FISHERY RESEARCH

# KOOTENAI RIVER FISHERIES INVESTIGATION: STOCK STATUS OF BURBOT

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## Project Progress Report

### 2007 Annual Report


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# CHAPTER—1 KOOTENAI RIVER FISHERIES INVESTIGATION: STOCK STATUS OF BURBOT

## ABSTRACT

Objectives of this investigation were to 1) monitor the population status and recruitment of burbot *Lota lota* in the Kootenai River, Idaho and British Columbia, Canada during the winter of 2006-2007; 2) evaluate the selective withdrawal system in place at Libby Dam to maintain the river temperature near Bonners Ferry between 1-4°C (November-December) to improve burbot migration and spawning activity; and 3) determine if a hatching success of 10% of eyed burbot embryos could be achieved through extensive rearing and produce fingerlings averaging 9.8 cm in six months. Water temperature did not fall below the upper limit (4°C) until mid-January but was usually maintained between 1-4ºC through February. Snowpack was characterized by a 110% of normal January runoff forecast and discharge from Libby Dam was not operated to the benefit of burbot. Adult burbot were sampled with hoop nets and slat traps. Only two burbot were captured in hoop nets: one at Nicks Island (river kilometer [rkm] 144.5), and one in the Goat River (rkm 152.7). No burbot were caught in either slat traps or juvenile sampling gear indicating the population is nearly extinct. Burbot catch per unit effort in hoop nets was 0.001 fish/net d, the lowest recorded since study began. Experimental rearing was attempted by the release of 100,000 eyed burbot embryos into Sinclair Lake. We sampled with light traps, ½ m nets, and minnow traps but were unable to show any hatching survival. The results of hatching in four incubators suggested hatching may have been about 0.05% but the collection of eggs shells in the incubators indicated it might have been as high as 2.75%. Dissolved oxygen (4.3 ppm) for a two-week period may have been too low to ensure survival. While the results of extensive rearing are inconclusive, the methodology deems further research.

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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. 2000) 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 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. 2000). Demographic studies indicate that the Kootenai River burbot population may likely become extinct 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, particularly during the winter when burbot spawn (Figure 2). The temperature regime and nutrient supply of the Kootenai River are also thought to be important factors for burbot spawning and recruitment; they too have changed since construction of Libby Dam (Partridge 1983; Snyder and Minshall 1996; Richards 1996).

The Kootenai River Fisheries Investigation was initiated in 1993 by the Idaho Department of Fish and Game (IDFG) to document burbot abundance, distribution, size structure, reproductive success, movement, and to identify factors limiting burbot. From 1993 through 1994 (Paragamian 1994), 25 burbot were caught between rkm 122 (Kootenay Lake) and 246 (Bonners Ferry) but only one burbot was captured between rkm 246 (Bonners Ferry) and rkm 275 (Montana state line). There has been little evidence of burbot reproduction in the Idaho reach. Only one juvenile burbot and one larval fish were collected between 1993 and 1998. However, numerous size-classes of burbot were in the catch, indicating some burbot were reproducing successfully albeit insufficiently to sustain the population while genetic analysis suggests some emigration has come from above Kootenai Falls (Paragamian et al. 1999). Cooperative sampling in the British Columbia reach of the river with the British Columbia Ministry of Environment (BCME) documented spawning burbot in the Goat River, British Columbia (Paragamian 2000), and during the winter of 2000-2001 a "spawning ball" of burbot was documented at Ambush Rock (Kozfkay and Paragamian 2002). Since then other potential spawners were captured in the same location, but the numbers have been low.

Studies completed during the winter of 1997-1998 indicated discharge from Libby Dam likely affected burbot spawning migration during winter (Paragamian 2000). Movement of burbot with sonic transmitters was significantly higher during low discharge test conditions designed to mimic pre-dam Kootenai River discharge. Movement upstream was also significantly higher during low discharge tests (170 $m^3/s$) than the control (170–736 $m^3/s$), despite the fact that there were low discharges during the controls. Post-dam winter discharges are now three to four times greater than they were historically when conditions were relatively stable (Figure 2). The specific effect of this disruption to burbot spawning migration and spawning is unknown, but it may have reduced spawning fitness or stamina or affected timing of burbot spawning which could have been sufficient to contribute to reduced spawning success and recruitment.

Because burbot in the Kootenai River are at risk of demographic extinction (Paragamian 2000), a Conservation Strategy (Anonymous 2002; KVRI Burbot Committee 2005) was prepared to outline measures necessary to rehabilitate the burbot population. The Conservation Strategy indicated that operational discharge changes at Libby Dam are required during winter to provide suitable conditions for burbot migration. However, the upper limit of discharge releases for adequate burbot spawning, migration, and flood control were unknown for inclusion in a more

recent Conservation Agreement (KVRI Burbot Committee 2005). Paragamian et al. (2005) used telemetry records of burbot collected from 1994 through 2000 to determine how discharge factors affect burbot travel distance and travel rate. The majority of seasonal burbot movements of 5 km or more in 10 d or less occurred when discharges were ≤300 $m^3/s$ from Libby Dam and averaged 176 $m^3/s$ (Paragamian et al. 2005). Results of additional movement studies indicated burbot moved more frequently during lower discharges. Consequently, it was recommended that discharge for burbot prespawning migration should range from 113 to 300 $m^3/s$ and average 176 $m^3/s$ for a minimum of 90 d (mid-November through mid-February) (Paragamian et al 2005).

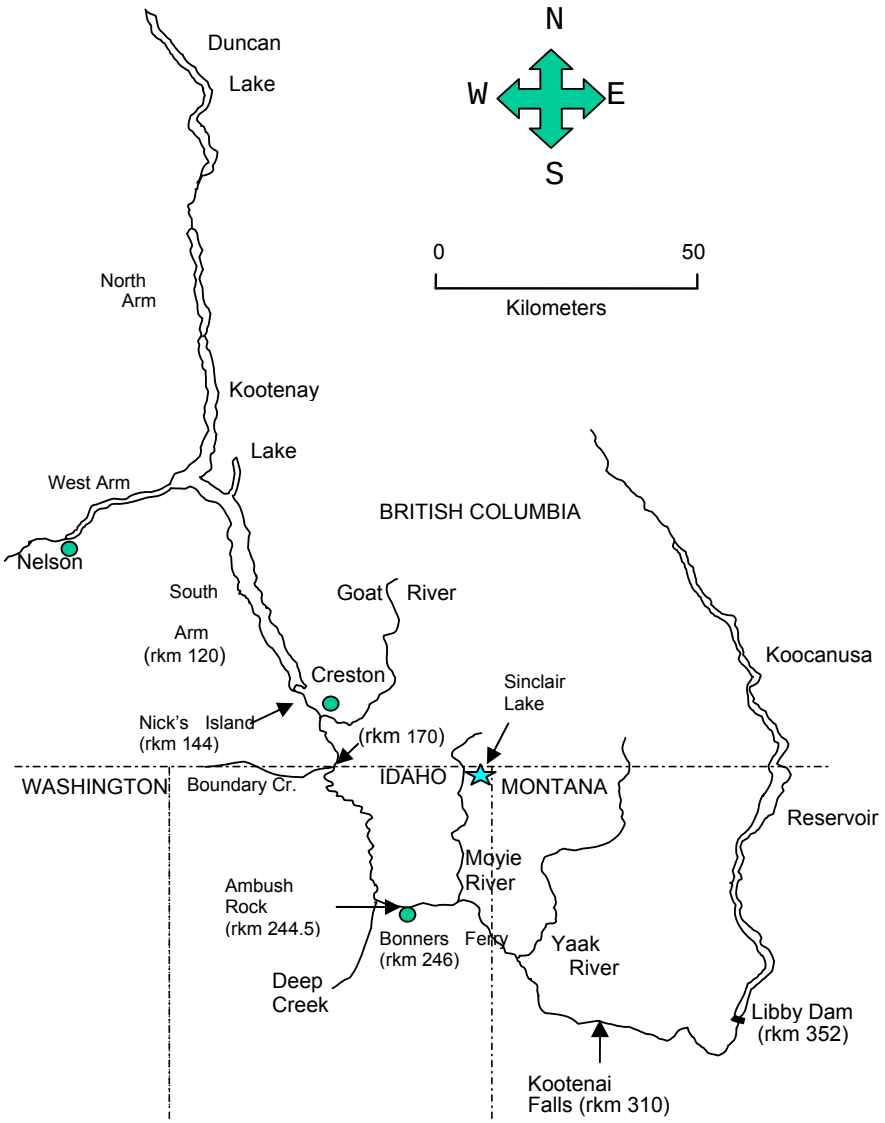


Figure 1. Location of the Kootenai River, Kootenay Lake, Lake Koocanusa, and major tributaries. The river distances from the northernmost reach of Kootenay Lake are in river kilometers (rkm) and are indicated at important access points.

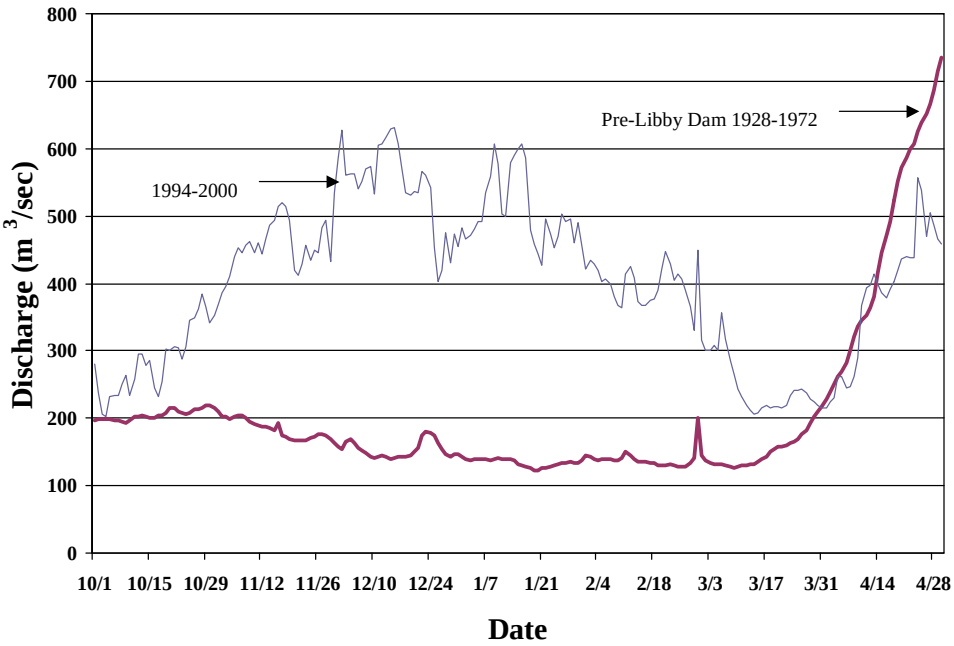


Figure 2. Mean daily discharge of the Kootenai River at Porthill, Idaho from 1962 through 1971 (pre-Libby Dam), and from 1994 through 2000 (post-Libby Dam).

Post-Libby Dam temperature changes are an additional factor affecting the spawning and recruitment of burbot in the Kootenai River (Paragamian and Wakkinen 2008). Partridge (1983) found temperature of the Kootenai River is now cooler in the summer and warmer in the winter by several degrees C (Figure 3). Burbot spawn at temperatures of 1-4°C (McPhail and Paragamian 2000), and even subtle temperature changes in the Kootenai River could have affected the timing and maturation rate of burbot. In addition, temperatures above 6°C cause mortality in larval burbot (Taylor and McPhail 2000). Paragamian and Wakkinen (2008) modeled burbot migrations based on temperature and discharge and found that burbot migration was predictable under pre-Libby Dam conditions but erratic post Libby Dam. This partially explained why burbot migrations post Libby Dam are late and occur at temperatures warmer than expected for spawning. Thus, it is important to determine how modifying the discharge and temperature from Libby Dam during winter may improve burbot migrations.

Conservation biologists and geneticists estimate that a minimum effective breeding population ($N_e$) of at least 50 to 500 individuals is necessary to sustain a viable population (Soule 1980; Lande and Barrowclough 1987). Genetic and demographic risks and uncertainties with fewer individuals are high (Allendorf and Ryman 2002; McElhany et al. 2000; Musick 1999). Currently there are perhaps fewer than 50 burbot in the population (Chapter 2, this document). Any expectations that this population can recover within the next decade are unreasonable even with the most suitable habitat, changes in winter discharge, winter temperatures, and improved

primary production. Thus, it is of crucial importance that remedial measures to improve this stock's abundance begin immediately.

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, although progressing, are not standardized sufficiently to consistently provide large numbers of young for stocking (Jensen et al. 2008; Vught et al. 2008). However, extensive rearing of eyed burbot embryos or larvae has been shown effective in burbot restoration (Dillen et al. 2008; Vught et al. 2008) and in the interim may be a more valuable tool in burbot rehabilitation than stocking eyed embryos.

Therefore, we evaluated the physical attributes of four prospective lakes for extensive rearing of burbot. We selected Sinclair Lake for extensive burbot rearing based on eight features: location, water source, water depth, boat access, shoreline access, absence of a fish community, temperature, and low perceived risk of summer or winter kill. Sinclair Lake has easy access with a boat ramp, is over 7 m deep, and has no outlet (a seepage lake). Sinclair Lake is in the Moyie River drainage, was previously treated with Rotenone to eliminate the fish community, and has sufficiently cool summer surface temperature (~20°C).

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. Coordination of this study with Matt Neufeld (BCME) and the University of Idaho Aquaculture Research Institute (UIARI) (Dr. Ken Cain and Nathan Jensen) indicated Moyie Lake burbot could be captured from Moyie Lake, spawned at UIARI, and eyed eggs transported to Sinclair Lake for extensive rearing.

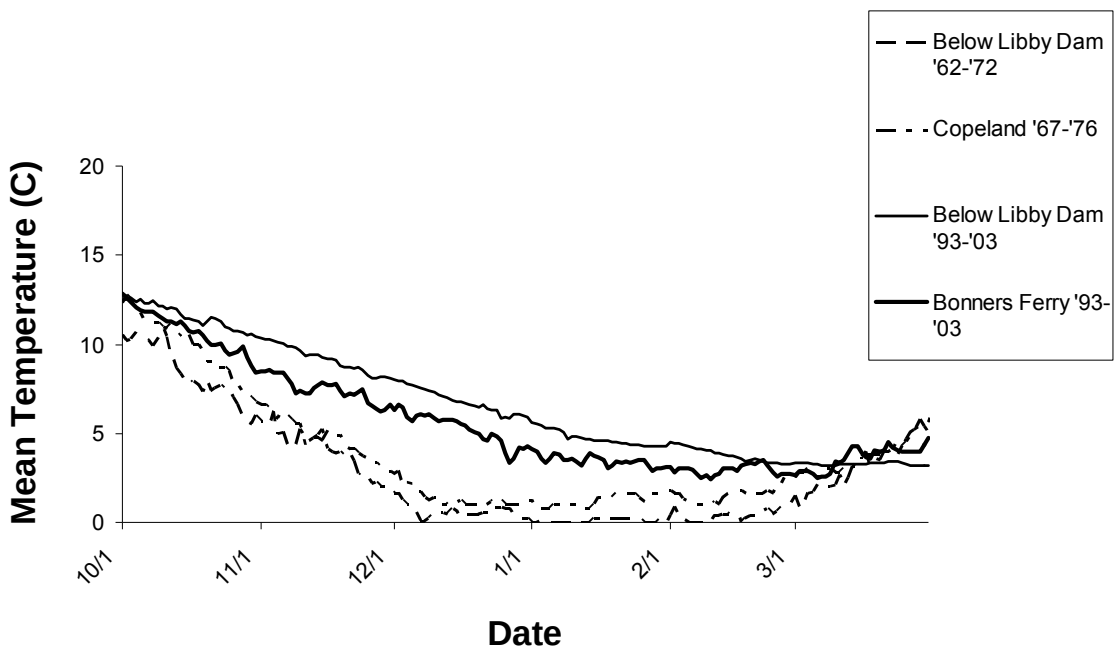


Figure 3. Pre-Libby Dam Kootenai River temperatures at the dam site 1962-1972, at Copeland, Idaho 1967-1972 and post Libby Dam below the dam from 1993-2003, and at Bonners Ferry, Idaho from 1993-2003.

