FISHERY RESEARCH

KOOTENAI RIVER FISHERIES INVESTIGATION: STOCK STATUS OF BURBOT

ANNUAL PROGRESS REPORT
April 1, 2008 — March 31, 2009

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IDFG Report Number 09-02
March 2009

CHAPTER 1

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Project Progress Report

2009 Annual Report

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To

U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97283-3621

Project Number 88-65
Contract Number 88-BI-93497

IDFG Report Number 09-02
March 2009

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ABSTRACT

Objectives of this investigation were: 1) to maintain the Kootenai River temperature near Bonners Ferry between 1-4°C (November-December) to improve burbot migration and spawning activity, and 2) to rear burbot larvae through extensive rearing to produce a survival rate of 10% or more and fingerlings up to 98 mm in length within four months. Water temperature fell below the upper limit (4°C) the last few days of December and stayed below for most of the spawning season. Snowpack was characterized by an 87% of normal January runoff forecast, and discharge from Libby Dam was held at 113 m^3/s for the benefit of burbot. Four adult burbot were captured with hoop nets: three in the Goat River and one at Nick's Island (rkm 144.5). Burbot catch per unit effort in hoop nets was 0.004 fish/net d. Extensive rearing by stocking 56,000 feeding burbot larvae on May 9 in a private pond met with modest success, but the presence of yellow perch *Perca flavescens* was a serious predation issue. However, light trapping in two net pens captured 26 larvae ranging in length from 10-25 mm TL on June 10, 18, 19, and 24, 2008. Burbot in net pens were inventoried in late August 2008. Forty-seven burbot were collected of 60 age 0 burbot released in May for an estimated net pen survival of 78%. Average length in August was 48 mm TL, range was 31 to 55 mm TL. Young burbot were tagged with Visible Implant Elastomer (VIE) tags to distinguish between net pen and pond raised juveniles, and 44 were released back into the pond, three mortalities. Fredericks Pond was pumped in December 2008 to drain the pond and eliminate remaining yellow perch. While draining the pond we collected nine age 0 burbot that had an average length of 88.2 mm TL; they ranged from 78 to 103 mm TL and weighed 3 to 8 g with a mean of 4.8 g. Of the nine burbot, four were recaptures of 44 previously marked fish from the net pens (marked in August prior to release). This enabled us to make a population estimate of 99 burbot (95% CI = ± 21) in the pond (including 44 released) in mid-August 2008. Based on this estimate the combined survival would have been 0.002%.

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INTRODUCTION

In Idaho, burbot *Lota lota* 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 indicated 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 (Figure 2). Libby Dam operations were implicated as the major factor with changes in winter temperatures and flow (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; Kootenai Valley Resource Initiative [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 conditions for burbot migration in temperature and discharge. 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 burbot temperatures of about 6°C were necessary for migration and cooler temperatures for spawning (Paragamian and Wakkinen 2008). The Conservation Strategy also identified Conservation Aquaculture as a remedial measure to help strengthen the depressed burbot stock.

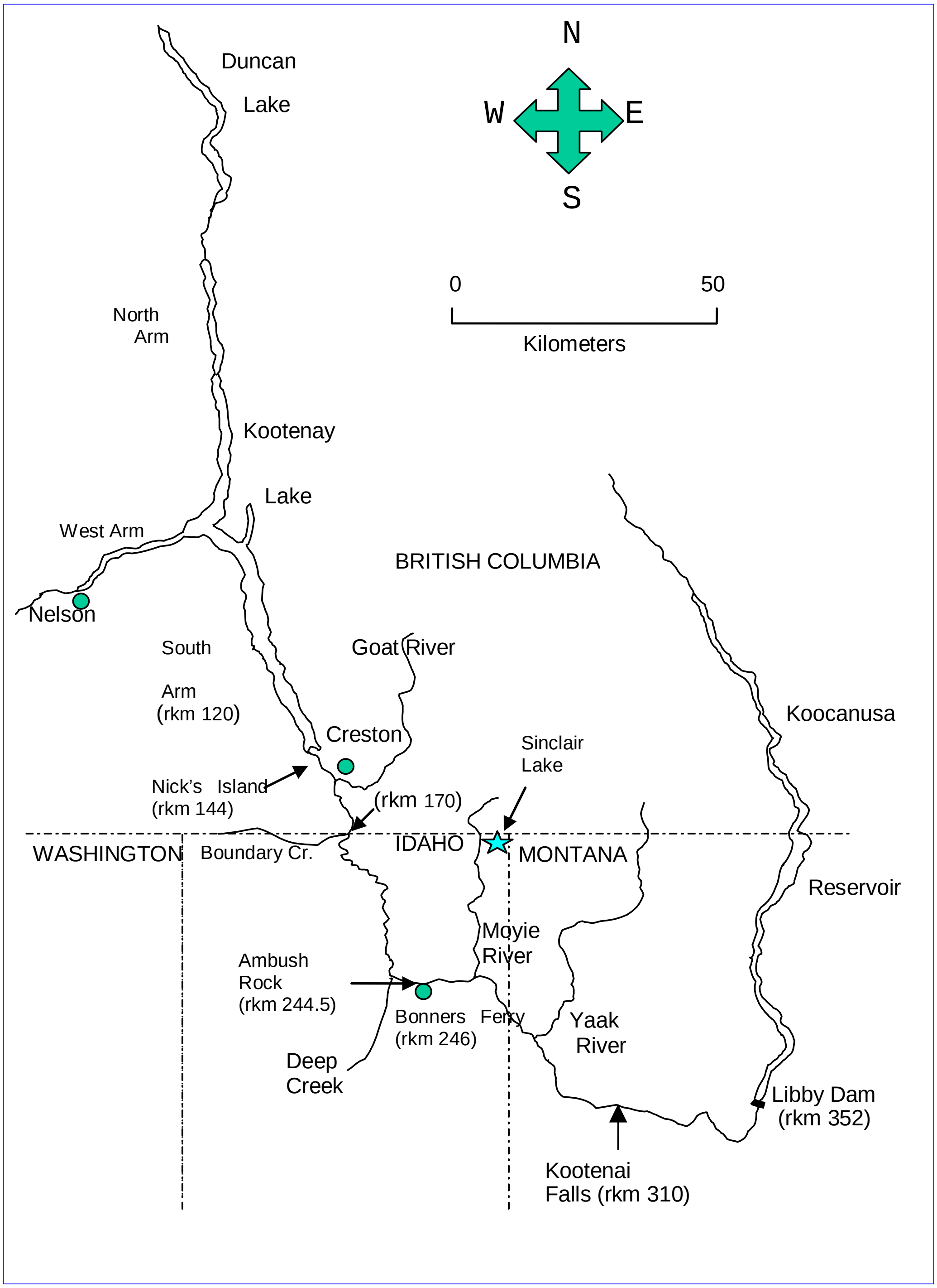

Figure 1. Location of the Kootenai River, Kootenay Lake, Lake Koocanusa, and major tributaries. The river distances from the northernmost reach of Kootenay Lake are in river kilometers (rkm) and are indicated at important access points.

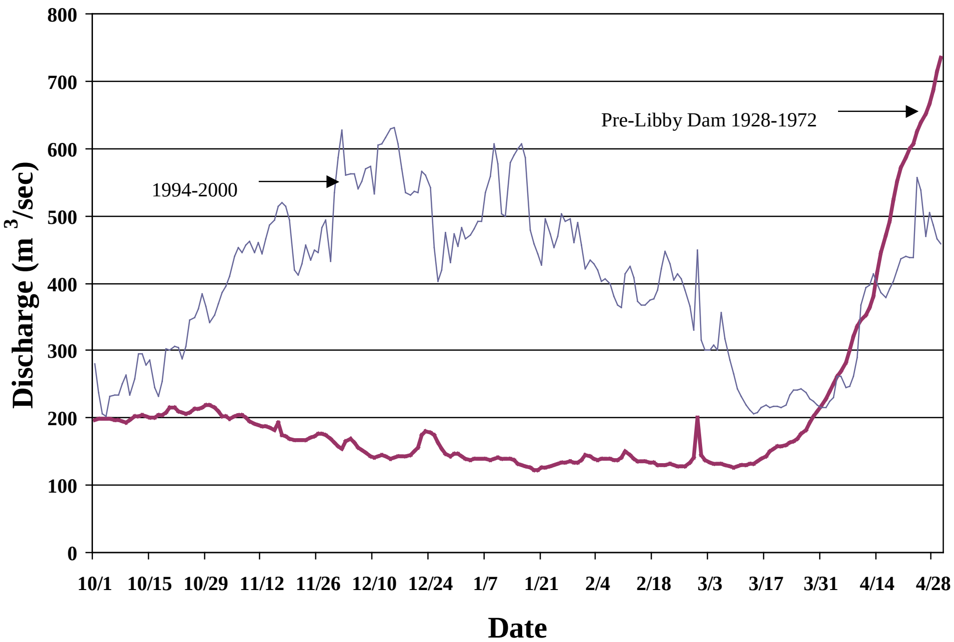

Figure 2. Mean daily discharge of the Kootenai River at Porthill, Idaho from 1962 through 1971 (pre-Libby Dam), and from 1994 through 2000 (post-Libby Dam).

