Review of Resident Game Fish Life History and Abundance Information for Babine Lake

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Skeena Fisheries Report #156

March 15, 2008

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1. Introduction

Babine Lake is the largest unimpounded lake entirely within the province of British Columbia, and likely receives more annual angler days than any other lake in Skeena Region. It is also the most important sockeye salmon nursery lake in the Skeena watershed, at present providing roughly 80% of the sockeye production in the Skeena system and thus supporting economically important commercial fisheries in the marine and freshwater environments.

The significance of Babine Lake's sockeye rearing environment led to substantial research in the 1950s and 1960s by the Department of Fisheries and Oceans into production constraints in the lake and its tributaries. These efforts culminated in the construction of three artificial spawning channels during the late 1960s and early 1970s, which greatly increased the sockeye smolt output and adult returns to the lake. Since that time, additional investigation has been directed to evaluating the success of the enhancement projects and the ongoing changes in the lake's fish production environment.

Despite the extensive research into the Babine Lake's limnology and sockeye rearing capacity, minimal effort has been directed to an understanding of the ecological relationships and productivity of its freshwater-resident fish populations including those which supply the regionally-important recreational fishery on the lake. However, concern for the status of the sport fish stocks, particularly rainbow trout, led to several studies during the latter half of the 1980s. These included an angling use survey, inventory of rainbow trout spawning streams, and an assessment of the abundance, life history an spatial distribution of the Sutherland River spawning population of rainbow trout. A draft management plan was prepared (de Leeuw 1990), and angling regulations for the lake were modified to reflect the results of the rainbow trout studies.

To revisit the status of the Babine Lake's recreational fishery and sport fish populations and evaluate the success of the present management approach, a concise summary and analysis of existing sport fish life history information is needed. Accordingly, the terms of reference for Ministry Service Contract CSKEN07114 included among its deliverables a report containing the following material:

1. descriptions and critical evaluation of the available information base;
2. evaluation of trends of Babine Lake's past and present limnological and chemical properties;
3. descriptions of resident sport fish population life history characteristics:
    - age, growth, maturity,
    - habitat use and known locations,
    - instantaneous and natural mortality rate estimates,
    - known or suspected lake community interactions and impacts,
    - habitat quality, threats and impacts (known or potential),
    - exploitation rates;
4. discussion of information gaps; and

5. recommendations for further study to address information gaps relevant to the management of resident sport fish species in Babine Lake.

The present document was prepared to comply with this portion of the contract. Other deliverables in the terms of reference included the creation of an MS Access "mini-FDIS" database to contain Babine Lake sport fish data not already available in the Fisheries Data Warehouse Oracle tables. The resulting min-FDIS database is included under this cover on CD-ROM.

1.1. Document Organization

Following this introduction, the document is organized into five principal chapters and four appendices.

Chapter 2 discusses the sources consulted to prepare this summary, and summarizes the most relevant details of methods used to collect data in the source material.

Chapter 3 provides the context for Babine Lake sport fish production, including the geographic and physical characteristics of the lake's watershed, its limnology, and the fish community.

Chapter 4 presents available information for the lake's kokanee populations. Although Babine Lake kokanee are not sought by anglers, they are important prey for the larger individuals of the rainbow trout and lake char stocks of the lake. Additional material relating to Babine Lake kokanee is provided in Appendix IV.

Chapter 5 summarizes research to date on the rainbow trout stocks of Babine Lake. Rainbow trout likely comprise 75% or more of the annual recreational angling catch at Babine Lake; the stock structure is incompletely described at present. The population which spawns in the Sutherland River watershed at the head of Babine Lake appears ecologically comparable to the pelagic piscivorous rainbow trout stocks of Kootenay, Quesnel, Okanagan and Shuswap lakes which achieve large body size by preying upon kokanee. Because native populations of the pelagic piscivorous form are rare and highly valued, other large lakes which support this ecotype are used in this document as the most relevant comparators for the limnology and fish community of Babine Lake.

Chapter 6 presents the limited available data for lake char of Babine Lake. The lake yields individuals of this species which are large, but not notably so, in a regional sport fishery context. Although second in importance to rainbow trout, the species is an important component of the sport fishery of the lake.

Chapter 7 provides a concise summary of recommendations from the previous chapters.

Insufficient information was obtained to warrant preparation of complete chapters for whitefish and burbot. The available material for each of these is included in Appendix I and Appendix II.

2. Sources and Methods

2.1. Limnology

Intensive investigation of the limnological characteristics of Babine Lake by the Department of Fisheries and Oceans (DFO) began in the 1950s (Johnson 1958). The context for data collection and analysis by DFO was, and is still, the maximization of sockeye smolt production. Research projects of significant scope and intensity have been conducted on the lake by the agency periodically since that time and have included studies of bathymetry, water temperature and circulation, water chemistry, phytoplankton and zooplankton (Johnson 1965; Stockner and Shortreed 1978; Shortreed and Morton 2000).

A second and interrelated motivator of data collection on Babine Lake water and sediment characteristics has been monitoring effects on aquatic ecosystems of industrial activity within the lake's watershed. Mining and forestry are recognized as having the potential to impact water and sediment chemistry, with resulting possible effects on lake and fish community ecology, and bioconcentration of compounds with toxic characteristics. The Babine Watershed Change Program, initiated in 1972, was a multi-agency program intended to collect baseline environmental data and understanding of processes required to assess the and distinguish the effects of sockeye enhancement from those of industrial activity in the watershed, in the context of fish production in the lake (Smith 1973). Results of the program were reported by Stockner and Shortreed (1974), Stockner and Shortreed (1975), Anonymous (1976); Stockner and Shortreed (1978), and likely in other DFO "gray literature" not available for review. Beginning in 1983, Westwater Research Centre conducted a 3 year study of the potential impacts of log transportation on Babine Lake littoral fish habitat and fish populations, motivated by Houston Forest Products' (HFP) plans to accelerate timber harvest in the Morrison Arm region due to a pine beetle infestation (Levy et al. 1984; Levy et al. 1985a; Levy et al. 1985b; Levy and Hall 1985). Mine impact studies (e.g. Basu 1984, Godin et al. 1985, Rescan 1993, Stantec 2002 and numerous other annual reports and documents cited within these references) have sampled and reported upon Babine Lake water characteristics, and this type of data collection is ongoing by the current owner of the mine properties.

Due to the volume of results and complexity of interpretation, particularly given the variety of methods of collection and laboratory analysis, comprehensive compilation and re-examination of the available material on Babine Lake's limnology is beyond the scope of this document. Instead, a synthesis of the more recent work is presented, relying heavily on Levy and Hall (1985) and Shortreed and Morton (2000). These references focus on the implications of the lake's physical and chemical limnology for sockeye salmon production. The present report will attempt to expand the context to freshwater resident sport fish species production, and to extend the comparison to other large British Columbia lakes with similar sport fisheries.

2.2. Fish Community

Babine Lake fish community information was mainly gleaned from sources described in greater detail in Section 2.3 below. If known, the status of non-game fish species as prey of the piscivorous sport fish is documented in the report sections dedicated to the sport fish species. Otherwise, however, the available material for the lake generally notes occurrences but does not address the ecological relationships or roles of the non-game fish species. References of greater geographic breadth, such as the work of McPhail (2007), should be consulted for information about the general ecology of these species in British Columbia fresh waters.

2.3. Sport Fish Relative Abundance and Life History

An overwhelming majority of biological data for freshwater resident sportfish populations of Babine Lake have been collected incidentally in the course of sockeye salmon investigations, especially during DFO research on the abundance and distribution of sockeye juveniles in the lake's pelagic zone. Two major exceptions were the research of McCart (1967; 1970) in the late 1960s, and Foote et al. (1987; 1989) in the middle 1980s which, with the cooperation of DFO, focused jointly on sockeye and kokanee and clarified much concerning the reproductive interactions between the two forms.

Monitoring and impact studies related to forestry and mining in the Babine Lake watershed have also occasionally collected data relating to resident sport fish. However, these samples have more typically been made in the lake littoral rather than the pelagial.

Finally, a small number of projects have focused on the sport fishery on Babine Lake (Bustard 1987) and in particular on the lake's rainbow trout (Bustard 1989a, Bustard 1990). The general details of all of these studies, and the characteristics of the resident sportfish data which have resulted, are described in the subsections below.

2.3.1. Salmon Escapement Annual Reports

Salmon escapement estimates, and other details and conditions relating to the channels in which spawning occurs, are reported annually on form BC16, the "Annual Report of Salmon Streams and Spawning Population". The format of the report has changed several times in the 80+ years for which Babine Lake tributary spawning runs have been surveyed. Types of information directly related to spawner abundance estimation include counts of spawners seen by date; proportions of males, females and jacks; and a final estimate of total escapement. Additional details may be recorded including stream stage, water temperature, condition of spawning areas, distribution of spawners, abundance of predators, other causes of pre-spawning mortality, redd superimposition also known as 'over-spawning', obstructions to migration, and occasionally information about non-salmon fish populations.

Because the timing and habitat used by kokanee spawners often overlaps with sockeye, and the two forms may hybridize, information about kokanee abundance is occasionally noted on the BC16 forms. Accordingly, digital images of all existing BC16 forms for Babine Lake tributaries with at least one record of sockeye spawning were reviewed for kokanee information. Caution in the interpretation of this information is necessary because kokanee and jack sockeye are relatively similar in body size and may occasionally be confused by less-experienced field staff.

2.3.2. Sockeye Production Investigations

Investigation of sockeye salmon production in the Babine system was initiated by the Fisheries Research Board of Canada in the 1940s (Wood et al. 1998). Several extensive programs of data gathering have been conducted, including research on the lake, its tributaries and the outlet channel. Sockeye spawners have been enumerated at a fence downstream of Nilkitkwa Lake annually beginning in 1946, and mark-recapture methods were used to estimate the number of outmigrating smolts each year between 1951 and the late 1990s (Johnson 1958; Jakubowski 2007).

2.3.2.1. Fish Predation on Sockeye Fry

During the Skeena River salmon investigations conducted by the Fisheries Research Board of Canada (Pacific Biological Station) in the 1940s, Babine Lake and several other sockeye nursery lakes in the Skeena drainage were subjected to standardized gillnetting to index the abundance of fish predators and their potential consumption of nerkid fry. Babine Lake was netted in a standardized fashion in 1946 and 1947, as described and reported upon by Withler (1948). Morrison and Nilkitkwa lakes were also netted, in addition to 6 other waters more distant from Babine Lake.

Gillnets were constructed of knotted cotton or linen twine, with five nets comprising a gang and no mixing of twine types within a gang. Each net was 45.7 m (50 yd) in length and 1.8 m (6 ft) in depth. Gangs typically included one net each of 3.8, 6.4, 8.9, 11.4, and 14 cm stretched mesh tied in that order.

The netting program separated Babine Lake into three divisions, although the geographic basis for the divisions is not given by Withler (1948). Ten netting locations were established in each division, and twice in each year 2 gangs (one cotton, one linen) were set on the bottom overnight at every location, resulting in a total annual effort of 4 gang-nights (20 net-nights) at all sites. Sets were made parallel to the shoreline, perpendicular to the shoreline, or "looped in and out from the shoreline" when the bottom was steeply inclined. To reduce bias, an attempt was made to set the smallest mesh offshore as often as onshore.

Regarding data collection, Withler (1948) states that "the number of individuals of each species caught in each net of a gang was noted and their length and sex recorded in field books along with a scale sample". Stomach contents were also identified and quantified volumetrically, for nearly all netted individuals of predator species and a subset of the non-predator catch. Items consumed were categorized as sockeye fry, other fish, and non-fish prey; kokanee fry would thus have been included with sockeye fry, and larger kokanee juveniles in the "other fish" category.

For each lake or division of a lake by year and predator species, Withler (1948) reported the total number of individuals netted and the average volume of the previously-mentioned prey categories. Additional presented results for Babine Lake were limited to a length-frequency plot for lake char gillnetted in a single division of Babine Lake in 1946

(Figure 9 of Withler 1948). Withler (1948) also states that "all data used in this paper are contained in the files of the Skeena River salmon investigation, at the Pacific Biological Station"; it is unclear whether other technical reports presented additional details about the length distributions of the gillnet catch, but the field data are probably held at present in the archives of the Pacific Biological Station in Nanaimo.

In his study of the behaviour and ecology of sockeye fry in the Babine River, McCart (1967) discussed rainbow trout as fry predators. He reported length at age for rainbow trout captured in 1965 in the upper Babine River (n = 37) and the portion of the North Arm adjacent to the lake outlet (n = 31), primarily by beach seine and gillnet with "a few taken by angling". The lengths were back-calculated to the previous annuli and the presented information does not allow recovery of the original (before back-calculation) length values, or distinction of lengths back-calculated to only the most recent annulus from lengths back-calculated to annuli of several years previous[1] which can display increased bias due to Lee`s phenomenon.

During 1970 and 1971, aspects of piscine predation on migrating fry were studied in trough-type artificial stream environments using rainbow trout predators and nerkid fry taken from the Fulton River (Ginetz 1972; Ginetz and Larkin 1976). However, these studies did not report any attempts to quantify the abundance or life history characteristics of rainbow trout or other piscine predators in the Fulton River.

Bustard (1990, page 17) reported mean length at age for Babine Lake rainbow trout from a "DFO predator study", providing no year for the sampling but giving the provenance of the values as "Data on file, Ministry of Environment, Smithers". However, the data were not located during the collection process for this report.

2.3.2.2. Sockeye Fry Abundance

Johnson (1956) utilized catch per effort and body size data from tow net sampling in pelagial areas during 1955 and 1956 to verify that nerkid relative abundance was much higher in Nilkitkwa Lake and the North Arm of Babine Lake than in the Main Arm of Babine Lake. He inferred that an unequal distribution of spawning grounds in combination with limited dispersal of fry was responsible for this pattern; he did not discuss the relative contributions of sockeye and kokanee to his results.

From 1966 to 1968, 1972 to 1973, and in 1977, an aluminum-hulled drum seine boat of length 10.7 m was used with a tow-off skiff to deploy a half-purse net of length 274.4 m and depth 18.3 m to capture nerkid fry in Babine Lake pelagial areas. Four different meshes of approximately 0.5 cm to 3.8 cm stretched measure, all knotless except the largest mesh, were employed in the net construction. The hydraulic system of the vessel did not allow simultaneous pursing and "drumming in", so these were alternated which is not standard procedure for seiners of this size[2] and might have reduced its effectiveness for larger fish. If deployed in a perfect circle, the fully-extended seine would enclose an area of just under 0.6 ha.

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[1] For instance, the mean back-calculated length at annulus 4 might have been estimated only using age 4+ individuals, or by using the back-calculated lengths at annulus 4 of all fish older than 4 (4+, 5+, 6+ and so on).

[2] This might have reduced the effectiveness for larger fish.

The approximate geographic location of each set was randomly selected and recorded using a predefined and arbitrarily numbered 400 m square grid (Scarsbrook and McDonald 1970). Thus the absolute geographic location of sets, and the water depth at each set location, were not reported or easily determinable from the published data tables. Sets were generally made at least 200 m offshore and in depth greater than 18.3 m, except in the arms of the lake where deeper water was not present in the selected cell (Scarsbrook and McDonald 1970). To stratify the general location of sets and ensure adequate geographic distribution of sampling, cells (and thus sets) were assigned to broader "fishing areas" (Figure 1), with the main lake divided into five fishing areas (numbered 1 to 5, north to south), and the 3 major lake arms each comprising a separate fishing area (Morrison, North, and Hagan, numbered 8 to 10 respectively). These fishing areas were the only usable geographic or physical factor for grouping catch results for the present analyses.

The seining program was intended to determine the spatial distribution and proportional occurrence of fin-clipped sockeye fry from Fulton River and Pinkut Creek, and not strictly designed to assess absolute or relative abundance of sockeye fry or other fish. However, all bycatch was identified by species and tallied for each haul. The taxa tallied in the catch included nerkid fry, post-fry nerkids, sockeye adults, coho juveniles, pink salmon fry, rainbow trout, lake char, whitefish not identified to species level, northern squawfish, burbot, redside shiner, peamouth chub, suckers unclassified to species level, lamprey unclassified to species, and unidentified fry. Other than the distinction between nerkid fry and nerkid post-fry, tallies do not reflect the age or size distribution of the catch.

Counts of seine sets classified by year, fishing area, and month are presented in Table 1 and Table 2. Caution is needed in summary and interpretation of catches with respect to species relative abundance, because the sampling was not spatially or temporally balanced, as shown in the tables. Some areas of the lake received few or no sets during particular months or years.

Although logarithmic transformation is often used for survey data to attempt to normalize the distributions (e.g. McDonald and Hume 1984), this approach fails when most catches are zero as is the case for fish species other than nerkid fry captured in the purse seining program. Instead of transforming the data, variances were estimated by bootstrap resampling using the “boot” package (version 1.2-28) of the statistical programming environment R (version 2.5-1; R Development Core Team 2006).

In addition to the interannual variation in the spatial and seasonal distribution of sampling effort, the proportion of sets which occurred during daylight, twilight, and night also varied between years (Table 3). Time of day is known to be an important factor in catchability of sockeye fry, whose diurnal vertical migration makes them inaccessible to the seine during daylight hours (McDonald and Hume 1984). In order to examine whether time of day was an important factor in analyses of catch patterns for other species, each set time was classified as day, night, morning or evening twilight, using date-specific sunrise, sunset, and civil twilight times for 54.75° North latitude[3]. Nighttime sets were considered to be those which occurred after evening civil twilight and before morning civil twilight; all other sets were considered as daytime. In lay terms this was equivalent to considering the 45 to 60

[3] Times of sunrise, sunset and civil twilight were obtained from http://www.hia-iha.nrc-cnrc.gc.ca/sunrise_adv_e.html. It was also necessary to readjust the set times from Pacific Daylight Savings Time to Pacific Standard Time.

minute period after sunset, and the equivalent period before sunrise, as daytime because ambient light was increasing during those times.

Besides nerkid fry, minimal reporting of biological data from the bycatch of the sampling program has occurred. Regarding the disposition of the purse seine catch, Scarsbrook and McDonald state: " … the catch was preserved in 10% formalin for sampling at a later date. Where the catch was large, only a sample was preserved and the remainder was released with minimal handling." It is unknown whether this approach applied to all captured species or only to nerkid fry; it is also unknown whether any such samples of preserved whole fish other than nerkid fry, or age structures, have been retained to the present in the archives of the Pacific Biological Station.

Griffiths (1968) reported back-calculated lengths at age using scales sampled from rainbow trout (n = 165) and lake char (n = 28) purse seined during 1967. Ideally, back-calculation to length at the most recent annulus standardizes size-at-age data, and improves comparability within and between studies when samples have been collected at different times in the seasonal growth cycle. However, the accuracy of back-calculation is dependent on conditions which are difficult to assess and may rarely be met (West 1983). Comparability to results of other studies is only improved when back-calculation is used by all, and most other sources of length at age data for Babine Lake have not followed this approach. Griffiths (1968) did not provide individual fish data, but the mean lengths for all cohorts back-calculated to each annulus are tabulated in his Appendix III. The average field lengths (before back-calculation) are also graphed in his Figure 7, so means of these data for rainbow trout could be estimated from the graph though the values obtained are very approximate. Scales are now generally considered of limited utility for ageing of lake char because the estimates are typically biased downward.

Beacham and McDonald (1982) presented stomach content analyses for kokanee, rainbow trout and lake char from the purse seine catch of various years during the late 1960s and early 1970s. In addition, they reported length, weight and scale-derived age data for rainbow trout (n = 158) and lake trout from the catch of these species in 1968; all are presented as means and variances with no individual fish data included.

McCart (1970, citing personal communication of J. McDonald) briefly referenced ageing results for 1 257 kokanee purse seined in the Main Arm of the lake in 1966. These results do not appear to have been published in more detail elsewhere.

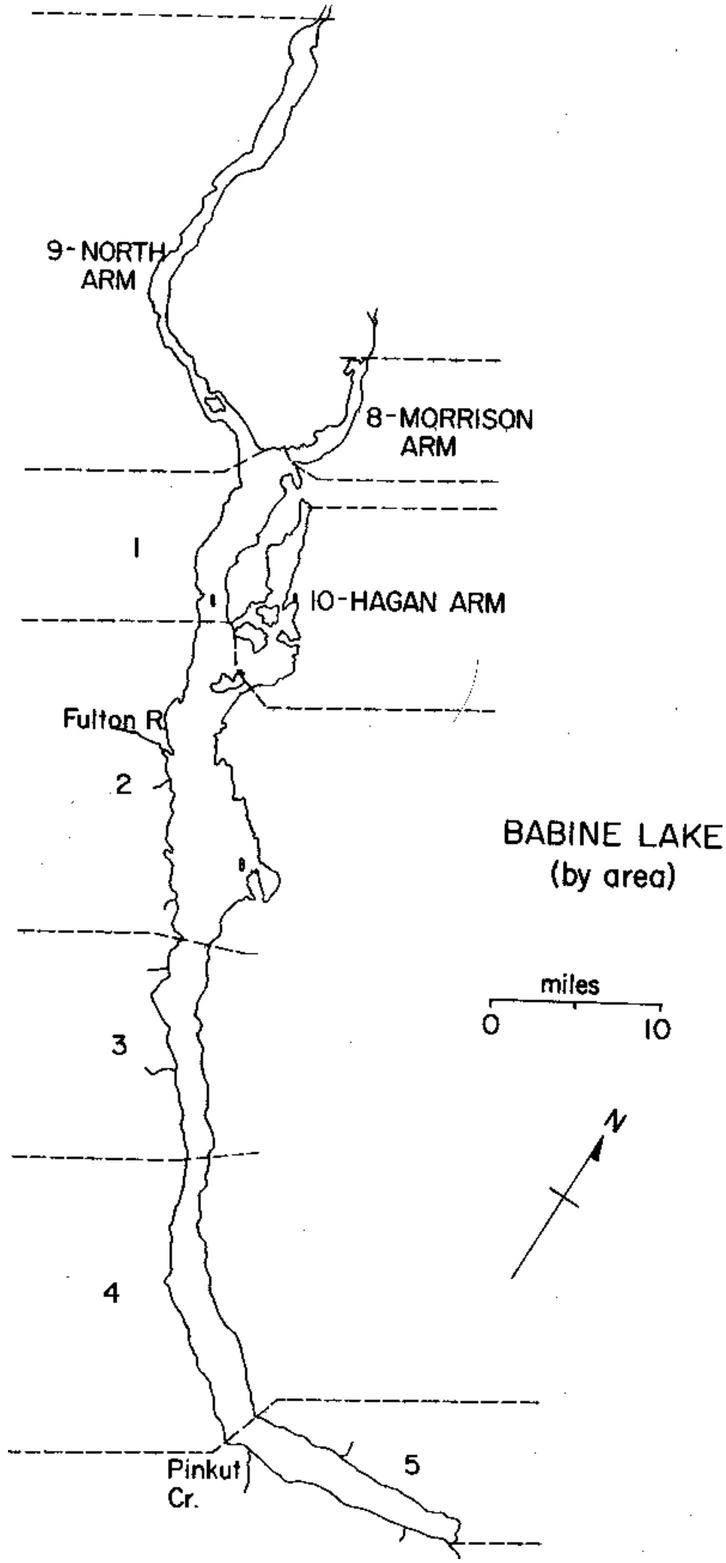

Figure 1. Fishing areas defined for sockeye fry purse seining on Babine Lake, 1966 to 1977. Map reproduced from Scarsbrook and McDonald (1970).

Table 1. Counts of seine sets made, by year and fishing area, during sockeye fry assessment studies on the indicated arms of Babine Lake from 1966 to 1977. Bold numbers in the table header row correspond to fishing areas shown in Figure 1.

Year	Main					Morrison	North	Hagan	Total
	1	**2**	**3**	**4**	**5**	**8**	**9**	**10**	
1966	28	81	49	51	42	0	7	2	260
1967	41	65	72	50	44	20	50	20	362
1968	30	39	74	30	30	20	30	10	263
1971	30	35	74	30	30	10	23	14	246
1972	30	42	38	30	30	34	30	15	249
1973	32	30	30	30	30	33	30	15	230
1977	30	30	31	29	30	15	30	15	210

Table 2. Counts of purse seine sets made, by year and month, during sockeye fry assessment studies on Babine Lake from 1966 to 1977.

Year	May	June	July	August	September	October
1966	0	36	48	56	35	85
1967	28	72	82	21	79	80
1968	0	0	78	67	46	72
1971	18	25	57	73	0	73
1972	22	17	70	70	0	70
1973	14	26	50	25	45	70
1977	0	17	53	70	0	70

Table 3. Counts of purse seine sets made, by year and period of day, during sockeye fry assessment studies on Babine Lake from 1966 to 1977. **Total Daytime** includes **Daylight** and **Twilight** sets.

Year	Daylight	Evening Twilight	Morning Twilight	Total Daytime	Night
1966	41	22	1	64	196
1967	142	53	1	196	166
1968	98	35	4	137	126
1971	6	27	3	36	210
1972	15	30	0	45	204
1973	12	20	6	38	192
1977	0	24	0	24	186

2.3.3. Log Transportation Impacts

Beginning in 1983, Westwater Research Centre (University of British Columbia) conducted a 3 year study of the potential impacts of log transportation on Babine Lake fish habitat and fish populations. The study was motivated by Houston Forest Products' (HFP) plans to accelerate timber harvest in the Morrison Arm region due to a pine beetle infestation. The transportation system included dumping of logs at littoral sites in Morrison Arm, barging of logs from Morrison Arm across the pelagial zone of Babine Lake to littoral dewatering locations near Topley Landing, and storage of logs in littoral areas adjacent to the dumping and dewatering sites. Because log residence time was likely to be much higher in the near-shore fixed sites than in transient use of the pelagial, and the shallow depth of the littoral water column could concentrate the effects of benthic debris accumulation, the impact investigations focused on inshore locations and their water chemistry, flora and fauna. Due to their commercial importance, sockeye fry received particular emphasis.

Reports resulting from the study include a general review of pre-existing data concerning the limnology and sockeye salmon ecology of Babine Lake (Levy and Hall 1985), three annual reports of the field investigations conducted for the project (Levy et al. 1984; Levy et al. 1985a; Levy et al. 1985b), and other documents relating to experimental components of the study (Power and Wentzell 1985; Power 1987). The final synthesis report for the project was never completed (Levy 2007).

The study's gillnetting of littoral fish populations, designed as pre-impact (1983) and post-impact (1984 and 1985) relative abundance monitoring, appears of greatest potential relevance to the present report. Gillnets comprised a gang of 9 panels of depth 2 m and length 18.6 m with diagonal stretch mesh of 25, 40, 52, 63, 75, 87, 101, 114 and 126 mm. Standard overnight sets were made parallel to the shoreline at the 2 m depth contour to fish the entire water column. During 1983 and 1985, soak time was roughly 14 to 16 hr, but in 1984 gillnets were deployed later in the evening so that soak time was 10 to 12 hr.

In 1983 and 1985, gillnetting was conducted at a log dump and a log storage site in Morrison Arm, two unimpacted reference sites in Morrison Arm, two log dewatering sites near Topley Landing, and two unimpacted reference sites near Topley Landing; all of the impacted sites sampled in 1983 and 1985 were associated with HFP operations. Fish sampling sites in 1984 differed in the addition of active (Northwood Pulp and Timber) and historical log transportation sites in other areas of the main lake and a reduction in number of HFP sites sampled relative to 1983 and 1985. In all years, every sampled site received two concurrent sets during each of 3 to 5 temporal "circuits" between May and July.

At a subset of sites in late June of 1983, gillnets were also set concurrently along the 2 m and 5 m depth contours. This experiment was intended to demonstrate the difference in fish species captures with water column depth.

In addition to the relative abundance data collected during the study, Levy et al. (1985b) provide stomach content analyses for fish taken from gillnets in 1985. Results were presented as "trophic spectrum diagrams" by site and fish species. These display the number and mean length (no variance) of sampled fish by species, along with pictograms which rank the abundance of types of food in the gut contents.

Beach seining in Morrison Arm in 1984 and 1985 was also conducted by the Department of Fisheries and Oceans (Orr 1984; Hamilton 1985), to independently assess log transportation impacts. Sockeye fry and smolts, coho, chinook and pink salmon juveniles, and rainbow trout were enumerated in the catch (Hamilton 1985), but estimated lengths for the latter species were recorded only sporadically and no other life history data were obtained. The configuration of the seine and the deployment method were also not reported.

2.3.4. Other Sources Of Babine Lake Fish Data

Narver (1975) reported on the length at age of 171 rainbow trout captured in the North Arm of Babine Lake, Nilkitkwa Lake, and the upper portion of Babine River above and below Nilkitkwa Lake. The lengths, and scales for ageing, were obtained by angling guides during the summer of 1969.

McCart (1970) examined the ecology, morphology and behaviour of sockeye and kokanee populations of Babine Lake during several years' research including a doctoral dissertation in the late 1960s. He documented the distribution and timing of kokanee spawning, and many additional details of both forms' biology and interactions in the watershed.

Foote (1987), Foote et. al (1989), and Foote et al. (1997) reported extensive research on mechanisms maintaining genetic isolation of sockeye and kokanee populations, with Pierre, Tachek and Twain creeks included among the experimental locations. These studies were instrumental in clarifying the genetic structure of *O. nerka* stocks of the lake, with strong incidental implications for population dynamics, but generally did not report detailed life history or abundance data.

During 1985 and 1986, Bustard (1987) conducted surveys of the sport fishery on Babine Lake utilizing overflight counts with roving and access point interviews. Estimated angler catch rates provide an index of relative abundance of sport fish species. Length, weight and age structures were collected from a sample of the 1986 catch of rainbow trout, lake char and kokanee (Bustard 1987).

Two gillnets of length 23 m, depth 3 m and mesh 11.5 cm and a single smaller gillnet of length 15m, depth 2.5 m and mesh 4 cm were deployed during the first three weeks of May 1989 in Babine Lake at the mouth of the Sutherland River to capture rainbow trout spawners for radio tagging (Bustard 1990). Size data and scale samples were collected from all netted fish (8 mortalities, 87 released), anchor tags were applied to all released fish, and a total of 24 individuals were radio tagged of which 19 were subsequently tracked during flights conducted approximately weekly through the end of June. Length and age data were also collected from 20 fish captured at that location in gillnets operated by members of the Yekooche First Nation. The release of anchor-tagged fish into the lake allowed a mark-recapture estimate of the total number of spawners present. Radio tracking revealed approximate information about the timing of entry of spawners to the river system, the time of residency, and the reaches used for spawning.

The only comprehensive synoptic survey of rainbow trout juvenile abundance in stream channels known or believed to be accessible to fish from Babine Lake was reported by Bustard (1989a). A total of 87 sample sites on 57 streams were sampled to quantify habitat characteristics and fish abundance. Two pass removal estimates, with seine net enclosures and electrofishing as the means of fish capture, were obtained at all sites. A subsample of rainbow trout were measured and aged so that length frequencies could be accurately transformed to age frequencies and age-structured abundance estimates could be made.

Fish captured for toxicological samples have occasionally yielded life history information for game species, although usually size data have been obtained but no ageing performed. For instance, Godin et al. (1985) provided lengths and weights for 7 rainbow trout captured in Hagan Arm in July 1984 but no age, sex, or maturity information was reported. Gillnets of unknown configuration set near the Granisle Mine site in late August 2002 captured 17 lake whitefish, 7 kokanee and 4 lake char; lengths with ages and sex were reported for the lake whitefish and kokanee although maturity was not given (Stantec 2002). In 1996 and 2006, the Lake Babine Fisheries Program collected lake char for tissue metals sampling, with lengths and otolith ages (Toth 2007), but the data were not available for the present report.

Each year from 2002 to 2005, the Lake Babine Fisheries Program (LBFP) conducted assessments of coho juvenile density in many tributaries to Babine Lake and the upper Babine River (LBFP 2003, LBFP 2004, LBFP 2005). At one to five sites per stream, a stop-netted 20 to 50m long section of channel was subjected to one to three removal periods of duration one hour, using roe-baited minnow traps. Rainbow trout were captured incidentally and were also enumerated. However, the life stages (fry or parr) were not recorded separately, and the catches were reported as counts by site and year rather than per removal period so abundance can only be estimated as “minimum number present”. Some streams such as those in the Sutherland River watershed, which are known from previous studies (Bustard 1989a) to be important for rainbow trout reproduction, could not be sampled effectively due to their size and inaccessibility. The implied densities are also not comparable to those estimated by studies such as Bustard (1989a) due to the substantial differences in methods.

Annual reports submitted by licenced angling guides were compiled digitally in the Angling Guide Management System database during the period 1990 to 2002. The accuracy of these reports is unknown, but they may provide an approximate index of relative abundance of the most common sport fish species.

3. Context for Babine Lake Sport Fish Production

3.1. Geographic and Physical Characteristics

3.1.1. Surroundings and Human Activity

Smith (1973), Levy and Hall (1985), and Shortreed and Morton (2000) provide reviews of the geographic and biophysical setting of the Babine Lake ecosystem. Much of the material presented in this section is drawn from their work, with data and descriptions updated where relevant and feasible.

Babine Lake lies at elevation of 708 m (2335 ft) ASL at the head of the Babine River on the Central Interior Plateau of British Columbia, within the watershed of the Skeena River, a major drainage system on the northern Pacific coast of British Columbia. The lake is 150 km in length and narrow, with widths of approximately 5 to 10 km along much of its main axis which is oriented northwest-southeast. As derived from 1:50 000 digital mapping (GeoBC 2007), the total surface area of the lake is465 km^2 and its drainage basin (including the lake's surface area) is 6 324 km^2. Mean and maximum depths of Babine Lake are 55 m and 186 m respectively (Johnson 1965); additional details of the lake's morphology and bathymetry are discussed in Section 3.1.2 below.

The Babine Lake watershed is located in the sub-boreal spruce biogeoclimatic zone. The dominant tree species of the surrounding landscape are white and hybrid spruce; subalpine fir; lodgepole pine; trembling aspen; and black cottonwood in alluvial areas.

Topographic relief is moderately hilly along much of the lake shore; low mountains are found at the southern end of the lake and to the northwest of its North Arm. Maximum elevations in most of the lake's tributary drainages are less than 1 000 m higher than the lake level, and nearly all completely lack glaciation. The exceptions to the latter are Fulton River and possibly Tsezakwa Creek, which are both headed in the Babine Range to the west and north of the lake where peak elevations exceed 2 000 m ASL.

The climate of Babine Lake is representative of the province's central interior, with cold winters and warm summers (Figure 2). Ice cover typically occurs by December or January, with break-up in late April or early May. Weather averages discussed below were obtained by summarizing data published on Canadian Daily Climate Data on CD-ROM – Western Canada (Environment Canada 2000a). During the period 1969 to 2000 at the Pinkut Creek spawning channel station near the southeast end of the lake, the average annual maximum temperature was 29.5°C (range 24 to 33.9°C), and the average annual minimum temperature was -31.9°C (range -17.5 to -44.4°C). Precipitation was highest in early winter and early summer, with moderately drier weather in the spring and fall periods. Average annual precipitation at this station was 49 cm of water equivalent. Weather at Topley Landing, near the mid-point of the lake, was very similar for the years 1966 to 2000 (Figure 2). Compared to Pinkut Creek mouth, Topley Landing was slightly warmer in summer with average annual maximum temperature of 30.1°C (range 25 to 34.4°C), slightly colder in winter with average annual minimum temperature of –34.3°C (range -20.5 to -

41.7°C), and slightly wetter with average annual precipitation of 53.4 cm of water equivalent. The average annual snowfall at Topley Landing was 2.3 m (range 0.8m to 4.4 m).

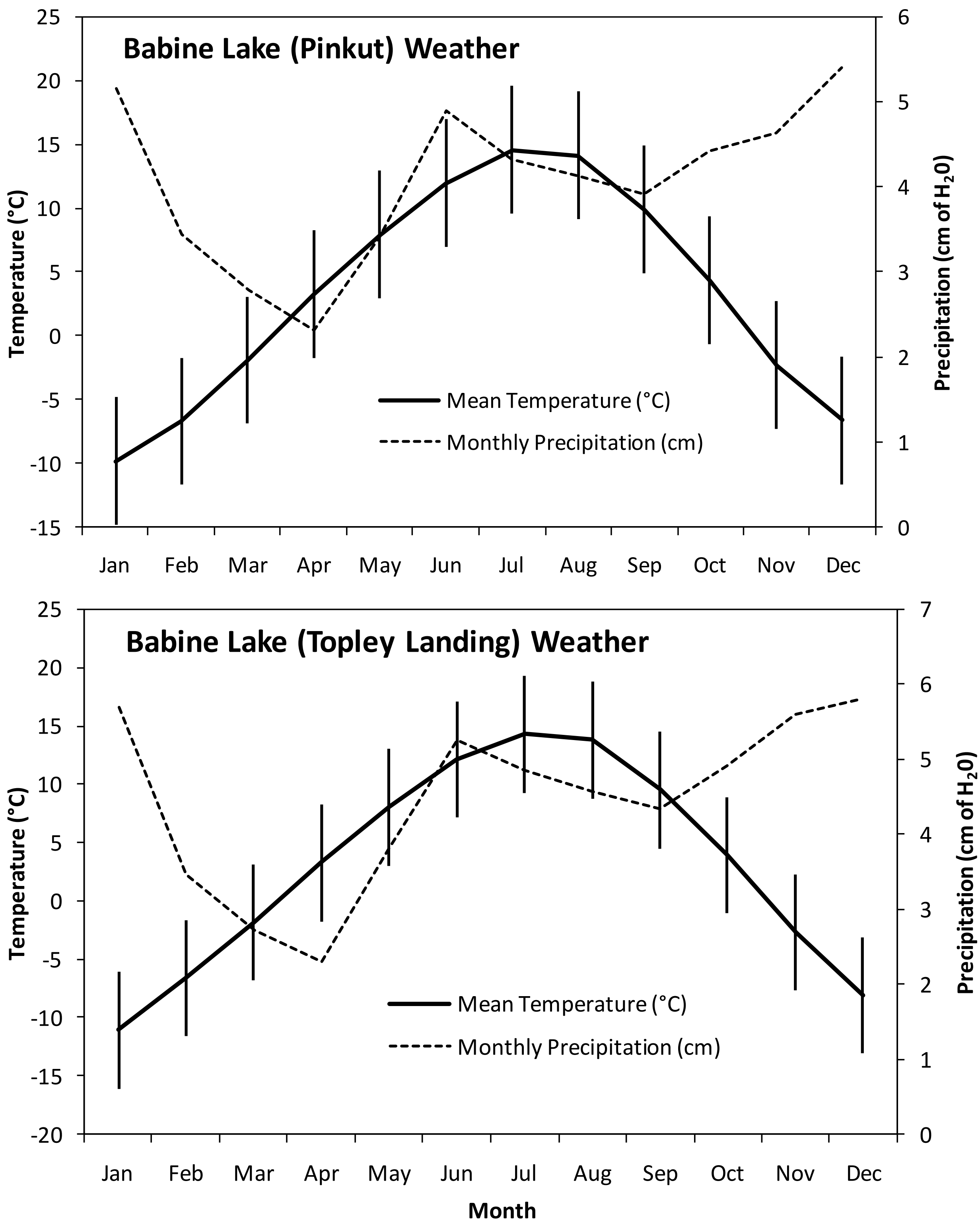

Figure 2. Monthly temperature and precipitation at the mouth of Pinkut Creek, Babine Lake, for the years 1969 – 2000, and Topley Landing for the years 1966-2000. The average daily mean temperature is shown for each calendar month; the vertical bars show the average daily maximum and minimum temperatures. Monthly average precipitation is also displayed.

Levy and Hall (1985) describe the geologic characteristics of the lake's drainage. Metamorphic bedrock occurs on the south side of the lake and in the vicinity of Boling's Point on the north shore. Otherwise, the north shore's exposed bedrocks display a complex mix of sedimentary, volcanic, and plutonic types, with copper deposits locally associated with the latter. Glacial and postglacial deposits, as tills and drift, blanket much of the watershed.

Babine Lake and its tributaries and outlet have been important locations for human harvest of fish for millennia, and much of the lake lies in the zone of overlap of the treaty claims areas of the Nat'oo'ten (Lake Babine) First Nation and the Yekooche First Nation. Sites which were pre-colonially inhabited at least seasonally and potentially year-round include Wit'at (Fort Babine) at the lake outlet; Nedo'ats (Old Fort, or Fort Kilmaurs) near the mouth of Morrison Arm; and Tachet (or Tachek) and Donald's Landing, both located on the western shore of the Main Arm. Although salmon fisheries were always most important in terms of the volume of catch, resident species such as whitefish, lake char, and rainbow trout were also harvested and seasonally significant.

Non-aboriginal habitation on the lake began with the establishment of Fort Kilmaurs by the Hudson Bay Company in 1822. The company relocated their trading operations on the lake to the present site of Fort Babine in 1871. The construction of the Grand Trunk Pacific railroad through the Nechako and Bulkley watersheds to the south brought the first large influx of non-aboriginal settlement to the region in the period 1909 to 1915.

