Duncan Dam Project Water Use Plan

Duncan Reservoir Burbot Monitoring

Implementation Year 2

Reference: DDMMON-11

Study Period: May 2009 to June 2010

Westslope Fisheries Ltd.
800 Summit Drive
Cranbrook, BC  V1C 5J5

Project lead and report author:
Westslope Fisheries Ltd.
Executive Summary

This interim report summarizes the results of the second year (May 2009 – June 2010) of a four-year Duncan Reservoir Burbot Monitoring Program. The primary aim of this monitoring program is to provide baseline information on the burbot population in Duncan Reservoir to better understand the relationship between reservoir operations and recruitment. The program will assess burbot spawning requirements (habitat use and distribution) through telemetry as well as provide an annual assessment of population size and age distribution through adult and juvenile sampling.

To date, juvenile burbot have not been captured within the study area, despite testing alternate sample timing and capture methods including; targeting preferred juvenile habitat features, alternate timing to avoid maximum water temperatures and target different water elevations. Capture methods tested included day and night-time electrofishing, pit-lamping, and trapping at depth using custom juvenile cod traps. Given the apparently low juvenile densities and difficulties in capture, a review of opportunities for an adult-only monitoring program is recommended.

As a potential alternative method to identify cohorts and examine the dam's operational conditions during periods of recruitment, development of a length-at-age model using otoliths from genetically similar populations (Moyie and Trout Lakes) and regionally similar populations (Kinbasket and Arrow Lakes Reservoirs) was investigated. The compiled otolith dataset is characterized by extreme variation in length-at-age. This extreme variation is consistent within all regional burbot populations except Columbia Lake. Grouping otoliths by sex within a population does not reduce the variation. As such, there is very little likelihood of creating a predictive model with the precision necessary to identify specific cohorts that could be linked in time back to specific operational impacts ($r^2 = 0.06, n=175$).

To test hypotheses regarding potential reservoir operational impacts on burbot spawning success, 29 adult burbot were surgically implanted with combined acoustic and radio transmitters (CART Tags) during April 2009. These tags are scheduled to expire April 2011 and this report presents the first year of a two-year monitoring program for these fish. All tagged fish have been located and accounted for during the 2009-10 tracking period.

Five (17%) burbot were either confirmed (n=4) or suspected (n=1) dead during the 2009-10 tracking period. One mortality was entrained sometime between tag implant (April 3, 2009) and monitoring station installation (June 19, 2009). Two mortalities were recovered at the base of avian perches April 12, 2010. Just 10 days previous, these burbot were located in the shallow ‘flats’ immediately upstream of the historic Upper Duncan River confluence area. This area has been identified as a potential spawning location and was in the process of dewatering as the Duncan Reservoir reached annual minimum water elevations.

The mean home range of adult burbot (n=28) was 7.1 km (95% C.I. 3.9 – 10.3 km, range 0.4 – 34.8 km). The reservoir area most utilized by burbot was the historic Duncan Lake - Upper Duncan River confluence area. In total, 86.2% (n=25) of the tagged fish were located within this area at some point during monitoring. Except for apparent spawning movements, Duncan Reservoir burbot were predominantly located within deepwater (>30 m depth) habitat below the minimum pool elevation. Typically, the mean depth of CART tagged adult burbot relocated during a tracking session outside the spawning period was 50 m. These locations and depths were predominantly associated with the historic Duncan Lake area.
The primary shallow water habitat utilized by Duncan Reservoir burbot was the seasonally inundated Upper Duncan River above the historic Duncan Lake. In total, 37.9% (n=11) of tagged fish were located within this area during the spawning season. Although no direct evidence could be obtained that spawning occurred, the timing of these movements suggested spawning was occurring during these migrations into the area. Reservoir elevations were declining to annual minimums during these apparent spawning movements (556.478 m Feb 14 to 548.477 m April 2 2010). At minimum reservoir elevations (546.9 m), the reservoir approximates the historic Duncan Lake water elevation. As a result, the valley bottom is dewatered and habitat becomes fluvial as the water begins flowing within the seasonally inundated river channel. If burbot spawn within the inundated river channel, then draw down may not dewater spawning habitat, eggs or early life stages. Regardless of dewatering impacts, if burbot spawn within this reach extreme turbidity and fine sediment transport likely impair egg and larval survivals. With declining reservoir levels, the river begins flowing, cutting through exposed lacustrine sediments deposited during inundation. In addition, there is excessive erosion of the silt-clay stream banks due to the highly modified valley bottom (i.e. complete deforestation and loss of riparian vegetation).

Year three spawning assessments should utilize a remote receiver at rkm 21.0. This would enable more complete monitoring of apparent spawning movements and patterns during the spawning season as well as documenting residence time, diel movement patterns, aggregations and synchronicity. This level of detail is not possible using weekly daylight mobile tracking.

Year two adult trapping (March-April 2010) was focused on maximizing catch rates to generate population estimates. In total, 61 adult burbot were captured in 450 trap sets for a mean catch per unit effort (CPUE) of 0.14 burbot per 48 hr trap-set (95% C.I. 0.11 – 0.17). This CPUE was significantly lower than year one sampling (CPUE = 0.29, 95% C.I. 0.23 – 0.35) and was also lower than CPUE reported for previous spring sampling in Duncan Reservoir (CPUE = 0.24 to 0.40 burbot). Due to the low burbot CPUE, some effort was redirected to target areas to test distribution and possible spawning aggregations of “missing fish”. Targeted sampling did not identify burbot aggregations within sampled areas (i.e. a significantly higher CPUE was expected if spawning or post-spawning burbot aggregations were present).

There were two recaptures from year one. Although recaptures do not meet the statistical minimum number required to avoid small sample bias, it is interesting to note that this recapture rate would result in a rough population estimate of 2,046 burbot. This would equate to the estimate of 3,313 (95% C.I. 1,123 – 12,011) burbot estimated in 2005-06 with similar low number of recaptures (n=4) and statistical limitations. Population status concerns for Duncan Reservoir burbot appear warranted given the low CPUE for 2009 (0.22) and 2010 (0.13). These CPUE’s are directly comparable to Windermere Lake (2006 = 0.12) and Columbia Lake (2006 = 0.58). Both Windermere and Columbia Lake have been closed to burbot angling due to population status concerns. Further sampling is required to compile a larger recapture history over several years to attempt population estimation using the program MARK.
Acknowledgements

The Duncan Reservoir Burbot monitoring program is a Duncan Dam Water Use Plan (DDWUP) requirement implemented by BC Hydro in partial fulfillment of requirements ordered by the Provincial Comptroller of Water Rights, and will specifically address clause 6(g) of BC Hydro’s Duncan Dam Conditional water License 27027.

Jeff Berdusco, Alf Leake, and Trevor Oussoren, BC Hydro project managers, are gratefully acknowledged for their assistance and support in the delivery of this program.

Westslope Fisheries Ltd. biologists Angela Prince and Scott Cope along with Canadian Columbia River Inter-Tribal Fisheries Commission (CCRIFC) technicians Jim Clairicoates, Mark Thomas and Virgil Benali conducted the field surveys.

Microtech, Juneau, Alaska (Kristen Munk) completed otolith aging and preliminary growth analyses.

Eagle Vision Geomatics & Archaeology Ltd. (Jose Galdamez), provided mapping and GIS services.

Burbot specialists (Colin Spence-MOE, Matt Neufeld-MOE, Steve Arndt-CBFWC) are gratefully acknowledged for use of their otolith collections as well as their review and comment in study design and interim results.

In addition we would like to thank Duncan Dam Operations staff for their assistance.
# Table of Contents

EXECUTIVE SUMMARY ............................................................................................................ I

ACKNOWLEDGEMENTS......................................................................................................... III

TABLE OF CONTENTS............................................................................................................ IV

LIST OF TABLES ..................................................................................................................... VI

LIST OF FIGURES................................................................................................................... VII

LIST OF APPENDICES .......................................................................................................... VIII

1. **INTRODUCTION** ............................................................................................................. 1
   1.1. **MONITORING PROGRAM RATIONALE** ........................................................................ 1
       1.1.1. Management Questions ................................................................................ 1
       1.1.2. Management Hypothesis ........................................................................... 1
       1.1.3. Key Water Use Decision Affected ......................................................................... 2
       1.1.4. Background ................................................................................................... 2
   1.2. **STUDY AREA** ........................................................................................................... 4

2. **METHODS** .......................................................................................................................... 7
   2.1. **SHORE-BASED JUVENILE BURBOT MONITORING** ............................................................. 7
   2.2. **TESTING OF ALTERNATIVE JUVENILE BURBOT MONITORING METHODS** .............. 7
       2.2.1. Data Analysis ........................................................................................................ 8
   2.3. **ADULT BURBOT CAPTURE AND TRACKING** ................................................................. 8
       2.3.1. Study Design ......................................................................................................... 8
       2.3.2. Gear Description .................................................................................................. 11
       2.3.3. Handling Procedures ........................................................................................... 12
       2.3.4. Data Analysis ...................................................................................................... 12
       2.3.5. Burbot Age Structure ........................................................................................... 13
       2.3.6. Migration and Movement ..................................................................................... 14
       2.4. **ENVIRONMENTAL DATA** .......................................................................................... 16

3. **RESULTS AND DISCUSSION** .......................................................................................... 17
   3.1. **SHORE-BASED JUVENILE BURBOT MONITORING** ............................................................. 17
   3.2. **TESTING OF ALTERNATIVE JUVENILE BURBOT MONITORING METHODS** .............. 18
       3.2.1. Night-time Electrofishing ..................................................................................... 18
       3.2.2. Pit Lamp Survey .................................................................................................. 18
       3.2.3. Juvenile Trapping ................................................................................................... 18
   3.3. **ADULT BURBOT CAPTURE AND TRACKING** ................................................................. 19
       3.3.1. Mean CPUE ........................................................................................................ 19
       3.3.2. Depth Preference ............................................................................................... 21
       3.3.3. Recapture Data .................................................................................................... 21
List of Tables

Table 2.3.1. Duncan Reservoir feature reference in relation to reservoir kilometers upstream from the Duncan Dam. ................................................................. 15

Table 2.3.2. Schedule of mobile tracking events Year 2, May 2009 – June 2010. ............. 16

Table 3.1.1. Duncan Reservoir shoreline electrofishing effort and catch June and October 2009. ......................................................................................... 17

Table 3.2.1. Duncan Reservoir juvenile trapping effort and catch October 19, 2009 – April 12, 2010. ......................................................................................... 19

Table 3.3.1. Species composition of fish captured with cod traps during the Duncan Reservoir adult burbot sampling program March - April 2010. ......................... 19

Table 3.3.2. Mean CPUE of Duncan burbot by sampling strategy, March - April 2010. ........ 20

Table 3.3.3. Mean CPUE of Duncan burbot by reservoir area (e.g. lower reservoir = Howser downstream to dam, mid-reservoir = Howser to Gallop Point, upper reservoir = Upper Duncan Confluence area above Gallop Point, arms = upper (north) and lower (south) arms. ................................................................. 21

Table 3.3.4. Population summary illustrating mean length and mean otolith age for seven Kootenay Region burbot populations as compiled from B.C. MOE and FWCP length-at-age databases................................................................. 25

Table 3.3.5. Comparison of mean length-at-age for two populations of burbot independently aged using identical otolith samples. ........................................ 28

Table 3.3.6. Sources of Mortality for Adult burbot of Duncan Reservoir. There were 29 CART tags applied in March-April 2009. ........................................................... 30

Table 3.3.7. Pattern of relative use for CART tagged adult burbot (n=29) within the Duncan Reservoir areas of similar habitat features. ........................................... 31
List of Figures

Figure 1.2.1. Duncan Reservoir burbot monitoring project study area. ........................................... 5
Figure 1.2.2. Mean daily Duncan Reservoir water surface elevation July 1, 2008 to June 1, 2010. ................................................................................................................................. 6
Figure 2.2.1. Photograph illustrating custom juvenile cod trap design. ........................................... 8
Figure 2.3.1. Random sampling grid generated for minimum pool adult burbot trapping. ............ 10
Figure 2.3.2. Photograph illustrating commercial cod trap design ................................................. 11
Figure 3.3.1. Burbot catch rates by depth (m) in Duncan Reservoir, 2010. Numbers above bars indicate the number of sets. Depth categories from Bernard et al. (1993). ................................................................. 22
Figure 3.3.2. Length frequency of adult burbot captured in Duncan Reservoir in March - April 2009 and 2010. ........................................................................................................... 23
Figure 3.3.3. Length-weight regression for adult burbot captured in spring within Duncan Reservoir 2009 (n=49) and 2010 (n=11) combined. ................................................................. 24
Figure 3.3.4. Length-at-age of burbot from Kootenay Region populations .................................... 26
Figure 3.3.5 Length-at-age of burbot from four Kootenay Region populations ............................. 27
Figure 3.3.6. Length-at age of female burbot from Moyie Lake, East Kootenay ......................... 28
Figure 3.3.7. Movement data of CART tagged adult burbot (BB11, BB12, BB13, BB14) in relation to mean daily inflows (Upper Duncan River), outflows (Duncan Dam) and reservoir elevation (Forebay). Each point represents a tracked location. ......................... 35
Figure 3.3.8. Movement data of CART tagged adult burbot (BB15, BB16, BB17, BB18) in relation to mean daily inflows (Upper Duncan River), outflows (Duncan Dam) and reservoir elevation (Forebay). Each point represents a tracked location ................. 36
Figure 3.3.9. Movement data of CART tagged adult burbot (BB19, BB20, BB21, BB22) in relation to mean daily inflows (Upper Duncan River), outflows (Duncan Dam) and reservoir elevation (Forebay). Each point represents a tracked location ......... 37
Figure 3.3.10. Movement data of CART tagged adult burbot (BB23, BB24, BB25, BB26) in relation to mean daily inflows (Upper Duncan River), outflows (Duncan Dam) and reservoir elevation (Forebay). Each point represents a tracked location. ................................................................. 38
Figure 3.3.11. Movement data of CART tagged adult burbot (BB27, BB28, BB29, BB30) in relation to mean daily inflows (Upper Duncan River), outflows (Duncan Dam) and reservoir elevation (Forebay). Each point represents a tracked location. ................................................................................. 39
Figure 3.3.12. Movement data of CART tagged adult burbot (BB31, BB32, BB33, BB34) in relation to mean daily inflows (Upper Duncan River), outflows (Duncan Dam) and reservoir elevation (Forebay). Each point represents a tracked location. ................................................................. 40
Figure 3.3.13. Movement data of CART tagged adult burbot (BB35, BB36, BB37, BB38) in relation to mean daily inflows (Upper Duncan River), outflows (Duncan Dam) and reservoir elevation (Forebay). Each point represents a tracked location. ................................................................................. 41
List of Appendices

Appendix A Duncan Reservoir Burbot Monitoring Project Map ................................................................. 61
Appendix B Environmental Data ........................................................................................................................ 63
1. Introduction

1.1. Monitoring Program Rationale

Burbot were identified by the Duncan Dam Water Use Plan Consultative Committee (DDM WUP CC) as a key fish species of concern in Duncan Reservoir due to the potential negative impact of reservoir operations on spawning success, egg survival, and juvenile stranding and due to the dearth of information regarding burbot biology in the reservoir. To address these concerns, the DDM WUP CC recommended that a life history and habitat use assessment be undertaken in Duncan Reservoir to gain a better understanding of how the current operating regime might be affecting the burbot population.