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. 2008; 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. 2008). Coordination of intensive culture and extensive rearing with the Kootenai Tribe of Idaho, BCME, and the UIARI (Dr. Ken Cain) could be an important rehabilitation measure in the near future.

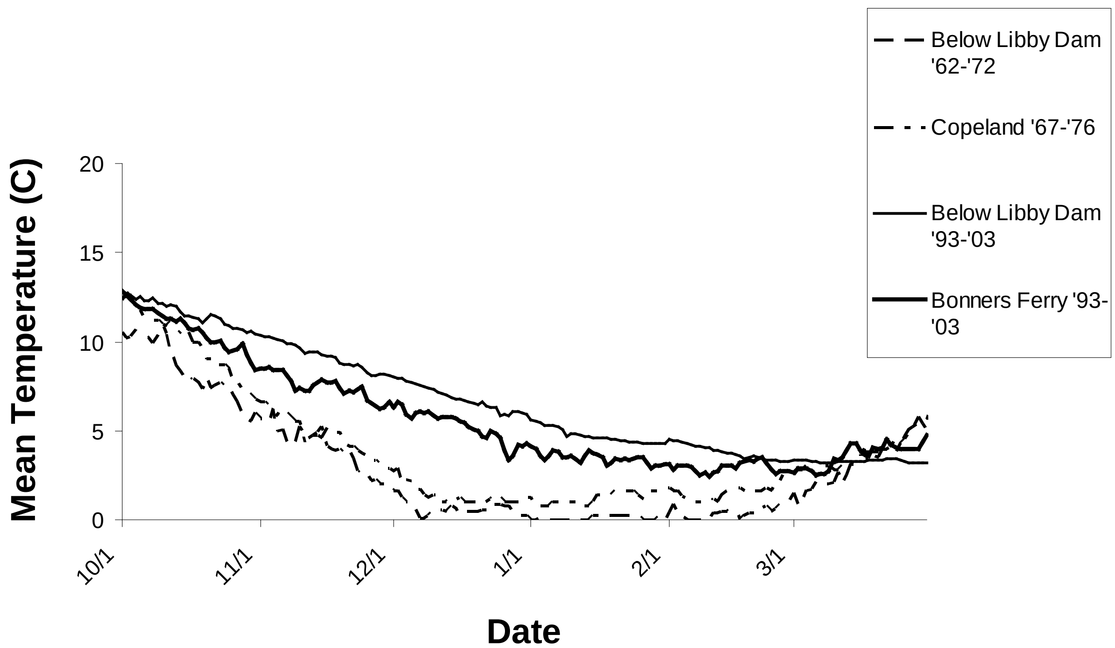

Figure 3. Pre-Libby Dam Kootenai River temperatures at the dam site 1962-1972, at Copeland, Idaho 1967-1972 and post Libby Dam below the dam from 1993-2003, and at Bonners Ferry, Idaho from 1993-2003.

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 harvest of burbot.

OBJECTIVES

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

2. Extensively rear feeding burbot larvae, to have a survival rate of 10% or more, and growth to 98 mm in total length within 4 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 selected in 2008 for the experimental release of feeding larval burbot for extensive rearing (Figure 4). The pond is on private property approximately 8 km (5 miles) from the Kootenai Wildlife Refuge and has easy access. 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 (260 x 120 ft) and is about 2.4 m (8 ft) deep (see Chapter 2). It is about 46 m (150 ft) from Burton Creek. 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. It is fenced from livestock. Typically, it is reported to be ice covered each winter.

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 US Geological Survey (USGS) office in Sandpoint, Idaho provided the daily discharge and temperature values for the Kootenai River. The US 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, Kootenai Tribe of Idaho, City of Bonners Ferry, and Boundary County) to the USACE and the Bonneville Power Administration (BPA). Like the previous year, the 2008-2009 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 and December using the selective withdrawal system in place at Libby Dam with a target range from 1-4°C (Figure 5). These months 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; and the Kootenai River at Porthill, Idaho and Nick's Island, British Columbia from October 2008 through March 2009. At each location, mean daily temperature was calculated from six evenly spaced daily measurements. In Boundary Creek, the thermograph was placed approximately 500 meters upstream from the confluence. Data from this logger was 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 indicates that Summit and Boundary creeks were historical burbot spawning areas.

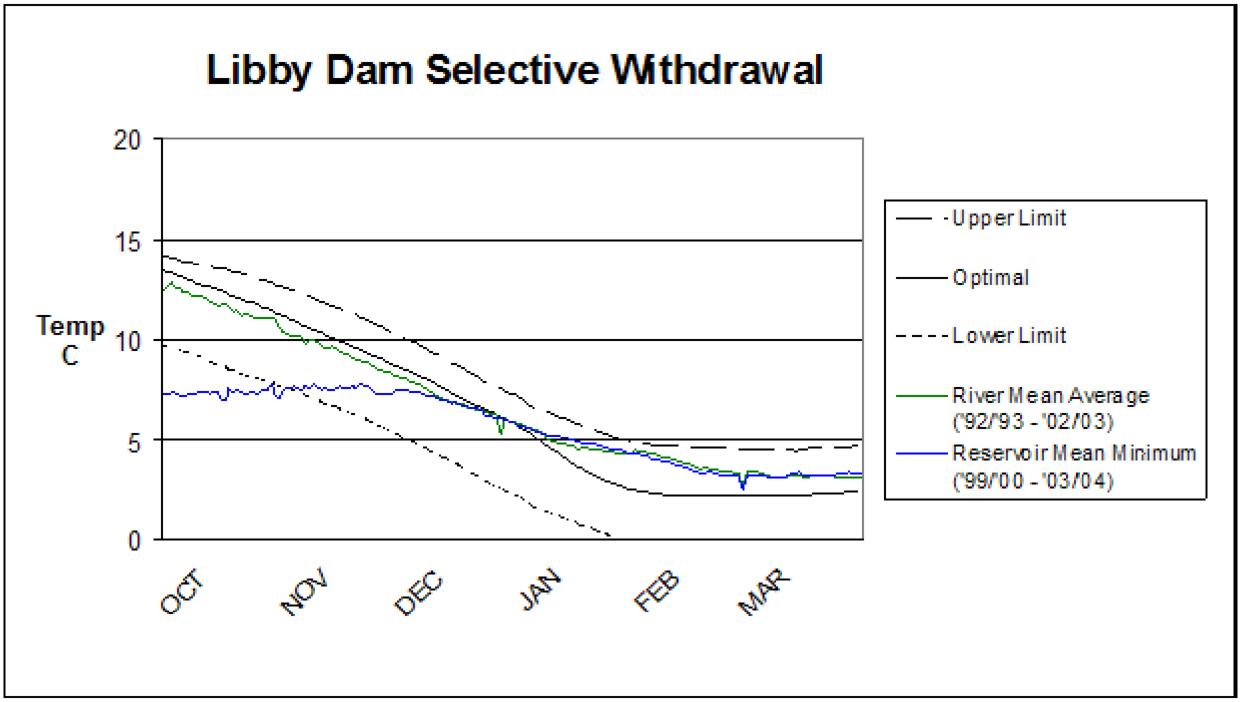

Figure 5. Selective withdrawal temperature guidelines for the Kootenai River below Libby Dam. Figure courtesy USACE.

Burbot Sampling

Adult Burbot

Technicians sampled adult burbot from November 2008 through March 2009 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 can be caught in 0.6 m diameter hoop nets with 25.4 mm bar web at about 350 mm TL but are not fully recruited until 450 mm TL. In an effort to predict burbot year class strength sooner than fish of 450 mm TL and evaluate recovery measures earlier, we had two hoop nets of 19 mm bar web constructed to compare to the catch to 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 (Jolly-Seber population estimate), 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 Nick's Island (rkm 144) near Creston, BC (figure 1). We sampled river reaches where burbot were more likely to be captured, e.g., Nick's Island, Boundary Creek and the international boundary, Goat River, and Ambush Rock, because burbot numbers are low and 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. We calculated relative weight (W_r; Fisher et al. 1996) for each burbot captured.

Extensive Burbot Rearing

Larval Release

An experiment devised to measure the success of extensive rearing was implemented by releasing 56,000 eyed burbot larva into Fredericks Pond, Idaho. 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. Adult brood fish were captured in November 2006 and February 2008 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. Burbot larvae were provided by the UIARI, Moscow, Idaho and were part of an intensive research sponsored jointly by the KTOI and UIARI. The Moyie Lake stock were provided to the UIARI by the BCME. We used light traps in the pond to monitor burbot growth with catch per unit of effort (CPUE) = one 24 h set.

