BC Environment

Status of the Information Base For Management of Atlin Lake Char

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Skeena Fisheries Report #127

September 5, 2000

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Executive Summary

The headwaters of the Yukon River are formed by the catchments of Tagish and Teslin lakes. Within these drainages the largest lake is Atlin. The town of Atlin on the eastern shore of the lake is the focus of human settlement in extreme northwestern British Columbia, and commercially is a centre for mining, trapping, and service provision of which tourism is a major component.

Atlin Lake is one of the largest lakes in British Columbia, in surface area and volume. The lake is deep and cold with very low nutrient loading. Fish species present include lake char, Arctic grayling, inconnu, lake whitefish, round whitefish, least cisco, northern pike, burbot, slimy sculpin, longnose sucker, and lake chub. Of these, lake char are most highly valued. However, the species is vulnerable to population decline throughout its range due to typically slow growth, late sexual maturity, low reproductive rate, and susceptibility to capture. Three fisheries exploit the char population of Atlin Lake: recreational angling, First Nations net fishing, and commercial net fishing. The latter presently occurs only in the Yukon Territory portion of the lake. In some years, a significant portion of the angling activity on Atlin Lake is conducted by commercial angling guide clients.

Four of the large lakes in the Teslin and Tagish drainages (Bennett, Tagish, Atlin, Teslin) are bisected by the Yukon Territory - British Columbia boundary. An inter-jurisdictional licence recognition agreement appears to be the most tractable approach to regulation of angling harvest, allowing coherent enforcement of consistent daily, possession and size limits on both sides of the boundary. However, Atlin Lake is the only one of the four large transboundary lakes with extensive road access to the portion within British Columbia, and Atlin residents have expressed concern that such an agreement will lead to an influx of angling effort by Yukon Territory residents. This document provides a summary of existing data for the lake char population and fisheries of Atlin Lake, particular addressing the utility of the present information base for management and regulation of the fishery.

Most limnological and fish population sampling activity on Atlin Lake has occurred within three distinct time periods. An initial fisheries survey was made in 1955 by the British Columbia Game Commission, in response to planned impoundment of the upper Yukon drainage. In the late 1970s and early 1980s, Placer Developments Ltd. investigated the feasibility of mining molybdenum in the Ruby Creek watershed, and commissioned an assessment of socio-economic and environmental values in the area including Atlin fisheries. Concurrently, the impoundment project again received active consideration, accompanied by an independent impact study. Skeena Region Fisheries Section sought discontinuance of the commercial fishery on Atlin Lake at this time and also collected char life history data in support of the request. Lastly, in 1992 Atlin residents' objections to provincial angling regulations prompted an examination of the status of the char population. Skeena Region Fisheries Section staff sampled the lake's fish populations in June of that year, focusing on life history and relative abundance.

Poorly documented methods and differences in net configuration and season of sampling in 1955, 1980 and 1982 limit the utility of gillnet catch results, for comparison to Atlin Lake char relative abundance in later years. For 6 MELP standard overnight sinking gillnet sets made in Atlin Lake in 1992, mean CPE for lake char was 16.0 (median 17.5; range 4.5 to

25.5). CPE for the six Atlin Lake sets made in 1992 lies within the zone of overlap between roadside (mean CPE 10.9; median 5.7) and aircraft-accessible lake char lakes (mean 55.0; median 39.2) in Skeena Region also sampled by MELP standard gillnets. Mean CPE of lake char for nine Yukon Territory surveys in the early 1990s was 6.0 (median 7.1; range 2.0 to 9.6). Results of this summary indicate that Atlin char numerical relative abundance is higher than typical for roadside lakes in Skeena Region and the Yukon Territory, although exceeded by most aircraft-accessed Skeena Region char lakes for which data are available. The gillnet samples do not suggest a decline between 1982 and 1992 in the occurrence of very large Atlin Lake char (≥ 600 mm FL) as a proportion of char ≥ 400 mm FL. But the data cannot be used to assess whether char ≥ 400 mm FL were as abundant in 1992 as in 1982 and earlier years, either in absolute terms or relative to the abundance of smaller char in those years.

Changes in population age and size structure or sexual maturity schedule can also indicate that declining survival or recruitment may be depressing population abundance. However, lack of a standardized net configuration invalidates comparison of the age and size structures of Atlin Lake gillnet samples made in 1980, 1982 and 1992. Similarly, the age and size structure of the creel sample from 1983 does not provide a viable comparison to angling derby data from 1992, due to the influence of the type of anglers participating and the size of fish likely retained. Lake char reproductive maturity is very difficult to determine, and criteria for maturity categories have not been recorded for Atlin Lake data. Between-year consistency in the data cannot be evaluated, so changes in length- or age-specific maturity are not determinable.

Atlin Lake char length at age revealed by scale sample ages (1955 and 1980 gillnet captures) is distinctly non-standard in appearance, casting doubt on the validity of the estimates even for fish less than 10 yr in age. For samples aged by bony structures using the full range of age classes, 1992 Atlin Lake char growth curves display greater length at age than samples from the early 1980s. However, the 1992 ages were obtained from fin rays, while early 1980s samples utilized otoliths. Fin ray sections often provide lower ages than otoliths, which gives poor confidence in the comparison.

Yukon Territory methods suggest an annual harvest of no more than 10 to 15 % of the estimated partitioned morphoedaphic MSY for lake char, in order to retain a "high quality" fishery. Applying the 10% criterion to data for Atlin Lake, char harvest could not exceed 4,280 kg/ yr. Insufficient data are available to assess the effectiveness of this guideline as a long term management strategy, but results from other jurisdictions suggest that sustained harvests of under 0.05 kg/ha/yr may be necessary to maintain current lake char population characteristics and 'trophy' recreational fishery attributes. This would imply a maximum annual harvest of char of less than 3,200 kg/yr from the lake. Results from studies during summer 2000 may suggest whether the lower value is more appropriate.

If char population density and angler catch rates are higher at Atlin Lake than for most Yukon Territory lakes, the Atlin fishery is likely to attract Yukon Territory anglers when a transboundary licencing agreement is implemented. Lake char harvest from the lake may increase relatively rapidly in the initial years of the agreement. Avoiding char stock depletion will require collection of creel and population data in these years, as well as agency willingness to adjust regulations quickly. Paucity of historical data suitable for comparative purposes necessitates conservative management during the fishery's transition period.

Table of Contents

List of Figures iv
List of Tables v
List of Appendices v

1. Introduction 1
2. Methods 4
2.1. History of Agency and Consultant Sampling 4
2.2. Physiochemical Information Sources 4
2.3. Fishery and Fish Population Information Sources 5
2.3.1. Recreational Fisheries 5
2.3.2. Domestic and Commercial Net Catch Statistics 5
2.3.3. Fish Sample Collection Methods 6
2.3.4. Population Age Composition and Growth Rate 7
2.3.4.1. Growth Rate 7
2.3.5. Sexual Maturity 8
2.3.6. Estimated Sustainable Yield 8
2.3.6.1. Thermal Habitat Volume 8
2.3.6.2. Partitioned Morphoedaphic Method 9
3. Results 11
3.1. Physiochemical Characteristics 11
3.1.1. Ions 11
3.1.1.1. Phosphorus and Nitrogen 11
3.2. Commercial and Subsistence Catch 13
3.3. Recreational Fisheries 16
3.4. Guided Angling 16
3.5. Lake Char Population Characteristics 18
3.5.1. Relative Abundance 18
3.5.1.1. Numerical Abundance 18
3.5.1.2. Biomass Abundance 20
3.5.2. Population Age Structure and Growth 23
3.5.3. Sexual Maturity 32
3.5.4. Estimated Sustainable Yield 33
3.5.4.1. Thermal Habitat Volume 33
3.5.4.2. Partitioned Morphoedaphic Method 34
4. Discussion 35
4.1. Status of the Atlin Char Information Base 35
4.2. Status of the Atlin Char Population 35
4.3. Sustainable Harvest 37
4.3.1. Thermal Habitat Volume 37
4.3.2. Partitioned Morphoedaphic Method 38
4.3.3. Summary 39
4.4. Other Management Considerations 40
5. Recommendations 42
6. Acknowledgments 43
7. Literature Cited 44

List of Figures

Figure 1.—Location of Atlin Lake (modified from Figure 1 of Chudyk 1983). 3
Figure 2.—Commercial and domestic (subsistence) gillnet catch of lake char in the Yukon Territory and British Columbia portions of Atlin Lake, 1972 to 1997. 14
Figure 3.—Lake char CPE plotted versus day of the year (January 1 is day 1) for sinking MELP standard gillnet sets, Skeena Region char lakes 19
Figure 4.—Lake char CPE plotted versus effort for sinking MELP standard gillnet sets, Skeena Region char lakes 20
Figure 5.—Lake char BPE plotted versus effort for sinking MELP standard gillnet sets, Skeena Region char lakes. 22
Figure 6.—Lake char length at age and Brody - Bertelanffy (BB) growth parameters for Atlin Lake angling samples 25
Figure 7.—Brody-Bertelanffy model fit to Atlin Lake char data obtained by angling, 1980, 1983 and 1992 26
Figure 8.—Lake char length at age and Brody - Bertelanffy (BB) growth parameters for Atlin Lake gillnet samples 27
Figure 9.—Brody-Bertelanffy model fit to Atlin Lake char data obtained by gillnet, 1982 and 1992 28
Figure 10.—Size at age for age classes 10+ yr and less, Atlin Lake char samples 1955, 1980, 1982 and 1992 29
Figure 11.—Mean size at age for age classes 10+ yr and less, gillnetted Atlin Lake char samples 1955 and 1980 (aged by scales), and Brody-Bertelanffy model fit to data sets from 1982 and 1992 (aged by otoliths and fin rays respectively). 30
Figure 12.—Lake char CPE plotted versus day of the year (January 1 is day 1) for Atlin Lake gillnet sets, 1982 and 1992 59
Figure 13.—Lake char CPE (upper panel) and percentage of all catch (lower panel), by length category, for pooled gillnet sets made in Atlin Lake in 1982 and 1992 61
Figure 14.—Percentage of recruited catch (fork length ≥ 400 mm), by length category, for pooled gillnet sets made in Atlin Lake in 1982 and 1992 62
Figure 15.—Skeena Region lake surface water TDS and [P_{total}]. 65
Figure 16.—Skeena Region lake surface water TDS and [N_{total}]. 66

List of Tables

Table 1.—Field work on Atlin Lake which is documented in BCE Skeena Region files 10
Table 2.—Physical and chemical parameter estimates for Atlin Lake from 6 sources........ 12
Table 3.—Estimates of Atlin Lake surface water ion content 13
Table 4.—Commercial and domestic gillnet catch of lake char in the Yukon Territory and British Columbia portions of Atlin Lake, 1963/64 to 1997/98 15
Table 5.—Number of angling guides permitted to guide on Atlin Lake, and total angler days permitted to those guides, 1990 through 1998 17
Table 6.—Guided angler catch, effort (unit is angler days), and CPE, Atlin Lake char 1990 through 1998 17
Table 7.—Brody - Bertelanffy (BB) growth parameters for Atlin Lake angling samples 23
Table 8.—Brody - Bertelanffy (BB) growth parameters for Atlin Lake char samples 24
Table 9.—Age at maturity for selected lake trout populations in Skeena Region. Included are sampling efforts which used otoliths or fin rays for age determination and recorded sexual maturity of captured lake trout........ 31
Table 10.—Length at maturity, Atlin Lake char 31
Table 11.—Length at maturity for Skeena Region lake trout populations 32
Table 12.—Estimated depth (unit = m) of the 8°C isotherm at each of 3 Atlin Lake sampling stations on July 7 and July 30, 1955........ 34
Table 13.—Estimated biomass captured per species by 6 sinking gillnet sets during June 1992, and biomass-proportioned maximum sustained harvest (MSH) and MSY estimated from MEI for Atlin Lake........ 34

List of Appendices

Appendix Table I.—Correspondence pertaining to Atlin Lake........ 48
Appendix Table II.—Lake trout individual data, Atlin Lake. 51
Appendix Table III.—Lake trout per-net summary, Atlin Lake 1982........ 57
Appendix IV.—Atlin Lake char gillnet CPE in 1955........ 58
Appendix V.—Atlin Lake char gillnet CPE in 1982 59
Appendix Table VI.—Thermal profiles, Atlin Lake July 1955........ 63
Appendix Table VII.—Characteristics of char lakes used to estimate THV - harvest relationship........ 64
Appendix VIII.—Skeena Region lake surface water TDS and [P_{total}]........ 65
Appendix IX.—Skeena Region lake surface water TDS and [N_{total}]........ 66

1. Introduction

The headwaters of the Yukon River are formed by the catchments of Tagish and Teslin lakes, which traverse the border between northwestern British Columbia and southwestern Yukon Territory. Both drainages hold numerous lakes. Within the Teslin basin, the largest are Gladys (7,300 ha) and Teslin (35,400 ha). The Tagish catchment holds Atlin (63,455 ha), Tutshi (5,583 ha), Bennett (8,680 ha) and Tagish (33,166 ha).

The largest of the Yukon headwater lakes is thus Atlin, of which approximately 97.5 % by area lies within British Columbia; the southern portion of the lake lies within Atlin Provincial Park. Commercial activities in the 11,000 km^2 Atlin Lake watershed include mining, trapping, and service provision. Tourism, including angling guiding and outfitting, is an important service component. The town of Atlin on the eastern shore of Atlin Lake (Figure 1) is the focus of human settlement in the portion of British Columbia northwest of the Stikine and Dease river drainages, and a centre for the named commercial activities.

Atlin Lake is one of the largest lakes in British Columbia, in surface area and volume. The lake is deep, cold, and nutrient-poor. Fish populations supported by Atlin Lake include lake char (*Salvelinus namaycush*), Arctic grayling (*Thymallus arcticus*), inconnu (*Stenodus leucichthys*), lake whitefish (*Coregonus clupeaformis*), round whitefish (*Coregonus cylindraceum*), least cisco (*Coregonus sardinella*), northern pike (*Esox lucius*), burbot (*Lota lota*), slimy sculpin (*Cottus cognatus*), longnose sucker (*Catostomus catostomus*), and lake chub (*Couesius plumbeus*). Of these, lake char are most highly valued because of their potential to reach large size and their good table qualities. However, lake char are vulnerable to population decline throughout their range due to typically slow growth, late sexual maturity, low reproductive rate, and susceptibility to capture in fisheries (Burr 1991; Lirette 1991).

During the last five decades, fisheries management agencies have identified three major potential anthropogenic impacts on Atlin Lake's char stock.

(1) Impoundment of the upper Yukon system for power generation.

Construction of dams in the Tagish and Teslin watersheds, to divert water into the Taku watershed for power generation, was first considered seriously by Northwest Power Industries in the middle 1950s. One market for the power would have been mine development in the Taku watershed, and construction of a road from Atlin to Juneau Alaska was also anticipated. The feasibility of impounding Atlin Lake was re-examined as late as the early 1980s by the Northern Canada Power Commission (NCPC), but the idea appears to have been abandoned permanently in the middle 1980s.

(2) Excessive mortality in commercial, subsistence and First Nations net fisheries.

Human settlement in the Atlin Lake area spiked dramatically during the gold rush to the Yukon River watershed after 1898. The extent of First Nations exploitation of Atlin Lake fish populations prior to the Gold Rush does not appear to have been documented. However, according to Reid Crowther and Partners et al. (1983),

> *"There have been three periods of relatively heavy commercial fishing in Atlin Lake: the first was during the Gold Rush, 1899 to 1910; the second from 1925 to 1835 to supply the mink and fox ranches in the*

area, and the third in the early 1940's when the catches were sold to the crews building the Alaska and Canol highways."

Atlin Lake presently supports a commercial fishery only in the Yukon Territory, which targets lake whitefish and lake char; regulation of the fishery reportedly began in 1961 (Reid Crowther and Partners et al. 1983). Commercial and domestic subsistence net fisheries in the British Columbia portion of the lake were discontinued in the middle 1980s. Lake char are also exploited by a First Nations food fishery on the lake (Atlin BC Environment Conservation Officer 1998, personal communication), the history of which is not documented in Fisheries Section files.

(3) Excessive mortality in the recreational fishery.

Fishing for lake char is a popular non-commercial recreational activity for many residents of the region. Boat-based angling during open water and ice-fishing are both common. The recreational fishery is also an important component of tourism in the area, and thus contributes to revenues of businesses offering meals and lodging, guiding, transportation, and other services.

Management of the fisheries resources of the upper Yukon drainage presently provides a distinct set of challenges for BC Environment. Four of the large lakes in the Teslin and Tagish drainages (Bennett, Tagish, Atlin, Teslin) are bisected by the provincial-territorial boundary. Cooperative management of the fish resources of these waters is needed. An inter-jurisdictional licence recognition agreement appears to be the most tractable approach to regulation of angling harvest, allowing coherent enforcement of consistent daily, possession and size limits on both sides of the boundary. At time of writing, cabinet approval of a transboundary technical agreement was imminent. The agreement would honor licenses from either jurisdiction on all parts of these transboundary waters, as well as mandating unified angling regulations for the same waters.

Atlin residents have expressed concern that such an agreement will lead to an influx of angling effort by Yukon Territory residents, particularly anglers originating in Whitehorse. All of the four large Tagish – Teslin transboundary lakes can be accessed by road in less than two hours' drive from Whitehorse, the largest population centre of the Yukon headwater region. However, Atlin Lake is the only one of the four with moderate road access to the portion within British Columbia.