This interim report summarizes the results of the second year (May 2009 – June 2010) of the Duncan Reservoir Burbot Monitoring Program. The Duncan Reservoir Burbot Monitoring Program is a four-year program designed to reduce uncertainty in burbot life history and potential operational affects of winter draw down on burbot spawning success and juvenile recruitment. This program includes assessment of potential indexing techniques for long-term monitoring, in consultation with BC Hydro and MOE, to ensure the objectives and approach of the study are consistent with the status of burbot stocks in the reservoir, and that the approach is effective in addressing management questions outlined for this study.

1.1.1. Management Questions

The fundamental management questions to be addressed by the burbot life history and habitat use assessment are:

1. What are some basic biological characteristics of burbot populations in Duncan reservoir (e.g. distribution, abundance, growth and age structure)?

2. Does winter draw down of Duncan Reservoir dewater burbot spawning habitat and affect spawning success?

3. Can modifications be made to the operation regime and rule curves of Duncan Reservoir to protect or enhance spawning success of this burbot population?

The monitoring program will assess burbot spawning requirements (habitat use and distribution) through telemetry as well as provide an annual assessment of population size and age distribution through adult and juvenile sampling and ageing, respectively. Specifically, the assessments will address uncertainty regarding the extent to which winter draw down of the reservoir affects burbot spawning success.

1.1.2. Management Hypothesis

The primary aim of this monitoring program is to provide baseline information on the burbot population in Duncan Reservoir to better inform on the relationship between reservoir operations and recruitment. It is designed to specifically test the following hypotheses:

HO1: Winter draw down of Duncan Reservoir dewater burbot spawning habitat and thus reduces egg survival and burbot spawning success.
This hypothesis will be addressed by assessing habitat use of spawning burbot. Habitat preference will be defined for the range of habitat conditions observed, and an overall evaluation of burbot spawning conditions provided by DDM WUP operations will be summarized as part of this study program.

**HO2: Burbot populations are negatively impacted by Duncan Reservoir operations.**

This hypothesis will be addressed by annually assessing juvenile burbot densities along the reservoir shoreline. Recruitment analyses will be correlated to both juvenile stock estimates and spawning conditions for the respective cohort years to determine if operations are influencing population size.

### 1.1.3. Key Water Use Decision Affected

Implementation of the proposed monitoring program will provide information to support more informed decision making with respect to the need to balance storage in Duncan Reservoir with impacts on fish populations in the reservoir. Where operational linkages to burbot spawning success are identified, mitigation of impacts to burbot may be incorporated into future water planning processes for Duncan Reservoir.

### 1.1.4. Background

It is known that prior to construction of the Duncan Dam, a burbot fishery of some magnitude was lightly exploited in the lower Duncan River and Duncan Lake (Peterson and Withler 1965), and a late summer fishery occurred at the extreme north end of Kootenay Lake in the vicinity of the Duncan River (Andrusak 1998). After construction of Duncan dam in 1967 and Libby Dam in 1972, the fishery in both Kootenay Lake and the Kootenay River rapidly declined. The Kootenay River fishery in Idaho was closed in 1992 and the Kootenay Lake fishery in B.C. was closed in 1997 (Paragamian et al. 2000). The Kootenay Lake population has been red listed (e.g. at risk of extirpation) by the B.C. Conservation Data Centre (CDC) and the West Arm sub-population at Balfour is thought to be extirpated (Neufeld 2006). Burbot in the Kootenay River are at risk of extirpation (Paragamian and Laude 2007). In the Kootenay River in B.C. and Idaho, the population has been estimated at less than 50 individuals (Pyper et al. 2004 in Neufeld 2006). Remnant populations of genetically similar burbot remain in the extreme North Arm of Kootenay Lake and the Duncan-Lardeau watershed including Duncan Reservoir and Trout Lake (Neufeld 2006). Currently, the latest Duncan Reservoir adult burbot population estimate is 2,983 (95% C.I. 1,011 – 10,810; Neufeld 2006).

The greatest potential impact of reservoir operations on burbot populations may be the dewatering effect of winter draw down on spawning success and egg survival in sites along the shoreline and in lower sections of tributaries. In lakes, spawning usually occurs over near-shore shallows or over shallow offshore reefs and shoals, generally between 0.3 to 3 m deep (Ford et al. 1995, McPhail 1997, Spence 1999, Prince and Cope 2008). In rivers and tributaries, burbot spawn in low velocity areas in main channels and in side channels behind depositional bars (McPhail 1997). In many cases, spawning is often associated with tributary confluences or upwelling (Ford et al. 1995, McPhail 1997, Andrusak 1998, Baxter et al. 2002, Spence and Neufeld 2002, Prince and Cope 2008). Burbot spawning activity has been identified in the reservoir – tributary transition area near the elevation of the original Duncan Lake at two locations, Glacier Creek (e.g. lower Duncan River before impoundment) and in the upper Duncan River (Spence and Neufeld 2002). Peterson and Withler (1965) previously identified...
both of these locations before inundation as “gravel beds probably used by sportfish for spawning”.

This species typically spawns between late January and late February (Arndt and Hutchinson 2000, Spence and Neufeld 2002, Prince and Cope 2008), and has an egg incubation period of about 1.5 months (McPhail 1997; Taylor and McPhail 2000). Spawning and egg incubation in the Duncan Reservoir likely occurs between January and April, which coincides with the period when reservoir water levels are declining to annual minimums.

Concern has also been expressed that winter draw down of reservoirs may also reduce the productivity of burbot populations by stranding of juvenile fish. Young-of-the year and juvenile burbot (e.g. < 30 cm) essentially occupy the same habitat; shallow littoral environments with rocks, weeds or debris for cover (McPhail 1997, Taylor 2002). In addition to potential stranding, productivity within this draw down zone may also limit productivity for juvenile rearing (Moody et al. 2007).

One of the main reasons the current project was proposed and undertaken was due to the results of a previous adult burbot radio telemetry study that suggested declining water levels may interfere with burbot spawning migration and spawning activity (Spence and Neufeld 2002). Spence and Neufeld (2002) noted the extent of spawning migration into the upper Duncan River appeared to be influenced by reservoir water levels and related impacts on back-flooding and stream velocity. As back flooding from Duncan Reservoir declined, burbot tended to move downstream into areas with lower water velocities than the locations they had abandoned. Since stream spawning burbot tend to spawn in low velocity stream habitats (McPhail 1997), the burbot may have been moving downstream to more suitable lower velocity spawning sites. Burbot are known to have low swimming endurance and telemetry results in the Kootenay River below Libby Dam suggest that spawning migrations of burbot in the Kootenay River may be disrupted by high flows produced during hydropower production and flood control (Paragamian 2000).

The placement of the Duncan Dam approximately 5 km downstream from the Duncan Lake outlet resulted in the flooding and loss of prime spawning gravel beds in the lower Duncan River and Glacier Creek (Peterson and Withler 1965). Similarly, the Duncan Dam flooded approximately 25 km of upper Duncan River upstream from the historic Lake inlet. This reach contained much gravel that was probably used for spawning purposes (Peterson and Withler 1965). Peterson and Withler (1965) also describe extensive slough areas in the lower Duncan River and immediately upstream of the upper Duncan River inlet. They rated these sloughs as excellent rearing ponds for juvenile game fish. These slough areas were also inundated. Downstream slack water areas are another repeating feature of preferred burbot spawning habitat (McPhail 1997).

Duncan Reservoir burbot are genetically similar to burbot from Kootenay Lake and the Kootenay River in Idaho (Baxter et al. 2002, Neufeld 2006) suggesting some gene flow between these known burbot concentrations and potential spawning areas. Entrainment of individual burbot has been documented at Duncan Dam in two separate studies (Ord and Olmsted 2000, Spence and Neufeld 2002), and this data lend support to the theory that the small remnant population of burbot at the north end of Kootenay Lake may be Duncan Reservoir fish that are entrained through the dam (Vonk 2001). It is unclear whether adfluvial burbot from Kootenay Lake were impounded by the Duncan Dam or whether the current stock originates from the Duncan system.
1.2. Study Area

Duncan Reservoir, formed behind Duncan Dam on the Duncan River, is located at Meadow Creek approximately 8 km north of Kootenay Lake in southeastern B.C. (Figure 1.2.1). The Duncan Dam was constructed in 1967 to provide storage for flood control and optimize energy generation at downstream facilities in Canada and the U.S as part of the Columbia River Treaty.

Duncan Reservoir has a full pool surface area of 7,140 ha (Vonk 2001). The medium sized Duncan Lake (2,600 ha) and 172 ha of shallow water habitat was inundated (Thorley 2008). Duncan Reservoir operates on a rule curve that dictates seasonal reservoir operating targets that normally range between a maximum pool level of 576.7 m and a minimum level of 546.9 m that result in annual water level fluctuations of up to 30 m. This results in a dewatered area of 5,153 ha and the minimum pool surface elevation approximates the original Duncan Lake (Vonk 2001).

Operation of the reservoir is dictated by the Treaty which sets constraints on high and low pool reservoir elevation timing. The reservoir usually reaches its lowest level in April, and fills from May through July (Figure 1.2.2). The reservoir is normally near full pool by August. Draw down begins in September when inflows diminish and system load increases, and continues through until May.

Before inundation, Duncan Lake divided Duncan River into two portions, the upper and lower Duncan River. Duncan Dam is located on the lower Duncan River. It is situated 1.0 km upstream from the Lardeau River confluence, or alternatively, approximately 5 km downstream from the original Duncan Lake outlet, and 8 km upstream from Kootenay Lake. The upper Duncan River is formed by a large number of small precipitous streams fed by melt-water from snowfields and glaciers and is highly turbid during spring and summer (Peterson and Withler 1965). The valley occupied by the reservoir is approximately 1.6 km wide, and is walled by moderately steep mountains (Selkirk and Purcell Mountains). The lower Duncan River is a meandering, braided river with an abundance of side channel and off-channel habitats that culminate in a large silt/sand delta spanning the extreme north end of Kootenay Lake.
Figure 1.2.1. Duncan Reservoir burbot monitoring project study area.
Figure 1.2.2. Mean daily Duncan Reservoir water surface elevation July 1, 2008 to June 1, 2010.
2. Methods

2.1. Shore-based Juvenile Burbot Monitoring

Following the methodology of Taylor (2002), juvenile burbot sampling was identified as a potential method for monitoring recruitment success in the Duncan Reservoir. This methodology was successfully applied in Columbia and Windermere Lakes (Taylor 2002) and application of these methods have the potential to provide a representative index of recruitment success and burbot abundance, with far less impact to the population than adult sampling techniques.

In year one (August 2008, Cope 2009), the shoreline of Duncan Reservoir was delineated into discrete reaches of 500 m. Given the 44 km length of Duncan Reservoir at full pool (Vonk 2001); this resulted in 256 discrete reaches. Following randomization procedures, 20 randomly selected reaches were chosen for sampling. As these methods were unsuccessful in capturing juvenile burbot (Cope 2009), randomization procedures were abandoned in favor of targeting most likely habitat (e.g. confluence areas, Upper Duncan River, Glacier Creek, rocky shoreline of appropriate gradient). At least for the interim (i.e. year 2) until distribution can be determined.

In addition, alternative seasons were also targeted; a) spring for cooler water temperatures and one year old juvenile burbot that may have over-wintered in shoreline habitat, and b) late fall for cooler water temperatures and young-of-the-year benthic juveniles.

At each site, a two or three-person crew sampled the index sites from the shoreline out to either 1 m depth or 27.5 m from shore whichever comes first. The length of shoreline sampled was 50 m and sites were open (i.e. not enclosed with nets). The actual length and width sampled was measured for each site. Fish were sampled using a 2008 Smith-Root LR-24 DC backpack electrofisher. Location (UTM), conductivity, water temperature and turbidity were recorded.

2.2. Testing of Alternative Juvenile Burbot Monitoring Methods

Testing of alternate sample methods for nocturnal, benthic orientated species was also completed including; a) night-time electrofishing, b) both shore based and boat based shoreline habitat pit-lamping, and c) trapping at depth using custom designed traps (Redden Nets, Custom Net Division, Port Coquitlam, B.C.).

Night-time electrofishing was completed using identical methods as above with the exception that sampling was conducted during darkness. All crewmembers were wearing LED headlamps and at least one netter provided additional illumination with a 5 million candlepower pit-lamp.

Tributary, confluence area and shoreline habitat was also sampled during darkness by traversing sites on foot and at a dead-slow idle speed by boat. At a minimum, two pit-lamps totalling 10 or 15 million candlepower were utilized.

Custom designed juvenile cod traps were tested at depths greater than 1 m (Figure 2.2.1). Traps were approximately ½ scale traps patterned after commercial black cod traps (see Section 2.3 Adult Burbot Capture). Juvenile cod traps were constructed from rubber-coated, welded metal frames measuring 38 cm in height, 89 cm in diameter at the base and 53 cm at
Netting consisted of black nylon knotless 1 cm (i.e. 3/8") stretch mesh. The entrance tunnel was 50 cm wide and 25 cm high, tapering to the opening. Exclusion panels consisting of either 5 cm or 7.6 cm stretch mesh were laced onto the tunnel entrance. The purpose of the exclusion panels was to exclude adult burbot from entering the trap. Traps were purchased fully fabricated from Pacific Net and Twine Ltd. in Richmond, British Columbia.

Figure 2.2.1. Photograph illustrating custom juvenile cod trap design.

**2.2.1. Data Analysis**

Length (mm), weight (g) and life-stage (i.e. young-of-the-year, juvenile, sub-adult, adult), were measured for all captured burbot. Incidental catch was enumerated and sub-sampled for length and weight. Depletion removal assumptions were applied to calculate a total burbot estimate for each site and then standardized to fish/100 m of shoreline. Standard habitat features will be collected for each site each year. These included but were not limited to; substrate composition (dominant/sub-dominant), percent cover (vegetation, woody debris, boulder, bank), average shoreline slope, temperature, turbidity and any distinguishing or unique features noted. Photodocumentation for each site was catalogued. Each site was geo-referenced by GPS and plotted on the study area composite map (Appendix A, Map A1).

**2.3. Adult Burbot Capture and Tracking**

**2.3.1. Study Design**

Adult burbot trapping and tagging was conducted in early spring (March-April), when burbot catch rates are highest and distribution shifts to shallow water habitats (Bernard et al. 1993, Neufeld 2006, Prince 2007). Burbot occupy significantly greater depths in the late fall compared to the spring. In the spring, Duncan burbot are captured in as little as 2 m depths while in the
fall; they have never been captured at depths < 16 m (Spence and Neufeld 2002, Neufeld 2006). In a previous study that radio tagged burbot in Duncan Reservoir in November and December, no burbot were captured at depths < 16 m and despite the use of decompression procedures, trauma was evident with 20% of fish showing severe hemorrhaging and either dying during surgery or shortly thereafter (Spence and Neufeld 2002). Similar mortality rates (i.e. death during surgery or immediately afterward) were reported for a late fall radio tagging study of adult burbot on the Arrow Lakes (Arndt and Baxter 2006). In this study it is recognized that some tags may be lost to natural mortality and emigration before the first winter spawning season; however these sources of tag loss were considered to be less than decompression mortality resulting from the prolonged exposure to surface pressure as fish are held for radio tagging after being pulled from depths > 15 m.

A spring capture and tagging session would not only reduce decompression trauma in tagged individuals and reduce mortality but would also reduce stress hormones that may interfere with the normal spawning behaviour and gamete maturation of adult fish. The trapping and tagging procedure has been shown to induce a severe and prolonged stress response in salmonids (Clements et al. 1992) and lingcod (Ophiodon elongates, Milston et al. 2006). Females show three times the plasma cortisol as compared with males and require up to 40 h of recovery before reaching resting concentrations. Post spawning fish have significantly lower plasma concentrations of cortisol, glucose, and lactate following application of an extreme stressor compared with pre-spawning fish (Clements et al 1992). Thus, researchers are encouraged to avoid the sensitive pre-spawning phase and conduct their research at other times of the year.

