FISHERY RESEARCH

KOOTENAI RIVER FISHERIES INVESTIGATION: STOCK STATUS OF BURBOT

ANNUAL PROGRESS REPORT

Period Covered: January 1, 1998 to December 31, 1998

Prepared by:

Vaughn L. Paragamian
Senior Fisheries Research Biologist

and

Vint Whitman
Senior Fisheries Technician

Idaho Department of Fish and Game

Boise, Idaho 83707

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ABSTRACT

We studied the H_o hypothesis that winter operation of Libby Dam does not inhibit burbot *Lota lota* migration to spawning tributaries in the Kootenai River. The U.S. Army Corps of Engineers (USACE) provided three minimum discharge (113 m^3/s) test periods from Libby Dam, unrestricted water management acted as the control. We captured 38 burbot in the Kootenai River, British Columbia (BC), Canada, and four more in Idaho. Catch averaged one burbot every 29 net days of effort (a net day is a single net set for a 24 h period) (total of 1,214.4 net days of effort). Burbot length ranged from 300 to 810 mm total length (TL) (mean = 577, SE = 20.7) and weighed from 175 to 4,100 g (mean = 1,465 g, SE = 138.6). Three ripe burbot were captured at the mouth of the Goat River during February and a single unspawned burbot was caught at Ambush Rock after the spawning season. Thirteen burbot were implanted with sonic transmitters, most were released at the capture locations. One additional burbot had an active transmitter from the previous season. Burbot were located by telemetry a total of 622 times from September 1, 1997 through August 31, 1998, of which 200 contacts occurred during winter flow tests. We rejected the H_o hypothesis; burbot movement is affected by high discharges during winter water management from Libby Dam. Five burbot each were monitored during the November and December, 1997 periods (replicates) while eight were tracked during the January 1998 period. Each period had a minimum of one five-day block of low flow tests of 113 m^3/s. χ^2 analysis indicated burbot moved (up and downstream) significantly ($P < 0.01$) more often during the low flow tests than the unrestricted water management, the control. They moved significantly more often upstream during the low flow tests than the controls ($P = 0.009$); and burbot moved upstream more often during the January tests ($P < 0.01$) than the November and December tests. No eggs or larval burbot were caught in our sampling efforts. A low flow test during January - February 1999 (five concurrent weeks) was recommended to determine how far burbot could travel under pre-Libby Dam conditions as compared to present operation of the dam.

Authors:

Vaughn L. Paragamian
Senior Fisheries Research Biologist

Vint Whitman
Senior Fisheries Technician

INTRODUCTION

Burbot *Lota lota* in the Kootenai River (Figure 1) once provided an important winter fishery to residents of north Idaho. Some anglers reported catching over 40 burbot a night during winter setline fishing (Paragamian 1994). The annual harvest of burbot from the Kootenai River by sport and commercial fisherman, in Idaho, prior to 1972 may have been in the tens of thousands of Kg. Three commercial anglers alone harvested an estimated 2,150 kg in 1958 (Idaho Department of Fish and Game Regional Archives). Burbot caught during the winter fishery are thought to have been part of a spawning migration from the lower river and Kootenay Lake, BC, Canada. However, after construction and operation of Libby Dam in 1972 by the USACE, the fishery rapidly declined and was closed in the early 1990's. Concomitant to the collapse in Idaho was the collapse of the burbot fishery in Kootenay Lake, BC (Paragamian 1993). Operation of Libby Dam for hydroelectric power and flood control has created major changes in the river hydrograph, particularly during the winter when burbot spawn (Figure 2). The temperature regime and nutrient supply of the Kootenai River are also important and have changed (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 address burbot abundance, distribution, size structure, reproductive success, movement, and to identify factors limiting burbot in the Kootenai River. Few burbot were captured between rkm 246 and the Montana border (rkm 275) from 1993 through 1994. There has been little evidence of reproduction in Idaho.

Only one juvenile burbot was captured from 1993 to 1996, and no larval fish have been collected. However, we found numerous age groups in our catch, indicating some burbot were reproducing successfully. Previous studies had failed to document a spawning run of burbot from the lower river or Kootenay Lake, but cooperative sampling in the BC reach of the river documented spawning burbot in the Goat River, BC.

Burbot were captured in Idaho and BC prior to the spawning seasons from 1994 through 1996 and implanted with sonic transmitters. Telemetry of burbot during the winters of 1994-1995 and 1995-1996 suggested high velocities produced during power production and floodwater evacuation may be inhibiting spawning migration to Idaho. Ripe burbot were captured at the Goat River but few burbot were caught upstream, and no burbot have been tracked upstream into Idaho waters before the end of the spawning season.

GOAL

Restore the burbot population in the Idaho reach of the Kootenai River and improve fishing success to historic levels.

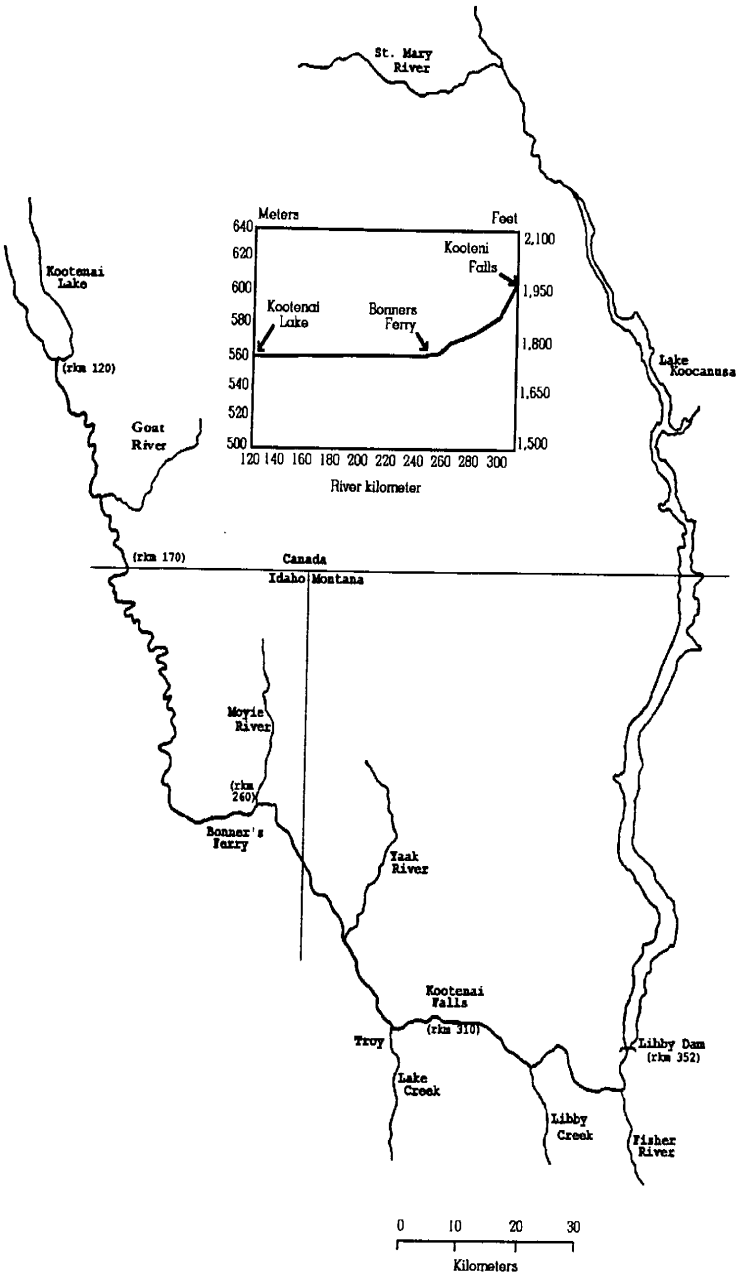

Figure 1. Location of the Kootenai River, Kootenay Lake, Lake Koocanusa, and major tributaries in Idaho. The river distances from the northern most reach of Kootenay Lake are in kilometers (rkm) and are indicated at important access points.

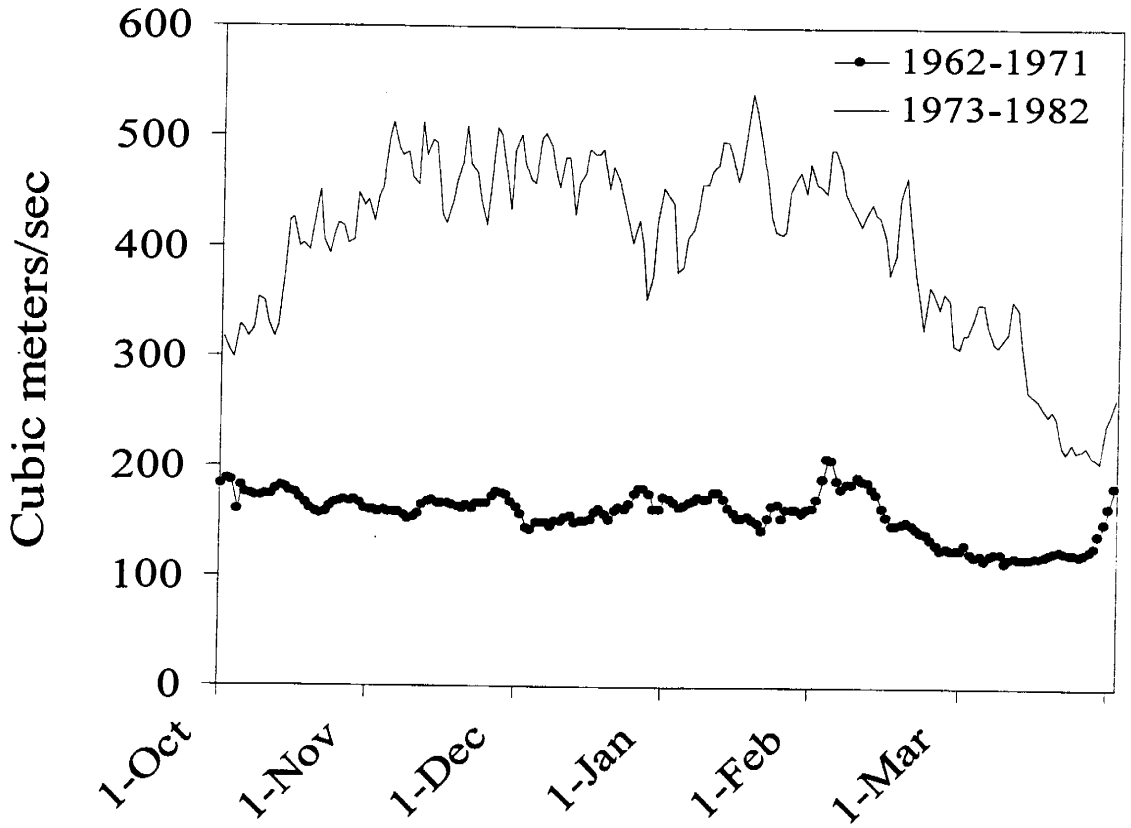

Figure 2. Mean monthly discharge of the Kootenai River at Porthill, Idaho, from 1962 through 1971 (pre-Libby Dam), and from 1973 through 1982 (post-Libby Dam).