In support of the development of a technical agreement for the management of transboundary waters, Skeena Region Fisheries Section requires summary of existing information about the lake char population and fisheries of Atlin Lake. This report provides such a compilation, with particular reference to the adequacy of the present information base for management and regulation of the fishery. A regional review of lake char data (De Gisi 2000) was prepared concurrently, and contains greater detail in discussion of sampling and analytical methods, lake char ecology, and management of lake char fisheries.

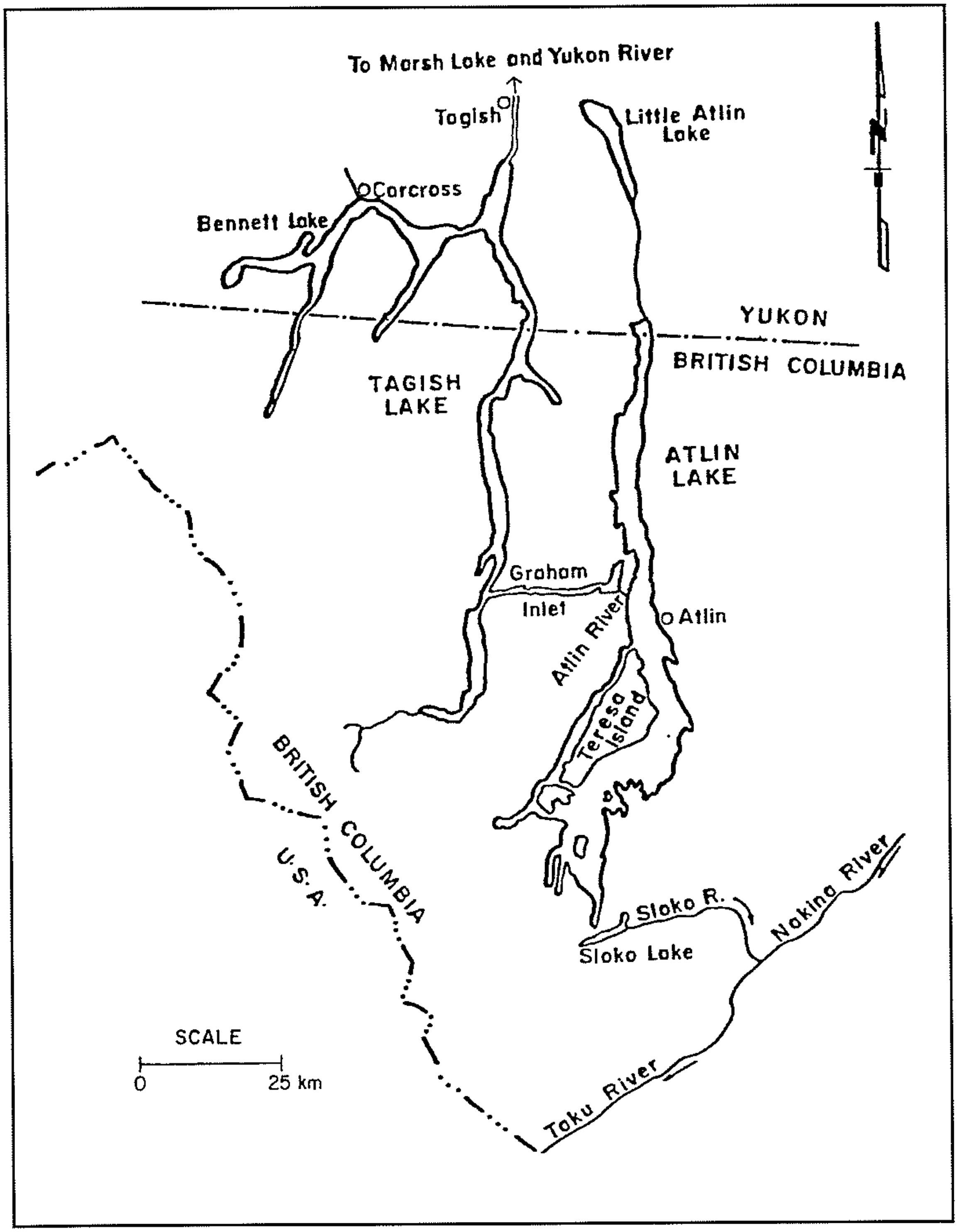

Figure 1.—Location of Atlin Lake (modified from Figure 1 of Chudyk 1983; figure appears to have originated in Withler 1956). Arrows indicate the direction of flow.

2. Methods

Information about the aquatic systems of Atlin Lake was obtained initially from BC Environment (BCE) Skeena Region offices in Smithers. Files maintained by Skeena Region Fisheries Technician S. Hatlevik hold hard copies of reports, data sheets and correspondence pertaining to Atlin Lake which are organized in folders chronologically or otherwise according to their subject. These materials were examined and catalogued; the parent folders of items relevant to this report are documented in Table 1 and Appendix Table 1. Digital files were obtained from Fisheries Section Head D. Atagi, as well as S. Hatlevik.

2.1. *History of Agency and Consultant Sampling*

Skeena Region files document 11 sources of limnological and/or fish population data for Atlin Lake resulting from agency or consultant sampling efforts (Table 1). Most sampling activity has occurred within three distinct time periods.

(1) An initial fisheries survey of Atlin Lake was made in 1955 by the British Columbia Game Commission, in response to Northwest Power Industries' plan to impound the upper Yukon drainage.

(2) In the late 1970s and early 1980s, Placer Developments Ltd. (now operating as Placer Dome Inc.) investigated the feasibility of mining molybdenum in the Ruby Creek area northeast of the Atlin townsite, and commissioned an assessment of socio-economic and environmental values in the area including Atlin fisheries. Concurrently, the hydroelectric and road project again received active consideration, so an impact study was conducted independently[1]. The Skeena Region Fisheries Branch sought discontinuance of the commercial fishery on Atlin Lake at this time (Chudyk 1982), and collected char life history data in support of the request. The initial reason for concern is not recorded, but probably stemmed from a recommendation made by Withler (1956) that when hydroelectric development occurred in the Atlin basin the commercial fishery should be terminated in favor of recreational angling. The sport fishery was expected to expand significantly if the project was accompanied by a road to Juneau Alaska.

(3) Atlin residents' objections to new provincial angling regulations (Ministry of Environment, Lands and Parks 1992) prompted an examination of the status of the lake char population in 1992. Skeena Region staff sampled the lake's fish populations in June of that year, focusing on life history and relative abundance.

2.2. *Physiochemical Information Sources*

Estimates of the physical characteristics of the lake basin and the chemical properties of its water are given in Withler (1956), with minimal documentation of the methods used to derive them. Thermal profiles for three stations on three dates during 1955 are provided in Figure 3 of Withler (1956). The report text implies that the location of the stations are indicated on Figure 2 of that document which is the lake bathymetric map, but symbols for the stations are not evident on the figure and their location is thus unknown. Temperature at

[1] A copy of the unreleased consultant report for the NCPC (Reid Crowther and Partners et al. 1983) was obtained from Dr Robert Scace, SCACE Environmental Advisors, 2416 Sandhurst Avenue SW, Calgary Alberta, T3C 2M6, and provided to the Ministry of Environment.

depth was estimated from the July 1955 profiles and is given in Appendix VI; these data were necessary for calculation of July thermal habitat volume as discussed in Section 2.3.6 of this document.

Additional water chemistry data are provided in Taekema (1982) for two sites immediately offshore of the town of Atlin. Reid Crowther and Partners et al. (1983) report water chemistry data from their own field program as well as reproducing or citing results from 4 other references (Klohn Leonoff 1980; Klohn Leonoff 1981; Marles and Carmack 1981; Marles and Carmack 1982). The latter 4 references could not be obtained[2] during the preparation of this document.

Finally, Kirkland and Gray (1986) report summary results from limnological sampling of Atlin Lake in June, August and October 1982, and March 1983.[3] The full set of field data from this relatively intensive limnological study, including thermal profiles and individual water chemistry sample values, is not provided in Kirkland and Gray (1986) but is presented instead in an unpublished data report (Kirkland and Marles 1983). The data report was not available during the preparation of this document.

2.3. Fishery and Fish Population Information Sources

2.3.1. Recreational Fisheries

Memos on file at BC Environment refer to a creel census conducted by Conservation Officer Brian Petrar and a consultant in the summer of 1980. Life history characteristics of the sampled catch are included in BCE files in Smithers, but other results of the study are not given there. These memos are presumed to refer to the creel study reported in Envirocon (1981) but the latter reference could not be obtained so nothing is known of the methods used for the survey. Reid Crowther and Partners Ltd. et al. (1983) provides a summary of the results of the study in terms of angling harvest.

In 1983, a creel census was conducted between June 15 and September 30 (Chudyk 1983). Angler interviews were conducted daily in the afternoon or evening in areas near the Atlin townsite, and each Sunday in the area north of Fourth of July Creek. The majority of July's activity was unsampled due to a staffing issue.

2.3.2. Domestic and Commercial Net Catch Statistics

Data for the domestic (subsistence) and commercial net catch in the British Columbia portion of the lake were obtained from a memo (Sunde 1992) filed with other Atlin Lake materials. The memo presents catch summarized as annual counts and total poundage (presumed round weight) by individual permit for each species.

Yukon Territory commercial catch data were located in three different documents in the Atlin Lake folders, as well as a spreadsheet received from the Yukon Territorial Department of Renewable Resources (via D. Atagi, Skeena Region Fisheries Section Head, Smithers

[2] Results from Klohn Leonoff (1980) and Klohn Leonoff (1981) are given in Appendix A of Reid Crowther and Partners 1983, but the available copy of the latter reference lacked the portion of Appendix A which presents estimates from Marles and Carmack (1981) and Marles and Carmack (1982).

[3] It appears probable that Reid Crowther and Partners et al. (1983) cited the preliminary form of these results as Marles and Carmack (1981) and Marles and Carmack (1982), although apparent errors in the text of Reid Crowther and Partners et al. (1983) make it difficult to determine reliably whether this is the case.

BC). The sources disagree occasionally, which may reflect revisions, typographic errors, or another unknown factor.

Available statistics for the Yukon Territory net fisheries give only total poundage, and not counts of the catch. Neither fishery's statistics include any measure of effort.

2.3.3. Fish Sample Collection Methods

A variety of non-standardized methods were applied during sampling efforts on Atlin Lake before 1990. Extracts from the relevant reports are included here to display the variation in procedures and net configurations, as well as highlighting the imprecision of the methods descriptions, particularly those for gillnet sampling.

Withler (1956) states that "fish were sampled with gill nets at three stations in late July and again in September. The stations were situated in the southern, central and northern portions of the lake. Gill nets of graduated sizes from 1½ inch to 5½ inch stretched measure were set on the bottom in two gangs with the smaller mesh on shore and the sections of larger mesh extending diagonally from shore to depths of approximately 50 feet. Two consecutive overnight sets were made at each station in July and again in September." Total gillnet length and depth was thus unreported and soak time imprecise (Withler 1956), so insufficient documentation is available to convert the 1955 gillnet sampling effort to a standardized unit comparable to later data. In general, individual fish data are not presented in the report either, so the possibility of re-analysis is limited.

During the 1982 sampling conducted by Ken Weagle for Reid Crowther and Partners "all gill netting was done with a gang of three nets, 20 meters long by 1.25 m deep with stretch meshes ranging from 6.43, 8.9 to 11.4 cm. The nets were set with the smallest mesh size near shore and perpendicular to the shorelines. The shallow end of the sets were generally in less than 2 m of water. There were no deep sets made during the survey ..." (Reid Crowther and Partners et al. 1983). Telephone contact with the sampler confirmed that each set constituted 60 m of sinking net as a gang of three 20 m panels, soak time was overnight for roughly 12 hr, and gillnet filaments were braided fibre rather than monofilament (Weagle 2000). The resulting lake char catch data in Reid Crowther and Partners et al. (1983) are not fully documented. Each location-date combination, excluding those labeled as spot check, appears to comprise the catch from a single overnight set (Appendix Table II of this document) implying the per-set catch and CPE summary presented in Appendix Table III of this document.[4]

Skeena Region lake char data collected by MELP standard methods, including the 1992 net sets on Atlin Lake, utilizes the BCE reconnaissance inventory standard monofilament gillnet consisting of a gang of six panels, of mesh size 25 mm, 76 mm, 51 mm, 89 mm, 38 mm and 64 mm. Total length is 300 ft (91.2 m) and depth is 2.4 m. Sinking nets are typically set perpendicular to shore.

Survey gillnet catch per effort (CPE) for all years was standardized to number of individuals captured per 100 m length of net per 24 hr of soak time. No attempt was made to adjust for differences in mesh size, for 1955 and 1982 data. Gillnet biomass catch per effort

[4] This interpretation of 1982 results in Reid Crowther and Partners. et al. (1983) is reinforced by the statement in that report that "eight sites were fished during the July and August visits", which matches the presented data. Any sets which failed to capture lake trout would not be represented, thus causing a potential upward bias of mean CPE for the dataset.

(BPE) was standardized to kg of char round weight captured per 100 m lengthof net per 24 hr of soak time.

2.3.4. Population Age Composition and Growth Rate

Prior to summer 1980, ages for lake char from Atlin Lake were obtained from scales, which are now known to provide char age estimates that are biased downward particularly for older char. Withler (1956) felt that scales provided accurate ages for Atlin Lake char up to 10+ yr. Brown et al. (1976) reported that most Atlin Lake char scales were regenerated, but that the oldest readable scale was 10+ yr. Scales were also collected from 129 char captured by under-ice gillnet in February 1980. Skeena Region staff assigned ages to 122 of the scale samples, again stating that only ages up to 10+ yr were considered reliable. Approximately 20 of these 129 scales were also examined by R. Beamish (DFO Pacific Biological Station, Nanaimo, BC) who found the scales essentially unreadable, but did estimate ages which were much lower than those eventually assigned to the samples by Skeena Region staff. His recommendation of the use of otoliths for aging lake char was followed for collections in the summer of 1980 (Atlin CO and probably Envirocon), summer of 1982 (Reid Crowther and Partners et al. 1983), and summer of 1983 creel survey (Chudyk 1983). Collections made by gillnet and sampling of the angling derby catch in June 1992 utilized fin rays for age determination.

2.3.4.1. Growth Rate

Selection of a standard method of characterizing lake char growth is discussed in greater detail in the companion report (De Gisi 2000). Two modifications of the Brody - Bertalanffy growth model (Ricker 1975) were applied to population datasets with length and age for at least 15 individuals. First, L_∞ and K were estimated[5] by numeric search, with simple sum-of-squares as the fitting criteria, applied to individual data (rather than mean length at age). Second, the approach of Payne et al. (1990) was followed in computing an empirically-determined surrogate parameter L_∞', calculated as the geometric mean length of the longest 5% of the length-age sample, leaving only K′ to be estimated by numeric search. For both of these parameterizations, t_0 was fixed at 0 thus forcing the growth curve through the origin, and all ages of fish in the sample were used. Bootstrapped standard error estimates for growth parameters (Sokal and Rohlf 1995) were made using 1000 resamples, for the first parameterization method only.

Because interpretation of K is not intuitive, the Brody - Bertalanffy growth parameters were used to estimate the age at which an average fish would reach 500 mm fork length, as:

$$A500 = -\log e\,(-(500 / L_\infty - 1)) / K \qquad [1]$$

The calculation was repeated to obtain A400 for comparison with other Skeena Region lake char populations, many of which display L_∞ less than 500 mm (De Gisi 2000).

Ages for 1955 and 1980 samples utilized scales, which were considered accurate at the time of collection to age 10+ at best. To compare 1992 and 1982 growth rates to those from

[5] The parameter L_∞ is equivalent to the greatest length that would be achieved by the average fish in a population if it lived to extreme old age ("how big do they get"); the parameter K approximates how rapidly that size is approached ("how fast do they get there").

1955 and 1980 fish age 10 and younger, Brody – Bertalanffy growth parameters were also estimated for 1992 and 1982 data using only age classes 10 yr and younger.

2.3.5. Sexual Maturity

Criteria for categorization of sexual maturity have not been recorded for any of the fish sampling datasets for Atlin Lake. As a result, comparison of maturity schedules through time is difficult to accomplish with any degree of confidence.

The youngest mature and oldest immature fish sampled were used to characterize the range in age of maturity, for each gender. For samples with at least 30 individuals of known gender the gender-specific age of maturity, designated AR_{50}, was estimated as the mean of the youngest mature and oldest immature fish ages.

For length-based maturity summary, fish were pooled by 50 mm fork length categories and the proportion of fish which were reproductive (maturing, mature or spawning / spent) was calculated for each category. The shortest length category with proportion reproductive of 0.5 or greater was considered length at 50% maturity (LM_{50}) for the population.

2.3.6. Estimated Sustainable Yield

2.3.6.1. Thermal Habitat Volume

Payne et al. (1990) found that thermal habitat volume (THV), defined for lake char as the volume of water between the 8°C and 12°C isotherms with dissolved [O_2] greater than 6 mg/L, was a good predictor of lake char harvest for 20 fully-exploited Canadian lakes. They described the relationship in quantitative terms as

$$\log_{10}(H) = 2.15 + 0.714 \log_{10}(\text{July THV}) \qquad [2]$$

where H is potential lake char harvest in kg/yr and July THV is expressed in cubic hectometres, a unit equivalent to 100 m cubed. Two methods of calculating July THV are described in Payne et al. (1990). Fifteen large char lakes[6] (Christie and Regier 1988) exhibited wide variation in the seasonal pattern of thermal profile development. The geometric mean THV from three mid-summer period estimates corresponding approximately to the month of July was found to best explain variation in lake char harvest (Payne et al. 1990). For another 5 small Ontario char lakes added to broaden the analysis, "individual July temperature profiles were ... averaged across depths ... the resulting single profile for each lake was then combined with interpolated area-at-depth to calculate volume."

