HABITAT AND BIOTIC FACTORS INFLUENCING THE DISTRIBUTION AND RECRUITMENT OF JUVENILE CUTTHROAT TROUT IN THE TETON RIVER, IDAHO

by

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ABSTRACT

Habitat and Biotic Factors Influencing the Distribution and Recruitment of Juvenile Cutthroat Trout in Two Tributaries to the Teton River, Idaho

by

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Utah State University, 2006

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Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*) in the Teton River, Idaho, have experienced precipitous declines in recent years, which are hypothesized to be linked to poor recruitment. We investigated whether specific habitat attributes could be limiting cutthroat fry recruitment and at which life stage a recruitment bottleneck may be operating. As a result of preliminary sampling in 2002 and 2003 and historically documented biological importance, sampling efforts were focused on Fox Creek and Teton Creek, the primary spawning and rearing streams for cutthroat in the Teton River. Cutthroat spawning activity peaked around the second week of June for Fox Creek and Teton Creek, with a total of 33 and 37 “definite” redds located, respectively. In Fox Creek, redds were concentrated largely in the upper portion of the perennial stream habitat, with a similar but more diffuse pattern occurring in Teton Creek. Egg-to-fry survival for Fox Creek and Teton Creek was estimated as 20% and 25%, respectively.

These egg-to-fry survival rates were similar to those observed in other systems, and were not likely to be limiting cutthroat recruitment.

Habitat variables that explained the greatest variation in cutthroat fry abundance were related to documented spawning locations of fluvial cutthroat trout from the previous spring, suggesting that the number of cutthroat fry is more likely limited by low seeding than by spawning habitat availability. Overwinter survival of cutthroat fry was best in Teton Creek but similar to other systems and fell within the range of expected values for other age-0 trout. Overwinter survival of age-1 cutthroat trout was lower than expected and much lower compared to survival rates of brook trout and rainbow trout. This pattern indicates that the habitat currently available is suitable for cutthroat trout and that low survival of age-1 cutthroat trout may be attributable to competition with introduced rainbow and brook trout for overwinter habitat. Such low survival at later age classes can reduce reproduction rates below replacement levels, resulting in long-term declines.

Whirling disease is widespread throughout the Teton Valley, but the prevalence and intensity of the disease are both highly spatially and temporally variable. Teton Creek and Fox Creek showed moderate to high levels of infection in 2003 and 2004, but high survival rates of all age classes of rainbow trout and brook trout in these tributaries may cast doubt on the impact of the parasite or on our understanding of the differential susceptibility between trout species.

(148 pages)

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I thank Jim Fredericks of the Idaho Department of Fish and Game not only for his logistical support in providing equipment and personnel, but more importantly, for his insightful intellect and unwavering commitment to ensuring the success of this investigation. Bill Schrader provided my initial education on the Teton River and was always willing to provide background data, reports, and advice on how to proceed. Without the help of the Keith Johnson and the staff at the Eagle Fish Health Laboratory, none of the whirling disease assessment would have been accomplished. The staff at the USDA Forest Service Fish and Aquatic Ecology Unit in Logan, UT has been invaluable in their support of this research. I thank Brett Roper for his statistical (and angling) recommendations and for never being too busy to ignore one more phone call to help me out. Eric Archer, Rick Henderson, Marc Coles-Ritchie, and Greg Kliewer and the rest of the “people downstairs” all contributed generously from their individual specialties to the design and implementation of this project.

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INTRODUCTION

Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*) are native to the Snake River watershed above Shoshone Falls (Behnke 1992), and the Teton River in southeast Idaho remains one of the last strongholds for native fluvial Yellowstone cutthroat trout. Following the arrival of European settlers to the western United States, the range of Yellowstone cutthroat trout has been severely reduced to the point where only 10% of the original stream range is still inhabited (Varley and Gresswell 1988). Hybridization with nonnative rainbow trout (*Oncorhynchus mykiss*) has been a primary factor reducing populations of Yellowtone cutthroat trout (Allendorf and Leary 1988; Krueger and May 1991; Rieman and McIntyre 1995; Kruse et al. 2000). Other causes include competition with nonnative brook trout (*Salvelinus fontinalis*) (Griffith 1972; 1988; Petersen et al. 2004), habitat alteration and degradation through water storage and diversion, grazing, mining and timber harvest as well as human exploitation (Thurow et al. 1988; Varley and Gresswell 1988; Gresswell 1995).

The Idaho Department of Fish and Game (IDFG) has managed the Teton River with restrictive harvest regulations since 1990 and as a wild trout fishery since 1994, when stocking was discontinued. Despite these efforts, Yellowstone cutthroat trout have continued to decline in the Teton Valley section of the Teton River. Recent population assessments indicate densities of Yellowstone cutthroat trout have declined by 96% to less than 2 trout/ha in the most representative sample site, as estimated by the 2003 census (Garren et al. *In press*). Since 1987, Quality Stock Density (QSD) was measured as the ratio of the number of fish captured greater than 40 cm to the number of fish captured greater than 20cm and has continued to increase while trout densities have simultaneously decreased (Garren et al. *In press*). Meyer et al. (2003) reported similar findings in the Teton River, with the percentage of fish 10-20cm long having decreased from an average of 48% in 1980 to 8% in 1999-2000, while the proportion of fish larger than 30cm simultaneously increased from an average of 8% to 64%. These data suggest that recruitment of young fish may be limited, with adult fish slowly aging and dying out. The Idaho Department of Fish and Game has hypothesized that several factors might be responsible for these declines, including the loss of spawning and early rearing habitat, loss of overwinter habitat, cessation of stocking, hydrologic alteration and recruitment failures associated with whirling disease.

Yellowstone cutthroat trout require sufficient spawning, rearing and overwinter habitats to maintain adequate survival and recruitment. In the Teton Valley, challenges such as water diversion, grazing and land development have reduced cutthroat spawning and rearing habitat availability and quality. This may have in turn compromised the production, survival and subsequently the recruitment of age-0 cutthroat trout. Cutthroat fry often associate closely with complex stream-margin habitats, woody debris, undercut banks, and heterogeneous substrates (Moore and Gregory 1988; Bozek and Rahel 1991; Rosenfeld et al. 2000), but the specific habitat attribute that may ultimately limit cutthroat fry recruitment in the Teton Valley is currently unknown.

Habitat may play a paramount role in limiting trout populations, especially in highly altered systems. Like many other systems, native salmonids in the Teton Valley also face additional threats from whirling disease (Vincent 1996; Nehring and Walker 1996) and introduced salmonids (Harig et al. 2000; Peterson et al. 2004). Little information is currently available regarding the habitat associations of juvenile Yellowstone cutthroat trout in low gradient valley streams, such as those in the Teton Valley. An understanding of specific habitat features associated with differing densities of age-0 cutthroat in tributaries to the Teton River is needed in order to focus management efforts on specific protection, enhancement and mitigation practices to improve habitat conditions that are limiting (Bozek and Rahel 1991). Understanding limiting conditions in spawning and rearing tributaries will provide the insights necessary to make effective decisions for the recovery of the Teton River fishery.

The goal of this study was to investigate potential causes of reduced recruitment of Yellowstone cutthroat trout in the valley section of the Teton River. Our first objective was to investigate which habitat attributes explained the most variation in local young cutthroat trout abundance, in order to identify a potential limiting habitat factor. The second objective was to determine at which life stage cutthroat trout were likely experiencing the highest mortality, in order to hypothesize where a recruitment bottleneck may be operating.

LITERATURE REVIEW

Despite the fact that Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*) are considered to be the most widely dispersed and abundant inland cutthroat trout subspecies in North America (Varley and Gresswell 1988), recent declines have made the future of Yellowstone cutthroat trout questionable throughout southeastern Idaho. Following the arrival of European settlers to the western United States, the range of Yellowstone cutthroat trout has been severely reduced as a result of non-native fishes, environmental degradation and human exploitation (Varley and Gresswell 1988). Thurow et al. (1997) found that strong populations of Yellowstone cutthroat trout were found only in 32% of their potential range, nearly all of which occurs in Wyoming (cited in Meyer et al. 2003). May (1996) reported similar findings, indicating that viable populations of Yellowstone cutthroat were found in only 43% of their historical range in Idaho. More recently, Yellowstone cutthroat trout were petitioned for listing under the Endangered Species Act. Although the listing was deemed as “not warranted”, Yellowstone cutthroat trout are considered are considered “sensitive” by the US Forest Service and are designated a “Species of Special concern-Class A” by the American Fisheries Society (Gresswell 1995).

“The Yellowstone cutthroat trout is native to all the Snake River system except for waters between Jackson Lake and Palisades Reservoir, where finespotted Snake River cutthroat trout exist” (Behnke 1992). However, rainbow trout (*Oncorhynchus mykiss*) have replaced Yellowstone cutthroat trout in the Henry’s Fork of the Snake River (Behnke 1992), and a similar pattern may be developing in the Teton River. Contrary to the findings of Behnke (1992) and Meyer et al. (2003), recent population assessments in the Teton Valley section (Figure 1.1) show rainbow trout and brook trout (*Salvelinus fontinalis*) to be more abundant in the Teton River (Garren et al. *In press*). Van Kirk and Benjamin (2001) concluded the status of native salmonids to be poor in 70% of the Greater Yellowstone Ecosystem, which includes the Teton River. Despite these results, the mainstem Teton River and the South Fork of the Snake River remain the last strongholds of fluvial Yellowstone cutthroat trout in eastern Idaho.

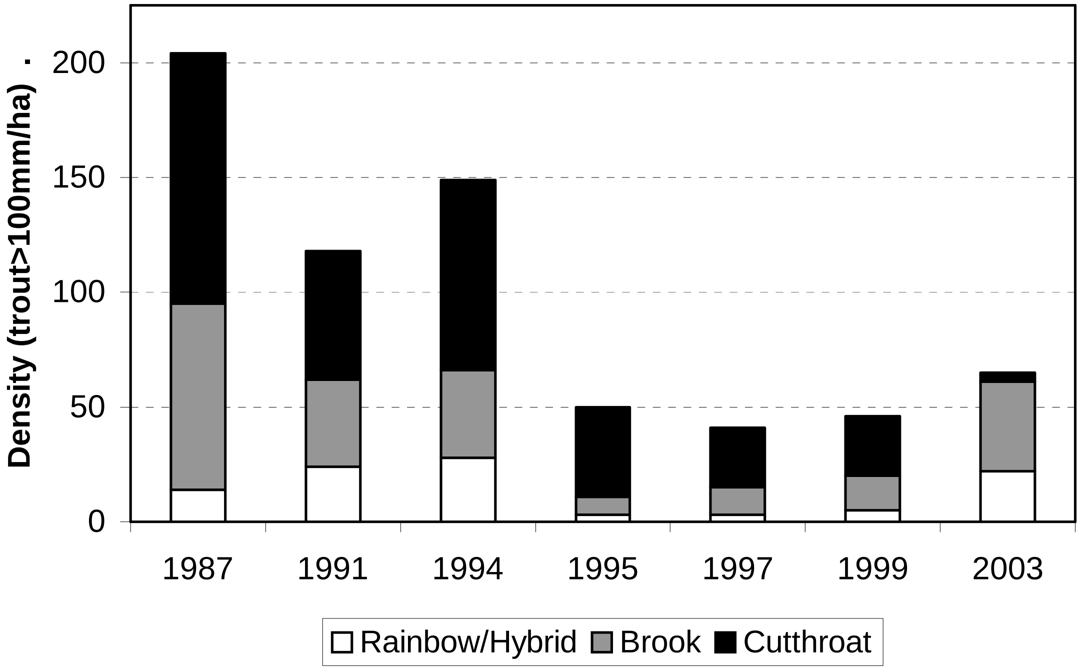

Figure 1.1. Trends in overall trout abundance in the Nickerson reach of the Teton River (Garren et al. *In press*).

The Idaho Department of Fish and Game (IDFG) has performed quantitative population assessments of trout (all species) in the valley section of the Teton River since 1987. Since then, these population assessments have been performed seven times, with the most recent survey completed in fall of 2003. The data collected by IDFG suggest a declining trend in all trout species (Figure 1.1), and reductions in Yellowstone cutthroat trout densities are especially noticeable (Figure 1.2). Since 1987, densities of Yellowstone cutthroat trout in the Teton River have declined by 96% in the most representative sample site as estimated by the 2003 census (Garren et al. *In press*). Angler catch rates measured in trout per hour show a 62% decline, falling from 1.58 trout/hour in 1974 to 0.58 trout/hour in 2000 (Garren et al. *In press*).

Quality Stock Density (QSD = # fish >16 inches/# fish >8inches) for the valley reach of the Teton River has continued to increase, while trout densities have simultaneously decreased (Garren et al. *In press*). Meyer et al. (2003) reported similar findings, with the percentage of fish 10-20cm long having decreased from 48% to 8% between 1980 and 1999-2000, while the proportion of fish larger than 30cm simultaneously increased from 8% to 64%. These data suggest that recruitment of young fish may be limited, with adult fish aging and slowly dying out. The Idaho Department of Fish and Game has hypothesized that several factors might be responsible for the decline, including the loss of spawning and early rearing habitat, loss of overwinter habitat, cessation of stocking and recruitment failures associated with whirling disease. The goal of this study was to identify and investigate factors responsible for the reduced recruitment of young Yellowstone cutthroat trout in the valley section of the Teton River.

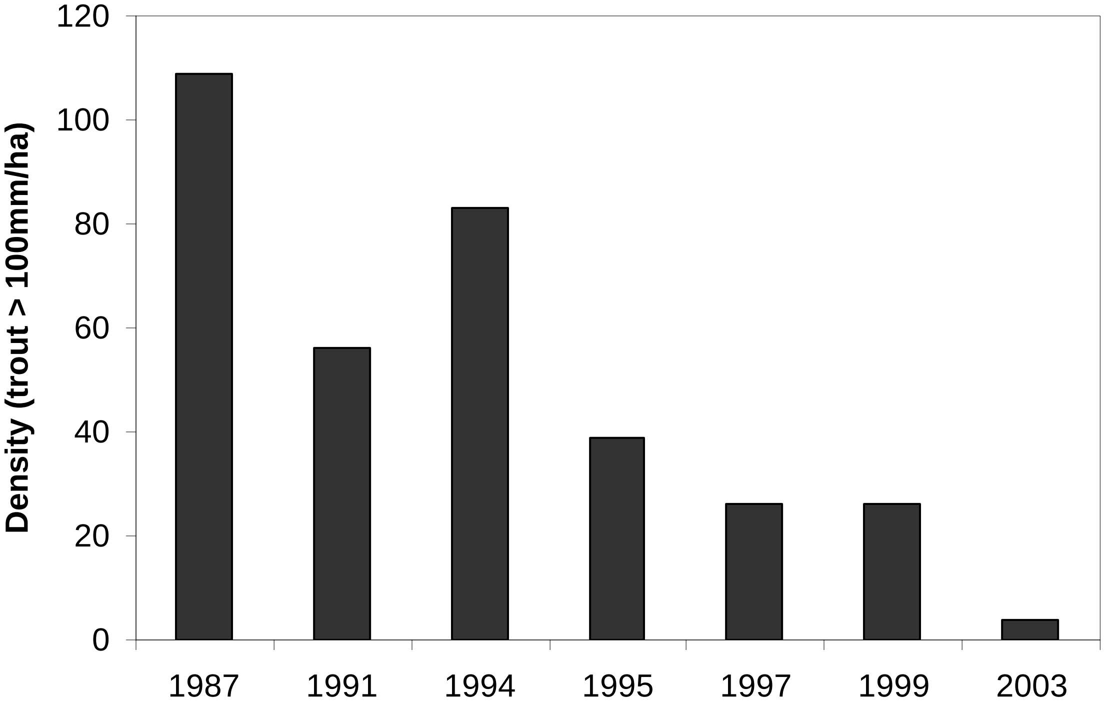

Figure 1.2. Trends in Yellowstone cutthroat trout density (trout/ha) in the Nickerson reach of the Teton River (Garren et al. *In press*).

Quantitative data describing both juvenile and adult abundance is necessary for a clear understanding of the stock-recruitment relationship. Adult abundance estimates of cutthroat trout in the Teton River have been performed over several years by the Idaho Department of Fish and Game. Fisheries investigations of the Teton River have focused almost exclusively on adult trout in the mainstem. However, little information describing the distribution and/or abundance of juvenile trout in the Teton valley is currently available. Data collected by the Idaho Department of Fish and Game indicate that very few age-0 fish have been captured while sampling the upper Teton River. Length-frequency histograms (IDFG, unpublished data) dating back to 1974 show very few instances where trout less than 100 mm were recorded. Although size-selective bias associated with boat-mounted electrofishing gear cannot be completely ruled out, these juveniles are thought to reside in spawning tributaries (Schrader 1996) until they migrate as sub-adults to the mainstem Teton River. Previous research has identified that Fox Creek and Teton Creek are two such tributaries and may play an important for spawning fluvial cutthroat trout in the Teton River.

"Effective management of vulnerable populations [of a species] is often confounded by an absence of quantitative data on distribution and habitat associations" (Rosenfeld et al. 2000). In the case of cutthroat trout, habitat associations have been described for coastal cutthroat (Moore and Gregory 1988; Rosenfeld et al. 2000; Rosenfeld and Boss 2001), greenback cutthroat trout (Harig and Fausch 2002; Young and Guenther-Gloss 2004), Apache trout (Clarkson and Wilson 1995), and Colorado River cutthroat trout (Bozek and Rahel 1991). Most of the above-mentioned literature focuses on habitat associations of cutthroat trout in smaller, high elevation, higher gradient tributaries and little information is currently available regarding the habitat associations of juvenile Yellowstone cutthroat trout in low gradient valley streams, such as those in the Teton Valley. An understanding of specific macrohabitat features associated with differing densities of age-0 cutthroat in tributaries to the Teton River is needed in order to focus management efforts on specific protection, enhancement and mitigation practices to improve habitat conditions that are limiting (Bozek and Rahel 1991). Understanding limiting conditions in spawning and rearing tributaries such as Fox Creek and Teton Creek will provide further insight into what factors or combination of factors may limit recruitment of cutthroat trout to the Teton River.

Observations from previous sampling efforts in the Teton River and several tributaries have provided some insights into potentially important habitat associations of juvenile trout within the tributaries to the Teton River. Root structures of bankside vegetation such as willows were often associated with deeper habitats within a reach. These zones of scour and structure may serve as areas of concealment and velocity refugia. Reaches with extensive shallow habitat and little cover for concealment often held few YOY trout. Shallow near-shore environments with low velocities contained the highest numbers of YOY trout. Additionally, reaches with extensive siltation rarely produced large numbers of YOY cutthroat trout, whereas reaches dominated by gravel often produced higher numbers of YOY cutthroat trout. Investigating physical habitat features such as the number of pools, substrate, width/depth, and bankside vegetation and fish habitat use over stream-wide scales may provide valuable insights into understanding juvenile cutthroat distributions in spawning tributaries to the Teton River.

Several authors have documented the associations of complex bank habitat with juvenile cutthroat and rainbow trout (Moore and Gregory 1988; Bozek and Rahel 1991; Mitro and Zale 2002). Moore and Gregory (1988) described the importance of lateral stream habitat for emergent cutthroat fry. These lateral habitats were characterized by heterogeneous substrates, slow, shallow water and provided gradients of depth, velocity and cover. In the Henry's Fork of the Snake River, bank habitats consisting of large substrates, woody debris and undercut banks were the only habitats to support age-0 trout through the winter (Mitro and Zale 2002). These results are consistent with the findings of Rosenfeld et al. (2000), who found that glides held the greatest numbers of age-0 cutthroat in coastal streams. Other habitat attributes such as pool abundance and channel width have also been shown to influence salmonid growth and abundance (Elliot 1994; Clarkson and Wilson 1995; Kershner et al.1997; Kruse et al. 1997, as seen in Young and Guenther-Gloss 2004).

While complex lateral habitats (such as those described above in Moore and Gregory 1988b) and glides may be critical to age-0 abundance, cutthroat parr abundance has been shown to correlate with the number of pools in a stream (Rosenfeld et al. 2000; Young and Guenther-Gloss 2004), suggesting that this may be an important habitat variable related to cutthroat trout abundance. In fact, Rosenfeld and Boss (2001) demonstrated that age-0 cutthroat trout preferred pools to riffles, even though pools often held lower densities of age-0 cutthroat. In addition to the number of pools, pools with physical structure such as woody debris or undercut banks limit cutthroat populations (Rosenfeld et al. 2000; Harig and Fausch 2002). Quantifying the relative contributions of pools and riffles and the spatial orientation of these habitat types will aid in elucidating patterns of cutthroat density in Teton valley tributaries.

Densities of juvenile cutthroat trout are related to stream depth and width. In coastal streams studied by Rosenfeld et al. (2000), bankfull channel width was the best predictor of cutthroat presence. Juvenile cutthroat were disproportionally more abundant in small streams, perhaps as a consequence of greater relative edge habitat availability. Bozek and Rahel (1991) also found that width was negatively correlated with young cutthroat density in Wyoming streams. In addition, these authors concluded that small, shallow streams supported greater densities of cutthroat trout.

Substrate may also be an important variable in determining the habitat utilization of juvenile cutthroat trout. Moore and Gregory (1988) documented that 65% of cutthroat fry observed were in association with heterogeneous substrates of cobble, pebbles and gravel, with fry rarely seen in association with fine homogenous substrates. Bozek and Rahel (1991) also reported that the abundance of cutthroat fry was best predicted by the proximity of shallow water with abundant spawning gravels. In coastal systems, juvenile cutthroat are more abundant at sites where gravel is the dominant substrate and least abundant at sites where boulders dominate (Rosenfeld et al. 2000). Streams heavily affected by siltation as a result of cattle grazing and agriculture may likely support fewer cutthroat fry.

The productivity of lateral habitats where juvenile cutthroat are found is potentially influenced by the presence and composition of riparian vegetation (Moore and Gregory 1988). Moore and Gregory (1988) compared juvenile cutthroat size and growth rates between coniferous, deciduous and open riparian habitats and concluded that canopy cover type influenced both size and growth rates. In the heavily impacted low gradient valley segments of the Teton River tributaries, canopy cover, where still intact, is largely in the form of bank-side willows and grasses. Riparian areas with intact willow communities may represent an important habitat component for juvenile cutthroat trout. Willows can provide not only overhanging cover, but also help maintain bank stability and may contribute to complex lateral habitat quality in the form of submerged root structures and their associated velocity refugia and undercut banks. These riparian features that form fry-rearing habitat in summer also create the largest and most persistent refuge habitat to sustain juvenile trout through the winter (Moore 1987).

Livestock grazing impacts are widespread in the Teton River watershed and have contributed to the deterioration of riparian areas by stream bank sloughing, channel instability, erosion and sedimentation (Thurow et al. 1988). Detrimental impacts from grazing include increased stream temperatures, increased sedimentation, increased channel width due to bank sloughing and the resulting loss of trout cover, decreased winter temperature, channel trenching or braiding, and alterations of the plant community that result in reduced bank cohesiveness, cover and terrestrial food inputs (Platts and Raleigh 1984). Clarkson and Wilson (1995) found that streams that received little grazing supported the highest standing crops of trout. In addition to physical habitat alterations resulting from grazing, *Tubifex tubifex* (the initial host for whirling disease) may be more abundant in degraded sites. Low flows combined with high percentages of fine sediments characterized sites (Krueger 2002 as seen in Downing et al. 2002) of highest infectivity. Measures of bank stability may serve as good surrogates to gauge the relative impact of local grazing on the stream environment and may help explain local juvenile cutthroat trout densities.

Spawning

The density and spatial distribution of redds in Fox Creek and Teton Creek may provide important information related to overall stock assessment, the abundance of cutthroat trout fry and the locations of fry rearing habitat. Redd counts afford an inexpensive alternative to weirs for estimating adult abundance and distribution over several tributaries that might function as potential spawning sites for fluvial cutthroat trout. Previous studies have shown that redd counts are often correlated with juvenile recruitment (Beard and Carline 1991; Beland 1996, but see Al-Chokhachy et al. *in press*).

Redds are relatively easy to identify, especially when created by large migratory salmonids. This has resulted in an uncritical acceptance of redd counts as a means of monitoring populations of migratory salmonids (Dunham et al. 2001). Dunham et al. (2001) caution that redd surveys may suffer from substantial count error and high interobserver variability, which may obscure important trends. To address these concerns, the redd survey in this study will use only one observer and will individually mark redds to improve estimates of redd numbers. Redd counts may yield useful information describing the spawning population of fluvial cutthroat trout in the Teton valley and may help to explain the distribution and local densities of cutthroat fry.

In the Madison River, redd density and fall fry density have been correlated, suggesting that fry may remain in close proximity to spawning locations during the early stages of life (Downing et al. 2002). These findings support those of Bozek and Rahel (1991), who found that local abundance of spawning gravel was the best habitat variable to predict fry densities. Knowing the location of active spawning sites from the previous spring may provide an important variable in explaining the summer and fall distributions of fry density in tributary streams.

Other Species

The primary focus of this study concerns juvenile cutthroat trout and so comparatively little information will be presented here regarding other species. However, data will also be collected on other salmonids. These data may be useful in evaluating potential patterns between cutthroat trout density and location.

Young and Guenther-Gloss (2004) reported that the abundance of age-0 cutthroat trout fry was negatively correlated with the number of adult fish exceeding 200 mm. Collecting data on all salmonids will be instructive in exploring these kinds of relationships. For example, Hughes (1998) presented a method to infer interannual movements of stream salmonids based on the pattern of age segregation along the length of a river. Data concerning other species will be important later in explaining patterns of juvenile trout density.

When Yellowstone cutthroat trout are in sympatry with brook trout, they appear less likely to persist (Griffith 1988). Behnke (1992) documented this negative effect of brook trout presence on cutthroat trout persistence. In one example, Behnke described the virtual replacement of cutthroat trout by brook trout in Black Hollow Creek within 5 years. Griffith (1988) cites a very similar example in the Shields River of Montana, where in 9 years Yellowstone cutthroat trout declined by 66% and brook trout became the dominant species. The introduction of brook trout in Yellowstone National Park streams has usually resulted in the elimination of cutthroat trout (Griffith 1988). Gresswell (1995) hypothesized that this may be a result of competitive exclusion and greater niche overlap with brook trout than with other salmonid species. As a result, brook trout have replaced cutthroat trout in many streams and are viewed as one of the greatest threats to cutthroat trout recovery (Benhke 1992; Harig et al. 2000; Dunham et al. 2003). Until recently, the actual mechanism by which brook trout replace cutthroat trout has been unknown, with most studies focused on individual-level mechanisms (Griffith 1970; Novinger 2000). Griffith (1972) concluded that interactions between cutthroat and brook trout were most likely to occur at the age-1 and age-2 life stages. This was partly affirmed by Peterson et al. (2004), who demonstrated a population-level mechanism by which brook trout replace cutthroat trout through age-specific interactions primarily at the age-0 and age-1 life stages.

Yellowstone cutthroat trout spawn in spring, usually after rainbow trout, and well after brook trout fry have emerged from the previous fall. Brook trout are often 20-40mm larger than similar age cutthroat (Gregory and Griffith 2000), putting cutthroat fry at a significant size disadvantage compared to sympatric brook trout or rainbow trout, which may hinder cutthroat throughout their lives (Griffith 1972 as cited in Griffith 1988). Griffith documented extremely low rates (4%) of overwinter survival of cutthroat trout when held in sympatry with brook trout as compared to 84% survival when held in allopatry with brook trout.

Hybridization with introduced rainbow trout and non-native subspecies of cutthroat trout is a major cause in the decline and extirpation of Yellowstone cutthroat trout populations (Varley and Gresswell 1988; Gresswell 1995). Hanzel (1959) reported that hybridization with rainbow trout had occurred in almost all drainages in Montana where they were stocked. Hybridization led to the virtual disappearance of Yellowstone cutthroat trout from the Henry’s Fork of the Snake River within 8 years of rainbow trout introduction (Gresswell 1988). Moyle and Vondracek (1985) documented a similar replacement of Lahontan cutthroat trout by rainbow trout and brown trout in Martis Creek, California. Correlations between juvenile cutthroat trout abundance and the abundance of other trout species may reflect such negative interactions, and thus could help explain recruitment declines of cutthroat trout.

Whirling Disease

Whirling disease is caused by the parasite *Myxobolous cerebralis*, which was accidentally introduced from Europe, where it has been known to exist since 1893 (Hoffman 1990). It was first discovered in the United States in 1958 (Hoffman 1990). Whirling disease may have been introduced to Idaho as soon as 1966 as a result of stocking infected trout across state lines (K. Johnson, Eagle Fish Health Laboratyr – IDFG, *personal communication*). However, it was not detected until 1987 (Hiner and Moffitt 2002). The disease has been responsible for the virtual elimination of susceptible trout species in streams from Montana to Colorado (Gustafson 1998). Currently, *M. cerebralis* is established in 21 river systems throughout Idaho, but overall, salmonid populations across the state do not appear to be impacted (K. Johnson, Eagle Fish Health Laboratory – IDFG, *personal communication*).

The parasite has demonstrated great geographic variation in its impact, but severe infections my lead to recruitment collapses of age-0 fish (Nehring and Walker 1996; Vincent 1996; Downing et al. 2002). Even in highly infected systems, sentinel fish exposures have shown the prevalence of infection can vary greatly over space and time (Downing et al. 2002). For example, in portions of the Colorado, Gunnison, Rio Grande and South Platte rivers, whirling disease is severe enough to eliminate almost the entire cohort of wild rainbow trout fry every year (CDOW 1999). In contrast, the Big Thompson River near Estes Park tested positive for M. *cerebralis* in 1994, yet recruitment of rainbow trout is excellent (CDOW 1999). In the Madison River, Downing et al. (2002) reported typical differences of disease severity between sites in close proximity of at least two orders of magnitude.

Only young-of-the-year fish are severely affected by the disease (Gustafson 1998), as the parasite attacks cartilaginous skeletal structures before ossification is complete. External signs of infection may include, but are not limited to black tails, spinal curvature, cranial depression, and erratic swimming. Hedrick et al. (1999) reported that rainbow trout are by far the most susceptible to the disease, with cutthroat trout showing no clinical signs of the disease when exposed after three months post-hatch. Vincent (2002) also reported that rainbow trout were the most susceptible of the salmonids tested and classified them as having “very high susceptibility.” Brook trout were classified in the same category as rainbow trout, but Yellowstone cutthroat trout were ranked two categories lower in the “moderate susceptibility” class.

These data suggest that the distribution of infectivity in relation to spawning and rearing habitat may be critical to determining the potential impacts of whirling disease on cutthroat trout recruitment. “When and where salmonids spawn and rear may greatly influence their level of exposure to M. cerebralis” (Downing et al. 2002). A juvenile trout assessment within streams known to contain the parasite should describe not only the distribution of juvenile cutthroat trout and whirling disease infection, but also the location of spawning and rearing habitats. Documenting the timing of spawning in tributaries to the Teton River will be important when interpreting whirling disease test results and the differential risk of exposure associated with varying life histories of cutthroat.

Given that trout species differ in their susceptibility to whirling disease, one might anticipate that rainbow trout and brook trout would be more adversely affected than

Yellowstone cutthroat trout within the same stream, all other factors being equal (Vincent 2002). However, recent IDFG population surveys in the mainstem Teton River, which show brook trout and rainbow trout outnumbering cutthroat trout, may cast doubt on the prevalence of the parasite or perhaps our understanding of differential susceptibility between species. Understanding where juvenile cutthroat are most likely to become infected will help guide recovery and management strategies.

