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Project 8—Hatchery Trout Evaluations
Subproject 1: Sterile Trout Investigations
Subproject 2: Zooplankton Quality Index
Subproject 3: Effects of Size at Stocking and Return-to-Creel

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Subproject #1: Sterile Trout Evaluations

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ABSTRACT

Triploid rainbow trout *Oncorhynchus mykiss* may have important applications in fishery management programs. Triploids are functionally sterile and do not pose genetic risks to indigenous populations. Sterile fish may also grow faster and live longer than normal diploid fish. We began research in 1996 to develop methods to produce triploid rainbow trout and triploid rainbow x cutthroat trout *O. clarki* hybrids. We also began testing the performance of sterile trout in recreational fisheries.

To date, we have developed methods that produced 90% to 100% induction of rainbow trout, completed two years of stream tag return evaluations of sterile catchables, and continued monitoring sterile fish previously stocked in seven reservoirs in 1996. From a total of 37 rainbow trout comparisons, over two years involving 2,913 total tag returns, sterile catchables have demonstrated nearly equal performance (49% of all tag returns) to their control plants. The drawback to sterile catchables has been a moderate increase in production costs. In 1998, the sterile female fish cost 14% or US$24.00/1,000 more than standard catchables.

Sterile female rainbow trout stocked in reservoirs have had equal or slightly better survival compared to controls. In Daniels and Treasureton reservoirs, the combined catch from 1997 and 1998 surveys was 114 sterile and 91 control fish. Mean weight for sterile and control rainbow trout was similar at age-1, but control fish surpassed sterile fish in both reservoirs at age-2. In October 1998, the mean weight of age-2 sterile and control rainbow trout in Treasureton Reservoir was 904 g (SD = 82g) and 1,005 g (SD = 225), respectively. In Daniels Reservoir, mean weight of the sterile fish was 1,166 g (SD = 136 g) compared to 1,428 g (SD = 225) for controls. The difference in mean weights may have resulted from gamete production that was beginning to show in the control fish but not in the sterile rainbow trout. We will continue to monitor growth and survival of the sterile rainbow trout in 1999.

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INTRODUCTION

Over the last decade, the production and use of sterile fish as a fishery tool has received increasing attention. Rationale for using sterile fish in stocking programs is generally based on two distinct and separate needs: 1) the desire for a longer-lived, faster growing hatchery product, and 2) protecting the genetic integrity of indigenous stocks. Although early researchers focused on the predicted growth and longevity benefits and the trophy potential of sterile fish, such benefits have not been documented in recreational fisheries.

With or without growth benefits, sterile fish represent a fishery management tool with potentially broad applications. For example, the demand for consumptive stream trout fishing in Idaho is largely met by stocking hatchery rainbow trout *Oncorhynchus mykiss* catchables in selected waters. Despite emphasis on wild trout management over the last two decades, about 40% of stream plants occur in waters with viable trout populations (J. Dillon, Idaho Department of Fish and Game, unpublished data). Using sterile rainbow trout catchables to meet these demands would minimize concerns for genetic impacts on indigenous rainbow and cutthroat trout *O. clarki*.

Techniques to produce sterile salmonids are well developed, particularly within the aquaculture industry, and triploid rainbow trout eggs are available from many commercial egg suppliers. The most widely used approach is chromosome manipulation, specifically for induction of triploidy. Triploidy is induced by thermal, pressure, or chemical shock of eggs shortly after fertilization. This causes retention of the second polar body of the egg and results in an embryo with two sets of maternal and one set of paternal chromosomes. Triploid salmonids are functionally sterile, although males may still develop secondary sex characteristics and exhibit spawning behavior (Feist 1996).

Although production techniques are fairly well developed, information on performance of triploid salmonids in recreational fisheries is lacking (Simon et al. 1993). Sterile fish must survive, grow, and return to anglers at rates comparable to normal fish if they are to be useful in stocking programs (Dillon et al., in review).

MANAGEMENT GOAL

To minimize genetic risks to indigenous rainbow trout and cutthroat trout in Idaho streams from hatchery trout and enhance hatchery supported lake and reservoir fisheries.

OBJECTIVES

1. Evaluate return-to-creel of commercially-supplied triploid rainbow trout in put-and-take stream fisheries.

2. Evaluate relative survival and growth of triploid rainbow trout in lakes and reservoirs.

METHODS

Sterile Stream Catchables

In 1997, we purchased 19,485 all-female triploid and 17,112 mix-sexed diploid rainbow trout eggs from Mt. Lassen Trout Farms, Inc. in Red Bluff, California. Triploidy was induced by heat shocking eggs shortly after fertilization (Dan Brown, Mt. Lassen Trout Farms, Inc., personal communication). Eyed eggs were shipped on July 30, 1997, to Idaho Department of Fish and Game's (IDFG) hatchery in Nampa, Idaho, where they were hatched and reared. We assessed hatching rate and survival-to-feeding rates for the triploid and diploid (control) groups. We compared relative rearing costs per catchable-size sterile and control fish using total egg costs plus total feed costs for each group.

When test fish reached adequate size for blood sampling, we sacrificed a total of 87 sterile and 30 control fish to confirm ploidy. We collected blood from individual fish by severing the caudal peduncle, and fixed the blood in Alsever's solution. Samples were shipped on ice to the Washington State University Veterinary Sciences Lab, where each sample was evaluated for ploidy level using flow cytometry (Thorgaard et al. 1982; Utter et al. 1983).

From May 22 to July 21, 1998, we stocked each of 19 streams with 200 sterile and 200 control rainbow trout. Study streams were located throughout Idaho (Figure 1) and represented a broad range of stream sizes and productivity. All fish were tagged with size 8 Monel jaw tags, and held in hatchery raceways one to seven days prior to transport and stocking. Jaw tags were sequentially numbered to identify individual streams and treatment group. Each fish stocked was measured to the nearest mm TL.

To promote tag returns, we placed signs along stocked sections of each stream informing anglers of the presence of tagged fish and providing mail-in instructions. We specifically requested information on date and location of catch and angler address and telephone number. As an incentive, we offered one chance at three gift certificates worth up to $200 for each tag returned. Because we sought only to compare relative returns for sterile and control fish, we did not attempt to adjust tag return data for non-response bias.

We completed an a priori power analysis for paired t-tests as part of the experimental design process (Cohen 1988; Peterman 1990). To choose an effect size, we subjectively assumed that if sterile fish return to the creel at 75% the rate of normal fish (effect size 0.25), most fishery managers would elect to use them to reduce genetic risks to native stocks. We further assumed a range of tag return rates similar to that observed in preliminary studies (S.D. . 26 tags) and that return of sterile and control fish within streams would be highly correlated (r = 0.80). We set ∀ = 0.05. Based on these assumptions, our design with 19 paired stocking events would provide a 98% chance of avoiding type II error for the above effect size.

We used a two sample t-test (Zar 1974) to compare mean total length at stocking (mm) for sterile and control fish in each stocking event. We compiled tag return data (through October 31, 1997) for sterile and control fish by stream and by time (d) between stocking and harvest. We used a paired t-test (Zar 1974) to test the hypothesis that the mean difference in tag returns from sterile and control fish was not significantly different from zero. In addition, we derived an estimate of mean time to harvest (d) for each stocked group and stream using stocking dates and the harvest dates provided by anglers.