The discrepancy between Payne et al. (1990) use of the geometric mean THV in the first case and apparently arithmetically averaging profiles to create a single July profile in the second case was unexplained. Both approaches were attempted with the available thermal profiles for Atlin Lake, those being for July 1955 (Withler 1956).

Area at depth for Atlin Lake was not available but Withler (1956) does report that 11% of the total surface area of the lake lies above the 50 ft depth contour. This implies an average decline in area at depth of 0.72% per metre, which was used in THV calculations

[6] Located in Ontario, Manitoba, Saskatchewan, and the Northwest Territories

along with thermal profiles for three Atlin Lake stations on July 7 and July 30, 1955 depicted in Figure 3 of Withler (1956). Estimated profiles for these stations for July 18, 1955 were calculated by linear interpolation of temperature at depth on July 7 and July 30. The profiles correspond well to the July periods (July 9, 19 and 29) of Figure 1 for Payne et al. (1990).

2.3.6.2. Partitioned Morphoedaphic Method

All-species sustainable yield (MSY), as estimated by Yukon Territory Renewable Resources methods (Thompson 1996), was computed using the formula:

$$\log_{10}(MSY) = 0.05\ TEMP + 0.28\ \log_{10}(MEI) + 0.236 \qquad [3]$$

where MSY is expressed in kg/yr, TEMP is the mean annual air temperature in degrees Celsius, and MEI is the morphoedaphic index which is calculated as total dissolved solids (TDS; unit is mg/l or ppm) divided by lake mean depth in m (Schlesinger and Regier 1982).

Most available estimates of the ionic content of Atlin Lake water were made as specific conductance (conductance calibrated to 25°C, or C_{25}, unit is µS/cm or µmhos) rather than TDS. A general formula for conversion of conductance to TDS is provided by equation 3 of Schlesinger and McCombie (1983). However, Kirkland and Gray (1986) utilized 35 samples from Atlin, Tagish, Marsh and Laberge lakes to estimate the relationship between C_{25} and TDS for Yukon River headwaters as:

$$TDS = 0.479\ C_{25} + 6.405 \qquad r^2 = 0.892 \qquad [4]$$

Over the range of values of C_{25} exhibited by Atlin Lake samples, conversion using equation [4] provides lower estimates of TDS than equation (3) of Schlesinger and McCombie (1983). Equation [4] is assumed to provide more accurate conversion due to its geographic specificity, and was utilized for all conversions necessary for this report.

Mean annual air temperature[7] for Atlin Lake (ecodistrict 918) was not available. The average of the two adjacent ecodistricts, southwest (ecodistrict 916: – 1.1°C) and northeast (ecodistrict 905: – 1.9°C) of Atlin Lake, was applied instead giving a value of – 1.5°C.

The MSY estimate was partitioned into species-specific MSY using biomass values from June 1992 gillnet samples. To estimate biomass of unweighed species captured during 1992 net sets, regional length-weight relationships were applied (see Table 3 of De Gisi 2000).

[7] Available from Agriculture Canada at http://res.agr.ca/cansis/nsdb/ecostrat/district/climate.html

Table 1.—Field work on Atlin Lake which is documented in BCE Skeena Region files, Smithers.

Year	Project Type	Description of Data	Comments
1955	Lake survey	Length and weight range, gut contents; physical and chemical data	No individual fish data, avg length & weight at age. Reported in Withler 1956. In Atlin file box folder "Atlin Lake – 1955/56".
1975	Lake survey	Length mean & range, weight mean & range, maximum scale age	Reported in Brown et al. 1976; most information is repeated from Withler 1956 but very minor samplings were made from the commercial catch of April 1975. In Atlin file box folder "Atlin Lake – Misc."
1980	Under-ice gillnet sets	Length, weight, age (scales), sex, capture location	Gillnet sets made by Conservation Officer and samples from commercial catch; 129 lake char samples. Aging by BCE staff. In Atlin file box folder "Atlin Lake – 1980".
1980	Angling samples	Length, weight, age (otoliths), sex, maturity, capture location	Samples by conservation officer of the sport catch of 1980. Aging by K. Tsumura, BC Environment Fisheries Section. In Atlin file box folder "Atlin Lake – 1982".
1982	Water sampling	Chemical analyses	Data collected from two sites. In Atlin file box folder "Atlin Lake – 1982".
1982	Gillnet sets Water sampling	Length, weight, age (otoliths/scales), sex, maturity; water chemistry	Documented in Reid Crowther and Partners et al. 1983.
1982 - 1983	Physical, chemical and biological limnology	Physiochemical profiles, phytoplankton and zooplankton species composition and abundance	Documented in Kirkland and Gray 1986.
1983	Creel survey	Effort: number of anglers, angler days. Catch: number, capture location, age (scales/otoliths)	Data for LT and GR. Survey interrupted and scaled-down due to bad weather. Reported in Chudyk 1983. In Atlin file box folder "Atlin Lake - 1983"
1990	Angling samples	Length, age (otoliths), sex, maturity	Approximately 14 fish captured in the Atlin River (Taku Island) by Bruce Johnson. In Atlin file box folder "Atlin Lake 1990 - 1993".
1992	Angling derby samples	Length, weight, age (fin rays)	Sample of 20 fish in total, 18 length – age pairs. Aging by North – South Consulting. In Atlin file box folder "Atlin LT Data - June 92".
1992	Gillnet sets	Length, weight, age (fin rays), sex, maturity, gut contents, capture location, gillnet effort	64 lake char captured by 6 gillnet sets totaling 130 net·hrs. Aging by North – South Consulting, Winnipeg MB. In Atlin file box folder "Atlin LT Data - June 92".

3. Results

3.1. Physiochemical Characteristics

Atlin Lake physical and chemical characteristics which may be linked to fish production are given in Table 2. Estimates of the lake's surface area, depth and volume given in Kirkland and Gray (1986) were reportedly taken from Withler (1956), although there is a discrepancy in the area estimate (Table 2) which is assumed to constitute a typographical error by Kirkland and Gray. Withler (1956) and Kirkland and Gray (1986) note a south to north gradient in water chemistry including turbidity, due to variation in the geology of tributary basins. Present glaciation is much more prevalent at in drainages at the southern end of the lake, with inlet turbidity plumes present during the warmer months.

3.1.1. Ions

Summary of Atlin Lake dissolved ion content is presented in Table 3. Values for Atlin Lake TDS provided by Withler (1956) are much greater than those obtained by converting estimates of C_{25} made by various studies during the early 1980s (Table 3). As the sample sites and chemistry methods of Withler (1956) are undocumented, no explanation of the difference can be suggested. According to Kirkland and Gray (1986) page 4, "Atlin Lake had specific conductivities typically 20% higher than those of Tagish Lake." In their summary Table 13, Kirkland and Gray devote one column to Atlin and Tagish lakes together, with the single entry "45 - 55" for TDS (ppm) for the two lakes. Taking these statements together, it is inferred that mean TDS for their Atlin Lake samples was roughly 55 ppm. Kirkland and Gray (1986) do not provide individual estimates of chemistry parameter values so their data are not represented in Table 3, with the exception of values attributed by Reid Crowther and Partners et al. (1983) to Marles and Carmack (1981, 1982) which are likely drawn from Kirkland and Gray's preliminary data. The mean TDS value of 54 ppm presented in Table 3 agrees closely with the inferred value of 55 ppm from Kirkland and Gray (1986), and is assumed to provide an adequate basis for estimation of MEI and potential fish production of Atlin Lake.

3.1.1.1. Phosphorus and Nitrogen

Results of sampling by Kirkland and Grey (1986) indicated that Atlin Lake total phosphorus concentrations were very low. Again, although they do not provide individual estimates of chemistry parameter values, Kirkland and Grey (1986) state that "total phosphorus rarely reached 10 ppb." After excluding their Station A3 as unrepresentative, Kirkland and Grey report an annual mean for [P_{total}] of 2.4 ppb (Table 2). They also state that "the dissolved fraction was usually less than 5 ppb and was often at or below the detection limit of the method (1 ppb or 1 μg/L)". The annual mean concentration of particulate phosphorus was 46% of the mean annual [P_{total}]. Nitrogen concentrations, while low, were rarely below the detection limit (Kirkland and Grey 1986). Appendix VIII depicts the relationship between TDS and [P_{total}] for Skeena Region lakes for which data were available. Appendix IX depicts the relationship between TDS and [N_{total}] for available data from the same set of lakes.

Table 2.—Physical and chemical parameter estimates for Atlin Lake from 6 sources. Taekema (1982) sampled two stations very near each other, both results are given. Reid Crowther and Partners et al. (1983) sampled at nine sites, during April, July and September; for each parameter the mean, range, and number of estimates (in bold typeface) are given. Kirkland and Gray (1986) sampled at an unknown number of sites and only summary information is available.

Parameter	**Withler 1956**	**Klohn Leonoff 1980**	**Klohn Leonoff 1981**	**Taekema 1982**	**Reid Crowther et al. 1983**	**Kirkland and Gray 1986**
Area (ha)	63,455					58,900
Mean Depth (m)	85.6					86
Maximum Depth (m)	283.5					283
Volume (m^3)	$5.44x10^{10}$					$5.44x10^{10}$
TDS (ppm)	97; 93-100; **3**	[55, 74][8]				55
pH		7.76, 7.83	6.9; 6.8-7.1; **4**	8.1, 8.1	7.5; 6.8-8.1; **14**	
C_{25} (µmhos)			77; 65-100; **5**	108, 108	83; 75-92; **8**	
Alkalinity		47, 48			65; 60-80; **4**	
N_{total} (ppb)				50, 110		66.3
P_{total} (ppb)				4, 5		[2.4][9]
$P_{dissolved}$ (ppb)				4, 5		1.3
MEI = TDS / Z_{mn}	1.13					0.64

[8] Klohn Leonoff (1980) as reported in Reid Crowther and Partners (1983) provide two estimates of 'dissolved solids (mg/l)', but no information about their analytic method is available so it remains unclear whether the estimates are equivalent to TDS.
[9] Value excludes results from sample station A3; including station A3 the lakewide annual mean was 2.9 ppb

Table 3.—Estimates of Atlin Lake surface water ion content. Estimates of specific conductance (**C_{25}**, unit is μmhos) were converted to total dissolved solid (**TDS,** unit is ppm) equivalents by equation [4]. In the column headed **Source**, RC is an abbreviation for the document cited herein as Reid Crowther and Partners et al. (1983).

Date	Station	C_{25}	TDS	Source
Aug-1955			93	Withler 1956
Aug-1955			97	Approximate; inferred from Withler 1956
Aug-1955			100	Withler 1956
06-Jul-1982	AL-1	79	44	RC Table 10
06-Jul-1982	AL-2	80	45	RC Table 10
07-Jul-1982	AL-3	75	42	RC Table 10
07-Jul-1982	AL-4	85	47	RC Table 10
07-Jul-1982	AL-5	75	42	RC Table 10
06-Apr-1982	1	90	50	RC Table 11
06-Apr-1982	2	92	51	RC Table 11
06-Apr-1982	3	90	50	RC Table 11
Aug-1980	A1	70	40	RC p. A-14, from Klohn Leonoff 1981
Oct-1980	A1	65	38	RC p. A-14, from Klohn Leonoff 1981
Aug-1980	A2	100	54	RC p. A-14, from Klohn Leonoff 1981
Sep-1980	A2	71	40	RC p. A-14, from Klohn Leonoff 1981
Oct-1980	A2	78	44	RC p. A-14, from Klohn Leonoff 1981
27-Jul-1982		108	58	BCE Memorandum dated December 1, 1982
27-Jul-1982		108	58	BCE Memorandum dated December 1, 1982
Aug-1982		65	38	RC p. 59, citing Marles and Carmack 1981
Aug-1982		96	52	RC p. 59, citing Marles and Carmack 1981
Aug-1982		104	56	RC p. 59, citing Marles and Carmack 1981
Mar-1982		100	54	RC p. 59, citing Marles and Carmack 1981
Mar-1982		104	56	RC p. 59, citing Marles and Carmack 1981
Mean			**54**	

3.2. Commercial and Subsistence Catch

Catch of lake char in commercial and domestic net fisheries in the British Columbia and Yukon Territory portions of Atlin Lake are depicted graphically in Figure 2, and given in tabular format in Table 4. The commercial fishery on Atlin Lake existed at least as early as the year 1900 (Reid Crowther and Partners et al 1983) but difficulties with cold storage and transport of the catch apparently were early limiting factors. During the period for which data are available, the maximum reported combined harvest for these fisheries ranged between 600 and 900 kg, in the early 1980s. All forms of netting on the British Columbia portion of the lake were discontinued in the middle 1980s, with the exception of First Nations fisheries for which no catch statistics are available. The commercial fishery in the Yukon Territory has continued to operate to the present. Catches declined during the late 1980s, increased briefly during the early 1990s, and were less than 200 kg per annum between 1993 and 1997. Material on file indicates that during the early 1980s the commercial quota for lake char for the Yukon portion of the fishery was 2,000 lb (907 kg) and the aggregate quota for lake whitefish and lake char in the same fishery was 4,000 lb (1814 kg). No documentation of any change in this quota has been made.

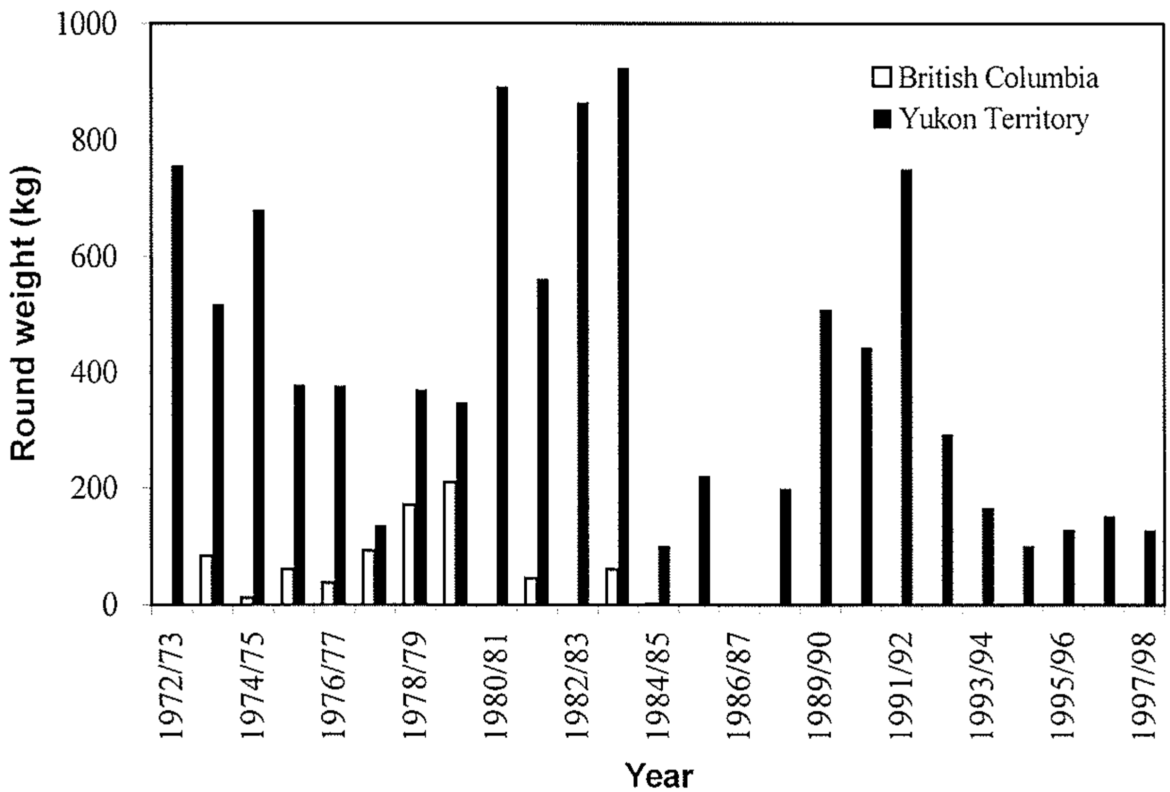

Figure 2.—Commercial and domestic (subsistence) gillnet catch of lake char in the Yukon Territory and British Columbia portions of Atlin Lake, 1972 to 1997.

Table 4.—Commercial and domestic gillnet catch of lake char in the Yukon Territory and British Columbia[10] portions of Atlin Lake, 1963/64 to 1997/98. For Yukon catches, Sources: A = J. Burdek memo 19 Jan 1982; B = undated document on file; C = Excel file "Yukon com fishery.xls" obtained from D. Atagi. Shaded cells indicate a discrepancy between sources.