OBJECTIVES

1. Identify factors limiting burbot within the Idaho portion of the Kootenai River drainage and recommend management alternatives to restore the fisheries to self-sustainable levels.

2. Define factors limiting burbot migration and reproductive success to improve survival and recruitment of young burbot.

3. Test H_o hypothesis that winter operation of Libby Dam does not inhibit burbot migration to spawning tributaries.

STUDY AREA

The Kootenai River (spelled Kootenay for Canadian waters) is the second largest tributary to the Columbia River. Originating in Kootenay National Park, BC, the river flows south into Montana where Libby Dam impounds water into Canada and forms Lake Koocanusa (Figure 1). From Libby Dam the river flows west and then northwest into Idaho, then north into BC and Kootenay Lake. The Kootenai River at Porthill, Idaho drains about 35,490 km^2. The reach in Idaho is 106 km long. Kootenay Lake drains out the West Arm and eventually the river joins the Columbia River near Castlegar, BC.

The Kootenai River presents three different channel and habitat types as it passes through Idaho. As the river enters Idaho, steep canyon walls and a gradient of about 0.6 m/km typify the corridor. The river begins a short braided reach about one km below the Moyie River, then at Bonners Ferry the river transitions to a lower gradient of approximately 0.02 m/km and meanders through a broad flood plain. Tributary streams of the Kootenai River are typically high gradient as they pass through mountain canyons but revert to lower gradients when they reach the valley floor, where most have been channelized.

METHODS

Discharge and Temperature

A conditional agreement was formulated with Bonneville Power Administration (BPA) and USACE to provide three experimental minimum flow tests for burbot pre-spawn and spawning migrations. Our intention was to test the H_o hypothesis that winter operation of Libby Dam does not inhibit burbot migration upstream to spawning tributaries. The USACE provided three minimum discharge (113 m^3/s) tests from Libby Dam of approximately five to seven days duration (including ramp up), one each during November and December 1997 and January 1998. We hypothesized these minimum flow tests would replicate pre-dam winter flow conditions and provide conditions for burbot to move upstream. In turn, we expected that the return of unrestricted winter water management, the control, after each minimum test flow would inhibit continued upstream movement or necessitate burbot to move back downstream.

The time required for flow releases from Libby Dam to reach the Idaho/BC border (rkm 170) is about 24 h. Velocity in the Kootenai River is reliant on flow from Libby Dam and the elevation of Kootenay Lake, BC. Kootenay Lake is at its lowest elevation during winter at about 531.5 m above sea level. Flows at the International border can be substantially higher than at Libby Dam, ranging from 155 to 1,566 m^3/s, depending on water management and daily precipitation.

Daily discharge and temperature values for the Kootenai River were obtained from USACE and the U.S. Geological Survey (USGS) office in Sandpoint, Idaho. Stowaway XI temperature loggers were used to monitor daily water temperatures for Smith, Boundary, and Summit Creeks, the Goat River in BC and the Kootenai River in Idaho, from November 1, 1997 to March 31, 1998.

Sampling Adult Burbot

Burbot sampling during the 1997-1998 season was a joint effort by IDFG and the British Columbia Ministry of Environment, Lands and Parks BC (MELP) fisheries staff. We partitioned the Kootenai River into two study segments, with slight overlap, which we sampled independently. The MELP crew sampled for burbot from the Kootenai River mouth to about Nick's Island (rkm 119.0 to 144.9) and IDFG sampled burbot in the Kootenai River in Idaho and BC, from Nick's Island, BC to Ambush Rock in Idaho (rkm 143.9 to 244.8). We anticipated intercepting burbot moving from Kootenay Lake and the lower river to historic spawning areas in Idaho and BC. We sampled for burbot with 2 to 11 hoop nets of two sizes from October 1, 1997 through May 11, 1998 (see Paragamian 1995 for a description of the nets and the method of deployment).

Nets were usually lifted on Monday, Wednesday, and Friday of each week. Fish captured in hoop nets were identified by species, enumerated, measured for total length (TL) and weighed to the nearest gram (g). All burbot were implanted with passive integrated transponder (PIT) tags in the left opercular muscle and a small piece of pelvic fin tissue was collected for genetic analysis to be archived. Relative Weights (W_r; Fisher 1997) were calculated.

Sonic Telemetry of Burbot

Adult burbot used for telemetry were captured in hoop nets and surgically implanted with sonic transmitters having 60 and 420 d life expectancies (see Paragamian 1995 for a description of the surgical procedures). Sonic transmitters were cylindrical in shape and measured 16 mm by 37 mm and 4 g (60 d) or 18 mm by 65 mm and 8 g (420 d transmitter). Sex of each burbot was determined during surgery, when possible.

Seasonal habitat use and movement of burbot were studied from September 1, 1997 through August 31, 1998. The primary period of study was from early November through February. Sonic telemetry was conducted primarily from a boat on alternate days of lifting nets and occasionally on the same day as net lifts. When burbot were located by telemetry, the location was recorded to the nearest 0.1 rkm, depth was measured with a digital echo sounder and converted from ft to the nearest m, and nose velocity was measured within 15 cm of the bottom using a Marsh-McBirney 2000 SVC electronic current meter.

Egg and Larval Sampling

We set two drift nets (mouth area = 0.847 m^2) in the Goat River, BC from February 2-13, 1998, to capture burbot eggs drifting from spawning areas. Drift nets were secured in the lower half of the water column with anchors and ropes, and marked with buoys. A Gurley 2030 R current meter was mounted in the mouth of each net. Nets were fished for approximately 24 h per set. Effort was calculated using total set time and total volume of water (m^3) filtered through each net was calculated (current velocity X mouth opening area).

On March 11, 25, and April 13, 1998, we towed two ½ m nets (mouth area = 0.7854 m^2) at the surface in the Kootenai River, to capture larval burbot downstream from the Goat River mouth. Gurley 2030 R current meters were mounted in the mouth of each net and tows were made in a downstream direction. Effort was calculated using total towing time. Total volume of water filtered through each net was also calculated (rotation counts per second from the flow meters X mouth area).

Juvenile Sampling

Four gear types were used to sample for juvenile burbot from July to September 1998. D-ring nets (mouth area = 0.589 m^2), with flow meters mounted in the mouth of each net, were towed at or near the river bottom using 4.5 kg cannon ball weights to submerge each net. Effort was calculated as described above for larval sampling with ½ m nets. Sampling at surface and subsurface depths was conducted with ½ m nets. No weight was used for surface tows, 2.3 kg of weight/net was usually needed to reach mid column depths.

Benthic trawls were conducted in the Kootenai River in cooperation with Montana Department of Fish, Wildlife and Parks (MDFWP) during July and early August 1998 to sample juvenile burbot. A steel frame held the mouth of the benthic trawl open and trawl time was used as a measure of effort. Shrimp net trawls were conducted on September 9 and 10, 1998 to sample for juvenile burbot in Idaho. Otter boards spread the mouth of the shrimp net trawl and trawl time was also used as a measure of effort. Both types of trawls were towed along the river bottom in a downstream direction moving slightly faster than the river current.

Statistical Analysis

Our statistical design for testing the H_o hypothesis was to provide three temporally distinct replicate periods (November, December, and January) and two treatments. The treatments were a minimum of five days duration (which included flow ramp up) of low flow tests (113 m^3/s). The remaining days of each period were unrestricted water management, the control, for hydroelectric power production or flood control (evacuation of water from Lake Koocanusa). Burbot were located with telemetry to document no movement, upstream movement of $\geq$ 0.1 km, or downstream movement of $\geq$ 0.1 km. Within the first study period all burbot were to be at large for about the same amount of time, burbot implanted late in a study period were not included in the analysis for that time frame. We used χ^2 analysis to determine differences in burbot movement during test periods and unrestricted water management (control) and to detect differences between the three temporal replicates. We set $P \leq 0.01$ for our significance level.

ANOVA was used to determine differences in nose velocities of burbot during flows (from Libby Dam) of 113 m^3/s and higher discharges primarily during unrestricted water management.

RESULTS

Discharge and Temperature

Three test flows were provided by the USACE during the winter of 1997-1998 (Figure 3). Flows during the unrestricted water management from Libby Dam ranged from 113 to about 660 m^3/s. Power peaking was a common practice, particularly during November through February (Figure 3).

Kootenai River temperatures at Porthill, Idaho were measured from December 23, 1997 to March 31, 1998. Temperatures from October 1 to December 22 were provided by USACE (Figure 4). Kootenai River temperatures ranged from a high of 12.5°C on November 1, 1997 to a low of -0.1°C on January 15, 1998. We monitored water temperatures with thermographs in two Idaho tributaries from October 1, 1997 to March 31, 1998 (Figure 5). Boundary Creek temperatures ranged from <0.0°C during much of December and January, to 6.0°C on March 15, 1998. Smith Creek temperature was lowest in November, December and January (0.1°C), and was highest on November 3 and 7, 1997 (4.3°C). Low water levels in March exposed the Smith Creek thermograph to atmospheric air by March 5, 1998. Therefore, most of the data for March was deleted from the Smith Creek portion of Figure 5.

We monitored temperatures in Goat River and Summit Creek, BC with thermographs from October 1, 1997 to March 31, 1998 (Figure 6). The Goat River thermograph was found hanging from a dead tree well above the high water mark on April 1, 1998. Temperature data suggest that the Goat River thermograph was likely removed from the water on March 27. Therefore, the last five days of data were deleted from the Goat River portion of Figure 6. Temperatures for the Goat River ranged from a low of 0.2°C during January 12-15 to 6.7°C on March 11 and 14, 1998. All of the tributaries monitored had heavy surface ice during mid-January. Summit Creek temperatures ranged from <0.0°C on November 13,16, and 18, 1997 to 6.9°C on March 13, 1998 (Figure 6).