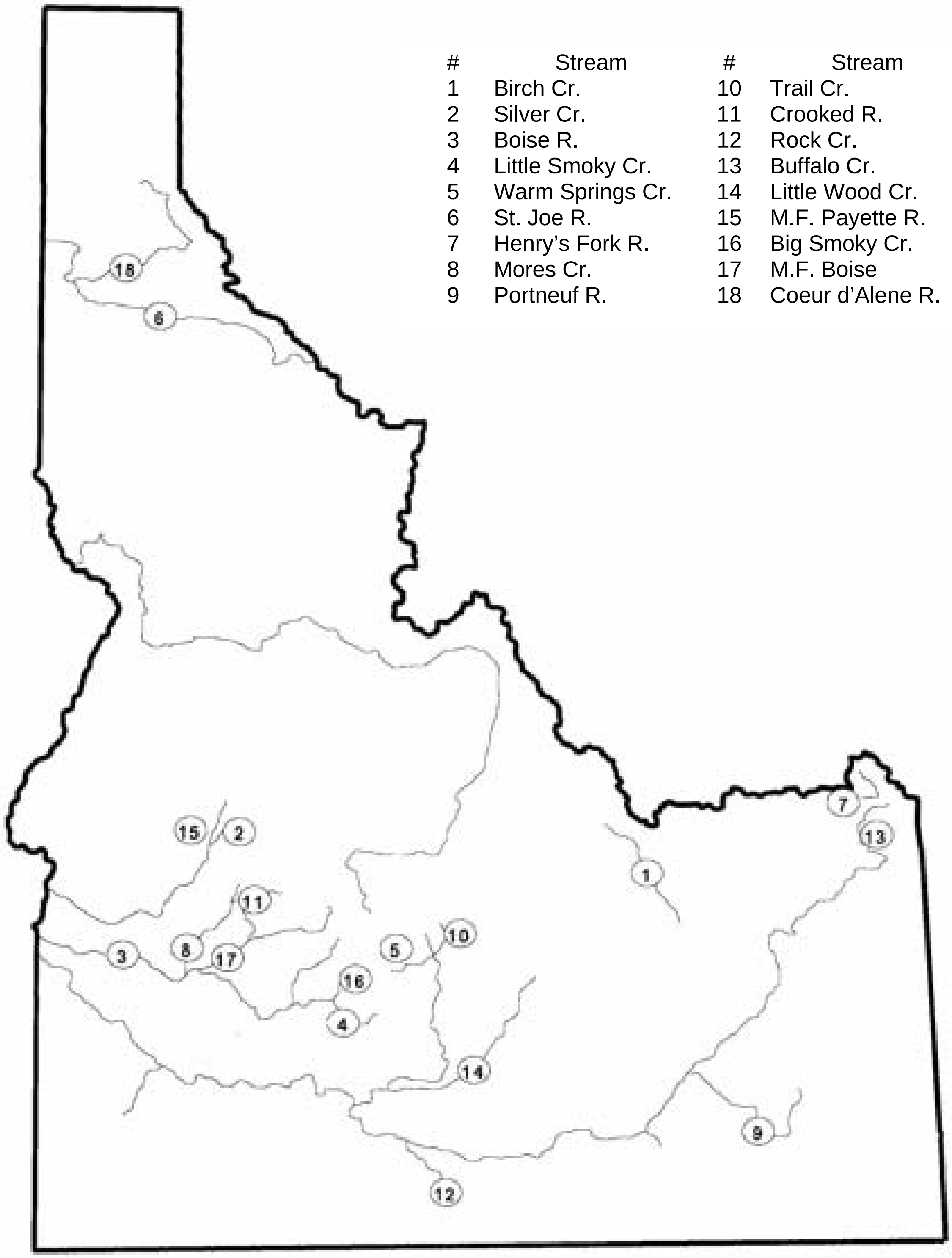


Figure 1. Location of waters stocked with sterile catchable rainbow trout.

Sterile Fingerlings in Lakes and Reservoirs

In April 1996, IDFG received 60,000 all-female triploid (sterile) rainbow trout eggs from Trout Lodge and an equal number of all-female diploids (control). The eggs were scheduled for use as fall 1996 fingerling plants in lakes and reservoirs statewide. They were hatched and reared at the Nampa State Fish Hatchery. Prior to release, we differentially marked the sterile and control groups with fluorescent grit dye (Nielson 1990). Sterile fish were dyed red and controls green. In October 1996, the fingerlings were stocked in roughly equal proportions in seven waters (Table 1). To assess relative survival and growth, a combination of gillnetting and electrofishing surveys were completed by both staff from this project and regional management personnel.

Table 1. Study waters and stocking dates for sterile and control fingerling rainbow trout stocked in seven Idaho lakes and reservoirs.

			Stocked		
System	**Acres**	**Harvest Regulations**	**Date**	**Sterile**	**Control**
Daniels Reservoir	375	2 (20" minimum)	15 Oct 96	7,965	7,938
Treasureton Reservoir	143	2 (12"-16" slot)	15 Oct 96	5,900	6,030
Brundage Reservoir	340	2 (12" -20" slot)	15 Oct 96	1,003	1,016
Little Payette Reservoir	1,450	2 (20" minimum)	15 Oct 96	5,015	5,080
Lost Valley Reservoir	750	General	16 Oct 96	12,980	12,700
Warm Lake	640	General	16 Oct 96	5,015	5,080
Tule Lake	7	2 (20" minimum)	16 Oct 96	100	100

Data collection and analysis will be ongoing through 1999 or later. Therefore, most of the statistical analysis will not be reported in this document. Once all the data are collected, a chi-square test will be used to compare relative survival. Our goal is to sample a minimum of 172 grit marked fish from each study water. Data from different sampling gear and time periods will be pooled if the data pass a standard chi-square test of homogeneity (Elrod and Frank 1990). If we sample 172 fish, we will be able to detect a 20% change from a stocking ratio of 50:50 ($\forall$ = 0.10, 1 - $\exists$ = 0.80). A two-factor analysis of variance will be used to test the hypothesis that there is no significant difference in mean TL between the sterile and control rainbow trout at age-1, age-2, and age-3. Lakes will be considered a random effect and ploidy considered fixed.

RESULTS

Sterile Stream Catchables

Culture Performance and Flow Cytometry

Culture performance for sterile rainbow trout varied. In 1998, the hatch rate for sterile eggs was 66% (Table 2). Mortality after hatch was minimal for sterile and control groups. Food conversion efficiency (g feed / g of fish) was 1.23 for sterile fish and 1.42 for controls. Food conversion also favored sterile fish in 1997 (Table 2).

Despite a measured advantage in food conversion, egg costs and hatching mortality combined to make sterile fish more expensive to rear. In 1997, Mt. Lassen egg costs were US$40.00/1,000 for sterile eggs and US$16.50/1,000 for control eggs. With hatch mortality included, the cost for 1,000 fry was US$64.00 for sterile fish and US$21.00 for controls. Feed cost per 1,000 fish stocked was US$131.00 for sterile and US$150.00 for control fish. The net overall cost for rearing sterile fish was an additional US$24.00/1,000 fish produced (Table 2).

Results of the flow cytometry analysis (Paul Wheeler, Washington State University, unpublished data) showed that 68 of 87 (78%) of the treatment fish were triploid. We were aware of the low induction rate prior to stocking but continued with the experiment as a supplement to 1997 results. Flow cytometry results also indicated that one of 30 (3%) of the control lot was triploid.

Field Performance

There was a small but detectable difference in size at stocking for the two test groups. Mean total length at stocking was 241 mm TL (SD = 18 mm) for sterile fish and 237 mm TL (SD = 17 mm) for controls. With a total of 7,482 fish measured, this overall difference in size at stocking was significant ($t_{0.05(2),7480}$, $P < 0.001$).

Relative tag returns for sterile and control fish varied by location, but were similar overall. A total of 896 tags were returned from the 7,600 tagged fish stocked, for an overall return rate of 11.8% (Table 3). The overall return rate dropped markedly from 1997 (17.1%). Because tag returns were not adjusted for non-response bias, true return-to-creel rates are unknown. Of the total tag returns for all 19 streams, 398 were from sterile fish and 498 were from control fish. Percent return was 10.5% for sterile fish and 13.1% for controls. Results of the paired t-test indicated that the overall difference in mean tag returns was significant ($t_{0.05(2),18} = 2.20$, $P = 0.04$).

Table 4 shows return timing for sterile and control catchables. Most of the fish caught by anglers were harvested relatively quickly. The mean number of days at large was 32 for sterile fish and 36 for controls. For sterile fish, the time for returns to reach 50%, 75%, and 90% of the cumulative total was 25 d, 44 d, and 66 d, respectively. There was no detectable difference in tag return timing for sterile and control catchables ($t_{0.05(2),18} = 1.56$, $P = 0.14$).

