NECHAKO RESERVOIR
IMPACTS OF TIMBER SALVAGE ON FISH AND FISH HABITAT

1997 STUDIES

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

Page

LIST OF APPENDICES

Page

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The study was administered by Ministry of Environment, Lands and Parks (BC Environment), Smithers regional office, under the direction of Mr. Dana Atagi, Senior Fisheries Biologist. The study was conducted as part of a larger program evaluating the salvage of submerged timber in the Nechako Reservoir system, coordinated through BC Environment's Smithers office.

The field component of the study was successful largely as a result of assistance provided by Mr. Alex Sartori, Mr. Cory Williamson and Mr. Shawn Davies. Mr. Davies also assisted with data compilation.

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EXECUTIVE SUMMARY

Hatfield Consultants Ltd. (HCL) has been contracted by the Ministry of Environment, Lands and Parks, Smithers, BC (MoELP) to undertake studies to identify potential impacts of proposed harvesting of submerged timber on fish resources in the Nechako Reservoir. HCL has been undertaking these studies in collaboration with BC Research Inc. who were contracted separately (together with Limnotek Research and Development Inc.) to monitor impacts on sediment, water quality, and benthic communities.

The Nechako Reservoir was created in 1954 by construction of the Kenney Dam to supply water to the Alcan power generating station at Kemano. The reservoir flooded approximately 50,000 ha of land containing several million cubic metres of Crown timber. Small amounts of timber have been removed from the reservoir since formation. In 1996, the Ministry of Forests (MOF) issued two 10 year licences for large-scale timber removal (3 to 3.5 million cubic metres for each licence). One licence was issued to a joint venture between Canadian Forest Products and the Cheslatta Development Corporation (Canfor/CDC) for salvage of timber from the portion of the reservoir that lies within the MOF Lakes Timber Supply Area. The second licence was issued to the Cheslatta Carrier Nation Resource Corporation (a joint venture between the Cheslatta Carrier Nation and Fibrecon Management Ltd. - CCNRC) for salvage of timber from the portion of the reservoir that lies within the MOF Morice Timber Supply Area. Timber salvage methods to be used by the licencees and potential environmental effects are not certain. Interim Development Plans were prepared for the later part of 1996 to enable licencees to experiment with harvesting techniques on a small scale and to initiate collection of environmental data related to these operations.

The goal of the fisheries resource studies is to determine effects of submerged and floating timber salvage on sensitive fish populations in the Nechako Reservoir and to develop recommendations for protecting fish resources at sensitive locations and times. Studies conducted in 1997 are the second year of a multi-year assessment program that began in 1996. The 1997 fisheries studies were undertaken in early and late summer and comprised intensive studies of fish and fish habitat in Ootsa Lake, Tahtsa Reach, Eutsuk Lake and reconnaissance level surveys of tributary streams. This report presents the results of the lake fish and fish habitat studies.

The following activities were undertaken for the 1997 fish resource studies: collection of additional baseline data (early summer) to supplement 1996 data (late summer) for Ootsa Lake sample locations; collection of baseline data for two reference locations (one reservoir location, Tahtsa Reach, and one watershed location, Eutsuk Lake); collection of data immediately post-harvest for one Ootsa sample location (Andrews Bay) as well as one reference location; preliminary assessment of acute effects of timber salvage on fish resources; and development of recommendations for fish protection.

The 1997 lake studies involved sampling in nearshore timber salvage areas at different times of day using a variety of sampling equipment. Sampling was undertaken in inner embayments

close to stream mouths and in outer bay sites away from stream mouths. Sampling was undertaken in three main areas of Ootsa Lake: a bay off the mouth of Wells Creek; Andrews Bay; and an old lake site, five to six kilometres east of Wells Creek, submerged after reservoir impoundment. Two reference locations were selected to reflect habitat characteristics found in the Ootsa Lake sample locations. Reference locations include: a bay off the mouth of Whiting Creek in Tahtsa Reach; and a bay off the mouth of Bone Creek in Eutsuk Lake.

Wells Creek bay and areas near the submerged lake are located along the south shore of the lake and within the Canfor/CDC timber salvage Development Plan area proposed for 1997. Wells Creek bay is characterized by a distinctive narrow inner bay and a broader outer bay. Wells Creek flows into the head of the inner bay. Wells Creek bay was chosen as a sample location because it represented a salvage location at the mouth of a major tributary to the lake (Wells Creek) and was the location intended for initial timber salvage trials by Canfor/CDC.

Andrews Bay is located at the west end of Ootsa Lake on the north side of the lake and within the CCNRC timber salvage Development Plan area proposed for 1997. Andrews Bay possesses a similar inner bay configuration to Wells Creek bay. Andrews Bay was selected as a sample location to enable comparison with data collected from inner and outer portions of Wells Creek bay.

The old lake site was chosen from maps prepared by Alcan on which the pre-inundation shoreline are superimposed on current shorelines; these maps show a distinctive lake or wetland feature within the previously forested area. This location was selected as a sample location because it represented a shoreline area similar to the outer bay of Wells Creek bay and exhibited treed and untreed submerged areas for comparative sampling.

Whiting Creek bay is located on the north side of Tahtsa Reach east of Huckleberry Mountain. It was selected as a reference site as it lies within the reservoir and is not scheduled for timber harvest in the near future. The inner bay also possesses a similar configuration to that of Andrews and Wells Creek bay.

Bone Creek bay is located in Eutsuk Lake within the boundary of Tweedsmuir Provincial Park. It was chosen as an alternative reference site because it lies within the reservoir watershed but is not part of the reservoir proper.

Priority for the 1997 field program initially was collection of early summer baseline data. Priority was subsequently changed to collection of post-harvest data from the Andrews inner bay given the opportunity presented by a late summer harvest event scheduled for that location by CCNRC. Elements of the reservoir fish and fish habitat assessment were timed to overlap with other timber salvage impact assessments (Water Quality Impact and Stream Reconnaissance Inventory).

Biological sampling of fish communities included fish capture with gillnets, minnow traps, and boat and backpack electrofishers. Fish capture data were used to evaluate species composition and relative abundance in nearshore timber salvage areas, including inner embayments close to stream mouths. Biological data were analyzed to determine size and growth, reproductive status and condition.

Within the funds available for the 1997 study year, emphasis was placed on data collection, to add early summer and additional reference sample locations to the baseline database and to collect data on short-term effects of harvesting in Andrews Bay. This report summarizes data collection results with emphasis on short-term post-harvest data collected in the late summer. Detailed data analysis was not possible with the funds available and is intended as the priority activity for the 1998 study year. For the 1997 report, data summaries were prepared for comparison among the main habitat areas sampled in early and late summer (inner and outer bays for Wells Creek bay and Andrews Bay, and the submerged lake basin). Summaries of reference site data are currently limited to the post-harvest sampling event at Andrews Bay. Data for the early summer reference locations (Eutsuk Lake and Whiting Creek bay) will be presented in the 1998 report. The data represent fish resource conditions for the period of sampling (early summer and late summer).

The current water level in Ootsa Lake is approximately 40 m above the pre-impoundment lake shoreline. At present reservoir levels, Ootsa Lake averages 3 km in width. Temperature depth profiles at two locations on Ootsa Lake indicate that weak thermal stratification occurs during summer months and water is mixed over winter and early spring.

Data collected in 1997 from Andrews Bay shortly after timber harvest suggest greater abundance of northern squawfish, compared to seasonal pre-harvest data, but no difference in numbers of other species. The data do not suggest that limited timber salvage has a substantial short-term effect on fish communities in inner embayments close to stream mouths. However, further statistical analysis of the data will be required to make conclusive statements about salvage influences.

In general, fish in nearshore timber areas were captured with sampling gear in greater abundance at night. All salmonids found in the lake (rainbow trout, kokanee, and mountain whitefish) were captured in small inner embayments near stream mouths. In these areas, both rainbow trout and kokanee nighttime abundance was slightly higher than daytime abundance. Spatial differences in abundance of all species were seen as a decrease with increasing distance from stream mouths. Kokanee were mainly absent during the day and overall were found in lesser abundance than during sampling in 1996, but at night represented a high proportion of fish caught in outer bay areas (up to 80% in some locations). Mountain whitefish relative abundance was low. Northern squawfish were the dominant species captured during 1997 and catches per unit effort were double those encountered in 1996.

Rainbow trout captured during the late summer 1997 studies were comparably sized to inner bay rainbow trout captured in 1996 inner bay sampling (1997: 192.4 mm ± 56.0 mm; 1996: 208.6 mm ± 36.0 mm). Andrews Bay rainbow trout captured in 1997 were smaller than those caught in any of the other sampling events (180.2 mm ± 60.5 mm). Most aged specimens in 1996 and 1997 were 2 to 4 years of age.

Kokanee were captured in lesser abundance during 1997 sampling compared with 1996 studies. This is likely the result of sample timing as kokanee generally move into spawning creeks in late September (when 1996 sampling was done) and would be more likely to be caught at this time. Kokanee captured in 1997 were comparably sized to those caught in 1996 (1997: 170.0 mm ±

15.3 mm; 1996: 187.2 mm ± 13.2 mm). Most kokanee (87%) captured in late summer 1997 were aged at 2 years with the other 13% being 3 year olds.

Mountain whitefish were captured in marginally greater abundance during 1997 sampling compared with 1996 studies. This is possibly the result of an increased sampling effort in 1997 but also may have to do with an earlier sample time than in 1996. Aged mountain whitefish from inner bay locations averaged 4.1 years ± 1.8 years and ranged from 1 to 7 years old.

Of all species captured, northern squawfish showed the greatest difference in abundance between 1996 and 1997. Although increases were observed at all locations, changes were greatest in the inner bay of Andrews Bay. Overall changes may be the result of sampling in different seasons in the two years while the large increase at Andrews Bay is possibly the result of an attraction by sqauwfish to the disturbed area. Further analysis will be required to establish the significance of timber salvage effects on northern squawfish abundance in Andrews Bay.

Stream surveys conducted in 1997 indicate three major streams flowing into Tahtsa Reach have potential spawning and rearing areas accessible to fish from the lake. These are:

- Whiting Creek (180-866000-37500)
- Kasalka Creek (180-866000-45200)
- Rhine Creek (180-866000-58200)

Rainbow trout were captured in lower reaches of all streams sampled. A subjective appraisal of habitat quality and lengths of stream potentially accessible to fish from the reservoir suggests all three streams are important as contributors to reservoir fish populations.

General fish protection timing windows have been developed for different parts of the province to reduce risks to fish species in sensitive locations. Timing windows that apply to the Nechako Reservoir area for key species found in the reservoir are:

Species	Timing Window
Rainbow trout	July 15 - April 15
Kokanee	June 01 - August 31
Mountain whitefish	June 01 - September 15

In order to accommodate all three species this would mean a timing window of July 15 to August 31 in which timber salvage activity could take place with minimum risk to salmonids. A preliminary recommendation is application of this window to all stream mouths suspected of containing salmonids.

Inner embayments such as those at Andrews Bay and Wells Creek are steep, narrow portions of flooded stream channels. These will be passage ways during spawning migrations and should be included in application of the above operational windows.

The 1998 field program is intended quantify habitat types in the main sample areas. Refinements to sample collection for 1998 are outlined.

1.0 INTRODUCTION

Hatfield Consultants Ltd. (HCL) has been contracted by the Ministry of Environment, Lands and Parks, Smithers, British Columbia (MoELP) to undertake studies to identify potential impacts of proposed harvesting of submerged timber on fish resources in the Nechako Reservoir. HCL has undertaken these studies in collaboration with BC Research Inc. (BCRI), who were contracted separately (with Limnotek Research and Development Inc.) to monitor impacts on sediment, water quality, and benthic communities.