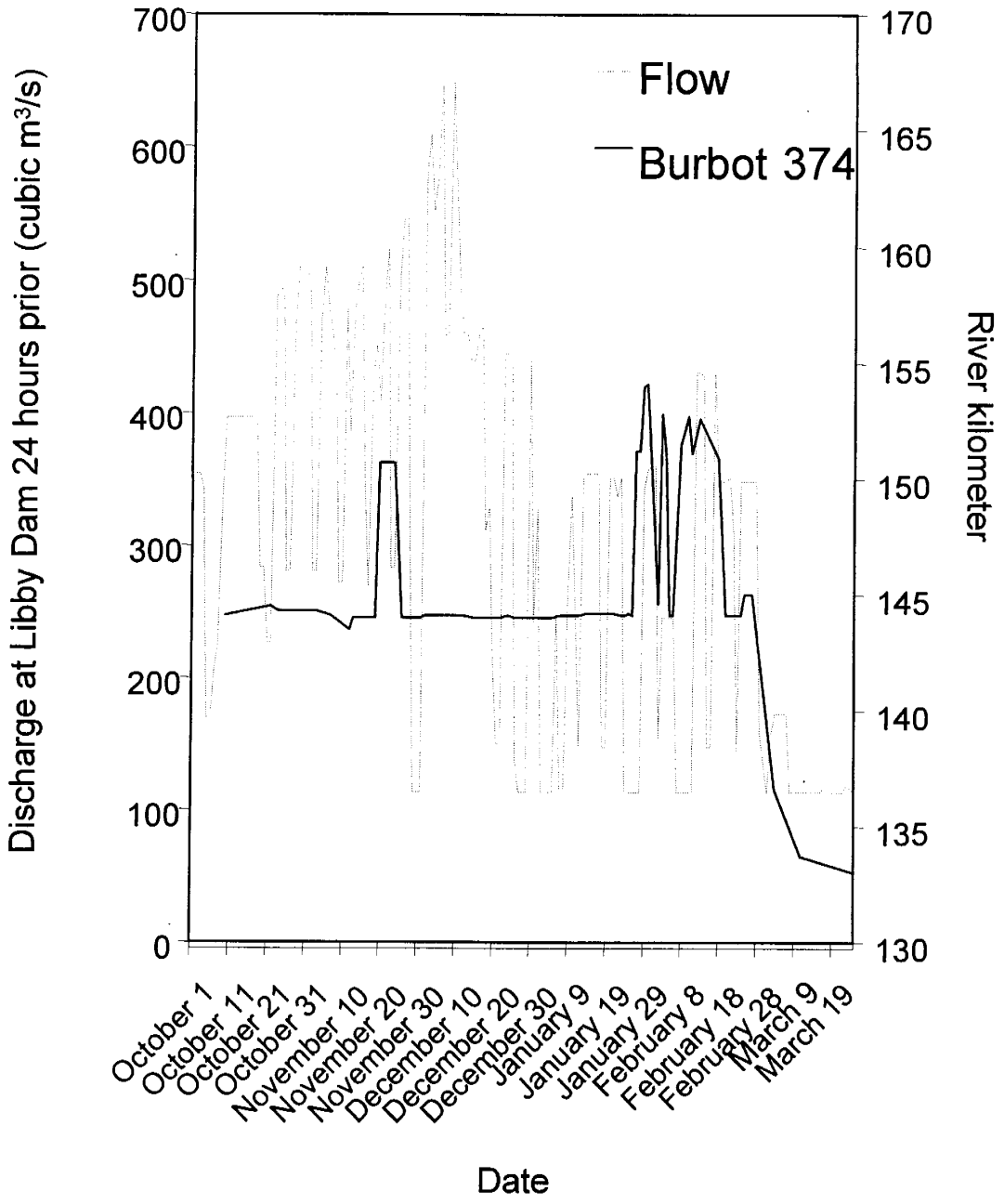

Figure 3. Kootenai River flow at Libby Dam, test flows, and movement of burbot 374 October 1, 1997 through March 25, 1998. Test flows have occurred November 28 - December 2, and December 25-30, 1997 and January 23-29, 1998.

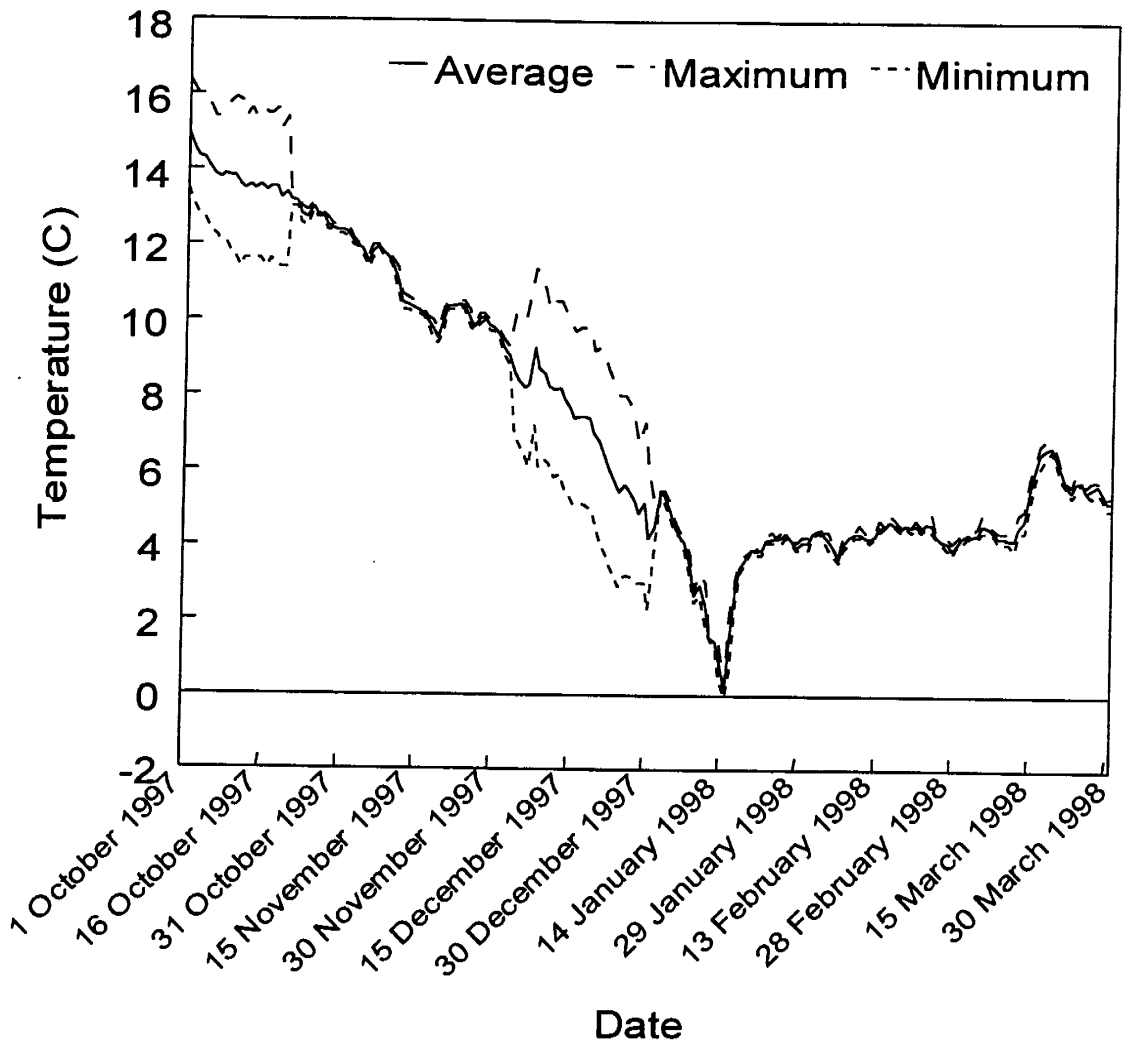

Figure 4. Temperature of the Kootenai River at Porthill, Idaho from October 1, 1997 through March 31, 1998.

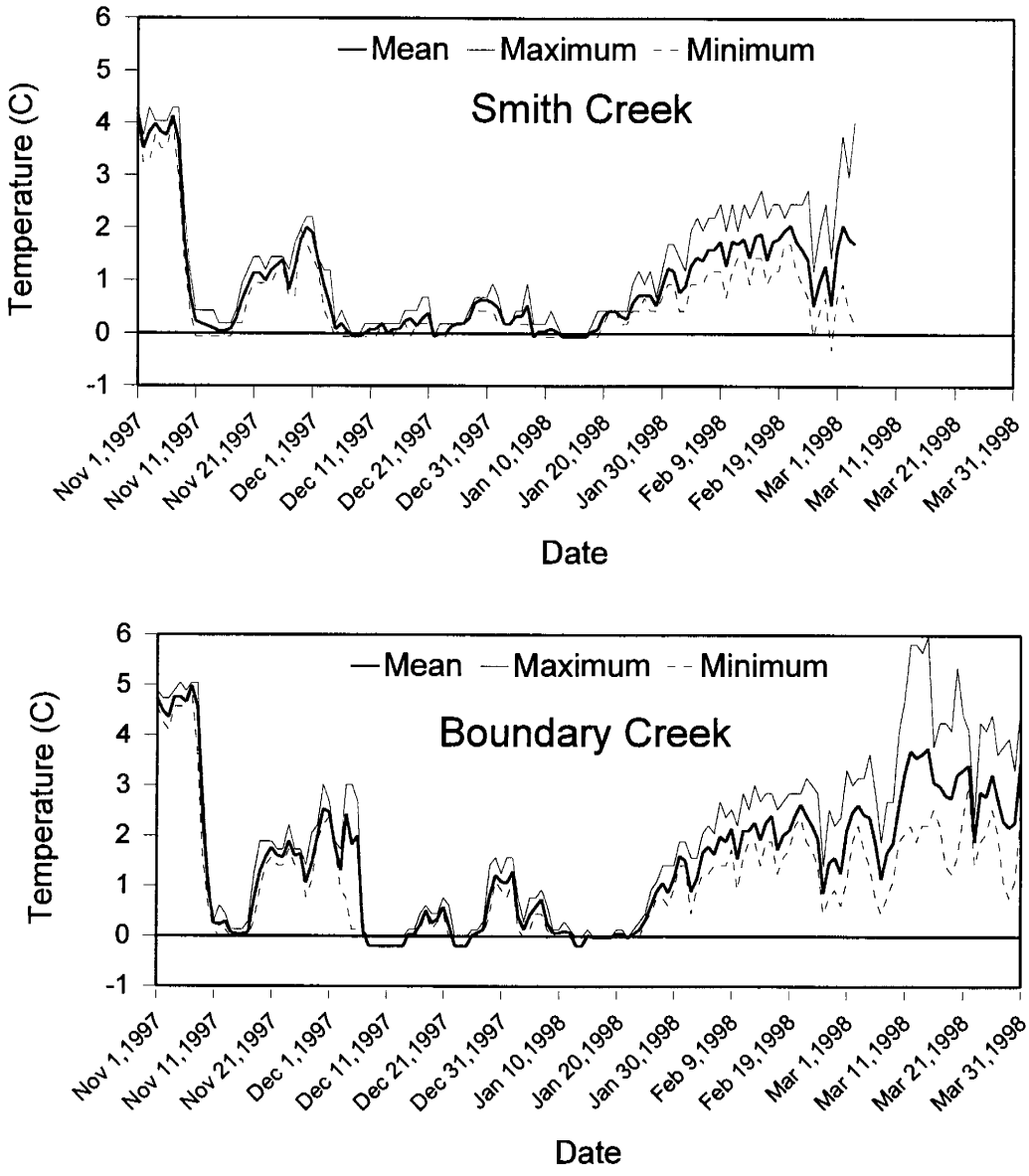

Figure 5. Temperature of two Kootenai River tributaries in Idaho, October 1, 1997 through March 31, 1998. Top figure is Smith Creek; lower figure is Boundary Creek.