By 1925, dirt roads connected the southern shore of the lake to communities such as Burns Lake and Topley which are located along the railroad to the south, and small-scale harvest of timber near the lake for railroad ties had begun (Smith 1973). Forest harvest activity on or near the lakeshore continued to grow: in the early 1950s there were at least 11 stationary or portable sawmills at Pendleton Bay and others near Topley Landing, and logs were being towed and boomed on the lake itself (Smith 1973). By 1971, the sole licensee for timber harvest in this management unit had closed all of the mills on the lake itself and all processing was occurring at a mill in the town of Houston. The logging practices of the 1950s and 1960s created some very large clear cut openings on or near the lake but the size of openings was reduced during the 1970s. Timber which had begun to be harvested in the drainages on the north shore of the lake was trucked to the lake for off-loading and then boomed and towed to the south shore for reloading and trucking to mill. Smith (1973) was not able to provide an estimate for the proportion of the Babine Lake watershed which had undergone timber harvest at that time. Levy and Hall (1985; their Figure 2) included an overview map showing the extent of logging in the watershed but did not give the percentage of the land base thus affected; the Pinkut and Fulton drainages had been harvested most heavily at that time but activity along Morrison and Hagan arms was expanding, including the Morrison Creek watershed. Shortreed and Morton (2000) stated that at that time, 71% of the watershed was forested and unlogged, while 13.5% comprised selectively- and clear-cut areas, lakes and streams totaled 9%; the remaining 6.5% was attributable to wetlands, agricultural lands, town sites and residential areas, and otherwise "barren lands". Additional map-based analyses of land use were not completed for the present report.

During the 1960s, open-pit mining of large copper-bearing deposits in the vicinity of Hagan Arm became the second major landscape-altering activity in the Babine Lake watershed. O'Keefe (1993) provides a detailed history of mining exploration and development on Babine Lake. As early as 1913, claims were staked on Silver Island near Donald's Landing, and on Copper Island and Newman Peninsula in the vicinity of Hagan Arm. A small amount of mining appears to have occurred on Silver Island in the 1920s, and exploratory drilling was conducted on Copper Island. However, mine-related activity on the lake was minimal until 1955, when copper prices motivated Granby Mining to begin staking and drilling to establish the characteristics of the deposits. During the next decade Granby moved to develop the deposit on Copper Island, and in November 1966 Granisle mine on Copper Island went into production. Meanwhile, in 1962 Noranda Mines Limited established the presence of a large ore body on Newman Peninsula, and the company's Bell Mine on Newman Peninsula began production in 1972. To house the mine workers and their families, in 1965 the development of the community of Granisle began on the western shore of the lake north of Topley Landing. By the end of 1966 the population was 300, and at its peak during the next 10 to 15 years the town had as many as 2800 residents. The Granisle mine was acquired by Noranda in 1980 and the two mines were amalgamated, but declining copper prices caused the closure of the mines in 1982. Bell Mine reopened in 1985 but closed again in 1992 and has remained inactive since then. The present population of Granisle is several hundred. Potential impacts of mine operation on Babine Lake fish populations include the recreational angling activity of the residents and additional summer visitors engendered by the development of the community of Granisle, occasional direct leaks of tailings material in the past and probable (ongoing) leaching of metals by groundwater flowing into the lake, and the winter operation of bubbler systems to maintain passage for ferries between the mines and the western shore of the lake.

3.1.2. Morphology and Bathymetry

Johnson (1965) documented the bathymetry of the Babine and Nilkitkwa lake basins. A detailed bathymetric drawing, on three mapsheets at scale 1:50,000 with contour interval of 10 m, is maintained in the Babine Lake file (MOE 2007) and presumably results from his work though it is not labeled as such.

Most authors have considered Babine Lake to comprise four arms, those being the Main, North, Hagan and Morrison, though some have counted the southeastern reach of the lake from Boling's Point to the lakehead (Sutherland River mouth) as the fifth arm. The form of the shoreline including points and islands, the depth of water where the arms meet, and the volume of inflow all interact to determine whether the circulation of water and movement of aquatic organisms may be restricted between arms. Although the orientation of the lake's axis changes east of Boling's Point, there is no significant restriction in terms of shoreline or depth in that vicinity. However, shallow sills along with island groups and main shoreline points do isolate the basins of Hagan, North and Morrison arms from the Main Arm.

The four major tributaries to Babine Lake are the Fulton, Pinkut, Sutherland and Morrison systems which drain 21.1, 13.3, 13.1 and 6.8 % of the lake's watershed respectively (Levy and Hall 1985). Smaller streams thus drain the remaining (approximately) 45 % of the lake watershed. Mean annual discharges (MAD) for the Fulton, Pinkut and Morrison watersheds have been estimated as roughly 16, 5 and 4 m^3/s; there are no data available for Sutherland River but MAD for Babine River at the outlet of Babine Lake is about 46 m^3/s (Environment Canada 2000b).

Physical properties of the four arms of Babine Lake, recalculated from values published by Johnson (1965), are shown in Table 4. Recalculation was necessary in order to aggregate his smaller sections of the lake into Main Arm and North Arm, with the Main Arm defined here as extending from the lake head to McKendrick Island exclusive of Morrison and Hagan Arms, and the North Arm demarcated as McKendrick Island to the lake outlet. As mentioned previously, Shortreed and Morton estimated the total surface area of the lake as approximately 6% less than the value given by Johnson; they digitized contours from "a bathymetric map of the lake" which seems likely to have been the work of Johnson, and reported the mean depth of the Main Arm as 71 m, which also differs significantly from the estimate of 62.5 m (Table 4) obtained by recalculation from Johnson's mapping and planimetry. Further consideration to the sources of these discrepancies is not given here; bathymetric mapping of lakes in British Columbia typically applies methods which are prone to fairly large errors at all stages of the process. To be conservative, any calculations of potential harvest which rely on area or volume should use the lesser of the available measures of the size of the lake.

Annual discharge estimates are lacking for the majority of smaller channels which enter Babine Lake, so only approximate statements can be made about the water replacement rates of the arms, though they clearly differ significantly with respect to the average surface inflow. Hagan Arm receives no large channels and thus very little stream surface flow relative to its depth and volume. In contrast, the volume of Morrison Arm is small due to its shallow depth and it receives significant inflow from Morrison Creek. The minimal dataset for Morrison Creek discharge[4] estimates the mean annual total volume as 0.13 km^3 (Environment Canada 2000b), which would by itself replace the water volume of Morrison arm in roughly 1.5 yr. Although there are no large tributary channels entering the North Arm, the entire discharge of the lake to the Babine River must pass through due to the location at the lake outlet; the mean annual total volume of discharge of the Babine River at Fort Babine between 1929 and 1985 was estimated at 1.46 km^3 (Environment Canada 2000b), which would displace the volume of the North Arm in roughly 8 mo but would require over 17 yr to replace the volume of the Main Arm.

[4] recorded at the outlet of Morrison Lake and thus excluding one important and several minor tributaries to the creek downstream of Morrison Lake

Table 4. Physical properties of the four arms of Babine Lake, recalculated from values reported by Johnson (1956). The column $\mathbf{z_{mn}}$ gives the mean depth and the column $\mathbf{z_{max}}$ gives the maximum depth, both in units of metres. The column headed **% of Drainage Area in Stream Inflow** provides the percentage of the entire Babine Lake watershed which drains directly to the named arm, thus excluding flows which occur within the lake itself.

Arm	**Surface Area (km^2)**	**Volume (km^3)**	**z_{mn} (m)**	**z_{max} (m)**	**Length (km)**	**% of Drainage Area in Stream Inflow**
Main	405.2	25.3	62.5	186	110.4	79.7
North	53.4	1.1	20.1	46	39.8	8.7
Morrison	17.7	0.2	11.4	31	13.4	10.7
Hagan	14.3	0.4	28.4	83	9.0	0.9

3.2. Limnology

3.2.1. Physical

Babine Lake is dimictic, with ice cover between early winter and mid-spring. Temperature isoline plots in Shortreed and Morton (2000, their Figures 3 through 7) depict development of the thermal structure during May to October of 1994 and 1995, at three stations in the Main Arm and one each in North and Morrison arms. These plots and previous years' data demonstrate that interannual differences in the timing of warming can be significant (Levy and Hall 1985; Shortreed and Morton 2000). However, following ice-off which occurs on average in early May, surface waters of the Main Arm of the lake typically achieve thermal stratification by mid-June, and warm to 18°C ±2°C by mid-July with average thermocline depth of 12 m to 15 m. The shallowness of Morrison Arm leads to more rapid warming; both the North and Morrison arms are more protected from wind mixing and thus usually display shallower thermoclines. In contrast, conditions in the Main Arm are quite driven by wind: even in mid-summer cool windy periods can cause surface water temperatures to drop by more than 5°C in a few days, while a calm hot week can allow surface temperatures to increase by 8°C or more (Levy and Hall 1985). Within the Main Arm, average thermocline depth during open water in 1995 increased from north to south by a factor of two (Shortreed and Morton 2000). Seasonal average epilimnetic temperatures during the May to October period ranged between 13.0°C and 15.8°C in 1994 and 1995 at the stations monitored by Shortreed and Morton (2000), who also compared their temperature data to those collected in 1972 and 1973 during the Babine Watershed Change Program (Farmer and Spearing 1975), and considered the thermal structure of the lake to have been similar in the two periods both seasonally and spatially. According to Shortreed and Morton (2000), Babine Lake's thermal conditions continue to provide a favorable physical environment for young sockeye, and will be more resistant to the impacts of climate warming than many lakes in southern British Columbia due to size and latitude.

Babine Lake is classified as dystrophic because the water is organically stained and light is rapidly vertically attenuated, thus water clarity is relatively low with estimated seasonal average Secchi disk depths of 4.2 to 5.6 m at the stations of Shortreed and Morton (2000). Seasonal average euphotic zone depth (EZD) ranged from 6 to 7.7 m which was 50% to 90% of the associated average thermocline depth. Neither Secchi nor EZD displayed definite seasonal patterns in 1994 and 1995, though Levy and Hall (1985) suggested that the southernmost portion of the lake did display moderate seasonal variation due to plankton blooms. Regardless, low illuminated volume due to staining does not prevent lakes from offering good rearing conditions for sockeye if sufficient nutrients are available (Shortreed and Morton 2000). Both the average thermocline depth and EZD for Babine lake are less than the median reported values for other lakes with rainbow trout predator stocks supported by pelagic nerkid prey populations (Table 5).

3.2.2. Chemical

Babine Lake is slightly basic, with moderately low dissolved solids (TDS) and total alkalinity. The data of Shortreed and Morton (2000), and the discussion of Levy and Hall (1985) concerning results of prior field studies on the lake, suggest that there is very little variation in these parameters at Main Arm stations and only slight difference of Morrison Arm water chemistry compared to the Main Arm. Compared to estimates of the same parameters for other lakes with similar native fish communities and sport fisheries (Table 5), Babine Lake TDS is slightly lower than the median whereas alkalinity is equal to the median available value.

Babine Lake epilimnetic phosphorus concentrations are indicative of the middle to upper range of oligotrophy, and were similar in average values and temporal trends in 1994 and 1995, being highest in the spring and lowest in late summer to fall (Shortreed and Morton 2000); the seasonal mean epilimnetic total phosphorus concentration for the two years was 5.5 µg/L. This is very similar to the seasonal mean value of 5.3 µg/L for the same parameter in 1976 (Levy and Hall 1985, citing Stockner and Shortreed 1978). In the same period of 1994 to 1995, epilimnetic nitrate concentrations varied much more substantially, both between years and seasonally though articulate carbon, phosphorus and nitrogen exhibited minimal seasonal variation. Shortreed and Morton (2000) considered Babine Lake to have a relatively abundant nitrogen supply, though decreased in 1994 and 1995 relative to data from the 1970s (see discussion below), and found the lake severely phosphorus limited based on the C:N:P ratio of 473:45:1. This ratio is similar to some sockeye rearing lakes in the Fraser system (such as Shuswap Lake) but much less severely phosphorus limited than many coastal sockeye lakes in the province (Shortreed and Morton 2000). Again, in comparison with other lakes having similar sport fisheries, Babine Lake phosphorus and nitrate concentrations are slightly higher than the median (Table 5).

Shortreed and Morton (2000) also discussed the annual phosphorus budget for Babine Lake, with particular reference to the land use and salmon enhancement activities in the watershed from the 1970s onward. They suggest that the logging of roughly 12 % of the Babine Lake watershed in the final three decades of the 20^{th} century, and associated activities of road construction and slash burning, likely resulted in only transitory low-magnitude increases in fluvial nutrient and sediment loading to the lake. However, they estimated that the annual total phosphorus loading to the Main Arm of the lake has increased by 40% due to import of marine-origin nutrients by enhanced abundance of sockeye spawners. Their calculations neglected the increased export of phosphorus and nitrogen from the lake via sockeye smolts following salmon enhancement, but such exports are generally believed to be a small proportion (5 to 25 %; Moore and Schindler 2004) of nutrient imports when spawner abundance is high. Among other evidence, Shortreed and Morton (2000) suggest that lower nitrate concentrations in 1994 and 1995 relative to data from earlier decades suggests a greater biological demand on nitrogen in the later years.

3.2.3. Phytoplankton and Bacterioplankton

Chlorophyll concentration is often considered an analog for primary productivity. Seasonal average chlorophyll concentrations in the Main Arm were 1.80 µg/L in 1973, and 2.57 µg/L in 1995 (Shortreed and Morton 2000). These values reinforce the classification of Babine Lake as oligotrophic, as do the bacterial concentrations obtained by Shortreed and Morton (2000). However, relative to other lakes with similar sport fisheries, Babine Lake chlorophyll concentrations are higher than the median though data are not available for many such waters. In addition, the 43% increase in chlorophyll concentrations supports the interpretation that Babine Lake became more productive during the period between the early 1970s and the middle 1990s, with sockeye enhancement the most likely explanation.

Photosynthetic rates provide a more direct measure of lake primary productivity. Shortreed and Morton (2000) compared their estimates of seasonal average daily photosynthetic rate for Babine Lake in 1994 and 1995 to values estimated in 1973. Significant adjustment to the earlier data was necessary due to differences in methods[5] but assuming accuracy of the adjustment, photosynthetic rate was approximately 40% higher in the later period. Photosynthetic rates for lakes with comparable sport fisheries have been published only for the waters listed in Table 5 which are all sockeye nurseries; Babine Lake`s seasonal average daily photosynthetic rate (from 1994 – 1995) is second highest of the four for which estimates are available (Shortreed et al. 2001).

3.2.4. Zooplankton

Zooplankton are the most important food of juvenile nerkids in Babine Lake, so the seasonal and spatial patterns of zooplankton abundance have a strong effect on growth and survival of juvenile nerkids (Levy and Hall 1985). Thirteen zooplankton species have been identified in Babine Lake samples (Levy and Hall 1985); of these, the large calanoid copepod *Heterocope septentrionalis* and the moderately large cladoceran *Daphnia galeata* are most important in the diet of young nerkids (Shortreed and Morton 2000). The latter species in particular is a preferred food item and its relative abundance is often strongly negatively correlated with planktivore population density.

Shortreed and Morton (2000) attempted to compare mid- to late-summer zooplankton abundance at Babine Lake in the years 1994 and 1995 with data collected in the 1950s and early 1970s, to examine how sockeye enhancement and the greatly increased abundance of juvenile nerkids might have affected the species composition and standing crop of the zooplankton community. Methodological differences in zooplankton sampling complicated

[5] Specifically, the earlier data used non-alkalized scintillation cocktails which were assumed to have overestimated PR by a factor of 1.49

the comparison. In addition, bottom-up effects of primary productivity and top-down effects of predator abundance can impact zooplankton standing crop, and both of these types of factors have likely changed in the period of reference. Finally, juvenile nerkid abundances in Babine Lake in the years 1994 and 1995 were among the lowest to have occurred since sockeye enhancement, which reduced the effective scope of the data. However, daphnid abundance was more than 5 times as high during the 1950s than in 1973, and over twice as high in the 1950s than in 1994 – 1995.

As with photosynthetic rates, seasonal average zooplankton dry biomass for lakes with comparable sport fisheries have been published only for a low number of sockeye nursery waters (Table 5). Babine Lake`s total zooplankton biomass for the 1994 – 1995 period was the highest of the four waters for which estimates are available, but *Daphnia* biomass at Babine Lake was extremely low compared to the reference waters (Shortreed et al. 2001).

3.2.5. Paleolimnology

Cores taken in deep lake regions in 1972 were used to examine possible trends in the trophic state of Babine Lake, and in the accumulation of copper and zinc. Diatom abundance appeared to have increased in the 50 to 100 years prior to 1972 with no obvious reasons for the change, particularly as it appeared to predate the increased forestry activity and sockeye enhancement in the watershed (Smith 1973). Copper and zinc concentrations appeared to vary markedly in the near-surface sediments.

3.2.6. Synthesis

The chemical and physical limnology of Babine Lake is relatively similar in most respects to other lakes in the province which sustain comparable fish ecotypes and sport fisheries. The lake's trophic status appears intermediate, relative to the comparison lakes: other large interior lakes in the southern regions of the province often display higher productivity than Babine, but the large coastal lakes are much more oligotrophic.

Phosphorus most likely limits primary productivity in the pelagic zone of Babine Lake, and loading of this nutrient has likely been elevated in the decades since sockeye enhancement due to increased spawner carcass abundance. Chlorophyll concentrations and photosynthetic activity appear to have increased in the same time frame, supporting the interpretation that increased salmon escapement has elevated primary production. However, based on the parameters usually evaluated to determine trophic status, Babine Lake is still moderately oligotrophic and the nutrification due to sockeye enhancement does not pose a risk in terms of water quality for fish production or human uses. Due to complexity of the lake ecosystem which includes top-down and bottom-up effects on phytoplankton, zooplankton and other fish populations all resulting from sockeye enhancement, the impact of increased primary productivity of Babine Lake on sport fish populations is not readily predictable.

3.3. Fish Community

The most commonly captured fish species during sampling activities in Babine Lake are (not in order of abundance): sockeye and coho salmon as anadromous members of the genus *Oncorhynchus*; rainbow trout and kokanee as freshwater members of the same genus; lake char, commonly known as lake trout or simply char; coregonids including mountain, pygmy, and lake whitefish; catastomids being coarsescale, white, and longnose sucker; cyprinids including redside shiner, longnose dace, peamouth chub, and northern pikeminnow; cottids being prickly sculpin; and gadids being burbot.

Other species present at least occasionally in the lake include chinook and pink salmon which spawn in low numbers in Fulton River and Morrison Creek; cutthroat trout; and char which may include Dolly Varden or bull trout or both. For the less abundant freshwater-resident salmonid species, presence in the lake may represent straying from the usual range of their populations in the upper Babine watershed downstream of Babine Lake. Lake chub are present in Babine Lake's tributary watersheds and thus likely occur in the lake itself, though whether as a distinct population is unknown. Bustard (1990) captured brassy minnow in the Sutherland River watershed and, assuming a persistent population there, individuals probably also disperse at least occasionally into Babine Lake. Pacific lamprey are also likely present in the lake and adjacent streams.

Fish species believed to occur in 17 lakes which support comparable rainbow trout ecotypes and fisheries are listed in Table 6. The species lists do reflect substantial uncertainty in some cases. In addition to rainbow trout, from 2 to 28 other fish species are present in the reference lakes and lake surface area is clearly a strong correlate of fish species richness. Babine is the largest unimpounded water of these lakes and its species richness is second highest of them. Only 5 of the reference lakes also are presently accessible to anadromous fish species. A majority (11 of 17) appear to support piscivorous char populations, either lake char or bull trout or both (Table 6). In summary, the pelagic piscivorous rainbow trout ecotype is displayed in lakes with widely varying fish communities, and the presence of kokanee appears to be the primary prerequisite for the occurrence of this ecotype.

Table 5 (modified from De Gisi 2003)**.** Physical and water chemistry parameters for lakes which support indigenous populations of pelagic piscivorous rainbow trout. **Watershed** gives the parent catchment, where C = Columbia, F = Fraser, L = Lyre and S = Skeena. **Surface Area** unit is km^2. All **Depth**s are in metres. [P] = total phosphorus; **Alk** = total alkalinity; **Daily PR** = photosynthetic rate (milligrams of carbon per square metre per day); **Zooplankton Biomass** = dry weight biomass of zooplankton standing crop, where the first value in each cell is the total biomass and the smaller value is *Daphnia* biomass; ppm = parts per million; µg/L = micrograms per litre. Blank cells indicate data may exist but could not be located; NA indicates data are known not to exist; V indicates this parameter varies spatially to such a degree that a single value cannot be given.

Lake	**Water-shed**	**Surface Area**	**Mean Depth**	**Max Depth**	**Thermo-cline Depth**	**Euphotic Zone Depth**	**TDS (ppm)**	**Nitrate (µg/L)**	**[P] (µg/L)**	**Chloro-phyll a (µg/L)**	**Alk (ppm)**	**Daily PR (mg C/m^2)**	**Zooplankton Biomass (dry mg /m^2)**
Nechako Res.	F	1200	NA	>300	~20	18.0	23	5.5	5.9	1.19	20.2		
Arrow Res.	C	526	83	287	V	25.4	60	145.0	4.0	1.80	55.0		
Babine	**S**	**490**	**61**	**186**	**11.3**	**6.9**	**60**	**26.0**	**5.5**	**2.20**	**36.6**	**140**	**1031 / 28**
Kootenay	C	407	102	154	>30	21.0	~120	90.0	~10	2.50			
Okanagan	C	360	70	232	15.0	14.0	160	20.0	~ 9	3.90			
Shuswap	F	290	62	162	10.0	12.3	80	18.0	5.1	1.81	35.7	171	1005 / 400
Quesnel	F	264	158	530	12.4	15.5	88	68.0	2.8	1.03	46.4	102	829 / 237
Eutsuk	F	245	106[6]	323	19.0	29.1	19	20.0	2.3	0.75	14.5		
Kamloops	F	62	74	151			78		10.0				
Mabel	F	60	120	201			99						
Bonaparte	F	39	40	98	14.8	13.3		1.6	5.0		38.8	131	816 / 301
Isaac	F	33	60	174			~108[7]						
Crescent	L	20	101	191	~25	>50	75	~1.0	> 3	0.38	49.1		
Tesla	F	19	41	108			26						
Nadina	F	9	15	35			38						
Khtada	S	6	66	158	14.0	28.5	7		< 3	1.20	4.5		

[6] rough estimate only, from Lyons and Larkin (1952)
[7] No water chemistry data were accessible for Isaac Lake; the listed TDS is for Cariboo Lake downstream

Table 6 (modified from De Gisi 2003)**.** Fish community characteristics of lakes which appear to support indigenous populations of the pelagic piscivorous rainbow trout ecotype. Definitions of **Fish Species Codes** are provided in Appendix III; codes in parentheses in this table are species whose presence in the lake is suspected but unconfirmed. **Anadr Access** = do anadromous fish access the lake? Where Historic indicates past access but not current; **Pisc Char** = are piscivorous char resident in the lake?; **Species Complete** = is the list of species present likely a complete and accurate list?

Lake	**Anadr Access**	**Pisc Char**	**Fish Species Codes (Current Presence)**	**Species Count**	**Species Complete**
Nechako Res.	No	No	BB CAS CSU KO LKC LSU MW NSC	8	Yes
Arrow Res.	Historic	Yes	BB BSU BT CAS CBA CCG CCN CP CRH CT EB KO LDC LKC LMB LSU LW MW NSC PMB PMC PW RSC SG UDC WP WSG YP	28	Unknown
Babine	**Yes**	**Yes**	**BB BT CAS CH CO CT (DV) KO L LSU LNC LT LW MW PMC PW PK NSC RSC SK WSU**	**21**	**Yes**
Kootenay	No	Yes	BB BT CAS CSU KO LNC LSU PMC MW WSG	10	Unknown
Okanagan	Historic	Yes	BB CAS CCG CMC CSU KO LNC LSU LT LW MW NSC PMC PW RSC	15	Unknown
Shuswap	Yes	Yes	BB BT CAS CH CO CSU KO LNC LSU LT LW MW PW NSC PK PMC RSC SK SU WSG	20	Unknown
Quesnel	Yes	Yes	BB BT CH CO KO LT LNC MW NSC PMC RSC SK SU	13	Unknown
Eutsuk	No	No	BB CC CSU KO (LNC) LSU MW NSC	8	Yes
Adams	Yes	Yes	(BB BT CAS CH CO CSU) KO (LNC LSU LT LW MW PW NSC PK PMC RSC) SK (SU WSG)	20	Unknown
Kamloops	Yes	Yes	BB BT CH CAS CSU LSU MW NSC PMC RSC SK ST	12	Unknown
Mabel	Yes	Yes	BB BT CC CH CO CSU KO LT LNC LSU MW NSC PMC RSC SK	15	Unknown
Bonaparte	Recent	No	CSU KO LNC MW NSC PMC RSC	7	Unknown
Isaac	No	Yes	KO LT MW	3	Yes
Trout	No	Yes	BB BT CAS CRH CSU (CT) KO LKC LNC LSU MW NSC RSC	13	Unknown
Crescent	No	No	CT KO PW	3	Yes
Tesla	No	No	CSU KO LSU MW NSC	5	Yes
Nadina	Sporadic	Yes?	(BT) KO LSU MW SK	5	Yes
Khtada	No	No	DV KO	2	Yes

4. Kokanee

This report follows convention in referring to populations of *Oncorhynchus nerka* whose members are dominantly anadromous as sockeye salmon, or sockeye, while populations whose members rear to sexual maturity in lakes are called kokanee. Kokanee can occur in lakes which are isolated from anadromy by barriers downstream, or can co-occur with anadromous sockeye salmon. The term "nerkid" is used include both sockeye and kokanee, usually at the early life stages where the two forms use the same lacustrine habitats and cannot be easily distinguished by size or external morphology.

Recreational fisheries target large-bodied kokanee populations in some British Columbia lakes such as Okanagan and Kootenay. There is no documented sport fishery directed at kokanee in Babine Lake, presumably due to their small body size and the presence of other (larger) species forms of greater appeal to anglers. Kokanee are thus reported in the Babine Lake recreational catch relatively rarely, although an additional factor is that participants may confuse the species with rainbow trout. Nevertheless, this form of *O. nerka* has significant ecological importance to the recreational fisheries of the lake, since kokanee are often prey for the larger piscivorous game fish species such as rainbow trout and lake char.

The primary motivator of Babine Lake kokanee data collection to date has been the desire to understand the ecological interactions between the two forms and how the abundance and management of commercially-important sockeye might be affected. In contrast to early researchers on Quesnel Lake and other waters managed by the International Pacific Salmon Commission (Sebastian et al. 2003), pioneer investigators of Babine Lake salmon production did not appear to view kokanee as a serious competitive threat to sockeye output based on the content of their published work. As a result, there have been no long-term data collection efforts for Babine Lake kokanee. Research projects of shorter duration, and incidental data collection, have added significantly to an understanding of kokanee ecology in Babine Lake as detailed in the sections which follow.

4.1. Population Structure of O. nerka

Early investigators of *O. nerka* reproduction in Babine Lake tributaries (Hanson and Smith 1967; McCart 1970) observed participation of male kokanee during sockeye spawning. In particular, kokanee males often sneak-spawn with sockeye females in early streams where the two forms are present with the same approximate seasonal timing. McCart (1970) hypothesized that "quite possibly, the *O. nerka*, sockeye and kokanee, spawning in the early streams constitute a single, panmictic population, a population quite different from those utilizing the large, stable streams[8]", implying minimal (or no) genetic differentiation between the two forms in the early spawning streams where both are relatively abundant. To help clarify spawning stream fidelity and the resulting implications for *O. nerka* population

[8] He also asked "Why, however, is the polymorphism confined almost exclusively to the early stream populations in the Main Lake area? One possible explanation is that the offspring of female kokanee, which suffer from an initial size disadvantage, cannot tolerate intense intraspecific competition such as occurs in high-density nursery areas like the North Arm. Thus, a sockeye/kokanee polymorphism might be a viable strategy only in areas like the Main Lake where low densities of sub-smolt offspring limit intraspecific competition."

genetics and stock dynamics, McCart (1970) performed extensive displacement experiments by tagging migrating sockeye and kokanee attempting to enter the mouths of spawning streams and then releasing them in the lake at distances of up to 15 km to assess their ability to return to the location of capture. However, he also emphasized the weakness of this experimental approach, stating that "displacement experiments are at best an unsatisfactory method of determining rates of straying" and thus add little to the understanding of population structure.

Subsequent survey of variation in allozymes during the 1980s and 1990s established that despite sneak spawning by kokanee males and early viability of hybrid fry in a hatchery setting, Babine Lake sockeye and kokanee are genetically divergent morphs and not simply ecological phenotypes within one or more polymorphic populations. The restriction in gene flow between sympatric kokanee and sockeye in the Babine Lake system, and the greater genetic similarity of kokanee of different Babine Lake tributaries to each other than to sockeye populations spawning in the same lake tributaries (Foote et al. 1989), appear typical of the evolution of the two morphs in other lakes where they co-occur (Wood and Foote 1996; Craig and Foote 2001).

Allozyme, mitochondrial, and microsatellite DNA evidence collected in the last two decades led Wood et al. (1998) to consider the early, mid- and late-run sockeye of the Babine Lake system as sub-populations connected by relatively high levels of gene flow, rather than discrete populations. Kokanee populations of Takla Lake appear to show gene flow between tributaries similar in magnitude to that displayed by sockeye using the same tributaries (Wood and Foote 1996). Comparable data for Babine Lake kokanee do not appear to have been reported, so the implied rates of straying and implications for population genetics and abundance dynamics cannot be assessed.

Methods which can distinguish juveniles of kokanee and sockeye have not been applied to nerkid fry during Babine Lake residence. As a result, research on unmarked fry and yearling nerkids in Babine Lake to date may have described the behaviour and dynamics of either sockeye alone, or (more likely) both forms together. Yearling nerkids, in their second summer of Babine Lake residence, also represent a mix of sockeye and kokanee. It is believed that roughly 98% to nearly 100% of Babine Lake sockeye smolt in May or June of their second year (Johnson 1956; McCart 1970, citing Dombroski 1954) [9], and are thus referred to as one-summer smolts. The remaining smolts are nearly exclusively two-summer fish (McCart 1970). But although the two-summer fish are an essentially inconsequential proportion of sockeye smolt output and adult returns, they may form a substantial component of the yearling and older nerkid numbers present in Babine Lake in most summers, and could confound kokanee abundance estimation and any other data collection for kokanee yearlings. For instance, since the construction of spawning channels on Pinkut Creek and Fulton River, the average annual output of Babine Lake has been on the order of 72 million smolts (Wood et al. 1998). If an average of 1% of the spring outmigration are two summer smolts, this suggests that 750,000 or more yearling sockeye were present in the lake the previous summer. Assuming a total of 40,000 kokanee spawners, the total number of yearling and older kokanee in the lake might be 600,000 or less in most years. In other words, yearling sockeye could outnumber all post-fry kokanee in many years since sockeye enhancement; in

[9] Numerous other references rarely provide data to confirm the proportions

most years before enhancement sockeye yearlings were probably still a very significant component of the post-fry *O. nerka* numbers in the Main Arm of the lake.

4.2. Kokanee Ecology and Life History

4.2.1. Spawning Geography, Timing, and Habitat Choice

Johnson (1958) provides the first discussion of Babine Lake kokanee reproduction in the available literature. Based on information provided by the Fisheries Officer[10] charged with enumerating sockeye on Babine Lake tributaries, Johnson listed Tachek Creek as the principal kokanee spawning ground, with Grizzly [Shass] Creek of high secondary importance; Twin, Pierre and Pendleton creeks of moderate importance; and Four Mile, Five Mile, Six Mile, Nine Mile and Sockeye creeks supporting " a few hundred [kokanee] spawners at most." He also noted that "some spawning in the lake is suspected."

Several categories of nerkid spawning streams were recognized by McCart (1970) for the Babine Lake drainage, who stated that roughly 15 smaller spawning streams and 4 larger streams are utilized, inclusive of Nilkitkwa Lake and the Babine River immediately downstream but exclusive of the Morrison system. The larger streams are lake fed, more stable and warmer, and include the upper and lower Babine River, Fulton River, and Pinkut Creek. The smaller streams are known as the early streams because sockeye spawners enter and spawn there earlier in the year than in the larger streams. In the period 1949 to 1966, the early streams were believed to have averaged slightly more than 10% of the sockeye escapement to the Babine Lake system as defined previously, with Pierre Creek alone receiving about half of the early stream total. The early streams are "heavily shaded and have little or no drainage from lakes, marshes, beaver dams or other sources of warm water" (McCart 1970) and at typical discharge, water temperatures seldom exceed 15°C; McCart (1970) measured water temperatures of 10 to 13°C in the early streams in mid-August 1966 during the peak of sockeye spawning. Water temperatures in the late streams do not decline to this temperature range until late September to October, which is when sockeye spawning typically occurs in these streams. Based on tagging results, subsequent researchers have divided McCart's (1970) late streams into middle and late, with Pinkut Creek and Fulton River occupying the middle designation and the upper and lower Babine River considered late runs (Wood et al. 1998).

McCart (1970) further distinguished three types of early streams. Type 1 streams including Pierre, Twain, Four Mile and Shass creeks, nearly always convey sufficient flow for sockeye to enter although occasional low discharge can create high water temperatures and reduced dissolved oxygen concentrations causing partial mortalities to sockeye spawners. Type 2 streams are those which are normally accessible to spawning salmon but are dewatered during years of sub-normal rainfall. Streams of this type include Five Mile, Nine Mile, Tachek, Sockeye and Gullwing creeks. Type 3 streams include Kew, Forks, Pendleton and Donald's creeks: these are normally dry during the spawning season but are utilized by sockeye in years of above-normal precipitation.

[10]L.J. Gelley, whose tenure as Fisheries Officer on Babine Lake spanned at least two decades

McCart (1970) states that kokanee have at least occasionally been observed spawning in all of the sockeye spawning streams of the Babine Lake system, but that only in the early streams tributary to the Main Arm of Babine Lake do kokanee comprise more than a small proportion of *O. nerka* spawners. In the years 1964 to 1967 inclusive, McCart (1970) attempted to enumerate kokanee in all of the streams in the Babine Lake system where spawning was believed to occur, and concluded that more than 95% of the kokanee escapement during that period occurred to six streams, namely Pierre, Twain, Tachek, Four Mile, Shass and Sockeye creeks (Table 13). McCart (1970 citing personal communication of C. Groot) also suggested "there is some indication that, prior to spawning, large numbers of kokanee leave the North Arm and move into the Main Lake. These presumably spawn in streams flowing into the Main Lake."

Regarding timing, McCart (1970) reported that in all streams where kokanee spawning has been observed in the Babine Lake system, including both early and late streams, late July or August was the period utilized. Thus in the early streams, kokanee spawning activity occurs concurrent with that of sockeye. In the middle and late streams, kokanee spawning occurs earlier than (and generally does not overlap with) sockeye reproduction. McCart (1970, his Figure 11) monitored the sex-specific seasonal periodicity of stream entry by sockeye and kokanee spawners to Four Mile Creek, from late July to early September during 1964 through 1966. His counts showed that most of the large daily movements of sockeye and kokanee occurred in the first half of August and that the midpoint of entry had occurred by August 10[11]. However, day to day fluctuations in entry numbers of the two forms were not synchronized, implying independence of their migrations. On average, non-jack males of both forms entered the stream slightly earlier than females, with the 50th percentile of the male run passing the fence 1 to 3 days earlier than that of the females; the midpoint of the jack sockeye entry occurred 2 to 7 days later than that of the female sockeye component.

McCart (1970) used daily stream surveys for fish which had been tagged at the weir to estimate the stream life of sockeye and kokanee spawners in Four Mile Creek. Recovery of 61% and 83% of carcasses of tagged kokanee and sockeye respectively showed no significant difference in the mean duration of stream life of the sexes of either species, but a marked linear seasonal decline in the mean stream life for both forms. The overall mean duration of stream presence was about 13 and 11 days respectively for kokanee and sockeye, but a twofold or greater reduction in this statistic was observed over the course of the run. Mean stream life was 16 to 19 days for kokanee which entered Four Mile Creek during the first week of the run in 1965 and approximately 8 days for those which entered two to three weeks later (McCart 1970, his figure 12).

McCart (1970) observed that kokanee were able to access and use streams and portions of streams which were unavailable to sockeye due to water depth and obstructions. For instance, sockeye were present in the lake at the mouth of Gullwing Creek but unable to enter during a 7 to 10 day period in 1965 and 1966, until he rechanneled the stream to allow their access; kokanee had been able to enter throughout this period and to pass similar obstructions upstream which barred sockeye movement. Beaver dams also blocked the passage of the majority of sockeye spawners, particularly males, in places where kokanee

[11] McCart also noted that in each year, late runs of up to 200 sockeye entered the stream after the removal of the fence in early September but that additional kokanee were not seen at this time.

were able to “wriggle through the interstices” (McCart 1970). During the period of his research in the middle 1960s, he found that dams requiring blasting for sockeye passage were particularly common on the early streams which enter the west shore of Babine Lake between Fulton River and Pinkut Creek.

Regarding the use of habitat within a particular stream, McCart (1970) found that both kokanee and sockeye ascended Four Mile Creek to the first impassable waterfall, and no important differences in the general distribution within the accessible section. However, based on a relatively limited sample in 1966, their redd sites appeared to differ on average in characteristics related to water depth and velocity and gravel permeability. Kokanee tended to spawn in shallower water with lower velocity, in sites along the edges of the channel, in pools and behind boulders; kokanee redd locations showed a greater proportion of fines in the substrate resulting in lower permeability (McCart 1970, his table XIV). McCart hypothesized that the difference in site choice of kokanee was not due to the presence of sockeye. In the low water years of 1965 and 1966, kokanee accessed Gullwing Creek a week or more before sockeye, but the early kokanee entrants chose redd sites similar to those chosen by later kokanee arrivals when sockeye were also present.

Although kokanee are present in Morrison Lake, the population is presumed distinct from those of Babine Lake. Spawning locations for Morrison Lake kokanee are not well documented (Bustard 2004), but at a salmon enumeration fence near the mouth of Morrison Creek during the 1990s very few (< 20) kokanee spawners from Babine Lake were recorded entering the creek (Diversified Ova Tech 1996; Diversified Ova Tech 1999).

Despite the commentary of Johnson (1958), significant use of the lakeshore for spawning by kokanee in Babine Lake now appears unlikely. Wood et al. (1995) questioned the accuracy of historical assumptions that discrepancies in counts of sockeye spawners in the Babine Lake system were attributable to substantial shoal spawning. Instead, they suggested that biases in the counts were the most parsimonious explanation, and that lakeshore spawning was probably very minor in quantity. Diver surveys of substrate distribution along the Main Arm lakeshore along with experimental placement of sockeye eggs and late winter sampling of natural redds (Emmett and Convey 1992; Emmett 1992) all suggested that:

- the quantity of such spawning by sockeye is low as it was observed only in one year of three,
- very little suitable gravel/cobble substrate relatively free of fine sediment occurs at depths great enough to avoid winter freezing,
- substrate at greater depths was typically silt or hard clay,
- dissolved oxygen concentrations were low in the substrates even near stream outwash fans,
- the survival to emergence of deposited eggs was low.

As mentioned previously, kokanee in Babine Lake tributaries appear to utilize smaller substrate with higher proportions of fines than do sockeye (McCart 1970). In addition, the timing of lakeshore surveys utilized by Wood et al. (1995) might have been too late to observe spawning kokanee. For both of these reasons, the lack of confirmation of lakeshore-spawning kokanee by Wood et al. (1995) cannot be interpreted as proving that it does not occur. The low dissolved oxygen concentrations would also be problematic for kokanee regardless of the greater tolerance of fines. In short, though shoal spawning kokanee are important in other large lakes such as Okanagan and Quesnel, there is little indication of this for Babine Lake. Further investigation of the physical habitat differences between the lake shorelines would provide additional assurance of the validity of this conclusion.

4.2.2. Age, Size and Sex Ratio of Kokanee

The earliest available published information with respect to the age, size, and sex ratio of Babine Lake kokanee is again provided by Johnson (1958), for kokanee spawners. He states that "there appears to be a consistent predominance of males in the spawning populations (about 75%). […] Most specimens examined were maturing in the fourth year of life; however a few 3-year-old and 5-year-old spawners have also been noted. Mean fork length at maturity is about 10 inches."

