*Wyoming Game and Fish Department*
*Fish Division, Administrative Report 2012*

# Performance of Firehole and Eagle Lake strain rainbow trout in two tailwater fisheries: Miracle Mile and Cardwell reaches of the North Platte River

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## *Abstract*

Performance of Firehole and Eagle Lake strains of rainbow trout (*Oncorhynchus mykiss*) was investigated in two tailwater sections of the North Platte River (Miracle Mile and Cardwell). Performance attributes investigated include growth, condition, survival, pattern in seasonal abundance, contribution to the overall trout population, and return to anglers. Equal numbers of each strain were stocked annually from 2005 – 2008. Fish were sampled annually in September at Cardwell and in July 2006, 2008 and 2009 in the Miracle Mile. In addition, fish were sampled at the Miracle Mile monthly from June to October, 2009 to investigate seasonal abundance. No clear differences in growth or condition were apparent in the Miracle Mile. Firehole rainbows tended to be larger in Cardwell, but analysis was hampered by low sample size. The population of stocked rainbow trout in the Miracle Mile was more or less equally split between Firehole and Eagle Lake strains as was return to anglers. Firehole outnumbered Eagle Lake rainbows three to one in the Cardwell reach. From a cohort perspective in the Miracle Mile, Firehole were more numerous 50% of the time, Eagle Lake 25%, and tied 25%. Recommendations were made to stock Firehole rainbows in the Miracle Mile and discontinue all stocking at Cardwell.

## *Introduction*

Stocking plays an integral role in the establishment and sustainability of salmonid populations in many Wyoming tailwater streams. Wiley (2003) stated the two preferred options for trout management in Wyoming streams are complete dependency on natural reproduction, or judicious use of hatchery reared fish. While the majority of Wyoming trout streams are managed as wild fisheries, many tailwaters are managed under the yield concept and managers are responsible to ensure that hatchery production is used wisely.

Water developments alter the hydrologic regime of downstream river reaches. Decreased peak flows allow for the accretion of fine sediments. Concurrently, reservoirs retain bed-load material and effectively halt recruitment of new gravels into a tailwater system (Wenzel 1993). Hydroelectric power generation can result in rapid flow fluctuations which have been shown to be detrimental for downstream fish and invertebrate production (Cushman 1985). Additively, these factors can result in unfavorable environments for natural salmonid production forcing fishery managers to adopt stocking strategies to maintain publicly acceptable trout populations. For example, Welker (1998) concluded stocking was essential for the sustainability of quality rainbow trout angling in the Bighorn River. Similarly, Zafft and Vogt (1992) determined flow variations were detrimental to natural reproduction in the Miracle Mile.

It has been well documented in the literature that stocking salmonids into stream environments is wrought with problems (Wiley 1989). Survival of planted fish has been shown to be impacted by nutrient limitations (Ersback and Haase 1983) and predation (Walters et al. 1997). Stocked fish are often poorly represented in the population within a year of stocking (Johnson and Fowden 1991, Johnson 1997) and return poorly to anglers (Bailey 2002, Cavalli 2007). Genetic variation among different strains of trout offers managers a tool to optimize the success of stocking programs by selecting the strain best suited to individual waters. Many authors have found it is possible to improve stocked trout fisheries and maximize the economics of a stocking program by choosing a particular strain based on measured performance attributes (Rawstron 1972, Babey and Berry 1989, Braun and Kincaid 1982, Moring 1982).

Stocking and strain evaluations in Wyoming have largely centered on maximizing growth and return to anglers in large reservoir fisheries (Wengert 1990, Whaley 1993, Deromedi 2000). Studies on stocking in rivers generally found poor performance of stocked rainbow trout (Kanaly 1969, Johnson and Fowden 1991). Of the various rainbow trout strains available in Wyoming prior to 1990, none had been selected based on an affinity for lotic systems.

In 1991, a river rainbow trout (RRB) strain was developed from wild rainbow trout populations in the Middle Fork Powder River (Johnson County), Deer Creek (Converse County) and Bates Creek (Natrona County). The broodstock was developed on the premise that these fish would outperform conventional rainbow strains in streams. Johnson (1997) evaluated RRB in the Sweetwater River and found poor survival of these plants. By 1999, the RRB strain was discontinued due to poor egg quality (Jim Barner, personal communication). The Firehole strain (FHR) was developed as a replacement for the RRB as a strain better suited to flowing water. The original broodstock was developed from adult fish captured in 1998 and 1999 from the Firehole River, Yellowstone National Park.

The purpose of this study was to evaluate performance of FHR relative to Eagle Lake strain (ELR) rainbow trout in two tailwater sections of the North Platte River. In contrast to FHR, ELR would be considered a lake adapted fish. The strain is indigenous to Eagle Lake, California. The current captive brood stock maintained in Wyoming was developed in 1981 using eggs from Mt. Shasta, California along with eggs from the Newton Lakes near Cody. The original purpose of ELR was to provide a piscivorous trout although this trait has not been well documented in Wyoming (Diekema and Barner, 2010).

Performance attributes investigated include growth, condition, survival, contribution to the overall trout population, and return to anglers. Also, proportion by strain was investigated both spatially and seasonally. It was hypothesized that A) FHR would exhibit better growth and condition than ELR due to FHR being a "river" strain; and B) ELR numbers would vary seasonally due to movements into downstream reservoirs. The results of the comparisons will be used to choose the most appropriate strain for stocking into these two tailwaters.

### *Study Area*

The Miracle Mile reach of the North Platte River extends from Kortes Dam to Pathfinder Reservoir and is located approximately half-way between Casper and Rawlins in north central Carbon County (Figure 1). The reach can vary from as little as six miles to as many as 15 miles, depending on Pathfinder Reservoir storage elevation. The reach is defined in Wyoming fishing regulations as ending at the confluence with Sage Creek, 7.4 miles below Kortes Dam. This reach is classified as blue ribbon trout water, and typically holds more than 1,500 pounds of trout per mile (WGFD 2009). The trout population generally approximates 50% brown trout (*Salmo trutta*) and 50% rainbow trout (*Oncorhynchus mykiss*). The RBT population includes individuals that were stocked directly into the Miracle Mile, as well as wild RBT and fall strain RBT stocked into downstream Pathfinder Reservoir. Snake River cutthroat trout (*Oncorhynchus clarkii ssp.*) and walleye (*Sander vitreum*) are present in low numbers. Flows in the Miracle Mile are highly variable ranging from base winter flows of 500 cfs to as high as 4,500 cfs during peak irrigation demand. Typical summer flow varies from 1,700 cfs to 2,500 cfs. Due to hydroelectric generation, this reach can be subject to diurnal fluctuations of more than 500 cfs as well (Wichers 1996).

