FISHERY RESEARCH

KOOTENAI RIVER FISHERIES INVESTIGATION: STOCK STATUS OF BURBOT

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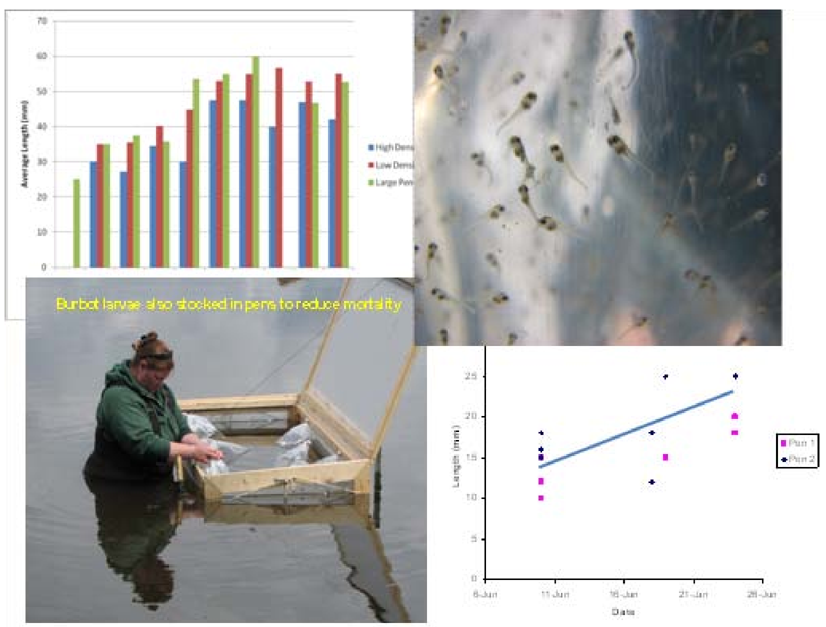

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Project Progress Report

2010 Annual Report

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ABSTRACT

The Kootenai River burbot *Lota lota maculosa* population is near extirpation with the goal of this investigation to rehabilitate it to a fishable stock. Objectives of this investigation were: 1) to maintain the Kootenai River temperature near Bonners Ferry between 1-4°C (December-February) to improve burbot migration and spawning activity, and 2) to rear burbot larvae through extensive rearing to produce a survival rate of ≥10% and fingerlings up to 98 mm in length within four months. Water temperature seldom rose above the upper limit of the System Operation Request for the Kootenai River (4°C) and stayed below for most of the spawning season, suggesting water temperature can be managed better with control structures at Libby Dam. Five adult burbot were captured with hoop nets at Ambush Rock (rkm 244.5). Burbot catch per unit effort in hoop nets was 0.005 fish/net d. Extensive rearing in a private pond met with poor success; 15,000 feeding burbot larvae were stocked in May 2009 and none were found during sampling. The continued presence of yellow perch *Perca flavescens* was a serious competition issue; despite draining the pond in December 2008, some adult yellow perch were either reintroduced or survived to bring off a successful brood. Burbot larvae were reared in pens for the second season and the technique was thought to be successful. Two pens (1,830 L each) were stocked at low density of 0.018 larvae/L and 0.019 larvae/L; two pens were stocked at moderate density of 0.039 larvae/L each; and a fifth, larger net pen (3,660 L) was stocked at a high density of 0.095 larvae/L. Survival rates in pens were: low density averaged 43.5%, moderate density averaged 43.3%, and the (larger) high density pen was 7%. Food availability and stocking density are likely limiting factors to survival. Survival exceeded objective expectations but rearing for four months in confinement is counterproductive due to cannibalism.

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INTRODUCTION

In Idaho, burbot *Lota lota maculosa* are endemic only to the Kootenai River (spelled Kootenay for Canadian waters) (Simpson and Wallace 1982). Burbot in the Kootenai River (Figure 1) once provided an important winter fishery to residents of northern Idaho and nonresidents. This fishery and that of Kootenay Lake, British Columbia, Canada (Paragamian et al. 2000a) may have been the most robust in North America (Paragamian and Hoyle 2005). However, after construction and operation of Libby Dam by the U.S. Army Corps of Engineers (USACE) in 1972, the fishery in Idaho rapidly declined and closed in 1992. Concomitant to the collapse in Idaho was the collapse of the burbot fishery in Kootenay Lake and Kootenay River, British Columbia (Paragamian et al. 2000b). Demographic studies indicate the Kootenai River burbot population might become extirpated by 2015 (Pyper et al. 2004; Paragamian et al. 2008). Operation of Libby Dam for hydroelectric power and flood control created major changes in the river's seasonal discharge and temperature, particularly during the winter when burbot spawn (Figures 2 and 3). Libby Dam operations were implicated as the major factor with changes in warmer winter temperatures and higher flow in winter (Paragamian 2000; Paragamian et al. 2005; Paragamian and Wakkinen 2008).

Because burbot in the Kootenai River are at risk of demographic extinction (Paragamian et al. 2008), a Conservation Strategy was prepared to outline measures necessary to rehabilitate the burbot population (Anonymous 2002; KVRI Burbot Committee 2005; Ireland and Perry 2008). The Conservation Strategy indicated that operational discharge changes at Libby Dam are required during winter to provide suitable temperature and discharge conditions for burbot migration. Studies recommended discharge at Bonners Ferry average 176 m^3/s for a minimum of 90 d (mid-November through mid-February) for burbot migration and spawning (Paragamian 2000; Paragamian et al. 2005; Paragamian and Wakkinen 2008). Results of additional movement studies indicated preferred burbot water temperatures of about 6°C were necessary for migration and cooler temperatures of 1-4°C for spawning (Paragamian and Wakkinen 2008). The Conservation Strategy also identified Conservation Aquaculture as a remedial measure to help strengthen the depressed burbot stock.

With each passing year, burbot stock limitations become an increasing factor to rehabilitation. One way to enhance the Kootenai River burbot population may be through the introduction of progeny of a donor stock. Intensive rearing techniques for burbot are evolving (Jensen et al. 2008a; Jensen et al. 2008b; Vught et al. 2008) while extensive rearing of larvae has been shown effective in burbot restoration (Dillen et al. 2008; Vught et al. 2008). Recent analysis of the cytochrome B region of mtDNA indicated Columbia and Moyie lakes, British Columbia burbot were of a similar phylogenetic group as Kootenai River burbot (Powell et al. 2008) and may be suitable as a donor stock. Moyie Lake is in the Kootenai River basin, and burbot from the lake have been previously provided to the University of Idaho Aquaculture Research Institute (UIARI) for spawning and experimental intensive culture (Jensen et al. 2008a). Coordination of intensive culture, extensive rearing, and pen rearing with the Kootenai Tribe of Idaho (KTOI), BCME, and the UIARI (Dr. Ken Cain) could be an important rehabilitation measure in the near future.