Annual differences in infection severity may have important population effects (Downing et al. 2002). As a result, it may be imperative to have multiple years of data documenting infectivity. Whirling disease was identified in the Teton River in 1995 (Elle and Schill 1999), and data describing infection severity was collected from only a few sites in 1997 (Elle 1998). Since 1997, no additional sampling has been completed in the Teton River. More recent and widespread testing is needed to better resolve the spatial distribution, severity and factors that determine the impact of the parasite of infection in the Teton Valley.

Multiple years of infection data may be necessary to help explain fish abundance declines over time. Population level declines may exhibit a lag time of several years before a significant effect of the disease may be noticed (De la Hoz and Budy 2004). Other factors such as water temperature, water flow, and the spatial and temporal variation in triactinomyxon production and the relative distribution of fry will determine the extent of whirling disease infection (Vincent 2002). This study will add to the current knowledge base with two additional years of collection and a greatly expanded distribution of sites.

Preliminary sampling conducted in 2003 on Teton Creek, Fox Creek, Woods Creek and the mainstem Teton River suggests that juvenile cutthroat trout are patchily distributed and that abundance is highly variable within and among streams (Tables A.1-A.14, Figures A.1-A.4). The goal of this study is to investigate the spatial distribution and abundance of young-of-the-year Yellowstone cutthroat trout in these tributaries in an effort to understand factors potentially limiting recruitment. My first objective is to investigate patterns of juvenile cutthroat trout abundance in Fox Creek and Teton Creek and determine which habitat and biotic variables best explain the greatest variation in reach scale abundance. The second objective is to describe at which season or life stage cutthroat trout are experiencing the highest mortality rates and therefore where recruitment limitations are originating. Specifically, the study aims to investigate habitat and biotic variables, such as redd location and introduced salmonids and their relation to the distribution of young-of-the-year cutthroat trout in these tributaries and to identify the most likely factor limiting cutthroat trout recruitment to the Teton River.

STUDY SITE

The Teton Valley in southeastern Idaho is the only large mountain valley that occurs in the Henry's Fork of the Snake River watershed (Van Kirk and Benjamin 2001). In the Teton Valley, the Teton River above South Leigh Creek has a drainage area of 867.6km^2 with a mean annual discharge of 11.3m^3/s. The Teton River originates from a combination of snowmelt and spring-fed discharge, with peak flows usually occurring between late May and early June.

In addition to the native Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*), the Teton River also contains populations of introduced brook (*Salvelinus fontinalis*) and rainbow trout (*Oncorhynchus mykiss*). The Teton River supports fluvial Yellowstone cutthroat trout (Thurow et al. 1988), which reside in large streams or rivers, but migrate to smaller tributaries to spawn in the spring following annual high flows (Jaeger et al. 2000). Progeny of fluvial cutthroat trout are thought to reside in spawning tributaries 1 to 3 years until later migrating as sub-adults to the mainstem Teton River (Varley and Gresswell 1988; Gresswell 1995; Schrader 1996; Thurow et al. 1988).

Teton Creek and Fox Creek are major tributaries that support important spawning and rearing habitats for fluvial cutthroat trout (Figure 1.3; Appendix A; Appendix B, Thurow et al. 1988; Schrader 2003). Other tributaries such as Trail Creek and South Leigh Creek may also be important to cutthroat trout in the Teton River. Fox Creek and Teton Creek were selected to serve as index representing a range of habitat conditions from spring-dominated streams to snowmelt runoff dominated stream found throughout

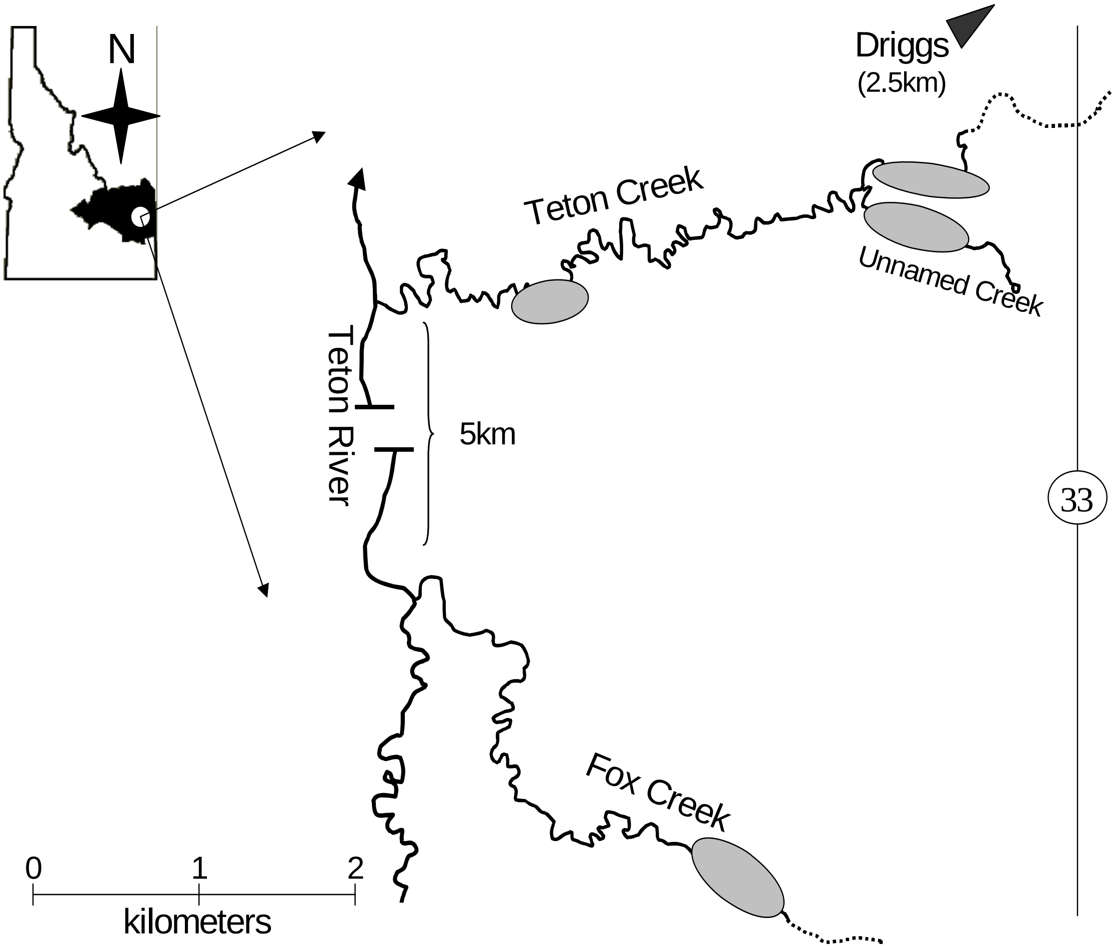

Figure 1.3. Map of study site in the Teton Valley, southeast Idaho. Shaded portions show areas of concentrations of cutthroat trout spawning activity in Spring 2004.

the Teton Valley. As such the patterns and relationships found there would be representative of similar tributaries in the valley.

Teton Creek and Fox Creek are heavily affected by diversions near the National Forest boundary as the streams transition from the high gradients of the Teton Range to the valley floor. Irrigation diversions have greatly increased the time that long sections of these tributaries remain dry during the year. One of the most immediate consequences of such hydrologic alteration has been the loss of preferred spawning habitat for fluvial Yellowstone cutthroat trout in tributary stream reaches between the base of the Teton Range and the Teton River (Van Kirk and Jenkins 2005). Additionally, diversion of tributary stream flows and groundwater recharge associated with irrigation conveyance has resulted in an overall shift in habitat conditions from those of runoff-dominated streams (cottonwood forests, large woody debris, large substrates) to those more characteristic of ground water streams (willow communities, small woody debris, small substrates) (Van Kirk and Jenkins 2005). Van Kirk and Jenkins (2005) concluded that Yellowstone cutthroat in the Teton Valley were more abundant relative to rainbow trout in years when flows were dominated by runoff and that the shift towards ground water-dominated hydrology has favored invasive trout species.

Lower Fox Creek and Teton Creek are roughly 6.5 km and 9 km in length, respectively and benefit from extensive ground water inputs as they progress towards the Teton River. As a result, these lowest sections (west of US Highway 33) represent the total effective length of connected perennial tributary habitat available to fluvial trout and their offspring in these tributaries, even during periods when diversions are not operating at upstream locations. Redd count surveys of several potential spawning tributaries suggest these lower perennial reaches of Fox Creek and Teton Creek function as the primary spawning and rearing habitat available for fluvial cutthroat trout in the Teton River (Figure 1.3; Appendix B).

Lower Fox Creek is a fourth order tributary to the Teton River. The stream is typical of meandering spring creeks, with a gradient of 0.5-1% throughout the study sections. Discharge is fairly constant due to excessive ground water input, with summer flows in June around $2m^3/s$. Abundant macrophyte cover develops through the summer, but dies and sloughs off through the fall and winter. Habitats are mostly intact and have well developed meanders and associated pools in the upper reaches. Willows (*Salix spp.*) also populate the banks of this upper section and provide abundant stable banks and overhanging cover. As Fox Creek nears the Teton River, the riparian corridor of willows is heavily reduced, and bank integrity begins to degrade. Substrates in this section become increasingly dominated by silt and width/depth ratios are increased. Land-use activities on Fox Creek currently include limited hay farming in the lower portions of the study area, while middle and upper reaches have residential subdivisions in early stages of development.

Teton Creek is a fourth order tributary more characteristic of a higher gradient snowmelt dominated stream. On the valley floor, average gradient in the study section is approximately 1%. Summer flow in June is approximately $2m^3/s$ with spring peak flows reaching greater than $14m^3/s$ in May as high-elevation snowmelt arrives. The active floodplain of Teton Creek is much wider than that of Fox Creek, with large substrates and depositional bars abundant throughout the upper reaches. As in Fox Creek, lower reaches of Teton Creek are heavily affected by siltation. The lower two-thirds of the study reach see very little land-use currently as much of this section has been placed under conservation easement. In contrast, the upper reaches of Teton Creek are subject periodically to intense cattle grazing throughout most of the summer. A fairly intact riparian corridor along lower portions of Teton Creek consists largely of willows, while upper portions of the study reach show reduced willow canopies and stretches of open stream bank.

METHODS

Trout Abundance Assessment

I used a two-stage, systematic sampling scheme (Hankin and Reeves 1988) to estimate fish abundance and distribution in Teton and Fox Creeks. The first stage consisted of single-pass electrofishing (Kruse et al. 1998) while the second stage consisted of multiple-pass depletion electrofishing with a minimum of three passes (Riley and Fausch 1992). Fifty-meter long reaches were established along the perennial lengths of lower Fox and Teton Creeks. Shorter reaches were intended to increase sampling precision by allocating effort to sampling more sites of shorter lengths (Mitro and Zale 2000). The total length of accessible perennial stream was measured using digital 1:24,000 USGS topographic maps (Terrain Navigator 5.0). After random assignment of the first sample reach, reaches were distributed along each stream in a systematic interval and made up a combined total length of approximately 10% of the accessible perennial stream length. Sampling effort was randomly assigned (single or multiple pass) at the first reach, with every third reach designated as a multiple-pass site thereafter. Teton Creek and Fox Creek were each stratified into two strata by a distinct gradient break evident in their longitudinal profiles, created using digital 1:24,000 USGS topographic maps (Terrain Navigator 5.0). Unnamed Creek, a tributary to upper Teton Creek, was treated as a third stratum of Teton Creek.

Fish sampling took place in September of 2004 and again before runoff in early April 2005. September was chosen as the initial fall sampling time, since most fry should have already emerged (Varley and Gresswell 1988), weather and stream flow conditions were likely to be favorable, and because preliminary sampling in 2003 conducted during October indicated that fry were readily present in each creek (Koenig 2006). Electrofishing crews consisted of two backpack electrofishing units and two or three additional persons netting. In wider sections of each stream, three electrofishing units and three additional netters were used. Reaches were assumed to be biologically closed and block nets were not used during electrofishing passes (Bohlin et al. 1989; Mitro and Zale 2000).

All fish were measured (FL) and identified to species. Rainbow trout and cutthroat/rainbow hybrids were segregated based on morphological characteristics (Kruse 1998). Fish in the genus *Oncorhynchus* with white fin margins, no or faint red throat slashes and numerous spots towards the anterior of the body were pooled as rainbow trout (Kruse 1998; Meyer et al. 2003). Species determinations for rainbow trout and cutthroat trout were sometimes difficult with fish smaller than 75mm. However, given the temporal segregation in spawning of rainbow and cutthroat trout in 2004 (Figure B.1 – B.3), rainbow trout fry appeared on average to be 20-30 mm larger and were readily distinguished from young-of-the-year cutthroat trout.

Length-frequency histograms by stream and species were used to determine seven size/species groups for abundance estimate calculations: young-of-the-year cutthroat (YOY), Yellowstone cutthroat 80-150 mm (YCT1), cutthroat ≥150 mm (YCT2), brook trout <150 mm (EBT1), brook trout ≥150 mm (EBT2), rainbow trout <120 mm (RBT1) and rainbow trout ≥120 mm (RBT2) (Figures C.1-C.5). Electrofishing capture data for multiple-pass sites were analyzed using the closed-capture maximum-likelihood estimator in Program MARK (White and Burnham 1999). Estimates of abundance and capture probability were calculated for each size/species group by sampling site. Capture probability was assumed to be constant across all passes for each size/species group, as the dataset was not sufficiently large to produce reliable results when accounting for differing capture probabilities on subsequent passes.

Capture probabilities were averaged by stream for each species/group, as they did not significantly differ between sites (due to overlapping 95% confidence intervals). Average capture probability was weighted according to the total catch per site (of the first three removals only, to equalize effort across all sites) and calculated across all multiple-pass sites. Capture probabilities equal to 1 and less than 0.05 for a given species/size group were not included when calculating average capture probabilities, as these values resulted from low “n” or poor depletions and were not considered reliable.

Fish abundance estimates for each size/species group at single-pass sites were calculated by dividing the total catch by the weighted average capture probability of the stream (Young and Guenther-Gloss 2004). Reach-level fish abundance estimates were used to extrapolate to stream-wide fish population estimates for each species/size group using the stratified random sample calculation methodology presented in Elzinga et al. (1998). When the calculated lower bound of the 95% confidence intervals for stream-wide population estimates was less than the total number captured, the lower bound was set equal to the total number of fish captured for that species/size group. Apparent mortality was used as a surrogate for survival, as I was not able to distinguish between mortality and emigration from the stream. Apparent survival over the winter was calculated for each size/species group by comparing the stream-wide abundance estimates from Spring 2005 to Fall 2004 (Mitro and Zale 2002).

Habitat Assessment

Physical habitat data was collected during base flows in July 2004 at all electrofishing survey sites prior to fish sampling. Habitat metrics included percent pools/riffles within a reach, percent willow present, substrate particle size distribution, percent spawning gravel, bank stability, undercut bank depth, average width and depth. Percent pools/riffles riffle within the reach was classified based on the criteria outlined in Kershner et al. (2004) and was measured using a tape measure. Willow cover was measured at each reach using a modified line intercept method. Measurements were taken along transects parallel to each bank in an upstream direction. “Present” or “absent” measurements were recorded every two meters within one meter of the edge of bankfull stage, resulting in 50 data points per reach. For “absent” to be assigned, willows must have been absent for at least a distance of 1m along the transect to accommodate branches of one willow that may stretch into another section. The number of “present” data points was then converted into a percentage to describe the percent of bank with willows present.

Riffle particle size distribution within each reach was determined using Wolman pebble counts as described in Harrelson et al. (1994). In reaches with multiple riffles, each riffle was sampled proportionally to the total riffle habitat it constituted within the reach, for a total of 100 particles measured. Percent spawning gravel was determined using spawning gravel size distribution data collected during spring redd surveys (Koenig 2006) and was defined as the percentage of riffle particles that fell within the interquartile range of the spawning gravels measured from cutthroat trout redds.

Bank stability was characterized by measuring the length of stable stream bank in each reach using a tape measure (Bozek and Rahel 1991). Stability was defined based on criteria presented in Kershner et al. (2004). Undercut bank depth was recorded with a meter stick every two meters along each bank for a total of 50 measurements and then averaged over the reach. Depth and bankfull width were recorded at five equidistance points along five equally spaced transects, resulting in 25 depth measurements and five width measurements per reach.

Regression Analyses

Relationships between local abundance of young-of-the-year (YOY) Yellowstone cutthroat trout (YCT) and reach-level habitat and biotic variables were evaluated using multiple linear regression techniques in SAS 9.1 (SAS 2003). Given that Fox Creek and Teton Creek are quite different in morphology, regression analyses were performed independently for each stream. Additionally, different factors may have explained YOY abundance in each stream, so individual analyses were done to reduce the likelihood of failing to include significant model variables that may be uniquely significant in each stream.

Reach abundance of YOY cutthroat trout was regressed against several explanatory variables. Model variable selection was accomplished using a combination of techniques. Correlations between the explanatory variables as well as potential nonlinear relationships were first examined using a correlation matrix and scatter plots (Proc Corr) using SAS 9.1 (SAS 2003). Only one variable from a highly correlated pair ($r^2 > 0.7$) was included in the analysis to reduce the initial number of variables and to minimize multicollinearity in the analysis. Habitat variables that remained after this preliminary screening included percent riffle, percent willow cover, percent stable bank, width/depth ratio, average undercut depth, and percent spawning gravel. Biotic variables remaining after this initial screening included the number of brook trout smaller than150 mm (EBT1), brook trout larger than 150 mm (EBT2), the number of rainbow trout smaller than 120 mm (RBT1) and rainbow trout larger than 120 mm (EBT2). Other remaining variables also included were the number of YCT redds within 200 m upstream of the reach, the distance to the nearest upstream documented YCT redd, and distance from the mouth

Lists of candidate regressions were produced using adjusted R-square selection, AIC selection and Mallow’s Cp selection. Additionally, backward and stepwise regression (SLE, SLS = 0.05) was used to generate addition candidate models for comparison. We limited our selection of the most parsimonious model to the best 1, 2, and 3 variable models only, regardless to selection procedure, given the limited sample size and degrees of freedom from each stream. After analyzing the distribution of the residuals, reach-level abundance estimates of YOY cutthroat trout were natural log transformed (log (x +1)) to meet the assumptions of identical, independent and normally distributed errors. Examination of condition indices from candidate models ensured that multicollinearity was within acceptable levels (defined here as values less than 20).

Egg-to-fry Survival

The estimated total egg deposition and subsequent overall egg-to-emergent fry survival was calculated using a combination of redd-survey data (Koenig 2006) and the fish abundance (electrofishing survey) data. Several assumptions were made during the calculations which included, (1) one female per redd, (2) female egg retention was zero, (3) fertilization was 100% and that (4) all eggs were deposited into the redd site. The number of female cutthroat trout spawning in Teton Creek and Fox Creek was determined using weekly redd counts in which each cutthroat redd was individually marked. Redds of large fluvial fish were easily identified by a single well-trained observer (Dunham et al. 2001), and a portion of the total redds counted as “definite” were excavated to determine what percentage actually contained eggs. We used 350 mm as the minimum spawner length based on the length at sexual maturity data presented in Meyer et al. (2003) for the South Fork Snake and Teton Rivers. Mean egg deposition per female was calculated according to $F = 0.0026 \times TL^{2.2255}$ (Meyer et al. 2003) where F is the number of eggs deposited into the gravel, and TL is the average spawner length in millimeters, taken from the mean length of cutthroat trout captured in the Teton River greater than 350mm during the 2003 population assessment (Garren et al. *In press*).

F was then multiplied by the product of the total redds counted and the proportion of redds containing eggs (as a correction factor to account for false redds) to obtain the total eggs deposited into each stream. Upper and lower bounds of the egg deposition estimate were determined using the 95% confidence bounds around the mean spawner length. Egg-to-fry survival was determined by dividing the estimated total number of eggs deposited into each stream by the stream-wide population estimates of fry sampled during September. Maximum and minimum egg-to-fry-survival estimates were determined using the highest and lowest bounds for both the number of eggs and number of fry to obtain “best” and “worst” case scenarios.

RESULTS

Regression Analyses

Abundance of juvenile Yellowstone cutthroat trout and young-of-the-year cutthroat trout (YOY) was highly variable among sampling locations within streams (Table 1.1). Rainbow trout abundance was variable both within and among streams (Table 1.1). YOY abundance in Fox Creek appeared to be consistently concentrated in upper portions of the study reach (Figure 1.4) and was positively related with distance from the mouth ($r^2 = 0.76$), negatively related to the distance to the nearest upstream redd ($r^2 = 0.58$), and positively related to both size classes of rainbow trout ($r^2 = 0.76$ and 0.47, respectively) according to simple linear regressions (Table 1.2). Other important singular explanatory variables in Fox Creek included percent spawning gravel, mean width, brook trout (>150mm) and percent riffle ($r^2 = 0.41 – 0.45$) (Table 1.2).

Results from the multiple regression analyses for Fox Creek produced similar results. Several equations with high adjusted-R^2 values were produced, but we limited our selection to models with a maximum of two explanatory variables due to the low number of observations (Table 1.3). A model containing “distance from the mouth (m)” and “percent riffle habitat” best explained Fox Creek abundance of YOY cutthroat trout with and adjusted $R^2 = 0.8358$ and all parameters except the intercept significantly different from zero (Table 1.4).

Table 1.1. Estimated reach-level trout abundance and selected associated habitat characteristics for Fox and Teton Creek, Fall 2004. “Est. YOY” refers to young-of-the-year cutthroat trout.

Site	Est. YOY	Distance From Mouth	Redds Upstream (200m)	Nearest Redd (upstream)	% Riffle	% Spawn	% Stable	WD Ratio	Mean Width	Est. EBT1 <150mm	Est. EBT2 >150mm	Est. RBT1 <120mm	Est. RBT2 >120mm
Fox Creek													
FC02	0	753	0	2254	0.0	0	100	17.6	14.8	1	1	0	2
FC03	0	1261	0	1746	0.0	0	100	18.8	13.8	4	3	0	0
FC04	0	1809	0	1198	0.0	0	100	21.9	12.5	11	4	0	0
FC05	1	2338	0	669	0.0	0	66	19.3	11.6	36	3	27	2
FC06	4	2797	0	210	0.0	0	58	23.6	13.5	11	3	36	3
FC07	92	3236	0	720	41.4	55	68	25.0	10.6	5	5	36	3
FC08	5	3643	0	333	19.8	61	100	12.3	6.8	2	0	4	6
FC09	42	4239	0	561	0.0	0	62	25.9	10.2	39	1	34	11
FC10	112	4801	3	23	65.6	62	100	25.0	10.8	11	7	44	11
FC11	104	5280	3	71	8.0	57	87	14.4	8.3	14	29	43	29
FC12	165	5838	3	109	40.1	53	93	22.7	9.7	0	26	38	18
FC13	73	6341	7	14	25.6	60	100	21.7	10.0	18	19	105	13
FC14	61	6768	1	76	0.0	0	100	14.1	9.0	46	33	33	32
Teton Creek													
TC02	0	722	0	1703	0.0	0	57	21.6	13.1	15	2	0	0
TC03	0	1248	0	1177	0.0	0	67	20.7	14.1	12	6	1	0
TC04	5	1734	0	691	17.0	43	70	22.5	14.0	24	2	0	0
TC05	15	2235	1	190	0.0	0	83	22.8	14.6	5	6	0	0
TC06	5	2767	2	64	52.8	61	62	30.5	13.5	5	1	1	2
TC07	44	3493	0	723	0.0	0	85	25.8	13.2	17	11	0	0
TC08	0	3946	0	319	37.8	53	73	27.3	13.2	19	11	0	0
TC09	220	4615	0	1757	33.6	55	89	20.2	12.1	10	3	1	0
TC10	88	5289	0	1083	0.0	0	100	16.7	11.4	31	23	0	0
TC11	0	5787	0	585	32.4	60	100	24.0	12.1	10	0	0	0
TC12	16	6331	0	41	16.6	61	100	19.9	8.7	27	10	0	0
TC13	0	7037	1	197	34.8	56	70	32.0	14.9	2	2	0	0
TC14	0	7566	0	268	36.6	41	60	29.0	13.1	10	6	0	0
TC15	209	8228	3	13	38.2	41	90	22.7	10.4	29	20	0	0
TC16	93	8717	1	48	46.8	34	53	25.7	8.0	51	17	0	0
TC17	218	9173	3	65	25.2	18	59	25.3	9.2	37	8	0	0
TC18	0	8753	[a]	[a]	21.6	28	60	55.4	13.2	12	6	0	0
TC19	63	9233	[a]	[a]	27.0	34	100	33.2	12.5	35	0	0	0
UN1	236	8396	2	37	21.2	24	95	17.9	6.2	9	6	0	0
UN2	114	8792	5	32	51.2	35	100	10.7	3.7	6	3	0	0
UN3	17	9210	3	67	72.6	19	100	15.5	4.1	4	1	0	0
UN4	1	9663	0	0	70.0	25	100	25.0	5.3	2	0	0	0

[a] No redd survey data recorded, treated as missing values.

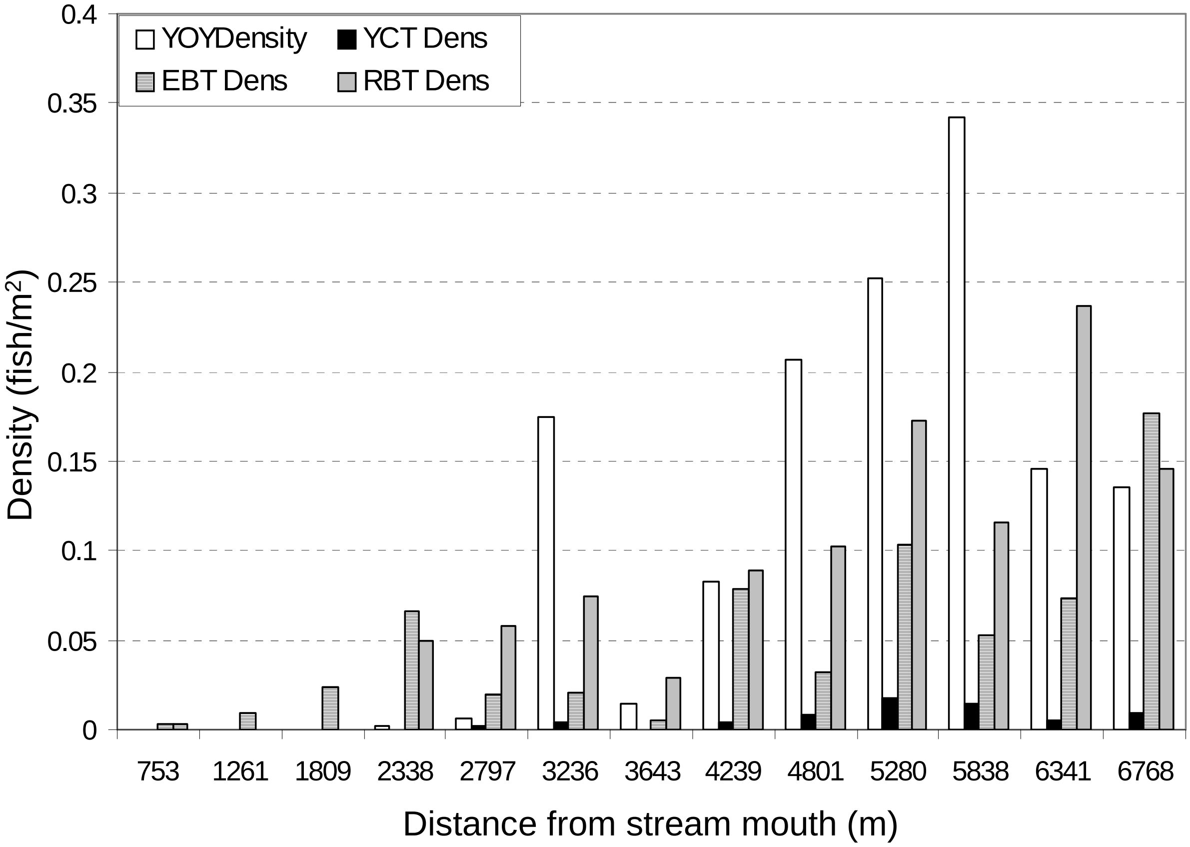

Figure 1.4. Density of trout (trout/m^2) versus distance from the mouth (m), Fox Creek, Fall 2004. Densities are combined across species / size groups except for cutthroat fry, labeled as “YOY Density.”

Table 1.2. Univariate regressions with Ln (YOY+1) as the dependent variable for Fox Creek and Teton Creek, Fall 2004.

Independent Variable	df	*F*-value	r^2	*P*	Estimate	Intercept
Fox Creek						
Distance from mouth (m)	12	35.44	0.76	<0.0001	0.0009	-0.755
Nearest redd upstream (m)	12	15.73	0.58	0.002	-0.002	4.072
Rainbow trout >120mm (fish/50m)	12	11.64	0.51	0.006	0.139	1.313
Rainbow trout <120mm (fish/50m)	12	9.75	0.47	0.010	0.050	1.179
Spawning gravel (%)	12	9.11	0.45	0.012	0.046	1.486
Mean width (m)	12	8.31	0.43	0.015	-0.589	9.124
Brook trout >150mm (fish/50m)	12	7.84	0.42	0.017	0.112	1.565
Riffle (%)	12	7.52	0.41	0.019	0.061	1.78
Width:Depth ratio	12	0.55	0.05	0.476	0.099	0.710
Brook trout < 150mm (fish/50m)	12	0.33	0.03	0.575	0.023	2.370
Bank stability (%)	12	0.04	0.003	0.854	-0.006	3.314
Willow cover (%)	12	0.02	0.002	0.880	-0.006	2.789
Undercut bank (m)	12	0.02	0.002	0.889	1.602	2.530
Redds upstream (within 200m)	12	6.15	0.36	0.031	0.577	1.960
Teton Creek						
Distance from mouth (m)	21	2.76	0.12	0.112	0.0003	1.015
Nearest redd upstream (m)	19	0.36	0.02	0.557	-0.0005	2.840
Rainbow trout >120mm (fish/50m)	21	0.12	0.01	0.731	-0.417	2.585
Rainbow trout <120mm (fish/50m)	21	0.02	0.001	0.9001	-0.176	2.573
Spawning gravel (%)	21	0.28	0.02	0.6055	-0.012	2.914
Mean width (m)	21	5.18	0.21	0.034	-0.283	5.646
Brook trout >150mm (fish/50m)	21	3.86	0.16	0.064	0.132	1.686
Riffle (%)	21	0	0.002	0.945	0.002	2.503
Width:Depth ratio	21	4.33	0.18	0.051	-0.105	5.151
Brook trout < 150mm (fish/50m)	21	5.14	0.20	0.0347	0.075	1.287
Bank stability (%)	21	3.02	0.13	0.098	0.045	-1.057
Willow cover (%)	21	0.04	0.002	0.848	0.003	2.450
Undercut bank (m)	21	0.03	0.002	0.862	-2.325	2.665
Redds upstream (within 200m)	19	6.8	0.27	0.018	0.778	1.778

Table 1.3. Summary of best two two-variable and three-variable multiple regression models with Ln (YOY+1) as the dependent variable and the associated selection criteria.

Variables	R^2	Adj. R^2	C(p)	AIC
Fox Creek				
Distance, % Riffle	0.8632	0.8358	-	-2.1285
% Riffle, RBT2	0.8375	0.8050	-	0.1087
Teton Creek				
Redds Upstream, FEBT2	0.4977	0.4386	2.25	22.4084
Redds Upstream, FEBT1	0.4732	0.4112	3.0473	23.3612
Redds Upstream, % Stable, FEBT1	0.6030	0.5286	0.8461	19.702
WDratio, Redds Upstream, FEBT2	0.5593	0.4767	2.2606	21.7914

In Teton Creek, higher local abundances appeared to be more variable along the length of the stream, but often appeared higher in upper reaches, as well as the small spring-fed tributary Unnamed Creek (Figure 1.5). Abundance of YOY cutthroat trout in Teton Creek was only weakly negatively related to mean width ($r^2 = 0.21$) and positively to brook trout (<150 mm) ($r^2 = 0.16$) and to the number of redds within 200 m upstream ($r^2 = 0.27$) using simple linear regressions (Table 1.2). These results suggest that young cutthroat trout were often higher in abundance in reaches further upstream, were associated with other juvenile trout, and were close to areas of spawning activity.

