FISH AND WILDLIFE COMPENSATION PROGRAM

PEACE REGION

BULL TROUT (*Salvelinus confluentus*) REDD COUNT SURVEYS IN SELECT WILLISTON RESERVOIR TRIBUTARIES (2001 – 2010) AND RECOMMENDATIONS FOR FUTURE SURVEYS

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EXECUTIVE SUMMARY

During September, 2010 bull trout redd counts were conducted by aerial and ground surveys on four tributaries to the Williston Reservoir. Select sections of the Davis and Misinchinka rivers and Point and Scott creeks were surveyed in a similar manner to previous year's surveys. The highest redd count during the 2010 survey was in Scott Creek with 22.1 redds per km and the lowest count was in Point Creek (6.2 redds/km). Davis River counts were also high (21.3 redds/km) while the Misinchinka River counts were intermediate (8.9 redds/km). The longest time series of counts are from the Davis River with ten years of data and the 2010 count was considerably higher than any other year. The 2010 Misinchinka and Point Creek counts were also the highest in the last five years. The question is—what do these counts mean and are they useful for trend analysis?

The literature is rich with recent studies on bull trout and the efficacy of redd surveys because this species is listed as endangered in the United States and is a species of concern in British Columbia. Since this monitoring technique is relatively inexpensive and easy to conduct it is most often the only practical means of measuring population trends, especially on systems as large as the Williston Reservoir. While redd counts often provide a cost effective method of obtaining an index on adult escapement, their precision and accuracy are often compromised as a result of their uncertainty and ability to detect sensitive changes in population status. Observer errors, inter-observer variability in counts, temporal and spatial variation have all been identified as potential sources of error when using redd counts. Depending on the priority of the monitoring, reducing the uncertainty in redd counts can be accomplished by conducting replicate counts within an index site, measuring observer efficiency, measuring sources of observer efficiency and having a better understanding of the spatial and temporal variation in spawning activity. However, implementing these measures can often be financially prohibitive, especially in a system such as the Williston Reservoir. Importantly, the report discusses some of the benefits and shortcomings of utilizing redd counts for monitoring trends in abundance of bull trout populations over time.

While the Williston tributary redd counts provide an initial index for monitoring bull trout, limited information can be inferred from the index at a population level due to the large spatial and temporal variation in spawning. The index does not provide a sense of total numbers of redds per system and they likely represent the "best" spawning sites that would be selected for even if the total spawning population was low, limiting the ability for detection of trends at the population level. The current redd survey can become much more meaningful for understanding population trends by conducting full stream length redd counts on the smaller systems and use of

a randomly stratified design at selected reaches on the larger rivers. Furthermore, installation of a resistivity counter on the Misinchinka River would provide a direct total spawner count and the ability to calibrate future redd counts. Priority for this recommendation is warranted especially if a retention fishery is permitted on the Misinchinka River in future. Alternatively if a counter cannot be used, then it is recommended that a full length redd survey of the Misinchinka River be conducted to reduce any uncertainty from the existing index. Simultaneously, it is recommended a roving creel census be conducted to obtain independent estimates of harvest during the fishery on the Misinchinka River.

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INTRODUCTION

Bull trout (*Salvelinus confluentus*) have been identified as a species of special concern in British Columbia owing to their vulnerability to fishing as well as natural and human caused impacts to their spawning and rearing habitat. Moreover, this species has been blue-listed by the BC Conservation Data Centre.

Prior to formation of the Williston Reservoir in 1968, bull trout were indigenous to the Peace, Parsnip and Finlay rivers as fluvial forms (Langston and Cubberley 2008). Creation of the Williston Reservoir resulted in large scale habitat alterations that appear to have impacted native bull trout populations both positively and negatively. The reservoir's bull trout populations have been negatively affected by a number of factors including: a substantial change from a riverine to a lacustrine environment, loss of interconnectedness (gene flow), habitat degradation, inter-specific competition (i.e., lake trout) and loss of spawning and rearing habitat. On the other hand as with many other BC storage reservoirs such as Arrow Lakes and Kinbasket the greatly increased Williston pelagic habitat does provide a good growing environment for kokanee that bull trout are reliant upon as a prey source (Sebastian et al. 2000; Decker and Hagen 2008). Native kokanee (*Oncorhynchus nerka*) populations existed in the Peace drainage prior to reservoir formation and their numbers began to increase once the reservoir was formed (Blackman 1992). Knowing that kokanee are a pelagic planktivore the Ministry of Environment (MOE) and FWCP-P "jump started" the existing population by means of stocking the reservoir from 1990 to 1998 (Langston and Murphy 2008) and their population size has rapidly expanded (Sebastian et al. 2009; Andrusak *in* Sebastian et al. 2010 draft report). One outcome of this introduction has been the expectation that the adfluvial bull trout population(s) would take advantage of this expanded prey population.

In recognition of the huge impacts to fish and wildlife due to the formation of the Williston Reservoir BC Hydro and the Ministry of Environment in 1989 formed the Fish and Wildlife Compensation Program – Peace (FWCP-P) to assist in restoration efforts as a result of the losses to both the fish and wildlife resources. Over the last decade bull trout have been one of the primary sport fish species that the FWCP-P has focused on in an effort to gain a better understanding of their current status; specifically, is their abundance trending upward as anticipated? Currently it is apparent that adfluvial bull trout now utilize numerous tributaries to the Williston Reservoir for spawning and rearing but virtually no information exists on the status of these populations. With such uncertainty there is on-going concern regarding their sustainability since they are extremely vulnerable to fishing when staging off spawning streams as well as when they are spawning usually during July-September.

Abundance trend monitoring has been identified by the FWCP-P as an important and possibly only practical method of determining current status of bull trout numbers and a possible means of monitoring effectiveness of implementation of management and enhancement initiatives. Williston Reservoir is so large that the only practical way of monitoring trends in population abundance is by means of following the reproductive portion of the population(s) typically by developing an index of abundance through spawner or redds counts.

While redd surveys are often the easiest and cost efficient way to monitor adult bull trout abundance and trends, there is concern over their sensitivity of detecting population trends over time (Rieman and Myers 1997). Dunham et al (2001) found significant spatial and temporal variability in bull trout spawning activity which need to be considered when establishing index sites for redd counts. In addition, Muhlfeld et al. (2006) described how observer error can also be major sources of bias and variability in redds surveys. Despite these problems numerous studies (Al-Chokhachy et al. 2005, 2009; Gallagher et al. 2007; 2010; and many others) have demonstrated that there can be good correlations between redd counts and independent estimates of spawner numbers. In recent years there has been a great deal of work carried out in the Pacific North West including BC that involve a number of bull trout assessment techniques such as redd counts, spawner counts and direct spawner enumerations using resistivity counter technology (Decker and Hagen 2008; Andrusak 2010).

Owing to the size of the reservoir it has been cost prohibitive to assess all Williston bull trout spawning populations. Therefore the FWCP-P fisheries program nearly a decade ago began to conduct bull trout redd counts on select portions of known spawning systems in an effort to develop an index of abundance. The question has arisen as to how meaningful are these counts and will they provide the required trend data to ascertain bull trout status? The fisheries technical committee of the FWCP-P wants to be certain that the redd surveys are science based and are rigorous enough to be able to detect abundance trends in the bull trout population(s). This report summarizes bull trout redd counts in four key tributaries that are being considered as index sites for long term monitoring of trends in abundance. In this report a review of the current methodologies and their utility towards detecting trends for Williston Reservoir bull trout numbers is provided. The results of the 2001 – 2010 bull trout redd counts from the Williston tributaries are summarized, analysed, and compared with similar work on southern BC systems, and recommendations for future monitoring methods and options are made. This report also addresses the question of whether or not a retention fishery on the Misinchinka River could be considered, and if redd count methodology (and the existing index site) could be used to detect the impact of the fishery.

BACKGROUND

The Williston Reservoir was created in north-central B.C. by the construction of the W.A.C. Bennett Dam in 1967 across the Peace River. Approximately 1,650 km^2 of forested land within the Peace, Parsnip and Finlay River valleys were flooded and more than 600 kilometres of main stem and large river tributary habitat was lost. Depending on reservoir pool elevation, Williston Reservoir covers a surface area that ranges between 1,647 km^2 to 1,800 km^2. However, the reservoir did not reach full pool until 1972, five years after completion of the dam. Currently, the Williston Reservoir is the 9th largest man-made lake in the world. This hydroelectric project has had significant impacts on fisheries and other resources in the area. The biological productivity of the reservoir has been described as “boom and bust” with a 10 year “boom” period followed by a 20 year decline in productivity to its current oligotrophic state (Stockner et al. 2005).

Early aquatic studies on the Williston Reservoir and its tributary streams made an effort to document the fish assemblages in the newly formed reservoir and these are detailed in two compendiums; Phase 1 work from 1959-1989 (French 1999) and Phase 2 from 1988-1998 (Rae and French 1999). Importantly, these compendiums provide good reference points for understanding “what was already known” and “what had already been accomplished at that time” on this system and served as the basis for the development of the Strategic Plan for the Peace/Williston Fish and Wildlife Compensation Program (2000, PWFWCP). Most notable were the initial post impoundment fish stock assessments of the reservoir and its tributary streams that were conducted in 1974-75 by Barrett and Halsey (1985) and Bruce and Star (1985). These reservoir studies consisted of extensive gillnet sampling at numerous near-shore stations to assess fish species composition and relative abundance.

Following the review by Barrett and Halsey (1985), Blackman (1992) re-sampled with gillnets in 1988 using similar methods as in the original fish assessment of 1974-75, with additional off-shore gillnetting to assess the pelagic fish community. Blackman summarized, analyzed and compared data collected from the two studies (1974-75 and 1988) and concluded that the species composition and relative abundance had changed to favour species adapted to the lacustrine habitat. More recent studies (Pillipow and Langston 2002) confirmed Blackman’s earlier findings and reported the species composition shift was continuing. Introduced kokanee have expanded rapidly and now dominate the pelagic habitat (Sebastian et al. 2009) while top predators such as lake trout and bull trout appear to be taking advantage of increased kokanee abundance. Despite probable reduction in reservoir productivity over time as evidenced in numerous reservoir studies (Wetzel 2001; Stockner 2003; Stockner et al. 2005; Decker and Hagen 2008) bull trout appear to do fairly well provided there is an abundance of prey.