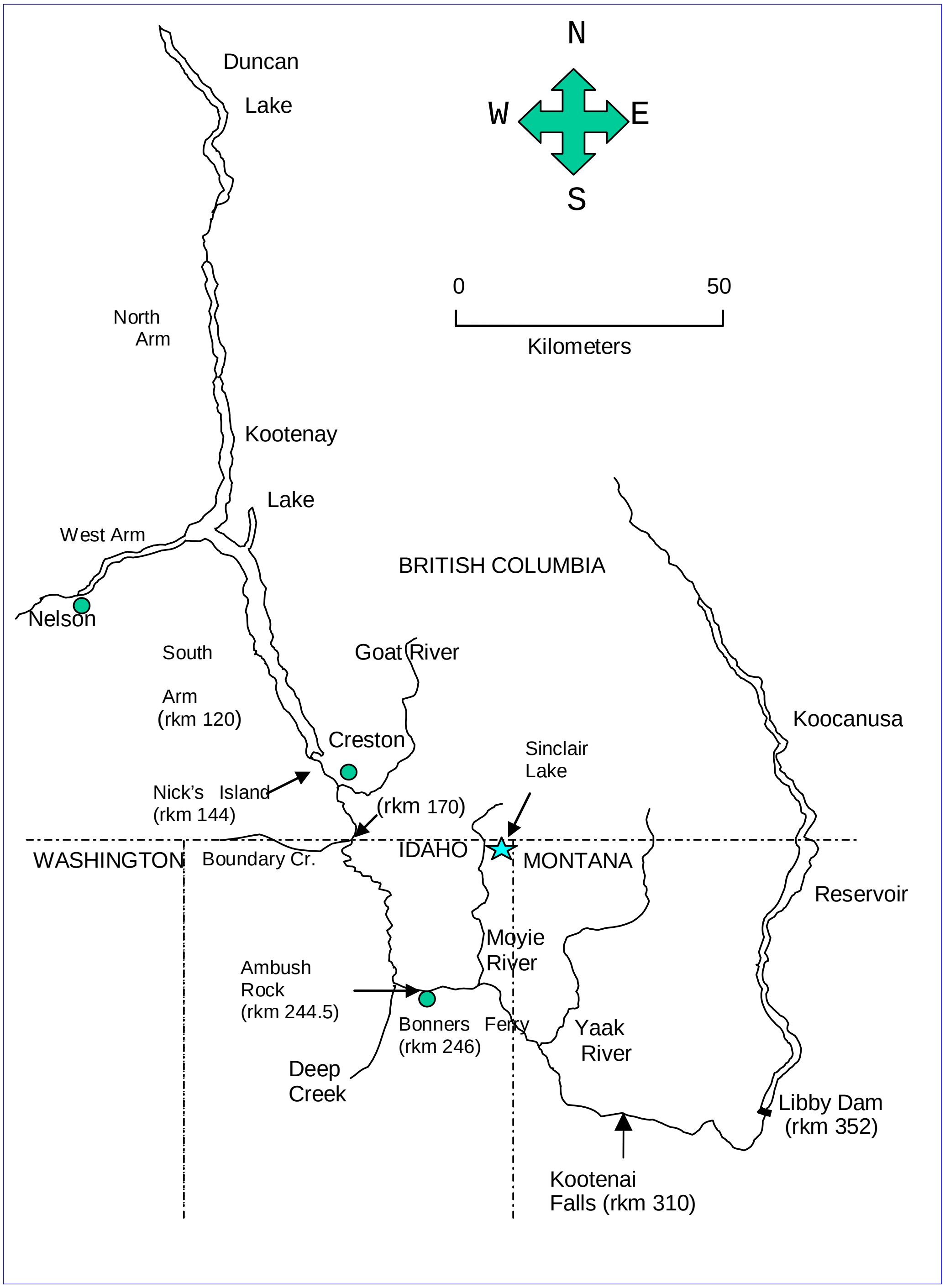

Figure 1. Location of the Kootenai River, Kootenay Lake, Lake Koocanusa, and major tributaries. The river distances from the northernmost reach of Kootenay Lake are in river kilometers (rkm) and indicated at important access points.

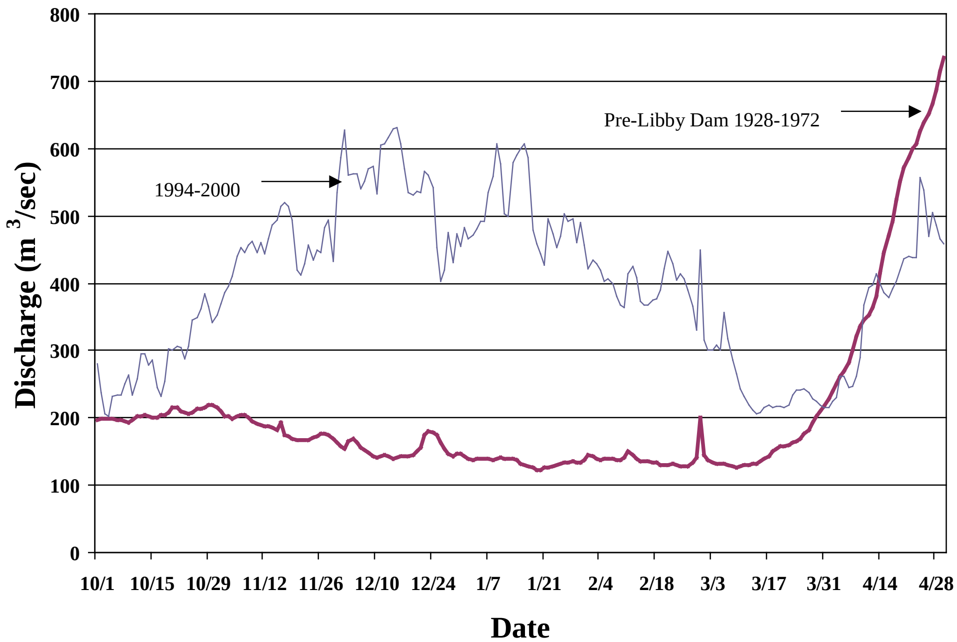

Figure 2. Mean daily discharge of the Kootenai River at Porthill, Idaho from 1962 through 1971 (pre-Libby Dam), and from 1994 through 2000 (post-Libby Dam).

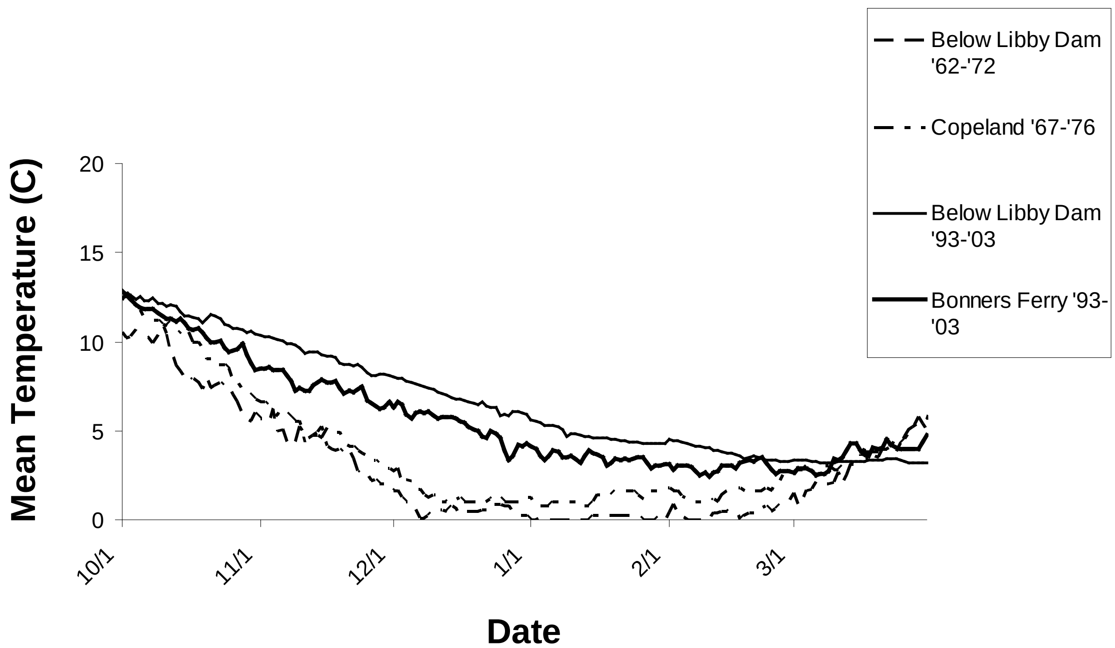

Figure 3. Pre-Libby Dam Kootenai River temperatures at the dam site 1962-1972, at Copeland, Idaho 1967-1972 and post Libby Dam below the dam from 1993-2003, and at Bonners Ferry, Idaho from 1993-2003.

GOAL

The fishery management goal of this study is to restore the burbot population in the Idaho reach of the Kootenai River to provide an annual sustainable sport harvest of burbot.

OBJECTIVES

1. To have Kootenai River temperature near Bonners Ferry between 1-4°C (December-February) to improve burbot migration and spawning activity.

2. Extensively rear feeding burbot larvae to achieve a minimum survival rate of ≥10% and growth to 98 mm in total length within four months.

STUDY AREA

The Kootenai River is one of the largest tributaries to the Columbia River. Originating in Kootenay National Park, British Columbia, the river discharges south into Montana, where Libby Dam impounds water into Canada and forms Lake Koocanusa (Figure 1). From Libby Dam, the river discharges west and then northwest into Idaho, then north into British Columbia and Kootenay Lake. Kootenay Lake drains out the West Arm, and eventually the river joins the

Columbia River near Castlegar, British Columbia. The Kootenai River at Porthill, Idaho, drains about 35,490 km^2. The reach in Idaho is 106 km long.

Fredericks Pond was used in 2009 for the second season of experiments of releasing feeding larval burbot for extensive rearing (Figure 4). The pond is on private property approximately 8 km (5 miles) from the Kootenai Wildlife Refuge. It is in the Kootenai River drainage in Boundary County, Idaho and located off the West Side Road. The pond is rectangular and 79 x 37 m and is about 2.4 m deep (see Chapter 2). Fredericks Pond is about 46 m from Burton Creek and has easy access. The pond is isolated in that the water source is seepage from under a county road and a dyke that separates it from Burton Creek, surface runoff, and the outlet drains into a pasture. The pond is fenced from livestock. It is reported to be ice covered most winters. An extensive limnological survey was conducted in 2009 (Wilhelm 2010).

Figure 4. Robert Fredericks Pond located 7 km from the Kootenai River Field Station; Burton Creek is just beyond the dyke.