The Cardwell reach of the North Platte River extends 4.1 miles from Pathfinder Dam to Alcova Reservoir and is located approximately 30 miles southwest of Casper in south central Natrona County (Figure 1). The majority of the North Platte River is routed directly from Pathfinder Reservoir to Alcova Reservoir via a tunnel to facilitate power generation. A perennial 75 cfs flow was established in 2002 from Pathfinder Dam to allow development of a trout fishery. The reach is classified as blue ribbon water supporting 1,400 pounds of trout per mile (WGFD 2010). The trout population has historically been comprised of over 98% RBT, but BNT have been increasing in numbers and currently represent 27% of the total trout population. Unlike the Miracle Mile, RBT in Cardwell are either stocked into the river or are wild as RBT from downstream Alcova Reservoir are blocked from moving upstream into Cardwell by a natural fish barrier in Fremont Canyon.

## Methods

### *Marking and Stocking*

Approximately 40,000 individuals of each strain were stocked annually in the Miracle Mile and 1,000 of each strain into Cardwell from 2005 through 2008. Size at stocking for the two strains was requested at 3.5 inches. The actual average size at stocking varied between 3.2 and 5.0 in among years. The largest size discrepancy between stains in a single year was 1.0 inch. Stocking occurred in mid August. To differentiate between strains, each strain was given a unique fin-clip. Firehole rainbow received a left pelvic clip while ELR received a right pelvic clip. Fish were clipped in mid July and held for a minimum of twenty one days before stocking. To minimize mortality and facilitate handling, fish were anesthetized prior to clipping in a solution of 1 g tricane methanesulfonate per 5 gallons of water (53 mg/L) every year except 2007. In 2007, AQUI-S (95% Isoeugenol) was used at a rate of 0.3 ml/L under FWS INAD 10-541. Fish of each strain were sub sampled after clipping to determine the proportion with partial, incorrect, or no marks.

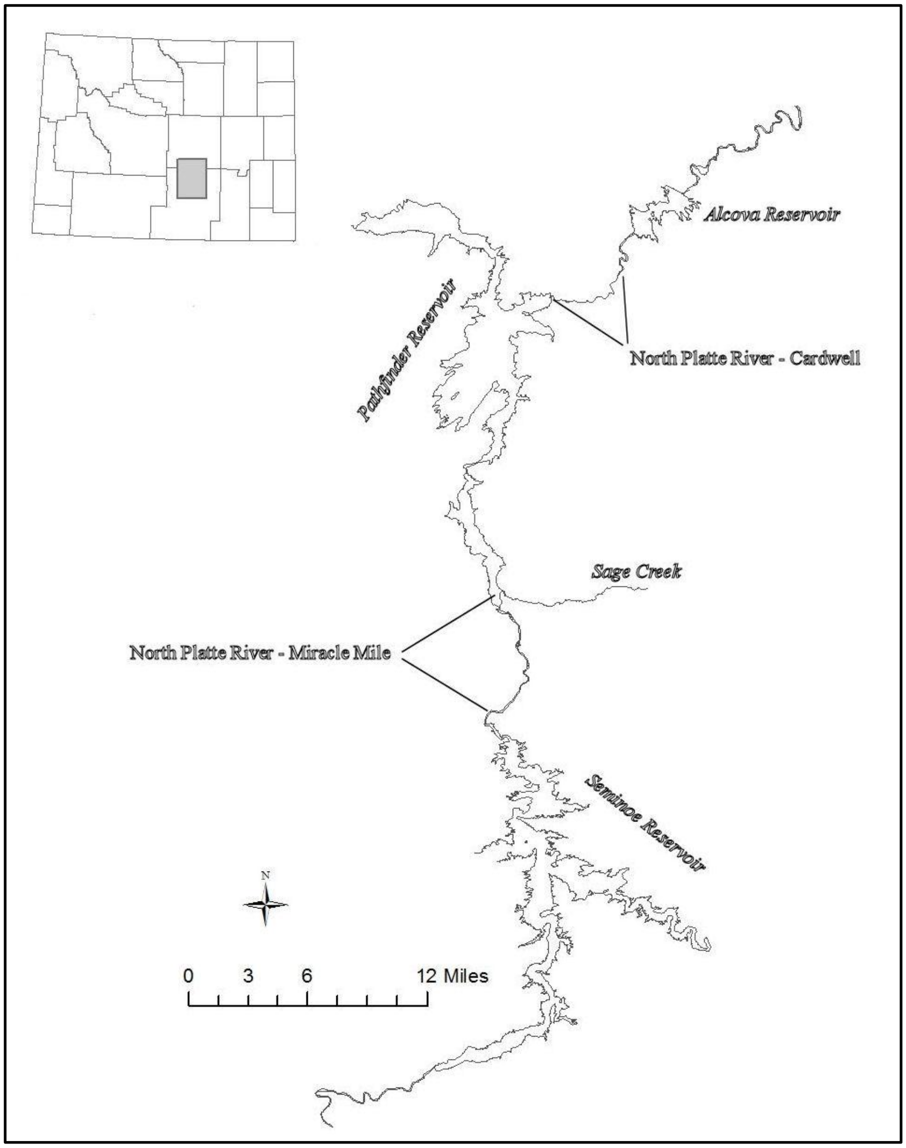


FIGURE 1. Map of study area.

***Fish Sampling (Miracle Mile)***

Four-pass mark/recapture population estimates were conducted in mid July 2006, 2008 and 2009. Two electrofishing rafts with two netters each were run simultaneously down the river. River discharge ranged from 500 to 600 cfs during electrofishing. In 2006, four passes were completed in two days. Since there were concerns about fish not being dispersed on the second and fourth passes, sampling was switched to a four day period in 2008 and 2009. Fish were anesthetized with compressed $CO_2$ gas, measured to the nearest 0.1 inch, weighed to the nearest 0.01 pound, and given a fin notch unique to that particular pass. Population estimates were generated using model M(t) of the program Capture.

In 2009, additional seasonal and spatial sampling was conducted. One pass electrofishing was employed between the upper end of the population station (13T 345438, 4672922, NAD 83), and the confluence with Sage Creek in June, August and October. A single raft (two netters), was used for the majority of the river. However, a single jet boat (two netters) was used downstream of 13T 343431, 4678228 due to low gradient. Sampling in the Chalk Bluffs area was not conducted in October 2009 because of a large increase in Pathfinder Reservoir storage which inundated the majority of that reach.

To assess spatial differences in strain abundance, individual fish data from seasonal electrofishing was pooled and broken down into five discrete sections based on habitat types (Table 1). Section one is composed largely of steep rapids with large substrates, multiple channels and deep holes. Section two is composed of long, shallow riffle reaches with wide shallow pools. Section three is largely composed of low gradient, featureless runs with extensive macrophyte beds and many split channels. Section 4 is similar to section 3 in gradient, but lacks multiple channels. Section 5 is very low gradient and is below the high water elevation of Pathfinder Reservoir.