Net pens were constructed for a secondary investigation to determine the survival and growth of burbot larva totally protected from predation, with the exception of cannibalism. The net pen dimensions were 1.83-m X 0.91-m X 0.91-m, volume was 1.53 m^3 and the mesh was 500 µm Nitex™.

Fredericks Pond Temperature

We deployed a single HOBO® temperature logger in Fredericks Pond to monitor daily temperatures from April to October 2008.

RESULTS

Kootenai River Discharge

The USACE resumed load following during the winter of 2008-2009 with an estimated January volume forecast of 87% followed by February at 86% and 84% in March forecasts. As a result, discharge in the Kootenai River at Bonners Ferry ranged from a low of 128 m^3/s on January 26, 2009 to as high as 728 m^3/s on December 18, 2008. Discharge was stable from January 15, 2009 through March 13, 2009 ranging from 128 to 155 m^3/s (Figure 6).

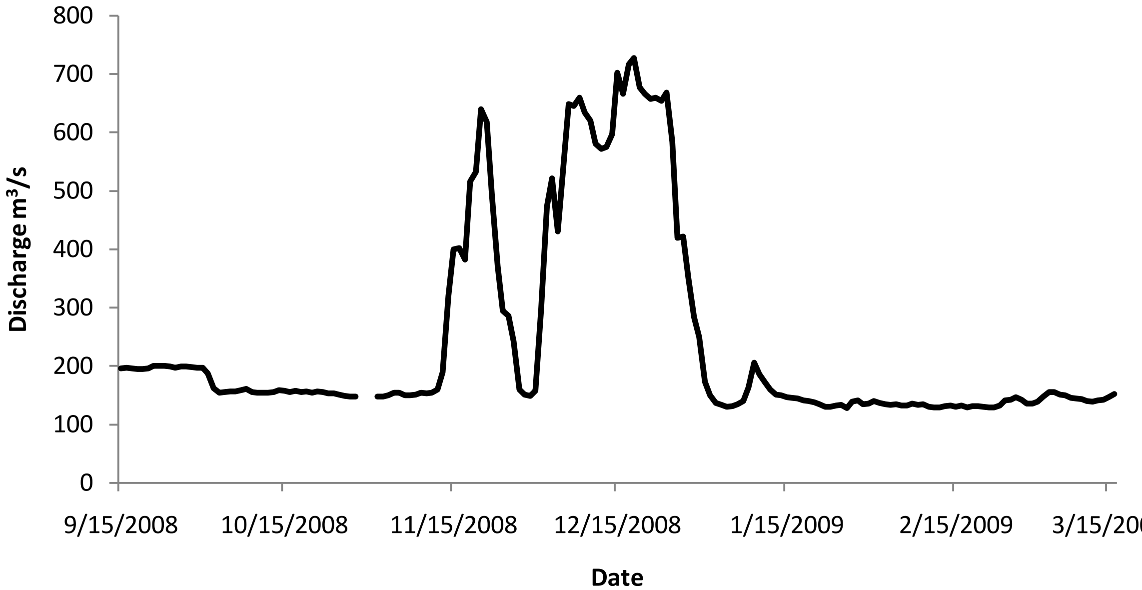

Figure 6. Daily mean discharge (m^3/s) near Bonners Ferry, USGS gaging station 12310100.

Kootenai River Temperature

Mean water temperature at the USGS gage 12309500 near Bonners Ferry, Idaho (rkm 245.7) was 6.14°C ranging from 0°C to 14.8°C. Mean water temperature at Porthill, Idaho (rkm 169.8) was 2.99°C ranging from 0.20°C to 6.8°C. Mean temperature at Nick's Island (rkm 144.5) was 2.97°C ranging from 0.195°C to 6.61°C (Figure 7).

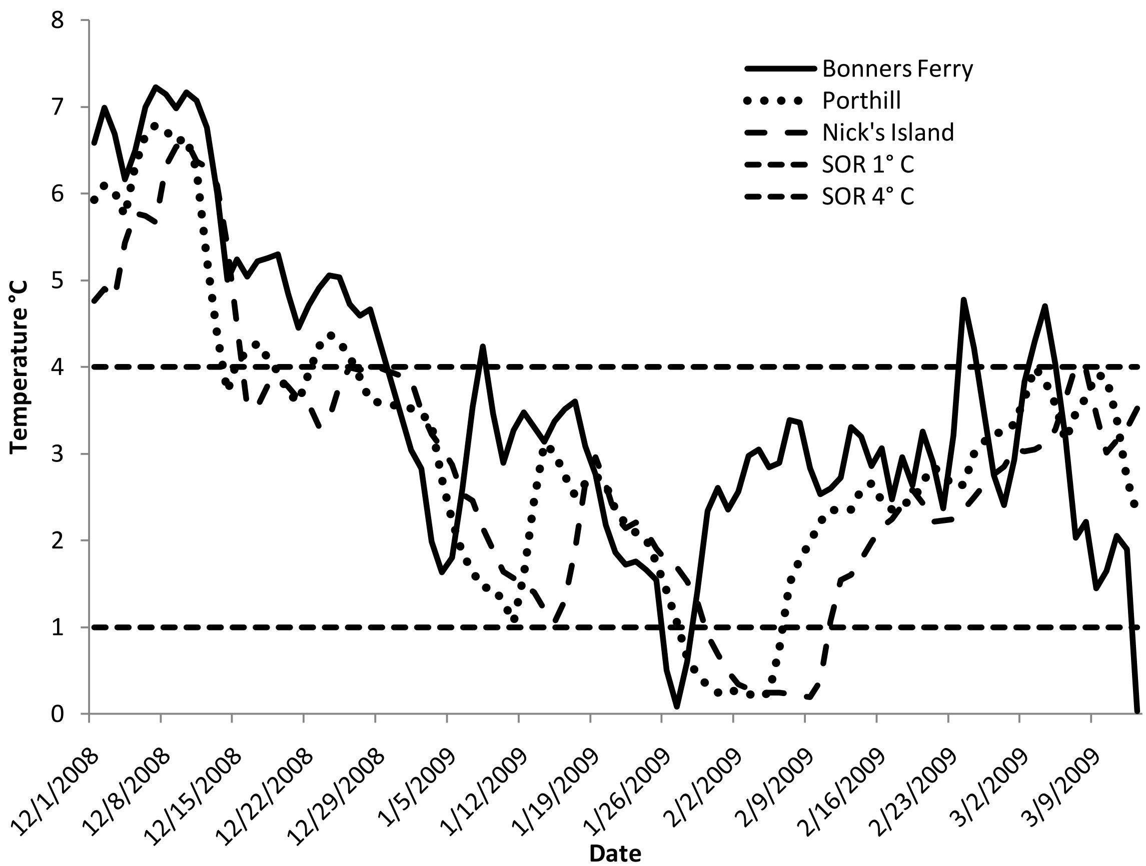

Figure 7. Mean daily temperature (°C) for the Kootenai River at Bonners Ferry (rkm 245.7) and Porthill, Idaho (rkm 170), and Nick's Island, BC (rkm 144.5) profile December 1, 2008 to March 13, 2009. Horizontal bars represent the target temperature values for the SOR.

Tributary Temperatures

Thermographs were deployed in Deep and Boundary creeks in Idaho and in the Goat River, BC, Canada from November 2008 to March 2009. Due to ice cover and stream conditions, the Deep Creek and Goat River thermographs were lost.

Idaho

Mean water temperature of Boundary Creek was 0.73°C ranging from 0.23°C to 1.67°C (Appendix 1).

Canada

The Goat River thermograph was lost and not recovered.

Sampling Adult Burbot

Total Catch

Baited hoop nets were fished from November 25, 2008 through March 18, 2009 for a total of 24,432 h or 1018 net d. Twenty-seven fish were caught encompassing six different species of fish, and the crayfish *Pacifastacus spp.* were also caught (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 0.0265 fish/net d for all species of fish (excluding crayfish).

Hoop Net Catch of Burbot

Throughout the 2008-2009 winter, four burbot were captured in baited hoop nets (Tables 1 and 2, Figure 8, and Appendix 3). Three burbot were captured in the Goat River and the fourth was captured at Nick's Island (RKM 144.5). The third capture from the Goat River may have been a recapture from February 20, 2009. It did not have a PIT tag when captured on March 4, 2009; however, it had a very distinguishable spiral shaped scar on the left opercal, was within 3 mm TL, and was 591 g less in weight than the first capture. On February 20, this fish was accompanied in the hoop net by a flowing male, which leads us to believe that this was a female that traveled up the Goat River, spawned, and then returned to the Kootenai River. Hoop net catch per unit effort for burbot was 0.0039 fish/net d or 254.5 net d/fish with effort in Idaho and BC (Table 1 and 3 and Appendix 3).