METHODS

Kootenai River Discharge and Temperature

The USACE and the U.S. Geological Survey (USGS) office in Sandpoint, Idaho provided the daily discharge and temperature values for the Kootenai River. The U.S. Fish and Wildlife Service made a systems operation request (SOR) for winter of 2008-2009 on behalf of the Kootenai Valley Resource Initiative's (KVRI) Burbot Recovery Committee (which included the IDFG, Office of Species Conservation, KTOI, City of Bonners Ferry, and Boundary County) to the USACE and the Bonneville Power Administration (BPA). Like the previous year, the 2009-2010 SOR focused on cooler water temperature. Expecting a measurable biological response to a temperature SOR was not reasonable because the burbot population is stock limited. As a result, the intent was an experiment to provide the coolest water possible in November (6°C and cooler December–February) using the selective withdrawal system in place at Libby Dam with a target range from 1-4°C (Figure 5). November through February are important to burbot migration (Paragamian and Wakkinen 2008). However, once Lake Koocanusa becomes isothermal, usually late December or early January, it is not possible to provide water cooler than the reservoir.

Tributary Temperatures

HOBO® or StowAway® XI temperature loggers were used to monitor daily water temperatures for Deep and Boundary creeks in Idaho; the Goat River in British Columbia; the Kootenai River at Porthill, Idaho and Nicks Island, British Columbia from October 2009 through March 2010. At each location, mean daily temperature was calculated from six evenly spaced four-hour daily measurements. In Boundary Creek, the thermograph was placed approximately 500 meters upstream from the confluence. Data from this logger were used to assess whether infiltration of Kootenai River surface water into the creek mouth was substantial. Infiltration of river water may obscure coldwater cues used by migrating burbot (Paragamian 2000). Although no burbot spawning has been documented in tributaries recently, anecdotal data indicate that Summit and Boundary creeks were historical burbot spawning areas.

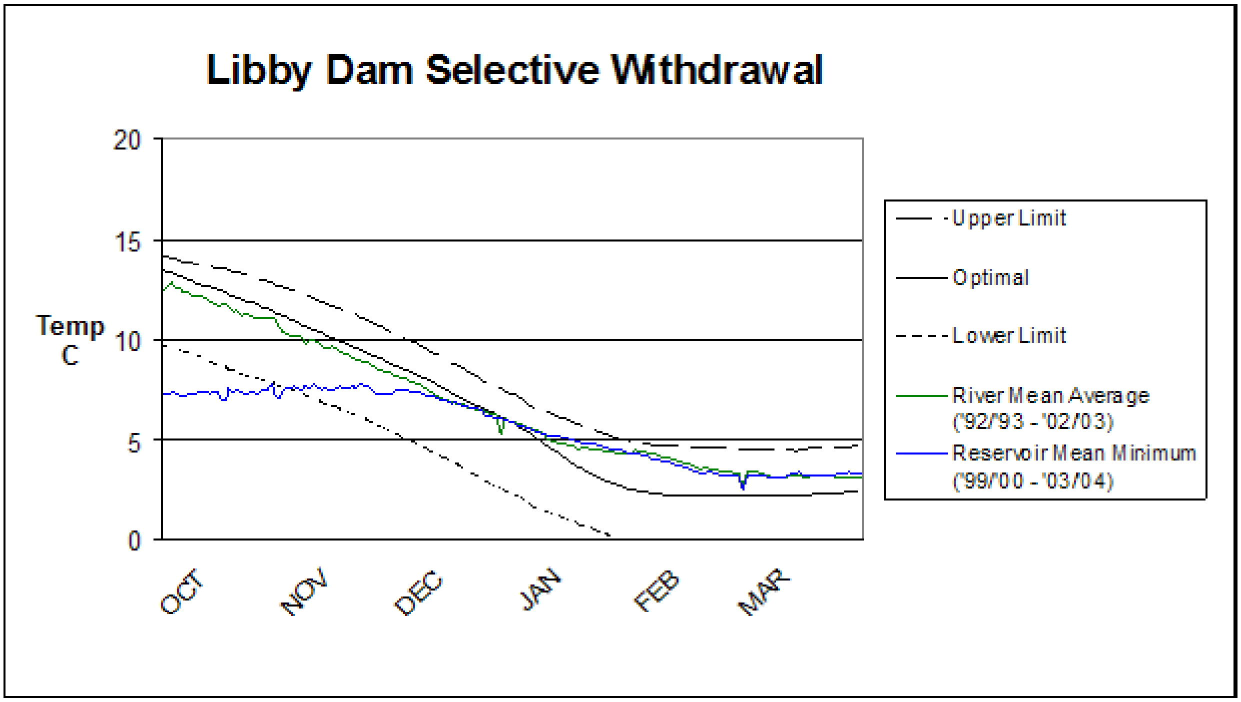

Figure 5. Selective withdrawal temperature guidelines for the Kootenai River below Libby Dam. Figure courtesy USACE.

Burbot Sampling

Adult Burbot

Technicians sampled adult burbot from November 2009 through March 2010 with up to 11 baited hoop nets. Hoop nets had a maximum diameter of 0.61 m (see Paragamian 1995 for a description of the nets and the method of deployment). Bernard et al. (1991) found that burbot larger than 350 mm TL can be caught in 0.6 m diameter hoop nets with 25.4 mm bar web with full recruitment at 450 mm TL. In an effort to predict burbot year class strength at smaller fish sizes and evaluate recovery measures earlier, we had two hoop nets of 19 mm bar web constructed to compare the catch of the standard web of 25.4 mm. We used nine nets with 25.4 cm bar mesh, pairing two of them with nets having 19 cm bar mesh for a total of 11 nets. The objective was to determine if the smaller mesh would capture smaller, younger burbot (Gunderman and Paragamian 2003).

We sampled at established index locations to measure changes in population numbers, size structure (PSD), body condition (W_r), and abundance (CPUE) (see Paragamian and Laude 2008 for a description of index locations). We deployed nets in deep (usually the thalweg) areas of the Kootenai River between Ambush Rock (rkm 244.5) near Bonners Ferry, Idaho; Porthill, Idaho (rkm 170); and Nicks Island (rkm 144) near Creston, BC (Figure 1). We sampled river reaches where burbot were more likely to be captured, e.g. Nicks Island, and the international boundary (rkm 170), Goat River, and Ambush Rock because burbot numbers are low and it was important to maximize our opportunity to capture them. We also sampled two tributary streams including Boundary Creek, which enters the Kootenai River at Porthill, Idaho (rkm 170), and the Goat River, near Creston, BC (rkm 152).

We usually lifted nets on Monday, Wednesday, and Friday of each week. Fish captured in hoop nets were identified, enumerated, measured for total length (TL), and weighed (g). We implanted all burbot with a passive integrated transponder (PIT) tag in the left opercular muscle. Biopsies were not performed in an effort to reduce stress; therefore, sex of burbot could not be determined.

Extensive Burbot Rearing

Larval Release into Pond

Adult brood fish, for artificial hatchery propagation for extensive rearing, were captured in November 2006 and February 2008 and 2009 from Moyie Lake, BC, Canada using baited cod traps (Spence 2000; Neufeld and Spence 2005) and angling. Moyie Lake is in the Kootenai River drainage and located about 20 km north of Sinclair Lake, Idaho. Adults and fertilized eggs (fertilized on location) were soon transported to the University of Idaho Aquaculture Research Institute Moscow, Idaho (UIARI). Burbot larvae were later provided for extensive rearing by the UIARI and were part of an intensive research program sponsored jointly by the KTOI and UIARI.

An extensive rearing study was designed to assess the value of two applications of this technique to rear hatchery propagated burbot. Extensive rearing is the process of raising fish in an outside environment where there is less environmental control as opposed to intensive culture in a building. One application was to release feeding burbot directly into the pond while the second was to release them at different densities in pens.

We built and deployed five fully enclosed pens constructed of 500 um Nitex for Fredericks Pond; four were 1.83 m X 0.91 m X 0.91 m with a volume of 1.53 m^3 (1,530 L), and the fifth was 1.83 m X 1.83 m X 0.91 m with a volume of 3.66 m^3 (3,660 L). Pens were constructed to determine the survival and growth of burbot larva totally confined and protected from predation, with the exception of cannibalism.

A screen was installed at the pond outlet to prevent the escape of burbot. On May 15, 2009, approximately 15,000 feeding burbot larvae were released into Fredericks Pond. Of the total, 467 larvae were placed among the five net pens within the pond. Light traps were set in the pens beginning June 23. We used light traps (Fisher 2000) in the pond and the pens to monitor burbot growth. Light traps were made from four plastic cylinders joined laterally, described as a quatrefoil, measuring approximately 25 cm high by 30 cm wide. Traps were suspended near the water surface and powered by a 12 h photochemical stick.

Fingerling and Juvenile Burbot Releases

A total of 30 age 2- and 3-year-old hatchery reared burbot from the UIARI were sonic tagged at the UIARI lab and then released into the lower reach of the Goat River on October 21, 2009 by the British Columbia Ministry of Environment. An array of previously deployed VEMCO VR2 receivers monitored their movements in the Goat and Kootenai rivers (Neufeld and Rust 2009). There were an additional 217 fingerling burbot released between four sites in the Goat and Kootenai rivers and Snow and Deep creeks during October and through November 2009.

RESULTS

Kootenai River Discharge

The USACE resumed load following during the winter of 2009-2010 with an estimated January volume forecast of 90% followed by February at 86% and 80% in March forecasts. As a result, discharge in the Kootenai River at Bonners Ferry ranged from a low of 129 m^3/s on January 08, 2010 to a high of 673 m^3/s on December 10, 2009. Discharge was stable from January 1, 2010 through March 15, 2010 ranging from 129 to 163 m^3/s (Figure 6).