Before examining the results of Johnson (1958) and McCart (1970) with respect to life history characteristics of Babine Lake kokanee including age at reproduction, a review of terminology is necessary. Though not explicitly stated, McCart (1970) provides sockeye ages using the Gilbert-Rich designation (see Burgner 1991, p. 11). Thus, he designates Babine jack sockeye as 3_2; this is the same as stating that for jack spawners, 3 full years have passed between their deposition as an egg and their return to attempt reproduction. Equivalently, from deposition as an egg, the jack has lived through 3 winters in total by the time it returns to spawn. The subscript 2 in the formula indicates the jack sockeye migrated to the ocean after its second winter, having spent one winter as an egg in the spawning gravel and one winter as a juvenile in Babine Lake. The Gilbert-Rich designation of 3_2 for Babine Lake jack sockeye is equivalent to 1.1 in the age designation system currently in use by North American salmon scientists (Burgner 1991; Wood et al. 1998). The 1.1 formula denotes the number of freshwater and ocean (winter) annuli visible in the scale, in that order and separated by the decimal point, no annulus having formed during the winter as an egg and no annulus being present for the final year of life because post-spawning mortality occurs before its formation. For kokanee, McCart (1970) provides ages for both spawners and lake-captured fish as single integers: 3, 4, or 5. Current convention in North America for age designation of freshwater fish is similar to the present Pacific salmon system, in that (winter) annuli are counted; when circuli are present at the margin distal to the last annulus, these are usually indicated with the '+' symbol following the annulus count. If McCart's (1970) kokanee spawner ages (3,4,5) provide the number of winters of life including the egg stage, in concordance with his Gilbert-Rich ages for sockeye, then his ages for kokanee spawners would correspond to 2+, 3+ and 4+ by the present freshwater scale age designation system.[12]

The sex-specific age compositions of the1964 and 1965 kokanee spawning runs to Four Mile Creek, an "early" stream tributary to the Main Arm of Babine Lake, were sampled

[12]This appears most likely to be the case, but the issue is somewhat confused by the wording of McCart's (1970) text. For instance, on page 1 he states that "most Babine Lake kokanee spawn in their fourth year". This introduces an additional element of uncertainty because if the age of a fish is initiated at the time of its deposition as an egg, spawning presumably occurs (on average) at the transition between years of age, for example at the interface between the fourth and fifth year; a fish which is in its fourth year of life is not yet four years old. Johnson (1958) perhaps clarifies the imprecise usage by stating that most specimens examined were *maturing* in their fourth year of life but that a few 3 year old and 5 year old *spawners* also occur (italics added).

by carcass examination and reported by McCart (1970, his Table IX); graphical and tabular representation of his results are given by Figure 3 and Table 7. In addition, he reported the sex-specific age composition of kokanee captured in Babine Lake by gillnet in 1958 and 1959, and purse seine in 1966; Table 7 extracts these results and graphical representation is provided by Figure 4. Finally, McCart (1970, his Table XI) provided the unaged sex ratio of in-migrating Four Mile Creek kokanee spawners examined at a weir at the mouth of the stream in 1966, as well as the unaged sex ratio of kokanee captured in Babine Lake by gillnet in 1957, 1960 and 1965 and by purse seine in 1965; these results are extracted here in Table 7.

Males were 57.5% (n = 1711) and 59.1% (n = 1132) of the examined carcasses in Four Mile Creek in the two years 1964 and 1965; a second estimate of the proportion of males in 1964 was 71.2 % (Table 7) though the discrepancy between the two values for 1964 is unexplained. Enumeration of in-migrating spawners at the mouth of Four Mile Creek in 1966 (n = 3242) estimated that 72.5% were males. Lake gillnet and purse seine samples, which presumably captured kokanee originating from multiple streams comprising a mix of fish which would have spawned in the year of capture and others which would not, showed percentage of males ranging between 51.6% and 65.7% for all ages aggregated, though the range was 57.5% to 60.3% for the larger samples with n > 750 (Table 7; Figure 4). For lake-captured fish, there was no consistent trend in percentage of males with age. In summary, the available data suggest that Babine Lake kokanee populations tend to be dominated by males by the age of 2 yr or earlier, with the percentage of males potentially in the range of 55% to 70%.

Both male and female kokanee spawners at Four Mile Creek were predominantly age 4 in both 1964 and 1965 (Figure 3); the relative abundance of age 5 spawners was much greater in 1965, when they comprised 18.8% of all spawners, than in 1964 when only about 4.3% of spawners were age 5. Conversely, age 3 spawners were 7.6% of the run in 1964 and 3.1% in 1965. For kokanee captured in the lake by both gillnet and purse seine (Figure 4), the proportions at age reflect abundance in combination with the size selection curve of the sampling method; without knowing the form of the latter, the true underlying age distributions cannot be discerned. Purse seining is an active sampling method and probably selects for younger smaller fish whose ability to escape the seine is less due to reduced swimming velocity (Figure 4 lower panel), whereas gillnetting may select for larger individuals whose greater average swimming velocity can increase both their probability of encountering the fixed-location gear and their probability of retention in the mesh (Figure 4 upper and middle panels). In addition, samples collected in the lake during spring and summer reflect a mix of spawners and non-spawners. Regardless, the gillnet and seine data appear to verify that age 5 kokanee typically comprise a very small proportion of the Babine Lake population.

Surprisingly few reports of kokanee lengths and weights are available in the published material. In their study of mate selection by spawning Babine Lake sockeye, conducted in Four Mile Creek in 1964 and 1965, Hanson and Smith (1967) stated that “kokanee form a discrete group between 15 cm and 26 cm in length and are always smaller than any anadromous fish.” They did not state whether this generalization applied to all Babine Lake tributaries or only Four Mile Creek, and did not provide the type of length measurement used though their subsequent data are reported as the posterior edge of the eye socket to the posterior edge of the hypural plate; these lengths are designated POH and are utilized for adult *O. nerka* due to sexual dimorphism in snout length at spawning as well as erosion of the caudal fin at this time (Gustafson et al. 1997). McCart (1970) provided POH length-at-age data for kokanee and sockeye spawners at Four Mile Creek in 1965, measured in cm. Equations for conversion of POH to fork length (snout to tail fork length, abbreviated as SNF by Gustafson et al. 1997) for kokanee do not seem to have been published. Ricker (1982, as cited by Gustafson et al. 1997) provided sex-specific linear regression equations for the conversion of POH to SNF for ocean-caught male and female sockeye salmon, but these equations appear inappropriate for kokanee of the size produced by Babine Lake[13]. For very general and approximate purposes, fork length may be 120% of POH length based on the slopes of the equations of Ricker (1982) and neglecting the sex-specific differences in morphology. Assuming this to be the case, re-conversion of the lengths at age for Four Mile Creek kokanee spawners in 1965 given by McCart (1970, his Figure 6) is shown in Figure 5; lengths are only approximate due to the reconversion and the change in units. Estimated male kokanee fork lengths ranged between 17 and 25 cm, with the mode for both age 4 and age 5 male spawners being 22 cm (Figure 5). The range of female fork lengths was 19 cm to 25 cm, with the modal fork length again 22 cm for both 4 and 5 year olds (Figure 5). Regardless of the imprecise conversion of spawner measurements for comparability to non-spawning *O. nerka*, McCart (1970) found no overlap in the in the POH length frequency distributions of the kokanee and sockeye spawners at Four Mile Creek in 1965: "the largest four and five year old kokanee were 21 cm and the smallest three year old male (jack) sockeye 24 cm in hypural [POH] length".

Additional mean lengths of female spawners were reported by McCart (1970) in his summary of kokanee fecundity data (Table 8). He reported egg counts for a total of 117 kokanee spawners from 5 Babine lake tributary streams in the period 1953 to 1965 and for each year-stream group he provided the mean POH length of the sampled females. It is unknown whether the females chosen were representative of the female spawner population size structure, but mean estimated fork lengths ranged between 22 cm and 25 cm. Although very small sample data sets, both 1953 samples displayed mean lengths which were more than 10% greater than subsequent year means.

Foote (1987) reported that kokanee male spawners in Pierre Creek ranged from 21 to 26 cm fork length. His observations were made in early to mid-August 1984.

Kokanee size data and scales were reportedly collected during a creel survey of Babine Lake in 1986 (Bustard 1987, page 6). However, the final document and appendices for the study provide this type of data only for rainbow trout, lake char and burbot but not kokanee.

Midwater trawling was utilized to collect limnetic fish during the sockeye fry abundance estimation study reported by Hume and MacLellan (2000). Fork lengths of the captured nerkids, by day of the year, are plotted in Figure 6 (Hume 2007 unpublished data). No means except age were available to distinguish sockeye from kokanee, so individuals in the age 0 and age 1 groups may be either form. Fish aged as 2+ were kokanee, and their fork

[13] The large negative intercept of the equation for male sockeye (Ricker 1982) implies that if applied in the size range of Babine Lake kokanee spawners, at the same POH length the SNF for males would be less than for females. This is clearly not true, as sexual dimorphism at spawning leads to exaggeration of male snout length relative to body size moreso than for females.

lengths ranged from 176 mm to 220 mm. However, it is unknown whether this group comprised only fish of age 2+, or also older kokanee.

Gillnet sets near Granisle Mine site on August 20 and 22, 2001, resulted in the capture of 7 kokanee of average fork length 207 mm (range 184 to 240 mm), of which 4 were males and 3 were females (Morris 2002; Stantec 2002). The longest individual was a 3 year old female, the shortest was a 3 year old male, and all others were aged as 2 yr. The state of sexual maturity was not reported, and as the collection occurred during the kokanee spawning season it is unknown whether the captured fish were migrating spawners, non-spawners for 2001, or a mixture.

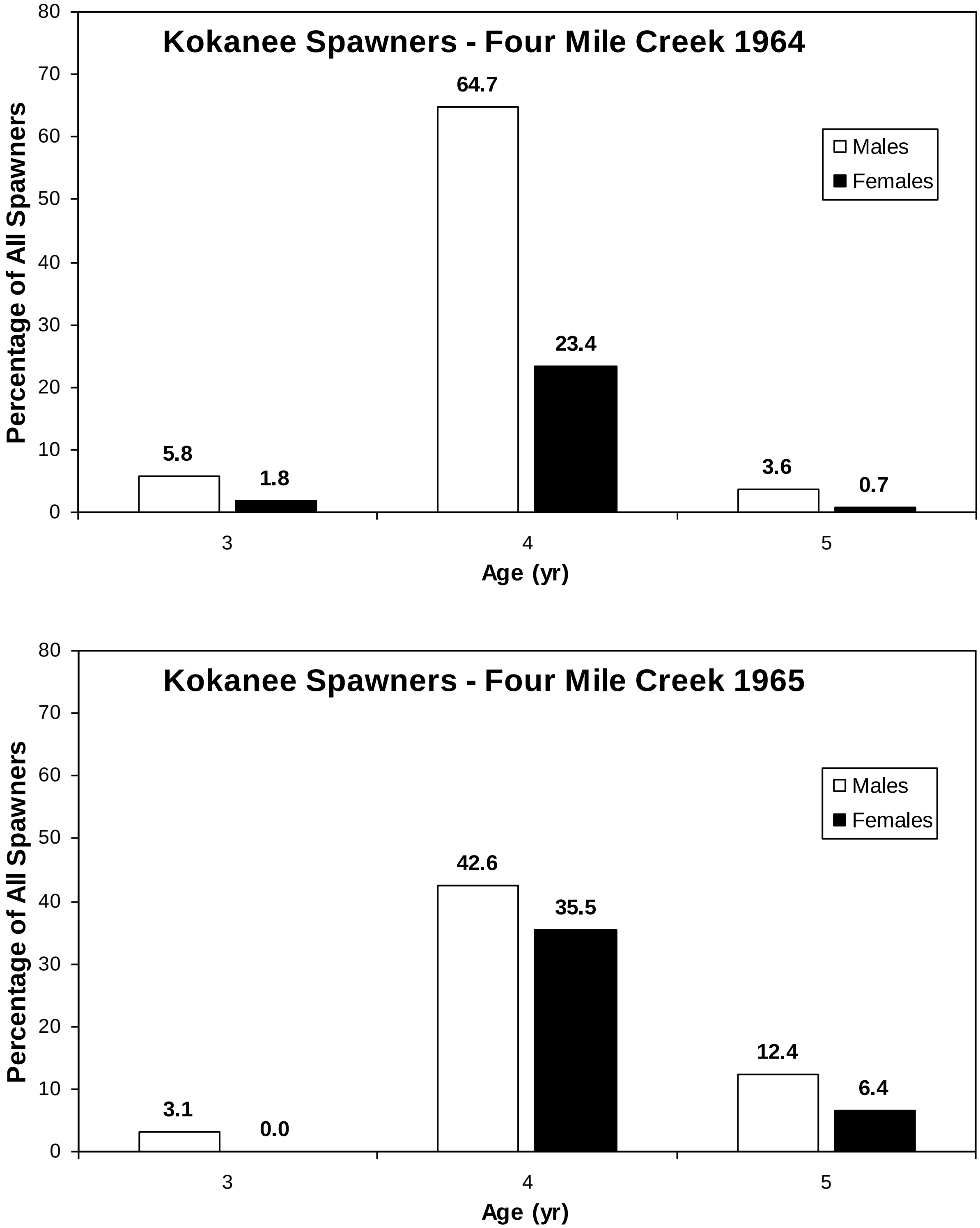

Figure 3. Percentage of kokanee spawners by age and sex, at Four Mile Creek in 1964 (upper panel) and 1965 (lower panel). Numbers above each histogram bar are the percentage values. Data of McCart (1970; his Table IX). There were no age 3 female spawners in the Four Mile Creek sample in 1965.

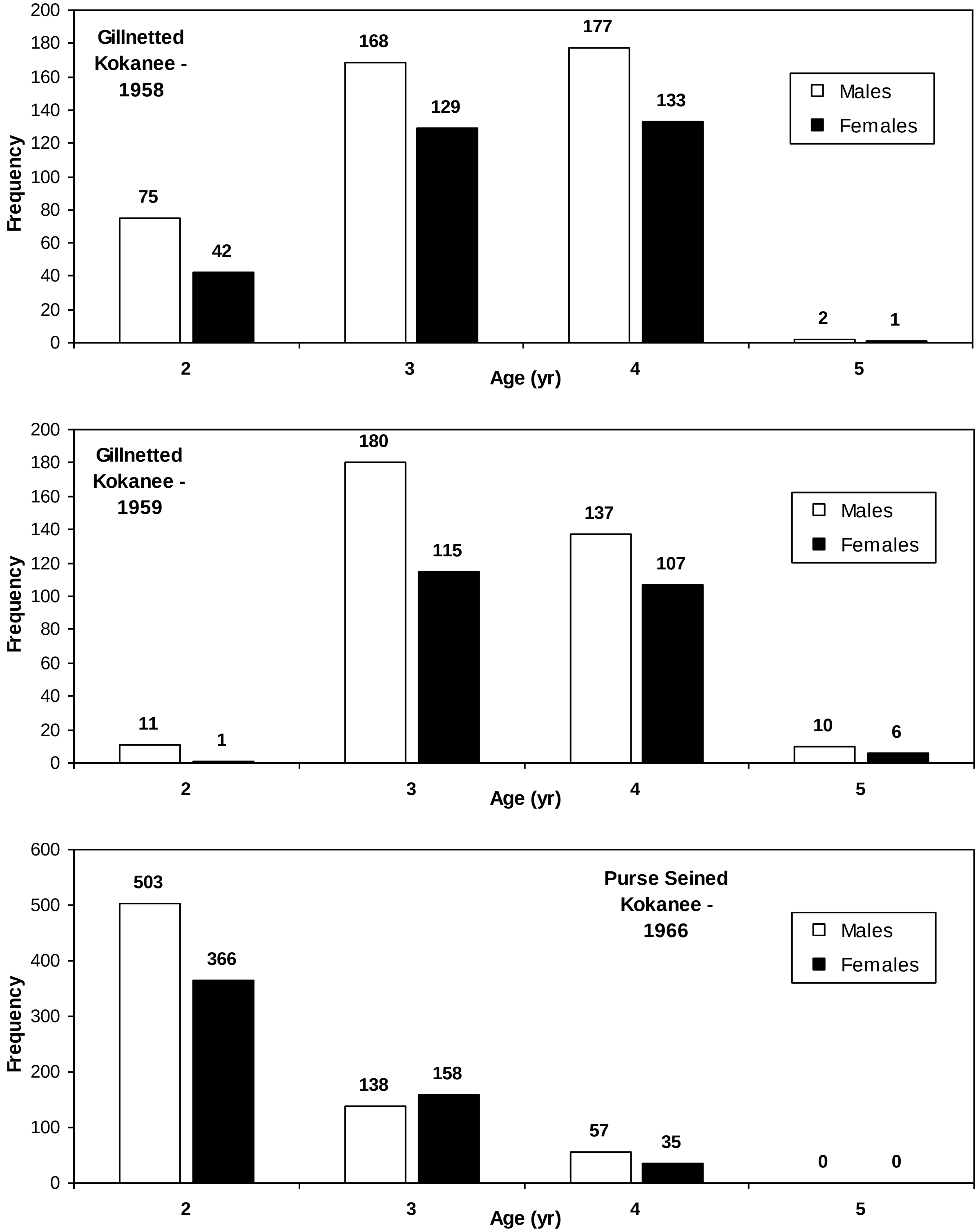

Figure 4. Frequency of kokanee by age and sex, for Babine Lake gillnetted samples in 1958 (upper panel) and 1959 (middle panel), and Babine Lake purse seined samples in 1966 (lower panel). Numbers above histogram bars are the frequencies. Data of McCart (1970; his Table XI) who credited W.E. Johnson for the gillnet data and J. McDonald for the purse seine data. There were no age 5 kokanee in the 1966 purse seine sample.

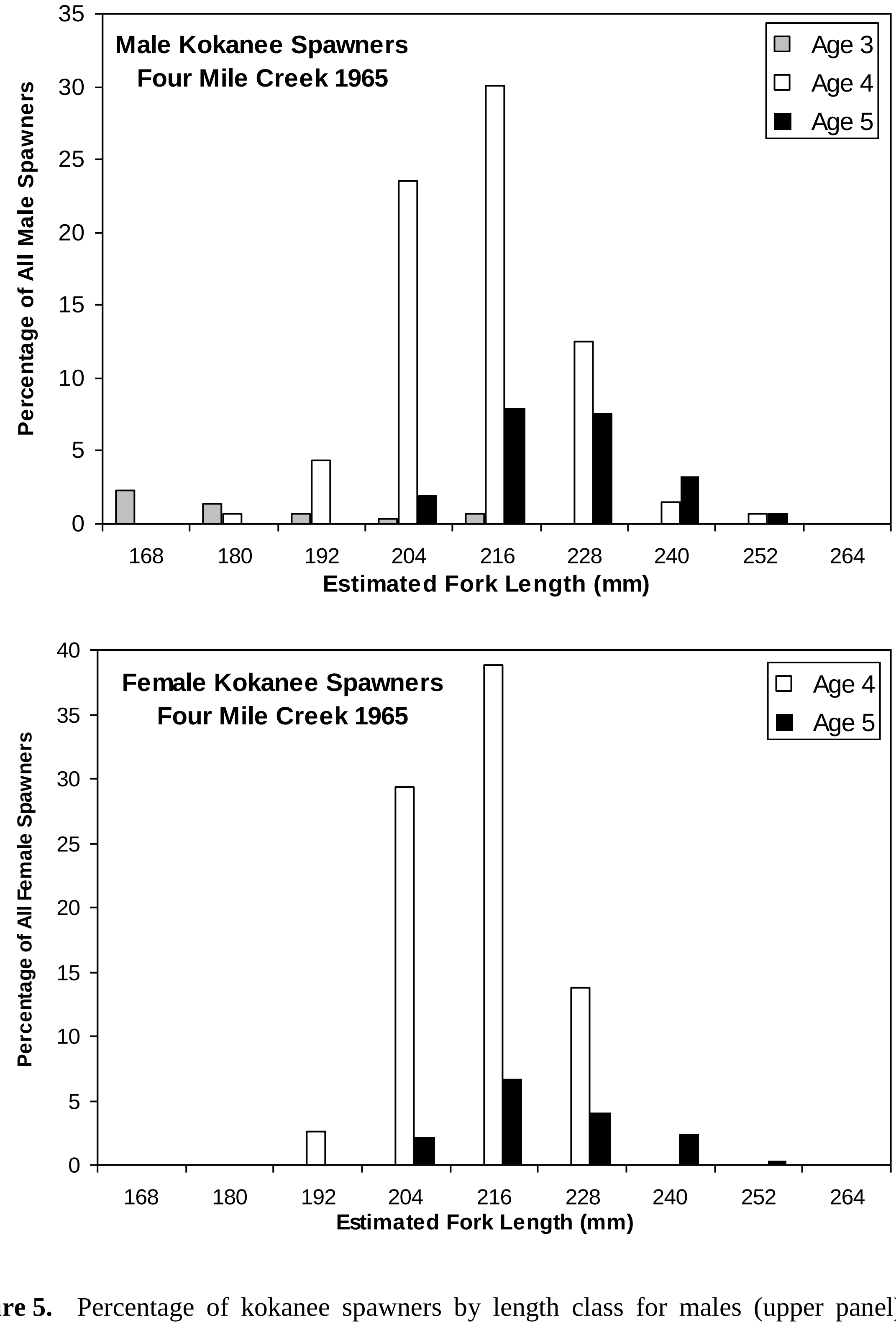

Figure 5. Percentage of kokanee spawners by length class for males (upper panel) and females (lower panel) at Four Mile Creek in 1965. Re-estimated from data of McCart (1970, his Figure 6), who provided POH lengths in cm which are converted here to estimated fork length by addition of 20%. There were no age 3 female spawners in the sample in 1965.

Table 7 (extracted, corrected and reformatted from **Table** IX and **Table** XI of McCart 1970). Age structure and sex ratios of kokanee captured in Babine Lake (**Where** = L) and in Four Mile Creek (**Where** = C). **Method**s of capture are: G = gillnet; PS = purse seine; DR = dead recovery; W = weir count; UN = unknown. For each age class **2** through **5**, as well as kokanee which were **Unaged**, the column headed **n** gives the sample size, and the column **%♂** gives the percentage of the sample identified as male**.** McCart (1970) credits unpublished data of W.E. Johnson for the 1957 to 1960 gillnet results, and that of J. McDonald for the purse seine results. Gillnet effort is unknown. For unexplained reasons, the aged and unaged data for Four Mile Creek in 1964 were included in McCart's Table IX but differed from unaged-only values given in his Table XI, whereas the 1965 data for the creek were identical in the two tables. Thus the two versions of the 1964 data are included below but the Table IX data are excluded from the Stream Total row.

Table	**Year**	**Months**	**Where**	**Method**	**2**		**3**		**4**		**5**		**Unaged**		**Total**	
					n	**%♂**	**n**	**%♂**	**n**	**%♂**	**n**	**%♂**	**n**	**%♂**	**n**	**%♂**
XI	1957	June-July	L	G									35	65.7	**35**	**65.7**
XI	1958	May-Oct.	L	G	117	64.1	297	56.6	310	57.1	3	66.7	480	56.7	**1207**	**57.5**
XI	1959	June-Sep.	L	G	12	91.7	295	61.0	244	56.1	16	62.5	448	61.2	**1015**	**60.3**
XI	1960	Aug.-Oct.	L	G									751	59.0	**751**	**59.0**
XI	1965	June	L	G									120	51.6	**120**	**51.6**
XI	1965	July	L	PS									94	55.3	**94**	**55.3**
XI	1966	June-July	L	PS	869	57.9	296	46.6	92	61.9	0		0		**1257**	**55.5**
Lake Total					**998**	**59.0**	**888**	**54.7**	**646**	**57.4**	**19**	**63.2**	**1928**	**58.4**	**4479**	**57.7**
IX	1964	August	C	UN			34	76.5	392	73.5	19	84.2	501	68.7	**946**	**71.2**
XI	1964	August	C	DR									1711	57.5	**1711**	**57.5**
XI	1965	August	C	DR	0	-	13	100.0	328	54.6	79	65.8	712	59.7	**1132**	**59.1**
XI	1966	July-Aug.	C	W									3242	72.5	**3242**	**72.5**
Stream Total (Table XI data only)					**0**		**13**	**100.0**	**328**	**54.6**	**79**	**65.8**	**5665**	**66.4**	**6085**	**65.8**

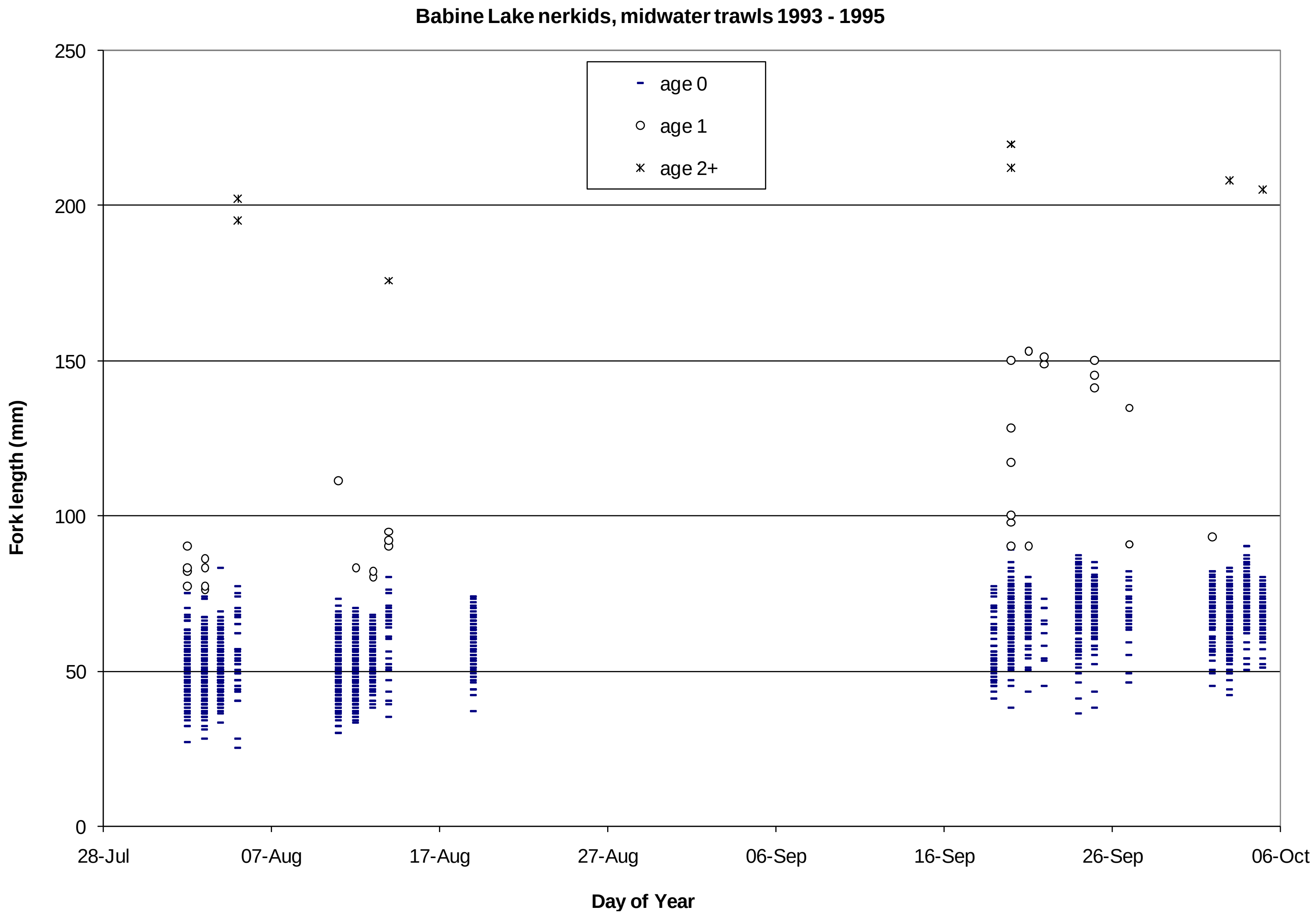

Figure 6. Fork length of nerkids captured in midwater trawls, plotted by day of the year, during the estimation program reported by Hume and MacLellan (2000). The group "age 2+" may include 3 year old individuals.

4.2.3. Kokanee Fecundity and Egg Size

Johnson (1958) stated that egg counts for a sample of 12 female kokanee spawners in 1953 yielded a mean of 390 eggs. The location of collection was not provided, but his data probably were the same as presented by McCart(1970) for Gullwing Creek and Sutherland River in 1953 (Table 8).

Egg counts for a total of 117 kokanee spawners from 5 Babine lake tributary streams in the period 1953 to 1965 were presented by McCart (1970) and are extracted in Table 8. The grand mean fecundity for his data was 290 eggs (range of means 260 to 411), and the grand mean fork length of the female kokanee was 22 cm. However, the spawners from 1953 were on average significantly longer and thus more fecund than those sampled later. Excluding 1953; the grand mean fecundity was 280 (range 260 to 302; Table 8). Fecundity at length for these Babine Lake populations appears higher than for most of the kokanee populations with data compiled by McGurk (2000).

McCart (1970) also compared counts of eggs from the left and right ovaries of kokanee and sockeye, as well as the weight of testes of unspawned non-jack males of both species, but the relevance of these data is not apparent so no further consideration is given here.

Weight distributions of sockeye and kokanee eggs taken from multiple females in Pierre Creek in 1964 and Four Mile Creek in 1965 and raised in hatchery until eyed were reported by McCart (1970). The mean weight of the Pierre Creek kokanee eggs was 0.079 g (n=100, minimum ≈ 0.063, maximum ≈ 0.093) which was only 68% of the mean weight of sockeye eggs. Similarly, for Four Mile Creek, eyed kokanee eggs (n=60) averaged 0.075 g which was 67% of the mean weight of sockeye eggs. For both creeks, the weight distributions of the samples of sockeye and kokanee eggs were essentially non-overlapping: the smallest sockeye eggs were as heavy or heavier than the largest kokanee eggs in these limited samples.

Johnson (1958) cited unpublished research of Withler and Aro in 1953, who placed pairs of ripe sockeye and kokanee into pens embedded in the substrate of Six Mile Creek so that the emerging fry could be sampled with origin known. The mean length of sockeye fry (27.5 mm, range 26 to 29 mm) was almost 20% greater than that of kokanee fry (23.1 mm, range 22 to 27 mm). Johnson stated that length frequency distributions of Babine and Nilkitkwa lake nerkid fry showed no clear bimodality. He used probability paper to further examine whether length frequencies showed evidence of non-normality suggestive of broadly overlapping size distributions. In 1956 and 1957, he compared samples taken from Nilkitkwa Lake and the North Arm of Babine Lake where kokanee were believed to be of low abundance, to those from the Main Arm of Babine Lake where kokanee were expected to be more common. As he expected, the Nilkitkwa / North Arm samples tended to display a single mode, while most of those from the Main Arm appeared to show two distributions with strong overlap. Johnson (1958) estimated that roughly 40 to 45% of nerkid fry in the Main Arm in these years may have been of kokanee origin, in concordance with the unusually high abundance of kokanee spawners in 1955 and 1956.

Table 8 (extracted from Table X of McCart 1970). Fecundity of 117 female kokanee sampled from five spawning tributaries to Babine Lake between 1953 and 1964. **Sample** provides the sample size. **Fecundity** and **POH (cm)** are mean values, where POH is the post orbital to hypural length in cm. **FL (mm)** gives the roughly-estimated snout to fork length, obtained by multiplying the mean POH in cm by 12.

Stream	Year	Sample	Fecundity	POH (cm)	FL (mm)
Sutherland River	1953	4	349	20.4	245
Gullwing [Six Mile] Creek	1953	7	411	20.7	248
Gullwing [Six Mile] Creek nets	1958	29	302	18.0	216
Tachek Creek	1958	14	301	17.9	215
Pierre Creek	1964	12	287	17.9	215
Four Mile Creek	1965	51	260	18.6	223
Grand Mean			**290**	**18.5**	**222**

4.2.4. Lake Residence

As emphasized in Section 4.1, due to the difficulty in distinguishing the young of the two forms, research on unmarked nerkid fry in Babine Lake to date may have described the behaviour and dynamics of either sockeye alone or both forms together and any fundamental differences between the lacustrine ecology of kokanee and sockeye fry remain undescribed. Kokanee egg diameter, and fry length at emergence, are known to be less than for sockeye. The initial difference in size, and subsequent length-dependent growth and mortality rates, may be the most significant ecological difference between the fry of the two forms. Notwithstanding the important differences in average body size which persist throughout their lifecycles, the general behaviour of sockeye and kokanee fry as pelagic planktivores is likely quite similar.

Nerkid fry emerge from the gravel of the Babine Lake spawning streams in May or June and migrate immediately to the lake (Johnson 1958). They may remain in littoral areas for a period of several weeks (McDonald 1969) but generally adopt a pelagic existence by mid-summer. Fry tend to rear in the arm of the lake which receives their natal stream, and minimal movement of fry between the North and Main arms appears to occur (McDonald and Hume 1984). Nerkids are almost completely zooplantivorous as fry (Levy and Hall 1985), and in Babine Lake typically display diel migration. This pattern of movement includes migration to near the surface around dusk to feed actively, movement slightly deeper during the hours of darkness, returning to the surface near sunrise, and then retreating to much deeper hypolimnetic water during daylight hours (Levy and Hall 1985). Post-fry kokanee do not appear to engage in regular diel vertical migration.

Beacham and McDonald (1982) reported on the stomach contents of kokanee collected between 1965 and 1967 during the sockeye fry purse seining program in the pelagic zone of Babine Lake. They categorized kokanee as small (≤ 160 mm) or large (> 160 mm), stating that the small kokanee corresponded mainly to age 2 fish and the large group mainly age 3 with some age 4. They found no differences in the dietary constituents of small and large kokanee in the areas and time periods examined. Both size classes fed mainly on plankton from July through October; insects were a larger proportion of the diet early in the season. Discounting the unidentified material, plankton comprised more than 90% of the stomach contents by volume. In 1967, identification of the genera of plankton consumed revealed that *Heterocope* were of greatest importance in July, with *Daphnia* much more important in August – September. By October, *Daphnia* were no longer present and calanoid copepods had gained in importance. Juvenile fish were not identified in the kokanee diet (Beacham and McDonald 1982); the diet of yearling and older kokanee appears to overlap almost completely with that of sockeye and kokanee fry.

Levy et al. (1985b) reported on the stomach contents of fish gillnetted in littoral areas of Morrison Arm in 1985. However, kokanee were not among the species for which food consumption was examined.

4.3. Kokanee Abundance

4.3.1. Angling Catch

Kokanee are reportedly captured during Babine Lake's recreational fisheries (Whately 1975; Bustard 1987; AGMS 2002). However, this form of *O. nerka* is generally not the focus of targeted sport effort due to the small body size in comparison with other available sportfish in the lake (Bustard 1987; Harrison 2007). The latter include lake char and rainbow trout which are available throughout the open-water season, and adult sockeye salmon which are present seasonally during the spawning migration.

Whately (1975) reported the effort and catch of participants in an angling derby on Babine Lake in late June 1975 in a memorandum which did not document the methodology of the survey; this likely utilized end-of-trip access point interviews on a single date. An estimated 280 angler days yielded a catch of 9 kokanee, implying an overall catch rate of 0.03 kokanee per angler day. However, it is unknown whether the results include released catch, if any occurred.

From mid-May through September in 1985 and 1986, kokanee comprised 10% and 5% respectively of the catch of interviewed anglers on Babine Lake (Bustard 1987). Estimated total catch of kokanee during that period of those years was 3452 and 414 respectively, resulting in implied overall catch per effort of 0.17 and 0.03 kokanee per angler day respectively (Bustard 1987).

During 2927 guided angler days recorded for Babine Lake in the 12 licence years between 1990/91 and 2001/02, angling guides reported client catch of 53 kokanee (AGMS 2002). The kokanee catch was reported in 5 different licence years, by parties whose activity totaled 23 angler days, resulting in average catch per effort of 2.3 kokanee per day by those parties but an overall catch rate of 0.02 kokanee per angler day by all anglers. Because angling guide reports do not record the target species, any days for which kokanee were targeted but not caught would not be evident. Species misidentification and other forms of mis-reporting are also problematic. For these reasons, as well as the low incidence of capture of the form, the annual average guided catch per effort is not a useful indicator of trends in relative abundance of kokanee.

In summary, existing recreational fishery data for kokanee are highly variable in terms of the method of collection, as well as the spatial and temporal scope of the studies. As a result, the data do not provide a reliable means of assessing changes in kokanee abundance through time.

4.3.2. Gillnet Catch

Programs of gillnet sampling of Babine Lake fish populations have been conducted on Babine Lake during the 1940s, 1950s and 1980s, as documented in the available literature. Withler (1948) did not provide the catch of kokanee during standardized gillnetting to assess fish predator species abundance in Skeena sockeye lakes in 1946 and 1947, but at least some of the data appear to have been reported by McCart (1970; see discussion in the next paragraph below). Johnson (1958) stated that the geographic distribution of gillnet (and tow net) catches of yearling and older nerkids in Babine Lake suggested that kokanee are found primarily south of Halifax Narrows, in other words in the Main Arm of the lake, but did not present data in support of this statement. Again, some or all of his gillnet data may have been reported upon by McCart (1970).

Accompanying his discussion of the relative abundance of nerkids in the North Arm of Babine Lake compared to the Main Arm, Table II of McCart (1970; reproduced here in Table 9) provided a summary of the results of the 1946 gillnetting program and also presented catches of a much less extensive gillnetting program in 1958. The nets and techniques used in 1946 were described by Withler (1948), but McCart (1970) does not document the methodology used in 1958, stating only that "Comparisons between the two years are not possible because of differences in nets and techniques […]. The ages of these kokanee are not known but the mesh sizes used (minimum 3.8 cm stretch mesh) suggest that most would have been age II or older." The difference in catch per set between the 1946 and 1958 data is roughly two orders of magnitude, but the relative difference in catch per set between the Main Arm and the North Arm - Nilkitkwa is consistent at approximately one order of magnitude in both years and appears to support the observation that the relative abundance of kokanee was much higher in the Main Arm than in the North Arm and Nilkitkwa Lake (Table 9).

Effort and catch of gillnetting conducted by Westwater Research Centre during 1983 to 1985, in log-impacted and unimpacted sites in the littoral area of Morrison Arm and the Main Arm, are summarized in Table 10. Catch per effort of kokanee was roughly 2.7 individuals per 100 m length of gillnet per night, and this value did not differ between impacted and unimpacted sites. Kokanee are generally pelagic in their behavior, meaning that their occurrence at littoral sites would likely reflect continual movement into and out of the sites rather than long-term occupancy of the site, so the lack of difference between impacted and unimpacted sites is unsurprising. The netting procedures used by the Westwater study were intended to capture littoral fishes, and the differences in methods and net construction between these results and other Babine Lake gillnetting studies mentioned previously prevent any comparison of kokanee relative abundance across the datasets.

Table 9. Reproduction of TABLE II of McCart (1970) captioned as follows: "Catches of kokanee in standard gillnet sets in the North Arm - Nilkitkwa and Main Lake regions of Babine Lake. Data for 1946 from F.C. Withler (personal communication). Data for 1958 courtesy of W. E. Johnson (personal communication)."

	1946		1958	
	No. of Sets	Catch / Set	No. of Sets	Catch / Set
North Arm - Nilkitkwa	155	0.06	6	4.0
Main Lake	365	0.52	14	40.5

Table 10. Gillnet **Effort**, **Catch** of kokanee, and **C**atch **P**er **E**ffort (**CPE**) of kokanee during sampling conducted on Babine Lake by Westwater Research Centre, as a component of the log transportation impacts study of 1983 to 1985. **Log Impacted** sites were located in areas where logs were stockpiled or dewatered, while **Reference** sites were located nearby in unimpacted locations. **Effort** unit is 100 m length of gillnet set overnight.

Year	**Log Impacted**			**Reference**			**All**		
	Effort	**Catch**	**CPE**	**Effort**	**Catch**	**CPE**	**Effort**	**Catch**	**CPE**
1983 - HFP sites	46.9	35	0.75	46.9	7	0.15	93.7	42	0.45
1984 - all sites	78.7	397	5.05	80.4	411	5.11	159.0	808	5.08
1984 - HFP sites	26.8	86	3.21	26.8	78	2.91	53.6	164	3.06
1985 - HFP sites	46.9	41	0.87	46.9	38	0.81	93.7	79	0.84
All years - HFP sites	**120.5**	**162**	**1.34**	**120.5**	**123**	**1.02**	**241.1**	**285**	**1.18**
All years - all data	**172.4**	**473**	**2.74**	**174.1**	**456**	**2.62**	**346.5**	**929**	**2.68**

4.3.1. Purse Seine Catch 1966-1977

Day and nighttime catches of kokanee per haul in defined fishing areas during the 1966 to 1977 nerkid fry purse seining program are compared in Figure 7. Only the results for May through July were utilized for this summary, because the catch rate of kokanee was consistently lower during August and later (Figure 8), and the sampling was unbalanced with respect to the months and fishing areas so including the post-July data could have created bias. For four of the five Main Arm fishing areas as well as Morrison Arm, the catch rate for kokanee was slightly to moderately higher during day than at night, but in the other fishing areas the night rates were higher or the two rates were very similar (Figure 7). Given the magnitude of the variance of the estimates, there was no consistent statistically confirmable difference between day and night catch rates.