Multiple regression models explained less of the variation in YOY cutthroat abundance in Teton Creek. Best-model selection was limited to models with a maximum of three explanatory variables (Table 1.3). Teton Creek abundance of YOY cutthroat trout was best explained by a three-variable equation containing “number of redds within 200m upstream,” “percent stable bank,” and “abundance of brook trout (<150mm).” The equation had an adjusted R^2 of 0.5286 and all parameters including the intercept were

Table 1.4. Parameter estimates for the linear regression models for abundance (Ln+1 transformed) of YOY cutthroat trout in Fox and Teton Creeks.

Dependent Variable	df	Parameter estimate	Standard error	*t*	*P*
		Fox Creek			
Intercept	1	-0.7160	0.5192	-1.38	0.1979
Distance from mouth	1	7.747×10^{-4}	1.340×10^{-4}	5.78	0.0002
% Riffle	1	0.03271	0.01210	2.70	0.0222
		Teton Creek			
Intercept	1	-3.527	1.881	-1.87	0.0792
Redds upstream (within 200m)	1	0.7250	0.2368	3.06	0.0075
% Stable bank	1	0.04794	0.02098	2.29	0.0361
Brook trout (<150mm)	1	0.09194	0.02721	3.38	0.0038

significantly different from zero (Table 1.4).The variables included in this model explained relatively little of the variation in YOY abundance individually (Table 1.2) but accounted for almost 53% of the variability in YOY abundance when combined.

The results from the initial regression analyses suggested that variability in YOY cutthroat trout abundance was largely explained by variables that are related to spawning activity. To determine which variables might be significant if influence of spawning-associated variables were removed, I performed a second set of regressions including only habitat variables typically unassociated with spawning. These variables included mean width, width / depth ratio, percent stable bank, percent willow cover, and average undercut bank depth (m). In Fox Creek, mean width was the only significant single variable and explained 43% of the variation in YOY cutthroat trout in Fox Creek (Table 1.2).

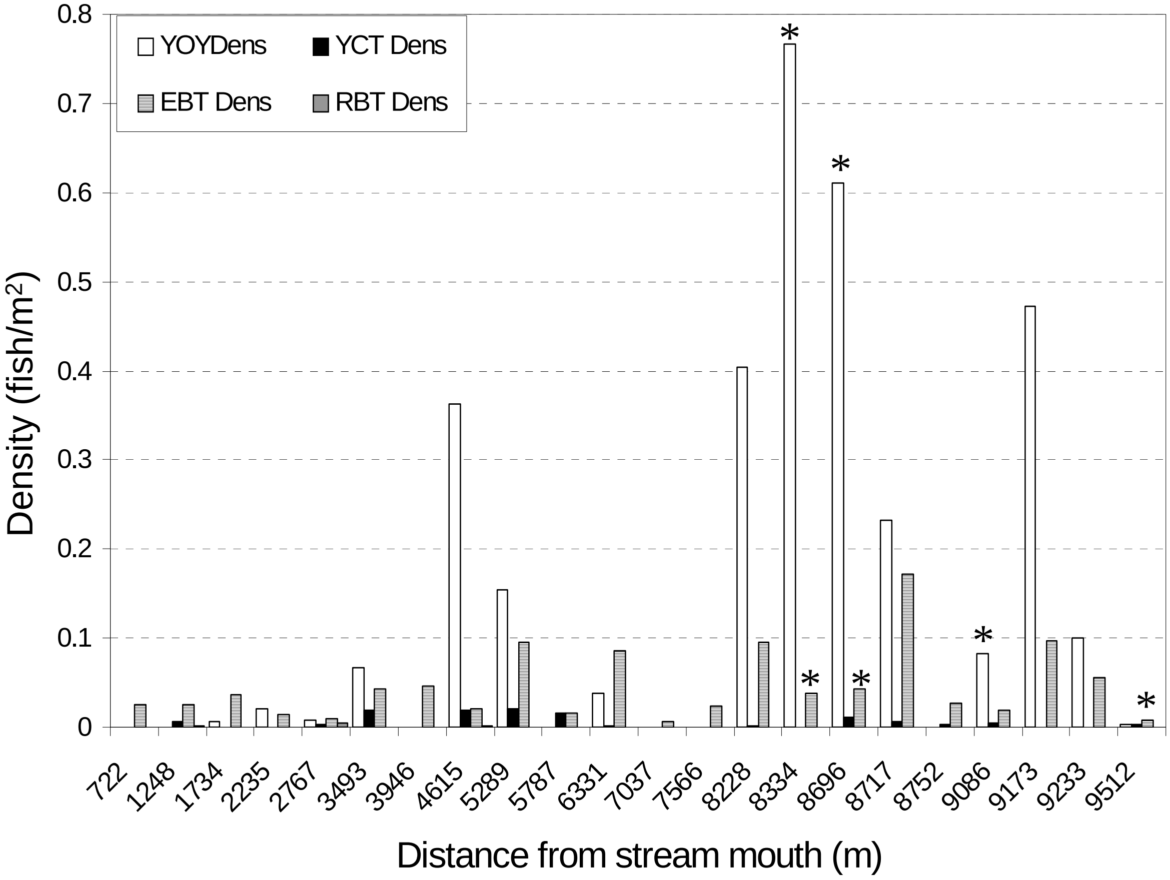

Figure 1.5. Density of trout (trout/m^2) versus distance from the mouth (m), Teton Creek, Fall 2004. Asterisks indicate data pertaining to Unnamed Creek, a small spring-fed tributary to upper Teton Creek. Densities are combined across species / size groups except for cutthroat fry, labeled as “YOY Density.”

However, YOY cutthroat trout abundance (A) was best explained by Ln (A+1) = 6.142 – $0.7619X_1 + 0.2411X_2$, where X_1= mean width and X_2 = width / depth ratio. The equation had an adjusted R^2 of 0.606 (Table 1.5). Both coefficients and the intercept were significantly different from zero (X_1, t = -4.36, P = 0.0014; X_2, t = 2.71, P = 0.0219; intercept, t = 2.90, P = 0.0157). These results suggest that YOY cutthroat trout are likely to be more abundant in narrow stream reaches (or reaches farther upstream) than those that are wide relative to their depth. Additionally, width/depth ratio appears to be significant only when combined with mean depth as explanatory variables.

Table 1.5. Statistical summary of the best linear regression models for YOY cutthroat trout, with and without spawning-related variables (respectively) for Fox Creek and Teton Creek, Fall 2004. The variable “Distance from the mouth” has been abbreviated to “Distance” and “Brook trout (<150mm)” has been abbreviated to “EBT1.”

Source of Variation	df	Sum of squares	Mean square	*F*	*P*	Adj R^2
Fox Creek: Ln(YOY+1) = Distance + % Riffle						
Model	2	43.84	21.95	31.55	<0.0001	0.8358
Error	10	6.956	0.6957			
Total	12	50.85				
Fox Creek: Ln(YOY+1) = Mean Width + WD ratio						
Model	2	34.16	17.08	10.23	0.0038	0.6060
Error	10	16.69	1.670			
Total	12	50.85				
Teton Creek: Ln(YOY+1) = ReddsUpstream + % Stable + EBT1						
Model	3	54.54	18.18	8.1	0.0017	0.5286
Error	16	35.90	2.244			
Total	19	90.44				
Teton Creek: Ln(YOY+1) = Mean Width [a]						
Model	1	20.48	20.48	5.18	0.034	0.1660
Error	20	79.08	3.954			
Total	21	99.56				

[a] Model parameters become insignificant when WD ratio added.

A similar pattern resulted for Teton Creek. When spawning-related variables were not included, mean width explained 20% of the variation in YOY cutthroat trout abundance (Table 1.2). YOY cutthroat trout abundance (A) was best explained by Ln (A+1) = 3.96 – 2.289X_1, where X_1 = mean width. The equation had an adjusted R^2 of 0.160 (Table 1.5). Both the intercept and the coefficient were significantly different from zero (X_1, t = -2.28, P = 0.0340; intercept, t = 3.96, P = 0.0008). No significant multiple regression models resulted from this suite of variables. These results suggest that local abundances of YOY cutthroat trout are largely influenced by spawning-related variables, and less so by the habitat variables we measured.

Stream-wide Abundance Estimate

Data collected from the Fall 2004 sampling (Table 1.6) indicated that YOY cutthroat were the most abundant size / species group in Fox Creek followed by young rainbow trout (<120 mm) (Figure 1.6). Eastern brook trout and rainbow trout accounted for the majority of age-1 and older trout. Estimates of total age-1 and older cutthroat trout were small compared to the numbers of Eastern brook trout and rainbow trout. Total abundance estimates from Spring 2005 indicated lower numbers of trout across all groups except rainbow trout (>120 mm). However, estimates from several size/species groups could not be distinguished between spring and fall, as evident by the overlapping confidence intervals (Figure 1.7). This was likely due to the large variation in abundance estimates among sites, resulting in wide confidence bands around the stream-wide estimates.

Table 1.6. Stream-wide trout abundance estimates for Fox Creek and Teton Creek in Fall 2004. Columns labels include each fish species/size (mm) group for which estimates were calculated.

Season	Parameter	YOY	YCT(80-150)	YCT(151+)	EBT (<150)	EBT (151+)	RBT(<120)	RBT (120+)
Fox Creek								
Fall 2004	Population Est.	7,535	302	61	2,164	1,537	4,508	1,497
	Variance	1,934,681.00	2,982.74	1,083.34	372,140.78	68,025.36	797,419.35	64,559.49
	Error bound	2,726.22	107.04	64.51	1,195.67	511.20	1,750.25	498.01
	Lower 95% CI	4,809	195	7[a]	968	1,026	2,758	999
	Upper 95% CI	10,261	409	125	3,360	2,048	6,258	1,995
Spring 2005	Population Est.	338	16	153	549	962	1,083	1,634
	Variance	8,035.59	220.65	6,913.49	69,588.35	162,098.54	352,750.50	445,313.57
	Error bound	175.70	29.11	162.97	517.04	789.12	1,164.10	1,307.94
	Lower 95% CI	162	3[a]	18[a]	32	173	16[a]	326
	Upper 95% CI	513	45	316	1,066	1,752	2,247	2,942
Apparent Survival		4%	5%	251%	25%	63%	24%	109%
Teton Creek								
Fall 2004	Population Est.	14,240	512	145	4,012	1,526	-[a]	-[a]
	Variance	14,004,296.42	31,852.24	1,884.76	321,945.98	86,759.71	-[a]	-[a]
	Error bound	7,334.77	349.81	85.09	1,112.11	577.32	-[a]	-[a]
	Lower 95% CI	6,905	162	60	2,900	949	3[b]	2[b]
	Upper 95% CI	21,575	862	230	5,124	2,104	-[a]	-[a]
Spring 2005	Population Est.	1,903	179	216	2,364	1,266	-[a]	-[a]
	Variance	20,264.07	2,945.99	3,187.78	35,419.26	90,000.72	-[a]	-[a]
	Error bound	279.01	106.38	110.66	368.87	588.00	-[a]	-[a]
	Lower 95% CI	1,623	73	106	1,995	678	3[b]	2[b]
	Upper 95% CI	2,182	286	327	2,732	1,854	-[a]	-[a]
Apparent Survival		13%	35%	150%	59%	83%	-[a]	-[a]

[a] Number captured too low to generate estimate

[b] Lower error bound set to actual number captured.

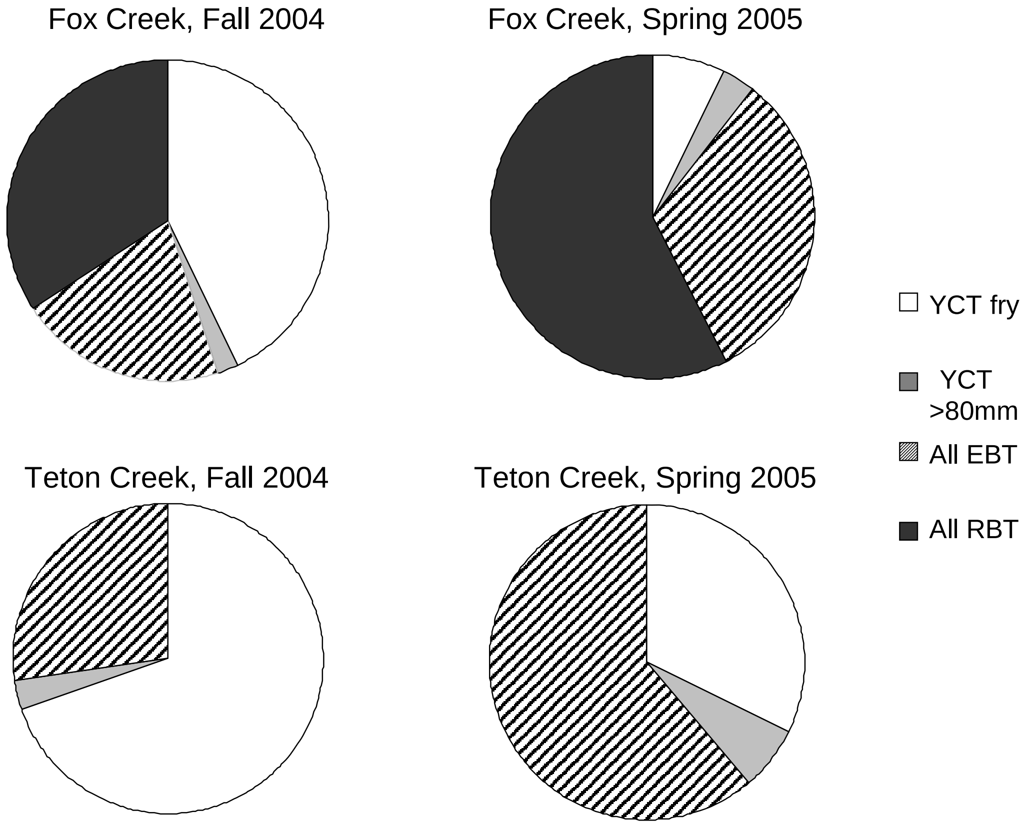

Figure 1.6. Species composition by total of estimated abundance by stream and season.

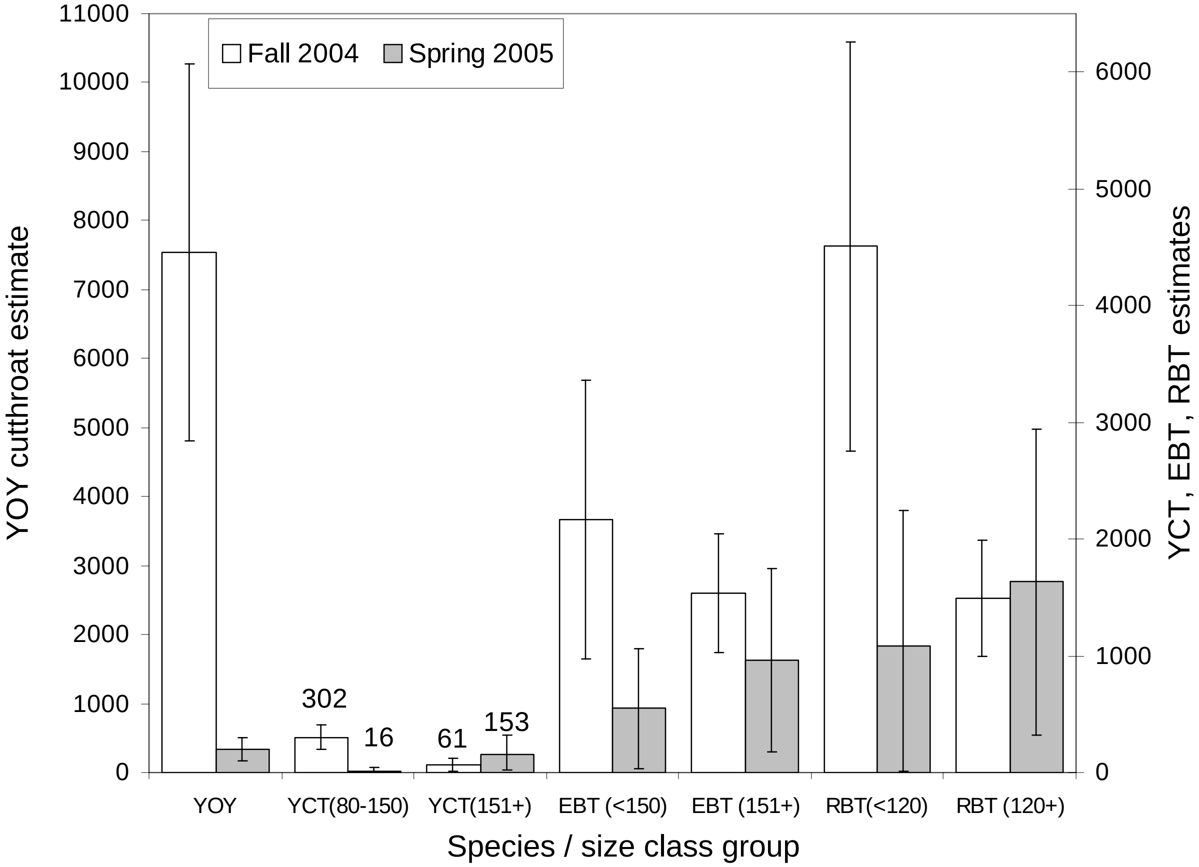

Figure 1.7. Stream-wide abundance estimates by season for Fox Creek. Estimates are shown for all trout species / size class groups with associated 95% confidence intervals.

Table 1.7. Parameters used to calculate estimated egg to fry survival of Yellowstone cutthroat trout in Fox Creek and Teton Creek (with Unnamed Creek included) for Fall 2004. ‘N Correct’ refers to the number of excavated redds containing eggs or fry.

Parameter	Fox Creek	Teton / UN Creeks
YCTredds	33	37
N Correct / N excavated	10 / 17	13 / 16
Mean YCT Length(mm)	432	432
Lower 95%CI Length(mm)	413	413
Upper 95%CI Length(mm)	451	451
Mean Eggs	36,960	57,086
Fry N	7,535	14,240
Lower 95%CI Fry N	4,809	6,905
Upper 95%CI Fry N	10,261	21,575
Min Surv Est	12%	11%
Mean Surv Est	20%	25%
Max Surv Est	31%	42%

Apparent survival in Fox Creek from Fall 2004 to Spring 2005 was lowest for YOY cutthroat and age-1 cutthroat trout (80-150 mm) (Table 1.6). Apparent survival for age-0 trout in Fox Creek and Teton Creek was estimated at 4% and 13%, respectively. Apparent survival for age-1 cutthroat trout in Fox Creek and Teton Creek was 5% and 35%, respectively. These results suggest that the majority of production potential in Fox Creek is monopolized by rainbow trout and brook trout.

During Fall 2004, YOY cutthroat trout also made up the largest group of trout in Teton Creek (Figure 1.6). Brook trout of both age-0 and older were the next most abundant species / size group (Table 1.6). Unlike Fox Creek, estimates of total age-1 and older cutthroat trout were greater than rainbow trout. Stream-wide abundance in Spring 2005 were lower than Fall estimates for most species groups, except cutthroat trout (150+ mm), rainbow trout (<120 mm) and rainbow trout (120+ mm), but confidence intervals around abundance estimates overlapped between Fall and Spring for all groups except YOY cutthroat and young brook trout (<150 mm) (Figure 1.8). Apparent overwinter survival was high for all species/size classes except cutthroat (80-150mm), which was below values reported in other studies (Scarnecchia and Bergersone 1986; Rieman and Apperson 1989; Petersen and Fausch 2004). Results suggest that most of the fish production potential of Teton Creek is utilized by brook trout and that rainbow trout have yet to establish a strong presence in Teton Creek.

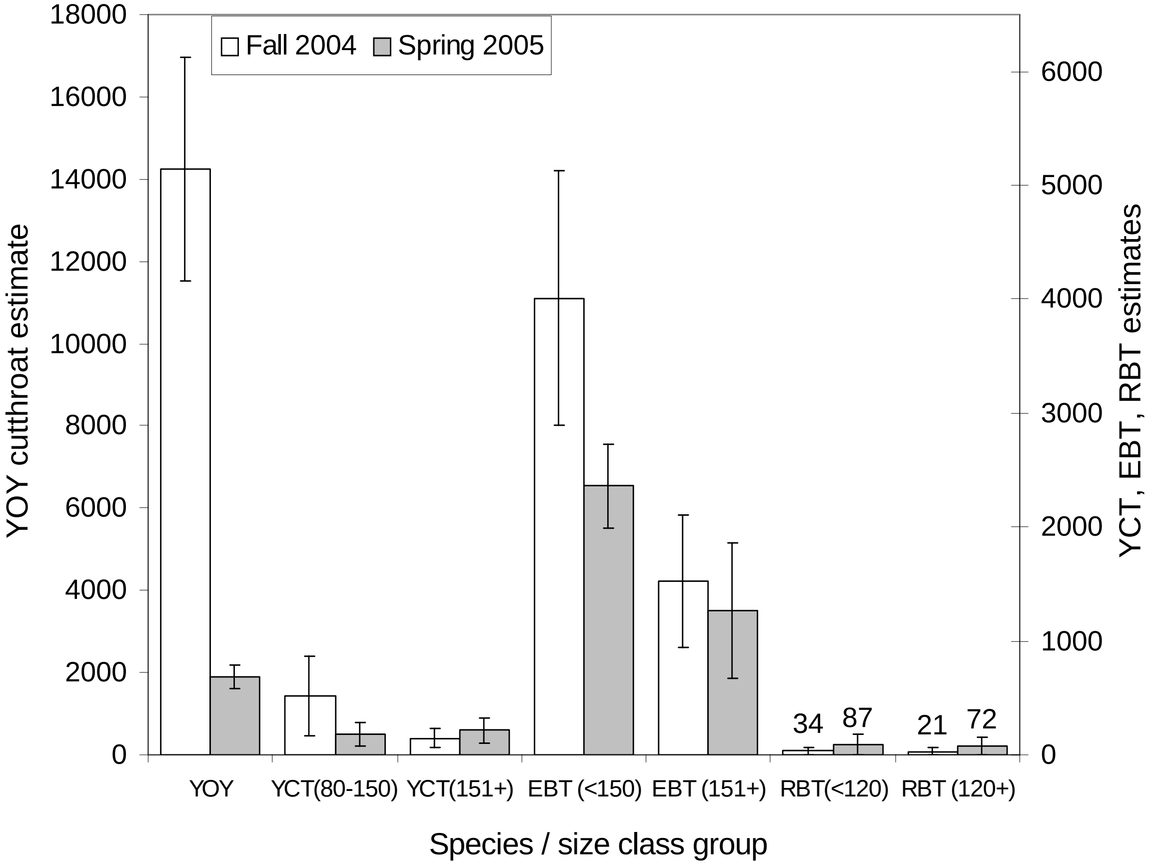

Figure 1.8. Stream-wide abundance estimates by season for Teton Creek. Estimates are shown for all trout species / size class groups with associated 95% confidence intervals.

Egg-to-fry- Survival Estimates

Egg-to-fry survival was similar between Fox Creek and Teton Creek (Table 1.7). Survival in Fox Creek was roughly 20%, with minimum survival estimated at 12% and a maximum of 31% (Figure 1.9). Egg-to-fry survival rates in Teton Creek were slightly higher at 25%, with minimum and maximum survival of 11% and 42%, respectively (Figure 1.9).

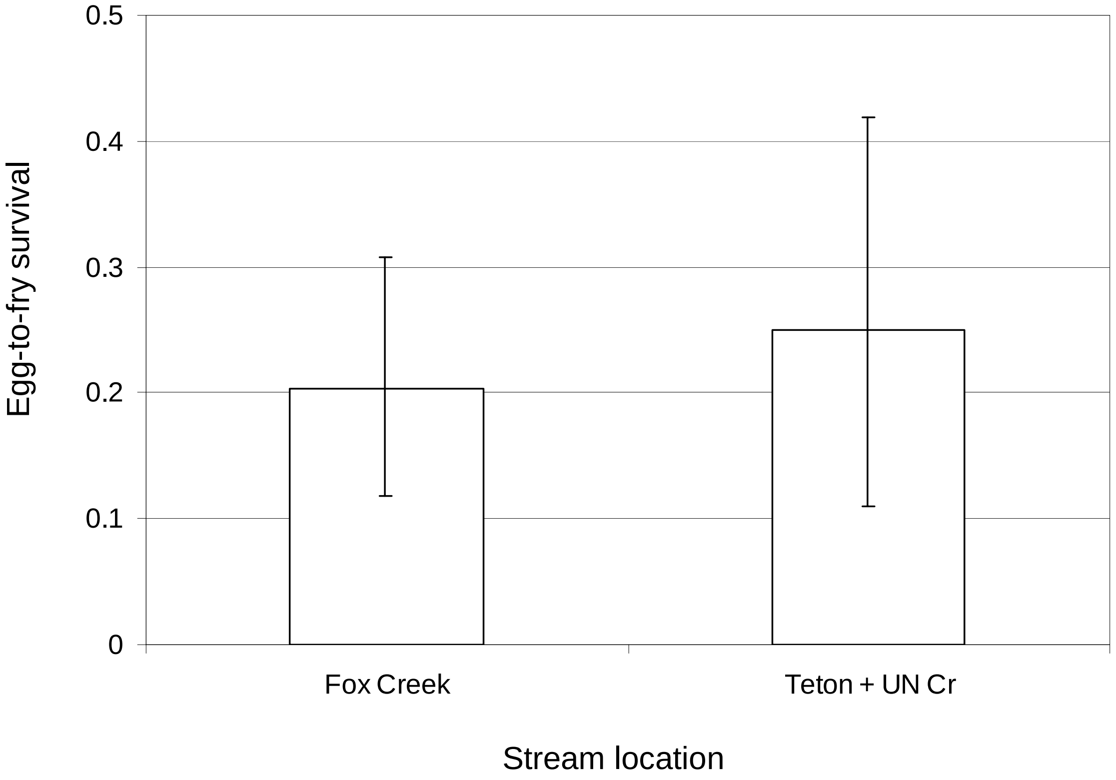

Figure 1.9. Estimated Yellowstone cutthroat trout egg-to-fry survival (percent) by stream for Spring 2004. Teton Creek values include those from Unnamed Creek. Error bars are maximum and minimum possible survival based on 95% CI of the mean adult spawning cutthroat size and stream-wide fry population estimates.

DISCUSSION

Habitat and Cutthroat Trout Fry Distribution

The first objective of this study was to determine which habitat attributes explained the greatest variation in cutthroat fry abundance. Multiple linear regression techniques have been used extensively to describe relationships between trout abundance and habitat variables (Binns and Eisermann 1979; Bowlby and Roff 1986; Scarnecchia and Bergersen 1987; Lanka et al. 1987; Fausch et al. 1988). One of the major objectives of regression-based approaches to explaining trout abundance in relation to habitat characteristics is to identify habitat attributes potentially limiting trout populations. A major assumption in using such an approach to identify limiting factors (by habitat type) is that the population of interest is actually limited by those habitat attributes that were measured, and not some factor such as fishing mortality, disease, or competition (Fausch et al. 1988; Clarkson and Wilson 1995). Our regression analyses results suggest that the distribution and localized abundance of cutthroat trout fry in Teton Creek and Fox Creek is largely related to spawning locations. Close association of spawning habitat and salmonid density has been demonstrated for brown trout (Solomon and Templeton 1976; Mortensen 1977; Beard and Carline 1991), juvenile Chinook salmon (*Oncorhynchus tshawytscha*) (Richards and Cernera 1989), golden trout (*Oncorhynchus mykiss aquabonita*) (Knapp et al. 1998), and cutthroat trout (Moore and Gregory 1988; Trotter 1989; Bozek and Rahel 1991).

The best single variable that explained YOY cutthroat abundance in Teton Creek was the number of redds upstream (within 200 m). Alone, this variable explained less than half of the variation in YOY cutthroat abundance compared to the three-variable model. In fact, each of the three variables explained relatively little of the total variation in YOY cutthroat abundance ($r^2 = 0.13\text{-}0.27$) but had an adjusted R^2 of 0.53 when combined, indicating the combination was important. Bozek and Rahel (1991) reported similar findings in which the proportion of spawning gravel explained little variation in cutthroat fry density unless combined with shallow depths. In contrast, we did find significant single-variable correlations of cutthroat fry to spawning sites, suggesting that spawning locations themselves are of predominant importance in determining local abundance of cutthroat fry in Teton Creek. Additionally, the best multiple regression equation for Teton Creek did not include percent spawning gravel as an explanatory variable. One explanation may be that there simply was not enough variation in the percent of spawning gravel between reaches to explain variability in YOY abundance. Alternately, YOY abundance may not depend on the percent of spawning gravel in Teton Creek. Compared to the streams studied by Bozek and Rahel (1991), Teton Creek is much larger with lower gradient. Suitable sizes of gravel may be inherently more abundant in Teton Creek as a function of its different geomorphology, such that gravel is not a factor limiting the current number of spawning adults.

The proportion of stable bank was another variable included in the best Teton Creek model. Our definition of stable bank was based on that outlined in Kershner et al. (2004), where stability is largely a function of the amount of bank cover. Such cover usually came in the form of perennial vegetation, root mats, large gravel or woody debris. Shortly after emergence, cutthroat fry occupy habitats suitable to their size and metabolic capacity. These areas provide appropriate gradients of depth, velocity, cover and food

(Moore and Gregory 1988). The features associated with stable banks in our study likely provided these low-velocity, complex margin habitats required by cutthroat trout fry (Bustard and Narver 1975; Aho 1977; Moore and Gregory 1988). In this sense, bank stability may play a part in providing the conditions important to the success of cutthroat fry during their first summer.

Brook trout of both younger and older size classes, EBT1 (<150 mm) and EBT2 (>150 mm) respectively, were correlated with YOY cutthroat abundance. Brook trout abundance was an important variable in both of the best three-variable regressions as well as the best two-variable regressions. Brook trout have similar spawning habitat requirements as cutthroat trout, so it is not surprising to see correlations of age-0+ brook trout to cutthroat spawning locations (Moyle 2002). Consistent inclusion of brook trout abundance as explanatory variables indicates that cutthroat fry in Teton Creek are also closely associated with both size-classes brook trout, and that overlap in habitat utilization likely exists between the species.

Similar to Teton Creek, the distribution of YOY cutthroat trout in Fox Creek was largely explained by spawning-related variables. The best single explanatory variable was “distance from the mouth”, followed by the “distance to the nearest redd upstream”. In the case of Fox Creek, these two variables are almost equivalent, given that cutthroat spawning locations were almost exclusively concentrated in upper portions of the stream. Similar concentrations of spawning sites have been reported in Montana on the Madison River (Downing et al. 2002) and in the Gallatin River basin (Magee et al. 1996). The best multivariable model that explained local YOY cutthroat abundance was the combination of “distance from the mouth” and the “percent riffle habitat”. “Percent riffle habitat” explained relatively little of the variation in YOY abundance, but became important when combined with “distance from the mouth” (Table 1.2). This suggests that riffle areas farther upstream were closely associated with YOY cutthroat trout. Given that most of the spawning locations were concentrated farther upstream and that redds are usually located in riffle areas, the combination of percent riffle habitat with distance upstream reinforces the idea that YOY cutthroat are largely associated with spawning locations. Close associations of cutthroat trout fry to spawning areas suggests that dispersal from natal areas may be limited during early life stages. Other authors have reported similar findings for cutthroat trout (Moore and Gregory 1988; Trotter 1989; Bozek and Rahel 1991), as well as brown trout (Elliot 1986; Newman and Waters 1989; Beard and Carline 1991) juvenile Chinook salmon (*Oncorhynchus tshawytscha*) (Richards and Cernera 1989), and golden trout (*Oncorhynchus mykiss aquabonita*) (Knapp et al. 1998).