Sterile Fingerlings in Lakes and Reservoirs

Sampling effort in 1998 indicated that most of the rainbow trout stocked in four of the seven waters have been caught or died of natural causes. No marked fish were sampled from Little Payette, Lost Valley, Warm, and Tule lakes. Grit marked fish were collected from Treasureton, Daniels, and Brundage reservoirs. In Brundage, six marked fish (two sterile and four control) were collected in four 12-hour gillnet sets. The mean length of control fish was 251 mm TL compared to 249 mm TL for the two sterile fish. For Brundage, small sample size prevented statistical comparisons.

In Treasureton Reservoir, during two nights of electrofishing in May, we sampled 29 (62%) sterile and 18 (38%) control fish. The mean length for the sterile fish was 396 mm TL and 401 mm TL for controls (Figure 2). The 5 mm difference in mean TL was not significant ($t_{0.05(2),45}$ = 0.80, *P* = 0.43). However, the relative differences in mean weight in the spring samples were much larger. Average weight for control fish was 812 g (SD = 119 g) compared to 708 g (SD = 121 g) for sterile fish ($t_{2,0.10,df=45}$ = 2.88, *P* <0.01).

In October, we sampled roughly equal proportions of sterile (25 total, 51%) and control fishes (24 total, 49%). Both groups gained nearly 200 grams (0.44 lb.) of weight between the May and October samples (Table 5). Similar to May, mean lengths for sterile (446 mm TL) and control (448 mm TL) fish were very similar, but weights were significantly different (Table 5).

In our May sample from Daniels Reservoir, we caught only three marked fish (two controls and one sterile, Figure 3). In October, we sampled 27 marked rainbow trout (19 sterile and 8 control). The ratio of sterile to control fish was 2.4 to 1. Because of the small sample size, however, the difference was not significant (Π^2 = 2.34, *P* > 0.10). Control fish were significantly larger (length = 501 mm TL, weight = 1428 g) than sterile fish (length = 475 mm TL, weight = 1166 g). The differences in size were significant in both cases (Table 5, Figure 3).

Table 2. Culture performance and production costs for sterile and control rainbow trout stocked in 19 Idaho streams.

	1997		1998	
	Sterile Mixed Sex	**Control Mixed Sex**	**Sterile All Female**	**Control Mixed Sex**
Eyed Eggs	22,222	23,908	19,485	17,112
Fry	14,536	17,730	12,812	14,214
Number Stocked	12,752	15,775	12,137	13,794
Survival (%)				
Hatch	65%	74%	66%	83%
Hatch-to-Plant	88%	89%	95%	97%
Feed (kg)	2,558	3,549	2,065	2,673
Fish Stocked (kg)	1,912	2,174	1,685	1,881
Feed Conversion	1.34	1.63	1.23	1.42
Costs ($)				

Eggs / Fish Stocked	0.070	0.030	0.064	0.021
Feed / Fish Stocked	0.155	0.174	0.131	0.150
Total / Fish Stocked	0.225	0.204	0.195	0.171

Table 3. Stream width, total dissolved solids (TDS), and percent tag returns (uncorrected for non-response) from 19 Idaho streams stocked with control (diploid) and sterile (triploid) catchable rainbow trout. We stocked 300 fish per group in 1997 and 200 fish per group in 1998. Stream width was a mean of at least four measurements taken at the fish planting location.

			Tag Returns (%)					
			1998		**1997**		**Means (1997&1998)**	
Stream	**Width (m)**	**TDS (ppm)**	**Control**	**Sterile**	**Control**	**Sterile**	**Control**	**Sterile**
Birch Cr.	8	238	29.0	28.5	45.7	39.3	37.4	33.9
Silver Cr.	11	26	12.5	5.5	26.0	27.3	19.3	16.4
Boise R.	16	42	16.0	14.5	24.3	24.3	20.2	19.4
Little Smoky Cr.	7	116	25.0	26.0	23.3	20.7	24.2	23.4
Warm Spring Cr.	9	101	16.0	17.0	21.0	21.0	18.5	19.0
St. Joe R.	28	37	29.0	11.5	15.0	25.3	22.0	18.4
Henry's Fork R.	45	67	11.0	11.0	18.7	18.0	14.9	14.5
Mores Cr.	11	66	7.0	5.0	13.0	21.3	10.0	13.2
Portneuf R.	17	310	9.0	10.5	17.0	15.3	13.0	12.9
Trail Cr.	11	227	6.0	1.5	14.3	15.3	10.2	8.4
Crooked R.	8	35	4.0	5.5	14.7	14.3	9.4	9.9
Rock Cr.	7	109	12.5	15.5	11.3	14.0	11.9	14.8
Buffalo R.	39	69	15.5	6.0	12.0	12.7	13.8	9.4
Little Wood R.	8	149	9.0	5.5	13.0	10.7	11.0	8.1
M.F. Payette R.	24	27	9.0	7.0	11.7	7.7	10.4	7.4
Big Smoky Cr.	18	95	14.5	7.5	9.3	7.7	11.9	7.6
M.F. Boise R.	32	-	5.0	3.5	9.3	6.7	7.2	5.1
Coeur d'Alene R.	36	43	14.0	7.5	6.3	8.7	10.2	8.1
S.F. Boise R.			5.0	10.0			5.0	10.0
		Means	**13.5**	**10.5**	**17.0**	**17.2**	**14.7**	**13.7**

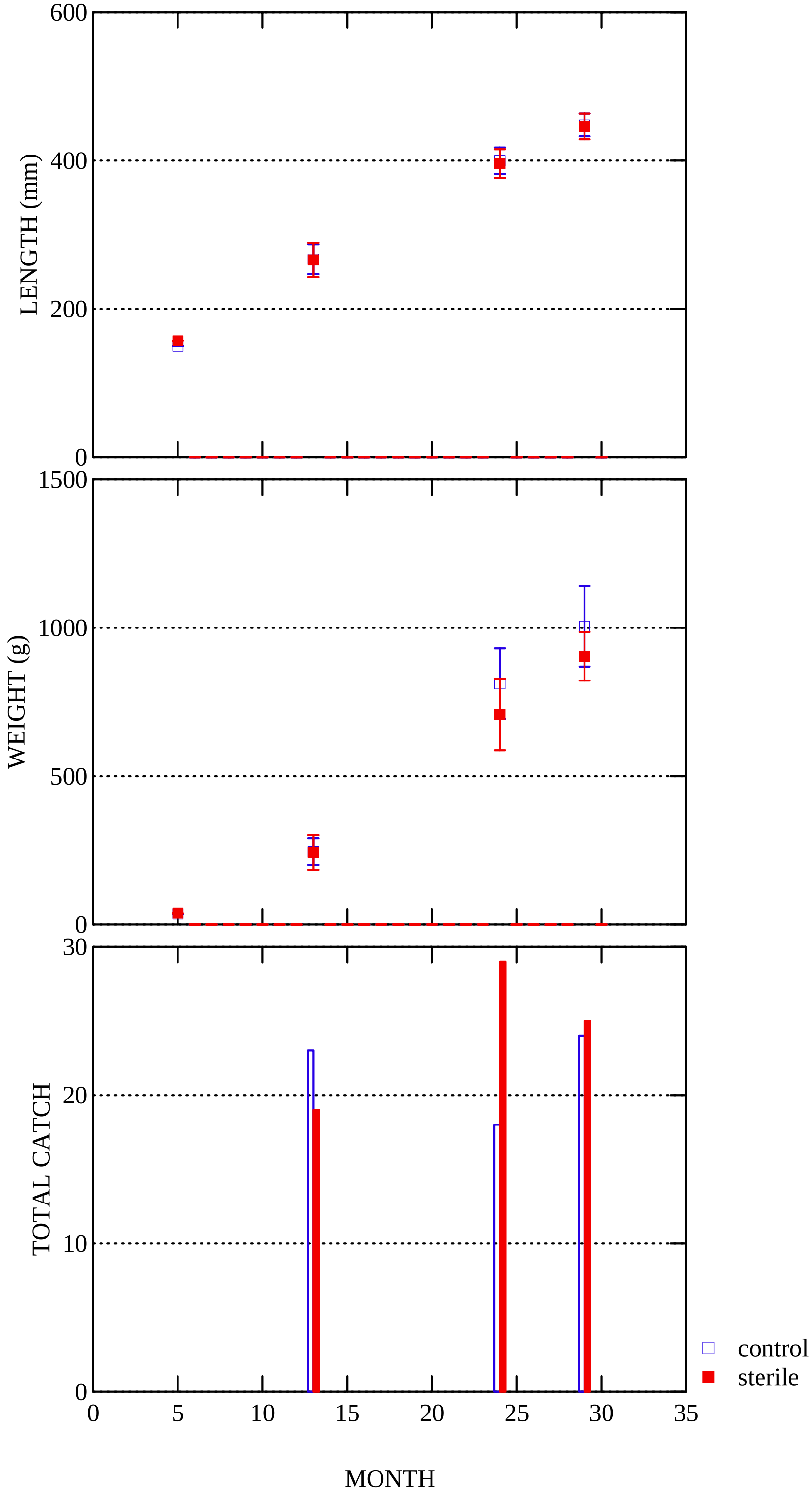
Table 4. Tag return timing (d) for sterile and control catchables stocked in 1997 and 1998.