Year	Yukon Weight (kg)			BC	
	Source A	Source B	Source C	Number	Weight (kg)
1963/64	N/A	N/A	N/A	414	903
1964/65	N/A	N/A	N/A		
1965/66	N/A	N/A	N/A		
1966/67	N/A	N/A	N/A	1	4
1967/68	N/A	N/A	N/A		
1968/69	N/A	N/A	N/A		
1969/70	N/A	N/A	N/A		
1970/71	N/A	N/A	N/A		
1971/72	N/A	N/A	N/A		
1972/73	756	756	N/A		
1973/74	518	518	N/A	67	83
1974/75	680	680	N/A	4	11
1975/76	378	378	N/A	42	60
1976/77	330	376	N/A	33	~37
1977/78	136	136	N/A	49	~92
1978/79	370	247	N/A	107	171
1979/80	348	348	312	116	209
1980/81	782	828	892		
1981/82	562	562	482	27	45
1982/83		865			
1983/84	N/A	N/A	924	18	60
1984/85	N/A	N/A	101	2	2
1985/86	N/A	N/A	221		
1986/87	N/A	N/A			
1987/88	N/A	N/A	199		
1989/90	N/A	N/A	509		
1990/91	N/A	N/A	444		
1991/92	N/A	N/A	750		
1992/93	N/A	N/A	294		
1993/94	N/A	N/A	166		
1994/95	N/A	N/A	101		
1995/96	N/A	N/A	129		
1996/97	N/A	N/A	153		
1997/98	N/A	N/A	128		

[10] Net fisheries operating in the British Columbia portion of Atlin Lake were discontinued in about 1985.

3.3. Recreational Fisheries

Reid Crowther and Partners et al. (1983) cited Envirocon Ltd. (1981)[11] as reporting that recreational anglers "took 600 to 900 lake trout from Atlin Lake" between July 31 and September 1, 1980. An average of 1.74 parties per day were observed angling on the lake, and average catch of 1.8 lake trout per angler day was estimated. As the latter reference was unavailable at time of writing, no other information on effort and catch could be obtained.

During other sampling activities on the lake in 1982, Reid Crowther and Partners et al. (1983) enumerated fishing parties by date. Eliminating Atlin River counts from their Table 27, on 9 dates in July and early August an average of two parties per day were encountered on the lake (Reid Crowther and Partners et al. 1983).

From the 1983 creel survey, a total of 427 angler days were estimated to have occurred during the June 15 to September 30 survey period, with 349 (82 %) of the days directed at lake char. Of 227 char captured by angling, 168 (74 %) were retained. Mean CPE was 0.65 fish per angler day. The average sampled lake char round weight was 2.6 kg. Two thirds of anglers were Atlin residents and 21 % resided in the Yukon Territory. Weather in the summer of 1983 was atypical and believed to have greatly reduced angling activity. No attempt was made to interpolate the results to estimate catch and effort in unsurveyed weeks during July (Chudyk 1983).

3.4. Guided Angling

Between one and four registered angling guides have requested angler days for Atlin Lake each year since 1990 (Table 5). Sixty to 1291 days per year have been permitted. Reported guided angler activity and catch are presented in Table 6. Between-year variability in reported activity is extremely high; a maximum of 462 angler days were reported for 1995/96 but for four of the nine years for which data are available 20 days or less were reported conducted.

During the nine year period, 457 char were reported killed by guided anglers and 1932 released, for an aggregate retention rate of 19 %. Annual mean CPE ranged between 1.6 to 2.8 fish per day for the five years where annual effort was 40 days or greater. Guide reports do not designate the target fish species, so some of the guided angler days may have been expended primarily in pursuit of grayling, which would cause the char CPE to be biased downward.

[11] Reid Crowther and Partners. et al. (1983) actually states that the angler study was conducted from July 31 to September 1, 1982. This is assumed to constitute a typographical error: the cited report by Envirocon was completed in 1981 and the study period was thus presumably during 1980 when BCE files also mention that the Atlin CO assisted an unnamed consultant in conducting a creel survey.

Table 5.—Number of angling guides permitted to guide on Atlin Lake, and total angler days permitted to those guides, 1990 through 1998. The symbol "+" indicates one or more guides did not specify the number of days. Source: MELP Skeena Region Angling Guide Management System database.

Year	North of Provincial Park		Within Provincial Park	
	No. Guides	Angler Days	No. Guides	Angler Days
90/91	1	60		
91/92	2	80+		
92/93	2	+		
93/94	3	90+		
94/95	4	200+		
95/96	4	1291		
96/97				
97/98			1	100
98/99			2	138

Table 6.—Guided angler catch, effort (unit is angler days), and CPE, Atlin Lake char 1990 through 1998. Source: Skeena Region Angling Guide Management System digital database.

Year	Retained	Released	Total Catch	Effort	Total CPE
90/91	3	1	4	8	0.5
91/92	25	181	206	20	10.3
92/93					
93/94	20	74	94	41	2.3
94/95	69	263	332	145	2.3
95/96	171	1138	1309	462	2.8
96/97	76	128	204	74	2.8
97/98	80	127	207	129	1.6
98/99	13	20	33	9	3.7

3.5. *Lake Char Population Characteristics*

3.5.1. *Relative Abundance*

3.5.1.1. Numerical Abundance

Poorly documented methods, differences in gillnet configuration including mesh sizes and filament type as well as net width, and inconsistent season of sampling constrain the comparability of data from 1955, 1980 and 1982 to each other or to 1992 samples. Appendix IV and Appendix V provide speculative analyses of relative abundance for the 1955 and 1982 data compared to 1992.

Other Skeena Region char lakes provide a more standard and precise baseline against which Atlin Lake char relative abundance in 1992 can be assessed. Figure 3 displays the potential effect of the season of sampling on estimates of char relative abundance by gillnetting. Atlin Lake netting in 1992 occurred earlier than most lake char sampling in the region. In 1989, Tagetochlain and Chapman lakes were sampled several times through the open water season; their CPE values are shown with a distinct plot symbol. The data for Tagetochlain - Chapman lakes appear to display reduced CPE for early and late season sets, relative to sets made mid-summer. This pattern is also mildly apparent for other Skeena Region char lakes in Figure 3. For this reason, the early sampling of Atlin in 1992 may have resulted in lower CPE than would have been observed by a mid-season effort.

In Figure 4, CPE is plotted versus effort; soak time is the main varying factor for these sets since net size is identical for all sets. Atlin Lake, other roadside lakes, and non-road accessed lakes are each displayed with distinct plot symbols. CPE is weakly negatively correlated with effort (soak time) perhaps due to net saturation or localized depletion of fish abundance. Lakes without road access tend to display higher relative abundance of char than those with road access.

For 6 MELP standard overnight gillnet sets made in Atlin Lake in 1992, mean CPE for lake char was 16.0 (median 17.5; range 4.5 to 25.5). CPE for the 1992 Atlin Lake sets lies within the zone of overlap between roadside (mean CPE = 10.9; median =5.7) and air-access lakes (mean CPE = 55.0; median = 39.2) in Skeena Region. In other words, Atlin Lake char numerical relative abundance is higher than average for roadside lakes in Skeena Region, although exceeded by most air-access char lakes for which data are available.

Using the same unit of numbers of individuals captured per 100 m of net per 24 hr of soak, Yukon Territory surveys in the 1990s included CPE for lake char in the following lakes: Kusawa 9.2, Laberge 2.1, Teslin 2.0 (Thompson 1996); Aishihik 9.6, Sekulmun 7.7, and Canyon 4.0 (de Graff 1993); Frances 3.6, Bennett 8.5 and Kluane 7.1 (de Graff 1992); the mean CPE for these nine Yukon lakes surveyed during the early 1990s was thus 6.0 (median = 7.1). Yukon Territory gillnets utilize mesh sizes which are slightly larger than those of the MELP standard gillnet; the effect on CPE is unknown but probably minor.

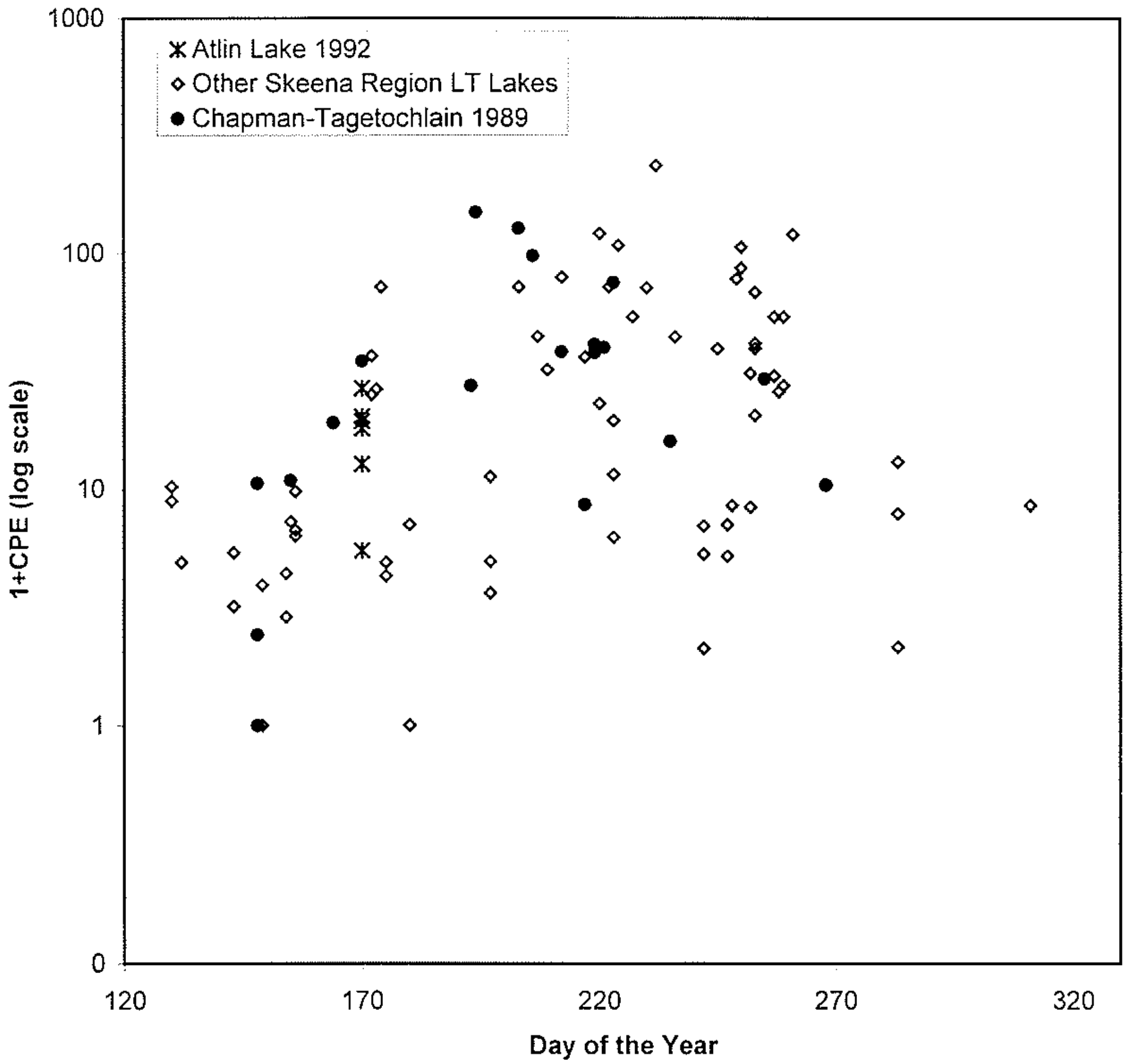

Figure 3.—Lake char CPE (unit is number of char captured per 100 m of net per 24 hr soak time) plotted versus day of the year (January 1 is day 1) for sinking MELP standard gillnet sets, Skeena Region char lakes. The y-axis is log transformed, so CPE has been transformed to 1 + CPE in order that occurrences of zero can be displayed.

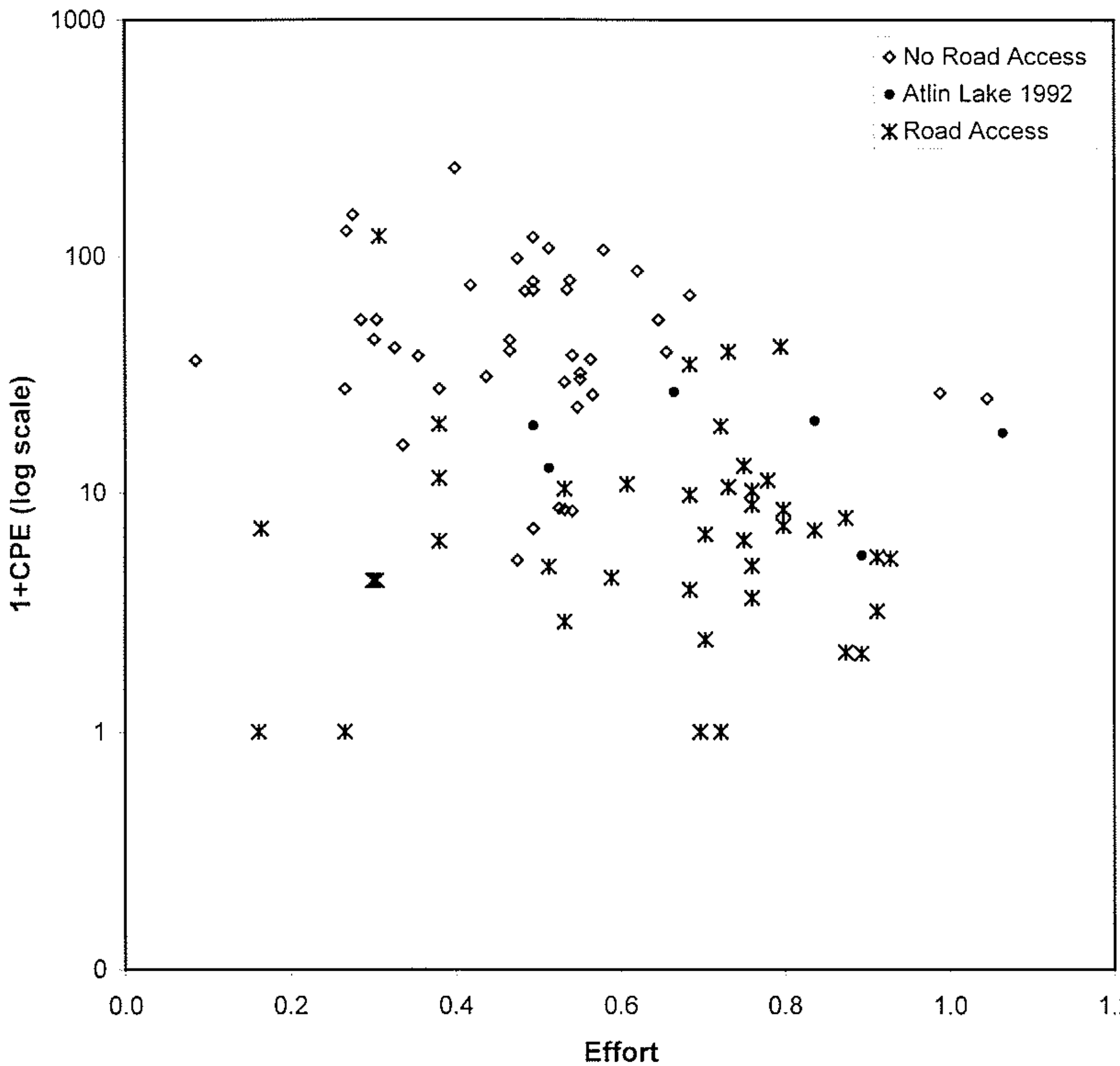

Figure 4.—Lake char CPE (unit is number of char captured per 100 m of net per 24 hr soak time) plotted versus effort (100 m of net · 24 hr soak time) for sinking MELP standard gillnet sets, Skeena Region char lakes. The y-axis is log transformed, so CPE has been transformed to 1 + CPE in order that occurrences of zero can be displayed.

3.5.1.2. Biomass Abundance

Again, non-standard gillnet methods in 1955, 1980 and 1982 impede their use for comparison of biomass relative abundance (BPE, expressed as kg of lake char captured per 100 m of net per 24 hr soak time) to 1992 netting results or to each other. The mean BPE of lake char for 6 MELP-standard Atlin Lake sets in 1992 was 16.1 (median 12.2, range 6.3 to 30.8).

Other Skeena Region char lakes provide a more precise comparison for Atlin Lake. Char catch in weight per unit effort (BPE) for sinking MELP standard gillnet sets in Skeena Region char lakes is depicted in Figure 5. Atlin Lake, as well as other road-accessed and non-road accessed lakes are displayed with distinct plot symbols. Again, BPE is weakly correlated with effort (soak time) for sets with non-zero catch, and lakes without road access tend to display higher BPE (mean 42.2, median 33.9) than those with road access (mean 12.3, median 9.0). BPE for the six Atlin Lake sets made in 1992 lies within the zone of overlap between roadside and air-accessed lakes. Atlin char relative abundance, in terms of biomass, is higher than average for other roadside lakes but lower than for many air-accessed char lakes.