Previous work on Williston Reservoir bull trout using radio telemetry technology provided confirmation that adfluvial populations utilize the Misinchinka and Davis Rivers (O'Brien and Zimmerman 2001: Langston and Cubberley 2008). In an effort to begin tracking trend in adfluvial bull trout population(s) the Ministry of Environment in 2001 established a bull trout redd count site in the upper Davis River, a tributary to the Finlay Reach. Project implementation was transferred to the FWCP-P in 2003. The wide distribution of adfluvial bull trout populations prohibited watershed scale assessments of population size therefore the FWCP-P later selected three other spatially separate streams to provide representation of bull trout abundance trends for the entire Williston Reservoir. Misinchinka River and Scott Creek were chosen to represent the Parsnip Reach and Point Creek was selected to represent the Peace Reach. Redd count methodology was employed similar to that described in Reiman and Myers (1997) and more recently Decker and Hagen (2008) and Andrusak (2010). Criteria for the index site selections are described in Langston and Cubberley (2008) that include high value bull trout spawning habitat, good access, good site visibility (aerial and ground) and readily repeatable counts. Concurrently, index of abundance estimates of the kokanee population in the reservoir and key spawning streams are also on-going.

The extended period of time of 2-3 months that adfluvial bull trout stage, emigrate upstream, spawn and migrate downstream to the reservoir means this species is vulnerable to angling. It is well known that spawning bull trout are easy to catch in their natal streams and most large lake systems in BC have seasonal angling closures to protect them. In such a huge reservoir as Williston the question does arise: can some bull trout angling in the tributaries be permitted if angling effort in the reservoir itself is perceived to be low?

Project Objectives

The provincial fisheries management agency has two program goals (MOE-Fisheries Program Plan 2007) that are applicable to the Williston:

1. Conserve wild fish and their habitats and,
2. Optimize recreational opportunities based on the fishery resource.

To attain these broad goals several strategic objectives need to be accomplished and these have been outlined in an older FWCP-P strategic plan (Peace/Williston Fish and Wildlife Compensation Program 2000). Over the years the FWCP-P has completed a number of fish habitat mitigation and habitat restoration projects in support of Goal 1. Two objectives of the FWCP-P that are interlinked with Goal 1 are to produce technically sound projects and evaluate and monitor those projects undertaken by the program. Additional objectives in support of Goal 1 have recently been described by the FWCP-P in a draft "Strategic Implementation Plan". An important one that is central to this report is to acquire scientific baseline information to enable maintenance or enhancement of existing bull trout populations. To be in a position to accomplish this objective a number of tasks need to be completed including:

- Monitoring bull trout spawning populations after assessment of the value and efficacy of current redd count methodology and suitability of the index sites to provide long term trend data.
- Developing monitoring techniques to determine bull trout numbers in the Misinchinka River.
- Determining monitoring requirements for a bull trout retention fishery.

The successful introduction of kokanee to the reservoir appears to be providing a good growing environment for top predators such as bull trout. At present the FWCP-P is pursuing a number of objectives to ensure not only conservation of Williston bull trout but also possibly moving forward with creation of some additional recreational fisheries. This latter objective is aligned with MOE's Goal 2 of creating recreational opportunities. To accomplish the goals of conservation and recreational opportunities some basic assessments of the population(s) are required and this report reviews the 2010 monitoring results and outlines the feasibility of long term trend monitoring of bull trout populations. Discussion is also provided on the concept of an in-river retention fishery for bull trout.

SITE DESCRIPTION

The four index streams assessed are geographically located throughout the Williston system. The Misinchinka River flows southwest into the Parsnip River which forms the Parsnip Arm of the reservoir. Scott Creek also flows in a westerly direction into the Parsnip Reach. Point Creek flows north into nearly the midpoint of the Peace Reach while the Davis River flows west into the upper part of the Finlay Reach (Figure 1).

Of the four systems assessed in 2010 the Misinchinka River is by far the largest. This river originates on the western slope of the Rocky Mountain Misinchinka Range flowing nearly 100 km in a south-west direction before joining the Parsnip River approximately 14 km (depending on reservoir level) south of the Williston Reservoir near the town of Mackenzie BC. The river mouth to Mackenzie by helicopter is 26 km in distance. Most of the lower half of the Misinchinka is low gradient characterized by wide meanders and is accessible by road whereas the upper half is steeper gradient, confined with access restricted to ATV and horses. Total length of accessible river was deemed to be 91 km, not including numerous tributaries that potentially contains spawning bull trout habitat. No barriers to upstream fish passage were noted. Fish access to the uppermost few kilometres is limited only by the diminishment of water as the stream branches into numerous first order and ephemeral feeder rivulets.

The Davis River flows southwest into the Finlay Reach of the reservoir a distance of ~ 180 km north of Mackenzie BC. A road bridge crosses the Davis River at the mouth. The Davis River watershed beyond the bridge has very limited access with the upper reaches only accessible by helicopter. This system is accessible for adfluvial bull trout spawners for a distance of at least 44 km of mainstem with no obvious migration barrier identified. The Graham River is the largest tributary to the Davis River with the confluence located approximately 15 km upstream from the reservoir. O'Brien and Zimmerman (2001) described movement and location of bull trout spawners that also migrate up the Graham River for an additional 10 km. The lower reaches of the Davis River are characterized by numerous meanders comprised of sands and silts with a few patches of small gravels owing to low gradient. The upper reaches upstream of the confluence with the Graham River is steeper with substrate comprised of cobbles and boulders with patches of gravels often in association with log jams.

Point Creek flows in a northerly direction before it enters the Peace Reach of Williston Reservoir. It is located ~ 70 km by air from MacKenzie BC and ~ 80 km from Bennett Dam. Access to a location approximately 4.5 km upstream from the mouth of Point Creek is currently possible via an old logging road. Past road deactivations, and bridge and culvert washouts suggest future access is doubtful. A helicopter is required to access all upper sections. Accessible length of available spawning habitat is ~ 8.2 km with the primary spawning sites located in the steeper upper reaches immediately upstream of the road crossing and below a migration barrier formed by a waterfall. Downstream of the road crossing the gradient is steep with a primarily cobble substrate with little or no spawning habitat for bull trout. A small waterfall (two 1 – 1.5 m step falls) approximately 2 km upstream of the road crossing may represent an area of difficult passage for some bull trout in some years.

Scott Creek flows in a westerly direction before it enters the Parsnip Reach of Williston Reservoir. It is located ~ 60 km from Mackenzie BC. The river is crossed by a main logging road bridge approximately 10 km upstream from the mouth. Old logging roads provide access to a few points immediately (within 1 km) below the bridge, while one road extends approximately 4 km upstream of the bridge. The habitat downstream of the bridge is meandering lower gradient with gravel and sand substrate. Accessible length of available spawning habitat is ~ 17.6 km with the primary spawning sites located in the steeper upper reaches below a migration barrier formed by a waterfall.

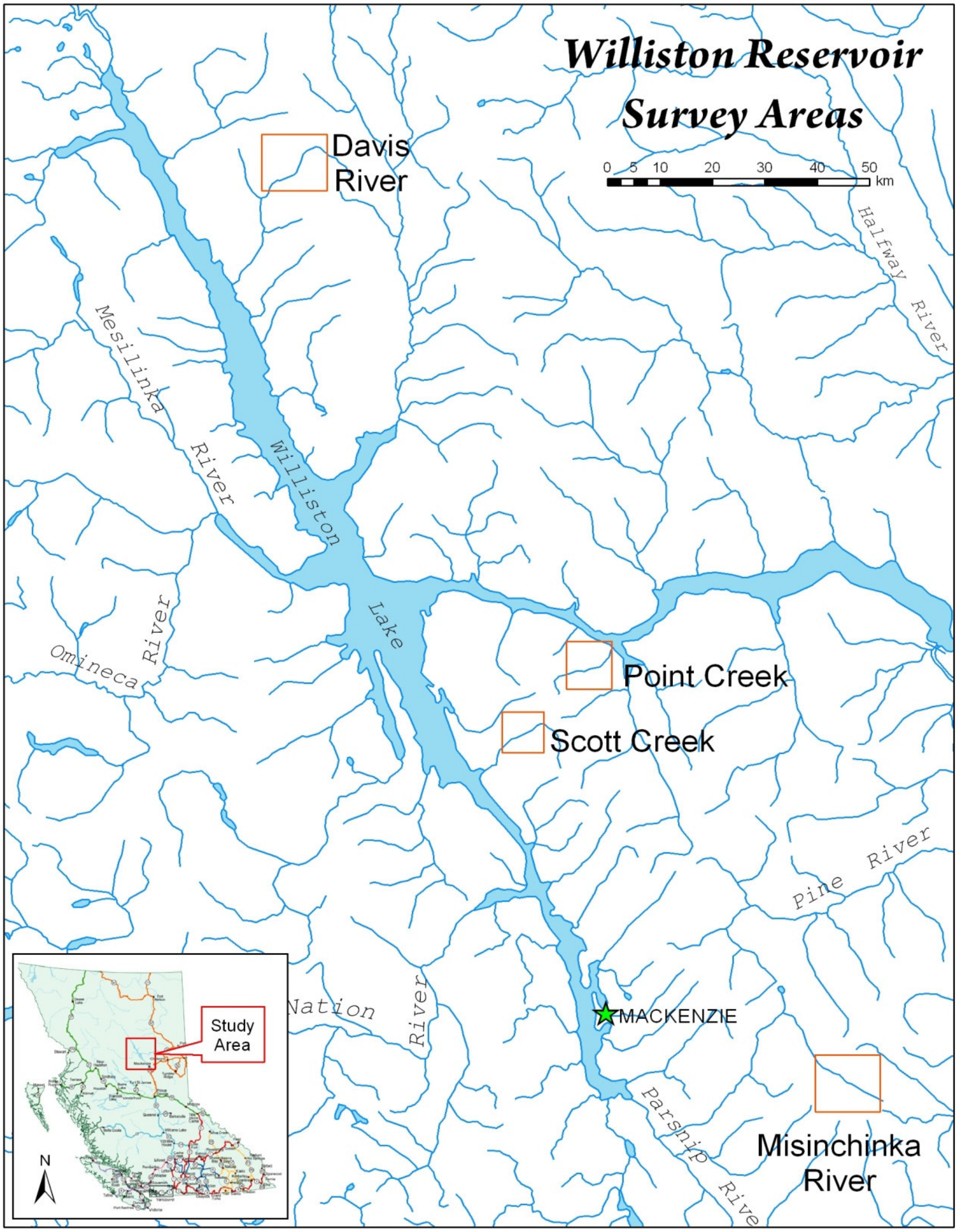

Figure 1. The Williston Reservoir and location of the four index systems: Davis River, Misinchinka River, Scott and Point creeks.