Unlike the results of Bozek and Rahel (1991) and Knapp et al. (1998), cutthroat fry in both Fox Creek and Teton Creek were not closely related to the proportion of available spawning habitat but were correlated with spawning locations. This distinction is rather subtle yet bears important conservation implications. A correlation to spawning habitat availability (such as percent spawning gravel) would suggest that spawning habitat is likely a limiting factor in the abundance of juvenile trout. However, we found no relationship between the percent of spawning gravel and cutthroat fry in Teton Creek, no relationship to percent riffle habitat in Teton Creek, and only a weak correlation (compared to other single variables) to percent riffle and percent spawning gravel in Fox Creek. The strongest relationships were those that were directly related to the locations of known spawning sites. In Teton Creek, the most important explanatory variable was the number of nearby redds and not the amount of spawning gravels or riffle habitat. The vast majority of cutthroat spawning in Fox Creek occurred in the uppermost portion of the stream. Therefore, we regard distance from the mouth largely to be a surrogate of local redd density. Distance from the mouth explained 76% of the variation in YOY cutthroat abundance alone. The addition of percent riffle habitat (included in the best multiple regression equation) added relatively little to the adjusted R^2 value, but did improve the model fit. This suggests that the juxtaposition of riffles and distance upstream may be more important than just upstream locations alone. Although the percent of spawning gravel alone was significantly correlated with YOY cutthroat abundance, it explained less variation than variables associated with the number of nearby redds.

It is possible that the sampling may have missed areas of high cutthroat fry densities. In this case, the habitat–abundance correlations I found may not accurately reflect the relationships between local abundance and habitat metrics I measured. However, accepting that the sampling accurately represents the abundance– relationships operating within these streams, then the habitat regression analysis indicates that fall abundances of YOY cutthroat trout are not limited by the amount of available spawning habitat, but rather by the number of adults actually spawning.

Overall, we found relatively little correlation of cutthroat fry abundance to non-spawning related variables such as undercut bank, percent willow cover, and percent stable bank, even when spawning-related variables were omitted from the analysis. Other researchers have also reported a lack of correlation to such variables (Newman and Waters 1989; Beard and Carline 1991; Bozek and Rahel 1991; Magee et al. 1996). Mean width did explain some of the variability in cutthroat fry abundance, and such negative correlations of fry abundance to width have been reported previously (Bozek and Rahel 1991; Rosenfeld et al. 2000). Narrow stream segments may provide relatively more edge habitat and benign hydrologic conditions required by newly emerged salmonid fry (Moore and Gregory 1988; Rosenfeld et al. 2000). Although width was significantly related to cutthroat fry abundance, non-spawning related variables explained much less of the variability in fry abundance. This suggests that on the scale of individual tributaries, there either was not enough variability in habitat conditions or that YOY cutthroat abundance is simply not related to the habitat variables we measured. Another possibility is that the abundance of cutthroat fry may have been too low in some locations to detect meaningful patterns. These results imply that sampling effort aimed at determining where young-of-the-year trout are most likely to occur may be better-spent documenting spawning locations rather than exhaustively measuring total available spawning habitat (Bozek and Rahel 1991).

Rosenfeld et al. (2000) suggested that the lack of correlation of juvenile cutthroat trout and coho salmon (*Oncorhynchus kisutch*) to rearing habitat attributes indicated that these populations were limited by factors other than summer rearing habitat. However, poor predictability from habitat models can result from inappropriate assumptions and omission of key habitat variables (Beard and Carline 1991). This is likely the case in the Teton Valley, where the number of spawning adults, not the available spawning habitat, largely determined numbers of cutthroat fry. When the assumption that fish abundance is limited by the habitat available is not met, weak correlations to habitat variables can result since too few fish are available to occupy suitable habitats (Beard and Carline 1991). In this case, it becomes difficult to identify correlations to specific habitat variables that would otherwise exist. Given the limited correlations to non-spawning habitat variables in Teton Creek and Fox Creek, we suggest that there are not enough YOY to sufficiently occupy available habitats, and that the current number of cutthroat fry are likely limited by non-habitat factors such as low seeding (Everest et al. 1987; Magee et al. 1996), competition or disease (Fausch et al. 1988; Clarkson and Wilson 1995).

Egg-to-fry Survival

The second objective of this study was to determine at which life stage cutthroat trout were likely to be the most impacted and to suggest likely explanations. The methods we used to calculate egg-to-fry survival depend on several assumptions and are intended only to be a rough calculation of the potential number of eggs deposited in each stream. Obvious sources of error include undercounting cutthroat trout redds present (as is likely for Fox Creek) and misidentifying actual redds as false redds, therefore leaving them out of the total egg deposition calculations. During the latter part of the redd survey on Fox Creek, access permission was temporarily denied. This probably resulted in an overestimate of the egg-to-fry survival rate, as we likely did not account for all cutthroat redds in Fox Creek such that the estimated number of eggs could be artificially low compared to the number of fry.

We addressed potential redd-identification error and false redds by including only the proportion of redds that actually contained eggs. In addition, marking redds individually with multiple markers helped reduce counting errors associated with redd superimposition. The proportion of “correct” redds in Fox Creek and Teton Creek (59%

and 81%, respectively) was higher than those reported by Magee et al. (1996), having found eggs in only 11 of 36 redds (31%) in a sediment-rich basin in Montana. Downing et al. (2002) reported finding eggs or fry in 86%-100% of redds searched in the Madison River, Montana. Lastly, the survival rates of both creeks are based on fry abundance in September, after fry have likely suffered some initial mortality soon after emergence in August. Therefore, we may alternately have underestimated survival from egg to newly emergent fry when considering the mortality incurred in the weeks post-emergence (Elliot 1989). The mean egg-to-fry survival rates are high enough to suggest that gravel quality on the spawning grounds is not limiting recruitment through poor embryo survival and that limiting rates of mortality or production are likely happening at later life stages.

Despite these potential limitations, our results fall well into the range of values reported by other researchers. Briggs (1953) reported 26% total egg survival from fertilization to emergence for coho salmon (*Oncorhynchus kisutch*), 14% for Chinook salmon (*Oncorhynchus tschawytscha*) and 35% for rainbow trout. Egg survival rates for Yellowstone cutthroat trout in tributaries to Yellowstone Lake were shown to range from 30% to 40% (Ball and Cope 1961), but would likely be less when including survival to the fry stage. Knight (1997) reported egg-to-fry survival rates for Bonneville cutthroat trout (*Oncorhynchus clarki utah*) in two tributaries to Strawberry Reservoir from 21%-46%. Magee et al. (1996) reported overall embryo survival (% emergence) for cutthroat trout as low as 8.5%. They suggested 8.5% was a low success rate, due to excessive fine sediments but concluded that spawning gravel was not limiting given the high densities of fry they observed. These results would suggest that spawning gravels in Teton Creek and Fox Creek are most likely suitable, and that poor gravel quality is probably not a significant source of mortality limiting the production of cutthroat fry in these streams. Examination of the results from our seasonal abundance estimates and the egg-to-fry survival suggest that poor overwinter survival may be responsible for limitations in cutthroat trout recruitment to the Teton River.

Apparent Survival and Invasive Salmonids

Results from the annual abundance estimates reveal several important trends. First, survival rates for cutthroat trout are lower compared to those for brook trout and rainbow trout. Young cutthroat trout showed the lowest apparent survival through the winter in both Fox Creek and Teton Creek, with YOY cutthroat having the lowest survival of all groups. However, low survival rates for cutthroat fry have been reported in the past (Ball and Cope 1961; Scarnecchia and Bergersen 1986). Interannual apparent survival rates for cutthroat fry of 4% and 13% (for Fox Creek and Teton Creek, respectively) are similar to those reported by other researchers. Rieman and Apperson (1989) reported that typical annual mortality of cutthroat fry was 95%, while Petersen et al. (2004) showed that age-0 cutthroat fry in mid-elevations streams with sympatric brook trout survived at 2.5%. Mitro and Zale (2002) reported interannual apparent survival for rainbow trout in the Henry’s Fork Snake River, a system similar to the Teton River, as 18-23% in Box Canyon, and 3-11% in the Last Chance stretch. These survival rates are more similar to those of cutthroat fry in our study streams, as young rainbow trout (found almost exclusively in Fox Creek) survived at approximately 24%.

Overwinter apparent survival estimates for brook trout and rainbow trout in Teton Creek and Fox Creek appear similar to other reported values, while larger cutthroat ($\geq$150 mm) and larger rainbow trout (≥150 mm) actually increased over the winter. Hunt (1969) found age-0 brook trout survived from 35%-73% based on 11 years of data, while Carlson and Letcher (2003) found age-0+ brook trout survived at 63%. Needham et al. (1945) reported survival rates of age-0+ brown trout (*Salmu trutta*) to range from 15% to 84% over 4 years. The increase in larger rainbow trout (>120 mm) in Fox Creek may be explained by several factors. Given the spring creek habitat, young fish that were close to the 120 mm break in Fall 2004 might have grown enough over the winter to be included in the next size category estimates for Spring 2005. This growth is reflected in the length-frequency histogram of rainbow trout in Fox Creek by the consistent right-shift of all size classes. Additionally, large fluvial rainbow trout began to migrate into Fox Creek from the Teton River during their annual spawning run, as evident in the increased number of adult-sized rainbows in Spring 2005 (Figure C.1).

The large increase in cutthroat trout (≥150 mm) in both Fox and Teton Creeks over the winter is likely attributable to the high variance of the population estimates. Given the very low numbers of these fish that were caught, combined with the large variation in abundance between individual sites, highly precise estimates would be difficult to obtain. This same explanation also holds true for rainbow trout in Teton Creek, where the same small number of fish (three and two) were captured each season. If we consider the apparent mortality rates of brook trout and rainbow trout to be relatively normal, this would suggest that the currently available habitat provides adequate overwinter habitat for both brook trout and rainbow trout. If habitat quantity and quality are not limiting the survival of young cutthroat trout, other variables such as emigration, disease and negative species interactions may be more influential.

Although apparent survival rates of cutthroat fry, brook trout, and rainbow trout in Fox Creek and Teton Creeks are similar to those reported in other systems, survival rates for age-1 cutthroat trout are lower than expected. Age-1 cutthroat trout apparent survival in Fox Creek and Teton Creek was only 5% and 35%, respectively, compared to 25% and 59% for brook trout, respectively. Rieman and Apperson (1989) suggested typical survival rates for age-1 and older cutthroat of 50-70%, while Petersen et al. (2004) found that age-1 cutthroat trout in mid-elevation streams survived at 23% when sympatric with brook trout and at 42% when brook trout were reduced to low densities. Data taken from Scarnecchia and Bergersen (1986) indicate an average apparent mortality rate of 44% for age-1 cutthroat trout across three streams. Mortality rates for age-0 fish are expected to be high, but increased rates of mortality at older age classes can reduce the reproductive rate of the population below replacement levels (Krebs 2001). Higher than expected rates of mortality for age-1 cutthroat trout in these tributaries could be limiting recruitment to the Teton River.

High apparent mortality for age-1 cutthroat trout due to emigration cannot be completely ruled out, but we suspect that these losses are relatively minor. Progeny of fluvial cutthroat often spend 1 to 3 years in tributary streams before migrating to the mainstem river (Varley and Gresswell 1988; Thurow et al. 1988). Length-frequency histograms of cutthroat and rainbow trout from the Teton River show very few instances where trout less than 120mm were recorded. Although size-selective bias associated with boat-mounted electrofishing gear cannot be completely ruled out, these juveniles are thought to reside in spawning tributaries (Schrader 1996) until later migrating as sub-adults to the mainstem Teton River. The bulk of juvenile cutthroat and rainbow trout in the mainstem Teton River begin to appear at approximately 140 mm, which coincides well with the maximum lengths of most cutthroat and rainbow trout from tributary length-frequency histograms. This lack of overlap in size distribution would suggest that most migratory rainbow and cutthroat trout from Fox and Teton Creeks move to the Teton River as age-2 fish (Hughes 1998).

Brook trout and rainbow trout have often been implicated in the decline of inland cutthroat trout species, and the Teton Valley is likely no exception. Griffith (1988) suggested that cutthroat trout were less likely to coexist with brook trout than with other salmonids, perhaps because of the greater niche overlap between the species (Young 1995). As a result, brook trout have replaced cutthroat trout in many streams and are viewed as one of the greatest threats to cutthroat trout recovery (Benhke 1992; Harig et al. 2000; Dunham et al. 2003). Until recently, the actual mechanism by which brook trout replace cutthroat trout has been unknown, with most studies focused on individual-level mechanisms (Griffith 1970; Novinger 2000). Griffith (1972) concluded that interactions between cutthroat and brook trout were most likely to occur at the age-1 and age-2 life stages. This was partly affirmed by Petersen et al. (2004), who demonstrated a population-level mechanism by which brook trout replace cutthroat trout through age-specific interactions primarily at the age-0 and age-1 life stages. Specifically, brook trout in mid-elevation streams caused declines in cutthroat by depressing reproduction and reducing survival of age-0 and age-1 cutthroat trout. Gregory and Griffith (2000) also found low winter survival of wild cutthroat when held in sympatry with brook trout, which they concluded was not due to size-selective mortality but instead to competitive effects. Brook trout are widespread and abundant in both Fox Creek and Teton Creek, and it is likely that under the current conditions of reduced and altered stream habitats, these fish are having a significantly detrimental effect on cutthroat trout recruitment.

The data indicate that both age-0 and age-1 cutthroat survive better in Teton Creek, which may be explained by inherent differences in overwinter habitat availability and species composition. Without using controlled experiments, we can only speculate as to the mechanisms underlying the differential survival rates of cutthroat trout in Teton Creek and Fox Creek. However, these two streams are similar in important ways to the nearby Henry's Fork Snake River, where previous research may lend clues to formulate a hypothesis. As a result of altered hydrology due to diversions and the local geology, both Fox and Teton Creeks in the study area function largely as spring-fed streams much like the Henry's Fork. Additionally, these streams exhibit extensive macrophyte growth throughout the summer, but the pattern is more pronounced in Fox Creek, where gradients are lower, sediments are finer, and macrophyte growth is much more dynamic. Fox Creek may be likened to the lower Henry's Fork through Last Chance, while Teton Creek contains larger substrates, higher gradients, and is less affected by summer macrophyte growth, making it more analogous to the Box Canyon stretch of the Henry's Fork.

Previous research in the Henry's Fork Snake River indicates that seasonal macrophyte growth provides extensive summer habitat for juvenile rainbow trout but provides little to no habitat throughout the winter (see Gregory 2000 for review; Van Kirk and Martin 2000; Mitro and Zale 2002). Juvenile trout that utilize mid-channel macrophytes during the summer move to complex bank habitats (in the form of cobble-boulder substrates, overhanging banks and submerged willows) throughout the winter as macrophyte densities decline (Griffith and Smith 1995; Simpkins et al. 2000; Mitro and Zale 2002). Trout occupying these suitable overwinter habitats tend to remain in these areas, and these habitats provide much higher rates of overwinter survival for juvenile rainbow trout than mid-channel macrophytes (Contor 1989; Meyer 1995; Meyer and Griffith 1997; Mitro and Zale 2002). This winter shift towards bank habitat coupled with brook trout and rainbow trout presence may be the critical link that explains poor survival of age-1 cutthroat trout. In the presence of brook trout, cutthroat trout are shown to occupy less energetically favorable habitats (Cummings 1987), are behaviorally subordinate (Griffith 1972; Novinger 2000), and show reduced growth rates and lower lipid reserves (Thomas 1996). We suggest one possible mechanism leading to poor age-1 cutthroat survival in these tributaries may be due to competitive exclusion from introduced salmonids that force cutthroat trout into sub-optimal ephemeral overwinter habitats.

Teton Creek may provide more of the suitable overwinter habitat in the form of cobble-boulder substrates and submerged willows than Fox Creek. In this sense, the higher survival rates of age-1 cutthroat trout in Teton Creek are analogous to those of rainbow trout in Box Canyon of the Henry’s Fork. In Fox Creek, age-1 cutthroat trout survival was much lower, which is more analogous to the Last Chance segment of the Henry’s Fork, where changes in seasonal macrophyte habitat abundance are dramatic. In addition, rainbow trout are largely absent from Teton Creek, which may reduce the competitive pressures on cutthroat trout as compared to Fox Creek, where both brook trout and rainbow trout are abundant. Peterson et al. (2004) found young cutthroat survival to be inversely proportional to brook trout density, a pattern also reflected in the higher proportions of invasive salmonids in Fox Creek.

Overwinter survival data from our study appear to support the hypothesis of Cunjak (1996) that space is the primary factor regulating stream fish populations. Cutthroat trout that must compete with invasive brook trout and rainbow trout for suitable overwinter habitat may be displaced into poor habitats. As a result, displaced juvenile cutthroat may emigrate from poor habitats (Bjorn 1971; Cunjak and Randall 1993; Griffith and Smith 1995; Meyer and Griffith 1997). This may be the case in Fox and Teton Creeks, where age-1 cutthroat trout that migrate to the mainstem Teton River are not likely to survive due to poor habitat conditions present there.

The Impact of Whirling Disease

Most of the previous discussion has been focused on habitat associations and invasive salmonids as possible factors limiting cutthroat trout recruitment in the Teton River. One final item of relevance is the role of disease, which will be only briefly discussed here (a more complete discussion of this topic can be found in Koenig 2006). Sampling for whirling disease conducted in 2003 and 2004 indicated that prevalence and intensity of the disease was both spatially and temporally variable throughout the Teton River and its tributaries (Table D.2 - D.12, Figure D.1 -D.3). Sentinel cage results from both years also indicated that rates of infection were high in Teton Creek as well as Fox Creek, and that the parasite *M. cerebralis* (the causative agent of whirling disease) was present throughout the length of each stream (Table D.2, Table D.3, Figure D.1, Figure D.2, Figure D.3).

The impact of the parasite can substantially vary from stream to stream, but severe infections my lead to recruitment collapses of age-0 trout (Nehring and Walker 1996; Vincent 1996). Even in highly infected systems, sentinel fish exposures have shown the prevalence of infection can vary greatly over space and time (Downing et al. 2002). For example, in portions of the Colorado, Gunnison, Rio Grande and South Platte rivers, impacts from the disease are severe enough to eliminate almost the entire cohort of wild rainbow trout fry every year (CDOW 1999). In contrast, the Big Thompson River near Estes Park tested positive for M. *cerebralis* in 1994, yet recruitment of rainbow trout remains high.

The susceptibility of young trout to whirling disease, and the differences in susceptibility between species combined with the habitat and abundance data, suggests that whirling disease may be playing only a limited role in controlling cutthroat trout recruitment in the Teton River. Only young-of-the-year trout are severely affected by the disease (Gustafson 1998; Ryce et al. 2005), as the parasite attacks cartilaginous skeletal structures before ossification is complete. However, our results indicate that age-0 survival of cutthroat trout from September to April was within the acceptable range of other studies where whirling disease was not considered a problem. Hedrick et al. (1999) reported that rainbow trout are by far the most susceptible to the disease, with cutthroat trout showing no clinical signs of the disease when exposed after three months post-hatch. Vincent (2002) also reported that rainbow trout were the most susceptible of the salmonids tested and classified them as having “very high susceptibility.” Brook trout were classified in the same category as rainbow trout, but Yellowstone cutthroat trout were ranked two categories lower in the “moderate susceptibility” class. We anticipate that at least rainbow trout and potentially brook trout would be more adversely affected than Yellowstone cutthroat trout within the same stream, all other factors being equal (Vincent 2002). However, rainbow trout in Fox Creek were similarly abundant and survived at much higher rates that cutthroat trout. Recent IDFG population surveys in the mainstem Teton River showing brook trout and rainbow trout outnumbering cutthroat trout suggests the impact of the parasite is minimal, or that our understanding of differential susceptibility between species is inadequate.

In summary, the habitat analysis work shows that variation in young cutthroat abundance in Fox Creek and Teton Creek is largely a function of the number and location of adult spawning cutthroat, and not a function of the amount or quality of the habitat currently available. Fox Creek and Teton Creek support mainly non-native brook and rainbow trout that survive better than native cutthroat. Additionally, rates of cutthroat survival are better in Teton Creek, where rainbow are still at very low levels. Previous research throughout the west has shown that cutthroat trout compete with non-native brook trout and rainbow trout, and that brook trout can often completely replace populations of cutthroat. Although *m. cerebralis* is prevalent throughout the Teton Valley, impacts from whirling disease are highly variable and are not likely to be limiting cutthroat trout in Teton and Fox Creeks. Poor rates of cutthroat overwinter survival coupled with excellent survival rates of brook and rainbow trout suggest that competition for overwinter habitat at the age-1 life stage may be limiting cutthroat recruitment to the Teton River, and hence the total cutthroat population.

SUMMARY

In July of 2003, FTR joined forces with Idaho Department of Fish and Game and Utah State University to address the decline of Yellowstone cutthroat trout in the Teton Valley. The Teton River had large adult cutthroat that were becoming older and fewer, with few new cutthroat entering the system (low recruitment). Past trout research in the Teton Valley has been done on Fox and Teton Creeks but was confined to very small accessible portions of each stream, preventing an overall assessment from being accomplished. Thus began the juvenile trout project, which has been an effort to understand why few of these young fish made it to adulthood in the Teton River. Thanks to the generous support of many local landowners such as the Beards, Moultons, Crairys, Mithuns, Hunstsmans, the Teton Regional Land Trust and others, we were able to investigate these streams as a whole, giving us a much more complete picture of the issues surrounding juvenile trout recruitment.

After preliminary investigation during the first year of the project, it became clear that efforts to solve this problem would be most productive if focused on Teton and Fox Creeks, the two major spawning and rearing tributaries for cutthroat in the Teton Valley. Understanding these two streams would give us the best ideas of what problems might explain cutthroat declines throughout the Valley.

The Juvenile Trout Project consisted largely of four interconnected components: spawning, habitat, abundance, and whirling disease. From March through July 2003, the spawning assessment included comprehensive weekly surveys of Teton and Fox Creeks to identify where and how many cutthroat trout were spawning in these tributaries. Next, we systematically inventoried the stream habitat in each tributary to be used later to explain local fish abundances, which were assessed during Fall 2004 and Spring 2005 over the length of each stream. In addition, we also sampled for whirling disease infection in Fall 2003, and early summer of 2004 throughout the mainstem Teton River and in Fox and Teton Creeks. Following are the major results from these components and their implications on the future of cutthroat in the Teton Valley.

Spawning surveys (or redd counts) produced three major findings. First, most of the cutthroat (and rainbow trout for that matter) spawned largely in upper portions of the perennial lengths of Fox and Teton Creeks. This pattern is especially pronounced in Fox Creek, where most fish spawned exclusively in the upper 1 km of stream, near the 600 South road crossing. This pattern was also similar for Teton Creek, where most cutthroat spawned just downstream from Highway 33 and in a small spring tributary called Six Springs Creek. Since these fish are migratory adults from the mainstem Teton River, it suggests that given the opportunity, these fish would migrate farther up each stream if habitat were available. However, fish run out of water just above the current spawning beds, preventing them from reaching their historic spawning habitats (which contained water for much longer periods under natural hydrologic conditions).

The second finding was that the total number of spawning cutthroat trout was very low. Considering the low population numbers reported in the Teton River, this was not surprising. In Fox Creek, we counted only 33 definite cutthroat redds (spawning sites). We documented 20 cutthroat redds in Teton Creek, with an additional 17 redds in Six Springs Creek. Another interesting discovery was that the number of rainbow trout spawning in Fox Creek outnumbered that of cutthroat trout. However, in Teton Creek, only four rainbow trout redds were discovered, leaving cutthroat as the spring-spawning majority.

Using the total number of spawning cutthroat found in each tributary and the average size of mature cutthroat from the Teton River, we calculated the total number of cutthroat eggs likely laid in each stream. We then compared this to the estimated number of cutthroat fry from the fall electrofishing surveys, producing a general estimate of egg-to-fry survival. The egg-to-fry survival rates were estimated at 20% and 25% for Fox and Teton Creeks, respectively. Knowing that a good portion of the eggs laid into the streambed actually result in cutthroat fry indicates that spawning gravel quality in each stream is suitable to support successful reproduction. In trying to solve the recruitment puzzle, we can eliminate poor spawning gravel quality as a likely cause, yet the artificially shortened stream lengths may limit the total amount of available spawning habitat with water in it.

For the habitat portion of the study, we wanted to identify particular habitat attributes that were highly correlated with fish abundance, such as bank stability, gravel size, width, or the distance to the nearest spawning site. Habitat attributes that are highly correlated to local fish abundance may limit the total number of fish. From our electrofishing data, we knew that cutthroat fry were patchily distributed in each creek. To identify the habitat variables controlling the variation in cutthroat fry abundance, we combined our electrofishing data with the habitat data using statistical techniques. The analysis showed that the variation in cutthroat fry abundance is best explained by spawning-related variables. In Fox Creek, variation in cutthroat fry was positively correlated to distance upstream from the mouth combined with percent riffle habitat within the sampling reach. This made biological sense, as young trout fry do not disperse far from where they were born, and most of the spawning in Fox Creek happened further upstream in riffles.

Results from the Teton Creek analysis tell a similar story. Local cutthroat fry abundance was almost entirely explained by the number of redds within 200 m of the sampling location, the number of young brook trout present, and to a small degree, the percent of stable bank. Since young trout fry do not move far from their place of birth, the fact that cutthroat fry numbers were correlated with proximity to redds and the number of young brook trout makes sense. (Brook trout presumably spawned in similar locations, only earlier in the year). Additionally, trout fry seek shelter along the margins of the stream to hide in cover like grasses and willows. These grasses and willows that comprise suitable margin habitat often are associated with stable banks.

However, we need to keep in mind the low number of adult cutthroat actually spawning, and hence the inherently low number of cutthroat fry produced. When using regression-based analyses (like those mentioned above) to determine factors limiting a fish population, we assume the population is actually limited by the factors we measured, and not something else like fishing mortality, disease or competition. We collected trout abundance data in Fall 2004 and again in Spring 2005, giving us the ability to calculate apparent survival through the winter. Based on studies in other areas, survival for young trout fry through their first winter is commonly poor – as low as 1-5% in most cases. Rates of cutthroat fry survival in Fox Creek and Teton Creek for their first winter were 4% and 13%, respectively. For older age classes of cutthroat, overwinter survival was much lower than expected. In Fox Creek, only 5% of age-1 cutthroat survived the winter, while only 35% survived the winter in Teton Creek. High rates of mortality are expected for age-0 fish, but increased rates of mortality at older age classes can result in population level declines.

Unlike cutthroat trout, brook trout and rainbow trout are not experiencing the same high rates of mortality at age-1 and age-2. Brook trout and rainbow trout did extremely well over the same period of time during which cutthroat declined heavily. Brook trout fry and rainbow trout fry in Fox Creek survived at 25% and 24%, respectively, whereas cutthroat survived at 4%. Teton Creek showed a similar trend in which brook trout fry survived at 59% compared to cutthroat fry at 13%. Thus, the currently available stream habitat appears suitable for spawning, yet most of the production potential of each stream is going into producing brook trout and rainbow trout.

To summarize the habitat and abundance surveys: (1) Fox Creek and Teton Creek are mainly supporting non-native rainbow and brook trout, (2) these trout are surviving better than native cutthroat, and (3) rates of cutthroat survival are better in Teton Creek, where rainbow are still at very low levels. Previous research throughout the west has shown that cutthroat trout compete with non-native brook trout and rainbow trout, and that brook trout can often completely replace populations of cutthroat. Poor rates of cutthroat overwinter survival coupled with excellent survival rates of brook and rainbow trout suggest that competition for overwinter habitat at the age-1 life stage may be limiting cutthroat recruitment to the Teton River, and hence the total cutthroat population.

Impacts from whirling disease can be highly variable between and within systems. For example, whirling disease is severe enough in portions of the Colorado, Gunnison, Rio Grande and South Platte rivers to eliminate almost the entire cohort of wild rainbow trout fry every year. In contrast, the Big Thomson River near Estes Park tested positive for M. *cerebralis* in 1994, yet recruitment of rainbow trout is excellent. Results from our whirling disease investigation indicate the parasite is widespread throughout the Teton Valley, and some locations are highly infected. Tributary sites like Fox Creek and Teton Creek are more highly infected than mainstem Teton River sites, with infection generally increasing downstream. However, the intensity of the infection varies between locations and seasons. Whirling disease affects only age-0 trout, and rainbow trout are commonly considered to be highly susceptible and more susceptible than cutthroat trout. If whirling disease were the predominant cause of cutthroat trout declines, we would expect to see equal if not greater declines in rainbow trout. In the context of habitat alteration and invasive species, it is difficult to clearly identify what impact the disease is having on the Valley's cutthroat trout.

Our habitat analysis work showed that variation in cutthroat abundance in both streams was largely a function of the number and location of adult spawning cutthroat and not so much the amount or quality of the habitat currently available. In the greater picture of Yellowstone cutthroat trout restoration for the Teton Valley, improving only the quality of the current habitat in these tributaries is not likely to result in more cutthroat trout. In fact, these efforts may result in stronger populations of brook and rainbow trout. Without increasing the quantity of total stream habitat available to cutthroat and addressing fundamental hydrologic changes to these tributaries, cutthroat trout are not likely to rebound to their historical abundance in the Teton Valley. Cutthroat recovery depends less on treating the symptoms of the habitat problem, and more on addressing the factors that limit the tributary habitat that favors cutthroat trout. Most importantly, water diversion modifies the hydrologic regime, and changes stream habitat conditions to favor invasive trout. Although easy to identify, addressing this problem is difficult. However, if local landowners continue to lend their support and become active participants in restoration efforts, wild Yellowstone cutthroat may still have a future in the Teton Valley.

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APPENDICES

APPENDIX A. Preliminary Electrofishing Data.

Methods

Fish abundance and size distribution data were collected using backpack electrofishing units. Sampling reaches were 50m in length and were sampled with multiple-pass depletion efforts with a minimum of three passes. Sampling reach locations on each stream were determined by random selection from a predetermined number of available sites. The number of available sites was determined by calculating the total number of 50m reaches possible within the accessible length of each stream from aerial photos and topographic maps. Once reaches were located in the field, reach lengths were measured with a drag tape along the thalweg length. Sampling proceeded in an upstream direction with at least one backpack unit and at least one person netting per backpack unit. On wider streams, two backpack units were often used in tandem with up to three persons netting. Shock times were recorded to ensure equal effort on subsequent passes.

All trout captured were identified to species and measured using fork length (mm). Young-of-the-year trout were classified as “YOY” and recorded as such. Young-of-the-year trout that exhibited any of the characteristics of rainbow trout (such as spots on the head and white anal fin margins) outlined in Kruse (1998) were classified as rainbow trout or hybrids. All juvenile fish 200mm and less were recorded, while most adult fish were usually not measured, but were noted in the data.

Abundance estimates were generated using MicroFish 3.0 software (Van Deventer and Platts 1989). Given that this study focuses exclusively on juvenile trout, abundance estimates were calculated for all fish less than or equal to 200mm fork length. Length-frequency histograms were generated for each survey reach (by species), and a combined length-frequency histogram was created for each survey stream. Abundance data was calculated according to the age/size categories presented by the length-frequency histograms for each species and reach with capture probabilities assumed to remain constant by group on each pass.

