FISHERY RESEARCH

Wild Trout Studies

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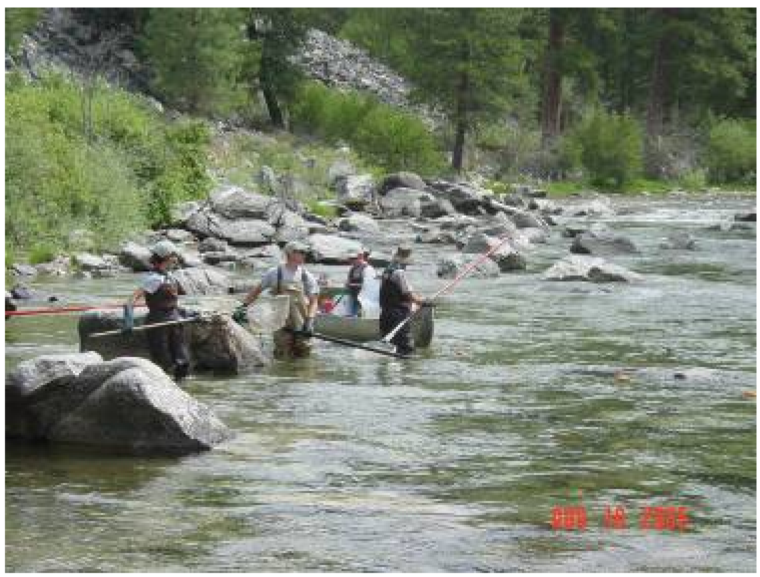

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Wild Trout Studies
Annual Performance Report

July 1, 2007 to June 30, 2008

Grant # F-73-R-30

Project 2: Wild Trout Investigations

Subproject #1: Competition between Wild and Hatchery Rainbow Trout

Subproject #2: Hooking Mortality Comparisons with Circle Hooks

Subproject #3: PIT Tag Retention In Stream Dwelling Wild Trout

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ANNUAL PERFORMANCE REPORT
SUBPROJECT #1: COMPETITION BETWEEN WILD AND HATCHERY RAINBOW TROUT

State of: Idaho

Grant No.: F-73-R-30, Fishery Research

Project No.: 2

Title: Wild Trout Competition Studies

Subproject #1: Competition Between Wild and Hatchery Rainbow Trout

Contract Period: July 1, 2007 to June 30, 2008

ABSTRACT

Idaho Department of Fish and Game has proactively dealt with potential adverse genetic effects of introduced trout on existing populations by stocking sterile rainbow trout *Oncorhynchus mykiss* since 2001, but concerns about ecological effects of introducing hatchery trout into streams and rivers supporting wild trout remain. This report summarizes year three of a five-year study to assess if stocking sterile hatchery rainbow trout of catchable size (catchables) in streams in Idaho reduces wild rainbow trout abundance, survival, growth, or recruitment in those streams. Catchables were stocked at a density of 3.8 fish/100 m^2 into treatment reaches on 11 study streams, which were paired with control study reaches where no stocking occurred. Total densities of wild rainbow trout increased at 17 of the 24 (71%) study reaches from 2006 to 2007. However, observed densities of wild rainbow trout in half of the treatment reaches were lower than densities observed the previous year after being corrected by the 2006 to 2007 change in densities at control sites. Treatment reach densities of wild rainbow trout averaged 13.4 fish/100 m^2, 16% more than 2006 densities. In 2006, 4,402 passive integrated transponder (PIT) tags were placed in wild rainbow trout larger than 100 mm TL, and 798 were recaptured in 2007. Using age-length keys from 2006, growth of PIT tagged fish averaged 56, 43, and 23 mm (44, 48, and 30 g) from age 1 to 2, age 2 to 3, and age 3 to 4 trout, respectively. Growth of wild rainbow trout between control sites and reaches receiving hatchery catchables were similar. With this being the second treatment year of a multiyear project, effects of catchables on wild rainbow trout populations cannot be fully addressed.

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INTRODUCTION

Hatchery trout play an important role in Idaho's stream fisheries but potentially pose a threat to wild trout populations. Maintaining put-and-take fisheries in streams, ponds, lakes, and reservoirs that previously held no game fish is a widely accepted use of hatchery-reared fish (Utter 1994; Epifanio and Nickum 1997). However, supplementing wild trout stream fisheries with hatchery trout raises concern over potential adverse genetic and ecological effects (Krueger and May 1991; Allendorf 1991). Idaho Department of Fish and Game (IDFG) has proactively dealt with potential adverse genetic effects of introduced trout on existing populations by exclusively stocking sterile rainbow trout *Oncorhynchus mykiss* since 2001, but concerns about adverse competitive interactions in streams and rivers supporting wild trout remain.

Competition, by definition, causes a reduction in fitness of an organism due to the limited supply of a resource held in common with other organisms, or the limited ability to exploit a resource because of interference by other organisms (Birch 1957). Reduced fitness levels in wild trout populations could translate to decreased survival, growth, and fecundity rates (Moyle and Cech 1982). Most competition studies have indirectly assessed changes in fitness levels, or found evidence of competition by inferring causal relationships between fitness and characteristics such as ability to maintain favorable positions (Griffith 1972; Fausch and White 1986; Peery and Bjornn 1996), win agonistic bouts (Griffith 1972; Mesa 1991; McMichael et al. 1999), gain weight (Dewald and Wilzbach 1992; Harvey and Nakamoto 1996), or survive (Kocik and Taylor 1994). These studies at the individual scale are much easier to replicate with different manipulations of fish compositions and densities for interspecific competition versus intraspecific competition comparisons. However, they do not directly address concerns at the population level (Fausch 1998), a scale at which competition investigations are rarely performed (Schoener 1983). Moreover, relatively few experiments of competition between hatchery and wild trout have been conducted despite widespread concern (Weber and Fausch 2003). The foremost studies conducted with hatchery and wild trout have had contradicting conclusions. In a series of studies, Miller (1952, 1954) concluded that stocking hatchery trout in streams already containing wild trout populations made little sense because hatchery trout could not effectively compete. Vincent (1987) concluded hatchery trout decreased the abundance and biomass of wild rainbow trout and brown trout *Salmo trutta* in the Madison River and O'Dell Creek, Montana, while Petrosky and Bjornn (1988) concluded catchables had little effect on wild cutthroat trout *O. clarkii* in the St. Joe River and wild rainbow trout in Big Springs Creek, Idaho.

In 2005, a total of 2,200,000 catchable-sized (i.e. 200-250 mm) sterile rainbow trout, hereafter called catchables, were stocked in 323 waters in Idaho. Most (64%) of these waters were lentic systems, including 60 reservoirs, 67 lakes, and 79 ponds. Idaho Department of Fish and Game stocks more than 500,000 catchables into streams annually (IDFG unpublished data). Most stream stocking locations received catchables multiple times, usually during spring and summer; the median stocking frequency was three events/year/stream. Stocking sites for catchables were not evenly distributed across Idaho's seven regions. The number of stocking sites in Idaho streams ranged from three in Region 1 to 33 in Region 3, with most sites (88%) in regions 3, 4, 5, and 6.

Stocking catchables allows for more angling opportunities for the public without changing seasons or regulations, but such practices may potentially have adverse effects on wild trout populations through direct or interference competition. The objectives of this study are to assess population-scale competition effects of stocked catchables on wild rainbow trout populations by quantifying changes in wild trout populations' abundance, survival, growth, and recruitment. We assumed any changes less than about 20% would be biologically unimportant.

OBJECTIVES

1. Determine whether stocking of hatchery rainbow trout catchables reduces abundance, growth, survival, or recruitment in wild rainbow trout populations by at least 20%.

STUDY AREA

The study area for this investigation included 11 streams across southern Idaho (Figure 1). Study streams ranged from 1,094 to 2,104 m in elevation (Table 1). Gradient ranged from 0.5 to 5.9% and conductivity ranged from 30 to 360 µS/cm. Nearly all study streams were adjacent to federal public land.

Study streams were grouped into three harvest categories: general (six fish limit), wild trout (two fish limit), and catch-and-release (Table 1). Streams in the latter category are not explicitly managed with catch-and-release regulations where fish are released; however, they function as such because of slow fish growth and a two fish limit, ≥356 mm length limit for two streams, and very limited public access and fishing pressure for the third stream. The fishing season for all streams is Memorial Day through November 30.

METHODS

Suitable study streams were selected during 2005, and baseline abundance data were collected at that time (High 2006). In addition to the above mentioned regulation categories, selection criteria for paired study sites were that: 1) the stream was not already stocked nearby (i.e. within 5 km); 2) 3 km could be established between two study reaches on each stream; and 3) rainbow trout dominated the salmonid composition of the stream. One study site from each pair of study sites on each study stream was randomly assigned as a treatment reach except at Badger Creek, where logistical constraints of planting catchables in a roadless canyon required that the upper site on Badger Creek serve as the treatment. The Middle Fork Boise River was large enough to accommodate two pairs of study sites. Thus, total sample size was 12 paired control vs. treatment study reaches.

Catchables ranging in size from 150 to over 300 mm were stocked into treatment reaches at a density of 3.8 fish/100 m^2. Treatment reaches were stocked three times during the growing season at monthly intervals. Stocking density was based on rates currently used for Silver Creek, a tributary of the Middle Fork Payette River. Treatment reaches were stocked in the middle as well as upstream and downstream of the reach boundaries with the same density of catchables. Most stocking sites were accessible directly by netting from the hatchery truck or trailer. Some sites, including the Little Weiser River and Little Lost River, required a 300 m in-stream transport downstream from an accessible point to the middle of the treatment reach. Badger Creek was not accessible by truck but was stocked using horses.

Trout populations were sampled using backpack and canoe-mounted electrofishing gear for conducting mark-recapture population sampling. All captured salmonids were identified to species, measured to the nearest mm (TL), and weighed to the nearest 0.1 g using a top-loading digital scale. Scale samples were collected from all wild rainbow trout, or a minimum of 10 individuals from each 1 cm size group. Passive integrated transponder (PIT) tags were implanted intraperitoneally in most wild rainbow trout captured in order to estimate growth and survival of recaptured fish in subsequent years.

Population estimates and 95% confidence intervals (CIs) were calculated using log-likelihood mark/recapture models in the Fisheries Analysis Plus (FA+) program (Fisheries Analysis + 2004). Estimates were made separately by size groups (25-50 mm) and summed to produce an estimate of total number of fish present. When the number of recaptures was low, we increased size groupings to 100 mm or more and used the modified Petersen model to estimate abundance and variance. Capture efficiencies for marked fish averaged 41.1%.

