FINAL SURVEY RESULTS OF SELECT LAKES IN THE KAMLOOPS AREA INHABITED BY KOKANEE - YEAR 4

2004

by

REDFISH CONSULTING LTD.

Nelson, British Columbia

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SUMMARY

In 2001, a four year investigation into the status of kokanee populations in 13 lakes in the Thompson-Shuswap watersheds was initiated by the Ministry of Water, Land and Air Protection (WLAP) with funding from the Habitat Conservation Trust Fund (HCTF). Results of the fourth year of field investigations conducted during 2004 are reported on and integrated with the previous three years results.

This four year survey provides regional fisheries management with solid data on the current status of kokanee populations in the study lakes. Location of key spawning habitat has been identified, magnitude of escapements have been determined and basic biological data such as size, age, fecundity and age-at maturity has been determined.

The International Pacific Salmon Commission library was found to be a good source of some historical data for kokanee in Adams, Shuswap, Mara, and Mabel lakes. Kokanee escapement estimates, lengths, age-at-maturity and fecundity estimates were found for most years from 1950 to 1963 and this data has been summarized in this report.

In the fourth and final year of this project emphasis was placed on confirming deep water spawning in Saskum, North and East Barriere lakes. Spawning kokanee were captured at depths of 30-50 m in East Barriere lake in mid-December and similar spawning is highly suspected fin Saskum and North Barriere lakes. The second priority for 2004 was fecundity determination and ageing of kokanee in those lakes deemed to have potential for increased production. Good samples were obtained from Shuswap, Mara, Bonaparte and Mabel lakes. Kokanee in Shuswap, Adams and Mara lakes are much larger than most kokanee and offer good opportunities for increased fishing.

Numbers of spawning kokanee observed in most of the study lakes in 2004 were low compared to the previous three years with the exception of Bonaparte and Lower Shuswap River where record or near record numbers were observed. Adams Lake spawners were virtually non existent in 2004 and Shuswap lake (Eagle River) numbers were higher (~50,000) than 2003 but far less than 2001(~1.2 million) and 2002 (~0.4 million). The Lower Shuswap River escapement estimate was ~124,000, the highest estimate in the last four years. The origin of these fish remains uncertain although the 2004 data suggests they are most likely from Mara Lake.

Most kokanee spawn at age 3+ with the exception of Sugar Lake (age 2+) and Bonaparte Lake (multiple ages 2+, 3+ and 4+). High fecundities (> 350) were recorded for Adams, Shuswap and Mara Lake kokanee while Mabel and Sugar Lakes had comparatively low average fecundities (< 250).

Theoretical production estimates using MEI and a modified kokanee biostandard provide some insight into potential lake production capacity. These estimates indicate that Bonaparte, Adams, Shuswap and Mabel lakes should produce much larger

numbers of kokanee than were observed during the four study years. Smaller lakes such as Machete, Eagan, Young, Saskum, North and East Barriere as well as Sugar lakes probably do not produce large numbers of kokanee, i.e., < 50,000 annually.

Results from this study have been used to develop a course of action for future work. A conservation plan is outlined for those lakes where kokanee are especially important and require further work to either protect existing populations and or they have potential for enhancement. One lake not included in the study due to budget constraints was Nicola Lake. This lake and it's kokanee population requires immediate attention and is considered the highest priority for future inventory work. Adams Lake is the highest priority for further assessment work given the small numbers of kokanee estimated during the four years of study. Shuswap and Mara lakes are the second highest priority as they have considerable potential for increased kokanee production and are also important for highly sought piscivorous trout and char that support economically important sport fisheries. Bonaparte and Mabel lakes should support far more kokanee than estimated during the four year study. Kokanee in these lakes may be suffering from either poor lake productivity problems or suffer from competitive interaction with juvenile sockeye salmon. The plan provides an outline on where work should be done, why and when.

This four year survey project has met all of the stated objectives and provides regional fisheries managers with a solid base of information that can be used to effectively manage kokanee in the study lakes.

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FINAL SURVEY RESULTS OF SELECT LAKES IN THE KAMLOOPS AREA INHABITED BY KOKANEE—YEAR 4

2004

by

H. Andrusak[1] and A. Morris[2]

INTRODUCTION

This is the fourth and final report on the status of kokanee populations that inhabit some of the lakes located in the North and South Thompson drainages. Survey work commenced in 2001 and the first three years results have been reported by Redfish Consulting Ltd. (2001; 2002; 2003). The final field season (2004) focused on confirming presence of kokanee in those lakes where they were not found in the previous surveys. Also, the 2004 survey work emphasized collection of biological data from those lakes where little data exists or where specific questions remained on origin of a particular population.

Kokanee (*Oncorhynchus nerka*) have become the center of attention for most fisheries managers in the southern part of the province because they are the keystone species in many large British Columbia lakes. Kokanee are most often the major source of forage for other predators such as burbot, sturgeon, rainbow trout, lake trout and bull trout. The Kamloops area has a number of moderate to large-sized lakes that support kokanee but until this current survey little was known about their distribution, abundance, and current stock status. In the southern half of the province kokanee are a valuable sport fish species sought by thousands of anglers. Provincially, they are third only to rainbow and cutthroat trout in sport fish catch (Ministry of Environment, Lands and Parks 2000).

Surveys of the lakes included in this study were initiated in response to numerous anglers and local residents in the Kamloops region reporting a general decline in kokanee. While it is not realistic to know the status of all kokanee populations, most provincial fisheries managers use data from a few key index streams to understand general trends over time. Despite numerous lakes that support kokanee in the Thompson River drainage there are none where an index of abundance has been established similar to that on Okanagan Lake (Andrusak et al. 2004), Kootenay Lake (Andrusak 2004) or Arrow Reservoir (Pieters et al. 2003). Much of the information on kokanee found in the study lakes has been anecdotal and has emanated from federal

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Department of Fisheries and Oceans Canada (DFO) during the course of salmon escapement investigations.

In the Thompson River basin some specific impacts are known to have impacted kokanee habitat, particularly the results of some poor land use practices associated with agriculture, forestry and urban development. Recent initiatives in land use planning have resulted in a growing demand for more information on kokanee numbers, spawning locations and identification of critical habitat. Except for Okanagan Lake, very little is known about habitat for kokanee in the remainder of the lakes in the southern portion of BC. In fact, for some lakes there has been uncertainty as to whether or not viable populations even exist. As angler interest for kokanee has grown recently, there appears to have been a general decline in numbers over the last ten years. The need to understand the status of these fish and their habitat is quite apparent and long overdue.

NOTE: *This report is the final of a series that is intended to document the status of kokanee in a group of lakes in the Thompson River watershed. The report summarizes data collected from 2001-2004 and includes some historical data from the Federal Department of Fisheries and Oceans Canada (DFO) and the International Pacific Salmon Commission (IPSC). The search for historical data was by no means complete and future work should be mindful of these important sources of data. Historic stocking records of kokanee into the study lakes have been summarized in this report (Appendix 1).*

BACKGROUND

Kokanee were seldom considered an important fish species until the late 1950s when Vernon (1957) provided an excellent account of the biology of kokanee in Kootenay Lake. On the contrary, during the 1940s and 1950s salmon biologists considered kokanee to be a competitor with sockeye and several investigations were conducted by the International Pacific Salmon Commission (IPSC) to determine the extent of the "kokanee problem". One report written on Quesnel Lake entitled: *"An Outline of the Kokanee Problem"* (C.P. Idyll 1944, MS) discusses the possible origin of kokanee with mention of how kokanee may impact sockeye numbers through inter-specific competition. Several other IPSC reports in the 1940s and 1950s express interest and concern about kokanee and their impact on sockeye. A series of annual reports in the 1950s by F. Ward provide some good data on kokanee size, fecundity, and stream specific escapements. Goodman (1958) summarized the 1950s work on Quesnel and Shuswap lakes as well as other important interior sockeye nursery lakes. Goodman concluded that kokanee and sockeye seldom compete for spawning sites and that there was no correlation between kokanee abundance and sockeye cyclical dominance at least in Quesnel Lake (a theory pursued by the IPSC for a number of years during the 1950s). Goodman summarized most kokanee work by the IPSC in an incomplete report dated 1964 that was found in their files. The IPSC files also included unauthored summaries of kokanee data for several of the study lakes.

Aside from the pioneer study by Vernon (1957), little work was directed by the provincial government at kokanee until the latter part of the 1960s because, (a) most fisheries managers were preoccupied with rainbow trout biology, and, (b) most believed that kokanee were quite abundant, requiring little attention. Annual escapements in the 1960s and 1970s in systems such as Arrow, Kootenay and Shuswap lakes were often 1-2 million, thus giving the impression that large populations were stable. At the time the perception was that such abundance extended to other kokanee dwelling lakes and there was no need to conduct even rudimentary surveys. The only fisheries activities related to kokanee prior to the 1960s were large scale eyed egg and fry plants into numerous streams flowing into the large lakes located in southern BC, e.g., Kootenay, Okanagan, Arrow, Shuswap lakes (see Appendix 1 for stocking history of the study lakes). All of this changed with the major disruptions to the Kootenay-Columbia ecosystem as a result of construction of the Columbia Treaty dams. Kokanee soon became a species of interest with the documented decline in Arrow and Kootenay Lake kokanee and rainbow trout populations (Northcote 1973), as well as the unexplained decline of Okanagan Lake kokanee. Today, the earlier perception of general kokanee abundance has changed and the prevailing view is that this keystone species appears to be in trouble in many interior lakes. The continued decline of kokanee numbers in Kootenay, Arrow and Okanagan lakes into the 1980s and 1990s due to decreased lake productivity and or competition for food from *Mysis relicta* has resulted in some urgency to better understand the ecological relationship(s) between kokanee and other trophic levels. Further, it is now fairly evident that other lakes supporting kokanee also appear to have experienced declines in numbers. While some of these lakes (e.g., Canim and possibly Mahood) have had *Mysis relicta* introduced, some have not (e.g., Quesnel, Adams, North Barrier) yet numbers have apparently declined. There is growing evidence that increased numbers of sockeye in some lakes are implicated in decreased kokanee numbers (Sebastian et al. 2004). Additionally, there is little doubt that many kokanee population declines are habitat related but this is difficult to quantify when there is such an absence of information on habitat use, angler harvest and escapement numbers over time.

File Data Review

An excellent data report on limnology and sockeye production in several of the study lakes was published by DFO in 2001. Shortreed et al. (2001) evaluated most sockeye nursery lakes in British Columbia with the question in mind of which lakes would be the most suitable for lake fertilization. Since lake fertilization has the potential to directly impact on kokanee it is instructive to summarize some of the results of this work by the DFO scientists. The following synopsis has been extracted from Shortreed et al. (2001) with some interpretation of what the data means relative to kokanee production in the study lakes.

Bonaparte Lake

This lake is of moderate size (3,367 ha) and until the Bonaparte fishway was completed by DFO and provincial fisheries in 1988 the lake was inaccessible to anadromous fish.

To date no sockeye salmon have been observed ascending the fishway but steelhead, chinook and coho have been counted through. The lake is considered to be a good candidate for juvenile sockeye rearing with slightly higher than average phosphorus levels. However, the nitrate levels were low through the summer and fall months. This is a somewhat unique situation and lake productivity could be easily increased with injection of relatively low cost nitrogen fertilizer. The lake is currently considered to be in the middle of the range of oligotrophy and *Daphnid* concentrations were considered high.

Kokanee density measured in 1992 was 120/ha and fall fry weighed 3.2 g, which is high for most fall fry kokanee. It is surprising that Bonaparte Lake does not support higher numbers of kokanee given the fairly productive environment and absence of sockeye. Kokanee production is either limited by spawning habitat or possibly by the imbalance of nutrients that limits primary production although *Daphnid* densities appear slightly above average.

East Barriere Lake

This lake is comparatively small (994 ha) and sockeye currently do not enter it due to partial barriers in the outlet Barriere River that flows into the North Thompson River. The lake is considered to be in the upper range of oligotrophy and does support a good population of kokanee according to hydroacoustics estimates (400/ha fall kokanee fry). Daphnia appeared to be in abundance.

DFO knows very little about available sockeye spawning habitat in the event that they were introduced into this lake. Because stream spawning kokanee have not been observed by DFO or BC Fisheries it is most likely deep water shore spawning is the primary form of spawning.

North Barriere Lake

One of the smaller lakes in this study group, North Barriere Lake has a surface area of 520 ha and is considered to be in a range of middle to upper oligotrophic. Similar to Bonaparte Lake the nitrate level becomes depleted in late summer yet the chlorophyll concentration was one of the highest of all the lakes studied by DFO. In 1988, the macrozooplankton densities were very low, probably the result of high sockeye production from the 1987 spawners. The lake was most likely at carrying capacity for juvenile nerkids in 1988; sockeye escapements reached a peak of 33 thousand in 1996. Since this lake supports only one of two sockeye populations in the North Thompson River, DFO is interested in enhancing this stock possibly through lake fertilization. The major sockeye spawning stream is Fennell Creek that supports an average escapement of about twelve thousand.

Kokanee were presumed to be a small component of the nerkids juveniles surveyed in 1988 and there have been no reliable reports on stream spawning kokanee suggesting that most are shore spawners.

Adams Lake

This lake is quite large and deep that provides a good physical environment for juvenile sockeye and therefore kokanee. Somewhat surprising is that the epilimnetic temperatures are > 20°C for extended periods of time, potentially limiting surface feeding by juvenile nerkids. Nitrogen (nitrate) loading is high and the lake is severely phosphorus limited. As a result, the lake is considered strongly oligotrophic as reflected in low average chlorophyll concentrations. Historically the lake is known to have supported very large numbers of sockeye but during the last half century the annual returns have been less than 7,000 (except in 1942 = 200,000). This system supports early and late run sockeye with the later component strength coinciding with the Shuswap Lake population. The early run is largely represented by the 1996 cycle and the progeny of the 1996 spawners were enhanced through fry outplants and lake fertilization in 1997. The sockeye response to lake fertilization has been very favorable and is scheduled to continue.

With the sockeye restoration and enhancement initiatives underway on Adams Lake there should also be a positive response by kokanee since *Daphnia sp.* appear to be abundant.

Shuswap Lake

The largest lake in this kokanee survey, Shuswap Lake has surface area of almost 31,000 ha. This lake is the nursery area to the largest sockeye population in British Columbia that spawns in the lower reaches of the Adams River as well as a few other rivers including the Eagle. The surface water temperatures often exceed 20°C through the summer months and DFO believes this limits growth for juvenile sockeye that may be unable to access the epilimnetic zooplanktors, i.e., temporary thermal barrier. The lake is considered to be in the upper range of oligotrophy yet juvenile sockeye growth is less than those in other less productive lakes. Nitrate depletion occurs by late summer but lake fertilization is not considered as a viable option. Emphasis on this sockeye population is to increase escapement levels in order to increase fry/smolt production.

Site Description

There are at least 25 large lakes located in the North and South Thompson River watersheds that are known or suspected to support wild kokanee populations. Provincial stocking has occurred in some of these lakes with Meadow Creek stock the origin of most plantings (Appendix 1). Regarding this study, one group of lakes is located in the Upper Bonaparte watershed and Clearwater area including Young, Mahood, Bonaparte, Machete, and Eagan lakes. A second group in the northeast part of the Thompson watershed includes Dunn, Saskum, North Barrier, East Barrier, Adams, Shuswap, Sugar, Mabel, Mara, Griffin, Summit, and Three Valley Gap lakes. Douglas, Chaperonne, and Nicola lakes represent a third group located south of

Kamloops in the Nicola Valley. These lakes were not included in this study but they should be assessed in the near future.