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Table A.1. Preliminary electrofishing sampling site locations for the Teton Valley by year, with UTM coordinates in NAD27 datum.

Reach Name	UTM	Season
Fox Creek #1	12T 486262E 4832927N	Fall 2003, Spring 2004
Fox Creek #2	12T 486815E 4832251N	Fall 2003, Spring 2004
Fox Creek #3	12T 486886E 4831727N	Fall 2003, Spring 2004
Fox Creek #4	12T 487428E 4831563N	Fall 2003, Spring 2004
Fox Creek #5	12T 487526E 4831558N	Fall 2003, Spring 2004
Teton Cr. #1	12T 487337E 4837864N	Fall 2003, Spring 2004
Teton Cr. #2	12T 487728E 4837862N	Fall 2003, Spring 2004
Teton Cr. #3	12T 489583E 4838380N	Fall 2003, Spring 2004
Teton Cr. #4	12T 489931E 4838670N	Fall 2003, Spring 2004
Teton Cr. #5	12T 490121E 4838582N	Fall 2003, Spring 2004
Unnamed Cr.#1	12T 489989E 4838293N	Fall 2003, Spring 2004
Unnamed Cr.#2	12T 490118E 4838269N	Fall 2003, Spring 2004
Teton R. #1	12T 486135E 4831490N	Fall 2003, Spring 2004
Teton R. #2	12T 486207E 4831389N	Fall 2003, Spring 2004
Teton R. #3	12T 485882E 4829878N	Fall 2003, Spring 2004
Teton R. #4	12T 485878E 4829719N	Fall 2003, Spring 2004
Woods Cr. #1	12T 487508E 4840426N	Fall 2003, Spring 2004
Woods Cr. #2	12T 487685E 4840432N	Fall 2003, Spring 2004
Elliot Cr. #1	12T 487467E 4834611N	Summer 2004
Elliot Cr. #2	12T 487666E 4834369N	Summer 2004
Elliot Cr. #3	12T 487964E 4834237N	Summer 2004
Elliot Cr. #4	12T 488233E 4834184N	Summer 2004
Elliot Cr. #5	12T 488513E 4834178N	Summer 2004
Elliot Cr. #6	12T 488816E 4834021N	Summer 2004
Elliot Cr. #7	12T 489141E 4833927N	Summer 2004
Elliot Cr. #8	12T 489437E 4833939N	Summer 2004

Table A.2. Abundance estimates by site for Fox Creek, Fall 2003.

		Site 1				Site 2				Site 3			
Species	Size	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI
YOY	(<80)	0	0.0%	0	0	2	13.3%	2	7	88	75.9%	76	104
YCT	(<100mm)	0	0.0%	0	0	2	13.3%	2	7	1	0.9%	1	1 [b]
YCT	(101-150)mm	0	0.0%	0	0	1	6.7%	1	1 [b]	0	0.0%	0	0
YCT	(151-200)mm	0	0.0%	0	0	1	6.7%	1	1 [b]	0	0.0%	0	0
EBT	(<100mm)	1	100.0%	1	1 [b]	1	6.7%	1	1 [a]	2	1.7%	2	15
EBT	(101-150mm)	0	0.0%	0	0	6	40.0%	6	10	3	2.6%	3	3 [b]
EBT	(151-200mm)	0	0.0%	0	0	0	0.0%	0	0	3	2.6%	3	8
RBT	(<100mm)	0	0.0%	0	0	0	0.0%	0	0	2	1.7%	2	7
RBT	(101-150mm)	0	0.0%	0	0	0	0.0%	0	0	1	0.9%	1	1 [a]
HYB	(<100mm)	0	0.0%	0	0	2	13.3%	2	7	9	7.8%	0	0 [c]
HYB	(101-150mm)	0	0.0%	0	0	0	0.0%	0	0	7	6.0%	7	7 [b]
Estimate	Totals	1	100.0%			15	100.0%			116	100.0%		
Site	Estimates	1		1	1	16		15	21	119		101	139

		Site 4				Site 5			
Species	Size	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI
YOY	(<80)	34	30.9%	23	63	46	31.9%	36	65
YCT	(<100mm)	2	1.8%	2	2 [b]	1	0.7%	1	1 [b]
YCT	(101-150)mm	1	0.9%	1	1 [a]	1	0.7%	1	1 [a]
YCT	(151-200)mm	3	2.7%	3	6	0	0.0%	0	0
EBT	(<100mm)	2	1.8%	2	7	20	13.9%	10	73
EBT	(101-150mm)	22	20.0%	19	31	26	18.1%	22	36
EBT	(151-200mm)	2	1.8%	2	15	2	1.4%	2	15
RBT	(<100mm)	11	10.0%	11	11	10	6.9%	10	12
RBT	(101-150mm)	8	7.3%	6	22	2	1.4%	2	7
HYB	(<100mm)	22	20.0%	15	46	25	17.4%	19	42
HYB	(101-150mm)	3	2.7%	3	6	11	7.6%	7	35
Estimate	Totals	110	100.0%			144	100.0%		
Site	Estimates	112		87	142	157		110	209

[a] No maximum likelihood estimate generated. Reason: only 1fish caught in all removals.

[b] No maximum likelihood estimate generated. Reason: all fish caught on 1st pass.

[c] Maximum likelihood estimate terminated at 5times the total catch.
Estimate has been arbitrarily reset to 1.5 times the total catch.
Population estimate termination was caused by a non-descending removal pattern.
Results should not be considered reliable.

Table A.3. Abundance estimates by site for Teton Creek, Fall 2003.

		Site 1				Site 2				Site 3			
Species	Size	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI
YOY	(<80)	7	24.1%	7	8	41	78.8%	40	44	252	72.6%	238	266
YCT	(<100mm)	0	0.0%	0	0	0	0.0%	0	0	2	0.6%	2	15
YCT	(101-150)mm	6	20.7%	0	0 [c]	1	1.9%	1	1 [a]	4	1.2%	4	4 [b]
YCT	(151-200)mm	0	0.0%	0	0	2	3.8%	2	2 [b]	0	0.0%	0	0
EBT	(<100mm)	1	3.4%	1	1 [a]	3	5.8%	3	6	53	15.3%	47	63
EBT	(101-150mm)	12	41.4%	0	0 [c]	5	9.6%	5	6	27	7.8%	27	29
EBT	(151-200mm)	3	10.3%	3	6	0	0.0%	0	0	9	2.6%	9	11
Estimate	Totals	29	100.0%			52	100.0%			347	100.0%		
Site	Estimates	35		0	0	52		51	55	349		332	366

		Site 4				Site 5			
Species	Size	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI
YOY	(<80)	92	80.0%	84	103	204	71.6%	180	228
YCT	(<100mm)	0	0.0%	0	0	0	0.0%	0	0
YCT	(101-150)mm	0	0.0%	0	0	5	1.8%	5	5
YCT	(151-200)mm	0	0.0%	0	0	2	0.7%	2	7
EBT	(<100mm)	11	9.6%	11	13	43	15.1%	41	48
EBT	(101-150mm)	11	9.6%	11	13	28	9.8%	28	30
EBT	(151-200mm)	1	0.9%	1	1 [b]	3	1.1%	3	3 [b]
Estimate	Totals	115	100.0%			285	100.0%		
Site	Estimates	117		107	129	283		262	304

[a] No maximum likelihood estimate generated. Reason: only 1fish caught in all removals.

[b] No maximum likelihood estimate generated. Reason: all fish caught on 1st pass.

[c] Maximum likelihood estimate terminated at 5times the total catch.
Estimate has been arbitrarily reset to 1.5 times the total catch.
Population estimate termination was caused by a non-descending removal pattern.
Results should not be considered reliable.

Table A.4. Abundance estimates by site for Teton River, Fall 2003.

		Site 1				Site 2				Site 3			
Species	Size	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI
YCT	(101-150)mm	1	3.6%	1	1[b]	0	0.0%	0	0	0	0.0%	0	0
YCT	(151-200)mm	1	3.6%	1	1[b]	0	0.0%	0	0	0	0.0%	0	0
EBT	(<100mm)	25	89.3%	14	69	75	85.2%	51	115	5	12.8%	5	8
EBT	(101-150mm)	1	3.6%	1	1[b]	10	11.4%	10	11	30	76.9%	30	32
EBT	(151-200mm)	0	0.0%	0	0	3	3.4%	3	3[b]	4	10.3%	4	9
Estimate	Totals	28	100.0%			88	100.0%			39	100.0%		
Site	Estimates	21		17	33	80		64	102	41		39	46

		Site 4			
Species	Size	EST	%	Low 95% CI	Upper 95% CI
YCT	(101-150)mm	0	0.0%	0	0
YCT	(151-200)mm	0	0.0%	0	0
EBT	(<100mm)	2	5.9%	2	15
EBT	(101-150mm)	31	91.2%	31	32
EBT	(151-200mm)	1	2.9%	1	1[a]
Estimate	Totals	34	100.0%		
Site	Estimates	34		34	36

[a] No maximum likelihood estimate generated. Reason: only 1fish caught in all removals.

[b] No maximum likelihood estimate generated. Reason: all fish caught on 1st pass.

Table A.5. Abundance estimates by site for Unnamed Creek, Fall 2003.

		Site 1				Site 2			
Species	Size	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI
YOY	(<80)	81	80.2%	0	0	[c] 25	56.8%	24	29
YCT	(<100mm)	3	3.0%	3	4	2	4.5%	2	15
YCT	(101-150)mm	5	5.0%	5	6	2	4.5%	2	7
EBT	(<100mm)	9	8.9%	9	10	11	25.0%	11	11
EBT	(101-150mm)	2	2.0%	2	2	[b] 2	4.5%	2	7
EBT	(151-200mm)	1	1.0%	1	1	[a] 2	4.5%	2	15
Estimate	Totals	101	100.0%			44	100.0%		
Site	Estimates	131		74	221	45		43	50

[a] No maximum likelihood estimate generated. Reason: only 1fish caught in all removals.

[b] No maximum likelihood estimate generated. Reason: all fish caught on 1st pass.

[c] Maximum likelihood estimate terminated at 5times the total catch.
Estimate has been arbitrarily reset to 1.5 times the total catch.
Population estimate termination was caused by a non-descending removal pattern.
Results should not be considered reliable.

Table A.6. Abundance estimates by site for Woods Creek, Fall 2003.

		Site 1				Site 2				
Species	Size	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI	
EBT	(<100mm)	3	16.7%	3	8	3	12.5%	3	4	
EBT	(101-150mm)	11	61.1%	11	12	15	62.5%	15	16	
EBT	(151-200mm)	4	22.2%	4	7	5	20.8%	5	5	[b]
HYB	(<100mm)	0	0.0%	0	0	1	4.2%	1	1	[a]
Estimate	Totals	18	100.0%			24	100.0%			
Site Estimates		19		18	23	24		24	25	

[a] No maximum likelihood estimate generated. Reason: only 1fish caught in all removals.

[b] No maximum likelihood estimate generated. Reason: all fish caught on 1st pass.

Table A. 7. Abundance estimate for Fox Creek, Spring 2004. Sites not listed indicate that no fish were captured.

		Site 2				Site 3				Site 4			
Species	Size	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI
YOY	(<90mm)	11	73.3%	11		10	35.7%	10	11	2	33.3%	2	7
YCT	(91-150mm)	1	6.7%	1	1 [b]	0	0.0%	0	0	0	0.0%	0	0
EBT	(<100mm)	0	0.0%	0	0	1	3.6%	1	1 [b]	0	0.0%	0	0
EBT	(101-150mm)	3	20.0%	3		12		12	12	1	16.7%	1	1 [a]
EBT	(151-200mm)	0	0.0%	0	0	2	7.1%	2	2 [b]	3	50.0%	3	6
RBT	(<100mm)	0	0.0%	0	0	1	3.6%	1	1 [b]	0	0.0%	0	0
RBT	(101-150mm)	0	0.0%	0	0	1	3.6%	1	1 [b]	0	0.0%	0	0
HYB	(101-150mm)	0	0.0%	0	0	1	3.6%	1	1 [b]	0	0.0%	0	0
Estimate	Totals	15	100.0%			28	100.0%			6	100.0%		
Site	Estimates	15		15	17	28		28	28	6		6	10

		Site 5			
Species		EST	%	Low 95% CI	Upper 95% CI
YOY	(<90mm)	6	60.0%	6	7
YCT	(91-150mm)	0	0.0%	0	0
EBT	(<100mm)	3	30.0%	3	8
EBT	(101-150mm)	1	10.0%	1	1 [b]
EBT	(151-200mm)	0	0.0%	0	0
RBT	(<100mm)	0	0.0%	0	0
RBT	(101-150mm)	0	0.0%	0	0
HYB	(101-150mm)	0	0.0%	0	0
Estimate	Totals	10	100.0%		
Site	Estimates	10		10	12

[a] No maximum likelihood estimate generated. Reason: only 1fish caught in all removals.

[b] No maximum likelihood estimate generated. Reason: all fish caught on 1st pass.

Table A.8. Abundance estimates by site for Teton Creek, Spring 2004.

		Site 1				Site 2				Site 3			
Species	Size	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI
YOY	(<90mm)	2	66.7%	2	26	25	64.1%	23	31	11	50.0%	11	12
YCT	(91-150mm)	0	0.0%	0	0	0	0.0%	0	0	1	4.5%	1	1 [a]
YCT	(151-200mm)	0	0.0%			0	0.0%	0	0	0	0.0%	0	0
EBT	(<100mm)	0	0.0%	0	0	10	25.6%	8	21	3	13.6%	3	6
EBT	(101-150mm)	0	0.0%	0	0	3	7.7%	3	4	7	31.8%	7	8
EBT	(151-200mm)	0	0.0%	0	0	1	2.6%	1	1 [b]	0	0.0%	0	0
RBT	(101-150mm)	1	33.3%	1	1 [b]	0	0.0%	0	0	0	0.0%	0	0
HYB	(101-150mm)	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0
Estimate	Totals	3	100.0%			39	100.0%			22	100.0%		
Site	Estimates	3		3	8	39		35	48	22		22	24

		Site 4				Site 5			
Species	Size	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI
YOY	(<90mm)	3	100.0%	3	3 [b]	23	57.5%	0	0 [c]
YCT	(91-150mm)	0	0.0%	0	0	1	2.5%	1	1 [a]
YCT	(151-200mm)	0	0.0%	0	0	1	2.5%	1	1 [a]
EBT	(<100mm)	0	0.0%	0	0	1	2.5%	1	1 [a]
EBT	(101-150mm)	0	0.0%	0	0	8	20.0%	8	9
EBT	(151-200mm)	0	0.0%	0	0	5	12.5%	5	7
RBT	(101-150mm)	0	0.0%	0	0	0	0.0%	0	0
HYB	(101-150mm)	0	0.0%	0	0	1	2.5%	1	1 [a]
Estimate	Totals	3	100.0%			40	100.0%		
Site	Estimates	3		3	3	48			

[a] No maximum likelihood estimate generated. Reason: only 1fish caught in all removals.

[b] No maximum likelihood estimate generated. Reason: all fish caught on 1st pass.

[c] Maximum likelihood estimate terminated at 5times the total catch.
Estimate has been arbitrarily reset to 1.5 times the total catch.
Population estimate termination was caused by a non-descending removal pattern.
Results should not be considered reliable.

Table A.9. Abundance estimates for the Teton River, Spring 2004.

		Site 1				Site 2				Site 3			
Species	Size	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI
EBT	(<100mm)	1	20.0%	1	1 [b]	0	0.0%	0	0	3	16.7%	3	6
EBT	(101-150mm)	3	60.0%	0	0 [c]	1	50.0%	1	1	8	44.4%	8	10
EBT	(151-200mm)	1	20.0%	1	1 [a]	0	0.0%	0	0 [a]	3	16.7%	3	8
RBT	(<100mm)	0	0.0%	0	0	0	0.0%	0	0	4	22.2%	4	4 [b]
RBT	(101-150mm)	0	0.0%	0	0	1	50.0%	1	1 [a]	0	0.0%	0	0
Estimate	Totals	5	100.0%			2	100.0%			18	100.0%		
Site	Estimates	8		4	50	2		2	15	19		18	23

		Site 4			
Species	Size	EST	%	Low 95% CI	Upper 95% CI
EBT	(<100mm)	2	40.0%	2	2 [b]
EBT	(101-150mm)	3	60.0%	3	4
EBT	(151-200mm)	0	0.0%	0	0
RBT	(<100mm)	0	0.0%	0	0
RBT	(101-150mm)	0	0.0%	0	0
Estimate	Totals	5	100.0%		
Site	Estimates	5		5	5

[a] No maximum likelihood estimate generated. Reason: only 1fish caught in all removals.

[b] No maximum likelihood estimate generated. Reason: all fish caught on 1st pass.

[c] Maximum likelihood estimate terminated at 5times the total catch.
Estimate has been arbitrarily reset to 1.5 times the total catch.
Population estimate termination was caused by a non-descending removal pattern.
Results should not be considered reliable.

Table A.10. Abundance estimates for Unnamed Creek, Spring 2004.

		Site 1				Site 2			
Species	Size	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI
YOY	(<90mm)	29	70.7%	29	31	16	43.2%	16	18
YCT	(151-200mm)	0	0.0%	0	0	1	2.7%	1	1 [a]
EBT	(<100mm)	5	12.2%	5	6	7	18.9%	7	8
EBT	(101-150mm)	6	14.6%	6	7	12	32.4%	12	12
EBT	(151-200mm)	1	2.4%	1	1 [a]	1	2.7%	1	1 [a]
Estimate	Totals	41	100.0%			37	100.0%		
Site	Estimates	41		41	43	37		37	38

[a] No maximum likelihood estimate generated. Reason: all fish caught on 1st pass.

Table A.11. Abundance estimates for Woods Creek, Spring 2004.

		Site 1				Site 2			
Species	Size	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI
EBT	(<100mm)	2	15.4%	2	2 [a]	7	36.8%	7	9
EBT	(101-150mm)	6	46.2%	6	6 [a]	6	31.6%	6	6
EBT	(151-200mm)	4	30.8%	4	4 [a]	6	31.6%	6	6 [a]
RBT	(<100mm)	1	7.7%	1	1 [a]	0	0.0%	0	0
Estimate	Totals	13	100.0%			19	100.0%		
Site	Estimates	13		13	13	19		19	20

[a] No maximum likelihood estimate generated. Reason: all fish caught on 1st pass.

Table A.12. Abundance estimates for Elliot Creek, Summer 2004. No fish were captured at Site 1 and Site 3.

		Site 2				Site 4				Site 5			
Species	Size	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI
YOY	(<90mm)	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0
YCT	(91-150mm)	1	14.3%	1	1 [a]	0	0.0%	0	0	0	0.0%	0	0
EBT	(<100mm)	3	42.9%	3	6	0	0.0%	0	0	8	80.0%	8	10
EBT	(101-150mm)	0	0.0%	0	0	0	0.0%	0	0	1	10.0%	1	1 [b]
EBT	(151-200mm)	3	42.9%	3	8	18	100.0%	6	140	1	10.0%	1	1 [b]
Estimate	Totals	7	100.0%			18	100.0%			10	100.0%		
Site	Estimates	7		7	15		6	6	140	10		10	11

		Site 6				Site 7				Site 8			
Species	Size	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI	EST	%	Low 95% CI	Upper 95% CI
YOY	(<90mm)	0	0.0%	0	0	5	55.6%	3	32	0	0.0%	0	0
YCT	(91-150mm)	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0
EBT	(<100mm)	19	95.0%	15	32	1	11.1%	1	1 [b]	0	0.0%	0	0
EBT	(101-150mm)	1	5.0%	1	1 [b]	1	11.1%	1	1 [b]	1	16.7%	1	1 [a]
EBT	(151-200mm)	0	0.0%	0	0	2	22.2%	2	2 [b]	5	83.3%	5	5
Estimate	Totals	20	100.0%			9	100.0%			6	100.0%		
Site	Estimates	20		16	29	7		7	9	6		6	7

[a] No maximum likelihood estimate generated. Reason: only 1fish caught in all removals.

[b] No maximum likelihood estimate generated. Reason: all fish caught on 1st pass.

Table A.13. Percent composition of total catch by species and stream, Fall 2003.

Species	Size	Fox Cr	Teton Cr	Unnamed Cr	Woods Cr	Teton River
YOY	(<80)	40.9%	71.4%	80.3%		
YCT	(<100mm)	1.4%	0.2%	2.5%		0.5%
YCT	(101-150)mm	1.2%	1.9%	3.5%		0.5%
YCT	(151-200)mm	0.9%	0.5%		3.2%	
Total YCT		3.5%	2.6%	6.0%	3.2%	1.0%
EBT	(<100mm)	5.9%	13.7%	10.1%	48.4%	58.9%
EBT	(101-150mm)	14.2%	10.3%	2.0%	32.3%	36.1%
EBT	(151-200mm)	2.6%	1.9%	1.5%	16.1%	4.0%
Total EBT		22.7%	25.9%	13.6%	96.8%	99.0%
RBT	(<100mm)	5.4%				
RBT	(101-150mm)	3.8%				
Total RBT		9.2%	0.0%	0.0%	0.0%	0.0%
HYB	(<100mm)	19.6%				
HYB	(101-150mm)	4.0%				
Total HYB		23.6%	0.0%	0.0%	0.0%	0.0%

Table A.14. Percent composition of total catch by species and stream, Spring 2004.

Species	Size	Fox Cr	Teton Cr	Unnamed Cr	Woods Cr	Teton River
YOY	(<90mm)	49.20%	56.80%	57.70%		
YCT	(91-150mm)	1.70%	2.10%			
YCT	(101-150)mm					
YCT	(151-200)mm		1.10%	1.30%		
Total YCT		1.70%	3.20%	1.30%	0.00%	0.00%
EBT	(<100mm)	6.80%	12.60%	15.40%	28.10%	18.80%
EBT	(101-150mm)	28.80%	18.90%	23.10%	37.50%	53.10%
EBT	(151-200mm)	8.50%	6.30%	2.60%	31.30%	12.50%
Total EBT		44.10%	37.80%	41.10%	96.90%	84.40%
RBT	(<100mm)	1.70%			3.10%	12.50%
RBT	(101-150mm)	1.70%	1.10%			3.10%
RBT	(151-200mm)					
Total RBT		3.40%	1.10%	0.00%	3.10%	15.60%
HYB	(<100mm)					
HYB	(101-150mm)	1.70%	1.10%			
HYB	(151-200MM)					
Total HYB		1.70%	1.10%	0.00%	0.00%	0.00%

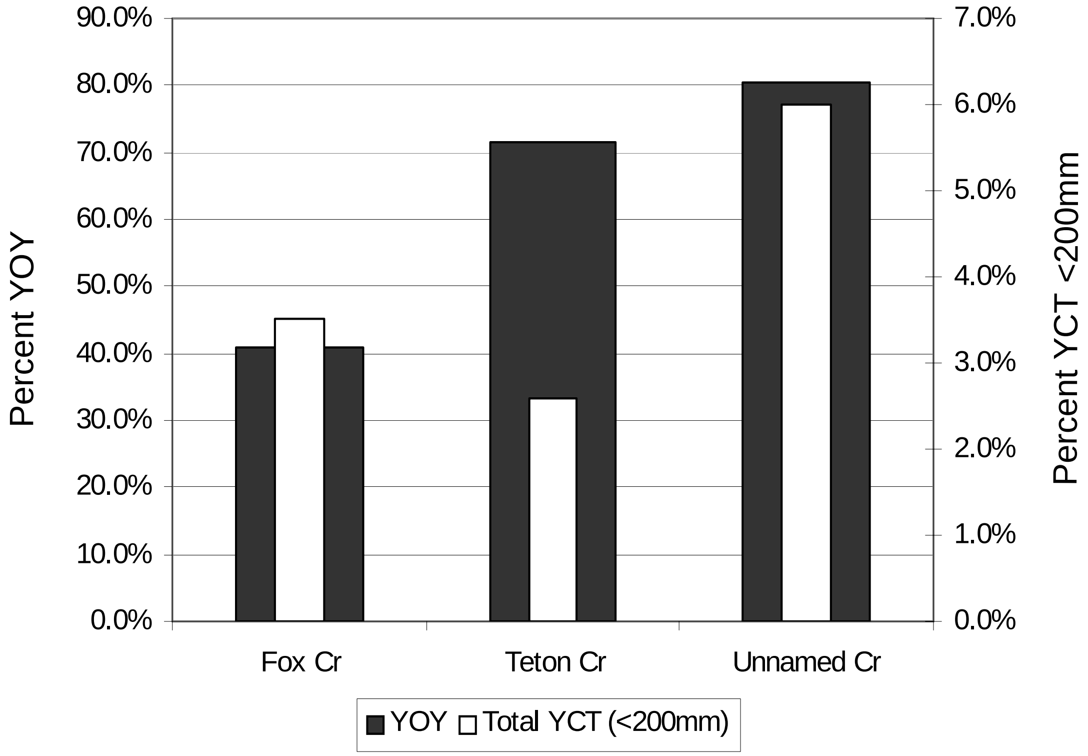

Figure A.1. Percent YOY and YCT (<200 mm) of total trout catch in Fall 2003.

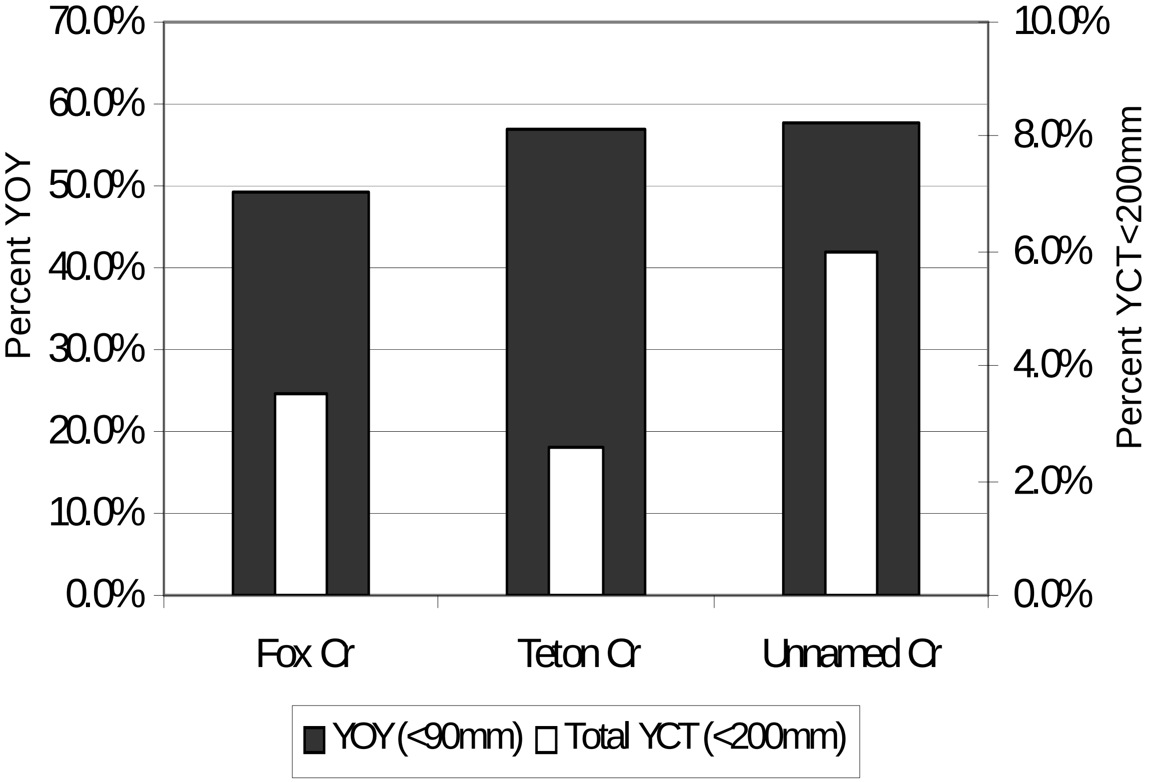

Figure A.2. Percent YOY and YCT (<200 mm) of total trout catch in Spring 2004.

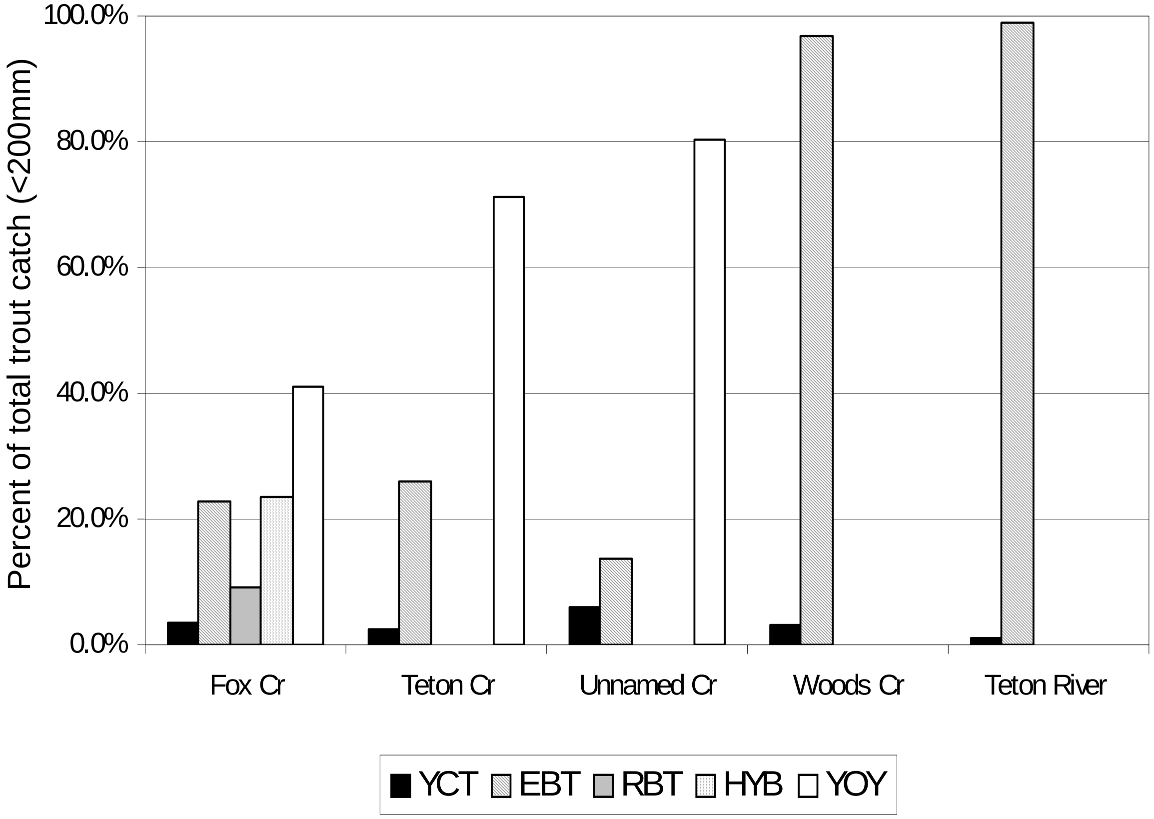

Figure A.3. Percent composition (trout <200 mm) of total trout catch by stream in Fall 2003.