Year	**Group**	**25%**	**50%**	**75%**	**90%**
1997	sterile	9	22	39	56
	control	10	24	42	59
1998	sterile	13	26	45	66
	control	14	32	52	69

Table 5. Comparisons of relative survival (catch) and growth of sterile and control rainbow trout stocked on October 10, 1996, in Treasureton and Daniels reservoirs. Chi-square statistics were calculated to test if the ratio of caught fish was significantly different from their stocked proportions. Two sample t-tests were used to compare average lengths and weights.

	Catch				**Length (mm)**		**Weight (g)**	
	Sterile	**Control**	Π^2	***P***	**Sterile**	**Control**	**Sterile**	**Control**
Treasureton								
At release Oct 96					157	150	38	36
June 1997	19	23	0.43	>0.50	266	267	243	245
May 1998	29	18	1.31	>0.10	396	401	708	812*
Oct 1998	25	24	0.01	>0.90	446	448	904	1005*
Daniels								
At release Oct 96					157	150	38	36
April 1997	21	16	0.34	>0.50	187	183	70	68
May 1998	1	2	0.17	>0.50	418	429	950	647^{NT}
Oct 1998	19	8	2.34	>0.10	475	501*	1166	1428*

* indicates that control fish were significantly larger than sterile fish ($\Delta < 0.01$)
^{NT} indicates that samples size was too small to complete statistics


600
400
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LENGTH (mm)
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WEIGHT (g)
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TOTAL CATCH
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10
15
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25
30
35
MONTH
control
sterile

Figure 2. Relative survival (total catch) and growth of sterile and control rainbow trout in Treasureton Reservoir. Error bars represent one standard deviation.

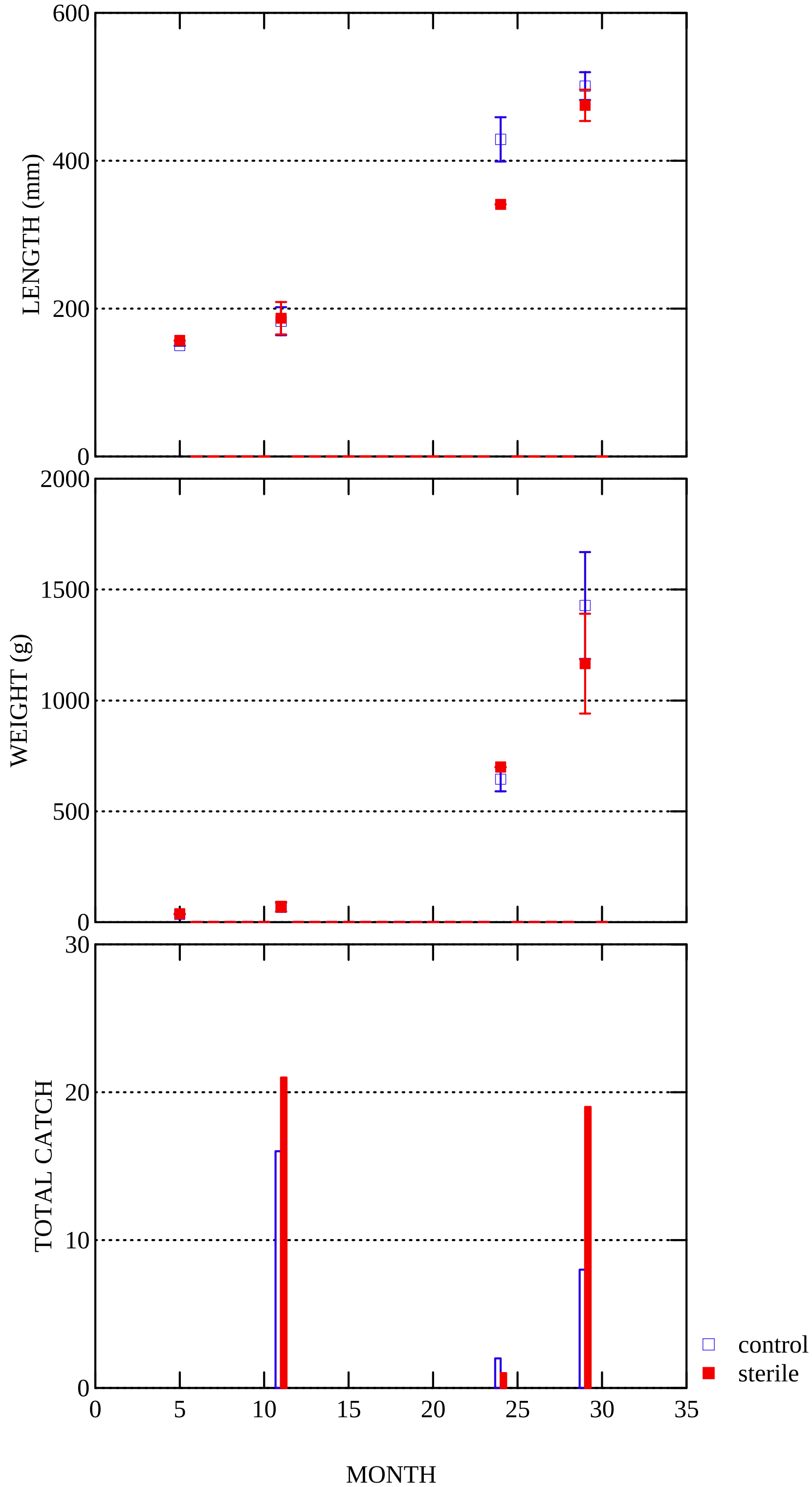

Figure 3. Relative survival (total catch) and growth of sterile and control rainbow trout in Daniels Reservoir. Error bars represent one standard deviation.

DISCUSSION

Sterile Stream Catchables

Numerous researchers have documented a range of genetic impacts on wild fish from introduced hatchery fish. Effects have ranged from no detectable introgression (Krueger and Menzel 1979; Wishard et al. 1984; Jones et al. 1996) to virtually complete replacement of locally adapted stocks by hybrid swarms (Gyllentsen et al. 1985). Fishery managers today more clearly recognize potential genetic risks than in the past, but still attempt to balance wild fish conservation with public and political pressures to provide consumptive angling opportunity. If sterile trout can meet fishery goals as well as normal fertile trout, they will be a valuable tool with which managers can address both issues.