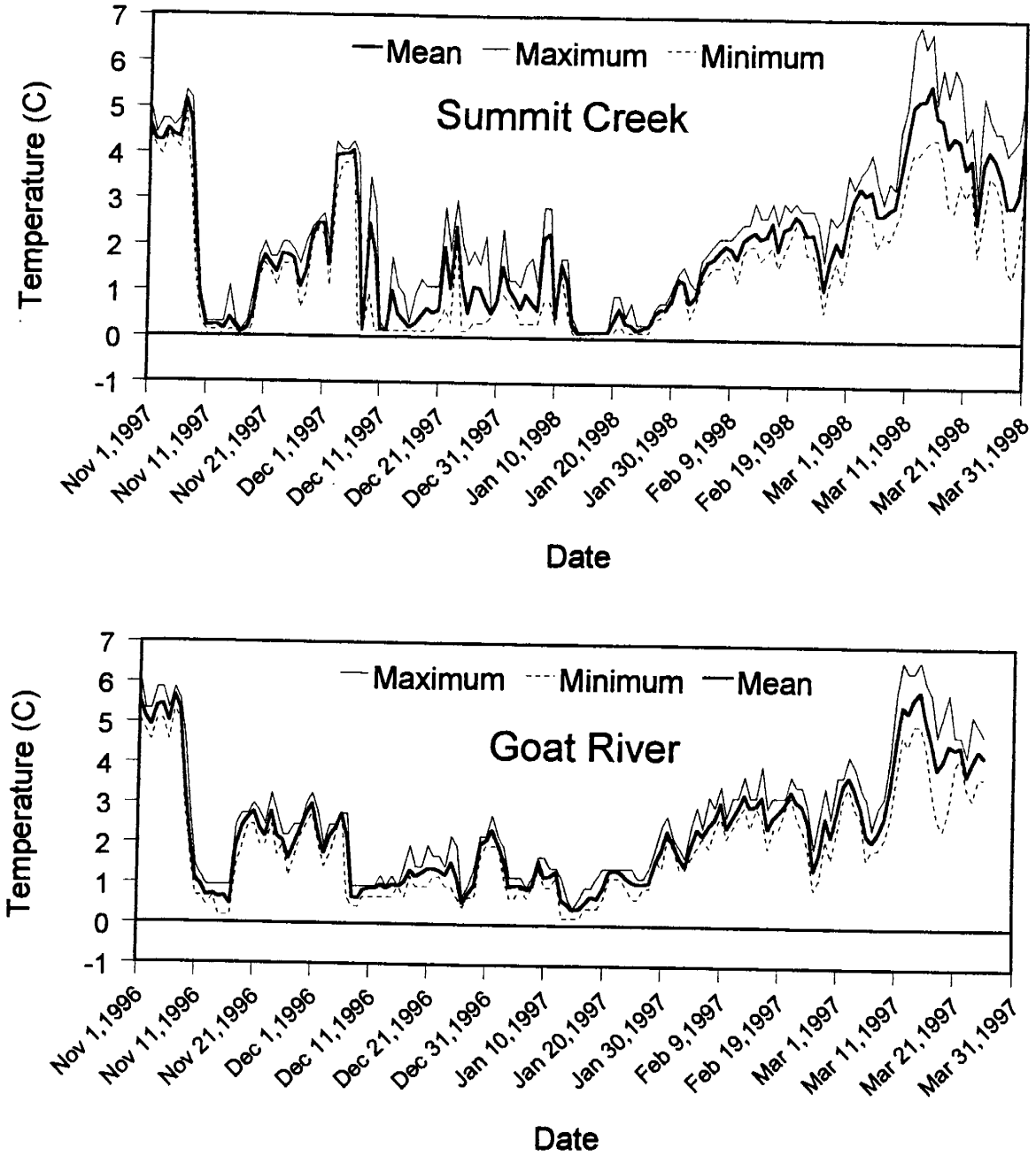

Figure 6. Temperature of two Kootenai River tributaries in BC, Canada, October 1, 1997 through March 31, 1998. Top figure is Summit Creek, lower figure is Goat River.

Sampling Adult Burbot

Total Catch

IDFG fished baited hoop nets from October 1, 1997 to May 11, 1998 for a total of 1,207 net days. A total of 219 fish were caught comprising ten different species (Table 1). Catch/unit of effort was 0.18 fish/net day for all species combined and 0.03 fish/net day for burbot (Table 1) or one burbot/29 net days.

Hoop Net Catch of Burbot

We captured a total of 42 burbot in Idaho and BC (Table 1, Figure 7). Four burbot were caught in Idaho: two near Smith Creek, one at Porthill, and one at Ambush Rock. The remaining 38 burbot were caught in BC (32 in the Kootenay River and six in the Goat River). Four burbot marked in previous years were captured for a second time and one was captured for a third time. Burbot ranged from 300 to 810 mm TL (mean=577, SE=20.7) (Figure 7) and weighed from 175 to 4,100 g (mean=1,465 g, SE=138.6). Relative weights ranged from 72 to 121 and averaged 94 (SE=1.78).

Spawning Burbot

Six burbot were captured in hoop nets set at the mouth of the Goat River between January 20 and February 17, 1998 and two of those fish were identified as ripe females (extruded eggs). Three female burbot were captured just outside the Goat River mouth in the Kootenai River during February and one burbot was captured at Ambush Rock in Idaho after the spawning season, on April 29, 1998. Biopsies indicated they did not spawn.

Table 1. Hoop net catch by number, weight (kg), and catch per unit effort (CPUE)[a], Kootenai River, Idaho and BC, and Goat River, BC, October 1997 through May, 1998.

Species	Number	Total Weight (kg)	CPUE[a]
Bull trout *Salvelinus confluentus*	1	0.95	0.0008
Brook trout *S fontinalis*	2	0.15	0.0017
Rainbow trout *Oncorhynchus mykiss*	3	0.93	0.0025
Black bullhead *Ameiurus melas*	4	0.48	0.0033
Yellow perch *Perca flavescens*	4	0.38	0.0033
White sturgeon *Acipencer transmontanus*	7	0.80	0.0058
Peamouth chub *Mylocheilus caurinus*	22	2.90	0.0182
Sucker[b] *Catostomus catostomus* and *C. macrocheilus*	32	14.28	0.0265
Northern pike minnow *Ptychocheilus oregonensis*	106	27.90	0.0878
Burbot	42	66.54	0.0348
Total	223	115.47	0.1848

[a]A unit of effort is a single 24-hour set.
[b]Species of suckers were not differentiated; longnose and largescale suckers are known to reside in the Kootenai River.

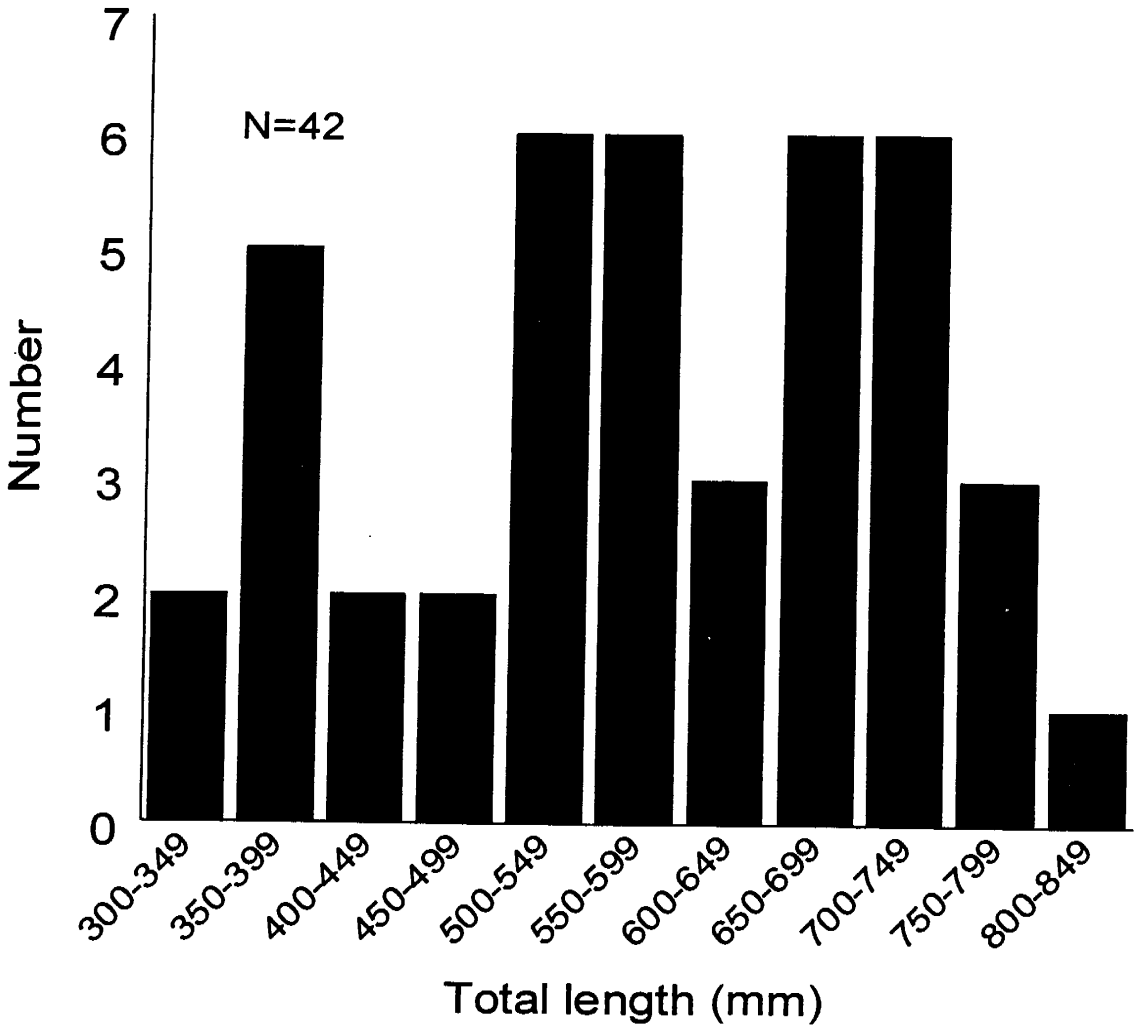

Figure 7. Length frequency distribution of burbot caught by baited hoop nets in the Kootenai River, Idaho and BC, and the Goat River, BC, October 1, 1997 through April 30, 1998.