Another benefit of a spring tagging session is the reduction in effort required to implement a randomized grid study design to generate abundance indices. Since Duncan Reservoir is drawn down to near low pool in the spring, much of the habitat in the north end and some in the south are dewatered, effectively concentrating the burbot population. Thus, the effort needed is reduced at this time of year.

The randomized grid design is widely used for providing abundance indices in burbot populations (Lafferty et al. 1992, Bernard et al. 1993, Burr 1995, Prince 2007, Neufeld 2008) as it reduces bias compared with a targeted approach and allows for the estimation of several population parameters including abundance, survival and recruitment. Since precision of these estimates is improved with increasing tag recoveries, trapping should begin immediately after ice-off, when catch rates for this species are highest (Bernard et al 1993, Neufeld 2006, Prince 2007).

For each sample session, Duncan Reservoir cod trapping locations were randomly selected from a sample grid where each block represented an area of 200 m x 200 m. Since significant differences in mortality can occur when burbot are captured at depth (Bernard et al. 1993, Neufeld and Spence 2004, Prince 2007), the sampling grid was restricted by depth. To minimize severe decompression trauma (i.e., stomach evulsion or ruptured blood vessels) while maximizing sample area, the traps were restricted to depths < 30 m and special handling procedures followed. Therefore, the sample grid was bounded by the projected April 2010 water surface elevation (547 m) and the 30 m depth contour. The 30 m depth contour was estimated from preliminary digital elevation bathymetry data provided by BC Hydro (T. Oussoren, BC Hydro, Castlegar, B.C., file data). The resulting sample grid contained 644 sample cells that were, at least in part, between the 0 m and 30 m depth contours (Figure 2.3.1).
Figure 2.3.1. Random sampling grid generated for minimum pool adult burbot trapping.
In total, 280 potential trap locations were randomly selected from the sample grid for each of the two scheduled 14-day sample sessions (i.e. 14 days sample effort x 20 traps per day). Two spring sessions were scheduled to coincide with maximum catch rates and to meet closed population model assumptions for 1-year, two-sample experiments using Chapman’s modification of the Petersen Model (Ricker 1975).

2.3.2. Gear Description

Adult burbot were captured using commercial cod traps (Figure 2.3.2). Detailed descriptions of cod traps are provided in Spence (2000). Briefly, traps were patterned after commercial black cod traps. Traps were constructed from rubber-coated, welded metal prawn trap frames measuring 60 cm in height, 96 cm in diameter at the base and 66 cm at the top. Netting consisted of black nylon knotless 2.5 cm (i.e. 1") stretch mesh. The entrance tunnel was 50 cm wide and 25 cm high, tapering to the opening. Traps were purchased fully fabricated from Redden Net Company in Vancouver, British Columbia.

Each cod trap was baited with two kokanee spawner carcasses that were scored and placed into a mesh bag attached opposite the trap throat. The baited trap was lowered under tension to the bottom and an individually numbered floating buoy attached for retrieval and identification. Depth, time, location (UTM), grid cell and float number were recorded. Traps were soaked for approximately 48 hours as Bernard et al. (1991) showed that trap effectiveness was reduced after 48 hours. Each trap’s catch was processed and released at the capture site and the empty trap stored on board. Traps were not reset until all previous deployments had been recovered; then, traps were re-baited and redeployed in another randomly selected grid cell. Typically, 20 traps were set and pulled each day.
2.3.3. Handling Procedures

Handling procedures follow the methods developed by MOE and detailed descriptions of these methods are provided in Neufeld (2006) and Neufeld and Spence (2004). Traps were set and retrieved by a three-person crew. One person piloted the boat and recorded data while the other two handled traps, tagged and sampled captured burbot. Previous research has found that handling mortality may be minimized by deflating burbot (Bruesewitz et al. 1993) and limiting the time they are exposed to the surface (Neufeld and Spence 2004, Neufeld 2006). Recent evidence suggests deflation techniques may be increasingly harmful for fish captured from progressively deeper waters (Wilde 2009). Thus, deflating burbot was reserved for a “last resort” before burbot mortality.

Rather than rely on deflation techniques, decompression trauma was mitigated by limiting depth of capture and the time the fish was exposed to the surface. To minimize surface exposure time, an electric winch was used to rapidly retrieve traps. All captured burbot were examined for tag presence and, if absent a numbered Floy tag was inserted at the base of the anterior dorsal fin. To minimize surface time the collection of life history data is dependent on depth of capture.

Fish captured < 15 m depth were measured for total length (mm) and weight (g), fish captured > 15 m but < 20 m depth were sub-sampled for length and weight, and fish captured > 20 m depth were Floy tagged and released as quickly as possible. Depending on the number of burbot in the traps, the handling process should take less than one minute (Neufeld 2006). These methods were chosen over prolonged (e.g. multiple day) retrieval methods designed to alleviate decompression trauma. Previous experience with prolonged decompression techniques was not encouraging, for time scales that would be practical (i.e. 48 hrs; Spence and Neufeld pers. comm.). Given the documented stress response to handling procedures (Clements et al. 1992, Milston et al. 2006), prolonged holding of implantation specimens may simply be trading one trauma for another.

Trauma results from gases coming out of solution with the rapid decline in ambient pressure from decreasing water depth. Since the rate of diffusion is affected by water temperature, sampling when temperatures are cool and isothermal (i.e., just after ice off) may further reduce the incidence of trap-induced mortality. During April, the Duncan Reservoir is approximately 4 °C and isothermal (Perrin and Korman in Vonk 2001).

Once tagged, the fish were then placed in a weighted, open bottom cage that was immersed and suspended off the side of the boat. Once the entire catch was processed, the cage was inverted and lowered to the bottom. There, fish were released with a quick pull of the tether rope (attached to the top) and the cage retrieved. Crews remained at the capture location for another 3-5 minutes to observe any resurfacing burbot resulting from decompression trauma or escape from the cage on the descent (Neufeld and Spence 2004). Mortalities were further sampled for sex, stomach contents, and age determination (otolith).

2.3.4. Data Analysis

Mean catch per unit effort (CPUE) and variances were calculated (Parker et al. 1987). Because few burbot enter traps during daylight and traps stop fishing after 48h (Bernard et al. 1991) catches were not adjusted for the few hours deviation in soak times from the standard 48 hours. Adjusting catches for longer or shorter soak times introduces significant bias as a division of catch does not adjust “zero” catches but does adjust large ones (Parker et al. 1987).
Equation 1) \[ \text{Mean CPUE} = \frac{\sum_{j=1}^{m} x_j}{E_j} \text{ where } x_j = \frac{C_i}{E_j} \]

Equation 2) \[ \text{Variance of mean CPUE} = \sum_{j=1}^{m} \frac{(x_j - x)^2}{m (m-1)} \]

Where:
C = catch;
E = effort in units of 48 hours; and
m = number of sets

In subsequent years, with multiple sampling events, abundance of burbot will be estimated by mark-recapture. A combination of methods, Jolly-Seber (Jolly 1965, Seber 1965) and Petersen (Ricker 1975), are used to extend the range of estimates according to the approach suggested in Pollock (1982). Once Duncan Reservoir has been sampled for at least three events, estimates of abundance, survival rate, recruitment and their variances may be calculated using the program MARK (White and Burnham 1999). Recaptures during a single event were considered captured only once to estimate abundance with the mark-recapture experiments, but were considered captured every time to estimate mean CPUE.

Catchability coefficients from the mark-recapture experiments are calculated as the ratio of mean CPUE to density of burbot (Bernard et al. 1993):

Equation 4) \[ q_{ij} = \frac{A_i \times \text{meanCPUE}_{ij}}{N_{ij}} \]

Where:

\[ N_{ij} = \text{the estimated abundance during the } j \text{th survey of the } i \text{th population} \]

\[ q_{ij} = \text{Catchability coefficient for the } j \text{th survey of the } i \text{th population} \]

\[ A_i = \text{surface area (ha) of the lake containing the } i \text{th population and} \]

\[ \text{meanCPUE}_{ij} = \text{mean CPUE for the } j \text{th survey of the } i \text{th population} \]

### 2.3.5. Burbot Age Structure

Given concerns for the population status of the Duncan Reservoir burbot population, lethal collection of otoliths for determination of population age structure has not been possible. The lack of juvenile captures and lengths further limits the ability to assess age distribution and results in continued uncertainty regarding the extent to which winter draw down of the reservoir affects burbot recruitment.

As a potential alternative method to identify cohorts and examine the dam's operational conditions during periods of recruitment, development of a length-at-age model using otoliths from genetically similar populations (Moyie and Trout Lakes) and regionally similar populations (Kinbasket and Arrow Lakes Reservoirs) were utilized in an attempt to develop a predictive model. The few samples obtained from the Duncan target population via incidental mortalities could then be used to validate the model.
Otoliths (n=201) from existing collections at the British Columbia Ministry of Environment (Matt Neufeld, MOE, Nelson, B.C.) and Columbia Basin Fish and Wildlife Compensation Program (Steve Arndt, FWCP, Nelson, B.C.) were utilized.

2.3.5.1. Preparation
A whole otolith was sectioned through the center and one half was burned using the conventional “break and burn” technique (Christensen 1964). Break and burn technique snaps an otolith through the otolith center on the dorsal-ventral axis. An otolith half is then held in an alcohol flame to carbonize the protein component of the otolith material, which is predominantly the otolith material accreted during a season of slower growth (“winter”), and which is enumerated as the annulus. Very small otoliths obviously of younger age (<3yr) were prepared for aging by immersing in water and viewing whole. The burned otolith half was stuck into clay and ‘painted’ with mineral oil. This oil creates a lens over the broken surface and the presumed “winter zones” appear darker. Microscopic viewing was conducted using a Leica stereomicroscope equipped with 16X eyepieces, 1.0X objective, and with a magnification factor range of 0.63 to 4.0. Sections were illuminated with an aperture controlled reflected light source.

2.3.5.2. Age Assessment
Growth patterns were evaluated and “aged” using general protocols that recognized pattern changes across the stages from juvenile to adult growth. Expected changes from juvenile to adult growth include recognizing a “transition zone”; a period of years where the animal presumably changes from faster to slower growth, where emphasis on somatic increase changes to an increasingly reproductive effort. The capture date was considered in assigning final age, that is, the capture date influenced enumeration of the partial year of growth in process. For example, a specimen collected in January to approximately June is aged “5yr” with the last enumerated annulus counted “to the edge” (otolith margin); while if collected approximately July through December, the assigned age is 4yr (4+) with enumeration of the last visible annulus inside the leading growth margin and where the new growth on the otolith margin is presumably accreted during the year-in-process (Note that “late in the year capture dates” will artificially inflate the length at age for any age class because their assigned age is to the previous December-January threshold, and does not allow for the growth year in process). Obviously young otoliths viewed in water were additionally measured for “otolith height” (dorsal ventral); measurements <2 mm were considered to reflect a fish of ≤~1yr old.

All specimens were aged once, and subsequently approximately 20% were re-examined. Resolutions to the assigned age were made when appropriate, few reassignments were made, and no reassignments exceeded 2 years.

Upon submission of the data and receipt of fish length and gender information, apparent “age-length outlier” specimens were reviewed. This review suggested that outliers were more likely due to a capture date effect (length inflation to assigned age not reflecting the partial year of growth in-process) or perhaps extremely fast versus slow growth rate (animal specific, or lake effect), and less likely a result of age-reading error.

2.3.6. Migration and Movement
There are 29 adult burbot implanted with transmitters (Code 11 to 39) using radio frequency 150.380 mHz and acoustic frequency 76.8 kHz. To facilitate tracking and data capture,
nomenclature used in databases and reporting follows the pattern of species-Code. For example, BB23 refers to burbot, code 23, on the above frequencies.

To facilitate location reporting, Duncan Reservoir kilometers as delineated from the reservoir centerline have been plotted on the reference map (Appendix A). When tracking burbot, UTM co-ordinates and reservoir kilometer (rkm) are recorded. The following reference table (Table 2.3.1) illustrates the rkm of unique features used to delineate the reservoir into areas of habitat similarities.

Table 2.3.1. Duncan Reservoir feature reference in relation to reservoir kilometers upstream from the Duncan Dam.

<table>
<thead>
<tr>
<th>Feature or Area</th>
<th>Location</th>
<th>rkm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duncan Dam (DDM)</td>
<td>Meadow Creek</td>
<td>0.0</td>
</tr>
<tr>
<td>Glacier Creek Alluvial Fan</td>
<td>Lower Reservoir Area</td>
<td>3.8 – 5.0</td>
</tr>
<tr>
<td>Outlet Historic Duncan Lake and start shallow water</td>
<td>Howser</td>
<td>5.2</td>
</tr>
<tr>
<td>Gallop Point</td>
<td>Gallop Creek</td>
<td>18.0</td>
</tr>
<tr>
<td>Inlet Historic Duncan Lake and start shallow water</td>
<td>Black Bluffs</td>
<td>20.5</td>
</tr>
<tr>
<td>Historic Upper Duncan River Confluence Area</td>
<td>Black Bluffs</td>
<td>20.5-23.0</td>
</tr>
<tr>
<td>Extent of Reservoir at Low Pool</td>
<td>Howser to Historic Lake Upper Confluence Area</td>
<td>5.2-20.5</td>
</tr>
<tr>
<td>Extent of Reservoir Full Pool</td>
<td>DDM to Beartrap Creek</td>
<td>0.0-44.0</td>
</tr>
<tr>
<td>Lower Reservoir Area</td>
<td>DDM to Howser</td>
<td>0.0 – 5.2</td>
</tr>
<tr>
<td>Mid Reservoir Area</td>
<td>Howser to Gallop Point</td>
<td>5.2-18.0</td>
</tr>
<tr>
<td>Upper Reservoir Area</td>
<td>Gallop Point to Historic Lake Upper Confluence</td>
<td>18.0-20.5</td>
</tr>
<tr>
<td>Seasonally Inundated Upper Duncan River</td>
<td>Upper Duncan River Draw down Zone</td>
<td>20.5-44.0</td>
</tr>
</tbody>
</table>

In year one, some opportunistic monitoring and gear testing was conducted in April 2009 with the implantation of combined acoustic and radio tags (CART Tags). The first complete tracking event was scheduled for Year two (June 2009). Additional tracking sessions were scheduled to occur October and December 2009, and during the spawning period (n=6, 15 February – 12 April, 2010). Similar tracking effort will be conducted in Year three (tag expiry April 2011) and the tracking schedule will be reviewed following the year two results.

Mobile tracking utilizes a Lotek SRX 400 radio receiver with an ultra-sonic up-converter, 3 element directional Yagi antenna, and hydrophone with 50 m cable to detect the combined radio and acoustic tags. The 50 m cable length was necessary to deploy the hydrophone below the reported thermocline depth (Perrin and Korman 1997) to maximize detection range.

Tracking was conducted primarily by boat, supported by vehicle in the upper reservoir – upper Duncan River as necessary. Aerial helicopter tracking flights (n=2) were completed during the

July 15, 2010
February - March spawning season for the Duncan Reservoir and the Upper Duncan River. Aerial tracking began at the Duncan Dam (rkm 0) and progressed upstream through the reservoir and the Upper Duncan River from the low pool elevation approximately 40 km upstream, well past the full pool elevation (rkm 44.0) and approximately 20 km further up the Upper Duncan River (rkm 64.0).