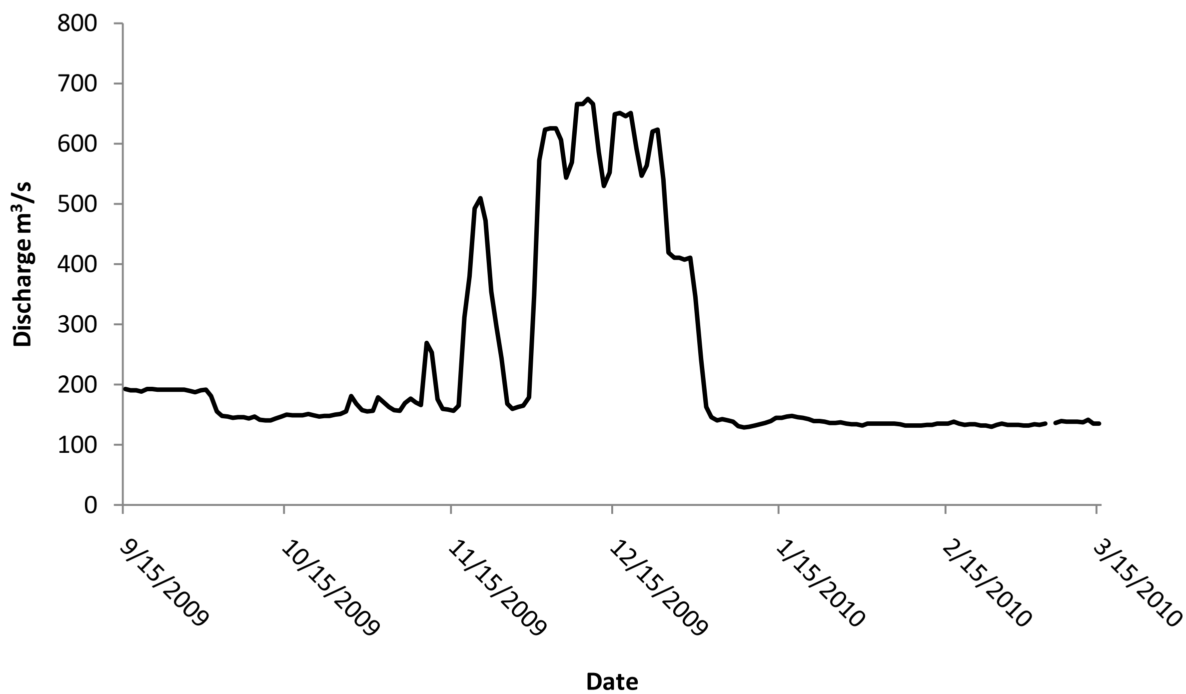

Figure 6. Daily mean discharge (m^3/s) near Bonners Ferry, USGS gauging station 12310100.

Kootenai River Temperature

Mean water temperature at the USGS gage 12309500 near Bonners Ferry, Idaho (rkm 245.7) was 4.47°C ranging from 0.4°C to 6.7°C. Mean water temperature at Porthill, Idaho (rkm 169.8) was 4.38°C ranging from 1°C to 7.28°C. Mean temperature at Nicks Island (rkm 144.5) was 4.41°C ranging from 1.33°C to 6.98°C (Figure 7).

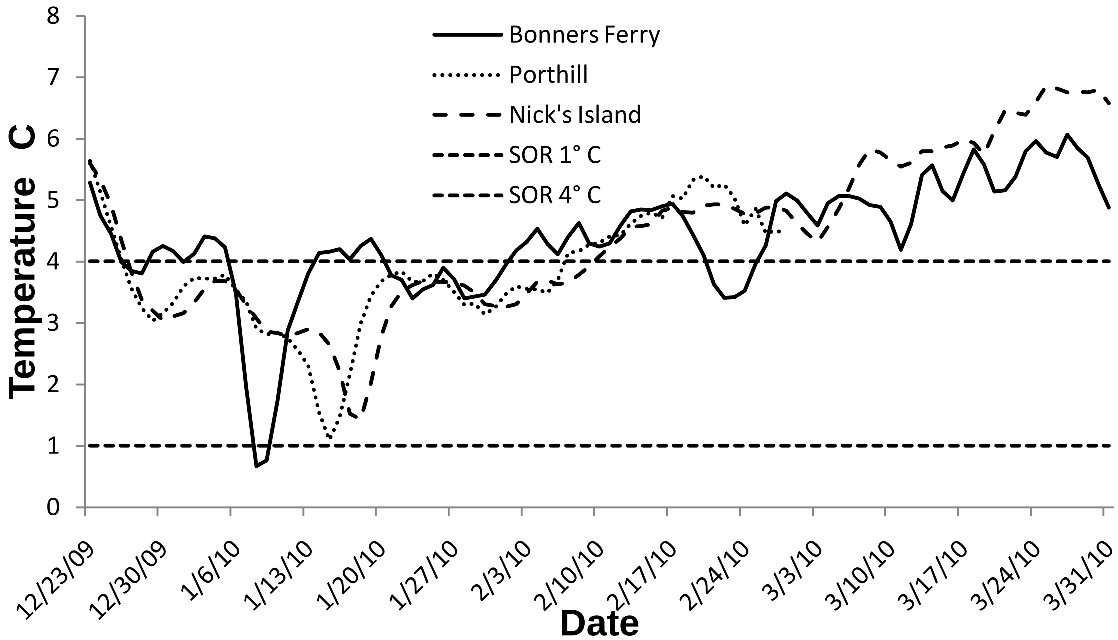

Figure 7. Mean daily temperature (°C) for the Kootenai River at Bonners Ferry (rkm 245.7) and Porthill, Idaho (rkm 170), and Nicks Island, BC (rkm 144.5) profile December 23, 2009 to March 31, 2010. Horizontal bars represent the target temperature values for the SOR.

Tributary Temperatures

Thermographs were deployed in Deep and Boundary creeks in Idaho and in the Goat River, BC, Canada from December 2009 to March 2010.

Idaho

Mean water temperature of Deep Creek was 1.6°C ranging from 0.2°C to 4.8°C (Appendix 1 and 2). Mean water temperature of Boundary Creek was 1°C ranging from 0°C to 2.5°C (Appendix 1).

Canada

Mean water temperature of the Goat River was 3.3°C ranging from 0.9°C to 7.9°C (Appendix 3).

Sampling Adult Burbot

Total Catch

Baited hoop nets were fished from December 15, 2009 through March 11, 2010 for a total of 24,615 h or 1026 net d. Forty-two fish were caught encompassing seven species of fish, plus crayfish *Pacifastacus spp.* (Table 1). Northern pikeminnow *Ptychocheilus oregonensis* was the most abundant species caught totaling 18 fish in the hoop net bycatch (Figure 8 and Table 1). Catch per unit effort was 0.041 fish/net d for all species of fish.

Hoop Net Catch of Burbot

Throughout the 2009-2010 winter, five burbot were captured in baited hoop nets (Tables 1 and 2, Figure 8, and Appendix 4). All five burbot were captured at Ambush Rock (RKM 244.5) of which one was a recapture with a PIT tag. Hoop net catch per unit effort for burbot was 0.005 fish/net d or 205 net d/fish with effort in Idaho and BC (Tables 1 and 3 and Appendix 3).

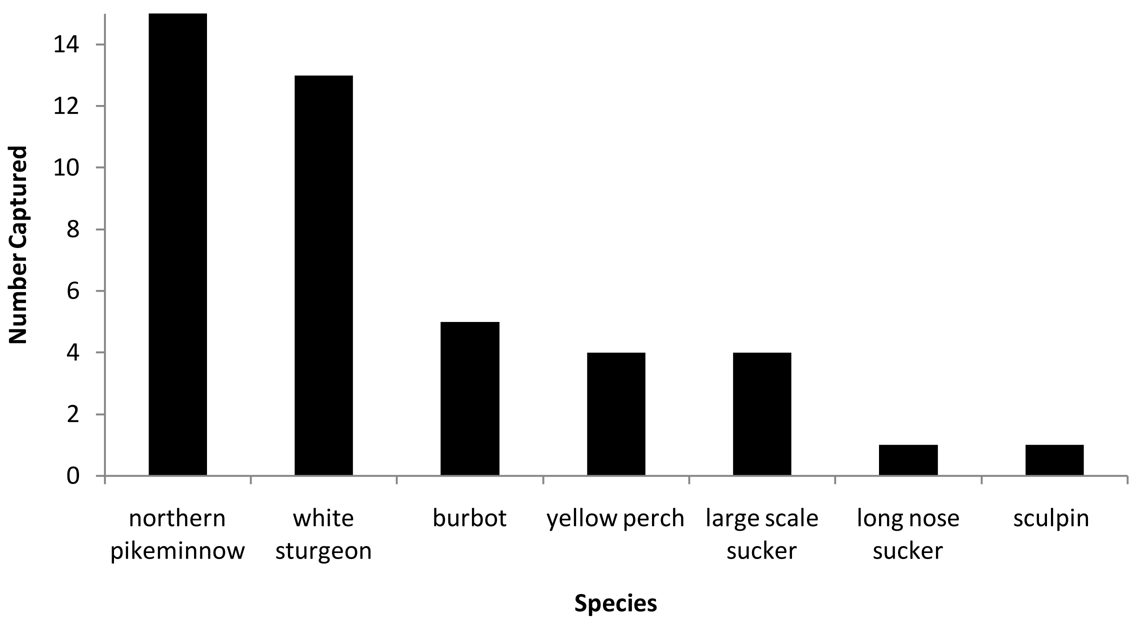

Figure 8. Hoop net catch for the Kootenai River, Idaho and BC from December 2009 through March 2010.