## 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. Determine if the selective withdrawal system in place at Libby Dam can maintain the river temperature near Bonners Ferry between 1-4°C (November-February) to improve burbot migration and spawning activity.

2. Determine the population trajectory and vital statistics of burbot through mark and recapture studies (survival, population numbers, recruitment, size structure).

3. Determine if releasing eyed burbot embryos reared extensively can produce a hatching rate of 10% or more and fingerlings up to 98 mm in length within 6 months of stocking.

## 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.

## 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 2006-2007 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 2006-2007 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 1-4ºC (Figure 4). 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 Smith, Deep, Myrtle, and Boundary creeks in Idaho; Corn, and Summit creeks and the Goat River in British Columbia; and the Kootenai River at Porthill, Idaho and Nicks Island, British Columbia from October 2006 through March 2007. At each location, mean temperature was calculated from five evenly spaced daily measurements. A temperature logger was deployed less than 50 meters upstream from each tributary creek confluence with the Kootenai River. In Summit and Boundary creeks, an additional thermograph was placed approximately 500 meters upstream. Data from these loggers would be used to assess whether infiltration of Kootenai River surface water into creek mouths 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.

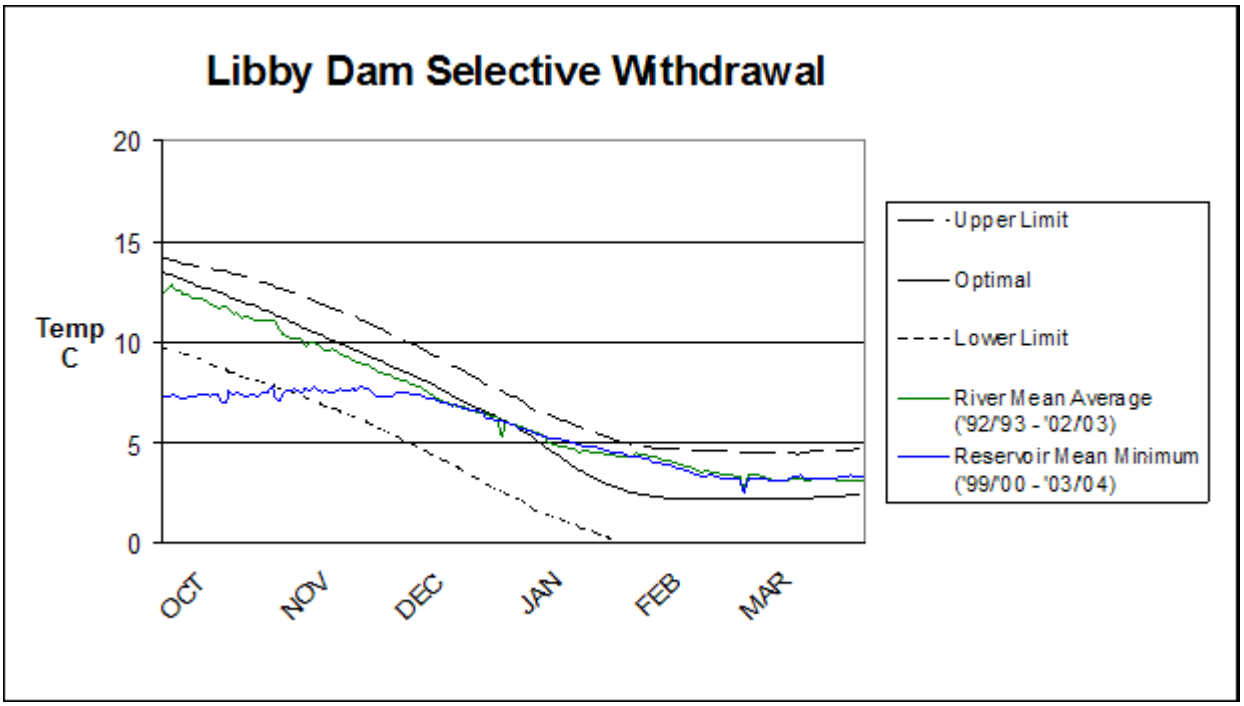


Figure 4. Selective withdrawal temperature guidelines for the Kootenai River below Libby Dam. Figure courtesy USACE.

## Burbot Sampling

### Adult Burbot

Technicians sampled adult burbot from early November 2006 through March 2007 with up to 15 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 three hoop nets of 19 mm bar web constructed to compare to the catch to the standard web of 25.4 mm. We used 12 nets with 25.4 cm bar mesh, pairing three of them with nets having 19 cm bar mesh for a total of 15 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, chapter 2), size structure (PSD), body condition ($W_r$), and abundance (CPUE) (see Paragamian and Laude in progress 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, 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, Boundary Creek and the international boundary, Goat River, and Ambush Rock, because burbot numbers are low and we wanted to maximize our opportunity to capture them. We also sampled three tributary streams including Deep Creek near Bonners Ferry, Idaho (rkm 240); 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; sex of burbot could not be determined. We calculated relative weight ($W_r$; Fisher et al. 1996) for each burbot captured.

**Burbot Telemetry**

In 2006-2007, we continued monitoring the movement of burbot tagged the previous season. We implanted Vemco V13-1L-R04K coded acoustic pinger transmitters in burbot during the winter of 2005-2006. This transmitter is 13 mm and is 36 mm, has an approximate battery life of 3 years, and weighs 6 grams in water. We deployed an array of passive Vemco VR2 sonic fixed telemetry receivers from Kootenay Lake, British Columbia upstream into Idaho near the Montana border during the previous three seasons for the Kootenai River white sturgeon *Acipenser transmontanus* project (Rust and Wakkinen 2005). This array allows for efficient, cost-effective monitoring of sturgeon and burbot movements throughout the Kootenai system and will aid in our understanding of seasonal movement patterns and seasonal behavior.

Seven burbot were implanted with Vemco coded transmitter tags between October 2005 and March 2006 and because the later data were unavailable for our previous report, we included them here. Three were tagged near Nicks Island (rkm 144.5), two were tagged near the mouth of the Goat River (rkm 152.7), and two were tagged at Ambush Rock (rkm 244.5). Vemco VR2 single channel monitoring receivers were placed in Deep, Smith, and Boundary creeks in Idaho, and in the Goat River and Summit Creek in Canada to determine burbot use of the tributary streams. Vemco receivers in the Kootenai River were also monitored for burbot movement.

## Larval Burbot

### Light Traps

Technicians sampled for larval burbot in the Kootenai River with light traps described by Fisher (2000). Light traps were made from four plastic cylinders joined laterally, described as a quatrefoil measuring approximately 25 cm by 30 cm. Traps were suspended near the water surface and powered by a 12 h photochemical stick. We deployed three light traps per night on May 21, 2007 and May 22, 2007 between Ambush Rock (rkm 244.5) and Deep Creek (rkm 240.3). The light traps were deployed at dusk and checked the next morning.

## Extensive Burbot Rearing

### Eyed Embryo Release

An experiment devised to measure the success of extensive rearing was implemented by releasing eyed burbot embryos into Sinclair Lake, 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. Sinclair Lake is about 3 km south of the international border on east side of the Moyie River (Figure 1). Eyed burbot embryos 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. Adult brood fish were captured in November 2006 from Moyie Lake, BC, Canada using baited cod traps (Spence 2000; Neufeld and Spence 2005). Moyie Lake is in the Kootenai River drainage and located about 20 km north of Sinclair Lake. Available eyed burbot embryos were to be released under the ice in March of 2007.

### Incubators

Hatching success was experimentally measured by suspending four 1-liter bottles that held 1,000 eggs each. Each incubation bottle had a 5 x 10 cm panel cut out of two sides and replaced with fine mesh (to allow respiration and gas exchange) and was filled with marbles to separate eggs (Figure 15). Bottles were retrieved only after sufficient thermal units had accumulated to ensure some eggs had hatched.

### Light Traps

When ice melted off Sinclair Lake, we sampled for larval burbot with light traps described by Fisher et al. (1996). Up to eight traps were deployed at dusk and checked the next morning.

### ½ Meter Net Tows

We sampled for larval burbot in Sinclair Lake by towing a single ½ m net (mouth area = 0.79 $m^2$) with a 3.5 m boat. We towed the net at the surface with a Gurley 2030R current meter mounted in the mouth of the net. Tows were made at the margins of aquatic macrophyte growth in about 3 m of water and across the midpoint of the lake. Effort was calculated using total towing time and rotation counts per second from the current meters x mouth area (0.79 $m^2$) to

calculate the total volume of water filtered through each net. Four ½ m net tows were made on June 6, 2007 followed by four more on June 18, 2007.

### Minnow Traps

Standard minnow traps measuring 228.6 mm in diameter by 444.5 mm in length were deployed to capture age-0 burbot. We deployed six minnow traps periodically from July 23 through August 16, 2007; half were baited with commercial cat food while the remainder were unbaited (Fredericks and Fleck 1995).

### Zooplankton

Surface and vertical tow samples were collected six times between March 12, 2007 and June 26, 2007. Surface samples were collected using a 10L bucket. The sample was then poured through a 63µm filter. Vertical tow samples were collected using a 63µm Turtox plankton net.

### Water Quality

Ammonium (NH4), nitrate (NO3), percent dissolved oxygen (%DO), dissolved oxygen (DO), temperature (°C), barometric pressure (mmHG), depth (m), total dissolved solids (TDS), PCY, specific conductivity (SPC), turbidity (NTU) and pH levels were collected six times between March 12, 2007 and June 25, 2007. Measurements were taken at the surface and 1.6 m of depth with a Hydrolab© DS5 and attached SURVEYOR© 4a handheld display (Table 5).

### Sinclair Lake Temperature

We deployed a single HOBO® temperature logger in Sinclair Lake to monitor daily temperature fluctuations (Appendix 13).

## RESULTS

### Kootenai River Discharge and Temperature

Snow pack the winter of 2006-2007 averaged 110% and flows from Libby Dam were not managed for burbot migration or spawning. However, peak flow for the winter occurred for a short period at Bonners Ferry at about 820 $m^3/s$ the second week in November 2006 while the peak discharges from Libby Dam occurred in December 2006 and late January 2007 (Figure 5). Discharge from Libby Dam followed a typical power peaking pattern for the winter of 2006-2007 with the lowest discharge matching up with holidays when the power demand was lowest.

### Kootenai River Temperature

Mean water temperature at the USGS gage near Bonners Ferry, Idaho (rkm 245.7) was 4.3ºC ranging from 2.0°C to 7.9°C (Figures 6 and 7). Mean water temperature at Porthill, Idaho (rkm 169.8) was 8.1°C ranging from -0.6°C to 17.8°C (Figure 6 and 7). Mean water temperature at Nicks Island (rkm 144.5) was 3.4ºC ranging from 1.6°C to 5.3°C (Figures 6 and 7).

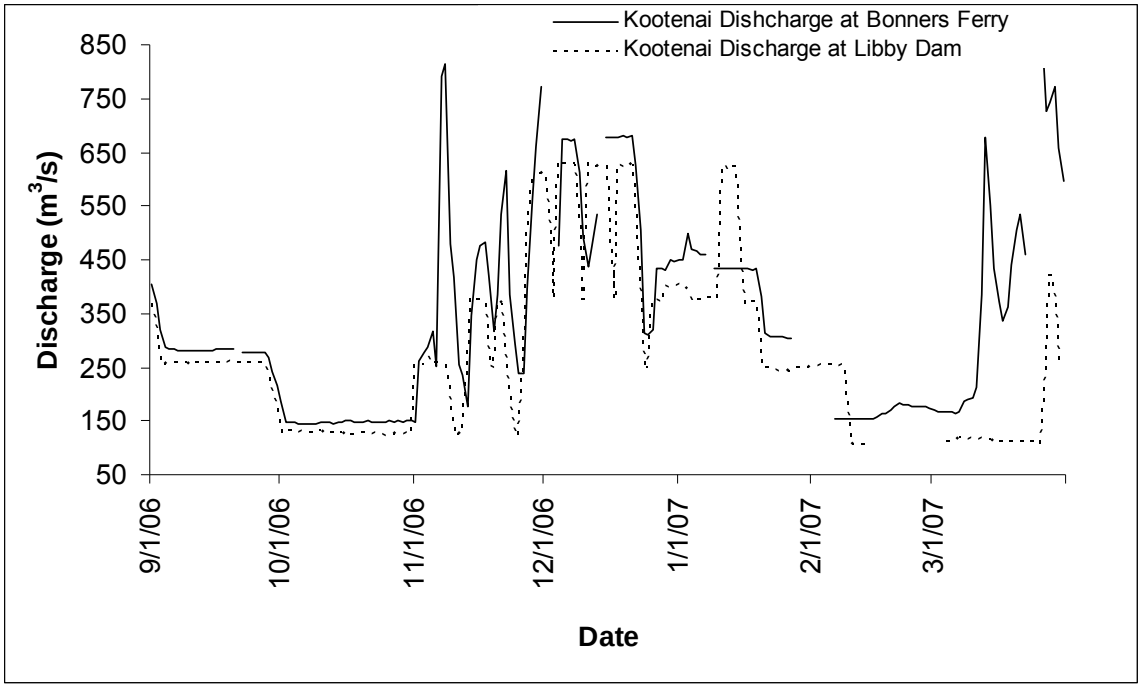


Figure 5. Discharge at Libby Dam and as estimated at Bonners Ferry, Idaho winter 2006-2007. The Kootenai Basin was at about a 110% snow pack winter as measured in the Canadian Rockies for the winter of 2006-2007.

Mean water temperature at Bonners Ferry for the months of November through December were usually well above the upper limit of 4ºC as prescribed by the 2006-2007 SOR but usually below 6ºC (Figure 7). Water temperature did not fall below the upper limit until mid-January but was usually maintained between 1-4ºC through February.

## Tributary Temperatures

### Idaho

Mean water temperature of Deep Creek was not recorded due to a missing thermograph and the Smith Creek thermograph was lost to vandalism. Water temperature did not record on Myrtle Creek or upper Boundary Creek due to malfunctioning thermographs. Mean water temperature of lower Boundary Creek was 0.6°C ranging from -0.6°C to 5.3°C (Appendix 1).

### Canada

Mean water temperature in the upper Goat River was 0.7°C, with temperatures ranging from -0.1°C to 5.3°C (Appendix 2). The lower Goat River thermograph was damaged by local wildlife and temperature data were lost. Mean water temperature in upper Corn Creek was 0.7°C ranging from -0.1°C to 3.2°C (Appendix 3). Mean temperature in lower Corn Creek was 1.3°C ranging from 0.2°C on to 4.9°C (Appendix 4). Mean water temperature in Summit Creek was 0.1°C ranging from -1°C to 2.4°C (Appendix 5).

Figure 6. Kootenai River at Bonners Ferry, Idaho (rkm 244.5), Porthill, Idaho (rkm 170), and Nicks Island, BC (rkm 144.5), (°C) mean daily temperature profile November 1, 2006 to March 14, 2007.

## Adult Burbot Sampling

### Total Catch

Baited hoop nets were fished from November 16, 2006 through March 8, 2007 for a total of 35,938 h or 1,497 net d. Forty-four fish were caught including nine different fish species and one species of crayfish *Pacifastacus spp.* (Table 1). Northern pikeminnow *Ptychocheilus oregonensis* was the most abundant species caught (n = 16), totaling 35% of the hoop net bycatch (Figure 8). Catch per unit effort was 0.026 fish/net d for all species of fish (excluding crayfish).