The Nechako Reservoir, created in 1954 by construction of the Kenney Dam, supplies water to the Aluminum Company of Canada (Alcan) power generating station at Kemano. The reservoir flooded approximately 50,000 ha of land which held several million cubic metres of Crown timber. A small amount of timber has since been harvested: Alcan has removed 5,000 to 10,000 m^3 to provide safe navigation for recreational boaters in high traffic areas; commercial salvage was also initiated on a small scale in the late 1960s (Bond Brothers), though it was discontinued after several years.

In 1996, the Ministry of Forests (MOF) issued two ten-year licences for large-scale timber removal (3 to 3.5 million m^3 for each licence). One licence was issued to a joint venture between Canadian Forest Products Ltd. and the Cheslatta Development Corporation (Canfor/CDC) for salvage of timber from the portion of the reservoir lying within the MOF Lakes District Timber Supply Area. The second was issued to the Cheslatta Carrier Nation Resource Corporation (a joint venture between the Cheslatta Carrier Nation and Fibrecon Management Ltd. [CCNRC-Fibrecon]) for salvage of timber from the portion of the reservoir lying within the MOF Morice Timber Supply Area. Timber salvage methods to be used by the licencees and potential environmental effects are not certain. Interim Development Plans were prepared during the latter part of 1996 to enable licencees to experiment with harvesting techniques on a small scale and to initiate collection of environmental data related to these operations.

The goal of the fisheries resource studies is to determine effects of submerged and floating timber salvage on sensitive fish populations in the Nechako Reservoir and to develop recommendations for protecting fish resources at sensitive locations and times. Study objectives are:

- to determine diurnal and seasonal changes in fish use of or association with submerged timber;
- to assess the sensitivity of various fish species found in the reservoir to the impacts of timber salvage activities;
- to identify sensitive fish habitats within the reservoir;
- to provide recommendations on "in-lake" operational/harvesting windows; and
- to provide recommendations for future study.

Studies conducted in 1997 are the second year of study in what is intended to be multi-year assessment program. The 1997 fisheries studies consisted of two sampling events. The first sampling event in late June-early July was intended to enhance fish and fish habitat baseline data collected in Ootsa Lake in late summer/early fall 1996 as well as gather background data from control sites in the reservoir and Eutsuk Lake. The second sampling was initiated immediately after timber harvest from a small embayment in late August to assess acute effects on reservoir fish communites. This information was complemented with reconnaissance level surveys of reservoir tributary streams in Tahtsa Reach. This report presents the results of the lake fish and fish habitat studies. Results of the reconnaissance stream surveys are presented separately in a series of individual stream reports (Hatfield Consultants Ltd. 1997 & 1998).

The 1997 lake studies involved sampling in different types of nearshore habitat at different times of day using a variety of sampling equipment. Sampling was undertaken in inner embayments close to stream mouths and, to a lesser extent, in outer bay sites away from stream mouths.

Within the funds available for the 1997 study year, emphasis was placed on data collection, to add early summer and additional reference sample locations to the baseline database and to collect data on short-term effects of harvesting in Andrews Bay. This report summarizes data collection results with emphasis on short-term post-harvest data collected in the late summer. Detailed data analysis was not possible with the funds available and is intended as the priority activity for the 1998 study year. For the 1997 report, data summaries were prepared for comparison among the main habitat areas sampled in early and late summer (inner and outer bays for Wells Creek bay and Andrews Bay, and the submerged lake basin). Summaries of reference site data are currently limited to the post-harvest sampling event at Whiting Creek bay. Data for the early summer reference locations (Eutsuk Lake and Whiting Creek bay) will be presented in the 1998 report. The data represent fish resource conditions for the period of sampling (early summer and late summer).

2.0 STUDY AREA AND METHODS

2.1 STUDY AREA

The Nechako Reservoir fish and fish habitat study area is shown in Figure 2.1. Fish sampling activities for the 1997 data collection program were conducted at sites in Ootsa Lake, Tahtsa Reach, and Eutsuk Lake.

2.1.1 Overview of Nechako Reservoir

The Nechako Reservoir was formed in 1954 by the damming of the Nechako River in Nechako Canyon and flooding the Tahtsa/Whitesail drainage basins. Kenney Dam is a rockfill dam with a maximum height of 95 m and a top length of 450 m; no water is released from this structure. The entire Nechako Reservoir has a surface area of approximately 1,200 km^2 and a useful storage capacity of 7,100 million m^3. Water exits the reservoir at two locations: the Kemano penstock, located at the west end of Tahtsa Lake; and the Skins Lake spillway, located at the east end of Ootsa Lake and draining into the Cheslatta River and eventually the Nechako River.

The Tahtsa drainage basin extends from Tahtsa Lake, located east of the town of Kemano, to Ootsa Lake (approximately 60 km long prior to flooding). The Eutsuk drainage basin lies south of the Tahtsa Lake/Ootsa Lake basin and consists of Eutsuk and Tetachuck lakes. Eutsuk Lake is part of the drainage but was not inundated by the reservoir. Flows from the Eutsuk system join the Tahtsa basin to form the Nechako River, flowing north and east towards Prince George. The Kenney Dam impounds water at 40.8 m above the original level of Ootsa Lake, thereby connecting the two basins into one reservoir.

2.1.2 General Features of Ootsa Lake

At present reservoir levels, Ootsa Lake averages 3 km in width. At the main historic river inflow location at the western end of the lake, a depth profile indicates the impoundment of 40 m of water over a relatively flat flood plain (Transect #5; Figure 2.2). Approximately two thirds of the way down the lake to the east, the depth profile (Transect #6) indicates a maximum depth of approximately 100 m at the present reservoir height.

The Skins Lake spillway is located on the northeastern side of the lake and can be opened to release water from the reservoir into the Murray/Cheslatta system to the north. This drainage basin flows into the Nechako River downstream of Kenney Dam. The spillway releases flows for fisheries purposes as well as excess water inflows for flood control as necessary. Since 1987, flow releases for fisheries have been made under provisions of the Settlement Agreement between Alcan and the federal and provincial governments, regarding water resource

INSERT FIGURE 2.1

INSERT FIGURE 2.2

management in the Nechako River. The maximum release of water allowed by the Water Comptroller is 283 m^3/s.

Temperature depth profiles at two locations on Ootsa Lake indicate that thermal stratification occurs during summer months and mixing occurs during the winter and early spring.

The Ootsa Lake watershed lies within the Fraser Plateau Ecoregion of the Central Interior Ecoprovince. Within this ecoregion, the north shore of the lake lies within the Bulkley Basin Ecosection; uplands on the south shore west of McIvor Creek lie within the Nechako Plateau Ecosection.

The north side of Ootsa Lake and much of the south side fall within the Sub-boreal Spruce (SBS) Biogeoclimatic Zone. The north side of the lake falls primarily within the Dry Cool Sub-zone of the SBS while lower elevations on the south side fall within the Moist Cold Sub-zone of the SBS. Mature forests within the study area are dominated by hybrid white spruce (*Picea engelmannii* x *glauca*) and subalpine fir (*Abies lasiocarpa*); lodgepole pine (*Pinus contorta*) and trembling aspen (*Populus tremuloides*) occur as seral species. Higher elevations on the south side of Ootsa Lake lie within the Engelmann Spruce - Subalpine Fir Biogeoclimatic Zone (ESSF).

2.1.3 Fish Sample Sites

Fish sample sites for 1997 data collection are shown in Figures 2.3, 2.4, and 2.5. Sampling was undertaken in three main areas.

- Ootsa Lake
- Tahtsa Reach (reservoir control site)
- Eutsuk Lake (watershed control site)

2.1.3.1 Ootsa Lake

As in 1996, sampling in Ootsa Lake was conducted in Andrews Bay, Wells Creek bay, and an old lake basin inundated by the development of the reservoir

Andrews Bay

Andrews Bay is located at the west end of Ootsa Lake on the north side of the lake. Andrews Bay is characterized by a distinctive narrow inner bay and a broader outer bay (Figure 2.3). Andrews Bay was selected as a sample location in 1996 as it shares similar characteristics to Wells Creek bay. The inner bay was scheduled for timber harvest in 1997 by CCNRC-Fibrecon. Sampling in Andrews Bay enables comparison with data collected from inner and outer portions of Wells Creek bay.

INSERT FIGURE 2.3

INSERT FIGURE 2.4

INSERT FIGURE 2.5

Andrews Creek and two nearby streams flowing into Andrews Bay were included in 1996 stream reconnaissance surveys. Andrews inner bay contains standing and floating timber; a large amount of floating timber occurs near the head of the bay and blocks boat passage to the mouth of Andrews Creek. A portion of this timber was removed in August 1997 to prepare for the installation of a boat launch. The outer bay contains emergent standing timber, mainly in pockets along the south shore of the bay; submerged standing timber is evident in much of the bay when utilizing echosounders. Timber was extracted from portions of the outer bay in the mid-1980s and early 1990s.

Fish sampling took place at three sites in the inner bay of Andrews Bay: close to the entrance of the inner bay, at a mid-point along the length of the inner bay, and near the mouth of Andrews Creek. Fish were collected at inner bay sites with floating gillnets and minnow traps. Boat electrofishing was also used near the mouth of Andrews Creek. Fish were collected from the outer bay location using floating and sinking gillnets. Sampling at the inner bay sites was conducted in both the early and late summer while outer bay sampling was limited to a single effort in early summer.

Wells Creek Bay

Wells Creek bay and areas near the submerged lake are located along the south shore of Ootsa Lake and within the Canfor/CDC timber salvage Development Plan area proposed for 1996. Wells Creek bay possesses a similar inner bay configuration to Andrews Bay (Figure 2.3). Wells Creek flows into the head of the inner bay (Figure 2.3). Wells Creek bay was chosen as a sample location because it represented a salvage location at the mouth of a major tributary to the lake (Wells Creek) and was the location intended for initial timber salvage trials by Canfor/CDC. Data were collected from both the inner and outer bay areas in 1997. Most standing timber in the inner bay was cut several metres below the surface and removed by Alcan, together with floating timber, in 1991. Snags exist along the margin of the inner bay and stumps and snags can be seen below the water surface around the bay. Wells Creek was included in 1996 stream reconnaissance surveys conducted at the same time as the 1996 lake studies.

Fish sampling took place at three inner bay and three outer bay sites in 1997. Inner bay sites included a site at the entrance of the inner bay, a site close to the mouth of Wells Creek, and one at a mid-point along the inner bay. Fish were captured at inner bay locations using floating gillnets and minnow traps. In addition, boat electrofishing was used to establish fish presence and diversity near the mouth of Wells Creek. Inner bay sites were sampled in early and late summer while the outer bay was only sampled in the early summer. Fish were captured in the outer bay using floating and sinking gillnets. Further details on Wells Creek bay can be found in the report on 1996 baseline data collection in the reservoir (Winsby *et al*. 1997).

Submerged Lake Basin

The old lake site was chosen from maps prepared by Alcan on which the pre-inundation shoreline was superimposed on current shorelines. These maps show a distinctive lake or wetland feature within the previously forested area. This location was selected as a sample location because it represented a shoreline area similar to the outer bay of Wells Creek bay and exhibited treed and untreed submerged areas for comparative sampling. Fish were captured with floating and sinking gillnets at three sites in the submerged lake basin. Sampling in 1997 was limited to a single effort in the early summer.