TABLE 1. Station number, start and end coordinates (NAD 83, zone 13), thalwag distance, elevation drop and station slope for the Miracle Mile.

| Section | UTM start | UTM end | Distance(ft) | Drop(ft) | Slope |
|---|---|---|---|---|---|
| 1 | 345581, 4672751 | 345597, 4674114 | 5,430 | 35 | 0.0064 |
| 2 | 345597, 4674114 | 345077, 4674616 | 2,460 | 10 | 0.0041 |
| 3 | 345077, 4674616 | 345115, 4675594 | 4,000 | 5 | 0.0013 |
| 4 | 345115, 4675594 | 344573, 4677210 | 6,315 | 10 | 0.0016 |
| 5 | 343431, 4678228 | 343132, 4680440 | 8,601 | 7 | 0.0008 |

A programmed creel survey was conducted March 15 – October 31, 2009 (Cook, 2010, in preparation). Creel clerks conducted angler interviews eight days per month during the duration of the survey. All RBT observed in angler creels were measured and inspected for fin-clips. Determining catch rates by strain in a largely catch and release fishery proves troublesome. The odds of a creel clerk encountering an angler in the act of landing a fish are quite low. Attempts were made in 2008 to have anglers report marked fish, but the ability of anglers to identify marked fish due to regeneration of fins was deemed questionable (FMCR 2008). Since the majority of anglers practice catch and release, estimates of catch rate by strain were unable to be directly measured. Rather, it was assumed that anglers do not selectively harvest one strain over another, so the ratio of FHR to ELR in the creel likely reflects the ratio of all fish caught.

***Fish Sampling (Cardwell)***

Three-pass depletion estimates were employed on a 1,200 foot reach each year in early September. A single electrofishing raft with one netter was operated while two additional netters operated from the bank. Captured fish were anesthetized with compressed $CO_2$ gas, weighed to the nearest 0.01 pound, measured to the nearest 0.1 inch, inspected for fin-clips and released. Population estimates were generated in Excel using the Zippin method (Van Den Avyle 1993).

***Statistical Analysis***

Alpha was set at 0.1 to maximize the probability of detecting real differences given the power constraints of low sample sizes of marked fish. All statistical analyses were performed using Minitab version 15. Graphs were generated in either Microsoft Excel or Sigmaplot version 10.0.

Length-at-age was estimated from length frequency histograms. Age 1 and 2 fish were easily distinguished. Age 3 and 4 fish in 2009 were indistinguishable from each other by length-frequency and as such, were pooled. One way analysis of variance was used to test for differences in length and relative weight between strains by age-class. Multiple comparisons were done *a posteriori* using Tukey's method which adjusts individual confidence intervals for inflated experiment wise error rate (Day and Quinn 1989).

The quality of population estimates for individual strains and year-classes was highly variable due to low sample sizes and number of recaptures especially for older fish. Therefore, Differences in abundance between strains were investigated using the number of a particular strain relative to the total number of marked fish captured. Two assumptions have to be met for this approach to be valid. First, the number of each strain stocked in a given year must be equal. Second, the two strains must be equally susceptible to capture. Analysis of stocking data and capture probabilities from population estimates using two-sample t-tests and one-way ANOVA support both assumptions.

Chi-square goodness-of-fit was employed to determine differences in abundance of strains relative to each other. When multiple comparisons were made, a Bonferroni correction was applied to alpha. Due to low sample sizes, Fisher's exact test, with Bonferroni corrected alpha was used to investigate seasonal and spatial differences in abundance for each strain (Steel et al. 1997). Return to anglers versus the population was compared using chi-square (two-way table).

Due to very low sample sizes of stocked fish at Cardwell in any given year, data from 2006 – 2009 were pooled. As such, data analysis was limited to size, condition and comparison of total numbers by strain. Kruskal-Wallis one-way analysis of variance was used to test for differences in length and relative weight among strains at Cardwell.

## Results

### Miracle Mile

***Growth and Condition***

From length-frequency histograms, age 1 fish were determined to range from 6.0-11.9 inches, age 2 fish were 12.0-15.4 inches, fish ages 3 and 4 ranged from 15.5-20.0 inches. There were statistically significant differences in length at age 1 (one-way ANOVA, $F_{4,590} = 4.68$, $p < 0.001$). Multiple comparisons show significant differences between FHR in 2006 and 2008, and between FHR and ELR in 2008. Age 1 FHR sampled in 2009 were excluded from the analysis due to poor survival which limited sample size ($n = 18$) and likely influenced mean length. The maximum difference in mean length at age 1 between any two groups was 0.5 inches. Significant differences in length at age were detected in age 2 fish (one-way ANOVA, $F_{3,104} = 3.11$, $p = 0.03$). Multiple comparisons indicated significant differences between age 2 fish in 2008 and 2009 with FHR being the longer strain in each case. The maximum difference in mean length at age 2 was 0.9 inches. No significant differences in length among fish ≥ age 3 were apparent (one-way ANOVA, $F_{3,52} = 1.55$, $p = 0.21$). When adult fish (≥ age 2) from all sample events were pooled, there was no significant difference in length between strains (Kruskal-wallis, $H$=1.91, $df = 1$, $p = 0.167$: Figure 2).

All mean relative weights were greater than 100, implying all fish regardless of strain or year, are in excellent condition (Figure 3). There were significant differences in relative weight of age 1 fish (one-way ANOVA, $F_{4,583} = 12.02$, $p < 0.001$). Multiple comparisons revealed age 1 ELR captured in 2006 had lower relative weights ($p < 0.01$) than all other stocked RBT at age 1. All age 1 cohorts exhibited mean relative weights greater than 100. Among age 2 fish, there were no significant differences in relative weight between strains or across years (one-way ANOVA, $F_{3,98} = 0.60$, $p = 0.62$). A significant difference existed among age 3 and older fish (one-way ANOVA, $F_{3,52} = 4.48$, $p = 0.008$) with the only significant comparison ($p < 0.016$) being between ELR captured in 2008 and FHR captured in 2009.

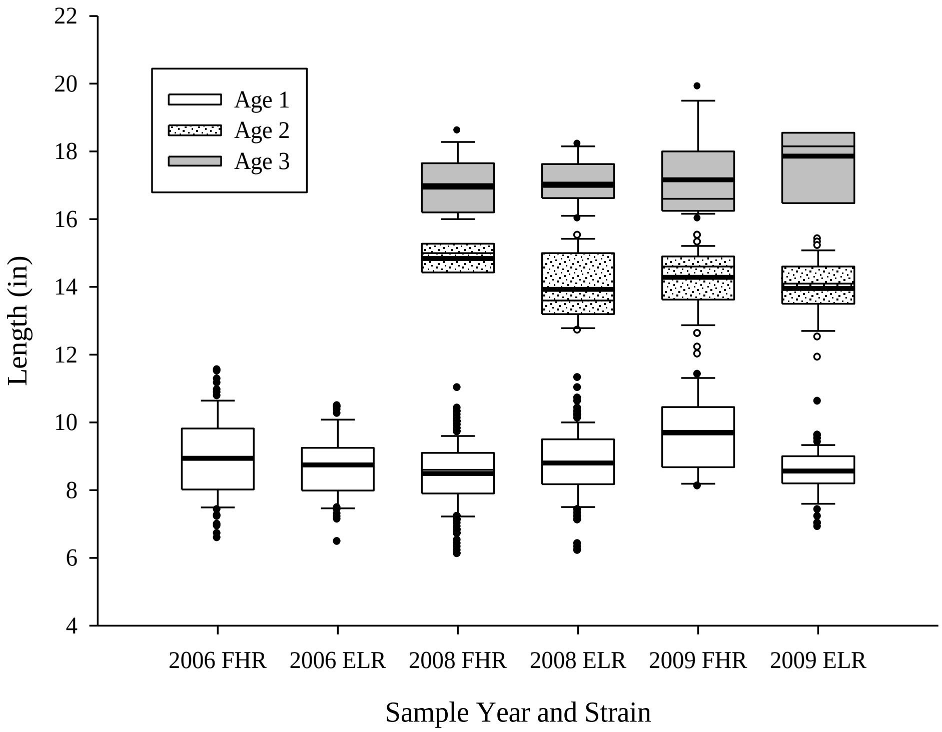


FIGURE 2. Box plots of RBT length at age among strains and sample years at the Miracle Mile. Thick lines represent means.