Densities of wild rainbow trout were compared between treatment and control sections on each stream by comparing the control:treatment ratios between years. If the treatment (i.e. stocking hatchery fish) were affecting density, the control:treatment ratio should increase in years 2 and 3 compared to year 1 (pretreatment) as densities of wild trout in the stocked reaches decreased due to the presence of hatchery fish. A one-way Analysis of Variance (ANOVA) was used to test for a change in this ratio between years. This methodology assumes that within-stream rates of recruitment, mortality, emigration, and immigration are the same for each of the control and treatment reach pairs between years.

Growth of wild rainbow trout PIT tagged in 2006 and recaptured in 2007 (n = 798) was assessed by comparing the gain in length and weight over the year between fish caught in the treatment and control reaches, using 95% CIs. Lengths and weights of wild rainbow trout in treatment and control reaches were compared for each available age class. Ages of these PIT-tagged fish at the time of tagging in 2006 were assigned using scale-based age-length keys (Devries and Frie 1996) developed in 2006 for each of the study sites.

RESULTS

Differences in the effects of competition among the three fish regulation categories were not apparent, so results from all study streams were combined. Average densities of all wild rainbow trout ranged from 1.5 to 133.6 trout/100 m^2 in the Middle Fork Boise River and Willow Creek, respectively (Table 2), and increased from 2006 levels at 10 of the 12 control reaches and 9 of 12 treatment reaches (71% of the study reaches. Initial control:treatment ratios in 2005 (prestocking) averaged 1.20 and decreased in 2006 to 0.99 but increased in 2007 to 1.51. However, most of this increase was due to the change in Willow Creek. If Willow Creek were removed from our analyses, control:treatment ratio began in 2005 at 1.09, decreased slightly to 1.04 in 2006, and again in 2007 to 0.92. Based on ANOVA results, this ratio was not statistically different between years (F = 3.28, df = 35, P = 0.62).

Growth of PIT-tagged wild rainbow trout varied between and within streams. In 2006, 4,402 wild rainbow trout >100 mm were PIT tagged, and in 2007, 798 were recaptured. Growth of wild rainbow trout averaged 56, 43, and 23 mm from age 1 to 2, age 2 to 3, and age 3 to 4 trout, respectively (Figure 3). Growth in length was statistically higher in treatment reaches for age 1 fish in the Little Weiser and age 3 fish in the East Fork Weiser River, and statistically lower in the treatment reach for age 1 fish at Squaw Creek, while the remaining comparisons did not differ significantly (Figure 3). Growth in weight averaged 44, 48, and 30 g from age 1 to 2, age 2 to 3, and age 3 to 4, respectively (Figure 4). Six comparisons of growth differences between control to treatment reaches were statistically significant, with two showing greater growth in the control reach while four showed greater growth in the treatment reach (Figure 4). The remaining available comparisons were not statistically significant.

DISCUSSION

Strong conclusions cannot be made at the midpoint of this long-term study on competition between wild and hatchery trout. However, after two years of stocking it does not appear that abundance of wild rainbow trout has been significantly reduced by the stocking of hatchery rainbow trout in the reaches we have studied. In fact, control:treatment ratios have increased rather than decreased after stocking commenced. Although statistically insignificant in our study, such a pattern would not be expected if stocking reduced densities of wild trout. Unfortunately, substantial habitat alterations in Willow Creek by beaver *Castor canadensis* likely make any inferences based on changes in population dynamics from 2006 to 2007 invalid for this stream, reducing our overall sample size.

It appears that 2006 was a good spawning year for rainbow trout, with densities of wild rainbow trout increasing at 71% of the study sites. Densities may also have increased as a function of lower stream surface area. The majority (88%) of study reaches had decreased average wetted widths in 2007 when compared to 2006. The narrower stream widths alone increased rainbow trout densities by an average of 11%.

Growth rates of wild rainbow trout did not appear to be affected by stocking catchables. It was clear that different study streams have different rates of growth, but growth rates in terms of length and weight largely appeared to be similar for treatment and control reaches on the same stream (Figures 3 and 4). With the continuation of the study, and the addition of 3,837 PIT tagged wild rainbow trout (average of 310/stream) in 2007, stronger conclusions on stocking effects on wild rainbow trout growth will be possible next year.

Individually marked wild rainbow trout will also prove useful in future analyses. As the study progresses, we will be able to utilize cohort analyses and multiple mark and recapture robust designs such as Pollock's robust design (Cormack 1964; Jolly 1965; Seber 1965) in combination with catch curve analyses to better estimate and confirm impacts of stocking catchables on wild trout population mortality and recruitment rates.

In summary, preliminary findings indicate some statistically measurable impacts of catchables on wild trout populations. However, biologically significant impacts, such as changes at the 20% level, have yet to be clearly observed. This project will continue again in 2008, which will enable further investigation into effects of catchables on wild trout populations. This will be particularly beneficial for not only comparing differences in abundance and growth, but for recruitment and survival rates as well.

RECOMMENDATIONS

1. Continue study in 2008 by stocking treatment reaches with catchables at density of 3.8 fish/100 m^2 at three monthly intervals during the growing season.

2. Continue monitoring abundance, growth, mortality, and recruitment of wild rainbow trout populations at each site using mark-recapture estimation methods.

3. Apply program MARK to data with individually marked fish to provide a second estimate of abundance, survival, and recruitment for comparison purposes to existing methods.

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Table 1. Study reach locations, abiotic descriptions, treatment stocking rates, and source of catchables.

Stream	Site	Elevation (m)	Conductivity (µS/cm)	Zone	Easting	Northing	Gradient (%)	Stream order	Ownership	Drainage area (km^2)	Annual rainfall (cm)	Geology	Catchables stocked per planting	Source hatchery
General regulation streams														
Fourth Fork Rock Creek	Lower	1577	50	11	726775	4681619	4.8	3rd	Sawtooth National Forest	25	46	Basalt	51	Hagarman
	Upper	1800	50	11	725117	4678773	3.5	2nd	Sawtooth National Forest	14	46	Basalt	-	-
East Fork Weiser River	Lower	1260	70	11	550180	4961897	3.3	2nd	Payette National Forest	70	91	Basalt	-	-
	Upper	1481	60	11	553858	4962111	5.9	2nd	Payette National Forest	50	91	Basalt	39	Nampa
Little Weiser River	Lower	1163	80	11	555728	4927393	1.8	3rd	Payette National Forest	116	82	Basalt	70	Nampa
	Upper	1306	60	11	560119	4929915	2.2	3rd	Payette National Forest	85	82	Basalt	-	-
Wild trout regulation streams														
Squaw Creek	Lower	1149	30	11	555742	4913591	1.4	3rd	Boise National Forest	96	78	Basalt	-	-
	Upper	1254	30	11	556947	4920060	1.8	3rd	Boise National Forest	66	78	Basalt	88	Nampa
Clear Creek	Lower	1267	50	11	612447	4884548	3.1	3rd	Boise National Forest	136	84	Granite	124	Nampa
	Upper	1562	40	11	615483	4892526	2.5	3rd	Boise National Forest	93	84	Granite	-	-
Little Lost River	Lower	2036	70	12	313446	4909346	1.2	4th	Salmon-Challis National Forest	192	60	Sedimentary	57	Mackay
	Upper	2104	50	12	310744	4914244	1.6	4th	Salmon-Challis National Forest	116	60	Sedimentary	-	-
Willow Creek	Lower	1717	160	11	691836	4817640	2.5	3rd	Sawtooth National Forest	51	67	Basalt/Granite	23	Nampa
	Upper	1790	190	11	690451	4819520	2.9	3rd	Sawtooth National Forest	31	67	Basalt/Granite	-	-
Medicine Lodge Creek	Lower	1737	360	12	380935	4904871	1.6	4th	Bureau of Land Management	409	47	Sedimentary	44	Mackay
	Upper	1806	310	12	376226	4907857	1.7	4th	Bureau of Land Management	394	47	Sedimentary	-	-
Catch-and-release regulation streams														
South Fork Bosie River	Lower	1343	90	11	660998	4827702	1.6	5th	Boise National Forest	917	90	Granite	-	-
	Upper	1604	100	11	664707	4828430	1.7	5th	Boise National Forest	899	90	Granite	227	Hagarman
Middle Fork Boise River	Site 1	1094	50	11	613554	4843073	0.5	5th	Boise National Forest	984	90	Granite	303	Nampa
	Site 2	1171	60	11	618340	4848149	0.5	5th	Boise National Forest	905	90	Granite	-	-
Middle Fork Boise River	Site 3	1269	50	11	626494	4849524	0.4	5th	Boise National Forest	757	90	Granite	270	Nampa
	Site 4	1305	60	11	631618	4852102	1.0	5th	Boise National Forest	647	90	Granite	-	-
Badger Creek	Lower	1646	200	12	477674	4862215	4.4	3rd	Private	150	68	Sedimentary/volcanics	-	-
	Upper	1698	200	12	480530	4863772	0.9	3rd	Private	145	68	Sedimentary/volcanics	181	Ashton

Table 2. Summary of wild rainbow trout abundance in relation to study site area and abundance of other salmonid species present (RBT = rainbow trout, BKT = brook trout, BLT = bull trout, BRN = brown trout, and MWF = mountain whitefish) in 2006.

Stream	Site	Length (m)	Average width (m)	Total RBT (95% CI)	Percent efficiency	Salmonid percent composition RBT	BKT	BLT	BRN	MWF
General regulation streams										
Fourth Fork Rock Creek[a]	Lower	835	3.3	867 (811-923)	53.5	0.97	0.01	0	0.02	0
	Upper	502	2.7	509 (432-586)	32.4	0.82	0.15	0	0	0
East Fork Weiser River[b]	Lower	497	4.7	651 (607-695)	61.1	>0.99	<0.01	0	0	0
	Upper	493	5.6	604 (547-661)	51.9	>0.98[d]	0	0	0	0
Little Weiser River[b]	Lower	650	9.7	907 (608-1,206)	34.9	>0.99	0	0	0	<0.01
	Upper	612	8.4	584 (471-697)	42.7	>0.99	<0.01	<0.01	0	0
Wild trout regulation streams										
Squaw Creek[b,e]	Lower	1,063	6.4	200 (125-275)	21.4	0.85	0	0	0	0.15
	Upper	845	9.5	739 (544-934)	26.8	>0.99	0	0	0	<0.01
Clear Creek[b]	Lower	722	11.7	919[e] (447-1,391)	11.9	>0.99	0	<0.01	0	<0.01
	Upper	323	10.2	497 (395-599)	36.4	1.00	0	0	0	0
Little Lost River[b]	Lower	746	6.1	920 (842-998)	43.2	0.98	<0.01	0.01	0	0
	Upper	574	5.9	706 (639-773)	46.4	0.83	0.14	0.01[f]	0	0
Willow Creek[b]	Lower	565	6.1	570 (505-635)	44.3	1.00	0	0	0	0
	Upper	300	2.9	1,166 (1,025-1,307)	45.9	1.00	0	0	0	0
Medicine Lodge Creek[b]	Lower	620	5.1	259 (228-290)	71.9	>0.99[g]	<0.01	0	0	0
	Upper	644	5.4	93[e] (73-113)	66.7	0.99	0.01	0	0	0
Catch-and-release regulation streams										
South Fork Boise River[a]	Lower	1,785	21.7	540 (491-589)	47.9	0.39	0	0.01	0	0.60
	Upper	1,100	16.6	290 (236-344)	34.4	0.36	0	<0.01	0	0.64
Middle Fork Boise River[a]	Site 1	810	27.8	389[e] (202-576)	15.9	0.71	0	0	0	0.29
	Site 2	826	29.9	375 (319-431)	32.3	0.57	0	0	0	0.43
	Site 3	981	23.2	549 (453-645)	29.3	0.81	0	0.01	0	0.18
	Site 4	932	21.2	423 (321-525)	31.8	0.72	0	0.01	0	0.27
Badger Creek[b,c]	Lower	280	10.7	676 (608-744)	54.1	0.98[h]	0	0	0	0.02
	Upper	540	13.7	1,657 (1,549-1,765)	49.1	1.00[h]	0	0	0	0