2.1.3.2 Tahtsa Reach (Whiting Creek Bay)

Whiting Creek bay is on the north shore of Tahtsa Reach, east of Huckleberry Mountain and is the largest bay in the reach (Figure 2.4). This area was selected as a reservoir reference site for timber salvage in Ootsa Lake based on similarities to the Ootsa Lake sample areas. Although larger than both Andrews and Wells Creek bays, Whiting Creek bay contains abundant standing and floating timber that is not immediately scheduled for harvest. Whiting Creek, a large sixth order stream, was included in the 1997 reconnaissance level stream surveys. Sampling in Whiting Creek bay involved the use of floating gillnets and minnow traps at three sites in the inner bay and sampling was conducted once in the early summer and once in the late summer.

2.1.3.3 Eutsuk Lake (Bone Creek Bay)

Eutsuk Lake is located south of Whitesail Lake and drains into but is not part of the Nechako Reservoir (Figure 2.5). A small bay surrounding Bone Creek in the southern portion of the lake was selected as a reference site for the Ootsa Lake sample sites. This reference site differs from the Tahtsa Reach reference site in that it is within the Nechako watershed but outside of the reservoir. Bone Creek bay was chosen as an area within the lake similar to the sample areas in Ootsa Lake. Bone Creek is similar in size to Andrews, Wells and Whiting creeks. Also, the bay is proximal to field camp facilities operated by a local guide/outfitter. Fish sampling within Bone Creek bay consisted of one early summer sampling at three sites within the bay. Sampling involved the use of floating and sinking gillnets as well as minnow traps. Backpack electrofishing was also performed at the mouth of Bone Creek.

2.2 STUDY METHODS

The following activities were undertaken for the 1997 fish resource studies:

- collection of additional baseline data from the Ootsa Lake sample sites;
- collection of baseline data from both reference sites;
- collection of data from Ootsa sample sites and Tahtsa reference site immediately following timber harvest in Andrews Bay; and
- Continuation of reconnaissance level stream inventories of reservoir tributaries.

The 1997 field program was adjusted after commencement to enable collection of field data immediately following timber harvest in Andrews Bay. Elements of the 1997 reservoir fish and fish habitat assessment were timed to overlap with other timber salvage impact assessments (Water Quality Impact Assessment [Perrin *et al.* 1998] and Reconnaissance Level Stream Inventories Hatfield Consultants Ltd. 1998]).

Biological sampling of fish communities included fish capture with gillnets, minnow traps, and boat and backpack electrofishers. Sampling was undertaken in early summer (June 16-26 and July 8-16, 1997) and in late summer (August 27 to September 2, 1997). Field survey procedures followed those prescribed in *RIC 1997 Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Standards and Procedures*. Emphasis during preliminary review of data and air photos was on areas not previously sampled in 1996. Information for these areas was accumulated to aid in sample site selection and mobilization for data collection during early and late summer. A glossary of common and scientific names of species captured during the current study and referred to in previous investigations is presented in Table 2.1.

2.2.1 Fish Capture

Fish were captured using floating and sinking gillnets, boat and backpack electrofishers, and minnow traps. In the inner bays of Wells Creek Bay, Whiting Creek bay, Bone Creek bay, and Andrews Bay, fish were captured using floating gillnets and with electrofishers. In outer bay locations at Wells Creek and Andrews bays, and at the submerged lake basin, fish were captured with floating and sinking gillnets. Minnow traps were also used in all inner and outer bay sample areas. Each method was used for fish sampling during both the day and night. The work boat used for fish capture was a 6.4 m Gregor aluminum jetboat outfitted for electrofishing.

2.2.1.1 Gillnet Capture

Standard six-panel experimental monofilament floating gillnets were used for fish capture. These gillnets consisted of six 15.2 m long by 2.4 m deep panels, with panel mesh sizes arranged in the following sequence: 25 mm, 76 mm, 51 mm, 89 mm, 38 mm, and 64 mm. Each gillnet contained small floats along the top to maintain buoyancy and a lead line to keep the net stretched through the water column. Air photos were used to aid identification of gaps among standing trees in inner bays where the risk of nets snagging on trees was considered low. Only floating nets were used at these locations as submerged snags were evident during depth sounding and bottom conditions were uncertain. For outer bay locations, air photos and large open areas identified during echosounding in 1996 were used to identify sample locations for floating and sinking nets.

Table 2.1 Glossary of common and scientific names of species identified during current or previous investigations.

Common Name	Scientific Name	MOELP/DFO Species Code
Kokanee	*Oncorhynchus nerka*	KO
Rainbow trout (Kamloops trout)	*O. mykiss*	RB
Mountain whitefish (Rocky Mountain whitefish)	*Prosopium williamsoni*	MW
Burbot (Ling)	*Lota lota*	BB
Lake chub	*Couesius plumbeus*	LKC
Northern squawfish	*Ptychocheilus oregonensis*	NSC
Peamouth chub	*Mylocheilus caurinus*	PCC
Largescale sucker (Coarsescale sucker)	*Catostomus macrocheilus*	CSU
Longnose sucker (Fine-scaled sucker)	*C. catostomus*	LSU
Prickly sculpin	*Cottus asper*	CAS
Slimy sculpin	*C. cognatus*	CCG

Gillnets were deployed from large tubs placed at the bow of the work boats. For floating gillnets, the end of the first gillnet panel was attached to a tree or float (as site conditions warranted); the gillnet was slowly fed out of the tub with the boat operating in reverse. At the end of the net set, an anchor was attached using a rope length corresponding to the depth of the water column at that location. For sunken nets, anchors were attached to both ends of the net using short ropes; appropriate rope lengths were used to connect the ends of nets to surface floats. To avoid snags, anchor ropes and surface lines were adjusted to set nets several metres above the bottom of the reservoir. Even with this precaution, bottom snags caused small tears in several panels of submerged nets.

Retrieval of the nets was initiated from the downwind end with two personnel on the bow of the boat. Each crew member pulled in either the float or lead line and the net was placed back into its tub. Fish were carefully removed to minimize damage to the fish and gillnet, and placed into a large bucket appropriately labeled for later identification and measurement.

Setting gillnets for day capture consisted of deploying the net as close to sunrise as weather conditions and site logistics allowed, and retrieving close to dusk. Similarly, setting gillnets for night capture consisted of deploying the net around dusk and retrieving it close to sunrise.

Gillnet set and retrieval time was recorded as well as UTM coordinates. UTM coordinates were collected using a Garmin 45 GPS unit.

2.2.1.2 Minnow Trapping

Day and night minnow trap sets were used to capture fish at sample sites in all areas. Gee-type minnow traps (approximately 40 cm length, 23 cm diameter at the mid-point; ¼ inch mesh size) were baited with salted salmon roe and placed in the lake at each sample location. Twelve minnow traps were deployed at each site with six of the traps set in less than 1 m of water and the other six set on the lake bottom in water usually greater than 6 m deep. Traps were deployed from the work boat and tied onto a snag or standing tree. Set and retrieval times were recorded as well as the UTM coordinates. Traps were retrieved and captured fish were identified and measured.

2.2.1.3 Electrofishing

Fish were captured using a boat electrofisher in nearshore areas at the mouths of Wells, Whiting, and Andrews creeks. A backpack electrofisher was employed at the mouth of Bone Creek. Boat electrofishing equipment was comprised of a 6.4 m Gregor aluminum jetboat fitted with extendible bow electrodes and a Coffelt model VV-15 boat-mounted electroshocker unit. The electroshocker was powered by a 5,000 watt Honda generator producing 600 volts at 0.25 to 0.5 amperes. Output voltage was kept to a maximum due to low conductivity and the wide range of depths electrofished. Electrofishing was undertaken during the day and after sundown. The boat was equipped with bow-mounted lighting for night electroshocking. Personnel on the bow of the boat used long dipnets to retrieve electroshocked fish. Fish were placed temporarily in a bucket until they could be identified, measured, and later released. The backpack electrofisher employed at Bone Creek bay consisted of a Smith-Root Model 12-B POW run at 700 volts, 60 Hz, and 8 ms. Electrofishing coordinates were recorded using the GPS.

2.2.1.4 Biological Measurements

All captured fish were identified and measured for fork or total length. Live specimens captured in minnow traps or with electrofishing equipment were sedated with sodium bicarbonate to enable easier handling. The fish were then measured before being revived in a bucket of fresh lake water and released back into the lake. Fish captured in gillnets were placed in plastic bags for later identification and measurement on shore. Lengths and weights were taken for all gillnetted fish. All salmonids (rainbow trout, kokanee, and mountain whitefish) as well as a subsample of each coarse fish species were dissected and additional measurements were taken. For dissected fish, sex and maturity were recorded, external and internal anomalies noted, and gonads and livers weighed. Maturity ratings were based on a six stage scale of 1 (immature), 2 (maturing), 3 (mature), 4 (spawning), 5 (spent), and 6 (resting) (Resource Inventory Committee 1997). Stomachs and aging structures were removed from all dissected specimens for later analysis.

2.2.2 Underwater Noise Measurement

Underwater noise emissions from Fibrecon – CCNRC timber harvesting activity in Whitesail Reach were monitored during a three day period from September 9 to 11, 1997. This coincided with the late summer program and followed the capture of fish immediately following timber harvesting activities in Andrews Bay. During the period of underwater sound monitoring, activities of Fibercon – CCNRC logging company included the use of an underwater hydraulic cut-off saw operated from a barge. Sound monitoring was conducted at various distances from the operation both during harvesting and while operators were bundling salvaged timber, launching complete bundles from the barge into the water and towing the bundles from the harvest site using a doser boat.

An array of 12 hydrophones was used to provide a broad band monitoring capability. The array consisted of four different types of hydrophones with three of each kind. Additional information is provided in Appendix A2 for the specific hydrophone elements. With the combination of hydrophones, it was possible to provide calibrated signal monitoring for sound frequencies from extremely low frequency (0 to 20 Hz) up to 200 KHz.

A fourteen channel tape recorder was used to record the sound measurements. One track was used for each hydrophone as well as separate tracks for voice logging and recording surface noise from the harvesting operations. The use of three hydrophones of each type provided redundancy in the monitoring program should any of the hydrophones experience interference due to orientation or localized signal blocking. A description of the way in which sound levels were analyzed is provided in Appendix A2.

Measurements were taken at various distances from the timber harvesting operation to determine attenuation (i.e. rate of decrease with distance). Under field operating conditions measured attenuation rates can be compared to known attenuation rates in open water conditions (Winsby *et al*. 1997).

Timber harvesting activities were limited to one method of harvesting (i.e. using hydraulic cut-off saws) as this was the system of harvesting that proved to be most effective, at least for harvesting to a depth of approximately 8 to 10 meters.

2.2.3 Data Analysis and Interpretation

Data analysis for the purposes of this report was scoped to funds available after field data collection. Priority was placed on data collected in the late summer to assess potential short-term effects on fish after timber harvest in Andrews inner bay. Further analyses of combined 1996 and 1997 data are intended for presentation in a subsequent report to be prepared in 1998/1999.

Fish capture data were used to evaluate species composition and relative abundance in nearshore timber salvage areas, including inner embayments close to stream mouths and outer bay areas. Data collected during daytime were compared to data collected at night for each gear type at each capture location. Percent species composition and species catch per unit effort (CPUE) were calculated for fish captured in late summer to enable relative comparisons among catch locations.

