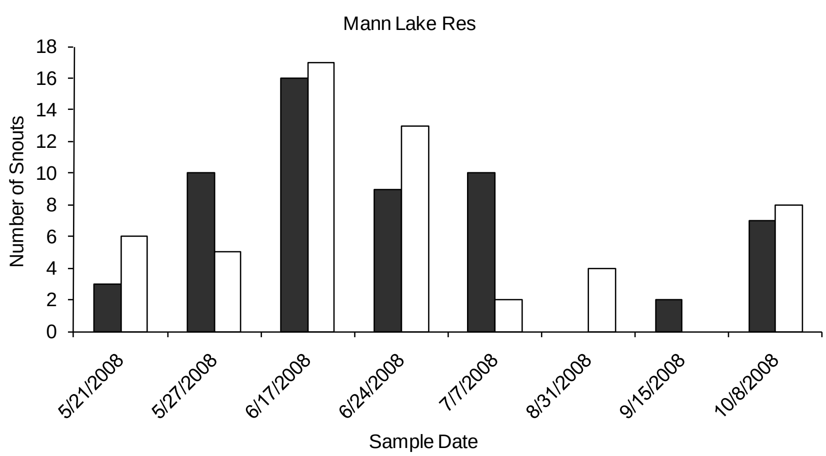


Figure 11. Counts of diploid (2N) and triploid (3N) coded wire tags returned by anglers using "snout collection boxes" by collection date during 2008.







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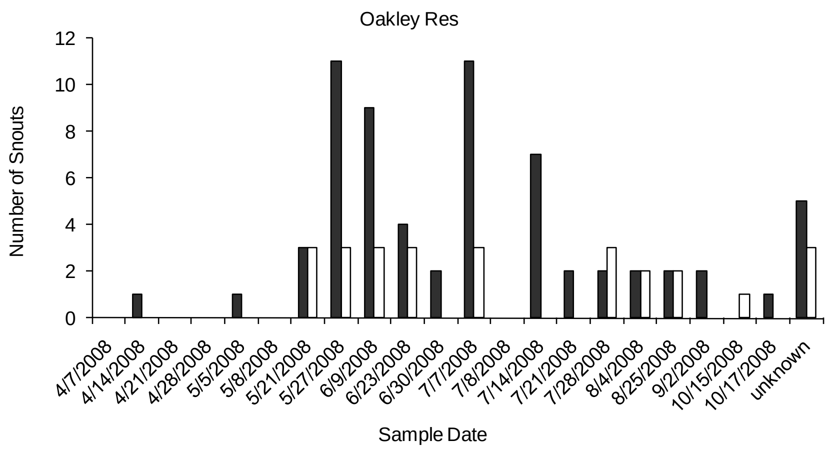