Sonic Telemetry of Burbot

Twelve sonic tagged burbot were monitored during the 1997-1998 field season (Table 2), two additional burbot may have perished or shed tags. Although all locations of burbot were recorded, only fish known to be active were included in our analysis. Burbot with sonic tags 596 and 639 were not included because we believe they shed their tags or died soon after surgery. We made 622 telemetry contacts with burbot from September 1, 1997 through August 31, 1998. A total of 200 telemetry contacts were used for statistical analysis during the three test periods.

November Period

Five burbot were monitored during November 1997 (Appendices 1-5, Figure 3, and Table 2). The November period included November 19 through 27 for the unrestricted treatment (control) and November 28 through December 2, 1997 for the test. Flows from Libby Dam prior to the first test ranged from 269 to 547 m^3/s and temperatures from 9 to 12°C.

Prior to the November period little movement took place. However, the most notable movement was that of 374 which was monitored for the third consecutive season (Figure 7). This burbot had traveled from rkm 133 during late September to rkm 144.3, remained there until November 20, then traveled to rkm 150.7 when flow was rising from about 270 to 440 m^3/s, stayed two days then returned to rkm 144.3.

Table 2. Summary of sonic telemetry data and physical characteristics of 14 burbot in the Kootenai River, Idaho and BC, Canada, September 1997 through August 1998.

Sonic code	Date Implanted	Release site (rkm)	Total length (mm)	Weight (g)	PIT tag number	Sex	Last date located
374	2/20/96	152.6	648	2100	7F7D0D7748	F	4/1/98
2246[a]	10/27/97	144.4	637	1,710	7F7D365561	M	2/26/98
3344	10/27/97	144.4	688	1,850	7F7D403703	M	4/22/98
284[a]	10/27/97	144.4	631	1,510	7F7D39523A	Unk.	4/22/98
269	11/18/97	177.3	650	1,900	7F7D431B3C	F	2/20/98
583	11/19/97	170.1	715	2,480	7F7D401B28	F	Recovered
639[b]	12/2/97	123.5	700	2,050	7F7D381334	F	Shed
844[b]	12/15/97	141.5	745	2,480	7F7D0A426B	F	8/12/98
592	1/2/98	149.9	720	2,150	7F7D433107	F	4/22/98
578	1/14/98	149.7	729	2,150	7F7D0C124D	Unk.	5/6/98
243	1/13/98	144.0	747	2,750	7F7D321B4E	F	2/12/98
596	1/23/98	152.7	610	1,850	7F7D42473D	F	Shed
233	1/28/98	152.7	653	1,900	7F7D41374F	F	4/22/98
279	1/28/98	149.7	675	1,950	7F7D430015	F	4/22/98

[a]Sixty day transmitters, all other transmitters had a 14-month minimum life expectancy.
[b]Captured by BC Ministry of Environment.

We had a total of 43 telemetry contacts during the November period: 11 records indicated burbot moved downstream, 13 records indicated upstream movement and 24 records indicated when there was no movement. None of the five burbot moved >1 km, although some short-range movement was recorded (≤1.0 >0.1 km). There were 14 occasions during the test treatment when burbot moved 0.1 km or more, four times downstream, ten times upstream, and thirteen times when there was no movement.

December Period

The same five burbot were monitored during the second flow test provided during the last week in December (Appendices 1–5, Figure 3, and Table 2). The December period included December 3 through 24 for the unrestricted water management (control) and December 25 through December 30, 1997 for the test. Flows from Libby Dam during the December control ranged from 113 to 649 m^3/s. Kootenai River temperatures ranged from 4°C to 10°C. Temperature of the Goat River ranged from <1°C to 3°C. Flow on December 25 was reduced from 442 to 113 m^3/s.

We had 54 telemetry contacts with burbot during the December period: 16 records indicated downstream movement, 15 records indicated upstream movement, and 23 records indicated no movement. There were 11 occasions during the test when burbot moved ≥ 0.1 km, five times downstream, six times upstream, and seven times when there was no movement

January Period

Eight burbot were monitored during the January period (Appendices 1–5 and 9-11, Figure 3, and Table 2). The unrestricted treatment was from December 31, 1997 through January 22, 1998. The third test began January 23 when flow from Libby Dam was reduced from 351 m^3/s to 113 m^3/s and ended January 29, 1998. Flows from Libby Dam during January ranged from 113 to 360 m^3/s and temperatures ranged from <1°C to 5°C.

We had 103 total telemetry contacts for analysis during the January period: 31 contacts indicated movement downstream, 46 records indicated upstream movement, and 26 contacts indicated no movement. There was a total of 50 contacts during the January test flow, 27 records indicated upstream movement ≥0.1 km, 18 records indicated downstream movement ≥0.1 km, and 5 records indicated no movement. There were 15 instances when burbot moved 1.0 km or more during the test treatment.

Spawning Period

Following the third period, load following operations were frequent at Libby Dam. Daily flows ranged from 113 to 430 m^3/s during February. Dam releases in March were held at or near the minimum of 113 m^3/s. Most burbot appeared to move with changes in flow, moving upstream with lower flows then downstream as discharge increased. For example, burbot 374 made three

extensive journeys from rkm 144 to 154, back to rkm 144 and then back to rkm 153 (Figure 3). Migrations into the Goat River by spawning burbot occurred about February 13 when the water temperature of the Goat River was 3.2°C. Five burbot were recorded in the Goat River, but at least 6 of the 12 burbot tracked during this last period were moving frequently and showed no behavioral traits indicative of spawning. All burbot that we believe spawned moved downstream and several entered Kootenay Lake.

Post-spawn Period

Eight burbot were monitored during the post-spawn period, which began in late February when burbot with transmitters left the Goat River (Appendices 1-4, 9, 10, 13, and 14). Burbot 374 returned to rkm 133.7, where it had been during the summer and autumn of 1996 and 1997. Concurrent to the cessation of burbot movement was a rise in river temperature and discharge from April through May 8, 1997. Most burbot became relatively sedentary and remained in deep pools when the river temperature reached 7°C. Discharge rapidly increased to over 1,600 m^3/s through May and June. The increase in river discharge was due to precipitation and runoff rather than the Kootenai River white sturgeon test flows (Paragamian et al. in press). All 60 d transmitters expired by mid-April 1998 but several burbot with longer duration transmitters were monitored through the August record for this Annual Report.

Burbot with tag 578 (Appendix 10) drifted downstream to rkm 133.1 after spawning and in late April moved upstream to Idaho (rkm 177.1). By early May burbot 578 had moved upstream to rkm 243. When local inflow began to rise in mid-May this burbot drifted a few km downstream, only to move back upstream to 244.5. The transmitter battery in this burbot failed at the end of June 1998.

Egg and Larval Sampling

We searched for burbot eggs to document spawning in the Goat River from March 2-13, 1998. We used two drift nets to sample 9.4 m^3 of water in 329 net hours[a]. Paired ½ m meter nets did not capture any burbot eggs or larva in the Goat or Kootenai Rivers. A total of 16 tows with the ½ m nets sampled about 13,600 m^3 of water.

Juvenile Sampling

Two types of trawl nets were towed in the Idaho reach of the Kootenai River to sample juvenile burbot. Benthic trawls were conducted on 13 days between July 1 and August 7, 1998. Seventy-two benthic trawls sampled an average of 13.37 minutes per trawl. A shrimp net trawl was used on September 9 and 10, 1998. Fifteen shrimp net trawls sampled an average of 4.86 minutes per trawl. No juvenile burbot were captured with either of the active trawling methods.

[a]Goat River currents were usually too slow to turn the mechanical current meter therefore, the volume of water filtered through drift nets is probably underestimated.

Statistical Analysis

Burbot movement (upstream and downstream) during flow tests occurred with nearly twice the frequency of those during unrestricted winter water management (control) 45% and 28%, respectively. χ^2 analysis indicated burbot moved 0.1 km or more with significantly higher frequency during the low flow tests as compared to unrestricted conditions (Pearson χ^2 = 8.913, P = 0.012). χ^2 analysis also indicated burbot moved upstream with significantly greater frequency $\geq$ 0.1 km during the tests compared to unrestricted controls (Pearson χ^2 = 6.739, P = 0.009). Additional analysis indicated there was no significant difference in the amount of burbot movement (up and downstream) between the three periods (Pearson χ^2 = 9.81; P = 0.04). There was no detectable difference in the direction of movement for the first two test periods (Pearson χ^2 = 5.41 and P = 0.067; Pearson χ^2 = 0.418 and P = 0.811, respectively). However, movement upstream during the January flow test was significantly higher than the other periods (Pearson χ^2 = 11.967, P = 0.003).

Power analysis, using an approach suggested by Casandra et al. (1978) in Zar (1984), for burbot movement detection indicated for power = 95% (1 – beta = 0.95) and chance of a type 1 error = 5% (alpha = 0.05), a sample size of 168 is required. For power of 95% and error of 1% a sample of 227 is needed, for 99% and error of 5% a sample of 233 is needed, and for power of 99% and error of 1% a sample of 302 is necessary.

Nose velocities were periodically measured at the locations of 13 burbot during the winter study period of 1997-1998 (Appendices 1–6 and 7-14). Velocities measured during unrestricted dam operation averaged 11.85 cm/s (SE=1.44, N=40) while those measured during the controlled test period averaged 7.46 cm/s (SE=0.68, N=59). One-way ANOVA testing indicated nose velocities measured during the low flow test treatment were significantly different than the days of unrestricted dam operation (F with 1, 97 DF; P=0.01, F=6.96; test F=9.28).

DISCUSSION

Burbot Population Status

Burbot in Idaho are near demographic extinction. The lower Kootenai River and Kootenay Lake serve as a reservoir for the few remaining burbot and even fewer are upstream of the Goat River. We captured only five burbot from late November 1995 through March 1997 in Kootenai River, Idaho. Previous studies confirmed low densities of burbot in the Kootenai River, Idaho (Paragamian 1994 and 1995) and this genetically distinct stock of fish may soon be beyond recovery (Paragamian et al. In Press). Our studies have determined important distribution, biological, and genetic findings for the population. Several hypotheses of what is limiting the population have been presented. A recovery plan has not been devised; but a Kootenai River Burbot Recovery Committee (an international multi-agency panel) has been formed to develop a Conservation Strategy for burbot in the Kootenai River.

Burbot Flow Test

Flow management at Libby Dam likely affected burbot spawning migration during winter. Movement upstream of burbot with sonic transmitters was significantly higher ($P<0.01$) during low flow conditions, which were designed to replicate pre-dam Kootenai River flow. Winter flows are now three to four times greater than they were historically (Figure 2), when conditions were relatively stable, and now daily differences in flow can range up to 652 m^3/s.