METHODS

Genesis of Williston Reservoir bull trout redd monitoring surveys (1999 – 2009)

At the Program inception in 1989 MOE and FWCP-P were aware that bull trout were present in the Williston Reservoir. No project bull trout monitoring design was developed nor envisioned in 1989; however, over the last decade efforts to examine bull trout populations have evolved significantly. At the onset a 1999 bull trout radio telemetry project, supported by an aerial reconnaissance of the upper Davis River resulted in MOE staff selection of the Davis River as the initial redd count index site. The site was chosen for annual redd count surveys due to the following characteristics:

- it possessed habitat attributes (hydrology, substrate type, flow, stability and cover) conducive to bull trout spawning and redd counting,
- it was believed to encompass the majority of the bull trout redd spawning in Davis River,
- it was believed all spawners were adfluvial Williston Reservoir resident bull trout,
- its midpoint geographical location in the Finlay Reach potentially made it a representative system that inferences could be made for the rest of the Finlay Reach tributaries.

Using the Davis River rationale and criteria two more systems were selected in 2006: one from the Peace Reach (Point Creek) and one from the Parsnip Reach (Misinchinka River) with an additional centrally located Parsnip Reach tributary, Scott Creek, added in 2009. The decision to assess a tributary from each reach was based on available literature at the time especially by Bonar (1997) who emphasized the need to assess spatially separate parts of a system rather than focus on one system. Selection of the index streams was supported by aerial reconnaissance surveys undertaken from 2003-2008. These surveys identified redd locations/concentrations, areas of difficult passage, waterfalls, and attempted to delineate the uppermost and lowermost bull trout spawning locations. As a result, Misinchinka River was identified as a good candidate and the site selected was felt to represent the majority of bull trout spawning. Misinchinka spawners were confirmed as adfluvial during 2004-2005 through a radio telemetry study (Langston and Cubberly 2008) and redd counts of the index site commenced in 2006. It should be noted that in 2009 and 2010 a 0.8 km section was added to the upstream end of the index site, though all data collected in the new upper site was recorded separately to enable comparison of the initial index site from 2006-2010.

Point and Scott creeks, both small tributaries, were selected using the same criteria as Davis and Misinchinka rivers. In all cases the index sites were selected due to the observed high(er) numbers of redds therefore they were not randomly selected. The lengths in kilometres of the index sites are shown in Table 1. As noted one change has occurred since the original sites were chosen: a 1 km section has been added to the upstream end of the Misinchinka site. Redd counts from this additional section is recorded separately. Note: the Scott Creek site is actually split by a steep boulder cascade section that is not assessed.

Table 1. Williston Reservoir bull trout Index streams, years surveyed, UTM's and length of stream surveyed[1]

Stream	Years	UTM Start	UTM End	Survey (km)
Davis River	2000-2010	10.420919.6294848	10.418399.6292006	5.1 km
Misinchinka River	2006-2010	10.541722.6118064	10.537987.6119942	6.2 km
Misinchinka River	2009-2010	10.542451.6117879	10.541722.6118064	1.0 km[2]
Point Creek	2006-2010	10.481168.6197480	10.483852.6198923	3.7 km[3]
Scott Creek (upper)	2009-2010	10.471368.6184252	10.469871.6183067	3.0 km[4]
Scott Creek (lower)	2009-2010	10.469195.6182550	10.467455.6180978	2.8 km

1 Length of index sites were determined by summing right bank polyline segment lengths extracted from 1:20,000 TRIM (Waterlines layer) and Orthophoto maps. Lengths are reported to the nearest 100 m.

2. Added 1 km to upstream end of Misinchinka site in 2009

3. Mainstem length is 3.7 km. A braid in the mid section requires surveying one to two 600 m braids (depending on water levels)

4. 1.2 km not surveyed between upper and lower sites.

Survey Methodology

Survey Timing

Redd counts on the Williston Reservoir tributaries have been conducted on or during the third week of September, within a range from September 19 to September 25 since 2001. Survey timing was originally developed from radio telemetry work conducted by MOE (O'Brien and Zimmerman 2001). Importantly, telemetry data demonstrated that the majority of bull trout out-migrated immediately following spawning, allowing for ideal conditions for observing redds. Day time surveys begin once adequate light levels were attained (generally after 0930 hrs) and were completed before light levels faded by 1700 hrs.

Aerial Based Counts

Aerial based Davis River redd counts were initiated by Ministry of Environment personnel in 1998 and transferred to FWCP-P in 2002. Aerial surveys were continued through 2004; data is on available in FWCP-P files 2001-2004 (Prince George, BC). The aerial based surveys were conducted to: locate redds outside of the selected index site, and to determine if aerial based surveys could replace or substantiate ground based surveys. Counts were conducted by 2 experienced observers from a helicopter flying in an upstream direction at a height of 30-50 m and speed ranging from 25 – 40 km/hr. Redd locations were captured with a GPS equipped hand held computer. Counts were not conducted in 1999 due to poor weather and these aerial based redd count surveys were discontinued after 2004.

Ground Based Counts

Except for 2002, ground based surveys have been conducted annually on the Davis River since 2001 and are detailed in Appendix 1 and 2. These surveys were expanded to include the Misinchinka River detailed in Appendix 3 and Point Creek in 2006 detailed in Appendix 4, and Scott Creek in 2009 detailed in Appendix 5. All index sites were accessed via helicopter near their upper end of the designated survey site. One crew of two experienced observers walked in a downstream direction completing one pass of the index site. Polarized glasses were used to assist in redd identification. Redd site locations were geo-referenced using a hand held GPS recorder and a GPS equipped hand held computer. Additional data: distance to cover, type of cover, size of the redd, and proximity to other nearby redds was recorded along with the redd location. The data is stored on FWCP-P computer files and Ministry of Environment Field Data Information System (FDIS) database. Redd size, cover and substrate characteristics have been documented for most years and this data is on file at the FWCP-P office.

Redd Site Identification

Redds were identified as approximately dish-shaped excavations in the bed material, often of brighter appearance than surrounding substrates, accompanied by a deposit beginning in the excavated pit and spilling out of it in a downstream direction. Disturbances in the bed material caused by fish were discriminated from natural scour by: i) the presence of tail stroke marks; ii) an over-steepened (as opposed to smooth) pit wall often accompanied by perched substrate that could be easily dislodged down into the pit, and often demarcated by sand deposited in the velocity break caused by the front wall; iii) excavation marks alongside the front portion of the deposit demarcating the pit associated with earlier egg laying events (bull trout will deposit eggs in several nests as the redd is built in an upstream direction); and iv) a highly characteristic overall shape that included a 'backstop' of gravel deposited onto the unexcavated substrates, a deposit made up of gravels continuous with this backstop and continuing upstream into the pit, and a pit typically broader than the deposit and of a circular shape resulting from the sweeping of gravels from all sides to cover the eggs (in a portion of redds gravels are swept into the pit from only one side, often a shallow gravel bar on the shore side).

A second important determination was whether fish had actually spawned at a location where an excavation had been started. 'Test digs' were considered to be pits, often small, accompanied by substrate mounded up on the unexcavated bed material downstream but with no substrate swept into the pit itself, which would denote at least one egg deposition event. In the case of a 'test dig' determination the mound of gravels would typically be short and narrow around the downstream side of a relatively small pit.

The index sites are located in hyper-stable headwaters, often with little bed (substrate) movement following spring run-off. Redds from the previous year are sometimes visible the following year. Crews examine each redd for: presence and orientation of periphyton accumulation on tailspill gravel, presence of fines from recent redd excavation, and general flattening of tailspill gravel to determine if the redd was created in a previous year. Redds from previous years were not recorded. In areas of limited gravel or high redd abundance, or where spawning site selection is highly specific, superimposition of redds can occur (Baxter and McPhail 1999). For this study, the redd count was based on a subjective evaluation, with the most recent complete redd(s) counted and the disturbed remains of prior redds being included. A greatly extended deposit length (subjectively evaluated to be at least twice the length of a 'typical' deposit length) was examined to understand if a second female had made use of the same pit created by a first female to construct a separate redd. Fortunately, such cases usually represented a very small proportion of the total redds present.

In an effort to add greater objectivity to redd identification the survey crew in 2003 experimented by classifying redds according to Shepard and Graham (1983) classifications of: *Definite*, *Probable*, and *Possible*. This practise was abandoned after initial testing as it became apparent *Possible* classifications inappropriately inflated redd counts, and the *Definite* and *Probable* classifications were too similar and may inappropriately reduce redd counts. Survey crews erred on the side of caution and only recorded redds that they were certain were redds.

Redd size, cover and substrate characteristics have been documented for most years and this data is on file at the FWCP-P office.