In 2004, the field survey crew spent most of their time on the following 13 lakes (Fig. 1) to determine kokanee spawner numbers and distribution:

1. Bonaparte-Clearwater lakes: Eagan, Machete, Bonaparte (including Lupin Lakes), Young and Saskam lakes (Figs. 2, 3).

2. Shuswap-Adams lakes area: Saskum, North and East Barriere, Adams, Shuswap, Mara, Mabel and Sugar lakes (Figs. 4-7).

With the exception of Machete Lake the remaining lakes are believed to be dependent upon natural reproduction. Survey results during 2001-2003 indicated that the earliest run timings were for those kokanee in Machete, Eagan and Bonaparte lakes, consequently, the Bonaparte-Barrier group of lakes was initially assessed commencing in late August 2004. North and East Barriere lakes were assessed during September-November with the all of the Shuswap area lakes investigated from mid September through to early November. Shore spawning kokanee in Adams Lake were surveyed into late November.

The file data suggested that run timing and some good counts were available for 11 rivers/streams for the Shuswap-Adams group of lakes. Most spawning appeared to occur from mid September to mid October.

Project Objectives

There are four main project objectives.

1. Assess and document key kokanee spawning stream habitat and preferred spawning sites for five lakes in the Bonaparte-Clearwater area and nine lakes in the Shuswap-Adams lake area.

2. Obtain key data for protecting kokanee-spawning habitat in the face of increased human activity (logging, urban development, water withdrawals and agriculture).

3. Implement a systematic, standard procedure for enumerating kokanee with the intent of establishing key sites as indices of abundance.

4. Develop a conservation plan.

METHODS

In the initial year of this project (2001), field work was intentionally exploratory with the purpose of simply locating spawning kokanee and identifying which streams supported any appreciable number of spawners. The ground and aerial surveys were also conducted to identify the location of key stream spawning habitat and preferred spawning sites, as well as determine run timing and peak of spawning activity. In most cases, the 2002 surveys identified spawning areas and provided a good indication of peak spawning activity for the study area streams. This allowed field crews to reduce the number of reconnaissance surveys on each individual stream in 2003 and 2004, and focus on conducting surveys during the peak of spawning activity to obtain a peak count.

In 2004, continued emphasis was placed on collection of biological data for kokanee of various life stages. Summer gillnetting was completed to collect juvenile age classes and seining or dip netting was conducted to collect mature kokanee from spawning streams. Additionally, gillnetting was conducted in North and East Barriere lakes to identify shore spawning.

Ground surveys were conducted on the smaller spawning streams that had limited aerial visibility to estimate spawner numbers. The larger river systems on the big lakes with extensive potential spawning areas were surveyed by helicopter overflights (supplemented by some visual estimates on the ground) during the suspected peak spawning periods.

In 2004, summer gill netting was repeated in Saskum Lake, East and North Barriere Lakes. Bonaparte, Sugar and Mara lakes were also gill netted during the summer, 2004. Two gillnet gangs consisting of 5 panels (mesh size ranging from 25 mm to 38mm) were again used in each lake in order to capture all available age classes. Surface sets were made on those lakes which had not yet thermally stratified. For those lakes which had formed a thermocline, a dissolved oxygen meter was used to determine at what depth in the water column the thermocline was located and net sets were suspended at or below this point. This methodology allowed field crews to successfully capture kokanee into the summer months, even when lake surface temperatures exceeded 20^{o}C. Up to three age classes of juvenile kokanee were captured for each lake surveyed.

The smaller Bonaparte-Clearwater lakes (Eagan, Machete, and Bonaparte lakes) were surveyed on ground throughout September:

Stream Name	Lake Name	Date Surveyed
Machete Creek	Machete Lake	09-Sep-04
Machete Creek	Eagan Lake	16-Sep-04
Lupin Creek	Bonaparte Lake	06-Sep-04
		12-Sep-04
		16-Sep-04

Stream enumerations were conducted by walking along the stream and counting fish with the use of hand counters. Polaroid sunglasses and brimmed hats were worn on all counts to increase visibility and to decrease the effect of glare off the water surface. Crews attempted to keep the sun at the behind whenever possible to reduce glare. Because fish tend to move upstream when frightened, counting while moving downstream was the method of choice. When possible, crews walked along the stream banks and observed down onto the water thus providing the best visual opportunity. When high densities of spawners were observed during aerial surveys ground counts were conducted to confirm numbers. This was the case for the Eagle River where strip counts of portions of the river were conducted to improve the accuracy of the aerial estimate.

The Shuswap-Adams lakes; including North and East Barriere, Saskum, Adams, Shuswap, Mara, Mabel and Sugar lakes, were surveyed in 2004 using helicopter overflights and/or stream walks:

Stream Name	Lake Name	Date Surveyed
Barriere River	Saskum Lake	08-Jul-04
		21-Sep-04
Harper Creek	North Barriere Lake	18-Oct-04
Barriere River	North Barriere Lake	18-Oct-04
Eagle River	Shuswap Lake	10-Sep-04
		23-Sep-04
Anstey River	Shuswap Lake	23-Sep-04
Seymour River	Shuswap Lake	23-Sep-04
Wap Creek	Mabel Lake	08-Oct-04
Lower Shuswap River	Mara Lake	13-Oct-04
Middle Shuswap River	Mabel Lake	06-Oct-04
		07-Oct-04
Upper Shuswap River	Sugar Lake	14-Sep-04
		08-Oct-04
Sinmax Creek	Adams Lake	05-Oct-04
		15-Oct-04
		25-Oct-04
		15-Nov-04
Momich River	Adams Lake	07-Oct-04
		15-Oct-04

Based on the extensive helicopter flights conducted in previous years of the project which did not identify any kokanee spawners in the streams of North Barriere, East Barriere and Saskum lakes, the 2004 surveys focused on identifying fall and winter shore spawning kokanee by gillnetting:

Lake Name	Date Surveyed
Saskum Lake	21-Sep-04
North Barriere Lake	18-Oct-04
East Barriere Lake	01-Dec-04
	15-Dec-04

Shuswap Lake tributaries (Eagle, Anstey and Seymour rivers) were surveyed by helicopter during the peak of spawning on September 23, 2004. The Upper Shuswap

River (tributary to Sugar Lake) was surveyed by helicopter on September 14 and October 8, 2004 and the Lower Shuswap River was surveyed on October 13, 2004.

The Middle Shuswap River below Mabel Lake was surveyed on October 6 and 7, 2004 by drift boat. This method of enumeration has been conducted in the same manner for a number of years (Chamberlain et al. 2001; Morris and Caverly 2002) and allows the survey crew crews to efficiently access mainstem and side channel kokanee spawning areas. A 15 km section of the Middle Shuswap River between Mabel Lake and Shuswap Falls (Wilsey Dam) is surveyed each year by this method and it is believed that an accurate enumeration of the kokanee spawner population is achieved. Morris and Caverly (2002) describe the actual methods in greater detail.

On Adams Lake, Sinmax Creek was surveyed by visual ground counts on October 5, 15 and 25 and November 15, 2004; and the Momich River was surveyed on October 7 and November 15, 2004. Surveys for shore spawning kokanee in Adams Lake were conducted on the same days that the stream surveys were conducted for Sinmax Creek and the Momich River.

Insufficient data points and good carcass counts over time to obtain an estimate of residency time precluded the use of the area under the curve method (AUC) described by Hill and Irvine (2001) for determination of total numbers of spawning fish. As an alternative the crude method described by Andrusak and Sebastian (*in* Andrusak et al. 2000) of expanding the peak count by 1.5 was used.

Attempts were made to determine upper extent of spawning fish within each stream/river. This was done by using estimates based on locating obvious physical map features (barriers, log jams, smaller tributary inflow sites, etc.). The stream lengths were taken from Arcview TRIM coverages in meters and converted to km (see Appendix 3). Water temperatures were taken using a hand-held pocket thermometer and temperature loggers were placed in several key spawning streams where Water Survey Canada data is not available. Photos were also taken of some key spawning sites and these are on file in the Kamloops office of WLAP.

In 2004, fish samples were obtained from the identified primary spawning streams on Machete Creek (Eagan Lake), Eagle River (Shuswap Lake), Upper Shuswap River (Sugar Lake), Middle Shuswap River (Mabel Lake), Lupin Creek (Bonaparte Lake), Sinmax Creek (Adams Lake), and Lower Shuswap River (Mara Lake). Where possible, fish samples (50 male and 50 female per stream) were collected to determine fecundity, fork length, weight and age. Additional samples were obtained from shore spawning kokanee in East Barriere Lake. Only females whose eggs were still in the skeins were used for fecundity determination.

Fish samples were collected using several methodologies, including; gill netting for pre-spawn kokanee in lake habitat and for shore spawners, beach seining (Eagle River, Middle Shuswap River and Lower Shuswap River) and dip netting (Lupin Creek).

For fecundity determination skeins from "green" females were removed whole and boiled for five minutes and then the eggs were enumerated by direct egg counts. Scales and/or otoliths were collected for age determination and read by independent contractors.

IPSC methods of kokanee capture were usually by beach seine although gill nets were used to capture some pre-spawners in the lakes. Most of the kokanee were captured during the course of sockeye assessments. A regression formula was used by IPSC biologists to convert female standard fish length to numbers of eggs. The formula was based on raw data from a large number of fish from Eagle and Lower Shuswap kokanee. The formula used was:

Log eggs = 0.00592*log (SL [mm]) + 1.2453

Virtually all the IPSC fish lengths were measured as standard lengths. To compare with recent data collected by DFO and or BC Fisheries, a regression formula of fork vs. standard length was developed. Both standard and fork length measurements were made in 1954, 1959 and 1962 on a small number (n=63; R^2=0.97) of Shuswap Lake kokanee and this data was used to generate the following equation:

Fork length = 1.1381* standard length (mm) - 9.9248.

Additional dual measurements will be sought to improve on this formula. Fecundity was often reported as means but sample size was most often not recorded.

Age analysis by IPSC biologists was done by reading fish scales. The file data shows considerable efforts were made to age kokanee including counts of individual circuli. Unfortunately, sample size was seldom recorded but most of the data appears to have been derived from large samples. Aging of the 2001-2004 data was conducted by reading otoliths from spawners and scales from gill net captured fish.

RESULTS

The study lakes vary considerably in size, depth and productivity (Table 1). Lakes such as Shuswap and Adams that have been well studied, were not sampled for biological data to the same degree as those lakes where there is either no data or very little.

Table 1. Key attributes of the 13 study lakes including Lupin lakes.

Lake	TDS	Surface Area (ha)	6m Surface Area	Mean Depth (m)	Maximum Depth (m)	Approximate Length of Lake (km)
Mahood	84	3,311	179	94	208	20
Machete	62	440	122	6.2	10.6	7.5
Young	78	340	275	29	66	10
Eagan	92	411	≈380		25	4.5
Lupin #1	27	5.4		n/a	2.1	1
Lupin #2	27	28		n/a	9.8	1.5

Bonaparte	70	3,367	296	40	98	17
Saskum	80	111.6	22	18	34	1.7
N. Barriere	99	520	10	34.7	54	7
E. Barriere	104	994	207	48	100	11.5
Adams	57	13,760		169	457	62
Sugar	45	2,080	480	35	83	12
Mabel	99	5,986		120	201	35.5
Shuswap	80	30,960		62	162	73 + 64 = 137
Mara	82	1943		18	46	17

Escapements

Bonaparte-Clearwater Area Lakes Group

The survey crew began walking the spawning streams for this group of lakes in early Sept. 2004. Appendices 4 and 5 provide the details of survey dates and results of the 2004 spawner counts at each lake.

Saskum Lake

Saskum Lake is located on the northeast side of the North Thompson River in the upper reaches of the Barrier River watershed (Fig. 4). The outlet of Saskum Lake flows south and west for approximately 20 km before entering North Barriere Lake.

This lake continues to be a conundrum in terms of identifying where kokanee spawn. Gill netting results during 2002-2003 and again in the summer 2004 confirmed the presence of kokanee in this lake but no spawners were observed on the shoreline, nor in Upper Barriere River or the small tributaries. The entire shoreline was surveyed on July 8th to better define potential spawning habitat and again on September 21st but no spawners were observed. In previous years this lake was flown by helicopter in November and the entire shoreline observed by boat expecting to see some shore spawning since none had been found in the streams. Based on confirmation that deep water spawning occurs in the East Barriere Lake (see below) it is almost a certainty that deep water spawning also occurs in North Barriere and Saskum lakes.

Machete Lake

Machete Lake is located in the headwaters of the Bonaparte River (Figs. 2, 3) and it is known to support kokanee as evidenced by the observations made in 2001. The few fish observed in 2001 were spawning approximately 3 km upstream of the lake but beaver dams near the lake appear to obstruct upstream movement. No kokanee were observed in upper Machete Creek in 2002 despite ten days of observations that took place from mid-August to late Sept. On Sept. 10, 2003, some 50 spawners were found on the stream bank, dragged there most likely by avian predators. Extremely low stream flow (stream width only 1. 5 m, 0.1 m deep) made it easy for predators to capture the spawners. Local residents had removed a beaver dam at the stream outlet into the lake in late August, allowing about 50 fish to move upstream. In 2004 only one survey day was spent on this system and no spawners were observed. It is not surprising to see spawner presence in one year then none the following year (Table 2) as upper Machete Creek is marginal kokanee habitat strewn with beaver dams that no doubt can cause total obstructions to fish passage.

Eagan Lake

Eagan Lake is located downstream and west of Machete Lake (Figs. 2, 3). Lower Machete Creek flows out of Machete Lake for approximately 4 km before it enters Eagan Lake. In 2002, Lower Machete Creek was ground surveyed on eight occasions from mid August to early October and kokanee were observed in the second and third weeks of September. An apparent peak count of 350 was made on Sept. 4th. The 2002 peak count was a week earlier and the 2001 count was three times higher (Table 2). The spawner count for 2003 was 43,500 on Sept. 11th when the stream temperature was 9.2°C. A single count of 10,000 was made on September 16 2004 and spawners were observed within 100 m of Machete Lake. Beaver dams that are problematic in this stream were not evident in 2004 hence the reason why spawners were seen so far upstream, close to Machete Lake.

Bonaparte Lake

Bonaparte Lake is located south of Machete and Eagan lakes (Fig. 3) and is much larger than either of them with a surface area of about 3,325 ha with a mean depth of 40 m and maximum depth of 98 m. The major inflow and primary kokanee spawning sites exist in the form of a series of very shallow basins and wetlands collectively called Lupin Lake(s). Several other tributaries to the lake have steep gradients that offer little spawning habitat for kokanee and are not considered significant contributors to kokanee production. The outlet of the lake has a low level dam constructed to augment fish flows in the Bonaparte River and for agricultural irrigation. The outlet river (Upper Bonaparte River) flows in a northwest direction where it joins the outlet of Eagan Lake to form the Bonaparte River. The only tributary checked for spawners was the outlet stream from the Lupin Lakes chain. In 2004 three separate counts were conducted on September 6, 12 and 16th (Table 2; Appendix 4). A peak count of just over 16,578 was made on September 6th. In terms of timing, the 2004 peak count was one ten days earlier than the peaks (assumed) determined in previous years. In 2001, the highest count was on Sept. 15th; in 2002 it was on Sept. 12th, and on Sept. 16th in 2003. The 2003 estimate represents the lowest recorded in the five years of comparable data.