The highest average catch rates for kokanee in the May to July period occurred in Morrison Arm (area 8). Average catch rates in the remaining areas of the lake were lower than Morrison Arm but relatively similar to each other, with Hagan Arm (area 10) lowest of all (Figure 7).

To examine whether the catch rates display any possible trend in the relative abundance of kokanee through the 12-year duration of the data, which spans the period of implementation of sockeye enhancement on Babine Lake, Figure 8 shows the seasonal catch rates for the Main Arm only (fishing areas 1 through 5). Again, unbalanced sampling required the elimination of other fishing areas from this summary. The May to July catch rates show no clear trend through time, particularly given the high variance of the estimates. The August - September catch rates appear higher in 1966 and 1968 than in later years, although the intervening year of 1967 showed the lowest catch rate for these months. In short, no strong consistent change in relative abundance of kokanee between 1966 and 1977 is apparent from the purse seining dataset.

One explanation for the much lower catch rates for kokanee in the late summer and autumn is that mature individuals leave the lake at this time to spawn in tributaries. However, this factor alone appears an inadequate explanation for the decrease in catch rates, because spawners should represent only a moderate proportion of the yearling and older kokanee. Other factors may have reduced the catchability of kokanee later in the year; for example, the increased depth of the thermocline may have increased the volume of habitat occupied by kokanee and thus reduced their (gear) encounter probability. Conversely, one possible reason for the higher catch rates of kokanee in Morrison Arm is that the shallow water in that portion of the lake compressed their vertical distribution and increased their catchability.

It also appears possible that two-summer (age 1+) sockeye were included in the kokanee tallies during purse seining, as it would not have been possible to distinguish them from kokanee yearlings. Available data do not address whether the proportional abundance of two-summer sockeye smolts changed after sockeye enhancement. If the percentage of two-summer smolts remained similar, their absolute abundance should have increased following enhancement. Assuming these smolts were included in the kokanee tallies, their increased abundance could have masked any decline in kokanee abundance after enhancement. The magnitude of this effect would also depend on the unknown difference in seine catchability between the age (size) classes of the fish counted as kokanee. In summary, the uncertainties attached to the purse seine dataset are significant, and would impede any conclusion about trends in kokanee abundance even if the variance of the estimates was reduced.

4.3.2. Kokanee Escapement

BC-16 forms for Babine Lake tributaries have recorded a variety of conditions related to sockeye and kokanee spawning, and provide historical perspective when considering whether land-use activities in the watershed have altered flows, temperatures and other hydrological conditions during the spawning season. For many smaller streams, low flow or no flow is conveyed in late summer during the majority of years, completely preventing use for spawning by *O. nerka*. At some channel mouths, gravel bars often form due to bedload deposition during spates as well as wave action from storms; these can lead to shallow braided channels which fish are unable to traverse at typical late-summer flows. Under these conditions, the small size of kokanee occasionally allows entry and spawning when sockeye cannot. Some channels appear to have developed water temperatures too high for sockeye spawning even prior to forestry activity in their drainages. Log jams and beaver impoundments have frequently created persistent problems for fish passage in some early streams, such that crews were needed to clear obstructions; kokanee have been observed to be more capable of slipping through gaps in jams and dams to access spawning habitat upstream, due again to their small body size.

The dominant majority of BC-16 forms on file make no mention of the abundance of kokanee. Those which do are enumerated in Table 12. At least two, and occasionally three, DFO entities were involved in sockeye escapement surveys on Babine Lake tributaries during the 1950s and 1960s and sometimes shared information leading to estimates (Harrison 2007). The district Fishery Officer usually made his own estimates of sockeye escapement. Technical staff based at the salmon counting weir on the Babine River downstream of Nilkitkwa Lake also surveyed Babine Lake streams for fish which had been disk-tagged at the weir, to identify run timing as well as possibly utilize mark-recapture methods for abundance estimation. Research staff based on the lake also may have conducted stream walks. For either sockeye or kokanee, the method by which the total escapement estimate was obtained was almost never recorded on the BC-16 forms, so it is usually unknown whether peak count, dead pitch, mark-recapture, or some other method was used. The "area under the curve" (AUC) method of salmon escapement estimation which is currently favored for streams without weirs requires a minimum of several independent visits combined with an estimate for spawner residency time, and this approach was not applied on Babine Lake streams until approximately the last decade prior to writing. The Lake Babine Nation Fisheries Program has conducted the sockeye counts on the early streams during recent years, and for the last several years also compiled counts of kokanee usable for AUC estimation (Toth 2007). However, the kokanee data were not reported on the BC-16 forms, and are not currently available for analysis (McIntyre 2007).

Several Babine Lake researchers have also presented data or reported observations about kokanee escapement which may or may not be independent of the estimates recorded on BC-16 forms. In the context of his investigation of the potential nerkid fry carrying capacity of the arms of Babine Lake, Johnson (1958) discussed his observations of kokanee spawner abundance as follows (material in square quotes added for clarity):

The abundance of spawning kokanee in 1954 was less than average and, considering the large number of anadromous spawners, was probably inadequate to contribute significantly to fingerling populations south of Halifax Narrows [i.e. in the Main Arm of Babine Lake]. *However, an unusually great abundance of kokanee spawners in 1955, and even greater numbers in 1956, make it possible that some considerable portion of the fingerlings south of the Narrows in 1956 and 1957 may have been progeny of kokanee. For example, Mr. Gelley* [the Fishery Officer] *estimated the number of kokanee spawning in Tachek Creek in 1955 as 400,000 to 500,000, and that the total for all tributaries may have been 1,000,000 or more. Assuming 75% males, and an egg content one-eighth that of anadromous sockeye, a million kokanee would be the equivalent of 62,500 anadromous sockeye with a 50-50 sex ratio; that is, they would contain more than double the number of eggs in the 27,800 anadromous spawners south of Halifax Narrows in 1955. Thus, approximately 70% of the fingerling sockeye south of Halifax Narrows in 1956 may have been progeny of kokanee. Similarly, an even greater abundance of kokanee spawners in 1956 (possibly 1.3 million) suggests that their progeny may have comprised about 35% of the fingerling population south of Halifax Narrows in 1957.*

McCart (1970) reported four years of sockeye and kokanee escapement estimates for 12 early streams in addition to Pinkut Creek, Fulton River, and the upper and lower Babine River (Table 13) although he did not describe his method of estimating escapement. His results in terms of total annual escapement of kokanee are summarized in the text quoted from McDonald and Hume (1984) below. McCart (1970) found that Pierre, Twain and Tachek creeks together received 75% of the total kokanee escapement to streams he monitored; Four Mile, Shass and Sockeye creeks together received approximately 20%. In other words, he estimated that during the period of reference, only 6 early streams received 95% of the total kokanee escapement.

McDonald and Hume (1984) discussed the varying abundance of kokanee spawners in the Babine Lake system as follows:

The abundance of [kokanee] spawners has varied greatly. Johnson (1958) cited reports of over 1 million spawners in 1955 and 1956, and H.W.D. Smith (Fisheries and Oceans, Vancouver, B.C., personal communication) observed about the same number in 1963. McCart (1970), after almost complete coverage of kokanee spawning streams from 1964 to 1967, estimated an average of 40 800 spawners per year (range 18 000 – 64 000). Comparable coverage by H.W.D. Smith in 1968 (personal communication) and by J. McDonald in 1969, 1970 and 1972 (unpublished data) revealed an average of 32 500 (range 26 000 – 35 000).

Foote (1987) enumerated the kokanee present in Pierre Creek on August 2, August 5, and August 15, 1984. He reported that 5 178, 10 629 and 9 295 kokanee were present on those dates respectively. The BC-16 form for Pierre Creek in 1984 noted the presence of 6 000 to 7 000 kokanee on August 2 (Table 12), an estimate which agrees relatively well with that of Foote (1987) for the same date. Pierre Creek was also found to be an important kokanee spawning stream by McCart (1970), who estimated an average annual escapement of 12 500 kokanee (range 5 000 to 30 000) in the period 1964 to 1967 (Table 13)

In summary, although time series of kokanee escapement data are lacking for Babine Lake tributaries, the modest number of annual lakewide totals found in the published material include several years prior to and during the implementation of sockeye enhancement. The estimates of McCart (1970) for the years 1964 to 1967 are relatively similar to those of Smith in 1968 and McDonald in 1969, 1970 and 1972 (McDonald and Hume 1984) and taken together suggest average annual lakewide spawning returns of approximately 17 000 to 64 000 kokanee, with roughly 30 000 to 40 000 spawners in most years. Estimated escapements of roughly one million kokanee or more reported for 1955, 1956 and 1963 differ by more than an order of magnitude from all other annual totals.

Two questions about these latter data warrant consideration. First, are the estimates of one million or more spawners credible? Second, if credible, how anomalous were these high-abundance years? Regarding credibility, the individuals involved in recording these observations[14] were very experienced in Babine Lake sockeye abundance monitoring, including years when kokanee escapements were much lower. There appears little reason to believe that these observers recorded severe overestimates of kokanee abundance. Due to the paucity of available data, it is much more difficult to assess the degree of anomaly represented by the high-abundance years of 1955, 1956 and 1963. It is noteworthy that the strong kokanee spawning years of 1955 and 1956 lag by four years the weak sockeye returns of 1951 and 1952, which occurred due to the obstruction of sockeye migration at the Babine slide. However, sockeye counts through the Babine River fence were also abnormally low in the years 1955 and 1960, but not in the year 1959 which precedes the kokanee high-abundance year of 1963. Because the age structure of the kokanee spawners in the high-abundance years was not sampled, it is unknown whether the maturity schedule might have accelerated in response to favorable growth conditions, but the linkage between low numbers of sockeye spawners and subsequent kokanee abundance is only moderately suggestive as a result.

Regarding the 4-year cycles of run strength often displayed by sockeye salmon, McCart (1970) stated that “kokanee in the early streams do not have regular cycles of abundance even though most of them mature at the same age, in their fourth year”; he did not document his source of knowledge for the broad scope of this statement. McCart (1970) also suggested that the lack of abundance cycles in kokanee might result from increased conversion to the sockeye form by kokanee progeny when growth conditions in the lake are good, though this theory about plasticity of form appears to have been discredited by subsequent genetic surveys.

Sebastian et al. (2003) compiled kokanee escapement estimates for six large lakes in southern British Columbia (Table 15), to emphasize that kokanee population density at Quesnel Lake was very low. Again, it remains uncertain whether the Babine Lake estimates for the years 1964 through 1967 provided by McCart (1970) were representative of typical conditions before sockeye enhancement, and it is unknown whether his methods for estimating total escapement were comparable to those used to acquire the data reported by Sebastian et al. (2003). However, assuming “ballpark” accuracy of McCart’s estimates, in other words that total escapement of Babine Lake kokanee is typically 50 000 or less, the

[14] namely H.W.D. (Howard) Smith, L.J. Gelley, and W.E. (Wally) Johnson

population density of Babine Lake kokanee also appears very low in comparison to other large lakes (Table 15).

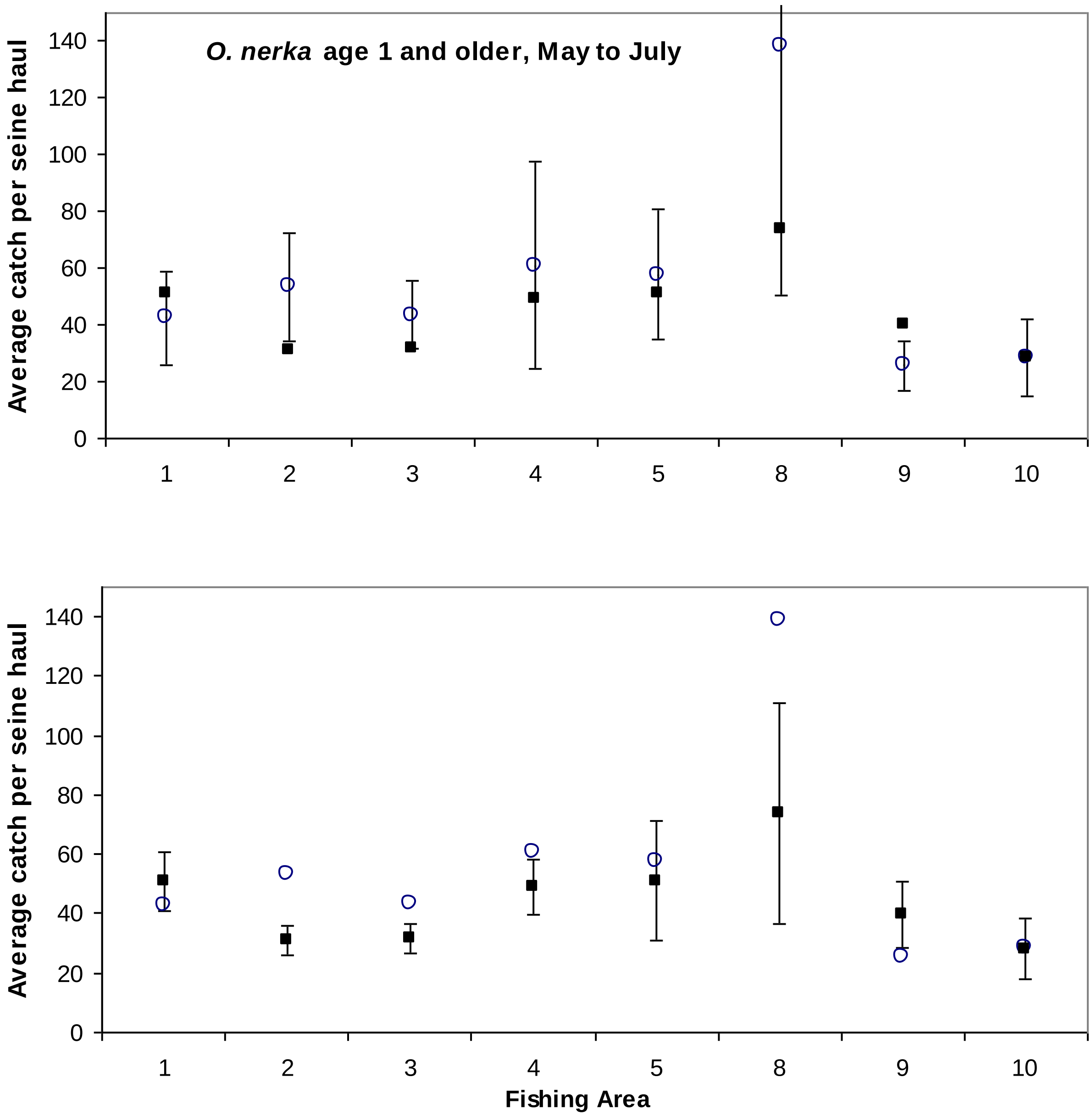

Figure 7. Comparison of daytime (open circles) and nighttime (filled squares) mean catch of *O. nerka* of age 1 and older per purse seine haul in defined fishing areas (see Figure 1) of Babine Lake during May to July, for seven calendar years between 1966 and 1977 inclusive. The panels are identical, except that the upper panel shows the 95% confidence intervals for daytime means while the lower panel show the 95% confidence intervals for the nighttime means. Night was defined as beginning at evening civil twilight and ending at morning civil twilight; day comprised all remaining hours. Confidence interval estimation used non-parametric bootstrap resampling, which is also explained in the report text.

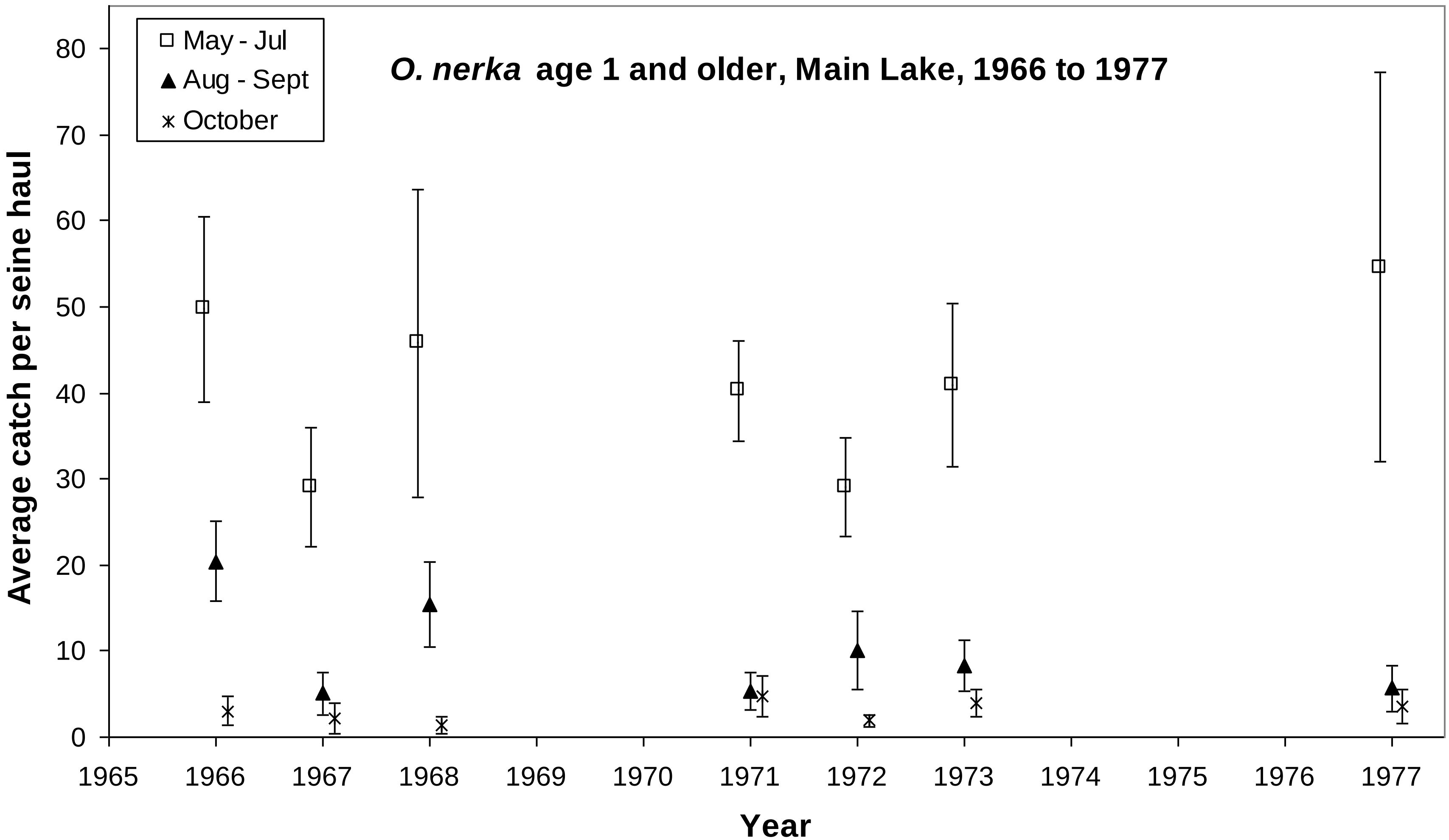

Figure 8. Early season (May-July, open squares), mid season (August-September, filled triangles), and late season (October, asterisk) mean nighttime catch of *O. nerka* of age 1 and older per purse seine haul in main lake fishing areas (see Figure 1) of Babine Lake, for seven calendar years between 1966 and 1977 inclusive. Nighttime was defined as beginning at evening civil twilight and ending at morning civil twilight; day comprised all remaining hours. Confidence interval estimation used non-parametric bootstrap resampling, which is also explained in the report text.

Table 11. Babine Lake tributary streams for which sockeye escapement estimates, and annual escapement survey reports (BC16 forms) exist, 2004 and earlier. BC16 forms are often submitted even when an inspection or estimate was not made. The leftmost three digits (460 for Babine River drainage) of all **Watershed Code**s are not shown.

Stream	Other names	Watershed Code	Geometric Mean Escapement	Geometric Mean Escapement (Top 5 Years)	Years of BC16 Forms	Years of Numeric Escapement Estimates	Kokanee Comments
Bernann	Deep	880746	307	307	11	5	No
Big Loon	Wright	739100	94	94	34	5	No
Donalds	Donald Landing	881300	167	470	50	11	No
Five Mile		452300	118	1,037	61	38	Yes
Forks		579300	600	600	31	1	No
Four Mile		964000	3,038	12,386	71	53	Yes
Fulton	pre-channels	697200	85,286	164,577	55	21	No
	post-channels		340,559	653,163		34	No
Gullwing	Six Mile, Wiggins	953800	626	5,457	68	48	Yes
Hazelwood		599600	50	50	24	1	No
Kew	Driscoll	793000	229	229	40	3	No
Morrison	Hatchery	598800	8,275	36,175	69	55	No
Nine Mile		474600	833	5,015	73	50	Yes
Cross	Pendleton	863300	464	2,585	63	31	Yes
Pierre	Tilticha	802100	16,038	59,824	75	53	Yes
Pinkut	pre-channel	927700	26,727	62,967	76	21	No
	post-channel		152,240	434,001		33	No
Shass	Grizzly, Ogston	993600-18700	4,474	19,164	74	46	Yes
Sockeye		742900	1,033	5,873	63	48	Yes
Sutherland	Beaver	993600	465	492	52	6	Yes
Tachek		705800	1,104	7,361	76	51	Yes
Telzato	Monica	992900	237	237	35	4	No
Tsezakwa	Trail	422000	212	1,093	60	15	No
Twain	Twin	816400	7,785	21,524	76	53	Yes

Table 12. Comments and escapement estimates pertaining to kokanee, recorded on annual escapement survey (BC16) forms for Babine Lake tributary streams during the period 1925 to 2004. BC16 forms were not submitted for all streams in all years during this time frame; Appendix Table IV lists the years for which forms are available.

Stream	Kokanee comments
Five Mile	**1988**: few kokanee (5) observed, no sockeye **1984**: few kokanee
Four Mile	**1986**: Aug 11 - 2,000 kokanee **1985**: Aug 16 - few kokanee
Gullwing	**1986**: Aug 11 - 2000 kokanee **1985**: few kokanee
Nine Mile	**1947**: Aug 5th - 125 kokanee
Cross	**1988**: heavy kokanee spawning **1986**: Aug 12 - water temp 13.5C and 2000 kokanee spawning, Aug 22 - water very low, a few kokanee left **1985**: Aug 16 - few kokanee and very low water **1984**: some kokanee in the upper reaches **1952**: some kokanee entered but water too low for sockeye
Pierre	**1986**: Aug 12 - stream water temp 10C and kokanee 200, Aug 22 - few hundred kokanee **1985**: few kokanee **1984**: Aug 2? - 6-7000 kokanee in stream
Shass	**1951**: 12000 kokanee **1948**: about 400 kokanee on this stream **1947**: 1250 kokanee on the area **1941**: first salmon arrived at the Beaver on 22 July accompanied by an exceptionally heavy run of kokanee salmon
Sockeye	**1988**: high kokanee population **1985**: few kokanee

Table 12 continued. Comments and escapement estimates pertaining to kokanee, recorded on annual escapement survey (BC16) forms for Babine Lake tributary streams during the period 1925 to 2004.

Stream	Kokanee comments
Sutherland	**1930**: "sockeye show no inclination to go above Grizzly Creek [Shass Creek] though many kokanee were above" … "10 miles above Grizzly Creek and just below where Gravel Creek[15] flows into the Beaver [Sutherland] about a mile of gravel bars are found but shows no signs of having been disturbed in years, except by kokanee a number of which were seen spawning"
Tachek	**1985:** few kokanee **1984**: approximately 50,000 to 70,000 kokanee (inspected 31 July and 24 Aug) **1983**: estimate 10,000 kokanee spawning in creek (inspected 30 Jul and 25 Aug) **1969**: passable for kokanee above private road (Spindrift Lodge) **1952:** estimated over 30,000 kokanee spawned in the lower reaches **1947**: 2400 kokanee (appears to have counted 754 on Aug 1) **1946**: 1300 kokanee **1941**: large run of 4500 kokanee this season
Twain	**1988**: very high kokanee number **1987**: kokanee spawning throughout the system **1986**: few hundred kokanee **1985**: Aug 15 - lots of kokanee **1984**: 70,000 kokanee

[15] The BC Watershed Atlas (1:50,000) shows the Gravel Creek confluence with the Sutherland River to lie approximately 20 channel kilometres (roughly 12 channel miles) upstream of the mouth of Shass Creek [Grizzly Creek].

Table 13 (reproduced from McCart 1970 with corrections). His caption: "Numbers of sockeye and kokanee spawning in streams at Babine Lake, 1964 to 1967. Dash indicates no estimates available but numbers small."

Water	1964		1965		1966		1967		Four Year Average	
	Sockeye	Kokanee	Sockeye	Kokanee	Sockeye	Kokanee	Sockeye	Kokanee	Sockeye	Kokanee
Lower Babine[16]	46,000	200	176,000	a few	113,900	0	54,000	--	**97,475**	**< 100**
Upper Babine[17]	222,000	--	120,000	--	69,000	--	133,000	--	**136,000**	**< 100**
Five Mile	50	0	150	0	150	15	100	200	**113**	**54**
Nine Mile	1,500	2	500	0	600	100	1,000	500	**900**	**150**
Fulton	120,500	--	141,300	--	90,000	200	136,500	--	**122,075**	**< 500**
Tachek	3,000	7,000	700	3,000	150	2,000	900	17,000	**1,188**	**7,250**
Sockeye	2,000	2,000	50	0	900	7,000	600	1,000	**888**	**2,500**
Kew	0	100	dry		2	350	0	150	**1**	**150**
Pierre	22,000	5,000	10,000	5,000	8,000	10,000	32,000	30,000	**18,000**	**12,500**
Twain	9,000	12,000	3,000	5,000	3,500	16,000	9,000	10,000	**6,125**	**10,750**
Cross	1,350	1,300	dry		dry		dry		**1,350**	**325**
Donalds	800	1,000	dry		dry		dry		**800**	**250**
Pinkut	146,000	--	34,000	a few	30,000	250	33,400	--	**60,850**	**< 200**
Gullwing	1,500	800	100	70	200	400	1,000	100	**700**	**343**
Four Mile[18]	2,500	1,900	1,400	4,400	1,600	3,400	3,600	2,800	**2,275**	**3,125**
Shass	8,000	3,000	5,000	30	3,500	5,000	2,600	2,000	**4,775**	**2,508**
TOTAL	**586,200**	**34,302**	**492,200**	**17,500**	**321,502**	**44,715**	**407,700**	**63,750**	**451,901**	**40,800**

[16] Presumed to be the portion of Babine River downstream of Nilkitkwa Lake
[17] Presumed to be the portion of Babine River downstream of Babine Lake and upstream of Nilkitkwa Lake
[18] Hanson and Smith (1967) estimated the number of kokanee spawning in Four Mile Creek in 1964 and 1965 as 1750 and 4483 respectively.

Table 14 (modified from De Gisi 2003). Availability of kokanee abundance and growth data for lakes known to support pelagic piscivorous rainbow trout.

Lake	Abundance	Growth	Comments
Nechako Res.	No	No	Research for submerged timber harvest did not use floating gillnets in pelagic zone, so kokanee were not captured
Arrow Res.	Yes	Yes	Hydroacoustic estimates of lakewide kokanee abundance, trawl capture for age samples; also stream surveys of spawner escapement
Babine	**Yes?**	**Yes**	**See discussion in present document**
Kootenay	Yes	Yes	Hydroacoustic estimates of lakewide kokanee abundance, trawl capture for age samples; also stream surveys of spawner escapement
Okanagan	Yes	Yes	Hydroacoustic estimates of lakewide kokanee abundance, trawl capture for age samples; also stream and lake surveys of spawner escapement
Shuswap	Yes	Yes	
Quesnel	Yes	Yes	Hydroacoustic estimates of lakewide kokanee abundance, trawl capture for age samples; also stream and lake surveys of spawner escapement
Eutsuk	No	No	Unknown results of age samples collected during 1982 survey
Kamloops	No	Unk	
Mabel	No	Yes	Single year of kokanee growth data
Bonaparte	No	Unk	
Isaac	No	No	
Crescent	No	No	
Tesla	No	Yes	Single year of kokanee growth data
Nadina	No	No	
Khtada	Yes	Yes	Single year of kokanee abundance and growth data

Table 15 (modified from Table 12 of Sebastian et al. 2003). Comparison of kokanee relative abundance. **Low Escapement Per km²** divides the low value of the estimated escapement range for each lake by the surface area of the lake, as a representation of kokanee relative abundance. **Mysis** = are *Mysis relicta* present; **SK** = are sockeye present; Y = Yes, N = No.

Lake	**Surface Area (km²)**	**Estimated Escapement (millions)**	**Low Escapement Per km²**	**Mysis**	**SK**
Adams	137	< 0.15	< 1095	N	Y
Arrow	498	0.50 – 1.00	1004	Y	N
Babine	490	0.02 – 1.00	41	N	Y
Kootenay	389	0.20 – 4.00	514	Y	N
Okanagan	350	0.05 – 0.75	143	Y	N
Quesnel	207	< 0.20	966	N	Y
Shuswap	310	0.50 – 1.50	< 1612	N	Y

4.3.3. Hydroacoustic Surveys

Mathisen and Smith (1982) reported a hydroacoustic survey of the abundance and distribution of nerkid fry in Babine Lake conducted in October 1975. The spatial patterns of biomass density observed were similar to those of concurrent purse seining, and their estimates of fry abundance were plausible when compared to the estimated smolt output of the following spring, after accounting for the unknown contribution of targets other than nerkid fry and overwinter mortality before smolting. The equipment and resulting data do not appear to allow any separation with respect to the size of the targets, and thus could not be used to estimate the number of post-fry nerkids including kokanee.

Nighttime hydroacoustic surveys combined with midwater trawling were used to assess nerkid fry abundance in Babine Lake during mid-August 1995 and early autumn of 1993, 1994 and 1995 (Hume and MacLellan 2000). Raw abundance estimation was accomplished using the echo-sounding data, while trawl results verified the species and size structure of the fish targets and were used to adjust the raw data. Biochemical methods for distinguishing sockeye and kokanee fry were not applied (Hume and MacLellan 2000). In the Main and North arms of the lake, 99% and 97% respectively of the trawl catches were nerkid fry, with nearly all of the remaining catch consisting of yearling and older *O. nerka*. Hume and MacLellan (2000) concluded that there should have been no size-based difference in their trawl selectivity for nerkids from 15 mm up to 150 mm in length. Although a small proportion of 1+ nerkids might have been longer than 150 mm by late September (Figure 6), this size range would essentially include all fry and yearlings during the months of the surveys. Age 2+ and older kokanee were presumably under-represented in the trawls due to ability to avoid or escape the gear. If the catchability of yearling nerkids was equivalent to that of fry, the 1 to 2% representation of yearling nerkids reveals little about the abundance of kokanee, because an unknown but possibly large proportion of the yearlings may have been two-summer sockeye.

Reprocessing of the results from the hydroacoustic surveys of the 1990s in order to estimate the abundance of kokanee might be possible (Hume 2007), similar to the methods used by Sebastian et al. (2003) for Quesnel Lake data. Again, two-summer sockeye may form a substantial component of the yearling and older nerkid numbers present in Babine Lake in most summers, and could confound the reprocessing for that size class. Limnetic targets in the length range of 160 to 230 mm would likely represent age 2+ to age 4+ kokanee; if the abundance of these targets could be isolated and larger targets such as rainbow trout and lake char eliminated, the data might provide a baseline estimate of these age classes for comparison to spawner counts and future hydroacoustic data.

4.4. Kokanee Synthesis

Although Babine Lake kokanee do not directly provide a valued sport fishery, they are likely an important prey item for the largest size classes of sport fish species such as rainbow trout and lake char. Piscivorous lake char can also achieve notable size with only whitefish as the dominant prey, but pelagic rainbow trout resident in large oligotrophic lakes may be dependent on consumption of yearling and older kokanee to achieve growth rates leading to "trophy" size (Sebastian et. al 2003). For pelagic rainbow trout in other large British Columbia lakes, increased abundance of nerkid fry does not appear to offer an adequate bioenergetic substitute for the meal size provided by yearling and older nerkid prey (Sebastian et al. 2003).

Babine Lake is the dominant producer of sockeye in the Skeena River watershed and thus the basis of an important commercial fishery. DFO research efforts on the lake environment and fish community began in earnest during the 1940s, and the reproductive and ecological relationship between the two forms of *O. nerka* was initially of significant interest to DFO. Through the 1980s, intensive research projects of moderate duration, along with incidental data collection, added significantly to an understanding of kokanee ecology in Babine Lake. However, there has been no ongoing acquisition by DFO of the type of data needed to monitor Babine Lake kokanee. In fact, basic life history and abundance data have not been collected broadly for Babine Lake kokanee since the late 1960s. The reasons are not specified in the available material, but presumably relate to the modest abundance of kokanee as potential competitors for sockeye in the Babine Lake system, stomach contents surveys indicating that adult kokanee are not a predator of sockeye fry in the lake, biochemical studies which established the reproductive isolation of the two forms, and the absence of a DFO mandate for management of freshwater resident species. The lack of a kokanee sport fishery on the lake, and the undocumented and uncertain importance of Babine Lake kokanee to the ecology of the lake's other valued game fish, have together prevented these populations from becoming a regional MOE priority. Available information thus provides a poor basis for evaluating the present status of Babine Lake kokanee stocks and how abundance or life history characteristics may have changed as the lake and its watershed have been modified by human activity.

Declines of kokanee populations in lakes such as Kootenay, Okanagan and Quesnel have impacted kokanee sport fisheries, but also appear to have been accompanied by reductions in size and number of pelagic piscivorous rainbow trout. The putative reasons for reductions in kokanee abundance in these lakes have differed. Kootenay Lake experienced lowered nutrient loading and the introduction of *Mysis*, an invertebrate competitor. Habitat degradation and water extraction in the Okanagan Lake watershed has been implicated in kokanee decline, along with *Mysis*. Competition due to increased sockeye returns since 1990 is speculatively linked to reduced numbers of kokanee at Quesnel Lake and Adams Lake (Sebastian et al. 2003).

Although data are unavailable to assess how the abundance and life history characteristics of Babine Lake kokanee may have changed following sockeye enhancement at Fulton River and Pinkut Creek, a variety of information speculatively suggests that sockeye may competitively suppress the growth and abundance of kokanee. One line of evidence predates enhancement, and relates to kokanee response to reduced abundance of sockeye. Kokanee spawners were extremely abundant in some years following the Babine River slide of 1951 when sockeye escapement was greatly reduced. Based on extremely limited data, female kokanee spawners may have also displayed greater average fork length in 1953 relative to later data, and these 1953 spawners had experienced some years of growth conditions when sockeye fry abundance was presumably lower due to the slide. Kokanee eggs and emergent fry are smaller than those of sockeye (Johnson 1958; McCart 1970), and nerkid fry mortality is size-selective (West 1983). If predator abundance increased in response to enhancement, kokanee fry might be disproportionately affected. Conversely, the research of Shortreed and Morton (2000) suggests that the primary productivity of Babine Lake has increased significantly due to nutrient imports by sockeye spawners; enhanced primary production could have increased the growth rates of all nerkid fry, including kokanee, and resulted in better survival of kokanee. In short, the effect of sockeye enhancement on kokanee abundance is likely mediated through a complex set of trophic and ecological relationships including food competition, predation, parasites and disease. Abundance estimates for Babine Lake kokanee from escapement surveys and (ideally) hydroacoustic studies are needed as a first step in assessing the present status of these stocks.

Additional life history data, age samples, and abundance estimates for Babine Lake kokanee may be present in DFO technical publications not obtained, or in unpublished DFO files. For example, the catalog of the scientific archives of the Pacific Biological Station[19] refers to kokanee scales collected during Babine Lake sampling, in several different record groups (Simpson et al. 1985). The personal notes of two pioneer investigators of Babine Lake, W.E. (Wally) Johnson and H.W.D. (Howard) Smith have not been cataloged (Miller 2007), but McCart (1970) as well as McDonald and Hume (1985) published previously unreported kokanee data received from Johnson and Smith. It is unknown whether these personal materials contain additional quantitative or subjective data. Finally, the type and status of kokanee data collected during the nerkid fry purse seining studies on the lake between 1966 and 1977 remains unknown, but (for instance) McCart (1970) refers to a dataset for 1257 kokanee aged in 1966 which does not appear to have been published elsewhere, so the files of this study might represent a significant additional resource. Magnetic tapes containing data from the program are now unreadable (Hume 2007); paper

[19] Nanaimo, B.C.

copies of datasheets and/or scale samples may still exist. Investigation of these materials at the Pacific Biological Station should be considered important, but secondary in priority to the acquisition of contemporary data for Babine Lake kokanee.

5. Rainbow Trout

Babine Lake rainbow trout are, with lake char, the subjects of the most popular large-lake sport fishery in Skeena Region. Although they do not regularly reach body sizes greater than 10 kg in weight historically achieved by this species in lakes such as Kootenay, Okanagan, and Quesnel, Babine Lake rainbow trout can exceed 7 kg (Bustard 1990) and in most years the recreational catch likely includes individual rainbow trout over 4.5 kg. The most active rainbow trout fisheries on the lake can be loosely sub-divided: springtime fisheries at the mouths of Pinkut Creek and Fulton River where rainbow trout congregate to prey on migrating sockeye fry; the North Arm fishery which occurs essentially as an extension of the Rainbow Alley and Nilkitkwa Lake fly-fishery; a Morrison Arm fishery in which bucktailing is particularly popular (Bustard 2007); and the open water troll fishery on the Main Arm which also exploits lake char and occurs more or less throughout the ice-free period. First Nations net fisheries on the lake also capture rainbow trout, including the gillnet fishery in May at the mouth of the Sutherland River which targets in-migrating spawners (Bustard 1990), and the sockeye Escapement Surplus to Spawning Requirements (ESSR) beach seine fisheries conducted near the mouths of Pinkut Creek and Fulton River in early August (Atagi 2007).

The importance of the rainbow trout fisheries has prompted a limited amount of directed research, most of which occurred in the latter half of the 1980s and included two years of angling use studies, a single year of rainbow trout juvenile surveys on the lake's tributaries, and a radio telemetry study of Sutherland River watershed spawners. Much of the remaining life history and other data for Babine Lake was collected during sockeye studies in the 1960s, in part to determine whether rainbow trout predation might impact sockeye production.

5.1. Rainbow Trout Ecology and Life History

5.1.1. Spawning Geography, Timing, and Habitat Choice

Among the resident fish species present in the Babine / Nilkitkwa lakes watershed, rainbow trout likely exhibit the most extensive geographic distribution and display several life histories in this drainage, with probable but undocumented spatial overlap. Radio tagging studies during the 1990s showed that the upstream extent of steelhead use of the mainstem Babine system likely occurs just below the outlet of Nilkitkwa Lake, where significant numbers of steelhead spawn in the river upstream of the salmon counting weir and others utilize Boucher Creek which enters the Babine River from the northeast in this section. Headwater-resident populations of rainbow trout are present in streams and lakes above barriers in most of the major tributaries to Babine Lake. The population structure of the rainbow trout which grow and mature in Babine Lake itself, and spawn in an unknown number of adjacent accessible streams channels, is incompletely understood at present as detailed in the material which follows.

Prior to the 1970s, nearly all of the federally-pursued stream investigations in the Babine Lake watershed related to their importance to spawning sockeye. Although resulting data about location of upstream barriers to migration is also important in the context of rainbow trout spawning geography, the focus on sockeye excluded the collection of information on rainbow trout usage of stream channels except as predators of sockeye eggs and fry. Extensive provincially-mandated reconnaissance-level fish and fish habitat inventory has been conducted in the Babine Lake watershed during the last four decades, including lake surveys which typically include sites on adjacent inlet and outlet channels, and mining- and forestry-related stream inventories. In particular, the intensity of surveys related to forest harvest and stream classification, as well as watershed assessment and restoration, was quite high in the latter half of the 1990s. The dominant majority of the recent work was likely performed in areas inaccessible to Babine Lake rainbow trout, though additional precise documentation of barriers on some smaller tributaries probably occurred. The value of a map-based synthesis of such work[20] is obvious, but a complete review of aquatic inventory of the stream channels accessible from Babine Lake with respect to rainbow trout reproduction and rearing was beyond the scope of this document.

Summary of the single-year survey results of Bustard (1989a) with respect to juvenile rainbow trout abundance in Babine Lake tributary streams is provided in Table 16. Fry and parr densities estimated and extrapolated by Bustard (1989a) suggest that the Sutherland River and its major tributaries including Duncan Creek could produce nearly 80% of the total rainbow trout fry and 60% of the total rainbow trout parr in tributary reaches accessible to rainbow trout from Babine Lake. For some streams outside of the Sutherland watershed, estimated fry densities were lower than parr densities; it is unknown whether this reflects imprecision in the methodology, year-to-year variation in year class strength, or in-migration of rainbow trout juveniles from other streams.