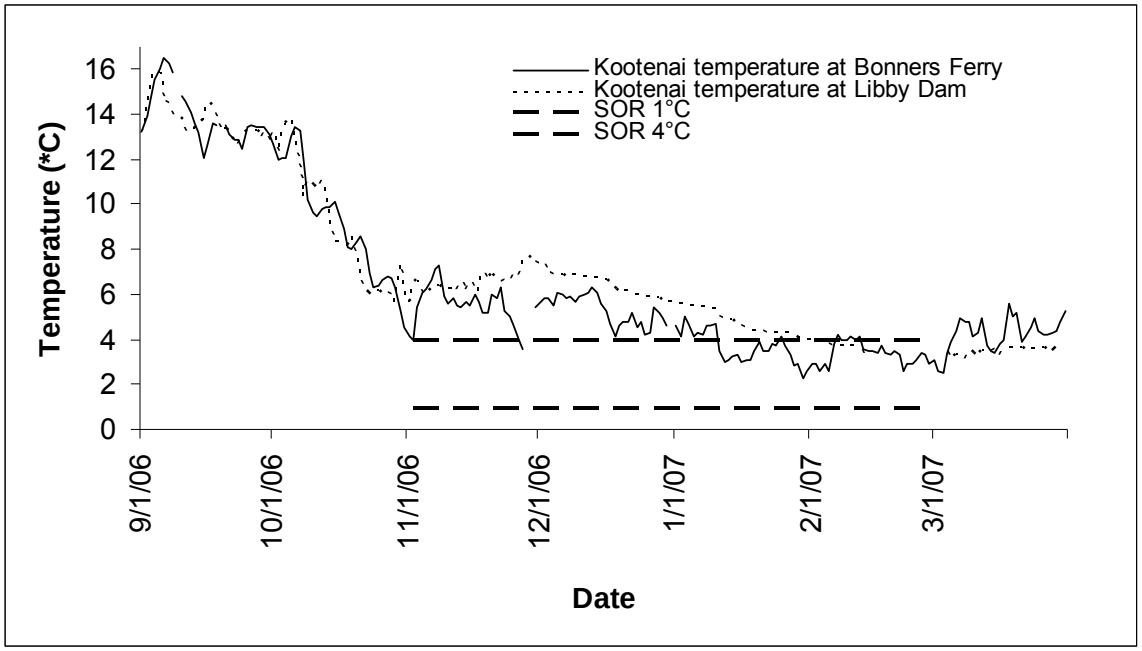


Figure 7. Temperatures of the Kootenai River at Libby Dam and Bonners Ferry, and the horizontal dashed lines indicate the upper and lower bounds for the Systems Operation Request temperature range of 1 and 4°C.

After two weeks of sampling at Ambush Rock excessive snags, debris, and overall net loss prompted the removal of hoop nets for the season and replaced with wooden slat traps. Wooden slat traps were deployed from February 5, 2007 through March 7, 2007 for a total of 1,438 h or 60 trap d. No fish were caught in the slat traps during this time. Slat trap effort was not used in catch-per-unit effort calculations because they were not used in previous years and would introduce gear bias in the long term data set.

**Hoop Net Catch of Burbot**

Throughout the winter of 2006-2007, two burbot were captured in baited hoop nets (Figure 8 and Table 1). The first burbot was captured in the Goat River on February 19, 2007. It was a mature, gravid female. She did not have a PIT tag so it is likely this fish was not captured in prior years. The second burbot was caught at rkm 150 on February 26, 2007 of unknown sex, and did not have tags or evidence of prior tags. Hoop net catch per unit effort for burbot was 0.001 fish/net d or 749 net d/fish with effort divided between Idaho and British Columbia (Tables 2 and 3). Burbot total lengths were 633 mm and 766 mm TL. Burbot weights were 1,600 g and 2,199 g.

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 2006 through March 2007 with 1,497 d of effort (35,938 h of effort).

| Species | Number | Total Weight (g) | CPUE[a] |
|---|---|---|---|
| Northern Pikeminnow *Ptychocheilus oregonensis* | 16 | 8656 | 0.011 |
| Burbot *Lota lota* | 2 | 3,799 | 0.001 |
| Sucker[b] *Catostomus catostomus* and *C. macrocheilus* | 2 | 236 | 0.001 |
| White Sturgeon *Acipenser transmontanus* | 3 | 392 | 0.002 |
| Yellow Perch *Perca flavescens* | 2 | 132 | 0.001 |
| Bullhead *Ameiurus spp* | 7 | 458 | 0.005 |
| Pumpkinseed Sunfish *Lepomis gibbosus* | 3 | 10 | 0.002 |
| Mountain Whitefish *Prosopium williamsoni* | 4 | 443 | 0.003 |
| Crayfish *Pacifastacus* spp | 5 | 254 | 0.003 |
| Total[c] | 44 | 14,380 | 0.026 |

[a] A unit of effort is a single hoop net set for 24 hours.
[b] Includes longnose and largescale sucker.
[c] Crayfish excluded from data.

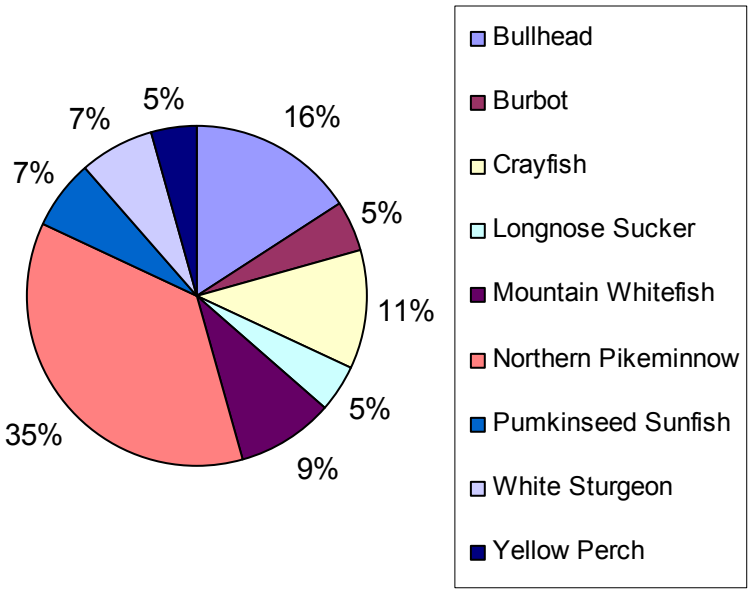


Figure 8. Hoop net species composition for the Kootenai River, Idaho and British Columbia from November 16, 2006 through March 8, 2007.

Table 2. Idaho Department of Fish and Game burbot hoop net captures and capture effort in at Nicks Island, vicinity of Creston Boat ramp/Goat River, and Ambush Rock, October 2003-April 2004, November 2004-April 2005, October 2005-March 2006, and November 2006-March 2007.

| Sample year | River kilometer | Number of burbot captured | Total net days | CPUE (fish/net day) |
|---|---|---|---|---|
| 2003-2004 | 120-152.9 | 0 | 378 | 0 |
| | 153-169.9 | 0 | 47 | 0 |
| | 170 + | 19 | 1540 | 0.123 |
| 2004-2005 | 120-152.9 | 2 | 807 | 0.002 |
| | 153-169.9 | 0 | 0 | 0 |
| | 170 + | 16 | 587 | 0.027 |
| 2005-2006 | 120-152.9 | 11 | 897 | 0.012 |
| | 153-169.9 | 0 | 0 | 0 |
| | 170 + | 3 | 501 | 0.006 |
| 2006-2007 | 120-152.9 | 2 | 1223 | <0.001 |
| | 153-169.9 | 0 | 175 | 0 |
| | 170 + | 0 | 100 | 0 |

Table 3. Idaho Department of Fish and Game burbot hoop net captures and capture effort (burbot/hoop net day), winters (Wtr.) of 1993-2007.

| Sampling Season | Number of Burbot Captures | Total Net Days | CPUE (burbot/net day) |
|---|---|---|---|
| Wtr. 1993: Mar. 1993-May 1993 | 17 | 554 | 0.031 |
| Wtr. 1994: Oct. 1993-April 1994 | 8 | 910 | 0.009 |
| Wtr. 1995: Nov. 1994-Feb. 1995 | 33 | 689 | 0.048 |
| Wtr. 1996: Nov. 1995-Mar. 1996 | 28 | 496 | 0.056 |
| Wtr. 1997: Oct. 1996-Mar. 1997 | 23 | 1,061 | 0.022 |
| Wtr. 1998: Oct. 1997-May 1998 | 42 | 1,241 | 0.034 |
| Wtr. 1999: Oct. 1998-April 1999 | 44 | 1,454 | 0.030 |
| Wtr. 2000: Oct. 1999-April 2000 | 36 | 1,713 | 0.021 |
| Wtr. 2001: Oct. 2000-Mar. 2001 | 73 | 2,085 | 0.035 |
| Wtr. 2002: Oct. 2001-April 2002 | 17 | 1,530 | 0.011 |
| Wtr. 2003: Oct. 2002-Mar. 2003 | 11 | 1,810 | 0.006 |
| Wtr. 2004: Nov. 2003-Mar. 2004 | 19 | 1,965 | 0.010 |
| Wtr. 2005: Nov. 2004-April 2005 | 18 | 2,046 | 0.009 |
| Wtr. 2006: Oct. 2005–Mar. 2006 | 14 | 2,000 | 0.007 |
| Wtr. 2007: Nov. 2006-Mar. 2007 | 2 | 1,497 | 0.001 |
| Totals | 385 | 21,050 | 0.018 |
| Mean | | | 0.024 |

**Burbot Movement**

Because telemetry data were unavailable for the previous report, we have included a summary of results for all fish (Table 4 and Appendices 6 through 12). Burbot 338 was tagged on January 13, 2006 at rkm 244.5. It had very limited movement, remaining within one kilometer of the tagging site until the last contact on August 1, 2006 (Appendix 6). Burbot 341 was tagged on March 2, 2006 at rkm 244.5. It remained within three kilometers of the tagging site until June 4, 2006. It then moved upstream to rkm 275.5 on August 7, 2006 (Figure 9 and Appendix 7). Burbot 339 was tagged on February 8, 2006 at rkm 152.7. It moved into the Goat River on February 15, 2006, and then moved back to the Kootenai River on February 21, 2006 (Figure 10 and Appendix 8). It then moved downstream and briefly entered Summit Creek, re-entered the Kootenai River, and continued downstream to rkm 122.5 near Kootenai Lake on February 22, 2006. It was detected several times between March 15, 2006 and August 31, 2006 at rkm 113 in Kootenay Lake. Burbot 327 was tagged on December 21, 2005 at rkm 144.5. It was detected at rkm 140.5 on December 29, 2005 (Figure 11 and Appendix 9). The Summit Creek Vemco receiver detected burbot 327 on February 26, 2006 and again on March 5, 2006. This fish was detected several hundred times in the Kootenai River near the mouth of Summit Creek (rkm 140.5) from March 17, 2006 through April 2, 2006. It then moved upstream to the point of last detection at rkm 147 April 7, 2006. Burbot 335 was tagged December 12, 2005 at rkm 144.5 and made a steady downstream movement between the tagging site and the last contact December 30, 2005 at rkm 113 in Kootenay Lake (Figure 12 and Appendix 10). Burbot 340 was tagged February 8, 2006 at rkm 152.7 and recorded on the Goat River Vemco receiver on February 24, 25, and 28, 2006, again on March 23, 2006, and once more on February 11, 2007 (Appendix 11). It was not detected in the Kootenai River. Burbot 334 was tagged on November 30, 2005 at rkm 144.5 and was detected at rkm 140.5 on December 20, 2005 through December 24, 2005 (Figure 13 and Appendix 12). This fish then moved upstream and was detected at rkm 199.1 on March 28, 30 and April 4, 2006. The next detection was at rkm 184.9 on May 10, 2006. Burbot 334 then moved upstream and was detected at rkm 224.2 on December 10, 2006. The last known location of this burbot was rkm 184.9 on March 22, 2007.

Table 4. Burbot identification number, location of capture, date of capture, total length, weight, and tag code for burbot implanted with sonic transmitters.

| Fish ID number | Location of capture (rkm) | Date of capture | Total Length | Total Weight (g) | Tag Type | Tag Code |
|---|---|---|---|---|---|---|
| 333 | 144.5 | 11/1/05 | 383 | 322 | na | |
| 279 | 144.5 | 11/14/05 | 732 | 2,793 | na | |
| 329 | 244.5 | 11/18/05 | 645 | 1,596 | na | |
| 334 | 144.5 | 11/28/05 | 714 | 2,294 | Vemco | 282 |
| 335 | 144.5 | 12/9/05 | 539 | 965 | Vemco | 285 |
| 327 | 144.5 | 12/16/05 | 561 | 1,126 | Vemco | 106 |
| 336 | 144.5 | 1/3/06 | 368 | 366 | na | |
| 337 | 144.5 | 1/9/06 | 515 | 781 | na | |
| 338 | 244.5 | 1/12/06 | 714 | 2,662 | Vemco | 283 |
| 339 | 152.7 | 2/6/06 | 624 | 1,673 | Vemco | 082 |
| 340 | 152.7 | 2/6/06 | 588 | 1,235 | Vemco | 284 |
| 341 | 244.5 | 2/23/06 | 713 | 1,860 | Vemco | 111 |
| 342 | 150 | 2/26/07 | 766 | 2,199 | na | |
| 999[a] | 244.5 | 3/7/06 | 460 | na | na | |
| 999[a] | 150.3 | 3/21/06 | na | na | na | |
| 999[a] | Goat R. | 2/19/07 | 633 | 1,600 | na | |

[a] Data insufficient to assign fish number.

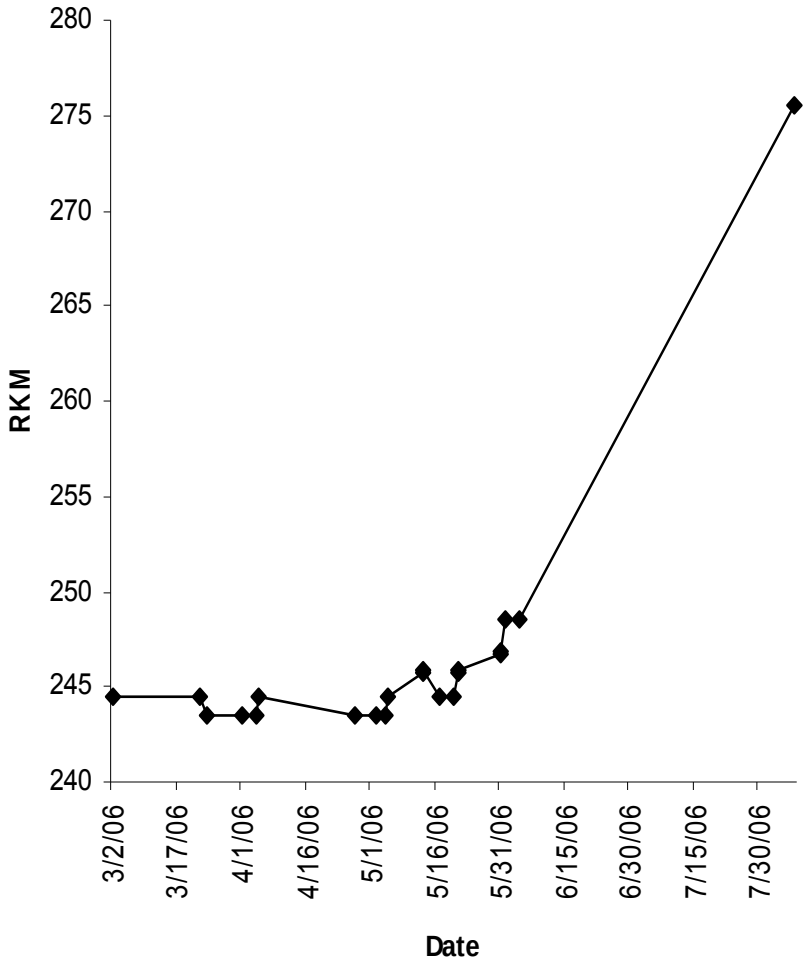

Figure 9. Burbot 341 movement between March 2, 2006 and August 7, 2006.