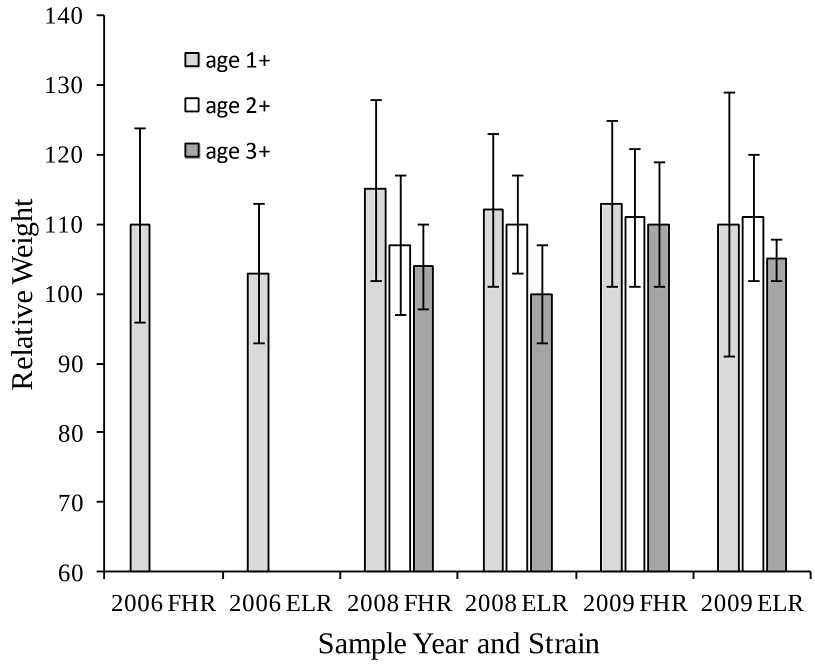


FIGURE 3. Mean RBT relative weight at age among strains and sample years at the Miracle Mile. Error bars are ± 1 SD.

***Survival by strain***

Firehole strain had a numerical advantage over ELR in two of seven comparisons, while ELR had a numerical advantage in one comparison. The two strains were statistically similar in four of seven comparisons (Table 2).

TABLE 2. Sample year, fish age, total number of marked, FHR and ELR captured at the Miracle Mile, and results of Chi-square analysis. Bold type indicates significant differences ($\alpha = 0.015$).

| Year | Age | *n* marked | *n* FHR | *n* ELR | $\chi^2$ | *p* |
|---|---|---|---|---|---|---|
| 2006 | 1 | 137 | 73 | 64 | 0.59 | 0.442 |
| 2008 | **1** | **385** | **251** | **134** | **35.56** | **<0.001** |
| | 2 | 19 | 8 | 11 | 0.47 | 0.490 |
| | 3 | 31 | 17 | 14 | 0.29 | 0.590 |
| 2009 | **1** | **95** | **18** | **77** | **36.64** | **<0.001** |
| | 2 | 88 | 53 | 35 | 3.68 | 0.055 |
| | **3** | **19** | **17** | **2** | **11.84** | **0.001** |

***Seasonal population composition***

Neither strain showed an obvious change in relative abundance in the Miracle Mile on a seasonal basis which would indicate an inclination to move out of the river, most likely downstream into Pathfinder Reservoir. Sampling conducted in June, July, August and October 2009 found no significant difference in the proportion of stocked fish comprised of either strain (Table 3, Figure 4). Low sample size is a concern. While no significant differences were detected, retrospective power analysis indicated that with sample size constraints in August and October, the minimum detectable change in abundance at $\alpha = 0.1$, $\beta = 0.8$ was 38%.

TABLE 3. P-values from Fisher's exact tests comparing seasonal composition of age 2 and older stocked fish populations at the Miracle Mile ($\alpha = 0.008$).

| | July | August | October |
|---|---|---|---|
| June | 0.81 | 0.40 | 0.23 |
| July | | 0.27 | 0.10 |
| August | | | 0.88 |

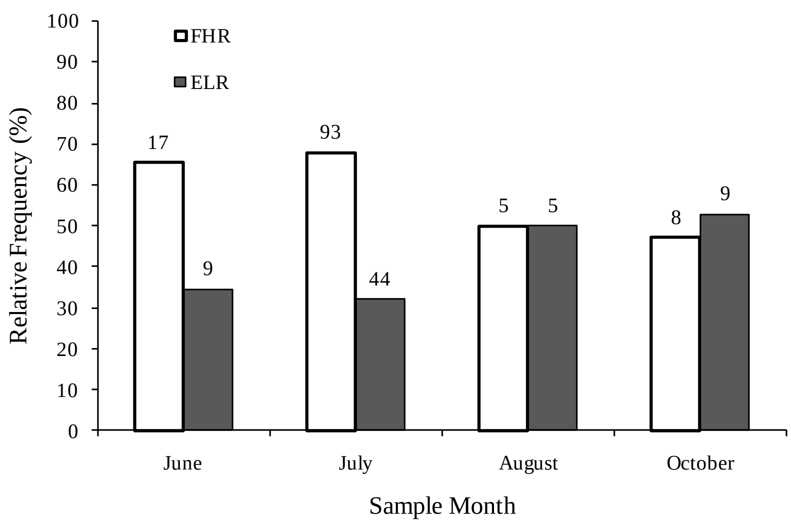


FIGURE 4. Relative frequencies by month of age 2 and older ELR and FHR in 2009 at the Miracle Mile. Numbers above bars indicate sample size of fish ≥ 2 years of age.

***Spatial Population Composition***

There were no differences in the composition of stocked RBT populations ≥ age 2 among any combination of sections (Table 4). However, similar to the seasonal composition data, sample sizes are limited (mean $n = 11$, range = 4-19). As such, power was limited. Retrospective power analysis indicated the minimum difference in strain composition which could be detected at α = 0.1, β = 0.8 is 40%. There is evidence to suggest river slope somewhat influences the ratio of ELR to FHR in a particular reach. River slope explained 58% of the variation in the ELR to FHR ratio throughout the river (Figure 5), but this relationship was not statistically significant ($p$ = 0.135).