Netting at the mouth of the Sutherland River and subsequent radio tracking of 19 rainbow trout revealed approximate information about the timing of entry of spawners to the river system (Bustard 1990). Due to the inaccessibility of much of the watershed, most tracking of spawners was accomplished from aircraft flights at intervals ranging between 3 and 8 days. This constrained the spatial and temporal resolution of the information, although inference about spawning sites was strengthened by examining the habitat types where fish were located during tracking. In 1989, the south end of Babine Lake was still covered by ice in the last week of April, but spawners were apparently already present at the mouth of the Sutherland River. The highest catch per effort during lake gillnetting for tagging captures occurred in the first week of May. Most of the fish tagged at this location did not enter the river immediately, and some subsequently roamed as far as the mouth of Pinkut Creek before entering the Sutherland River. Many of the radio tagged fish began to ascend the Sutherland River during the second week of May, though a few were not detected in the river until the last week of May and the first week of June. Spawning activity apparently spanned the period of mid-May to the end of June. Four fish (21%) appeared to have spawned in the lower four reaches of Duncan Creek; 13 (68%) spawned in the mainstem Sutherland River, with 12 of these using sites in the section of the river from 4 km downstream of Gravel Creek confluence to 8 km upstream of the confluence. Time of residency was longer for males than for females, and males often seemed to have spawned at more than one location; ultimately,

[20] some (but not all) of which is reflected in the FISS

however, residency time was difficult to summarize with confidence because 9 tags were still located in the Sutherland watershed on the final tracking date in late June and it was unknown whether these represented tag regurgitations, spawning mortalities, fish which had not yet completed their spawning activities, or some combination of these possibilities.

Summary of rainbow trout juvenile capture results for four years of the Lake Babine Nation Fisheries Program coho surveys is given by Table 17; the caveats offered in Section 2.3.4 should be recalled, in particular the lack of coverage in the Sutherland River watershed. Of the 12 streams sampled in at least two years, Cross Creek displayed the highest estimated density of rainbow trout juveniles, and their relative abundance was high in all years. Telemetry studies suggest that Boucher Creek (ranked second in average lineal catch in Table 17) is used for steelhead spawning, so the abundance of juvenile rainbow trout in this channel may not reflect importance for non-anadromous rainbow trout production. Deep, Tachek and Six Mile creeks also yielded moderate numbers of rainbow trout juveniles, though with greater apparent variability between years; the average for Deep Creek may be biased upward by the values for 2004 which are quite uncertain due to the lack of site lengths for that year. Nevertheless, the sustained relative abundance of rainbow trout juveniles at Cross Creek during the coho surveys suggests that this stream could also contribute at least moderately to rainbow trout recruitment to Babine Lake; this result differs from that of Bustard (1990), who found no fry and a low number of parr in his single Cross Creek site.

Although this document treats the Morrison Lake drainage as essentially independent with respect to resident fish species of Babine Lake, an unnamed stream (watershed code 480-598800-10000) which flows east into Morrison Creek downstream of Morrison Lake does appear to have significant importance for Babine Lake rainbow trout production (Bustard 1989a; Bustard 1989b; Bustard 2004). Tagging studies have not been conducted to provide definitive evidence, but Bustard (2007) suggests that this population supplies the recreational fishery for rainbow trout in the Morrison Arm (e.g. Ookpik Lodge) which may not typically yield rainbow trout individuals of the body size observed in the southern Main Arm but can occasionally do so, and is a quality sport fishery according to regular participants (Bustard 2004).

Table 16 (modified from Table 2 of Bustard 1989). Abundance and potential contribution of rainbow trout juveniles for Babine Lake tributary **Stream**s. **Length** gives the estimated accessible channel length in km. **Fry/m** and **Parr/m** give the estimated abundance of those life stages per lineal meter of channel with **Juv/m** providing a total of the two. The columns headed **% of Fry** and % **of Parr** extrapolate the production to the entire estimated length of accessible channel to provide the potential contribution by that channel to the fry or parr production of all tributary streams sampled. Streams are listed in descending order of their potential **% of Parr** production. For the widest channels, indicated by an asterisk following the stream name, the estimated lineal densities from sites were doubled to obtain the lineal values for the stream because sites reflected abundance along only one stream bank but rainbow trout production presumably occurs along both banks.

Stream	Length	Fry/m	Parr/m	Juv/m	% of Fry	% of Parr
Sutherland River *	70.5	4.1	1.0	5.1	67.6	51.4
Morrison Tributary	9.8	2.8	1.3	4.0	6.4	8.6
Duncan Creek *	7.0	7.2	1.3	8.5	11.8	6.4
Lamprey Creek	3.8	2.3	2.2	4.5	2.1	5.7
Hawthorn Bay Creek	2.5	0.4	2.6	2.9	0.2	4.4
Tsak Creek	3.9	0.9	1.4	2.4	0.9	3.9
Eleven Mile Creek	2.8	2.7	1.8	4.5	1.8	3.6
Wilkinson Creek	9.2	0.7	0.5	1.2	1.5	3.2
Tachek Creek	5.2	0.2	0.8	1.0	0.2	2.9
Surprise Creek	2.0	1.1	1.7	2.8	0.5	2.3
Cross Creek	6.4	0.0	0.4	0.4	0.0	2.0
17 other creeks	28.6	0.1	0.1	0.1	0.4	1.6
Big Loon Creek	4.6	0.3	0.3	0.6	0.3	0.9
Redrock Creek	4.5	0.0	0.3	0.3	0.0	0.8
Hagan Arm Creek	1.8	1.7	0.5	2.2	0.7	0.7
Six Mile Creek	4.5	2.1	0.2	2.3	2.2	0.6
Unnamed Creek	1.7	0.9	0.5	1.4	0.4	0.6
Shass Creek	1.0	3.6	0.7	4.3	0.8	0.5
Pierre Creek	1.5	4.5	0.0	4.5	1.6	0.0
Five Mile Creek	4.1	0.6	0.0	0.6	0.6	0.0

Table 17. Summary of juvenile rainbow trout captures during coho assessments conducted by the Lake Babine Fisheries Program. **Sites** gives the number of sample sites on the named channel. For each of the years **2002** through **2005**, the minimum number of rainbow trout juveniles (tallied catch) present per lineal metre of the sample site length is given; the column headed **Total** provides the unweighted mean value for all years of sampling and the streams are sorted in descending order of the value of this column. Values preceded by an asterisk indicate that one or more site lengths were not recorded; the grand mean site length for all years (38 m) was used in these cases to estimate the catch per lineal metre. Blank cells indicate no sampling in that year on the stream.

Stream	Sites	Minimum Rainbow Trout Juveniles Per Lineal Meter				
		Total	**2005**	**2004**	**2003**	**2002**
Cross Creek	3	0.85	0.87	0.56	1.17	0.81
Boucher	2	0.71	0.36	0.56	1.20	
Deep	2	0.51	0.10	* 1.39		0.03
Tachek	3	0.35	0.26	0.10	0.92	0.13
Nine Mile	2	0.29	* 0.58		0.00	
Six Mile	2	0.18	0.04	0.24	0.05	0.38
Five Mile	2	0.17	* 0.52		0.00	0.00
Duncan	1	0.15				* 0.15
Four Mile	2	0.15	0.43	0.00		0.03
Big Loon	1	0.09	0.09			
Morrison	2	0.02			0.02	* 0.03
Sockeye	2	0.02	0.02	0.02		0.02
Twain	2	0.01		0.02		0.00
Pierre	2	0.01		* 0.01	* 0.00	
Sutherland	5	0.01				* 0.01
Wilkinson	2	0.00	0.00			
Tsezakwa	1	0.00	0.00			

5.1.2. Age, Size, Sex Ratio, and Mortality

Characteristics of six length-at-age datasets for Babine Lake rainbow trout collected between 1965 and 1989 are shown in Table 18 and Table 20, and depicted in Figure 9 through Figure 12. Two samples for the upper Babine River (Rainbow Alley) and Nilkitkwa Lake, from 1965 and 1969, are included. Parameters of Von Bertelanffy (VB) growth curves fit to the mean lengths at age are also summarized in Table 18 and displayed in Figure 9 through Figure 12. Figure 13 shows the VB growth curves in a single plot for comparative purposes, excluding the Rainbow Alley / Nilkitkwa Lake samples.

McCart (1967) provided the earliest published length-at-age data for Babine Lake rainbow trout in the available literature (Figure 9). His samples were collected by beach seine and gillnet in the portion of the North Arm adjacent to the outlet; for each age class he reported only the mean and range of lengths, back-calculated to the annuli. McCart (1967) also published similar results for rainbow trout captured in the upper Babine River. The comparability of his estimates to later work is degraded by his use of back-calculation, which results in reduced length at age compared to in-season field data. However, the North Arm rainbow trout in his catch were smaller-bodied and younger than his Rainbow Alley - Nilkitkwa Lake sample. They also displayed much slower apparent growth than the North Arm 1969 dataset reported upon by Narver (1975), which showed the longest lengths-at-age of any of the non-spawner datasets (Figure 13). In addition to the problems of limited sample size for McCart's data and of comparing back-calculated lengths reported by McCart to the field values of Narver, the latter data were acquired from fish captured by angling which may select for the more active and faster-growing individuals of a population. Back-calculation could explain a minor proportion of the very large difference in size at age of North Arm fish reported by these two authors as displayed in Figure 13; age interpretation seems likely to be a major factor. The contributions of differences in capture and ageing methods cannot be distinguished from a possible ecological change across the six-year span of the two datasets.

Griffiths (1968) and Beacham and McDonald (1982) reported size at age for samples of rainbow trout captured throughout Babine Lake, during the sockeye fry pelagic purse seining programs of 1967 and 1968 respectively (Figure 12). Because the samples were collected by a single capture method in the same approximate geographic area one year apart, the apparent growth curves are illustrative of the challenges of interpretation. The range of ages assigned was similar for the two years: Griffiths' sample from 1967 included rainbow trout he aged as 2+ to 11+, while Beacham and McDonald (1982) interpreted ages ranging between 2+ and 12+ for their sample from 1968. The estimated grand mean lengths of the two samples were also very similar: 247 mm for the 1967 dataset and 251 mm for 1968. VB growth curves fit to the mean lengths at age appear to provide a reasonable representation of the data in each case (Figure 10). However, the age distributions differ greatly, with Griffiths' results displaying modal age of 2+ while Beacham and McDonald's data showing modal age of 4+ (Figure 10). With respect to size at age, the net result is that the VB growth curve from the 1967 data is shifted significantly upward (leftward) in comparison to the 1968 data (Figure 13). For instance, the VB fit to Griffiths' results for 1967 implies a mean length of 353 mm at age 5+ while Beacham and McDonald's 1968 data suggest a mean length of 272 mm for the same age ; alternatively, the 1968 data suggest that Babine Lake rainbow trout do not typically reach 350 mm until age 7+, which is two years later than implied by

Griffiths' data from 1967. Interannual variation in year class strength might explain part of the difference in the age frequency distributions, but the apparent shift of the growth curves across the entire range of ages suggests differences in age interpretation as the most plausible explanation. No means are available to assess which set of results is most accurate. Compared to the results of Beacham and McDonald (1982), the VB growth curve implied by data of Griffiths (1968) is more similar to those of Bustard (1987) for angled rainbow trout and Bustard (1990) for Sutherland spawners (Figure 13), though Griffiths' lengths at age are still much lower than the latter two studies. Bustard (1987) reported upon rainbow trout which were angled lakewide so the locations of capture are roughly equivalent to the purse seine data; however, angled fish may be more active and faster-growing and thus not necessarily representative of the population. Conversely, larger and more active fish are presumably more able to avoid or escape the purse seine, so this capture method may also introduce selectivity even within a given cohort.

For the two rainbow trout datasets reported in Bustard (1987) and Bustard (1990), ages were likely assigned by the same person[21] which does not eliminate the subjectivity of ageing but should improve the comparability[22] of the two samples. Mean length at age was considerably greater for the gillnetted spawners than for rainbow trout sampled from the 1986 recreational fishery (Figure 13) though there is considerable overlap in the range of lengths for each age (Figure 12). The Sutherland spawner dataset displayed the highest mean lengths for all ages classes greater than 7 yr; the growth trajectory estimated for the sample collected by Narver (1975) from the North Arm recreational catch in 1969 showed the largest body size at age for age classes 3 yr to 6 yr (Figure 13). Growth curves of piscivorous fish may display an inflection or "hinge" at the age (size) when piscivory becomes bioenergetically dominant; however, this would presumably occur prior to sexual maturity, and (identifiable) data for immature members of the Sutherland stock are not available.

Few additional rainbow trout length-age data have been reported for Babine Lake rainbow trout. Mean lengths at age from an undated DFO predator study were given by Bustard (1990; cited as: Data on file, MOE, Smithers), but any evidence of this dataset could not be located during the compilation stage of the current project; the implied growth pattern of these fish appears most comparable to the results of Beacham and McDonald (1982), in other words among the "slowest" growth curves estimated for Babine Lake rainbow trout. Gillnet sets on the Main Arm of Babine Lake near Granisle Mine site on August 20 and 22, 2002, yielded 2 male rainbow trout of fork length 393 and 513 mm, aged 4 and 7 yr respectively with the state of reproductive maturity unreported (Morris 2002). The lengths at age of these individuals appear most comparable to those displayed by the Sutherland spawners (Table 20).

None of the Babine Lake samples discussed include rainbow trout younger than 2+ yr despite a variety of collection methods in pelagic and littoral habitats, suggesting that migration to the lake typically occurs after two or more summers' residence in streams. Yearling and older parr are present in tributary stream reaches which are accessible and in some cases known to be used for reproduction by Babine Lake rainbow trout (Bustard

[21] probably aged by David Bustard (Bustard 2007)

[22] The comparability is complicated slightly by the difference in the season of capture of the two samples. Data from Bustard (1987) were collected during the summer when the outermost annulus would usually be followed by "plus growth", whereas spawners scales may not show the most recent annulus clearly (or at all) due to resorption at the margin. Bustard (1990) does not provide details about interpretation of spawner scales, so it is unknown whether the edge of the scale was considered an annulus, though it seems likely.

1989a). However, none of this information provides conclusive evidence that fry or yearling migrants to the lake do not contribute at all to recruitment or disperse via the lake to other tributaries. Due to predation risk, yearling rainbow trout present in the lake might occupy habitats not sampled by purse or beach seining. Scale circuli patterns, which have not been reported for Babine Lake rainbow trout, also do not necessarily provide reliable means of determining timing of lake entry (Burrows 1993). Otolith trace element analyses might be technically more feasible than marking studies which have been used elsewhere to clarify this aspect of life history.

Comparison of Sutherland[23] rainbow trout spawner size-at-age and life history characteristics to native pelagic piscivorous rainbow trout stocks of other large lakes in British Columbia is provided in Table 19 and Table 20, and depicted in Figure 14. The largest unimpounded lakes of this group (Kootenay, Okanagan, Quesnel, and Shuswap) support the best-known fisheries for large rainbow trout; generally the most information regarding life history and abundance of pelagic piscivorous stocks exists for these waters. Based on the single year of data reported by Bustard (1990), Sutherland rainbow trout appear to first achieve sexual maturity at age 6 yr or later, comparable to though perhaps slightly later than average for the comparison lake populations which tend to mature initially at ages between 5 and 7 yr. Body size at first maturity of 1.5 kg appears slightly to significantly lower for the Sutherland population than for the corresponding lakes, and maximum documented size of 7.3 kg for the Sutherland population[24] is less than the values of 9 to 14 kg displayed for the same comparison lakes. As a result, size at age for Sutherland spawners is markedly lower than for comparable stocks (Figure 14), with the exception of recent values for the Quesnel Lake population spawning in the Horsefly River; size at age and other life-history attributes of Quesnel Lake pelagic piscivorous rainbow trout appear to have become less productive in the last decade as a result of sockeye enhancement in the watershed (Sebastian et al. 2003). In summary, if the gillnet data of Bustard (1990) are a representative sample of spawners, the Sutherland River rainbow trout stock appear to grow more slowly to smaller maximum size, and may reach first maturity at slightly older ages than native pelagic piscivorous rainbow trout of the analogous large lakes in the British Columbia interior.

A noted by Bustard (1990), based on limited sampling of retained fish at angling access points, a relatively small proportion of the 1986 recreational harvest was composed of rainbow trout of the sizes displayed by Sutherland spawners in 1989 (Figure 15). However, a crude morphoedaphic-type estimator calculated by Bustard (1987) suggested that Babine Lake rainbow trout harvest might have approached or even exceeded sustainability at that time. Figure 16 superimposes the characteristics of the total estimated recreational harvest of 8 500 rainbow trout in 1986 (Bustard 1987) on the total estimated escapement of 500 Sutherland watershed spawners for 1989 (Bustard 1990), in each case with the length frequencies provided by sampled catch. This hypothetical comparison neglects several important details, but illustrates the fact that if the estimates (Bustard 1987; Bustard 1990) of the numerical totals and size structure of the angling harvest and spawning escapement were roughly accurate and representative of the late 1980s, a relatively large proportion of potential spawners (rainbow trout over 45 cm in length) were likely harvested in the recreational fishery each year. Pooling the estimates for all fish over 45 cm in this manner

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[23]This document refers to the Sutherland River and Duncan Creek spawners as the “Sutherland rainbow trout population”, this is primarily for convenience as the stock structure within the Sutherland River watershed is unknown at present

[24] Anecdotal reports of Sutherland rainbow trout as large as 16 kg (Bustard 2007) are unconfirmed by any independent source

suggests that up to 80% of the spawner-sized rainbow trout might be harvested in the recreational fishery annually. The likelihood of this scenario is not known, but it assumes that all of the recreational catch of fish over 45 cm were Sutherland spawners, which is improbable. The size-aggregated mark-recapture estimation of total escapement (Bustard 1990) also utilized methods subject to bias. More accurate means of enumerating the spawning escapement are needed.

Rainbow trout datasets found for Babine Lake rainbow trout have generally not recorded the sex of the sampled fish. However, Bustard (1990) reported that the sex ratio of 116 in-migrating spawners gillnetted at the mouth of the Sutherland River was approximately 1:1 (51% females; Bustard 1990). No fecundity data for Babine Lake rainbow trout stocks appear to have been reported to date.

Reliable estimation of mortality rates does not appear possible with the data collected to date for Babine Lake rainbow trout. The “catch curve” method for estimating total mortality requires constant survival, recruitment stability, and equal catchability across the age classes included in the analysis, or if catchability is not constant that the relationship between catchability and age (body size) is known (Ricker 1975). Due to the capture methods, neither of the catchability conditions appears likely to be met by any of the available datasets, even when the youngest age classes (ascending limb of the catch curve) are excluded. For fishing methods such as seining, gillnetting, and angling, catchability is a function of (among other factors) gear encounter and retention probabilities which both usually vary with body size. Natural mortality alone can be estimated from body growth parameters and environmental temperature (Griffiths and Harrod 2006) but the precision of such estimates is very low, and would be further reduced by the small sample sizes of the available ageing data and the unknown accuracy of ageing.

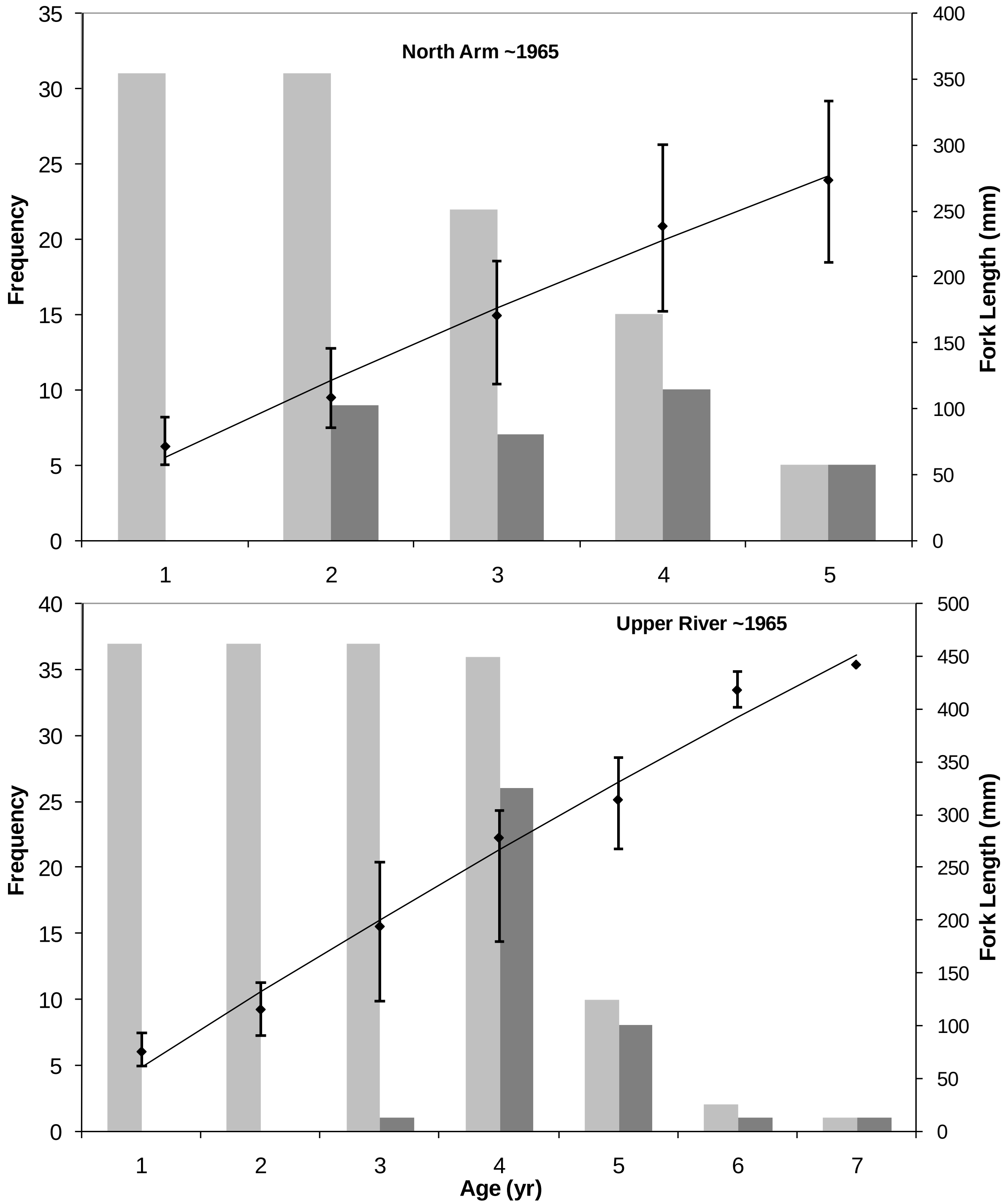
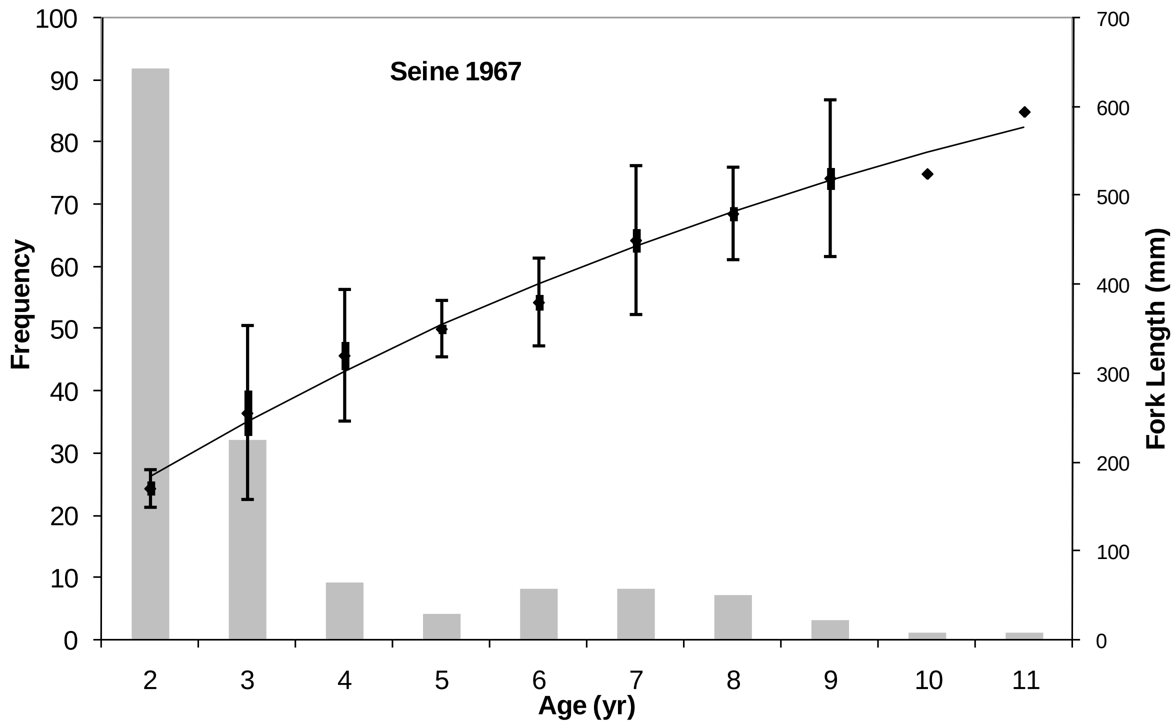


Figure 9. Length at age for samples of rainbow trout from the North Arm of Babine Lake, and the upper Babine River, as reported by McCart (1967). For length at age, the means are shown by the filled diamond symbols and the brackets display the range of values. Lengths were back calculated to the annuli; the light gray (left) frequency bars show the number of back calculated lengths used in estimating the means; the dark gray (right) frequency bars show the estimated number of sampled fish in the age class. The fitted line is a VB growth relationship, parameterized to the means as explained in the report text.



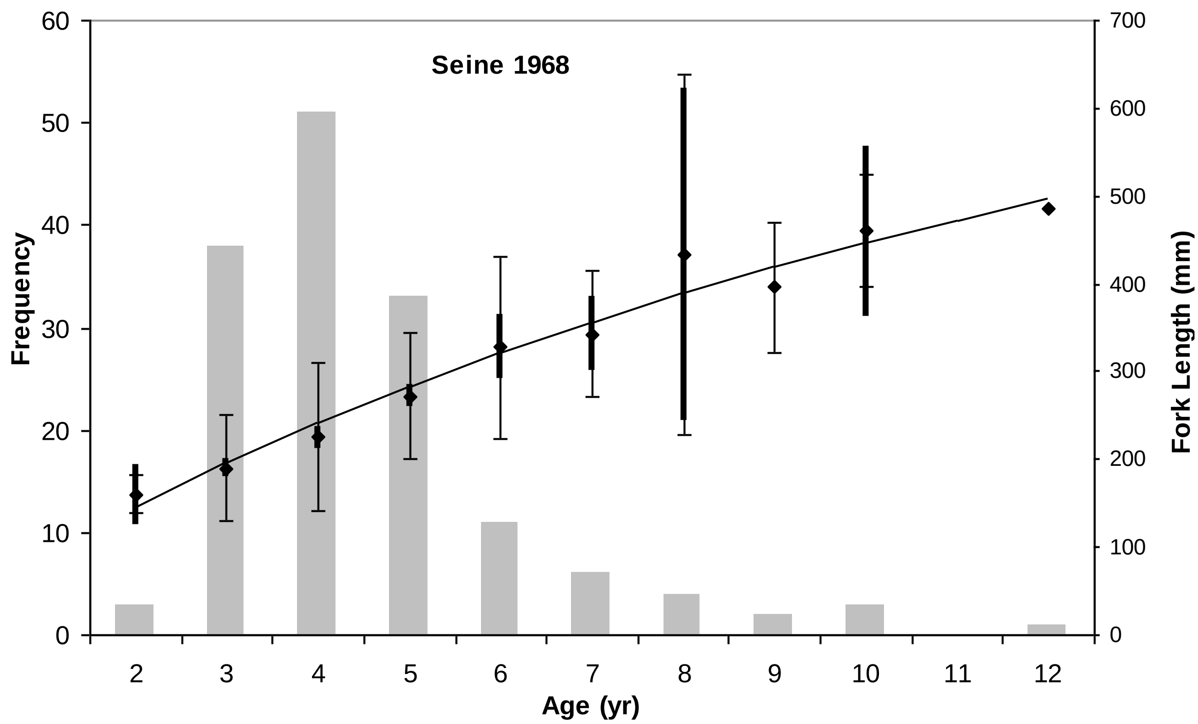


Figure 10. Age frequency, and length at age, for samples of rainbow trout from Babine Lake purse seine captures in summers of 1967 (n = 165; Figure 7 of Griffiths 1968) and 1968 (n = 158; Beacham and McDonald 1982). For length at age, the means are shown by the filled diamond symbols and the heavy black bars show the 95% confidence interval for the mean, while the lighter t-bar brackets show ±2 standard deviations. The fitted line is a VB growth relationship, parameterized to the means as explained in the report text.

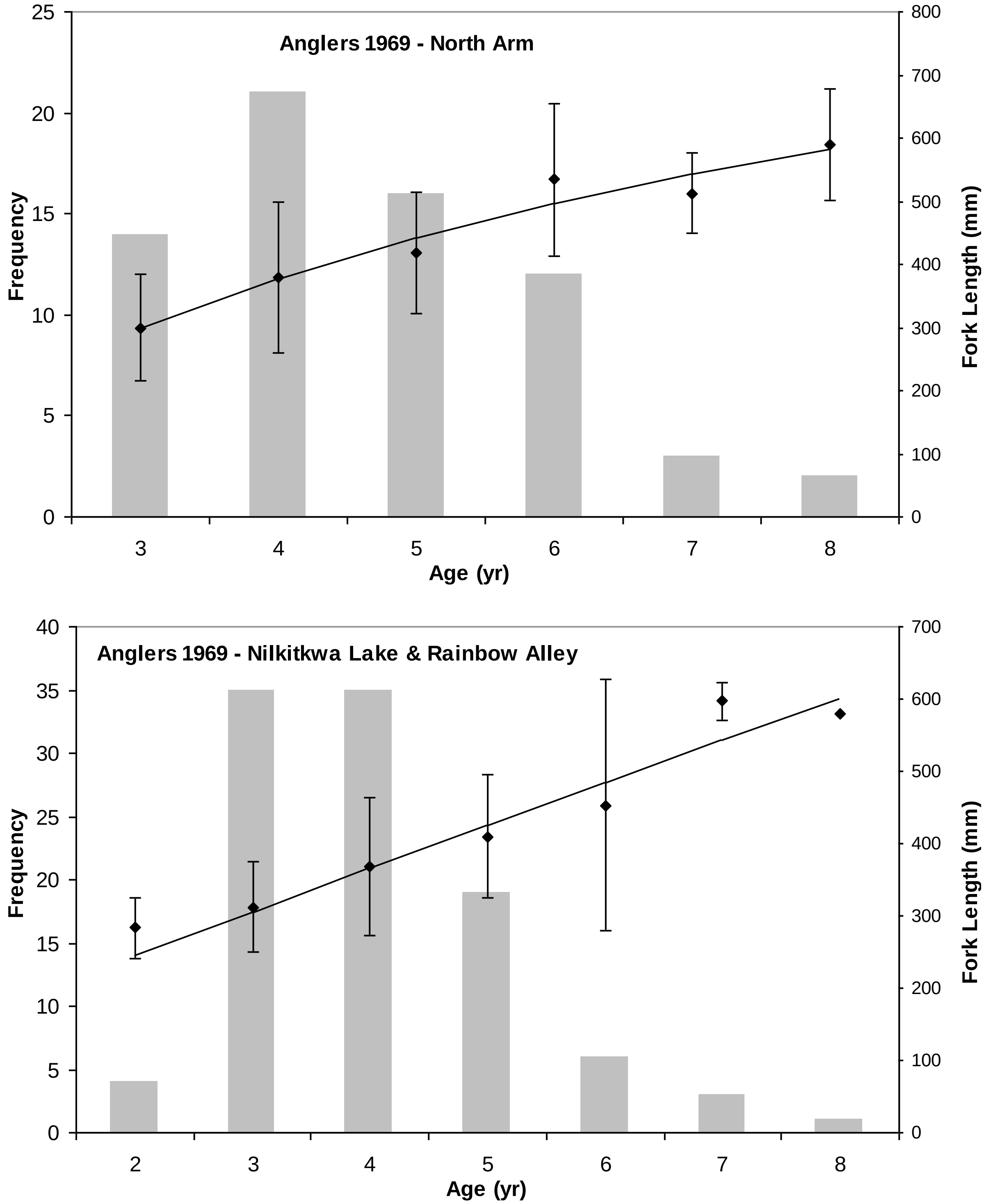


Figure 11. Age frequency, and length at age, for two samples of rainbow trout collected by Babine Lake angling guides in 1969 (Narver 1975). For length at age, the means are shown by the filled diamond symbols and the heavy black bars show the 95% confidence interval for the mean, while the lighter t-bar brackets show ±2 standard deviations. The fitted line is a VB growth relationship, parameterized as explained in the report text.

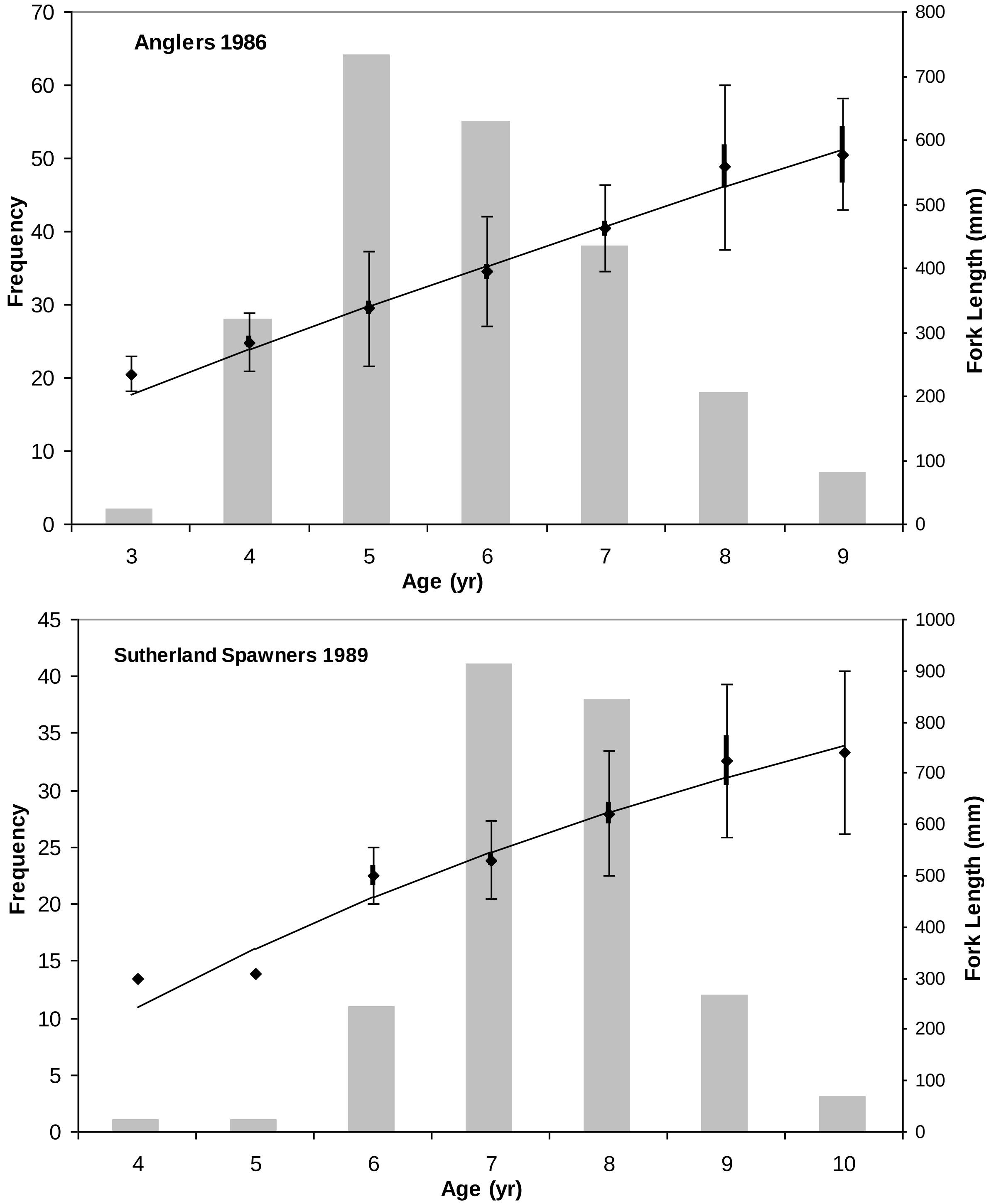


Figure 12. Age frequency, and length at age, for samples of Babine Lake rainbow trout collected from Main Arm anglers in summer 1986 (upper panel, Bustard 1986), and upstream migrating spawners collected at the Sutherland River delta by gillnet in May 1989 (lower panel, Bustard 1989). For length at age, the means are shown by the filled diamond symbols and the heavy black bars show the 95% confidence interval for the mean, while the lighter t-bar brackets show ±2 standard deviations. The fitted line is a VB growth relationship, parameterized as explained in the report text.

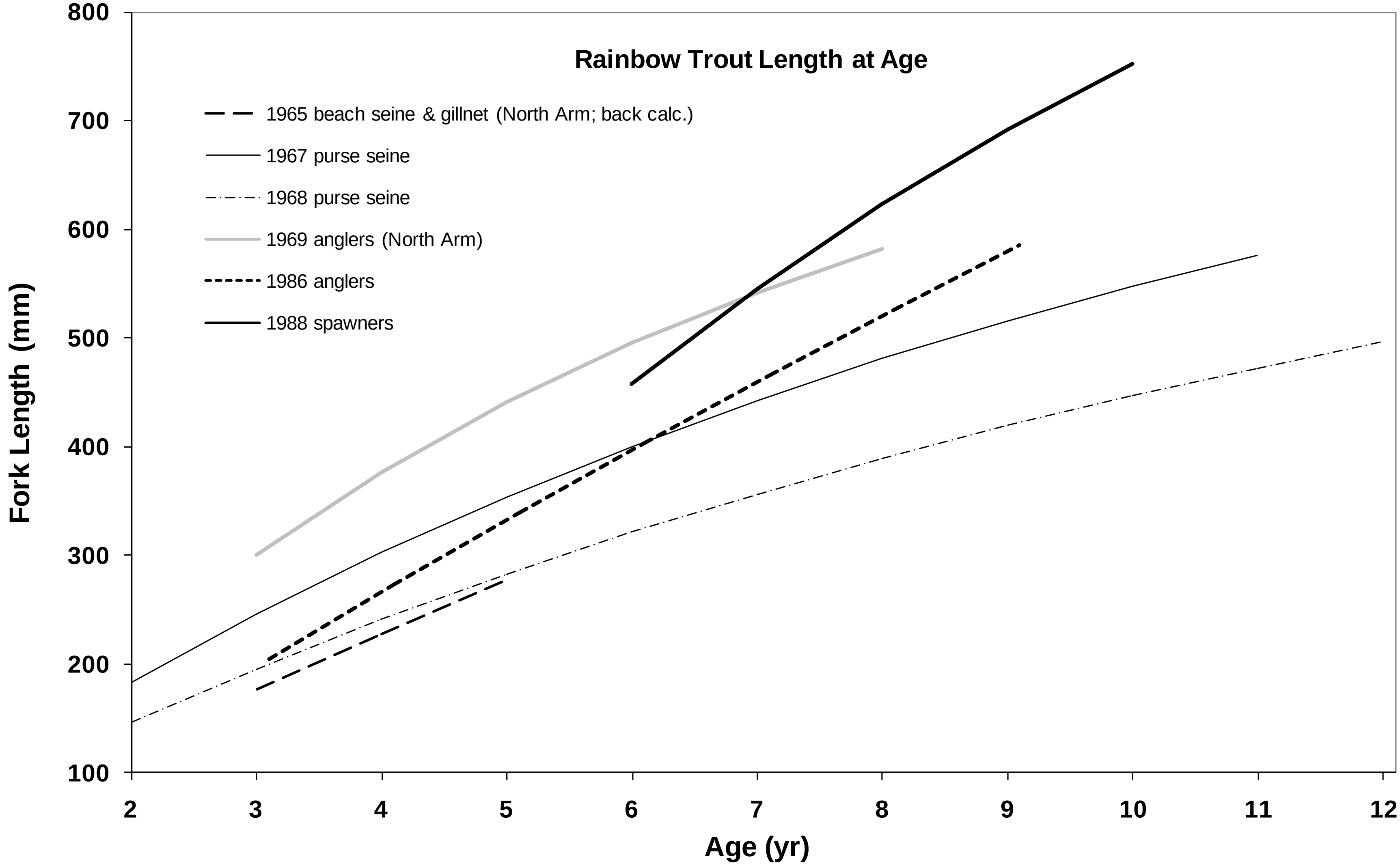


Figure 13. Comparison of Von Bertelanffy growth relationships fitted to six rainbow trout samples obtained from Babine Lake between 1965 and 1988. Sample sizes and mean lengths at age, with confidence intervals for the means and standard deviations, are displayed in Figure 9 through Figure 12. Parameterization is explained in the report text.