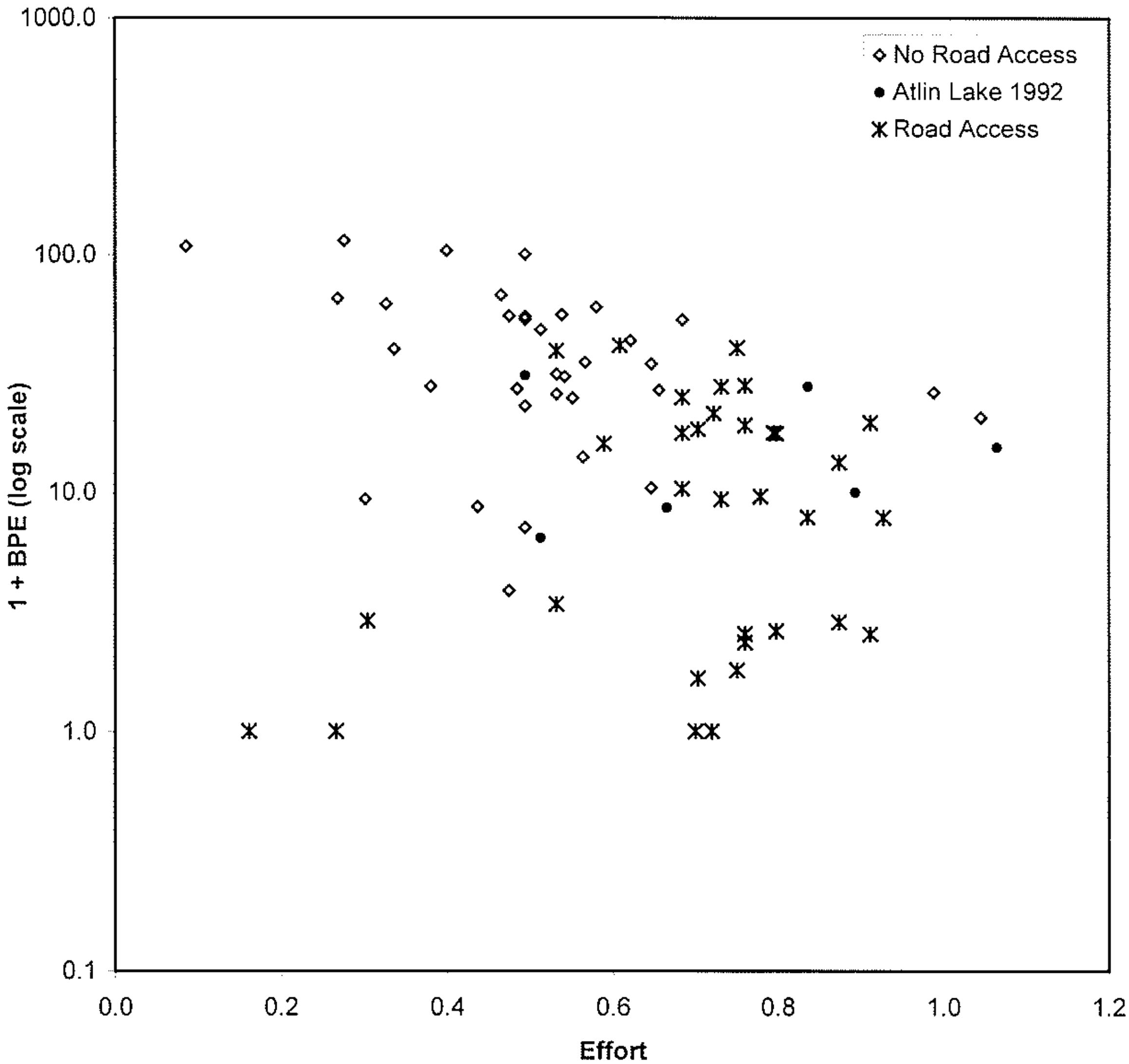

Figure 5.—Lake char BPE (unit is kg of char captured per 100 m of net per 24 hr soak time) plotted versus effort (100 m of net · 24 hr soak time) for sinking MELP standard gillnet sets, Skeena Region char lakes. The y-axis is log transformed, so CPE has been transformed to 1 + CPE in order that occurrences of zero can be displayed.

3.5.2. Population Age Structure and Growth

Brody-Bertalanffy growth parameters for Atlin Lake char gillnet and angling samples are presented in Table 7, with parameter confidence intervals estimated by bootstrap shown in Table 8. Model fits to angling samples are depicted in Figure 6 and Figure 7; apparent growth for gillnet samples are displayed in Figure 8 and Figure 9. Comparison of growth for age classes 10+ yr and under, for samples with at least 30 age structures in this age range, are depicted in Figure 10 and Figure 11.

For both gillnet and angling samples using fin rays or otoliths and the full range of age classes, 1992 growth curves display greater size at age (more rapid growth) than samples from the early 1980s. Growth displayed by samples aged by scales (1955 and 1980 gillnet captures) is distinctly non-standard in appearance, casting doubt on the validity of the estimated ages even for fish less than 10 yr in age. Model fit for 1992 gillnet data is also suspect; the best-fit parameterization appears to overestimate length at age for younger smaller char, and underestimate length at age for older larger individuals. Atlin char growth may occur in stanzas associated with the transition from omnivory to piscivory as has been noted for lake char populations elsewhere; such growth might be better described by two independent curves.

Table 7.—Brody - Bertelanffy (BB) growth parameters for Atlin Lake angling samples. **Type** indicates collection method (A = angling, G = gillnet). **N** gives the sample size. Explanation of fitted versus empirically-determined L_{∞} is given in the text. Unit is mm for fitted and empirical L_{∞}, and yr for A500 and A400. K is dimensionless.

			Fitted L_{∞}				Empirical L_{∞}			
Year	**Type**	**N**	**L_{∞}**	**K**	**A500**	**A400**	**L_{∞}**	**K**	**A500**	**A400**
1980	A	68	592	0.120	15.6	9.4	729	0.074	15.8	10.8
1982	G	73	921	0.070	11.3	8.2	814	0.085	11.2	8.0
1983	A	29	776	0.091	11.3	7.9	761	0.095	11.3	7.9
1992	G	64	806	0.105	9.2	6.5	787	0.109	9.3	6.5
1992	A	18	1185	0.062	8.8	6.6	970	0.096	7.6	5.5

Table 8.—Brody - Bertelanffy (BB) growth parameters for Atlin Lake char samples. **Type** indicates collection method (A = angling, G = gillnet). **N** gives the sample size. Explanation of fitted versus empirically-determined L_∞ is given in the text. Unit is mm for fitted and empirical L_∞, and yr for A500 and A400. K is dimensionless.

Year	Type	N	L_∞	$L_\infty \pm 2SE$	A500	A500 ± 2SE
1980	A	68	592	456 - 728	15.6	14.2 – 17.0
1982	G	73	921	669 - 1173	11.3	11.0 – 11.6
1983	A	29	776	468 - 1084	11.3	10.1 – 12.5
1992	G	64	806	378 - 1234	9.2	8.6 – 9.8
1992	A	18	1185	365 - 2005	8.8	7.4 – 10.2

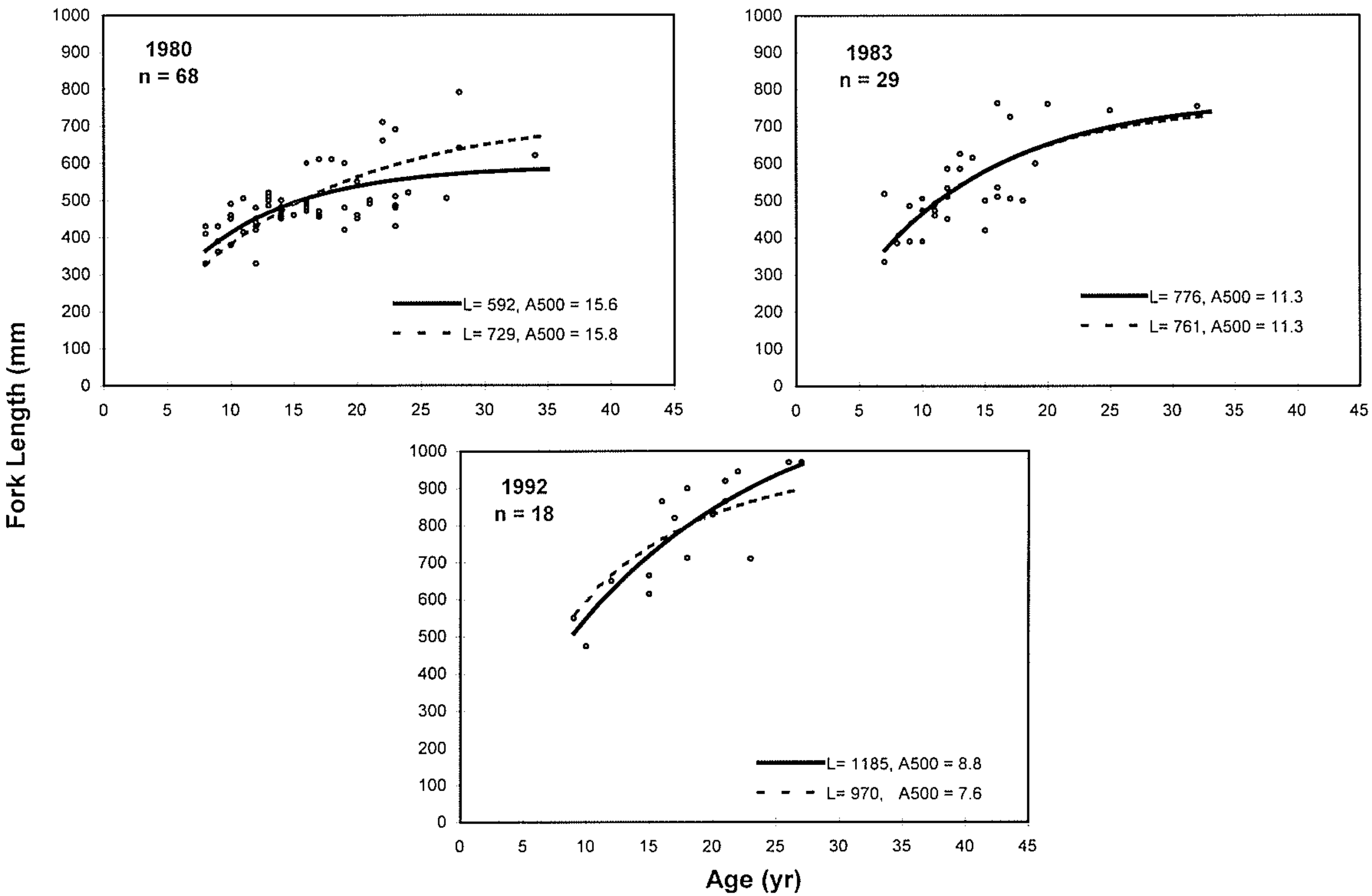

Figure 6.—Lake char length at age and Brody - Bertelanffy (BB) growth parameters for Atlin Lake angling samples. Solid lines depict standard BB fitting forced through the origin; broken lines depict BB fitting with L_{∞} determined empirically.

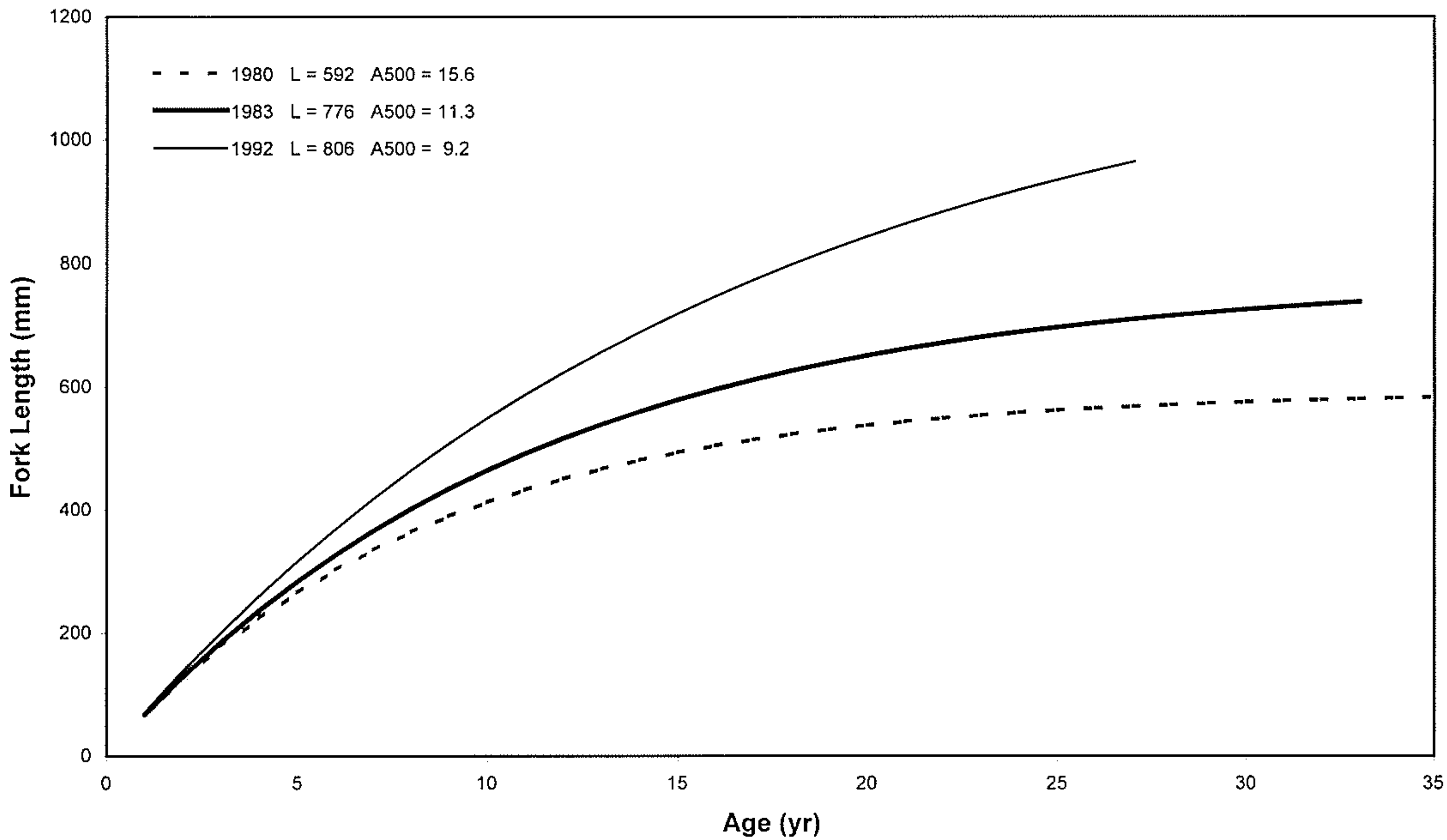

Figure 7.—Brody-Bertelanffy model fit to Atlin Lake char data obtained by angling, 1980, 1983 and 1992. Method for model fit described in the text. Age structures were otoliths for the first two years' data, and fin rays in 1992.

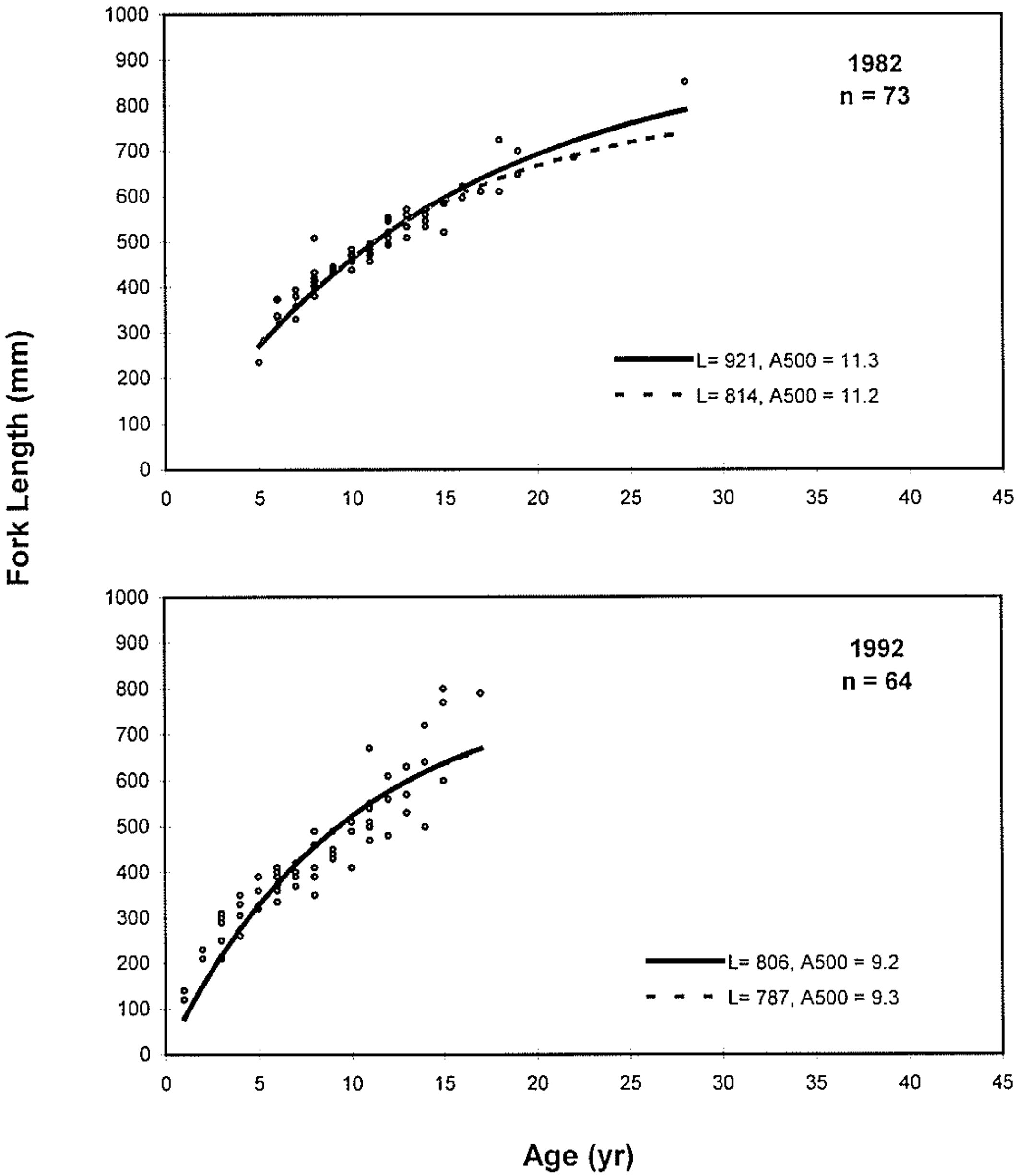

Figure 8.—Lake char length at age and Brody - Bertelanffy (BB) growth parameters for Atlin Lake gillnet samples. Solid lines depict standard BB fitting forced through the origin; broken lines depict BB fitting with L_{∞} determined empirically.