Biological data were analyzed to determine size and growth (mean length, mean weight, mean age of each sex), maturity/reproductive status (state of maturation and gonad development, mean age of each maturity stage, gonad weight and gonadosomatic index), and fish condition (condition factor and hepatosomatic index). Gonadosomatic and hepatosomatic indices, expressed as organ weight as a percentage of body weight (Nikolsky 1963, Nielson and Johnson 1983), were calculated for all dissected fish and Fulton's condition factors, equal to w/l^3 (Ricker 1975, p. 209) were calculated for all species. Stomach contents were archived, together with benthic and plankton samples, for laboratory analysis in 1998. Species biological data were compared among the main habitat areas sampled (inner and outer bays for both Wells Creek bay and Andrews Bay, and the submerged lake basin and inner bays for Whiting Creek bay and Bone Creek bay). Catch data were compared for compositional differences using the Shannon-Weiner Function (Krebs 1989):

$$D = -\sum_{i=1}^{s}\left[\frac{Ni}{N}\log_2\frac{Ni}{N}\right]$$

where	*D*	=	Diversity index;
	s	=	number of taxa;
	Ni	=	number of individuals of the i^{th} taxon; and
	N	=	total number of individuals in sample.

These data are intended to provide baseline data (early summer) and data describing conditions immediately post-harvest. The data represent fish resource conditions for the period of sampling (late summer/early fall).

The data were used as the basis of a preliminary assessment of timber salvage effects on fish resources in the reservoir, for development of fish protection recommendations, and for recommendations to guide future studies.

3.0 RESULTS

Fish sampling results presented in this report emphasize gillnet data collected during the late summer from Andrews, Wells Creek, and Whiting Creek bays immediately following timber harvest in Andrews Bay. Summaries of biological data collected in early and late summer from Ootsa Lake and the reference site in Tahtsa Reach are presented in Appendices A3 through A10. These data, along with other early and late summer 1997 data, will be compared with data collected in the reservoir in 1996 to evaluate short term effects of timber removal in Andrews Bay. Fish capture data for all 1997 sampling is presented in Appendix A1.

3.1 EARLY SUMMER FISH CAPTURE PROGRAM

Biological data for fish species captured in early summer in Andrews Bay, Wells Creek bay, Submerged Lake Basin, and Whiting Creek (late summer only) are summarized in the appendices. Further analysis along with summaries of early summer data for Whiting Creek bay and Bone Creek bay are intended for presentation in the 1998 report, comparing results of all 1996 and 1997 sampling in the Nechako Reservoir.

3.2 LATE SUMMER FISH CAPTURE PROGRAM

Fish capture data collected after timber harvest in Andrews inner bay are presented for Andrews Bay. These data are compared to data collected from the same location in September 1996 and June 1997, and from Wells Creek bay and Whiting Creek bay in August/September 1997.

3.2.1 Andrews Bay

Species composition of late summer gillnet catches in the inner bay of Andrews Bay are summarized in Table 3.1. Catch per unit effort data (CPUE) are summarized in Table 3.2 and Figure 3.1. Data from September 1996 and June 1997 are also shown in Figure 3.1.

Species Composition

Northern squawfish were the most abundant species captured at all sites in the inner bay during night sets (83% at Site 1, 90% at Site 2, 84% at Site 3) and at Sites 1 and 2 during day sets (84% at Site 1, 63% at Site 2). Rainbow trout were the most abundant species at Site 3 during day sets (81%). Most other species were caught in relatively low numbers, however, significant numbers of largescale suckers were captured in Site 1 making them the second most abundant species captured at that site (11%). Shannon-Wiener Function values are shown in Table 3.3. Species diversities were comparable for all sample sites and times ranging from 0.676 to 1.258.

Table 3.1 Species composition of gillnet catches at sites in Andrews Bay, August/September 1997.

Site	Day or Night Set	Floating or Sinking	Date	No. of Fish Captured[1]									Total Catch
				RB	KO	MW	NSC	CSU	LSU	LKC	BB	CAS	
Inner Bay 1	Day	Float	31-Aug	5 (2)	0 (0)	0 (0)	194 (84)	25 (11)	6 (3)	0 (0)	0 (0)	0 (0)	230
Inner Bay 2	Day	Float	31-Aug	8 (27)	0 (0)	3 (10)	19 (63)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	30
Inner Bay 3	Day	Float	31-Aug	13 (81)	2 (13)	0 (0)	1 (6)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	16
Inner Bay 1	Night	Float	30-Aug	2 (1)	0 (0)	0 (0)	187 (83)	25 (11)	11 (5)	0 (0)	0 (0)	0 (0)	225
Inner Bay 2	Night	Float	30-Aug	4 (3)	3 (2)	4 (3)	114 (90)	2 (2)	0 (0)	0 (0)	0 (0)	0 (0)	127
Inner Bay 3	Night	Float	30-Aug	1 (2)	8 (15)	0 (0)	46 (84)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	55
All Sites	All Times	Float	All Times	33 (5)	13 (2)	7 (1)	561 (82)	52 (8)	17 (2)	0 (0)	0 (0)	0 (0)	683

RB = rainbow trout, KO = kokanee, MW = mountain whitefish, NSC = northern squawfish, LSU = longnose sucker, CSU = largescale sucker, BB = burbot, LKC = lake chub, CAS = prickly sculpin.

[1] Percent composition represented in parentheses.

Table 3.2 Catch per unit effort of gillnet catches at sites in Andrews Bay August/September 1997.

Site	Day or Night Set	Floating or Sinking	Date	Soak Time (hrs)	Catch Per Unit Effort (no. fish/hour)									
					RB	KO	MW	NSC	CSU	LSU	LKC	BB	CAS	All Species
Inner Bay 1	Day	Float	28-Aug	11.00	0.45	0.00	0.00	17.64	2.27	0.55	0.00	0.00	0.00	20.91
Inner Bay 2	Day	Float	28-Aug	9.83	0.81	0.00	0.31	1.93	0.00	0.00	0.00	0.00	0.00	3.05
Inner Bay 3	Day	Float	28-Aug	9.08	1.43	0.22	0.00	0.11	0.00	0.00	0.00	0.00	0.00	1.76
Inner Bay 1	Night	Float	27-Aug	12.25	0.16	0.00	0.00	15.27	2.04	0.90	0.00	0.00	0.00	18.37
Inner Bay 2	Night	Float	27-Aug	13.75	0.29	0.22	0.29	8.29	0.15	0.00	0.00	0.00	0.00	9.24
Inner Bay 3	Night	Float	27-Aug	14.75	0.07	0.54	0.00	3.12	0.00	0.00	0.00	0.00	0.00	3.73
All Sites	All Times	Float	All Times	70.66	0.47	0.18	0.10	7.94	0.74	0.24	0.00	0.00	0.00	9.67

RB = rainbow trout, KO = kokanee, MW = mountain whitefish, NSC = northern squawfish, LSU = longnose sucker, CSU = largescale sucker, BB = burbot, LKC = lake chub, CAS = prickly sculpin.

Insert Figure 3.1

Table 3.3 Species proportions and Shannon-Wiener Function for communities sampled at Wells Creek bay, Whiting Creek bay, and Andrews Bay, August/September 1997.

General Sample Area	Sample Location	Sample Method	Time	Species Proportions									Shannon-Wiener Value
				RB	KO	MW	NSC	CSU	LSU	LKC	BB	CAS	
Wells Creek Bay	Inner Bay 1	Gillnet	Day	0.133		0.067	0.600	0.067	0.133				1.738
			Night	0.019		0.032	0.801	0.109	0.038				1.054
	Inner Bay 2	Gillnet	Day	1.000									0.000
			Night	0.114	0.086		0.800						0.919
	Inner Bay 3	Gillnet	Day	0.200			0.200					0.600	1.371
			Night	0.066	0.028		0.877	0.028					0.716
Whiting Creek Bay	Inner Bay 1	Gillnet	Day			0.500				0.500			1.000
			Night			0.773	0.136			0.045	0.045		1.085
	Inner Bay 2	Gillnet	Day	0.583	0.250		0.167						1.384
			Night	0.091	0.109		0.782		0.018				1.046
	Inner Bay 3	Gillnet	Day	1.000									0.000
			Night	0.200			0.700		0.100				1.157
Andrews Bay	Inner Bay 1	Gillnet	Day	0.022			0.843	0.109	0.026				0.812
			Night	0.009			0.831	0.111	0.049				0.847
	Inner Bay 2	Gillnet	Day	0.267		0.100	0.633						1.258
			Night	0.031	0.024	0.031	0.898	0.016					0.676
	Inner Bay 3	Gillnet	Day	0.813	0.125		0.063						0.868
			Night	0.018	0.145		0.836						0.725

RB = rainbow trout, KO = kokanee, MW = mountain whitefish, NSC = northern squawfish, LSU = longnose sucker, CSU = largescale sucker, BB = burbot, LKC = lake chub, CAS = prickly sculpin.

Catch per Unit Effort

Catch per unit effort (CPUE) data for Andrews Bay are summarized in Table 3.2. Floating gillnet CPUE data (summarized in Figure 3.2) indicate:

- northern squawfish catch per unit effort was much greater at Site 1 (16.46 fish/h) than at either Site 2 or Site 3 (5.11 and 1.62 fish/h respectively);
- northern squawfish catches were higher at Site 1 of Andrews Bay than for any species sampled at any location during 1997 Nechako studies;
- daytime rainbow trout catches per unit effort (0.87 fish/h) were higher than at night (0.12 fish/h) for all sample sites:
- daytime northern squawfish CPUE (17.64 fish/h) at Site 1 were higher than at night (15.27 fish/h).

Coarse fish other than northern squawfish and largescale suckers were captured in very low numbers.

3.2.2 Wells Creek Bay

Species composition of late summer gillnet catches in the inner bay of Wells Creek bay are summarized in Table 3.4. Catch per unit effort data (CPUE) are summarized in Table 3.5 and Figure 3.2.

Species Composition

Northern squawfish were the most abundant species captured at all sites in the inner bay during night sets (80% at Site 1, 80% at Site 2, 88% at Site 3). Largescale suckers were the second most abundant species at night at Site 1 (11%) although rainbow trout were more abundant at Sites 2 and 3 (11% and 7% respectively). Gillnet day catches in Wells Creek bay were low compared with night catches. Northern squawfish comprised 42% of the day catch from all three sites while rainbow trout were the second most abundant species making up 17% of the catch. Shannon-Wiener Function values are shown in Table 3.3. These data indicate greater species diversity at Sites 1 and 3 compared to Site 2.

Catch per Unit Effort

Catch per unit effort (CPUE) data for Wells Creek bay are summarized in Table 3.5. Floating gillnet CPUE data (summarized in Figure 3.2) indicate:

- catch was comparable among Wells Creek day and night floating gillnet catches for rainbow trout (0.30 to 0.45 fish/h);

Table 3.4 Species composition of gillnet catches at Wells Creek bay, August/September 1997.

Site	Day or Night Set	Floating or Sinking	Date	No. of Fish Captured[1]									Total Catch
				RB	KO	MW	NSC	CSU	LSU	LKC	BB	CAS	
Inner Bay 1	Day	Float	31-Aug	2 (13)	0 (0)	1 (7)	9 (60)	1 (7)	2 (13)	0 (0)	0 (0)	0 (0)	15
Inner Bay 2	Day	Float	31-Aug	4 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	4
Inner Bay 3	Day	Float	31-Aug	1 (20)	0 (0)	0 (0)	1 (20)	0 (0)	0 (0)	0 (0)	0 (0)	3 (60)	5
Inner Bay 1	Night	Float	30-Aug	3 (2)	0 (0)	5 (3)	125 (80)	17 (11)	6 (4)	0 (0)	0 (0)	0 (0)	156
Inner Bay 2	Night	Float	30-Aug	8 (11)	6 (9)	0 (0)	56 (80)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	70
Inner Bay 3	Night	Float	30-Aug	7 (7)	3 (3)	0 (0)	93 (88)	3 (3)	0 (0)	0 (0)	0 (0)	0 (0)	106
All Sites	All Times	Float	All Times	25 (7)	9 (3)	6 (2)	284 (80)	21 (6)	8 (2)	0 (0)	0 (0)	3 (1)	356

RB = rainbow trout, KO = kokanee, MW = mountain whitefish, NSC = northern squawfish, LSU = longnose sucker, CSU = largescale sucker, BB = burbot, LKC = lake chub, CAS = prickly sculpin.