Fluctuating flows from Libby Dam, caused by hydropower production and floodwater evacuation, continuously disrupted upstream burbot migrations. When power peaking or load following was a water management factor burbot demonstrated repeated sequences of movement upstream, no movement, and fallback. Nose velocities at burbot locations were also significantly higher ($P<0.01$) during unrestricted winter operation of Libby Dam than during low flow test treatment. The specific affect of this disruption to burbot spawning migration and spawning is unknown, but may have reduced spawning fitness or stamina and affected timing of burbot spawning. One or all of these possible reasons could have been enough to reduce spawning success and reduce adequate recruitment to sustain the fishery. Jones et al. (1974) found burbot had the lowest swimming stamina of 20 species studied, velocities higher than 25 cm/s were too great for even the largest burbot to maintain a stable position. Malinin (1971) reported burbot moved slowly during their spawning migration, at speeds that did not exceed 10 m/min, and remained in the river thalweg where current velocities were low (e.g., 30 - 40 cm/s). Breeser et al. (1988) monitored burbot spawning movement in an unregulated Alaskan river but did not report long periods of little or no movement or fallback. Some burbot in the river system they studied moved into smaller tributaries in late summer after water velocities had dropped.

Upstream movement of burbot was significantly higher ($P<0.01$) during January than during other months of study. The motivation to move more during January was probably a result of the temporal proximity to spawning which usually occurs during the first two weeks of February. Breeser et al. (1988) found burbot moved extensive distances, and that most movement occurred during the spawning season.

Burbot are thought to be highly synchronous in their spawning (Becker 1975). Burbot spawning synchrony may have been disrupted in several ways. We found burbot travel time was slower during flows higher than 113 m^3/s (Paragamian and Whitman 1997). Telemetry findings during winter 1994-1995 indicated that three burbot that migrated to Idaho from Kootenay Lake and the Kootenai River in BC did not arrive until a month or more after the spawning season (Paragamian 1995). When they did arrive water temperatures were warmer than burbot prefer for spawning (Paragamian 1995). These burbot demonstrated no behavior indicative of spawning. Inhibition of spawning movement may also explain why three unspawned females were captured in a preliminary study (Paragamian 1994). Burbot are known to travel long distances to spawn in some river systems (Breeser et al. 1988). At least one burbot in this study traveled over 120 km during the spawning migration period. Burbot are naturally slow moving, and may take nearly a month to travel from Kootenay Lake to spawning tributaries in Idaho. Any disruption is likely to affect timing of spawn.

Warmer winter temperatures in the Kootenai River could have masked the location of spawning tributaries. During the winters of 1994-1995 burbot appeared attracted to the colder water of the Goat River compared to the Kootenai River (1°C and 4°C, respectively) (Paragamian 1995). Soon after this observation burbot ascended the Goat River to spawn. However, when the temperature of the two rivers was similar several days later, three additional burbot bypassed the Goat River on a suspected spawning journey into Idaho (none of these burbot demonstrated any behavior indicative of spawning). The Goat River is the largest tributary to the Kootenai River between Bonners Ferry and Kootenay Lake. The Goat River also has the largest cold water input. Although other tributaries were substantially cooler than the Kootenai River, their low volume was diluted by the higher flow in the river.

Migrations of burbot may be further complicated by higher velocity characteristics of some segments of the Kootenai River. Telemetry studies of 1994-1996 indicated few burbot moved above rkm 153. Velocity measurements during winter 1995-1996 indicated this reach had significantly higher velocities than other randomly selected sites. We speculate there may be other locations in the river that may have substantially higher velocities. Accordingly, future management of the river for burbot migrations may also need to take into consideration velocities at specific locations when discharge is reduced.

We believe modification of present flood rule curves and the return of flow in the Kootenai River during January and the first two weeks in February to pre-dam levels (113 m^3/s) would benefit migrating burbot. Burbot would thus be conceded a travel corridor similar to natural conditions and allowed to migrate unimpeded to historic spawning tributaries.

At the present time natal fidelity of burbot is poorly understood. Thus, after appropriate flow changes are made for burbot migration, it may also be necessary to establish spawning runs to specific tributaries by transplanting adult fish of similar genetic make-up and life history to traditional spawning sites.

Burbot Biology

Martin (1976) speculated burbot might be alternate year spawners. Our recaptures of three burbot at the Goat River during the 1997 spawning run and five in 1998 (tagged the previous spawning season) and the return of burbot 374 to the Goat River for the third consecutive time indicates that at least a segment of the population are annual spawners. Recaptures of more burbot are needed to substantiate this hypothesis.

RECOMMENDATIONS

1. Test the H_o hypothesis that travel distance of burbot during unrestricted water management (power production and floodwater evacuation) in January is as far as burbot migration during a flow of 170 m^3/s. Our findings suggest that January may be the most critical month to burbot migration to spawning tributaries. We recommend a five-week test from January 1, 1999 through the first week in February 1999 during a flow of 170 m^3/s.

2 Determine the distance traveled by burbot migrating in January to estimate the necessary time needed for migrations to Boundary, Smith, and Parker Creeks in Idaho.

3. Capture and examine burbot after the spawning season to determine whether or not they spawned. This may provide evidence that burbot spawning synchrony has been disrupted by stress caused by high flows during vitellogenesis.

4. Continue experimental larval burbot capture techniques with midwater trawls, sleds, beam trawls, shrimp net trawls, drop nets, meter nets, seine nets, etc.

5. Complete the mtDNA analysis of burbot tissue samples collected from Duncan Lake, by BC MELP in 1998. Burbot from Duncan Lake may be genetically similar to burbot in the Kootenai River and they may be a potential donor stock.

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APPENDICES

Appendix 1. Location, date, velocity, water temperature, and depth of burbot 374.

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
9/2/97[a]	133.7			15.0
9/12/97	133.7	23	4	
9/17/97	133.6	22	28	
9/26/97	144.3	27	12	
10/10/97	144.1	27	0	
10/22/97	144.5	27		10.0
10/24/97	144.3	30		9.3
10/27/97	144.4			9.4
10/29/97	144.3			9.4
10/31/97	144.3			9.0
11/3/97	144.3			8.0
11/7/97	144.1	21	12	8.5
11/12/97	143.5			7.5
11/13/97	144.0	26	20	6.5
11/17/97	144.0			6.0
11/19/97	144.0	22		6.3
11/20/97	150.7	30		7.0
11/24/97	150.7	27		7.1
11/26/97	144.0			6.5
11/28/97	144.0			7.0
11/29/97	144.0	33		6.5
11/30/97	144.0	31		12
12/1/97	144.0			
12/2/97	144.1	24	7	6.1
12/5/97	144.1	29		
12/10/97	144.1	26		8.0
12/12/97	144.1	31		8.0
12/15/97	144.0			6.5
12/18/97	144.0	23		6.5
12/22/97	144.0	28		6.0
12/24/97	144.1			6.0
12/26/97	144.0	29		5.8
12/27/97	144.0	25	5	5.0
12/28/97	148.5	34		4.5
12/29/97	144.0	33		6.0
12/31/97	144.0	34		6.0
1/5/98	144.0	27		5.8
1/7/98	144.1	20		5.0
1/12/98	144.1	29		2.0
1/14/98	144.2	27		2.0
1/16/98	144.2	21		3.6
1/20/98	144.2	20		4.9

Appendix 1. (continued)

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
1/21/98	144.2			4.8
1/23/98	144.1			5.0
1/24/98	144.1	34		
1/25/98	144.2	33		4.9
1/26/98	144.1	29		5.5
1/27/98	151.2	10	3	5.8
1/28/98	151.2			3.0
1/29/98	154.0	14	6	5.0
1/30/98	154.1	20		4.8
2/2/98	144.6	6		5.7
2/3/98	152.8	19		
2/4/98	151.1	11		4.0
2/5/98	144.1			4.0
2/6/98	144.1	27		4.0
2/8/98	151.5	14		3.8
2/10/98	152.7	13	7	5.0
2/11/98	151.1	10		4.2
2/13/98	152.6			4.5
2/18/98	150.9	10	4	4.0
2/20/98	144.1	21		4.5
2/24/98	144.1	29		4.0
2/25/98	145.0	9		4.0
2/26/98	145.0	10		
2/27/98	145.0	9		4.3
3/4/98	136.6	18		4.5
3/11/98	133.7			3.0
3/25/98	133.0			6.8
4/1/98	133.6			6.0
5/20/98	134.9			10.0
6/3/98	133.7			11.0
6/10/98	133.5			12.5
6/17/98	133.6			11.8
6/24/98	133.6			14.0
7/1/98	134.2			17.0

[a]This fish was originally captured, implanted with a 14-month sonic transmitter and released on 2/20/96.

Appendix 2. Location, date, velocity, water temperature, and depth of burbot 2246.

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
10/24/97[a]	144.4	27		9.3
10/27/97[b]	144.4			
10/29/97	144.3			9.4
10/31/97	144.3			9.0
11/7/97	144.3	25	20	8.5
11/12/97	144.2			7.5
11/13/97	144.2	30	28	6.5
11/17/97	144.2			6.0
11/19/97	144.2	23		6.3
11/20/97	144.2	28	19	7.0
11/24/97	144.2			7.1
11/26/97	149.7			6.5
11/28/97	151.5	12	17	7.0
11/29/97	151.5	14	15	6.5
11/30/97	151.4	11	10	
12/1/97	150.9	12	3	6.1
12/2/97	151.0	11		6.3
12/5/97	151.2	8		
12/10/97	151.0	11		8.0
12/12/97	151.0	11		8.0
12/15/97	151.1			6.5
12/18/97	151.4	10		6.5
12/22/97	151.5	12		6.0
12/24/97	151.4	11		6.0
12/26/97	149.8	12		5.8
12/27/97	149.8	11	10	5.0
12/28/97	151.4	11	15	4.5
12/29/97	151.3	11		6.0
12/31/97	148.6	10		6.0
1/7/98	132.4	7		5.0
1/14/98	133.1	10	5	2.0
1/16/98	132.3	10		3.6
1/21/98	132.4			4.8
1/24/98	133.7	15	3	5.0
1/27/98	148.6	9	7	5.8
1/28/98	150.2			3.0
1/29/98	148.8	9	8	5.0
1/30/98	145.8	6		4.8
2/3/98	139	14		
2/4/98	150.1	9		4.0
2/5/98	148.3			4.0

Appendix 2 (continued)

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
2/8/98	133.0	12		3.8
2/10/98	132.5	9	6	5.0
2/12/98	133.5	9		4.4
2/24/98	121.0			4.4
2/26/98	121.5	9		

[a]Date of capture.
[b]Date of sonic transmitter implant (60-day battery) and release.

Appendix 3. Location, date, velocity, water temperature, and depth of burbot 3344.