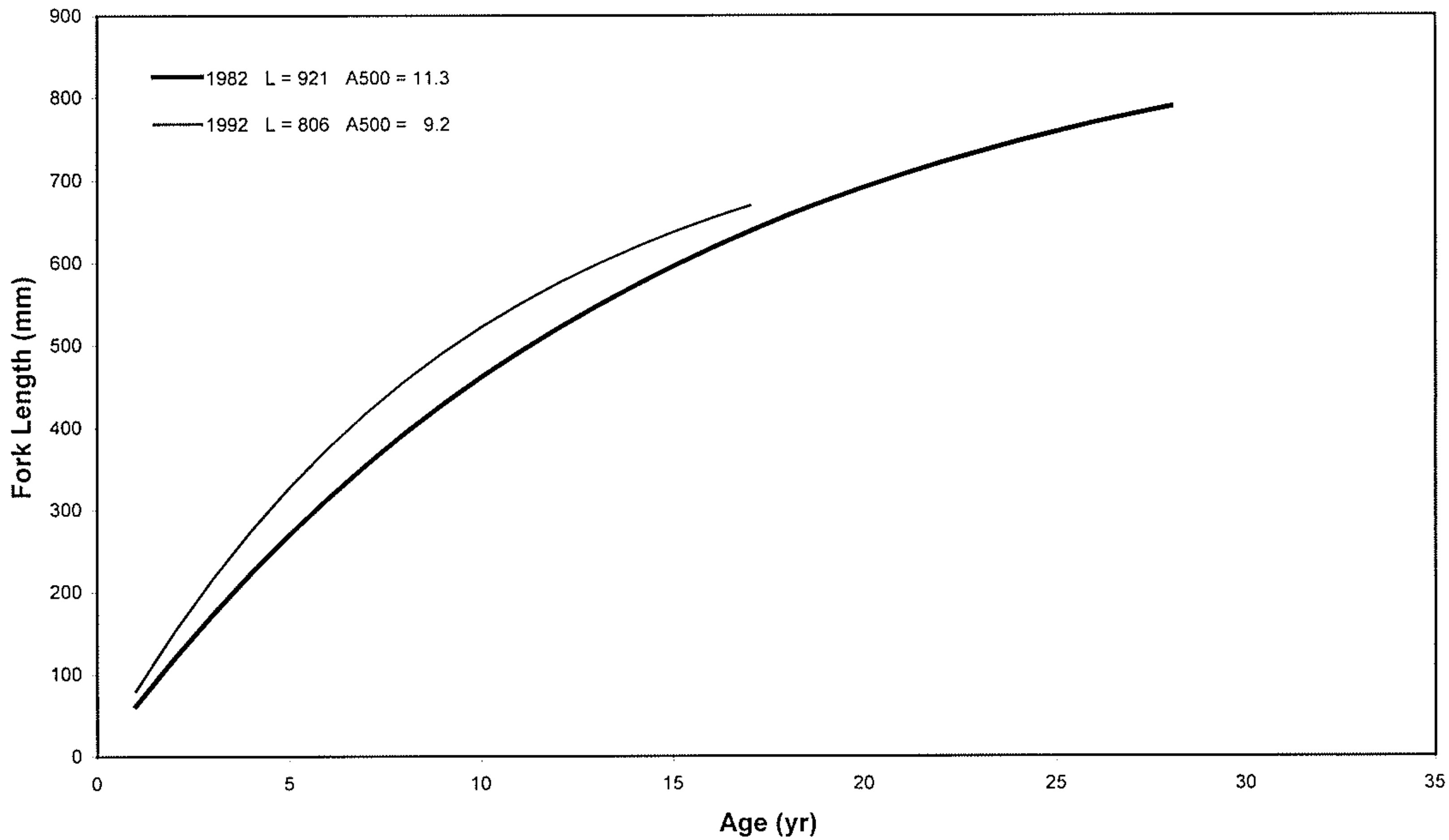

Figure 9.—Brody-Bertelanffy model fit to Atlin Lake char data obtained by gillnet, 1982 and 1992. Method for model fit described in the text. Age structures were otoliths for 1982, and fin rays in 1992.

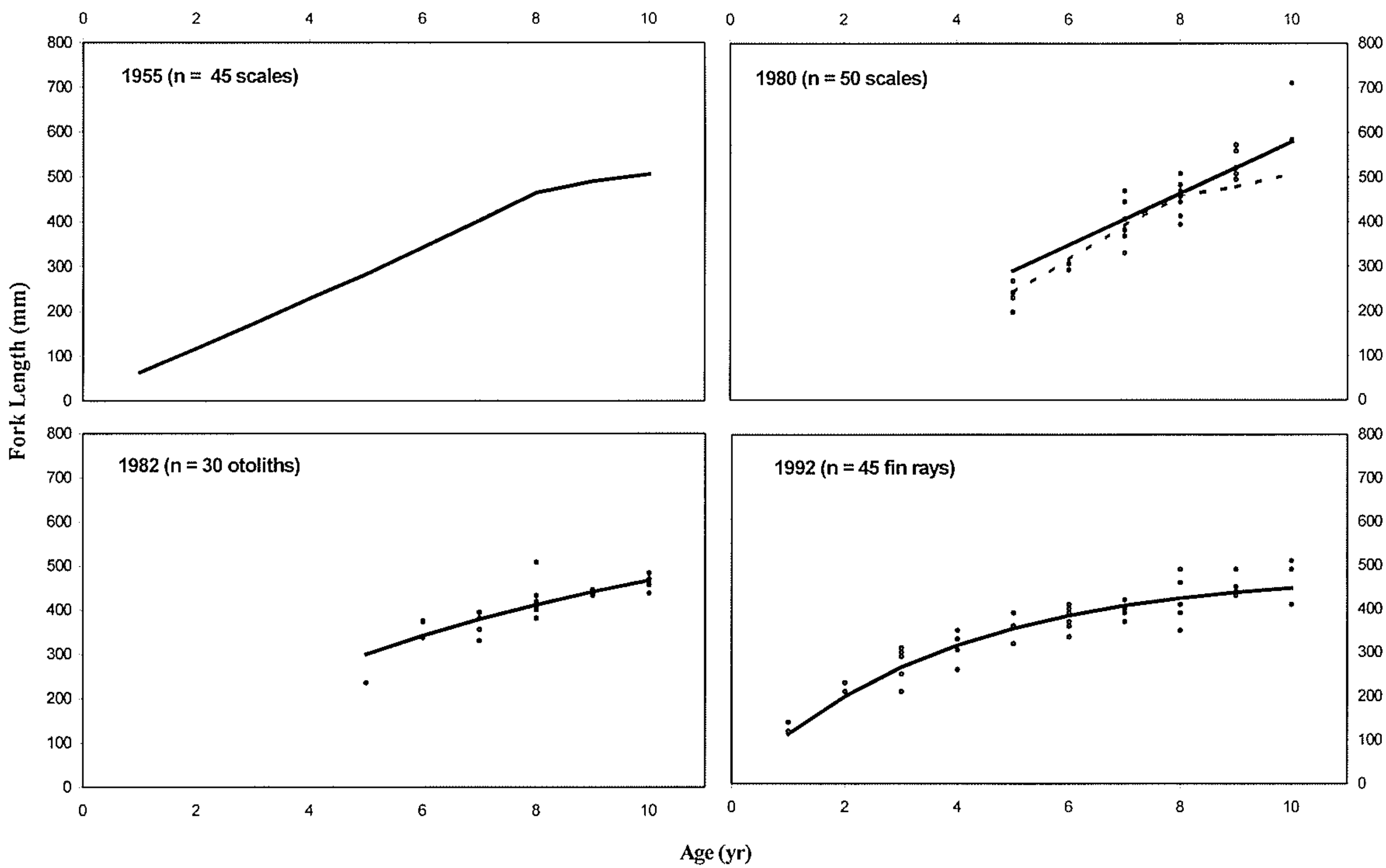

Figure 10.—Size at age for age classes 10+ yr and less, Atlin Lake char samples 1955, 1980, 1982 and 1992. Heavy lines show the Brody-Bertelanffy model fit to each data set, except 1955 for which only means are available. For 1980, the available raw data (50 fish) differ from the reported means of the full sample of 122 fish; the dashed line shows the age-specific means of the full sample.

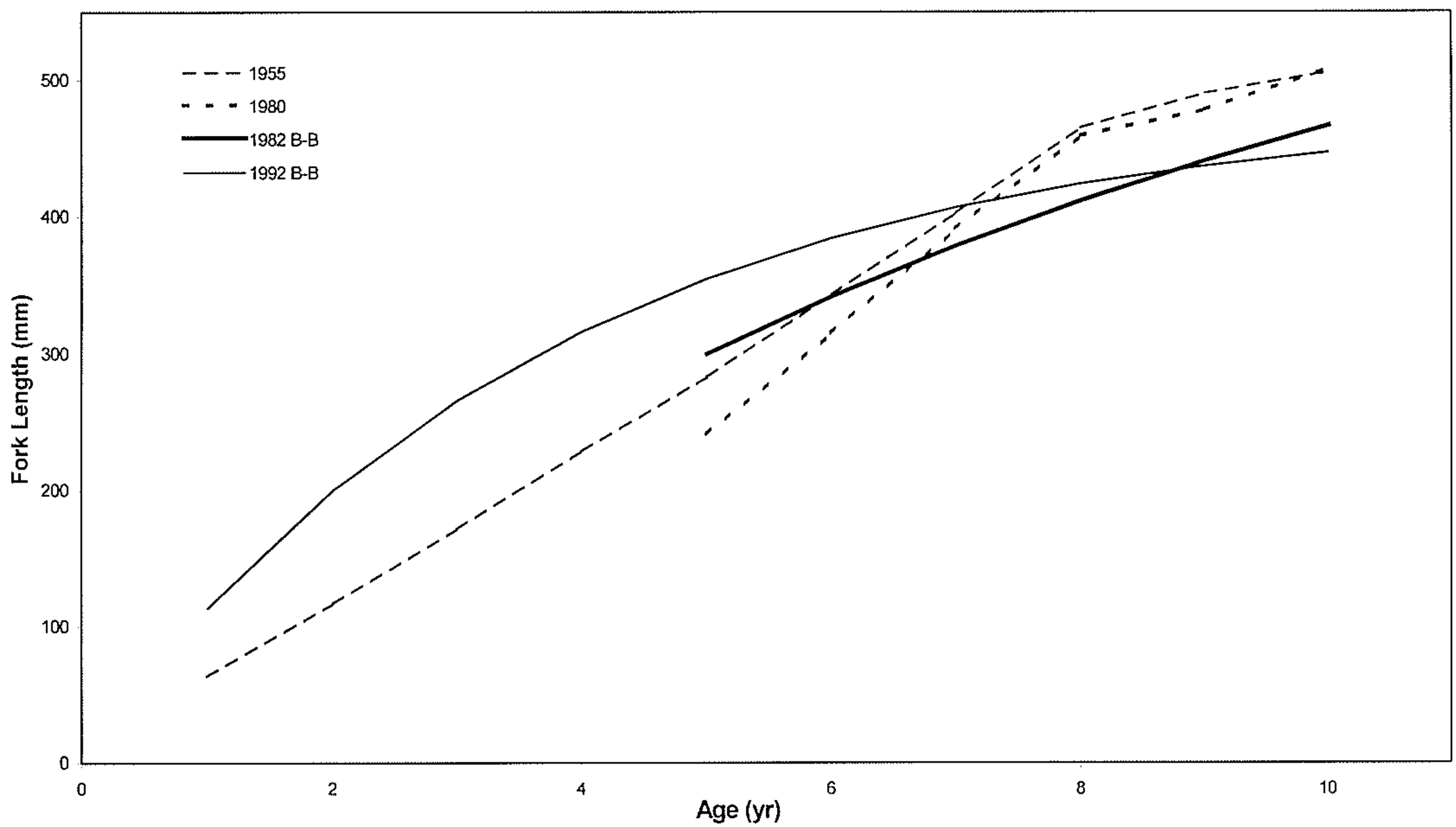

Figure 11.—Mean size at age for age classes 10+ yr and less, gillnetted Atlin Lake char samples 1955 and 1980 (aged by scales), and Brody-Bertelanffy model fit to data sets from 1982 and 1992 (aged by otoliths and fin rays respectively).

Table 9.—Age at maturity for selected lake trout populations in Skeena Region. Included are sampling efforts which used otoliths or fin rays for age determination and recorded sexual maturity of captured lake trout. Data are tabulated by gender: **Unknown, Male and Female**. **N** gives the sample size, **Min age** is the minimum age (yr) recorded for the sample, **Yng mat** is the youngest age of a sexually mature individual of the gender sample, and **Old imm** is the oldest age of a sexually immature individual of the gender sample. **AR_{50}** designates the gender-specific mean age of reproduction, estimated only for samples n > 30.

Water	Year	Gender Unknown				Female					Male				
		N	Min age	Young mat	Old imm	N	Min age	Young mat	Old imm	AR_{50}	N	Min age	Young mat	Old imm	AR_{50}
Atlin	**1982**					33	7	8	13	**10.5**	36	5	8	11	**9.5**
Atlin	**1992**					35	1	9	9	**9**	29	2	7	11	**9**
Blue Swan	**1996**	23	5	9	13	21	9	9	11	**10**	14	12	12	17	**14.5**
Captain	**1996**	17	3		11	15	4	6	6	**6**	15	2	8	10	**9**
Tagetochlain	**1989**	1	4		4	28	5	9	15	**12**	24	5	13	19	**16**
Tutshi	**1987**	4	5		7	17	9	12	19	**15.5**	17	8	11	11	**11**
Upper Tootsee	**1996**	12	4		12	22	7	7	8	**7.5**	15	6	7	6	**6.5**

Table 10.—Length at maturity, Atlin Lake char. For each year, the row labeled **%** gives the percentage of fish in the length class which were reproductive (maturing, mature or spent). The row labeled **N** gives the sample size for the length class. Length class labels are *mid-points* of bins: i.e. 225 includes fork lengths of 200 to 249 mm.

Year		Length class (mm)														
Total N		175	225	275	325	375	425	475	525	575	625	675	725	775	825	875
1982	%		0		0	18	78	85	96	100	100	100	100			100
115	N	0	1	0	4	11	18	20	28	16	5	2	3	0	0	2
1992	%		0	0	0	0	22	88	67	67	100	100	100	100	100	
64	N	0	5	3	8	12	9	8	6	3	4	1	1	2	1	0

3.5.3. Sexual Maturity

Table 9 presents age at maturity for Atlin Lake char, and other Skeena lake char populations for which a data set meeting minimal sample size requirements was available. Samples for Atlin Lake 1992 displays gender-specific age at reproduction slightly lower than the 1982 sample. Atlin char age at reproduction is intermediate relative to those displayed by the limited number of other Skeena Region lake char population whose sample sizes allow a reasonably confident estimation of this parameter.

Length at maturity (LM_{50}) for Atlin Lake char, and for other Skeena Region char populations, is presented in Table 10 and Table 11. For 1992, Atlin Lake char LM_{50} is slightly higher (475 mm) than in 1982 (425 mm). Differences in seasonal timing of sampling prevent any firm conclusion about whether this population parameter truly differed between the two years' samples. Atlin char length at maturity is high, relative to other Skeena populations (Table 11).

Table 11.—Length at maturity for Skeena Region lake trout populations with maturity sample N >30. **Total N** gives the maturity sample size. Individuals recorded as maturing, mature, or spawning / spent were considered mature. Percentage of individuals reproductive was tabulated by 50 mm fork length class (genders pooled), as described in the text. $\mathbf{LM_{50}}$ is the shortest length class for which at least 50% of individuals were mature. Asterisked value of LM_{50} indicates that although more than 50% of individuals were reproductive in the length class given, longer length classes also displayed less than 50% maturity.