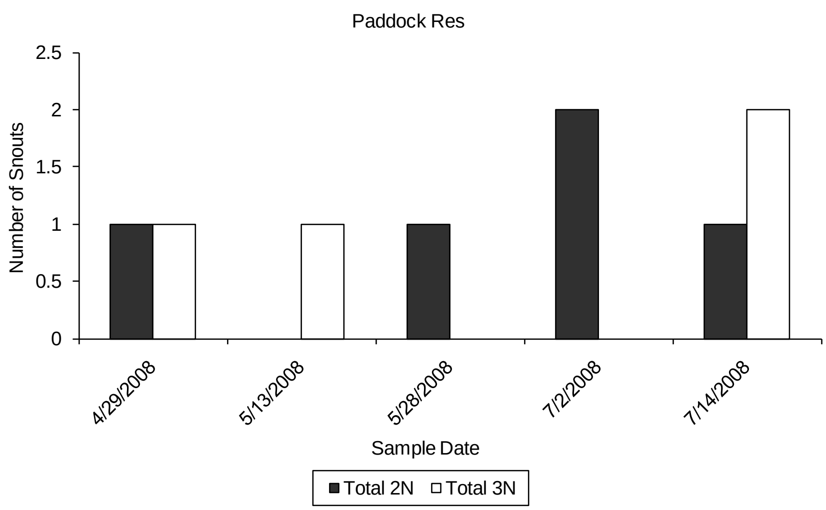

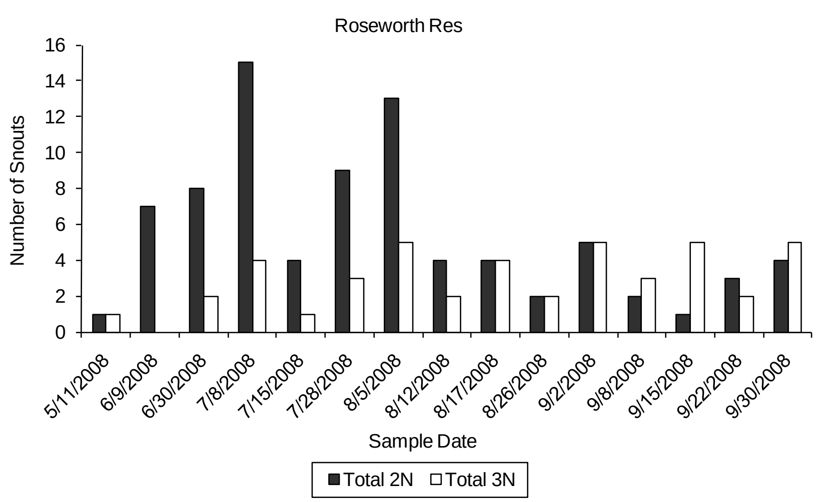

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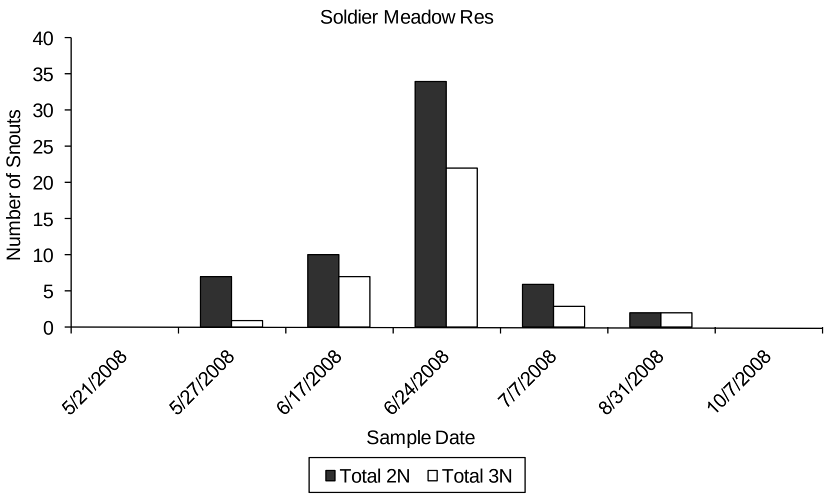

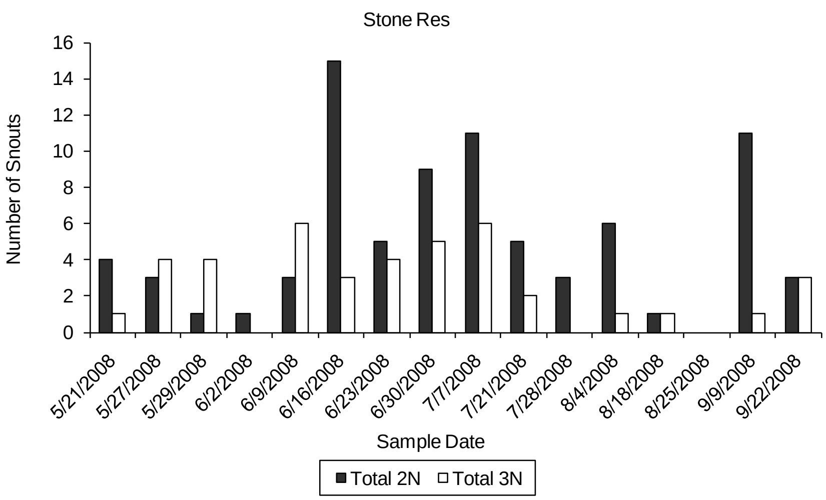

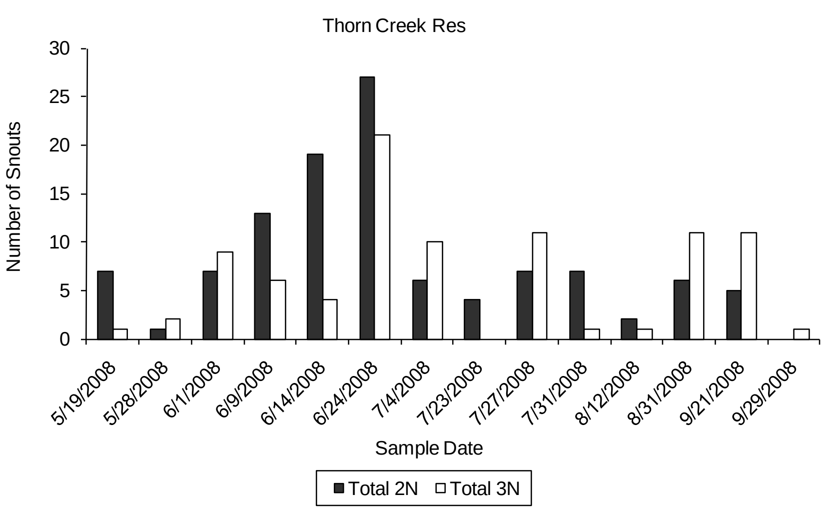

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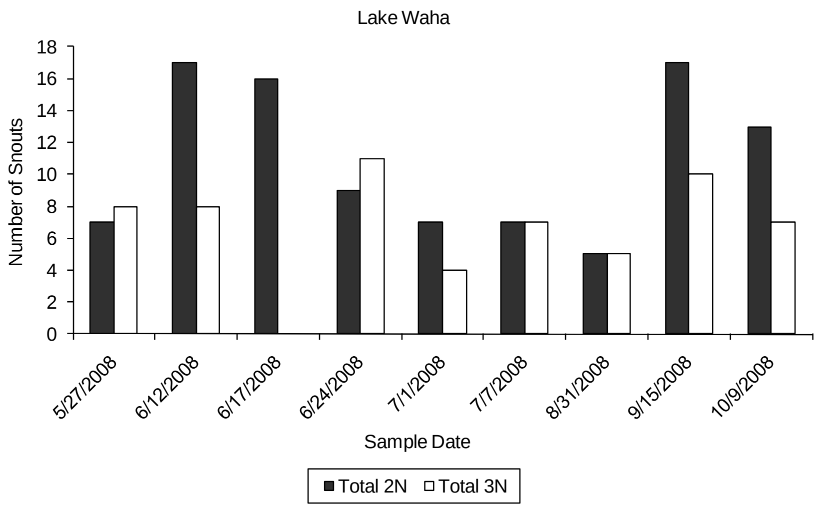

Figure 11. Continued.

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