2010 Surveys

Aerial and ground based surveys of the four index systems were undertaken during the week of September 20-25th 2010 based out of Mackenzie BC. A Bell Jet Ranger 206B helicopter was used to access each of the systems and an over flight of the index site (s) was initially conducted. The aerial reconnaissance flight of the stream was conducted to provide a general indication of: upstream limit of spawning habitat and concentrations/presence of redds below the index sites. Ground based surveys were then performed employing the same protocols used for the previous nine years as described above. Redd locations and their sizes were geo-referenced in UTMs with a GPS unit. Observations on stream characteristics were recorded on note pad and representative photos were taken, see photo data on file at the FWCP-P office. Some underwater photos were also taken of redds and associated spawning habitat and these are on file at the FWCP-P office. Redd sizes have been measured over a number of years to the nearest 0.1 m and this data is maintained on file at the FWCP-P office.

Analysis of Trends

The long-term trend in the bull trout redd count data in each of the three creeks with multiple years of data was analysed using a general linear model with a log link function and log-normal errors implemented within a Bayesian framework. In the case of Davis River the difference in observer efficiency between ground and air-based surveys was accounted for using an additive term. Here, observer efficiency simply refers to the relationship between ground and air-based counts. The linear Bayesian models were implemented using R scripts (R Development Core Team 2010) which interfaced with WinBUGS 1.4.3 (Gilks et al. 1994) using the R2WinBUGS library (Sturtz et al. 2005). The model assumed uniform low information prior probabilities. The posterior probabilities were derived from 1,000 Markov Chain Monte Carlo (MCMC) simulations thinned from the second halves of three MCMC chains of 100,000 iterations in length (Ntzoufras 2009). Convergence was confirmed by ensuring that $\hat{R}$ (the Gelman-Rubin-Brooks potential scale reduction factor) was 1.0 for each of the parameters in the model (Gelman & Rubin 1992; Brooks & Gelman 1998).

The probability of detecting a statistically significant (negative) relationship (the power) was estimated by using WinBUGS to simulate 100 datasets for each scenario. We focused on detecting declines[1] in abundance based on bull trout conservation objectives. Nine scenarios

[1] Based on the objectives, scenarios with increasing abundance were not examined. Given the analytical methods, the power to detect increases would be expected to be similar, though simulations would be required to confirm, given, for example, the log-scale used in the simulations.

were examined: three different periods of time (10, 25 and 50 years) and three percent decreases (25%, 50% and 75%) in the expected mean counts over these time periods, from a starting point of 50 observed redds. These scenarios are similar to those used in other power analyses for bull trout redd count programs (e.g., Al-Chokhachy et al. 2009), and represent combinations of rates of decline and duration monitored. For example, the 75% over 10 years and 25% over 50 years scenarios represent relatively rapid (3.75 redds per year) and very slow (0.25 redds per year) rates of decline, respectively. Note that the duration monitored and rate of decrease are inversely related for these scenarios. For a given decline (e.g., 25%), the rate of decline differs for the 10, 25 and 50 year scenarios (1.25, 0.5 and 0.25 redds per year, respectively). The 10 year scenarios are likely most relevant for resource management decisions. The simulations assumed that the uncertainty in the error variation (i.e., process and/or measurement error) was as estimated for Davis River. The simulated datasets were then analysed using the general linear model described above and the power calculated from the proportion of the analyses with a negative trend[2] and p-value less than 0.05.

RESULTS

Weather conditions during the survey week were excellent providing the survey crew with optimal viewing conditions as evidenced by the photos, photo data on file at the FWCP-P/W office. Stream flow conditions were considered unseasonably low thus providing excellent visual conditions.

2010 Surveys

Davis River

A portion of this river has been surveyed for nine of the last ten years with some preliminary "scoping" surveys completed during 1998-2000 by the MOE (Appendix 1 and Appendix 2). Aerial based redd count surveys were completed in 1998 and 2000-2004. Davis River is quite remote and it takes approximately 1 hour of helicopter time to fly from Mackenzie to the river mouth. During the 2010 survey the 5.1 km index site of mainstem river upstream of the Graham River confluence was ground surveyed by a two person crew. Initially an aerial overview flight of the entire Davis River mainstem was flown and observations noted. The lower reaches of the river is dominated by low gradient, large meanders, braids and adjacent muskeg type habitat. The river gradient increases upstream of the Graham River confluence where it is believed the

[2] Any negative trend significantly different from zero was considered a 'successful' detection of trend (i.e., the estimated magnitude of the trend for the simulated dataset did not have to match the true magnitude in the simulated scenario).

majority of bull trout spawn. Low primary production (periphyton) on the substrate made it difficult to identify redds from the helicopter. The 5.1 km section surveyed was dominated by cobbles, large boulders and logs that often created pools with pockets of gravel selected by spawning bull trout. A total of 85 redds were identified during the ground survey in the 5.1 km section with the total length of the river being 44 km although no definite migration barrier was identified. The 2010 over flight extended approximately nine kilometres upstream of the index site to the alpine headwaters and no barrier to upstream fish passage was observed. Upstream fish migration for the last few kilometres of the river is limited only by the diminishment of water as the main stream is formed by numerous first order and ephemeral feeder rivulets. Only a few redds were visible from the air upstream of the index survey site with most relatively close to the index site.

<u>Misinchinka River</u>

The mouth of the Misinchinka River where it joins the Parsnip River is located ~26 km southeast of Mackenzie BC. From the confluence, the Parsnip River flows another 14 km northwest to Williston Reservoir (at full pool). The aerial flight by helicopter covered the river where it joins the Parsnip upstream to the very headwaters. Total river length (along river channel) is 91 km. The lower 56.5 km of the Misinchinka River is accessible at several locations by highway. This potentially would make it possible to set up a counter with the placement of a power pole from the two phase power line running along the highway. However, the power line is only close to the lower and middle reaches of the Misinchinka River where it is simply too wide and too deep to enable use of a resistivity counter. The lower river is very windy with numerous oxbows and beaver ponds. There are also a number of tributaries (e.g., Caswell, Bijoux, Honeymoon, Ralston, Old Friend and Atunatche creeks) that while small, may afford some bull trout spawning habitat in their lower reaches.

A logging road near Bijoux Creek may allow access by ATV into parts of the upper river depending on road condition (a primitive bridge for ATVs to cross the Misinchinka River crossing was observed from the air near Bijou Creek). Most bull trout spawning habitat appears to be located upstream of Atunatche Creek where the river flows from the southeast and moves away from the highway. Upstream of Atunatche Creek, it is another 23 km to lower end of the surveyed section. There are several tributaries in this section, some of which may have spawning habitat and others that are too steep to be accessible for fish.

The section surveyed was 6.2 km long in which 59 redds were counted (Appendix 3). An additional 1 km of the river upstream of the site was also surveyed for redds and the over flight extended approximately four kilometres upstream of the index site into the headwaters. No barriers to upstream fish passage were observed and similar to the Davis River headwaters the only impediment to up streaming migrant bull trout is the ever decreasing size of the stream. Well upstream of the survey section there may be some additional spawning habitat since there are no barriers but little useable habitat is available with the very headwaters being mere rivulets. The first 2 km of the small tributary located at the downstream end of the survey site was aerial surveyed. Though some spawning was possible, available habitat was of low quality with no redds observed. It is conceivable there is some marginal spawning in the first 1 km of this tributary. As with the other systems surveyed, water levels were possibly 25% lower than normal this year.

Point Creek

This stream was assessed the first day (September 20th) of the survey due its close proximity to Mackenzie and concern over the cloudy but clearing weather conditions. Blue sky conditions persisted after the first survey day. A definite barrier to fish passage was observed at a waterfall (10U 478358E 6197136N) with a smaller falls downstream that was not a barrier to fish passage. The index site is located 1.3 km downstream of the upper barrier. The length of this site is 3.7 km (excludes 600m of braiding of the mainstem that was surveyed). A total of 10 km of mainstem length is accessible to bull trout prior to the impassable water fall. No tributaries of suitable size for bull trout spawning are present. A total of 24 redds were confirmed by ground survey (Appendix 4). A few redds from the 2009 spawning period were observed, but not recorded. From the lower end of the index site it is 5 km to the reservoir.

Aerial reconnaissance of the accessible habitat indicates little or no spawning habitat is present in the lower ~5 km extending from the creek mouth upstream to the lower boundary of the ground based redd survey. No redds were observed from the air and the habitat was noted as higher gradient with cobble and small boulder substrate with no observed gravel patches suitable for bull trout spawning.

Scott Creek

A waterfall located 16.7 km upstream of the reservoir is a complete barrier to fish migration. The uppermost point of the survey section was this barrier. The Scott Creek survey was split into two sections. The upper section (beginning at the impassable waterfall) extends downstream 3.0 km. This is followed by a 1.2 km section of boulder, cascade habitat near the midpoint that was excluded due to a 500 m section of bedrock/canyon, steep slopes and unsafe walking terrain. Downstream of this 1.2 km section is the lower survey site that is 2.8 km in length. Thus 5.8 km of stream was actually surveyed. A total of 106 redds were counted: 86 in the section above the cascade chute area and 20 downstream of it (Appendix 5). This was the highest count of the 4 systems surveyed in 2010. There is road access to the lower end of Scott Creek from Mackenzie (~1 hour drive) to a bridge crossing the creek. Near the road bridge there are some good sites for installing a counter (Note: a fish trap weir style counting fence was constructed just below the bridge in 1991). There is no power in this area. The total distance from road to falls on the creek is 8.7 km. Aerial reconnaissance of the site in 2010 indicated an old logging road, initiating near the road bridge, parallels the north side of the creek extending up to the lower boundary of the survey site providing possible vehicle access to this area. A foot trail was also noted at the waterfall indicating people have hiked to the impassable waterfall in the past. There is also a recently constructed helipad near the waterfall that still represents the best means of access for the survey crew. A few logging roads allow access to a few points on Scott Creek for about 500 m downstream of the bridge crossing. The remainder of stream to the reservoir is 5.7 km and is accessible only by foot. Photo data on file at the FWCP-P office.