Water	Year	Total N	LM_{50}
Aconitum Lake	1996	53	275
Atlin Lake	1982	115	425
Atlin Lake	1992	64	475
Blue Swan Lake	1996	59	325
Captain Lake	1996	51	375
Cold Fish Lake	1994	41	375
Cry Lake	1985	32	425
Eaglehead Lake	1980	53	375
Kahan Lake	1996	50	375
Kedahda Lake	1991	41	525
Long Lake	1996	35	375
Lower Nome Lake	1996	48	* 425
Melgard Lake	1996	57	375
Moose Lake	1980	31	275
Nome Lake	1996	35	425
Ruth Lake	1997	31	325
Tagetochlain Lake	1989/90	64	575
Turnagain Lake	1980	53	275

3.5.4. *Estimated Sustainable Yield*

3.5.4.1. Thermal Habitat Volume

Appendix IX provides elements of the calculation of lake char THV for Atlin Lake in July, based on thermal profiles provided in Withler (1956). None of the July 1955 profiles exhibited water temperature greater than the char upper THV threshold of 12°C. Dissolved oxygen data are not available but it is very probable that the concentration was above the lower THV threshold of 6 mg/L throughout the Atlin Lake epilimnion in that month (Kirkland and Gray 1986). For these reasons, the only relevant detail in estimating THV for these profiles is the depth of the 8°C isotherm (Appendix Table VI), and the method chosen to integrate information across stations and dates. The following computational approaches were applied:

(1) estimate a single July thermal profile by arithmetically averaging temperature at depth for all stations and dates; the resulting yield estimate is 94,066 kg/yr or **1.48 kg/ha/yr**;

(2) estimate a single July thermal profile by geometrically averaging temperature at depth for all stations and dates; the resulting yield estimate is 74,770 kg/yr or **1.18 kg/ha/yr**;

(3) estimate a single thermal profile for each of three July dates by arithmetically averaging temperature at depth for all stations; estimate THV for each date and geometrically average[12] July THV; the resulting yield estimate is 11,862 kg/yr or **0.19 kg/ha/yr**;

(4) estimate the THV represented by each station on each date, by assigning each station an area equal to one-third of the lake's surface area; sum the resulting THVs for each date and geometrically average the THVs for the three dates; the resulting yield estimate is 81,196 kg/yr or **1.28 kg/ha/yr**.

Limited data are available to assess whether thermal conditions of the water column in July 1955 were typical of the mid-summer season for Atlin Lake. Reid Crowther and Partners (1983) report surface water temperature for 5 Atlin Lake sites on July 6-7, 1982 (mean = 13.6°C; median = 13.1°C; range 12.2 to 15.3°C) which are much higher than surface water temperature measurements at the 3 stations on July 7, 1955 (mean = 7.0°C; median = 6.7°C; range 5.6 to 8.8°C). Although Withler (1955) mentions a south to north positive gradient in surface temperature, the precise location of the three stations in 1955 are not given so their comparability to the 1982 sites is not known.

Payne et al. (1990) discuss the relationship of lake char yield to the morphoedaphic index for the 20 lakes used to develop their THV model, but present only the lake physical characteristics and not the morphoedaphic or water chemistry data. Atlin Lake is deeper than all but one of the THV model lakes. Using the thermal profile for July 1955 obtained by arithmetically averaging temperature at depth, as in approach **(1)** above, the relative thickness of the Atlin Lake thermal habitat volume is greater than for any of the THV model lakes (THV divided by lake surface area, Appendix Table VI).

[12] For this case the July 7 THV is 0, which cannot be geometrically averaged, so a surrogate value of 1 was used in its place. The geometric mean is of course extremely sensitive to this surrogate value.

Table 12.—Estimated depth (unit = m) of the 8°C isotherm at each of 3 Atlin Lake sampling stations on July 7 and July 30, 1955. N/A indicates that the entire water column exhibited temperature less than 8°C. For each date, the column headed **Mean** gives the depth of the 8°C isotherm for a hypothetical thermal profile calculated by averaging the temperature at depth for the 3 stations on that date. Estimates for July 18 were calculated by linear interpolation of temperature at depth on July 7 and July 30. THV estimate unit is cubic hectometres. THV estimates for each station utilize an area equal to one-third of Atlin Lake's surface area. Other computational details are provided in the text.

Date	**7-July-1955**				**30-Jul-1955**				**18-Jul-1955 (interpolated)**			
Station	**1**	**2**	**3**	**Mean**	**1**	**2**	**3**	**Mean**	**1**	**2**	**3**	**Mean**
Depth of 8°C	N/A	N/A	18.3	N/A	18.3	24.4	32.0	22.9	N/A	9.1	30.5	15.2
THV (hm^3)	0	0	3,615	0	3,615	4,707	5,987	13,330	0	1,862	5,741	9,003

3.5.4.2. Partitioned Morphoedaphic Method

Table 13 presents sustained yield partitioned by 1992 species-specific gillnet biomass, calculated by Yukon Territory Renewable Resources methods (Thompson 1996). Estimated MSY for Atlin Lake char is 42,830 kg/yr or 0.68 kg/ha/yr. To maintain "high quality" lake char sport fisheries, Yukon Territory methods suggest an annual harvest of no more than 10 to 15 % of the estimated biomass-proportioned MSY for lake char (Thompson 1996; Toews 2000). For Atlin Lake, annual harvest of char could not exceed 6,425 kg or 0.102 kg/ha to meet the 15% criterion, and 4,280 kg or 0.068 kg/ha to meet the 10% criterion.

Table 13.—Estimated biomass captured per species by 6 sinking gillnet sets during June 1992, and biomass-proportioned maximum sustained harvest (**MSH**) and MSY estimated from MEI for Atlin Lake. MSY values do not sum to the indicated total due to rounding.

Species	**Estimated Biomass (kg)**	**Percentage of Biomass**	**MSH (kg) for Atlin Lake**	**MSY (kg/ha/yr)**
Lake char	66.255	52.7	**42,830**	**0.68**
Grayling	17.310	13.8	11,190	0.18
Round Whitefish	23.073	18.4	14,920	0.24
Lake Whitefish	12.932	10.3	8,360	0.13
Least Cisco	6.066	4.8	3,920	0.06
Total	**125.636**	**100**	**81,220**	**1.28**

4. Discussion

4.1. Status of the Atlin Char Information Base

A broader collection of fish population information exists for Atlin Lake than for any other char lake in Skeena Region. Data sets from 1955, 1980, 1982, 1983 and 1992 would appear to provide good temporal scope, for detection of trends in population parameters which might indicate changes in resilience of the population to exploitation. Unfortunately, shortcomings of each dataset limit their utility for inferring trends in Atlin Lake char population density.

1. Gillnet samples prior to 1992 were collected by nonstandard methods, and characteristics that would allow precise estimation of effort and thus relative abundance were not always reported.
2. Available data from 1983 and 1992 angling samples are unsuited to comparison of the relative abundance of age or size classes. No effort information is available. Differences in size and thus age selectivity of the 1992 angling derby data relative to the 1983 creel survey are likely significant.

In the absence of direct or relative information about fish abundance, size at age can offer an alternative indicator of population trends. When exploitation or reduced recruitment depresses fish population density, growth of the remaining individuals may respond positively due to greater availability of food or other resources. Other population characteristics such as size- or age-specific maturity schedules can also provide evidence about population density (Healey 1978a; Healey 1978b). Again, shortcomings of the available datasets lead to low confidence in their interpretability.

1. Sample sizes are inadequate at accepted levels of statistical certainty, and only marginally adequate for exploratory analyses.
2. There has been no consistency in age structures utilized, or the personnel or laboratory performing the age analyses.
3. Lake char reproductive maturity is difficult to determine, and criteria for maturity categories have not been recorded so inter-year consistency is difficult to evaluate.

In summary, although a moderate quantity of historical data are available for Atlin Lake char, inconsistency in methods and incomplete documentation hinder their use for assessing historical trends in population parameters. The need for future acquisition of consistently-obtained data of appropriate quantity is reiterated in subsequent sections. Tentative inferences which can be made from the existing dataset, including comparison to population parameters for lake char elsewhere in Skeena Region and the southwestern Yukon Territory, are given in the next section.

4.2. Status of the Atlin Char Population

Previous discussion emphasized the inability of the historical dataset to shed strong light on any trend in abundance of Atlin Lake char. Although the Atlin Lake watershed is predominantly unroaded wilderness at present and much of the lake is relatively inaccessible during open water, it is clear that the char population has experienced varying but substantial exploitation during the last century. The intensity of net fisheries during the first half of the twentieth century is not well documented, but was likely significant in some decades, and considerable harvests have been taken intermittently during the 1970s and 1980s by the commercial fishery. The historical commercial exploitation is relevant due to the long life span of lake char, and in combination with the more recent recreational fishery on the lake implies that the present char population should not be expected to display characteristics of a pristine stock. Available data support that assertion; the paucity of old char (age > 25 yr) in the 1992 data is a caution flag, but the low sample sizes and the shift in age determination methodology in 1992 both lend uncertainty to any conclusion about over-exploitation.

Comparison of 1982 and 1992 gillnet data suggests that the expanding recreational fishery during the 1980s did not differentially impact abundance of very large lake char (those ≥ 600 mm FL) relative to all char longer than 400 mm FL. Confidence in this assessment is hampered by differences in mesh size and seasonality of sampling between the years, and the low number of sets in 1992. The data cannot be used to assess whether char longer than 400 mm FL were as abundant in 1992 as in 1982, either in absolute terms or relative to the abundance of char less than 400 mm FL in length in those years.

Atlin Lake char population density, as revealed by gillnet CPE, is higher than for most roadside lakes in the region and in the Yukon Territory but lower than for most Skeena Region aircraft-access char lakes. These results are not surprising, although the magnitude of the difference between Atlin Lake and the Yukon Territory char lakes was unexpected, as was the generally higher CPE for Skeena Region lake char lakes than for those in the Yukon Territory. Confidence in the results of comparisons with Yukon Territory data must again be tempered by differences in methodology. The Yukon Territory results are based on sets of 24 hr soak time, and lake char CPE appears negatively correlated with soak time. Longer soak time for Yukon Territory sets would thus exaggerate the difference between Yukon Territory and British Columbia lake char gillnet CPE. Current Yukon Territory methods utilize a high number of very short sets. This can reduce sample mortality and may improve estimate precision, but the correlation of CPE with soak time will make it difficult to compare recent results with previous data from long sets of 12 or 24 hr.

In terms of growth, the 1982, 1983 and 1992 estimates of L_∞ for Atlin Lake char are statistically indistinguishable based on the bootstrapped standard errors, due to high variance in length at age and small sample sizes. However, the 1980 age sample displays growth to an L_∞ which is lower than the values estimated for later years, and the difference does appear statistically reliable. The lack of variability in the 1982 length at age is particularly suspicious and suggests that aging was not independent of length data, which could have led to upward bias in the estimate. Length-at-age variability of the 1980 sample is higher than later years, due to the presence of a greater number of fish which are relatively old for their size. A number of possible explanations exist, but the data do not allow distinction between them. An additional caution note is warranted due to the use in 1992 of fin rays, which can underestimate otolith ages by a varying amount (De Gisi 2000). In summary, despite the lack of statistical rigor and the variation in methods, the available data do *suggest* that lake char size at age has increased through time at Atlin Lake. In the absence of reliable information about population density, the size-at-age information should be treated as a definite caution flag indicating the need for more and better data, or cautious management, but preferably both.

4.3. Sustainable Harvest

In Canadian jurisdictions, one approach to estimation of potential sustainable harvest of lake char has been regression modeling of lake physiochemistry and bathymetric data. Morphoedaphic predictors have a longer history of use, but investigation by the Ontario Ministry of Natural Resources has suggested that thermal habitat volume may provide a better indication of potential aggregate yield (Christie and Regier 1988; Payne et al. 1990). In the following sections, each of these methods is discussed with respect to available data for Atlin Lake.

4.3.1. Thermal Habitat Volume

Estimates of July 1955 thermal habitat volume for Atlin Lake vary widely depending on the method of computation. The typical pattern of thermal stratification for temperate lakes is the development of a well defined summer epilimnion, with a surface stratum which becomes warmer than preferred by lake char. Weather and the influence of glacial inflow may differentiate Atlin Lake from the lakes in the analysis of Payne et al. (1990). Runoff from snowmelt is mostly complete in the Atlin Lake area by early June, but peak flows from glacial sources occur in about mid-August (Kirkland and Grey 1986). Glacial inflow may cause thermal turbulence in the epilimnion and reduce the thermal gradient considerably (Wetzel 1983). This may in turn allow wind-driven deep convective mixing to continue until later in the summer, and depending on weather may result in a deep thermocline and cool epilimnion which lacks a surface layer that is too warm for lake char. The thickness of the August 1955 THV was much greater for Atlin Lake than for any lake of comparable size in the dataset used to establish the char yield relationship (Payne et al. 1990). The net result is that Atlin Lake appears to provide a large volume of lake char thermal habitat for its size, when compared with char lakes in the THV analysis. To a degree, the thermal character of Atlin Lake (at least from the 1955 data) places it outside of the range of prediction for the THV model of Payne et al. (1990). In other words, alternate constraints on biological production may occur in the case of lakes such as Atlin, though the model cannot suggest when or how.

As well, it is unknown whether July 1955 Atlin Lake thermal conditions were accurately measured and were even approximately representative of average conditions. Limited data available for 1982 differ greatly from those of 1955; more detailed data were collected by the National Hydrology Research Institute study in 1982 (Kirkland and Gray 1986) but were inaccessible at time of writing. Regardless, either year or both could be anomalous.

In short, doubts remain if available thermal data for Atlin Lake are representative, as well as questions about whether the THV model can be extended to lakes with strong mid-summer glacial influences. The uncertainty in computing THV for Atlin Lake is symptomatic of the latter issue. Although further investigation is warranted, the THV model cannot be presently recommended as a basis for estimating potential char yield of the lake. Following sections present additional discussion of Atlin lake chemistry, turbidity and thermal conditions and their possible impacts on biological production, which might also be relevant to any future consideration of THV as a basis for char yield estimation for glacial lakes.

4.3.2. Partitioned Morphoedaphic Method

There are a number of general objections to the partitioned morphoedaphic approach to estimation of potential sustainable harvest of lake char. The partitioning of yield by species, using survey gillnet catch, assumes that each species' abundance in the lake is accurately represented in the net samples. However, gillnets are notoriously selective on the bases of fish species, size and behaviour and there is abundant reason to suspect that lake trout might be over-represented in survey gillnet catch, on a biomass basis. Even if species' gillnet catch were proportional to standing crop, sustainable yield is a function of production not standing crop. Late-maturing and low-fecund predator species such as lake char are less productive in terms of yield per unit of biomass.

Notwithstanding these objections, the partitioned morphoedaphic method has been applied in the Yukon Territory for management of char lakes, by reducing the estimated sustainable yield to 10 to 15% of the MEI - MSY value for the species. Adjusting the sustained yield to a relatively low fraction of the initial morphoedaphic estimate could alleviate over-prediction of the lake char component of all-species yield, which stems from gillnet sampling details explained previously. Reducing harvest below the potential maximum is also necessary to maintain other sport fishery attributes, such as catch rate and fish size, at levels which optimize recreational values. Finally, use of a low fraction is a cautious response to the very high uncertainty of the underlying regression predictor.

As discussed previously, the glacial nature of Atlin Lake may influence characteristics relevant to physiochemical modeling of fish production. In the morphoedaphic method of estimating potential yield, TDS is an easily-measured surrogate for nutrients that provide the underpinnings of aquatic biological productivity. In northern temperate lakes, availability of phosphorus or nitrogen is usually believed to limit primary production. Reconnaissance inventory data for other Skeena Region lakes provide a weak basis for assessing whether phosphorus and nitrogen concentrations in the Atlin Lake epilimnion are typical of other Skeena Region lakes which display similar levels of TDS. Minimum detectable concentrations are inconsistent in the inventory dataset, and are often higher than appropriate given the nutrient-poor status of most lakes in the region. Despite the weakness of the data, review suggests that [P_{total}] for Atlin Lake is lower than for most Skeena Region lakes of comparable TDS though the data for [N_{total}] are less definitive. In addition, the particulate phosphorus fraction is a high proportion of Atlin Lake total phosphorus loading. Bioavailability of particulate phosphorus is variable but would have a significant effect on the overall phosphorus bioavailability (Gray and Kirkland 1982). The glacial source of Atlin Lake suspended sediments suggests that they are high in apatite, and that bioavailability of particulate phosphorus would be low (Kirkland and Gray 1986).

As well as low phosphorus concentration, the glacially-aided sustained deep convective mixing of Atlin Lake probably inhibits algal production by mixing cells to depths below the photosynthetic compensation point (Kirkland and Gray 1986). Glacial turbidity also limits primary production by light attenuation in the southern portion of the lake.

4.3.3. Summary

The predictive power of physiochemical sustainable yield models is extremely marginal. Typically, the area component explains an extremely high proportion of variation, and physiochemical data provide little gain. Confidence intervals for yields predicted from the THV regression are generally an order of magnitude in width; those for the all-species morphoedaphic regression are initially narrower but the additional variance associated with species partitioning probably renders the total uncertainty of char yield estimates similar in magnitude to those of the THV method (Payne et al. 1990).

Despite the stated objections and uncertainty, the partitioned MEI approach provides a starting point for expectations about the potential harvest biomass which lake trout populations might provide while continuing to sustain a quality fishery. Given the glacial influences and nutrient-poor limnology of Atlin Lake, it appears that the Yukon Territory 10% criterion would provide the most appropriate initial target for maximum harvest. Management experience for large lakes in the Northwest Territories has suggested that sustained harvests of 0.05 kg/ha/yr or less can be necessary to maintain 'trophy' recreational fishery characteristics for nutrient-poor char lakes (De Gisi 2000); the 10 % criterion for Atlin Lake would result in a maximum harvest which is about 0.02 kg/ha greater than that value, or about 1000 kg greater annually for the lake as a whole. Depending on the results of field work during year 2000, the lower value of 0.05 kg/ha/yr may appear more appropriate.