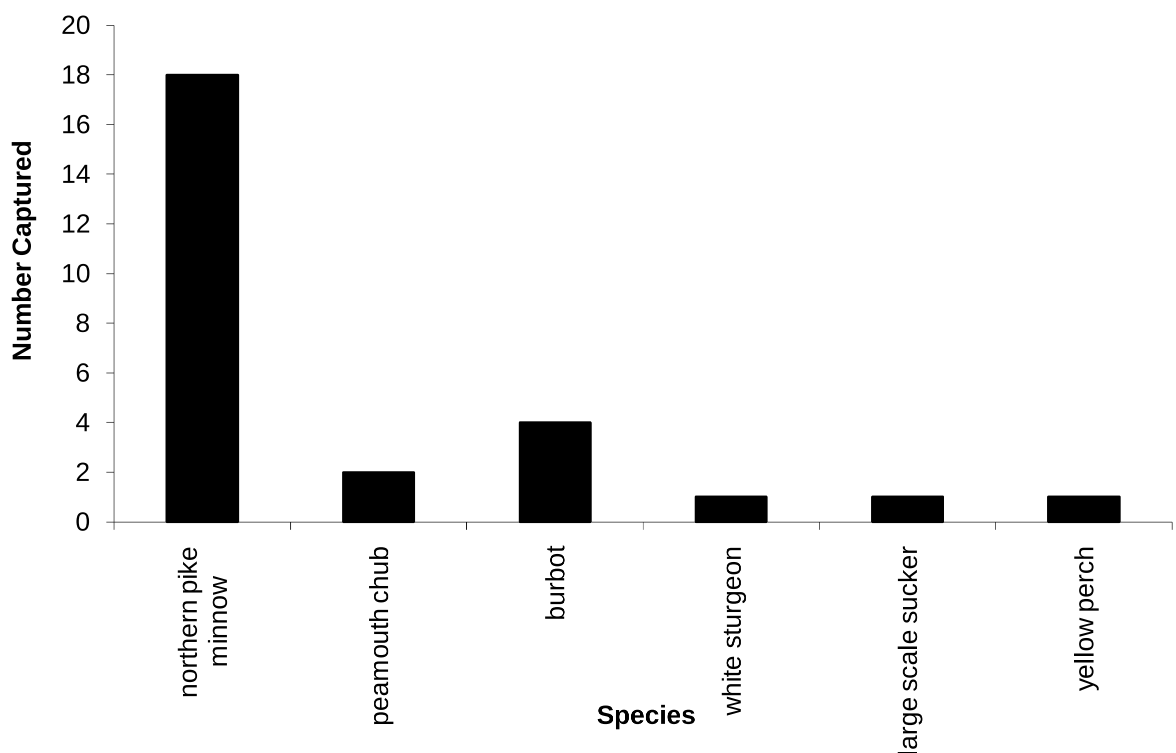

Figure 8. Hoop net bycatch for the Kootenai River, Idaho and BC from November 2008 through March 2009.

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, November 2008 through March 2009 with 1018 d of effort (24,432 h of effort).

Species	**Number**	**Total Weight (g)**	**CPUE[a]**
Northern Pikeminnow *Ptychocheilus oregonensis*	18	5867	0.0177
Burbot *Lota lota*	4	6879	0.0039
White Sturgeon *Acipenser transmontanus*	1	--	0.0010
Yellow Perch *Perca flavescens*	1	96	0.0010
Peamouth Chub *Mylocheilus spp*	2	107[b]	0.0020
Large Scale Sucker *Catostomus macrocheilus*	1	83	0.0010
Total	27		0.027

[a] A unit of effort is a single hoop net set for 24 h.
[b] Only one Peamouth Chub was weighed due to equipment failure.

Table 2 Burbot identification number, location of capture, date of capture, total length, and weight, and tag number for captures from November 2005 through March 2009.

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

Table 3. Burbot hoop net captures and capture effort in three primary locations, October 2003—March 2009.

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

Extensive Rearing and Pond Temperature

We built and deployed two fully enclosed net pens for Fredericks Pond and installed a screen at the pond outlet to prevent the escape of burbot. We stocked about 56,000 burbot larvae on May 9 (~60 in net pens, balance in pond). We began light trap sampling May 27 with one larvae caught in the pond with an effort of 30.0 d (720 h) with one catch per unit of effort (CPUE) = one 24 h set, which results in a CPUE of 0.0333 or an (CPUE [h] = 0.0014).

Unfortunately, we found yellow perch in the pond shortly after releasing the larval burbot. The pond was reported to be fishless. We immediately removed about 650 yellow perch by seining and then deployed two gill nets for the remainder of the summer with nearly 800 taken from the pond by August.

We also set one light trap in each of the two net pens and captured a total (many possible recaptures) of 26 larvae ranging in length from 10-25 mm TL on 10, 18, 19, and 24 June, 2008 for a total net pen light trap effort of 24.00 days (576.00 h) CPUE 3.500 (CPUE [h] 0.1458). All burbot appeared healthy; guts were packed full of zooplankton and were growing (Figure 9). Burbot in net pens were inventoried and removed in late August 2008. We collected 47 of the 60 age 0 burbot released in May for an estimated net pen survival of 78%. Average length in August was 48 mm TL, range was 31 to 55 mm TL. Young burbot were tagged with Visible Implant Elastomer (VIE) tags to distinguish between net pen and pond raised juveniles.

We had three mortalities during tagging with the balance of 44 burbot released back into the pond.

To eliminate remaining yellow perch, Fredericks Pond was pumped from December 9 through 11, 2008 to a knee-deep mud bottom and the inlet closed subjecting perch to freezing and anoxic conditions. During the pond draining process, we eliminated over 200 additional yellow perch by seining them from the pond or catching them by hand. While draining the pond we also collected nine age 0 burbot that had an average length of 88.2 mm TL; they ranged from 78 to 103 mm TL and weights of 3 to 8 g with a mean of 4.8 g. Of the nine burbot, four were recaptures of 44 previously marked fish from the net pens (marked in August prior to release). This enabled us to make a population estimate of 99 burbot (95% CI = ± 21) in the pond (including 44 released) in mid-August 2008. Based on this estimate the combined survival (we stocked about 56,000 burbot larvae on May 9 in the pond and ~60 in pens) would have been 0.002%. On December 30, 2008 fisheries technicians returned to Fredericks Pond and found DO levels to range from 1.3 ppm (11.1%) at the inlet and 0.5 ppm (3.9%) at the opposite end of the inlet. This was exceptionally low DO and almost certain death to any fish faunal survivors. Fredericks Pond mean temperatures ranged from 5.4°C to 19.7°C with an average of 13.9°C (Appendix 2).

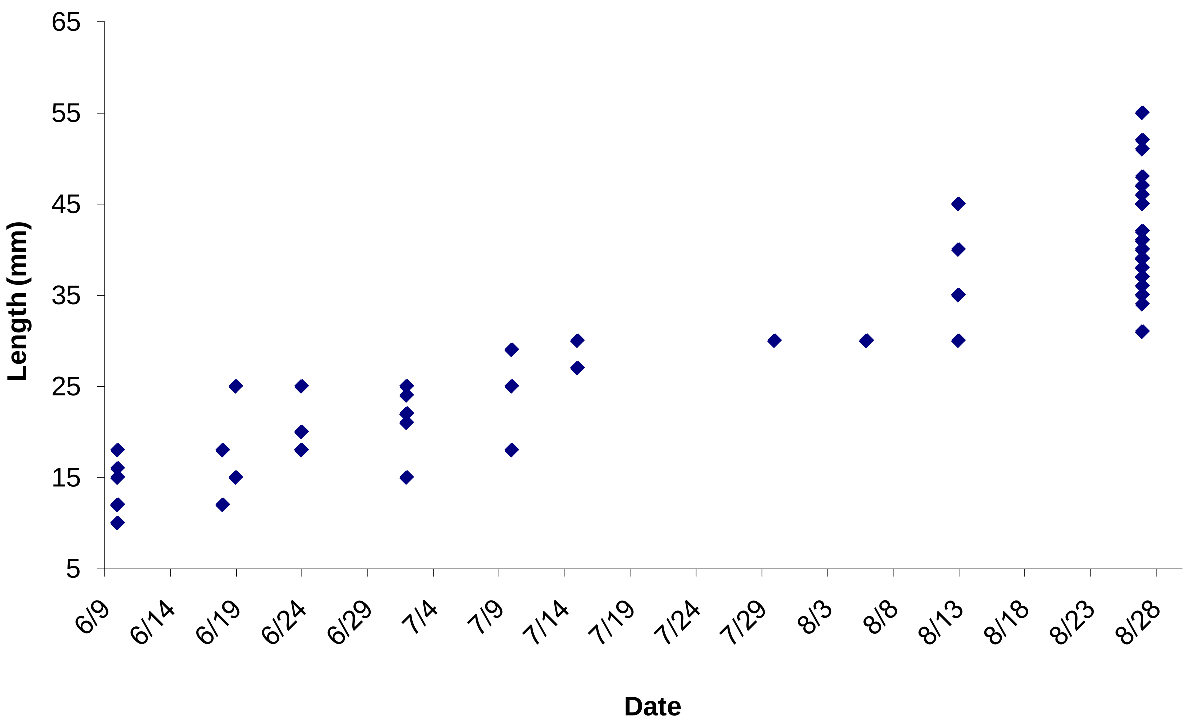

Figure 9. Fredericks Pond burbot length at capture in light traps June 2008 through August 2008.