Table 18. Sample characteristics, and parameters of Von Bertelanffy growth relationships, fitted to rainbow trout length-at-age data obtained from Babine Lake, and the Upper Babine River, between 1965 and 1988. The columns $\mathbf{t_0}$, $\mathbf{L_\infty}$ and **k** are the VB growth parameters; **ω** is the product of $\mathbf{L_\infty}$ and **k;** and the columns **A300** and **A500** give the age in years at which the fork length of 300 mm and 500 mm respectively would be reached by a fish whose growth was determined by the given VB relationship. Rows in italic font represent lengths back-calculated by the **Author** to the previous annular check.

Location	**Method**	**Year**	**Author**	**n**	**Age Range**	**Length Range**	$\mathbf{t_0}$	$\mathbf{L_\infty}$	**k**	**ω**	**A300**	**A500**
North Arm	*Beach seine, gillnet*	*1965*	*McCart 1967*	*31*	*2 - 5*	*85 to 334*	*0.174*	*1119*	*0.056*	*63*	*5.7*	*10.7*
Upper Babine R.	*Beach seine, gillnet*	*1965*	*McCart 1967*	*37*	*3 – 7*	*124 to 436*	*-0.021*	*2080*	*0.036*	*75*	*4.3*	*7.6*
Main Lake	Purse seine	1967	Griffiths 1968	165	2 - 11	*170 to 595	-0.476	862	0.096	83	4.0	8.6
Main Lake	Purse seine	1968	Beacham and McDonald 1982	158	2 - 12	*160 to 485	-0.057	771	0.082	63	6.0	12.7
North Arm	Angling	1969	Narver 1975	68	3 - 8	*300 to 590	0.154	802	0.164	132	3.0	6.1
Upper Babine R. & Nilkitkwa L.	Angling	1969	Narver 1975	103	2 - 8	*283 to 597	-2.591	8832	0.007	58	2.7	6.3
Main Lake	Angling	1986	Bustard 1986	212	3 -9	225 to 710	0.214	2378	0.032	76	4.4	7.6
Sutherland R. mouth	Gillnet	1989	Bustard 1989	107	4 - 10	300 to 830	2.200	1210	0.125	151	4.5	6.5

Table 19 (modified from De Gisi 2003). Life history characteristics of North American indigenous populations of the pelagic piscivorous rainbow trout ecotype, in descending order of lake surface area. UN = value unknown due to insufficient data. Weight unit is kg, ages are yr. Two values given in a particular cell on distinct rows (e.g., Quesnel Lake) correspond to two distinct stocks.

Lake	**Primary Spawning Location(s)**	**Age at First Maturity**	**Weight at First Maturity**	**Maximum Weight**	**Maximum Age**	**Spawning Number**
Nechako Res.	UN	UN	UN	7	UN	UN
Arrow Res.	Camp C, Tonkawatla C, Columbia R ?	UN	UN	14	UN	~1000
Babine	**Sutherland R / Duncan C**	**6**	**>1.5**	**7.3**	**10+**	**500**
Kootenay	Lardeau R	5 to 6	2 to 4	14	9+	800 - 1200
Okanagan	Mission C	5 to 6	3 to 7	10	10	300 - 500
Shuswap	Eagle R Scotch C	5 to 7 UN	3.5 UN	9 UN	9? UN	500 - 1000 UN
Quesnel	Horsefly R / McKinley C Mitchell R	6 to 7 5	4 UN	>12 UN	10 UN	200+ UN
Eutsuk	UN	UN	UN	7	10+	UN
Kamloops	Barriere R	5 to 6	2.5 - 3	5.5	7	low 100s
Mabel	Duteau C	5 to 6	UN	>4.5	7	200 - 400
Bonaparte	Bonaparte R	UN	UN	4	9	UN
Isaac	Cariboo R	6	UN	7.5	UN	UN
Crescent	Lyre R	4 to 6[25]	2.5	10.4	9+	70 - 318
Tesla	UN	UN	UN	6	UN	UN
Nadina	UN	UN	UN	UN	UN	UN
Khtada	Khtada R ?	7 to 8	2	5.5	9+	UN

[25] ages questionable, probably low by one year or more based on later data

Table 20 (modified from De Gisi 2003)**.** Length at age for selected rainbow trout populations. * indicates back-calculated values.

Lake	**Reported**	**n**	**Age (yr)**									
			3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Region 6 non-piscivore lakes	De Gisi unpublished	1472	23	27	30	32	35	40				
Arrow Res.	Sebastian et al. 2000 Table 18	36	27	38	42	53	66	88				
Babine North Arm ~1965*	**McCart 1967**	**42**	**17**	**24**	**27**							
Babine (lakewide) 1967	**Griffiths 1967 (Figure 7)**	**68**	**26**	**32**	**35**	**38**	**45**	**48**	**52**	**53**	**60**	
Babine (lakewide) 1968	**Beacham and McDonald 1982**	**149**	**19**	**23**	**27**	**33**	**34**	**43**	**40**	**46**		**49**
Babine North Arm 1969	**Narver 1975**	**68**	**30**	**38**	**42**	**53**	**51**	**59**				
Babine DFO predator study (yr. unknown)	**Bustard 1990**	**?**				**37**	**39**	**43**	**45**			
Babine (lakewide) 1986	**Bustard 1986**	**212**	**24**	**28**	**34**	**39**	**46**	**56**	**58**			
Babine (Sutherland spawners) 1989	**Bustard 1990**	**104**				**50**	**53**	**62**	**72**	**74**		
Kootenay spawners 1949-98	Hagen unpublished	124		50	65	74	77	80				
Okanagan	Anonymous 2003	2288	38	49	61	69	72	75	70	66		
Okanagan spawners (Mission C.)	Anonymous 2003	393	37	47	57	64	70	79	78			
Shuswap	Bison 1991	1121	35	44	54	61	67	77				
Quesnel (Mitchell R non-spawners) 1986-88	Sebastian et al. 2003	39	38	46	54							
Quesnel (Horsefly R non-spawners) 1986-88	Sebastian et al. 2003	195	37	43	52	65						
Quesnel (Horsefly R spawners) 1986-87	Sebastian et al. 2003	44		39	53	61	70	78	90			
Quesnel (Horsefly R spawners) 1999-02	Sebastian et al. 2003	89		35	43	49	53	57	60	62		
Eutsuk	De Gisi 2002	246	31	38	45	52	59	65		76		
Mabel 1984	Jantz 1986	44?	39	43	50	52	61					
Bonaparte	Murdoch and Watts 1994 p.15	67	39	37	47	53	63	66	72			
Crescent 1949-52 (convert TL)	Meyer and Fradkin 2002 p.22	18	40	44	58	66						
Crescent 1996-99 (convert TL)	Meyer and Fradkin 2002 p.23	22		34	41	45	58	53	54			
Khtada	De Gisi unpublished	73	17	26	35	38	50	58	59			

Figure 14. Comparison of Von Bertelanffy (VB) growth relationships fitted to five samples of rainbow trout spawners from large-lake populations for which kokanee are likely a dominant prey item.

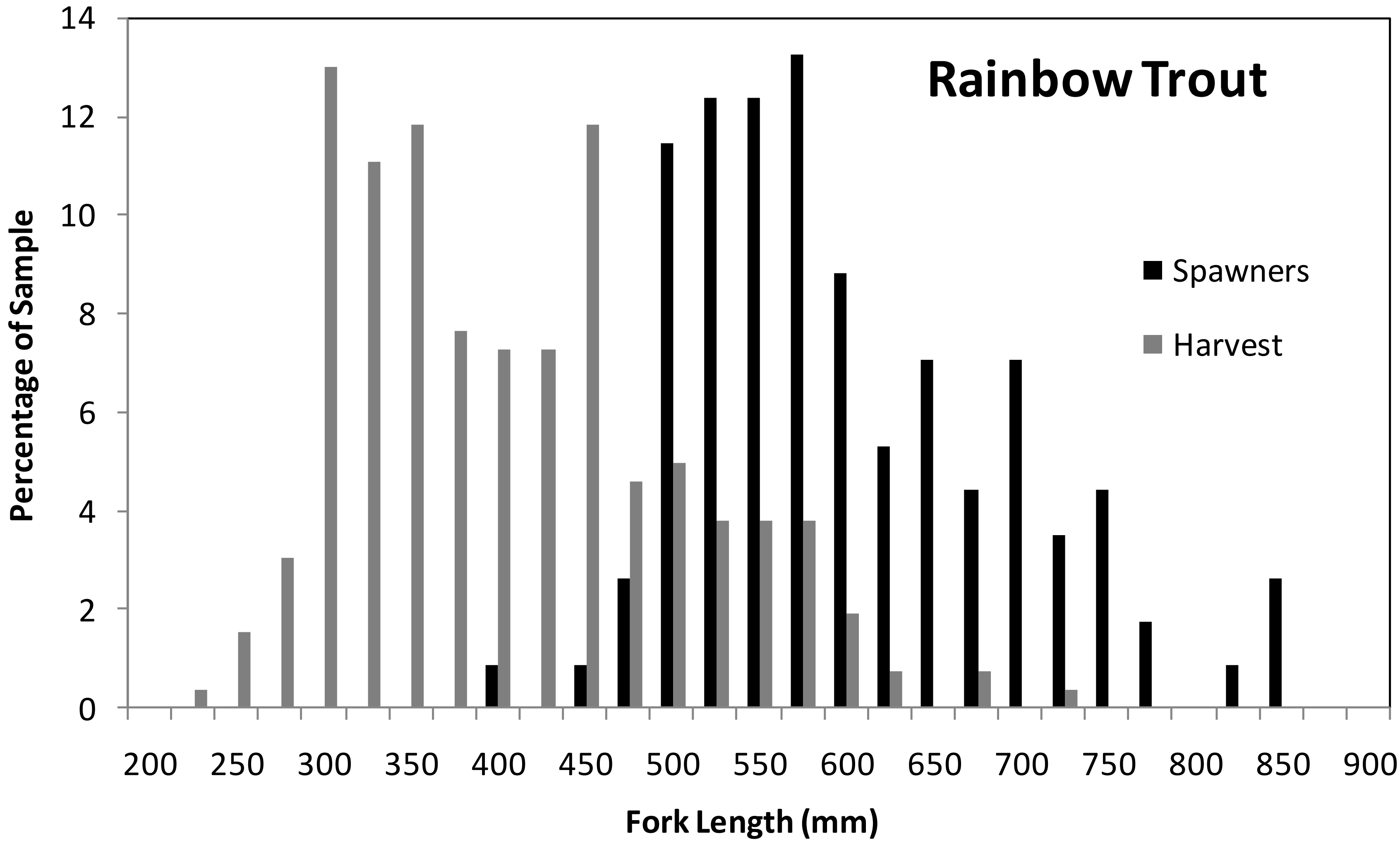


Figure 15. Length frequency distributions, expressed as **Percentage of Sample**, for rainbow trout sampled from the open-water recreational angling **Harvest** in 1986 (n = 261), and in-migrating **Spawners** in the spring of 1989 (n = 113) gillnetted at the mouth of the Sutherland River. Bin labels are the upper bounds of the fork length categories.

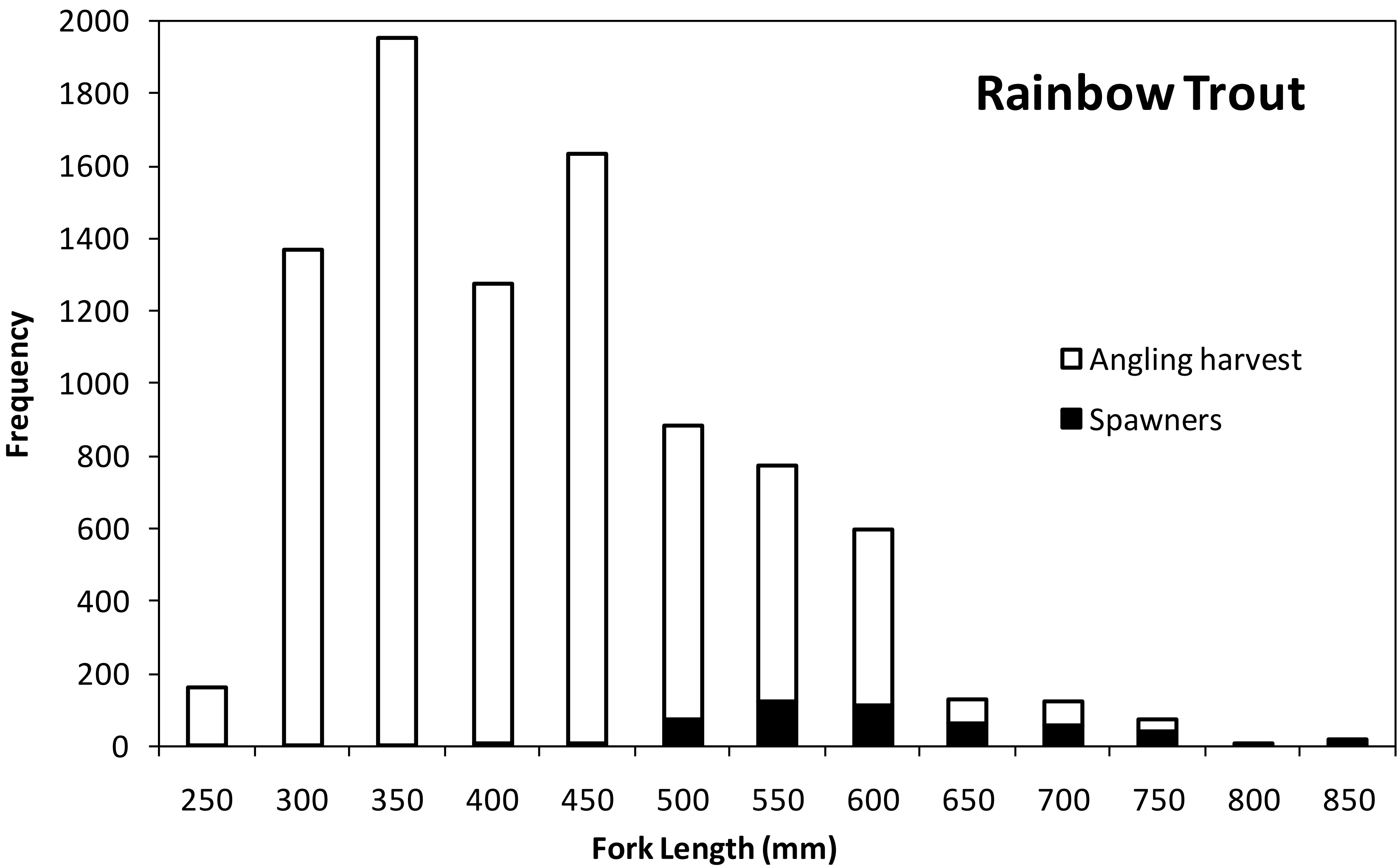


Figure 16. Length frequency distributions of the entire estimated recreational **Angling harvest** of 8 500 rainbow trout on Babine Lake in 1986 (n = 261), and of an estimated 500 in-migrating **Spawners** gillnetted at the mouth of the Sutherland River in spring 1989. Estimates were extrapolated from the samples plotted in Figure 15. Bin labels are the upper bounds of the fork length categories.

5.2. Rainbow Trout Abundance

5.2.1. Angling

Effort and catch of angling derby participants on Babine Lake in late June 1975 were documented by Whately (1975), though the methodology of the survey was not reported; it was likely a single access point end-of-day sample. An estimated 280 angler days yielded a catch of 60 rainbow trout[26], giving an overall average catch rate of 0.21 rainbow trout per angler day. It is unclear whether the results include unharvested fish, although catch-and-release angling was not prevalent at that time.

Bustard (1987) estimated total catch of rainbow trout on Babine Lake from mid-May through September as 20 000 in 1985 and 10 100 in 1986. Effort estimates for the same two years were 20 906 angler days and 14 680; the resulting overall mean catch rates were 0.96 and 0.69 rainbow trout per angler day respectively, with roughly 85% of the catch harvested. The totals include estimated activity and catch in Rainbow Alley and Nilkitkwa Lake, where catch rates were higher; unbiased estimates of the catch rates in Babine Lake alone would likely be 5 to 10% lower than those shown above.

A creel survey conducted at Fulton River and Pinkut Creek mouths at Babine Lake in May - June 1990 resulted in an estimated catch (killed plus released) rate of 0.49 rainbow trout per day adjacent to Pinkut Creek and 0.86 rainbow trout per day at the mouth of Fulton River (De Leeuw 1991). The combined average catch rate for the two locations weighted by angling effort was 0.60 rainbow trout per day.

Beere (1990) also recorded that in the period May 17 to 20, 1990, a creel survey recorded 59 boaters on Babine Lake in the Fulton River bay area between Topley Landing and Granisle, who conducted 55 rod days (78.7 rod hours) of angling and captured 38 rainbow trout among the 50 fish of all species which were angled. This represents a catch rate of 0.69 rainbow trout per rod day. All but 2 fish were retained.

During 513 angler days estimated to have occurred on 19 dates within the period 10 August to 7 September 2006, recreational anglers caught an estimated 68 rainbow trout in the fishery which targets sockeye salmon in the vicinity of the mouth of the Fulton River (Macintyre 2007). The average estimated catch rate for rainbow trout was thus 0.13 fish per angler day, though only one party of those surveyed was targeting rainbow trout.

Angling guides reported client catch of 5307 rainbow trout for an overall catch per effort of 1.8 rainbow trout per angler day, during 2 927 guided angler days recorded for Babine Lake in the 12 licence years of 1990/91 to 2001/02 inclusive. Angling guide reports do not indicate the target species, but rainbow trout catch was reported for parties with activity totaling 2508 angler days (86%), resulting in an average catch rate of 2.1 rainbow trout per angler day (Table 21). Although the reliability of the data is unknown, they display no clear trend in relative abundance of Babine Lake rainbow trout during the period of record (Table 21).

[26] 5 of the 60 rainbow trout were greater than 60 cm in length, with the largest recorded as 67.3 cm

Some guided angling effort on the extreme northern end of the North Arm of Babine Lake may also have been included within reported activity on Rainbow Alley and Nilkitkwa Lake[27]. Of the 10 563 guided angler days reported on these waters during the 12 licence years of record, rainbow trout catch was reported for 10 466 days (99%). Overall average catch per effort of rainbow trout for Rainbow Alley / Nilkitkwa Lake was over twice as high as Babine Lake at 4.9 fish per angler day; reported catch per effort was apparently higher during the final 4 years of the dataset than during the previous 8 years (Table 21).

Table 21. Guided angling effort and rainbow trout catch for Babine Lake, and Rainbow Alley of Babine River including Nilkitkwa Lake, for licence years 1990/91 through 2001/02 as recorded in the Skeena Region AGMS database. **All AD** gives the total number of guided angler days reported for the water; **AD with RB** is the number of angler days on the water with reported rainbow trout catch; **Catch** gives the number of rainbow trout reported to have been angled (harvested or released) by guided anglers; **CPE** is the **c**atch **p**er **e**ffort by guided anglers in parties reporting rainbow trout catch, in units of rainbow trout per angler day.

Year	Babine Lake				Rainbow Alley / Nilkitkwa Lake			
	All AD	AD with RB	Catch	CPE	All AD	AD with RB	Catch	CPE
1990/91	44	44	90	2.0	871	849	4,034	4.8
1991/92	99	87	261	3.0	813	811	3,424	4.2
1992/93	61	56	134	2.4	802	802	3,905	4.9
1993/94	98	85	163	1.9	1,084	1081	4,337	4.0
1994/95	817	684	1,816	2.7	924	924	3,280	3.5
1995/96	718	708	1,166	1.6	815	788	3,184	4.0
1996/97	128	61	81	1.3	913	889	3,078	3.5
1997/98	92	57	102	1.8	1,480	1468	5,816	4.0
1998/99	551	521	1,079	2.1	618	618	4,698	7.6
1999/00	102	60	115	1.9	1,032	1032	6,215	6.0
2000/01	117	103	197	1.9	686	686	6,511	9.5
2001/02	100	42	103	2.5	525	518	3,301	6.4
Total	**2,927**	**2,508**	**5307**	**2.1**	**10,563**	**10,466**	**51,783**	**4.9**

[27] These waters appear to have been generally lumped together as 'BABINE R 2' in the AGMS database

5.2.2. Gillnet

Standardized gillnetting to assess fish predator species population density in Skeena sockeye lakes was conducted by Withler (1948) during 1946 and 1947, and provides the earliest estimates of rainbow trout relative abundance in the materials obtained for this review. Summary of his results for Babine Lake, and for reference lakes (Morrison, Nilkitkwa and Morice) is shown in Table 22. The data for Babine Lake were separated into three geographic divisions, but these were undefined in the report. Aggregate catch per effort (CPE) of 0.026 rainbow trout per 100m of net per night in Babine Lake was much lower than for any of the comparison lakes. Rainbow trout CPE for Morrison and Nilkitkwa lakes was approximately twice that of Babine Lake, and CPE for Morice Lake was roughly six times greater. In addition to inherently high variance associated with gillnetting as a sampling method, a variety of factors other than fish abundance can influence gillnet CPE, so it is not clear that these CPE values accurately reflect differences between these waters in population density of rainbow trout. For instance, Babine Lake received much greater netting effort than all other lakes, which might reflect netting during time periods and at locations (depths) of lesser effectiveness and could cause CPE to be biased downward relative to other waters; lake char CPE at Babine Lake was also much lower than for Morrison and Morice lakes (Section 6.2.2).

McCart (1970) presented kokanee catches of a much less extensive gillnetting program on Babine Lake in 1958. However, relative abundance of rainbow trout captured during this assessment program was not reported in the available literature.

Effort and catch of gillnetting conducted by Westwater Research Centre during 1983 to 1985, in log-impacted and unimpacted sites in the littoral area of Morrison Arm and the Main Arm, are summarized in Table 23. CPE of rainbow trout was roughly 1.5 individuals per 100 m length of gillnet per night, and this value was slightly lower at impacted sites than at unimpacted reference sites.

The results of Withler (1948) pre-date much of the industrial and human population growth in the Babine Lake watershed as well as sockeye enhancement, and the Westwater study probably occurred sufficiently later than these developments to adequately reflect their effects on rainbow trout abundance. Unfortunately however, as was stated with kokanee, the differences in net construction and net deployment locations and methods between the studies prevent any meaningful comparison of rainbow trout relative abundance across time.

Table 22. Gillnet **Effort**, **Catch** and **Catch Per Effort** of rainbow trout on Babine Lake and comparison waters during 1945 to 1947, as reported in Withler (1948) which provides no explanation for the geographic divisions of Babine Lake. Rows in bold font are grand totals for all years of sampling in the named waters. **Effort** unit is 100 m length of gillnet set overnight. Net characteristics and details of the netting protocol are given in Section 2.3.2.1.

Water	Year	Net Nights	Effort	Catch	Catch Per Net Night	Catch Per Effort
Babine Lake Division I	1946	185	423	5	0.03	0.012
	1947	100	229	5	0.05	0.022
Babine Lake Division II	1946	180	411	25	0.14	0.061
	1947	215	491	12	0.06	0.024
Babine Lake Division III	1946	155	354	3	0.02	0.008
Morrison Lake	1946	45	103	5	0.11	0.049
	1947	65	149	9	0.14	0.061
Nilkitkwa Lake	1946	20	46	2	0.10	0.044
	1947	40	91	5	0.13	0.055
Morice Lake	**1945**	**50**	**114**	**18**	0.36	0.158
Babine Lake (all Divisions)	**1946-47**	**835**	**1908**	**50**	0.06	0.026
Morrison Lake	**1946-47**	**110**	**251**	**14**	0.13	0.056
Nilkitkwa Lake	**1946-47**	**60**	**137**	**7**	0.12	0.051

Table 23. Gillnet **Effort**, **Catch** of rainbow trout, and **C**atch **P**er **E**ffort (**CPE**) of rainbow trout during sampling conducted on Babine Lake by Westwater Research Centre, as a component of the log transportation impacts study of 1983 to 1985. **Log Impacted** sites were located in areas where logs were stockpiled or dewatered, while **Reference** sites were located nearby in unimpacted locations. Effort unit is 100 m length of gillnet set overnight.

Year	Log Impacted			Reference			All		
	Effort	Catch	CPE	Effort	Catch	CPE	Effort	Catch	CPE
1983 - HFP sites	46.9	53	1.13	46.9	29	0.62	93.74	82	0.87
1984 - all sites	78.7	162	2.06	80.4	194	2.41	159.03	356	2.24
1984 - HFP sites	26.8	45	1.68	26.8	82	3.06	53.6	127	2.37
1985 - HFP sites	46.9	27	0.58	46.9	62	1.32	93.74	89	0.95
All years - HFP sites	**120.5**	**125**	**1.04**	**120.5**	**173**	**1.44**	**241.1**	**298**	**1.24**
All years - all data	**172.4**	**242**	**1.40**	**174.1**	**285**	**1.64**	**346.5**	**527**	**1.52**

5.2.3. Purse Seining 1966-1977

Figure 17 depicts a comparison of day and nighttime catches of rainbow trout per haul, in defined fishing areas during the 1966 to 1977 nerkid fry purse seining program. Only the results for July through October were summarized, because the catch rate of rainbow trout was consistently lower during May and June (Figure 18), and including the pre-July data could have created bias because the sampling was unbalanced with respect to the months and fishing areas. Lower catch rates during May-June could reflect the migration of mature rainbow trout to fluvial spawning areas, as well as possibly the absence of the year's rainbow trout parr which may not have completed their out-migration from streams to the lake's pelagic areas until late spring. Nighttime catch rates of rainbow trout were slightly to moderately higher than daytime catch rates in all of the defined fishing areas except area 5 (see Figure 1), the southernmost portion of the Main Arm. It is unknown whether this reflects increased ability of rainbow trout to avoid the seine during daylight, occupation of different habitats (depth strata) during day and night periods, or a combination of these or other factors.

The highest observed catch rates for rainbow trout in the July to October period occurred at night in Morrison Arm (area 8). Pooling the day and nighttime catch rates within each area, the Main Arm fishing areas and Morrison Arm generally displayed relatively similar catch rates, with Morrison Arm slightly higher due to greater nighttime catch rates, and the North and Hagan arms markedly lower (Figure 17). Catch rates may vary between areas of the lake due to population density, but vulnerability to the sampling gear might also be an important factor. For instance, the shallowness of Morrison Arm may compress the vertical distribution of rainbow trout thus increasing their catchability. The data do not allow discrimination of the contributions of abundance and catchability.

Figure 19 displays the July-October catch rates for the Main and North arms through the 12-year duration of the data. Again, unbalanced sampling required the elimination of other fishing areas from this summary. The Main Arm catch rates show no clear trend in catch rate with time. North Arm catch rates appear to have increased, because the lowest two annual estimates were in 1966 and 1967 and the highest was in 1977, but this is not statistically confirmable due to the high variance of the estimates.

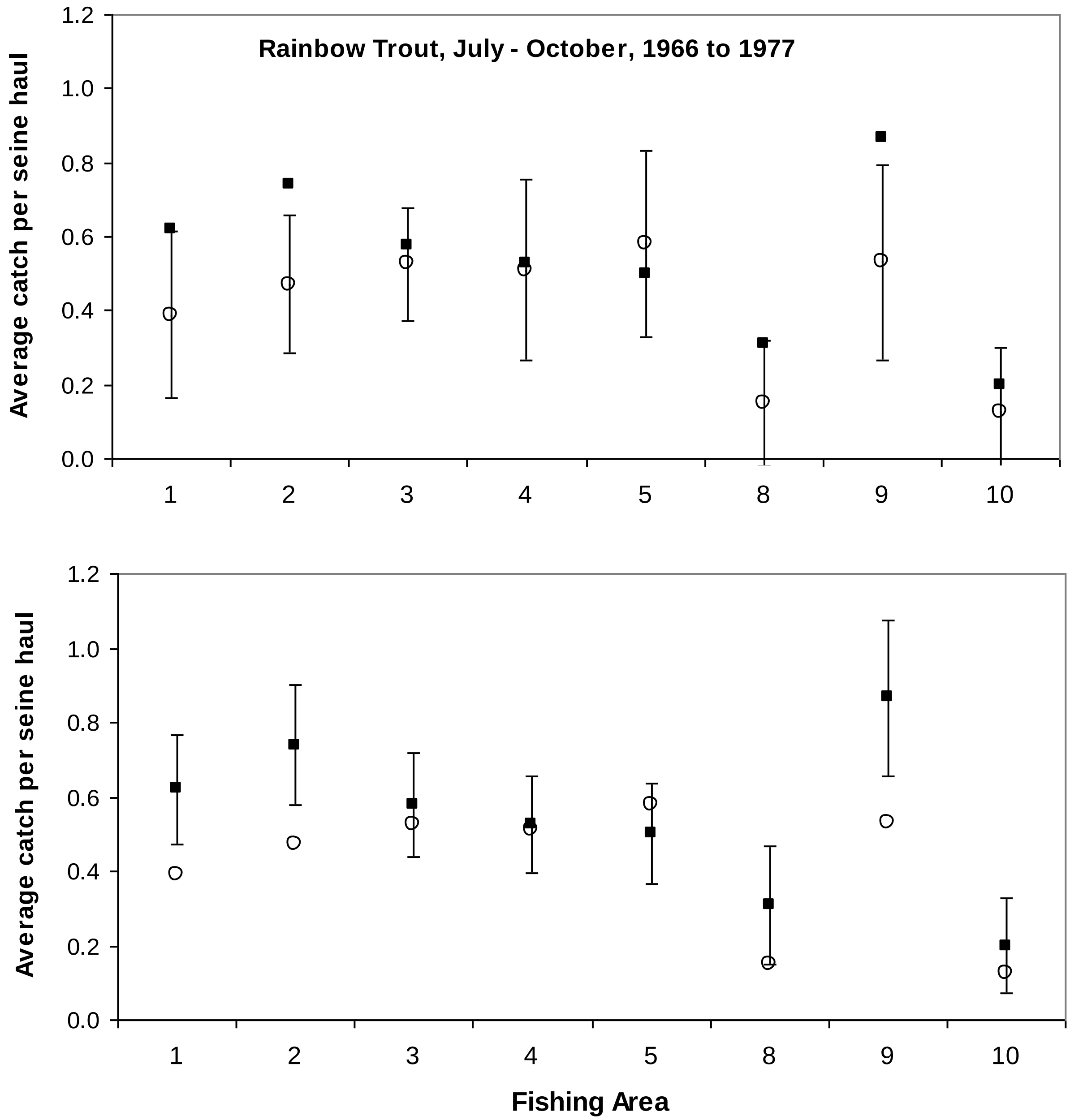


Figure 17. Comparison of daytime (open circles) and nighttime (filled squares) mean catch of rainbow trout per purse seine haul in defined fishing areas (see Figure 1) of Babine Lake during July to October, for seven calendar years between 1966 and 1977 inclusive. The panels display the same results, except that the upper panel shows the 95% confidence intervals for daytime means while the lower panel show the 95% confidence intervals for the nighttime means. Night was defined as beginning at evening civil twilight and ending at morning civil twilight; day comprised all remaining hours. Confidence interval estimation used non-parametric bootstrap resampling, which is also explained in the report text.

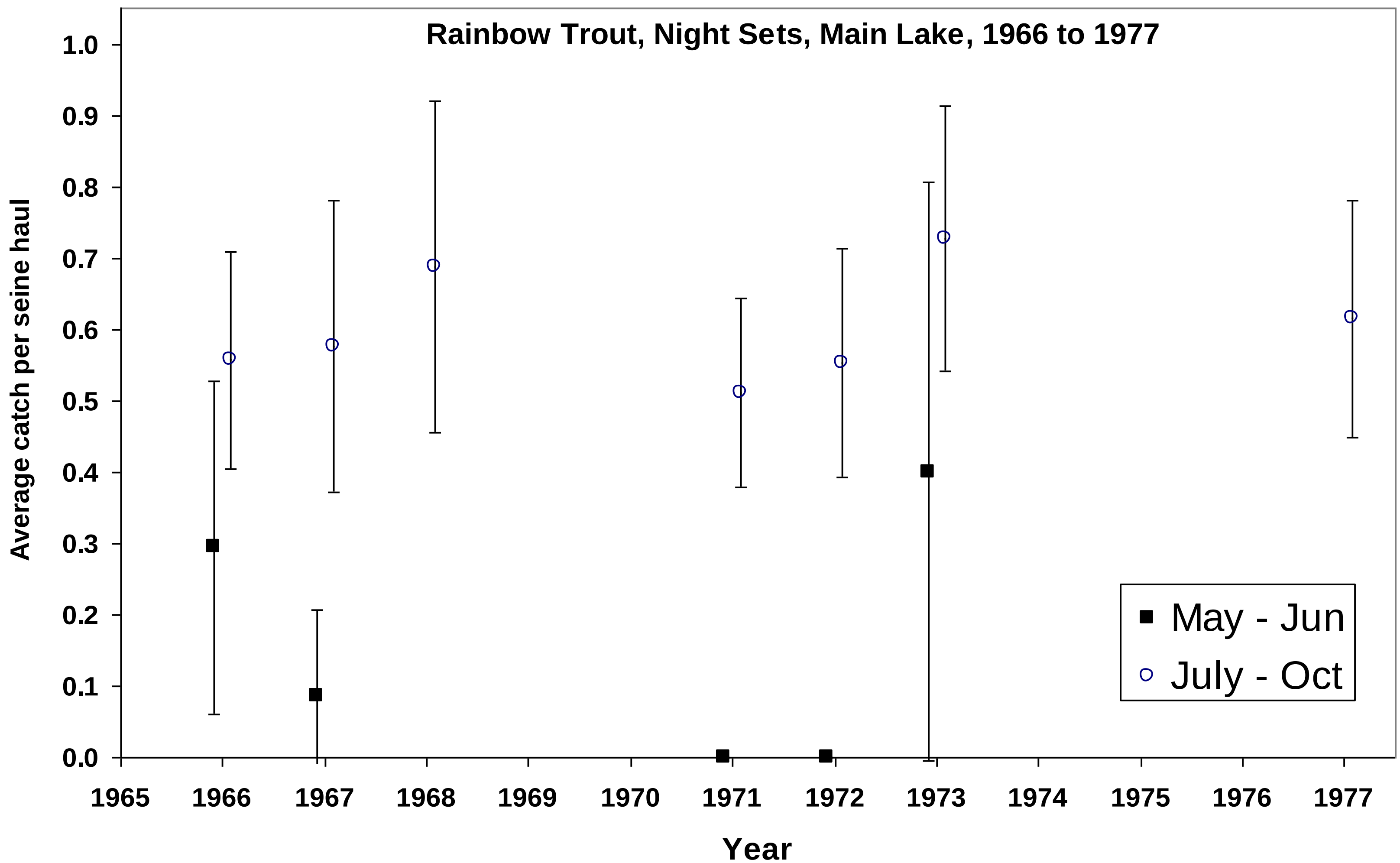


Figure 18. Comparison of mean nighttime catch of rainbow trout per purse seine set in the main basin (Areas 1 to 5 in Figure 1) of Babine Lake during early season (May-June, closed squares) and the remainder of the year (July-October, open circles), for seven calendar years between 1966 and 1977 inclusive. The 95% confidence intervals shown were estimated by non-parametric bootstrap. Sets made in May-June of 1971 and 1972 did not capture any rainbow trout. There were no sets made during May-June 1977.

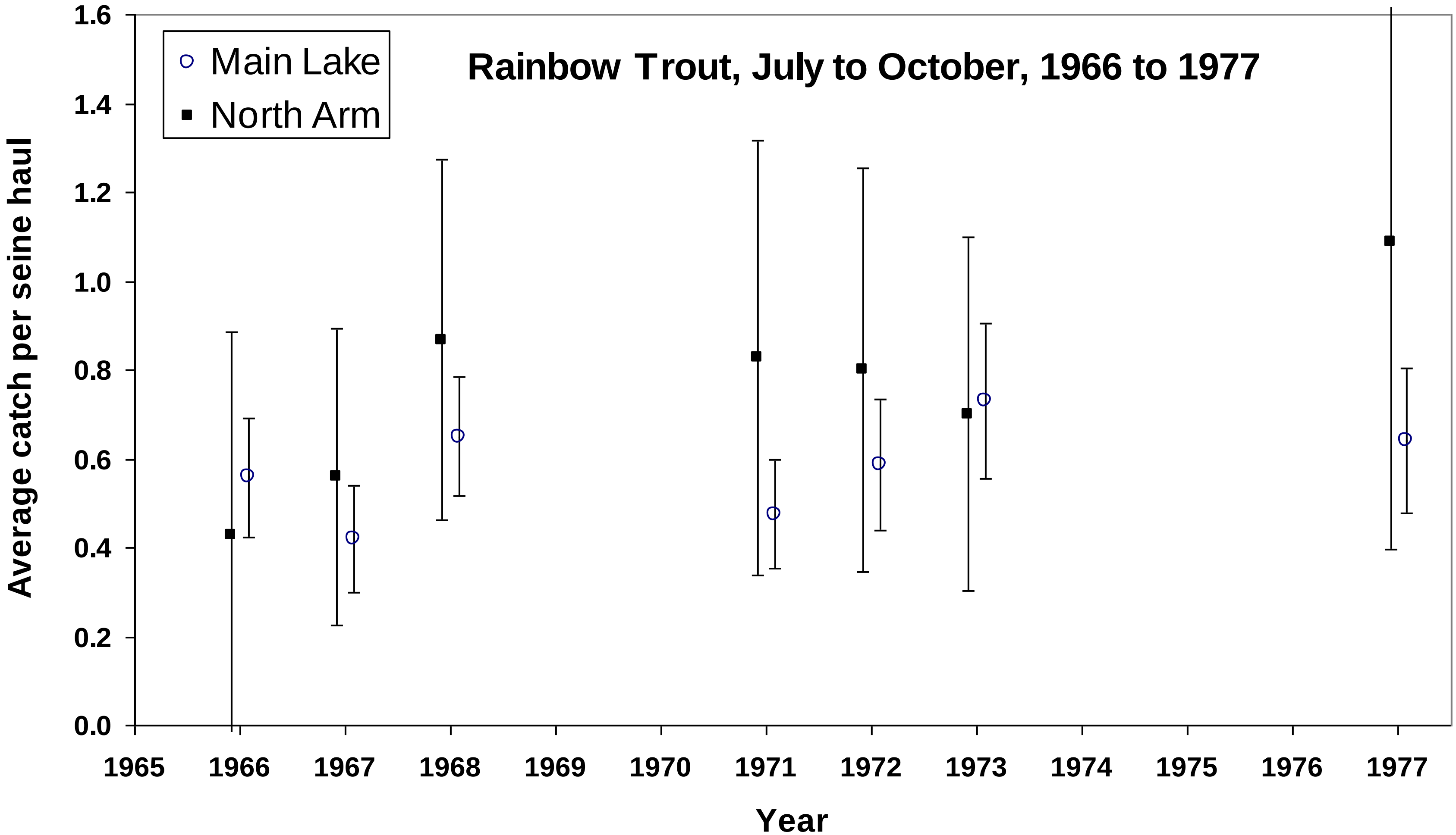


Figure 19. Mean nighttime catch of rainbow trout per purse seine set in the main basin (Areas 1 to 5 in Figure 1) and north arm (Area 9 in Figure 1) of Babine Lake, for seven calendar years between 1966 and 1977 inclusive. The 95% confidence intervals shown were estimated by non-parametric bootstrap.

5.3. *Rainbow Trout Synthesis*

Significant uncertainties remain about the life history and population structure of Babine Lake rainbow trout. These information gaps contribute to the difficulty of assessing the sustainable productivity of the fisheries provided by these stocks and the suitability of the present approach to conservation and management.