[1] Percent composition represented in parentheses.

Table 3.5 Catch per unit effort of gillnet catches at Wells Creek bay, August/September 1997.

Site	Day or Night Set	Floating or Sinking	Date	Soak Time (hrs)	Catch Per Unit Effort (no. fish/hour)									
					RB	KO	MW	NSC	CSU	LSU	LKC	BB	CAS	All Species
Inner Bay 1	Day	Float	31-Aug	8.25	0.24	0.00	0.12	1.09	0.12	0.24	0.00	0.00	0.00	1.82
Inner Bay 2	Day	Float	31-Aug	7.83	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51
Inner Bay 3	Day	Float	31-Aug	6.83	0.15	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.44	0.73
Inner Bay 1	Night	Float	30-Aug	16.58	0.18	0.00	0.30	7.54	1.03	0.36	0.00	0.00	0.00	9.41
Inner Bay 2	Night	Float	30-Aug	17.00	0.47	0.35	0.00	3.29	0.00	0.00	0.00	0.00	0.00	4.12
Inner Bay 3	Night	Float	30-Aug	17.92	0.39	0.17	0.00	5.19	0.17	0.00	0.00	0.00	0.00	5.92
All Sites	All Times	Float	All Times	74.41	0.34	0.12	0.08	3.82	0.28	0.11	0.00	0.00	0.04	4.78

RB = rainbow trout, KO = kokanee, MW = mountain whitefish, NSC = northern squawfish, LSU = longnose sucker, CSU = largescale sucker, BB = burbot, LKC = lake chub, CAS = prickly sculpin.

- INSERT FIGURE 3.2

- catches for kokanee were higher on average for the three sites during the night (0.23 fish/h) than during the day (0.00 fish/h);
- northern squawfish catch per unit effort was much greater at night (3.29 to 7.54 fish/h) than at day (0 to 1.09 fish/h); and
- catch per unit effort for largescale suckers was considerably higher at Site 1 at night (1.03 fish/h) than during the day (0.24 fish/h) or than catches at Site 2 or 3 (0.00 to 0.17 fish/hr).

Mountain whitefish and longnose suckers were present at Site 1 in small numbers but none were captured at Sites 2 or 3. A small number of prickly sculpins was caught in Site 3 but not elsewhere.

3.2. 3 Whiting Creek Bay

Species composition of gillnet catches in the inner bay of Whiting Creek bay are summarized in Table 3.6. Catch per unit effort data (CPUE) are summarized in Table 3.7.

Species Composition

Northern squawfish were the most abundant species captured at Sites 2 and 3 in the inner bay during night sets (78% at Site 2, 70% at Site 3), however, mountain whitefish were the dominant species at Site 1 (77%). Low catch numbers were encountered during day sets and no species dominated the species composition at all sites; however, rainbow trout were the only species captured at Site 3 and were the most abundant species captured in Site 2 (58%). Shannon-Wiener Function values are shown in Table 3.3. Community diversities were comparable for all sample sites and times (values ranging from 1.000 to 1.384) except for day sampling at Site 3 where only rainbow trout were captured.

Catch per Unit Effort

Catch per unit effort (CPUE) data for Whiting Creek bay are summarized in Table 3.7. Floating gillnet CPUE data (summarized in Table 3.7 and Figure 3.1) indicate:

- catches per unit effort were consistently higher for night sampling at each site (all species combined);
- highest catch per unit effort was recorded for northern squawfish for night sampling at Site 2 (2.76 fish/h).
- catches of mountain whitefish were higher than in Andrews Bay and Wells Creek bay while longnose and largescale sucker catches were lower in Whiting Creek bay.

Table 3.6 Species composition of gillnet catches at Whiting Creek bay, August/September 1997.

Site	Day or Night Set	Floating or Sinking	Date	No. of Fish Captured[1]									Total Catch
				RB	KO	MW	NSC	CSU	LSU	LKC	BB	CAS	
Inner Bay 1	Day	Float	2-Sept	0 (0)	0 (0)	2 (50)	0 (0)	0 (0)	0 (0)	2 (50)	0 (0)	0 (0)	4
Inner Bay 2	Day	Float	2-Sept	7 (58)	3 (25)	0 (0)	2 (17)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	12
Inner Bay 3	Day	Float	2-Sept	4 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	4
Inner Bay 1	Night	Float	1-Sept	0 (0)	0 (0)	17 (77)	3 (14)	0 (0)	0 (0)	1 (5)	1 (5)	0 (0)	22
Inner Bay 2	Night	Float	1-Sept	5 (9)	6 (11)	0 (0)	43 (78)	0 (0)	1 (2)	0 (0)	0 (0)	0 (0)	55
Inner Bay 3	Night	Float	1-Sept	2 (20)	0 (0)	0 (0)	7 (70)	0 (0)	1 (10)	0 (0)	0 (0)	0 (0)	10
All Sites	All Times	Float	All Times	18 (17)	9 (8)	19 (18)	55(51)	0 (0)	2 (2)	3 (3)	1 (5)	0 (0)	107

RB = rainbow trout, KO = kokanee, MW = mountain whitefish, NSC = northern squawfish, LSU = longnose sucker, CSU = largescale sucker, BB = burbot, LKC = lake chub, CAS = prickly sculpin.

[1] Percent composition represented in parentheses.

Table 3.7 Catch per unit effort of gillnet catches at Whiting Creek bay, August/September 1997.

Site	Day or Night Set	Floating or Sinking	Date	Soak Time (hrs)	Catch Per Unit Effort (no. fish/hour)									
					RB	KO	MW	NSC	CSU	LSU	LKC	BB	CAS	All Species
Inner Bay 1	Day	Float	2-Sept	7.58	0.00	0.00	0.26	0.00	0.00	0.00	0.26	0.00	0.00	0.53
Inner Bay 2	Day	Float	2-Sept	7.08	0.99	0.42	0.00	0.28	0.00	0.00	0.00	0.00	0.00	1.69
Inner Bay 3	Day	Float	2-Sept	7.67	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52
Inner Bay 1	Night	Float	1-Sept	14.92	0.00	0.00	1.14	0.20	0.00	0.00	0.07	0.07	0.00	1.47
Inner Bay 2	Night	Float	1-Sept	15.58	0.32	0.39	0.00	2.76	0.00	0.06	0.00	0.00	0.00	3.53
Inner Bay 3	Night	Float	1-Sept	15.83	0.13	0.00	0.00	0.44	0.00	0.06	0.00	0.00	0.00	0.63
All Sites	All Times	Float	All Times	68.66	0.26	0.13	0.28	0.80	0.00	0.03	0.04	0.01	0.00	1.56

RB = rainbow trout, KO = kokanee, MW = mountain whitefish, NSC = northern squawfish, LSU = longnose sucker, CSU = largescale sucker, BB = burbot, LKC = lake chub, CAS = prickly sculpin.

A summary of gillnet catch per unit effort for all species at each site is presented in Table 3.8.

Table 3.8 Floating gillnet catch per unit effort (no. of fish/h) - all species, Nechako Reservoir, August/September 1997.

Location	Site	Day	Night
Wells Creek Bay	Inner Bay Site 1	1.82	9.41
	Inner Bay Site 2	0.51	4.12
	Inner Bay Site 3	0.73	5.92
Whiting Creek Bay	Inner Bay Site 1	0.53	1.47
	Inner Bay Site 2	1.69	3.53
	Inner Bay Site 3	0.52	0.63
Andrews Bay	Inner Bay Site 1	20.91	18.37
	Inner Bay Site 2	3.05	9.24
	Inner Bay Site 3	1.76	3.73

Both Andrews Bay and Wells Creek bay showed higher catches for all species at Site 1 near the mouth of the inlet creek. Relatively low catches in Site 1 of Whiting Creek possibly reflect the location of the sampling gear within the mouth of the Whiting Creek. Whiting Creek is a sizably larger stream than either Andrews or Wells Creek. Larger streams have greater fluvial influence on estuaries than smaller streams and may produce different habitats and fish communities at their mouths.

3.3 UNDERWATER NOISE

Preliminary results of underwater sound pressure monitoring are provided in Table 3.9. These data have been selected from recordings made during three days of harvesting operations. Data were selected to be representative of a range of sound characteristics, particularly those displaying sound pressures in frequencies that potentially elicit behavioural responses in fish (<300 Hz). The reported values are subject to the particular operating window sampled (i.e., three-day period) and site constraints associated with location of harvesting activity during the sound monitoring program. In particular, the majority of measurements were recorded while the harvesting operation was located in a dense stand of trees in a shallow area near shore. Recordings taken towards the end of the three-day period documented activity in deeper water away from shore. Although the latter measurements were at greater distance, as measured between the harvest barge and recording hydrophones, these measurements indicated similar and in some cases higher sound levels than some of the near shore measurements. This confounded attempts to determine attenuation rates due to the variable nature of the activity being monitored.

Spectrograms used to obtain values reported in this table are shown in Appendix A2. Sounds were recorded over a large range of operational and recording conditions, and distances between operational activities and hydrophones. Among spectrograms examined, those characterized by sounds of branches breaking, described as cracking, popping and snapping sounds, commonly exhibited sound pressures at frequencies lower than 300 Hz, though relative sound intensity was very low.

Table 3.9 Characteristics of selected underwater sounds near timber harvesting operations.

Activity Monitored	Distance to Monitoring Station (Meters)	Sound Description	Sound Signature Parameter					Comments
			Approximate Duration of Sound Event (sec)	Duration of Most Intense Sound (sec)	Selected Frequency Range (Hz)	Intensity Above Presumed Background (dB)	Estimated Absolute Sound Intensity (dB)	
1. Cut-off saw used at depth	30	saw in operation	2.0	1.8	80 - 300 300 - 16k	-5 20	15 40	some trees between source and hydrophone: shallow bathymetry
2. Cut-off saw used at depth	30	saw in operation	2.5	0.5-0.8	<300 3k - 12k	background 20	- 40	some trees between source and hydrophone; near shore
3. Cut-off saw used at depth	30	saw in operation	6.5	<0.2	240 - 300 300 - 8k	10 20	30 40	some trees between source and hydrophone; near shore
4. Cut-off saw used at depth	40	saw in operation	4.0	0.5	160 - 300 300 - 60k	-5 20	15 40	some trees between source and hydrophone; near shore
5. Cut-off saw used at depth	40	saw in operation	4.5	2.5	<300 300 - 16k	background 20	- 40	some trees between source and hydrophone; near shore
6. Cut-off saw used at depth	50	saw in operation	3.2	0.2	<300 300 - 8k	background 20	- 40	some trees between source and hydrophone; near shore
7. Cut-off saw used at depth	50	saw in operation	3.8	0.3	<300 300 - 12k	background 20	- 40	some trees between source and hydrophone; near shore
8. Cut-off saw used at depth	55	saw in operation	1.2	<0.2	<300 300 - 8k	background 18	- 38	some trees between source and hydrophone; near shore
9. Cut-off saw used at depth	100	saw in operation	3.5	<0.2	<300 300 - 28k	background 18	- 38	some trees between source and hydrophone