DISCUSSION

Index Sampling Sites and Population Status

We used index sampling sites for the fifth season during the winter of 2008-2009 in an effort to maximize our catch and evaluate stock status, which continues to be extremely depressed. We captured only 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.

Three of the four burbot were captured in the Goat River in 2008-2009. This tributary was one of the last two known spawning locations for burbot and provided a major portion of the total winter catch in previous years. One burbot each was captured in the Goat River during winter 2006-2007, 2000-2001, and winter of 2001-2002 (Kozfkay and Paragamian 2002; Gunderman and Paragamian 2003) and none in 2007-2008 (Paragamian and Laude 2008), which is an additional indicator of the depressed status of burbot in the Kootenai River.

The Kootenai River burbot will likely become extinct within the decade (Paragamian et al. 2008). There will always be a remnant stock but this will only be due to emigration of a few burbot from above Kootenai Falls (Powell et al. 2008). These fish will not have an admix of Pacific and Mississippi clade genetics but will be exclusively Mississippi clade (Powell et al. 2008). Which means, providing there is recovery of burbot, the next generation may not be of the original genetic stock.

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. It is important that a rehabilitation goal be set in order to establish benchmarks of success for rehabilitation measures regardless if it is through wild/natural recruitment or the release of artificially propagated burbot. 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 of 2006) and an annual survival of 38%. An interim abundance target of 5,500 individuals (45 fish/km; 3.0 fish/ha) within 25 years was reported when each adult produced 0.85 recruits per year, along with an ultimate abundance target of 17,500 individuals (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. It is of crucial importance that remedial measures to improve this stock's abundance begin immediately. This would require habitat changes be in place and assume 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 larval burbot in Fredericks Pond provided an excellent foundation to continue and expand pond rearing. We estimated about 55 burbot were reared in the pond during the summer of 2008 with an additional 47 in the net pens. The net pens were designed to protect larval burbot from all predation with the exception of cannibalism. Survival in the net pens was estimated at 78% for the three-month period, whereas for the same period it was estimated at <0.01% in the pond based on mark and recaptures. Having any survival in the pond was unexpected, because in spite of the pond having over 1,000 yellow perch some larval burbot survived. In addition to the perch, winter draining of the pond revealed large predacious diving beetles (Dytiscidae) that could have also contributed to the mortality. For this next season, we plan to expand the number of net pens, increase the size of at least one, and experiment with two stocking densities in the four pens. Further experiments with extensive rearing should follow with multiple trials in at least one additional pond with an array of controls using larvae (Dillen et al. 2008). Although new in North America, extensive rearing has met with good success in Europe showing positive results for burbot recovery in Belgium (Dillen et al. 2008; Vught et al. 2008). To compare intensive and extensive rearing, Belgian researchers stocked intensively reared burbot as recently hatched larva in a Belgian river. Research efforts failed to document any survival. A contingent representing the same families was held for an additional period to rear extensively to fingerling length. The fingerling burbot were stocked into the same river and were recaptured several months later.

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 (Jensen et al. 2008). Thus in summers with exceptionally high air temperatures, the burbot rearing may be limited to a shorter period.

Our first experimental burbot extensive rearing, at Sinclair Lake in winter 2007, met with very modest success (Paragamian and Laude 2008). To our knowledge, this was the first attempt to implement extensive rearing in North America. Of approximately 4,000 eyed embryos placed in incubation jars, set in Sinclair Lake, we found 20 larvae in the jars and 110 eggshells suggesting many other larvae hatched but perished under confined conditions. We calculated a hatching success grand average of 0.5% and 3.25% when based on the number of eggshells. All of the larvae we collected from incubation jars were dead. Of the eggs released into Sinclair Lake, approximately 65% were eyed, range 53-75%, while hatching success of a contingent of the same family held in the laboratory was observed to be >50% survival (Nathan Jensen, University of Idaho, personal communication). Had we calculated our estimate of hatching success based on the percent of eyed eggs, survival would have been higher. We did not use the eyed percentage because of the wide range and the point was moot; survival would still be less than satisfactory. Although no age 0 burbot were captured through our sampling efforts in 2007 and 2008 some larvae could have hatched but their numbers were so low they remain undetected. In our study the cause of mortality is unknown, but DO at the surface and at 1.6 m at Sinclair Lake were 4.3 and 1.7 ppm, respectively, while that of laboratory experiments of Jensen et al. (2008) were 10.0 ppm. We concluded that similar lake DO was not suitable for larval survival at hatching. Taylor and McPhail (2000) found that about 75% of the burbot larvae they hatched under laboratory conditions died within the first four weeks of life.

IDFG extensive rearing of burbot is only a part of a much larger Conservation Aquaculture program with the Kootenai Tribe of Idaho, BCME, and UIARI. UIARI has been researching numerous aspects of intensive and extensive rearing since 2005 in addition to following research protocols for eventual stockings of fingerling burbot for rehabilitation. For example, in 2008, about 7.6 million eggs were collected (from adults at Moyie Lake and those adults maintained at the UIARI station) of which 6.7 million eggs were fertilized (Dr. Ken Cain, UIARI, personal communication, and FY09 Burbot Statement of Work). An important area of research for the UIARI staff is survival from the egg to early larval feeding stage when the population of larva was reduced to 1.2 million. Of this last group, IDFG received 56,000 larva. The next major transition for UIARI researchers will be studies feeding from live-prey items to a commercial diet; in 2008 these studies resulted in production of about 1,000 juvenile burbot that completely transitioned to artificial diets. UIARI is also experimenting with extensive rearing and will add an additional pond in Boundary County/Kootenai River drainage. Further, UIARI is investing in tasks that will become important to the release of burbot fingerling (fish health and disease studies) for rehabilitation e.g., increasing hatch success, developing and characterizing diagnostic tools (cell lines and characterization of their viral susceptibility), and assessing juvenile pathogen susceptibility.

Burbot SOR

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 2008–2009 by using a selective withdrawal system at Libby Dam. Mean water temperature near Bonners Ferry, Idaho (rkm 245.7) was 6.14°C ranging from 0°C to 14.8°C. From late December through the spawning season, the temperature stayed within the SOR target maximum temperature of 4°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 2008-2009.

In 2007-2008 prespawn water temperature was above 6°C in early November 2007 but fell below after November 10 through most of December. Water temperature was usually maintained between 1 and 4°C throughout January and February 2008 and was acceptable. However, the attempt was not acceptable for the winter of 2006-2007 because the water was too warm. For most of November and December of 2006 water temperature at Bonners Ferry was held between 4°C and 6°C. The coldest period was during late November when temperature fell to about 3.8°C. Water temperature remained below 5.5°C during late December and through most of January. River water less than 6°C is important to stimulate prespawn migration and water temperatures <4°C are preferred for spawning (Paragamian and Wakkinen 2008). The results during the winter of 2004–2005 were also less than satisfactory because river water temperature was too warm (Paragamian and Laude 2006) while temperatures of 2005-2006 were cooler (Paragamian and Laude 2008).

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. During 2004–2005 a similar effort showed that cooler water could be achieved in early November, during a time in which burbot may be migrating in response to thermal conditions. After mid-November there is little opportunity to make a difference because the reservoir temperature is isothermal, allowing only a limited opportunity to mechanically change temperature. Thus, 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. Each fall as the surface cools and the density gradient erodes, all it takes is a wind event to cause turnover. As soon as turnover occurs, the ability to influence temperature in the discharge ends as water becomes isothermal (Brian Marotz, Montana Fish Wildlife and Parks, personal communication). Water is most dense at 4°C so unless there is a chemocline (sometimes observed in Lake Koocanusa) the water at the bottom will be no colder than 4°C.

There is a chance for atmospheric cooling between Libby Dam and the lower Kootenai River, so the artificially warmer discharge from the reservoir can chill as it moves downstream. This effect is dependent on discharge volume because air temperature has more effect on water temperature at lower discharge volumes. Prior to Libby Dam, the Kootenai River often super-cooled, caused ice jams and associated ice scour (Figure 3).

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 maintained from 1 to 4°C for the duration of December through February, which includes the migration and spawning season. A study of the relation 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 that studies 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 Nick's Island, the Creston Boat Ramp, Boundary Creek, the international border, Goat River, Ambush Rock, and near Deep Creek.