Young Lake

This lake is located on the south side of the Bonaparte River watershed 18 km downstream and west of Eagan Lake (Fig. 2). No spawner enumerations were conducted in 2004. In 2001, no spawning kokanee were upstream in the Bonaparte River. In 2003, only one day was dedicated to enumeration on the Bonaparte River and some 1,850 Young Lake spawners were counted in the vicinity of the Forest Road Bridge (≈ 1 km upstream from the lake).

Table 2. Kokanee escapement records (peak counts) for study lakes in the Bonaparte-Clearwater area.

Lake	Stream	1992	2000	2001	2002	2003	2004
Mahood	Canim River				100	n/a	n/a
	Deception			0	0		
Machete	U Machete Cr.			47	0	50	0
Eagan	L. Machete Cr.			1,043	350	43,500	10,000
Bonaparte	Lupin Lake (s)	6,034	6,950	25,880	4,180	2040	16,578
Young	Bonaparte River			1	1,600	1850	n/a

Shuswap-Adams Lakes Area: Saskum; North and East Barriere; Adams, Shuswap; Mabel; and Sugar Lakes.

North and East Barriere Lakes

These two lakes flow in a south westerly direction into the Barriere River, which in turn flows into the North Thompson River (Fig. 4). A large amount of time has been directed at locating spawning kokanee in these two lakes since it is known that kokanee are present in both lakes. In 2002, North Barriere Lake was checked extensively for spawning kokanee on 11 separate days from mid August through to mid November, including seven days when helicopter overflights were conducted. These surveys focused on potential stream spawners while shore spawners were the focus of the checks in October and November. Gill netting at the mouth of the Barriere River in mid August did not yield any kokanee that may have been staging there. There were seven kokanee observed in the Barriere River on Sept. 5, 2002, and these fish were intermixed with spawning sockeye. No other kokanee were observed on any other dates in 2002.

In 2002, seven days of observations from mid August to mid October on East Barriere Lake streams and shoreline resulted in no sightings of kokanee spawners. The mouth of the East Barriere River was also gill netted on August 13, 2002, in an attempt to capture staging spawners but none were captured. In 2003, the lake was flown on November 6th and the entire shoreline was checked but no spawners observed. The conclusion was made that kokanee in both lakes must spawn in deep water.

In 2004 the Barriere River and Harper Creek were surveyed on October 18th but no spawners were observed. Gill netting in July and October yielded immature kokanee (Appendix 3). Finally, persistence by the survey crew paid off with gill netting capturing mature kokanee in East Barriere Lake on December 2 and 10 2004. These fish were dark colored and ripe and were captured in sinking gill nets set at depths of 30-50 m.

Adams Lake

Adams Lake is a large, very deep and relatively unproductive lake best known for being the home of the world's largest sockeye run at the lake outlet. Early run (summer) sockeye utilize the Momich River and Upper Adams River and the juveniles rear in the lake but until recently, spawner numbers have been low. In 1997 DFO fertilized the lake in an effort to increase zooplankton production for sockeye (Hyatt et al. 2004). This work appeared to cause an increase in spawner numbers in 2001 but the 2003 and 2004 escapements have been greatly reduced due to aggressive harvest by the Fraser River commercial fishery. The more famous late run (fall) Adams sockeye that spawn primarily in the outlet (lower Adams River) coincides with the timing of the Shuswap Lake sockeye population that spawns in a number of tributaries.

The survey work on Adams Lake kokanee has tended to focus on both stream and shore spawners. In 2001, small numbers of kokanee were enumerated in Sinmax Creek (Fig. 5a) and the Momich River (Fig. 5b) and these two spawning streams were selected as primary index sites for enumerations from 2002-2004. DFO/First Nations operates a temporary salmon enumeration fence on Sinmax Creek, located approximately 0.5 km upstream from the lake, the timing of kokanee spawning in this system is known and some good historical escapement data is available. It should be noted that when installed for coho enumeration (usually part way through the kokanee run) this fence serves as a partial barrier to kokanee, and therefore, old DFO records of kokanee numbers were strongly influenced by actual date of fence installation. Nonetheless, the data is useful for comparing with data obtained from this four year study. The kokanee spawning run into Sinmax Creek is unusual, characterized by a very extended period of spawning spanning nearly two months with bimodality displayed in some years.

- *Sinmax Creek*

Wide fluctuations in spawner numbers utilizing Sinmax Creek were observed during the four study years. In 2001 a peak count of 1,761 was made with the survey crew finding evidence of later spawning. In 2002, there was a suggestion the escapement pattern was biomodal with a small peak in mid October and a larger peak (4864) in mid November. In 2003, kokanee spawners were already present in the stream on the first day the survey crew conducted a count. A peak count of about 10,500 was made on October 23rd (Fig. 8) and the true peak was probably about a week prior to that. Similar to 2002, a smaller second peak was recorded on November 13th (Fig. 9). The spawners observed on that day were "fresh", spawning amongst carcasses present from those spawners that were in the stream earlier by as much as six weeks. Undoubtedly, spawning superimposition occurred in 2003. The 2003 count was the highest recorded in three years but still falls considerably short of the numbers recorded by the Federal government in the 1950s.

In 2004 the survey crew walked Sinmax Creek on October 5, 15, 25 and November 15th-the time frame that spawners are usually present. Less than 100 fish were observed during the survey days and no shore spawners were observed during these same four days. Evidently there was a failure with the 2000 parental year since these fish are known to be age 3+ at maturity.

- *Momich River*

In 2001 a peak count of 737 kokanee was made based on four survey days. A count of 3,200 spawners was made on October 18, 2002, with no fish present in mid-November, so it appears these fish peak in their spawning activity in mid October. The Momich River was surveyed three times in 2003 (October 6, 8th and 29th). A count of 1,770 was made on the 8th with only a few hundred remaining on October 29th. In 2004 the shoreline area on the Momich River delta was surveyed on October 7, 15 and November 15th. No shore spawning activity was observed and only 104 spawners were estimated in the river.

Shore spawning

The very small numbers of kokanee stream spawners observed in Adams Lake tributaries is troubling and led to the conclusion in 2003 that shore spawning must be the preferred method of spawning in this lake. In 2003 the survey crew spent some time looking for shore spawners during November. Boat surveys were conducted on November 12th, 14th, and 20th. Small groups of shore spawning kokanee were observed in four locations: Skwaam Bay (outlet area for Sinmax Creek); Bush Creek alluvial fan, Momich River delta; and Honeymoon Bay, located some 50 km north of Skwaam Bay. The Skwaam Bay site had the largest numbers in 2002 (≈ 1,000) and in 2003 the estimate was ≈ 2,000, most of which were spawning underneath boat docks on the south side of the bay. A helicopter flight revealed that these fish spawn to depths of ≈ 8 m. Only a few hundred spawners were observed off Bush Creek while about 100 were observed at the Momich River delta and Honeymoon Bay during a helicopter flight on November 6th. The lake surface temperature on October 29th was 11.7°C the optimum temperature when shore spawning seems to commence in Okanagan Lake (Andrusak et al. *in* Andrusak et al. 2003).

The 2004 survey revealed that little if any shore spawning occurred despite reasonable effort directed at locating spawning fish. Skwaam Bay has been the site of most observed shore spawning yet none were seen in 2004. The inescapable conclusion is that Adams Lake currently supports very few kokanee unless deep water spawning remains undetected. Although this form of spawning may occur there has been no anecdotal information recorded on floating spawned out fish as has been the case in othe lakes known to have deep water kokanee spawners (Morris and Caverly 2003).

Historical Data

The IPSC data file provided some good historical escapement data from Sinmax (Pass) Creek illustrated in Figure 9. Despite somewhat different enumeration methods it is fairly evident that far greater numbers of kokanee spawned in this stream in the 1950s and 1960s compared to the estimates made in the 2000s. Sinmax Creek appears to be the primary Adams Lake spawning stream and the present day escapement levels are less than 50% of the historic numbers. Kokanee counts in the Momich River from the IPSC files were sparse but some 1,400 were estimated in 1954 and 1,500 in 1958, comparable to most of the estimates in the 2000s.

The lack of appreciable numbers of kokanee in such a large lake is problematic suggesting that in-lake competition with sockeye juveniles may be a problem as is the case in Quesnel Lake (Sebastian et al. 2004).

Shuswap Lake

There is a wealth of information on salmon (sockeye, coho and chinook) that spawn in the Shuswap Lake system. Perhaps the most studied lake in British Columbia, Shuswap Lake (Fig. 6) is the primary nursery system for the Adams River sockeye population. In recent years the chinook salmon numbers have been on the increase. The lake also supports one of the largest kokanee populations in British Columbia and certainly the most kokanee of any of the study lakes. Shuswap Lake supports the largest sport fishery for kokanee of any of the study lakes, although the harvest level appears to be less than 10,000.

Survey work in 2001 and 2002 led to the general conclusion that so few kokanee spawned in the smaller streams compared to the Eagle River that they were not critically important to assess. This decision was based on the overwhelming numbers (> 1.2 million) estimated in the Eagle River in 2001 and again in 2002 (≈400,000). In 2003 and again in 2004, the Eagle, Seymour, and Anstey rivers were surveyed by helicopter in mid-Sept. (Appendix 4). In the last two survey years considerably fewer kokanee were observed in the Eagle River with the 2003 estimate at 50,000 and the 2004 numbers estimated on September 23rd at 120,650 (Fig. 10). The Seymour River in 2003 had ≈100 with the same number in 2004. However this latter count was based on only one flight at the expected peak of spawning. Similarly ≈200 spawners were noted in the Anstey River in 2003 but none in 2004 (Fig. 11).

Historical Data

The IPSC files revealed some good escapement estimates for the Eagle and Anstey rivers. However, there is some uncertainty as to whether or not the entire Eagle River was enumerated or only a portion as suggested by notes on file, so these estimates probably represent the majority fish but are definitely under-estimates. Spawner numbers appear to be higher today than in the 1950s and 1960s. The huge swings in numbers during the last four years are somewhat troubling, possibly explained by interspecific competition with the dominant sockeye cycle (2002). The Anstey River escapement estimates (Fig. 11) are perhaps more reliable because the river length and available spawning habitat is much smaller. Regardless, there were greater numbers of spawning kokanee in this river in the 1950s and 1960s compared to the low numbers estimated from 2001-2004.

Given the importance of kokanee as forage for piscivores and their contribution to the Shuswap Lake sport fishery it is imperative that more effort should be directed at determining the Eagle River escapement numbers. This system should be monitored annually as a measure of relative abundance of kokanee.

Mara Lake

Mara Lake (Fig. 6) appears to be an extension of Shuswap Lake and was not surveyed as a separate lake in 2001. However, juvenile nerkids otoliths samples analyzed for strontium: calcium ratios indicated that resident salmonids (i.e., kokanee) were present (Volk 2000), therefore, this lake for this report is treated as one separate from Shuswap Lake. However as noted below (biological data section) there still remains doubt as to the origin of all the kokanee in this system. A single count of Lower Shuswap River (located between Mara and Mabel lakes) spawners on October 13 2004 resulted in an estimated 124,350 fish. Previous peak counts were low at 3,600 (2002); 7,800 (2003) and an intermediate 50,300 in 2001 (Fig. 12).

Historical Data

The IPSC files provided some good estimates of peak kokanee spawner numbers in the Lower Shuswap River for the 1950s and 1960s (Fig. 12). Estimates have been as high as 337,000 with the majority ranging from 50,000-100,000. The file notes also indicate that estimates were made only for portions of the river so these annual estimates are low. The key point is that most of the historical annual escapements, even if only partial counts, exceed the 2001-2004 estimates.

Mabel Lake

Most Mabel Lake kokanee appear to spawn in the middle Shuswap River although there are several other streams that have some good kokanee spawning habitat, e.g. Wap Creek. Chamberlain et al. (2001) reported that Mabel Lake kokanee spawn in the Middle Shuswap River downstream of Wilsey Dam (located 55 km upstream of Mabel Lake) with the majority spawning in the lower half of the river (Fig. 7). Kokanee spawning habitat in this river has been impacted for several decades by fluctuating flows due to hydro generation. Recent operational changes have improved the conditions for spawning kokanee (Chamberlain et al. 2001). The flow is also regulated by Peers Dam located at the outlet of Sugar Lake some 27 km upstream of Wilsey Dam.

In 2003 and 2004, the river was assessed using the same methods employed by Chamberlain et al. (2001) that involved a helicopter overflight on one day followed by a drift boat count the next day to confirm the helicopter estimate. The 2003 estimate by drift boat was much higher than the helicopter overflight with ≈ 34,000 estimated from the boat compared to only 7,000 by air. In 2004 far fewer spawners were observed with a peak count of only 5,231. A similar very low estimate of only about 3,600 was made in 2002 but in 2001 the estimate was ≈ 43,500 (Fig. 13). Since the aerial surveys were conducted at known time of peak spawning it can be concluded that few kokanee spawn in this stream despite an apparent abundance of good spawning habitat.

The 2003 survey was too late (October 21st) to observe any kokanee in Wap Creek but none were observed on October 8 2004 despite spawners being present in the Middle Shuswap River. In 2001, Wap Creek was surveyed from the air on three separate days (Sept. 27, October 2, 22) with the highest count of 2,500 made on October 2nd but in 2002 only one count (n=27) was made on October 7th.

Historical Data

Good estimates of kokanee spawners were found in the IPSC files for the Middle Shuswap River, Bessette Creek, and Wap Creek (Appendix 6). The estimates for the Middle Shuswap River (Fig. 13) for most years in the 1950-1960s exceeded 10,000 with some years ≈ 50,000. Bissette Creek numbers were not included in these estimates with most years approximating 7,000. The counts from 1986-2004 for the Middle Shuswap included Bessette Creek, therefore, the historical numbers appear to have been far higher than recent years estimates.

Sugar Lake Reservoir

Sugar Lake outlet has a dam (Peers Dam) that operationally can result in a maximum drawdown of nearly 7 m (Chamberlain et al. 2001). The major tributary is the Upper Shuswap River that has some excellent kokanee spawning habitat with the majority of fish spawning in the mainstem river between Spectrum and Vigue creeks (Chamberlain et al. 2001). Sugar Lake was originally stocked with kokanee but today this population is self-sustaining and considered a “naturalized” wild population. In 2003, this system was flown three times (Sept. 5th, 19th, and 29th) and a peak count of slightly over 27,000 was estimated on Sept. 29th. This estimate is by far the highest recorded, compared to the 2001 estimate of 3,500, and 2002 estimate of only 2,100. In 2004 two aerial flights were made (Sept. 14; Oct 8) and viewing conditions were poor with only 4,500 fish estimated on October 8th (Fig. 14).

Biological Data

The final year (2004) of this survey work focused on those lakes where little data has been collected to date and or those lakes where future work is anticipated. In 2003, samples were obtained through gill netting or from spawners from all the lakes, except Shuswap, Sugar and Mabel lakes. Since these three lakes are expected to be subject to further work beyond the scope of this project sampling them in 2004 was a priority. Additional field effort (gill netting) was directed at Saskum, East and North Barriere lakes in an effort to identify deep water shore spawning. Some limited fecundity data was obtained from some samples and an emphasis was placed on ageing kokanee from all the lakes by reading otoliths from spawners or scales from summer caught fish.