[a]Estimate is for wild rainbow trout ≥100 mm
[b]Estimate is for wild rainbow trout ≥75 mm
[c]Estimate includes Yellowstone cutthroat trout and rainbow x cutthroat hybrids
[d]Brook x bull trout hybrids comprised 1.8% of the salmonid composition
[e]Redband trout population estimate made using Modified Peterson analysis method
[f]Brook x bull trout hybrids comprised 2.2% of the salmonid composition
[g]Includes rainbow x cutthroat trout hybrids
[h]Includes Yellowstone cutthroat trout and rainbow x cutthroat trout hybrids

Table 3. Summary of wild rainbow trout density and the ratio of densities between control and treatment reaches from 2005 (pretreatment) to 2007. Changes in the ratio over time compared to the initial ratio would suggest a treatment effect.

			2005				2006				2007				Control:treatment ratio			
			Area	Fish/	95% CIs		Area	Fish/	95% CIs		Area	Fish/	95% CIs					
Stream	Site	Site Type	(m^2)	100m^2	Lower	Upper	(m^2)	100m^2	Lower	Upper	(m^2)	100m^2	Lower	Upper	2005	2006	2007	Average
Fourth Fork Rock Creek	Lower	Treatment	na	23.8	21.5	26.1	2,691	27.4	22.9	32.0	2,945	29.4	27.5	31.3	1.48	0.78	1.28	1.18
Fourth Fork Rock Creek	Upper	Control	na	35.3	30.0	40.7	1,352	21.5	16.7	26.3	1,345	37.8	32.1	43.5				
Willow Creek	Lower	Treatment	237	8.0	8.0	8.2	2,000	17.4	12.0	22.8	3,430	16.6	14.7	18.5	2.41	0.45	8.04	3.63
Willow Creek	Upper	Control	223	19.3	19.3	19.3	2,187	7.8	5.0	10.5	873	133.6	117.5	149.7				
Second Fork Squaw Creek	Lower	Control	918	4.3	4.3	4.7	10,960	1.7	1.1	2.4	6,846	3.2	2.1	4.3	0.46	0.16	0.19	0.27
Second Fork Squaw Creek	Upper	Treatment	902	9.3	8.9	10.0	10,301	10.8	10.4	11.2	7,985	16.7	11.3	22.1				
East Fork Weiser River	Lower	Control	2,768	16.5	14.2	18.8	2,824	21.0	18.8	23.1	2,316	28.3	26.4	30.3	0.85	1.56	1.29	1.23
East Fork Weiser River	Upper	Treatment	3,090	19.5	16.9	22.0	3,265	13.5	9.8	17.1	2,751	22.0	19.9	24.0				
Little Lost River	Lower	Treatment	4,539	12.0	10.8	13.2	4,357	18.7	17.5	20.0	4,551	20.2	18.5	21.9	1.73	1.33	1.03	1.37
Little Lost River	Upper	Control	3,064	20.8	19.4	22.2	2,888	25.0	21.4	28.6	3,381	20.9	18.9	22.9				
Middle Fork Boise River	1	Treatment	18,672	0.9	0.5	1.3	21,840	0.4	0.2	0.6	22,502	1.6	0.8	2.4	0.76	2.61	0.95	1.44
Middle Fork Boise River	2	Control	33,802	0.7	0.5	0.9	32,575	1.1	0.5	1.6	24,697	1.5	1.3	1.7				
Middle Fork Boise River	3	Treatment	21,449	1.7	1.4	2.0	27,771	2.0	1.1	2.9	22,759	2.4	2.0	2.8	0.70	0.58	0.89	0.72
Middle Fork Boise River	4	Control	19,995	1.2	1.0	1.4	20,391	1.1	0.8	1.5	19,758	2.1	1.6	2.7				
South Fork Boise River	Lower	Control	28,486	2.3	1.8	2.9	37,862	1.2	1.0	1.4	38,681	1.8	1.7	2.0	1.34	0.88	1.12	1.11
South Fork Boise River	Upper	Treatment	26,145	1.8	1.4	2.2	24,106	1.4	1.0	1.8	17,743	1.6	1.3	1.9				
Badger Creek	Lower	Control	1,104	9.5	9.1	10.0	3,248	14.3	12.0	16.6	2,999	15.6	14.2	16.9	1.71	1.28	0.91	1.30
Badger Creek	Upper	Treatment	1,962	5.6	5.4	5.8	7,656	11.2	8.4	14.0	7,387	17.2	15.9	18.4				
Little Weiser River	Lower	Treatment	5,603	20.1	18.4	21.7	7,872	8.3	7.2	9.4	6,305	14.4	9.6	19.1	1.45	1.24	0.61	1.10
Little Weiser River	Upper	Control	3,777	29.2	27.5	30.9	6,358	10.3	9.0	11.6	5,159	8.8	6.9	10.6				
Clear Creek	Lower	Treatment	1,280	5.0	4.6	5.7	5,950	16.2	11.7	20.7	8,447	10.3	5.2	15.5	1.24	0.74	1.46	1.15
Clear Creek	Upper	Control	982	6.2	6.0	6.7	5,700	12.0	9.8	14.1	3,295	15.1	12.0	18.2				
Medicine Lodge Creek	Lower	Treatment	930	5.4	5.3	5.8	3,271	10.9	9.1	12.8	3,131	8.1	7.1	9.0	0.30	0.26	0.37	0.31
Medicine Lodge Creek	Upper	Control	1,240	1.6	1.6	1.7	3,773	2.8	2.1	3.6	3,490	3.0	2.3	3.6				
Average				10.8				10.7				18.0			1.20	0.99	1.51	1.23
Average (without Willow)				10.6				10.6				12.8			1.09	1.04	0.92	1.02

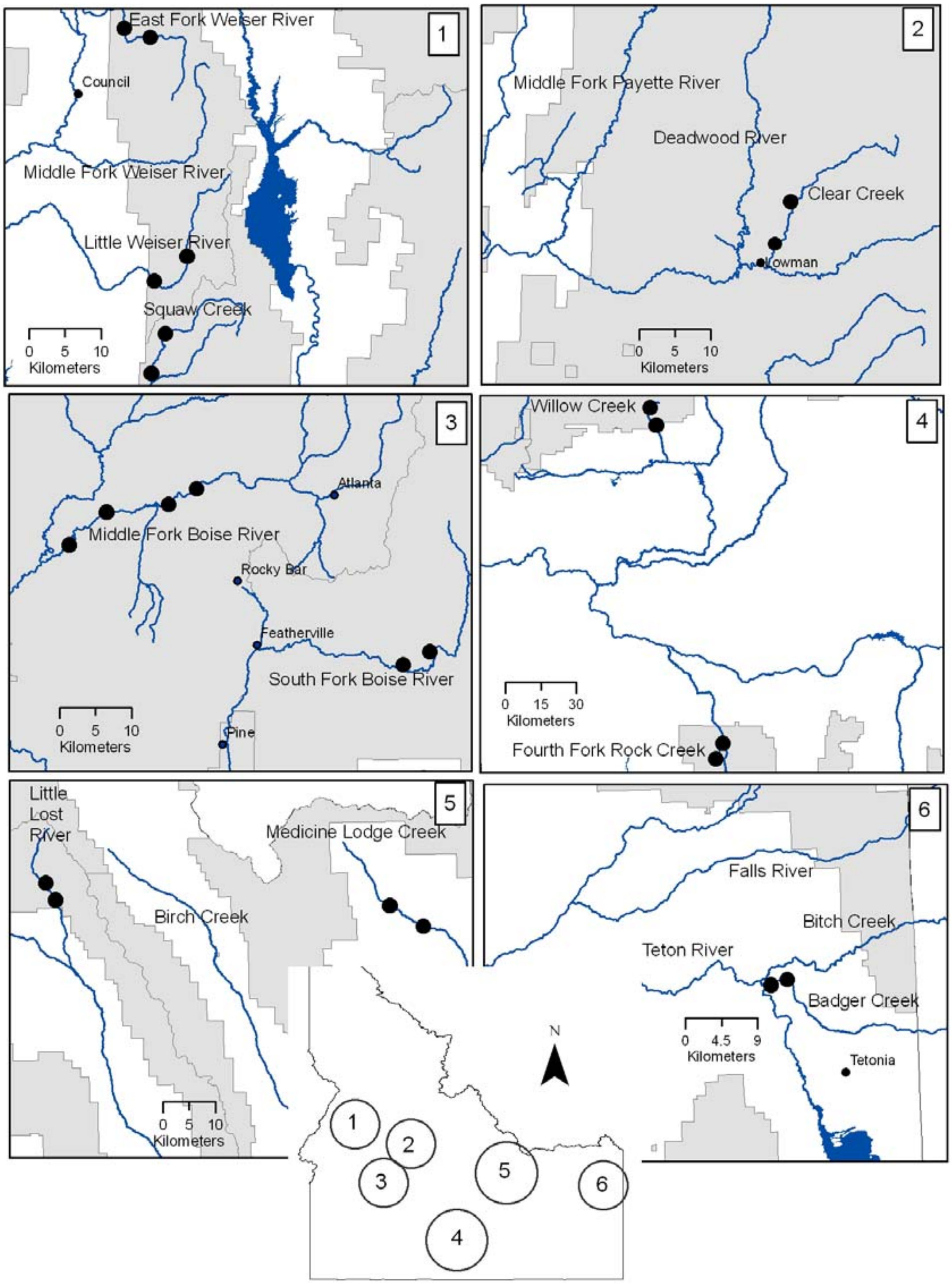

Figure 1. Study streams sampled during 2006 with study areas marked with closed circles.