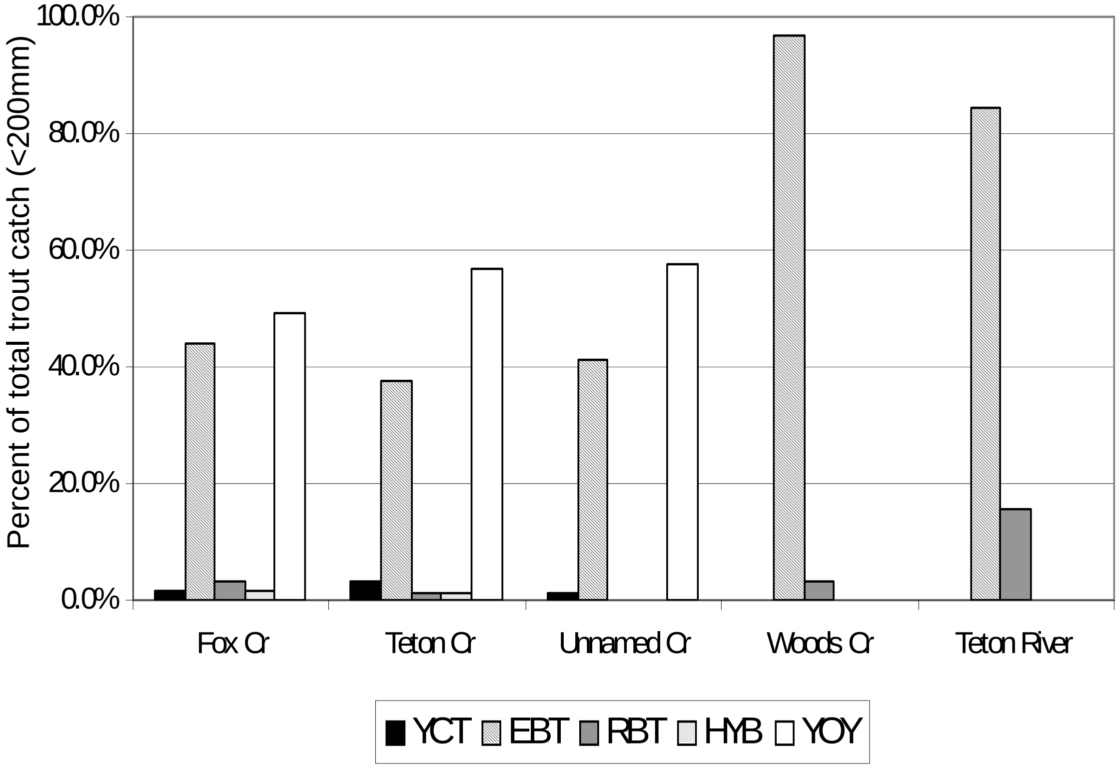

Figure A.4. Percent composition (trout <200 mm) of total trout catch by stream in Spring 2004.

APPENDIX B. Redd Survey Data.

Methods

Redd surveys were conducted on sections of Fox Creek and Teton Creek that comprised most of the length of perennial flow available to spawning cutthroat. Surveys of Teton Creek began at the mouth and ended just west of Highway 33, which marks the end of perennial flow and upward fish migration with an impassable logjam (Figure 1.3). The survey length of Fox Creek stretched from the mouth to the uppermost granted land access, approximately 500m south of the 600 South road bridge. Due to lack of land access along the highest section of Fox Creek, it was difficult to determine the endpoint of perennial flow. However, judging from aerial photos, perennial flow likely ended within 1km on the end of the surveyed length.

Surveys of Fox Creek, Teton Creek and Unnamed Creek (a small spring creek tributary to Teton Creek) began in March and were conducted weekly (as personnel availability and private land access allowed) into the month of June. Surveys on Fox Creek had to be discontinued prematurely due to an unexpected loss of property access to a significant portion of the stream. Start and end locations, times, weather, water temperature and turbidity will be recorded during each survey occasion.

Once a redd was located, it was scored according to the following criteria: 1 = “definite redd”, fish present, 2 = most likely a redd, fish absent, characteristic pit/tailspill present (Thurow and King 1994), 3 = possible redd, disturbed substrate, pit/tailspill less well defined. Redds were counted differently during the first part of the survey while rainbow trout were spawning. During this period (up to May 15, 2004) total daily counts of all redds were made during each survey occasion. Therefore, an absolute count of rainbow trout redds was not possible to obtain, only maximum total daily counts. During the second half of the survey when cutthroat began to spawn, each “definite” redd was individually marked, enabling the total enumeration of all cutthroat redds located.

During each survey occasion, 50 pebbles were measured (intermediate axis) out of every other redd scored with a 1 or 2 until 50 total cutthroat redds were sampled. Pebbles were drawn at random from five equidistant transects perpendicular to the flow across the tail-spill of the redd in a downstream to upstream fashion. Redd locations were recorded with using a GPS unit with NAD27 map datum. In addition, each cutthroat trout redd was marked using a stake implanted on the adjacent stream bank and a cobblestone painted fluorescent orange was placed in the pit of each “definite” redd as a second marker.

To estimate the percentage of recorded redds that contained eggs, shovel surveys followed after cutthroat trout were thought to have emerged. Excavation was delayed until after emergence in order to minimize the impact to cutthroat trout recruitment. Every fifth redd previously identified as a 1 or 2 was excavated. Redds were excavated from the upstream edge of the tailspill and working downstream using a Surber sampler positioned below the redd to collect any eggs or remaining fry. The total number of dead eggs was recorded and excavation was halted if live fry were still present. Summary statistics for pebble count and excavation data were generated using SAS 9.1 (SAS 2003).

References

Thurow, R. F. and J. G. King. 1994. Attributes of Yellowstone cutthroat trout redds in a tributary of the Snake River, Idaho. Transactions of the American Fisheries Society 123:37-50.

SAS 9.1. 2003-2004. SAS Institute Inc. Cary, NC, USA.

Table B.1. Redd survey excavation results of Yellowstone cutthroat trout redds, Spring 2004.

Sample Stream	"Definite" Redds	Num. Redds Excavated	% Containing Eggs/Fry	Mean Dead Eggs	SD Eggs	Mean Fry	SD Fry
Teton Cr	20	8	88	13.5	20.1	1.8	4.1
Unnamed Cr	17	8	75	2.9	5.6	6.1	7.7
Fox Cr	33	17	59	7.3	20.2	29.4	111.3

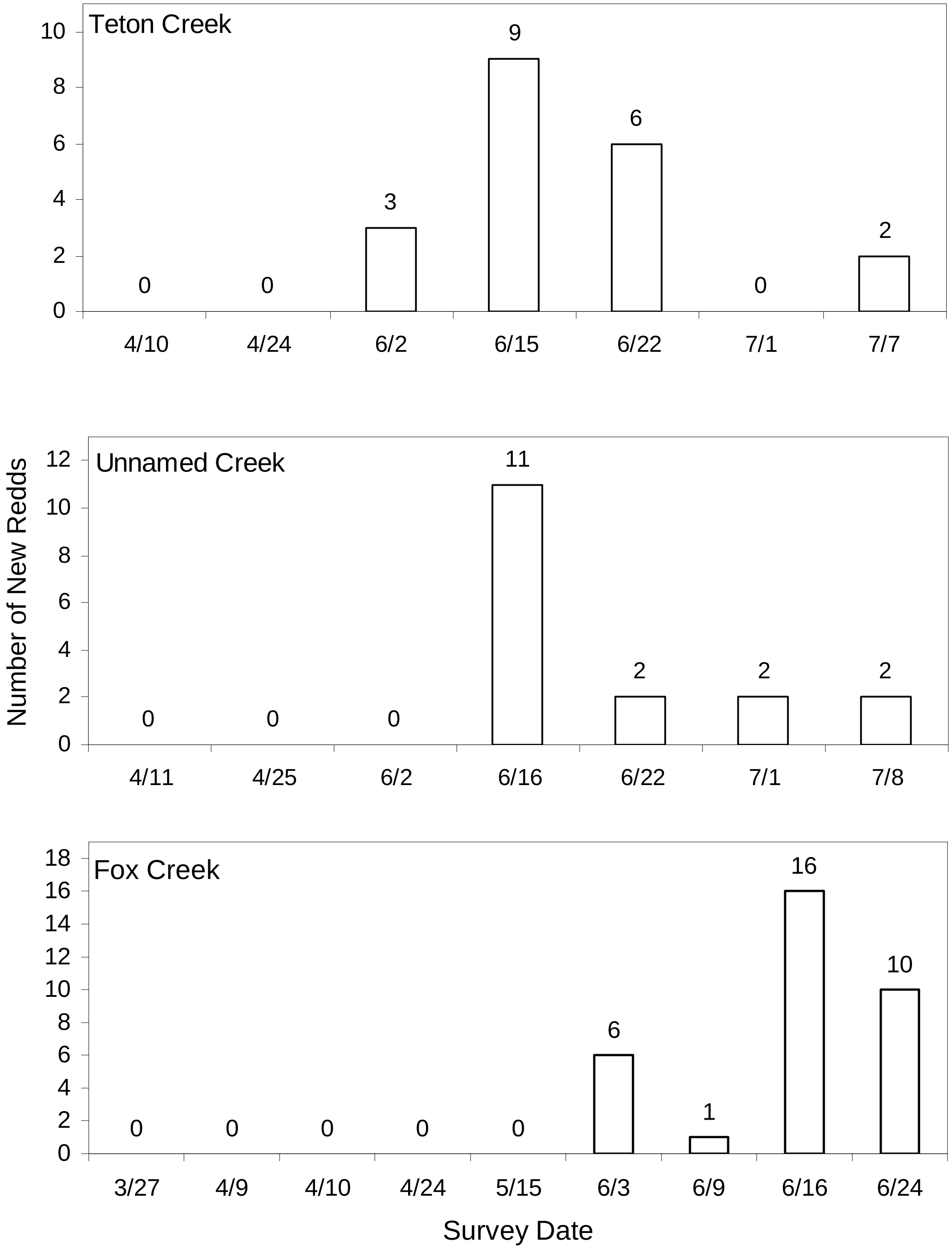

Figure B.1. Number of new Yellowstone cutthroat redds by stream during the duration of the redd survey period.

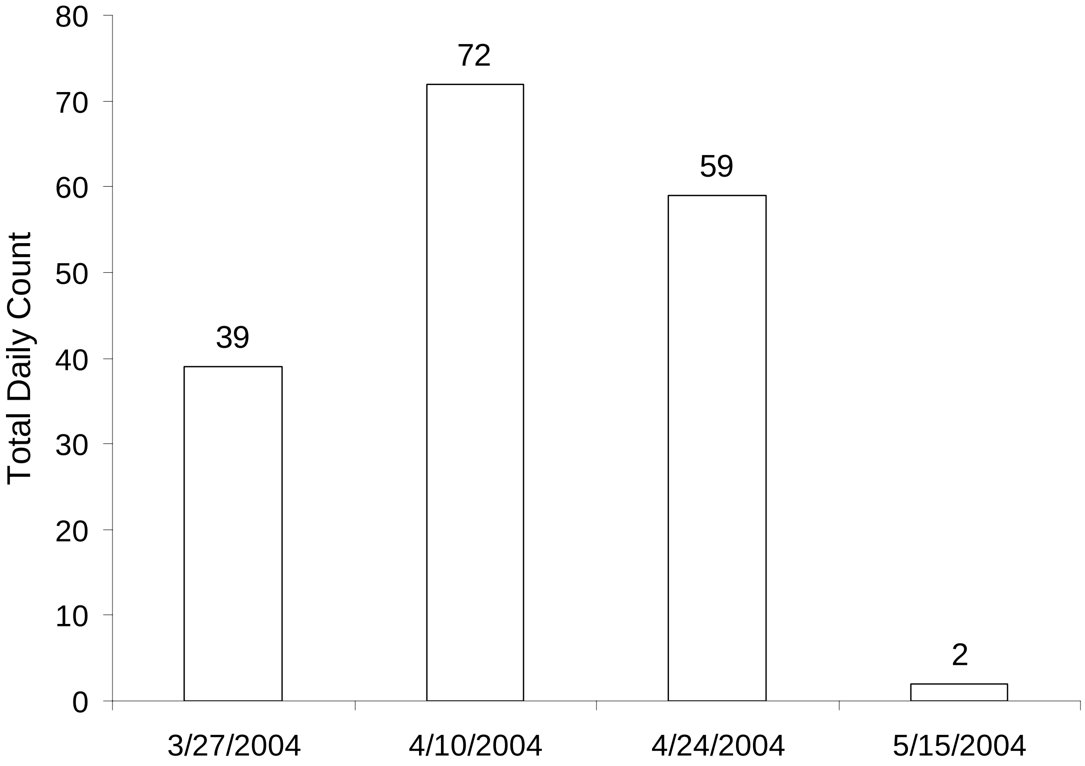

Figure B.2. Total daily count of rainbow trout redds in Fox Creek, Spring 2004.

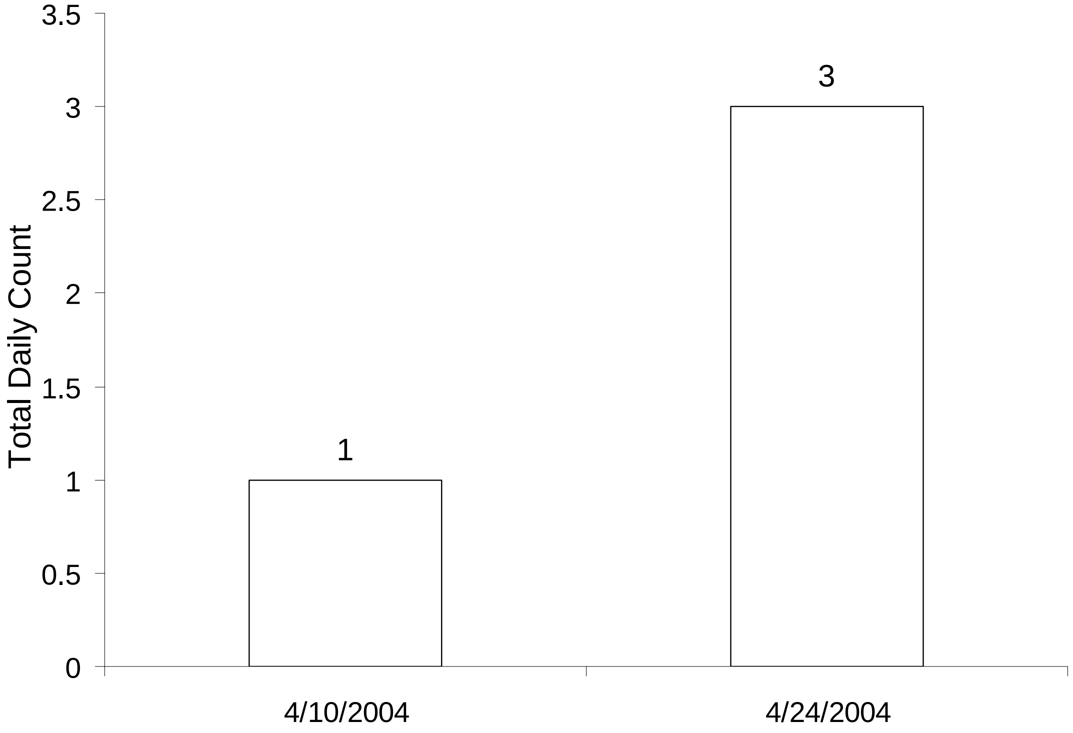

Figure B.3. Total daily count of rainbow trout redds in Teton Creek, Spring 2004.

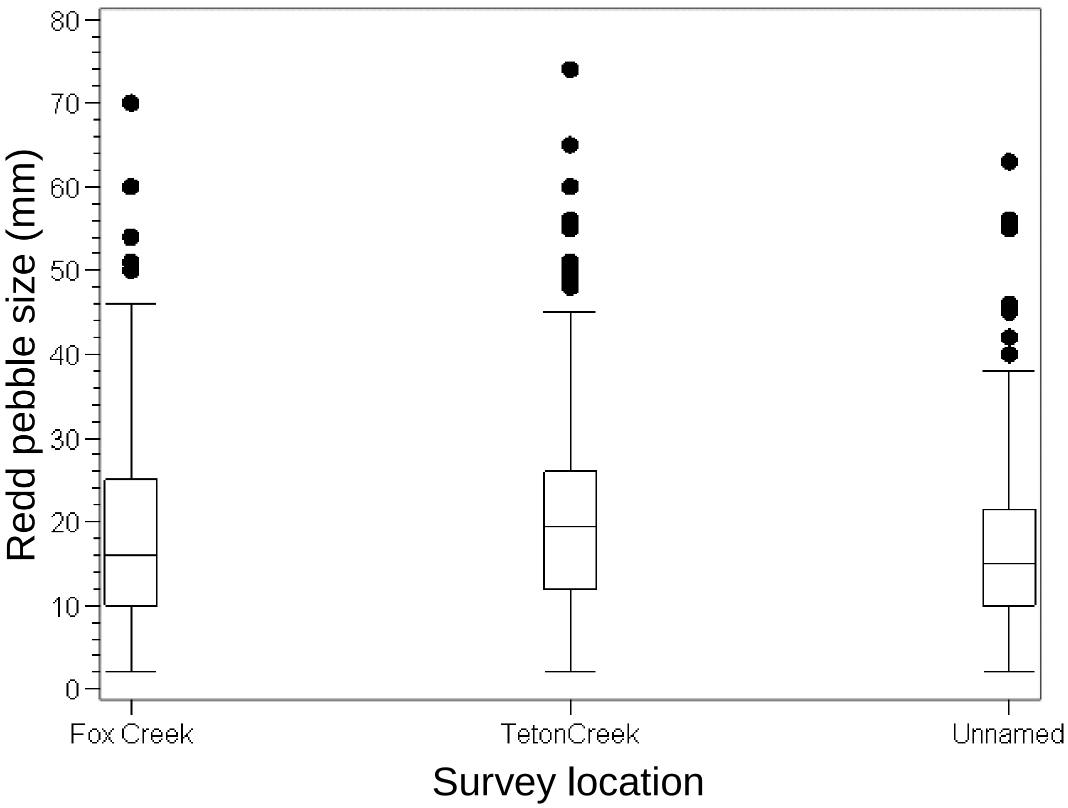

Figure B.4. Particle size distribution of Yellowstone cutthroat trout redds by survey stream for spring 2004.

APPENDIX C. Length-frequency Histograms.

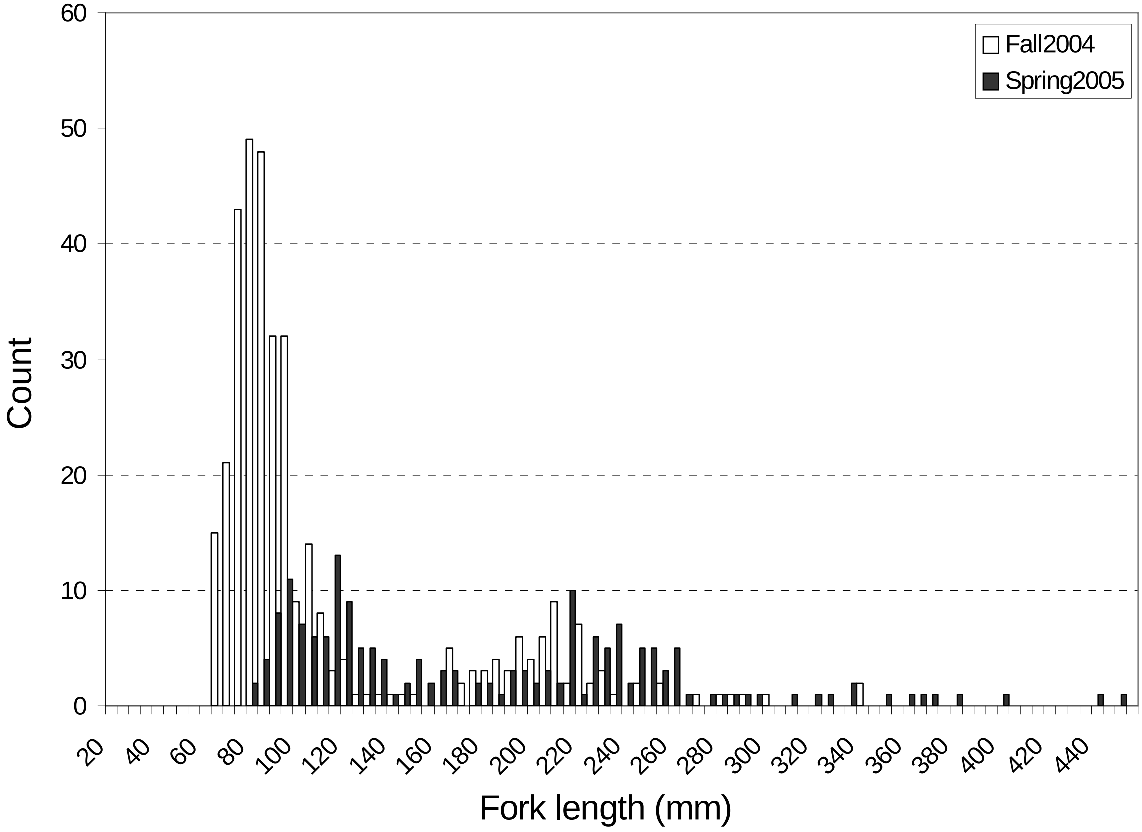

Figure C.1. Rainbow trout length-frequency histogram by season for Fox Creek, 2004-2005.

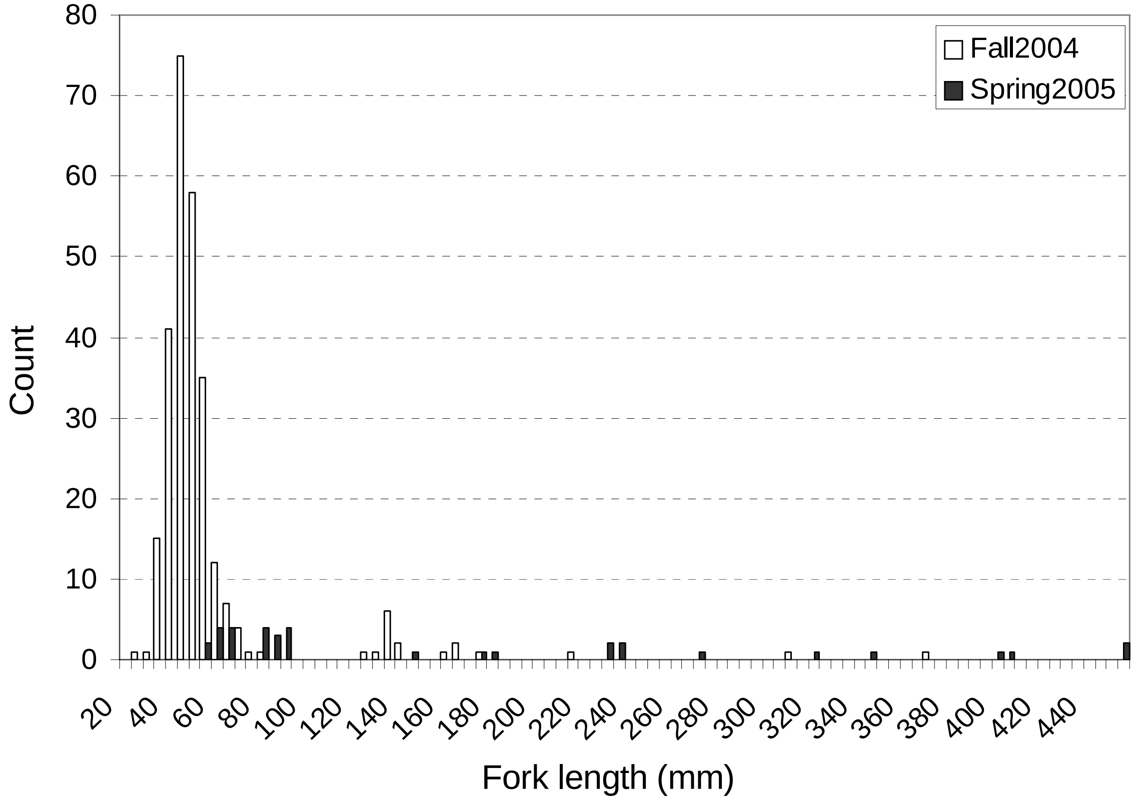

Figure C.2. Yellowstone cutthroat trout length-frequency histogram by season for Fox Creek, 2004-2005.

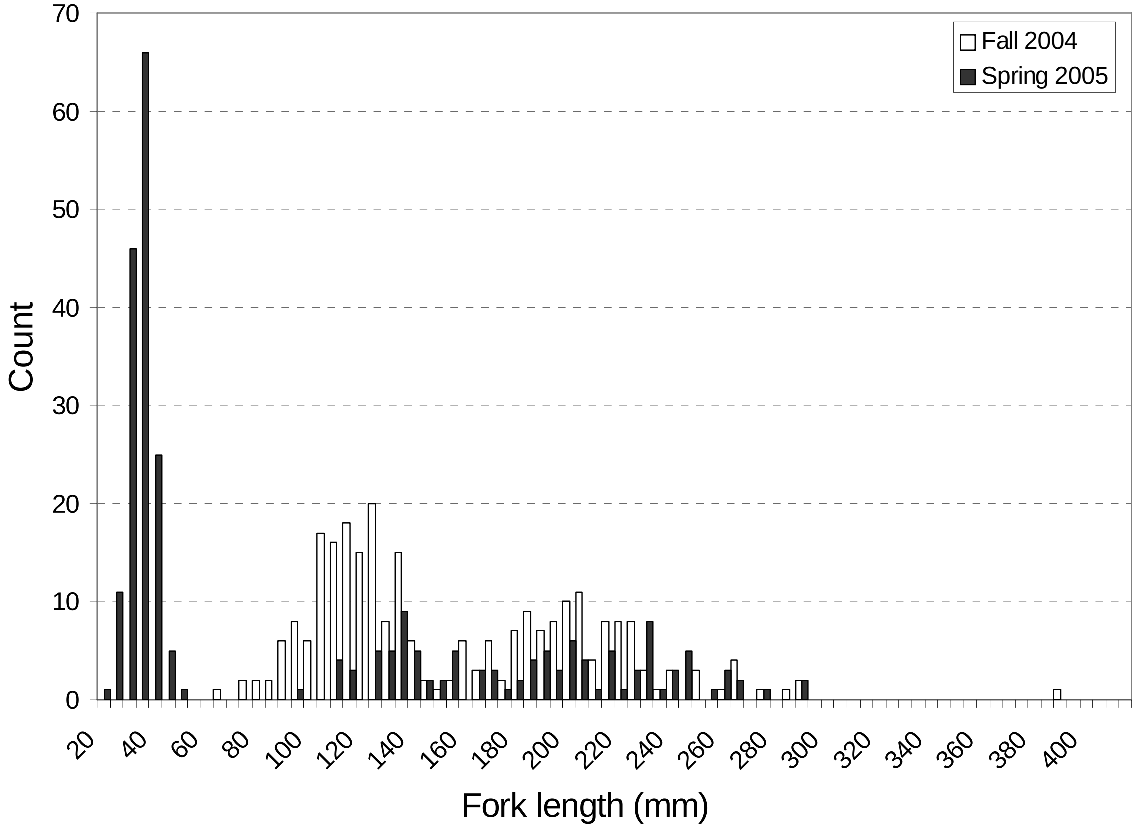

Figure C.3. Eastern brook trout length-frequency histogram by season for Fox Creek, 2004-2005.

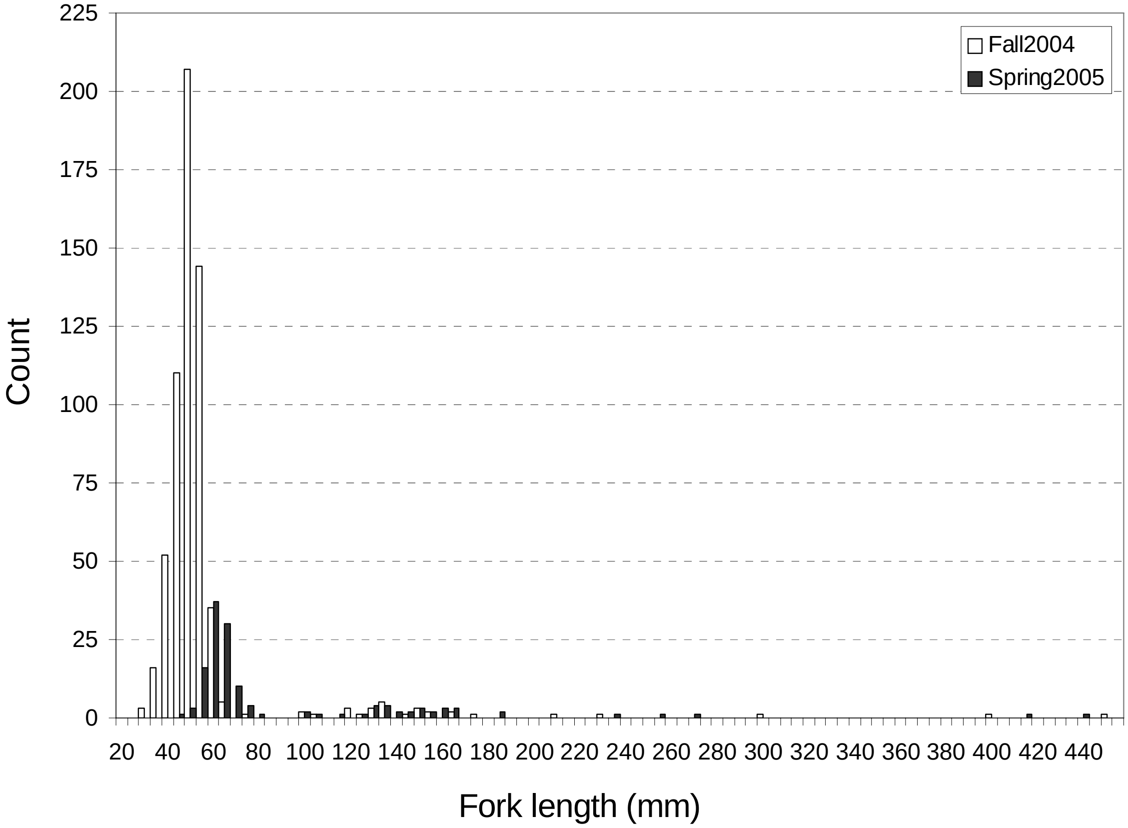

Figure C.4. Yellowstone cutthroat trout length-frequency histogram by season for Teton Creek, 2004-2005.

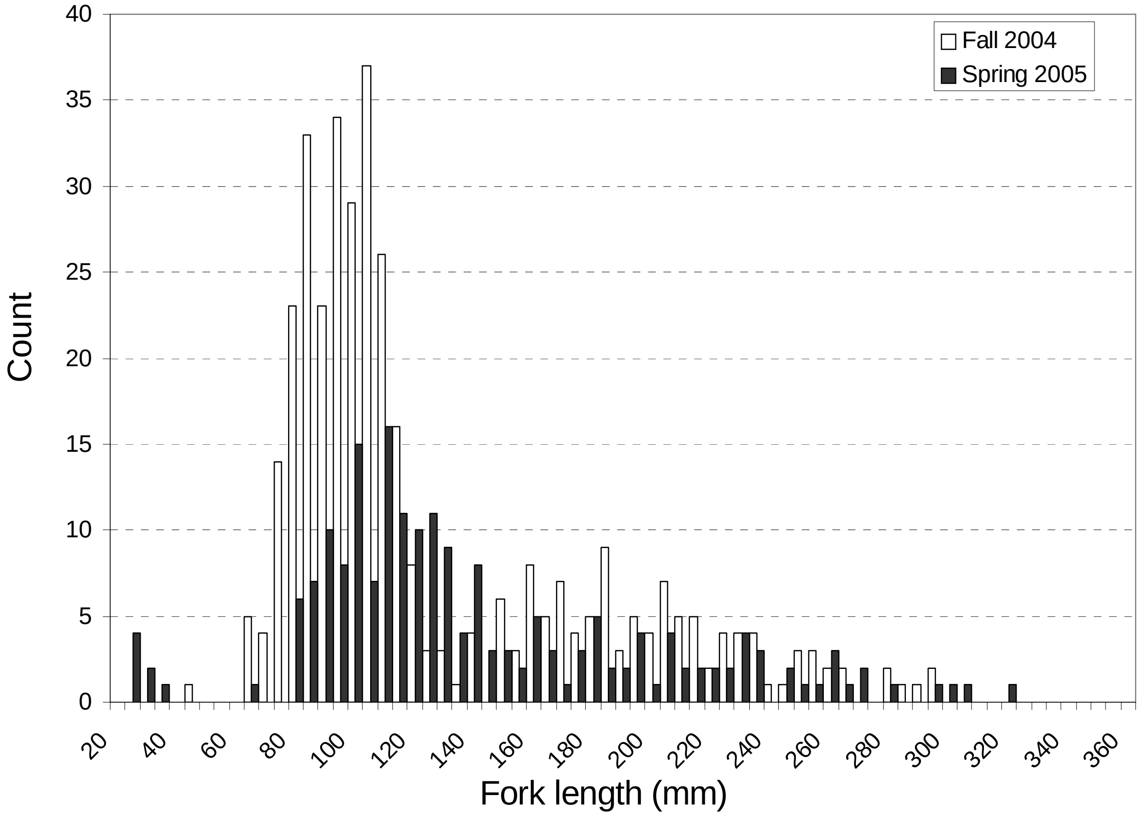

Figure C.5. Eastern brook trout length-frequency histogram by season for Teton Creek, 2004-2005.