Length-at-Maturity, Age and Fecundity

Eagan Lake

Because the 2003 escapement into Machete Creek was very large (43,500) it was easy to obtain a good sample of Machete Creek spawners and therefore the 2004 spawners were not sampled. From 2001-2003 the size of spawners has been highly variable with extremely large fish sampled in 2001, followed by very small fish in 2002 (Fig. 15a). Spawner size in 2003 (Fig. 15b) was intermediate with mean size 236 mm (n=106) compared to 361 mm in 2001 and 190 mm in 2002. All of the 2002 (N=9) and 2003 (N=106) samples were aged by reading otoliths and were determined to be age 2+ with the exception of one 2003 fish aged as 3+. In 2002, a mean fecundity of 332 (range 183-458) was determined from 29 females that averaged 235 mm. Fecundity of 44 females sampled in 2003 was 335 (range 183-458 s.e. 10.8, s.d. 72) with a mean size of 235 mm, virtually identical to 2002.

Young Lake

No biological samples were collected from Young Lake in 2004. A small sample of gill netted fish in July 2002, suggested two age groups based on two distinct modes evident in the length-frequency distribution (Fig. 16a). Age determinations by scale reading of a few of these fish indicated two small fish (< 130 mm) were age 1+ while the fish ranging in size from 170-220 cm were age 2+. Gill nets were set on July 9, 2003, and a reasonably large sample (N=107) of kokanee was obtained. The length-frequency distribution of the 2003 samples also portrayed two modes; a mode at 120 mm and the other at 180 mm (Fig. 16b). No samples were obtained from the 2003 spawners observed in the Bonaparte River but in 2002 spawners sampled (n=87) in August to September were very small (mean size 185 mm) and showed little growth between July and September. These fish were all aged as 2+ (n=85). Fecundity of 11 females from the 2002 sample averaged 206 (mean size=190 mm).

Age determinations of the 2003 gill net samples confirmed results from 2002, i.e., the smaller mode (110-140 mm) were age 1+ and those from 160-210 mm with some evidence of sexual maturity were age 2+.

Machete Lake

No biological samples were obtained from Machete Lake in 2004. In 2003, some success was achieved in capturing a few kokanee from Machete Lake. On July 11, 2003, gill nets captured 23 kokanee and the length-frequency histogram (**Fig. 17**) suggests two age groups with a mode evident at 170 mm and the other at 300 mm. Age determination confirmed that the smaller mode were age 2+ and the larger mode were ages 3+.

Bonaparte Lake

Spawners captured in Lupin Lake streams from 2001-2003 were quite small (**Fig. 18**) ranging in size from 190-250 mm. In 2004 a few samples (n=11) were obtained from gill nets set in Bonaparte Lake in June and a large sample (n=85) was obtained from Lupin Creek in September 2004 (**Fig. 19**). The gill net samples were comprised of ages 1+ and 2+ fish while the spawners that were aged were predominately age 3+ (n=49) with a few aged as 4+ (n=11) (**Fig. 20**). These fish appear to be quite slow growing and the mean size of spawners for 2004 was only 217 mm (n=85).

The 2004 spawner size was actually slightly larger than the 2003 mean of 206 mm (n=13) that were all age 3+ but virtually the same size as those measured in 2002 (mean 214 mm, n=98). The 2002 spawners were aged (n=-95) as predominately age 3+ (n=85) with a few as ages 2+ and 4+. Fecundity samples were obtained primarily in the years 2002 and 2004. In 2002, mean fecundity of 43 females was 214, very similar to that of comparable sized kokanee from Meadow Creek on Kootenay Lake. Only two females were sampled in 2003 with egg counts of 227 and 319. In 2004 the mean fecundity of 33 samples was 332 and the mean for all data (n=78) was 276. The 2004 fecundities were much higher than 2002 values and they appear to be much higher compared to Arrow Reservoir kokanee and Kootenay Lake North Arm kokanee. Such wide variance in fecundity is unusual and warrants further study especially since this lake should support much greater numbers of kokanee (see below).

A regression of egg vs. length for all samples (**Fig. 21**) results in a regression formula of:

$$\text{Log } Y = 3.1946 * \log L \text{ (mm)} - 5.023.$$

Saskum Lake

Gill net sampling from 2002-2004 confirmed kokanee do reside in this lake. Summer gill netting yielded samples that were bimodal with one mode at 120 mm with a second mode at 200 mm (**Fig. 22**). These modes for all years were aged as 1+ and 2+ based on the largest sample (n=55) obtained in 2003. Despite fairly intensive observations of the streams and shoreline over four years no spawners were observed. It is suspected that deep water spawning occurs in Saskum Lake similar to those found in East Barriere Lake.

North Barriere Lake

Gill netting during 2002-2004 also produced a few kokanee demonstrating that they do inhabit this lake. However locating spawners proved difficult leading to the conclusion that they must spawn in deep water. Despite setting sinking nets late in 2004 no spawners were captured as was the case in East Barriere Lake (see below). Most of the 2003 gill netted (surface nets) fish were immature, comprised largely of age 1+ (size range 107-135 mm) with two age 2+ (155-175 mm) (**Fig. 23**).

East Barriere Lake

Similar to North Barriere Lake locating spawning kokanee proved very difficult. However, finally in late 2004 a few spawners were obtained by gill nets set at depths of 30-50 m. Mature males and females (N=8) were captured on December 1st and 15th thereby confirming deep water spawning. Two immature fish (172, 193 mm) were also captured on these dates (**Fig. 24**). The mature fish (mean= 231 mm) ranged in size from 220-248 mm and were all aged as 4+. The older age at maturity determined in 2004 was reaffirmed when 23 samples from 2003 gill netted fish were determined to be mostly age 4+ (n=20) with three as age 3+.

Adams Lake

A large number of spawners were obtained from Sinmax Creek on October 6th and 23rd, 2003 but only two spawners were sampled in 2004 since there were virtually none present (<100). The 2003 fish were identical in size to those captured in 2002 (**Fig. 25a, b**) with a single mode evident at 300 mm. Of the 161 fish measured the mean was 294 mm having a small range from only 248 mm to 334 mm. Such a large mean size with a very narrow size range results in a far different regression formula [eggs vs. fork length] (**Fig. 26**). The 2002 (n=41) and 2003 fish (n=76) were all aged as 3+ while two samples obtained in 2004 were also age 3+. A few fish (n=14) were obtained from the Momich River in 2003 and their mean size (287 mm) was similar to those from Sinmax Creek. From the 2003 sample 13 fish were aged as 3+ while one fish was found in the Momich River in 2004 and aged as 3+ (283 mm).

Few shore spawners were observed in Adams Lake during this four year study. A few spawners were sampled Sqwaam Bay (n=27) at the outlet of Sinmax Creek and from the alluvial fan area of Bush Creek (n=29) during 2002. All of these fish were age 3+.

The IPSC files provided some data on age and fecundity for kokanee sampled primarily from Sinmax Creek in the 1950-60s (Table 3). Mean fecundity for the 1950s and 1960s ranged from 354-715, quite comparable to this study's results. Female spawners obtained in 2002 and 2003 were examined to determine if eggs were still in the skeins. Intact skeins were preserved and the eggs counted at a later date. The 2002 mean fecundity was 606 (n=21) [range 240-700 s.e. 17, s.d. 68] and the 2003 mean count was 602 eggs/female (n=59) [range 309-986, s.e. 19, s.d. 144]. These kokanee are larger and more fecund compared to Kootenay Lake or Arrow Reservoir kokanee but similar in size to Okanagan Lake kokanee. Age-at-maturity was consistently recorded by IPSC biologists as 3+. Otoliths obtained from 73 fish in 2003 were also aged as 3+.
MARLA---IN THE TABLE BELOW ADD AGE 3+ TO THE 02 SAMPLES PLEASE

Table 3. Age and fecundity of Sinmax Creek kokanee.

Year	53	54	55	56	57	58	60	61	62	63	02	03	04
Mean fecundity[1]	490	458	354	369	497	687	410	635	715	688	606	602	n/a
Mean age (M&F)	3+	3+	3+	3+	3+	3+	3+	3+	3+	3+		3+	3+

[1] Log egg = 0.00592 log (mm) + 1.2453 used for data 1953-1963

Shuswap Lake

Shuswap Lake kokanee spawners are found in a number of streams but by far the Eagle River supports the vast majority therefore most biological data was obtained from this system. No samples were obtained in 2003 but reasonable numbers were obtained in 2001, 2002 and 2004. For the three years these fish ranged in size from 249-320 mm with a mean of 285 mm, just slightly smaller than the size of Adams Lake kokanee. In 2002 and 2004, some 29 "green" females were sampled to determine a mean fecundity of 527 (range 237--794). These kokanee are comparatively large and should provide good recreational fishing for anglers during the summer months.

Historical Data

There was a reasonable amount of kokanee data found in the IPSC files but much of it was not comparable with contemporary data either because standard lengths were measured or no sample size was provided. Gill net data from summer of 1954 and 1959 are shown in the top portion of Figure 27 to illustrate possibly three age groups with the larger sized fish (230-280 mm) most likely mature fish. This group of fish would continue to grow to the size of mature fish measured over the years from the Eagle River. Some comparable data from beach seined Eagle River spawners (females only) in 1962 were similar in size to those captured in 2001, 2002 and 2004 (Fig. 27).

Age-at-maturity data was also available for a number of years as shown in Table 4. Unfortunately, sample size(s) were not available but based on other ISPC data sets it is believed that sample sizes were generally > 30. In any event, standard lengths were provided and these have been converted to fork length based on a regression formula (y = 1.08 x SL (mm) + 7.56) derived from 23 measurements made from Eagle River fish in 1962 when both standard and fork lengths were recorded. The majority of Eagle River kokanee spawn as age 3+ but a few fish were aged as 2+. This was confirmed when 103 fish from 2002 were all aged as 3+ while a sub sample of the 2004 data (31 males; 30 females) was aged with confidence as age 3+.

Table 4. Size-at-maturity (standard and fork lengths), age of Eagle River kokanee and mean fecundity determined by IPSC biologists (1953-1963).

	Male				Female				
	Age 3 (2+)		Age 4(3+)		Age 3(2+)		Age 4 (3+)		Mean Fecundity
Year	S	F	S	F	S	F	S	F	
1953			256	281			248	272	517
1954			255	280			247	271	524

1955	188	204	255	280	188	204	249	273	476
1956			220	240			214	234	321
1957			202	220			199	217	280
1958			220	240			215	235	344
1959	200	218	259	285	200	218	246	270	503
1960			245	269			240	263	330
1961			233	255			226	247	439
1962			253	278			248	272	561
1963									845
2001				290				275	
2002				297				284	585
2004				283				276	455

Mara Lake

Of this projects' study lakes Mara Lake has been the most baffling and least understood. For a considerable period of time the origin of middle Shuswap River kokanee has been uncertain. Does Mara Lake support its own population of kokanee or do these spawners originate from Shuswap Lake? This question puzzled IPSC biologists (see historic information below) and remains unsolved to this day. Analysis of otolith Strontium:Calcium ratios by Volk (2000) indicated that Mara Lake trawl captured juvenile nerkids consisted of sockeye and resident kokanee. Data from this study that supports the hypothesis that Mara Lake has its own kokanee population separate from Shuswap Lake include: (a) there is nearly a month difference in timing between the Eagle River spawning run and the lower Shuswap River run; (b) mean size of Eagle River fish in 2002 was 290 (n=103) while the lower Shuswap River kokanee mean was 311 (n=105) and in 2004 it was 279 and 289 mm respectively; and, (c) fecundity of 36 lower Shuswap River females in 2002 was 679 compared to 585 for Eagle River kokanee (note: too few samples were obtained in 2004 to make any comparisons). The IPSC fecundity data ranges from 231-289 for lower Shuswap River fish compared to 280-845 for Eagle River fish (Tables 4, 5).

Due to the uncertainty of origin of lower Shuswap River kokanee there was greater emphasis placed on sampling Mara Lake in 2004. Gill netting in June and July 2004 yielded only one kokanee, a surprising result since identical fishing in all the other study lakes produced varying numbers of kokanee. The 2004 spawner samples from the Lower Shuswap River tend to support the theory that these fish are not from Shuswap Lake—at least based on size. Sizes of these spawners were significantly larger ($P < 0.01$) than those sampled from the Eagle River in both 2002 and 2004 (**Figs. 28a, b**). However, age analysis shows these fish are nearly identical to Eagle River fish despite the size differences. The 2002 spawners from Lower Shuswap River were aged as 23+ (n=1050. Only 7 samples were obtained in 2003, and 6 of the 7 samples were age 3+ with 1 aged as 4+. In 2004 51 otoliths from Lower Shuswap River were aged and all were age 3+, the same age as the Eagle River spawners.

In summary, the size data appears to support the theory that Mara Lake has its own population of kokanee that spawn in the Lower Shuswap River. The age data indicates they spawn at the same age as Eagle River kokanee. Clearly this information is by no means conclusive and therefore it is instructive to turn to the historical data found in the IPSC files in an attempt to better understand the origin of Lower Shuswap River kokanee.

Historical Data

Additional IPSC file data has been uncovered that provides more insight into the source of Lower Shuswap River kokanee. Evidently this question was of particular interest to F.J. Ward of the IPSC who spent a considerable amount of time in the early 1950s investigating Shuswap Lake kokanee that were thought to be competitors with sockeye salmon. It was also felt that sockeye cyclical dominance could be explained by studying the life history of kokanee since it was assumed that they would also display cyclical dominance in concert with sockeye. Goodman (1958) later summarized the IPSC data on Shuswap Lake kokanee and concluded that kokanee were neither serious competitors nor did kokanee fluctuate in sequence with the quadrennial dominance found in the sockeye population.

Ward (1953, 1954, and 1955) was intrigued by the differences in timing and size of kokanee that migrated to the Eagle and Lower Shuswap rivers. The following excerpts illustrate Ward's thought process:

From Ward (1953):

"The mean circuli counts of Eagle and Anstey River spawners are very similar (Table VII) indicating that the same or a similar environment was utilized by both these races during the first year of growth. It is immediately apparent that the Lower Shuswap River race differs greatly from the other two stocks. The circuli count of this race was only eight. The Lower Shuswap River flows into Mara Lake and thence into Shuswap Lake (Figure 5). It is possible that kokanee fry are reared in Mara Lake which is a poor producer of trout and perhaps a poor producer of kokanee. If the Lower Shuswap kokanee spent all their life in Mara Lake one would expect the mean length of the resulting spawners to be considerably less than the lengths of either Eagle or Anstey spawners, however such is not the case. Lower Shuswap fish are slightly smaller but the difference could be caused by sampling errors.