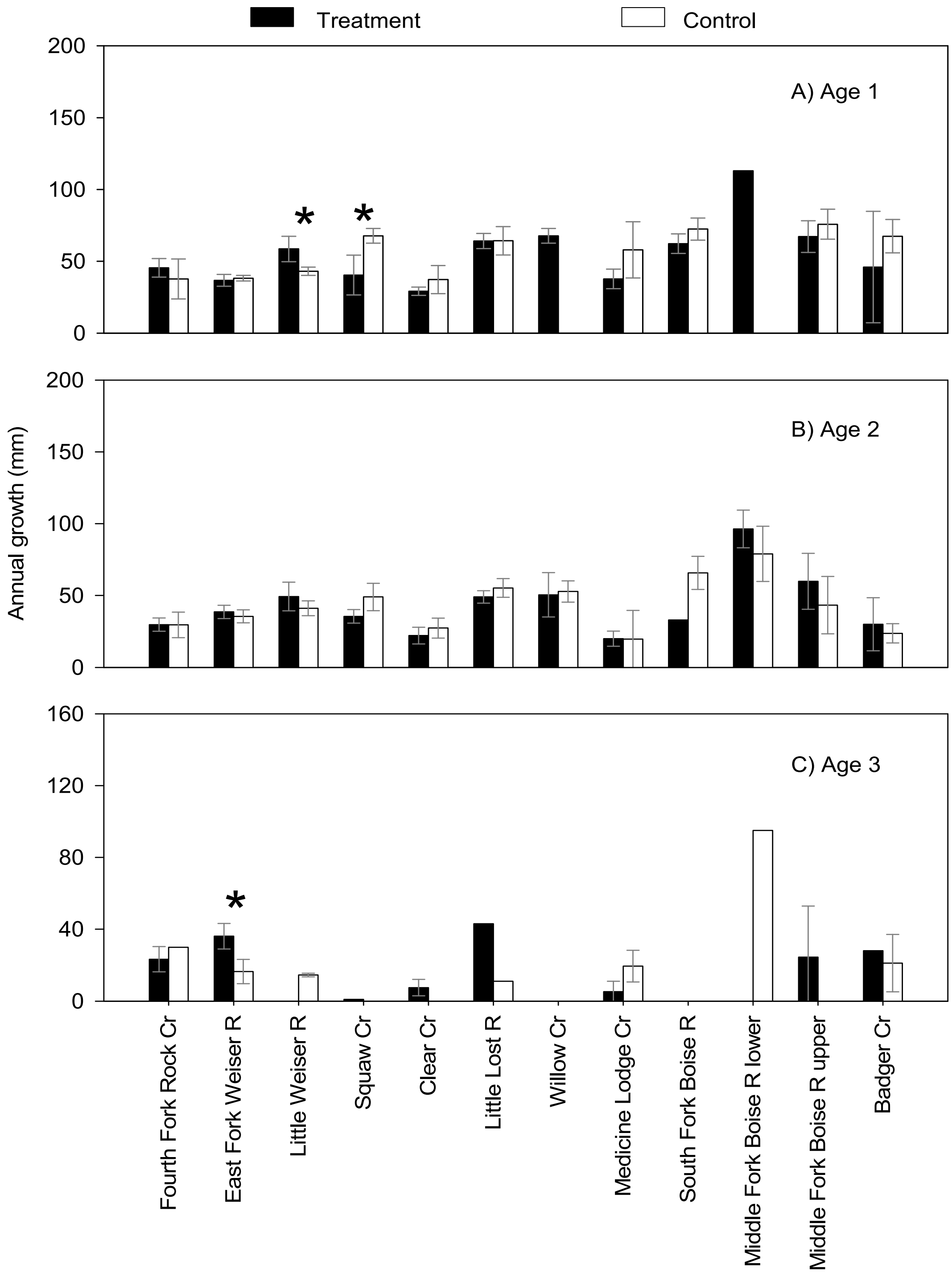

Figure 2. Average growth (mm) and 95% confidence intervals for wild rainbow trout captured and PIT-tagged in 2006 as age 0 (A), age 1 (B), and age 2 (C) and recaptured in 2007. Growth was for age 1 to 2, age 2 to 3, and age 3 to 4. Asterisks (*) indicate significant differences in growth rates between control and treatment study sites.

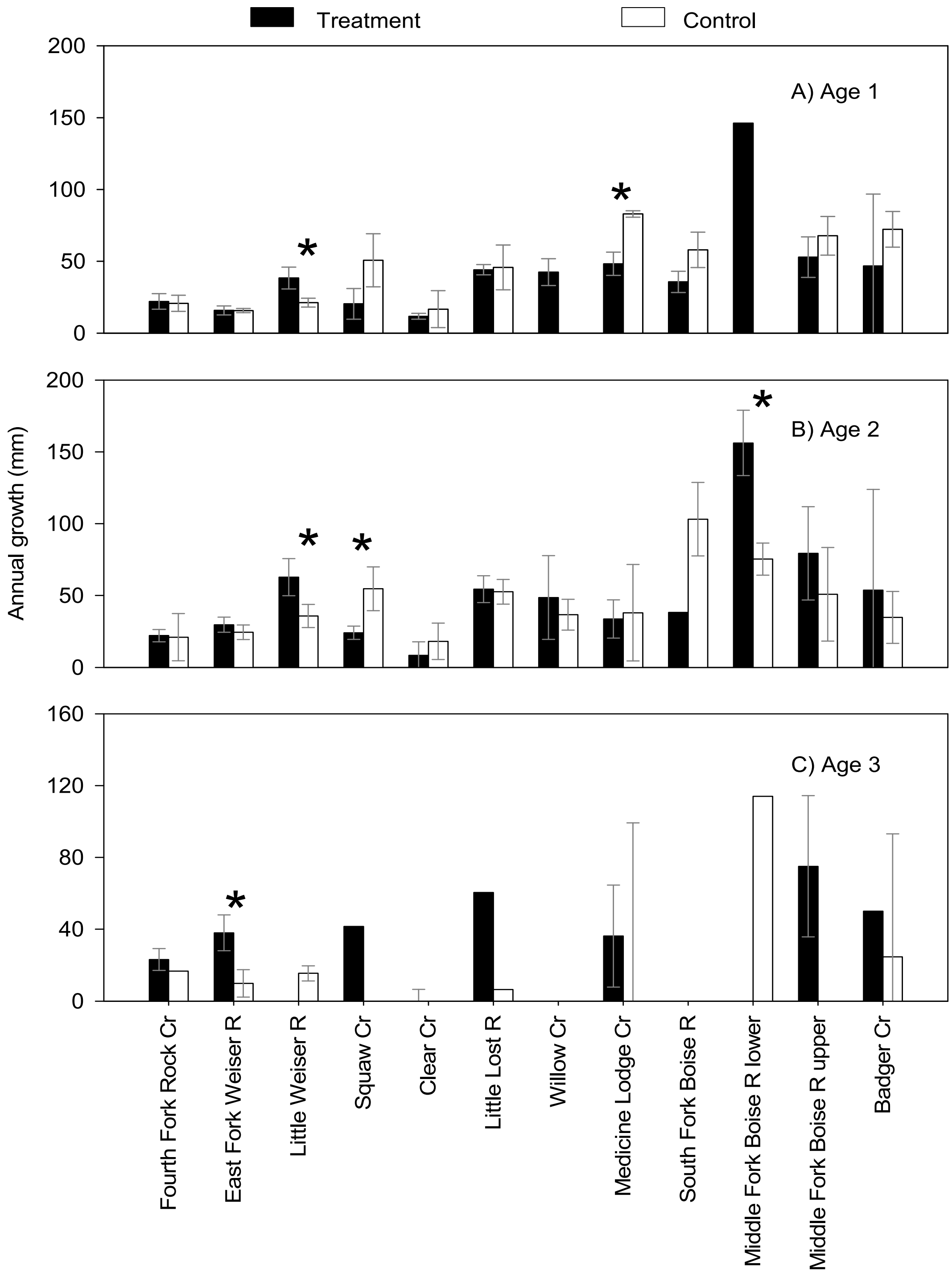

Figure 3. Average growth (g) and 95% confidence intervals for wild rainbow trout captured and PIT-tagged in 2006 as age 0 (A), age 1 (B), and age 2 (C) and recaptured in 2007. Growth was for age 1 to 2, age 2 to 3, and age 3 to 4. Asterisks (*) indicate significant differences in growth rates between control and treatment study sites.

ANNUAL PERFORMANCE REPORT
SUBPROJECT #2: HOOKING MORTALITY FROM BAITED CIRCLE HOOKS

State of: Idaho

Grant No.: F-73-R-27, Fishery Research

Project No.: 2

Title: Wild Trout Studies

Subproject #2: Hooking mortality comparisons using circle hooks

Contract Period: July 1, 2007 to June 30, 2008

ABSTRACT

We compared short-term (1 d) and long-term (69 d) hooking mortality of trout caught with barbed baited circle hooks to other common hook types such as barbed single-hook dry flies, barbed treble hook spinners, and barbed baited J-hooks. Experienced anglers captured 300 wild Yellowstone cutthroat trout *Oncorhynchus clarkii bouvieri*, rainbow trout *O. mykiss*, cutthroat x rainbow trout hybrids, and residualized hatchery rainbow trout in the lower end of Badger Creek, an unexploited tributary of the Teton River. The study section was isolated by installing temporary weirs at the upper and lower ends of a 1 km reach. Test fish were marked using an adipose fin clip and passive integrated transponder (PIT) tags. Short-term mortality was evaluated by searching for expired fish within the isolated section of Badger Creek during and immediately after the fishing period. No test fish carcasses were discovered; however, one test fish deep-hooked with a J-hook died shortly after capture prior to marking. Deep-hooking rates were highest with baited J-hooks at 21%, followed by spinners at 5%, baited circle hooks at 4%, and dry flies at 1%. Mark and recapture population surveys were used to assess mortality of captured fish over the 69 d holding period. Overall, mortality rates during the holding period were low for each of the hook types, averaging 16%. However, mortality rates of trout captured with J-hooks (25%) and treble hook spinners (29%) were significantly higher than mortality rates of fish caught using dry flies (4%) and circle hooks (7%). Although circle hooks successfully reduced bait-hooking mortality of trout in Badger Creek, applicability to state angling regulations may be limited due to the potential inability of anglers to properly fish with circle hooks, inequalities among available circle hooks, and potential difficulties in enforcement.

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INTRODUCTION

Increasing angler effort on popular trout fisheries has often resulted in implementation of special regulations such as slot limits, minimum size limits, and catch-and-release, which are aimed at reducing fishing mortality rates. Such management strategies assume negligible amounts of post-release mortality. Westerman (1932) was the first to document post-release or hooking mortality of a resident trout species (brook trout *Salvelinus fontinalis*). Since this work, numerous researchers have investigated effects of different fishing gear on hooking mortality rates of various salmonids. Nearly all studies comparing hooking mortality rates for trout when using bait versus artificial flies and lures have concluded that the use of bait results in three to six times higher mortality rates (Shetter and Allison 1955; Hunsaker et al. 1970; Mongillo 1984). With bait hooking mortalities reported up to nearly half of the fish released, it is not surprising that restrictions on the use of bait have been a common tool used by fishery managers striving for population-level results to regulation changes. However, social issues cannot be ignored. Fishery managers often choose not to alienate bait fishermen, weighing the social cost of bait-restrictive regulations against the cost of increased hooking-mortality rates of wild fish populations.