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
10/24/97[a]	144.4	18		9.3
10/27/97[b]	144.4			9.4
10/29/97	141.3	18		9.4
10/31/97	141.3	19		9.0
11/3/97	141.6	14		8.0
11/7/97	141.3	18	20	8.5
11/13/97	133.8	33	28	6.5
11/19/97	133.6			6.3
11/20/97	133.6	25	20	7.0
11/24/97	133.6	24		7.1
11/28/97	141.6	30		7.0
11/29/97	147.8	11	1	6.5
11/30/97	148.4	19	12	
12/1/97	148.2	17	3	6.1
12/2/97	148.5	12		6.3
12/5/97	149.0	13		
12/10/97	147.5	11		8.0
12/12/97	144.1	30		8.0
12/15/97	144.0			6.5
12/18/97	148.8	11		6.5
12/22/97	147.5	11		6.0
12/24/97	148.0	10		6.0
12/26/97	148.5	9		5.8
12/27/97	148.5	12	8	5.0
12/28/97	148.5	10		4.5
12/29/97	148.6	10		6.0
12/31/97	147.0	10		6.0
1/5/98	147.0	10		5.8
1/7/98	147.0	10		5.0
1/12/98	147.1	10		2.0
1/14/98	148.0	10	9	2.0
1/16/98	147.5	12		3.6
1/20/98	147.5	9		4.9
1/21/98	147.6	9		4.8
1/23/98	149.0			5.0
1/24/98	133.7	10	2	5.0
1/25/98	149.8	18		4.9
1/27/98	149.8	11	4	5.8
1/28/98	142.6			3.0
1/29/98	140.1	19	23	5.0
1/30/98	140.1	10		4.8

Appendix 3. (continued)

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
2/3/98	144.6	14		
2/4/98	148.6	10		4.0
2/5/98	152.5			4.0
2/6/98	152.4	13		4.0
2/8/98	150.6	13		3.8
2/10/98	148.0	9	3	5.0
2/11/98	147.5	14		4.2
2/12/98	142.2	12		4.4
2/13/98	138.0			4.5
2/18/98	136.0	16	10	4.0
2/20/98	135.5	18		
2/24/98	135.5	13		
3/4/98	135.8	13		
3/11/98	135.5			3.0
4/1/98	135.5	15	19	6.0
4/22/98	135.5			8.0
5/20/98	135.5			10.0
6/3/98	136.0			11.0
6/10/98	135.4			12.5
6/17/98	136.2			11.8
6/24/98	136.3			14.0
7/1/98	136.0			17.0
7/7/98	136.4			18.0
7/15/98	136.3	16		16.8
7/22/98	136.0			
7/29/98	136.5			
8/5/98	136.4			
8/12/98	136.1			17

[a]Date of capture.
[b]Date of sonic transmitter implant (14-month battery) and release.

Appendix 4. Location, date, velocity, water temperature, and depth of burbot 284.

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
10/24/97[a]	144.4	27		9.3
10/27/97[b]	144.4			9.4
10/29/97	144.4			9.4
10/31/97	144.3	19		9.0
11/3/97	144.5	14		8.0
11/7/97	144.5	9	40	8.5
11/12/97	144.2			7.5
11/13/97	144.2	30	28	6.5
11/19/97	144.1	24		6.3
11/20/97	144.1	30		7.0
11/24/97	144.1	24		7.1
11/26/97	144.1			6.5
11/28/97	144.1	25		7.0
11/29/97	144.1	25	10	6.5
11/30/97	144.1	27	2	
12/1/97	144.1	27	2	6.1
12/2/97	144.2			6.3
12/5/97	144.2	27		
12/10/97	144.2	28		8.0
12/12/97	144.2	27		8.0
12/15/97	144.1			6.5
12/18/97	144.1	24		6.5
12/22/97	144.1	30		6.0
12/24/97	144.1			6.0
12/26/97	144.1	29		5.8
12/27/97	142.9	16	4	5.0
12/28/97	143.3	12		4.5
12/29/97	145.0	10		6.0
12/31/97	149.9	14		6.0
1/5/98	149.8	17		5.8
1/7/98	149.9	18		5.0
1/12/98	150.8	13		2.0
1/14/98	150.9	14	8	2.0
1/16/98	147.5	27		3.6
1/20/98	151.8	9		4.9
1/21/98	152.4	17		4.8
1/23/98	156.8			5.0
1/24/98	152.8	16	6	5.0
1/25/98	153.0	10		4.9
1/26/98	152.9	8		5.5
1/27/98	153.0	18	4	5.8

Appendix 4. (continued)

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
1/28/98	153.1			3.0
1/29/98	152.7	19	4	5.0
1/30/98	152.7	18		4.8
2/2/98	149.8	20		5.7
2/3/98	150.9	21		
2/4/98	149.4	9		4.0
2/5/98	148.4			4.0
2/6/98	148.4	10		4.0
2/8/98	148.0	11		3.8
2/10/98	148.5	13	8	5.0
2/11/98	148.8	12		4.2
2/12/98	148.2	10		4.4
2/13/98	148.2			4.5
2/17/98	148.2			4.8
2/18/98	148.0	10	13	4.0
2/20/98	148.0	9		4.5
2/23/98	148.0	11		4.5
2/24/98	148.0	8		4.4
2/25/98	148.0	10		4.0
2/26/98	148.0	9		
2/27/98	148.0	9		4.3
3/4/98	148.4	8		4.5
3/11/98	148.0			3.0
4/1/98	148.8			6.0
4/13/98	148.0			5.0
4/22/98	148.8	8.0		

[a]Date of capture.
[b]Date of sonic transmitter implant (60-day battery) and release.

Appendix 5. Location, date, velocity, water temperature, and depth of burbot 269.

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
11/14/97[a]	177.1			6.5
11/18/97[b]	177.1			
11/19/97	176.1	16		6.3
11/20/97	175.2	34		7.0
11/24/97	170.2	21		7.1
11/26/97	170.1			6.5
11/28/97	169.3	16	25	7.0
11/29/97	169.3	17	16	6.5
11/30/97	169.5	17	14	
12/1/97	169.5	17	7	6.1
12/5/97	166.5	17		
12/10/97	165.0	26		8.0
12/12/97	165.0	25		8.0
12/15/97	165.0			6.5
12/18/97	165.0	24	13	6.5
12/22/97	164.0	11		6.0
12/24/97	164.0	12		6.0
12/26/97	164.0	13		5.8
12/27/97	161.4	28	6	5.0
12/28/97	161.4	28	5	4.5
12/29/97	161.4	34		6.0
12/31/97	161.4	30		6.0
1/5/98	161.4	29		5.8
1/7/98	161.4	32		5.0
1/12/98	161.4	30		2.0
1/16/98	161.4	23		3.6
1/20/98	157.0	15		4.9
1/21/98	157.1	21		4.8
1/23/98	157.0	19		5.0
1/25/98	161.4	35		4.9
1/26/98	159.0	18		5.5
1/27/98	159.0	19	12	5.8
1/28/98	159.7			3.0
1/29/98	160.8	16	2	5.0
1/30/98	161.2	14		4.8
2/2/98	159.1	10		5.7
2/3/98	160.6	14		
2/4/98	155.9	12		4.0
2/6/98	161.4	29		4.0
2/10/98	151.9	14	2	5.0
2/11/98	151.0	8		4.2

Appendix 5. (continued)

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
2/12/98	151.2	11		4.4
2/13/98	151.5			4.5
2/15/98	150.9			5.0
2/17/98	151.9			4.8
2/18/98	151.5	12	20	4.0
2/20/98	142.7		27	4.5
8/5/98	136.6			
8/12/98	136.5			17.0

[a]Date of capture.
[b]Date of sonic transmitter implant (14-month battery) and release.

Appendix 6. Location, date, velocity, water temperature, and depth of burbot 583.

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
11/19/97[a]	170.1	8		6.3
11/19/97	170.3	15		6.3
11/20/97	170.2	24	0	7.0
11/24/97	170.3	19		7.1
11/26/97	170.3			6.5
11/28/97	170.1	27	25	7.0
11/29/97	170.1	23	5	6.5
11/30/97	170.2	24	4	
12/1/97	170.2	6	24	6.1
12/5/97	165.0	16		
12/10/97	165.0	26		8.0
12/12/97	164.9	23		8.0
12/15/97	165.0			6.5
12/18/97	163.0	23	19	6.5
12/22/97	162.0	13		6.0
12/24/97	160.0	14		6.0
12/26/97	157.7	11		5.8
12/27/97	157.9	13	10	5.0
12/28/97	157.0	13	8	4.5
12/29/97	155.5	17		6.0
12/31/97	154.0	14		6.0
1/5/98	154.0	11		5.8
1/7/98	154.0	20		5.0
1/12/98	152.8	19		2.0
1/14/98	152.8	23	14	2.0
1/16/98	152.7	19		3.6
1/20/98	152.7	8		4.9
1/21/98	152.7	16		4.8
1/23/98	152.7			5.0
1/25/98	152.7	13		4.9
1/26/98	152.7	11		5.5
1/27/98	152.7	16	5	5.8
1/28/98	152.6			3.0
1/29/98	152.7	14	4	5.0
1/30/98	152.7	12		4.8
2/2/98	152.7	8		5.7
2/3/98	152.7	16		
2/4/98	152.7			4.0
2/6/98	152.5	10		4.0
2/10/98	152.7	13	7	5.0
2/11/98	152.7	15		4.2
2/12/98	152.7	9		4.4
2/13/98	152.6	5.0		4.5

Appendix 6. (continued)

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
2/15/98	152.6			5.0
2/15/98	152.5			5.0
2/17/98	152.1			4.8
2/18/98	152.1	8	13	4.0
2/20/98	152.0	6		4.5
2/23/98	152.1	6		4.5
2/24/98	152.1	5		2.0
2/25/98	152.1	6		4.0
2/26/98	152.1	6		
2/27/98	152.1	7		4.3
3/4/98	152.0	6		4.5
3/11/98	152.1			3.0
3/25/98	152.0			6.8
4/1/98	151.8	5		6.0
4/13/98	152.0			5.0
4/21/98	152.0			8.0
4/22/98[b]	152.0			

[a]Date of capture, sonic transmitter implant (14 month battery), and release.
[b]Shed transmitter was retrieved by divers.

Appendix 7. Location, date, velocity, water temperature, and depth of burbot 639.

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
12/1/97[a]	123.5	19		
12/2/97[b]	123.5			6.3
12/12/97	121.2	11		8.0
1/7/98	123.0	8		5.0
1/12/98	122.4	7		2.0
1/14/98	123.0	9	9	2.0
1/21/98	122.5			4.8
1/24/98	122.4			5.0
1/27/98	122.2	8		5.8
1/29/98	122.2	5		5.0
2/4/98	122.1	9		4.0
2/8/98	122.1	12		3.8
2/10/98	122.1	10	6	5.0
2/18/98	122.1	9		4.0
2/24/98	122.1			4.0
2/26/98	122.1			
3/4/98	122.1			4.5
5/20/98	122.1			10.0
6/3/98	122.1			11.0
6/10/98	122.1			12.5
6/17/98	122.1			11.8
6/24/98	122.1			14.0
7/1/98	122.1			17.0
7/7/98	122.1			18.0
7/15/98	122.1			16.8
7/22/98	122.1			
8/5/98	122.1			
8/12/98	122.1			17.0
8/31/98	122.1[c]			14.5

[a]Date of capture by B.C. Ministry of Environment.
[b]Date of sonic transmitter implant (14-month battery) and release.
[c]Transmitter was apparently shed at this location during February 1998.