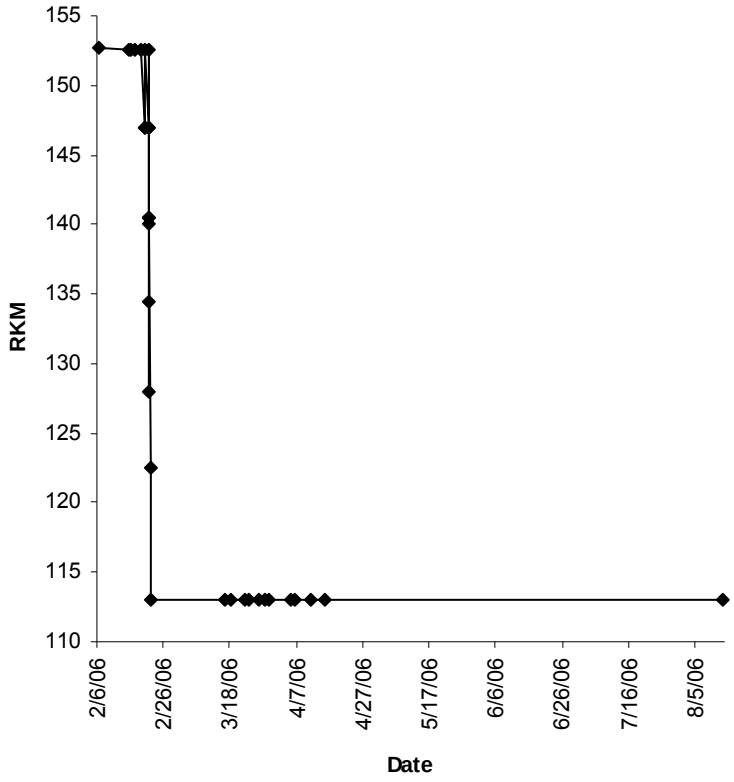

Figure 10. Burbot 339 movement between February 8, 2006 and August 31, 2006.

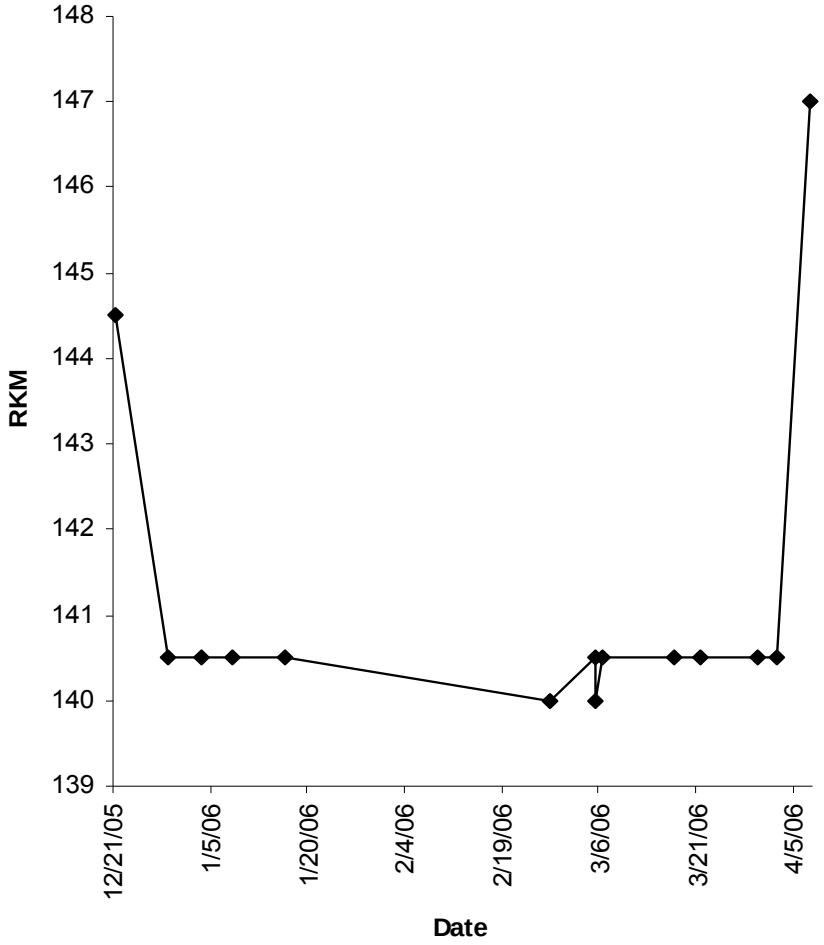

Figure 11. Burbot 327 movement between December 29, 2005 and April 7, 2006.

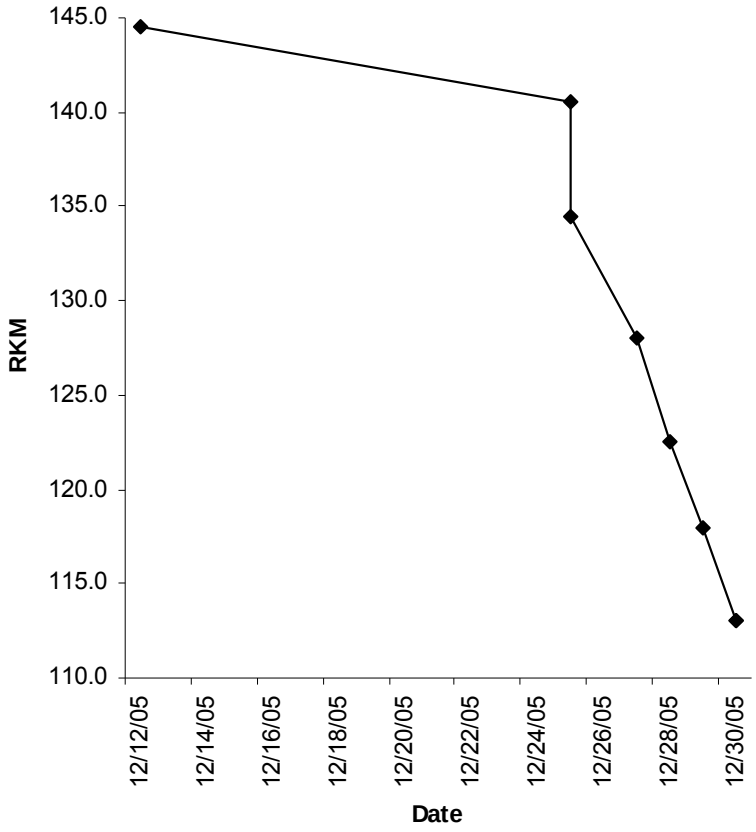

Figure 12. Burbot 335 movement between December 12, 2005 and December 30, 2005.

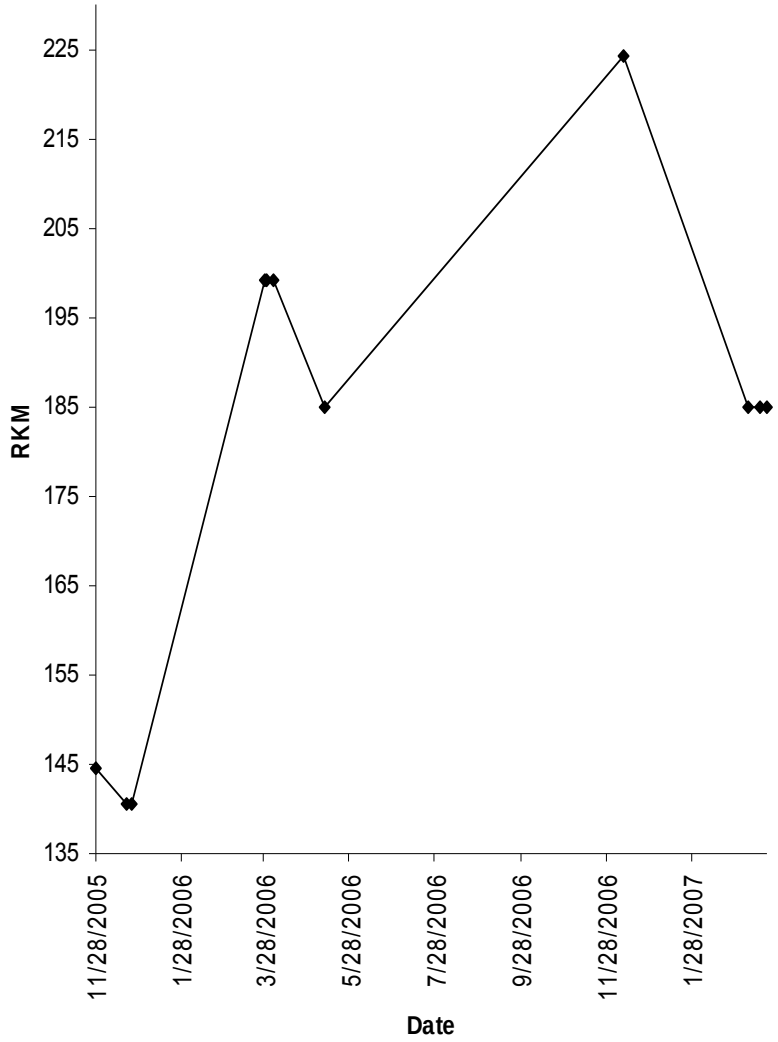

Figure 13. Burbot 334 movement between November 28, 2005 and March 22, 2007.

### Light Traps

Six light trap sets were operated for a total time of 96 h. Two light traps were damaged and were not included in the effort calculation. No larval burbot were captured.

## Extensive Burbot Rearing and Sinclair Lake

### Water Quality and Temperature

Twelve water quality parameters were collected on six days from March 12, 2007 to June 25, 2007 at the surface and depth of 1.6 m (Table 5). Ice out on Sinclair Lake began the last week of March 2007. Dissolved oxygen ranged from 0.38 mg/L on March 12, 2007 to 8.2 mg/L on April 12, 2007. Turbidity ranged from 0.1 NTU under ice cover on March 12, 2007 to 2.0 NTU on June 25, 2007. We deployed a single temperature logger in Sinclair Lake (Appendix 13). After ice out in late March 2007, Sinclair Lake temperature increased rapidly reaching almost 28°C by mid July 2007. Surface temperature ranged from 0.2°C to 29.4°C.

### Zooplankton

Analysis of zooplankton samples is in progress.

### Eyed Embryo Release

On March 15, 2007, about 100,000 burbot embryos of the Moyie Lake, British Columbia stock were released under the ice at Sinclair Lake (Figure 14). Later studies by the UIARI researchers indicated on average 65% of the embryos were actually eyed.

### Incubators

In addition to the under ice release, a contingent from the same brood family of about 1,000 eyed embryos each, were placed in four incubators which were marked with yellow buoys and placed under the ice March 15, 2007 (Figure 15). To study hatching success under more controlled conditions, the three incubators were retrieved from the lake at about one week intervals (two weeks after the release while the fourth was recovered about one month later) (Table 6). We found 11, five, zero, and four larvae in incubators in succession. None of the larvae was alive but 111 eggshells were counted. Thermal units at incubator retrieval were 142 degree days on March 22, 2007; 186 degree days on April 2, 2007; 220 degree days on April 9, 2007; and 324 degree days on April 24, 2007. Estimated hatching success in the incubators based on larvae counts ranged from zero to 1.1% with an average hatching success of 0.47%; we did not adjust for the 65% eyed estimate.

### Light Traps

Light trap effort totaled 1,344 h, no burbot larvae were captured in any of the light traps placed in Sinclair Lake.

Table 5. Twelve water quality measurements from Sinclair Lake, Idaho winter through spring 2007.

| Water Quality | Sample Date | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 03/12/07 | | 03/15/07 | | 04/12/07 | | 05/23/07 | | 06/06/07 | | 06/25/07 | |
| | Surface | 1.6 m | Surface | 1.6 m | Surface | 1.6 m | Surface | 1.6 m | Surface | 1.6 m | Surface | 1.6 m |
| Ammonium ($NH_4$) (mg/L) | 0.10 | 0.09 | 0.05 | 0.07 | 0.03 | 0.33 | 0.04 | 0.03 | 0.02 | 0.03 | 0.02 | 0.02 |
| Nitrate ($NO_3$) (mg/L) | 1.46 | 1.66 | 1.13 | 0.99 | 0.80 | 0.97 | 0.82 | 0.89 | 2.79 | 1.58 | 1.78 | 1.82 |
| Percent Dissolved Oxygen (%DO) | 6.7 | 3.4 | 44.2 | 15.5 | 90.3 | 82.0 | 90.6 | 88.6 | 89.6 | 90.2 | 90.8 | 86 |
| Dissolved Oxygen (DO) (mg/L) | 0.81 | 0.38 | 4.33 | 1.66 | 8.2 | 8.16 | 7.49 | 7.4 | 6.9 | 6.94 | 6.59 | 6.7 |
| Temperature (°C) | 1.5 | 3.09 | 1.3 | 2.87 | 11.6 | 5.43 | 15.9 | 15.69 | 19.46 | 19.5 | 22.5 | 8.94 |
| Barometric Pressure (BP) (mmHg) | 687.7 | 688.55 | 697.7 | 697.9 | 690.7 | 694.0 | 695.1 | 695.8 | 684.4 | 684.6 | 694.4 | 695.7 |
| Depth at collection (m) | 0.15 | 1.46 | 0 | 1.40 | 8.53 | 8.53 | 1.52 | 1.83 | -0.64 | 0.52 | -0.27 | 1.31 |
| Total Dissolved Solids (TDS) (kg/L) | .0210 | 0.0221 | 0.0159 | 0.0211 | 0.017 | 0.0165 | 0.0173 | 0.0173 | 0.0174 | 0.0174 | 0.0179 | 0.0178 |
| PCY | 1240 | | 95 | 2814 | 0 | 553 | 0 | 0 | 0 | 0 | 0 | 0 |
| Specific Conductivity (SPC) (µs/cm) | 33.9 | 34.5 | 24.7 | 33.1 | 26.5 | 26.0 | 26.8 | 27.0 | 27.2 | 27.3 | 28.0 | 27.8 |
| Turbidity (NTU) | 0.1 | 0.4 | 0.4 | 1.3 | 0.9 | 1.0 | 1.4 | 1.3 | 1.7 | 1.5 | 2 | 1.8 |
| pH | 6.48 | 6.55 | 6.59 | 6.56 | 6.93 | 6.88 | 7.35 | 7.23 | 7.72 | 7.45 | 7.4 | 7.43 |

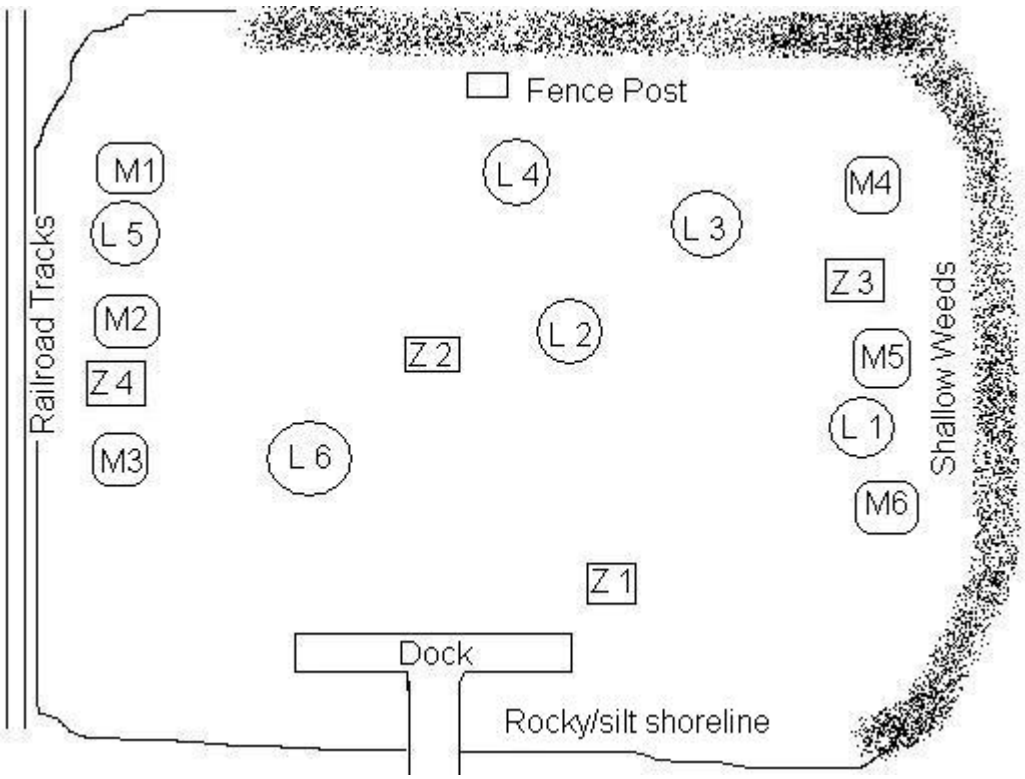


Figure 14. Sinclair Lake, Idaho showing location of embryo release (Z), zooplankton samples (Z), water quality (Z), incubators (Z), meter net tow beginning locations (M), light traps (L), and minnow traps (M).