To explain this discrepancy the theory is presented that Lower Shuswap kokanee fry enter Mara Lake where they spend one year and then migrate into Shuswap Lake where they grow more rapidly to maturity. Netting operations during the summer of 1953 carried out of Shuswap Lake near the mouths of the Eagle and Lower Shuswap yielded eleven maturing fish of brood year 1949. The mean first year circuli counts of this group was 9.4 rings. This count suggests that the catch was composed of both Lower Shuswap fish and Eagle River fish. During October scale samples from maturing fish of brood year 1949 were obtained from the B. G. Game Dept. These samples were *obtained after the Eagle River and Anstey River populations had spawned. Either these fish were about to enter the Lower Shuswap R. or were fish of some unidentified race. This last possibility cannot be disregarded but a survey of various streams did not reveal any additional populations. The mean first year circuli count of this sample of twenty-one fish was 9.01. This count is higher than that obtained from the Lower Shuswap spawning ground collection (Table VII) but the discrepancy could be accounted for by the small numbers of fish involved in this gill-net catch. Further investigations are required on this problem."*

From Ward (1954):

"Gill nets were set off the mouth of the Lower Shuswap River in Shuswap Lake at the time that Lower Shuswap fish if they were in Shuswap Lake might be expected to be moving upstream on their spawning migration. Table X1 shows the mean first year circuli counts of the gill net caught kokanee of the Lower Shuswap spawners and of the River spawners.

Table X1. *Mean first year circuli counts of kokanee caught off the mouth of the Lower Shuswap River and from the Lower Shuswap and Eagle River spawning grounds.*

	First year circuli count
Gill net sample	*8.87*
Lower Shuswap River spawners	*8.20*
Eagle River spawners	*11.24*

It will be noted that the gill net samples resembles the Lower Shuswap spawning ground sample more than it does the Eagle River sample. Furthermore the peak of spawning of the Eagle River fish is approximately Sept. 15 about a month before Lower Shuswap peak of spawning. All of the fish were gill netted Sept. 20 when no mature Eagle River fish should have been in the vicinity."

From Ward (1955):

"Lake of Origin of Lower Shuswap Kokanee

The characteristics of the nuclear area of the scales of Lower Shuswap kokanee are very different from those of other streams tributary to Shuswap Lake. The ring-count is about three rings lower than any of the other streams yet the mean length of the spawners is about the same. Stan Killick made the suggestion that perhaps the Lower Shuswap population spent its first year in Mara Lake and then went down to Shuswap Lake. We then had to be sure that they went into Shuswap Lake at all. This fall we set some gill-nets in Shuswap Lake off the mouth of the Lower Shuswap at the time when the Lower Shuswap run should have been migrating. A number of fish were caught at *this location. The ring-count of these fish is compared with the ring-counts of the spawning ground samples from the Lower Shuswap and Eagle Rivers.*

Location	***No. in Sample***	***Mean Nuclear Ring Count***	***Peak of Spawning***
Eagle River	*189*	*10.9*	*Sept. 20*
Lower Shuswap	*172*	*7.7*	*October 15*
Gill net sample (caught after Sept. 25)	*95*	*8.2*	

Obviously the gill-net sample and the Lower Shuswap spawners are most similar. The mean of a gill-net sample caught nearly in June was 9.7. This catch was composed of members of both populations."

Some limited age-at-maturity data for Lower Shuswap River kokanee was found in the IPSC files. Table 5 summarizes the data that was felt to be reliable with the standard lengths converted to fork lengths. These fish are relatively large compared to Mabel and Sugar Lake kokanee and the historic data suggests they are similar in size to the Eagle River fish.

Table 5. Size and age-at-maturity of Lower Shuswap River kokanee.

Lower Shuswap River

		Male				**Female**				
		Age 2+		**Age 3+**		**Age 2+**		**Age 3+**		**Mean Fecundity**
Year	**N**	**S**	**F**	**S**	**F**	**S**	**F**	**S**	**F**	
1953				256	281			249	273	
1954		224	245	256	284	224	245	251	276	
1955		200	218	242	269	200	218	236	259	
1956				220	245			220	240	
1957				210	234			207	226	
1958				224	249			221	242	
1961				251	279			245	269	
1962				268	297			261	287	
2001										
2002	105								311	679
2003	7				290				304	
2004	52				293				287	

S-standard length (mm)
F-fork length (mm)

Taking into account the contemporary and historical data leads to some tentative conclusions:

Lower Shuswap River kokanee spawners are a different spawning population than those found in the Eagle River. However, given the apparent low numbers in Mara Lake based on the 2004 gill netting results some portion of the population may rear in Mara Lake before moving into Shuswap Lake until maturity. This life history strategy would be comparable to the Seton-Anderson sockeye where the majority spawns in upstream Anderson Lake but most of the juveniles' rear in Seton Lake (Geen and Andrews 1961). The possibility of a separate Mara Lake population cannot be discounted. This issue could possibly be resolved by capturing some migrant fish at the mouth of the Lower Shuswap River at Sicomous, tagging them and look for the tags in Lower Shuswap River spawners. At the same time additional gill netting Mara Lake during early summer would also confirm presence of "resident' kokanee in the lake, i.e., older age groups.

Mabel and Sugar Lakes

Good samples of Middle Shuswap River kokanee were collected on October 3, 2003 (N=70) and on October 6, 2004 (N=79) during the course of spawner counts. These fish were much smaller than those measured in 2001 (Fig. 29). The 2003 fish (N=73) were all aged as age 3+. The 2004 sample (N=58) were comprised of mostly age 3+ fish although two were aged as 2+ and one as 4+.

No samples were collected from Sugar Lake kokanee that spawned in Upper Shuswap River in record high numbers during 2003 (Fig. 14) nor in 2001 or 2002. Sugar Lake at time of writing was also being assessed for bull trout spawning distribution therefore additional information will become available (WLAP Penticton office files). A few kokanee spawner samples (N=14) were obtained during 2004. These fish were all aged as 2+; mean length 241 mm (range 228-254 mm) and mean fecundity for six females was 333 (range 268-393). These fish were of comparatively good size and should provide for some excellent summer fishing. File data from 1974 confirms this assertion; a sample of 42 Sugar Lake sport caught kokanee in July 1974 averaged 20.4 cm and ranged in size from 17.1 -22.5 cm.

Historical Data

The IPSC files did have some data on Mabel Lake kokanee but none for Sugar Lake since it is inaccessible to salmon, and therefore, was of little interest to federal government biologists. Mabel Lake kokanee were aged by IPSC biologists predominantly as age 3+ at maturity with a few age 2+ spawners noted for a couple of years (Table 6). Age determination from otoliths for the 128 fish reviewed from the 2003 and 2004 data indicated that 98 % (N=125) were age 3+. Fecundity data was obtained from Mabel Lake during 2001-2004 but the IPSC file data suggests mean fecundity was much lower than kokanee from Adams, Shuswap, or Mara lakes ranging from 167-399 with most years around 250+.

Table 6. Size-at-maturity and age of Middle Shuswap River kokanee.

	Mabel Lake								
	Male				Female				
	Age 2+	Age 2+	Age 3+	Age 3+	Age 2+	Age 2+	Age 3+	Age 3+	Mean Fecundity
Year	S	F	S	F	S	F	S	F	
1953	168	181			164	177			
1954			195	212			194	211	167
1955			180	195			176	190	194
1956			200	218			196	213	262
1957	198	215	209	228	197	214	202	220	276
1958			244	268			235	258	399
1960			188	204			184	199	222
1961			191	207			186	202	222
1962			210	229			201	219	272
1963									334
2001									n/a
2002				196				192	n/a
2003				196				191	n/a
2004				188		167		196	n/a

DISCUSSION

Results of this four year survey project provide a solid basis for future fisheries management work on the study lakes. Initial years work was exploratory focusing on locating spawners and identifying key spawning streams. The final two years In particular provided some much needed basic biological data for most of the study lakes. In 2004 the emphasis was on trying to locate deep water spawners in Saskum, North and East Barriere lakes. Increased biological sampling for Bonaparte, Shuswap, Mabel, Mara, Mabel and Sugar lakes was also a priority in 2004 since these systems are likely to be the focus of more intensive fisheries management effort.

Little effort was directed towards Eagan, Machete and Young lakes in 2004 and only minimal effort was directed towards Saskum, East and North Barriere lakes during the summer. The latter three lakes were known to be inhabited by kokanee but shore or stream spawners had not been identified. It was learned in 2002 that a DFO survey employee working on nearby Dunn Lake recalled observing darkened, morbid kokanee washing out of the lake onto a coho fence in late November. He also confirmed that no spawning kokanee had been seen in the stream or shoreline. For this reason periodic gill netting was conducted from October-December in Saskum, North and East Barriere lakes. Spawners were finally captured in East Barriere Lake on November 30th and December 15th at depths of 30- 50 m just days before the lake froze over. Ice on Saskum and North Barriere lakes during the same time period prevented the survey crew from confirming spawners at similar depths.

Age determinations from 2003 and 2004 data were completed thus providing some good insights into kokanee growth in the study lakes. The age and fecundity data for Bonaparte Lake kokanee (Lupin Creek kokanee) was the most surprising. These fish were small but quite fecund and were represented by three age groups that completely overlapped in size. Most kokanee spawners in the other study lakes were age 3+ with Sugar Lake kokanee the exception (age 2+).

The 2002 report provided a summary of the stocking history of the study lakes (Appendix 1). Mahood Lake has been influenced by kokanee plants in upstream Canim Lake and was dropped from the 2003 and 2004 surveys. Kokanee appear to have become naturalized in Machete Lake after an initial planting of kokanee fry occurring in 1989 and virtually every year since then. This suggests that Eagan Lake almost certainly has been influenced by these transplants given its location downstream of Machete Lake.

Bonaparte Lake has not been stocked with kokanee, therefore, kokanee in Young Lake are probably of wild stock origin although downstream spawner displacement from Machete and Eagan Lakes and upstream migration and spawning in Bonaparte Lake streams cannot be ruled out.

East and North Barriere lakes were stocked with Meadow Creek kokanee eggs and fry in the late 1940s and early 1950s (Appendix 1). The vast majority of the stocking(s) were with eyed eggs and it is unlikely that these introductions had much influence on wild stocks that are assumed to have been present prior to any introductions.

Shuswap Lake was also stocked with Meadow Creek kokanee eggs and fry in 1914 and in the 1940s and 1950s. Again these introductions were virtually all eyed eggs and the impact on the wild stock was probably insignificant given the numbers of wild fish that were probably present then as well as today (≈ 0.5-1.5 million spawners annually).

A review of stocking techniques dating back well over the last half century brings into question the effectiveness of many of the kokanee plantings. Eyed eggs were the most common form of stocking until the 1960s and most often the eggs were planted into streams or rivers that in retrospect were poor candidates for kokanee. During this era basic kokanee biology was poorly understood such as accumulated thermal units (ATUs) and eggs were often planted into streams that could not provide sufficient heat units in the spring to ensure fry emergence during spring plankton blooms. Many streams and lakes were planted with kokanee eggs that to this day do not support any kokanee spawning. Having said this, some transplants were successful and Sugar Lake is one such example. This lake was stocked with eggs and some fry from 1950-1952 and these plantings clearly must have survived since there is no record of a wild population prior to stocking.

The review of historical kokanee stocking indicates that Bonaparte, Saskum, Adams, Mara and Mabel lakes have never been stocked, and therefore, it is believed their kokanee populations are indigenous. It is most likely that Shuswap Lake kokanee are also of wild origin despite some kokanee eyed egg plants and two years of fry plantings in the 1950s.

Similar to results from the previous three years, spawning kokanee observed in tributaries of lakes surveyed in the Bonaparte-Clearwater area peaked in mid September. Minimal effort was directed at spawner enumerations in these lakes during 2004 but again, enumerating kokanee in lower and upper Machete creeks was problematic due to dense overhanging brush and beaver dams making good counts difficult to make. No fish were observed in Machete Lake (upper Machete Creek). Single counts were made in 2004 of Eagan Lake spawners (~10,000) and Bonaparte Lake spawners (~17,000) with the Bonaparte numbers higher than the previous two years and close the ≈ 26,000 recorded in 2001. The low spawner numbers in 2002 and 2003 in Bonaparte Lake put into question why this lake appears to produce so few fish considering the size of the lake. Since no other tributary stream supports much, if any spawning kokanee, either shore spawning occurs undetected or there may be an in-lake production problem that warrants further investigation.

Wide swings in recruitment in Machete and Eagan lakes appear to occur because the primary spawning streams are partially or totally blocked by beaver dams. Evidently, in some years kokanee spawners move beyond the dams and good fry production results while in other years spawners are completely blocked and virtually no successful spawning takes place.

Timing of spawning runs in the study lakes around the Shuswap Lake basin appear to be later, with most peaking in late September or mid-October. The 2004 escapements (Figs. 10-14) were similar to 2003 and again mostly lower than runs observed in 2001 and 2002. The exceptions to this were the lower Shuswap River (Fig. 12) in 2004 (~124,000) and the 2003 Sugar Lake estimated escapement of ≈ 27,000 (Fig. 14). Escapements to Adams Lake streams and/or beach areas were again surprisingly low, similar to 2003. As mentioned previously, the 2004 gill netting results to date again confirmed that kokanee are in Saskum, East and North Barriere lakes. Deep water spawning was finally confirmed in East Barriere Lake at depths of 30-50 m. Similar depths of spawning are suspected for kokanee in Saskum and North Barriere lakes.

The 2004 escapement to Adams Lake streams was virtually non existent and considered highly unusual considering the size of the lake and the fact that over 100 km of stream is potentially available for spawning (Appendix 2). Sinmax Creek is the primary stream used as a measure of relative abundance and the 2004 estimate was < 100 spawners, the lowest year in the past four years. Spawner estimates in the study years fall far short of the historic numbers found estimated by the IPSC biologists in the 1950s (Fig. 9).

The Eagle River escapement (Fig. 10) in 2004 (~121,000) was higher than the 2003 (~50,000) estimate but far lower than 2001(~1.3 million) and 2002 (~0.4 million).). The historic data for the Eagle River from the 1950s and 1960s indicates much smaller numbers compared to the 2001 and 2002 estimates although the 1966 estimate was by far the highest (Fig. 10). However, it is believed that the IPSC estimates were made on only portions of the river therefore under representing peak counts. In the previous three years only a few hundred spawners were observed in the Anstey and Seymour rivers but none were observed in 2004 (Appendix 4). The Anstey River estimates suggest the run sizes in the 1950s were much higher than those recorded in recent years (Fig. 11).

The origin of Lower Shuswap River kokanee spawners remains unresolved although the 2004 data suggests they may be Mara Lake fish. Size, fecundity and run timing of these spawners is quite different compared to Eagle River fish. However, a reasonable amount of gill netting in Mara Lake in the summer 2004 yielded only one fish yet the lower Shuswap escapement was quite large (124,000) and similar in magnitude to those counted in the Eagle River i.e. netting effort on other study lakes suggest far greater numbers should have been caught in Mara Lake. However, the historic data for the lower Shuswap and Eagle rivers do not match in terms of timing or magnitudes of run size. Large escapements to the Eagle River in 1966 and 2001 were not paralleled by similar large escapements to lower Shuswap River. Furthermore, the large escapement to the lower Shuswap River in 1962 was the opposite to the Eagle River when the numbers were comparatively low.

The confusing and contradictory data between the two spawning populations leads to a potential third scenario. It is possible that Lower Shuswap River kokanee are from Shuswap Lake with Mara Lake serving as a juvenile rearing area similar to Anderson-Seton lakes where sockeye spawn in Anderson Lake streams but many of the progeny rear in Seton Lake (Geen and Andrews 1961). This theory was initially suggested by the early IPSC workers. Lack of kokanee captured in gill nets results in 2004 in Mara Lake certainly lends some credence to this theory. Only more intensive (future) sampling can resolve this interesting question about origin of Lower Shuswap River kokanee.