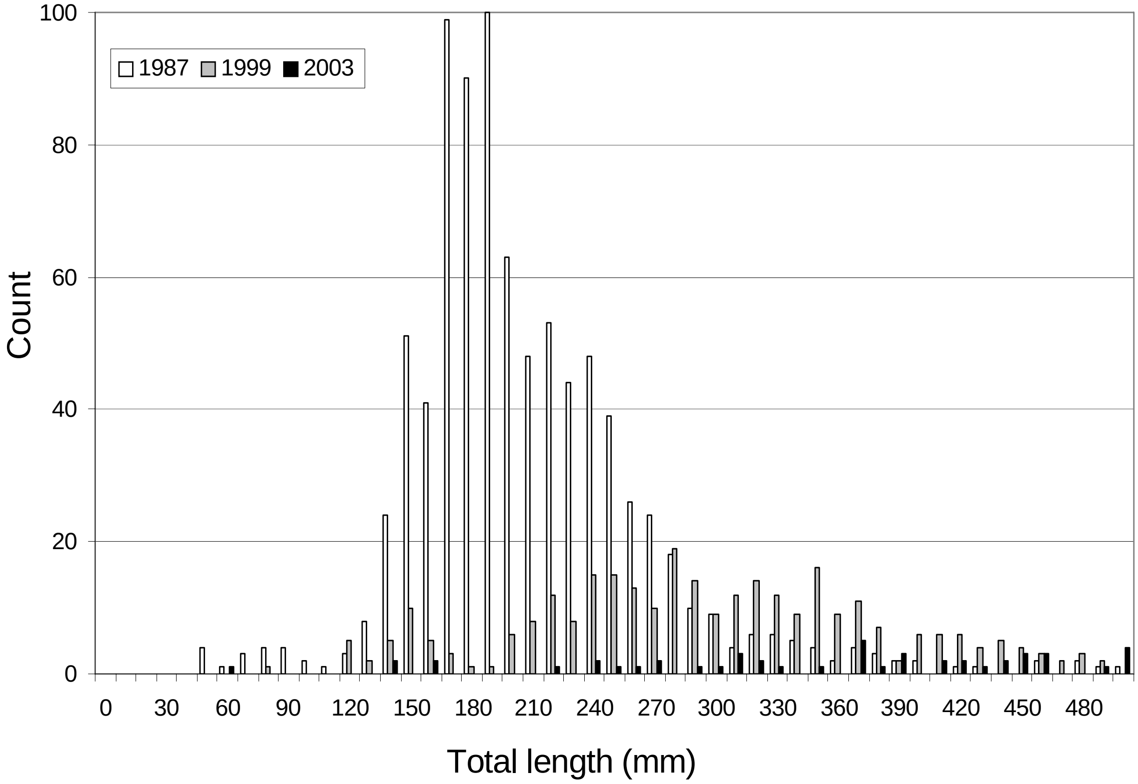

Figure C.6. Cutthroat trout length-frequency histogram by year for the mainstem Teton River collected in September, (Garren et al. *In press*).

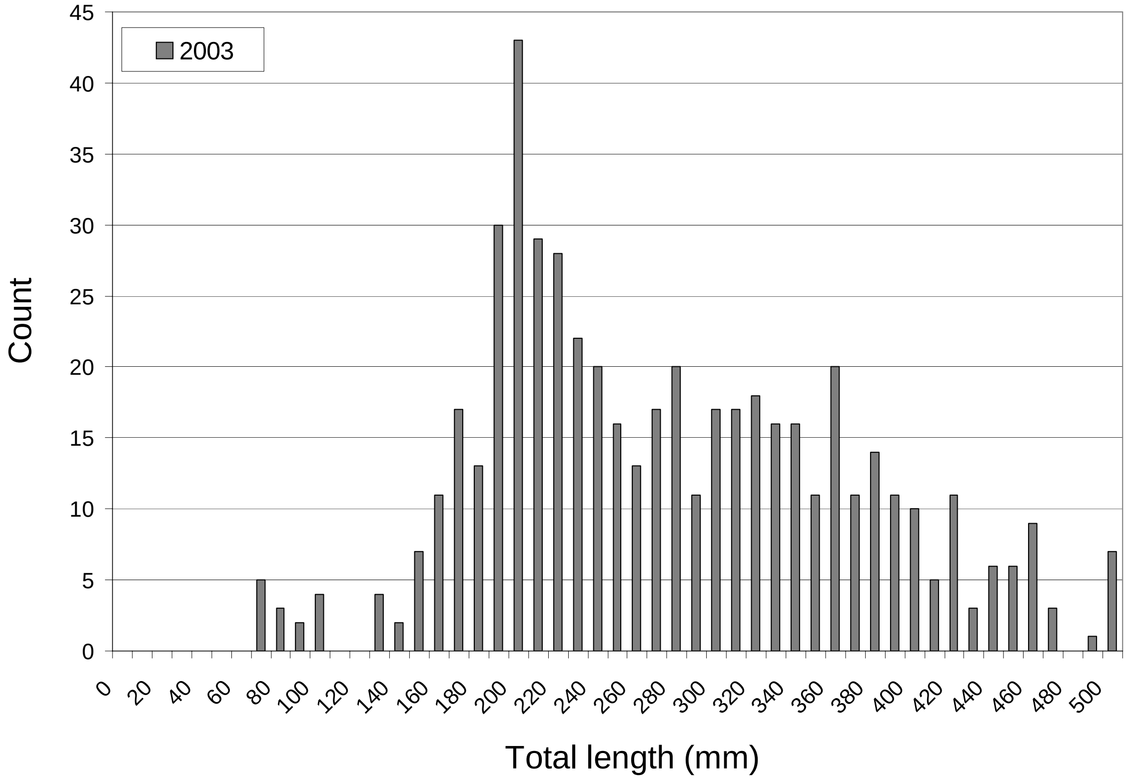

Figure C.7. Rainbow trout length-frequency histogram for the mainstem Teton River collected in September2003, (Garren et al. *In press*).

APPENDIX D. Whirling Disease Assessment.

Introduction

Since 1987, densities of Yellowstone cutthroat trout in the Teton Valley stretch of the Teton River have declined by 96% in the most representative sample site as estimated by the 2003 census (Garren et al. *In press*). These population surveys showed reduced adult cutthroat trout abundance with an overall lack of young cutthroat trout in the Teton River, suggesting that recruitment may be a factor limiting adult abundance. The Idaho Department of Fish and Game has hypothesized that population declines might be attributed to loss of spawning and early rearing habitat, loss of over-wintering habitat, cessation of stocking and possible recruitment failures associated with whirling disease.

The Teton River drainage, with the exception of upper headwaters areas is considered a high-risk area for whirling disease. The disease was first detected by IDFG in 1995 during a statewide investigation (Elle 1998). IDFG histology data indicated that 72% of fish at all Teton Valley sentinel sites had high level infections, with fish in tributary streams more heavily affected than those in the mainstem Teton River (Elle 1999). Elle suggested that these data might indicate that whirling disease is limiting trout production in the Teton valley.

This previous work assessing whirling disease in the Teton River was limited in scope and duration. Sentinel fish exposures have shown that the prevalence of infection can vary greatly over space and time (Downing et al. 2002). As part of a larger juvenile trout study in the Teton Valley, we investigated the prevalence of whirling disease using an expanded number of sentinel sites over two years. Infection was assessed with both histology and spore counts.

Methods

We used sentinel cage test fish to determine the prevalence and intensity of whirling disease infection throughout the Teton Valley, as they are one of the most reliable methods for establishing the presence or absence of M. cerebralis (Hoffman 1990). Sentinel cages exposures were conducted in two consecutive years at a total of 11 sites each year, with five of the eleven sites repeated in each year. The 2003 exposure series began on September 8th and included six mainstem Teton River sites, four tributary sites and one control (Table D.1). The 2004 exposure series began on June 28th and included two mainstem Teton River sites, eight tributary sites and one control (Table D.1). Exposures in 2003 were intended to characterize the broad scale distribution of whirling disease throughout the Teton Valley, while exposures in 2004 were focused on characterizing infection in Fox Creek and Teton Creek tributaries and replicating important sites from the initial exposure. During the 2004 exposure series, sentinel cages in Fox and Teton Creek were spaced in an “top”, “middle” and “bottom” pattern to quantify the spatial variation in infectivity. Remaining cages were used to replicate sites sampled in 2003 in order to compare yearly fluctuations in results.

Each sentinel cage contained 50 Yellowstone cutthroat trout fry originating from Mackay Hatchery. During the 2003 exposure, Henry’s Lake stock cutthroat fry weighing and average of 0.4g were used. The 2004 exposure series used cutthroat fry from the Jackson National Fish Hatchery stock raised at Mackay Hatchery averaging 0.65g. The sentinel cage experiments were conducted using the protocol outlined in

Burton et al. (2000) and consisted of a 10-day exposure period. Following exposure, fish then be reared at the Eagle Fish Health Laboratory in Eagle Idaho for at least 1300 Celsius temperature units (CTU). Feeding was scheduled daily for the first ten days, and three times weekly thereafter. Feeding rates are typically 3% of body weight/day.

Prevalence and intensity were determined using both hystopathology as well as spore counts. Ten fish from each exposure group chosen at random were sacrificed for histological analysis at 900 CTU, with one half head was preserved with 10% neutral buffered formalin, and the other half retained frozen for quantitative PCR pending future funding and interest. Previous research has indicated histopathology is maximized at 900 CTU (K. Johnson, Eagle Fish Health Laboratory, Idaho Fish and Game, personal communication) and that spore numbers plateau at 1200 CTU (K. Johnson, Eagle Fish Health Laboratory, Idaho Fish and Game, personal communication). Half-head samples sent to Colorado HistoPrep for staining and mounting prior to analysis. Slides of cranial tissue will be examined and scored according to a severity index (ranging from 0 to 5) based on that of Baldwin (2000) and were examined independently by personnel at the Washington Animal Disease Diagnostic Laboratory at Washington State University. Quantitative spore counts using pepsin-tripsin digest (PTD) were conducted after the 1300 CTU rearing period was completed. Fish samples (resulting in two half-heads) were prepared following the IDFG protocol of Hogge (2004) and all PTD samples were examined at the Eagle Fish Health Laboratory facility in Eagle, Idaho. Sample sizes varied for PTD spore count analysis depending on the number of remaining fish at the end of the rearing period. External clinical signs of the disease were recorded for each at the time of sacrifice.

Results/Discussion

The prevalence of *m .cerebralis* was noticeably different between the 2003 and 2004 exposure trials. In 2003, the mean percent positive (by pepsin/trypsin digest) by site was 33.46% with a maximum of 78.6% positive, compared to 94.6% and 100% positive in 2004, respectively. Mean average histology scores in 2003 and 2004 were 1.6 (median = 1.5) and 4.1 (median = 4.4), respectively. Mean average quantitative spore counts per sentinel fish in 2003 and 2004 were 6,595 and 30,860, respectively. Prevalence in the Teton River appeared to decrease downstream in 2003, but did not show a distinct trend in 2004. On the whole, tributary sites had higher prevalence than did mainstem sites in 2003, but in 2004, both tributary and mainstem sites were similarly infective.

Even in highly infected systems, sentinel fish exposures have shown the prevalence of infection can vary greatly over space and time (Downing et al. 2002). Our results are consistent with those of Downing et al (2002) and suggest that a single sample during one time period is probably inadequate to characterize the prevalence of m. cerebralis within the stream of interest. Infection appears to vary between locations and years, which may be function of seasonal changes in the prevalence of *m. cerebralis*.

The fish abundance sampling results presented in Chapter 2 and Appendix A indicate that Yellowstone cutthroat trout in the Teton Valley are dominated by rainbow and brook trout across all streams sampled. In light of the prevalence of *m. cerebralis* in the Teton Valley, one might anticipate that rainbow trout and brook trout would be more adversely affected than Yellowstone cutthroat trout within the same stream, all other factors being equal (Vincent 2002). Recent IDFG population surveys in the mainstem Teton River (brook trout and rainbow trout outnumber cutthroat trout) may cast doubt on the impact of the parasite or our understanding of differential susceptibility between trout species.

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Table D.1. List of sentinel exposure site locations for the Teton Valley by stream.

Location	Description	Site Name	UTM	Year Sampled
Fox Creek IDFG	Lower Fox Creek	Fox Cr. 1	12T 0486664E 4832711N	2003, 2004
Fox Creek Restoration	Middle Fox Creek	Fox Cr. 2	12T 0487202E 4831530N	2004
Fox Creek 600S.	Upper Fox Creek	Fox Cr. 3	12T 0488310E 4831291N	2004
Steel Bridge	Lower Teton Creek	Teton Cr. 1	12T 0487567E 4837844N	2003, 2004
Middle Teton Creek	Middle Teton Creek	Teton Cr. 2	12T 0489481E 4838275N	2004
Teton Creek Upper	Upper Teton Creek	Teton Cr. 3	12T 0490439E 4838595N	2003, 2004
Unnamed Creek	Unnamed Creek	Unnamed Creek	12T 0490115E 4838246N	2004
Teton River	Harrops Bridge	Teton R. 1	12T 0481298E 4852263N	2003, 2004
Teton River	Cache Bridge	Teton R. 2	12T 0483199E 4847429N	2003
Teton River	Buxton Bridge	Teton R. 3	12T 0484944E 4840971N	2003
Teton River	Bates Bridge	Teton R. 4	12T 0486766E 4837967N	2003
Teton River	White Bridge	Teton R. 5	12T 0485981E 4831659N	2003, 2004
Teton River	C. Ross Property	Teton R. 6	12T 0485845E 4829767N	2003
Trail Creek Lundquist	Lower Trail Creek	Trail Cr. Lundquist	12T 0486742E 4830003N	2004
Trail Creek	Trail Creek Diversion	Trail Cr. Diversion	12T 0494488E 4823237N	2003

Table D.2. Summary statistics for the number of spores per fish (x1000) by year for Teton Valley cutthroat trout fry sentinel exposures.

Location	Site	N	% Positive	Mean Spores / fish (x1000)	Std Dev	Minimum	Maximum	Lower 95% CI	Upper 95% CI
				2003					
Control	Control	35	0	0	0	0	0	.	.
Fox Cr IDFG	Fox Cr. 1	34	44	3.676	7.55409	0	30	1.040724	6.3122
Steel Bridge	Teton Cr. 1	23	78	42.887	68.31522	0	263.3	13.34524	72.429
Teton Cr Upper	Teton Cr. 3	33	73	4.700	5.749837	0	20	2.661197	6.7388
Harrops Bridge	Teton R. 1	22	0	0.000	0	0	0	.	.
Cache Bridge	Teton R. 2	35	5.7	0.143	0.619908	0	3.3	-0.07009	0.3558
Buxton Bridge	Teton R. 3	29	3.5	0.231	1.244159	0	6.7	-0.24222	0.7043
Bates Bridge	Teton R. 4	35	54	8.054	13.79881	0	53.3	3.314227	12.794
White Bridge	Teton R. 5	35	57	5.480	9.460376	0	40	2.230247	8.7298
Charlie Ross	Teton R. 6	37	0	0.000	0	0	0	.	.
Trail Cr	Trail Cr Div	37	19	0.581	1.244284	0	3.3	0.166216	0.9959
				2004					
Control	Control	20	0	0	0	0	0	.	.
Fox Cr IDFG	Fox Cr. 1	24	100	39.0958333	42.76809	1.7	186.7	21.03645	57.155
Fox Cr Restoration	Fox Cr. 2	5	100	38.68	34.7881	3.3	96.7	-4.51513	81.875
Fox Cr 600S	Fox Cr. 3	30	100	23.22	31.56315	1.7	150	11.43412	35.006
Steel Bridge	Teton Cr. 1	14	100	68.5714286	37.16111	10	133.3	47.11524	90.028
Teton Cr Middle	Teton Cr. 2	29	97	25.1758621	25.14262	0	96.7	15.61212	34.74
Teton Cr Upper	Teton Cr. 3	29	100	15.9206897	20.30785	1.7	93.3	8.195996	23.645
Harrops Bridge	Teton R. 1	7	100	40	29.39263	3.3	76.7	12.81635	67.184
White Bridge	Teton R. 5	23	100	17.973913	15.2697	1.7	46.7	11.3708	24.577
Trail Cr	Trail Cr Lund	26	100	40.5692308	56.84616	1.7	240	17.60857	63.53
UnNamed	UnNamed Cr	8	50	3.325	4.707365	0	13.3	-0.61046	7.2605

Table D.3. Summary statistics for histology scores per fish by year for Teton Valley cutthroat trout fry sentinel exposures.

Location	Site	N	% Positive	Mean Score / fish	Std Dev	Minimum	Maximum	Range
				2003				
Control	Control	10	0	0	0	0	0	0
Fox Cr IDFG	Fox Cr. 1	10	80	1.7	1.2516656	0	4	4
Steel Bridge	Teton Cr. 1	10	100	4.4	1.0749677	2	5	3
Teton Cr Upper	Teton Cr. 3	10	80	2.3	1.6363917	0	5	5
Harrops Bridge	Teton R. 1	10	0	0	0	0	0	0
Cache Bridge	Teton R. 2	10	20	0.2	0.421637	0	1	1
Buxton Bridge	Teton R. 3	10	30	0.7	1.2516656	0	3	3
Bates Bridge	Teton R. 4	10	70	2.7	2.2632327	0	5	5
White Bridge	Teton R. 5	10	70	2.1	1.8529256	0	4	4
Charlie Ross	Teton R. 6	10	20	0.5	1.0801234	0	3	3
Trail Cr	Trail Cr. Div	10	40	1.2	1.8135294	0	5	5
				2004				
Control	Control	10	0	0	0	0	0	0
Fox Cr IDFG	Fox Cr. 1	10	100	4.4	1.0749677	2	5	3
Fox Cr Restoration	Fox Cr. 2	10	100	5	0	5	5	0
Fox Cr 600S	Fox Cr. 3	10	100	4.1	1.3703203	1	5	4
Steel Bridge	Teton Cr. 1	10	100	4.4	0.843274	3	5	2
Teton Cr Middle	Teton Cr. 2	10	100	4.7	0.9486833	2	5	3
Teton Cr Upper	Teton Cr. 3	10	100	4.8	0.6324555	3	5	2
Harrops Bridge	Teton R. 1	10	50	5	0	5	5	0
White Bridge	Teton R. 5	10	100	3.5	1.5811388	1	5	4
Trail Cr	Trail Cr. Lundquist	10	100	4.3	1.3374935	1	5	4
UnNamed	Unnamed Cr.	10	100	1	1.3333333	0	4	4

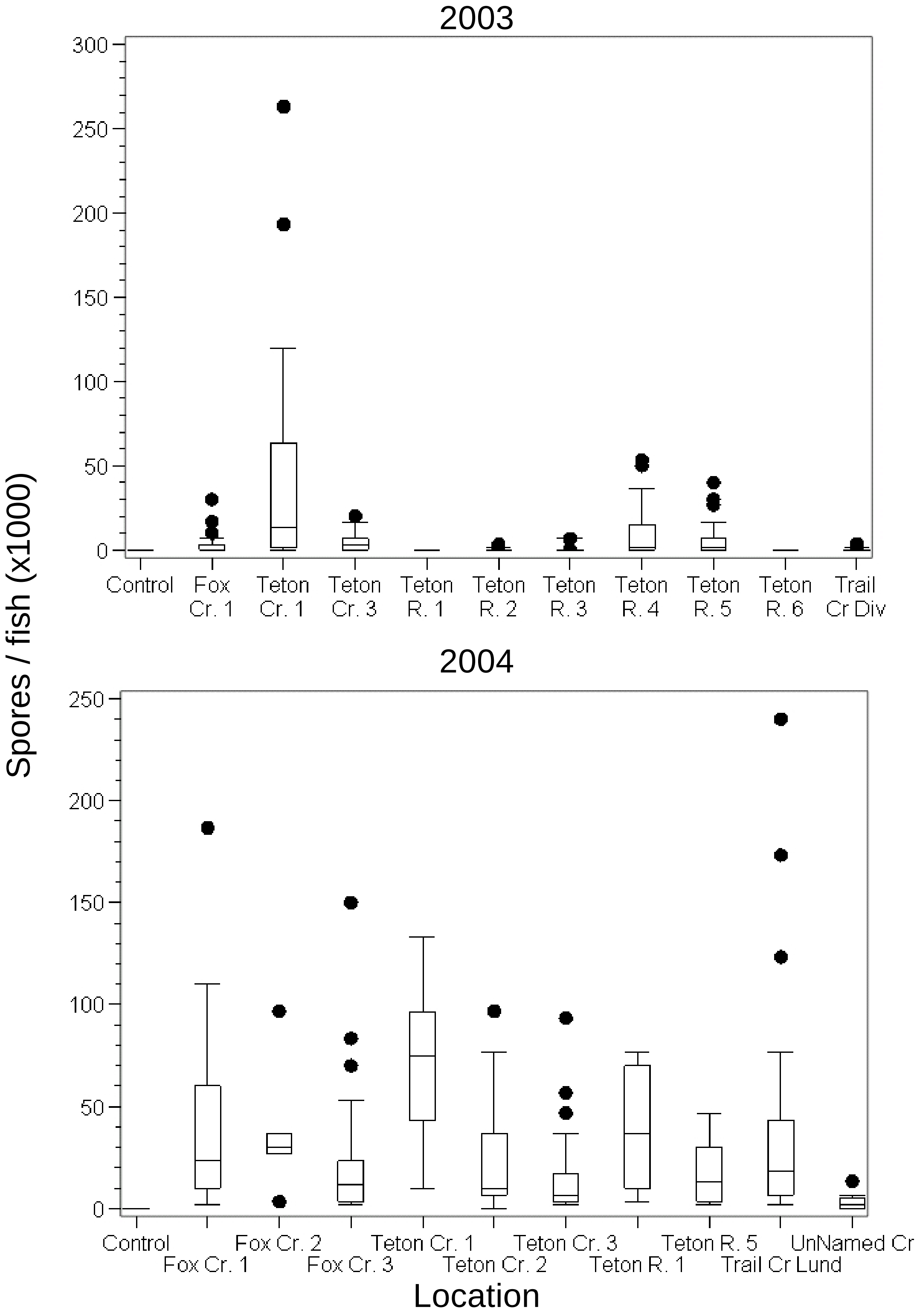

Figure D.1. Box plot of spore counts (x1000) by location and year for the Teton Valley cutthroat trout fry sentinel exposures. Brackets indicate 1.5 times the interquartile range.

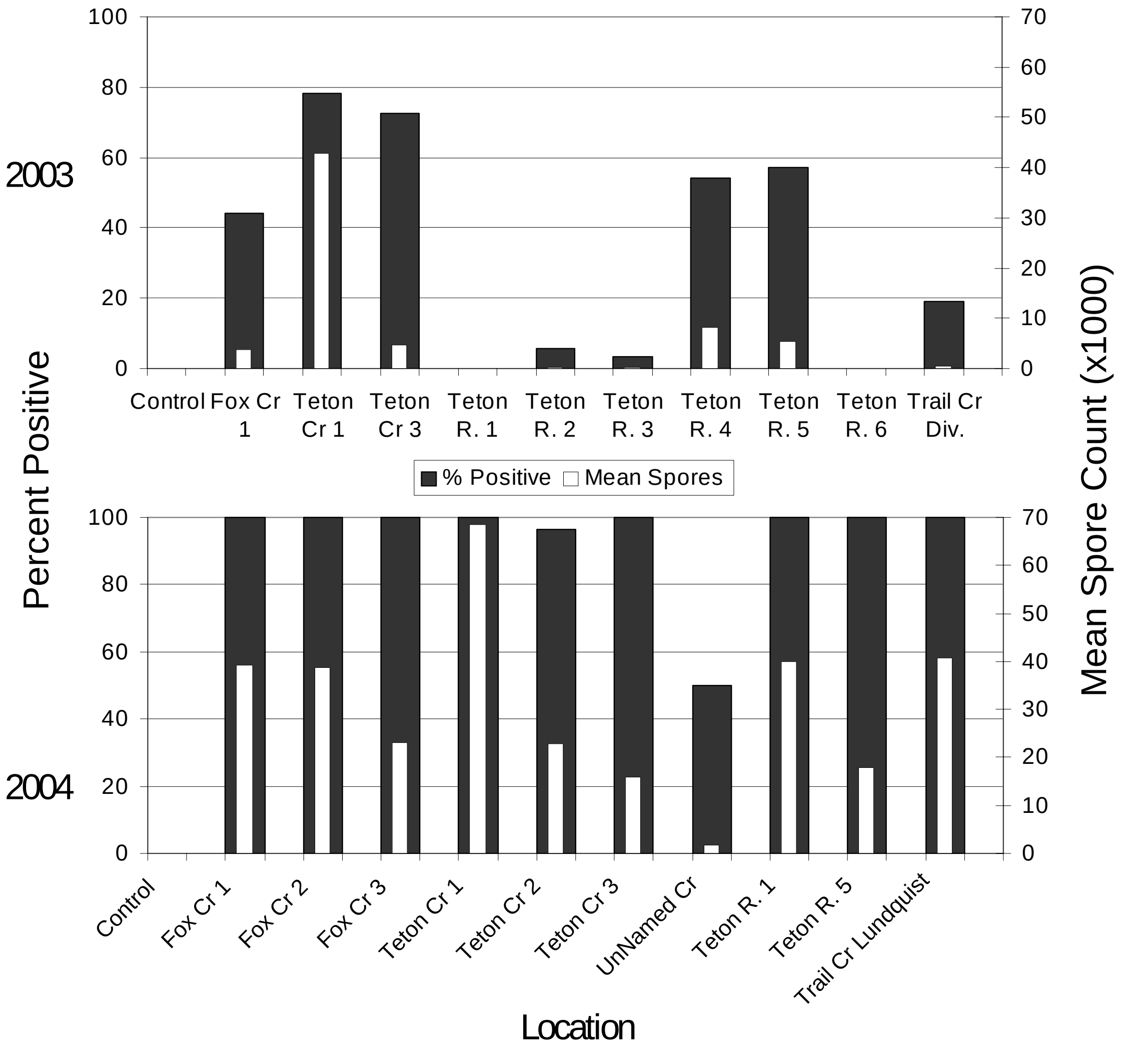

Figure D.2. Percent positive and mean spore count (x1000) by year for Teton Valley cutthroat trout sentinel exposures.

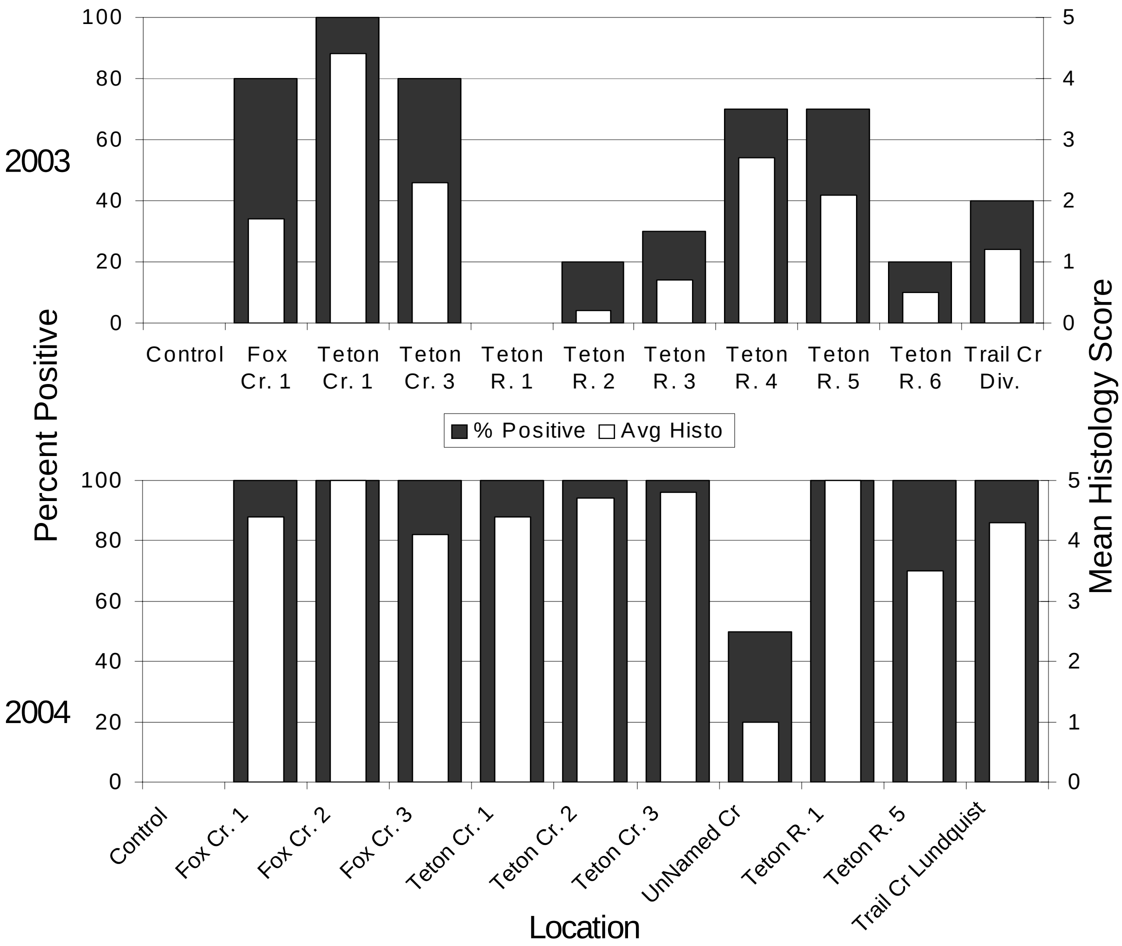

Figure D.3. Percent positive and mean histology score by year for Teton Valley cutthroat trout sentinel exposures.