10. Cut-off saw used at depth	100	saw in operation, and cracking/popping sounds	0.8	0.2	20 - 300 300 - 16k	15 20	35 40	some trees between source and hydrophone; away from shore

Table 3.9 (cont'd)

Activity Monitored	Distance to Monitoring Station (Meters)	Sound Description	Sound Signature Parameter					Comments
			Approximate Duration of Sound Event (sec)	Duration of Most Intense Sound (sec)	Selected Frequency Range (Hz)	Intensity Above Presumed Background (dB)	Estimated Absolute Sound Intensity (dB)	
11. Cut-off saw used at depth	250	saw in operation, and cracking/popping sounds	5	5	20 - 300 300 - 40k	0-5 20	20-25 40	no trees between source and hydrophone; away from shore
12. Cut-off saw used at depth	250	saw in operation, and cracking sounds	3.5	<0.2	20 - 300 300 - 80k	5 20	25 40	no trees between source and hydrophone; away from shore
13. Lowering of hydraulic shear to cut-off depth	25	branches cracking	6	<0.2	20 - 300 300 - 50k	10 20	30 40	some trees between source and hydrophone; near shore
14. Lowering of hydraulic shear to cut-off depth	30	branches cracking	0.7	<0.2	20 - 300 300 - 40k	10 20	30 40	some trees between source and hydrophone; near shore
15. Lowering of hydraulic shear to cut-off depth	30	branches cracking	5.5	1	20 - 300 300 - 40k	5 20	25 40	some trees between source and hydrophone; near shore
16. Lowering of hydraulic shear to cut-off depth	30	branches making popping sound	3.0	<0.2	40 - 300 300 - 40k	-5 - 0 18	15-20 38	some trees between source and hydrophone; near shore
17. Lowering of hydraulic shear to cut-off depth	40	branches cracking	0.4	<0.2	20 - 300 300 - 50k	3 20	23 40	some trees between source and hydrophone; near shore
18. Lowering of hydraulic shear to cut-off depth	40	branches making popping sound	0.5	<0.2	20 - 300 300 - 12k	3 20	23 40	some trees between source and hydrophone; near shore

Table 3.9 (cont'd)

Activity Monitored	Distance to Monitoring Station (Meters)	Sound Description	Sound Signature Parameter					Comments
			Approximate Duration of Sound Event (sec)	Duration of Most Intense Sound (sec)	Selected Frequency Range (Hz)	Intensity Above Presumed Background (dB)	Estimated Absolute Sound Intensity (dB)	
19. Lowering of hydraulic shear to cut-off depth	40	branches making popping sound	2.0	<0.2	20 - 300 300 - 16k	3 20	23 40	some trees between source and hydrophone; near shore
20. Lowering of hydraulic shear to cut-off depth	55	branches making combined snapping, cracking and popping sounds	1.5	<0.2	20 - 300 300 - 40k	5 20	25 40	some trees between source and hydrophone; away from shore
21. Lowering of hydraulic shear to cut-off depth	100	branches making cracking and popping sounds	1.5	<0.2	20 - 300 300 - 60k	10 15	30 35	some trees between source and hydrophone; away from shore
22. Lowering of hydraulic shear to cut-off depth	250	branches cracking	1.0	<0.2	20 - 300 300 - 60k	10 18	30 38	no trees between source and hydrophone; away from shore
23. Lowering of hydraulic shear to cut-off depth	250	branches cracking and popping	0.3	<0.2	20 - 300 300 - 40k	10 18	30 38	no trees between source and hydrophone; away from shore

4.0 DISCUSSION

4.1 TIMBER REMOVAL OPERATIONS DURING 1997

Timber salvage licensees (CCNRC-Fibrecon and CDC-Canfor) collected both standing and floating timber from areas of Ootsa Lake and Whitesail Reach in 1997. Both licensees field tested methods for extracting standing timber from depth; barges were used as working platforms in both cases. Preferred extraction methods in shallow areas utilized feller bunchers to pull from the bottom or cut above stumps/roots. Other methods included the use of choker cables/grapples or processing equipment to pull trees to the surface, removing roots at the surface, and placing timber in bundles for transport along the lake.

Initial salvage activities were small as methods continue to be refined. The majority of timber removed in 1997 was floating and standing timber in the Huckleberry Island area in Whitesail Reach (west of Andrews Bay). CDC-Canfor focused efforts near the submerged lake basin. Most relevant to the study of fish and fish habitat in the reservoir was timber removed from Site 2 of Andrews inner bay in August 1997 to facilitate the construction of a boat ramp. Timber removal from this site allowed comparison of pre- and post-harvest data in an enclosed bay near a stream mouth. Eventually, salvage is expected to take place over approximately five to six months each year, with each operator harvesting 0.5 to 1.0 million trees per year (300,000 to 350,000 m^3).

4.2 SHORT TERM EFFECTS OF TIMBER REMOVAL

The intent of this discussion is to provide a preliminary comparison of data collected from Andrews Bay immediately post-harvest with baseline data collected in the fall of 1996 and with other locations (Wells Creek bay and Whiting Creek bay) in August/September 1997. Although some salvage activity took place outside the Wells Creek bay area in 1997, the most significant removal relevant to this study was from the inner bay of Andrews Bay. Additional sample sites were established in the inner bays of both Andrews Bay and Wells Creek bay during 1997. The new site in Wells Creek bay showed higher abundance than the other two established sites (renamed Sites 2 and 3 for 1997 sampling).

4.2.1 Species Composition

The fish community in Ootsa Lake and elsewhere in the Nechako Reservoir has been described in Winsby *et al*. (1997). The reservoir is known to contain three species of salmonids (rainbow trout, kokanee, and mountain whitefish), burbot, two species of sucker (largescale and longnose), three species of cyprinid (northern squawfish, lake and peamouth chub) and two species of sculpin (slimy and prickly). No new species were identified during the 1997 studies.

Assessing changes in fish community diversity and abundance resulting from the 1997 timber harvest in Andrews Bay was a major objective of sampling in late summer 1997. Comparison of gillnetting data with baseline and post-harvest data for Wells Creek shows a greater proportion of coarse fish in 1997 [Andrews Bay - 80% (1996) to 92% (1997); Wells Creek bay –63% (1996) to 89% (1997)] and, correspondingly, smaller porportions of salmonids at both of these areas. Further statistical analysis will be required to establish these changes as significant.

Shannon-Weiner values for species diversity declined slightly after harvest for all Andrews inner bay sampling (late summer/early fall 1996 – 1.320; late summer 1997 – 1.036). Similarly, species diversity at Site 2, the site of timber removal, decreased post-harvest (fall 1996 – 1.564; late summer 1997 – 0.876). These values are undoubtedly influenced by the large numbers of squawfish caught near the creek mouths in 1997. In 1996, northern squawfish in Andrews Bay comprised 76% of the total gillnet catch. This value increased to 82% in late summer 1997 sampling. Other influences might include sample timing as kokanee would be more prevalent in the bay during their spawning run later in the fall (when 1996 sampling was done). Other species for which the catch proportion changed substantially between 1996 and 1997 include rainbow trout which decreased from 10% to 5% and kokanee which decreased from 7% to 2% between 1996 and 1997. Further analysis will be required in order to establish these changes as statistically significant.

Wells Creek bay showed similar changes in species proportions and diversity to Andrews Bay between 1996 and 1997 despite no timber removal from the inner bay. Shannon-Wiener values declined slightly (late summer/early fall 1996 – 1.379; late summer 1997 – 1.126) and, similar to Andrews Bay, Wells Creek bay showed a proportional increase in coarse fish (from 63% in 1996 to 89% in 1997). Again a decrease in kokanee and rainbow trout proportions was evident with rainbow trout declining from 16% to 7% in 1997 and kokanee decreasing from 22% to 3%. Significantly higher proportions of kokanee in the inner bay in late September (compared with late August) may be evidence of their using the inner bay as a migratory corridor.

4.2.2 Abundance

Overall, abundances at inner bay locations were higher in 1997 than 1996 as outlined in Table 4.1. Night catches were also higher than day catches at both Wells Creek bay and Andrews Bay suggesting a strong diel movement of kokanee into inshore/littoral areas at least during the season of the 1996 surveys (late summer/early fall). Day and night catch differences were marginal at Andrews Bay in 1997.

Table 4.1 Catch per unit effort for all species captured in Ootsa Lake floating gillnets, fall 1996 and late summer 1997.

Location	Year	Catch per unit effort (fish/hour)		
		Day	Night	All Times
Andrews inner bay - all sites	1996	1.84	6.68	5.07
	1997	9.23	9.99	9.67
Wells Creek inner bay - all sites	1996	0.48	4.36	2.88
	1997	1.05	6.45	4.78

Inner bay gillnet catches in both 1996 and 1997 were generally dominated by northern squawfish.

4.2.2.1 Rainbow Trout

Rainbow trout captured during the late summer 1997 studies were comparably sized to inner bay rainbow trout captured in 1996 inner bay sampling (1997: 192.4 mm ± 56.0 mm; 1996: 208.6 mm ± 36.0 mm). Andrews Bay rainbow trout captured in 1997 were smaller than those caught in any of the other sampling events (180.2 mm ± 60.5 mm). Most rainbow trout captured in 1996 and 1997 were smaller than fish reported in the sport fishery (few specimens were above 400 g during lake sampling while fish greater than 1 to 2 kg are commonly reported in the sport fishery). Most aged specimens in 1996 and 1997 were 2 to 4 years of age.

Inland rainbow trout (*Oncorhynchus mykiss*) exhibit three life history strategies that vary considerably depending on geographic location and habitat. Fish scales collected during the 1996 studies suggest most rainbow trout (approximately 70%) spend two years in streams before entering the reservoir. Rearing rainbow trout display seasonal movements in search of suitable feeding and overwintering habitats. These movements may be over a short distance in a small tributary or over several kilometres within a larger system (Ford *et al.* 1995). In larger lakes, rainbow trout are piscivorous and grow to a larger size than those rearing in smaller lakes where insects are the primary food source (Ford *et al.* 1995). Growth is generally faster in lakes than in streams (Carlander 1969), although local conditions may mask geographic variability.

4.2.2.2 Kokanee

Kokanee were captured in lesser abundance during 1997 sampling compared with 1996 studies. This is likely the result of sample timing as kokanee generally move into spawning creeks in late September (when 1996 sampling was done) and would be more likely to be caught at this time. Kokanee captured in 1997 were comparably sized to those caught in 1996: (1997: 170.0 mm ± 15.3 mm; 1996: 187.2 mm ± 13.2 mm). Most kokanee (87%) captured in late summer 1997 were aged at 2 years with the other 13% being 3 year olds.

Kokanee mature primarily in their fourth year, though a few 2-, 3-, and 5- year old fish are usually present. Thus, size at maturity varies considerably with age and among populations. Adults often move onto spawning grounds between August and February, but more commonly in September and October. Kokanee captured in Ootsa Lake during the 1996 surveys were in advanced spawning condition over late September. Kokanee were observed spawning in Andrews Creek in mid-September during stream surveys.

During the lake rearing period, kokanee adults prefer temperatures of 10 to 15°C and actively seek out these temperatures by moving into deeper water during the summer and winter. Summer observations of rearing kokanee adults have shown noticeable daily vertical and onshore-offshore movement. Intraspecific competition in the lake is a potential limiting factor for kokanee in terms of growth rate and survival as several age classes of kokanee and sockeye may be present in a lake simultaneously (Burgner 1991).