Mabel Lake kokanee spawn primarily in the Middle Shuswap River upstream from the lake to Bessette Creek, a distance of nearly 24 km. Bessette and Wap creeks are also important spawning streams. The 2004 escapement estimate of just over 5,000 (Fig. 13) is similar in magnitude to the parent year (2000) of about 3,000 since these fish are all age 3+ at maturity. In 2003, the estimate of 40,000 spawners in the river, including those in Bessette Creek, was comparable to the parent numbers reported in 1999 (47,000). The parent numbers in 2001 (≈42,000) means the 2005 escapement should be large. i.e. > 40,000.

Kokanee in Adams, Shuswap and Mara (?) lakes are considerably larger than most kokanee in BC with mean size approximating 30 cm. These fish are more fecund generally ranging in numbers from about 350-900 eggs per female. The larger size of these kokanee is not that surprising since they are rearing in comparatively more productive lakes and probably benefit from marine nutrient recycling as a result of huge numbers of salmon, particularly sockeye. The apparent lack of kokanee in Adams Lake is problematic unless of course undetected deep water spawning is occurring. The large size of these kokanee may reflect density dependent growth due to current low numbers.

In 2001, Mabel Lake kokanee were intermediate in size (Fig. 29) but the 2003 and 2004 fish were very small (19-20 cm) and some old file data placed 1974 angler catch size at 20 cm. Mabel Lake has good potential for fish production (trout and char) and currently supports a modest sport fishery; therefore, further investigation of the kokanee population is warranted given their small size and apparent vacant spawning habitat (e.g. Wap Creek).

Production Estimates

Although the kokanee data acquired to date greatly assists in identifying location of spawning in the 13 study lakes it falls short of providing insight into what kind of escapement numbers might be expected even if all streams were effectively enumerated at or near the peak of spawning. Ryder (1965) originally developed the morphoedaphic index (MEI) as a quick method of estimating potential fish yields from relatively unexploited north temperate fish populations. This index assumes depth is inversely proportional to production and that conductivity is a rough indicator of edaphic conditions hence some measure of productivity. The MEI is the ratio total dissolved solids (TDS) and mean depth of a lake and Northcote and Larkin (1956) demonstrated that these parameters can be primary indicators of productivity for a whole range of British Columbia lakes. In the 1980s, BC Fisheries biologists summarized kokanee data such as egg-to-fry survival rates and estimated sport fish yields from a number of the southern large lakes. They developed some crude estimates of theoretical kokanee yield per acre of surface water based on TDS and mean depth being primary indices of productivity.

For the study lakes, the MEI was plotted against the estimated kokanee yields (Anon 1987, MS) to determine potential yield at 5% and 10% egg-to-fry survival rates. These yields were then applied to the pelagic zone (> 20 m) surface area to determine the theoretical kokanee production levels at 5% and 10% survival rates (Table 7). Based on 5 kokanee per kilogram the number of kokanee that can be produced per lake was then calculated. Chamberlain et al. (2001) also used the MEI index to estimate theoretical kokanee production for Mabel and Sugar lakes.

A second method of estimating theoretical numbers of kokanee that a lake can produce is to use a biostandard of 5.6 kg·ha·yr estimated by Anon (1987, MS). Sebastian et al. (2000) used this value to make some crude estimates of theoretical kokanee production for Arrow Reservoir and these determinations were quite comparable to measured abundance (catch and escapement) data. Recent abundance estimates have been made using hydroacoustics for Arrow Lakes Reservoir and Kootenay Lake. These estimates are believed to be at a time when these systems are thought to be close to carrying capacity after several years of experimental lake fertilization. The yield estimates for Arrow Lakes Reservoir (4.8 kg·ha·yr) and 3.8 kg·ha·yr for Kootenay Lake are probably more realistic and up to date than the biostandard from Anon (1987, MS). The last column in Table 7 displays the theoretical estimate that each lake could theoretically produce using a biostandard of 4 kg·ha·yr.

Applying a biostandard of 4.0 kg·ha·yr to the pelagic area of the study lakes (> 20 m) results in theoretical estimates somewhat higher or lower than the estimated escapements that are on record. It is emphasized that these estimates should be used only as a guide for potential production levels based on numerous assumptions. For example, Eagan and Machete lakes cannot be expected to produce large numbers of kokanee due to their small size with both lakes also having annual production problems due to spawner migration disruptions in the form of beaver dams, therefore, "all or nothing" escapements occur. Smaller lakes such as Machete, Young, Eagan and Saskum are comparatively productive but shallow with available kokanee habitat (pelagic water) limited. Not surprisingly, the yield estimates for these lakes are low (Table 7) and realistic.

Spawner numbers for Saskum, East and North Barriere lakes may be impossible to determine with current technology since the fish spawn in deep water. Regardless, the yield estimates for these lakes indicate that large numbers are unlikely to be found, i.e., probably < 20,000 spawners per lake. Bonaparte Lake and Adams Lake escapement numbers are far lower than the calculated yield estimates and Mabel Lake numbers seem lower than would be expected. Shuswap, Mara and Sugar lake numbers appear to be close to the yield estimates. Based on the yield estimates for Adams Lake it is quite evident from the 2001-2004 survey results that escapements are very low and either large numbers of spawners remain undetected or the lake is under-producing kokanee possibly due to inter-specific competition with juvenile sockeye.

Table 7. Estimates of kokanee production for study lakes using (a) MEI and (b) 5.6 kg·ha·yr.

Lake	TDS	Mean depth (m)	MEI	Yield (kg/ha/yr)		Pelagic Area	Estimated Kokanee Production (kg) by MEI		Number of Adults Based on 5 fish/kg		Number of Adults Based on 4.0kg/ha/yr
				5%	10%	(ha)	5% S	10% S			
Mahood	83	94	0.27	1.3	2.2	3,132	4,072	6,890	20,358	34,452	62,640
Machete	58	6	2.95	3	7	318	954	2,226	4,770	11,130	6,360
Young	76	29	0.80	1.9	3.7	68	129	252	646	1,258	1,360
Eagan	78	6	3.96	3.5	7	30	105	210	525	1,050	600
Bonaparte	70	40	0.53	1.6	2.9	3,071	4,914	8,906	24,568	44,530	61,420
Saskum	80	18	1.36	2.4	4.5	93	223	419	1,116	2,093	1,860
N. Barriere	99	25	1.21	2.2	4.3	444	977	1,909	4,884	9,546	8,880
E. Barriere	72	48	0.46	1.6	2.8	991	1,586	2,775	7,928	13,874	19,820
Adams	57	169	0.10	0.8	1.8	13,760	11,008	24,768	55,040	123,840	275,200
Sugar	45	35	0.39	1.4	2.5	1,560	2,184	3,900	10,920	19,500	31,200
Mabel	85	120	0.22	0.90	1.8	5,283	4,755	9,509	23,774	47,547	105,660
Shuswap	80	62	0.39	1.50	2.5	30,960	46,440	77,400	232,200	387,000	619,200
Mara	82	18	1.39	2.3	4.5	1,943	4,469	8,744	25,026	48,964	38,860

Notes: Pelagic zone (> 20 m) unavailable for Adams, Mara and Shuswap lakes, therefore, used surface area. Eagan Lake pelagic zone was estimated @ 30ha since maximum depth is only 25 m.

On the basis of all available escapement data, and the theoretical yield estimates in Table 7, Adams, Bonaparte, Shuswap, Mara and Mabel lakes require further investigation since there is wide disparity between actual and theoretical estimates. For these lakes, there is either far more spawning than observed or there are in-lake production problems. Mara Lake requires further investigation to determine the origin of the Lower Shuswap River spawners.

Conservation plan

INTRODUCTION

The protection, maintenance and rehabilitation of native fish and their habitat to ensure their sustainability and diversity is the primary purpose of freshwater fisheries management. i.e. conservation. This four year investigation of kokanee inhabiting the thirteen study lakes has provided fisheries managers with a great deal of information previously unknown. Survey results also demonstrate that there is little known about the status of most of the kokanee populations, especially those in the large lakes. New information obtained from this study has been informative but is of little value unless it is used effectively to ensure conservation of kokanee into the foreseeable future.

Several strategic objectives need to be implemented and achieved to be successful in conserving kokanee in the study lakes. Foremost is the protection of fish habitat, especially critical kokanee spawning habitat. For some lakes more specific inventories of kokanee numbers need to be conducted while in at least two systems there is a need for some habitat restoration work. Population assessments and stock management through licencing and regulation is required on some of the large lakes, especially those supporting piscivorous stocks that rely on kokanee as forage. It is recognized that a “kokanee conservation plan” cannot be undertaken without understanding that a multitude of interactions at all trophic levels greatly influence and shape the size of the kokanee population (s). i.e. lake carrying capacity, extent of spawning habitat and predators. Paramount is protection of habitat that is undertaken by the Ministry of WLAP as part of its mandate. Therefore it is implicit that such work is constantly on-going and that there is daily communication between those responsible for habitat protection and fisheries managers who are focused on conserving and managing fish populations.

Overview

Results of the four year investigation of kokanee in the thirteen lakes provide some good indications of (future) priority activities for fisheries management. An overview of key findings is instructive in order to develop plans for future work:

1. Bonaparte Plateau Lakes

    - Small populations of kokanee were identified in Machete, Eagan and Young lakes with Mahood Lake mostly likely supporting a few fish that originate in Canim Lake that periodically has been stocked. The Machete Lake kokanee population originated from historic stocking and probably Eagan Lake was populated through downstream movement. The same could be true for Young Lake. The Machete and Eagan Lake populations appear to be small (< 10,000 spawners except Eagan in 2003 ≈ 44,000), limited by spawning habitat that is very marginal due to low flows, warm water and active beaver dam construction that periodically prevents upstream movement of kokanee spawners. These lakes have very limited pelagic habitat suitable for kokanee. There is little potential for improvement for these populations given the small size of the lakes and production constraints.

- Bonaparte Lake is relatively large (3,325 ha) with some good spawning habitat (Lupin lakes/stream chain) and sizeable pelagic area. This lake should produce far more kokanee than the numbers recorded (≈ 2-26,000) during this study. This lake has potential to produce 2-3 times more kokanee than current numbers indicate.

2. Clearwater-Barriere lakes

- Saskum, East and North Barriere lakes proved to be difficult to assess since no stream spawners were observed nor were shore spawners. However gill netting results indicated that kokanee resided in these lakes. By the end of year 3 deep water spawning was suspected and late in 2004 spawners were finally confirmed in East Barriere Lake through capture of kokanee in spawning condition by gill nets set in 30-50 m of water. These spawners were captured in December! It is virtually certain that similar spawning occurs in Saskum and East Barriere lakes. These lakes are relatively small and have limited kokanee production potential.

3. Adams Lake

- Despite its size, Adams Lake does not appear to support a very large kokanee population. Numerous small streams and two large inflowing rivers (Upper Adams and Momich rivers) provide ample habitat for spawning kokanee but very few (< 5,000) were observed in the rivers during the four study years. Sinmax Creek supported the largest number of spawners (< 10,000) enumerated in Adams lake streams between 2001-2004 but historical DFO records indicate spawner numbers were far higher (20-60,000) in the 1950s and 1960s. There was little evidence of extensive shore spawning with the exception being Skwaam Bay where Sinmax Creek enters the lake. A few thousand shore spawners were observed in 2002 and 2003 but virtually none (< 100) in 2004. Unless there's major undetected deep water kokanee spawning in Adams Lake it is fairly evident that this lake is under-producing kokanee possibly due to competitive interaction with sockeye. Adams Lake is fairly unproductive but theoretical production estimates suggest kokanee spawner numbers should be 100,000-300,000. Historically, the run of sockeye to Adams Lake in 1901, 1905 and 1909 was so great that every tributary was crowded with spawning sockeye," John Babcock, the first commissioner of fisheries for British Columbia said in a 1913 report.

- A logging company built a splash dam in 1908 just below the outlet of Adams Lake to flash-float logs down the Adams River. Spawning salmon were washed downstream by artificial floods that occurred six days a week. Between floods, the streambed nearly dried completely and only a few sockeye were able to spawn, severely impacting the famous lower Adams River run. The Upper Adams River run, almost entirely obstructed by a dam, was unable to reach its spawning ground. In 1922, the logging company ceased operation of the dam, and in 1945 the dam was removed.
- As far as can be determined, the Upper Adams sockeye run was driven to extinction by the combined effects of the splash dam and the effects of railway construction between 1911 and 1913 in the Fraser Canyon, that culminated in the Hell's Gate slide. No sockeye were observed in the Upper Adams River from about 1921 until 1954. Adams Lake is currently, fairly unproductive but theoretical production estimates suggest spawner numbers should be 100,000-300,000. In order to restore Adams lake fish stocks, including kokanee, to their historical size an aggressive fertilization program is required. Agencies, First Nations and stakeholders must all be involved. i.e. First Nations, DFO and MOE.
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4. Shuswap Lake

- Large but highly variable escapements were observed in the main spawning stream-the Eagle River. Over 1.2 million kokanee spawned in this river in 2001 but in the following three years the numbers ranged from 0.05- 0.5 million. All other rivers and streams support < 1,000 per year. It appears spawner numbers may be higher today higher than the 1950s and 1960s for the Eagle River but lower for the Anstey River, a moderately important kokanee spawning system. Shuswap Lake is comparatively productive and has the theoretical capacity to support over 0.5 million adult size fish per year. The competitive interaction between kokanee and juvenile sockeye requires further study.

5. Mara Lake

- The most important spawning stream associated with Mara Lake is the Lower Shuswap River. Gill netting in Mara Lake in 2004 yielded very few kokanee adding to the notion that this lake supports few kokanee with perhaps some fry inhabiting the lake during the first summer before moving into Shuswap Lake. This lake requires more study to understand the relationship between kokanee found in the two lakes. By itself, Mara Lake does not have a great deal of pelagic area with a potential of supporting < 50,000 fish. Considering the importance of kokanee to piscivorous rainbow trout and lake char sought in the Shuswap Lake fishery more kokanee spawner data is warranted and the origin of Lower Shuswap lake spawners requires more investigation.

6. Mabel Lake

- This lake was the third largest one surveyed in this study and has considerable potential for kokanee production. The Middle Shuswap River has supported upwards of 50,000 spawners but somewhat less than that in recent years. The high estimate during the four survey years was about 43,000 but the low was only about 3,600. Wap Creek offers good spawning habitat for kokanee but estimates over a number of decades have been < 10,000 with recent years < 3,000. The pelagic area is quite large having a potential to support between 50,000-100,000 adults. The river has been impacted by operations of a dam located mid reach as well as another dam located at the outlet of Sugar Lake. Size of these kokanee is troubling but even so anglers actively fish for them. This lake has potential to produce 2-3 times more kokanee than current numbers indicate.

7. Sugar Lake Reservoir

- This lake was originally stocked with kokanee in the early 1950s and since then the kokanee population has become naturalized. Peers Dam located on the lake outlet regulates Sugar Lake as much as 7.0 m. Spawner surveys during the last four years indicates wide fluctuations in numbers ranging from only 2,100 to nearly 27,000. This reservoir does have a moderate amount of pelagic area and but the theoretical carrying capacity suggests production would only be < 40,000 probably due to relatively unproductive water (TDS=45). The Upper Shuswap River offers an abundance of kokanee spawning habitat.