2. It is unlikely even with the most suitable habitat changes that burbot will recover in the Kootenai River. 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, 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 guidelines be developed for the minimum number of burbot fingerlings for stocking that would produce 5,500 adult burbot within 25 years in an interim rehabilitation goal and an extremely long-term population target of 17,500 adults.

ACKNOWLEDGMENTS

We thank John Mainio, Dallas Reed, and Kirk Handley for fieldwork. Diane Wakkinen with IDFG and temporary employees of IDFG assisted with summary data. Thanks appreciated are the editorial comments from Dan Schill with IDFG. Bonneville Power Administration provided funding for this investigation.

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CHAPTER 2

LIMNOLOGICAL ASSESSMENT OF A SMALL POND NEAR BONNERS FERRY, IDAHO

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October 2008

ABSTRACT

A small pond on the Kootenay River flood plain just west of Bonners Ferry was sampled once in August 2008 to describe its limnological conditions. The Idaho Department of Fish and Game requested these data as part of their use of the pond to rear Burbot *Lota lota* fry as part of an extensive culture research program of the species. The pond was surveyed to create a bathymetric map and samples for the analysis of water chemistry and zooplankton were obtained from the deepest point. Sediment samples to examine benthic macroinvertebrates were also obtained at the deepest point. The pond was shallow (max depth = 2.1 m, mean depth = 0.81 m), not thermally stratified and the entire bottom of the pond was covered with macrophytes. Chemically, the pond had a TN:TP ratio indicating p-limitation, however, the trophic state index indicated the pond was eutrophic. The zooplankton community was dense but composed of some of the smallest species of cladocerans, possibly indicating size selective predation by predators. Depending on the conditions required by burbot fry, the pond may be suitable for extensive culture of the species.

INTRODUCTION

Farm ponds are numerous across the US, estimated at over 2 million by the NRCS (Tuttle 2003), and more than 2.6 million by Smith et al. (2002). They usually serve a variety of purposes, ranging from stock watering, erosion control, potable water, to recreation (swimming and fishing). Smith et al. (2002) estimate that small farm ponds account for up to 20% of all standing water in the US. Although they form a significant portion of standing water, because of their small size they have generally been overlooked in research studies (but see Bailey 1973). Also, there is no comprehensive database documenting parameters for these water bodies. Generally, state agencies have undertaken localized studies and made recommendations on pond management (e.g., Saila 1952; Neal 2006). Because of their small size, typically 1/3 to ½ acre in size, their chemistry is largely influenced by the local geology and sediment transport from the catchment, which can be significant sources of nutrients given the predominant agricultural setting.

Ponds are typically constructed by damming a small stream in a depression or valley, or by constructing earthen berms at the base of a hill slope. In some cases, ponds are excavated entirely and left to fill with water from runoff, rain, or snowmelt (Tuttle 2003). Active management after construction can lead to desired characteristics such a clear water or high fish productivity.

Establishment of a recreational family fishery is often an important secondary purpose of ponds. It is impossible to estimate the number of ponds in which fish have been stocked or the health of those fisheries. However, because ponds are typically small and shallow, they tend to warm rapidly, thus enhancing growth rates of fish. As well, the shallowness means that often light penetrates to the bottom and the entire pond is a littoral area, which increases the production of invertebrate prey. Although these are general relationships, it is difficult to estimate the suitability of one pond over another for the production of fish without detailed studies of abiotic and biotic variables.

The objective of this study was to assess the physical, chemical, and biological conditions in the Fredericks Pond to obtain baseline data for the extensive burbot culture program operated by IDFG.

METHODS AND MATERIALS

To obtain bathymetric data, the pond was surveyed with a Lowrance LCX 25c digital sonar and GPS unit attached to a small boat. Depth, latitude, and longitude were recorded at 1 Hz while the boat was rowed over the pond following a rectangular grid pattern. The entire pond was covered with grid spacing at approximately 3 m intervals. To construct the bathymetric map, data were post processed in Quattro Pro (ver. X3), imported into ESRI ArcGIS (ver. 9.3) and used to construct a triangular irregular network (TIN) which was interpolated for evenly spaced 0.25 m depth contours.

To obtain profiles of temperature, dissolved oxygen, and conductivity, a YSI 85 multi-probe was lowered from the surface to the bottom at 0.5 intervals after anchoring the boat at the deepest spot in the pond (Figure 1). A secchi depth was attempted, but the disc could be seen on the bottom of the pond everywhere.

Integrated water samples for the analysis of Chlorophyll a were collected with a weighted 2L sampler. The sampler was lowered from the surface to 0.5 m above the bottom and raised. This was repeated until the sampler was full. Samples were transferred to labeled 2 L brown bottles, which were kept in a cooler for transport to the lab where samples were filtered through a 4.7 GF/C Whatman glass fiber filter. For analysis, samples were extracted with 10 ml ethanol, and absorbance read at 750, 649 and 665 nm with a spectrophotometer after centrifugation. Results were expressed as µg/L.

To obtain water samples for the analysis of alkalinity, dissolved phosphorus (DP), total phosphorus (TP), nitrate (NO_3-N) + nitrite (NO_2-N), and total nitrogen (TN), a 2L Van Dorn water sampler was lowered to 0.3 m and 1.5 m to obtain surface and bottom samples, respectively. Samples were stored in individual bottles on ice for transport to the Analytical Services Laboratory at the University of Idaho. Samples were processed using EPA standard methods (310.1, 350.1, 353.2, 365.2, and 365.4) and QA/QC procedures. A trophic state index (Carlson 1977) was calculated for TP and Chl a.

To sample zooplankton, triplicate samples using a 0.3 m diameter, 80 µm-mesh Wisconsin-style plankton net was hauled from 1.8 m to the surface. All material was rinsed into the cod end and transferred to a prelabeled vial. On shore, samples were preserved to a final concentration of 4% buffered ($MgCO_3$) formalin until analysis. To analyze samples, the formalin was removed by washing the sample through a 40 µm-mesh screen with water. The sample was then made up to a known volume and a 1-2 ml subsample was removed to identify and count all zooplankton. Samples were identified using keys in Thorp and Covich (2001) and Merritt and Cummins (1996). Final densities in number/L were back calculated from the subsample.

To obtain sediment for the enumeration of benthic macroinvertebrates, a 0.15 X 0.15 m Ekman sampler was lowered to the sediment and triggered. Two replicate samples were obtained from the deepest part of the pond. Samples were rinsed through a 500 µm mesh screen to remove sediment. Remaining material was preserved to a final concentration of 4% buffered formalin until analysis. To count invertebrates, samples were rinsed with water through a 230 µm mesh screen and split in half. All invertebrates were removed from ½ of the sample by scanning small portions of the sample in water under a WILD MB3 dissecting microscope with darkfield illumination. Invertebrates were then classified, counted, and densities back calculated to number per square meter.

To identify macrophytes, samples from around the pond were hand collected, stored in Ziploc bags, and placed on ice for transport to the laboratory. Identifications were based on Borman et al. (1999). No attempt to estimate percent composition of each was made because it was very windy and difficult to clearly see the pond bottom.

All data were summarized and compared to Bailey (1973) who studied a variety of north Idaho ponds.

RESULTS

The pond is located on the western edge of the Kootenay River flood plain, just east of the highway along the base of the Selkirks in the Panhandle of Idaho, northwest of the town of Bonners Ferry. The pond is a typical farm dugout pond, earthen berms on the south and east sides complete the basin. A small groundwater inflow enters the pond on the northwest corner and outflow drains into a field on the east side. The pond is relatively small and shallow with a surface area of 1,538.6 m^2, a maximum depth of 2.1 m and a mean depth of 0.81 m — calculated as the volume/area (Figure 1). Because the pond was so shallow, light penetrated to the bottom in all parts of the pond on the sampling date.

Chemistry

Profiles of temperature, dissolved oxygen, conductivity, and pH varied relatively little over the 2 m depth of the pond (Table 1). Briefly, temperature was 20.5°C at the surface and 18.4°C at the bottom; the oxygen concentration was 1.67 mg/L higher at the bottom at 10.9 mg/L than at the surface but was fully saturated or supersaturated at all depths; Conductivity increased slightly with depth to 51.6 µS/cm at the bottom. The pH was also slightly higher (0.3 units) at depth at 9.5 compared to the surface (Table 1).

Similar to profiles, water chemistry varied little between the surface and depth (Table 2). Concentrations of DP were less than detectable, while TP averaged 17 µg/L in the water column (Table 2). Nitrate + nitrite and ammonia were also below detectable concentrations, while total nitrogen averaged 28 mg/L (Table 2). This resulted in a TN:TP ratio of approximately 16. Alkalinity was 26 mg/L. The water column concentration of chlorophyll a averaged 18.1 (±7.6 SE) µg/L. Based on the equations in Carlson (1977), the trophic state index for Chl a was 59.3 and 45 for TP.