Table 1. Hoop net catch by number, weight (g), and catch per unit effort (CPUE) for the Kootenai River and its tributaries in Idaho and BC, December 2009 through March 2010 with 1026 d of effort (24,628 h of effort).

Species	Number	Total Weight (g)	CPUE[a]
Northern Pikeminnow *Ptychocheilus oregonensis*	18	7673	0.0175
Burbot *Lota lota*	5	8633	0.0049
White Sturgeon *Acipenser transmontanus*	13	987	0.0127
Yellow Perch *Perca flavescens*	4	265	0.0039
Large Scale Sucker *Catostomus macrocheilus*	4	1669	0.0039
Longnose Sucker *Catostomus catostomus*	1	112	0.0010
Sculpin sp.	1	—	0.0010
Total	42		0.041

[a] A unit of effort is a single hoop net set for 24 h.

Table 2. Burbot identification number, location of capture, date of capture, total length, weight, and tag number for captures from November 2005 through March 2010.

Fish ID number	Location of Capture (rkm)	Date of Capture	Total length (mm)	Weight (g)	Tag Type	Tag Code
333	144.5	11/1/05	383	322	na	na
279	144.5	11/14/05	732	2793	na	na
329	244.5	11/18/05	645	1596	na	na
334	144.5	11/28/05	714	2294	Vemco	282
335	144.5	12/9/05	539	965	Vemco	285
327	144.5	12/16/05	561	1126	Vemco	106
336	144.5	1/3/06	368	366	na	na
337	144.5	1/9/06	515	781	na	na
338	244.5	1/12/06	714	2662	Vemco	283
339	152.7	2/6/06	624	1673	Vemco	082
340	152.7	2/6/06	588	1235	Vemco	284
341	244.5	2/23/06	713	1860	Vemco	111
342	150	2/26/07	766	2199	na	na
214	244.5	1/10/08	720	2330	na	na
344	244.5	1/30/08	505	1061	na	na
345	244.5	1/30/08	620	1662	na	na
346	144.5	2/20/09	562	1351	na	na
347	152.7	2/20/09	521	707	na	na
348	152.7	2/20/09	712	2706	na	na
348	152.7	3/4/09	714	2115	na	Na
350	244.5	12/15/09	615	1772	na	na
353	244.5	12/15/09	734	2388	na	na
344	244.5	2/4/10	604	1399	na	na
351	244.5	2/4/10	615	1391	na	na
352	244.5	2/4/10	709	1683	na	na

Table 3. Burbot hoop net captures and capture effort in three primary locations, October 2003-March 2010.

Sample year	River kilometer	Number of burbot captured	Total net days	CPUE (fish/net day)
	120-152.9	0	377.8	0
2003-2004	153-169.9	0	47	0
	170 +	19	1,540.3	0.12
	120-152.9	2	806.9	0.002
	153-169.9	0	0	0
2004-2005	170 +	16	587.2	0.03
	120-152.9	11	896.6	0.01
	153-169.9	0	0	0
2005-2006	170 +	3	501.3	0.006
2006-2007	120-152.9	2	1,223.0	0.00007
	153-169.9	0	174.9	0
	170 +	0	99.5	0
	120-152.9	0	725.9	0
	153-169.9	0	0	0
2007-2008	170 +	3	314.9	0.003
	120-152.9	4	521.0	0.004
	153-169.9	0	0	0
2008-2009	170 +	0	175	0
	120-152.9	0	405	0
	153-169.9	0	0	0
2009-2010	170 +	5	397	0.013

Extensive Rearing

On May 15, 2009, approximately 15,000 feeding burbot larvae were released into Fredericks Pond. An additional 467 larvae were released between the five net pens within the pond. Two pens (1,530 L) were stocked at low density of 0.018 larvae/L and 0.019 larvae/L, two pens were stocked at moderate density of 0.039 larvae/L each, and a fifth, larger net pen (3,660 L) was stocked at 0.095 larvae/L (Table 4).

Light traps were set in the pens beginning June 23. We captured a total (many were possible recaptures) of 223 larvae; all were measured to estimate weekly growth (Figure 9). Total net pen light trap effort was 79 days (1,896 h) CPUE 2.8 (CPUE [h] 0.12). On September 2, 2009, we recovered 96 of the 467 age 0 burbot with an average total length of 49 mm with an estimated net pen survival of 21%. No burbot were recovered from the pond. Growth rates per pen were 0.46 mm/day for low density, 0.34 mm/day for high density, and the large pen was 0.44 m/day. Survival rates averaged 43.3% for high density pens, 43.5% for low density pens, and the large pen was 7% (Table 4 and Figure 10). Most burbot appeared healthy, with guts full of zooplankton in the low and medium density pens, but fish from the high density pen were emaciated with very little food showing in their gut. All burbot were measured and then transported to the KTOI hatchery for holding prior to tagging with VIE tags (Bonneau et al. 1995) for eventual release in the Kootenai River or a tributary in mid-October. Burbot young of the same age were also collected at Cow Creek Pond by KTOI and our staff.

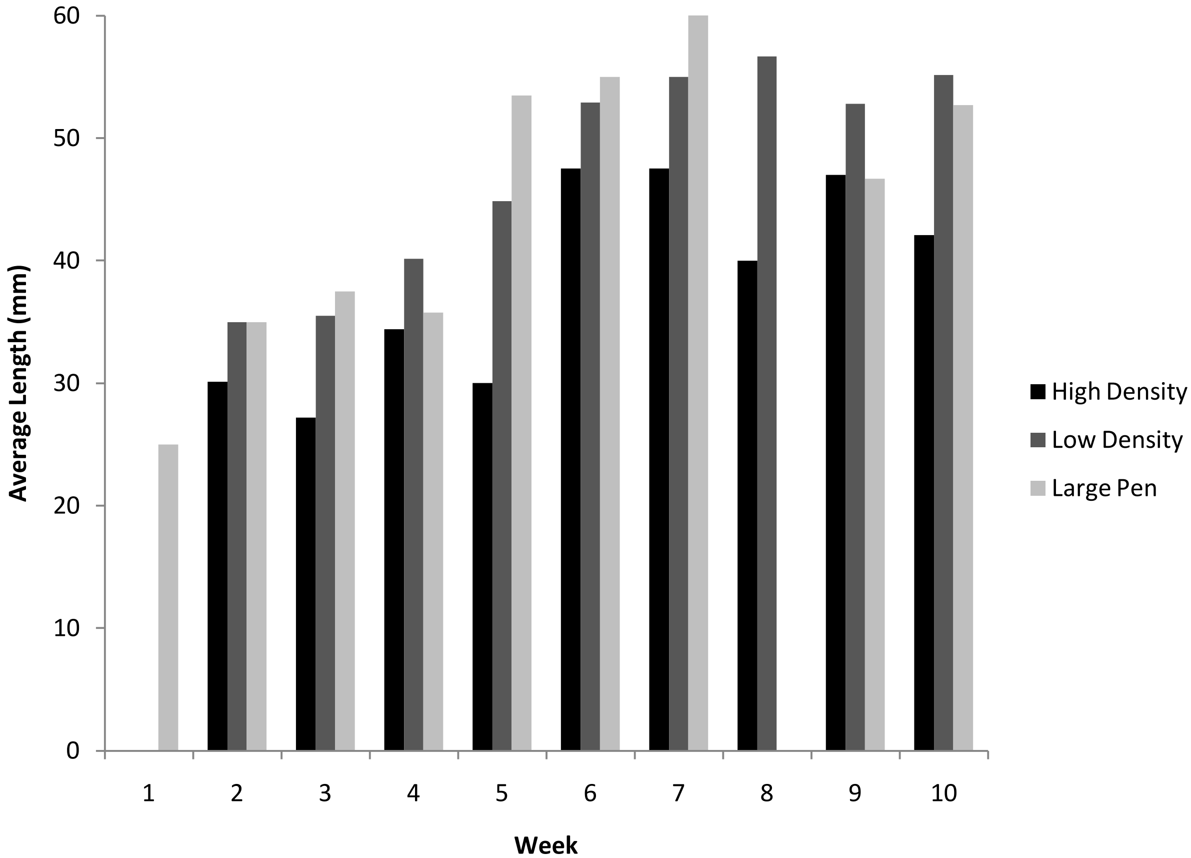

Figure 9. Average weekly growth of net pen burbot reared in Fredericks Pond, adjacent to Kootenai River, Idaho, 2009.