4.2.2.3 Mountain Whitefish

Mountain whitefish were captured in marginally greater abundance during 1997 sampling compared with 1996 studies. This is possibly the result of an increased sampling effort in 1997 but also may have to do with an earlier sample time than in 1996. Statistical comparisons between 1996 and 1997 whitefish catches will be difficult due to the small sample size in the inner bay in 1996. Aged mountain whitefish from inner bay locations averaged 4.1 years ± 1.8 years and ranged from 1 to 7 years old.

During the 1996 surveys, mountain whitefish were captured between September 21 and October 3 and were in advanced spawning condition. Spawning fish deposit their eggs in tributary streams and sometimes in gravel shoals in the littoral zone of nursery lakes (Ford *et al*. 1995). Fry emerge in early spring and spend several weeks in stream margins and backwaters downstream of the spawning ground before moving offshore. As adults, lake rearing mountain whitefish generally utilize the upper 5 to 6 m and are seldom found deeper than 20 m.

Although they are bottom feeders preying primarily on aquatic insect larvae and the pupae of chironomidae and other aquatic dipterans, whitefish will feed at any level (including the surface) if bottom fauna is not prevalent. Riverine populations have been found to have a more diverse diet than do lake dwellers (Carlander 1969).

4.2.2.4 Northern Squawfish

Of all species captured, northern squawfish showed the greatest difference in abundance between 1996 and 1997. Catches per unit effort in 1997 were double 1996 CPUE values at both Andrews Bay (1996: 2.82 fish/h; 1997: 7.94 fish/h) and Wells Creek bay (1996: 2.88 fish/h; 1997: 3.82 fish/h).

Day catches per unit effort at Andrews inner bay sites showed the most substantial increase between 1996 and 1997. Differences between day and night gillnetting catch per unit effort of squawfish in 1997 were small (day: 6.56 fish/h; night: 8.89 fish/h) while in 1996, night gillnetting catches were substantially higher (day: 1.84 fish/h; night: 6.68 fish/h). This large increase in catch may be due to the implementation of a new sample site (Site 1) near the mouth of Andrews Creek in 1997. The high catch at this site may bias the 1997 sample sufficiently to make it incomparable with the 1996 data. Further statistical analysis will be required to confirm the bias.

Average lengths of northern squawfish captured in inner bays of Andrews and Wells were very comparable between years (1996: 176.3 ± 43.4 mm; 1997: 175.0 ± 53.7 mm).

4.3 EFFECTS OF UNDERWATER NOISE

4.3.1 Sound Characteristics of Timber Harvesting Equipment

The timber harvesting equipment and techniques monitored during this study did not produce sound signatures of concern in the frequency ranges known to affect salmonid behavior. A detailed literature review of the effects of underwater sound on fish was completed prior to this investigation (Winsby *et al*. 1997). Previous studies indicated that:

- the main sensory receptor for detection of underwater sound is the lateral line and this structure is most responsive to stimuli in the range of 10 Hz to 170 Hz with an estimated upper limit of detection of 345 Hz (Carlson 1994)
- fish are very sensitive to both low frequency sound (<10 Hz) and have demonstrated avoidance of extremely high frequency sound (>120 KHz) though the mechanism of detection of these high frequencies is not known;
- fish are more sensitive to and less likely to habituate to sound signals that demonstrate rapid rise to amplitude; and
- fish have been shown to be able to detect signals that are 25 to 30 dB above background noise levels.

This investigation measured sounds emitted by timber harvesting activities; results showed that sound intensities were concentrated in frequency ranges well above the 345 Hz threshold for detection by fish and well below the 200 KHz levels.

The background underwater sound levels measured prior to any harvesting activity were well below those levels expected for lake systems. Average sound levels were in the order of 10 to 15 dB whereas average background levels of 20 to 25 dB would be expected. The presence of submerged trees with branches likely provides an effective sound dampening effect. Sound waves underwater propagate as longitudinal waves and the presence of submerged trees presents a series of convex surfaces which reflect sound waves. This dampening effect likely reduced the background sound intensities.

During field measurement, the largest source of underwater sound measured during the three-day period of observation appeared to result from the doser boat used to transport the bundles of logs after harvesting. However, these sounds levels, which were 30 to 40 dB above background were measured when the doser boat was in close proximity to the hydrophone array. When operating at a similar distance as the harvesting barge, the doser boat sound signature intensity was well below that of the cut-off saw.

Among data subject to spectral analysis, activity producing sounds within frequencies likely to elicit a fish behaviour response were cracking, snapping and popping sounds during limb breakage as the hydraulic cut-off saw head was lowered to cutting depth. These sounds were typically abrupt, irregular with rapid, almost instantaneous, rise in amplitude and sound frequencies usually below 300 Hz. Relative sound intensity at these lower frequencies was generally very low.

The hydraulic harvester cutting head has two hydraulic gripping arms that wrap around the selected tree and shear off the branches as the head is lowered to the cut-off depth. In some cases, sounds emitted by the snapping branches produced relative sound pressures of 20 dB above presumed background, at approximate distances of 25-30 m from the source (with some trees blocking) and up to 100 - 250 meters (no trees blocking). Characteristically snapping branches produced the majority of sound intensity at frequencies below 60 KHz, with sound components of greatest intensity occurring mainly between 4 KHz and 40 KHz. This sound tended to have rapid rise and fall in intensity.

The hydraulic cut-off saw produced a characteristic sound signal with the majority of sound pressure developed in the frequency range of 3 KHz to 40 KHz. At these frequencies, relative sound pressure for this activity was commonly up to 20dB above presumed background levels, including at a distance of 250 meters (with no trees blocking). Very little of the sound produced by the cut-off blade was in the detectable frequency range for fish. Usually no sound pressure above background was evident at frequencies less than 300 Hz. For sound signatures exhibiting sound pressures at frequencies less than 300 Hz, relative intensity was seldom greater than 20 dB above background; relative intensity was approximately 5 dB above presumed background at distances of 250 m, with no trees between the source and hydrophone.

Other activities that were monitored included placing of harvested wood on the barge and applying the bundle wraps around complete bundles. Timber was bundled on the barge and then launched into the water to be subsequently hauled away with the doser boat. Monitoring results of these activities indicated that underwater noise levels were generally low compared to the hydraulic cutting activity and other operational activities. Sound pressures did not demonstrate large pulse components and considerable sound dampening likely occurred as a result of the submerged trees, which affected the sound from the operation prior to detection at the hydrophone array.

4.3.2 Sound Attenuation Rates

Sound measurements were taken at various distances from timber harvesting operations. Our measurements were not sufficient to calculate a realistic sound attenuation rate for sounds arising from the harvesting activity. Attenuation at such a frequency can be low in the absence of significant dampening effects; the expected attenuation rate in open freshwater is approximately

1.0 dB (approximately 20%) per 10,000 km from the source (Carlson 1994). Assessment of sound attenuation was subject to a number of uncontrollable factors such as:

- the barge is intermittently moving as each tree is harvested in order to line up on the next tree;
- the presence of submerged trees and bathymetry between the barge and the point of underwater sound measurement are unknown; and
- Distance measurement between the monitoring station and the barge operation could only be estimated using rangefinding instruments which typically allow for 10% to 20% error factors for distance measurement in the ranges used for this study.

Sound appears to attenuate at greater rates in the very low background noise levels. It is likely that the tangle of branches and possibly the series of convex surfaces presented by the branches of numerous trees is an ideal sound absorbing surface. In order to determine sound attenuation rates in this environment, an alternate study design would be required. A series of hydrophones at different distances from the sound source would have to be monitored simultaneously in order to control the variables introduced by changes in locations and noise signatures of operations.

Submerged vegetation and possibly bottom topography in near shore areas of the reservoir likely play a large role in absorbing underwater sound originating with the timber harvesting operations. The potential dampening characteristics of submerged standing timber would be reduced as timber salvage proceeds.

4.3.3 Implications of Underwater Sound from Timber Harvesting Activities on Fish

The sound measurements indicate that the equipment in use at the time of the monitoring program does not emit sound intensities of concern in frequency ranges known to affect fish behavior. The underwater environment in areas of submerged trees appears to be acoustically quiet compared to background sound measurements previously measured in lakes without submerged trees. Submerged vegetation appears to have superior sound dampening properties likely resulting from the diffuse pattern of limbs and branches and the general convex surface which submerged trees would present to longitudinal sound wave propagation. The dampening effect resulting from submerged vegetation would effectively attenuate sound from the harvesting operation at a much greater rate than would be expected in open water. This reduces the area of influence to fish to a localized area in the immediate vicinity of the harvesting operation.

Based on sound spectrograms evaluated in this program, abrupt snapping sounds associated with breaking branches may represent sounds capable of causing startle responses in fish nearby. Some fish, such as Atlantic cod, can detect sound that is at least 10 dB above background (e.g., Buerkle 1968; Atlantic cod is a species with greater hearing sensitivity than salmonids), though studies generally indicate sound intensities of 25 - 30 dB above background are required before a response is detected. Behavioural studies (e.g, Schwarz and Greer 1984; Blaxter and Hoos

1981) indicate fish may respond with mildly negative behaviour such as avoidance (characterized by cessation of activity and slow moving away from the sound source), alarm (more rapid and intense behaviour typical of avoidance) and startle (powerful flexion of the body followed by 5 to 10 s of faster swimming). Herring have comparatively high hearing sensitivity, for example compared to salmonids, and have been the subject of studies to evaluate behavioural responses to underwater sound. Schwarz and Greer (1984) played recordings of fishing vessel noises and synthetic sound combinations to herring contained in a small netpen (3.3 m x 3.3 m). The speaker was located just outside the pen. All projected sounds were generally 30-40 dB above background. Avoidance responses were elicited by sounds of large vessels (seiners and trollers) approaching at constant speed, though not sounds of large vessels idling or departing, and by small vessels on an accelerating approach, though not approaching at constant speed. Alarm and less frequent startle responses were elicited by synthetic sounds having rapid rise in amplitude. The authors noted that during the studies the test fish showed no response to a variety of boats operating within approximately 200 m of the test location, including small boats operating within 15 m of the test fish. These and other studies (Schwarz 1985) suggest that the zone of effect around timber operational areas may be very small, given types of noise signatures evaluated thus far, possibly measurable in meters or tens of meters when operating in areas of submerged vegetation. Fish will likely become accustomed to operational activities and may be conditioned to associate operational noises with increased food abundance (Schwarz 1985), potentially leading to transient increases in fish abundance in operating areas.

4.4 DATA LIMITATIONS AND UNCERTAINTIES

The 1997 fish survey data indicate the nature of the fish community in nearshore timber salvage areas over early and late summer. Field data for the 1997 season were collected in the end of June/beginning of July (early summer) as well as in late August (late summer), and represent biological conditions for those periods. It should be emphasized that statistical analysis of this data will be required to make conclusive statements about timber salvage influences in the reservoir.

At the time of sampling, reservoir water was at extreme high level, even for the fall season when the reservoir water level is normally high. Uncertainties include: which species actively utilize habitat among snags and the base of trees; the degree to which fish use food organisms found on standing trees or snags, especially near the bottom; and the timing of spawning runs for key species, especially for streams considered most important for reservoir fish production.