Hooking mortality caused by the use of traditional bait fishing gear is significantly higher than artificial flies and most lures because of hooking location. Hooking mortality of caught-and-released fish is most strongly related to the anatomical site of hooking because of resultant injuries to vital organs (Mason and Hunt 1967; Wydoski 1977; Schill 1996). While artificial flies and lures are not immune from hooking fish in critical areas such as the esophagus, stomach, or gills, they generally penetrate critical areas less than 10% of the time, compared to roughly 50% when bait is used (Mongillo 1984).

Recent innovations in bait fishing hooks tout substantially reduced rates of hooking-related mortality (Parmenter 2000), potentially providing fishery managers avenues for reducing fishing impacts on wild trout populations. A hook design called a circle hook, which tends to lodge itself in a fish's mouth or jaw because of its circular shape, has become widely accepted for use in marine fisheries (Kaimmer and Trumble 1997; Trumble et al. 2000). Circle hooks are similar in shape to salmon egg hooks, except the point is bent toward the shank, which allows circle hooks to slip through the esophagus and mouth until its path of travel is changed. With widespread acceptance in commercial marine fisheries, the use of circle hooks in freshwater sport fisheries is slowly growing in popularity (Meka 2004).

Existing studies using circle hooks in freshwater systems have been limited to lentic systems and hatchery trout. Though hook manufacturers were unwilling to scale down their marine versions of circle hooks for research purposes as recently as the early 1990s (D. Schill, Idaho Department of Fish and Game, personal communication), Eagle Claw® did provide Parmenter (2000) with a size 12 prototype for a hooking mortality study. Circle hooks did not decrease the rates of deep hooking. However, the author observed volunteer anglers fishing circle hooks incorrectly (actively setting the hook), which likely confounded the results (Parmenter 2000). A later study using a single angler and the same circle hook reported at least 70% of the cultured rainbow trout caught were hooked in the mouth or jaw; however, mortality rates (9%) were still significantly greater than when cut-line J-hooks, treble hooks, Shelton hooks, and flies (all barbless) were used (Jenkins 2003).

Discrepancies among extant studies and the lack of wild test subjects warrant further investigation. Jenkins (2003) concluded circle hooks still caused higher mortality rates for hatchery rainbow trout *Oncorhynchus mykiss* than flies and treble hooks, but deep-hooking rates were 24% less than observed by Parmenter (2000), who found a significant decrease in hooking mortality when circle hooks were used versus standard J-hooks. Furthermore, the applicability of these studies to wild fisheries remains questionable as wild trout likely experience higher hooking mortality rates than their hatchery counterparts (Warner 1979; Mongillo 1984).

The purpose of this project was to assess the level of bait mortality using circle hooks in streams supporting native trout fisheries when limited angling mortality is necessary for the fishery to remain productive. Specifically, short-term (1 d) and long-term (60 d) hooking mortality for wild Yellowstone cutthroat trout *O. clarkii bouvierii* and rainbow trout was quantified as a function of hook type and hooking location in a natural stream setting.

OBJECTIVE

1. Quantify hooking mortality of wild trout caused by baited circle hooks relative to baited J-hooks, dry flies, and treble hook spinners.

STUDY AREA

Badger Creek is a tributary of the Teton River in the upper Snake River watershed draining west off the Teton Mountains (Figure 4). This highly productive third-order stream enters the Teton River in a deep narrow canyon section of the Teton River. The canyon associated with lower Badger Creek is approximately 6.5 km long and maintains perennial water flow from large springs near the upper end of the canyon. Upstream of the canyon, Badger Creek has an ephemeral section from the canyon springs upstream to irrigation diversions near the forested headwaters. The headwaters of Badger Creek also flow perennially. This study was implemented in the lower portion of Badger Creek, 2.0 km upstream from the mouth. Lower Badger Creek, with its water provided entirely by springs in summer and fall, strongly resembles a spring creek with relatively stable flow and temperature regimes. Water temperatures during the months of July and August in 2006 averaged 10.9°C and fluctuated between 8.8 and 14.5°C. Lower Badger Creek is surrounded by private land, and access is quite limited. Thus, fishing pressure is extremely low despite the fact that general fishing regulations (excluding the harvest of cutthroat trout) are in force.

METHODS

A 1,000 m section of Badger Creek was isolated with hardware cloth wire mesh (1.3 cm) weirs to prevent fish from entering or leaving the study area during a 60 d minimum holding period (Figure 4). The weirs were checked and cleaned frequently (every 2 days) to ensure proper function and to count and identify fish mortalities washed against the lower weir.

Wild cutthroat trout, rainbow trout, rainbow x cutthroat hybrids, and some residualized hatchery rainbow trout that had spent at least 10 months in Badger Creek were captured after the weirs had been built. Experienced anglers fished from July 5 to 8, 2007, using dry flies (size 4 to 14), treble hook lures (Panther Marten™ 3.5 g), circle hooks baited with nightcrawlers

(Eagle Claw® size 8), and traditional J-hooks baited with nightcrawlers (Renegade snelled size 8), all barbed. While fishing with bait, fishermen limited effort to pools and slack water to maximize potential of deep-hooking (Schill 1996). Circle hooks were fished according to manufacturer's recommendations, i.e. when a strike was detected, the angler slowly started reeling in to retrieve the fish without setting the hook. Captured trout were anesthetized (using 3 ml of 1:10 clove oil:alcohol solution in 11.5 L water), identified, measured to the neared 25 mm, and marked with an adipose fin clip. Passive integrated transponder (PIT) tags were placed intraperitoneally using a rinsed, 12 gauge hypodermic needle; the insertion point was ventral and posterior to the pectoral fin, offset slightly to the right or left side depending on the individual tagger. The anatomical location of hooking was noted as well as other observations including relative amount of bleeding, whether the hook was removed or the line was cut, and the presence of disease or existing health problems such as black spot disease (caused by digenic trematodes of the genus *Neascus*). Anglers cut the line when fish were hooked in the esophagus or deeper, leaving the hook in the test fish. Adipose fins were removed from test fish to quantify rates of PIT tag loss. Upon recovery, marked fish were released where they were captured. Short-term hooking mortality was assessed by searching the study area daily during the fishing period and the following day. For the remainder of the study, the reach was visually searched for mortalities during all weir check trips.

The mesh weirs used to enclose the study section were not functioning completely throughout the duration of the study period due to debris building up against the hardware cloth. Debris deposited by beaver activity caused the lower weir to partially fail so that water was spilling over the top at one corner on August 4, 2007. The weir was temporarily fixed August 5, 2007 and reinforced on August 8, 2007. The lower weir again partially failed on August 16, 2007 and was repaired August 17, 2007. A small tear at the bottom of the upper screen was also repaired August 17, 2007. The lower weir required one further repair on September 15, 2007, after one corner was leaking over the top for a day. After the study ended, electrofishing passes were made approximately 100 m above and below the weirs to capture test trout that escaped during weir failures. No study fish were captured in the 100 m section located downstream of the lower weir, but three were captured immediately upstream of the upper weir. No other test fish were capture in the next 500 m above the upper weir.

The study area was maintained for a 69 d holding period after the 4 d capture event. At the conclusion of the observation period, a mark-recapture electrofishing survey was conducted using backpack electrofishing units. All fish captured during electrofishing surveys were marked with a caudal clip, which enabled us to estimate abundance and 95% confidence intervals (CIs) of all trout in the study reach as well as the abundance of fish for each hook type. This was done using the log-likelihood method within FA+ (Fisheries Analysis + 2004), and estimates were adjusted for size-selectivity. We then calculated mortality rates over the test period for each hook type as follows:

$$M_n = \frac{A_n - B_n}{A_n}$$

where M_n = mortality rate for fish of hook type *n,* A_n = number of fish of hook type *n* initially tagged while angling, and B_n = end of study abundance estimate of fish of hook type *n*. Some test fish shed PIT tags during the holding period and, therefore, could not be traced back to hook type. We estimated how many fish shed PIT tags using the log-likelihood method in FA+. We assumed no differences in PIT tag shedding rates between hook types. We distributed the estimate of test fish that lost PIT tags and the corresponding variance back into the four hook types so that realistic mortality rates could be reported and compared. Because we estimated different abundances after the holding period for the different hook types, we weighted the adjustment for PIT tag loss based on the proportion of the total sample size estimated to remain after the holding period for each hook type. Statistically significant differences in mortality were noted by nonoverlapping 95% CIs around the estimates.

We tested whether the anatomical site of hooking location affected survival. We compared the ratio of deep to lightly-hooked test fish caught during the angling phase of the study to the ratio observed at the end of the holding period, as identified by PIT tags, using a Chi-square test (α = 0.05). J-hooks were the only hook type with sufficient deep-hooking observations to perform the test. Deep-hooking was defined as having the hook embedded in the gill arches or esophagus during capture (Figure 5). The remaining hook locations were grouped into the light-hooking category.

Hooking effectiveness and landing efficiency was compared among hook types. Hooking effectiveness was evaluated by keeping a tally of the number of strikes and the number of successful hook-ups for each type of hook used. The number of strikes was divided by the number of successful hook-ups to calculate an overall effectiveness rate. We also divided the number of first strike hook-ups by the number of fish hooked to provide a second metric of hooking effectiveness. We did not try to tease out the number of unsuccessful strikes per fish, as it was impossible to accurately determine if there was a single fish or multiple fish striking at the hook when unsuccessful strikes occurred. We simply kept a running total of the number of unsuccessful strikes prior to each successful hook-up and assumed that individual fish struck at, and missed, all the hook types in equal proportions. Landing efficiency was calculated for each hook type by dividing the number of fish landed by the number of fish hooked. In order to estimate hooking effectiveness and landing efficiency for circle hooks more completely, anglers actively set the hook on half of the fish, and with the remaining half, anglers passively hooked the fish by slowly reeling in until enough tension on the line existed to allow the angler to “play” the fish. The anatomical site of hooking was also noted for all fish. Hooking effectiveness and landing efficiency will be tested during the 2008 field season.

RESULTS

During a 4 d period, anglers caught and marked 300 fish using four different hook types. The average size of test fish was 252 mm TL (range 126 to 370 mm). Residualized hatchery rainbow trout comprised 12% of the test fish. Sample size for the four hook types was 76, 75, 75, and 74 for J-hooks, lures, circle hooks, and dry flies, respectively. The majority (72%) of the trout captured were hooked in the upper and lower jaws (Table 4). An additional 13% were hooked in the roof and floor of the mouth. Only one mortality was observed immediately after the release of a fish caught in the esophagus on a J-hook.