Appendix 8. Location, date, velocity, water temperature, and depth of burbot 844.

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
12/15/98[a]	141.5			6.5
1/7/98[b]	138.2	13		5.0
1/12/98	137.0	18		2.0
1/14/98	135.6	17		2.0
1/16/98	135.0	18		3.6
1/24/98	138.0	15	8	5.0
1/25/98	138.2	15		4.9
1/27/98	138.0	16	7	5.8
1/28/98	137.8			3.0
1/29/98	137.4	14	3	5.0
1/30/98	127.4	13		4.8
2/3/98	137.4			
2/4/98	137.4			
2/8/98	137.4			3.8
2/10/98	137.6	12	2	5.0
2/12/98	137.6[c]			4.4
2/13/98	137.6			4.5
2/18/98	137.6	16	4	4.0
2/20/98	137.6	11		4.5
2/26/98	137.6	10		
3/4/98	137.6			4.5
4/1/98	137.4			6.0
4/22/98	137.6			8.0
5/20/98	137.3			10.0
6/17/98	137.3			
7/1/98	137.6			
8/5/98	137.7			
8/12/98	137.7			17.0

[a]Date of capture by BC Ministry of Environment Lands and Parks.
[b]Date of sonic transmitter implant (14-month battery) and release.
[c]Transmitter was apparently shed at this approximate location during February 1998.

Appendix 9. Location, date, velocity, water temperature, and depth of burbot 592.

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
12/31/97[a]	149.9	20		
1/2/98[b]	149.9			5.5
1/5/98	149.6	16		5.8
1/7/98	149.0	16		5.0
1/12/98	150.9	12		2.0
1/14/98	151.0	13	8	2.0
1/16/98	151.1	10		3.6
1/20/98	151.1	9		4.9
1/21/98	151.0	9		4.8
1/23/98	150.9			5.0
1/24/98	150.7	14	4	5.0
1/25/98	151.1	10		4.9
1/26/98	150.6	20		5.5
1/27/98	150.7	7		5.8
1/28/98	150.4			3.0
1/29/98	151.0	12	6	5.0
1/30/98	151.5	9		4.8
2/2/98	152.6	8		5.7
2/3/98	152.5	10		
2/5/98	152.5			4.0
2/6/98	152.5	9		4.0
2/8/98	151.8	12		3.8
2/11/98	152.4	11		4.2
2/18/98	135.0	19	11	4.0
2/20/98	135.0	19		4.5
2/24/98	134.5	17		2.0
2/26/98	135.0	13		
3/4/98	139.3	9		4.5
3/25/98	135.0			6.5
4/1/98	134.9			6.0
4/22/98	138.0			8.0
5/20/98	133.1			10.0
6/3/98	132.7			11.0
6/10/98	132.5			12.5
6/24/98	133.0			14.0
7/1/98	134.4			17.0
7/4/98	133.0			18.0
7/15/98	130.0			
7/22/98	132.6			
7/29/98	135.5			
8/5/98	139.2			
8/12/98	137.3			17.0
8/31/98	132.3			14.5

[a]Date of capture.
[b]Date of sonic transmitter implant (14-month battery) and release.

Appendix 10. Location, date, velocity, water temperature, and depth of burbot 578.

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
1/13/98[a]	149.7			
1/16/98	149.7	17		3.6
1/21/98	151.0	9		4.8
1/24/98	151.1	11	6	5.0
1/25/98	152.8	18		4.9
1/26/98	153.0	13		5.5
1/27/98	153.3	10		5.8
1/28/98	153.6			3.0
1/29/98	153.5	12	3	5.0
1/30/98	153.5	11		4.8
2/2/98	155.4	14		5.7
2/3/98	156.5	13		
2/4/98	156.5	14		4.0
2/5/98	156.5			4.0
2/6/98	156.5	13		4.0
2/8/98	152.6	10		3.8
2/10/98	154.0	13	4	5.0
2/11/98	154.0			4.2
2/12/98	154.3	12		4.4
2/13/98	152.6			4.5
2/17/98	152.7[b]			2.5
2/26/98	152.7	11		
3/4/98	152.7	10		4.5
3/25/98	133.1			6.8
4/1/98	133.5			6.0
4/22/98	136.5			8.0
4/29/98	177.1			8.0
5/4/98	225.7			9.5
5/6/98	239.7			9.5
5/8/98	243.0			10.0
5/10/98	243.9			9.5
5/13/98	243.3			9.5
5/18/98	240.2			9.0
5/19/98	236.5			9.0
5/21/98	239.0			11.0
5/22/98	240.0			
5/24/98	241.3			11.0
5/26/98	243.0			10.5
5/28/98	243.7			9.0
5/31/98	243.8			11.0
6/4/98	244.1			11.0
6/6/98	244.5			12.0

Appendix 10. (continued)

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
6/8/98	244.0			12.0
6/11/98	244.0			13.0
6/12/98	244.0			13.0
6/14/98	244.0			12.5
6/15/98	243.1			12.0
6/19/98	242.9			12.0
6/23/98	242.4			13.0
6/25/98	242.8			15.0

[a]Date of capture, sonic transmitter implant (14-month battery) and release.
[b]Located in the Goat River, BC.

Appendix 11. Location, date, velocity, water temperature, and depth of burbot 243.

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
1/13/97[a]	144.0	20		5.0
1/14/98	144.2	26		5.5
1/16/98	144.1	33		3.6
1/20/98	144.0	18		4.9
1/21/98	144.0			4.8
1/23/98	143.9			5.0
1/24/98	144.0	21	3	5.0
1/25/98	144.0	18		4.9
1/26/98	144.1	23		5.5
1/27/98	143.8	11	5	5.8
1/28/98	144.5	11		3.0
1/29/98	148.7	11	4	5.0
1/30/98	149.9	8		4.8
2/2/98	149.7	20		6.0
2/3/98	150.7	29		
2/4/98	150.8	24		4.0
2/5/98	152.5			4.0
2/6/98	152.7	18		4.0
2/8/98	152.5	9.0		3.8
2/10/98	152.7	13	2	5.0
2/11/98	152.5	12		4.2
2/12/98	152.7	12		4.4

[a]Date of capture, sonic transmitter implant (14-month battery) and release.

Appendix 12. Location, date, velocity, water temperature, and depth of burbot 596.

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
1/20/98[a]	152.7	3		
1/23/98[b]	152.7			5.0
1/24/98	152.7	20	5	5.0
1/25/98	152.7	19		4.9
1/26/98	152.7	11		5.5
1/27/98	152.8	18	7	5.8
1/28/98	152.7			3.0
1/29/98	152.7	22	6	5.0
1/30/98	152.7	19		4.8
2/2/98	152.8	18		5.7
2/3/98	152.7	15		
2/4/98	152.7			4.0
2/5/98	152.7			4.0
2/6/98	152.7	19		4.0
2/8/98	152.8	24		3.8
2/10/98	152.7	18	3	5.0
2/11/98	152.7	13		4.2
2/12/98	152.7			4.4
2/13/98	152.7			4.5
7/4/98	152.7[c]			
7/22/98	152.7[c]			
7/29/98	152.7[c]			
8/12/98	152.7[c]			
8/19/98[d]	152.7			

[a]Date of capture.
[b]Date of sonic transmitter implant (14-month battery) and release.
[c]Transmitter was heard in the Goat River near its mouth.
[d]Transmitter was recovered from Goat River by divers.

Appendix 13. Location, date, velocity, water temperature, and depth of burbot 233.

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
1/26/98[a]	152.7	12		5.0
1/28/98[b]	152.8	12	14	3.0
1/30/98	152.8	11		4.8
2/2/98	152.9	13		5.7
2/3/98	152.8	21		
2/4/98	152.7			4.0
2/5/98	152.5			4.0
2/6/98	152.5	11		4.0
2/8/98	152.5	11		3.8
2/10/98	152.5	12	10	5.0
2/11/98	152.6	7		4.2
2/12/98	152.6	9		4.4
2/13/98	152.6			4.5
2/15/98	152.6			5.0
2/17/98	152.6			4.8
2/18/98	152.7[c]	4	5	2.7
2/23/98	152.7[c]	1		3.0
2/24/98	152.7[c]	3		2.6
2/26/98	152.6	10		
2/27/98	152.6	5		4.3
3/4/98	148.5	8		4.5
3/11/98	148.0			3.0
3/25/98	145.0			6.8
4/1/98	140.0	13	2	6.0
4/22/98	140.0			8.0
6/17/98	136.5			11.8
7/1/98	136.2			17.0
8/31/98	136.0			14.5

[a]Date of capture.
[b]Date of sonic transmitter implant (14-month battery) and release.
[c]Located in the Goat River, BC.

Appendix 14. Location, date, velocity, water temperature, and depth of burbot 279.

Date	Location (rkm)	Depth (m)	Velocity (cm/s)	Water temperature (°C)
1/26/98	149.7[a]	14		5.0
1/28/98	149.7[b]			3.0
1/30/98	149.7	18		4.8
2/2/98	149.8	16		5.7
2/3/98	149.8	14		
2/4/98	150.0	10		4.0
2/5/98	149.8			4.0
2/6/98	149.8	11		4.0
2/8/98	150.6	13		3.8
2/10/98	152.4	7	5	5.0
2/11/98	152.4	11		4.2
2/12/98	152.4	15		4.4
2/13/98	152.7[c]	3		3.3
2/20/98	152.7[c]	4		3.1
2/23/98	152.7[c]	3		3.0
2/24/98	152.7[c]	3		2.6
2/26/98	152.7[c]	4		1.9
2/27/98	152.7[c]	3		2.7
3/4/98	152.7[c]			3.5
3/11/98	152.7			3.0
3/25/98	151.2			6.8
4/1/98	146.0	6	1	6.0
4/13/98	144.2	27		5.0
4/22/98	141.3			8.0
5/20/98	130.5			10.0
6/3/98	133.9			11.0
6/10/98	132.1			12.5
6/17/98	133.2			11.8
6/24/98	132.3			14.0
7/1/98	132.0			17.0
7/7/98	130.3			18.0

[a]Date of capture.
[b]Date of sonic transmitter implant (14-month battery) and release.
[c]Located in the Goat River, BC.

Submitted by:

Vaughn L. Paragamian
Senior Fisheries Research Biologist

Vint Whitman
Senior Fisheries Technician

Approved by:

Virgil K. Moore, Chief
Bureau of Fisheries

Steven P. Yundt
Fish Research Manager