Table 2.3.2. Schedule of mobile tracking events Year 2, May 2009 – June 2010.

<table>
<thead>
<tr>
<th>Date</th>
<th>Mode</th>
<th>Coverage¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 27 - 29 2009</td>
<td>Boat</td>
<td>0.0 – 44.0 km</td>
</tr>
<tr>
<td>October 20 – 22 2009</td>
<td>Boat</td>
<td>0.0 – 44.0 km</td>
</tr>
<tr>
<td>Nov. 30 – Dec. 02 2009</td>
<td>Boat + Truck</td>
<td>0.0 – 44.0 km</td>
</tr>
<tr>
<td>February 15 – 17 2010</td>
<td>Boat</td>
<td>0.0 – 26.0 km</td>
</tr>
<tr>
<td>February 23 – 25 2010</td>
<td>Boat + Helicopter</td>
<td>-15.0 – 64.0 km</td>
</tr>
<tr>
<td>March 04 – 05 2010</td>
<td>Boat + Helicopter</td>
<td>0.0 – 50.0 km</td>
</tr>
<tr>
<td>March 12 - 14 2010a</td>
<td>Boat + Truck</td>
<td>0.0 – 42.0 km</td>
</tr>
<tr>
<td>April 02 – 04 2010</td>
<td>Boat + Truck</td>
<td>0.0 – 44.0 km</td>
</tr>
<tr>
<td>April 11 - 13 2010</td>
<td>Boat</td>
<td>0.0 – 22.0 km</td>
</tr>
</tbody>
</table>

¹ Note - extent reservoir full pool 0.0 km – 44.0 km. Above 44.0 km equals upper Duncan River and below 0.0 km equals lower Duncan River and Kootenay Lake confluence area.

On June 19, 2009 a remote radio telemetry station was installed at the Duncan Dam facility (rkm = 0.0). The station was housed in the gatehouse and consisted of a SRX 400 receiver connected to one 4 element Yagi antennae to detect and log coded transmitters that might pass through the discharge tunnels and exit on the downstream outlet into the discharge channel. The remote station was periodically downloaded and maintained throughout the year.

2.4. Environmental Data

Mean daily water surface elevation and reservoir discharge for Duncan Reservoir are provided by BC Hydro, Power Records. Upper Duncan River discharges are provided by the Water Survey of Canada (Stn # 08NH119). Some data utilized for summaries are preliminary and as such all data should be considered preliminary and source data should be consulted for possible discrepancies.

Measurement of water temperature, dissolved oxygen (DO), conductivity and pH were collected at depth intervals up to 60 m depth using a YSI 600-QS multi-meter.

Once potential spawning habitat was identified in spring 2010, reservoir thermistor deployment was scheduled to be completed. During the interim, spot surface, 30 m and 60 m depth water temperatures collected during juvenile and adult sampling and tracking sessions were utilized to characterize seasonal temperature variation.
3. Results and Discussion

3.1. Shore-based Juvenile Burbot Monitoring

Targeted shoreline electrofishing for juvenile burbot was completed June 23-27 and October 27-29, 2009. Sample timing was selected to represent alternative seasons to the year one August sampling session. June sampling for cooler water temperatures and one year old juvenile burbot that may have over-wintered in shoreline habitat, and October for cooler water temperatures and young-of-the-year benthic juveniles.

In June, reservoir surface water temperature ranged between 13.3 and 16.6 °C and tributary confluence areas ranged in water temperature between 2.7 and 6.8 °C. The Upper Duncan River sample sites ranged between 7.4 and 8.3 °C. In October, reservoir surface water temperature ranged between 10.8 and 12.7 °C and the Upper Duncan River sample site was 12.7 °C.

At the time of shoreline sampling the Duncan Reservoir water surface ranged from 562.742 - 563.880 m (June) and 572.759 – 572.711 m (October).

In total, 19 shoreline and tributary sites were single-pass electrofished for a total of 4,150 lineal m and 39,005 m² shoreline habitat between 0 m and 1.2 m deep (Table 3.1.1). There were no burbot captured. Appendix A (Map A1) illustrates the distribution of shoreline sample effort within the study area. Electrofishing summary data (Table 3.1.1.) includes night-time electrofishing sessions in June and October. These methods were also unsuccessful in capturing juvenile burbot and are discussed in the following section (see Section 3.2. Testing of Alternative Juvenile Burbot Monitoring Methods).

Table 3.1.1. Duncan Reservoir shoreline electrofishing effort and catch June and October 2009.

<table>
<thead>
<tr>
<th>Sample Method</th>
<th>Number</th>
<th>Dates</th>
<th>BB</th>
<th>BT</th>
<th>MW</th>
<th>CCG</th>
<th>CSU</th>
<th>NSC</th>
<th>RSC</th>
<th>LNC</th>
<th>RB</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF</td>
<td>15</td>
<td>23-27 June</td>
<td>0</td>
<td>6</td>
<td>8</td>
<td>34</td>
<td>6</td>
<td>13</td>
<td>66</td>
<td>58</td>
<td>1</td>
<td>192</td>
</tr>
<tr>
<td>EF</td>
<td>4</td>
<td>27-29 Oct</td>
<td>0</td>
<td>0</td>
<td>217</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>220</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>19</strong></td>
<td></td>
<td>0</td>
<td>6</td>
<td>225</td>
<td>34</td>
<td>6</td>
<td>13</td>
<td>69</td>
<td>58</td>
<td>1</td>
<td><strong>412</strong></td>
</tr>
</tbody>
</table>

BB=Burbot BT=Bull trout RB=Rainbow Trout
MW=Mountain whitefish CCG=Slippery sculpin
CSU=Largescale sucker NSC=Northern pikeminnow
RSC=Redside shiner LNC=Longnose Dace

To date, juvenile burbot electrofishing surveys have been completed over a wide range of habitat including reservoir shoreline, tributary confluence areas and lower reaches of tributaries. Also to date, juvenile burbot electrofishing surveys have been completed during spring (June 2009), summer (August 2008) and fall (October 2009) conditions. The absence of juvenile captures over such a wide range of apparently suitable habitat remains a significant uncertainty and concern for the recruitment health of the Duncan Reservoir burbot population.

Given the apparently low juvenile densities and difficulties in capture, a review of opportunities for an adult-only long-term monitoring program is recommended.
3.2. Testing of Alternative Juvenile Burbot Monitoring Methods

3.2.1. Night-time Electrofishing

Night-time electrofishing was tested on three separate occasions (June 24, 25 and October 27, 2009) to test if juvenile burbot were not being captured due to nocturnal habits. No burbot were captured or observed. Habitat sampled included cobble-boulder low gradient (<3%) shoreline, tributary confluence area and lower tributary habitat.

June sampling was hindered by moderate turbidity (NTU = 1.5 – 5.5) and as such, the late fall (NTU = 0.00) is recommended for any further night-time sampling considerations.

Of note were the extremely high densities of mountain whitefish parr (i.e. fork length range 100 mm to 200 mm) captured in Glacier Creek in October (Table 3.1.1). These fish were captured in a very restricted area located immediately upstream of the Glacier Creek – reservoir backwater limits. The actual densities were much higher as it was estimated that capture efficiency was, at most, 50%. This site was re-sampled the following day with a downstream stop-net, however there were zero captures. It was assumed that these fish had moved into the deeper pool habitat and were not accessible using the shoreline electrofishing methods during daylight.

3.2.2. Pit Lamp Survey

Night-time pit lamp surveys were conducted on three separate occasions (June 24, 25 and October 27, 2009) to test if juvenile burbot could be observed nocturnally (Appendix A, Map A1). Boat based observations were completed for reservoir shoreline habitat approximately 0 - 4 m deep from Howser boat launch downstream on the west shoreline to a point directly across from Glacier Creek. The east shoreline from Glacier Creek downstream to and including the dam face in the forebay were also surveyed by boat. The Glacier Creek confluence area and the lower 500 m of Glacier Creek were also surveyed by traversing the area by foot.

Additional shoreline habitat at Gallop Point and Griz Creek were pit lamp surveyed during the spawning assessments (see Section 3.3.8.4.3 Reservoir Shoal Spawning).

No burbot were observed. Largescale sucker, mountain whitefish, redside shiner, longnose dace, and sculpin were observed.

3.2.3. Juvenile Trapping

No burbot were captured during testing of juvenile cod traps (Table 3.2.1). In total, 127 trap sets were deployed October 19, 2009 to April 12, 2010. Appendix A (Map A1) illustrates the distribution of sample effort within the study area. Habitat sampled included reservoir shoreline, reservoir at depth, tributary confluence areas and tributary habitat (Glacier Creek, Upper Duncan River within full pool elevation including side-channel habitat). Depths fished ranged from 1 m to 84.5 m.
3.3. Adult Burbot Capture and Tracking

In total, 61 adult burbot were captured in 450 trap sets March 8 to April 14, 2010 (Table 3.3.1, Appendix A, Map A1). All original burbot captures (n=58) were floy tagged and there were no immediate mortalities. There were three recaptures from earlier programs. Two were recaptures from the 98 floy tags applied the previous year (Cope 2009) and one was recaptured from a previous program in 2005-06 (Neufeld 2006). In addition, 63 fish representing a variety of species were captured as by catch (Table 3.3.1).

Water surface temperatures ranged from 3.5 °C to 5.8 °C and although sample timing was three weeks earlier than year one (2009) studies, these water temperatures were virtually identical to 2009 studies (3.8 °C to 6.1 °C). Spring sample timing coincides with the normal operational minimum pool elevation of 546.9 m and reservoir levels have been similar for the first two years of sampling. In 2010, reservoir elevation during adult trapping declined from 552.139 m to 548.214 m (spring 2010 minimum 547.822 m). In 2009, reservoir elevation during adult trapping declined from 548.819 m to 547.097 m (spring 2009 minimum 547.082 m).

3.3.1. Mean CPUE

Mean catch per unit effort (CPUE) in year two was 0.14 burbot per 48 hr trap-set (95% C.I. = 0.11 – 0.17). This was lower than year one (CPUE = 0.29 burbot per 48 hr trap set, 95% C.I. = 0.23 – 0.35, Cope 2009). The 2010 CPUE was also lower than those reported for previous spring adult burbot programs on Duncan Reservoir (CPUE = 0.24 to 0.40 burbot per 48 hr trap-set, Neufeld 2006).
Unlike year one, CPUE for targeted locations (CPUE = 0.16 burbot per 48 hr trap-set) was not significantly different from random locations (CPUE = 0.13 burbot per 48 hr trap-set, Table 3.3.2). Random sampling was conducted March 8 to April 14 and targeted sampling was conducted concurrently (March 16 – April 14).

Table 3.3.2. Mean CPUE of Duncan burbot by sampling strategy, March - April 2010.

<table>
<thead>
<tr>
<th>Trap Method</th>
<th>N (traps)</th>
<th>Burbot Catch</th>
<th>CPUE</th>
<th>95% C.I.</th>
<th>S.D.</th>
<th>Min Catch</th>
<th>Max Catch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random</td>
<td>361</td>
<td>47</td>
<td>0.13</td>
<td>0.04</td>
<td>0.37</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Targeted</td>
<td>89</td>
<td>14</td>
<td>0.16</td>
<td>0.08</td>
<td>0.37</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>450</td>
<td>61</td>
<td>0.14</td>
<td>0.03</td>
<td>0.37</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Initially, all sampling was scheduled to utilize random sampling methodology. Due to the low burbot CPUE, some effort was redirected to target areas to test for potential spawning aggregations of “missing fish”. Targeted sampling did not identify burbot aggregations within sampled areas (i.e. a significantly higher CPUE and/or ripe fish were not detected beyond those observed in the random sampling design). Targeted trapping was conducted within the following areas:

- Upper Duncan River deep pool and side-channel habitat within fluvial habitat below the full pool elevation (rkm 34.0 – 42.0). CART tagged burbot (n=2) were located within this reach and may have been spawning.
- Gallop Point and suspected shoal spawning areas to the south on the west shoreline were targeted for potential burbot aggregations.
- Historic Upper Duncan River confluence area at the the 20-30 m depth range. CART tagged burbot aggregations are located in the deeper water at this location year round.
- Howser Bay outlet drop-off (i.e. historic outlet of Duncan Lake to Lower Duncan River) was targeted for potential burbot aggregations.

The trend of highest to lowest CPUE among the reservoir areas (i.e. Upper, Mid-, lower reservoir, arms, Table 3.3.3) was similar to 2009 results but lower in all cases. The largest decrease in mean CPUE occurred in the upper reservoir and mid-reservoir. Targeting habitat within these areas did not improve CPUE.

In 2009, mean CPUE was much higher in the upper reservoir area (63%) that represents the Upper Duncan River confluence area (Cope 2009). Burbot spawning activity was previously identified within the upper reservoir sampling area in the reservoir – tributary transition area near the elevation of the original Duncan Lake and in the Upper Duncan River (Spence and Neufeld 2002). Tracking of CART tagged burbot during 2009 – 2010 consistently located aggregations of burbot within this area. Similar results (i.e. higher abundance of burbot within the upper reservoir sampling area of Gallop Creek to the historic Upper Duncan River confluence) were expected in year two, particularly given the earlier start and moderate increase in effort.
Table 3.3.3. Mean CPUE of Duncan burbot by reservoir area (e.g. lower reservoir = Howser downstream to dam, mid-reservoir = Howser to Gallop Point, upper reservoir = Upper Duncan Confluence area above Gallop Point, arms = upper (north) and lower (south) arms.

<table>
<thead>
<tr>
<th>Trap location</th>
<th>N (traps)</th>
<th>Burbot Catch</th>
<th>CPUE</th>
<th>95% C.I.</th>
<th>SD</th>
<th>Min Catch</th>
<th>Max Catch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Res.</td>
<td>129</td>
<td>10</td>
<td>0.08</td>
<td>0.05</td>
<td>0.27</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Mid. Res.</td>
<td>97</td>
<td>13</td>
<td>0.13</td>
<td>0.07</td>
<td>0.37</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Upper Res.</td>
<td>154</td>
<td>30</td>
<td>0.19</td>
<td>0.07</td>
<td>0.44</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Arms</td>
<td>70</td>
<td>8</td>
<td>0.11</td>
<td>0.08</td>
<td>0.32</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

3.3.2. Depth Preference

Mean trap depth was 20.5 m (range 1.2 – 30.0 m). This compares with 15.3 m in 2009. The mean depth in 2009 was biased low due to targeting shallow depths for CART tagging objectives. Given the preference of Duncan Reservoir burbot for depths greater than 20 m (Cope 2009), the deeper mean trapping depth was expected to increase CPUE.

Within the 30 m range of sample depths, captured burbot preferred depths greater than 10 m (Figure 3.3.1). The preference for depths > 20 m was not nearly as pronounced as the 2009 results (Cope 2009). Typically, burbot captured in other lakes during early spring do not show strong depth preferences (Bernard et al. 1993, Giroux 2005, Prince 2007). However, the Duncan reservoir is bounded by steep shoreline and there is very little available habitat with water depths less than 30 m deep, even at minimum pool (Figure 2.3.1). In addition, acoustic tracking results indicate burbot predominantly inhabit depths over 30 m deep (see Section 3.3.8.3 Reservoir Use). Previous Duncan Reservoir burbot investigations have captured burbot as deep as 47 m (Neufeld 2006). Scott and Crossman (1973) report burbot captured as deep as 213 m.