TABLE 4. P-values from Fisher's exact tests comparing spatial composition of stocked fish populations ≥ age 2 in the Miracle Mile (α = 0.005)

| | Section 2 | Section 3 | Section 4 | Section 5 |
|---|---|---|---|---|
| Section 1 | 0.65 | 0.51 | 0.77 | 0.24 |
| Section 2 | | 0.33 | 0.57 | 0.16 |
| Section 3 | | | 0.89 | 0.70 |
| Section 4 | | | | 0.64 |

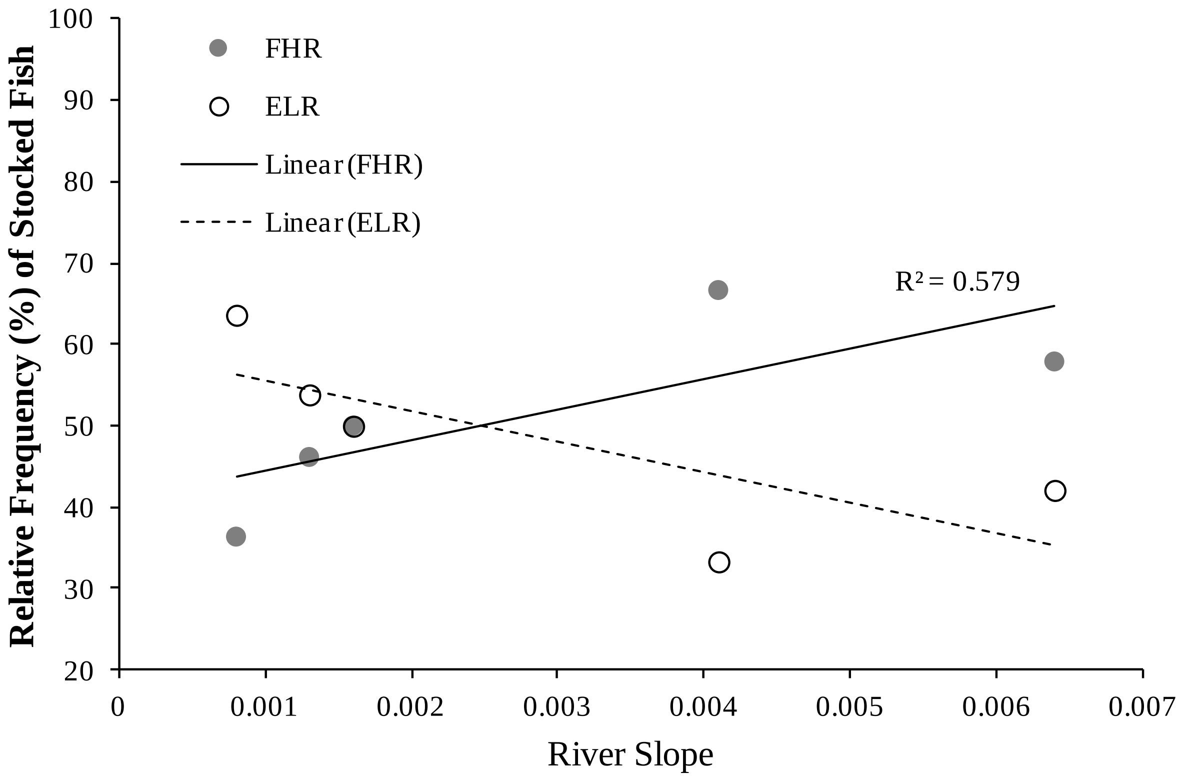


FIGURE 5. Scatterplot of relative frequency of ≥ age 2 stocked FHR and ELR with river slope from five sampling stations at the Miracle Mile.

***Contribution to the population***

On average, RBT stocked in the Miracle Mile comprise 40% of the total RBT population and 25% of the total trout population (Figure 6). Firehole rainbows on average constitute 22% of the total RBT population while ELR represent 18% of the total RBT. The difference of 4% is significant (Fisher's exact test, $p$ = 0.03). Year-to-year variation is higher for FHR (range = 15.2%-32.9%) than for ELR (16.1%-20.8%). The large variation among FHR is explained by one strong year class (2007) followed by one very poor year class (2008).

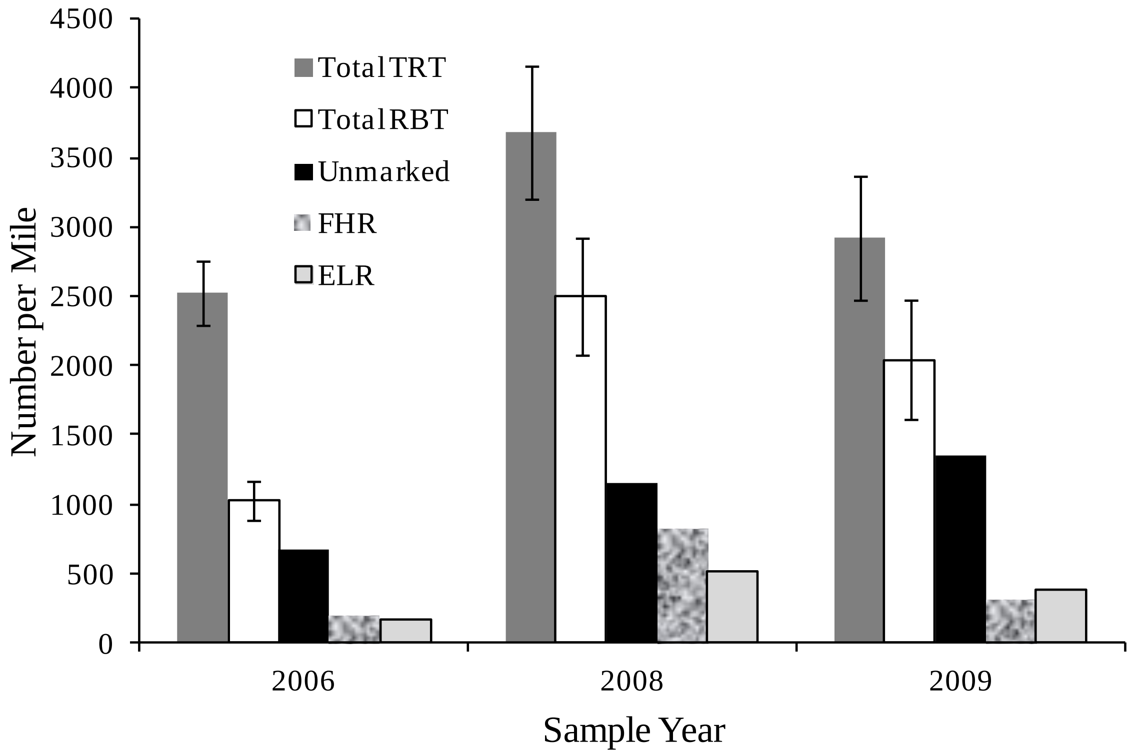


FIGURE 6. Total trout (TRT) per mile and total RBT per mile from population estimates at the historical population station at the Miracle Mile, 2006 - 2009. Due to limited recaptures, RBT are partitioned out from population estimates as unmarked, FHR and ELR based on percentages in the raw data. Error bars represent one SE.