Previous Years Surveys

Bull trout redd surveys on select tributaries to the Williston Reservoir have been undertaken as early as 2001 (Table 2; Appendix 1-5). Davis Creek has been assessed nine years of ten while the Misinchinka River and Point Creek have been surveyed for last five consecutive years (Appendix 1-5). Scott Creek has only been surveyed during the last two years. Based on the length (km) of each of the four index sites the number of redds per km has been quite consistent from year-to-year, especially the Misinchinka (Table 2). The 2010 estimates appear to be the highest yet recorded for three of the four index sites but considerable caution is required as to what these counts mean and the reasons for caution are discussed below.

Table 2. Number of bull trout redds observed at index sites of four Williston Reservoir tributaries. Length of stream surveyed indicated in brackets.

	Davis River (5.1 km)		Misinchinka River (6.2 km)		Point Creek (3.7km)		Scott Creek (5.8 km)	
Year	# redds	redds/km	# redds	redds/km	# redds	redds/km	# redds	redds/km
2001	39	7.6						
2002								
2003	42	8.2						
2004	69	13.5						
2005	43	8.4						
2006	67	12.9	58	9.4	39	10.5		
2007	37	7.3	44	7.1	21	5.7		
2008	54	10.6	37	6.0	18	4.9		
2009	65	12.7	35	5.6	5	1.4	58	10
2010	85	16.7	50	8.1	24	6.5	106	18.3

Analysis of Trends

The redd counts from the ground surveys appear to show a slight upward trend in counts, especially over the past two years (Figure 2). However, analysis from the linear Bayesian model of bull trout redd counts conducted on the three select index sites indicate no significant ($p<0.05$) trend for Davis Creek ($p=0.64$), Point Creek ($p=0.48$) or Misinchinka River ($p=0.87$), based on the period monitored. While no significant trends were identified, the model indicated a low statistical power to detect a trend due to the limited number of years surveys have been conducted, with the exception of Davis River.

Additional analysis using both parametric and non parametric analysis yielded similar results to the Bayesian modeling, but is considered less robust due to the limited number of years available for the index sites. Linear regression on transformed (log) counts by tributary indicated the slope was not significantly different from zero ($p > 0.05$; Figure 3). Utilization of non parametric Mann-Kendall test by tributary also indicated no apparent trends, with the slope not significantly different from zero ($p > 0.05$). Nonetheless, these plots demonstrate the amount of uncertainty in inter-annual variation around the mean, defined by confidence intervals (95%) illustrated as the shaded areas of Figure 3. Moreover, each system indicates a relatively high coefficient of variation (C.V.), as a result of inter-annual variability of counts (Table 3) due to process and / or measurement error. Measurement error could be evaluated and potentially reduced through replication within the site and understanding observer efficiency and sources of error affecting observers while conducting the stream surveys.

Table 3. Summary of annual bull trout redd count data for select index sites in the Williston Reservoir watershed from 2001.

Location	N	Mean	SD	C.V.
Davis River	12	57.2	20.1	0.35
Misinchinka River	5	44.8	9.5	0.60
Point Creek	5	21.4	12.2	0.57
Scott Creek	2	82.0	33.9	0.41

Use of MCMC simulations, based on known annual variability from the Davis River, indicates the overall probability of detecting decreases is directly related to the number of years surveys are conducted. Assuming redd numbers are related to abundance, at the current index sites one would need a minimum of 25 years of data to a statistically significant decline at a power of 0.8 if the true decline in abundance was 50% , or 10 years of data to detect a statistically significant decline at a power of 0.93 if the true decline in abundance was 75% (Table 4). Moreover, there is a high probability of failing to detect small declines (25%) that exist (i.e., high type II error rate) even with 50 years of data.

These results are based on the relatively conservative $p < 0.05$, which reflects conventional practice. However, less conservative p-values, and the resulting increased statistical power, may be preferred by decision makers, based on the relative consequences to the bull trout population of Type-I vs. Type-II statistical errors. A sensitivity analysis over a range of p-values was beyond the scope of this project

Table 4. Probabilities of detecting a change (i.e., statistical power to detect a decrease) in relationship of redd counts over time at $p < 0.05$ for index sites over a defined number of years.

Decrease	**Years**		
%	**10**	**25**	**50**
25%	0.20	0.30	0.49
50%	0.46	0.80	0.94
75%	0.93	0.97	1.00

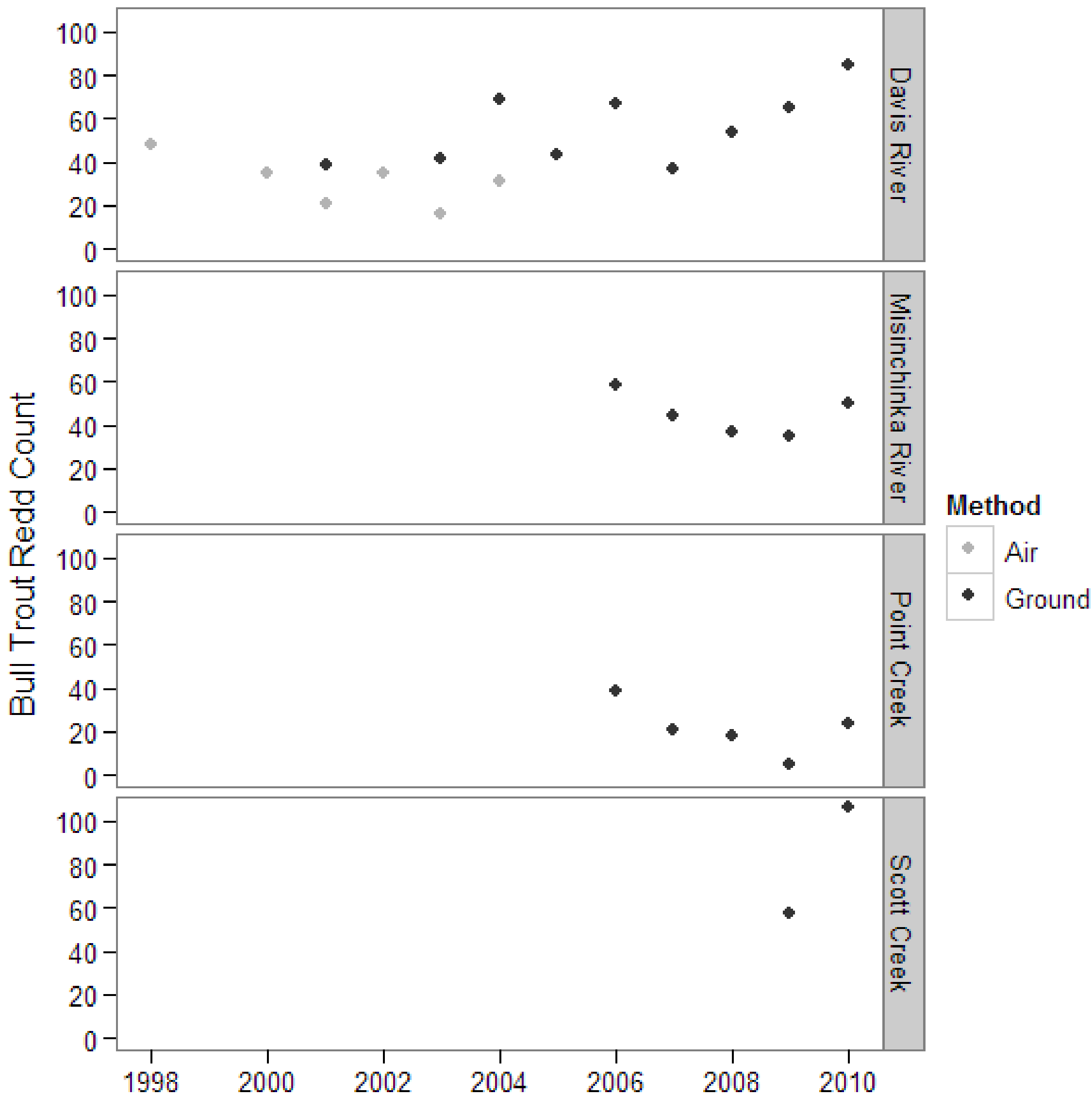

Figure 2. Bull redd counts (Air and Ground) for select index sites on Williston River tributaries since 2001.