Our results provide evidence that in stream fisheries, sterile triploid rainbow trout can provide put-and-take harvest opportunity comparable to fertile hatchery fish. Although we observed a modest reduction in tag returns for sterile catchables, the combined results from 1997 and 1998 did not exceed our assertion that a 25% loss in tag returns for sterile fish would be acceptable. In 1997, performance was extremely close between sterile (17.2%) and control (17.0%) catchables. In 1998, tag returns were 10.5% for sterile and 13.1% for controls.

Initial size at stocking and triploid induction rates are two limitations of the paired stocking experiment. Mean size at stocking for sterile fish was statistically greater ($\Delta < 0.05$) than for control fish. Because return-to-creel in streams has been shown to be positively correlated with size at stocking (Mullan 1956), our results could have been biased in favor of sterile fish returns. However, the 16 mm and 4 mm differences observed in the 1997 and 1998 experiments are smaller than that typically documented as affecting returns. Moreover, in a study completed jointly with this experiment, we found that a 40 mm difference in mean size at stocking failed to significantly increase tag returns (see abstract in this report). Secondly, the fact that we tested a group of fish that was only 78% triploid is troubling. The low sterility rates definitely weaken the 1998 results, and readers should interpret findings cautiously. Because 22% of the “sterile” group was actually diploid, the 2.6% difference in tag returns may have been related to other factors besides ploidy (i.e., general health or unfavorable rearing condition). In an effort to minimize length differences, the sterile fish were fed at a slightly lower ration the last few months prior to release. The lower ration may have negatively impacted the overall health of the “sterile” fish.

Increased production cost is a consideration that could affect the practicality of sterile fish in stocking programs. In this experiment, costs for triploid rainbow trout eggs were 2.4 times the cost of normal eggs, and survival to hatch for triploids was lower. Most of the expense of rearing catchable-size trout is feed costs rather than egg costs. Our estimated total rearing cost for triploid catchables was an additional 10% in 1997 and 14% in 1998. If triploid rainbow trout were to comprise a significant portion of hatchery production, differences in rearing costs would need to be accounted for by either increasing hatchery budgets or by slightly reducing total production and stocking rates. Fishery managers and policy makers must assess the tradeoffs of higher stocking costs or decreased stocking rates versus the ability to afford genetic protection to wild fish.

Our sole evaluation criterion was relative return to creel. We did not assess long-term survival, growth, or behavioral differences between sterile and control groups. Timing of returns suggest that survival and catchability were similar. In both groups and years, over 90% of returns occurred within 70 d of stocking, with very few returns thereafter. Because the rainbow trout used in this experiment were highly domesticated, we did not expect significant long term or overwinter survival in our study streams (Shetter 1941; Miller 1958; Reimers 1963; Bachman 1984). Behavioral differences, if they occur, could mean that sterile fish could have unexpected interactions with wild fish. We suggest that future evaluations monitor long-term survival and behavioral differences between sterile and control groups to more clearly describe potential interactions with wild fish.

Given the history of genetic impacts from hatchery fish introductions and the likelihood that public demand for consumptive stream fisheries continues, fishery managers must find innovative ways to meet competing agency mandates. Sterile hatchery trout represent a potentially valuable tool with which managers can help balance public demand with sound conservation strategies for wild trout. Additional research and management evaluation is needed to explore this potential.

Sterile Fingerlings in Lakes and Reservoirs

Preliminary results from 1997 and 1998 are not sufficient to completely evaluate the performance of sterile rainbow trout in lowland lakes and reservoirs. A survival and growth comparison post sexual maturation in the control fish is key to evaluating the performance of sterile fish. That information will be collected in 1999. In addition, we assumed that mark retention was similar for red and green grit mark dye. If retention was not similar, our results could be biased in favor of sterile or control fish. Nielson (1990), however, observed similar retention of green and red grit dye colors during a 12-year study. Nielson (1990) also reported that after six years, mark retention was 86% for grit dyed fingerlings.

Our estimates of relative survival for age-1 and age-2 sterile rainbow trout contradict findings from Brock et al. (1994). In Alaska, survival to age-1 from fingerling plants was significantly lower for sterile fish. Poor survival declined as fish aged, and in one of five lakes, sterile fish outperformed the control group (Brock et al. 1994). Additionally, Parkinson and Tsumura (1988) found that sterile kokanee survival was lower during the first few years after release, but catches of sterile fish exceeded controls when older age classes were compared. The authors concluded that the increased proportion of older kokanee (age-2 and older) might offset the higher mortality of younger kokanee.

RECOMMENDATIONS

1. Begin stocking sterile catchables in streams that are scheduled for rainbow trout stocking and where introgression with wild trout populations is a concern.

ACKNOWLEDGEMENTS

We thank Rick Alsager and staff at Nampa Hatchery for monitoring hatch and rearing data and assistance with fish tagging and transport. Gary Thorgaard and Paul Wheeler at Washington State University provided assistance with flow cytometry analysis of blood samples. Regional fishery managers Ned Horner, Steve Yundt, Fred Partridge, Richard Scully, and Mark Gamblin

helped select study streams. Richard Scully, Paul Janssen, Jim Mende, and numerous volunteers collected sterile fish samples for reservoir evaluations. Paul Janssen grit marked sterile and control fingerling rainbow trout.

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JOB PERFORMANCE REPORT
SUBPROJECT #2: ZOOPLANKTON QUALITY INDEX

State of:	Idaho	Grant No.:	F-73-R-21, Fishery Research
Project No.:	8	Title:	Hatchery Trout Evaluations
Subproject #2:	Zooplankton Quality Index		
Contract Period:	July 1, 1998, to June 30, 1999		

ABSTRACT

Simplified methods for processing zooplankton samples are described and two indices (ZPR and ZQI) for data interpretation provided. The indices are used to suggest stocking densities and evaluate the potential for and relative magnitude of competition for zooplankton food in 40 Idaho lakes and reservoirs. In 13 (33%) of the waters sampled, zooplankton forage resources were poor. Conversely, zooplankton forage was rated excellent in 18 of the reservoirs. Processing time for 268 zooplankton samples was 3 d, a savings of about 35 d of technician time had traditional methods for zooplankton analysis been employed. No microscope work was required.

INTRODUCTION

Measures of primary and secondary production are frequently used to predict fish yield (Downing et al. 1990), growth (Mills et al. 1989), and stocking densities (Koenings and Burkett 1987, Walters and Vincent 1973). In lentic systems, zooplankton variables have been particularly useful. Mills et al. (1987) described the use of zooplankton size as a predictor of fish survival and productivity in freshwater lakes. Schneidervin and Hubert (1987) related the collapse of a prominent rainbow trout fishery to a decline in density and size of *Daphnia sp*. in Flaming Gorge Reservoir, Wyoming-Utah. Similar processes can influence the survival and return-to-creel of stocked fingerling rainbow trout.

The Idaho Department of Fish and Game stocks about 6 million fingerling rainbow trout annually. Most of the fingerlings are stocked in lakes and reservoirs. Return-to-creel for fingerlings has ranged from <0.1% to 60% (Teuscher et al. 1998). Results from zooplankton monitoring showed that the presence of *Daphnia sp.* >2 mm was significantly related to the success of fingerling plants (Dillon and Alexander 1995). In a similar study, a zooplankton ratio index (ZPR) explained a significant proportion of the variation in carryover survival of hatchery rainbow trout in 28 Wyoming lakes and reservoirs (Dan Yule, Wyoming Game and Fish, unpublished data). Zooplankton monitoring, however, has not been adopted as a standard monitoring tool. Reluctance to collect zooplankton stems from traditional processing methods that are time consuming and expensive.

In this document, I describe an alternative (simplified) method for assessing zooplankton forage. The method was modeled after preliminary work completed by the Wyoming Game and Fish Department (WGFD). Additionally, zooplankton data from 40 Idaho lakes and reservoirs are presented. The results are interpreted using the Wyoming ZPR model and a zooplankton quality index (ZQI). Both parameters are useful tools that can help set rainbow trout stocking densities in flat-water fisheries.

MANAGEMENT GOAL

To maximize the effectiveness of trout stocking programs in Idaho.