3.3.3. Recapture Data

There were two recaptures from the 98 floy tags applied the previous year (Cope 2009). Both were originally captured at depths > 20 m and one was released with decompression trauma (bloating) noted. As a result, there was no life history data collected for growth analysis. Both recaptures occurred within the upper reservoir area (Gallop Point, Upper Duncan historic confluence area) and these fish had moved upstream to their current location 3.5 km and 12.0 km, respectively.

In addition, there have been four (2009 = 3, 2010 = 1) floy-tagged burbot recaptured from a previous program in 2005/06 (n = 320, Neufeld 2006). These recaptures were originally captured in deep sets (> 20 m) for a mark – recapture program and there was no life history data collected.
3.3.4. Population Estimation

It must be noted that the recapture number of two burbot is below the statistically acceptable minimum number for avoiding small sample biases in population estimators (Ricker 1974). Nevertheless, although confidence intervals cannot be derived and caution must be advised in the validity of the estimate, it is interesting to note that this recapture rate would result in a rough population estimate of 2,046 burbot. This would equate to the no mortality, no tag loss estimate of 3,313 (95% C.I. 1,123 – 12,011) burbot estimated in 2005-06 with similar low number of recaptures (n=4) and statistical limitations (Neufeld 2006).

Population status concerns for Duncan Reservoir burbot appear warranted given the low CPUE for 2009 (0.29) and 2010 (0.14). These CPUE’s are comparable to Windermere Lake (2006 = 0.12) and Columbia Lake (2006 = 0.58, Prince 2007). Both Windermere and Columbia Lake have been closed to burbot angling due to population status concerns.

Further sampling is required to compile a larger recapture history over several years to apply a stock population estimation using the program MARK (White and Burnham 1999).
3.3.5. Handling Mortality

There were no recorded mortalities during the 2010 sampling. Typically, if there are going to be immediate trap induced mortality it occurs within 10 minutes of capture and is predicated by the appearance of pale gill filaments, indicative of a ruptured aorta (Neufeld and Spence 2004). These fish are typically retrieved bloated (decompression trauma) on the surface within a few minutes of returning to depth. After returning burbot to depth the sample team remained on site for at least several minutes to ensure no bloated fish returned to the surface.

Burbot captured at depths less than 15 m typically have 0% mortality while fish captured deeper than 35 m can experience significant (25-31%) mortality (Bernard et al. 1993, Prince 2007). The use of special handling procedures (i.e. limiting depth and rapidly retrieving and returning them to depth) is believed critical in reducing decompression trauma (Neufeld and Spence 2004). Trauma results from gases coming out of solution with the rapid decline in ambient pressure from decreasing water depth. Since the rate of diffusion is affected by water temperature, sampling when temperatures are cool and isothermal (i.e., just after ice off) may further reduce the incidence of trap-induced mortality.

3.3.6. Length, Weight, and Condition

Mean length of Duncan Reservoir adult burbot in 2010 (n=58) was 702.8 mm (SD 106.23) and ranged from 505 mm to 965 mm (Figure 3.3.2). The corresponding mean weight was 1,910 g (SD 970) and ranged from 960 g to 4,500 g. This compares with a mean length and weight in 2009 of 749.41 mm (n=49) and 2,166 g (n=49), respectively.

![Figure 3.3.2. Length frequency of adult burbot captured in Duncan Reservoir in March - April 2009 and 2010.](image-url)
Like Arrow and Moyie Lake populations, the length-weight slope for Duncan burbot was < 3 (Figure 3.3.3) indicating that burbot become less rotund as they increase in length (Anderson and Neumann 1996, Arndt and Baxter 2006, Prince 2007).

Captured burbot were externally examined for spawning evidence by gentle abdominal pressure to expel gametes to determine if fish were ripe. On April 5, a male 649 mm in length captured in the Howser area was ripe (expressed milt). On March 21, a burbot 688 mm captured in the mid-reservoir area was assessed as spent (i.e. red and swollen vent, very skinny and flaccid abdomen). No ripe females were captured.

Figure 3.3.3. Length-weight regression for adult burbot captured in spring within Duncan Reservoir 2009 (n=49) and 2010 (n=11) combined.

3.3.7. Age Structure Model

Since no mortality occurred in 2009 or 2010, otoliths were not collected and data on the age structure of adult Duncan Reservoir burbot are not available from the present investigation. As a potential alternative method to identify cohorts and examine the dam's operational conditions during periods of recruitment, development of a length-at-age model using otoliths from genetically similar populations (Moyie and Trout Lakes) and regionally similar populations (Kinbasket and Arrow Lakes Reservoirs) was investigated.

The BC Kootenay Region otoliths were typical relative to other burbot examined from Alaskan populations (K. Munk, Microtech, Juneau AK, pers. comm.). That is, otolith morphology and
general growth patterns were consistent with expectations from burbot otoliths examined from several lake systems in Alaska. These BC burbot growth patterns were clearly from several water bodies, that is, it seemed that among them there were “stock patterns” (growth which reflects lake specific conditions) which ranged from generally faster to slower growth. Stock-specific patterns are apparent through increment-widths (wider, finer), or as “noisy” (more challenging to age) versus “quiet” (easier to age). BC burbot otoliths ranged from noisy (mostly this type) to quiet (less this type) and generally wider than finer increment spacing. Burbot from Alaska systems tend to have more consistently spaced increments and “quiet” growth patterns. Confidence in these data was rated as good and age estimates were considered representative of true age (K. Munk, Microtech, Juneau AK, pers. comm.).

In general, there appear to be three groups of populations with growth similarities (Table 3.3.4.). The Columbia Lake population was unique from all other populations with its small size and early maturity. These fish were captured at a spawning tributary fence and, for the most part, were mature spawners. These fish were excluded from any further analyses in regards to length-at-age investigations for Duncan Burbot. Moyie Lake and Arrow Lakes Reservoir populations are similar in mean age, with Arrow Lakes illustrating a faster growth rate. These populations dominate the remaining samples (75%, Table 3.3.4). The remaining populations (Trout Lake, Kinbasket Reservoir, Duncan Reservoir, Kootenay Lake) can be loosely grouped by their older mean ages; however, sample sizes for these populations are severely limited.

Table 3.3.4. Population summary illustrating mean length and mean otolith age for seven Kootenay Region burbot populations as compiled from B.C. MOE and FWCP length-at-age databases.

<table>
<thead>
<tr>
<th>Waterbody</th>
<th>Otoliths (N)</th>
<th>Mean Length (mm)</th>
<th>Mean Otolith Age (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columbia Lake</td>
<td>26</td>
<td>397.9</td>
<td>4.3</td>
</tr>
<tr>
<td>Moyie Lake</td>
<td>91</td>
<td>620.5</td>
<td>9.7</td>
</tr>
<tr>
<td>Arrow Lakes Reservoir</td>
<td>60</td>
<td>681.1</td>
<td>9.8</td>
</tr>
<tr>
<td>Trout Lake</td>
<td>7</td>
<td>572.9</td>
<td>12.9</td>
</tr>
<tr>
<td>Kinbasket Reservoir</td>
<td>14</td>
<td>673.9</td>
<td>13.6</td>
</tr>
<tr>
<td>Duncan Reservoir</td>
<td>2</td>
<td>595.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Kootenay Lake</td>
<td>1</td>
<td>940.0</td>
<td>16.0</td>
</tr>
<tr>
<td>Total</td>
<td>201</td>
<td>613.2</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Nevertheless, it would appear that Trout Lake, Kinbasket Reservoir and Duncan Reservoir burbot populations have slower growth rates and a higher mean age than other regional populations (Moyie Lake and Arrow Lakes Reservoir). Intuitively, this would be consistent with habitat conditions expected for these water bodies. Arrow Lakes Reservoir and Moyie Lake have had *Mysis relicta* shrimp introductions. Arndt and Baxter (2006) note the high condition factor of Arrow lakes burbot and commonly observed large numbers of *Mysis* in the diet of these fish. Scott and Crossman (1973) note that deepwater invertebrates, especially *Mysis*, make up the majority of the diet for burbot up to 500 mm. In addition, Arrow Lakes are the subject of a large-scale nutrient supplementation program to mitigate for lost productivity due to reservoir creation (Moody et al. 2007). Trout Lake, Kinbasket Reservoir and Duncan Reservoir are
headwater lakes with low productivity. Reservoir creation may further limit productivity (Moody et al. 2007) and hence burbot growth potential for Duncan and Kinbasket reservoirs.

The compiled otolith dataset is characterized by extreme variation in length-at-age (Figure 3.3.4). Apart from the Columbia Lake population, this extreme variation is consistent within all regional burbot populations (Figure 3.3.5). Similarly, length-at-age by sex, within a population does not reduce the variation. Figure 3.3.6 illustrates the length-at-age variation for Moyie Lake females (n=41); the largest sample size available for a sex differentiated population.

As such, there is very little likelihood of creating a predictive model with the precision necessary to identify specific cohorts that could be linked in time back to specific operational impacts. For example, a 600 mm burbot could be between 5 to 16 years old in Moyie or Arrow Lakes, between 7 to 19 years old in Kinbasket Reservoir, and 9 to 21 years old in Trout Lake. Burbot of this size range (470 –1010 mm) were expected to be between four and greater than 13 years of age (Scott and Crossman 1973).

There were two otolith samples for Duncan Reservoir. These burbot were 570 mm and 620 mm in length and were 6 and 24 years old, respectively. Apart from the extreme variation, it is also interesting to note the burbot ages of up to 24 years for fish of only 620 mm. These potentially long-lived fish have important management implications when burbot as large as 1,010 mm have been captured in Duncan Reservoir.

Figure 3.3.4. Length-at-age of burbot from Kootenay Region populations.
Figure 3.3.5 Length-at-age of burbot from four Kootenay Region populations.
Many of the Arrow Lakes otoliths had previously been aged by an independent source with burbot aging experience (Arndt and Baxter 2006). Arndt and Baxter (2006) noted that the variation in banding patterns for Arrow Lakes burbot otoliths resulted in uncertainty. Unfortunately, the increased sample size, across additional populations, using an independent aging lab with recognized burbot experience, did not result in any improvement in precision. Table 3.3.5 illustrates summary statistics for those otoliths that were independently aged by both laboratories. While there was some individual variation, the results were consistent suggesting the variation in length-at-age is characteristic of these populations and is not an observer effect or a result of methodology.

Table 3.3.5. Comparison of mean length-at-age for two populations of burbot independently aged using identical otolith samples.

<table>
<thead>
<tr>
<th>Waterbody</th>
<th>Otoliths (N)</th>
<th>Mean Length (mm)</th>
<th>Mean Otolith Age 1&lt;sup&gt;a&lt;/sup&gt; (yrs)</th>
<th>Mean Otolith Age 2&lt;sup&gt;b&lt;/sup&gt; (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moyie Lake</td>
<td>29</td>
<td>586.6</td>
<td>8.55</td>
<td>8.00</td>
</tr>
<tr>
<td>Arrow Lakes Reservoir</td>
<td>56</td>
<td>677.7</td>
<td>9.77</td>
<td>9.20</td>
</tr>
</tbody>
</table>

<sup>a</sup> - Microtech, Juneau, Alaska (Kristen Munk).

<sup>b</sup> - Josh Taylor, Vancouver, B.C.

In addition to productivity differences (including potential temperature differences) among water bodies that may influence growth, the length-at-age variation for burbot may also be due to individual feeding behaviour and cannibalism. Observations during burbot culturing in a...
hatchery setting have documented some individuals grow much faster, and can eliminate smaller individuals in short order. If these cannibals maintain their aggressive feeding behaviour throughout their life the variation (Matt Neufeld, MOE, Nelson, B.C. pers. comm.).

Given concerns for the population status of the Duncan Reservoir burbot population, collection of otoliths for determination of population age structure has not been possible. The lack of juvenile captures and lengths further limits the ability to assess age distribution and uncertainty regarding the extent to which winter draw down of the reservoir affects burbot spawning success. Intensive tracking of CART tagged individuals to better understand life-history patterns is recommended. Life history data provide the basic foundation for all management, mitigation and habitat compensation programs (McPhail 1997) and currently, the Duncan burbot population dynamics are still poorly understood. This approach likely provides the best opportunity to better understand how winter draw down may impact burbot spawning and recruitment.

### 3.3.8. Migration and Movement

Burbot tracking and location data within the reservoir has been compiled from March-April 2009 tag implantation to June 2010. To date, 10 tracking sessions have been completed including April, June, October, December 2009, and six sessions during February through April 2010. All tagged fish have been located and accounted for during the 2009-10 tracking period. Tracking is scheduled to continue until April 2011.

Remote monitoring at the Duncan Dam for entrainment had two ‘gaps’ in detection monitoring. The first was the period March 30 to June 19, 2009 from the first tag implant to installation of the remote station. The second gap occurred during 23 days in November 2009 when the power cord was unplugged.

BB15 was detected in the outlet channel when the remote station was installed June 19, 2009. Therefore, this burbot was entrained sometime between tag implant (April 3, 2009) and station installation (June 19, 2009). All other tagged burbot were confirmed within the reservoir on subsequent tracking sessions confirming no further entrainment prior to remote station installation.

After the fall 2009 detection gap all tags with the exception of (BB39) have subsequently been confirmed within the reservoir. Range and detection testing combined with repeated discharge outlet channel scans and an aerial flight scan of the lower Duncan River and outlet into Kootenay lake provide confidence that detection efficiency is high and the Duncan Reservoir can be considered a closed system with all tags accounted for within the Duncan Reservoir. All tags have consistently been relocated during the 2009-10 tracking period. The only exception is BB39. This burbot was last located at rkm 20.0 (historic Upper Duncan River confluence area) June 27, 2009.

#### 3.3.8.1. Biological Characteristics

CART tagged burbot ranged in length and weight from 629 mm to 1,010 mm and 1,470 g to 5,050 g. The mean length and weight of these fish was 792.17 mm (SD=107.74mm) and 2,406 g (SD=922.8), respectively. The sex was determined for 8 (27%) males and 4 (14%) females; 17 (59%) burbot were unknown sex. Several males expressed milt. There were no ripe females noted.
3.3.8.2. Sources of Burbot Mortality

Five (17%) of the CART tagged burbot were either confirmed (n=4; tag recovered) or suspected (n=1; tag not recovered but tracked within 3 meters) dead during the 2009-10 tracking period (Table 3.3.6).

Table 3.3.6. Sources of Mortality for Adult burbot of Duncan Reservoir. There were 29 CART tags applied in March-April 2009.

<table>
<thead>
<tr>
<th>Code</th>
<th>Date</th>
<th>Transmitter</th>
<th>Location (rkm)</th>
<th>Mortality Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>BB12</td>
<td>16 Feb 2010</td>
<td>Y</td>
<td>Glacier Cr. in draw down zone (3.8)</td>
<td>Unknown</td>
</tr>
<tr>
<td>BB15</td>
<td>19 Jun 2009</td>
<td>Y</td>
<td>Discharge Channel (-0.6)</td>
<td>Entrainment</td>
</tr>
<tr>
<td>BB22</td>
<td>12 Apr 2010</td>
<td>N</td>
<td>West Shore above Howser (14.0)</td>
<td>Unknown</td>
</tr>
<tr>
<td>BB28</td>
<td>12 Apr 2010</td>
<td>Y</td>
<td>East Shore above Howser (14.0)</td>
<td>Avian</td>
</tr>
<tr>
<td>BB29</td>
<td>12 Apr 2010</td>
<td>Y</td>
<td>East Shore at Historic Confluence area (20.0)</td>
<td>Avian</td>
</tr>
</tbody>
</table>

BB15 was recovered in the discharge outlet channel June 19, 2009. This burbot was entrained sometime between tag implant (3 April 2009) and installation of the Duncan Dam remote station (19 June 2009). It is uncertain if BB15 was a 'natural' entrainment event or may have been influenced by the effects of handling and surgery. Given that this entrainment event was an isolated incident that was not replicated in either spring 2009 or 2010, and given that this event occurred sometime within the first 76 days at large after tag implantation, it may be due to handling effects (i.e. fish was captured and released at rkm 5.1 Howser).