Table 4. Pen number, volume, stocking numbers, density, and survival in Fredericks Pond 2009.

Pen	Volume (m^3)	Starting N fish	Original stocking density (larvae/L)	Ending fish N	Ending Density (fish/L)	Survival (%)
1	1,530	27	0.018	10	0.007	37.04
2	1,530	30	0.019	15	0.009	50.00
3	1,530	60	0.039	36	0.024	60.00
4	1,530	60	0.039	16	0.010	26.67
5	3,060	290	0.095	19	0.006	6.55
	Total	467		96		

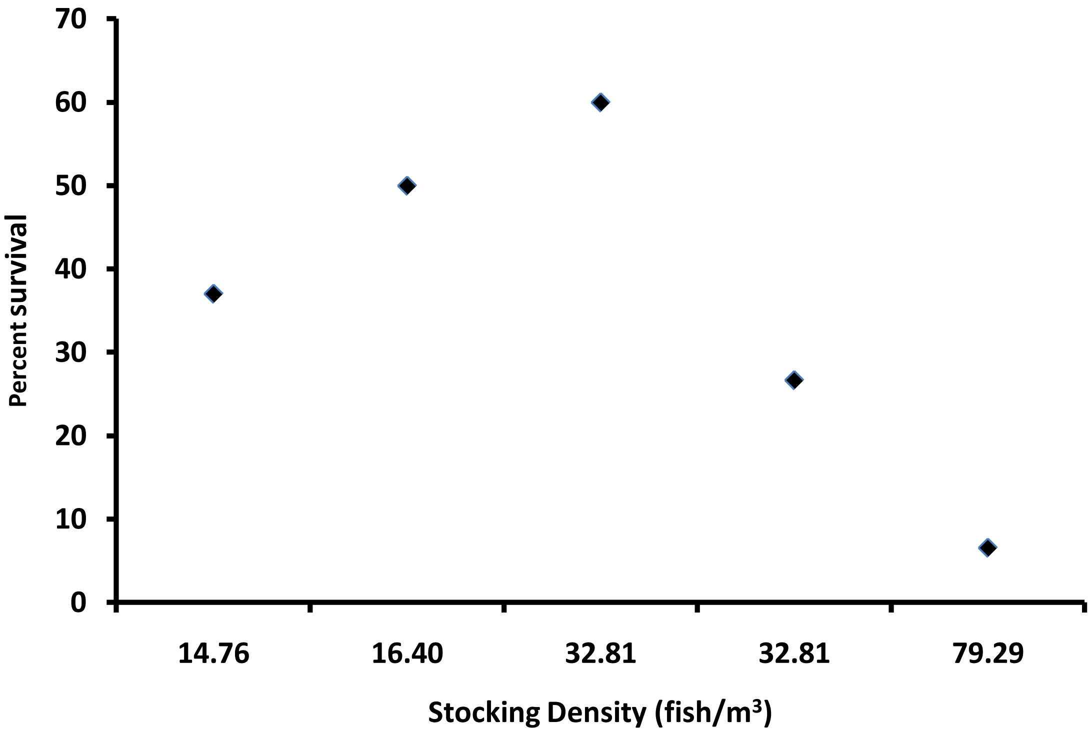

Figure 10. Percent survival of burbot larvae stocked at different densities in net pens, based on original stocking density in May 2009.

Fingerling Releases into Kootenai River and Tributaries

A total of 175 fingerling and subadult burbot were released into the Kootenai drainage of Idaho and BC in fall of 2009 (Table 5). On October 7, 2009, 20 burbot (reared in pens) were removed from KTOI hatchery tanks for release in Snow Creek. While burbot were being removed from the tank, four dead burbot were found that appeared to have been attacked by a conspecific; one appeared to be partially digested. Most of the burbot looked thin, while one was about 1.5 times longer than the remainder (potentially cannibalistic). Burbot were allowed to acclimate in the cooler water of Snow Creek for about an hour by gradually adding cooler water to their bucket. Water temperatures at the hatchery circular tanks were around 9°C while temperatures at Snow Creek were 3°C. We released burbot throughout three pools in Snow Creek spacing them out in each of the pools. Burbot immediately sought cover. The pink VIE tag was visible in all fish we released.

Table 5. Burbot fingerling and subadult release locations and tag types.

Number released	Release Location	Tag Type	Tag location
30	Goat River	Vemco ~ sonic	Abdomen
1[a]	Kootenai River Ambush Rock	PIT	Left Opercula
21	Kootenai River Ambush Rock	VIE ~ pink	Ventral to the pectoral fin
20	Snow Creek	VIE ~ pink	Ventral to the left pectoral fin
175	Deep Creek	VIE ~ green	Ventral to the pectoral fin
Total 247			

[a] This burbot was the single survivor from the 2008 Fredericks Pond winter draining. It was further reared at the KTOI hatchery and was named as Salvatore (Buckskin Sal).

On November 2009, 227 burbot from the UIARI were tagged and released into tributaries and the Kootenai River (Table 5). Of this total, 30 were age-2 and -3 subadults and were implanted with VEMCO sonic tags (Neufeld et al. 2011).

Telemetry Monitoring of Juveniles

Fixed location receivers in the Goat River were downloaded one week following the release of 30 juvenile burbot, from UIARI, to determine movements. Twenty-eight burbot were detected at the receiver sites (Neufeld et al. 2011). Of the 28 tags detected, 100% were detected on both receivers (one is within 275 m of the Kootenay River). Most transmitters were detected downstream (probable movement out of the river) on October 22 and 23, with several being detected as late as October 25.

DISCUSSION

Index Sampling Sites and Population Status

We used index sampling sites for the seventh season during the winter of 2009-2010 in an effort to maximize our catch and evaluate stock status, which continues to be extremely depressed. We captured five burbot the winter of 2009-2010 for a CPUE of 0.013 fish/net d, four burbot the winter of 2008-2009, and three in 2007-2008, which yielded a CPUE of 0.004 fish/net d and 0.003 fish/net d, respectively. This was less than the capture of 14 burbot and CPUE of 0.007 fish/net d the winter of 2005-2006, similar to the previous winter's (2004-2005) capture of 18 fish and CPUE of 0.009 fish/net d.

An additional indicator of the depressed status of burbot in the Kootenai River is that no burbot were caught in the Goat River, BC. This tributary was one of the last two known spawning locations for burbot and provided a major portion of the total winter catch in the early 1990s. Three burbot were captured in the Goat River the winter of 2008-2009; one burbot each was captured during the winters of 2006-2007, 2000-2001, and 2001-2002 (Kozfkay and Paragamian 2002; Gunderman and Paragamian 2003). No burbot were captured in the winter of 2007-2008 (Paragamian and Laude 2008).

A Burbot Conservation Strategy was prepared by the Burbot Subcommittee of the Kootenai Valley Resource Initiative (KVRI Burbot Committee 2005; Ireland and Perry 2008), but a rehabilitation goal (population number) was not included. However, Paragamian and Hansen (2009) used demographic statistics (Paragamian et al. 2008) in a stochastic density-dependent population model to estimate recruitment rates in order to rehabilitate burbot. The model was developed with an adult stock of 46 burbot (equivalent to the estimate in 2006) and an annual survival of 38%. They reported an interim abundance target of 5,500 individuals age 4 and older (longer than 250 mm) (45 fish/km; 3.0 fish/ha) within 25 years when each adult produced 0.85 recruits per year and an ultimate abundance target of 17,500 individuals age 4 and older (longer than 250 mm) (143 fish/km; 9.6 fish/ha) when each adult produced 1.1 recruit per year. However, recent demographic analysis indicated there may only be two adults remaining by the end of 2009. Thus, any expectations that this population can recover within the next decade are unreasonable even with the most suitable habitat, lower winter discharge, colder winter temperatures, and improved primary production. Further, Paragamian and Hansen (in progress) developed an age-structured simulation model to estimate the number of age-0 burbot (fall fingerlings) to stock annually to rebuild the population in the Kootenai River in 25 years. They found with the estimated annual survival of about 0.38 that 110,000–900,000 age-0 burbot will have to be stocked annually to rebuild the burbot population, depending on the rehabilitation goal, either 5,500 burbot age 4 and older as an interim goal or 17,000 burbot age 4 and older as an ultimate goal. If annual survival is higher at 61% then the stocking numbers could range from 12,000 to 35,000 age-0 fingerlings annually. Thus, it is important that remedial measures to improve this stock's abundance begin immediately. This would also require habitat changes be in place when the initially stocked burbot reach maturity, in four years, and assumes cultured and remaining wild fish would respond to improved conditions and provide recruits to the population to affirm rehabilitation within 25 years.