OBJECTIVES

1. Describe the relationships among lake and reservoir characteristics and performance of stocked rainbow trout.

2. Develop stocking guidelines for put-grow-and-take rainbow trout fisheries in Idaho lakes and reservoirs.

METHODS

The method used to quantify zooplankton size structure and abundance did not require tedious microscope work or high tech equipment (Table 6). Instead, zooplankton were collected using three nets fitted with small (153:), medium (500:), and large (750:) mesh. The nets were standard Wisconsin-type nets with a 0.5 m mouth opening and were 1.5 m deep. The nets were used to estimate total zooplankton production potential (samples from the 153: net), the proportion of zooplankton large enough to be captured in the gill rakers of rainbow trout (500: samples), and the proportion of very large zooplankton that are preferred prey items (750: samples). Zooplankton smaller than 600: in length pass freely through the 500: and 750: nets (Seda and Dostalkova 1996) and are generally not susceptible to trout predation.

Zooplankton samples were collected in 40 lakes and reservoirs between August 4 and September 1, 1998. In large reservoirs, we sampled near the dam, mid, and upper portion of each reservoir (3 nets X 3 locations = 9 total samples). In small waters (<100 acres), two locations were sampled. Tows were pulled from 9.1 m to the surface. If the maximum depth was less than 10.1 m, we sample from 1 m off the bottom to the surface.

Zooplankton samples were preserved in denatured ethyl alcohol. A concentration of 1:1 (sample volume:alcohol) was used. After several days in alcohol, phytoplankton were removed from the samples by re-filtering through a 153: mesh sieve. Preservation in alcohol is necessary for removing phytoplankton. However, the zooplankton weights will change over time due to dehydration in alcohol. To minimize dehydration variance, preservation time should be standardized (2 to10 days). After filtering out the phytoplankton, the remaining zooplankton were blotted dry with paper towels and weighed to nearest 0.1 g.

Zooplankton were analyzed using methods developed by the WGFD. For each lake and location, zooplankton biomass collected with the 750: net was divided by the biomass collected in the 500: net (ZPR). The greater the ZPR ratio the more favorable are the forage conditions. The ZPR index can be used to set stocking densities. The WGFD established the following standards: 1) stock only catchables in waters with ZPR <0.25, 2) stock moderate (75–150 per acre) densities of fingerlings in waters with ZPR between 0.25 and 0.60, and 3) stock between 150 to 300 fingerlings per acre in waters with ZPR >0.60. A limitation of the ZPR model, however, is a failure to consider zooplankton abundance. To account for abundance, I developed the zooplankton quality index (ZQI) by multiplying the sum of the zooplankton weight collected in 500: and 750: nets by the ZPR ratio. In short, the ZQI is a measure that includes both abundance and zooplankton size.

Table 6. Methods and equipment used to collect zooplankton samples. Estimated equipment costs are also provided.

	Method	Description
Data Collection	Three nets	153:, 500:, and 750: mesh
	Tow depth	9.1 m to surface or 1 m off bottom to surface
	Sample location	dam, mid, upper reservoir
	Replication	3 nets X 3 locations = 9 total
	Time of year to sample	August
	Time of day to sample	10:00 to 17:00 hr
	Preservative	Ethyl alcohol (50% by volume)
Lab Work	Refilter through 153: sieve	After 2 d to 10 d in alcohol (removes phytoplankton)
	Blot dry samples	Use paper towels
	Weigh	0.1 g with electronic balance
Data Analysis	Estimate ZPR	Biomass in 750: net / biomass in 500: net
	Estimate ZQI	(500: biomass + 750: biomass) ZPR
Equipment List	Zooplankton Nets (each)	$180.00
	Weed Sprayer	$15.00
	Brass Sieve 153:	$30.00
	Ethel Alcohol (gal)	$60.00
	250 ml Nalgene Bottles	$50.00
	Electronic Balance	$150.00
	Total	**$845.00**

RESULTS AND DISCUSSION

Among the 40 waters sampled, ZQI varied by a factor of 300. Fish Creek Reservoir had the highest ZQI at 2.11 g/m followed by American Falls Reservoir (2.10), and Henry's Lake (1.99). Waters with very limited zooplankton resources were Waha and Brush lakes and Manns Creek Reservoir (Table 7). Waters with poorest ZQI contained very low densities of usable zooplankton and virtually no preferred zooplankton prey.

Figure 4 shows zooplankton quality results by region. As expected, the North Idaho lakes demonstrated the lowest overall zooplankton production. However, Bonner, Hauser, and Smith lakes supported zooplankton densities that were probably not limiting for fingerling rainbow trout as demonstrated by relatively high overall biomass accompanied with high proportions of large zooplankton.

The zooplankton data can be used to assess the potential for resource competition. Competition for zooplankton prey may occur in waters with low productivity or waters with substantial production but few zooplankters large enough in size for fish to eat. Both scenarios are represented in the data set. For example, mean zooplankton biomass in the 153: net was 0.02 g/m in Manns Creek compared to 0.72 g/m in Devils Creek. Small zooplankton are 36 times more abundant in Devils Creek. However, both waters share the same density of preferred prey (0.01 g/m). In Manns Creek, fingerling rainbow trout may have poor survival and growth because there is simply no food. In Devils Creek, fingerlings may also have trouble foraging because there are too many predators cropping zooplankton prey. Other waters that fit the Manns Creek scenario include Waha, Brush, Bloom, and Lower Salmon. Examples of good production potential but evidence of fish cropping include Anderson Ranch, Cocolalla, Oakley, and Walcott (Table 7).

The zooplankton biomass estimates can be used to help establish stocking densities or prioritize fish plants. If summer zooplankton results indicate limited forage, fall fingerling plants should be reduced or stocked elsewhere. Conversely, in plankton rich waters, emphasize fingerling plants over larger more expensive hatchery trout. Table 7 shows a range of suggested stocking densities based on zooplankton values. The suggested stocking densities are patterned after WGFD standards. Although the Wyoming standards were derived from successful prediction of rainbow trout carryover, they do not consider overall zooplankton biomass. Failure to include overall densities may lead to high fingerling stocking densities in waters with very poor forage conditions. For example, in Lower Salmon Reservoir, the Wyoming model based on a ZPR value of 0.80 would suggest a high fingerling-stocking rate. However, the reservoir had extremely low zooplankton biomass (<0.06 g/m in all three nets) and would not likely support substantial fingerling plants (Table 7). Therefore, as a general rule, the Wyoming stocking standards based on ZPR can be useful but should be qualified with density data provided by the ZQI.

It is important to note that the zooplankton indices should not be the sole criteria for evaluating a stocking program. Other major factors to consider are fishing pressure, predators, alternative forage, and usable trout habitat. For example, in some waters, predation by birds may have a greater impact on fingerling survival than the availability of food. If possible, the zooplankton indices should be used in concert with other pertinent information and not as a stand-alone stocking model.