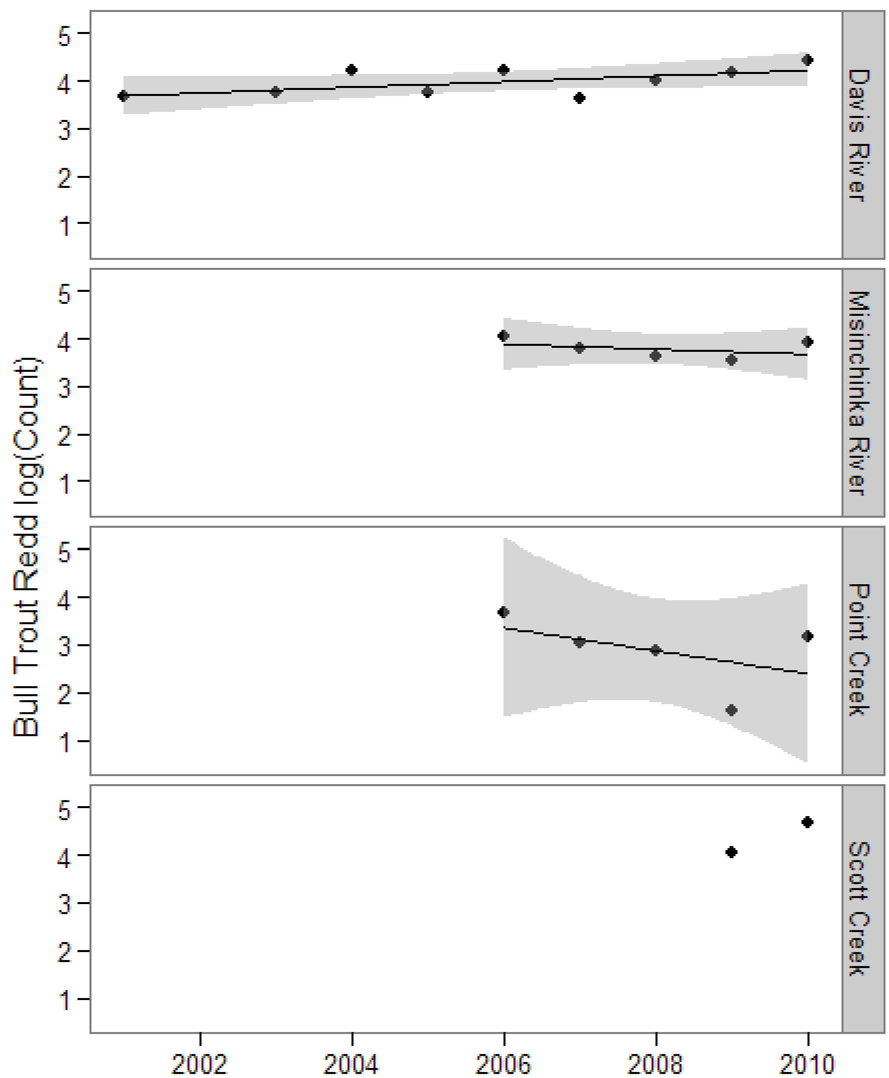

Figure 3. Transformed (log) redd counts fitted with a linear smoother function for select index sites on Williston Reservoir tributaries since 2001**.** Shaded area represents 95% confidence intervals.

DISCUSSION

The formation of the Williston Reservoir has resulted in vast changes to the landscape in the Peace region of British Columbia. The biology and life histories of all indigenous fish species has been radically altered with some species more adaptable to the change from riverine habitat to predominately a lacustrine environment. Monitoring changes to the fish assemblage in such a spatially large expanse of water is challenging to say the least. It has been observed elsewhere in reservoirs such as Arrow lakes and Kinbasket that fluvial forms of bull trout have been successful in switching to an adfluvial form (Hagen and Decker 2009). The large pelagic habitat formed by storage reservoirs provide suitable habitat for planktivore species like kokanee and lake whitefish that top predators such as bull trout can capitalize on. Bull trout in Kootenay Lake thrive as a result of high densities of kokanee that inhabit the pelagic zone albeit also greatly aided by lake fertilization (Schindler et al. 2007). The current status of Williston Reservoir bull trout population (s) is unknown and recently the FWCP-P has been making a concerted effort to design a monitoring program of representative spawner numbers that can serve as indices of abundance. The success of future bull trout conservation and management decisions will be dependent on the ability of biologists to accurately assess and monitor their status or abundance, particularly in response to management actions that are implemented.

Redd counts are widely used to provide an index of abundance or indices of spawning escapements on rivers where direct counts are often impractical or too cost prohibitive. There is a considerable amount of literature on the efficacy of redd counts since they are so widely used to ascertain trends in abundance and population status (Reiman and McIntyre 1996, 1997; Dunham et al. 2001; Al-Chokhachy et al. 2005, 2009; Jacobs et al. 2009). The impetus for much of the recent research on bull trout is due to their threatened status under the US Endangered Species Act in the US and blue listing in British Columbia. However, concerns over utility of redd counts to determine population status has been consistently debated (Dunham et al. 2001). Observer errors, inter-observer variability in counts, temporal and spatial variation have been identified as potential sources of error when using redd counts alone. Maxwell (1999) suggested using a detailed power analysis in identifying sources of uncertainty when designing a monitoring program for measuring population trends.

While redd counts often provide a cost effective method of obtaining an index on adult escapement, their precision and accuracy are often compromised as a result of their uncertainty and ability to detect sensitive changes in population status. Depending on the priority of the monitoring, reducing the uncertainty in redd counts can be accomplished by conducting replicate counts within an index site, measuring observer efficiency, measuring sources of observer efficiency and having a better understanding of the spatial and temporal variation in spawning activity. Some reduction in observer error can be accomplished by utilizing the same experienced observers year-after-year (Muhlfeld et al. (2006). Moreover, Al-Chokhachy et al. (2009) concluded that effective population monitoring requires precise estimates over a long period of time and their study found that a high degree of sampling effort was required to detect even moderate (25%) changes to bull trout population abundance. However, implementing these measures can often be financially prohibitive. While it is acknowledged that bull trout populations may have local and regional scale sub-populations, monitoring large spatial systems often precludes the ability to measure these local or geographic sub-populations. In order to gain some insight into the reservoir's bull trout population (s) and owing to its large expanse the spatial and temporal distribution within the watershed must surely be the priority for their conservation and population management.

Understanding the health and status of bull trout populations on a large system such as the Williston Reservoir relies on the ability to have an appropriate number of index sites that is assumed to be representative of the population in the watershed. Depending on the index sites and its length, a complete census is most appropriate and alleviates the confounding issues of sub-sampling from stratified random designs. Index sites that cannot have a complete census requires a study that implements a random stratified survey design. Isaak and Thurow (2006) suggest that conducting redd counts with a spatially continuous, temporally replicated sampling design will reduce errors associated with simple random designs and provide more accurate ecosystem views. Unfortunately, these designs can often be more time consuming and rely heavily on statistical inference that often cannot capture the spatial and temporal variation unless substantial effort is appropriated through replication. Invariably, there is a trade-off between coverage (more sites) that satisfies the population monitoring versus the ability to reduce the uncertainty or inter-annual variability within each index. As well, conducting redd counts in non-randomly selected index areas is not advised (Gallagher and Gallagher 2005). Moreover, index areas may not represent population dynamics of salmonids at a regional scale (Rieman and McIntire 1996) and may miss redds due to annual variation in spatial distributions or spawning activity (Maxell 1999; Dunham et al. 2001). Lack of randomization in site selection and shifts in fish distribution may bias results from index site monitoring and mask population trends (Isaak and Thurow 2006).

It is well understood that redd counts can be a cost effective method for monitoring trends in salmonid population abundance especially in such a huge system as the Williston Reservoir. There is little argument that such counts are less intrusive and less expensive than tagging, snorkel survey or trapping using a fish fence (Dunham et al. 2001). And, despite the problems associated with redd counts mentioned above they have been demonstrated to be significantly correlated to independent estimations of salmonid escapements (Al-Chokhachy et al. 1995, 1999;Gallagher et al. 2007; Decker and Hagen 2008; Andrusak 2010). Gallagher et al.(2007) provides a good summary of studies where redd counts have been shown to be related to independent estimates of salmonid spawner numbers and they recommend conducting redd counts over pre-determined 3-5 km stream reaches that are randomly selected with an annual selection of at least 10% of all reaches. They also suggest these counts be repeated every 1-2 weeks during the spawning event. This latter recommendation involving replicate counts might be one way to improve on the current monitoring program. In Gallagher's most recent paper (Gallagher et al. 2010) a comparison was made of three different techniques used in monitoring salmon escapements in northern California. This study compared capture-recapture estimates based on live fish counts (from weirs) with those estimates derived from redd counts converted to adult spawner numbers vs. AUC estimates vs. salmon carcass capture-recapture techniques. The conclusion reached by the authors was that redd counts "*were reliable indices for monitoring low-abundance salmonid escapement. Thus redd counts alone could serve as an index of annual escapement.*" This statement is made with the caveat that an independent estimator of the population is available.

Turning to the Williston data, the 2010 redd survey counts on select sites within the four tributary streams to the Williston Reservoir suggest that comparatively high numbers of bull trout spawned in three of the four systems. i.e. compared to previous years counts. These counts when adjusted for survey distance are comparable to those described by Decker and Hagen (2008) for several Arrow Lakes Reservoir tributaries and those recorded for the Kaslo River, Crawford Creek and their tributaries (Table 5; Table 6); these latter two systems are important bull trout spawning streams that flow into Kootenay Lake (Andrusak 2010). For example, the high Davis River densities are similar to the upper Kaslo River densities whereas the much lower Misinchinka River densities are comparable to the Crawford Creek tributary densities.

Despite the visual appearance of a slight upward trend from the count data, the statistical analysis from the linear Bayesian model indicates no significant trends from survey information collected on any system to date. Based on low statistical power of the tests, the analysis also suggests far more years of data needs to be collected to detect even moderate (< 50%) changes in abundance. Therefore, reducing the uncertainty within each index site may not be the best strategy but rather the focus of future work should be on continuing to monitor the same systems but more extensively by expanding the surveys to capture the majority of the spawning locations.

In the case of the Kootenay data the redd counts can be compared and are supported by actual counts from the counter (Table 7). Most reassuring is that, the observed expansion factors on these two systems are very similar to the average observed by Al-Chokhachy et al. (2005) of 2.68 bull trout per redd and remain well within the range (1.2 to 4.3 bull trout per redd) of all studies reported in the literature. Redd counts are meaningful provided they can be calibrated from an independent estimate of population size but this does not mean for each and every population. In the case of the sizeable Williston Reservoir there are currently no independent estimates of population to reference the redd counts and the sections of stream surveyed have not been randomly selected. As a minimum it is possible that one population monitored per reach of the Williston Reservoir may be sufficient to detect trend changes although it would be preferable to increase the number of systems monitored.

Table 5. Kaslo and Keen Creek, tributary to Kootenay Lake, bull trout redd counts 2006-2010.