Priority Management activities

The general sense emanating from this study is that few gains can be made to increase kokanee numbers in any of the surveyed small lakes. Limited pelagic areas and or poor spawning habitat greatly reduce the potential for increased kokanee numbers in Machete, Eagan, Young, Saskum, North and East Barriere lakes. Mahood Lake may have some potential but is still regarded as a low-medium priority system. The absence of many if any (e.g. Barriere lakes) stream spawning kokanee in most of the lakes co-habited by sockeye was a recurring theme that warrants further investigation, most appropriately at the local university research level.

Criteria used for prioritizing those lakes where further work is recommended include:

- The potential for increased kokanee production based on theoretical yield estimates (Table 7 in report) and or historic records;
- Available spawning habitat based on survey results;

- Potential competitive interaction between kokanee and juvenile sockeye salmon;
- Potential for increased recreational use by increasing kokanee numbers;
- Benefits to predator species that utilize kokanee as forage.

A summary of some proposed tasks on the priority lakes can be found in Table 8.

It should be pointed out that a conscious decision was made not include in this study three kokanee lakes located south of Kamloops due to budget constraints. In particular Nicola Lake supports a good kokanee sport fishery and this kokanee population is threatened by severe water use problems. So serious are the issues on Nicola Lake that despite it not being included in this study it is essential that investigative work begin immediately if this population is to be protected and maintained.

Priority # 1- Adams Lake

This lake remains as one of two (i.e. Mara Lake) least understood after four years of survey work. Absence of any large numbers of spawning kokanee despite reasonable levels of field survey effort elevates the amount of uncertainty surrounding this lakes ability to produce kokanee. Actual numbers of spawners observed were far less than the theoretical yield estimates. Kokanee spawners were sparse in the larger rivers and the primary stream, Sinmax Creek, produced just over 10,000 in the highest study year (2003) compared to historic numbers ranging from 20-60,000. A few shore spawners were observed but unlike some of the other study lakes there has been no anecdotal information suggesting deep water spawning occurs. Sinmax Creek warrants special effort to protect the riparian zone and low flows need to be addressed. To better understand Adams Lake kokanee hydroacoustic and trawl survey data is required. This data may already exist since DFO regularly surveys the lake. A joint study between DFO and WLAP would be the appropriate strategy for further work on Adams Lake.

Priority # 2-Shuswap and Mara lakes

Shuswap and Mara lakes have high potential for improving kokanee abundance that could result in increased recreational sport fishing. As well, increasing the forage base for piscivorous rainbow trout, lake char and bull trout has the potential of ultimately increasing their abundance. Ample kokanee spawning habitat exists for kokanee in a number of the lakes' tributaries but these systems are most likely limited in kokanee production by poor egg-to-fry survival and juvenile sockeye competition for preferred zooplanktors. Shuswap Lake is moderately productive and there is some evidence of cyclical production as noted in the Eagle River kokanee escapement data. i.e. over one million kokanee in one year, < 200,000 the next year. Increasing kokanee numbers most likely will require better data on the in-lake interactions between juvenile sockeye and kokanee as well as identifying if competition occurs for spawning habitat between the two.

Currently the lake char and rainbow trout populations are being assessed to determine rate of exploitation in the fishery. The extent of piscivore predation on kokanee should be measured an could be done quite easily. Further work is warranted on the role of Mara Lake for Shuswap Lake kokanee and rainbow trout.

Priority	year	Lake	Stock	Action required	Description	Comments
1	2006	Nicola	wild	Habitat protection	Low stream flows	Base stream flows need to be obtained
				Monitor	Conduct spawner counts Hydroacoustic estimate required	total in-lake population estimate desirable
1	2006	Shuswap & Mara	wild	Habitat protection	Lower Shuswap River riparian threatened by agricultural encroachment and some possible logging	High potential for increasing kokanee production piscivore rainbow trout, lake char and bull trout could benefit
					Eagle River linear development threatens stream integrity	major study required to ensure kokanee and trout sustainability
				Monitor	sockeye-kokanee competitive interaction hydroacoustic and trawl survey to estimate total kokanee Confirm Lower Shuswap River kokanee origin-genetics	
				Restoration	evaluate LWD in Eagle and Lower Shuswap rivers	
2	2006	Mabel	Wild	Habitat protection	Middle Shuswap River flows and riparian habitat require stringent protection measures from hydro regulation and agricultural development	Update required on flow regime agreement Wap and Bisette creeks integrity requires review
				Restoration	River bank stabilization with LWD required Lake fertilization ??	Agricultural developments have impaired riparian zone
				Monitoring	Kokanee growth, age-at-maturity data required	kokanee growth appears limited due to lake productivity?

					Lake productivity estimates required Predator utilization of kokanee required	Good candidate for HCTF project
3	2007	Bonaparte	Wild	Habitat protection	Basic protection measures for spawning streams	lake has high potential to produce greater numbers of kokanee
				Restoration	Evaluate Lupin Lakes for gravel placement	ideal spawning sites within Lupin Lakes chain could be enhanced
				Monitor	Conduct hydroacoustic and trawl survey	total in-lake population estimate desirable
					rainbow trout biological assessment	piscivore rainbow trout could benefit good candidate for HCTF project
4	2008	Adams	Wild	Habitat protection	Basic shoreline and stream protection measures	
					Sinmax Creek and Bay threatened by agricultural and recreational home developments	Protection plan should be devised between WALP and DFO
				Restoration	Low flows of Sinmax Creek require immediate attention	Meter current water use
					Support DFO lake fertilization	Low lake productivity likely impacts kokanee more than sockeye
				Monitor	Hydroacoustic and trawl surveys to determine in-lake kokanee abundance in cooperation with DFO	Current data may be sufficient to segregate kokanee and sockeye #s Use Sinmax Creek as index of abundance site Joint DFO-WLAP investigations?
5	2008	Sugar	Stocked naturalized	Habitat protection	Stream protection measures should be vigorous for Upper Shuswap River and tributaries	Mainstem river between Spectrum and Vigue creeks key spawning habitat for kokanee; tributaries important bull trout habitat
				Monitor	Reservoir productivity estimates	Reservoir probably limits kokanee

					desirable	production; ample spawning habitat available
6	On going	South Barriere	Wild	Habitat protection Monitor	Basic shoreline and stream protection measures Assess deep water spawning	low potential for increasing kokanee production Gill net deep water sites to confirm spawning low priority system for further fisheries work
7	On going	North Barriere	Wild	Habitat protection Monitor	Basic shoreline and stream protection measures Assess deep water spawning	low potential for increasing kokanee production Gill net deep water sites to confirm spawning low priority system for further fisheries work Medium potential for increasing kokanee production
8	On going	Saskum	Wild	Habitat protection Monitor	Basic shoreline and stream protection measures Assess deep water spawning	low potential for increasing kokanee production Gill net deep water sites to confirm spawning low priority system for further fisheries work
9	On going	Young	Wild	Habitat protection	Basic protection measures for Bonaparte River	lake has low potential for producing kokanee
10	2009	Mahood	Stock ed?	Habitat protection	Basic protection measures for spawning streams	lake has potential to support modest numbers of kokanee very few spawners observed in Canim River below falls no further assessment required at this

						time
11	On going	Eagan	Natur alized	Habitat protection Restoration	Basic protection measures for lower Machete Creek Possible to reduce beaver activity by trapping beavers	lake has low potential for producing kokanee marginal stream habitat impacted by beaver dams low priority system for further fisheries work
12	On going	Machete	Stock ed	Habitat protection Restoration	Basic protection measures for upper Machete Creek Possible to reduce beaver activity by trapping beavers	lake has low potential for producing kokanee marginal stream habitat impacted by beaver dams low priority system for further fisheries work no further assessment required at this time

Priority # 3-Mabel Lake

This lake is ranked number two because it has ample spawning habitat and a large pelagic area capable of supporting kokanee numbers far in excess of what was observed during the study. Further, upstream retention of nutrients due to hydro development may have reduced Mabel lake production. This could possibly be compensated by small nutrient additions thus increasing lake carrying capacity. De-watering of the Middle Shuswap River during winter flows may also contribute to reduced kokanee production. The spawning streams most likely limit kokanee production due to poor egg-to-fry survival and the lake possibly limits kokanee growth due to juvenile sockeye competition for preferred zooplanktors. Large lake management techniques and remedial measures undertaken on Okanagan and Kootenay lakes should be instructive for improving Mabel Lake kokanee.

Priority # 4- Bonaparte Lake

This lake is ranked high because it has the capability of producing far more kokanee and additionally it supports a piscivorous rainbow trout population that could be improved through increased kokanee production. The Lupin Lakes chain has potential for increasing kokanee spawning habitat through some strategically located gravel platforms. However, juvenile rainbow trout assessment should be conducted prior to any gravel placement. Some lake productivity measurements and hydroacoustic survey data is also required. Atagai (1992?) provides a good summary of the rainbow trout population that reside in the lake.

Priority # 5-Sugar Lake

Although a lower priority than some of the other lakes, further work on Sugar Lake may be warranted. The wide fluctuations in kokanee escapements are somewhat surprising given the ample amounts of spawning habitat in the Upper Shuswap River. As a minimum escapement estimates should be made annually and some preliminary investigation of piscivore rainbow and bull trout should be considered as this reservoir does offer some potentially good recreational fishing opportunities.

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Figure 1. Location of 2001 Study Area Lakes in the Thompson River Watershed.

Figure 2. Location of survey lakes in the Upper Bonaparte Watershed.

Figure 3. Location of spawning kokanee observed in Upper and Lower Machete creeks, 2001and 2002.

Figure 4. East, North Barriere and Saskum lakes.

Figure 5a. Sinmax Creek located on the westside of Adams Lake.

Figure 5b. Momich River located on the eastside of Adams Lake.

Figure 6. Shuswap Lake illustrating locations of kokanee observed spawning in 2001.

Figure 7. Location of kokanee observed spawning in the Middle and Upper Shuswap rivers, including tributaries to Mabel and Sugar lakes.

Appendix 1. Historical stocking records for study lakes.

Lake	Release Date	Number	Stock	Stage at Release
Shuswap	1/1/14	275,000	Meadow Creek	Fry
Shuswap	1/1/42	75,000	Meadow Creek	Eyed egg
Shuswap	1/1/43	100,000	Meadow Creek	Eyed egg
Shuswap	1/1/44	100,000	Meadow Creek	Eyed egg
Shuswap	1/1/45	100,000	Meadow Creek	Eyed egg
Shuswap	1/1/46	100,000	Meadow Creek	Eyed egg
Shuswap	1/1/47	100,000	Meadow Creek	Fry
Shuswap	1/1/48	100,000	Meadow Creek	Eyed egg
Shuswap	1/1/49	100,000	Meadow Creek	Eyed egg
Shuswap	1/1/50	100,000	Meadow Creek	Eyed egg
Shuswap	1/1/51	70, 000	Meadow Creek	Eyed egg
East Barriere	1/1/47	100,000	Meadow Creek	Fry
East Barriere	1/1/48	100,000	Meadow Creek	Eyed egg
East Barriere	1/1/49	50,000	Meadow Creek	Eyed egg
North Barriere	1/1/47	100,000	Meadow Creek	Fry
North Barriere	1/1/48	100,000	Meadow Creek	Eyed egg
North Barriere	1/1/49	50,000	Meadow Creek	Eyed egg
North Barriere	1/1/50	50,000	Meadow Creek	Eyed egg
North Barriere	1/1/50	50,000	Meadow Creek	Eyed egg
Canimred Creek	1/1/40	100,000	Meadow Creek	Eyed egg
Canim Lake	1/1/45	100,000	Meadow Creek	Eyed egg
Canim Lake	10/22/45	100,000	Meadow Creek	Eyed egg
Canim Lake	1/1/46	100,000	Meadow Creek	Eyed egg
Canim Lake	10/12/46	100,000	Meadow Creek	Eyed egg
Canim Lake	1/1/48	100,000	Meadow Creek	Eyed egg
Canim Lake	10/15/48	100,000	Meadow Creek	Eyed egg
Canim Lake	1/1/49	100,000	Meadow Creek	Eyed egg
Canim Lake	10/27/49	100,000	Meadow Creek	Eyed egg
Canim Lake	1/1/50	100,000	Meadow Creek	Eyed egg
Canim Lake	11/9/50	100,000	Meadow Creek	Eyed egg
Canim Lake	1/1/51	100,000	Meadow Creek	Eyed egg
Canim Lake	10/24/51	100,000	Meadow Creek	Eyed egg
Canim Lake	1/1/52	50,000	Meadow Creek	Eyed egg
Canim Lake	10/29/52	50,000	Meadow Creek	Eyed egg
Canimred Creek	11/1/81	400,000	Meadow Creek	Unknown
Canimred Creek	11/1/82	444,600	Norbury	Unknown
Canimred Creek	11/1/84	221,100	Meadow Creek	Unknown
Canimred Creek	11/1/84	51,850	Norbury	Unknown
Canim Lake	10/1/85	546,000	Kikomun/Meadow	Unknown
Canim Lake	4/12/94	275,000	Hill Creek	Fry
Canim Lake	5/1/95	140,026	Hill Creek	Fry
Canim Lake	5/2/96	85,000	Meadow Creek	Fry
Canim Lake	6/5/98	30,372	Meadow Creek	Fry
Machete Lake	5/3/89	100,000	Meadow Creek	Fry
Machete Lake	4/10/92	30,000	Hill Creek	Fry
Machete Lake	4/26/93	40,000	Hill Creek	Fry
Machete Lake	4/26/94	50,000	Hill Creek	Fry
Machete Lake	4/26/95	45,000	Hill Creek	Fry
Machete Lake	4/26/96	45,000	Meadow Creek	Fry
Machete Lake	5/5/97	45,000	Meadow Creek	Fry
Machete Lake	6/3/98	45,000	Meadow Creek	Fry
Machete Lake	5/18/99	45,000	Meadow Creek	Fingerling
Machete Lake	5/29/00	65,000	Meadow Creek	Fingerling
Machete Lake	5/22/02	30,000	Meadow Deka	Fingerling
Machete Lake	6/6/02	5,000	Meadow Deka	Fry

Appendix 2. Approximate length of tributary streams potentially accessible for stream spawning kokanee in the study lakes.

Lake Name	Total Accessible Stream/Lake (km)	Individual Accessible Stream Length: Tributary Stream	Stream Length (km)
Machete Lake	8.9	Machete Creek	8.9
Eagan Lake	9.1	Machete Creek	9.1
Young Lake	21.2	Bonaparte River	21.2
Bonaparte Lake		Lupin Lakes	
Mahood Lake	9.9	Canim River	7.4
Saskum Lake	6.7	Barriere River	6.7
East Barriere Lake	12.9	East Barriere River	12.9
North Barriere Lake	52.6	Fennel Creek	15.8
		Harper Creek	19.4
		North Barriere River	10.5
		Vermelin Creek	6.9
Adams Lake	101.4	Momich River	8.0
		Sinmax Creek	17.5
		Upper Adams River	76.0
Shuswap Lake	304.6	Deception Creek	2.5
		Anstey River	21.4
		Celista Creek	28.2
		Eagle River	64.6
		McNomee Creek	13.6
		Rathford Creek	15.2
		Ross Creek	13.7
		Salmon River	70.7
		Scotch Creek	45.4
		Seymour River	29.4
Mara Lake	73.4	Lower Shuswap River	73.4
Mabel Lake	174.9	Bessette Creek	25.2
		Cherry Creek	13.1
		Ferry Creek	15.4
		Kingfisher Creek	21.8
		Latewhos Creek	7.4
		Middle Shuswap River	23.8
		Monashee Creek	7.5
		Tsuius Creek	7.6
		Wap Creek	52.9
Sugar Lake	91.3	Gates Creek	2.9
		Lindmark Creek	1.8
		Spectrum Creek	5.4
		Upper Shuswap River	74.5
		Vanwyk Creek	3.4
		Vigue Creek	3.2

Appendix 3. Date, location and species of fish captured by gill nets in North and East Barriere lakes, Saskum and Young lakes summer 2003.