Figure 15. Incubation bottle prior to addition of eyed burbot embryos.

### Half Meter Net Tows

No burbot larvae were captured in ½ m net tows at Sinclair Lake.

### Minnow Traps

Minnow Trap effort at Sinclair Lake totaled 1,434 h. No burbot larvae were captured in minnow traps.

Table 6. Extensive rearing incubator set and pull dates, egg disposition, thermal units and estimated hatching success, Sinclair Lake, March and April 2007.

| ID Number | Set date | Pull date | Water temp. (°C) | Live eggs at pull | Dead eggs at pull | Egg shells | Larvae (N) | Therm. Units (degree days) | Est. hatching based on larvae (%) | Est. hatching based on eggshells (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3/15/07 | 3/22/07 | 1.3 | 89 | -- | 7 | 11 | 142 | 1.10 | 0.07 |
| 2 | 3/15/07 | 4/02/07 | 1.3 | 130 | -- | 33 | 5 | 186 | 0.38 | 3.0 |
| 3 | 3/15/07 | 4/09/07 | 1.3 | 96 | -- | 22 | 0 | 220 | 0 | 2.2 |
| 4 | 3/15/07 | 4/24/07 | 1.3 | 50 | -- | 48 | 4 | 324 | 0.40 | 4.8 |
| Total | | | | 365 | | 110 | 20 | | 0.05[a] | 2.75 |

[a] Based on an estimated total of 4,000 eyed embryos.

## DISCUSSION

### Index Sampling Sites and Population Status

We used index sampling sites for the third season during the winter of 2006-2007 in an attempt to maximize our catch and evaluate stock status. We captured only two burbot, which yielded a CPUE of 0.002 as compared to the capture of 14 burbot and CPUE of 0.007 fish/net d the winter of 2005-2006, slightly less than the previous winter (2004-2005) capture of 18 fish and CPUE of 0.009 fish/ net d (Table 3).

Only one burbot was captured in the Goat River, which is an additional indicator of the depressed status of burbot in the Kootenai River. This tributary is one of the last two known spawning locations for burbot and provided a major portion of the total winter catch in previous years. The last captures of burbot in the Goat River occurred in February of 2001 and winter of 2001-2002 (Kozfkay and Paragamian 2002; Gunderman and Paragamian 2003).

As expressed in Chapter 2 of this report and Paragamian et al. (2008), the Kootenai River burbot will likely be extinct within the decade. 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) but a rehabilitation goal (population number) was not included. The reason a goal was not set was that the pre-Libby Dam Kootenai River burbot population density, prior to their decline, is unknown. 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. Therefore, a sound goal for rehabilitation could be to base it, initially, on the population densities in Alaskan Rivers. A model could be produced with Kootenai River burbot population estimates and CPUE (Paragamian et al. 2008; Paragamian and Laude 2008). Published CPUE values of several Alaskan rivers could be used to project a range of recovery goals. CPUE has been used to compare burbot stock densities (Parker et al. 1988). For example, CPUE values for burbot in Alaskan rivers ranged from a CPUE in the Chena and Tanana rivers of about 0.5 and 1.0, respectively (Evenson 1993). Values for Alaskan lakes were higher, CPUE of up to 3.0 burbot/ net d (Parker et al. 1988). This method would assume that CPUE was directly proportional to population number or density of adult burbot. Any bias of using a least squares method can be calculated, thus explaining statistical precautions.

## Telemetry of Burbot

The Vemco single channel monitoring fixed location receivers were used for the second season and proved beneficial. They required less time to download in comparison to daily boat telemetry for burbot and saved operational money. However, they did not provide the precise locations that were possible with our previous use of ATS radio transmitters and Sonotronic acoustic transmitters. Also, in some cases burbot were out of the detection range of the fixed location receivers making it difficult to pinpoint times and locations. In addition, although some of the transmitters implanted in winter 2005-2006 persisted through the summer, none lasted into the winter study period (data were unavailable for the previous report).

Telemetry did provide previously undocumented evidence that at least some burbot move upstream of Bonners Ferry (rkm 246). Burbot 341, tagged at Ambush Rock, was found at rkm 275.5 just below Boulder Creek less than a km below the Montana border. During the previous year telemetry of two burbot contradicted previous findings that some burbot had fidelity for specific tributaries. At least one burbot (fish 339) ascended the Goat River during the spawning season, eventually moved out and reentered the Kootenai River, moved downstream, and entered Summit Creek. Burbot 339 was joined by burbot 327 in Summit Creek. This is also the first time we have recorded burbot in Summit Creek. A potential explanation is that burbot are group spawners (McPhail and Paragamian 2000) and that since burbot were not captured in the Goat River during the winter of 2005-2006, burbot 339 sought other conspecifics and entered Summit Creek.

## 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 2006–2007 by using a selective withdrawal system at Libby Dam. 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). The committee did not address discharge from Libby Dam because the burbot stock is so low a response is immeasurable.

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).

## Extensive Burbot Rearing and Sinclair Lake

Experimental extensive rearing of burbot at Sinclair Lake was our first attempt to rear burbot outside of the intensive forum of a hatchery facility. To our knowledge, this was the first attempt in North America but it has been implemented in Europe with good success 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 were 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.

Our attempt at extensive rearing met with only modest success. Of approximately 4,000 eyed embryos placed in incubation jars, set in Sinclair Lake, we found 20 larvae in the jars a hatching success average of about 0.05% and 2.75% based on egg shells. We also found 110 eggshells suggesting many other larvae hatched but perished under confined conditions. 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 have still been less than satisfactory. Although no age 0 burbot were captured through our sampling efforts some larvae could have hatched but their numbers were so low they remain undetected. 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. 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. Lake DO was not suitable for larval survival at hatching. Further experiments with extensive rearing should follow with multiple trials with an array of controls using larvae (Dillen et al. 2008). However, if this is not possible, the extensive rearing study should continue to apply known methods determined through previous studies and literature research.

### 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 <5°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 that studies will not compromise burbot rehabilitation.

## RECOMMENDATIONS

1. While the population of burbot 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.

2. We recommend a burbot prespawning migration and spawning discharge from Libby Dam ranging from 113-300 $m^3/s$ and averaging 176 $m^3/s$ for a minimum of 90 d, beginning November 15, 2005 and extending through February 15, 2006.

3. We recommend a burbot prespawning migration temperature from Libby Dam of <5.0°C should commence November 1 with the coldest available water being provided from December through February. This combined with low discharge should encourage earlier migration of burbot and achieve a longer migration potential to spawning locations.

4. Because there are so few burbot left, it is unlikely, even with the implementation of recommendations 2 and 3 alone, that burbot will recover in the Kootenai River. We recommend Moyie Lake burbot donor stock be used to evaluate extensive rearing of artificially produced larvae. The primary objectives would be to determine whether or not

burbot larvae could be reared to a minimum length of 25 mm, released, and recaptured. Successful rearing would lead to further development of extensive rearing methods and release as fingerlings for burbot rehabilitation.

5. We recommend that a rehabilitation goal in terms of a number for burbot in the Kootenai River population be established. This could be accomplished with density analysis of CPUE, corresponding population estimates, a target CPUE based on Alaskan burbot stocks, and Population Viability Analysis.

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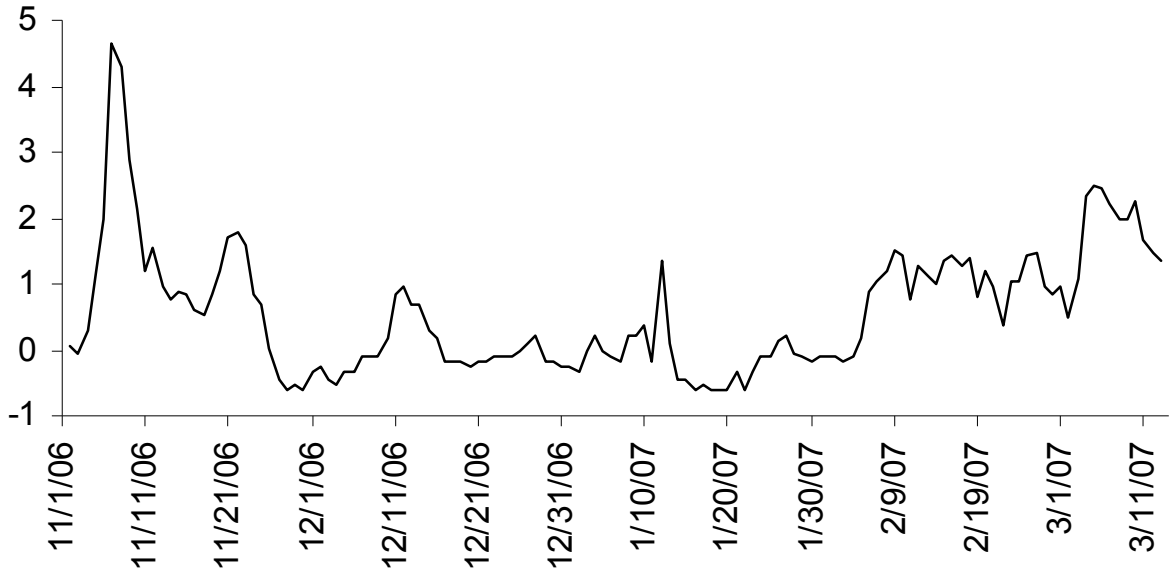
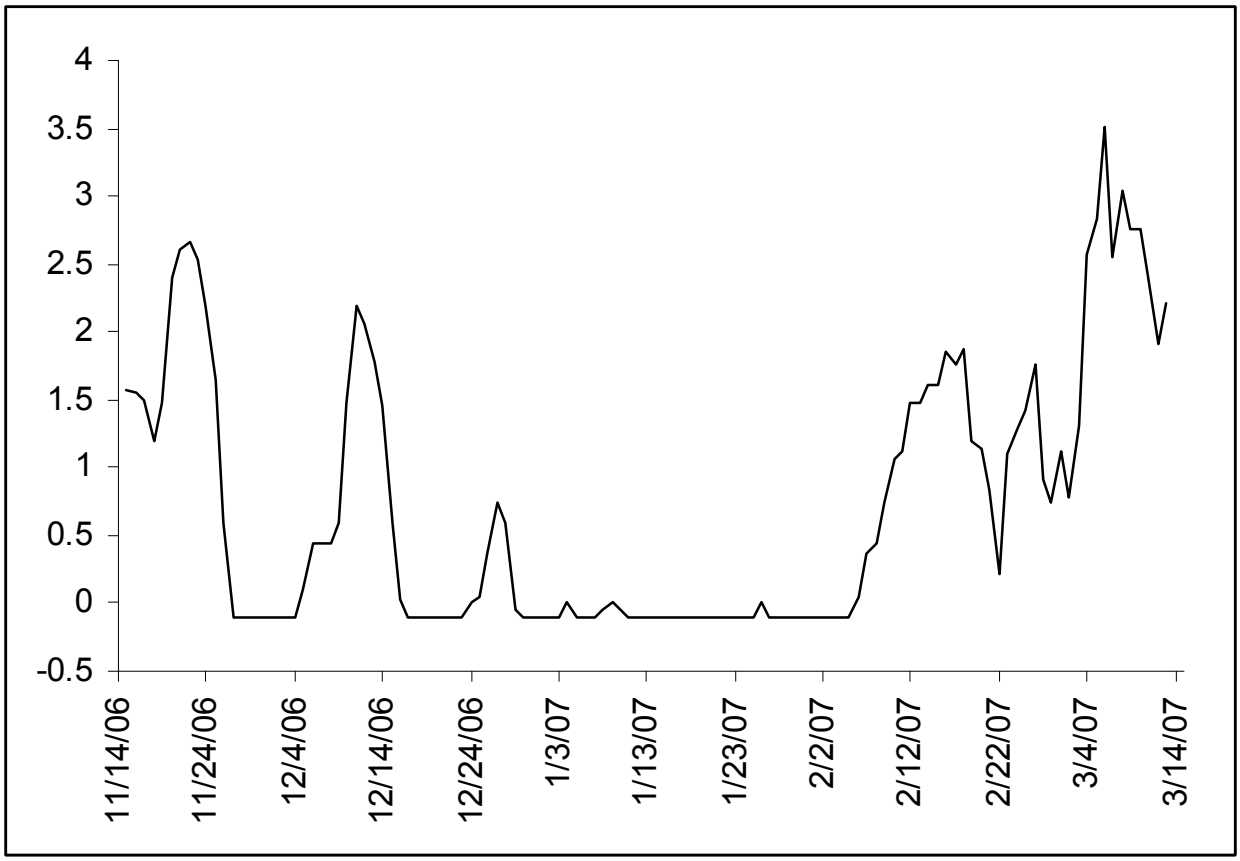
# APPENDICES

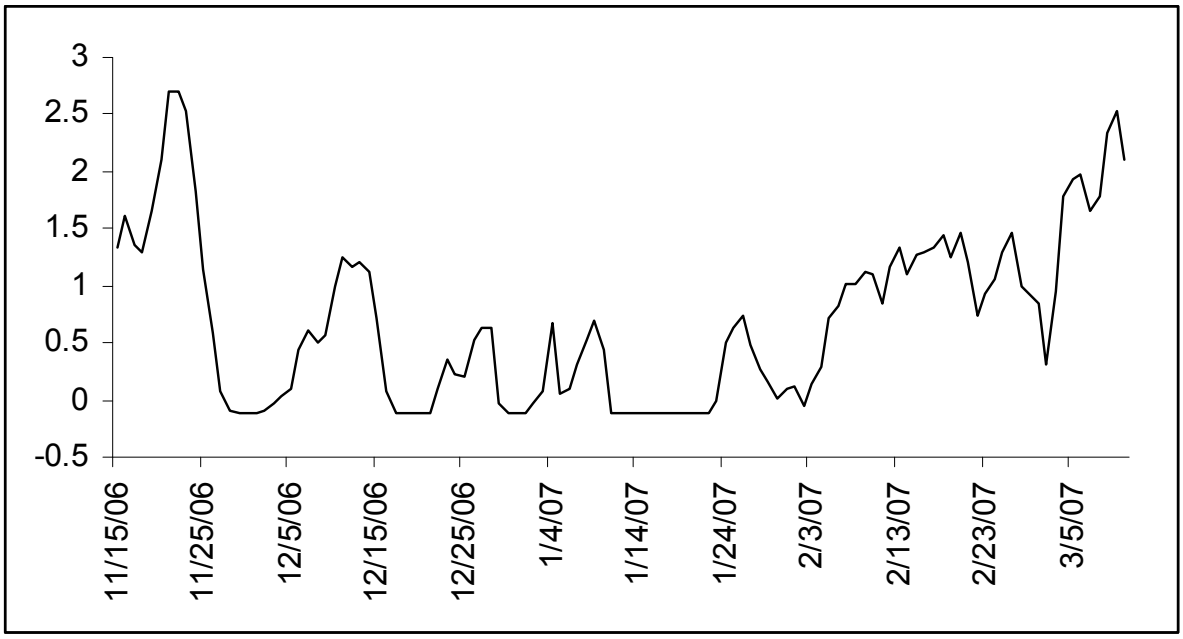
Appendix 1. Lower Boundary Creek (°C) mean daily temperature profile November 2, 2006 through March 13, 2007.