BB28 and BB29 were recovered at the base of avian perches. Just ten days before tag recovery (April 2), both these burbot were located in the shallow (water depth 3 m) ‘flats’ that are the seasonally inundated Upper Duncan River immediately above the historic Duncan Lake confluence (rkm 20.5 - 21.5). This area has been identified as a potential spawning location (Neufeld 2006) and was in the process of dewatering as the Duncan Reservoir reached annual minimum water elevations. Dewatering and stranding may have contributed to the vulnerability of these fish to avian predators.

BB12 was recovered within Glacier Creek below the full pool elevation (i.e. seasonally inundated). The mechanism of apparent mortality is unknown; however, this tag was recovered in what appeared to be fluvial spawning habitat. There is no cover within this section of Glacier Creek and burbot attempting to spawn would be extremely vulnerable to predation. It may also be possible that the tag was shed or expelled at this location during spawning (A. Prince, Westslope Fisheries Ltd., pers. comm.).

BB22 was not recovered but tracked to within 3 m (i.e. Gain = 0, power = 172). After extensive searching the tag was abandoned but assumed dead. The tag was located in 3 m depth along the west shoreline at rkm 14.0. The shoreline at this location had recognized burbot spawning preferences such as flowing springs and gravel-cobble substrate at depths 0 - 5 m.
3.3.8.3. Reservoir Use

From April 2009 to April 2010 we observed patterns of reservoir use for adult burbot within Duncan Reservoir. Twenty-eight (96.6%) fish have been relocated within the reservoir subsequent to tag implantation. The one exception (3.4%) was BB15 that was relocated as an entrainment mortality in the discharge channel downstream of the dam outlet. The mean home range of adult burbot (n=28) was 7.1 km (95% C.I. 3.9 – 10.3 km, range 0.4 – 34.8 km). BB15 was not included in home range analyses as this fish was at large for 76 days or less. The remaining four mortalities were included as these fish were at large for approximately one year, and movements were within the range of the remaining fish at large. Exclusion of all mortalities results in a mean home range (n=24) of 7.4 km, (95% C.I. 3.7 – 11.1 km, range 0.4 – 34.8 km).

The reservoir area most utilized by burbot was the historic Duncan Lake - Upper Duncan River confluence area (reservoir km 18.0 to 20.5). In total, 86.2% (n=25) of the tagged fish were located within this area at some point during monitoring (Table 3.3.7). This was followed by the mid-reservoir area (48.3%), the seasonally inundated Upper Duncan River (37.9%), the lower reservoir (10.3%) and the north arm (6.9%). These relative use patterns were similar to CPUE patterns reported during adult trapping (Table 3.3.3).

With a few notable exceptions, Duncan Reservoir burbot were predominantly located within deepwater (>30 m depth) habitat below the minimum pool elevation. Typically, the mean depth of CART tagged adult burbot relocated during a tracking session was 50 m. These locations and depths were predominantly associated with the historic Duncan Lake area and the deep water off the historic Upper Duncan River confluence area represented preferred habitat for Duncan Reservoir burbot.

Table 3.3.7. Pattern of relative use for CART tagged adult burbot (n=29) within the Duncan Reservoir areas of similar habitat features.

<table>
<thead>
<tr>
<th>Location</th>
<th>rkm</th>
<th>Burbot Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Reservoir Area</td>
<td>0.0 – 5.2</td>
<td>3 10.3</td>
</tr>
<tr>
<td>Mid Reservoir Area</td>
<td>5.2 - 18.0</td>
<td>14 48.3</td>
</tr>
<tr>
<td>Upper Reservoir Area</td>
<td>18.0 – 20.5</td>
<td>25 86.2</td>
</tr>
<tr>
<td>Seasonally Inundated Upper Duncan River</td>
<td>20.5 - 44.0</td>
<td>11 37.9</td>
</tr>
<tr>
<td>North and South Arms</td>
<td>2</td>
<td>6.9</td>
</tr>
</tbody>
</table>

The following figures (Figure 3.3.7 – 3.3.14) illustrate individual adult burbot movement patterns in relation to mean daily inflows (Upper Duncan River discharge), outflows (Duncan Dam discharge) and reservoir elevation. The following is a brief description of the individual movement patterns illustrated within the above figures. Burbot with similar life history movement patterns have been grouped together.

**BB11** (1,010 mm) and **BB14** (970 mm) undertook similar life history movement patterns. BB11 was tagged on March 31, 2009 in the lower reservoir outlet channel below Howser (rkm 4.2). On April 20, 2009 it was located at the historic Upper Duncan River confluence area (rkm 20.2). BB14 was tagged on April 2, 2009 at the historic Upper Duncan River confluence area (rkm...
On June 27, 2009 both fish were located in the Upper Reservoir within the seasonally inundated Upper Duncan River (rkm 37.5 – 39.0). Habitat represented the Upper Duncan River confluence area at reservoir water elevations at the time of tracking. BB11 and BB14 remained within this area (rkm 36.4 – 41.0) for the duration of tracking (June 27, 2009 to April 2, 2010). During the February – April spawning period this reach was fluvial habitat and these fish were monitored by helicopter and vehicle. Detailed positions were documented and the potential Upper Duncan River spawning locations were characterized and trapped (see Section 3.3.8.4 Spawning Assessment and Habitat).

BB12 (857 mm) was tagged on April 1, 2009 in the lower reservoir outlet channel (rkm 4.9) immediately below Howser. This fish remained within the lower reservoir between Howser and Glacier Creek (rkm 3.5 – 5.2) until the tag was recovered (i.e. mortality) February 16, 2010 within the seasonally inundated lower reach of Glacier Creek. The cause of mortality could not be determined but it was noted that the habitat the tag was recovered in was potential spawning habitat (see Section 3.3.8.4 Spawning Assessment and Habitat).

BB13 (777 mm) was tagged on April 2, 2009 at the historic Upper Duncan River confluence area (rkm 20.3). On April 25 this fish had begun moving down the reservoir (rkm 17.2) and from October 21 to December 1, 2009 was located immediately upstream of Howser on the outlet drop-off (rkm 6.0 – 7.5). On February 16, 2010 BB13 was once again located within the upper reservoir area (rkm 18.0). The fish remained within this general area (rkm 16.0 – 20.0) for the duration of tracking. On March 4, 2010 BB13 was detected briefly off Griz Creek in the upper or north arm during night-time monitoring of potential tributary and shoal spawning habitat (see Section 3.3.8.4 Spawning Assessment and Habitat).

BB15 (629 mm) was tagged on April 3 2009 at Howser (rkm 5.1). It was subsequently recovered (i.e. mortality) in the discharge outlet channel below the Duncan Dam during remote station installation and testing June 19. This burbot was entrained sometime between tag implantation and recovery.

BB16 (924 mm), BB20 (917 mm), BB22 (935 mm) and BB31 (782 mm) were tagged April 4 to 21, 2009 at the historic Upper Duncan River confluence area (rkm 20.2 to 20.7). During April 25 to June 27 2009 all four fish moved down into the mid-reservoir area, where they remained for the duration of tracking surveys. BB16 and BB31 were located at rkm 14.0 June 27 and ranged between rkm 13.0 - 16.0. BB20 was located at rkm 7.7 June 27 and ranged between rkm 7.0 - 8.5. BB22 was located at rkm 12.1 April 25 and ranged between rkm 12.0 - 14.0. On April 12 2010 BB22 was assessed as a mortality located in 3 m depth on the west shoreline (see Section 3.3.8.2 Sources of Mortality). There are a number of springs combined with clean gravel – cobble substrate that represent preferred shoal-spawning features along the west shoreline within this reservoir reach (see Section 3.3.8.4 Spawning Assessment and Habitat).

BB17 (794 mm), BB24 (685 mm), BB33 (744 mm) and BB37 (697) were tagged April 4 to 22 2009, at the historic Upper Duncan River confluence area and remained within this area for the remainder of the tracking sessions. These fish were tagged between rkm 20.2 - 20.7 and ranged between rkm 18.4 - 20.5.

BB18 (704 mm) and BB19 (692 mm) were tagged on April 4 and 5 2009 respectively, within the mid-reservoir area and remained within this area for the remainder of the tracking sessions. BB18 was tagged at rkm 10.7 and ranged between rkm 7.7 - 10.0. BB19 was tagged at rkm 8.9 and ranged between rkm 8.2 - 11.0.
BB21 (734 mm), BB29 (770 mm), BB30 (779 mm), BB32 (757 mm) and BB36 (724 mm) were tagged April 6 to 22 2009, at the historic Upper Duncan River confluence area (rkm 20.3 - 20.5). These fish ranged between rkm 19.8 - 21.5. Habitat above rkm 20.5 represents the ‘flats’ comprised of the historic Upper Duncan River and historic sloughs that have previously been identified as potential spawning habitat (see Section 3.3.8.4 Spawning Assessment and Habitat). BB21, BB32 and BB36 moved from deepwater habitat (> 30 m) at rkm 20.5 to backwatered shallow water habitat (< 6 m depth) at rkm 21.0 - 21.5 between February 16 and 24, 2010. These fish remained in the backwatered Upper Duncan River channel habitat until March 4 (BB32, BB36) and March 14 (BB 21) when they were re-located in deep water habitat at rkm 20.5. BB30 remained in the deeper habitat at the drop-off (at least during daylight tracking sessions) and was not located within the shallow water habitat above rkm 20.5 until March 14. This fish was still located within the shallow water habitat on the last tracking session April 12, 2010. BB32 was again located within the shallow water habitat (rkm 21, 3.0 m depth) on April 2 where it remained through April 12 (last tracking session). BB21 was again located within the shallow water river channel (rkm 21) on April 12. On April 2, 2010 BB29 was located within the historic Upper Duncan River confluence area (rkm 20.5) in water 3.0 m deep. BB29 was recovered (i.e. mortality) at the base of an avian perch on April 12 at rkm 20.0.

BB23 (1,002 mm) was tagged on April 7 2009 at Howser (rkm 5.2). Thirteen days later (April 20), this fish was located 15 km up the reservoir at the historic Upper Duncan River confluence area (rkm 20.2). Six days after this (April 26), BB23 was located 10 km down at rkm 10.0. These represent movements of approximately 1.2 to 1.7 km/day. On June 27, 2009 this fish was located 17 km upstream within the backwatered Upper Duncan River area (rkm 27.0). This fish remained at this location for the duration of the tracking sessions ranging between rkm 25.0 - 28.0.

BB25 (850 mm), BB27 (864 mm) and BB35 (752 mm) were tagged April 9 to 22 2009, at the historic Upper Duncan River confluence area (rkm 20.2 - 20.4). These fish remained within this general area (rkm 16.0 - 20.2) for the remainder of the tracking sessions. These fish were primarily located in the deep water off Gallop Point and the bays immediately south and north of Gallop Point (rkm 17.0 – 19.0), particularly during the assumed spawning season (February-March). This area had several springs and small tributaries identified as potential shoal spawning habitat (see Section 3.3.8.4 Spawning Assessment and Habitat).

BB26 (700 mm) was tagged on April 9 2009 in the mid-reservoir area (rkm 15.4). This fish was subsequently relocated on October 21 in the backwatered Upper Duncan River habitat above the historic confluence area (rkm 21.0). This fish remained in this area (rkm 21.0 to 21.7) into the spawning season (February 24, 2010) until it was located in the deeper water of the historic Upper Duncan River confluence area (rkm 20.0) March 4 2010. On April 2 and 12 this fish was again located in the shallow water Upper Duncan River habitat at rkm 21.0.

BB28 (634 mm) was tagged on April 21 2009 at the historic Upper Duncan River confluence area (rkm 20.4). Four days later, the fish was located in the area at rkm 19.4. This fish was not re-located until February 24 2010 when it was in the shallow water habitat of the backwatered Upper Duncan River (i.e. the ‘flats’ - rkm 21.0). Eight days later (March 4) this fish was located 9 kilometers down reservoir at rkm 12.0. On April 2, 2010 BB28 was again located within the historic Upper Duncan River confluence area (rkm 20.5) in water 3.0 m deep. On April 12 the tag was recovered (i.e. mortality) at the base of an avian perch on the east shoreline at rkm 14.0.

BB34 (728 mm) was tagged on April 22 2009 at the historic Upper Duncan River confluence area (rkm 20.6). This fish was located off Griz Creek (Upper or North Arm rkm U14.0 to U15.0).
for the remaining tracking sessions. This area had several springs and small tributaries identified as potential shoal spawning habitat (see Section 3.3.8.4 Spawning Assessment and Habitat).

**BB38** (684 mm) was tagged on April 23 2009 at Howser (rkm 5.3). Two days later this fish had moved into deeper water (rkm 6.5). BB38 was not relocated until October 21 at rkm 21.0 in the shallow water habitat of the backwatered Upper Duncan River (i.e. the ‘flats’). The next location was on February 24 2010 within the mid-reservoir reach (rkm 16.0 - 16.5). This fish subsequently moved down to rkm 8.0 (April 2) and back up to rkm 17.0 (April 12).

**BB39** (878 mm) was tagged on April 24 2009 at the historic Upper Duncan River confluence area (rkm 20.4). This fish was located in this area (rkm 20.0) June 27 2009 and has not been relocated since.

Additional burbot movement data and reservoir use is illustrated by the floy tag recapture locations in relation to their original capture location (Figure 3.3.15.). Recaptures (n=6) have been at large for up to 5 years. Five of six or 83.3% of tagged burbot were captured at different locations ranging between 4 km and 14.0 km from the original capture site. One fish was recaptured at the same location five years later.
Figure 3.3.7. Movement data of CART tagged adult burbot (BB11, BB12, BB13, BB14) in relation to mean daily inflows (Upper Duncan River), outflows (Duncan Dam) and reservoir elevation (Forebay). Each point represents a tracked location.
Figure 3.3.8. Movement data of CART tagged adult burbot (BB15, BB16, BB17, BB18) in relation to mean daily inflows (Upper Duncan River), outflows (Duncan Dam) and reservoir elevation (Forebay). Each point represents a tracked location.
Figure 3.3.9. Movement data of CART tagged adult burbot (BB19, BB20, BB21, BB22) in relation to mean daily inflows (Upper Duncan River), outflows (Duncan Dam) and reservoir elevation (Forebay). Each point represents a tracked location.
Figure 3.3.10. Movement data of CART tagged adult burbot (BB23, BB24, BB25, BB26) in relation to mean daily inflows (Upper Duncan River), outflows (Duncan Dam) and reservoir elevation (Forebay). Each point represents a tracked location.
Figure 3.3.11. Movement data of CART tagged adult burbot (BB27, BB28, BB29, BB30) in relation to mean daily inflows (Upper Duncan River), outflows (Duncan Dam) and reservoir elevation (Forebay). Each point represents a tracked location.
Figure 3.3.12. Movement data of CART tagged adult burbot (BB31, BB32, BB33, BB34) in relation to mean daily inflows (Upper Duncan River), outflows (Duncan Dam) and reservoir elevation (Forebay). Each point represents a tracked location.
Figure 3.3.13. Movement data of CART tagged adult burbot (BB35, BB36, BB37, BB38) in relation to mean daily inflows (Upper Duncan River), outflows (Duncan Dam) and reservoir elevation (Forebay). Each point represents a tracked location.
Figure 3.3.14. Movement data of CART tagged adult burbot (BB39) in relation to mean daily inflows (Upper Duncan River), outflows (Duncan Dam) and reservoir elevation (Forebay). Each point represents a tracked location.
Figure 3.3.15. Floy tag recapture locations (2009-10) in relation to original capture locations (2005-10) illustrating movement and reservoir use.
3.3.8.4. Spawning Assessment and Habitat

To date, there has been no confirmation of burbot spawning. At present, the criteria used for spawning behaviour are the movement of mature CART tagged burbot into shallow water habitat (<10 m depth) during the spawning season (February 14 to April 12 2010). The only documented spawning behaviour to date has been the nine burbot moving in and out of the historic Upper Duncan River confluence area. This shallow water habitat has previously been identified as potential spawning habitat both historically (Vonk 2001, Peterson and Withler 1965) and in previous burbot telemetry investigations since reservoir operation (Spence and Neufeld 2002).