Extensive Burbot Rearing and Fredericks Pond

Extensive rearing of feeding larval burbot in pens provided a general foundation to examine if survival of feeding burbot larvae is higher in pen conditions than in extensive or intensive culture. For example, the survival rate in pens at low densities of 0.02 to 0.04 burbot larvae/L, without supplemental feeding, averaged about 50% over about a three month period in 2008 and 2009. Survival at higher densities of 0.1 burbot larvae/L in a pen in 2009 was about 6%, similar to findings using a variety of intensive culture techniques (Vught et al. 2008; Jensen et al. 2008b). Under experimental intensive culture conditions, and feeding *Brachionus calyciflorus* and *Artemia*, Vught et al. (2008) had a 4% survival with 50 larvae/L (Harzevili et al. 2003). Jensen et al. (2008b) experimented with incubation jars and feeding of various zooplankton and commercial food diets and had a survival range of 0 to 9.2% in year one and 0.4 to 9.2% survival in year two with stocking densities of 25 and 250 larvae/L, respectively. In an additional extensive rearing study, survival of burbot stocked directly into Fredericks Pond was found to be about 0.01% for about a three-month post release (Paragamian and Laude 2010) but the pond was also found to be occupied by yellow perch. No burbot were found from the 2009 stocking of Fredericks Pond.

Growth of burbot larvae reared in pens at lower densities, feeding at an ambient zooplankton density, grew better than larvae fed under intensive conditions in controlled experiments (Vught et al. 2008; Harzevili et al. 2003; Harzevili et al. 2004; Jensen et al. 2008b). However, an unbiased assessment of differences in growth between this study and others was not possible because of differences in experimental design and objectives. As a point of reference, after about 70 d of growth burbot larvae in pens grew from about 9 mm TL at release to an average length of 48 mm TL (range 31 to 55 mm TL) in August 2008 and averaged 49 mm TL (range 39 to 58 mm) by the first of September 2009. In an experiment using different diets, Harzevili et al. (2003) found differences in burbot larvae growth increasing from about 5 mm TL to 9 mm TL in 35 d. Harzevili et al. (2004) used different light and temperature conditions and found that the best growth of burbot larvae after 20 d was with 16°C water, with burbot growing from about 4 mm TL to 8 mm TL, little difference was due to light but they found higher survival at 12°C. Jensen et al. (2008b) found in a treatment of feeding live prey only, in the first year of study, that larvae averaged 13.7 mm TL after 52 d post hatch. Jensen et al. (2008b) found in the second year of study burbot larvae fed brine shrimp *Artemia* only grew better than larvae fed brine shrimp and a commercial diet, 26 and 15.6 mm TL 31 d post hatch, respectively.

Availability of food was likely the most limiting factor to burbot growth and survival in pens. In 2008 and 2009, burbot larvae were not fed in the net pens. Zooplankton density in 2009 was visibly lower in pens after the fifth week for the two higher densities; growth in 2009 did not slow for the low density trial until the eighth week, and did not slow at all for the low density trial in 2008. It is even likely cannibalism took place in 2009 and was in part responsible for the lower survival. After harvest of burbot from pens in 2009, they were transferred to circular tanks at the KTOI Hatchery. These fish were checked daily and although fed zooplankton their numbers gradually diminished. While being removed from the tank for release in tributaries, four dead burbot were found that appeared to have been injured by conspecifics, one appeared partially digested. Most of the burbot looked thin, while one was about 1.5 times longer than the remainder (potentially cannibalistic). Cannibalism in intensive culture at the UIARI was not uncommon (N. Jensen, UIARI, personal communication). Burbot culture studies have shown larvae have a high level of dependence on live food (Harzevili et al. 2003), and use of commercial diets early in life usually have low success (Jensen et al. 2008b).

The temperature profile of Fredericks Pond approached 20°C during the summer of 2008. Temperatures of 20°C and more are approaching the upper limit for juvenile burbot rearing survival (Jensen et al. 2008a). Taylor and McPhail (2000) found temperatures approaching 20°C limited survival and believed fluctuations in temperatures during early life of burbot might have a large effect on recruitment. Thus in summers with exceptionally high air temperatures burbot rearing may be limited to a shorter period.

Pens worked well for providing high early survival of burbot but after about six weeks, burbot should be released to an environment with much lower competition. Burbot were also easy to collect. Food availability was believed to be a limiting factor to growth and survival and future research should experiment with supplemental feeding of live and commercial food. The practicality of pen rearing burbot cannot be fully addressed by this study alone. A limitation is that without supplemental feeding only low numbers of burbot could be reared in pens of 1,500 to 3,500 L. Far more pens would be required to rear sufficient numbers of burbot needed for burbot rehabilitation in the Kootenai River (Paragamian and Hansen, in progress).

Burbot Systems Operation Request

The burbot SOR mitigated for warmer winter water temperatures in the Kootenai River caused by the release of a large volume of warm surface water in Lake Koocanusa. The SOR request attempted to "cool" the Kootenai River during winter of 2009–2010 by using a selective withdrawal system at Libby Dam. From late December through the spawning season, the temperature varied above the SOR target maximum temperature of 4°C by less than 0.5°C, and would have been suitable for burbot spawning. In addition, the flow was low for most of the spawning season, which added to the ability of water temperatures in the river to be lower for winter 2009-2010. Managing water temperature at Libby Dam with the selective withdrawal system has appeared to improve water temperatures at Bonners Ferry. In 2008-2009 and 2007-2008, prespawn and spawning water temperature was above 6°C in early November 2007 but fell below after November 10 through most of December. Water temperatures were usually maintained between 1 and 4°C throughout January and February 2008 and were acceptable.

Maintaining cool water from Libby Dam is very dependent on uncontrollable factors such as microclimate, wind direction, and intense storms. These all play a role in fall turnover for Lake Koocanusa (18,819 ha and 113 m deep). Lake Koocanusa becomes isothermal after fall turnover and as winter progresses the pool continues to cool toward 4°C (Brian Marotz, Montana Fish Wildlife and Parks, personal communication). Only a thin layer of colder water exists at the surface, and surface water cannot be drawn into the turbines because of concerns for turbine cavitation. The only period that can provide cooler water is the period prior to the development of an isothermal state. The ability to attain cooler temperatures is contingent on the timing of fall turnover, which varies from year to year and can be affected by storms during fall.

Recommended Discharge and Temperature for Burbot Migration and Spawning

The best available recommendation for discharge will continue to rely on the studies of Paragamian et al. (2005) and Paragamian and Wakkinen (2008). As a result of these studies, it is recommended that discharge for burbot prespawning migration and spawning should range from 113-300 m^3/s and average 176 m^3/s for a minimum of 90 d (mid-November through mid-February). Temperature should decline to <6°C by the first week in November and be maintained from 1 to 4°C for the duration of December through February, which includes the migration and spawning season. A study of the relationship between “specific levels” of discharge and temperature from Libby Dam and burbot spawning migration and spawning cannot be successfully completed until there are sufficient numbers of burbot and will not compromise burbot rehabilitation.

RECOMMENDATIONS

1. While the burbot population is critically low, continue sampling index locations to measure changes in population numbers (Jolly-Seber population estimate), size structure (PSD), condition W_r, and abundance (CPUE). Effort shall continue at Nicks Island, the Creston Boat Ramp, Boundary Creek, the international border, Goat River, Ambush Rock, and near Deep Creek. With recent stockings of subadult and juvenile burbot, the CPUE could change in the near future.

2. Burbot recovery is unlikely without the intervention of supplementation. We recommend Moyie Lake burbot donor stock be used to evaluate extensive rearing of cultured larvae. The primary objectives would be to determine whether sufficient numbers of burbot

larvae can be reared with 10% or more survival, to a minimum length of 98 mm or larger (in three months), released, and recaptured. Successful rearing would lead to further development of extensive rearing methods and release as fingerlings for burbot rehabilitation.

3. We recommend that stocking of extensively reared and pen reared burbot continue and that a graduate study be designed to monitor outmigration from tributaries, habitat use, survival and growth.