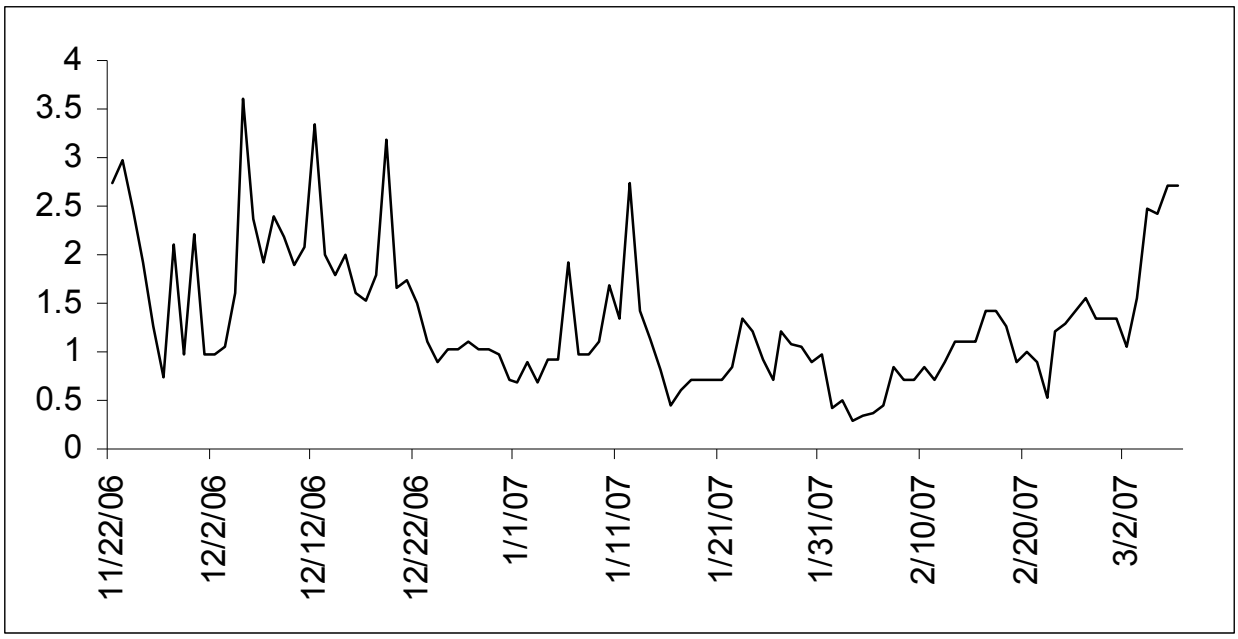
Appendix 2. Upper Goat River (°C) mean daily temperature profile November 15, 2006 through March 13, 2007.



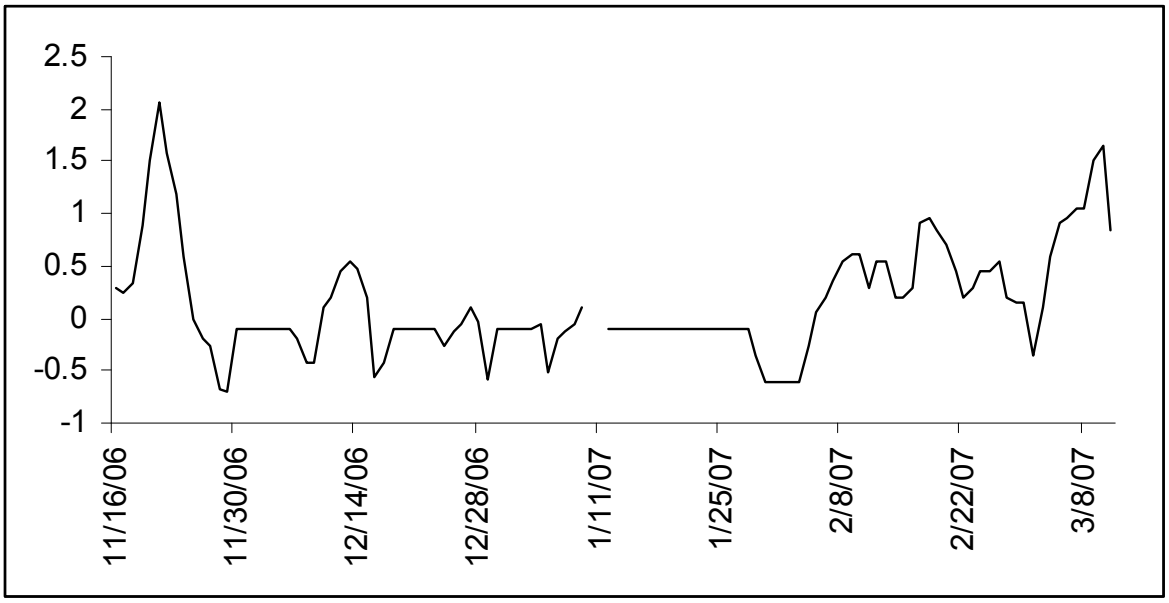
Appendix 3. Upper Corn Creek (°C) mean daily temperature profile November 15, 2006 through March 11, 2007.



Appendix 4. Lower Corn Creek (°C) mean daily temperature profile November 22, 2006 through March 7, 2007.



Appendix 5. Summit Creek (°C) mean daily temperature profile November 15, 2006 through March 11, 2007.



Appendix 6. Location and date of burbot 338 as determined by fixed Vemco receiver.

| Date | Location (rkm) | Date | Location (rkm) | Date | Location (rkm) |
|---|---|---|---|---|---|
| 1/20/2006 | 243.5 | 4/6/2006 | 243.5 | 7/4/2006 | 243.5 |
| 1/22/2006 | 243.5 | 4/7/2006 | 243.5 | 7/5/2006 | 243.5 |
| 1/23/2006 | 243.5 | 5/1/2006 | 243.5 | 7/6/2006 | 243.5 |
| 1/24/2006 | 243.5 | 5/2/2006 | 243.5 | 7/7/2006 | 243.5 |
| 1/25/2006 | 243.5 | 5/8/2006 | 243.5 | 7/8/2006 | 243.5 |
| 1/26/2006 | 243.5 | 5/9/2006 | 243.5 | 7/9/2006 | 243.5 |
| 1/27/2006 | 243.5 | 5/10/2006 | 243.5 | 7/10/2006 | 243.5 |
| 1/28/2006 | 243.5 | 5/11/2006 | 243.5 | 7/11/2006 | 243.5 |
| 1/29/2006 | 243.5 | 5/12/2006 | 243.5 | 7/12/2006 | 243.5 |
| 1/30/2006 | 243.5 | 5/13/2006 | 243.5 | 8/1/2006 | 243.5 |
| 1/31/2006 | 243.5 | 5/14/2006 | 243.5 | | |
| 2/1/2006 | 243.5 | 5/17/2006 | 243.5 | | |
| 2/2/2006 | 243.5 | 5/18/2006 | 243.5 | | |
| 2/3/2006 | 243.5 | 5/19/2006 | 243.5 | | |
| 2/4/2006 | 243.5 | 5/20/2006 | 243.5 | | |
| 2/5/2006 | 243.5 | 5/21/2006 | 243.5 | | |
| 2/6/2006 | 243.5 | 5/22/2006 | 243.5 | | |
| 2/7/2006 | 243.5 | 5/23/2006 | 243.5 | | |
| 2/8/2006 | 243.5 | 5/24/2006 | 243.5 | | |
| 2/9/2006 | 243.5 | 5/25/2006 | 243.5 | | |
| 2/10/2006 | 243.5 | 5/26/2006 | 243.5 | | |
| 2/11/2006 | 243.5 | 5/27/2006 | 243.5 | | |
| 2/12/2006 | 243.5 | 5/28/2006 | 243.5 | | |
| 2/13/2006 | 243.5 | 5/29/2006 | 243.5 | | |
| 2/14/2006 | 243.5 | 5/30/2006 | 243.5 | | |
| 2/15/2006 | 243.5 | 5/31/2006 | 243.5 | | |
| 2/16/2006 | 243.5 | 6/1/2006 | 243.5 | | |
| 2/17/2006 | 243.5 | 6/2/2006 | 243.5 | | |
| 2/18/2006 | 243.5 | 6/3/2006 | 243.5 | | |
| 2/20/2006 | 243.5 | 6/4/2006 | 243.5 | | |
| 2/21/2006 | 243.5 | 6/5/2006 | 243.5 | | |
| 2/22/2006 | 243.5 | 6/6/2006 | 243.5 | | |
| 2/23/2006 | 243.5 | 6/7/2006 | 243.5 | | |
| 2/24/2006 | 243.5 | 6/8/2006 | 243.5 | | |
| 2/25/2006 | 243.5 | 6/17/2006 | 243.5 | | |
| 2/26/2006 | 243.5 | 6/18/2006 | 243.5 | | |
| 2/28/2006 | 243.5 | 6/19/2006 | 243.5 | | |
| 3/1/2006 | 243.5 | 6/20/2006 | 243.5 | | |
| 3/2/2006 | 243.5 | 6/21/2006 | 243.5 | | |
| 3/3/2006 | 243.5 | 6/22/2006 | 243.5 | | |
| 3/4/2006 | 243.5 | 6/23/2006 | 243.5 | | |
| 3/5/2006 | 243.5 | 6/24/2006 | 243.5 | | |
| 3/6/2006 | 243.5 | 6/25/2006 | 243.5 | | |
| 3/10/2006 | 243.5 | 6/26/2006 | 243.5 | | |
| 3/12/2006 | 243.5 | 6/27/2006 | 243.5 | | |
| 3/13/2006 | 243.5 | 6/28/2006 | 243.5 | | |
| 3/18/2006 | 243.5 | 6/29/2006 | 243.5 | | |
| 3/18/2006 | 243.5 | 6/30/2006 | 243.5 | | |
| 3/23/2006 | 243.5 | 7/1/2006 | 243.5 | | |
| 3/27/2006 | 243.5 | 7/2/2006 | 243.5 | | |
| 4/5/2006 | 243.5 | 7/3/2006 | 243.5 | | |

Appendix 7. Location and date of burbot 341 as determined by fixed Vemco receiver.

| Date | Location (rkm) | Date | Location (rkm) |
|---|---|---|---|
| 3/22/2006 | 244.6 | 5/12/2006 | 244.6 |
| 3/23/2006 | 244.6 | 5/13/2006 | 244.6 |
| 3/24/2006 | 243.5 | 5/13/2006 | 245.8 |
| 3/25/2006 | 243.5 | 5/13/2006 | 245.9 |
| 3/26/2006 | 243.5 | 5/14/2006 | 244.6 |
| 3/27/2006 | 243.5 | 5/14/2006 | 245.8 |
| 3/28/2006 | 243.5 | 5/14/2006 | 245.9 |
| 3/29/2006 | 243.5 | 5/17/2006 | 244.5 |
| 3/30/2006 | 243.5 | 5/18/2006 | 244.5 |
| 4/1/2006 | 243.5 | 5/19/2006 | 244.5 |
| 4/4/2006 | 243.5 | 5/20/2006 | 244.5 |
| 4/5/2006 | 243.5 | 5/21/2006 | 245.8 |
| 4/5/2006 | 244.6 | 5/21/2006 | 245.9 |
| 4/6/2006 | 244.6 | 5/22/2006 | 245.8 |
| 4/7/2006 | 244.6 | 5/22/2006 | 245.9 |
| 4/8/2006 | 244.6 | 5/31/2006 | 246.7 |
| 4/9/2006 | 244.6 | 5/31/2006 | 246.8 |
| 4/10/2006 | 244.6 | 6/1/2006 | 248.6 |
| 4/11/2006 | 244.6 | 6/2/2006 | 248.6 |
| 4/12/2006 | 244.6 | 5/13/2006 | 245.8 |
| 4/13/2006 | 244.6 | 5/13/2006 | 245.9 |
| 4/14/2006 | 244.6 | 5/14/2006 | 244.6 |
| 4/15/2006 | 244.6 | 5/14/2006 | 245.8 |
| 4/16/2006 | 244.6 | 5/14/2006 | 245.9 |
| 4/17/2006 | 244.6 | 5/17/2006 | 244.5 |
| 4/18/2006 | 244.6 | 5/18/2006 | 244.5 |
| 4/19/2006 | 244.6 | 5/19/2006 | 244.5 |
| 4/20/2006 | 244.6 | 5/20/2006 | 244.5 |
| 4/21/2006 | 244.6 | 5/21/2006 | 245.8 |
| 4/22/2006 | 244.6 | 5/21/2006 | 245.9 |
| 4/23/2006 | 244.6 | 5/22/2006 | 245.8 |
| 4/24/2006 | 244.6 | 5/22/2006 | 245.9 |
| 4/25/2006 | 244.6 | 5/31/2006 | 246.7 |
| 4/26/2006 | 244.6 | 5/31/2006 | 246.8 |
| 4/27/2006 | 243.5 | 6/1/2006 | 248.6 |
| 4/27/2006 | 244.6 | 6/2/2006 | 248.6 |
| 4/28/2006 | 244.6 | 6/3/2006 | 248.6 |
| 4/29/2006 | 244.6 | 6/4/2006 | 248.6 |
| 5/2/2006 | 243.5 | 8/7/2006 | 275.5 |
| 5/3/2006 | 243.5 | | |
| 5/4/2006 | 243.5 | | |
| 5/5/2006 | 243.5 | | |
| 5/5/2006 | 244.6 | | |
| 5/6/2006 | 244.6 | | |
| 5/7/2006 | 244.6 | | |
| 5/8/2006 | 244.6 | | |
| 5/9/2006 | 244.6 | | |
| 5/10/2006 | 244.6 | | |
| 5/11/2006 | 244.6 | | |

Appendix 8. Location and date of burbot 339 as determined by fixed Vemco receiver.