During mark and recapture electrofishing sampling of the Badger Creek study area, 1,738 trout were handled, including 240 test fish with adipose clips. Electrofishing efficiency was 68.6% overall. We estimated 2,255 (±66) trout >100 mm were present within the 1,000 m study area, thus the 300 test fish comprised just over 13% of the fish present. We captured 44 test fish that had lost their PIT tags (16%), and estimated that another three had lost their tag. After adjusting for PIT tag loss, post-holding period population estimates for each hook type ranged from 58 to 71 (Table 5), which translated to mortality rates of 29% for lures, 25% for J-hooks, 7% for circle hooks, and 4% for flies; there were statistically significant differences between lures and J-hooks (higher mortality) and circle hooks and dry flies (lower mortality).

During the initial angling period, 21.1% of the J-hook test fish were hooked deep. Sixty-nine days later, 8.7% of the J-hook test fish that remained had been hooked deep during the angling period. Statistically speaking, however, anatomical site of hooking did not affect the post-holding period abundance of test fish caught on J-hooks, indicated by the Chi-square test results using $\alpha = 0.05$ ($X^2 = 2.653$, df = 1, $P = 0.10$).

DISCUSSION

Barbed circle hooks baited with nightcrawlers performed as well as dry flies at limiting long-term hooking-related mortality of wild trout in Badger Creek. After 69 d, mortality rates of wild trout captured using baited circle hooks and dry flies was less than 10%, significantly lower than mortality rates of test fish captured using lures and baited J-hooks (25 to 30%). Low mortality rates for trout caught with circle hooks in our study corroborated results of previous studies using circle hooks on hatchery rainbow trout, which report 9% mortality after 26 d (Jenkins 2003) and 10% mortality after 28 d (Parmenter 2000).

The anatomical site of hooking is strongly related to hooking mortality, i.e. deep-hooked trout often die because of damage to organs including the heart and liver (Mason and Hunt 1967; Schill 1996). In our study, deep-hooking rates of trout in the esophagus and gills most commonly occurred when fishing with baited J-hooks (21%), but were low relative to other studies. Jenkins (2003) reported over 60% of the hatchery rainbow trout he caught were hooked in the esophagus using J-hooks with powerbait while fishing net pens in a pond. The stream setting may have influenced our deep-hooking rates. While we attempted to maximize deep-hooking by fishing pools and backwater areas (Schill 1996), the pool and backwater type habitat in our study reach was not extensive. It is possible that flow within or adjacent to the pools affected our ability to allow trout to consistently swallow the bait as observed by Jenkins (2003) for J-hooks. Results of hooking studies performed in lentic systems may not be reproducible in lotic systems (Schill 1992). However, we did observe more deep-hooking of wild trout while fishing with J-hooks (21%) than circle hooks (4%). Similar to Jenkins (2003), trout caught with circle hooks were most commonly hooked in the jaws.

The effectiveness of circle hooks at light-hooking trout appears to be related to how they are fished. When fished passively, without setting the hook, circle hooks become lodged primarily in the jaws of the trout at the corner of the mouth, 83% for the current study and 70% in a California study (Jenkins 2003). In a California study, deep-hooking rates were much higher at 55% (Parmenter 2000), compared to 4% in this study, though the circle hooks used were identical. Although anglers were instructed to fish passively, Parmenter (2000) observed some anglers actively setting the hook and noted significant differences of deep-hooking rates among anglers.

Our study had some limitations. Several test fish lost PIT tags, which prevented us from identifying what hook type was used to catch the fish and where the hook was lodged during capture. We believe PIT tag loss had little effect on our findings because it is probably safe to assume that loss did not differ with hook type. Another shortcoming was that our weirs were not totally impassable by trout throughout the study. We believe the partial failing of the weirs bounding our study area did not impact our results. While it was possible for fish to move out of the study area during certain times of the holding period, the weirs did not fail until 25 d after the holding period had started. By this time, test fish near weirs would have been able to set up territories relative to habitat changes caused by the presence of the weir (Miller 1954). Moreover, during the electrofishing survey, we electrofished 100 m downstream of the lower weir and over 600 m upstream of the upper weir to look for escaped fish. Only three test fish we captured, immediately upstream of the upper weir.

We expected, but did not observe, a significantly lower proportion of test fish deep-hooked at the conclusion of the study than at the beginning. While the proportion did decrease, the difference was not statistically significant. However, the low incidence of deep-hooking translated into few post-holding period observations of test fish that were deep hooked, and thus we were barely able to satisfy minimum requirements of at least five observations in each contingency table cell for the chi-square test (Zar 1999). Thus, our chi-square test had very little statistical power.

We were surprised to find that mortality rates for test fish caught using Panther Martin™ lures (29%) were not significantly different from that for test fish caught with J-hooks (25%). Previous studies have indicated lures do not cause high hooking mortality rates within resident trout populations (Wydoski 1977; Dubois and Dubielzig 2004). We suspect the higher mortality rates were related to the small size of lure used, relative to the large fish size. We noticed a few of the test fish landed with spinners were hooked in the jaw, but had sustained damage to the gill arches. With the small size of lures used, mortality may have been caused by initial deep-hooking in the gill arches that ripped through that area prior to lodging in the mouth or jaw.

Fishery managers often must balance social preferences with biological constraints. Special regulations are often put in place to limit annual mortality rates of fish populations by reducing angling mortality. Unfortunately, special regulations have a tendency to alienate bait-fishing constituents. Traditional bait-fishing gear has been shown to cause high rates of hooking mortality (Shetter and Allison 1955; Stringer 1967; Mongillo 1984), and thus is not compatible with regulation schemes aimed at keeping hooking mortality low. However, we have demonstrated that circle hooks may be fished with bait for wild trout in a natural stream setting with resultant hooking mortality rates similar to dry flies. Thus, allowing bait fishing in the most restrictive types of special regulations may be possible if the use of circle hooks is mandated. Concern, however, lies in the fact that the tendency of circle hooks to lodge in the corner of a trout's mouth may be dependent on whether the hook is actively or passively set. Furthermore, we only tested one design of circle hook, which is now one of many commercially available hooks on the market in sizes applicable to stream trout. Not only do the shapes of the circle hook vary according to manufacturer, but the profile differs as well. We used an in-line style of hook, which translated into higher rates of light-hooking relative to offset circle hooks, where the point of an offset circle hook is off to the side of the shank when viewed from the top (Vecchio and Wenner 2007).

In conclusion, circle hooks have the potential to significantly decrease bait-hooking mortality compared to conventional bait hooks such as J-hook, and may prove useful in special regulation waters. However, the applicability of allowing baited circle hooks in special fishing regulation cases, where little hooking mortality can be tolerated, may be limited due to the potential inability of anglers to properly fish with circle hooks, inequalities among available circle hooks, and potential difficulties in enforcement.

RECOMMENDATIONS

1. Continue evaluating circle hook effectiveness at light-hooking stream trout.

2. In 2008, evaluate the landing efficiency of circle hooks compared to J-hooks.

3. In 2008, evaluate the effect of active hook-setting on anatomical hooking locations using circle hooks and compared to J-hooks.

4. Compare anatomical hooking locations among various circle hook manufacturers.

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Table 4. Summary of anatomical hooking locations for trout caught in Badger Creek using four different barbed hook types.

Hook location	**J-hook**	**Circle**	**Lure**	**Fly**	**Total**
Upper jaw	35	58	22	44	**159**
Lower jaw	9	4	23	20	**56**
Mouth roof	7	4	5	2	**18**
Mouth floor	5	3	6	6	**20**
Tongue	1		5	1	**7**
Gill	6		4	1	**11**
Esophagus	10	3			**13**
Belly (foul)			1		**1**
Eye	3	3	8		**14**
Unknown			1		**1**
Total	**76**	**75**	**75**	**74**	**300**

Table 5. Mark-recapture electrofishing results after the holding period and statistical groupings. Estimates and 95% confidence intervals are corrected values after test fish that lost PIT tags had been accounted for and added back into the hook type groups using a weighting method based on the post-holding period population estimate.

	Lure	**J-hook**	**Circle**	**Fly**
Fish marked	35	41	52	46
Fish captured (recapture run)	30	35	37	37
Marked fish in recapture run	24	30	34	29
Population estimate (95% CI)	53 (48-58)	57 (54-62)	70 (66-75)	71 (64-74)
Grouping	A	A	B	B

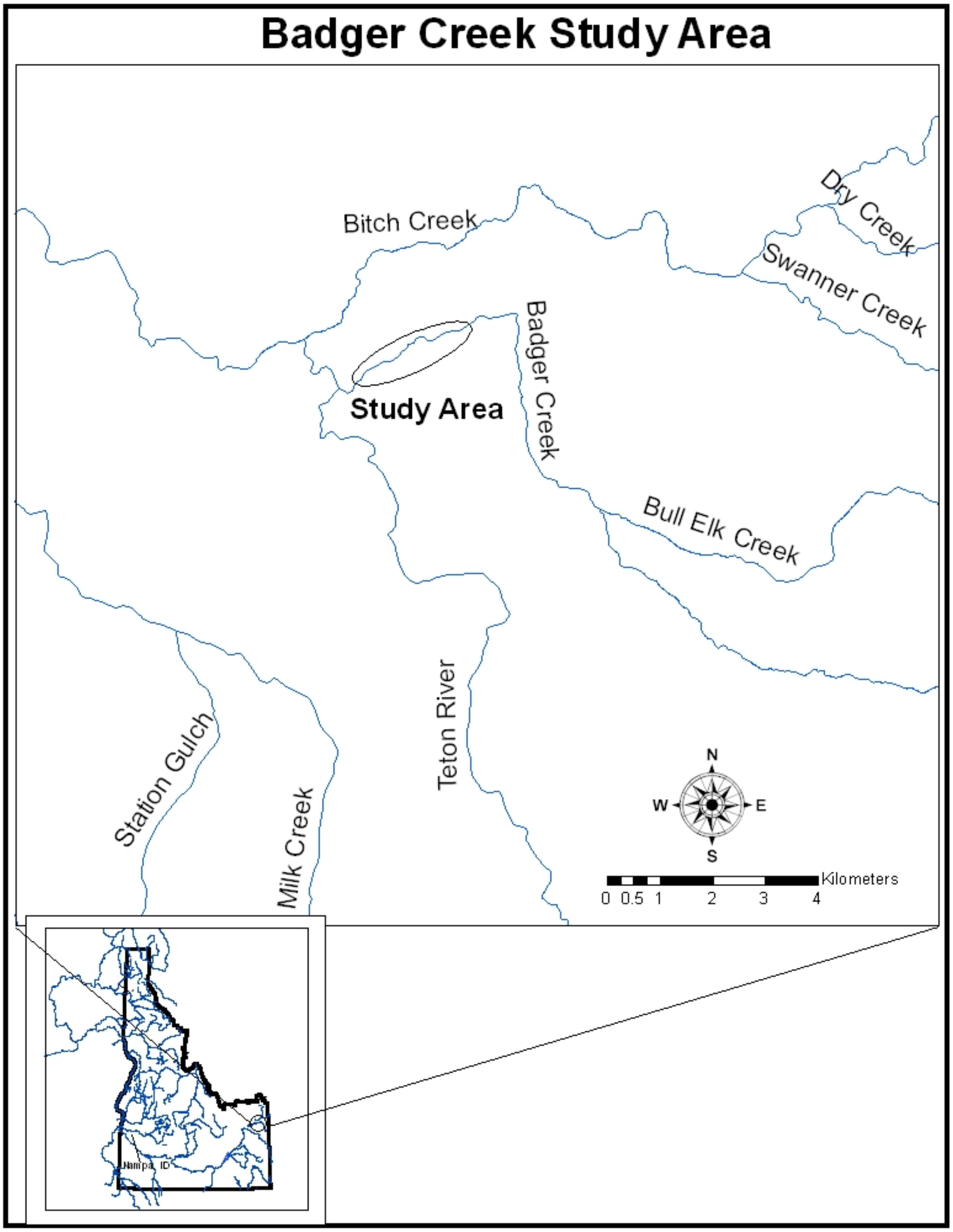

Figure 4. Map of study area on Badger Creek, tributary of the Teton River.