An additional two burbot moved into the Upper Reservoir above the historic confluence area and were located within shallow water rearing or feeding habitat (i.e. Upper Duncan River confluence area) outside the spawning season (May – June). These two fish remained within the upper reservoir throughout the year, including the spawning season.

Apart from the two exceptions above, Duncan Reservoir burbot were predominantly located within deepwater (>30 m depth) habitat below the minimum pool elevation. Typically, the mean depth of CART tagged adult burbot relocated during a tracking session was 50 m. These locations and depths were predominantly associated with the historic Duncan Lake area.

The following reviews the evidence for possible burbot spawning strategies, habitat conditions at potential spawning locations and potential operational impacts.

3.3.8.4.1. Upper Duncan River (rkm 30.0 – rkm 44.0)

This reservoir reach represents the historic Upper Duncan River and is characterized by variable habitat conditions due to reservoir operations. At full pool (576.7 m), the Duncan Dam floods the lower 25 km of the Upper Duncan River upstream of the historic lake confluence area. At minimum reservoir elevations (546.9 m) the reservoir approximates the historic Duncan Lake water elevation (Vonk 2001). As a result, the valley bottom is dewatered and the Upper Duncan River flows through the highly modified original stream channel that is characterized by deforestation (i.e. forest clearing prior to reservoir creation) and lacustrine deposition of glacial fine sediments resulting from annual inundation (Figure 3.3.16 to 3.3.20).

Two (BB11, BB14) CART tagged burbot or 6.9% of all tagged fish migrated into the upper reservoir at least 10 km above the historic Duncan Lake habitat. These fish migrated into this reach sometime in May – June as the reservoir was filling, creating backwater conditions at water surface elevations between 547 m (April 25 2009) to 564 m (June 27 2009). During the 14 February through 12 April tracking sessions and spawning assessment, these fish were located at rkm 36.4 to 41.0. Water elevations during this period declined from 556.5 m to 548.5 m. At these elevations any fish located between rkm 30.0 to 41.0 were above the reservoir elevation and fluvial (Figure 3.3.16 to 3.3.18), while any fish located below rkm 30.0 was backwatered shallow lacustrine habitat in February and was fluvial by April reservoir elevations (Figure 3.3.19 to 3.3.20).

Fluvial habitats above rkm 21.0 were accessed via helicopter (24 February and March 4, 2010) and 4x4 (March 14 and April 2) to locate burbot, identify holding and/or spawning habitat and to characterize fluvial habitat characteristics. During this period (Feb 14 to April 2, 2010) the mean daily Upper Duncan River Discharge averaged 10.3 m³/s (range 7.6 – 16.0 m³/s).
On March 4, 2010 at 14:30 PST BB14 and BB11 were located holding in pool habitat (Figures 3.3.16 and 3.3.17) adjacent to gravel bars and substrate that may represent spawning habitat (Figure 3.3.18). Pool habitat was estimated to be 3 – 4 m deep, substrate was silt and fine sand and water velocity was 0.26 m/s. Riffle habitat substrate ranged from gravel-sand to gravel-cobble; depending on water velocity. Riffle water velocities (n=4) ranged between 0.50 m/s and 1.17 m/s. An abundance of large woody debris and other hydraulic features (i.e. gravel bars, braiding, side-channels) provide velocity refuge.

On March 16 at 15:30 PST water quality data was collected in this area. Turbidity was 0.00 NTU, water temperature was 4.51 °C, conductivity was 150 µs, dissolved oxygen was 12.74 mg/l and pH was 7.96. Pool and riffle habitat features were the same as above and pool water velocities were 0.16 m/s to 0.28 m/s.

No spawning activity was noted during either aerial survey and clarity was excellent in shallow water habitat (Figure 3.3.18).

Test trapping was completed within main channel and side-channel habitat between rkm 34.0 and rkm 42.0 (n=10) March 16 – 18, 2010 (Appendix A, Map A1). Although two tagged burbot were within this reach and spawning was suspected, no burbot were captured.

The maintenance of position within the fluvial habitat is contrary to observations during previous radio telemetry investigations (Spence and Neufeld 2002). In this investigation, burbot within fluvial reaches moved progressively downstream with receding lake levels leading them to postulate that winter migration and spawning of burbot may be limited by back-flooding and stream velocities that exceed the upper limit of burbot tolerance. Within the rkm 30.0 to rkm 44.0 reach, this does not appear to be the case as there is an abundance of suitable, low velocity pool habitat for burbot to maintain position.

3.3.8.4.2. Historic Upper Duncan River Confluence Area (rmk 20.5 – rkm 26.0)

This reservoir reach represents the historic Upper Duncan River confluence area and has previously been identified as potential spawning habitat both historically (Vonk 2001, Peterson and Withler 1965) and in previous burbot telemetry investigations since reservoir operation (Spence and Neufeld 2002). Similar to the previous telemetry investigation, burbot utilized this area moving in and out during the spawning season (February 14 to April 12 2010). Prior to inundation, this area was described as gravel beds probably used for sportfish spawning purposes with extensive slough areas immediately upstream of the confluence area that would have been excellent rearing ponds for juvenile game fish (Peterson and Withler 1965).

In total, nine (BB21, BB23, BB26, BB28, BB29, BB30, BB32, BB36, BB38) CART tagged burbot or 31% were documented moving into this area (Figure 3.3.19 and 3.3.20) February 14 to April 12 2010. Conditions of BB23 at rkm 26.0 were more like those of the confluence area below (rkm 20.5 – 23.0) than the Upper Duncan River (rkm 30.0– 44.0) and have been included here.

Many fish were documented moving in and out on more than one occasion. Some fish remained within this area for the majority of the spawning period, while others were present for only one tracking session (i.e. less than 7 days). Although no direct evidence could be obtained that spawning occurred, the timing of these movements suggested spawning was occurring during these migrations into the area. Reservoir elevations were declining to annual minimums during these apparent spawning movements and declined from 556.478 m to 548.477 m (Feb 14 – April 2 2010).
Trapping for spawning burbot was conducted within this area March 10 to 14 (n=20, Appendix A, Map A1). The backwatered Upper Duncan River main channel on the east shore and the main slough channel on the west shore were fished. Mean water depth fished was 4.2 m and ranged between 3.0 m to 6.5 m. No burbot were captured. Reservoir elevations declined a further 3.86 m until annual minimums were reached April 19 2010. This would result in a mean maximum depth of 0.34 m (i.e. maximum thalweg depths were fished); however, with declining reservoir level, the water begins flowing within the seasonally inundated channel, cutting through exposed lake sediments in the process. The main channel cross-channel profile was surveyed using the boat depth sounder April 2-12 and maximum channel depths were between 1.5 m and 2.0 m; not 0.34 m. This erosion results in extreme turbidity and fine sediment transport. In 48 hours sediment transport ‘buried’ cod traps placed in this environment. Cod traps were 60 cm tall. If spawning occurred in these conditions, substrate and water quality conditions would likely impair egg and larval survival. These impacts were consistent with those observed by Spence and Neufeld (2002). Underwater viewing was attempted but not effective given the extreme turbidity within this reach.

3.3.8.4.3. Reservoir Shoal Spawning (rkm 5.2 – 20.5)

Based on the locations of tagged burbot and the associated shoreline habitat characteristics, several shoreline reaches of the reservoir were assessed for potential shoal spawning. Reaches assessed for possible shoal spawning were the Griz Creek confluence area in the Upper or North Arm (rkm U14.5) and the springs and small tributaries located on the west shoreline south of Gallop Point (i.e. ‘west shore’ rkm 14.0 – 17.0).

In lakes, spawning usually occurs over near-shore shallows or over shallow offshore reefs and shoals and is often associated with tributary confluences or upwelling (Cope 2008). Both the Griz Creek and west shore sites contained preferred burbot spawning features that included springs, small tributaries, and a diversity of substrate including silt, sand, fine gravel and gravel cobble (Figure 3.3.21).

On March 4 2010 night-time tracking, under-water viewing and shoreline pit lamp surveys were completed at the west shore and Griz Creek sites in an effort to identify shoal spawning or at least inshore shallow water movements indicative of shoal spawning (Appendix A, Map A1). At four sites (2 each at Griz Creek and west shore) the boat was anchored stationary in approximately 20 m depth. The CART tagged burbot to be monitored was located in the deeper water (typically in 45 to 70 m depth at the toe of the shoreline slope) and the shallow water shoal (3 m to 20 m depth) was located behind the boat. The receiver gain and power were monitored and a directional hydrophone utilized to monitor burbot movement. At the same time, an underwater viewer was lowered and monitored to scan for burbot. Some movement was noted. For instance, the signal strength became faint and the Griz Creek monitoring site had to be moved to the bay immediately north to follow the monitoring subject. On another occasion, a second tagged burbot arrived within detection range off the Griz Creek site. Despite some movement documented there was no evidence of fish migrating to shallower water (i.e. < 25 m) and no burbot observed.

3.3.8.4.4. Glacier Creek

A night-time pit lamp survey of the lowermost 1 km of Glacier Creek was completed March 10, 2009. Seasonally inundated stream channel from the confluence area upstream to the boulder step-pool reach (full pool elevation) was surveyed. No burbot were observed.
Figure 3.3.16. Upper Duncan River (rkm 39.0) illustrating BB14 pool residence habitat March 4, 2010.

Figure 3.3.17. Upper Duncan River (rkm 36.0) illustrating BB11 pool residence habitat March 16, 2010.
Figure 3.3.18. Upper Duncan River (rkm 38.5) illustrating water quality and substrate adjacent to burbot holding pools February 24, 2010.

Figure 3.3.19. Upper Duncan River (rkm 26.0 – Howser Creek confluence area) illustrating BB23 habitat February 24 – April 12, 2010.
Figure 3.3.20. Historic Upper Duncan River confluence area (rkm 21.0) illustrating potential spawning area at approximate reservoir elevation 548.5 m.

Figure 3.3.21. West shore mid-reservoir spring-small tributary potential shoal spawning area.
3.4. Environmental Data

Duncan Reservoir operations result in annual water surface elevation variation of 29.6 m between 576.5 m and 546.9 m (Figure 3.4.1). Early summer (May – June) burbot migrations into the upper reservoir above rkm 26.0 (n=3) occurred during rising reservoir elevations and backwatering of the annually inundated lower 25 km of the Upper Duncan River. Apparent burbot spawning activity within the historic Upper Duncan River confluence area (rkm 20.5 – 26.0) during early spring (February – April) occurs during declining reservoir elevations to annual minimums.

![Duncan Reservoir Elevation (m)](image)

Figure 3.4.1. Mean daily Duncan Reservoir water surface elevation July 1, 2008 to June 1, 2010.

Duncan Reservoir elevations are a result of inflows, primarily from the Upper Duncan River (Figure 3.4.2) and outflow releases from Duncan Dam (Figure 3.4.3). During early spring burbot migrations and apparent spawning activity, the Upper Duncan River discharge is at annual minimums. The mean monthly discharge (1962 – 2008, WSC Stn. #08NH119) for February and March are 7.94 m$^3$/s (range 5.52 – 14.0) and 9.61 m$^3$/s (5.36 – 17.7), respectively. The 2009 and 2010 mean discharge for February was 7.90 m$^3$/s and 8.03 m$^3$/s. March mean discharge was 7.27 m$^3$/s and 11.14 m$^3$/s, respectively.

Surface water temperatures in Duncan reservoir vary seasonally from approximately 18.0 – 20.0 °C in summer (July – August) to 2.9 - 4.0 °C in winter (Figure 3.4.4). Annual variation in water temperatures at 30 m depth varied between 3.53 to 10.00 °C. There was very little annual variation at 60 m depth (3.80 – 5.53 °C). Seasonal depth profile data for water temperature, dissolved oxygen, conductivity and pH are presented in Appendix B.
Duncan Reservoir Burbot Monitoring 2010 Interim Report

Figure 3.4.2. Upper Duncan River discharge July 1, 2008 to June 1 2010.

Figure 3.4.3. Duncan Dam Discharge July 1, 2008 to June 1, 2010.
Figure 3.4.4. Duncan Reservoir spot water temperatures July 1, 2008 to June 1, 2010.
4. Summary and Conclusions

Hypothesis 1

HO1: Winter draw down of Duncan Reservoir dewater burbot spawning habitat and thus reduces egg survival and burbot spawning success.

From April 2009 to April 2010 we observed patterns of reservoir use for adult burbot within the Duncan Reservoir. To date, there has been no confirmation of burbot spawning and at this point in the monitoring program we cannot reject hypothesis one. Although no direct evidence could be obtained that spawning occurred, the timing of movements by mature burbot into the shallow water habitat of the historic Upper Duncan River confluence area (rkm 20.5 - 26.0) suggested spawning was occurring during these migrations into the area.

In total, nine or 31% of all tagged burbot were documented moving into the shallow water habitat of the historic Upper Duncan River and confluence area February 14 to April 12 2010. Many fish were documented moving in and out on more than one occasion. Some fish remained within this area for the majority of the spawning period, while others were present for only one tracking session (i.e. less than 7 days). The timing of this apparent spawning activity was consistent with a previous burbot telemetry investigation in 2000 (Spence and Neufeld 2002).

This reservoir reach represents the historic Upper Duncan River and confluence area and prior to inundation was described as gravel beds probably used for sportfish spawning purposes with extensive slough areas immediately upstream of the confluence area that would have been excellent rearing ponds for juvenile game fish (Peterson and Withler 1965). Downstream slack water areas are a repeating feature of preferred burbot spawning habitat (McPhail 1997).

This reservoir reach is characterized by annual inundation and dewatering due to reservoir operations. This results in dramatic changes to habitat conditions during the burbot spawning season. At full pool (576.7 m), the Duncan Dam floods the lower 25 km of the Upper Duncan River upstream of the historic lake confluence area. At minimum reservoir elevations (546.9 m) the reservoir approximates the historic Duncan Lake water elevation. As a result, the valley bottom is dewatered and habitat becomes fluvial as the water begins flowing within the seasonally inundated river channel.

During the 2010 spawning season (Feb 14 – April 2 2010), reservoir elevations declined 8.0 m from 556.478 m to 548.477 m resulting in dewatering of the valley bottom habitat. If burbot spawn within the inundated river channel, then draw down may not dewater spawning habitat, eggs or early life stages. Regardless of dewatering impacts, if burbot spawn within this reach extreme turbidity and fine sediment transport likely impair egg and larval survivals. With declining reservoir levels, the river begins flowing, cutting through exposed glacial lacustrine sediments deposited during inundation. In addition, there is excessive erosion of the silt-clay stream banks due to the highly modified valley bottom (i.e. complete deforestation and loss of riparian vegetation).