| Date | Location (rkm) | Date | Location (rkm) | Date | Location (rkm) | Date | Location (rkm) |
|---|---|---|---|---|---|---|---|
| 2/15/2006 | 152.5 | 3/27/2006 | 113 | 5/17/2006 | 113 | 7/5/2006 | 113 |
| 2/17/2006 | 152.5 | 3/28/2006 | 113 | 5/18/2006 | 113 | 7/6/2006 | 113 |
| 2/19/2006 | 152.5 | 3/29/2006 | 113 | 5/19/2006 | 113 | 7/7/2006 | 113 |
| 2/20/2006 | 147 | 3/30/2006 | 113 | 5/20/2006 | 113 | 7/8/2006 | 113 |
| 2/20/2006 | 147 | 3/31/2006 | 113 | 5/21/2006 | 113 | 7/9/2006 | 113 |
| 2/20/2006 | 152.5 | 4/1/2006 | 113 | 5/22/2006 | 113 | 7/10/2006 | 113 |
| 2/21/2006 | 147 | 4/2/2006 | 113 | 5/23/2006 | 113 | 7/11/2006 | 113 |
| 2/21/2006 | 147 | 4/3/2006 | 113 | 5/24/2006 | 113 | 7/12/2006 | 113 |
| 2/21/2006 | 140.5 | 4/4/2006 | 113 | 5/25/2006 | 113 | 7/13/2006 | 113 |
| 2/21/2006 | 134.5 | 4/5/2006 | 113 | 5/26/2006 | 113 | 7/14/2006 | 113 |
| 2/21/2006 | 128 | 4/6/2006 | 113 | 5/27/2006 | 113 | 7/15/2006 | 113 |
| 2/21/2006 | 152.5 | 4/7/2006 | 113 | 5/28/2006 | 113 | 7/16/2006 | 113 |
| 2/21/2006 | 140.5 | 4/8/2006 | 113 | 5/29/2006 | 113 | 7/17/2006 | 113 |
| 2/21/2006 | 140 | 4/9/2006 | 113 | 5/30/2006 | 113 | 7/18/2006 | 113 |
| 2/21/2006 | 140.5 | 4/10/2006 | 113 | 5/31/2006 | 113 | 7/19/2006 | 113 |
| 2/22/2006 | 122.5 | 4/11/2006 | 113 | 6/1/2006 | 113 | 7/20/2006 | 113 |
| 2/22/2006 | 113 | 4/12/2006 | 113 | 6/2/2006 | 113 | 7/21/2006 | 113 |
| 2/23/2006 | 113 | 4/15/2006 | 113 | 6/3/2006 | 113 | 7/22/2006 | 113 |
| 2/24/2006 | 113 | 4/16/2006 | 113 | 6/4/2006 | 113 | 7/23/2006 | 113 |
| 2/25/2006 | 113 | 4/17/2006 | 113 | 6/5/2006 | 113 | 7/24/2006 | 113 |
| 2/26/2006 | 113 | 4/18/2006 | 113 | 6/6/2006 | 113 | 7/25/2006 | 113 |
| 2/27/2006 | 113 | 4/19/2006 | 113 | 6/7/2006 | 113 | 7/26/2006 | 113 |
| 2/28/2006 | 113 | 4/20/2006 | 113 | 6/8/2006 | 113 | 7/27/2006 | 113 |
| 3/1/2006 | 113 | 4/21/2006 | 113 | 6/9/2006 | 113 | 7/28/2006 | 113 |
| 3/2/2006 | 113 | 4/22/2006 | 113 | 6/10/2006 | 113 | 7/29/2006 | 113 |
| 3/3/2006 | 113 | 4/23/2006 | 113 | 6/11/2006 | 113 | 7/30/2006 | 113 |
| 3/4/2006 | 113 | 4/24/2006 | 113 | 6/12/2006 | 113 | 7/31/2006 | 113 |
| 3/5/2006 | 113 | 4/25/2006 | 113 | 6/13/2006 | 113 | 8/1/2006 | 113 |
| 3/6/2006 | 113 | 4/26/2006 | 113 | 6/14/2006 | 113 | 8/2/2006 | 113 |
| 3/7/2006 | 113 | 4/27/2006 | 113 | 6/15/2006 | 113 | 8/3/2006 | 113 |
| 3/8/2006 | 113 | 4/28/2006 | 113 | 6/16/2006 | 113 | 8/4/2006 | 113 |
| 3/9/2006 | 113 | 4/29/2006 | 113 | 6/17/2006 | 113 | 8/5/2006 | 113 |
| 3/10/2006 | 113 | 4/30/2006 | 113 | 6/18/2006 | 113 | 8/6/2006 | 113 |
| 3/11/2006 | 113 | 5/1/2006 | 113 | 6/19/2006 | 113 | 8/7/2006 | 113 |
| 3/12/2006 | 113 | 5/2/2006 | 113 | 6/20/2006 | 113 | 8/8/2006 | 113 |
| 3/13/2006 | 113 | 5/3/2006 | 113 | 6/21/2006 | 113 | 8/9/2006 | 113 |
| 3/14/2006 | 113 | 5/4/2006 | 113 | 6/22/2006 | 113 | 8/10/2006 | 113 |
| 3/15/2006 | 113 | 5/5/2006 | 113 | 6/23/2006 | 113 | 8/11/2006 | 113 |
| 3/16/2006 | 113 | 5/6/2006 | 113 | 6/24/2006 | 113 | 8/12/2006 | 113 |
| 3/17/2006 | 113 | 5/7/2006 | 113 | 6/25/2006 | 113 | 8/13/2006 | 113 |
| 3/18/2006 | 113 | 5/8/2006 | 113 | 6/26/2006 | 113 | 8/14/2006 | 113 |
| 3/19/2006 | 113 | 5/9/2006 | 113 | 6/27/2006 | 113 | 8/15/2006 | 113 |
| 3/20/2006 | 113 | 5/10/2006 | 113 | 6/28/2006 | 113 | 8/16/2006 | 113 |
| 3/21/2006 | 113 | 5/11/2006 | 113 | 6/29/2006 | 113 | 8/17/2006 | 113 |
| 3/22/2006 | 113 | 5/12/2006 | 113 | 6/30/2006 | 113 | 8/18/2006 | 113 |
| 3/23/2006 | 113 | 5/13/2006 | 113 | 7/1/2006 | 113 | 8/19/2006 | 113 |
| 3/24/2006 | 113 | 5/14/2006 | 113 | 7/2/2006 | 113 | 8/20/2006 | 113 |
| 3/25/2006 | 113 | 5/15/2006 | 113 | 7/3/2006 | 113 | 8/21/2006 | 113 |
| 3/26/2006 | 113 | 5/16/2006 | 113 | 7/4/2006 | 113 | 8/22/2006 | 113 |

Appendix 8. Continued.

| Date | Location (rkm) | Date | Location (rkm) | Date | Location (rkm) | Date | Location (rkm) |
|---|---|---|---|---|---|---|---|
| 8/23/2006 | 113 | | | | | | |
| 8/24/2006 | 113 | | | | | | |
| 8/25/2006 | 113 | | | | | | |
| 8/26/2006 | 113 | | | | | | |
| 8/27/2006 | 113 | | | | | | |
| 8/28/2006 | 113 | | | | | | |
| 8/29/2006 | 113 | | | | | | |
| 8/30/2006 | 113 | | | | | | |
| 8/31/2006 | 113 | | | | | | |

Appendix 9. Location of burbot 327 as determined by fixed Vemco receiver.

| Date | Location (rkm) |
|---|---|
| 12/29/2005 | 140 |
| 12/29/2005 | 140 |
| 1/3/2006 | 140 |
| 1/8/2006 | 140 |
| 1/9/2006 | 140 |
| 1/16/2006 | 140 |
| 2/26/2006 | 140.5 |
| 3/5/2006 | 140.5 |
| 3/6/2006 | 140.5 |
| 3/7/2006 | 140.5 |
| 3/8/2006 | 140.5 |
| 3/9/2006 | 140.5 |
| 3/10/2006 | 140.5 |
| 3/11/2006 | 140.5 |
| 3/12/2006 | 140.5 |
| 3/13/2006 | 140.5 |
| 3/14/2006 | 140.5 |
| 3/17/2006 | 140.5 |
| 3/18/2006 | 140.5 |
| 3/21/2006 | 140.5 |
| 3/22/2006 | 140.5 |
| 3/23/2006 | 140.5 |
| 3/24/2006 | 140.5 |
| 3/30/2006 | 140.5 |
| 4/1/2006 | 140.5 |
| 4/2/2006 | 140.5 |
| 4/7/2006 | 147 |

Appendix 10. Location of burbot 335 as determined by fixed Vemco receiver.

| Date | Location (rkm) |
|---|---|
| 12/12/2005 | 144.5 |
| 12/25/2005 | 140.5 |
| 12/25/2005 | 140.5 |
| 12/25/2005 | 140.5 |
| 12/25/2005 | 140.5 |
| 12/25/2005 | 140.5 |
| 12/25/2005 | 140.5 |
| 12/28/2005 | 122.5 |
| 12/28/2005 | 122.5 |
| 12/28/2005 | 122.5 |
| 12/28/2005 | 122.5 |
| 12/29/2005 | 118 |
| 12/30/2005 | 113 |
| 12/30/2005 | 113 |

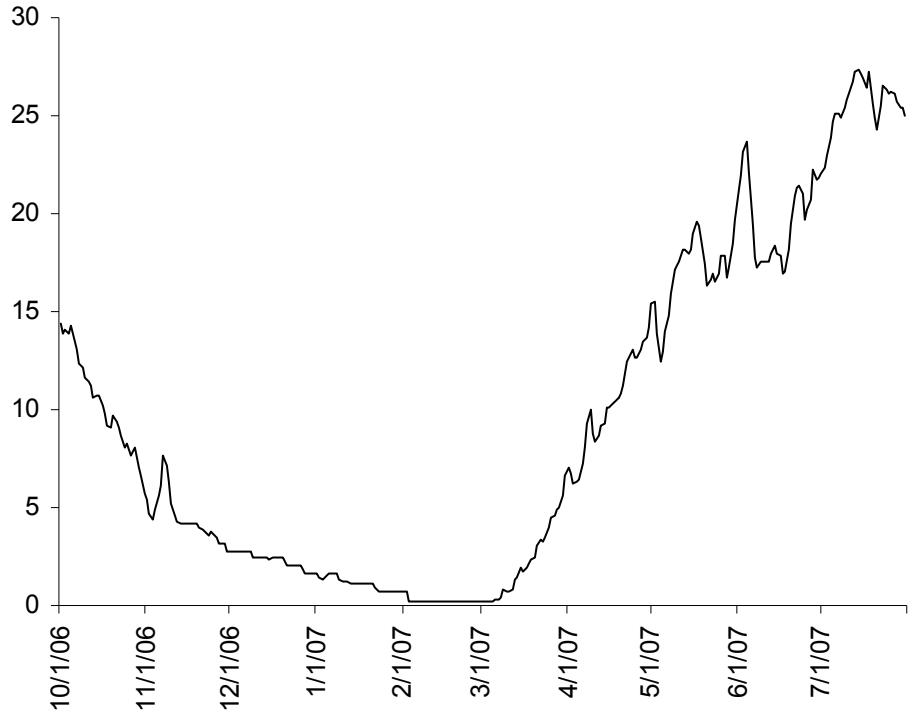
Appendix 11. Location of burbot 340 as determined by fixed Vemco receiver.

| Date | Location (rkm) |
|---|---|
| 11/15/2005 | Goat River |
| 11/15/2005 | Goat River |
| 11/15/2005 | Goat River |
| 11/15/2005 | Goat River |
| 11/15/2005 | Goat River |
| 2/24/2006 | Goat River |
| 2/24/2006 | Goat River |
| 2/24/2006 | Goat River |
| 2/25/2006 | Goat River |
| 2/25/2006 | Goat River |
| 2/25/2006 | Goat River |
| 2/25/2006 | Goat River |
| 2/28/2006 | Goat River |
| 2/28/2006 | Goat River |
| 2/28/2006 | Goat River |
| 2/28/2006 | Goat River |
| 3/23/2006 | Goat River |
| 3/23/2006 | Goat River |
| 2/11/2007 | Goat River |

Appendix 12. Location of burbot 334 as determined by fixed Vemco receiver.

| Date | Location (rkm) |
|---|---|
| 12/20/2005 | 140.5 |
| 12/21/2005 | 140.5 |
| 12/22/2005 | 140.5 |
| 12/23/2005 | 140.5 |
| 12/24/2005 | 140.5 |
| 3/28/2006 | 199.1 |
| 3/30/2006 | 199.1 |
| 4/4/2006 | 199.1 |
| 5/1/2006 | 184.9 |
| 12/10/2006 | 224.2 |
| 3/9/2007 | 184.9 |
| 3/18/2007 | 184.9 |
| 3/22/2007 | 184.9 |

Appendix 13. Sinclair Lake (°C) mean daily surface temperature profile October 1, 2006 through July 31, 2007.



## CHAPTER 2—STATUS AND POPULATION DYNAMICS OF BURBOT IN THE KOOTENAI RIVER, IDAHO AND BRITISH COLUMBIA, CANADA, 1993-2007


### ABSTRACT

We examined the status and population characteristics of Kootenai River burbot *Lota lota* using capture-recapture data from 1993-2007. This was an update from the 1993-2004 study. Our objective was to determine the time remaining before this population becomes functionally extinct and to help guide conservation efforts. A total of 438 burbot were captured from 1993 through 2007 (primarily with baited hoop nets), of which 302 were PIT tagged as new fish and released, 51 were not PIT tagged but 16 were floy tagged, and 84 were recaptures of fish tagged up to four years prior. Hoop net catch per unit of effort (CPUE) declined precipitously from 0.054 CPUE in 1996 to 0.001 CPUE in 2007. Two models were developed for capture-recapture analysis: one that included effort data through a series of river reaches and one without effort data. The effort model was deemed more reliable. Estimated abundance declined from 323 burbot in 1998 to 47 burbot in 2006. Recruitment declined from 259 burbot in 1997 to no recruitment by 2006. These data reconfirm that Kootenai River burbot are in serious decline and may have already passed the point of functional extinction where the population could not be expected to recover if favorable habitat conditions were restored. It is likely the population will reach extirpation within a decade.



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## INTRODUCTION

Mark-recapture experiments have been conducted in the Kootenai River since 1993 in an effort to better monitor population status of burbot *Lota lota*. Pyper et al. (2004) provided an extensive evaluation of burbot population status and dynamics in the Kootenai River from 1993 to 2004. The objective of this analysis was to update estimates of population abundance, recruitment, and survival of Kootenai River burbot for the most recent sampling years (2005-2007).

## METHODS

Burbot were sampled in the Kootenai River from 1993 to 2007 using baited hoop nets primarily during winter months (October-March) to coincide with seasonal migrations. Most sampling was conducted by the Idaho Department of Fish and Game (IDFG), and to a lesser extent by the British Columbia Ministry of Environment and the Montana Department of Fish, Wildlife and Parks (1998 only). A detailed description of sampling methods is provided by Pyper et al. (2004) and Paragamian (1995).

Most trapped fish were implanted with passive integrated transponder (PIT) tags and subsequently released. A few fish were not PIT tagged because they either died during capture or were captured during other sampling efforts when tagging equipment was unavailable. Fish marked with floy tags or sonic tags (but not PIT tags) were assumed to be unavailable for recapture in subsequent years due to limited tag-retention time or battery life.

Annual capture-recapture data were summarized by “sampling year” instead of calendar year to ensure that continuous sampling seasons had a consistent year designation. Sampling year was defined as October 1 through May 31. For example, fish captured in November of 1994 and February of 1995 were all designated as captures in sampling year 1994. Burbot recaptured in the same year of release or multiple times within the same sampling season (i.e. “within-year recaptures”) were excluded from the analysis. For each sampling year, we tabulated the total number of fish captured, released, and recaptured.

We computed catch-per-unit-effort (CPUE) for 1993-2007 using IDFG winter sampling data. These data did not include fish captured in weir traps, incidental summer captures, or British Columbia (BC) winter captures because capture methods were inconsistent. CPUE was defined as the number of burbot captured divided by total hoop net days (one hoop net day equals 24 h) for each sampling year. We calculated 95% confidence intervals for CPUE by assuming that the probability of capture followed a binomial distribution (slat trap data for 2006-2007 were not included).

Abundance and other demographic parameters were estimated using versions of the Jolly-Seber model in the program POPAN-5 (Arnason et al. 1998). The standard Jolly-Seber model provides estimates of period-specific capture probabilities ($p_t$) and apparent survival rates ($\varphi_t$) for an open population (i.e. subject to mortality and recruitment). These parameters are then used to estimate abundance ($N_t$) and net recruitment ($B_t$) for burbot 350 mm TL and longer. Other forms of the Jolly-Seber model that have fewer parameters or covariates such as sampling effort are easily implemented in POPAN-5 (Schwarz and Arnason 1996).

Following Pyper et al. (2004), we evaluated two capture-recapture models: 1) a model assuming constant survival and recapture probability across sampling years (i.e. "no effort model"); and 2) a model assuming constant survival but with recapture probability modeled as a function of annual sampling effort (i.e. "effort model"). Each model was fit via maximum likelihood and compared using Akaike's Information Criterion (AIC) (Burnham and Anderson 2002). The model with the lowest AIC value was considered the "best" model.

The formulation of the effort model differed slightly from that of Pyper et al. (2004). In this analysis, capture probability was modeled as a linear function of sampling effort:

$$p_t = \beta E_t ;$$

where $p$ is the capture probability in year $t$, $E$ is the sampling effort (total hoop net days), and $\beta$ is the slope parameter of the relationship between capture probability and effort.

Analysis of capture-recapture data was limited to sampling years 1996-2007 because none of the fish released prior to 1996 were subsequently recaptured. In addition, the capture-recapture models provided estimates of abundance and recruitment for years 1997-2006, but not for the first and last sampling years due to inseparability of model parameters (Arnason et al. 1998).