Table 1. Profiles of temperature, oxygen, conductivity, and pH for the Fredericks Pond on August 12, 2008.

Depth (m)	Temp (°C)	Oxygen (mg/L)	Oxygen (%)	Conductivity (µS/cm)	pH
0.0	20.5	9.3	103.8	50.2	9.5
0.5	20.3	9.49	104.4	50.5	
1.0	19.2	9.81	106.8	50.7	
1.5	18.5	10.84	114.1	51.0	
2.0	18.4	10.9	114.0	51.6	9.2

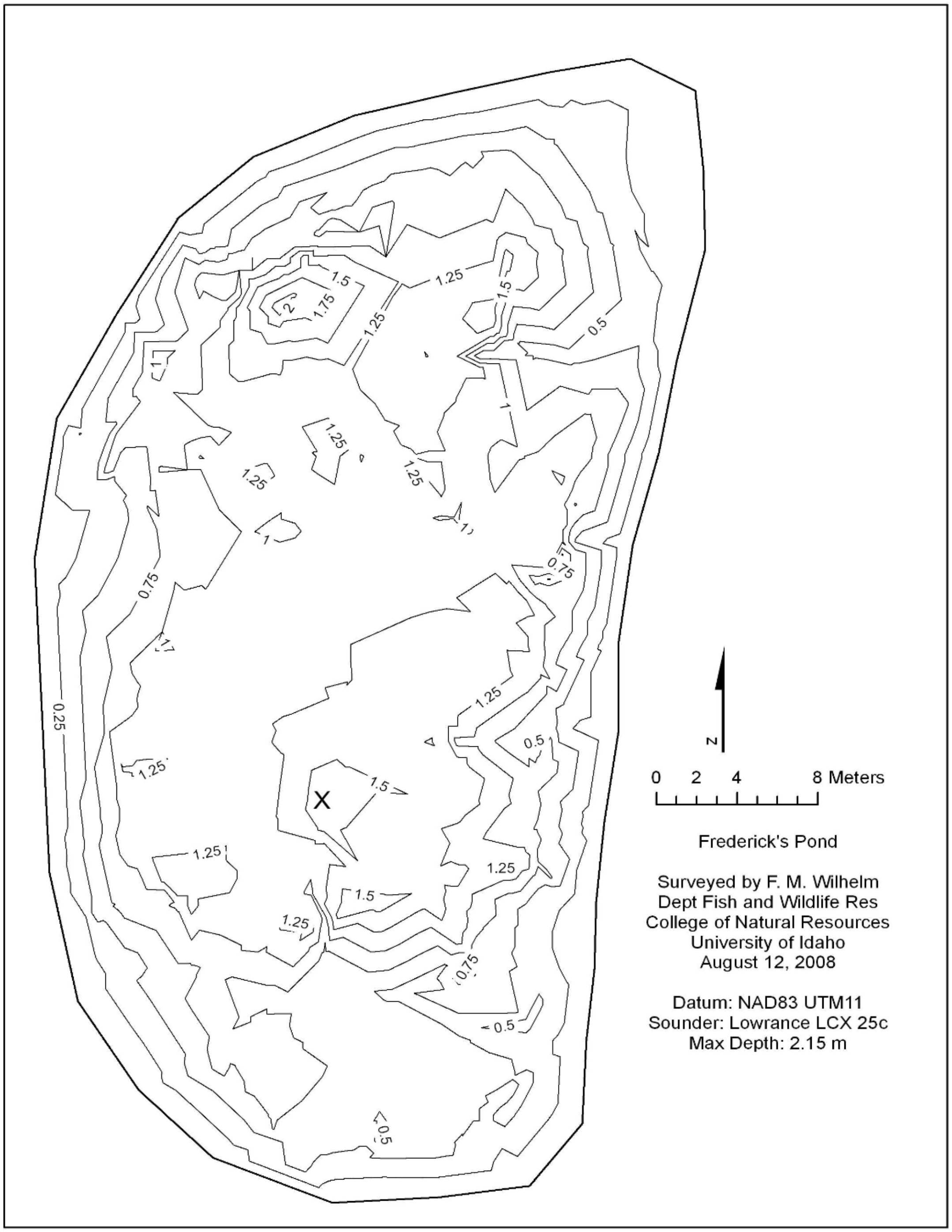

Figure 1. Bathymetric map of the Fredericks Pond used for the extensive culture of Burbot by IDFG. The location (X) marked near the southern 1.5 m deep site was used for sampling of abiotic and biotic parameters.

Table 2. Concentrations of nutrients and alkalinity in the Fredericks Pond used for extensive culture of Burbot.

Depth (m)	TP (µg/L)	DP (µg/L)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	TN (mg/L)	Alkalinity mgCaCO3/L	TN:TP
0.3	16	<6	<0.1	<0.1	0.24	26	15
1.5	18	<6	<0.1	<0.1	0.32	26	17.8

Zooplankton

The zooplankton community was composed of small-bodied cladocerans (*Bosmina* and *Ceriodaphnia*), while copepods were relatively scarce (Table 3). Numerically, copepod nauplii dominated at 112 ind./L. Of the cladocerans, *Bosmina* were most dense at 82 individuals/L (Table 3).

Table 3. Density of zooplankton sampled from the Fredericks Pond on August 12, 2008.

Taxon	Mean (Ind/L)		SE
Bosmina	82.1	±	13.0
Ceriodaphnia	56.5	±	3.7
Diaphanasoma	0.1	±	0.1
Calanoids	16.1	±	2.5
Cyclopoids	5.5	±	1.2
Nauplii	111.9	±	8.9

Few rotifers were observed and were at such low densities that they were not counted. Rotifer species observed included *Asplanchna*, *Keratella*, and *Kellicottia*.

Benthic invertebrates

Benthic invertebrates from the Ekman grab samples indicated a relatively simple community comprised primarily of oligochaete worms and chironomid larvae (Table 4). Several individuals of copepods, mites, and leeches were also found (Table 4).

Macrophytes

The macrophyte community was primarily composed of long-leaf pondweed (*Potamogeton amplifolus*), coontail (*Ceratophyllum demersum*). In sandy areas in the southwest corner, beds of plantain shoreweed (*Littorella uniflora*) were present. In the benthic grab samples several sprigs of Canadian pondweed (*Elodea canadensis*) were also found, indicating its presence.

Table 4. Benthic invertebrate community of the Fredericks Pond on Aug. 12, 2008.

Taxon	Average (ind/m^2)
Oligochaeta	3400.0
Chironomidae	1000.0
Copepoda	66.7
Ceratopogonidae	44.4
Hydrachnidia (Mites)	22.2
Hirudinae (leeches)	22.2

DISCUSSION

Overall this pond is a typical shallow water system in the clear water, macrophyte dominated state. The ground water input is relatively novel and may allow the temperature to be controlled to some degree. During this investigation, it was unclear if the inflow was being diverted or if it entered the pond. Two deep sites were noticed in the pond (Figure 1), one near the inflow at the northwest end of the pond and one near the southern end. Gill nets strung across the pond influenced the survey somewhat and tongues of land protruding into the pond on the east side may be due to the gillnets strung just under the surface. No correction was made for these. Some experimental boxes from IDFG near the maximum depth prevented anchoring and so samples were collected at the southern deep site (X on Figure 1).

Based on chemical analyses and the trophic state index calculations, the pond is eutrophic. This is relatively common for small ponds (Dokulil and Teubner 2003), and 11 ponds in Latah County examined by Bailey (1973) were all eutrophic. On the sampling day the pond was unstratified, and it is highly probable that this is the normal state throughout the year. As a result, oxygen concentrations were high throughout the entire water column and are likely to remain so for the entire open water season. The lack of stratification also means that as the pond warms from solar radiation, the entire water column will warm. The average water temperature on the sampling day was approximately 19°C, which was slightly cooler than other farm ponds examined by Bailey (1973). This may be the result of the groundwater inflow and should be considered for the culture of burbot. The TN:TP ratio was 16.5, indicating a balanced nutrient regime with regard to phytoplankton production (Wetzel 2001). However, TP concentrations were high 17 µg/L in the water column, indicating eutrophy. Thus the pond should not be manipulated for nutrient concentrations. The current balance is sufficient to prevent cyanobacteria blooms (Wetzel 2001) and should be monitored further. Although unstratified and eutrophic, the high oxygen and low ammonia concentrations make the pond suitable for the culture of fish based on these one-time estimates.