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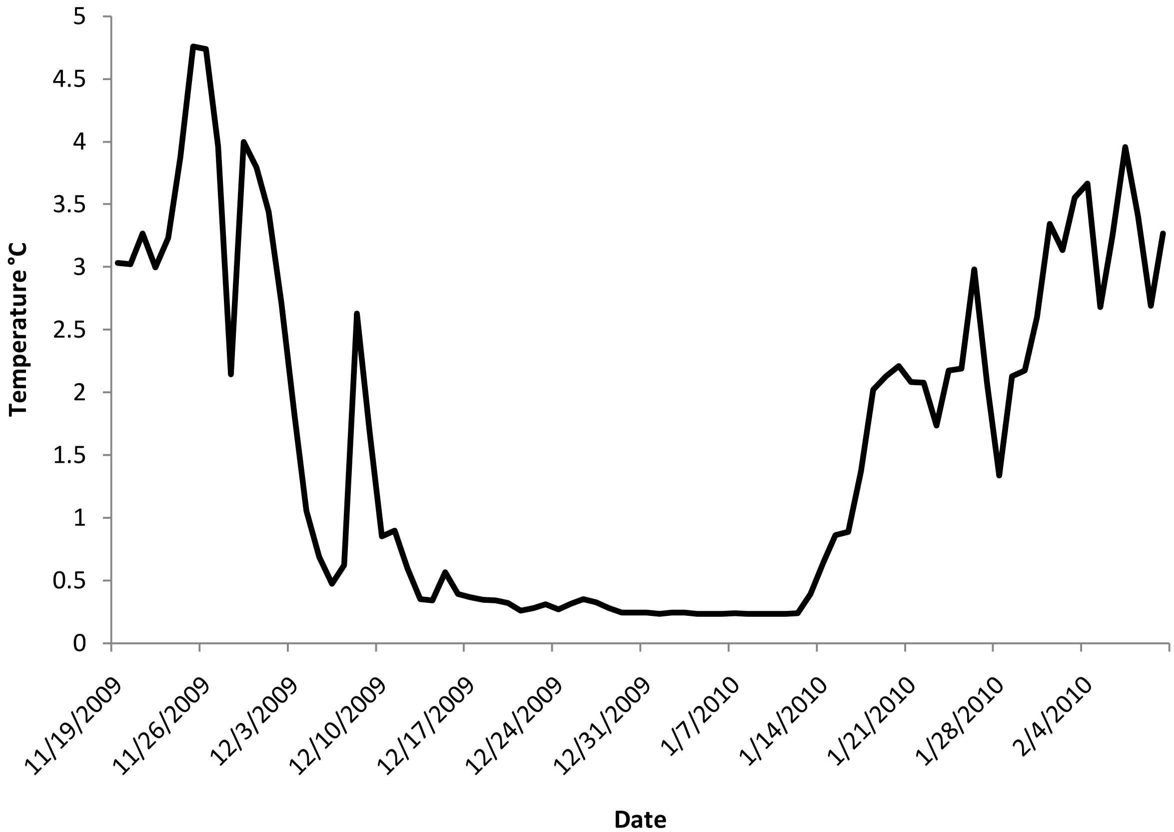
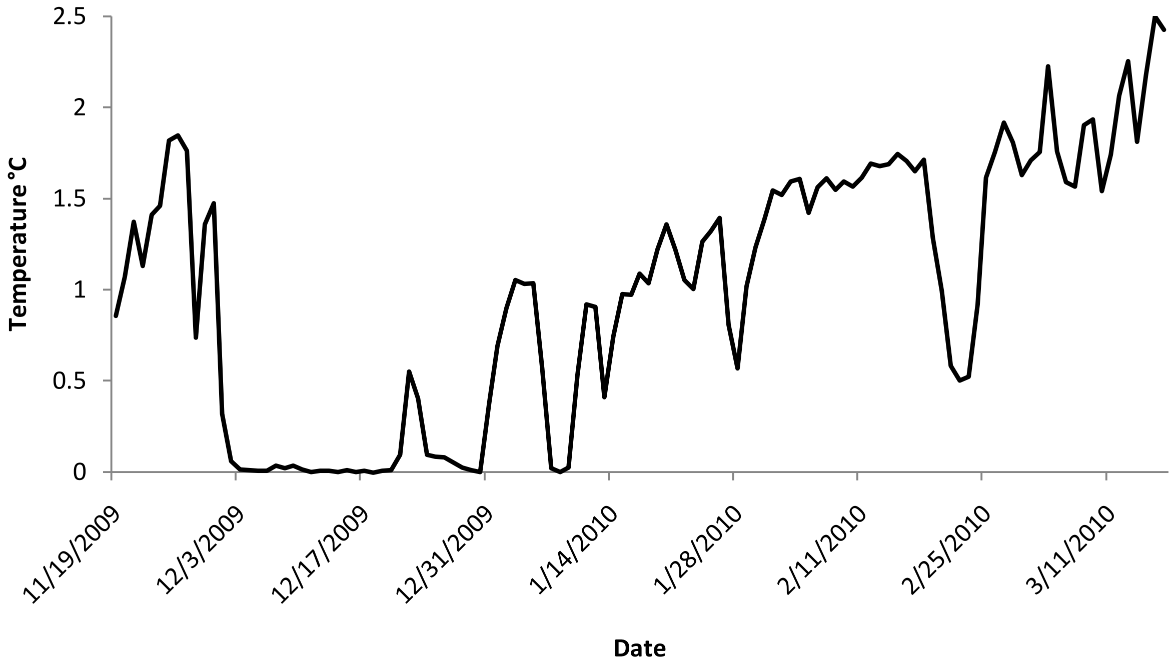
APPENDICES

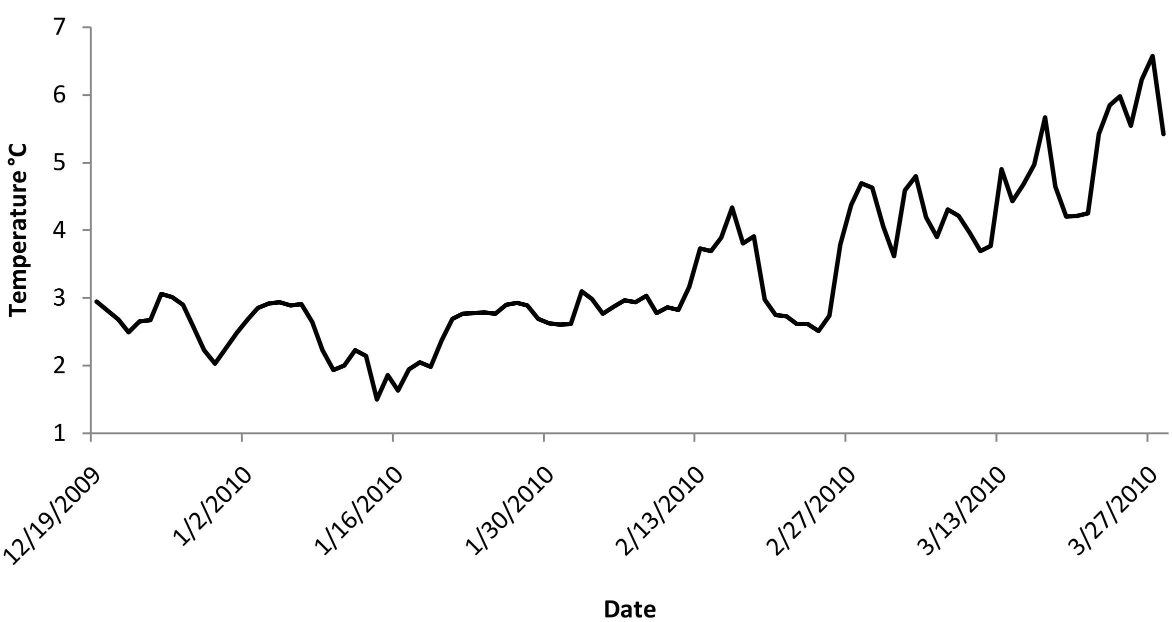
Appendix 1. Deep Creek (°C) mean daily temperature profile November 19, 2009 to February 10, 2010.



Appendix 2. Boundary Creek (°C) mean daily temperature profile November 19, 2009 to March 17, 2010.



Appendix 3. Goat River (°C) mean daily temperature profile December 19, 2009 to March 28, 2010.



Appendix 4. Idaho Department of Fish and Game burbot hoop net captures and capture effort (burbot/hoop net day), winters (Wtr.) of 1993-2010.

Sampling Season	**Number of Burbot Captures**	**Total Net Days**	**CPUE (fish/net day)**
Wtr. 1993: Mar. 1993-May 1993	17	554.2	0.031
Wtr. 1994: Oct. 1993-April 1994	8	909.8	0.009
Wtr. 1995: Nov. 1994-Feb. 1995	33	688.8	0.048
Wtr. 1996: Nov. 1995-Mar. 1996	28	495.8	0.056
Wtr. 1997: Oct. 1996-Mar. 1997	23	1,061.1	0.022
Wtr. 1998: Oct. 1997-May 1998	42	1,240.9	0.034
Wtr. 1999: Oct. 1998-April 1999	44	1,453.7	0.030
Wtr. 2000: Oct. 1999-April 2000	36	1,712.9	0.021
Wtr. 2001: Oct. 2000-Mar. 2001	73	2,085.2	0.035
Wtr. 2002: Oct. 2001-April 2002	17	1,529.9	0.011
Wtr. 2003: Oct. 2002-Mar. 2003	11	1,809.7	0.006
Wtr. 2004: Nov. 2003-Mar. 2004	19	1,965.1	0.010
Wtr. 2005: Nov. 2004-April 2005	18	2,045.7	0.009
Wtr. 2006: Oct. 2005–Mar. 2006	14	1,999.9	0.007
Wtr. 2007: Nov. 2006-Mar. 2007	2	1,497.4	0.001
Wtr. 2008: Nov. 2007-Mar. 2008	3	1,040.8	0.003
Wtr. 2009: Nov 2008-Mar. 2009	4	1,018.0	0.004
Wtr. 2009: Nov 2009-Mar. 2010			
Totals	392	23,108.9	0.017
Mean			0.019

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