Appendix 4. Summary of stream survey kokanee spawner counts 2004.

TO BE UPDATED BY MARLA

Stream Name	Lake Name	Date Surveyed	Survey Section	Stream Temp.	No. of live KO observed	No. of dead KO observed	Survey Method	Comments
Lupin Creek	Bonaparte Lake	3-Sep-03	Bonaparte Lake to 1st Lupin Lake	15.5	250	0	G	attempted to access Lupin Creek but backcountry access restrictions prevented a complete stream walk; KO count done directly above and below bridge crossing; fish holding, no fish spawning
		16-Sep-03	Bonaparte Lake to 1st Lupin Lake	7.5	2040	0	G	
		16-Sep-03	1st Lupin Lake to 2nd Lupin Lake	6.7	820	0	G	upper limit of kokanee just above 1st lake; 50% of fish spawning and 50% holding; no barriers to u/s migration although some small beaver dams and log jams may cause difficulty due to low flows; eagle and bear predation evident
		25-Sep-03	Bonaparte Lake to 1st Lupin Lake	8.0	300	3	G	
		25-Sep-03	1st Lupin Lake to 2nd Lupin Lake		582	12	G	no ko observed above the 2nd Lupin Lake

G-ground survey

Barriere River	Saskum Lake	16-Jul-03		9.8	0	0	G	walked lower 1.5 km; no KO observed
		6-Nov-03			0	0	H	conducted a helicopter overflight of shoreline and stream; no kokanee observed
		5-Dec-03						attempted to check Barriere and Saskum Lakes for late run shore spawning KO but no access due to snow and ice
Barriere River	North Barriere Lake	17-Sep-03	N. Barriere Lake to 1 km upstream	8.4	0	0	B/G	Set gill net at mouth-no KO captured; walked lower portion of the stream-no KO observed
		6-Nov-03	N. Barriere Lake to 6 km upstream				H	conducted a helicopter overflight of shoreline and stream; no kokanee observed, but a small group of potential redds were identified
		17-Nov-03			0	0	B	completed shoreline survey and set gill nets-both deep water and shoreline areas; no kokanee observed or captured; potential redds examined and no egg deposition observed-likely not redds
		5-Dec-03						attempted to check Barriere and Saskum Lakes for late run shore spawning KO but could not launch a boat due to snow and ice; surveyed 3/4 km of shoreline by foot-no KO observed

* DFO reports no KO observed instream during DFO sockeye stream walks.

Stream Name	Lake Name	Date Surveyed	Survey Section	Stream Temp.	No. of live KO observed	No. of dead KO observed	Survey Method	Comments
Barriere River	East Barriere Lake	6-Nov-03					H	conducted a helicopter overflight of shoreline and stream; no kokanee observed
		5-Dec-03					G	attempted to check Barriere and Saskum Lakes for late run shore spawning KO but no access due to snow and ice
Eagle River	Shuswap Lake	18-Sep-03	from mouth to 1st bridge	13.0	0	0	H	
		18-Sep-03	1st bridge to 2nd bridge		0	0	H	
		18-Sep-03	2nd bridge to 3rd bridge		750		H	
		18-Sep-03	3rd bridge to 4th bridge		950		H	
		18-Sep-03	4th bridge to 5th bridge		0		H	
		18-Sep-03	5th bridge to 6th bridge		20,300		H	
		18-Sep-03	6th bridge to 7th bridge		4,500		H	
		18-Sep-03	7th bridge to Perry R		1,850		H	
		18-Sep-03	u/s of Perry R		21,500		H	
		18-Sep-03	Perry River		350		H	
Eagle River		16-Oct-03					G	checked for late run October KO but no fish were observed
Anstey River	Shuswap Lake		lower km of river		~200		H	information from DFO sockeye overflights in Sept. and October
Seymour River	Shuswap Lake		lower km of river		~100		H	information from DFO sockeye overflights in Sept. and October
Wap Creek	Mabel Lake				0	0	H	No kokanee were observed in the Wap and no obvious redds, however it is a bit late for the WAP and flows were up from recent rainfall; water clear and viewing conditions good.

Stream Name	Lake Name	Date Surveyed	Survey Section	Stream Temp.	No. of live KO observed	No. of dead KO observed	Survey Method	Comments
Lower Shuswap River	Mara Lake	16-Oct-03						seined KO at lower bridge crossing; attempted to conduct a helicopter overflight to enumerate kokanee but we could not fly due to heavy rain and fog
		21-Oct-03	Enderby to Trinity Bridge		0	0	H	7800 spawning kokanee; high concentrations of fish in some specific areas; run size is not large compared to 2000 and 2001 where estimates are around 1 million; many vacant redds but still lots of active spawning in side-channels, the mainstem margins and in mainstem tail-outs; overcast conditions but good visibility in low, clear water.
		21-Oct-03	Trinity Bridge to the "Islands"		6,590			
		21-Oct-03	Above "Islands" to Cook Creek		1,190			
		21-Oct-03	Cook Creek upstream to Huppel		20			
Middle Shuswap River	Mabel Lake	7-Oct-03	Bessette Cr.		460	3	G	
			Bessette Cr. to Bigg Cr.	13.5	6,631	100	B	The kokanee are very small this year (average only about 150 mm) and lack the typical, bright red coloration. Many fish are spawning throughout the lower reach of the main river where substrate and velocity are suitable (in some cases right across the channel at a variety of depths) and are concentrated in several, shallow side-channels.
		8-Oct-03	Bigg Cr. to Mabel Lake		33,969	900	B	
Upper Shuswap River	Sugar Lake	5-Sep-03			650		H	KO observed during a Upper Shuswap BT tracking flight
		19-Sep-03			3,000		H	KO observed during a Upper Shuswap BT tracking flight; very poor visibility
		29-Sep-03			27,100		H	

Stream Name	Lake Name	Date Surveyed	Survey Section	Stream Temp.	No. of live KO observed	No. of dead KO observed	Survey Method	Comments
Sinmax Creek	Adams Lake	30-Sep-03		12.1	5,000	0	G	site visit with Harvey Andrusak; count only a rough estimate - we did not walk the entire length of spawning; fish observed staging at mouth
		2-Oct-03	from lake to ~4km upstream	12.3	8,041	180	G	KO evenly distributed throughout survey length; few fish holding, most spawning
		6-Oct-03	from lake to ~4km upstream	12.6				no count conducted; seined for biological samples, collected 50 males and 50 females
		23-Oct-03	from lake to ~4km upstream	8.6	10,530	2,500	G	conducted count with Adams Lake Band members; no fish observed holding, all fish spawning
		6-Nov-03	from lake to ~4km upstream				H	conducted a helicopter overflight of Adams Lake and Sinmax Creek; fish observed holding in lower portion of Sinmax Creek, suggesting a third run of pre-spawn fish into the stream
		13-Nov-03	from lake to ~4km upstream		3,702	1,370	G	
		5-Dec-03						checked for any late run KO, none observed
Momich River	Adams Lake	6-Oct-03		12.3			G	no count conducted; KO paired up and spawning
		8-Oct-03	from Adams Lake to Momich Lakes	12.0	1,770	124	G	
		29-Oct-03	from Adams Lake to Momich Lakes		271	35	G	

Appendix 5. Summary of kokanee shore spawner survey results 2003.

Lake Name	Location	Date Surveyed	Lake Temp.	No. of live KO Observed	No. of dead KO observed	Comments
Adams Lake	Skwaam Bay	2-Oct-03	16.5	800	20	surveyed for shore spawners - fish observed spawning in Skwaam Bay (south of boat launch among docks and on south shore of bay) - utilizing small gravels at shoreline
	Skwaam Bay	6-Nov-03		2,000		surveyed for shore spawners - fish observed spawning in Skwaam Bay (south of boat launch among docks and on south shore of bay) - utilizing small gravels at shoreline to depths of approximately 25 ft; helicopter flight allowed greater visibility of redds and shore spawner estimates from shore and boat are likely missing 1/2 the KO present
	Momich River confluence	29-Oct-03	11.7	100	60	surveyed for shore spawners - fish observed spawning just north of Momich River confluence - digging redds in small gravels, tight to shoreline;
	Momich River confluence	6-Nov-03		30	10	surveyed for shore spawners during helicopter overflight
	Honeymoon Bay	6-Nov-03		~ 100		surveyed for shore spawners during helicopter overflight- small group of KO observed spawning at Honeymoon Bay (west shore of Adams Lake)
	Bush Creek	6-Nov-03		~ 200		surveyed for shore spawners at the mouth of Bush Creek - small group of KO and a few SK observed
Saskum Lake	entire lake shoreline	6-Nov-03	8.9	0		conducted helicopter overflight for shore spawning; no redds or KO observed
North Barriere Lake	entire lake shoreline	6-Nov-03		0		conducted helicopter overflight for shore spawning; no redds or KO observed
	entire lake shoreline	17-Nov-03	5.4	0		conducted boat survey; no KO observed in stream or along shoreline; surveyed entire shoreline; set gill nets along south shore; no redds observed in lower portion of stream; ~ 4 potential redds observed but no sign of egg deposition
East Barriere Lake	entire lake shoreline	6-Nov-03		0		conducted helicopter overflight for shore spawning; no redds or KO observed

Appendix 6. Historic data obtained from IPSC files on kokanee escapement estimates for Adams, Shuswap, Mara, Mabel and Sugar lakes. Note: EFS means effective female spawners used by IPSC biologists; these numbers have been converted assuming 1:1 sex ratio.

Adams Lake Peak Kokanee Spawner Estimates

	Sinmax (Pass) Creek			Momich River			Skwaam Bay	Momich Bay	Bush Cr. Bay	Honeymoon Bay
Year	**Peak Spawning**	**EFS**	**Peak**	**Peak Spawning**	**EFS**	**Peak**	**Peak**	**Peak**	**Peak**	**Peak**
1945			500							
1947			10,000							
1952	Nov 3-visit	2,750	5,500							
1953	Oct 27-30	1,323	2,645	approx. Oct 21	35	69				
1954	Oct 24-30	26625	57,691	Oct 18-24	4025	8,050				
1955	approx. Oct 15-18	21,373	42,746							
1956	Oct 18-20	8,740	17,480	none observed	0	0				
1957	Oct 18-21	5,175	10,350							
1958	Oct 20-approx	9,419	18,837	approx. Oct 20	750	1,500				
1960	Oct 15-18	10,925	21,850		5	9				
1961	Oct 11-18	5,635	11,270							
1962	Oct 25-29	13,823	27,646	before Oct 29	288	575				
1963	Oct 4-approx	5,000	10,000							
2001			1,761	Oct-18		737				
2002			5,503	Oct 18-24		3,200	1,000	15	200	60
2003			10,530			1,770	2,000	100	200	100

Shuswap Lake Peak Kokanee Spawner Estimates

	Eagle River			Anstey River			McNomee Creek			Seymour River		
Year	**Peak spawning**	**EFS**	**Peak**	**Peak spawning**	**EFS**	**Peak**	**Peak spawning**	**EFS**	**Peak**	**Peak spawning**	**EFS**	**Peak**
1946			present									
1947			present									
1949		100,000	200,000									
1953	Sept 1-15	115,000	230,000	Sept 12-20	17,280	34,500						
1954	Sept 15-20	27,252	48,208	Sept 10-15	1,166	2,332	Sept 1-10	44	22	Sept1-10	144	288
1955	Sept 11-15	42,150	84,300	Sept 8-10	221	442						
1956	Sept 15-18	21,965	43,930		0	0						
1957	Sept 15-23	103,500	207,000	Sept 16-?	5,175	10,350						
1958	Sept 12-18	38,773	77,545	Sept 20-25	2,990	5,980						
1959		4,000	8,000		1,250	2,500						
1960	Sept 17-25	16,675	33,350	no visit								
1961	10-Sep	104,995	209,990							Sept 8-12	3,985	7,970
1962	Sept 5-9	37,500	75,000	Sept 18-25	978	1,955		Present			present	
1963	Sept 8-18	30,223	60,446	approx. Sept 20	978	1,955						
1966		1,000,000	2,000,000									
2001	Sep-14		1,275,000	Sep-14		1,200				Sep-14		200
2002	Sep-18		405,300			300						10
2003			50,200			200						100

Mara Lake Peak Kokanee Spawner Estimates

	Lower Shuswap River		
Year	Peak Spawning	EFS	Peak
1950			100,000
1953	approx. Oct 26	4,600	9,200
1954	Oct 10-15	54,236	111,711
1955	Oct 15-18	33,695	67,390
1956	Oct 20-23	62,100	124,200
1957	Oct 18-24	57,500	115,000
1958	Oct 18-21	43,355	86,710
1961	Oct 15-18	18,769	37,536
1962	before Oct 18-24	168,500	337,000
1963		40,000	80,000
1965			75,000
1966			50,000
2001			50,300
2002			3,690

Mabel Lake Peak Spawner Numbers

Year	Middle Shuswap River			Bessette Creek			Noisy Creek			Wap Creek			Cottonwood Creek		
	Peak Spawning	EFS	Peak	Peak Spawning	EFS	Peak	Peak Spawning	EFS	Peak	Peak Spawning	EFS	Peak	Peak Spawning	EFS	Peak
1946											present			present	
1947											present			present	
1949					present										
1950												500			
1953									0						75
1954	Oct 1-6	4,704	9,407				Oct 4-8	895	2,358			856			
1955	Oct 3-5	25,760	51,520	Oct 1-4	3,921	8,634	Oct 2-5	366	731	Sept 30-Oct 4	428	2,530			0
1956	Oct 1-3	10,523	21,045	Oct 1-2	2,415	4,830	Oct 1-2	55	110	Oct 2-5	1,265	1,0695	Oct 8-12	604	1,274
1957				Oct 4-8	2,300	4,600				Oct 1-3	5,347		Oct 4-7	848	1,695
1958	Sept 25-Oct 1	7,935	15,870	Sept 25-Oct 1	103	205	Sept 28-Oct 5	141	281			393	Oct 1-3	271	541
1959					21	41		87	173	Sept 28-Oct 5	197				
1960				Sept 25-28	4,025	8,050									0
1961	1-Oct	16,675	33,350	27-Sep	4,629	9,258						2,000			800
1962	approx. est. Sept 25	6,532	13,064	Sep-25	1,840	3,680						2,000			800
1963	approx. Sept 18	25,000	50,000	18-Sep	7,820	15,640						2,000			800
1986			7,220												
1991			17,040			5,590									
1993			38,710												
1994			23,433												
1999			47,000												
2000			2,818												
2001	Oct 4-5		41,518			960				Oct 1-3		2500			
2002			3,608							Oct-07		27			
2003			33,969									0			