Shallow lakes typically occur in one of two states: turbid waters with high phytoplankton and suspended solids or clear water with high densities of macrophytes (Scheffer et al. 1993; Scheffer 1998; Dokulil and Teubner 2003). These are known as alternative stable states and systems can move between the two states. Macrophyte dominated systems generally occur in the absence of high water bird disturbance of macrophytes, and low planktivorous fish densities which allows large-bodied zooplankton to reduce phytoplankton abundance with high grazing pressure. A system can shift to a turbid state by disruption of macrophytes, or the introduction of planktivorous fish that graze zooplankton, thus releasing phytoplankton from grazing pressure. Blooms of algae then shade out macrophytes further releasing sediments that are no longer penetrated by roots. At the time of sampling, the Fredericks Pond was characteristic of a clear water system dominated by macrophytes, as they extended across the entire bottom and light penetrated to the bottom in all parts of the ponds. Photosynthesis from the macrophytes could explain the increasing oxygen concentration at depth (Table 1). Some macrophytes, especially coontail, are known to remove phosphorus from the water column and thus are favored amongst pond managers to control nutrients (Borman et al. 1999). The lack of detectable dissolved phosphorus concentrations (Table 2) may be an indicator of the effectiveness of the dense macrophytes. Care should be taken with future stockings that the macrophyte community continues to dominate to afford clear water for the rearing of fry. Drawdown and exposure of macrophyte roots to freezing temperatures may reduce the abundance of macrophytes and should be done with care. The macrophytes also provide good cover for small fish and zooplankton.

Zooplankton, although dense in the water column, are characteristics of communities affected by planktivore predation (Carpenter et al. 1985). *Bosmina* and *Ceriodaphnia* are two of the smallest cladoceran species, which typically become dominant with high planktivore predation (Brooks and Dodson 1965). Because they are so small, they can escape fish predation because they are not retained on gill rakers. Densities of the cladocerans were similar to those in farm ponds in Latah County (Bailey 1973). Numerically, copepod nauplii dominated the zooplankton (Table 3). Without additional samples, it is impossible to discern if this was a single population fluctuation or one of several cycles. Bailey (1973) observed two seasonal peaks in copepod abundance in ponds in Latah County. Peak densities typically occurred in July and March-April. Densities in the Fredericks Pond were comparable to those observed by Bailey (1973). Because cladocerans have a much slower escape response than copepods, they are a preferred food item of planktivorous fish. Thus, the plankton of the lake could be enhanced to a more diverse community of large-bodied cladocerans to provide a good prey base for planktivorous fish. This may be achieved by simply removing known planktivores. Water bodies contain a surprising diversity of resting eggs in sediments, which can easily build into healthy populations if given proper conditions. For example, after draining and dredging a small pond at Southern Illinois University, Martin (2007) found a diverse community of large-bodied *Daphnia* the following spring after the pond had refilled from winter snowmelt, without any other manipulations. A similar diversity may be achievable in the Fredericks Pond.

Benthic invertebrates were dominated by oligochaete worms and chironomid larvae. Many of the worms were ones that build tubes in sediments, and thus would be unavailable as prey to fish. Chironomid larvae were extremely small and thus may be hard to locate by fish. Other invertebrates may be present in upper parts of the macrophytes not adequately sampled by the Ekman grab sampler. However, the presence of large invertebrates is unlikely given the probable high predation of planktivores as indicated by the small-bodied zooplankton species in the pond. Additional collections at other times of the year should be undertaken to confirm the presence of absence of other large-bodied invertebrates.

This investigation presents a snapshot of the abiotic and biotic conditions in the Fredericks Pond on one day. Any conclusions reached here must be tempered by this fact. Additional seasonal investigations should be completed to ensure that the conditions observed on this one sampling occasion are a representative of conditions in the pond at other times of the year. Given the small size of the ecosystem, monthly samples should be sufficient to record significant changes.

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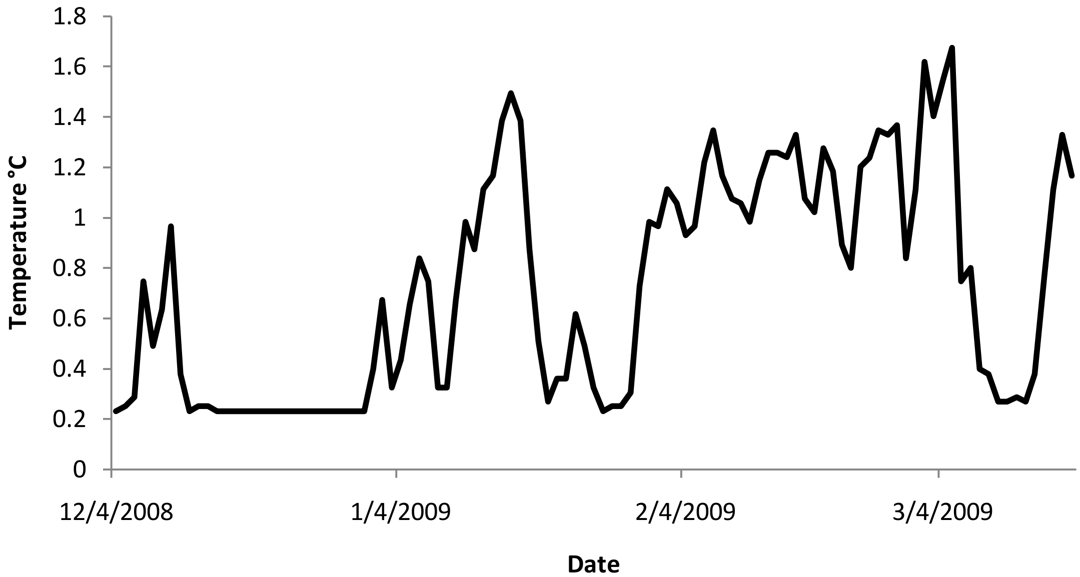
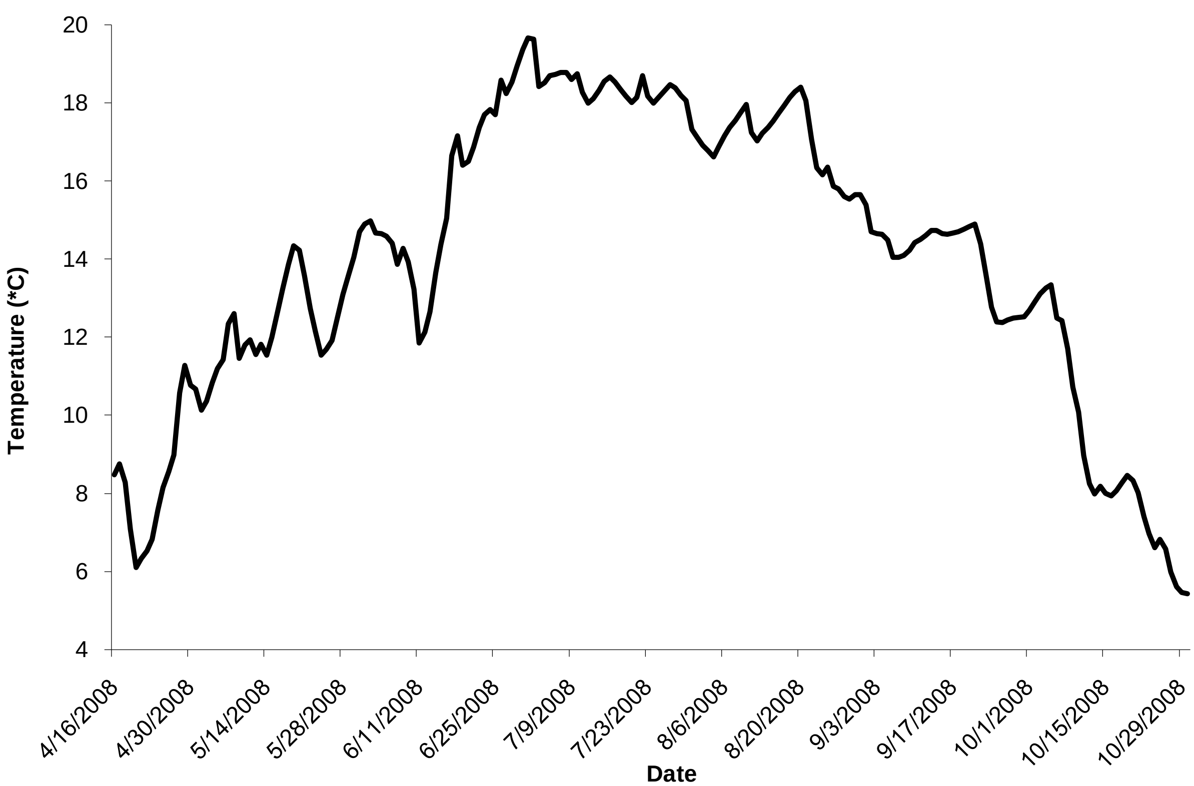
APPENDICES

Appendix 1. Boundary Creek (°C) mean daily temperature profile December 4, 2008 to March 18, 2009.



Appendix 2. Fredericks Pond (°C) mean daily temperature profile April 2008 to October 2008.



Appendix 3. Idaho Department of Fish and Game burbot hoop net captures and capture effort (burbot/hoop net day), winters (Wtr.) of 1993-2009.

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
Totals	392	23,108.9	0.017
Mean			0.019

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