***Return to Anglers***

During a creel survey that ran March 15 – October 31, 2009, interviewed anglers reported catching 5,937 RBT of which 98% were immediately released. Creel clerks examined 88 RBT that had been harvested by anglers. Eighty two of the harvested RBT were at least age 2 fish, indicating anglers disproportionately harvest fish age 2 and older relative to age 1 RBT. There was no difference in length between harvested and electrofished age 2 and older RBT (two-sample t-test, $t$ = 1.41, $df$ = 146, $p$ = 0.162). Therefore the assumption was made that age 2 and older RBT are randomly harvested from the population.

There were no differences in strain or wild fish occurrence between angler harvested RBT and RBT captured with electrofishing gear (Two-way chi-square, $x^2$ = 1.31, $df$ = 2, $p$ = 0.51) suggesting all subsets of the population return to anglers proportional to the frequency within the population (Figure 7).

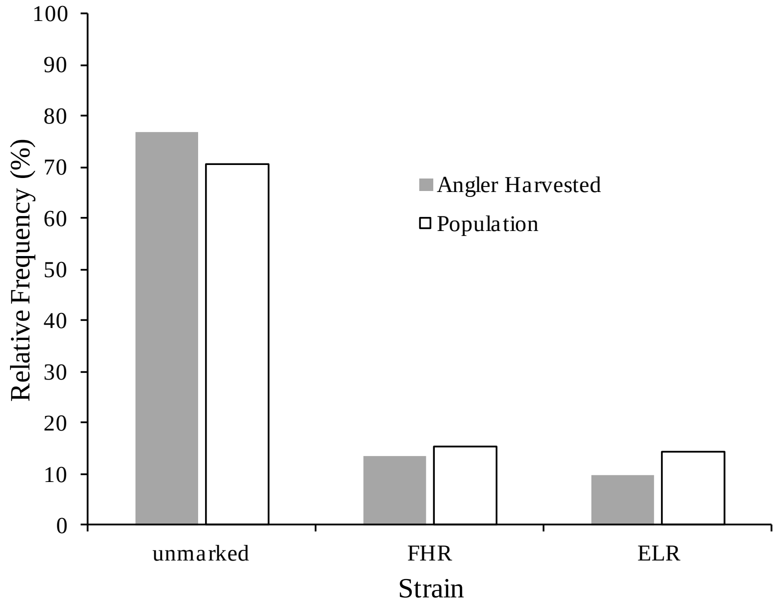


FIGURE 7. Relative frequency of unmarked, FHR and ELR from angler harvested and electrofished RBT in the Miracle Mile.

## Cardwell

Due to very low sample sizes of stocked fish in any given year, data from 2006 – 2009 were pooled. Even then, sample sizes were less than ideal (FHR = 21, ELR = 7) and certainly indicate neither strain contributes appreciably to the total RBT population. As such, data analysis is limited to size, condition and comparison of total numbers by strain.

### *Growth and Condition*

There was no significant difference in mean length among FHR, ELR and wild RBT (Kruskal-Wallis $H = 2.18$, $df = 2$, $p = 0.336$) (Figure 8). It is noteworthy that 48% of the FHR were greater than 18 inches, while only 14% of ELR exceeded 18 inches. With sample size constraints, fish could not be broken down into individual age-classes or into relative stock density categories. Fish were broken down as greater or less than 16 inches (RSD-Q for RBT). There was no significant difference in relative weight among fish less than 16 inches (Kruskal-Wallis, $H = 4.08$, $df = 2$, $p = 0.13$). Likewise, there was no significant difference in relative weight among fish larger than 16 inches (Kruskal-Wallis, $H = 1.52$, $df = 2$, $p = 0.47$: Figure 9).

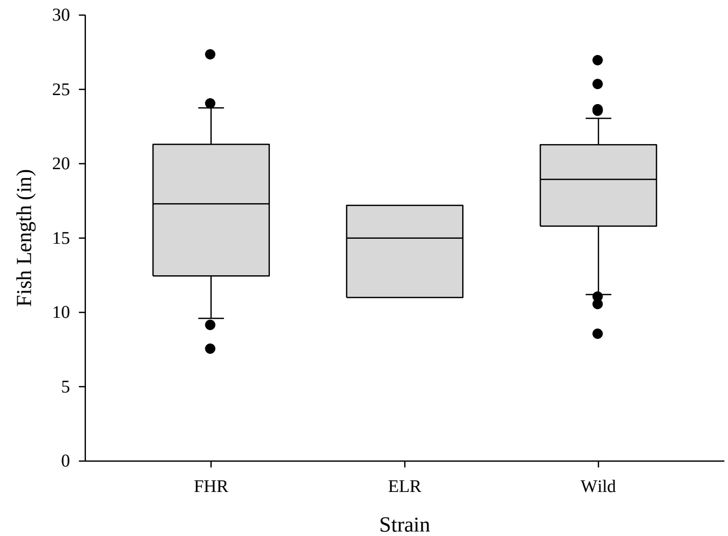


FIGURE 8. Box plots of fish length by strain for all fish pooled, 2006 – 2009 in the Cardwell reach.

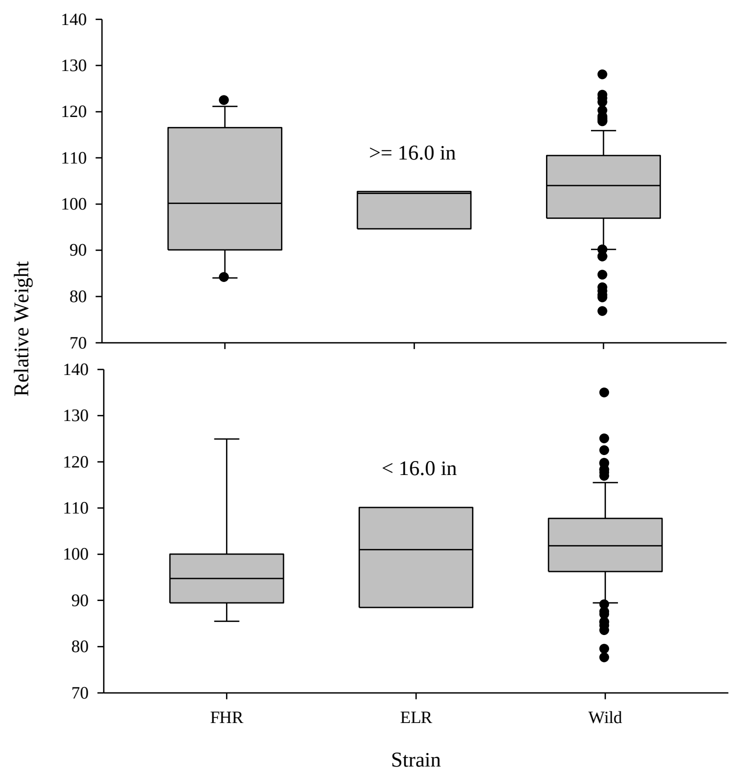


FIGURE 9. Box plots of relative weight by strain for fish less than 16.0 inches and fish greater than 16.0 inches from pooled samples, 2006 – 2009 in the Cardwell reach.