## RESULTS AND DISCUSSION

Analyses of 15 years of capture-recapture data confirm that burbot numbers are very low, numbers are declining, recruitment is poor, and the population is on the threshold of extinction. This conclusion is supported by annual abundance and recruitment estimates, declining CPUE in population surveys, and an increasing trend in average fish size (Paragamian et al. 2008).

A total of 438 burbot were captured between 1993 and 2007, including 49 within-year recaptures and 36 between-year recaptures (Table 7). Between-year recaptures were low throughout the study period, ranging from zero for several years to a high of eight in 2001 (mean = 2.6). Catch-per-unit-effort (CPUE) declined in recent years and ranged from a high of 0.056 in 1996 to a low of 0.002 in 2007 (mean = 0.022) (Table 8; Figure 16).

The "effort model" was selected as the best-fitting Jolly-Seber model according to AIC ($AIC_{effort}$ = 1,435; $AIC_{no\ effort}$ = 1,440; $\Delta AIC$ = 5). A difference in AIC of 5 indicates moderate to strong support for selecting the effort model as the best description of the data (Burnham and Anderson 2002). Both models, however, provided similar estimates of abundance and recruitment across years (Table 9 and 10).

Abundance and recruitment estimates showed marked declines in recent years (Figure 17 and Figure 18). For the effort model, abundance estimates ranged from a high of 323 in 1998 to a low of 38 in 2005 (Table 9; Figure 17), while net recruitment ranged from a high of 259 in 1997 to zero in 2007 (Table 10; Figure 18). The estimate of annual survival, which was assumed constant across years, was 38.2% (SE = 4.9%). It should be noted that the recent estimates of population number in this report are slightly higher during each year of sampling because of the Jolly-Seber model dynamics, but estimates are very similar to the old version in Pyper et al. (2004) and Paragamian et al. (2008). This more recent study has an additional

three years of mark and recapture data. Thus, some slight change is expected from past estimates because the model assumes a fixed survival rate and a fixed recapture probability (or relationship with effort) across years. In the more recent analysis, the functional relationship between effort and recapture probability (now a linear relationship) was changed in order to use POPAN. Likewise, the estimate of survival also differs between 37% in Pyper et al. (2004) and Paragamian et al. (2008) and 38% in this report.

Table 7. Summary of annual Burbot captures and recaptures in the Kootenai River, 1993-2007. The numbers of mortalities are shown in parentheses.

| | | Releases | | | | Between-year recaps | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year[a] | Total captured | New PIT-tags | No PIT tags | Total | Within-year recaps[b] | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | Total |
| 1993 | 17 | 0 | 16(1) | 16 | 1 | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1994 | 15 | 9 | 5 | 14 | 1 | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1995 | 33 | 20 | 13 | 33 | 0 | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1996 | 34 | 28(1) | 5(2) | 33 | 1 | - | - | - | - | 3 | 3 | 2(2) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| 1997 | 24 | 21(1) | 0 | 21 | 0 | - | - | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1998 | 59 | 50 | 3(2) | 53 | 3 | - | - | - | - | - | - | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 1999 | 47 | 41(3) | 1 | 42 | 2 | - | - | - | - | - | - | - | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 2000 | 36 | 31 | 1 | 32 | 3 | - | - | - | - | - | - | - | - | 7 | 2 | 0 | 1 | 1 | 0 | 0 | 11 |
| 2001 | 74 | 40 | 0 | 40 | 26(1) | - | - | - | - | - | - | - | - | - | 5(1) | 0 | 1 | 1 | 0 | 0 | 7 |
| 2002 | 33 | 19 | 2 | 21 | 5 | - | - | - | - | - | - | - | - | - | - | 0 | 0 | 0 | 1 | 0 | 1 |
| 2003 | 11 | 10 | 1 | 11 | 0 | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 | 0 | 0 | 0 |
| 2004 | 21 | 16 | 0 | 16 | 3 | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 0 | 0 | 4 |
| 2005 | 18 | 7 | 1 | 8 | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 0 | 2 |
| 2006 | 14 | 9 | 2 | 11 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 0 |
| 2007 | 2 | 1 | 1 | 2 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Totals | 438 | 302 | 51 | 353 | 49 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 1 | 8 | 7 | 0 | 2 | 6 | 3 | 0 | 36 |

[a] The year convention used in this table corresponds to the sampling year and NOT the calendar year. The sampling year began in the winter (roughly on November 1) and continued through the following spring (except for limited summer sampling in 1994 and 1996).

[b] Within-year recaptures include fish that were recaptured in the same year as the release or were recaptured multiple times within the same year.

Table 8. Kootenai River Burbot catch, effort, catch-per-unit-effort (CPUE), and 95% confidence intervals for CPUE by sampling year, 1993-2007.

| Sampling year | Burbot captured | Total hoop net days | CPUE (fish/net day) | CPUE 95% LCI | CPUE 95% UCI |
|---|---|---|---|---|---|
| 1993 | 17 | 554 | 0.031 | 0.018 | 0.045 |
| 1994 | 8 | 910 | 0.009 | 0.003 | 0.015 |
| 1995 | 33 | 689 | 0.048 | 0.032 | 0.064 |
| 1996 | 28 | 496 | 0.056 | 0.036 | 0.077 |
| 1997 | 23 | 1061 | 0.022 | 0.013 | 0.031 |
| 1998 | 42 | 1241 | 0.034 | 0.024 | 0.044 |
| 1999 | 44 | 1454 | 0.030 | 0.022 | 0.039 |
| 2000 | 36 | 1713 | 0.021 | 0.015 | 0.028 |
| 2001 | 73 | 2085 | 0.035 | 0.027 | 0.043 |
| 2002 | 17 | 1530 | 0.011 | 0.006 | 0.016 |
| 2003 | 11 | 1810 | 0.006 | 0.003 | 0.010 |
| 2004 | 19 | 1965 | 0.010 | 0.006 | 0.014 |
| 2005 | 18 | 2076 | 0.009 | 0.005 | 0.013 |
| 2006 | 14 | 2000 | 0.007 | 0.004 | 0.011 |
| 2007 | 2 | 1497 | 0.001 | 0.000 | 0.004 |

Note: Fish captures and effort data were from Idaho Department of Fish and Game (IDFG) winter sampling only and did not include fish captured in the weir trap, incidental summer captures, or British Columbia (BC) winter captures because capture methods differed.

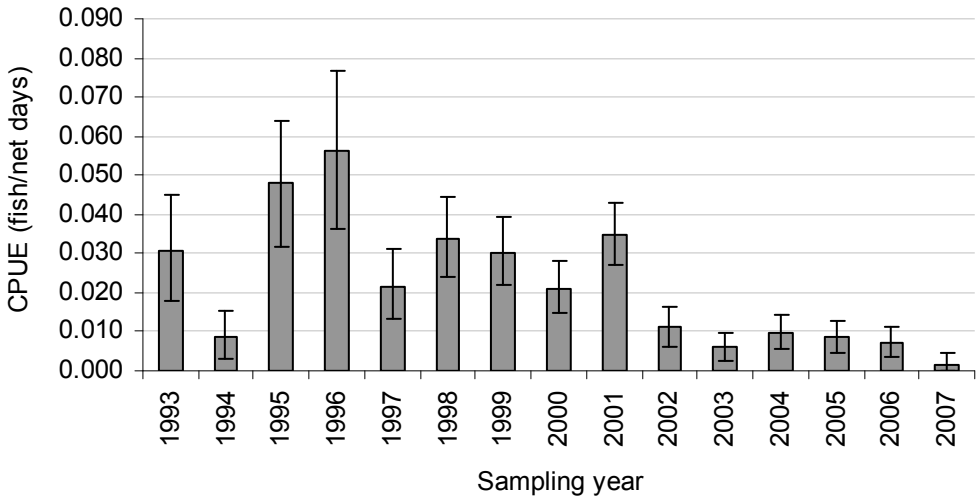


Figure 16. Kootenai Burbot catch-per-unit-effort (CPUE) by sampling year. Error bars represent 95% confidence intervals.

Table 9. Estimates of capture probability (P), apparent survival (Phi), net recruitment (B), and abundance (N), associated standard errors for model 1, the “no effort model” (i.e. constant Phi and P with no effort covariate included).

| Year | P | SE (P) | Phi | SE (Phi) | B | SE (B) | N | SE (N) |
|---|---|---|---|---|---|---|---|---|
| 1997 | 0.206 | 0.054 | 0.405 | 0.058 | 224 | 64 | 113 | 35 |
| 1998 | 0.206 | 0.054 | 0.405 | 0.058 | 121 | 38 | 269 | 77 |
| 1999 | 0.206 | 0.054 | 0.405 | 0.058 | 90 | 32 | 229 | 64 |
| 2000 | 0.206 | 0.054 | 0.405 | 0.058 | 144 | 43 | 180 | 52 |
| 2001 | 0.206 | 0.054 | 0.405 | 0.058 | 40 | 25 | 216 | 62 |
| 2002 | 0.206 | 0.054 | 0.405 | 0.058 | 21 | 18 | 127 | 38 |
| 2003 | 0.206 | 0.054 | 0.405 | 0.058 | 60 | 24 | 71 | 24 |
| 2004 | 0.206 | 0.054 | 0.405 | 0.058 | 14 | 15 | 89 | 30 |
| 2005 | 0.206 | 0.054 | 0.405 | 0.058 | 35 | 15 | 50 | 19 |
| 2006 | 0.206 | 0.054 | 0.405 | 0.058 | 0 | 0 | 55 | 18 |

Table 10. Estimates of capture probability (P), apparent survival (Phi), net recruitment (B), and abundance (N), associated standard errors for model 2, the “effort model” (i.e. constant Phi but with P as a function of annual effort).

| Year | P | SE (P) | Phi | SE (Phi) | B | SE (B) | N | SE (N) |
|---|---|---|---|---|---|---|---|---|
| 1997 | 0.146 | 0.035 | 0.382 | 0.049 | 259 | 67 | 170 | 54 |
| 1998 | 0.170 | 0.040 | 0.382 | 0.049 | 112 | 38 | 323 | 86 |
| 1999 | 0.200 | 0.047 | 0.382 | 0.049 | 72 | 28 | 234 | 61 |
| 2000 | 0.235 | 0.056 | 0.382 | 0.049 | 100 | 29 | 159 | 43 |
| 2001 | 0.286 | 0.068 | 0.382 | 0.049 | 62 | 24 | 160 | 42 |
| 2002 | 0.210 | 0.050 | 0.382 | 0.049 | 14 | 15 | 123 | 35 |
| 2003 | 0.249 | 0.059 | 0.382 | 0.049 | 47 | 18 | 60 | 19 |
| 2004 | 0.270 | 0.064 | 0.382 | 0.049 | 12 | 11 | 69 | 22 |
| 2005 | 0.285 | 0.067 | 0.382 | 0.049 | 33 | 13 | 38 | 13 |
| 2006 | 0.275 | 0.065 | 0.382 | 0.049 | 0 | 0 | 47 | 15 |

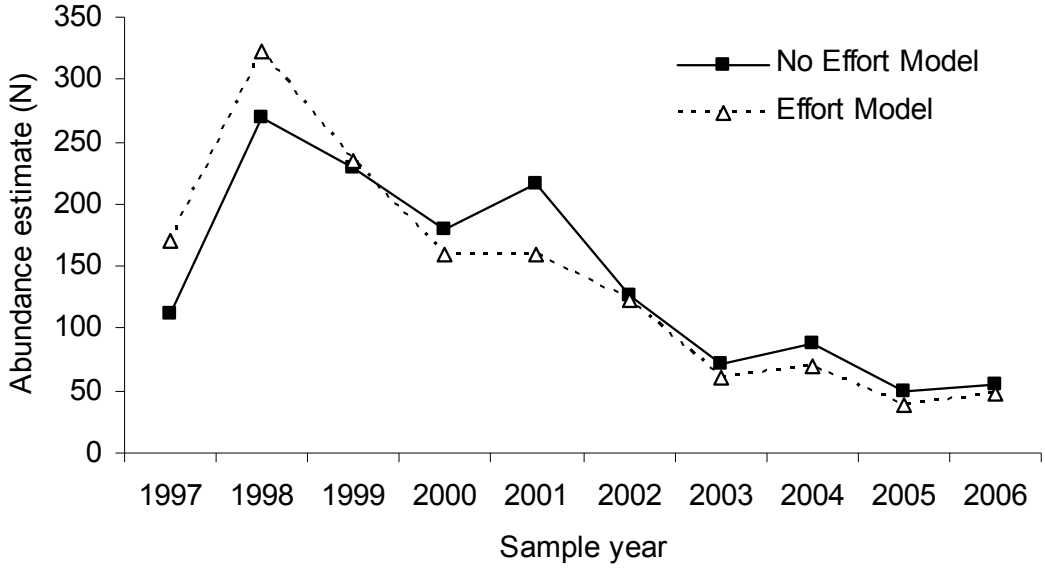


Figure 17. Estimates of Kootenai Burbot abundance ($N_t$) for two capture-recapture models.

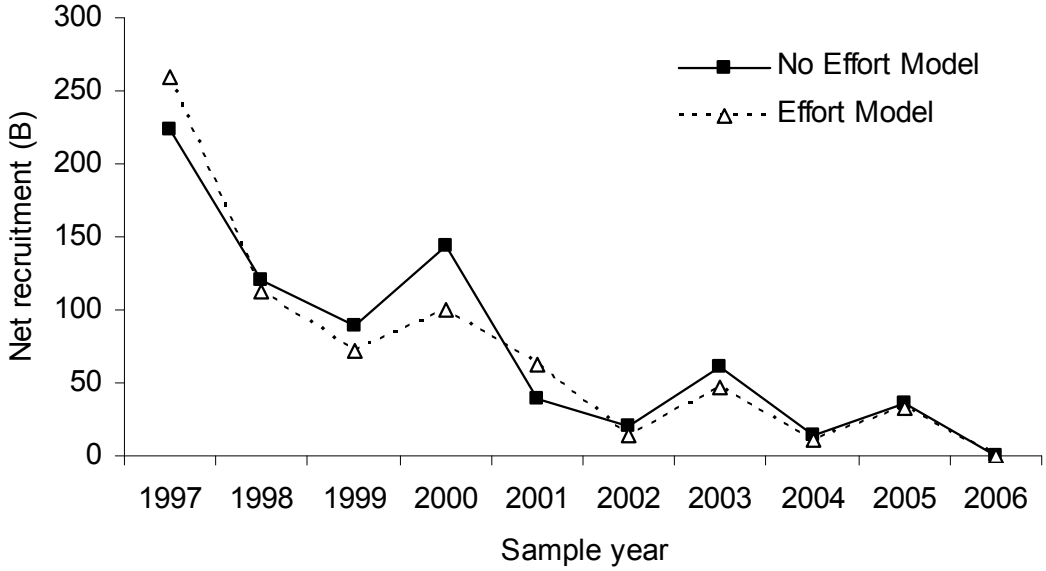


Figure 18. Estimates of Kootenai Burbot recruitment ($B_t$) for two capture-recapture models.

There was considerable uncertainty in the abundance and recruitment estimates for Kootenai River burbot, as indicated by the large standard errors (Table 9 and Table 10). Such uncertainty is expected given the small number of fish recaptured each year. Nevertheless, the relative precision of estimates across years, and the consistency of estimates between models suggest that the general magnitudes and trends in abundance and recruitment estimates are reasonably reflective of the actual population characteristics of burbot in the Kootenai River.

Even if suitable habitat conditions can be immediately restored, recovery of the small remnant population may be precluded by minimal stock numbers and genetic bottlenecks. Capture and artificial propagation of the last few wild individuals might be an option, but effective burbot propagation methods have yet to be developed, although recent studies show promise (Dillen et al. 2008; Vught et al. 2008; Jensen et al. 2008). Supplementation or reintroduction of burbot from other healthier populations is another alternative, but nonnative stocks might fare poorly and speed extinction of the locally adapted native population. Finally, without restoration of suitable habitat conditions for burbot, all conservation, recovery, or reintroduction measures are likely to meet with limited success.

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