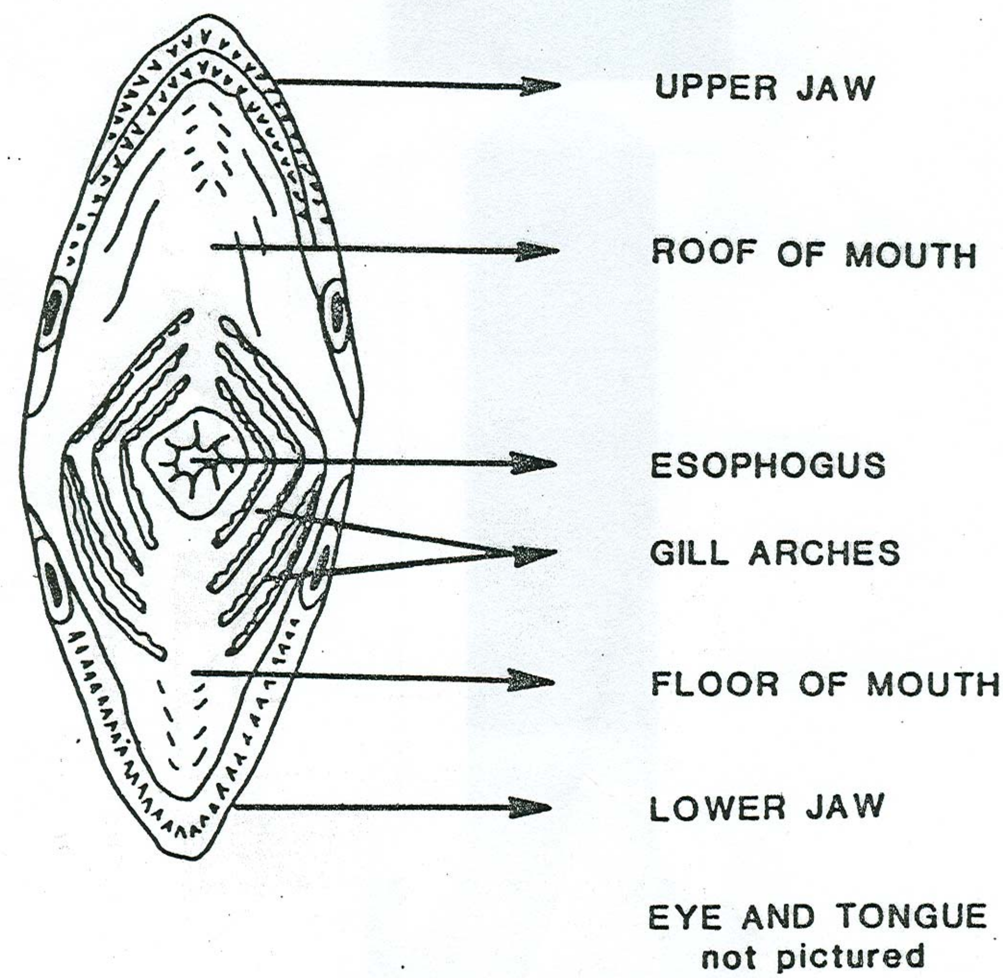

Figure 5. Diagram of a salmonid's mouth with anatomical groupings of hooking locations identified (adopted from Mongillo 1984).

ANNUAL PERFORMANCE REPORT
SUBPROJECT #3: PIT TAG RETENTION IN STREAM DWELLING WILD TROUT

State of: Idaho

Grant No.: F-73-R-27, Fishery Research

Project No.: 2

Title: Wild Trout Studies

Subproject #3: PIT tag retention in stream dwelling wild trout

Contract Period: July 1, 2007 to June 30, 2008

ABSTRACT

Passive integrated transponder (PIT) tags have been widely used as a tool for various monitoring and research needs, but retention rates have rarely been tested in resident salmonids. We quantified short-term (<1 week) and long-term (1 year) retention rates of PIT tags placed in the peritoneal cavity of small resident redband trout *Oncorhynchus mykiss gairdneri* and evaluated whether tagging experience and fish size influenced retention rates. Long-term retention rates for PIT tags averaged 80% and ranged from a low of 66% to a high of 91%. In comparison, short-term retention rates were at least 99.8% for all streams. In 8 out of 11 streams, experienced taggers produced higher retention rates; a chi-square test indicated experienced taggers had significantly less short-term loss rates than inexperienced taggers. Larger redband trout in similarly sized streams had lower retention rates than their smaller counterparts.

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INTRODUCTION

Passive integrated transponder (PIT) tags have been widely used as a tool for various monitoring and research needs, usually as a mechanism to mark individual organisms. They have been used to mark salmonids (Prentice et al. 1990), reptiles, amphibians (Camper and Dixon 1988), captive mice (Rao and Edmondson 1990), squirrels (Schooley et al. 1993), and sturgeon (Clugston 1996), among others. Furthermore, PIT tags have alternatively been used in fish populations as a tool for tracking small fish in shallow streams similar to the use of radio telemetry (Roussel et. al. 2000). When PIT tags are used for population dynamics studies, retention rates are assumed to be high, but are frequently not validated. Depending on the organisms being tagged and the tag placement, retention rates can be highly variable. For example, a 97% retention rate was found for squirrels tagged subcutaneously (Schooley et al. 1993), whereas an 85% retention rate was found for Atlantic salmon tagged intraperitoneally (Roussel et al. 2000). Other factors that may influence the retention rates include the experience and technique of the personnel performing the tagging, the duration of the study undertaken, and the behavior of the tagged organism. For fish tagged in the peritoneal cavity, fish size or maturity may affect the expulsion of the tag. Indeed, PIT tags have been shown to be lost during spawning when placed into salmonid body cavities (Prentice et al. 1990).

OBJECTIVES

1. Quantify short-term (<1 week) and long-term (1 year) retention rates of PIT tags placed in the peritoneal cavity of small resident trout.

2. Evaluate whether tagging experience and fish size influenced retention rates.

METHODS

During the summers of 2006 and 2007, as part of a companion study, we conducted mark-recapture electrofishing in 11 streams across southern Idaho using either backpack- or canoe-mounted electrofishers. Redband trout *Oncorhynchus mykiss gairdneri* were collected and anesthetized using a clove oil:ethanol (1:10) mixture. We measured all trout for total length (TL; mm) and weight (g) and removed a portion of the caudal fin as an external mark. We also removed adipose fins from redband trout receiving PIT tags. Any redband trout with an adipose clip from the previous year that had lost its PIT tag was given a new tag. We attempted to reduce secondary infection at our streamside work-up locations by sterilizing the PIT tag needle in a sponge soaked with ethanol. PIT tags were placed intraperitoneally using a rinsed, 12 gauge hypodermic needle. The insertion point was ventral and posterior to the pectoral fin, offset slightly to the right or left side depending on the individual tagger. The fish were then put into a recovery tank of fresh stream water until regaining their equilibrium, at which point they were released back into the stream near the point of capture.

Short-term retention rates were calculated as the proportion of redband trout with both adipose and caudal clips that were caught in the recapture run and that contained a PIT tag, compared to the total number captured in the recapture run with both fin clips. Long-term retention rates were calculated as the proportion of redband trout caught during either the mark or recapture runs that contained an adipose clip but not a caudal clip and that either contained a PIT tag, compared to the total number captured in either run that contained an adipose clip but not a caudal clip.

Short-term retention rates were compared between 2006 and 2007 as a comparison between novice and experienced taggers. In 2006, the personnel performing the tagging had no prior experience, whereas in 2007 all taggers had fairly extensive prior experience. We used a chi-square test ($\alpha = 0.05$) assuming random, independent samples from a normally distributed population and adequate samples for each cell of the contingency table to test our hypothesis that more experienced taggers experienced lower rates of short-term tag loss.

We also compared retention rates to fish length. We hypothesized that older, larger, mature fish lose PIT tags more frequently than smaller, younger, immature trout, possibly due to expulsion of tags during spawning (Prentice et al. 1990). All redband trout with healed adipose clip scars were assigned to one centimeter length groups. We attempted to control for differences in length at maturity in different sized streams by combining data by stream order. All second- and third-order streams were grouped together due to low sample size. Groupings were based on observed relationships between stream widths and lengths at sexual maturity of wild trout populations (Meyer et al. 2003; D. Schill, IDFG, unpublished data). The relationship between trout length and retention rate was investigated using linear regression.

RESULTS

Long-term retention rates for PIT tags averaged 80% and ranged from a low of 66% in Fourth Fork Rock Creek to a high of 91% in the Little Lost River (Table 6; Figure 6). In comparison, short-term retention rates (1-7 days) were at least 99.8% for all streams. In 8 out of 11 streams, experienced taggers produced higher retention rates (Figure 7). Chi-square tests indicated experienced taggers had significantly less short-term loss rates than inexperienced taggers ($\chi^2 = 13.9$, df = 1, $P = 0.0002$).

Larger redband trout in similarly sized streams had lower retention rates than their smaller counterparts. For second- and third-order streams and for fifth-order streams, there was a negative relationship between length of the trout and the retention rates (Figure 8). For fourth-order streams, this relationship was not significant.