A variety of fish sampling equipment was used to detect or capture fish in the nearshore study areas. Sampling among standing timber without incurring equipment loss or damage remains problematic. Problems are associated mainly with fallen or leaning trees underwater which create snags for equipment used in those areas. Consequently, ability to observe or collect specimens close to the bottom among trees is constrained. An alternate method to sample in these locations would involve use of divers to mark areas clear of snags through the use of weighted floats - sinking gillnet panels (possibly involving individual placement of panels that form the currently used six-panel gangs) would then be lowered following the surface floats.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Preliminary results of the 1997 lake fish resource studies indicate:

- Fish species composition and abundance data collected in 1997 after small-scale timber salvage in nearshore areas show similar characteristics to pre-harvest data and do not suggest a large difference in the fish community between years. However, further statistical analysis will be required to confirm this observation.
- In general, the nocturnal increase in abundance observed in 1996 was again observed for most species post-harvest in 1997. Rainbow trout were present at 89% of sample sites although a large nocturnal increase in CPUE was not observed at any site. Kokanee were present at most sites during night sampling but were seldom captured during the day.
- Kokanee abundance was much less in all areas than in 1996. This result is most likely due to 1997 sampling being performed at an earlier time of year (late August) than in 1996 (late September). Kokanee are known to move into reservoir tributaries for spawning during the fall and would be expected to be present around stream mouths in larger numbers at this time. Kokanee captured in Andrews Bay in late September were generally in an advanced maturing state and were likely preparing to move into reservoir tributaries for spawning in the early fall.
- Northern squawfish catch per unit effort was higher at all inner bay sites in late summer 1997 compared with fall 1996 values. Although increases were observed at all locations, changes were greatest in the inner bay of Andrews Bay. Overall changes may be the result of sampling in different seasons in the two years. The greater abundance at Andrews Bay may be the result of attraction by squawfish to the disturbed area, though also may be a result of other factors such as seasonal feeding behavior. Incorporation of new sampling sites in the inner bays in 1997 may also bias the sampling results. Squawfish were the highest proportion of the catch at both Andrews and Wells Creek bays (81%). Further analysis will be required to establish the significance of timber salvage effects on northern squawfish abundance in Andrews Bay. Squawfish represent an important potential predator of salmonid juveniles entering the lake from upstream locations in these areas.
- Rainbow catches suggest abundance in near shore areas of the reservoir is not high compared with other species (northern squawfish). Abundance of some species (largescale and longnose suckers) may be underestimated due to the difficulty in sampling near the bottom of embayments in treed areas. Fish scales read for aging indicate most rainbow trout captured in late summer were 2 to 3 years of age. Reservoir rainbow trout captured in the embayments in 1996 had two years of slow growth suggesting several years of residence in streams before entering the lake.

- Few mountain whitefish were captured during the 1997 surveys, mainly larger specimens approaching spawning condition. A higher proportion of whitefish were caught in Site 1 of Whiting Creek bay than at all other sites. This is possibly due to the location of sampling gear just inside the mouth of Whiting Creek where a small amount of flow was evident.
- Largescale suckers were captured at all inner bay locations; longnose suckers were captured at all locations except Whiting Creek bay. Lake chub and burbot were captured only in Whiting Creek. Prickly sculpin were only captured in Wells Creek bay however, minnow trapping results from 1997 that are yet to be analyzed show prickly sculpin presence in all bays.
- Most recorded operational noise emissions had frequencies and pressures not expected to cause long term behavioural changes in fish, partly because these noise parameters fell mainly in frequencies not suspected to have adverse effects on fish behavior, and partly because fish are expected to habituate to the types of noise measured. Noises that have potential to cause disturbance are those that are characterized by irregular rapid increases. Such noises were evident from breaking branches during salvage operations in progress at the time of underwater sound pressure measurement, but were characterized by low relative sound pressures.
- Stream surveys conducted in 1997 indicate three major streams flowing into Tahtsa Reach have potential spawning and rearing areas accessible to fish from the lake. Rainbow trout were collected in lower reaches and main tributaries of all streams sampled; most captured rainbow were ages 0+ to 2+. All streams surveyed in 1997, are likely important as contributors to reservoir fish populations; these are:
    - Whiting Creek (180-866000-37500);
    - Kasalka Creek (180-866000-45200);
    - Rhine Creek (180-866000-58200).

5.2 RECOMMENDATIONS

5.2.1 Fish Protection Measures

Preliminary recommendations for fish protection were presented in Winsby *et al*. 1997.

5.2.1.1 Tentative Timing Windows

General fish protection timing windows have been developed for different parts of the province to reduce risks to fish species in sensitive locations. Timing windows that apply to the Nechako Reservoir area for key species found in the reservoir are:

Species	Timing Window
Rainbow trout	July 15 - April 15
Kokanee	June 01 - August 31
Mountain whitefish	June 01 - September 15

In order to accommodate all three species, a timing window of July 15 to August 31 in which timber salvage activity near stream mouths could take place with minimum risk to salmonids was recommended, with application of this window to all stream mouths suspected of containing salmonids. Results of the 1997 studies do not indicate this recommendation should be changed.

5.2.1.2 Distances/Locations

Inner embayments such as those at Andrews Bay and Wells Creek bay are steep, narrow portions of flooded stream channels. These will be passageways during spawning migrations and should be included in application of the above operational windows. An interim measure recommended in Winsby *et al*. 1997 was to use a distance of 1 km from the lakeward end of the inner embayment to avoid fish disruption. Results of the 1997 noise and short-term effects studies suggest this distance is too stringent and can be greatly reduced. A distance of 100 metres is recommended.

5.2.2 Future Studies

5.2.2.1 Lake Sampling

Future field programs should include data collection during low water levels in early spring, with emphasis on characterization of fish habitat in the inner bays. Activities suggested for inclusion in future studies are:

- the qualification and quantification of fish habitat in the inner bays using diver surveys; estimating fish usage of the bay for rearing and spawning. Of particular interest is the possible use of submerged stream channels (thalweg) for lake spawning by kokanee or other species. With good visibility at low water levels, much of this work may be possible without divers due to the shallow nature of the inner bays;

- ongoing sampling at Ootsa Lake sample locations and reference sites to assess long-term effects of timber salvage on inner bay fish communities. Minimal fish sampling is recommended for 1998 due to the abundance of data collected in 1997 to assess acute effects;

- statistical analysis of 1996 and 1997 data to assess acute effects of timber salvage in Andrews Bay. Many of the trends observed in this report require statistical confirmation. Caution should be exercised in interpreting preliminary results; and

- an abundance of samples was collected in 1997 that have not yet been analyzed including: stomach contents and aging structures from all species at all locations; and benthic and zooplankton samples at all sites to aid diet interpretation. These samples should be analyzed to support interpretation of timber salvage effects.

5.2.2.2 Stream Reconnaissance Surveys

Stream surveys should be continued as a lower funding priority than intensive analysis of the 1996 and 1997 reservoir data base and additional reservoir habitat surveys. If funding is available to undertake further stream surveys, effort should be directed at streams along Whitesail Reach/Whitesail Lake. Streams along the west shore of Whitesail Reach have been previously surveyed; efforts should be directed towards streams not covered by those surveys.

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APPENDIX A2 NOISE/HYDROACOUSTIC DATA

Underwater noise measurement and processing takes place in three general steps. In the field, pressure input signals are detected by hydrophones and monitored as electrical signals. The electrical signals are converted to frequencies for magnetic data storage. In the laboratory, stored frequency data are played back and frequency signals are converted back to voltage signals. Calibration voltages from known signal sources are recorded in the field for use during laboratory playback and frequency signal conversions. Voltage signals are then digitized for graphical and waveform analysis.

The characteristics of the four hydrophones types used in the program are summarized below:

MODEL	GAIN FACTOR	FREQUENCY RESPONSE	DESCRIPTION
ITC 1089C	10	50Hz to 200KHz	Thin wall sphere Piezoelectric ceramic Lead zirconate titanate
ITC EX – 09	5	.01Hz to 2KHz	Thin wall plate Piezoelectric ceramic High dielectric constant
LAB-core PZ-DIA	20	20Hz to 47Khz	Bar type – flat plastic Thickness mode Piezoelectric Plastic Lead titanate
LAB-core PZ-04A	100	10Hz to 76KHz	Thin wall tube Thickness mode Piezoelectric ceramic Lead magnesium niobate High dielectric constant

The hydrophones have built in buffer amplifiers with gain adjustments fixed and very low noise. Outputs for all hydrophones are adjusted to 10mv @ +20 dBm pink noise in H_2O @ 3 feet from the sound source.

Output of the twelve hydrophones was relayed via coaxial cable to a terminal battery box. The hydrophones were grouped into three clusters with one of each hydrophone type in each cluster. In addition the voice log and surface microphone were connected to the terminal box in a similar fashion.

The hydrophone signals were recorded on a 14 channel Racal Recorder Model ST1405 using half-inch magnetic tape. The recording tape speed was 60 inches per second. The frequency response for the tape recording system was 20 Hz to 300 KHz AM and DC to 150 KHz FM.

Following field recordings, the tapes were played back through a mixer at 15 inches per second. Alternate (slower) tape speeds could be used to search for high frequency signals, if present (i.e. higher than the 88KHz upper limit of analytical equipment at the 15 IPS playback speed).

A test equalizer was used to calibrate the signals and adjust levels prior to introduction into a spectrum analyzer. The spectrum analyzer had a real time frequency response from 0.1Hz to 22KHz.

The spectrum analyzer was used to review the signals from the various hydrophones and could be adjusted to provide an integrated calibrated response curve in three dimensions (frequency/time/intensity) using a combination of hydrophone signals to cover the frequency range of 0 Hz to 88 Khz. Pass filters were used to limit each hydrophone to only those signals within the calibrated range (i.e., which varies depending on the type of hydrophone).

A PC computer (Intel 100meg) was used to view the output from the spectrum analyzer. Each tape recording was reviewed for significant events related to the ongoing log harvesting operations. Following a review of all recordings, characteristic events were printed as spectrograms using an HP 400 colour printer. The time domain (i.e. horizontal axis) was adjusted so that an entire event could be captured in the spectrogram.

The spectrograms require some conversion of axis units in order to represent real units of frequency (Hz), time (seconds) and intensity (dB). Because of the difference between the recording tape speed and the playback tape speed, the frequency values on the Y-axis have to be multiplied by 4 to determine the actual frequency. The time of the event can be determined by subtracting the lower time mark from the upper time mark and dividing this measurement by 4 (assuming a playback speed of 15 IPS).

The sound intensity scale is adjusted to indicate signal strength above random background noise. The –10dB level is a limit established by adjusting the gain to obtain a flat background. Background noise flattens at approximately –12dB to –17dB or just below the spectrogram set point of –10dB. In absolute terms, the real bottom is in the order of –20dB to –25dB. This would mean the random noise in the area under investigation is in the order of 10dB to 15dB, which is very low compared to other lakes (20dB to 25dB) or oceanic (35dB to 40dB) settings. In order to determine absolute intensity levels, the dB scale could be set at 10dB instead of –10dB and the sound intensity levels determined from the colour coded dB scale to a maximum of 40dB.

Examples of electrical noise signatures for emissions recorded at the Fibrecon-CCNRC site are shown in the following spectrograms (all spectograms were produced as colour images: five of the following spectograms are reproduced in colour to illustrate characteristics of the imagery). These represent sounds identified in the headers (e.g., tree branches cracking) and recorded at indicated distances (approximately 30 m to 250 m).

Appendix A1

Fish Capture Data

Appendix A2

Noise/Hydroacoustic Data

Appendix A3

Kokanee Biological Data

Appendix A4

Lake Chub Biological Data

Appendix A5

Largescale Sucker Biological Data

Appendix A6

Longnose Sucker Biological Data

Appendix A7

Mountain Whitefish Biological Data

Appendix A8

Northern Squawfish Biological Data

Appendix A9

Prickly Sculpin Biological Data

Appendices

Appendix A10

Rainbow Trout Biological Data