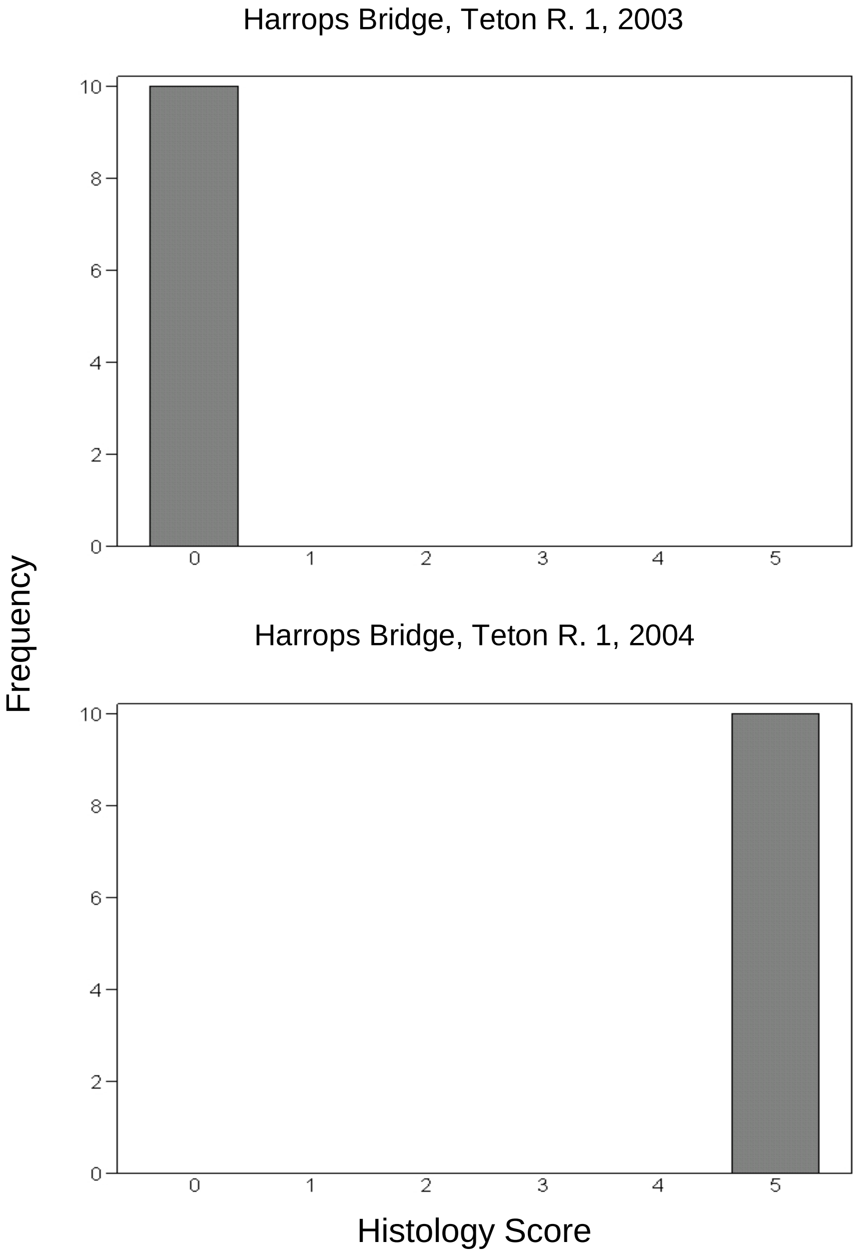

Figure D.4. Frequency distribution of histology scores for the Teton River at Harrops Bridge by year (N=10).

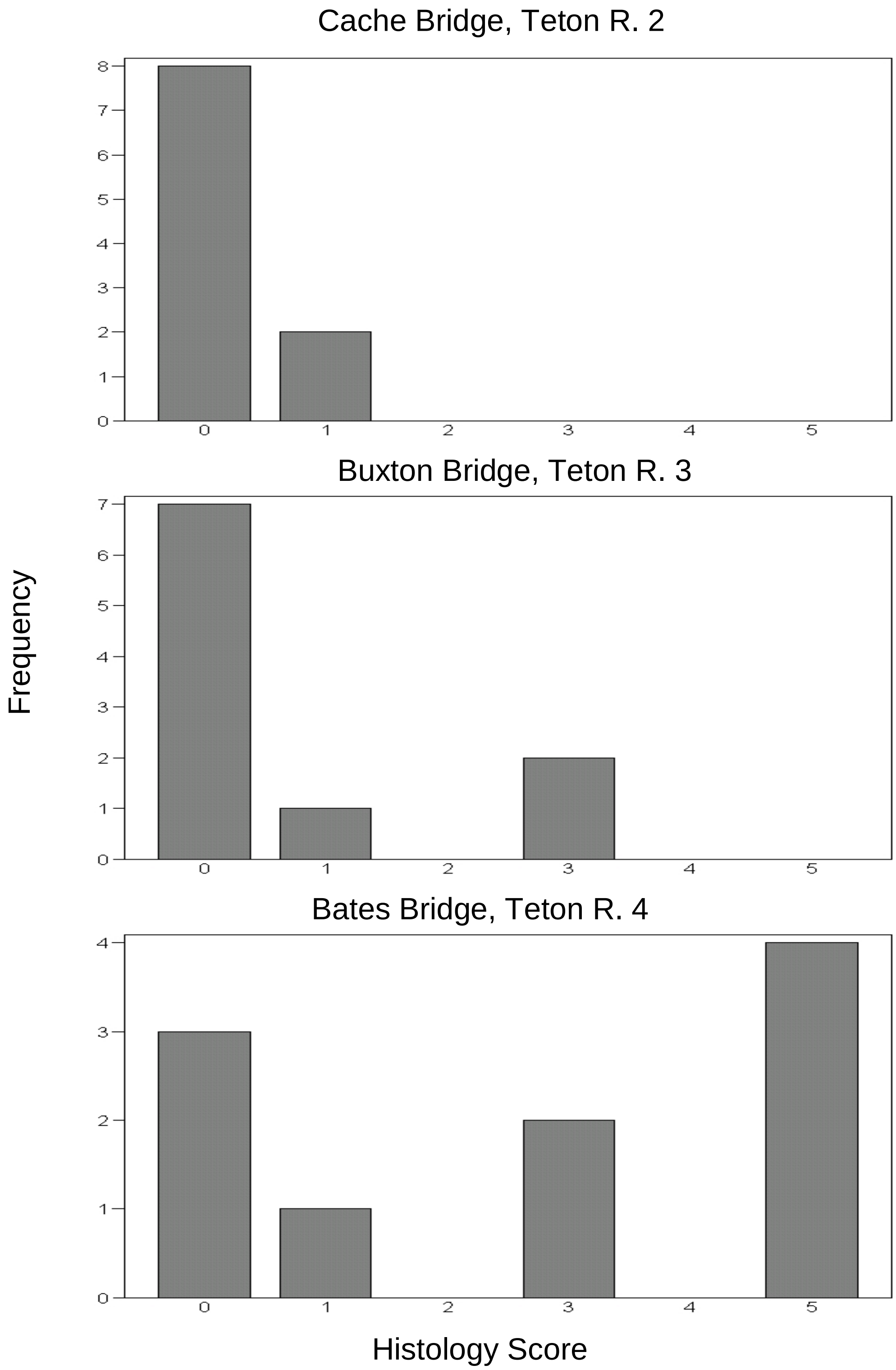

Figure D.5. Frequency distribution of histology scores for the Teton River at Cache, Buxton and Bates Bridges in 2003 (N=10).

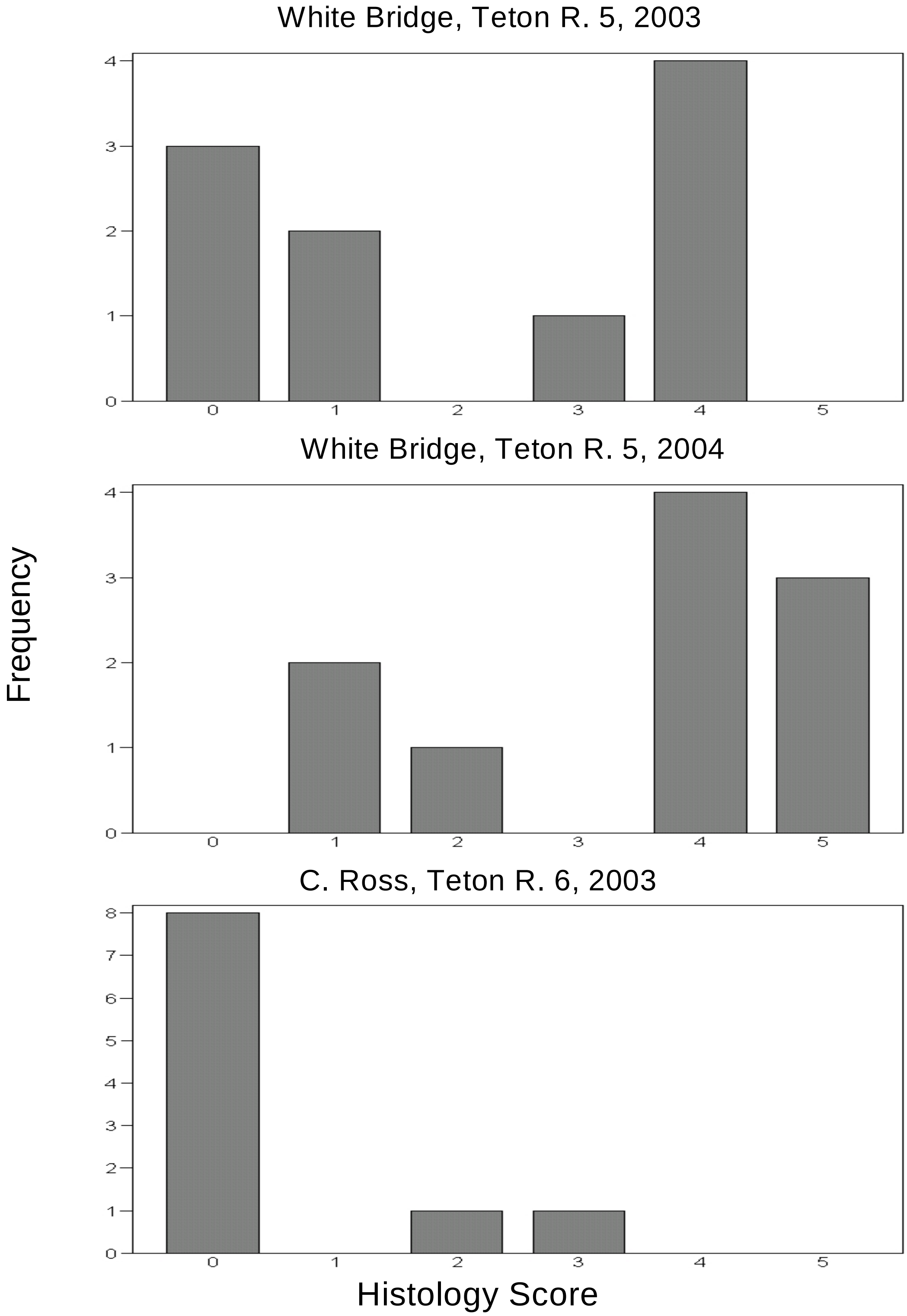

Figure D.6. Frequency distribution of histology scores for the Teton River at White Bridge in 2003 and 2004 and at the C. Ross property in 2003 (N=10).

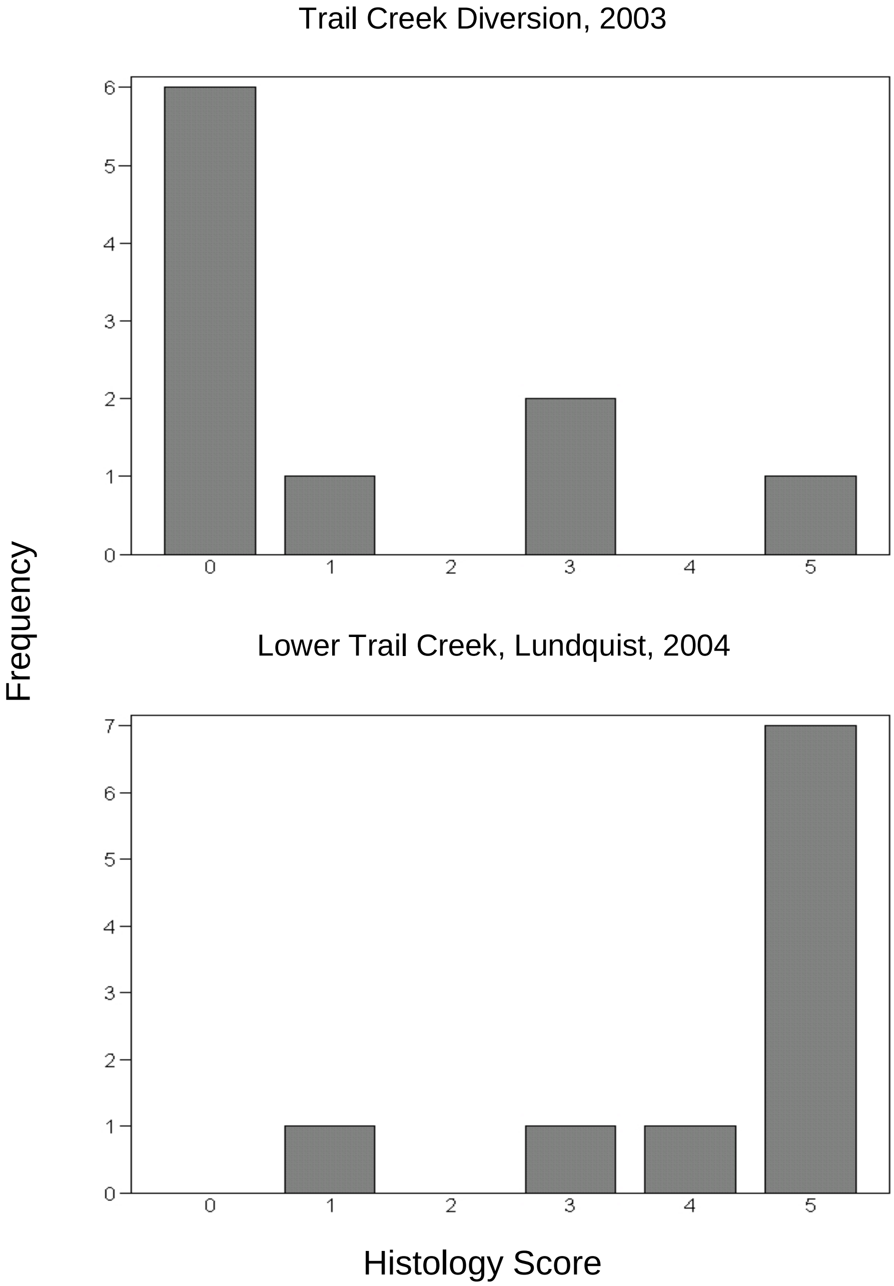

Figure D.7. Frequency distribution of histology scores for Trail Creek Diversion 2003, and at Lower Trail Creek, Lundquist property in 2004 (N=10).

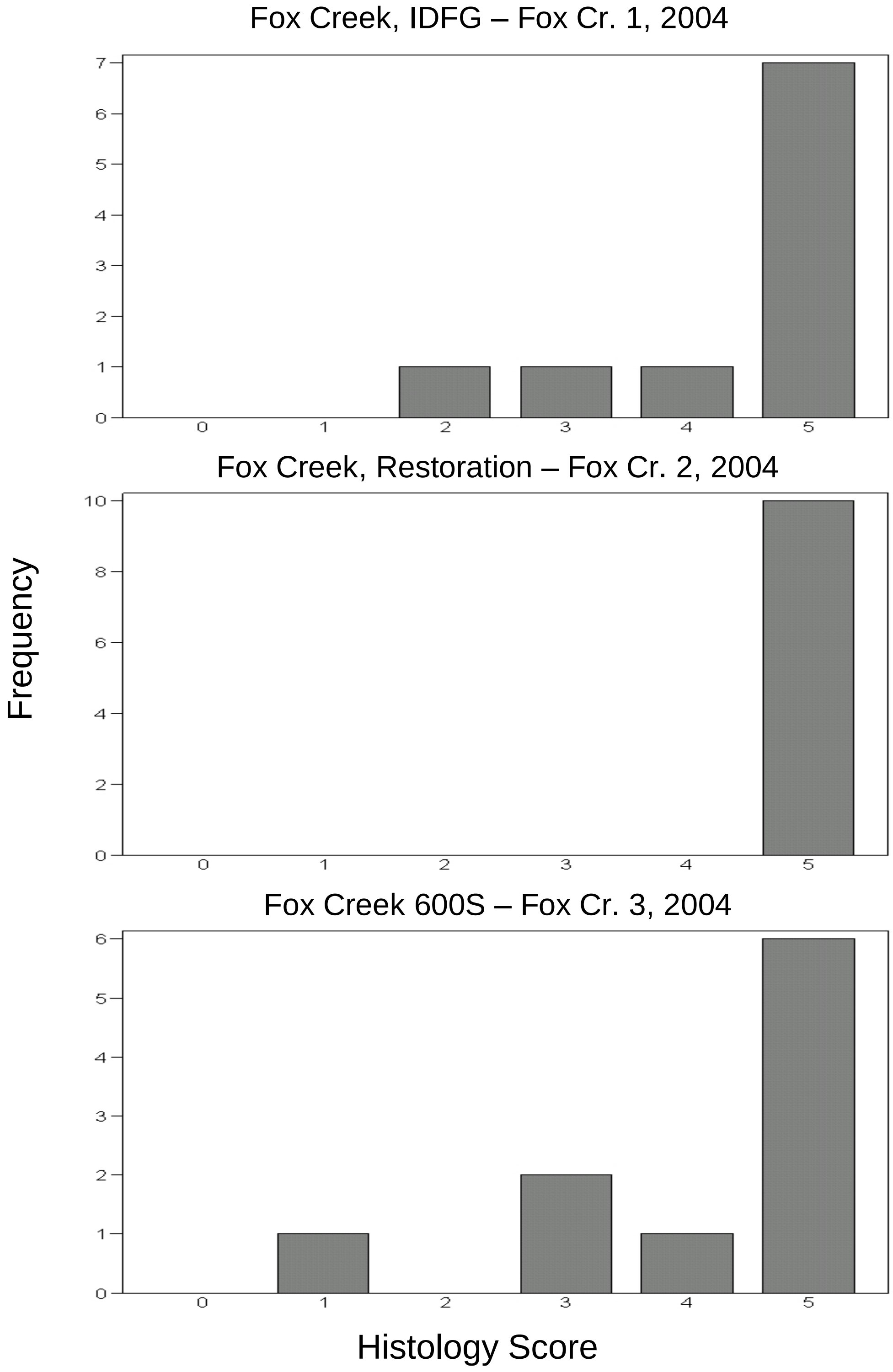

Figure D.8. Frequency distribution of histology scores for Fox Creek sites in 2004, numbered going upstream (N=10).

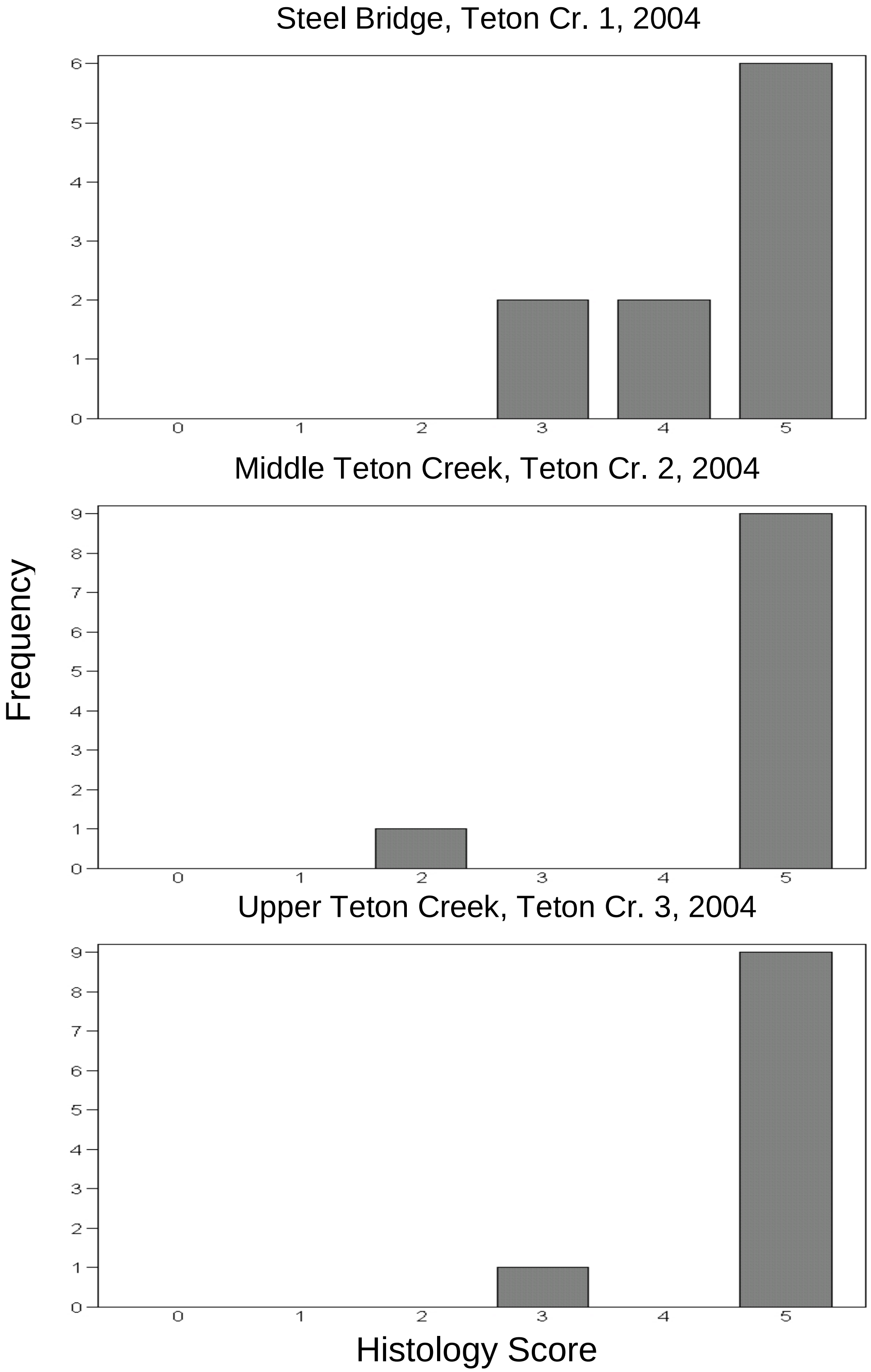

Figure D.9. Frequency distribution of histology scores for Teton Creek sites in 2004, numbered going upstream (N=10).

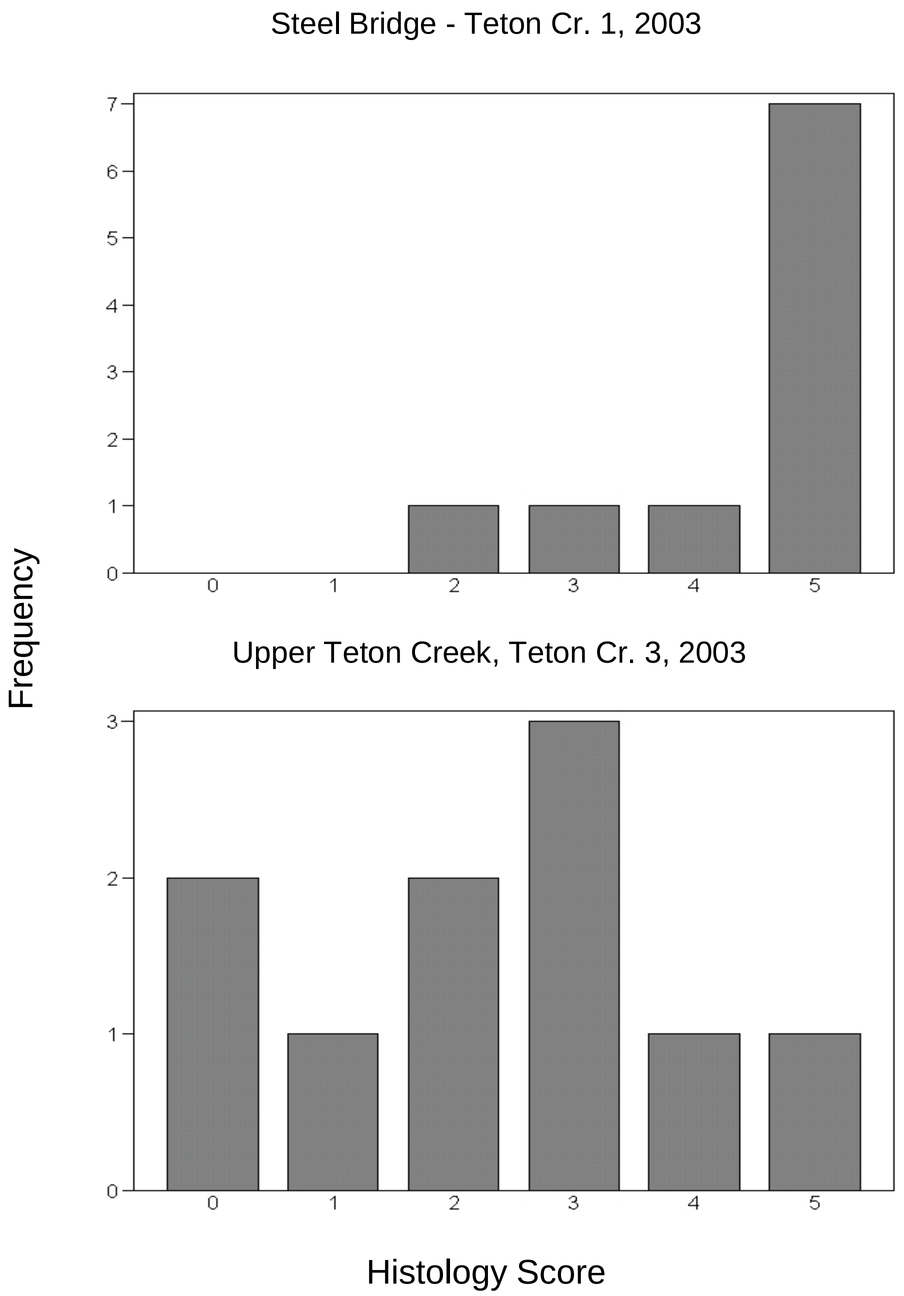

Figure D.10. Frequency distribution of histology scores for Teton Creek sites in 2003, numbered going upstream (N=10).

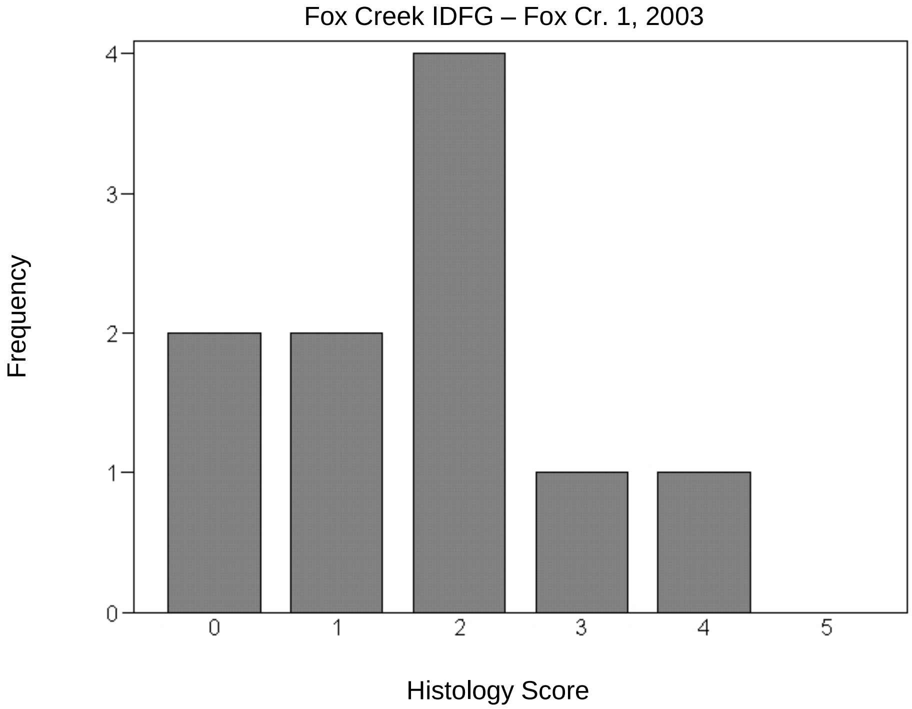

Figure D.11. Frequency distribution of histology scores for Fox Creek at the IDFG access in 2003, (N=10).

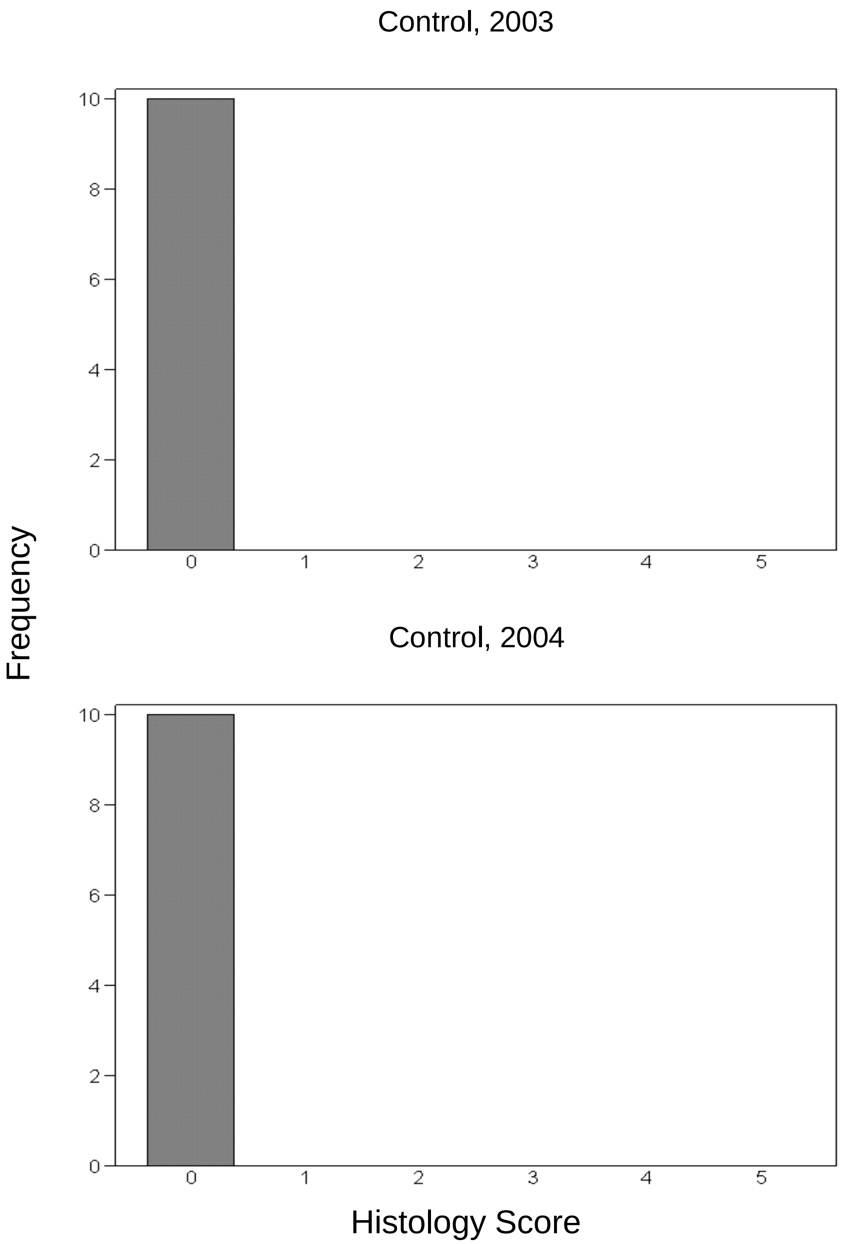

Figure D.12. Frequency distribution of histology scores for hatchery control exposures in 2003, and 2004 (N=10).