DISCUSSION

PIT tags are a useful tool in fishery research and management, providing biologists with a means of matching data collected at multiple intervals in a natural environment directly to an individual. They can be efficiently used to gather population mortality and growth estimates; however, biologists must be aware of the effects that experience plays on the resulting retention rates. We have shown a significant difference in short-term retention rates with experienced vs. novice taggers. However, both experienced and novice taggers had extremely high rates of short-term retention overall. It is possible that experience of taggers is only a concern when short-term loss has the potential to bias study objectives. The three streams that did not follow the expected trend could be attributed to the limited sample sizes. It should be noted that fish in the two streams with the lowest retention rates were tagged by first-time taggers.

Fish length also has an effect on long-term retention, as we have shown a significant difference in two of the three stream size groups tested. This is probably due to the larger fish gaining maturity and losing their tag in the peritoneal cavity through the process of spawning. As this study progresses over the next two years, it will provide the ability to compare long-term retention rates over periods longer than one year, perhaps answering the question of whether a fish that loses a tag during the first spawning season might retain tags in proceeding years.

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Table 6. Long-term retention of PIT tags by redband trout by stream.

Stream Name	Number of 2006 adipose clipped fish: Captured	Captured with a PIT tag	Retention rate (%)
Fourht Fork Rock Creek	73	49	67.1
Willow Creek	15	12	80.0
Squaw Creek	41	34	82.9
EF Weiser River	136	113	83.1
Little Lost River	87	80	92.0
MF Boise River	61	49	80.3
SF Boise River	66	44	66.7
Badger Creek	82	71	86.6
Little Weiser River	81	63	77.8
Clear Creek	52	45	86.5
Medicine Lodge Creek	112	92	82.1

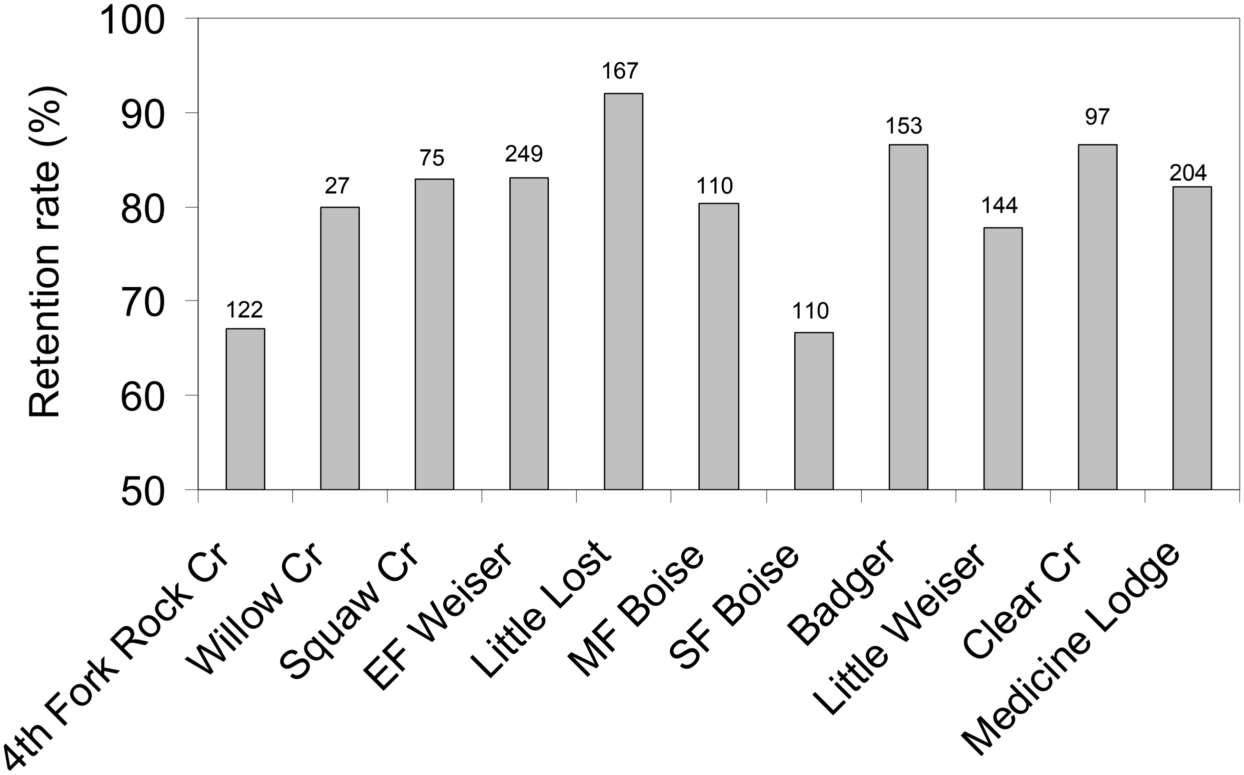

Figure 6. Annual (long-term) PIT tag retention rates for redband trout from 2006 to 2007 by stream.

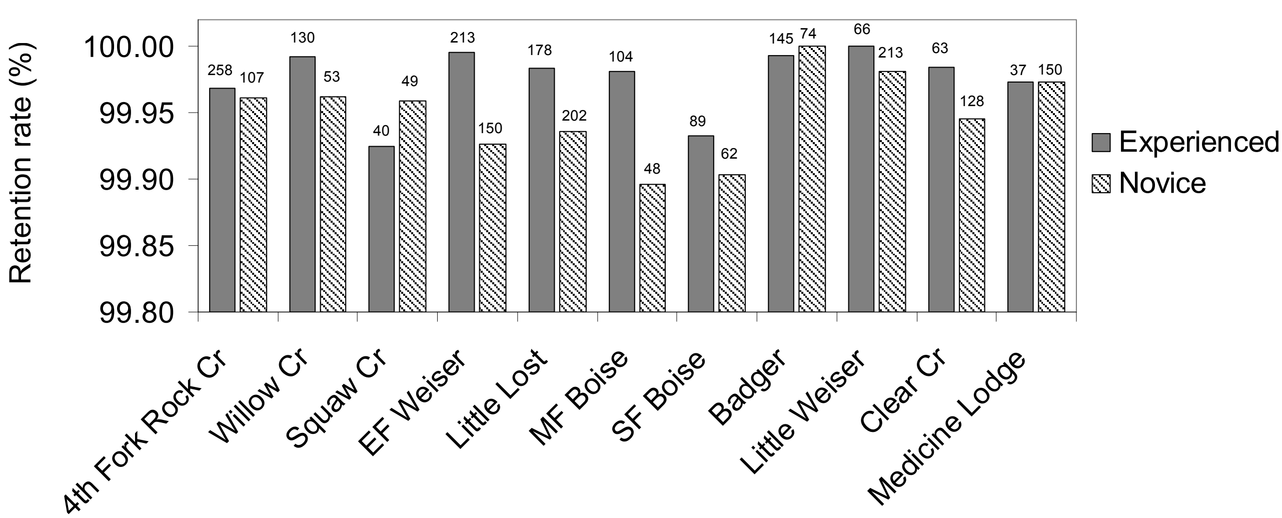

Figure 7. Short-term PIT tag retention rates for redband trout tagged with experienced vs. novice taggers.

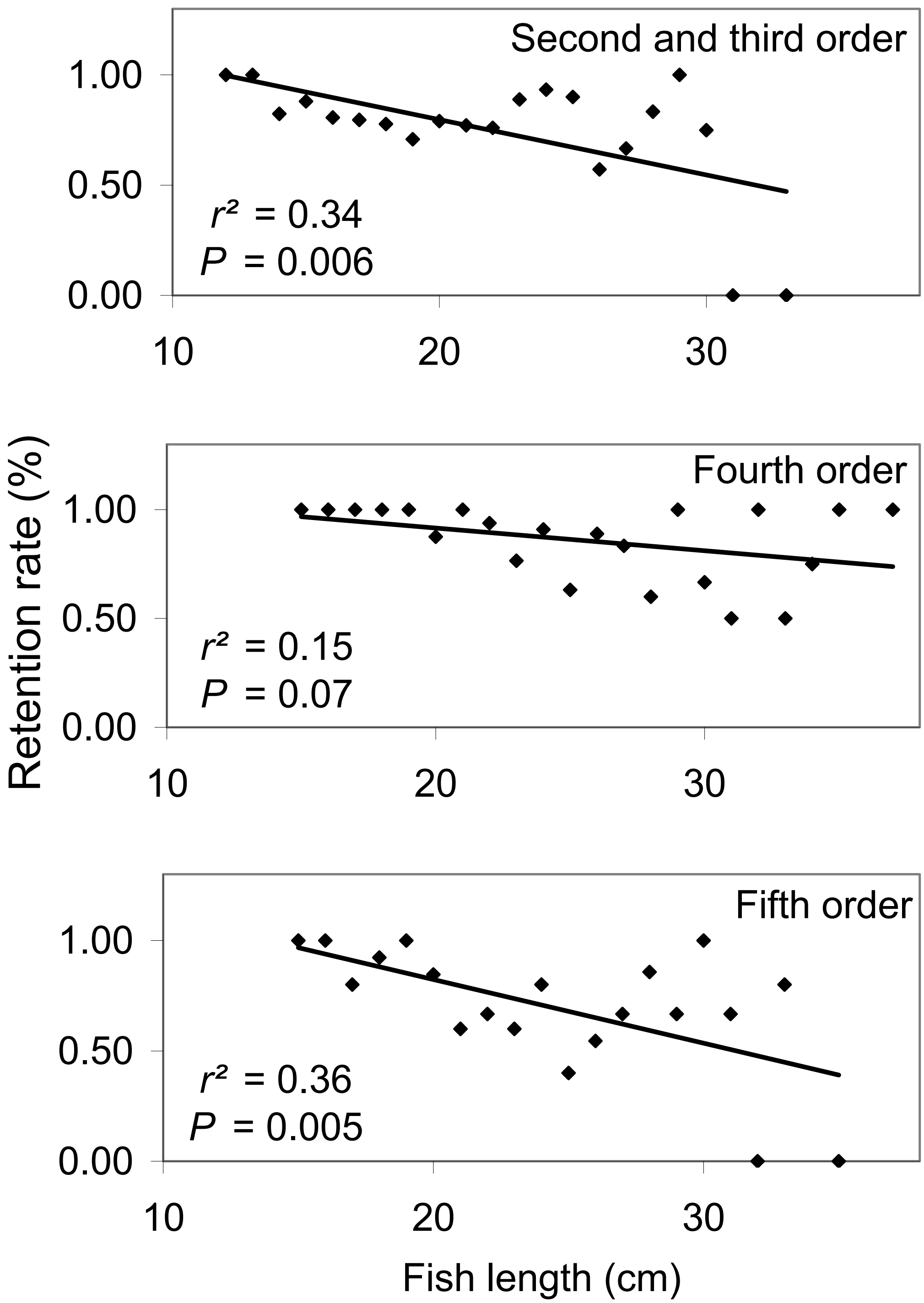

Figure 8. Long-term PIT tag retention rates for redband trout vs. fish length in second- through fifth-order streams.

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