The population structure of rainbow trout which utilize Babine Lake, including the number of spawning streams and the degree of genetic isolation among them, is presently undescribed; this information is fundamental to the development of a plan for sustainable management of the recreational fisheries on the lake. The Sutherland watershed is known to support one or more spawning populations of large-bodied rainbow trout which anecdotally are believed to be distinct and unique among the lake's rainbow trout; members of the Lake Babine Nation have not observed and are not aware of any other spawning concentrations of large-bodied rainbow trout in the Babine Lake basin (Toth 2007) and no other reports are known. Other anecdotal information suggests that an unnamed tributary to lower Morrison Creek likely provides reproductive habitat for rainbow trout which support the Morrison Arm recreational fishery. The proportional contribution of these spawning streams and others to rainbow trout recruitment to the recreational fisheries of Babine Lake, and of the important fly fisheries of Rainbow Alley including Nilkitkwa Lake, is essentially unknown. Mark and re-observation studies are often used to clarify aspects of population structure, but other than a minimal amount of tagging associated with the Sutherland spawner study, this type of program has not been conducted in the Babine Lake area. In some situations, spatial differences in growth trajectories can also be indicative of stock structure. Unfortunately, for Babine Lake rainbow trout differences in capture methods, collection locations, type of data reported, and subjectivity of scale aging performed by different interpreters, all seriously complicate the detection and interpretation of any spatial patterns among the length-at-age datasets available. The use of molecular methods to elucidate the species' population structure in the Babine Lake drainage has recently yielded promising results: preliminary genetic analyses for 500 rainbow trout juveniles collected from 10 different tributaries have verified that stock structure is discernible at the tributary level (Atagi 2007). When the relevant genetic markers have been identified, and assuming that the tributaries have included those identified as most probably important in Section 5.1.1 based on previous juvenile sampling, analyses should be extended to samples from the aforementioned recreational fisheries on the lakes and upper Babine River to examine tributary contributions. Consideration should also be given to otolith microchemistry investigations. Like genetic analyses, these methods can be used to discern stocks according to their stream of origin. Additionally, they can identify the timing of life history events such as migration from stream to lake which are necessary to understand the sustainable productivity of the populations.

Combined with other life-history information such as age at maturity, length-at-age data also allow the development of valid generalizations about the biology and conservation of similar populations within an ecotype. Similarities among stocks may allow management to proceed with acceptable confidence when detailed longer-term information can only be obtained for a subset of individual waters. Length-at-age data comprise the most frequently collected biological information available for Babine Lake rainbow trout, with the earliest such data reported from about 1965 and the latest from 1989. This type of data is often interpreted as representing the average growth trajectory of a population, though in reality it results jointly from processes of growth, selective mortality, and unequal vulnerability to the sampling gear. Again, because most of the Babine Lake rainbow trout length-at-age datasets were probable mixed-stock collections subject to the potential sources of inaccuracy mentioned previously, their utility for such comparisons is limited. However, data collected from Sutherland River spawners in 1989 do likely represent a discrete stock unit suited to comparison with native populations of this ecotype in other large lakes. The Sutherland spawners displayed similar late maturity, but smaller body size at age, relative to comparable populations of Kootenay, Shuswap, Okanagan and Quesnel lakes. In the absence of other information, the slower growth of the Sutherland population(s) suggests the need for additional caution in their management.

Changes through time in length at age may suggest trends in the production environment, such as prey body size and forage abundance. For instance, Sebastian et al. (2003) have inferred a possible reduction in kokanee abundance at Quesnel Lake following sockeye enhancement, after observing significant decline in size at age of rainbow trout spawners. This type of analysis could also be subject to confounding effects such as density dependence of growth, if abundance were simultaneously changing. Regardless, the length-at-age datasets collected to date for Babine Lake rainbow trout are not suited to this purpose due to the issues of accuracy and continuity of methods already discussed.

Time series of relative abundance data capable of displaying changes in rainbow trout population densities are also lacking for Babine Lake. Three gillnetting programs conducted on the lake between the 1940s and the 1980s varied greatly in filament materials, mesh configuration, and deployment methods and location types, so that valid comparison of catch rate changes through time is not possible. The sockeye fry purse seine data beginning in 1966 and ending in 1977 span the period of implementation of sockeye enhancement on Babine Lake. These show no obvious trends in relative abundance of rainbow trout during the period, but high variance in catches creates substantial uncertainty around this interpretation. In addition, Babine Lake rainbow trout are long-lived, and increased sockeye fry densities could impact rainbow trout populations in both direct and indirect ways which might only be fully evident after a decade or more of enhancement. Definitive evaluation of the effect of sockeye enhancement would require a longer time series of abundance estimates than is represented by the purse seine data. Comparable programs of gillnetting or purse seining have not been reported for other large lake rainbow trout populations. Advances in hydroacoustic methods may allow their use in abundance estimation for large rainbow trout in lakes. Otherwise, enumeration of spawners is the likely the most feasible method of estimation of absolute abundance, for monitoring purposes as well as the establishment of stock-recruitment relationships. Seasonal turbidity would prevent the usual of visual surveys of rainbow trout spawner numbers in most Babine Lake tributaries, including those of known importance such as the Sutherland River. Resistivity counters offer the possibility of accurately enumerating the entire escapement, and can possess some advantages over traditional fish-counting structures, though the inaccessibility of the Sutherland watershed would greatly increase the expense of any type of enumeration.

Characteristics of the Babine Lake recreational fisheries have not been quantified in over two decades. Angling catch per effort can also be an indicator of changes in abundance, though risky as the sole source for inferring population trends due to high variance and nonstationarity. Regardless, information about the characteristics of the fishery is needed in order to develop and maintain effective regulations. An angling use study of the type conducted by Bustard (1987) would be prohibitively expensive, but the data from that study could be used to model and estimate the potential accuracy of a redesigned (scaled-down) survey. Regular data are also needed for the Yekooche net fishery which targets the Sutherland watershed spawning population. Among the types of useful and necessary information which could be collected during this fishery are total harvest, relative abundance, and life history samples. The development of a sustained and productive working relationship with the Yekooche fishers has begun (Giroux 2007) but more work is needed (Beere 2007).

As with kokanee, additional life history data for Babine Lake rainbow trout may be present in DFO technical publications not obtained, or in unpublished DFO files. The catalog of the scientific archives of the Pacific Biological Station refers to mounted and unmounted rainbow trout scales collected during Babine Lake sampling, in several different record groups (Simpson et al. 1985). These may include scales which have been interpreted and reported upon, unprocessed samples, or both. The status of rainbow trout scale samples collected during the nerkid fry purse seining studies on the lake between 1966 and 1977 remains unknown; paper copies of datasheets along with scale samples, scale impressions and scale images are likely still held. Scales and scale impressions or images might have two uses: re-aging for comparability with contemporary scales, and the potential for recovery of genetic material for studies which might retrospectively estimate population abundance or other uses. Investigation of these materials at the Pacific Biological Station should be considered important, but secondary in priority to the acquisition of contemporary data; opportunistic investigation is suggested. Other age samples still in existence such as those collected by Bustard (1987; 1989) should also be obtained if possible and archived.

6. Lake Char

Along with rainbow trout, the lake char of Babine Lake supply the most popular large-lake sport fishery in Skeena Region. Much of the recreational catch of the species is taken by trolling in the Main and Morrison arms, but ice fishing also occurs though the extent of the winter fishery is poorly documented. In a regional context, Babine Lake is not known to produce very large lake char; 9 kg is probably the approximate upper limit of weight for the species in this lake. Bustard (1987) estimated that lake char comprised 15 to 20% (by number) of the recreational open-water catch between May and September in 1985 and 1986, with 95% of the lake char retained by anglers. Directed First Nations net fisheries on the lake also capture this species, particularly during spawning aggregations in autumn (Toth 2007).

No directed research has been conducted on the lake char population of Babine Lake. A minimal amount of data were collected in the course of sockeye predator investigations in the 1940s, and incidentally during sockeye fry studies in the 1960s. The resulting information included relative abundance and length at age although scales were used for age estimation and this method is now known to display severe downward bias for older lake char. Angling use studies on the lake in 1985 and 1986 collected catch rate, and length-at-age data using otoliths for a sample of the harvested catch.

6.1. Lake Char Ecology and Life History

6.1.1. Spawning Geography, Timing, and Habitat

Divers assessing lakeshore spawning by sockeye in 1962 observed that lake char were abundant at Red Bluff Point, though no spawning activity was seen (Emmett and Convey 1992, citing journals of W.E. Smith). During 1991, lake char eggs were observed by divers investigating sockeye spawning, at the southerly-exposed point which forms the western margin of Wilkinson Bay on October 16 (Emmett and Convey 1992). Wilkinson Bay is located on the eastern shore of the Main Arm of Babine Lake, opposite the mouth of Fulton River. The substrate was described as multilayered cobble, at depths of 2 m to 4 m (Figure 8 of Emmett and Convey 1992). Ripe and spawned-out lake char were captured in gillnets at the same location on this date (Emmett and Convey 1992). Redds present in the area were hypothesized to have been made by lake trout, but this was unverified by direct observation; lake trout are known to engage in substrate cleaning behaviours but generally do not construct redds (McPhail and Lindsey 1970). In 1992, lake char eggs were again observed at this site adjacent to Wilkinson Bay, although the date of the observation was not reported. No other reports of lake trout spawning locations were recorded in the available literature, although the naming of “Char Point” which forms the south-eastern margin of Wilkinson Bay suggests another possible site. The aforementioned locations were investigated due to their proximity to Fulton River, with the assumption that surplus sockeye returning to that stream were most likely to engage in lakeshore spawning nearby. Other factors would presumably be more important in determining the sites used for spawning by lake char, and without a comprehensive survey of lake char spawning in Babine Lake there is no reason to conclude that many other locations in Babine Lake are not also used.

6.1.1. Age, Size, and Sexual Maturity

Only three length-at-age datasets for lake char from Babine Lake have been reported to date in the available literature. Figure 20 shows the mean lengths at age from these studies. Figure 21 displays VB growth curves fit to the three datasets and provides the parameters for each.

Griffiths (1968) reported mean back-calculated lengths at age from 28 lake char captured during sockeye fry purse seining in 1967 (Figure 20). Scales were used for aging; the range of estimated ages was 1 yr to 12 yr, and the range of mean back-calculated lengths was 60 mm at age 1 (n=1) to 601 mm at age 12 (n = 3) Unfortunately, he did not provide individual data, ranges or variances of lengths at age, or field lengths (not back-calculated) for the sample [28] so the maximum length cannot be determined. Because scale aging is known to severely underestimate the age of lake trout older than about 8 years, this dataset is of limited utility.

Mean lengths at age for a sample of 20 lake char captured during the purse seining program of 1968 were reported by Beacham and McDonald (1982). Again, scales were used, with the range of estimated ages 4 yr to 13 yr, and the range of mean lengths 208 mm at age 4 (n=1) to 614 mm at age 11 (n = 1). Variances in length at age were provided, but not individual data or ranges; the single lake char aged as 11 yr and length 614 mm was apparently the largest fish in the sample. As with Griffiths' (1968) data, the use of scales for ageing is a major shortcoming of this study, as is the small sample size. VB growth curves fit to the 1967 and 1968 datasets show that up to about age 10, Beacham and McDonald's (1982) lengths at age were significantly greater than those of Griffiths (1968); this parallels the two studies' results for rainbow trout and suggests that differences in scale interpretation may be a factor.

Bustard (1987) obtained fork lengths and collected otoliths for ageing from 78 lake char harvested by recreational anglers, during the second year of an angling use study conducted on the lake in 1985 and 1986 (Figure 20 to Figure 22). The range of ages in his sample was 5 yr to 33 yr, and the range of fork lengths was 370 mm to 800 mm.

Although Withler (1948) did not report ages of lake char captured by gillnet during his study of the relative abundance of potential predators on juvenile sockeye in Skeena nursery lakes, he did provide length information which could be used to re-estimate the length frequency of his catch (Figure 23). The results of Bustard (1987) are also shown as a length-frequency plot in Figure 23 for comparison. The results of Griffiths (1968) and Beacham and McDonald (1982) cannot be represented accurately in this form because means and not individual data were presented. The capture methods differ in their size-specific selectivity, and the sample sizes and locations of capture effort are also dissimilar, so the length distributions are not directly comparable. However, with respect to the question of changes in the abundance of large lake char through time, it is clear that the longest lake char

[28] In addition, Griffiths plotted the lengths by calendar date of 33 underyearling (age 0+) lake char which were presumably also taken in the purse seine hauls.

reported to date from Babine Lake were collected from the recreational fishery in 1986. The minimal samples of lake char from the 1940s and 1960s did not contain individuals longer than 650 mm, whereas Bustard's (1987) sample included several lake char between 650 mm and 800 mm in length. Age interpretation has not yet been completed for a sample of 16 lake char gillnetted from Wright Bay of Babine Lake on October 16, 2006 for tissue metals analysis but individuals as long as 740 mm were captured (Ecometrix 2007).

Compilation of maximum recorded fork length for Skeena Region lake char waters was presented in De Gisi (2007). Of 66 lakes in Skeena Region for which any lake char length data were available, Babine was one of 26 lakes with maximum reported length greater than 750 mm.

An analysis of lake char growth in Skeena Region lake char waters was also presented by De Gisi (2007). For thirty lakes, lake char length/age data were considered minimally sufficient for estimation of VB growth parameters. Based on this analysis, lake char of Babine Lake were considered to display rapid growth to relatively large terminal size, in comparison with other lake char waters in the region.

No data relating sexual maturity to either age or size have been reported for lake char of Babine Lake. Fecundity estimates are also completely lacking.

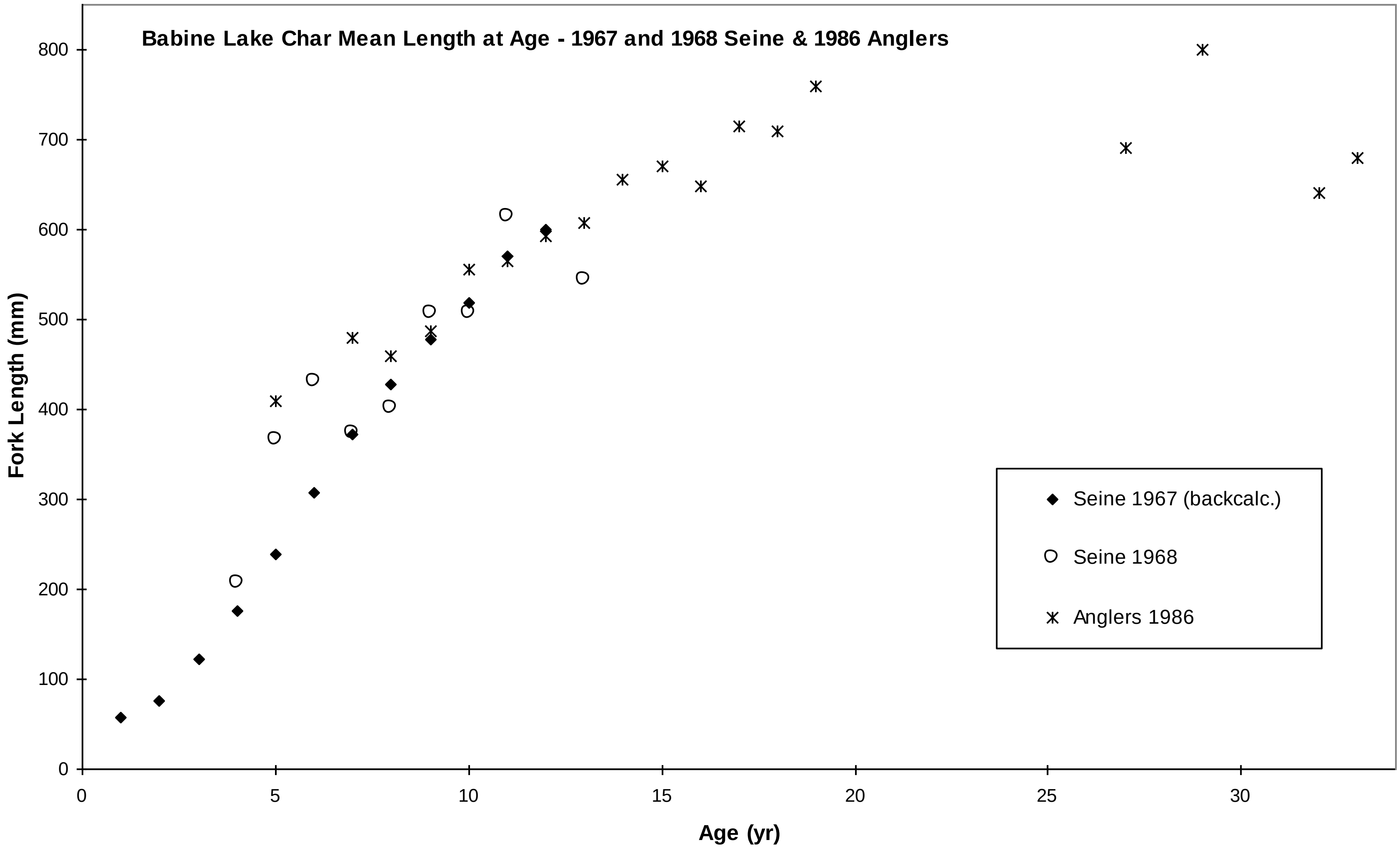


Figure 20. Comparison of mean length at age for lake char samples obtained from Babine Lake in the summer of 1967 and 1968 by pelagic purse seine (Griffiths 1968; Beacham and McDonald 1982), and the summer of 1986 by angling (Bustard 1986). The results for 1967 are lengths back calculated to the annuli; the 1967 and 1968 data utilized scales for age determination while the 1986 samples were aged by otolith; see report text for additional discussion.

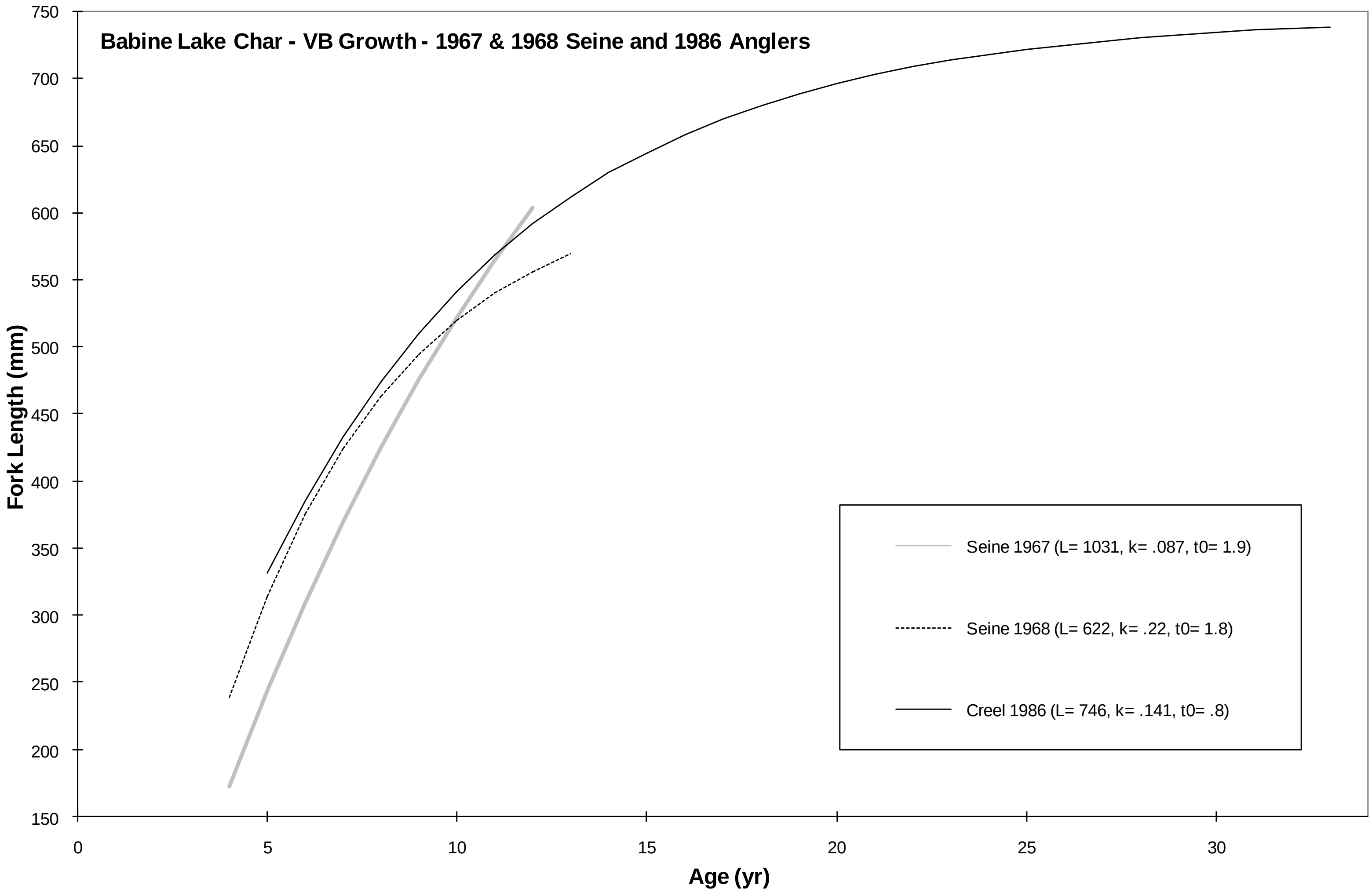


Figure 21. Comparison of Von Bertelanffy (VB) growth relationships fitted to lake char length at age samples obtained from Babine Lake in the summer of 1967 and 1968 by pelagic purse seine (Griffiths 1968; Beacham and McDonald 1982), and the summer of 1986 by angling (Bustard 1986). The results for 1967 are lengths back calculated to the annuli; the 1967 and 1968 data utilized scales for age determination while the 1986 samples were aged by otolith; see report text for additional discussion.

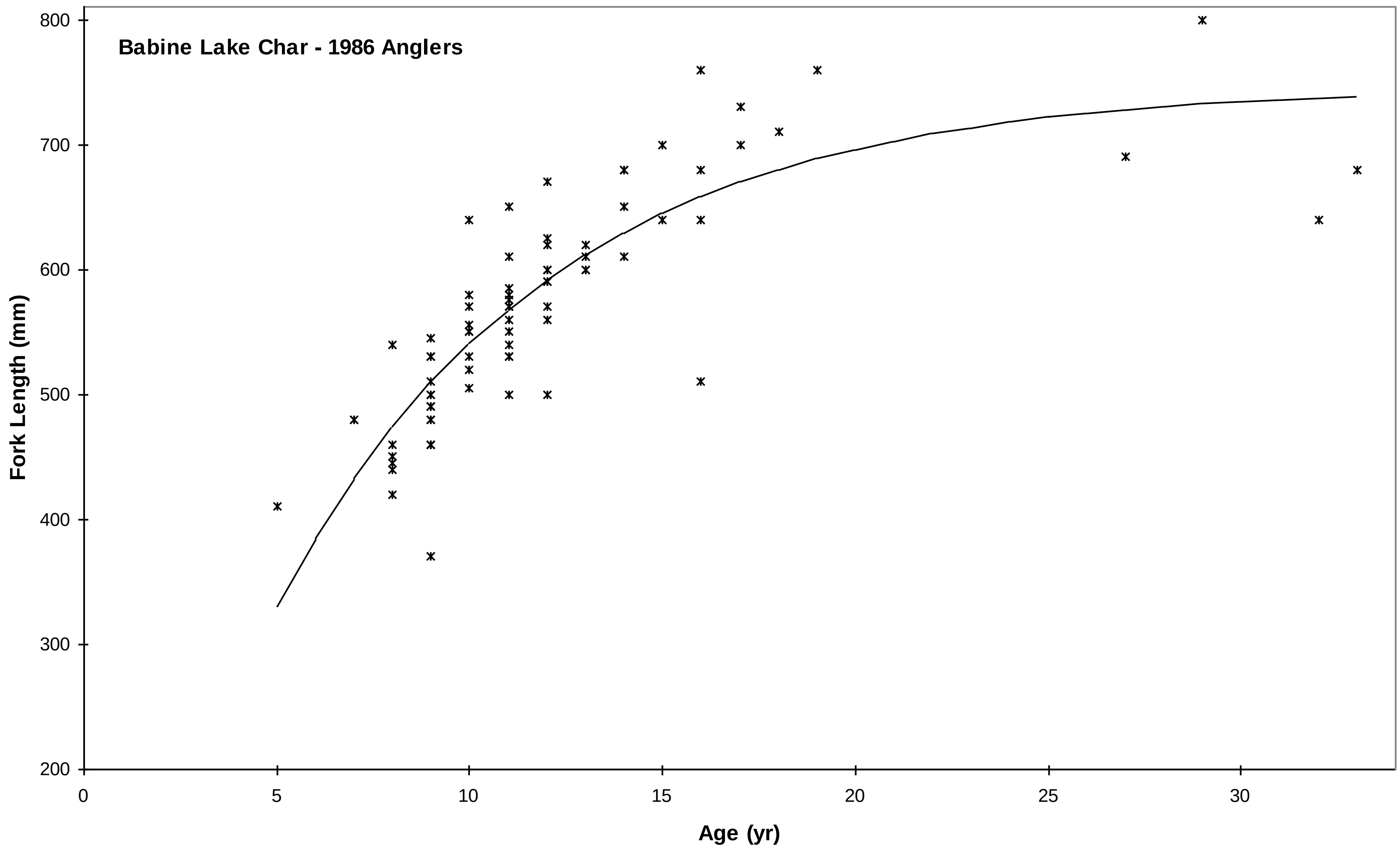


Figure 22. Length at age for 78 lake char harvested by anglers from Babine Lake in 1986, with the fitted VB relationship as parameterized in Figure 21. Samples were aged by otolith.

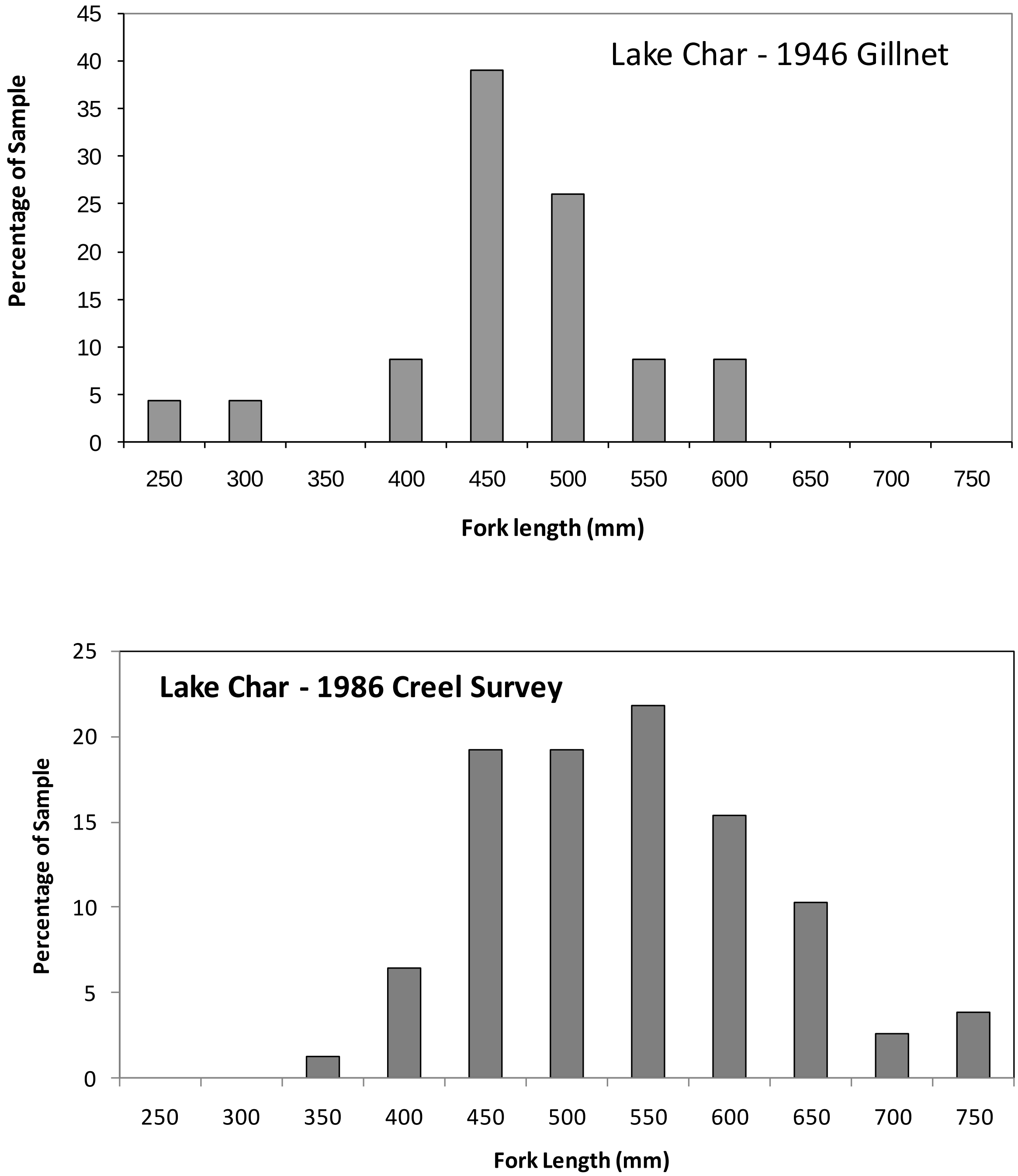


Figure 23. Upper panel: length distribution of 23 lake char captured by gillnet in Division I of Babine Lake in 1946; the data were re-plotted from Figure 9 of Withler (1948), who did not provide a geographical description of Division I. **Lower panel:** length distribution of 78 lake char sampled from the recreational angling catch on Babine Lake in 1986, reported by Bustard (1987). Bin widths are 50 mm; labels are the lower bounds of the bins.

6.2. Lake Char Relative Abundance

6.2.1. Angling

The effort and catch of participants in an angling derby on Babine Lake in late June 1975 were documented by Whately (1975), though the methodology of the survey was not reported. An estimated 280 angler days yielded a catch of 39 lake char[29], implying an overall catch rate of 0.14 lake char per angler day. The catch rate for rainbow trout was about 50% higher, at 0.21 per angler day. It is unclear whether the results include only retained catch, although it is likely that few if any lake char would have been released in that year.

Bustard (1987) estimated total catch of lake char on Babine Lake from mid-May through September as 3 415 in 1985 and 3 211 in 1986. Effort estimates for the same two years were 20 906 angler days and 14 680 angler days; excluding the Rainbow Alley portion of the survey where lake trout are not typically captured gives an adjusted total effort of 19 166 and 13 416 angler days respectively. The resulting overall mean catch rates excluding Rainbow Alley were 0.18 and 0.24 lake char per angler day respectively. Roughly 95% of the angled lake char were reported retained.

A creel survey conducted at Fulton River and Pinkut Creek mouths at Babine Lake in May - June 1990 resulted in an estimated catch (killed plus released) rate of 0.02 lake char per hour adjacent to Pinkut Creek and no lake char captured at the mouth of Fulton River (De Leeuw 1991). The average angling day length was 2.73 hr at Pinkut Creek, so the mean catch rate was approximately 0.05 lake char per day at that location and roughly 0.03 lake char per day for the two stream mouths combined.

During 513 angler days estimated to have occurred on 19 dates within the period 10 August to 7 September 2006, recreational anglers caught an estimated 27 lake char in the fishery which targets sockeye salmon in the vicinity of the mouth of the Fulton River (Macintyre 2007). The average estimated catch rate for lake char was thus 0.05 fish per angler day, though none of the parties surveyed were targeting lake char (Macintyre 2007).

During 2 927 guided angler days recorded for Babine Lake in the 12 licence years of 1990/91 to 2001/02 inclusive, angling guides reported client catch of 976 lake char for an overall mean catch per effort of 0.3 lake char per angler day. Angling guide reports do not indicate the target species. However, lake char catch was reported by parties with activity totaling 798 angler days (27%), resulting in an average catch rate of 1.2 lake char per angler day (Table 24) for anglers in parties recording catch of the species. Although the reliability of the data is uncertain, no clear trend in relative abundance of lake char in Babine Lake is displayed during the period of record (Table 24).

[29] 35 of the 39 lake char were greater than 60 cm in length, with the largest recorded as 70.5 cm

Table 24. Guided angling effort and lake char catch for Babine Lake, for licence years 1990/91 through 2001/02 as recorded in the Skeena Region AGMS database. **All AD** gives the total number of guided angler days reported for the water; **AD with LT** is the number of angler days with reported lake char catch; **Catch** gives the number of lake char reported to have been angled (harvested or released) by guided anglers; **CPE** is the **c**atch **p**er **e**ffort of lake char by guided anglers in parties who caught lake char, in units of fish per angler day.

Year	All AD	AD with LT	Catch	CPE
1990/91	44	10	5	0.5
1991/92	99	44	93	2.1
1992/93	61	29	15	0.5
1993/94	98	41	35	0.9
1994/95	817	171	199	1.2
1995/96	718	24	33	1.4
1996/97	128	105	157	1.4
1997/98	92	70	136	1.9
1998/99	551	93	123	1.3
1999/00	102	75	80	1.1
2000/01	117	94	36	0.4
2001/02	100	42	64	1.5
Total	**2,927**	**798**	**976**	**1.2**

6.2.2. Gillnet

In 1946 and 1947, Withler (1948) conducted a program of standardized gillnetting to assess fish predator species population density in Skeena sockeye lakes; these are the earliest estimates of lake char relative abundance for Babine Lake in the available literature. Table 25 shows a summary of his results including three reference lakes (Morice, Nilkitkwa and Morrison). Data from Babine Lake were separated into three geographic divisions which were undefined in the report. Aggregate catch per effort (CPE) of 0.051 lake char per 100m of net per night for Babine Lake was much lower than for Morice and Morrison lakes, but much higher than for Nilkitkwa Lake which may not support a self-sustaining population of this species. Lake char CPE for Morrison and Morice lakes was approximately four and six times that of Babine Lake respectively. As emphasized for rainbow trout, a variety of factors other than fish abundance can influence gillnet CPE in addition to inherently high variance associated with gillnetting as a sampling method. Accordingly, it is not clear that the CPE values accurately reflect differences between these waters in population density of lake char. For instance, Babine Lake received much greater netting effort than all other lakes, which might reflect netting during time periods and at locations (depths) of lesser effectiveness and could cause CPE to be biased downward relative to other waters; rainbow trout CPE at Babine Lake was also much lower than for Morrison and Morice lakes (Section 5.2.2).

A much less extensive gillnetting study on Babine Lake in 1958 was mentioned by McCart (1970). Relative abundance of lake char captured during this assessment program was not located in the available literature.

Table 26 summarizes effort and catch of gillnetting conducted by Westwater Research Centre during 1983 to 1985, in log-impacted and unimpacted sites in the littoral area of Morrison Arm and the Main Arm. CPE of lake char was roughly 0.2 individuals per 100 m length of gillnet per night, and this value was similar at impacted sites and unimpacted reference sites.

Results reported by Withler (1948) predate most of the industrial and human population development in the Babine Lake watershed as well as sockeye enhancement. The Westwater study probably occurred sufficiently later than these developments to adequately reflect their effects on sportfish abundance. However, the differences in net construction, net deployment locations, and netting methods between the studies prevent any meaningful comparison of lake char relative abundance across time, as was emphasized in the discussion concerning kokanee and rainbow trout.

Table 25. Gillnet **Effort**, **Catch** of lake char, and **Catch Per Effort** of lake char on Babine Lake and comparison waters during 1945 to 1947, as reported in Withler (1948) which provides no explanation for the geographic divisions of Babine Lake. The final rows of the table in bold font are grand totals for all years of sampling in the named waters. **Effort** unit is 100 m length of gillnet set overnight. Gillnet characteristics and details of the netting protocol are given in Section 2.3.2.1.

Water	Year	Net Nights	Effort	Catch	Catch Per Net Night	Catch Per Effort
Babine Lake Division I	1946	185	423	23	0.12	0.054
	1947	100	229	11	0.11	0.048
Babine Lake Division II	1946	180	411	22	0.12	0.053
	1947	215	491	27	0.13	0.055
Babine Lake Division III	1946	155	354	14	0.09	0.040
Morrison Lake	1946	45	103	20	0.44	0.195
	1947	65	149	29	0.45	0.195
Nilkitkwa Lake	1946	20	46	0	0.00	0.000
	1947	40	91	2	0.05	0.022
Morice Lake	**1945**	**50**	**114**	**36**	**0.72**	**0.315**
Babine Lake (all Divisions)	**1946-47**	**835**	**1908**	**97**	**0.12**	**0.051**
Morrison Lake	**1946-47**	**110**	**251**	**49**	**0.45**	**0.195**
Nilkitkwa Lake	**1946-47**	**60**	**137**	**2**	**0.03**	**0.015**

Table 26. Gillnet **Effort**, **Catch** of lake char, and **C**atch **P**er **E**ffort (**CPE**) of lake char during sampling conducted on Babine Lake by Westwater Research Centre, as a component of the log transportation impacts study of 1983 to 1985. **Impacted** sites were located in areas where logs were stockpiled or dewatered, while **Reference** sites were located nearby in unimpacted locations. **Effort** unit is 100 m length of gillnet set overnight. All other sampling details are provided in the report text.

Year	Impacted			Reference			All		
	Effort	Catch	CPE	Effort	Catch	CPE	Effort	Catch	CPE
1983 - HFP sites	46.9	12	0.26	46.9	4	0.09	93.74	16	0.17
1984 - all sites	78.7	18	0.23	80.4	21	0.26	159.03	39	0.25
1984 - HFP sites	26.8	2	0.07	26.8	5	0.19	53.6	7	0.13
1985 - HFP sites	46.9	2	0.04	46.9	8	0.17	93.74	10	0.11
All years - HFP sites	**120.5**	**16**	**0.13**	**120.5**	**17**	**0.14**	**241.1**	**33**	**0.14**
All years - all data	**172.4**	**32**	**0.19**	**174.1**	**33**	**0.19**	**346.5**	**65**	**0.19**

6.2.3. Purse Seining 1966-1977

The 1966 to 1977 nerkid fry purse seining program was unbalanced from year to year with respect to the diel pattern of sampling effort, the calendar months, and the fishing areas within the lake (Figure 1). Thus it was necessary to examine the potential effect of these factors on the catch of lake char per haul before considering whether relative abundance of the species appeared to vary spatially or between years of the study.

Day and nighttime catches of lake char per haul, in defined fishing areas, are shown by Figure 24. Unlike kokanee and rainbow trout, there appears to be no consistent difference between diurnal and nocturnal CPE for this species. In four of the eight fishing areas daytime catch rates were higher, while in the other four areas nighttime catch rates were higher (Figure 24). Mature lake char aggregate in shallower water to spawn during late September and October, which could reduce their vulnerability to purse seining conducted in the limnetic zone. Figure 26 displays the mean CPE of lake char for the Main Arm (areas 1 to 5) including all hours of the day, separated annually into the non-spawning period of May to August and the spawning period of September to October. In four of the seven years, lake char CPE was higher during the non-spawning period, while in two years it was higher during the spawning period and in one year the rates were essentially the same. Given the high variances associated with the estimates, any seasonal difference in vulnerability to seining is not consistently distinguishable.

Figure 25 compares the lake char mean catch rates by fishing area, with no distinction between time of day or calendar month. Again, the variances preclude any meaningful distinction, but the Main Arm areas appear lower than Hagan and North arms, with Morrison Arm higher than all others. Catch rates may vary between areas of the lake due to population density, but vulnerability to the sampling gear might also be an important factor. The data do not allow discrimination of the contributions of abundance and catchability.

Non-spawning and spawning period catch rates for the Main Arm through the 12-year duration of the data are displayed in Figure 26. Again, unbalanced sampling required the elimination of other fishing areas from this summary. Lake char CPE was highest in 1968, and was also high in that year in the other arms of the lake but more generally the Main Arm catch rates show no clear trend through time. The sampling variability associated with the estimates, as depicted by the confidence intervals in Figure 26, precludes any meaningful conclusion about how lake char abundance might have changed during this period.

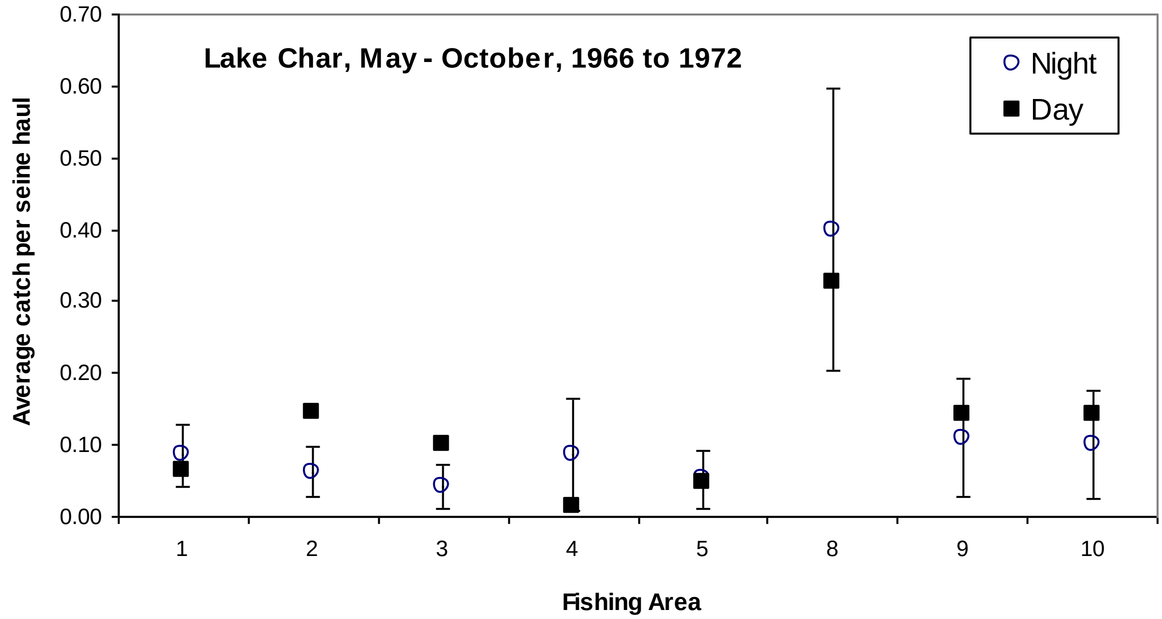


Figure 24. Mean daytime and nighttime catch of lake char per purse seine set, in defined fishing areas (Figure 1) of Babine Lake during May to October, for seven calendar years between 1966 and 1977 inclusive. The 95% confidence intervals for mean nighttime catch rates only are shown; these were estimated by non-parametric bootstrap.