***Survival by Strain***

Firehole strain had a numeric advantage over ELR in pooled 2006-2009 samples (Chi-square goodness of fit, $x^2$ = 7.0, $p$ = 0.008). Firehole strain outnumbered ELR 3 to 1 in the pooled sample and were more numerous relative to ELR in every sample year (Figure 10). Neither strain however, contributes much to the entire RBT population.

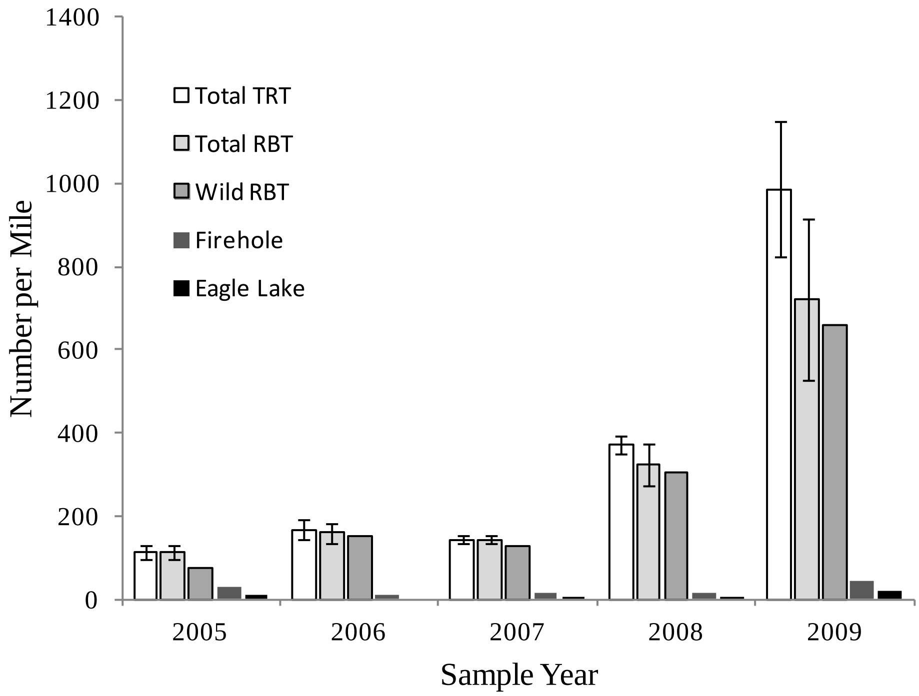


FIGURE 10. Estimated total number of all TRT and all RBT per mile from depletion estimates and estimated number per mile of wild, FHR and ELR from sample proportions at Cardwell. Error bars are 1 SE.

## Discussion

Neither strain exhibited a clear performance advantage in the Miracle Mile while FHR likely outperform ELR at Cardwell. Differences in length or condition were not consistent between strains or over time. The proportion of each strain by year class in the Miracle Mile showed no clear advantage in one strain over the other, while FHR were consistently more abundant in Cardwell, yet neither strain contributed meaningfully to the total RBT population. Neither strain showed an obvious pattern in seasonal relative abundance, which logically points to relatively equal rates of interchange among strains with Pathfinder Reservoir. Spatial data showed no strain strongly selecting for or against a river reach within the Miracle Mile, although FHR abundance showed some correlation with river slope. Finally, neither strain returned disproportionately to anglers.

The finding of some significant differences in length at age 1 and 2 in the Miracle Mile likely has little biological significance. There were no differences in relative weights among age 2 fish and while the difference in relative weight among 2008 age 3 ELR and 2009 age 3 FHR was significant, all relative weights were greater than 100 and any differences are likely not biologically meaningful. Therefore, it can be concluded that in the Miracle Mile, both strains perform equally in terms of growth and condition.

Differences in growth and condition in the Cardwell reach were confounded by low sample size. While no statistical difference in length was measured, the observation that 48% of FHR and only 14% of ELR exceeded 18 inches could be biologically substantial. Firehole rainbows proved capable of growing to impressive size in the Cardwell reach with the largest specimen measuring 27.3 in and 7.41 lb. In fact, 33% of the captured FHR exceeded 20 in. It is possible that FHR have a growth advantage over ELR in this reach. However, due to the rarity of stocked fish in the reach, obtaining sufficient sample sizes to make definitive conclusions is not feasible.

Neither strain survived to age 1 consistently relative to the other at the Miracle Mile. There was no difference in 2006, FHR had a significant advantage in 2008, and ELR had a significant advantage in 2009. In 2008, the fish were reared at the Dubois hatchery. It was noted during fin-clipping that MS-222 at the rate of 1 gram per 5 gallons of water was resulting in very high mortality. The dosage was reduced by 50%. Even then, significant mortality was evident and additional fish had to be marked. Analysis of lot histories and conversations with Travis Trimble (assistant superintendent, Dubois Hatchery) revealed no glaring problems with that particular lot of FHR. The FHR stocked in 2009, again came from Dubois, so additional sampling in 2010 may provide some insight whether the failed year-class was an isolated incident.

From a cohort perspective, there was no difference in 2005 stocked ELR and FHR. They were caught in relatively equal numbers and the ratio did not change over time. The 2006 fish, in contrast, were poorly represented at age 2 indicating poor survival of both strains, however significantly more FHR were caught in 2009 at age 3, perhaps indicative of greater FHR survival or ELR movements into Pathfinder Reservoir. The 2007 stocking resulted in excellent recruitment of both strains with FHR more numerous than ELR at age 1 and 2. Finally, the 2008 stocking strongly favored ELR, not because survival of the 2008 ELR was exceptional, but because mortality of the 2008 FHR was extremely high.

It was hypothesized that ELR numbers would vary seasonally due to movement downstream to Pathfinder Reservoir throughout the summer. It was demonstrated in 1995 and 1996 that ELR stocked into Pathfinder Reservoir returned well in the Miracle Mile in spring with decreasing return over the summer into fall and winter (Deromedi 2000). There was no solid evidence in this study supporting the emigration of adult ELR over the summer into Pathfinder Reservoir.

There were no obvious differences between the strains in terms of spatial distribution. With the hypothesis that ELR will have a tendency to move into Pathfinder Reservoir, it was expected that ELR abundance relative to FHR would increase moving downstream and would be highest in the low velocity, transitional zone near Sage Creek. While this pattern did not hold true, there did seem to be an interaction between river slope and strain abundance, with FHR tending to have a slightly greater affinity for higher gradient reaches than ELR. Given the low sample size and autocorrelation between proximity to the reservoir and river slope this effect could not be investigated further. It should be noted that the Cardwell reach, where it is likely that FHR have a significant growth advantage over ELR and were more numerous, has a higher gradient than the Miracle Mile (slope = 0.009). Cavalli (2007) found anecdotal evidence that FHR preferred higher gradient reaches. Given this pattern was duplicated in the current study it is a trait that warrants further investigation.

Rainbow trout stocked into the Miracle Mile represent 40% of the total rainbow trout population or about 25% of the total trout population. From an anglers perspective, each strain returned equally to the creel (12.5% of total rainbow catch each). In contrast, ELR and FHR stocked into Cardwell collectively averaged just 8% of trout standing stock since 2006.