	Upper Kaslo		**Lower Kaslo**		**Keen Creek**		
Year	**# Redds**	**(redd/km)**	**# Redds**	**(redd/km)**	**# Redds**	**(redd/km)**	**Total**
2006	321	16	n/a	n/a	100	17	421
2007	458	23	13	2	116	19	587
2008	471	24	3	0.5	137	23	611
2009	542	27	8	1	139	23	689
2010	302	15	n/a	n/a	94	16	396

Table 6. Crawford Creek and tributaries, tributary to Kootenay Lake, bull trout redd counts 2008-2010

	Crawford Creek		**Canyon Creek**		**Hooker Creek**		**Houghton Creek**		
Year	**# Redds**	**(redd/km)**	**# Redds**	**(redd/km)**	**# Redds**	**(redd/km)**	**# Redds**	**(redd/km)**	**Total**
2008	159	8	3	6	NA	NA	19	38	181
2009	233	12	12	10	10	31	13	23	268
2010	142	7	1	3	6	18	33	62	182

Table 7. Resistivity counter bull trout counts of down-streaming post spawners in the Kaslo River and Crawford Creek.

	Upper Kaslo			Crawford Creek		
Year	**# Redds**	**Electronic Count**	**Expansion Factor**	**# Redds**	**Electronic Count**	**Expansion Factor**
2006	321	716	2.2	n/a	n/a	n/a
2007	458	n/a	n/a	n/a	n/a	n/a
2008	471	1,197	2.5	188	336	1.8
2009	542	1,219	2.2	268	486	1.8
2010*	302	1,100	3.6**	182	389	2.1

* at time of writing counter data had not been analyzed

** higher expansion ratio due to one day low count due to rain event

While the Williston Reservoir redd count provides an important index for monitoring bull trout to date, it is acknowledged that there needs to be some modifications made to the current design. Firstly, it is essential to obtain estimates of total population size for some or all of the four index sites so that the current redd counts can be calibrated to estimated total abundance as illustrated in the Kootenay examples (Table 7). This should be achievable for at least Scott and Point creeks. Secondly, partial redd counts are problematic since for example, it appears that currently some of the counts have been made in the "best" spawning areas located near the upstream end of spawning habitat. Therefore, even if the population declined significantly these sites will remain highly selected for because they represent the best habitat. These counts over time are unlikely to detect any change. On the other hand, low use areas, for example close to the reservoir, will equally provide little trend information due to low use with little variation between low and high population levels. Either the entire accessible stream needs to be surveyed (e.g. Point and Scott creeks) or randomly selected sites within the system should be surveyed (e.g. Davis and Misinchinka rivers). This is essentially what is recommended by Gallagher et al. (2007). As an aside, recently Jacobs et al. (2009) described a generalized random tessellation stratified (GRTS) sampling design that appears to satisfy most concerns about sample bias that could be applied to redd counts. However, the extent of sampling required is far beyond what could possibly be conducted on a watershed basis the size of the Williston. Furthermore, in order to provide some measure of variation in the redd counts, replicate counts would have to be conducted. It is acknowledged that such a measure would be very costly considering the remoteness of the Williston index sites.

Retention Fishery

There has been public interest expressed to have a retention fishery for bull trout on the Misinchinka River especially since the harvest level in the reservoir is suspected to be very low (A. Langston FWCP-P fisheries biologist pers. comm.). The possibility of such a fishery has implications on the design of the future bull trout monitoring program thus some thought is required. Currently there is limited information available on this river to determine if such a fishery could be permitted. As a minimum the management of a retention fishery requires some sense of the population size and potential harvest. There is however at least some data: the average redd count over the last five years has been ~ 7.3 redds per km for the 6.2 km surveyed. It should be kept in mind that this metric is low compared to the Davis River and Scott Creek (Table 2).

The following crude analysis assumes the Misinchinka site represents the “best” of bull trout spawning densities within the accessible portion of the river. Based on telemetry work by Langston and Cubberley (2008) it appears that about two thirds of the mainstem river is utilized by bull trout spawners with highest use in the upper one third. Decker and Hagen (2008) and Andrusak (2010) also found that the upper half or upper one third of the rivers/streams they surveyed were preferred with little spawning in the lower third to half. Additionally, these authors also identified that lower reaches of many of the tributaries also supported virtually no spawning bull trout (e.g., Table 5, Table 3 in this report). The full length of accessible habitat for bull trout in the Misinchinka is ~ 90 km. Assuming that two thirds are actually used for spawning it is estimated that ~ 900 spawners could potentially be in the river in a given year (i.e. 60 km river x 7.3 redds/km x 2.2 per redd [Kaslo River data] =964 bull trout). This estimate is most likely high because the metric of 7.3 redds/km was probably determined from the highest use sites. On the other hand, while this density is arguably low compared to the Davis River and Scott Creek there are numerous Misinchinka tributaries are that are not included in the redd surveys. On balance it is believed that annual bull trout escapements to the Misinchinka of ~900 are realistic and very possible.

An on-going exploitation study on Kootenay Lake suggests a 25% exploitation rate on lake dwelling bull trout is sustainable (Andrusak and Thorley 2010; file data Redfish Consulting Ltd) but these fish grow in a far more productive system than the Williston and they are not all spawners. Adams Lake is more comparable to the productivity of Williston Reservoir where Bison et al. (2003) estimated bull trout fishing mortality was between 12-24% and they recommended more conservative fishing regulations to avoid overfishing (Johnston et al. 2007). This latter study on Lower Kananaskis Lake found that the retention fishery for bull trout had resulted in 50% mortality for adult size bull trout with this high mortality driving the population near to extinction. Applying a more conservative 10-20% exploitation rate suggests a potential harvest range of ~100-180 Misinchinka bull trout could be permitted or alternatively at least a catch and release fishery. It is suggested that a decision about a retention fishery on this river await the outcome of whether or not a resistivity counter can be located on this system (see below) which even after one year of operation could provide a far more accurate estimate of population size that could then be used to determine a sustainable harvest level.

In the event that a counter cannot be installed on this river then redd counts could be used as a crude estimator of harvest rate assuming some redd data is obtained prior to inception of a retention fishery and that in future total stream length is surveyed. The problem with this approach is that redd counts alone will only provide post-fishery counts therefore a roving census of the fishery would be advisable to obtain an independent estimate of harvest. Despite stated concerns that a retention fishery would render this system unsuitable as a long term index site this need not be the case if a creel survey is implemented. In addition some good biological data would be obtained from the census including fecundity which to date is poorly documented in British Columbia and would be most useful for developing simple yield per recruit analysis and an initial assessment of their population dynamics.

Monitoring Options

Since bull trout are a relatively long living salmonid (McPhail and Baxter 1996; McPhail 2007), any monitoring program for the Williston requires a long term commitment to monitoring, preferably on an annual basis. There are a number of methods that could be employed to improve upon and or supplement the current single pass redd count program.

1. Replicate counts

Replicate counts within an index site may be beneficial in understanding the within site variation in counts, improving the precision in a system over time. Replication could identify and reduce some of the uncertainty around sources of observer error, while getting independent estimates of observer efficiency. However, there is an assumption that replicate counts will have little variation.

2. Aerial counts

Redd counts from the helicopter were attempted in the early 2000s but abandoned after 2004. Inclement weather, forest canopy overhang and spawning associated with woody debris made aerial counts unreliable and often difficult depending on the system. However, this method may be valuable in identifying potential barriers and the spatial extent of spawning within a system. This information could be used to identify and confirm the lower and upper limits of spawning for conducting ground surveys.

3. Resistivity counters

Resistivity counters offer the ability to obtain an independent estimate of escapement within a system (McCubbing and Andrusak 2006; Andrusak 2010), identified as a crucial step in developing and implementation of monitoring trends over time (Gallagher et al. 2007). The resistivity technology has the ability to reduce some of the uncertainty in redd counts while providing a ratio estimator of fish per redd important for determining population abundance on a regional scale. Utilization of a counter reduces uncertainty around the spatial and temporal patterns during spawning, with accurate estimates of run timing. Moreover, the counter offers the ability to reduce and assess sources of observer error due to changing environmental conditions that often impair ground surveys (i.e. poor visibility). The technology is less intrusive than fish fences, captures the full behavioural aspect of spawning and requires little daily maintenance compared to fish fence operations. However, depending on the location, remote locations require higher maintenance compared to sites that have access to grid power. As a result, remote sites have the potential to lose power and require battery change out once every 7-10 days.

4. Kelt enumeration fence

Temporary counting fences have been successfully used for many years in tributaries of the Arrow Lakes Reservoir and the upper Columbia prior to the Revelstoke Dam (Martin 1976; Lindsay 1977, 1979). These early studies attempted to capture up streaming bull trout but high rainfall events often resulted in the fence(s) being blown out or overtopped. Fence avoidance is a problem such as in the case of the Deadman River steelhead where McCubbing et al. (2001) demonstrated that more than half the spawners would not pass through the fence and ended up spawning below the fence. When the fence was replaced with a resistivity counter the spawners again spawned at known sites upstream of where the fence had been located. In the case of migrating bull trout the best strategy is to place it in the river/stream just prior to spawning with the objective of capturing down streaming kelts rather than up streaming spawners. Daily maintenance of fences is usually required as organic drift such as sloughing algae and woody debris quickly plugs up the openings potentially causing over topping or collapse of the fence. Other problems with fences include abrasion issues, mortality of weak kelts caught on the fence and attractants for predators such as bears and mink that quickly learn where captured fish are held.

5. Radio telemetry

Use of radio telemetry to determine spawner population size by means of mark-recapture could have some application on the Williston especially if measures of observer efficiency during redd counts is required. Telemetry is especially advantageous in systems that are inaccessible and have numerous tributaries (O'Brien and Zimmerman 2001) such as in the case of the Misinchinka. The downside is that for big watersheds the number of tags required is usually high and capture methods can be time consuming and cost prohibitive. Furthermore, tagging mortality and tag malfunction can be problematic although these issues have been minimal during the on-going rainbow and bull trout tagging program on Kootenay Lake, using acoustic technology.