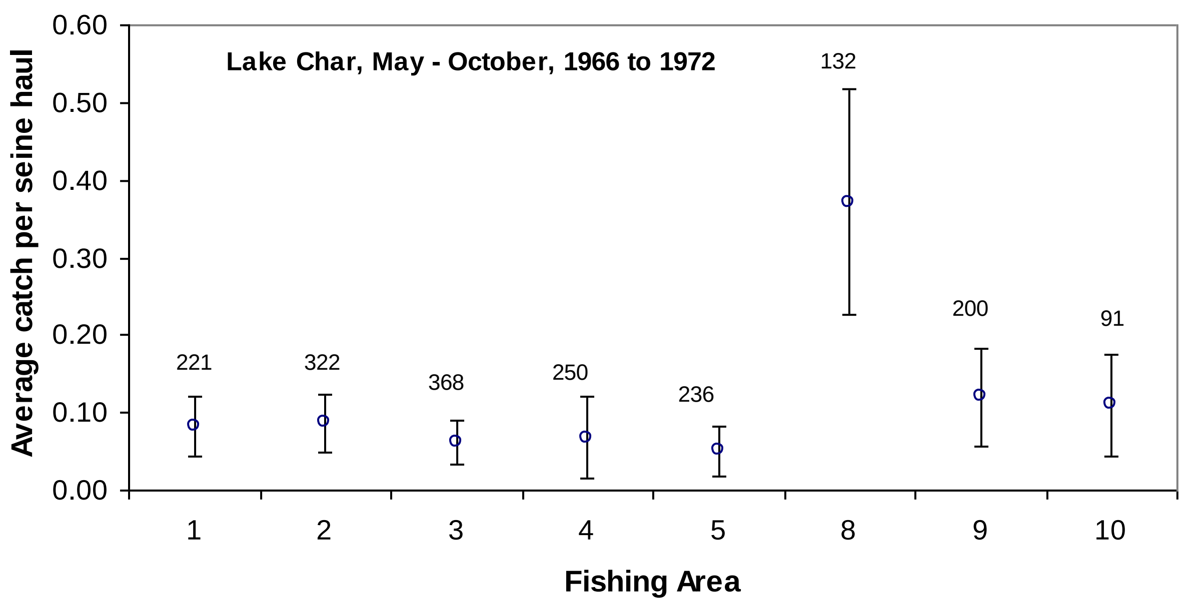


Figure 25. Mean catch of lake char per purse seine set, in defined fishing areas (Figure 1) of Babine Lake during May to October, for seven calendar years between 1966 and 1977 inclusive. The 95% confidence intervals shown were estimated by non-parametric bootstrap resampling. The number of sets in each area is also shown next to the plot symbols.

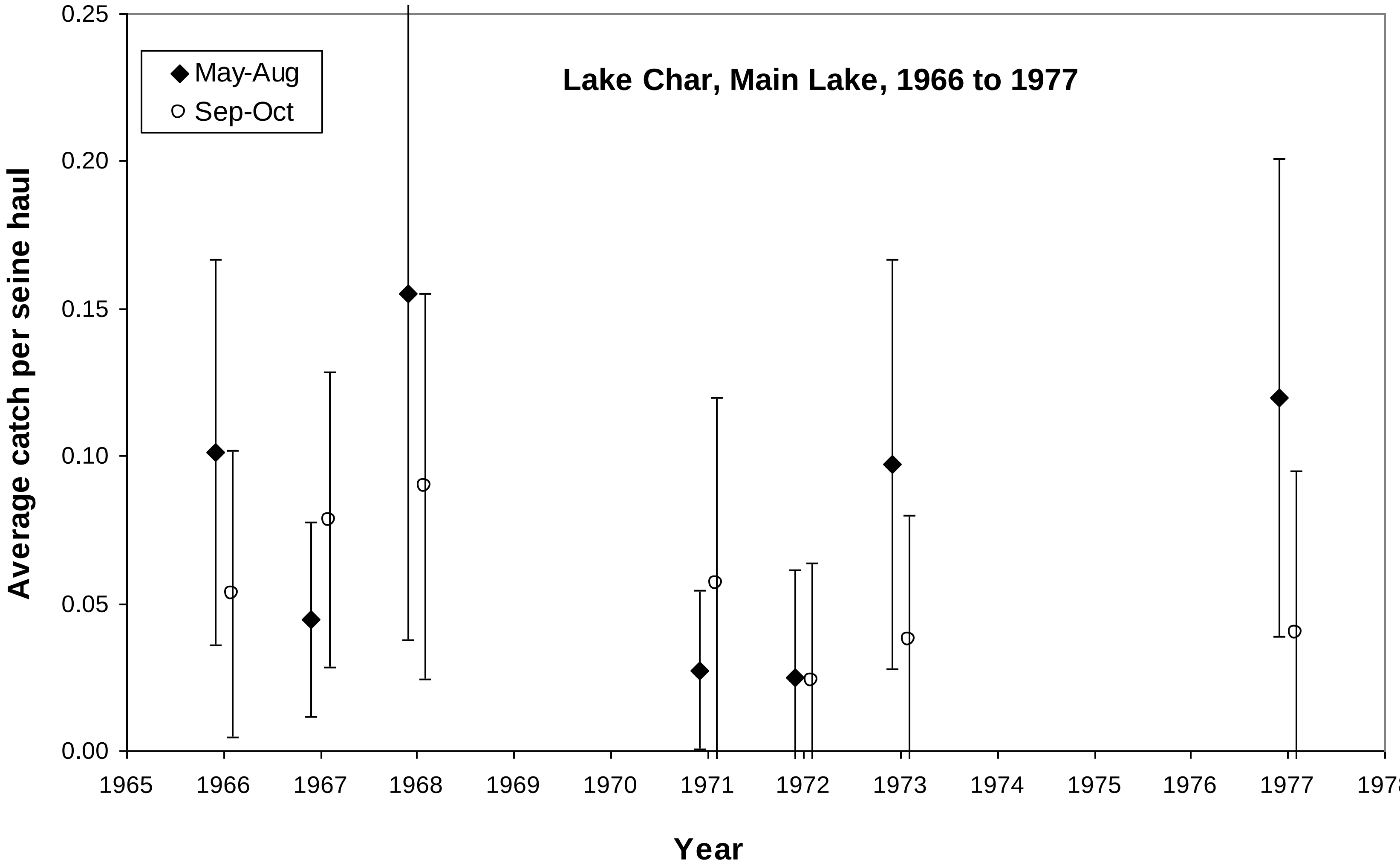


Figure 26. Mean catch of lake char per purse seine set during two calendar periods in the main basin (areas 1 to 5 in Figure 1) of Babine Lake, for seven calendar years between 1966 and 1977 inclusive. The 95% confidence intervals shown were estimated by non-parametric bootstrap.

6.3. Lake Char Synthesis

The biological characteristics of lake char of Babine Lake are very poorly documented considering the importance of the fishery on the lake. Stock structure, if any, is entirely unknown. A single length-at-age sample from the recreational fishery of 1986 comprises the only life history data compiled with presently accepted methods. Size or age at maturity are entirely undocumented. Abundance and mortality rates are also unknown.

Acquisition of additional life history data should be considered the action of highest priority for lake char of Babine Lake. New province-wide recreational angling regulations for lake char were being developed during 2007, and were expected to attempt to protect lake char populations from recruitment overfishing by limiting the harvest of fish smaller than the typical size at maturity (Giroux 2007). Without the relevant maturity schedule for Babine lake char, it would be impossible to assess whether the new regulations would achieve their intended effect on the recreational fishery. One potential source of additional life history data might be the First Nations net fisheries on the lake which could, at minimum, provide additional age composition and length-at-age data. However, if these fisheries target spawning aggregations, the catch may not be a representative sample for age-specific maturity so caution would be required in interpretation of the data. The recreational fishery is another potential source of life history data. A creel survey of scope equivalent to that reported by Bustard (1987) would be prohibitively expensive, but data could be collected less expensively at the most popular access point(s) on high-use weekends such as during the Fathers Day angling derby at Granisle.

Ideally, comprehensive stock assessment for Babine Lake char would also utilize information about age-specific absolute abundance, natural mortality, and exploitation rates in the recreational and net fisheries. Methods for estimating absolute abundance are likely to remain unaffordable for the foreseeable future. Total mortality could be estimated by the catch curve method using the data from the recreational fishery of 1986, or similar datasets from collections of the type discussed above. However, sample sizes are likely to be relatively small given the longevity of the species, and the unknown size- or age-selectivity of the collection method would inflate the uncertainty of the estimate. In the absence of reliable estimates of abundance, mortality and exploitation rates, indicators of population status may be used. These may include indices of relative abundance such as age- and size-specific catch rates in the recreational fisheries, and life history characteristics including size at age. Effective management of angling exploitation requires information about size-specific catch and harvest rates which can only be gauged accurately by a formal angling use study. As mentioned in the rainbow trout synthesis, an angling use study of the type conducted by Bustard (1987) would be prohibitively expensive, but the data from that study could be used to model and estimate the potential accuracy of a redesigned (scaled-down) survey.

Finally, the possibility of a cooperative effort toward formal documentation of First Nations traditional knowledge about Babine Lake fisheries and fish populations should be pursued. If undertaken, this should be managed by an individual or group with prior experience of similar initiatives. Such a project could provide a better historical perspective and context for the current condition of the lake’s game fish populations, as well as helping to build professional and interagency relationships which would be useful in future field-based projects and management efforts.

7. Recommendations

General

1. A cooperative effort toward formal documentation of First Nations traditional knowledge about Babine Lake fisheries and fish populations should be pursued.
2. Means of quantifying or indexing (relative to the 1985/86 study) the present effort, and catch and harvest by fish species in the Babine Lake recreational fishery should be sought.

Kokanee

3. An agreement should be pursued with the Fisheries Program of the Lake Babine First Nation, which currently conducts sockeye escapement estimates in the early streams tributary to Babine Lake, to extend their escapement estimation protocol to include kokanee with results to be shared with the Department of Fisheries and Oceans and the British Columbia Ministry of Environment.
4. Hydroacoustic estimation of post-fry kokanee abundance at Babine Lake should be sought, potentially by the Fisheries Science Section (Province of BC) or during sockeye fry assessments which are occasionally conducted by the Department of Fisheries and Oceans.
5. The possibility of reprocessing of the results from the hydroacoustic surveys of sockeye fry abundance at Babine Lake in the 1990s, in order to estimate the abundance of post-fry kokanee, should be investigated.
6. Additional life history data, age samples, and abundance estimates for Babine Lake kokanee present in DFO technical publications or in unpublished DFO files at the Pacific Biological Station, should be opportunistically pursued.

Rainbow Trout

7. The use of molecular markers to determine the stock structure of Babine Lake rainbow trout, including Rainbow Alley and Nilkitkwa Lake, should be pursued by sampling of the recreational fishery and juvenile rainbow trout in tributaries.
8. The potential for use of otolith microchemistry to validate molecular marker study results, and to gain additional information about the timing of rainbow trout life history events, should be investigated.
9. A means of monitoring the abundance of the key Sutherland River watershed rainbow trout population should be sought, and plans developed for long-term implementation at an appropriate frequency; possibilities which should be considered include spawner enumeration and juvenile surveys.
10. The status of rainbow trout age samples (or images) held at the Pacific Biological Station and by other Babine Lake researchers should be opportunistically determined, with samples obtained and archived if possible.

11. The development of a sustained and productive working relationship with Yekooche participants in the springtime fishery at the mouth of the Sutherland River should be pursued.

Lake Char

12. An agreement should be sought with the Fisheries Program of the Lake Babine First Nation for the episodic collection of life history data from lake char (and possibly other species) captured during food fisheries on the lake.
13. A means of assessing and monitoring the status of Babine Lake lake char, perhaps by an index netting program such as those currently in use in the Yukon Territory or the Province of Ontario, should be investigated, developed and applied at an appropriate frequency.

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Appendix I. Whitefish

I.1 *Whitefish Ecology and Life History*

The only Babine Lake whitefish life history data located during the present data compilation were a sample of 17 lake whitefish collected by gillnet on August 20-22, 2002 for tissue metals analysis, near the Granisle Mine site on the Main Arm (Morris 2002; Stantec 2002). Sexual maturity of the catch was not reported. Figure 27 displays the lengths at age from this sample, with reference values from other Skeena Region lake whitefish datasets.

Large numbers of whitefish[30] spawners have been observed at the salmon counting fence on Morrison Creek not far above its mouth (Bustard 2004, citing D. Lofthouse of Fisheries and Oceans Canada). The migration began in the second week of October, peaked in the third week of October and was complete by the second week of November, with "high hundreds per day" passing the fence at the peak (Bustard 2004).

I.2 *Whitefish Relative Abundance*

I.2.1 Angling

Lake whitefish are presently targeted in an ice fishery near Granisle (Harrison 2007). Effort and catch rates have not been recorded.

Incidental capture of lake and mountain whitefish also occurs during Babine Lake's open-water recreational fisheries for char, trout, and salmon. The effort and catch of participants in an angling derby on Babine Lake in late June 1975 were documented by Whately (1975). Although the methodology of the survey was not reported, no whitefish were recorded in the catch of 280 estimated angler days which included six other species of fish.

Bustard (1987) presented the results of surveys of the sport fishery on Babine Lake in 1985 and 1986. Of 266 fish creeled by checked anglers in 1985, 26 (9.4%) were whitefish (species unclassified). However, in 1985, only 5 of 505 fish (1%) caught by checked anglers were whitefish. He attributes the increased relative abundance of whitefish in 1985 to (at least partly) the higher proportion of interviews conducted at Rainbow Alley. Data presented in the report do not allow an accurate determination of the catch rate for whitefish, but the catch rate of all species combined was approximately 0.25 fish per rod hour in 1985 and 0.16 fish per rod hour in 1986. Applying the aforementioned percentages from the checked catch gives approximate catch rates of 0.024 and 0.0016 whitefish per rod day respectively. Using the mean length of angler days in the two years, 3.6 hr and 4.6 hr respectively, the implied grand mean catch rates would have been roughly 0.09 and 0.007 whitefish per angler day in 1985 and 1986.

[30] Presumed to be mountain whitefish, though this was not stated

During the period May 17 to 20, 1990, a creel survey recorded 59 boaters on Babine Lake in the Fulton River bay area between Topley Landing and Granisle, who conducted 55 rod days (78.7 rod-hours) of angling and captured 50 fish of all species (Beere 1990). The memorandum lists two separate tallies for mountain whitefish (4 mountain whitefish and 7 mountain whitefish, presumed a typographical error), but the attached datasheets appear to show 7 lake whitefish and 2 mountain whitefish. Nine whitefish captured in 55 rod days of effort represents a catch rate of 0.16 whitefish per rod day.

A more comprehensive creel survey conducted at Fulton River and Pinkut Creek mouths at Babine Lake in May - June 1990 estimated the catch (killed plus released) rate of whitefish as 0.11 per day adjacent to Pinkut Creek and 0.24 per day at the mouth of Fulton River (De Leeuw 1991). The combined average catch rate for the two locations weighted by angling effort was 0.15 whitefish per day. Not attempt was made to distinguish whitefish by species.

Angling guides reported client catch of only 3 whitefish (species unclassified) during a total of 2 927 guided angler days recorded for Babine Lake in the 12 licence years between 1990/91 and 2001/02 inclusive (AGMS 2002).

Purse Seining 1966-1977

Catch of whitefish, unclassified by species or age, during the 1966 to 1977 nerkid fry purse seining program are provided in Table 27. The mean catch per haul varied widely from year to year with no obvious time-linked pattern.

Table 27. Tallied **Catch** of whitefish (species unclassified), **Effort** (count of hauls) and **Catch Per Effort** of whitefish in purse seine sets made during sockeye fry assessment studies on Babine Lake from 1966 to 1977.

Year	Catch	Effort (Hauls)	Catch Per Effort
1966	23	261	0.09
1967	126	316	0.40
1968	164	264	0.62
1971	42	246	0.17
1972	121	249	0.49
1973	160	230	0.70
1977	86	210	0.41

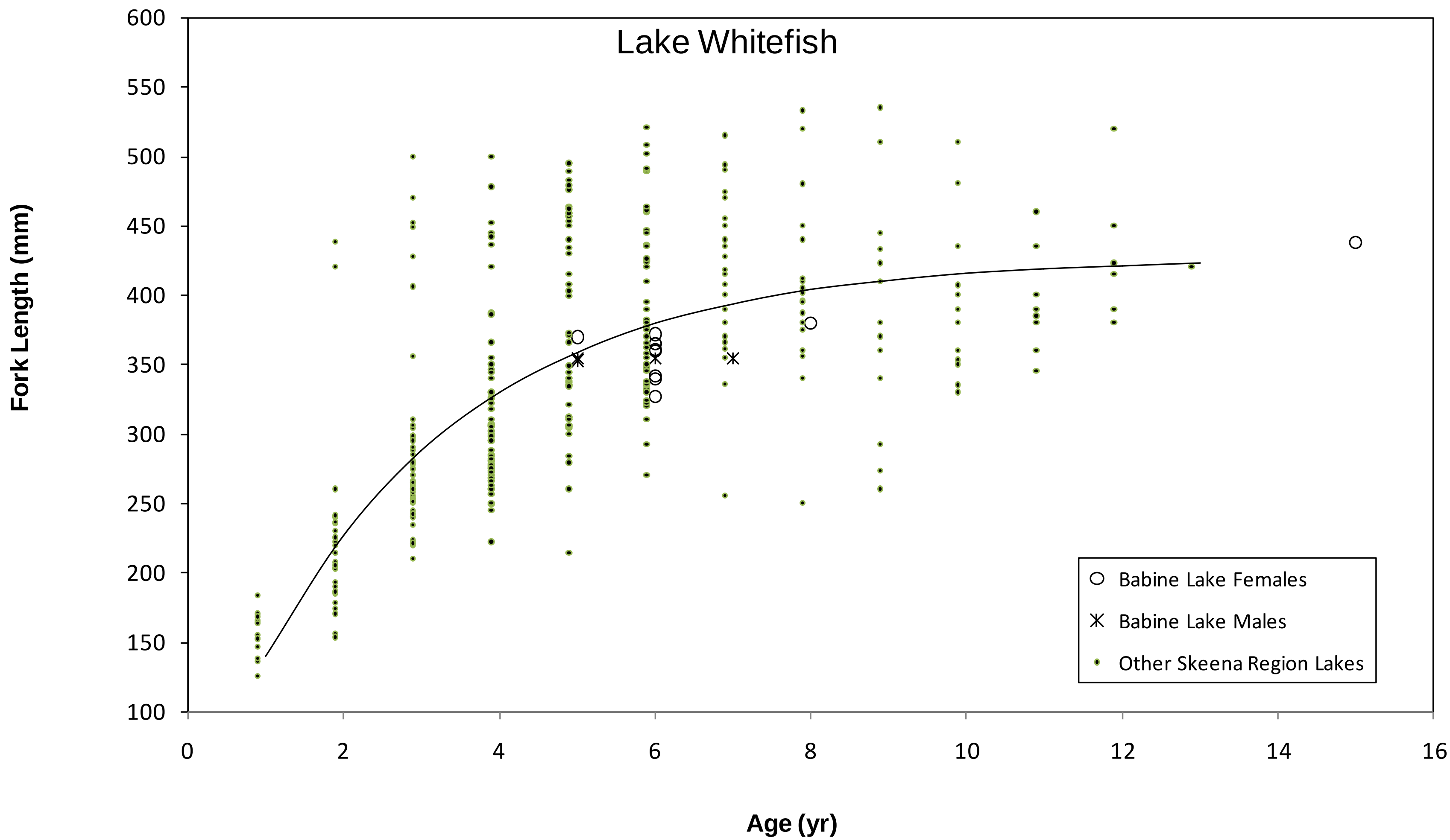

Figure 27. Length at age for a sample of 17 lake whitefish collected by gillnet on August 20 and 22, 2002, near the Granisle Mine site on the Main Arm of Babine Lake. Sexual maturity of the catch was not reported. For comparison, length at age and a fitted VB growth curve are shown for other Skeena Region lake whitefish data (n = 365). Plotting of the latter dataset is shifted slightly to the left so that the Babine Lake data points are unobscured.

Appendix II. Burbot

II.1 *Burbot Life History*

Bustard (1987) reported length at age for four burbot sampled from the recreational catch on Babine Lake in the summer of 1986, but no other life history data for Babine Lake burbot were located during this data compilation. However, length at age for 73 otolith-aged burbot collected during 1977 and 1978 mainly by setline near the outlet of Nilkitkwa Lake were included by Bustard (1987)[31]. Figure 28 displays length at age for the burbot from 1977/78 and 1986, plotted with a reference dataset[32] comprising 84 burbot from other lakes in the province. The Babine Lake sample of four individuals displays length at age similar to burbot sampled elsewhere in BC. However, the Nilkitkwa Lake growth curve appears implausible, with ageing error the most probable culprit. Nilkitkwa Lake burbot likely grow faster than typical for burbot populations in the province due to the seasonal abundance of sockeye smolt prey, but this seems unlikely to result in a growth anomaly of the magnitude displayed in Figure 28.

II.2 *Burbot Relative Abundance*

II.2.1 Angling and Setline

Table 28 provides information about reported setline[33] catches of burbot from Babine Lake in the period 1977/78 to 1984/85. The data appear to show a substantial increase in setline effort and harvest of burbot in the decade represented. However, the data are undocumented and their completeness is unknown, so it remains possible that the apparent pattern is an artifact of the data collection process.

[31] These data no longer appear to be present in the Babine Lake file at offices of Ministry of Environment, Skeena Region
[32] from the Fisheries Data Warehouse
[33] These data (printout in the files of David Bustard, 2007) are no longer present in the Babine Lake file at offices of Ministry of Environment, Skeena Region

Table 28. Setline data for Babine Lake, 1975/76 through 1984/85. **Permits** gives the number of permits issued; **Returns** is the number of catch reports returned, **Catch** provides the total number of burbot reported caught in the returns.

Year	Permits	Returns	Catch	Mean Weight	Total Weight
1975/76	NR	24	108	4.4	479
1976/77	NR	34	76	3.6	277
1977/78	NR	50	241	2.8	666
1978/79	NR	59	253	3.6	903
1979/80	NR	64	305	3.7	1 122
1980/81	137	73	414	3.8	1 573
1981/82	124	103	662	3.2	2 113
1982/83	196	125	521	3.5	1804
1983/84	181	115	306	NR	NR
1984/85	209	118	290	NR	NR

II.2.2 Gillnet

Table 29 gives the catch of burbot during the program of standardized gillnetting to assess fish predator species population density in Skeena sockeye lakes reported by Withler (1948). Aggregate catch per effort (CPE) of 0.014 burbot per 100m of net per night for Babine Lake was less than half of the comparable values for Nilkitkwa and Morrison lakes, though this difference may reflect variation between waters in abundance, vulnerability to the gear, or both.

Effort and catch of burbot during gillnetting conducted by Westwater Research Centre during 1983 to 1985, in log-impacted and unimpacted sites in the littoral area of Morrison Arm and the Main Arm, are given in Table 30. CPE of burbot was roughly 0.25 individuals per 100 m length of gillnet per night, and this value was similar at impacted sites and unimpacted reference sites. Unfortunately, the results of Withler (1948) are not comparable to those from the Westwater study, due to differences in the gear and methods.

Table 29. Gillnet **Effort**, **Catch** of burbot, and **Catch Per Effort** of burbot on Babine Lake and comparison waters during 1945 to 1947, as reported in Withler (1948) which provides no explanation for the geographic divisions of Babine Lake. The final rows of the table in bold font are grand totals for all years of sampling in named waters. **Effort** unit is 100 m length of gillnet set overnight. Gillnet characteristics and details of the netting protocol are given in Section 2.3.2.1.

Water	Year	Net Nights	Effort	Catch	Catch Per Net Night	Catch Per Effort
Babine Lake Division I	1946	185	423	2	0.01	0.005
	1947	100	229	2	0.02	0.009
Babine Lake Division II	1946	180	411	7	0.04	0.017
	1947	215	491	10	0.05	0.020
Babine Lake Division III	1946	155	354	5	0.03	0.014
Morrison Lake	1946	45	103	4	0.09	0.039
	1947	65	149	4	0.06	0.027
Nilkitkwa Lake	1946	20	46	4	0.20	0.088
	1947	40	91	0	0	0
Morice Lake	**1945**	**50**	**114**	**0**	**0**	**0**
Babine Lake	**1946-47**	**835**	**1908**	**26**	**0.03**	**0.014**
Morrison Lake	**1946-47**	**110**	**251**	**8**	**0.07**	**0.032**
Nilkitkwa Lake	**1946-47**	**60**	**137**	**4**	**0.07**	**0.029**

Table 30. Gillnet **Effort**, **Catch** of burbot, and **C**atch **P**er **E**ffort (**CPE**) of burbot during sampling conducted on Babine Lake by Westwater Research Centre, as a component of the log transportation impacts study of 1983 to 1985. **Log Impacted** sites were located in areas where logs were stockpiled or dewatered, while **Reference** sites were located nearby in unimpacted locations. Effort unit is 100 m length of gillnet set overnight.

Year - Sites	Log Impacted			Reference			All		
	Effort	Catch	CPE	Effort	Catch	CPE	Effort	Catch	CPE
1983 - HFP sites	46.9	8	0.17	46.9	13	0.28	93.74	21	0.22
1984 - all sites	78.7	32	0.41	80.4	27	0.34	159.03	59	0.37
1984 - HFP sites	26.8	7	0.26	26.8	19	0.71	53.6	26	0.49
1985 - HFP sites	46.9	3	0.06	46.9	8	0.17	93.74	11	0.12
All years - HFP sites	**120.5**	**18**	**0.15**	**120.5**	**40**	**0.33**	**241.1**	**58**	**0.24**
All years - all data	**172.4**	**43**	**0.25**	**174.1**	**48**	**0.28**	**346.5**	**91**	**0.26**

II.2.3 Purse Seining

Catch of burbot during the 1966 to 1977 nerkid fry purse seining program are provided in Table 31. The incidence of burbot in the catch was very low, presumably reflecting the demersal orientation of the species.

Table 31. Catch of burbot = count of individuals, **Effort** = count of sets, and **Catch Per Effort** of burbot in purse seine sets made during sockeye fry assessment studies on Babine Lake from 1966 to 1977.

Year	Catch	Effort	Catch Per Effort
1966	1	261	0.004
1967	4	316	0.013
1968	6	264	0.023
1971	2	246	0.008
1972	1	249	0.004
1973	2	230	0.009
1977	1	210	0.005

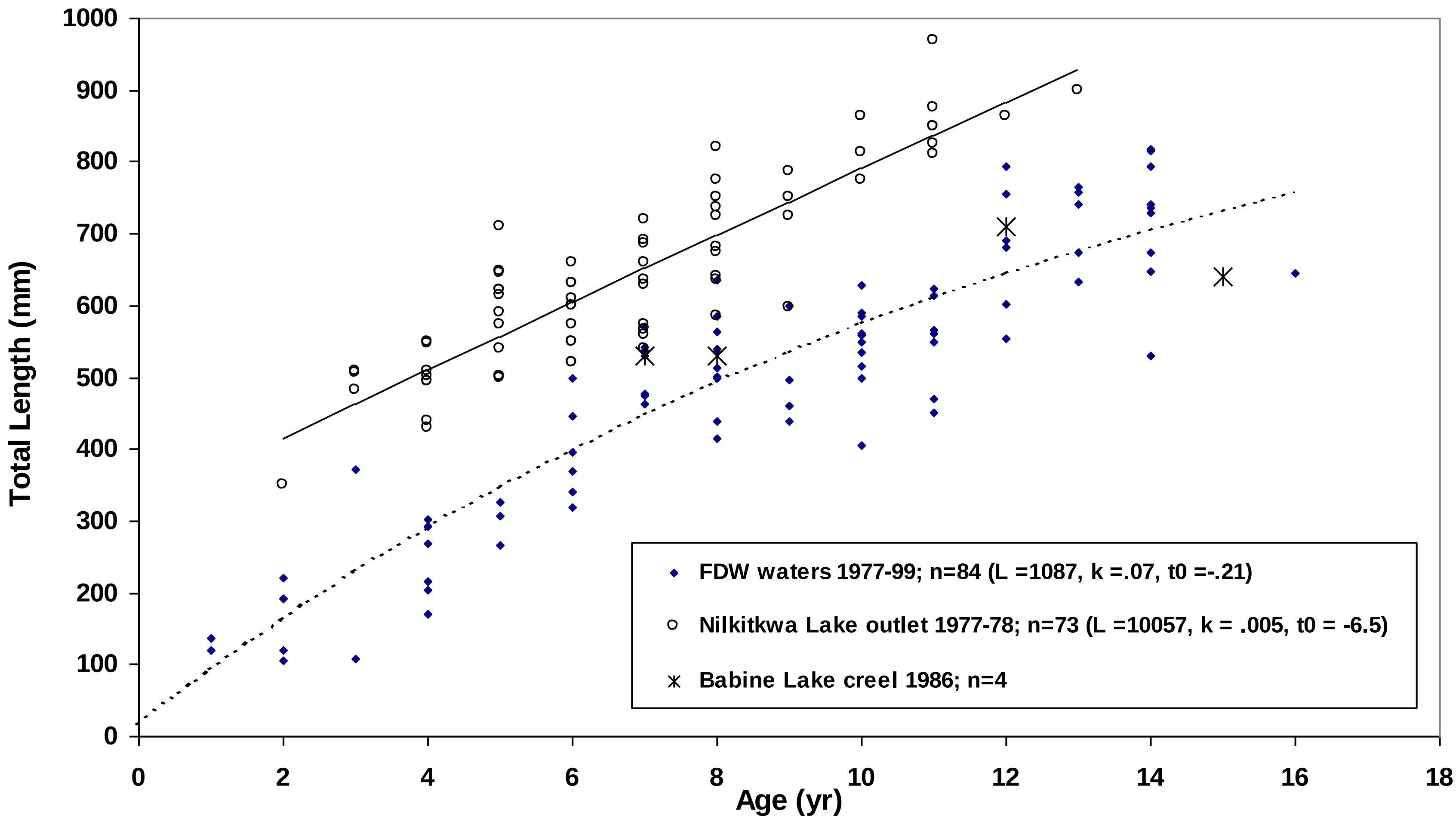

Figure 28. Length at age for burbot collected from Babine Lake anglers in 1986, by setline and other methods at the outlet of Nilkitkwa Lake in 1977 and 1978, and for a province-wide reference dataset drawn from the Fisheries Data Warehouse (FDW) in March 2007. The solid line shows the Von Bertelanffy (VB) growth relationship fit to the Nilkitkwa Lake outlet data, while the dashed line shows the VB growth relationship for the FDW dataset. Sample sizes (n) are given in the figure legend, along with parameters of the VB relationships; fitting methods are described in the report text. Samples were aged by otolith.

Appendix III. Fish Species Codes

Species Code	Species Common Name
BB	Burbot
BSU	Bridgelip sucker
BT	Bull trout
CAS	Prickly sculpin
CBA	Mottled sculpin
CC	Unidentified sculpin (family Cottidae)
CCG	Slimy sculpin
CCN	Shorthead sculpin
CH	Chinook salmon
CO	Coho salmon
CP	Carp
CRH	Torrent sculpin
CSU	Coarsescale sucker
CT	Cutthroat trout
DV	Dolly Varden char
EB	Eastern brook trout (brook char)
KO	Kokanee
LDC	Leopard dace
LKC	Lake chub
LMB	Largemouth bass
LNC	Longnose dace
LSU	Longnose sucker
LT	Lake trout (lake char)
LW	Lake whitefish
MW	Mountain whitefish
NSC	Northern pikeminnow (formerly northern squawfish)
PMB	Pumpkinseed sunfish
PMC	Peamouth chub
PW	Pygmy whitefish
RSC	Redside shiner
SK	Sockeye salmon
ST	Steelhead (rainbow trout)
SU	Unidentified sucker (family Catostomidae)
UDC	Umatilla dace
WP	Walleye
WSG	White sturgeon
WSU	White sucker
YP	Yellow perch

Appendix IV. Kokanee and Rainbow Trout Data

Table 32. Years for which BC-16 forms were available for review of kokanee data. Column headings are self-explanatory.

Stream	Other names	Watershed Code	Years of BC16	Number of Years	Pages
Bernann	Deep	480-880746	1994-2004	11	13
Big Loon	Wright	480-739100	1959-76; 1978-88; 1996-2000	34	39
Donalds	Donald Landing	480-881300	1953-77; 1979-2003	50	54
Five Mile		480-452300	1940; 1944-45; 1947-2004	61	74
Forks		480-579300	1959-63; 1965-80; 1994-2003	31	36
Four Mile		480-964000	1927-28; 1930-31; 1935; 1937-42; 1944-45; 1947-2004	71	95
Fulton		480-697200	1940; 1951-2004	55	89
Gullwing	Six Mile, Wiggins	480-953800	1925; 1930; 1935; 1937; 1939-42; 1944-45; 1947-2004	68	88
Hazelwood		480-599600	1980-2003	24	26
Kew	Driscoll	480-793000	1953-54; 1956-62; 1964-85; 1994; 1996-2003	40	42
Morrison	Hatchery	480-598800	1933; 1935-41; 1944-2004	69	94
Nine Mile		480-474600	1929-31; 1933-41; 1944-2004	73	93
Cross	Pendleton	480-863300	1938; 1940-41; 1944-45; 1947-2004	63	79
Pierre	Tilticha	480-802100	1925; 1928; 1930-31; 1933-41; 1943-2004	75	112
Pinkut	Anderson, Fifteen Mile	480-927700	1925; 1929-42; 1944-2004	76	114
Shass	Grizzly, Ogston	480-993600-18700	1925; 1929-31; 1933-47; 1949-2003	74	118
Sockeye		480-742900	1938; 1940-42; 1944; 1947-2004	63	81
Sutherland	Beaver	480-993600	1925; 1929-30; 1940-41; 1946-47; 1969-2003	52	59
Tachek		480-705800	1925; 1928; 1930-42; 1944-2004	76	120
Telzato	Monica	480-992900	1959-83; 1993-94; 1996-2003	35	39
Tsezakwa	Trail	480-422000	1929-31; 1934; 1949; 1944-52; 1959-2004	60	76
Twain	Twin	480-816400	1925; 1929-42; 1944-2004	76	108

Table 33. Locations and **Site Lengths** sampled during coho juvenile assessments conducted by Lake Babine Nation Fisheries Program in years from **2002** to **2005**. UTM coordinates (**Zone, Easting, Northing**) for each site are also given.

Stream	Site	Site Length				Zone	Easting	Northing	Location
		2005	2004	2003	2002				
Four Mile	1	47.3	30		32.4	10	349642	6037222	Approx 100m upstream from Babine Lake
	2	37.5	30						Approx 150m upstream from Babine Lake
Six Mile	1	45.9	32	31.5	31.5	10	346785	6040214	Approx 140m upstream from Babine Lake
	2		44	42		10	346781	6040143	Approx 100m upstream from site 1
Bernann	1	47	NA		36	10	346783	6040218	Located 100m upstream from Babine Lake
	2	42.5							Approx 200m upstream from the stream mouth
Cross	1	37.1	60	30	30	10	324878	6044098	Approx 10 meters downstream of site 2
	2	38.7	30	39	39.4	10	324881	6044086	Located directly behind abandoned homestead where stream crew normally initiates surveys
	3	35.5							20m upstream of Pendleton Bay Road (above culvert), approx. 200m above site 2
Sockeye	1	47.1	48		42	9	692196	6069429	Approx 200m upstream of Babine Lake
	2		50						300m upstream from stream mouth
Tachek	1	44.2	40	40	38	9	684644	6074954	Approx 100m downstream of road crossing
	2	40.2	50	40	51.5	9	684628	6074821	Approx 100m upstream of road crossing
	3			11.1		9	683142	6073652	Approx 4km upstream of road crossing, 400m downstream of falls
Big Loon	1	43.8							Approx 100m upstream from mouth
Wilkinson	1	39.7							Approx 100m upstream of mouth
	2	NA							Pond/entrapment slough at mouth
Nine Mile	1	42.5		45		9	653860	6120610	Approx 100-150m upstream from Babine Lake
	2	NA							Approx 250m upstream of stream mouth

Table 33 continued. **Location**s and **Site Length**s sampled during coho juvenile assessments.

Stream	**Site**	**Site Length**				**Zone**	**Easting**	**Northing**	**Location**
		2005	**2004**	**2003**	**2002**				
Five Mile	1	39.7		25	30	9	652622	6125761	Approx 60m upstream of stream mouth
	2	NA							Approx 250m upstream of stream mouth
Tsezakwa	1	35.6							Approx 100m upstream from confluence
Boucher	1	48.7	50	30		9	647480	6145222	Located under FSR bridge crossing
	2	48.9							2km upstream from confluence
Twain	1		57		30.5	10	318234	6054882	Approx 400m upstream from lake
	2		30		38	10	318193	6054827	Approx 40m upstream from site 1
Pierre	1								Located 100m upstream from lake; new site
	2					9	672893	6115294	Approx 600 meters upstream from Babine Lake; same location as 2002 site
Morrison	1			25		9	672889	6115284	Right and left stream margins immediately below road crossing
	2			25		9	672903	6115282	From bridge up at km39 of Hagan FSR
Sutherland	1				NA	10	359308	6039930	First 20m of sidechannel off right bank that serves as the junction of tributary stream
	2				NA	10	359516	6039765	Several hundred meters upstream of site 1 on left bank of Sutherland mainstem
	3				NA	10	378249	6026386	Accessed from Sutherland FSR extension beyond stream crossing for 9.0km and 500m walk to stream
	4				NA	10	380423	6022968	Approx 120m downstream from site 5
	5				NA	10	380652	6022901	Approx 80m downstream from Sutherland FSR crossing of stream
Duncan	1				NA	10	381608	6017146	Approx 20m downstream of Sutherland FSR crossing of the stream

Table 34. Sampling effort and catch of rainbow trout during coho juvenile assessments conducted by Lake Babine Nation Fisheries Program. For each **Stream** and **Site** in years from **2002** to **2005,** the column **Passes** gives the number of removal periods applied and the column **Count** gives the total catch of juvenile rainbow trout. Blank cells indicate no assessment occurred at the site in that year.

Stream	Site	2005		2004		2003		2002	
		Passes	Count	Passes	Count	Passes	Count	Passes	Count
Four Mile	1	3	19	1	0	1	0	2	1
	2	3	17	1	0				
Six Mile	1	3	2	3	5	3	1	4	12
	2			3	14	2	3		
Bernann	1	3	6	3	54			3	1
	2	3	3						
Cross	1	3	17	3	17	3	40	3	31
	2	3	54	3	25	3	39	3	23
	3	3	27			2	4		
Sockeye	1	3	1	3	2	1	3	3	1
	2			3	0				
Tachek	1	3	8	3	5	3	4	3	6
	2	3	14	3	4	3	2	3	5
	3					3	29		
Big Loon	1	3	4			1	1	1	0
Wilkinson	1	3	0						
	2	3	25						
Nine Mile	1	3	22			3	0	1	0
	2	3	25						
Five Mile	1	3	41			1	0	2	0
	2	3	0						
Tsezakwa	1	3	0						
Boucher	1	3	14	3	28	1	36		
	2	3	21						

Table 34 continued. Sampling effort and catch of rainbow trout during coho juvenile assessments.

Stream	Site	2005		2004		2003		2002	
		Passes	Count	Passes	Count	Passes	Count	Passes	Count
Twain	1			3	0	1	0	3	0
	2			3	1			1	0
Pierre	1			1	0	1	0		
	2			1	1	1	0		
Morrison	1					1	0	2	1
	2					1	1		
Sutherland	1							1	0
	2							1	0
	3							1	1
	4							1	0
	5							1	0
Duncan	1							1	6