Bailey (2002) formulated decision criteria for continued stocking in the Gray Reef reach of the North Platte River where stocked fish must constitute 25% of trout standing stock and angler catch rate must not exceed 0.5 fish per hour in the absence of stocked fish. At the Miracle Mile, stocked RBT averaged 25% of the total trout standing stock. Stocked RBT return was 25% of total RBT catch. Decreasing the estimated number of RBT caught by 25% decreases the estimate of total TRT caught from 10,107 to 8,147, decreasing catch rates from 0.51 fish per hour to 0.41 fish per hour. Hence, continued stocking at the Miracle Mile is warranted.

Stocked RBT at Cardwell do not approach 25% of standing stock. Spot creel data from 2007 shows the March through June average catch rate is 0.85 RBT per hour (WGFD 2008). It is highly unlikely that in the absence of stocked RBT, catch rates would dip below 0.50 fish per hour. Continued stocking at Cardwell cannot be justified and should be discontinued.

## *Recommendations*

- Stock 80,000 FHR annually in the Miracle Mile. While FHR did not have an obvious edge over ELR, they were consistently more numerous in samples (although usually not significantly). When recruitment to age 1 was high for both strains, FHR had a considerable edge over ELR in numbers. However, recruitment to age 1 for this strain should be closely monitored given the extremely poor performance of the 2008 stocked fish. If poor survival of stocked fish is again detected, investigate hatchery performance more closely or switch requests back to ELR.

- Discontinue stocking in the Cardwell reach. Stocked trout represent less than 10% of the total trout standing stock.

- Hatchery performance of various strains should be investigated. If performance differences in the field are negligible as in the case of the Miracle Mile, knowledge of performance in the hatchery in terms of survival, cost, susceptibility to disease etc. would be beneficial in order to make the most judicious use of limited hatchery resources.

## *Acknowledgements*

Thanks to Al Conder, Paul Gerrity, Dave Zafft, Kevin Gelwicks, Justin Binfet, Beth Bear, Nathan Cook, Bill Brinegar, Jason Hunter, Jon Stephens, Aaron Kerr, Dean Follett, Sean McAlpin, Brady Frude and numerous technicians for assistance with electrofishing over the years. Special thanks go out to Dave Miller and crew at Clark's Fork, Gordon Townsend and crew at Speas, and Jeff Stafford and crew at Dubois for assistance with fin clipping. This manuscript was greatly improved with comments from Al Conder, Nathan Cook, Steve Yekel, Travis Neebling, Robb Keith and Mike Snigg.

## *Literature Cited*

Babey, G.J. and C.R. Berry. 1989. Post-stocking performance of three strains of rainbow trout in a reservoir. North American Journal of Fisheries Management 9(3): 309-315.

Bailey, P. 2002. Evaluation of North Platte River trout stocking: Gray Reef Dam to Mills Bridge. Administrative Report. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Brauhn, J.L. and H.L. Kincaid. 1982. Survival, Growth and catchability of rainbow trout of four strains. North American Journal of Fisheries Management 2(1):1-10.

Cavalli, P. 2007. Trout population estimates and programmed creel survey data collected on the Green River at the Warren Bridge access areas during the summer of 2004. Administrative Report. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Cushman, R.M. 1985. Review of ecological effects of rapidly varying flows downstream from hydroelectric facilities. North American Journal of Fisheries Management. 5:330-339.

Day, R.W. and G.P. Quinn. 1989. Comparisons of treatments after an analysis of variance in ecology. Ecological Monographs 59(4) 433-463.

Diekema, S. and J. Barner. 2010. Brood stock history and maintenance, captive brood management, Eagle Lake rainbow trout. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Deromedi, J. 2000. Trout strain evaluation in the upper North Platte system. Administrative Report. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Ersbak, K. and B.L. Haase. 1983. Nutritional deprivation after stocking as a possible mechanism leading to mortality in stream-stocked brook trout. North American Journal of Fisheries Management 3(2):142-151.

Johnson, K.M. and M. Fowden. 1991. Evaluation of growth and survival of stocked trout in the lower 27 miles of the Green River, Wyoming 1988-1989. Administrative Report. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Johnson, K.M. 1997. Evaluation of the river rainbow strain in the canyon area of the Sweetwater River. Administrative Report. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Kanaly, J. 1969. An evaluation of trout stocking and harvest in the upper North Platte River. Wyoming Game and Fish Department Completion Report, Project 05-000-020. Cheyenne, Wyoming.

Moring, J.R. 1982. An efficient hatchery strain of rainbow trout for stocking Oregon streams. North American Journal of Fisheries Management 2:209-215.

Rawstron, R.R. 1972. Harvest, survival and cost of two domestic strains of tagged rainbow trout stocked in Lake Berryessa, California. California Fish and Game 58:44-49.

Steel, R.G., J.H. Torrie and D.A. Dickey. 1997. Principles and procedures of statistics, a biometrical approach.

Van Den Avyle, M.J. 1993. Dynamics of exploited fish populations. Pages 105-135 in C.C. Kohler and W.A. Hubert, editors. Inland Fisheries Management in North America. American Fisheries Society, Bethesda, Maryland.

Welker, M. 1998. Evaluation of a wild trout management strategy in the Big Horn River tailwater. Administrative Report. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Wengert, M.W. 1990. Rainbow strain evaluation, Flaming Gorge Reservoir – Utah-Wyoming. Administrative Report. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Wenzel, C.R. 1993. Flushing flow requirements of a large regulated Wyoming river to maintain trout spawning habitat quality. Master's Thesis, University of Wyoming, Laramie.

WGFD. 2008. Progress on the 2007 work schedule. Wyoming Game and Fish Department, Fish Division, Cheyenne, Wyoming.

WGFD. 2009. Progress on the 2008 work schedule. Wyoming Game and Fish Department, Fish Division, Cheyenne, Wyoming.

WGFD. 2010. Progress on the 2009 work schedule. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Whaley, R.A. 1993. An evaluation of Eagle Lake rainbow trout piscivory, Lake Viva Naughton, Lincoln County. Administrative Report. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Wichers, Bill. 1996. North Platte River, Kortes Dam to Pathfinder Reservoir (Miracle Mile). Basin Management Plan. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Wiley, R.W. 1989. Role of hatchery-reared trout in the management of streams of Wyoming. Administrative Report. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Walters, J.P., T.D. Fresques and S.D. Bryan. 1997. Comparison of Creel Returns from rainbow trout stocked at two sizes. North American Journal of Fisheries Management. 17(2):474-476.

Wiley, R.W., R.A. Whaley, J.B. Satake and M. Fowden. 1993. Assessment of stocking hatchery trout: a Wyoming perspective. North American Journal of Fisheries Management 13(1):160-170.

Wiley, R.W. 2003. Trout stocking guidelines for Wyoming fisheries. Administrative Report. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Zafft, D.J. and G.F. Vogt jr. 1992. Evaluation of the effects of rapid flow fluctuations on potential trout production in the Miracle Mile. Administrative Report. Wyoming Game and Fish Department, Fish Division, Cheyenne.