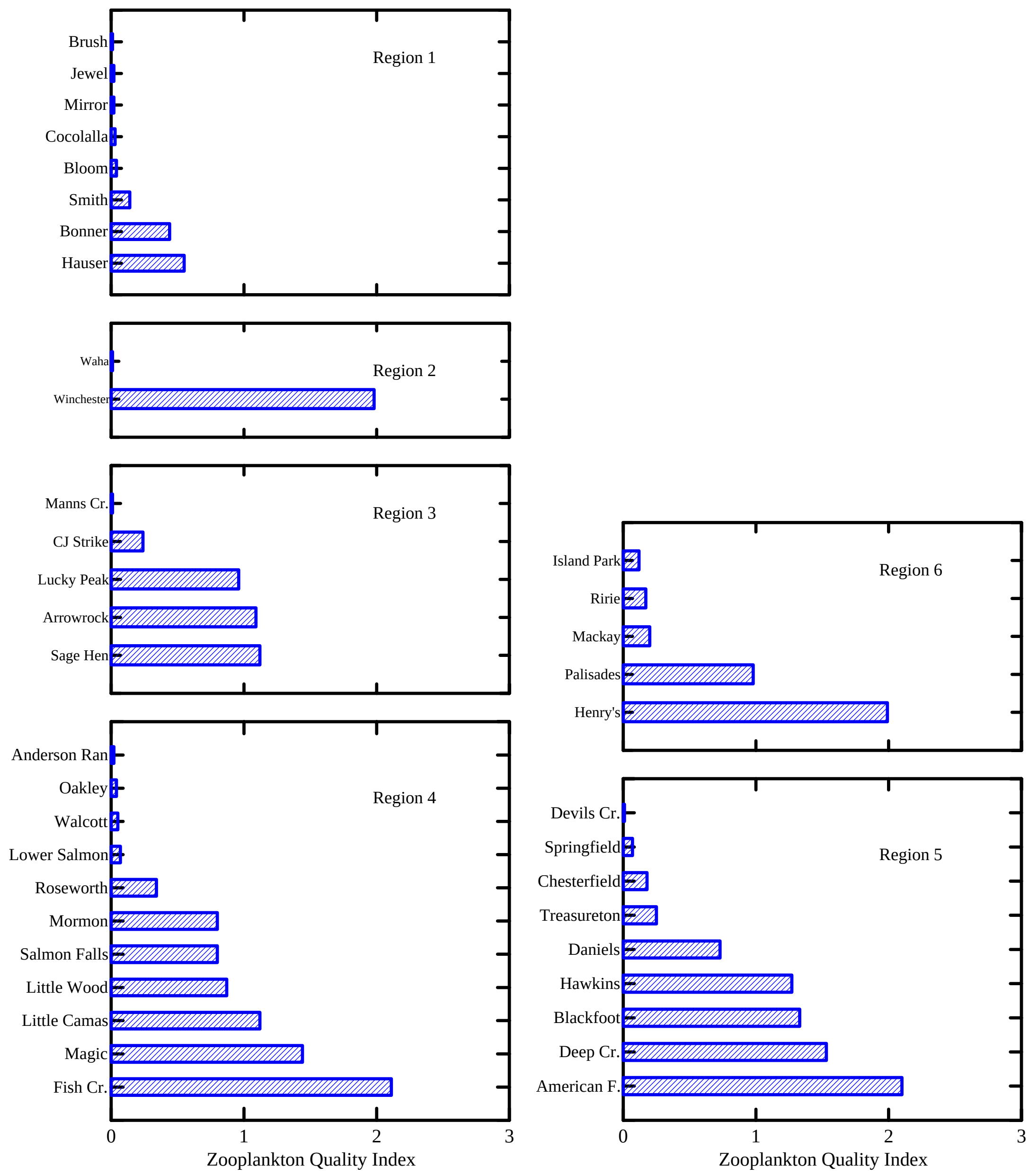

Figure 4. Zooplankton Quality indexes (ZQI) for 40 lakes and reservoirs in Idaho. The ZQI is a measure of total zooplankton abundance adjusted for the proportion of prey that are large enough to be consumed by rainbow trout.

Table 7. Mean zooplankton biomass, zooplankton ratio (ZPR), and zooplankton quality index (ZQI) for 40 lakes and reservoirs sampled in 1998. General stocking guidelines are based on Wyoming standards.

Water	Region	Biomass (g/m)			ZPR	ZQI
		153:	500:	750:	(750: / 500:)	(500:+750:)ZPR
Fish Cr.	4	0.72	1.00	1.04	1.03	2.11
American Falls	5	1.24	1.75	1.23	0.70	2.10
Henry's	6	1.87	1.37	1.10	0.80	1.99
Winchester	2	1.24	1.30	1.08	0.83	1.98
Deep Cr.	5	2.14	1.54	0.95	0.62	1.53
Magic	4	0.74	0.86	0.77	0.89	1.44
Blackfoot	5	1.69	1.36	0.83	0.61	1.33
Hawkins	5	2.68	1.49	0.82	0.55	1.27
Sage Hen	3	1.08	0.91	0.65	0.72	1.12
Little Camas	4	1.70	1.52	0.75	0.49	1.12
Arrowrock	3	0.43	0.56	0.55	0.99	1.09
Palisades	6	0.55	0.68	0.54	0.80	0.98
Lucky Peak	3	0.61	0.72	0.55	0.76	0.96
Little Wood	4	0.83	0.83	0.53	0.64	0.87
Salmon Falls	4	0.38	0.48	0.43	0.89	0.80
Mormon	4	2.08	1.74	0.59	0.34	0.80
Daniels	5	0.86	0.65	0.44	0.68	0.73
Hauser Lake	1	0.42	0.45	0.32	0.71	0.55
Bonner	1	0.28	0.43	0.27	0.63	0.44
Roseworth	4	0.65	0.45	0.22	0.50	0.34
Treasureton	5	0.84	0.48	0.18	0.37	0.25
CJ Strike	3	1.19	0.76	0.19	0.25	0.24
Mackay	6	0.52	0.36	0.14	0.40	0.20
Chesterfield	5	0.70	0.22	0.12	0.53	0.18
Ririe	6	0.77	0.32	0.12	0.38	0.17
Smith	1	0.12	0.29	0.10	0.35	0.14
Island Park	6	0.60	0.14	0.08	0.56	0.12
Lower Salmon	4	0.03	0.05	0.04	0.81	0.07
Springfield	5	0.09	0.07	0.04	0.65	0.07
Walcott	4	0.55	0.04	0.03	0.75	0.05
Bloom	1	0.04	0.05	0.02	0.47	0.04
Oakley	4	0.66	0.17	0.04	0.21	0.04
Cocolalla	1	0.32	0.15	0.03	0.18	0.03
Anderson Ranch	4	0.26	0.15	0.02	0.13	0.02
Mirror	1	0.10	0.10	0.02	0.17	0.02
Jewel	1	0.16	0.22	0.02	0.07	0.02
Brush	1	0.05	0.03	0.01	0.28	0.01
Manns Cr.	3	0.02	0.02	0.01	0.33	0.01
Devils Cr.	5	0.72	0.13	0.01	0.09	0.01
Waha	2	0.09	0.03	0.01	0.20	0.01

ZQI > 0.60 Competition for food unlikely; stock fingerlings from 150 to 300 per acre
0.60 > ZQI > 0.10 Competition for food may be occurring; stock fingerlings from 75 to 150 per acre
ZQI < 0.10 Forage resources are limiting; stock less than 75 fingerlings per acre or catchables

RECOMMENDATIONS

1. Incorporate zooplankton sampling in lowland and high-mountain lake surveys. Sample plankton with 153:, 500: and 750: nets and report data using ZPR and ZQI indices.

ACKNOWLEDGEMENTS

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JOB PERFORMANCE REPORT
SUBPROJECT #3: EFFECTS OF SIZE AT STOCKING AND RETURN TO CREEL

State of: Idaho Grant No.: F-73-R-21, Fishery Research

Project No.: 8 Title: Hatchery Trout Evaluations

Subproject #3: Effects of Size at Stocking and Return To Creel

Contract Period: July 1, 1998, to June 30, 1999

ABSTRACT

We used tag returns and rearing costs to evaluate the performance of standard (mean TL = 9.3 in) and large (mean TL = 11.2 in) catchable rainbow trout in 19 Idaho streams. Eyed eggs were purchased from a commercial source on June 25 and July 27, 1997. The catchables were reared in separate raceways at the Nampa State Fish Hatchery. Production costs were estimated by recording the amount of feed used to grow the catchables to their designated stocking sizes. Prior to release, each fish was fitted with a numbered Monel jaw tag. Equal numbers of standard (200) and large (200) catchables were stocked in each stream. Reward tags and streamside signs were used to encourage angler tag returns. Total tag returns were 14.9% for large and 13.1% for small catchables (Figure 6). The small difference in mean tag returns was not statistically significant ($t_{0.05(1),18} = 1.64$, $P = 0.06$). Production costs were $0.34 per fish for large catchables and $0.15 per fish for the standard group. Therefore, the cost (127% more expensive) far exceeded the benefit (14% increase in tag returns) of stocking large catchable rainbow trout. However, this economic and tag return analysis does not consider angler satisfaction for catching small vs. large fish. If there is a positive relationship between angler satisfaction and fish size, then our analysis may underestimate the true benefit of stocking large catchables. Future work should be completed to describe the relationships between angler satisfaction and fish size.