6. Snorkel surveys

Swim surveys are conducted to enumerate salmonid spawners, especially during steelhead migrations. Most adult spawner surveys are conducted where there is good road access and redds are often not obvious to the eye. It is unlikely that full snorkel surveys have application in the case of Williston bull trout where access is very limited and helicopters would be required to drop off and pick up the swimmers. There may be limited situations to use snorkel surveys in some systems where detailed information is required on spawner habitat preferences required to determine high vs. low use sites. e.g. Misinchinka River. Snorkel surveys may also be required at sites where redd counts are difficult to obtain such as in steep canyon areas. On the whole it would be unwise to initiate snorkel surveys instead of modifying the redd surveys as this would merely introduce a new set of problems (e.g. comparing observer efficiencies) trying to reconcile the current data set of redd counts with snorkel spawner and or redd counts. Finally, there is an assumption that spawner surveys provide total spawner counts but this can only be achieved through replication.

RECOMMENDATIONS

Modifications to Current Design

Despite some legitimate concerns of single pass redd counts this method is still the best choice for long term monitoring of Williston bull trout. The four Williston index sites currently used for bull trout redd counts were selected presumably because they were suspected of supporting large numbers of bull trout spawners and water clarity is excellent during the fall thus permitting good counts by the observers. The four sites should continue to be monitored rather than selecting new tributaries especially if they are glacial fed systems. Most glacial fed systems are often unsuitable for bull trout redd counts since they remain turbid until late fall. Decker and Hagen (2008) determined that redd counts could not be conducted on some large glacial rivers that flow into the Arrow Lakes Reservoir due to high turbidity. The following are modifications suggested to improve the value and accuracy of redd survey data. A key strategy for future surveys involves use of two crews, two per crew and a larger helicopter capable of transporting all four crew members. The following modifications are recommended:

1. **Recommendation # 1.**

   Status quo. Moving forward, this is not recommended but the cost for the 2010 survey is used for estimating the recommended changes. As a minimum, continuing the status quo in the interim of developing a more robust program is recommended as opposed to deferring surveys in 2011.

2. **Recommendation # 2.**

   a. The two smaller streams---Scott and Point creeks should be surveyed their entire length to obtain total redd counts and identification of upper and lower limits of spawning. (Note: it should be mentioned that previous years surveys have identified approximately where these limits are so only fine resolution is required for future surveys). This would eliminate concerns of sampling only in high or low density sites. Some replicate counts should be considered as this may be possible as discussed below. Furthermore, with full stream length counts a metric of redds/km could then be applied as a spawners/redd biostandard to other systems to obtain crude estimates of total spawner numbers for the entire watershed.

   b. Conduct a redd survey of randomly selected (annually) sites of sufficient reach numbers to survey redds in at least 10% of length of accessible mainstem Misinchinka and Davis rivers.

c. Establish a resistivity counter on the Misinchinka River, whereby, as a minimum, downstream counts would be easily obtained. Site selection would be dictated by a hierarchy of criteria: a) low gradient, laminar flow, shallow water; b) good access adjacent to power from two phase power source c) preferably at lower end of bull trout spawning and d) preferably upstream of upper end of kokanee spawning. If a counter cannot be used then reaches need to be defined and then randomly select each year sufficient reach numbers to survey redds in at least 10% of length of accessible mainstem river. In this case some snorkel surveys could assist in defining the lower extent of spawning.

3. Recommendation # 3

Full length redd surveys on the Misinchinka River.

- Due to the interest in having a retention fishery on this system and assuming a counter cannot be successfully placed on it then a full length survey of all redds should be conducted and then use a redd/spawner biostandard to provide a population estimate. Previous aerial surveys indicate that actual spawning habitat is restricted to the upper 30 km of the river but this needs confirmation.

4. Recommendation # 4

Misinchinka River seasonal creel survey if a retention fishery proceeds.

5. Recommendation # 5

Replicate sampling:

- Rather than undertaking replicate sampling to reduce observer error and temporal variation on the four index systems it is proposed that 2 more streams (one from Peace and Finlay reaches) be assessed in an effort to reduce the spatial and temporal differences and provide a more precise estimator of redds/km per reach.

Estimated Cost

The foregoing recommended modifications to the existing redd survey requires some measure of approximate cost to determine what is practical and feasible. The most recent 2010 survey is used as a baseline cost estimator. Project costs for the 2010 survey were ~ $6,000 (including all expenses and travel) for one technician for 7 days or ~ $800/day. This cost is assumed to be the same for the FWCP-P biologist. Helicopter cost was ~$13,000 and reporting was ~ $8,000 for a total of ~$27,000 + FWCP-P biologist cost. Total cost for the 2010 project including the FWCP-P biologist was ~ $34,000.

In 2010 a total of 20.8 km were surveyed in the four systems or ~ 5 km of stream per day although this ranged from 3.7-6.2 km/day (Table 1). Flight times (one way) to the index sites were one hour or less. but for future budgeting a minimum daily charge of 3h is expected and therefore assumed. It is also assumed that a Bell 407 helicopter would be used @ $2,000/h for a four person crew or a Bell 206B @ $1500/h for a two person crew. For sake of continuity it is assumed the FWCP-P biologist will continue to lead the surveys at cost equal to the other survey crew members.

The estimated costs of recommendations #2-5 above are displayed in Table 8.

Recommendation # 2 consists of two crews each with two observers would be used and Point and Scott creeks would be surveyed full length. The Scott Creek survey (2a) may possibly permit a replicate count on a portion of the stream since it is proposed that two crews conduct the survey in one day (i.e., <5.5 km/day for each crew). The Point Creek survey (2a) would unlikely allow for replicate counts within the proposed one day survey. The Misinchinka survey (2b) is minimal coverage (10% of length of ~30 km) for two crews and the same for the Davis River (2b). Recommendation # 2c involves installation of a resistivity counter on the Misinchinka at a location most likely in the upper half of the 90 km long system. A one day reconnaissance is required to firm up the feasibility of locating a suitable site. This budget assumes a site can be located powered by battery and solar backup. It is proposed that two people would travel to Mackenzie and fly to the site to change out batteries once every week over a six week period. Three days of travel and wages (Prince George/Mackenzie) are included (actually 6 half days) due to site location uncertainty. If rented or amortized the cost of the counter can be reduced to ~ $3,000/year. The tributaries are accessible by vehicle and it is proposed they be surveyed by two crews.

Recommendation # 3 considers a full redd survey of the upper half (assumed to be 30 km in length) the Misinchinka by two crews. This recommendation is the alternative if a resistivity counter cannot be installed. This budget assumes there is certainty that spawning is confined to the upper half of the river.

Recommendation # 4 is the estimated cost of conducting a two month roving creel survey of the Misinchinka River.

Recommendation # 5 proposes to increase the number of streams surveyed by at least two; one in the Peace Reach and one in the Finlay Reach. The budget is highly speculative since the locations of the two systems are unknown.

It is recognized that that the FWCP-P most likely cannot fund all recommended activities. Full stream length assessments of Scott and Point creeks should be easily incorporated into the existing survey budget. If it is deemed feasible the highest priority is that of establishing a resistivity counter on the lower end of the Misinchinka River using direct power. Cost of providing power, if any, needs to be determined by BC Hydro. Initial cost of a counter (~$27 K?) is high but it is proposed that monitoring would be carried out over at least 15 years. Furthermore, the counter would be available for spring time enumeration work at certain sites. Site location for a counter is critically important and the 2010 survey indicated a number of potential sites adjacent to the highway. However further reconnaissance is required as water depth in the lower river may be too great for a counter. If a counter cannot be placed on the river then redd density estimates should be conducted either full river length, or by selecting random sites that represent at least 10% of the mainstem river. In addition, tributary spawning would have to be assessed over a number of years since better estimation of total spawner numbers is required, especially if a retention fishery is contemplated. This work would not necessarily be required if a counter is installed.

A final summary comment on monitoring the Williston Reservoir bull trout is offered. Long term monitoring has been emphasized several times in this report. The Williston Reservoir is only four decades old and huge changes have occurred to the fish community and undoubtedly further changes will occur. Bull trout have had to adjust from a fluvial to adfluvial life history during a very short period of forty years or so. Since these fish are comparatively long-lived (ages 7-15 years at maturity) they have probably sustained only 5-6 generations as adfluvial forms. During only the latter half of this time kokanee, a significant and potentially primary food source, have become abundant. It is most likely that the full impact of bull trout expansion in this reservoir has yet to occur hence all the more reason to be positioned to effectively track their abundance over time.

Table 8. Approximate cost of each recommendation based on 2010 project cost. A minimum 3 hour helicopter charge is anticipated.

							Helicopter			
Option	**Task**	**Survey Length (km)**	**# Crew**	**Cost/day**	**Days**	**Survey Cost**	**Hour**	**Unit Cost**	**Analysis and report**	**Total**
1	2010 survey	20.8	2	$1,600	7	$11,200	8.6	$13,000	$10,000	**$34,000**
2a	Scott	11	4	$3,200	1	$3,200	3	$6,000		
2a	Point	10	4	$3,200	1	$3,200	3	$6,000		
2b	Misinchinka*	10	4	$3,200	1	$3,200	3	$6,000		
2b	Davis*	10	4	$3,200	1	$3,200	4	$8,000	$10,000	
		2 travel days	4	$3,200	2	$6,400				**$55,200**
2c	Misinchinka & counter	10	2	$1,600 $27,000	6	$14,400	6	$12,000	$10,000	**$63,400**
3	Misinchinka**	30	4	$3,200	5	$16,000	9	$18,000		**$34,000**
4	Misinchinka creel	na	1	$460	40	$18,400			$3,000	**$21,400**
5	2 Other tributaries	20	4	$3,200	4	$12,800	9	$18,000	$10,000	**$40,800**

* 10% of river length

** Full river length, 2 days travel included

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Appendix 1. Davis River redd surveys conducted from 2001-2005**,** attached separately.

Appendix 2. Davis River redd surveys conducted from 2006-2010, attached separately.

Appendix 3. Misinchinka River redd surveys conducted from 2006-2010**,** attached separately.

Appendix 4. Point Creek redd surveys conducted from 2006-2010**,** attached separately.

Appendix 5. Scott Creek redd surveys conducted from 2009-2010**,** attached separately.