Year three spawning assessments should incorporate a remote receiver at rkm 21.0. This would enable more complete monitoring coverage of apparent spawning movements and utilization during the spawning season as well as documenting residence time, diel movement patterns, aggregations and synchronicity. This level of detail is not possible using weekly daylight mobile tracking.
Preliminary results of life history movement patterns suggest there may be several alternate spawning strategies in the Duncan Reservoir. Further night-time tracking and underwater viewing at suspected shoal spawning sites (Griz Creek area and Gallop Point area) should be continued in Year three.

Intensive tracking of CART tagged individuals to better understand life-history patterns is recommended. Life history data provide the basic foundation for all management, mitigation and habitat compensation programs (McPhail 1997) and currently, the Duncan burbot population dynamics are still poorly understood. This approach likely provides the best opportunity to better understand how winter draw down may impact burbot spawning and recruitment.

**Hypothesis 2:**

**HO2: Burbot populations are negatively impacted by Duncan Reservoir operations.**

This hypothesis was to be addressed by annually assessing juvenile burbot densities along the reservoir shoreline. Recruitment analyses would then be correlated to both juvenile stock estimates and spawning conditions for the respective cohort years to determine if operations are influencing population size.

To date, no juvenile burbot have been captured during shoreline electrofishing or testing of alternative seasons, locations and sample methods. Therefore we cannot reject hypothesis two at this point in the monitoring program. Given the apparently low juvenile densities and difficulties in capture, a review of opportunities for an adult-only indexing program is recommended. Unfortunately, the extreme length-at-age variation in adult burbot will not allow back-calculation of cohort years from length frequency analyses.

Therefore, some limited sampling of juvenile habitat within the upper Duncan Reservoir (rkm 34 - 44) and lowermost reach of the Upper Duncan River (rkm 44 - 46) is recommended in year three. Several locations have been selected for sampling within these reaches based on habitat similarities from juvenile capture locations in other systems (i.e. Upper Arrow Lake, Columbia Lake), and based on location data within these areas of adult burbot during the spawning season.
5. Recommendations

5.1. Shore-based Juvenile Population Monitoring

Year three of the program will focus on sampling four locations identified as potential juvenile habitat based on possible adult spawning within the immediate area, preferred habitat features, and similarities to juvenile captures within Upper Arrow Lake. To this end, the following recommendations are made:

1. Abandon random sampling and target most likely habitat. In year three recommend targeting rkm 34.0 – 44.0 and the historic confluence area (rkm 21.0) where adult fish were located during the spawning period. In addition, the Upper Duncan River full pool confluence area and side-channels at rkm 44.0 – 46.0 have been identified as having habitat similarities to juvenile burbot capture locations within the Upper Arrow Lake.

2. Abandon experimental sample methods and target sample locations identified above using backpack electrofishing during both periods of daylight and darkness.

3. Review the opportunities for an adult-only sampling program that would address the management questions related to both reservoir interactions with spawning and population health.

5.2. Adult Burbot Tracking and Habitat Assessment

Year three of the program will focus on; a) tracking and life-history and habitat assessment in an effort to identify and evaluate potential spawning locations, and b) adult trapping will be focused on maximizing catch rates within the random sampling methodology to increase the sample size of floy tagged burbot. To this end the following recommendations are made:

1. Similar to year two, additional tracking sessions have been scheduled for September, November and December to provide life-history information and to examine habitat use of the potential spawning locations outside the spawning season.

2. Intensive tracking of CART tagged individuals during spawning season (February – April) is recommended as the best opportunity to better understand how winter draw down may impact burbot spawning and recruitment. Year three spawning assessments (February – April) should utilize a remote receiver at rkm 21.0. This would enable more complete coverage of apparent spawning movements and utilization during the spawning season as well as documenting residence time, diel movement patterns, aggregations and synchronicity. This level of detail is not possible using weekly daylight mobile tracking. In addition, nighttime tracking of individual burbot within the suspected spawning areas, particularly the historic Upper Duncan confluence area (rkm 21.0), should be completed in conjunction with February (i.e. as opposed to March in Year 2) spawning tracking sessions in an attempt to positively identify spawning aggregations and confirm spawning habitat.

3. Year three (April 2011) adult trapping will be focused on maximizing catch rates within the random sampling methodology for population estimation using the MARK program.
To this end, the sample period will be similar to year one (March 28 – April 26) that had a higher CPUE than the earlier Year two sample period (March 8 – April 14).

4. Some lethal sampling of limited numbers (n=6) of adult burbot is recommended to further evaluate length-at-age and recruitment hypotheses and deep-water densities. Limited sampling (n=7 trap-sets) between depths of 38 m and 79 m was completed in 2005-06 suggesting comparable average catch (n=4 burbot) to sampling depths <30 m. Given the limited sampling, recent life history movement data suggesting otherwise, and the need for otoliths to validate ages of the larger sized burbot, this is recommended in an effort to identify possible burbot aggregations. A permitted limit of six burbot mortalities is recommended.
6. Literature


Appendix A

Duncan Reservoir Burbot Monitoring Project Map

Map A1. – Sample Locations
Appendix B

Environmental Data

Table B1. Multi-meter depth profile data by location and season.
# Duncan Reservoir Burbot Monitoring 2009 Interim Report

## Appendix B

### Lower Duncan Reservoir at Howser June 28, 2009

<table>
<thead>
<tr>
<th>Location</th>
<th>Main Upper Duncan Reservoir Backflooded Channel June 28, 2009</th>
<th>Location</th>
<th>Lower Duncan Reservoir at Howser June 29, 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-ordinates</td>
<td>11 500472 5598234</td>
<td>Co-ordinates</td>
<td>11 504057 5574771</td>
</tr>
<tr>
<td>Total depth (m)</td>
<td>8.6</td>
<td>Total depth (m)</td>
<td>9.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Temperature (°C)</th>
<th>Conductivity (m/s)</th>
<th>Dissolved Oxygen (%)</th>
<th>Dissolved Oxygen (mg/l)</th>
<th>pH</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16.63</td>
<td>74</td>
<td>102.0</td>
<td>9.97</td>
<td>8.28</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>9.47</td>
<td>54</td>
<td>103.0</td>
<td>11.84</td>
<td>8.05</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>8.72</td>
<td>53</td>
<td>104.5</td>
<td>12.10</td>
<td>7.96</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Lower Duncan Reservoir at Howser Oct 22, 2009

<table>
<thead>
<tr>
<th>Location</th>
<th>Lower Duncan Reservoir at Howser Oct 22, 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-ordinates</td>
<td>11 504057 5574771</td>
</tr>
<tr>
<td>Total depth (m)</td>
<td>107</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Temperature (°C)</th>
<th>Conductivity (m/s)</th>
<th>Dissolved Oxygen (%)</th>
<th>Dissolved Oxygen (mg/l)</th>
<th>pH</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.46</td>
<td>60</td>
<td>114.0</td>
<td>12.15</td>
<td>8.21</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>12.46</td>
<td>60</td>
<td>113.4</td>
<td>12.10</td>
<td>8.07 Very Windy</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>12.45</td>
<td>60</td>
<td>113.6</td>
<td>12.08</td>
<td>7.97</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>12.43</td>
<td>60</td>
<td>113.4</td>
<td>12.10</td>
<td>7.94</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>11.82</td>
<td>60</td>
<td>107.2</td>
<td>11.53</td>
<td>7.78</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>10.00</td>
<td>65</td>
<td>103.4</td>
<td>11.66</td>
<td>7.55</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>9.13</td>
<td>68</td>
<td>105.2</td>
<td>12.14</td>
<td>7.52</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Lower Duncan Reservoir at Howser Dec 2, 2009

<table>
<thead>
<tr>
<th>Location</th>
<th>Lower Duncan Reservoir at Howser Dec 2, 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-ordinates</td>
<td>11 504181 5574578</td>
</tr>
<tr>
<td>Total depth (m)</td>
<td>101</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Temperature (°C)</th>
<th>Conductivity (m/s)</th>
<th>Dissolved Oxygen (%)</th>
<th>Dissolved Oxygen (mg/l)</th>
<th>pH</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.40</td>
<td>60</td>
<td>95.3</td>
<td>11.37</td>
<td>8.02 Cold -7C Air temp</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>7.41</td>
<td>60</td>
<td>95.1</td>
<td>11.46</td>
<td>7.99</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>7.42</td>
<td>60</td>
<td>95.2</td>
<td>11.46</td>
<td>7.94</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>7.42</td>
<td>60</td>
<td>95.2</td>
<td>11.47</td>
<td>7.90</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>7.41</td>
<td>60</td>
<td>95.8</td>
<td>11.49</td>
<td>7.86</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>7.39</td>
<td>60</td>
<td>96.1</td>
<td>11.55</td>
<td>7.81</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>7.37</td>
<td>60</td>
<td>96.3</td>
<td>11.56</td>
<td>7.78</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>6.69</td>
<td>62</td>
<td>95.6</td>
<td>11.60</td>
<td>7.75</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>5.53</td>
<td>69</td>
<td>92.4</td>
<td>11.64</td>
<td>7.66</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B

### Location: Historic Upper Duncan Confluence Area March 5, 2010

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Temperature (°C)</th>
<th>Conductivity (m/s)</th>
<th>Dissolved Oxygen (%)</th>
<th>Oxygen (mg/l)</th>
<th>pH</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.53</td>
<td>79</td>
<td>94.6</td>
<td></td>
<td></td>
<td>YSI motherboard fried while calibrating DO</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ship back to Hoskins for replacement and repairs</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Location: Lower Glacier Creek March 5, 2010

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Temperature (°C)</th>
<th>Conductivity (m/s)</th>
<th>Dissolved Oxygen (%)</th>
<th>Oxygen (mg/l)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.51</td>
<td>126</td>
<td>96.2</td>
<td>12.81</td>
<td>7.62</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Location: Historic Upper Duncan Confluence Area March 14, 2010

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Temperature (°C)</th>
<th>Conductivity (m/s)</th>
<th>Dissolved Oxygen (%)</th>
<th>Oxygen (mg/l)</th>
<th>pH</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.12</td>
<td>110</td>
<td>93.8</td>
<td>12.28</td>
<td>7.74</td>
<td>Secchi - 9.0 m</td>
</tr>
<tr>
<td>5</td>
<td>4.01</td>
<td>110</td>
<td>93.4</td>
<td>12.24</td>
<td>7.73</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>3.94</td>
<td>111</td>
<td>92.4</td>
<td>12.13</td>
<td>7.70</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>3.90</td>
<td>111</td>
<td>92.0</td>
<td>12.08</td>
<td>7.70</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>3.89</td>
<td>112</td>
<td>92.0</td>
<td>12.09</td>
<td>7.71</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>3.85</td>
<td>113</td>
<td>91.7</td>
<td>12.06</td>
<td>7.71</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>3.85</td>
<td>114</td>
<td>91.2</td>
<td>12.00</td>
<td>7.70</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>3.84</td>
<td>116</td>
<td>90.4</td>
<td>11.88</td>
<td>7.66</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>3.85</td>
<td>118</td>
<td>89.3</td>
<td>11.75</td>
<td>7.65</td>
<td></td>
</tr>
</tbody>
</table>

### Location: Lower Duncan Reservoir at Howser March 15, 2010

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Temperature (°C)</th>
<th>Conductivity (m/s)</th>
<th>Dissolved Oxygen (%)</th>
<th>Oxygen (mg/l)</th>
<th>pH</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.17</td>
<td>111</td>
<td>90.7</td>
<td>11.83</td>
<td>7.65</td>
<td>Secchi - 9.0 m</td>
</tr>
<tr>
<td>5</td>
<td>4.05</td>
<td>111</td>
<td>90.4</td>
<td>11.82</td>
<td>7.65</td>
<td>NTU's - 0.00</td>
</tr>
<tr>
<td>10</td>
<td>4.10</td>
<td>112</td>
<td>89.9</td>
<td>11.74</td>
<td>7.62</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>4.13</td>
<td>113</td>
<td>89.4</td>
<td>11.68</td>
<td>7.62</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>4.15</td>
<td>113</td>
<td>88.9</td>
<td>11.61</td>
<td>7.60</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>4.01</td>
<td>117</td>
<td>85.7</td>
<td>11.23</td>
<td>7.57</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>4.04</td>
<td>118</td>
<td>83.9</td>
<td>10.97</td>
<td>7.53</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>4.04</td>
<td>119</td>
<td>82.1</td>
<td>10.75</td>
<td>7.49</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>3.98</td>
<td>121</td>
<td>81.8</td>
<td>10.73</td>
<td>7.49</td>
<td></td>
</tr>
</tbody>
</table>
### Location: Upper Duncan Reservoir Rkm 42.0 March 16, 2010

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Temperature (°C)</th>
<th>Conductivity (m/s)</th>
<th>Dissolved Oxygen (%)</th>
<th>Dissolved Oxygen (mg/l)</th>
<th>pH</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.51</td>
<td>150</td>
<td>98.5</td>
<td>12.74</td>
<td>7.96 NTU's - 0.00</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Note River but within Full pool Elv.
- Potential Spawning Habitat
- Silt Sand Pools

### Location: Historic Upper Duncan Confluence Area April 7, 2010

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Temperature (°C)</th>
<th>Conductivity (m/s)</th>
<th>Dissolved Oxygen (%)</th>
<th>Dissolved Oxygen (mg/l)</th>
<th>pH</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.36</td>
<td>112</td>
<td>95.2</td>
<td>12.04</td>
<td>7.84 At depth where BB tags aggregate</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5.33</td>
<td>113</td>
<td>95.1</td>
<td>12.04</td>
<td>7.80</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>5.31</td>
<td>113</td>
<td>95.0</td>
<td>12.04</td>
<td>7.80</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>5.30</td>
<td>114</td>
<td>94.8</td>
<td>12.01</td>
<td>7.80 Windy</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>5.24</td>
<td>114</td>
<td>94.7</td>
<td>12.02</td>
<td>7.80</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>5.20</td>
<td>114</td>
<td>94.4</td>
<td>11.99</td>
<td>7.80 Substrate @ 30 m = silt/sand</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>4.75</td>
<td>116</td>
<td>92.3</td>
<td>11.86</td>
<td>7.80</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>4.33</td>
<td>116</td>
<td>89.6</td>
<td>11.64</td>
<td>7.77</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Substrate @ 30 m = silt/sand

### Location: Lower Duncan Reservoir at Howser April 7, 2010

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Temperature (°C)</th>
<th>Conductivity (m/s)</th>
<th>Dissolved Oxygen (%)</th>
<th>Dissolved Oxygen (mg/l)</th>
<th>pH</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.70</td>
<td>116</td>
<td>92.9</td>
<td>11.93</td>
<td>7.19</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>4.69</td>
<td>116</td>
<td>91.6</td>
<td>11.79</td>
<td>7.20</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>4.69</td>
<td>116</td>
<td>91.3</td>
<td>11.74</td>
<td>7.27</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>4.69</td>
<td>116</td>
<td>91.1</td>
<td>11.72</td>
<td>7.32</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>4.66</td>
<td>116</td>
<td>90.9</td>
<td>11.71</td>
<td>7.35</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>4.52</td>
<td>116</td>
<td>90.3</td>
<td>11.67</td>
<td>7.39</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>4.49</td>
<td>117</td>
<td>89.7</td>
<td>11.60</td>
<td>7.40</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>4.37</td>
<td>117</td>
<td>89.1</td>
<td>11.56</td>
<td>7.43</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>4.28</td>
<td>118</td>
<td>88.4</td>
<td>11.50</td>
<td>7.43</td>
<td></td>
</tr>
</tbody>
</table>

- Substrate @ 30 m = silt/sand