Results from the paired stocking experiment contradict findings reported by other researchers. Mullan (1956) and Dillon (1997) reported that stocking the same weight but fewer large catchables resulted in a net increase in return-to-creel. The contradiction can be explained by differences in experimental design. In both studies, the researchers sorted large and small fish from raceways to make their comparisons. The largest fish from the raceways were compared to the smallest fish from the same raceways. In our study, we compared tag returns from fish reared in separate raceways–no sorting. We increased rearing time to make the large catchables. Our design is more applicable to fish management, because it mirrors current Idaho hatchery operations used to meet stocking requests for large catchable rainbow trout (i.e. buy the eggs earlier).

It is important to note, however, that our data yields the same results as the Mullan (1959) and Dillon (1997) studies when analyzed similarly. Tag returns from within raceways showed a very strong linear relationship with size (Figure 7). In one of the raceways, tag returns from the smallest catchables were 5% compared to almost 25% for the largest fish from the same raceway (Figure 7).

Results from this study are being submitted to the North American Journal of Fisheries Management. That document will serve as the final report on this study.

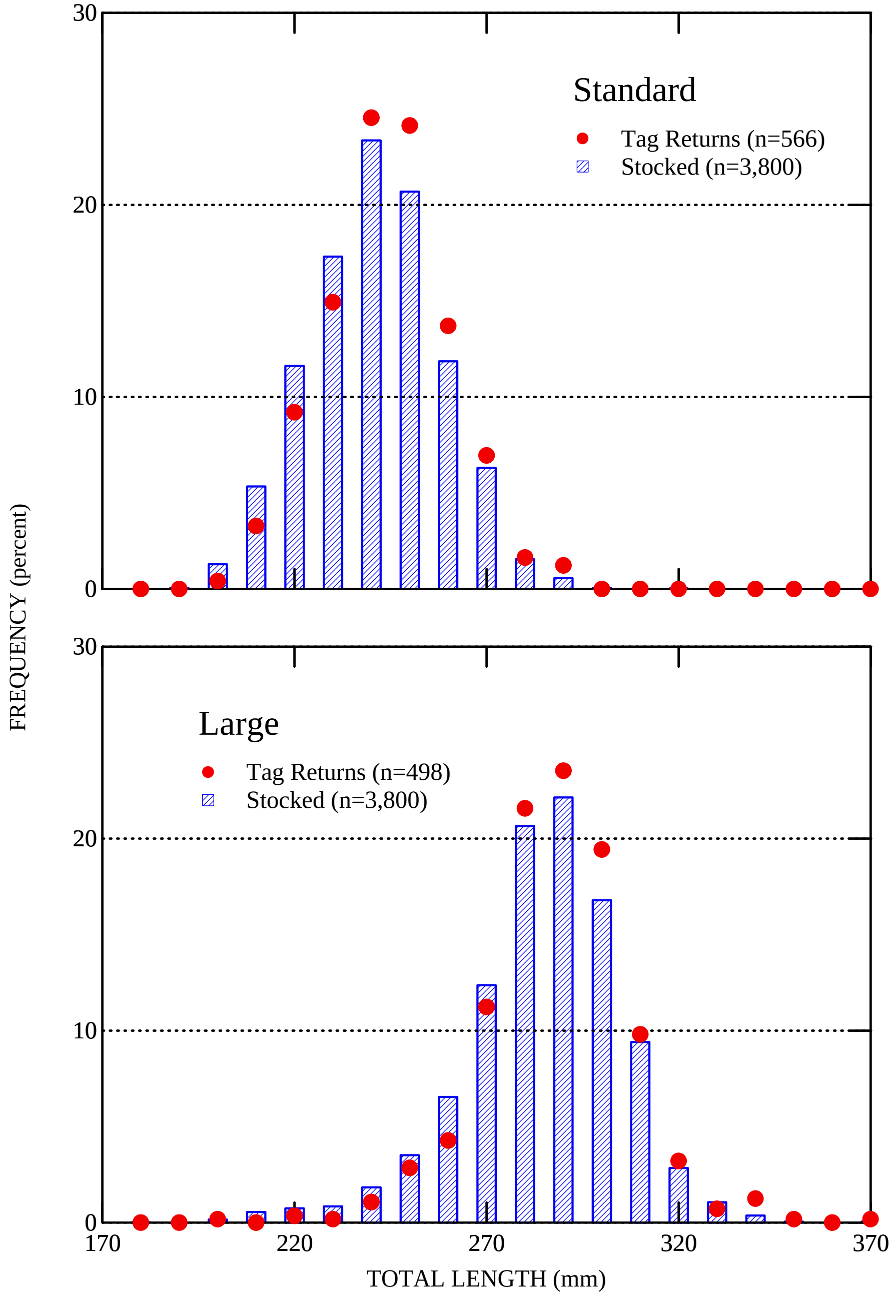

Figure 5. Length frequency distributions of hatchery rainbow trout stocked in 19 Idaho streams. The bars represent the frequencies of stocked fish. The circles represent the frequencies caught by anglers. Because initial length at stocking was used for both distributions, growth was not a factor.

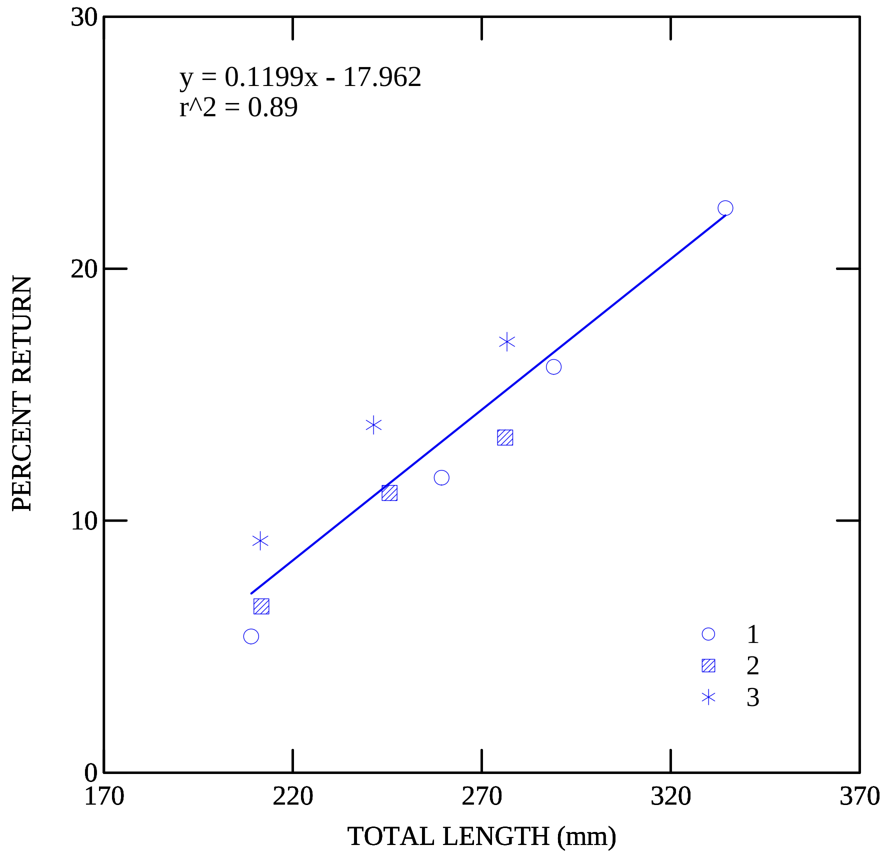

Figure 6. Percent tag returns from three raceways (1,2,3) plotted as a function of mean TL length. Fish from each raceway were grouped by 50 mm length bins. Percent tag returns from those bins are plotted as a function of the mean TL length of fish from each bin.

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