While the adjusted MEI prediction for yield provides a starting point, it is an aggregate estimate and does not model the char population parameters and fishery characteristics which are relevant to management. Canadian lake char fisheries vary widely, and British Columbia char angler values have not been quantified. For many participants, retaining char is of greatest importance, while other anglers are interested in hooking and playing trophy individuals but are satisfied with releasing much or all of their catch. In some cases, individual lakes may be managed to maximize either harvest or catch, but usually a balance is sought in order to allow a variety of recreational experiences. In addition to preserving non-harvest attributes of the recreational fishery, holding angling yield below the potential maximum reduces the risk of overexploitation.

Many Atlin residents place great value on the opportunity to harvest char from the lake. Clients of Atlin angling guides may be motivated less by harvest opportunities and more by the possibility of catching very large char, although not necessarily so. Atlin Lake char management will continue to involve a tradeoff between allowing harvest opportunities and maintaining sufficient abundance (and thus catch rates) of large char. This dynamic is not depicted in the MEI regression approach; nor does the MEI method model the parameters of the lake char population and fishery which determine production and yield and which are amenable to monitoring. As a result, decisions about the impact and effectiveness of angling regulation regimes are not facilitated by this approach.

One management alternative would be a simulation model of lake char population and fishery dynamics, which explicitly represents age and gender-specific population characteristics of abundance, growth, and sexual maturity. Such a model could be of sufficient complexity to allow the examination of regulation scenarios, yet simple enough to use in presentations or workshops with the public. The province of Ontario developed this type of software in the early 1990s (Ontario Ministry of Natural Resources 1992), but a more flexible tool could easily be developed on MS Excel or another current spreadsheet.

4.4. Other Management Considerations

The possibility of greater population density of lake char in Atlin Lake than for most road-accessible lakes in the Yukon Territory suggests that Atlin residents do have cause for concern about the maintenance of the present qualities of "their" fishery. If char relative abundance is higher at Atlin Lake than for most Yukon Territory lakes, resulting in higher angling catch rates, the Atlin fishery is likely to attract Yukon Territory anglers when a transboundary licencing agreement is implemented. Char harvest from the lake may increase relatively rapidly in the initial years of the agreement. Avoiding char population depletion will require collection of creel and char population data in these years, and agency willingness to adjust regulations quickly. The paucity of suitable historical data for comparative purposes necessitates conservative management during the fishery's transition period.

Summer weather in the Atlin area is relatively unstable. Prolonged periods of windy conditions can occur. Navigation on Atlin Lake is dangerous for small craft during such weather, which minimizes angling activity at those times. As a result, interannual variability in recreational fishery effort and catch may be high. Several consecutive years of creel study will be necessary initially to quantify the potential variability, which should be recognized in the management and monitoring plan for the fishery. Some of the negative reaction of Atlin residents to regulation changes in the early 1990s related to the frequently unfishable condition of the lake. Atlin Lake anglers argued that because weather conditions sufficiently calm to allow safe angling can occur relatively infrequently, and most of their catch is longer than 50 cm, a daily harvest limit of one char longer than 50 cm is overly restrictive. An angling use study conducted on Atlin Lake during the summer of 2000 should provide information about how often the present regulation does restrict anglers' harvest. However, a less-restrictive regulation which assumes frequent bad weather could lead to overharvest in years with abnormally calm conditions. An annual individual catch quota, such as currently in place for Shuswap Lake, could allow a higher daily limit to give local anglers greater flexibility without substantially increasing the risk of overexploitation.

Although creel studies might appear to provide indices of abundance (catch per angler hour or similar) which could be used to infer stability of char population density, comparison of angling catch rates through time can be problematic if anglers are becoming more efficient through learning or technological changes. For instance, downriggers, sonar and positioning systems have all likely contributed to increased angling effectiveness for lake char over the last two decades in North America. For this reason, short-set small-mesh survey netting will continue to be needed as a population monitoring technique unless an alternative approach can be developed.

Whether a particular angling mortality regime is sustainable, in terms of the fish population and fishery characteristics which are considered relevant, must be learned through management experience on a much longer time scale given the life history of lake char and the dynamic natural environment. That experience can only be gained if fishery and char population attributes are monitored consistently at a suitable interval across decades, not years. Cooperation between British Columbia and Yukon Territory fisheries agencies on transboundary waters could allow the jurisdictions to share the expense and expertise needed to refine lake char monitoring and management procedures, and perhaps compensate for the deficits of the present historical data set.

5. Recommendations

(1) A comprehensive survey of lake trout relative abundance is planned for the summer of 2000, using short sets of experimental gillnets as currently practiced in the Yukon Territory and other management jurisdictions. The survey should collect both fin rays and otoliths from any char mortalities so that assessment of their comparability for aging Atlin Lake char can be made.

(2) Design of the survey should also give careful consideration to determination of sexual maturity. Individuals conducting the survey should have received instruction in the use of a well-defined set of criteria for maturity determination. Collection and preservation of gonads in various states of maturity from char mortalities would be useful for future training purposes.

(3) Angling use studies planned for Atlin Lake should be designed to capture as much information as possible about the number and size of *released* char catch, as well as the harvested catch. Both types of information are needed in order to evaluate how harvest might change in response to modification of regulations.

(4) The commercial fishery on the Yukon Territory portion of Atlin Lake should be subjected to a sampling program, with collection of :

- char life history data from catches so that changes through time in length at age or maturity schedules may be detected, and
- some measure of netting effort in order that char relative abundance in the fishery can be monitored.

(5) Following the transition period related to the transboundary licencing agreement, consistent long-term monitoring of the Atlin Lake char stock and fishery should occur, with sampling population sampling and creel studies at an interval equal to about one-half the estimated age at maturity, or five years.

(6) BC Environment and Yukon Territory Renewable Resources should collaborate on the development of a lake char management model which explicitly represents age and gender-specific population characteristics of abundance, growth, and sexual maturity. Such a model should be of sufficient complexity to allow the examination of regulation scenarios, yet simple enough to use in seminars or workshops with the public.

(7) BC Environment and Yukon Territory Renewable Resources should agree upon quantitative targets for characteristics of the Atlin Lake recreational fishery for lake char based on attributes of the fishery which are revealed by the angling use study in summer 2000; these may include angling CPE and size structure of the catch.

6. Acknowledgments

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Appendix Table I.—Correspondence pertaining to Atlin Lake, on file at BC Environment Skeena Region, Smithers.

Year	Date	Description	Folder
1980	Feb 15	Memo from M. Chudyk to R. Beamish (DFO) accompanying lake char scales	Atlin Lake – 1980
	Feb 26	Memo from B. Petrar (Atlin CO) to M. Whately giving details of lake char data and scales collected from the Jan/Feb 1980 commercial fishery	Atlin Lake – 1980
	Mar 7	Memo from R. Beamish to M. Whately stating difficulty of scale interpretation	Atlin Lake – 1980
	May 9	Memo from W. Chudyk to B. Petrar regarding collection of data and age structures (otoliths) from the 1980 Atlin Lake sport fishery	Atlin Lake – 1980
	Jul 10	Memo from Fisheries Branch to DFO Whitehorse recommending closure of Atlin Lake commercial fishery in YT.	Atlin Lake – 1980
	Sep 15	Response from DFO suggesting broader reduction of harvest and requesting raw field data collected by BCE.	Atlin Lake – 1980
	Dec 15	Memo from BCE with data, again requesting closure of commercial fishery.	Atlin Lake – 1980
1981	various	Correspondence relating to the use of otoliths for lake char age determination	Atlin Lake – 1981
1982	Jan 19	Memo from DFO including historical commercial catch of lake char and whitefish (response to letter of Jan 7 which is not present in file).	Atlin Lake Com Fishing
	Jan 25	Correspondence relating to ages for samples from the 1980 sport fishery.	Atlin Lake – 1982
	May 25	Memo from BCE to DFO in Whitehorse describing harvest reductions of lake char in BC and recommending closure of the commercial fishery in the Yukon on Atlin Lake.	Atlin Lake – 1982
	Nov 22	Memo describing DFO intention of surveying Atlin Lake before revising commercial fishery. Mentions meeting between BCE and DFO on Nov 17; minutes of meeting are not present in file.	Atlin Lake – 1982
1984	Jan 20	Correspondence related to the final submission of Chudyk 1983 to the Yukon River Basin Study Committee	Atlin Lake – 1984
1985	Jan 9	Correspondence and notes relating to an application for development of a commercial tourist facility on Atlin Lake; details are not present	Atlin Lake – 1985

Appendix Table I continued.—Correspondence pertaining to Atlin Lake, on file at BC Environment Skeena Region, Smithers.

Year	Date	Description	Folder
1992	Jan 23	Letter from Atlin CO requesting lake and stream inventory in the Atlin District due to concerns about placer mining in the area.	Atlin Inventory Request
	Feb 27	Memo from S. Hatlevik to R. Hooton regarding inventory request.	Atlin Inventory Request
	Apr 10	Memo from Atlin CO advising Fisheries Branch that new regulations were not well received in Atlin.	Atlin LT Regulations
	May 13	Letter from G. Hill protesting new regulations.	Atlin Lake 1990 - 1993
	May 14	Letter from F. Musial protesting new regulations.	Atlin Lake 1990 – 1993
	May 22	Fax from S. Hatlevik to D. deLeeuw, of copy of letter from Atlin resident U. Kirschner to D. Narver protesting fishing derby and claiming decline of large lake char, and copy of reply to letter by D. Narver.	Atlin Lake 1990 – 1993
	May 27	Memo from S. Hatlevik to Colin Spence regarding a June 3 meeting about Atlin and lake char regulations.	Atlin Lake 1990 – 1993
	Jun 5	Fax from D. deLeeuw to B. Hooton, of a draft letter of response to F. Musial.	Atlin Lake 1990 – 1993
	Jun 12	Fax cover sheet, S. Hatlevik to A. Carlick (Taku River Tlingit) notifying the band of the public meeting in Atlin regarding lake char.	Atlin Lake 1990 – 1993
	Jun 17	Handwritten notes (S. Hatlevik) of summary and recommendations from public meeting in Atlin to address concerns about new regulations.	Atlin Trip
	Jul 10	Memo from D. deLeeuw to B. Hooton providing a summary of the proceedings of the June 1992 Atlin sampling trip and public meeting.	Atlin Lake 1990 – 1993
	Jul 31	Memo from L. Sunde (BCE) giving records of inland commercial fisheries, including the BC portion of Atlin Lake, 1964 through 1984/85	Atlin Lake – Com Fishing

Appendix Table I continued.—Correspondence pertaining to Atlin Lake, on file at BC Environment Skeena Region, Smithers.

Year	Date	Description	Folder
1993	Mar 22	E-mail from Large Lakes Committee (LLC) requesting input on changing lake char regulations.	Lake Char Regulations
	Mar 23	Memo from R. Hooton to LLC about the need to gather more information and develop options prior to changing lake char regulations.	Lake Char Regulations
	Mar 31 - Apr. 2	E-mails regarding proposed changes to lake char regulations.	Lake Char Regulations
	Apr 14	E-mail from R. Hooton to Victoria acknowledging that trout and char should be separated in the regulations.	Lake Char Regulations
1994	Apr 6	Letter from G. Hill requesting results from Atlin Lake 1992 field work.	Gary Hill - Atlin Lake
	Apr	Draft response by S. Hatlevik to G. Hill, explaining why 1992 data has yet to be analyzed and reported; no final copy of letter, unknown whether sent.	Gary Hill - Atlin Lake

Appendix Table II.—Lake char individual data, Atlin Lake.

Method codes: GN = Gillnet, UN = Unknown. **Length** unit = mm, **Weight** unit = g. **Sex** codes: M = male, F = female, U = Unknown / unrecorded. **Maturity** codes: IM = immature, M = mature, SP = spent. Age **structure** codes: SC = scale, OT = otolith, FR = fin ray, B = unknown bony structure (otolith or fin ray).

Year	Method	Set	Length	Weight	Sex	Maturity	Age	Structure	Comments
1980	GN		457	567	F		8	SC	S. IND. VIL.
1980	GN		521	1134	F		9	SC	S. IND. VIL.
1980	GN		508	816	F		8	SC	S. IND. VIL.
1980	GN		508	907	F		8	SC	S. IND. VIL.
1980	GN		711	2722	F		10	SC	S. IND. VIL.
1980	GN		470	680	M		8	SC	S. IND. VIL.
1980	GN		457	567	F		8	SC	S. IND. VIL.
1980	GN		521	907	M		9	SC	S. IND. VIL.
1980	GN		584	2041	F	M	10	SC	PETRAR
1980	GN		508	1361	U		8	SC	PETRAR
1980	GN		406	907	U		7	SC	PETRAR
1980	GN		483	1200	M		8	SC	ATLIN SCOTIA
1980	GN		483	1300	M		8	SC	ATLIN SCOTIA
1980	GN		508	1400	M		8	SC	ATLIN SCOTIA
1980	GN		483	1100	M		8	SC	ATLIN SCOTIA
1980	GN		445	900	F		7	SC	ATLIN SCOTIA
1980	GN		406	600	F		7	SC	ATLIN SCOTIA
1980	GN		483	1300	F		8	SC	ATLIN SCOTIA
1980	GN		394	500	M		8	SC	ATLIN SCOTIA
1980	GN		305	200	M		6	SC	ATLIN SCOTIA
1980	GN		229	50	M		5	SC	ATLIN SCOTIA
1980	GN		381	400	M		7	SC	ATLIN SCOTIA
1980	GN		267	100	M		5	SC	ATLIN SCOTIA
1980	GN		483	1200	M		8	SC	ATLIN SCOTIA
1980	GN		559	2000	F		9	SC	ATLIN SCOTIA
1980	GN		197	75	U	IM	5	SC	ATLIN SCOTIA
1980	GN		241	150	M		5	SC	ATLIN SCOTIA
1980	GN		406	600	M		7	SC	ATLIN SCOTIA
1980	GN		457	800	M		8	SC	ATLIN RED BLUFF
1980	GN		292	300	M		6	SC	ATLIN SCOTIA
1980	GN		267	200	M		5	SC	ATLIN SCOTIA
1980	GN		305	250	M		6	SC	ATLIN SCOTIA
1980	GN		445	900	M		8	SC	ATLIN RED BLUFF
1980	GN		495	1300	M		9	SC	ATLIN RED BLUFF
1980	GN		368	450	M		7	SC	ATLIN RED BLUFF
1980	GN		470	900	F		8	SC	ATLIN RED BLUFF
1980	GN		330	300	F		7	SC	ATLIN RED BLUFF
1980	GN		406	600	F		7	SC	ATLIN RED BLUFF

Appendix Table II continued.—Lake char individual data, Atlin Lake.

Year	Method	Set	Length	Weight	Sex	Maturity	Age	Structure	Comments
1980	GN		470	925	F		7	SC	ATLIN RED BLUFF
1980	GN		457	750	M		8	SC	ATLIN RED BLUFF
1980	GN		495	1200	M		9	SC	ATLIN RED BLUFF
1980	GN		406	750	M		7	SC	ATLIN RED BLUFF
1980	GN		413	600	M		8	SC	ATLIN RED BLUFF
1980	GN		406	650	M		7	SC	ATLIN RED BLUFF
1980	GN		464	850	M		8	SC	ATLIN RED BLUFF
1980	GN		470	1000	F		8	SC	ATLIN RED BLUFF
1980	GN		508	1300	M		9	SC	INDIAN VILLAGE
1980	GN		508	1200	M		9	SC	INDIAN VILLAGE
1980	GN		914	6800	M		R	SC	MACKENZIE
1980	GN		508	1300	M		9	SC	MACKENZIE
1980	GN		572	1900	F		9	SC	INDIAN VILLAGE
1982	GN		480	1247	F	M			Taku May 15
1982	GN		876	7711	M	M	28	OT	Taku May 15
1982	GN		508	1247	F	M	8	OT	Taku May 15
1982	GN		610	2693	M	M	18	OT	Scotia Bay June 5
1982	GN		419	907	F	M	8	OT	Taku July 5
1982	GN		553	2126	M	M	12	OT	Taku July 5
1982	GN		572	2268	F	M	13	OT	Site 1 July 6
1982	GN		489	1162	F	M	11	OT	Site 1 July 6
1982	GN		470	1247	F	M	10	OT	Site 1 July 6
1982	GN		483	1219	F	M	10	OT	Site 1 July 6
1982	GN		699	4990	F	M	19	OT	Site 3 July 7
1982	GN		445	1021	F	M	9	OT	Site 3 July 7
1982	GN		559	2552	M	M	14	OT	Scotia Bay July 10
1982	GN		419	907	M	M	8	OT	Scotia Bay July 10
1982	GN		559	2296	M	M	13	OT	Site 6 July 12
1982	GN		381	624	M	IM	7	OT	Site 6 July 12
1982	GN		597	2325	F	M	16	OT	Site 6 July 12
1982	GN		610	2494	F	M	17	OT	Site 6 July 12
1982	GN		851	9526	F	M	28	OT	Site 5 July 12
1982	GN		413	907	F	M	8	OT	Site 5 July 12
1982	GN		470	1106	F	M	11	OT	Site 5 July 12
1982	GN		235	142	M	IM	5	OT	Site 7 July 12
1982	GN		648	3000	M	M	19	OT	Site 8 July 13
1982	GN		622	2552	M	M	16	OT	Site 8 July 13
1982	GN		686	3856	M	M	22	OT	Site 8 July 13
1982	GN		457	992	M	IM	11	OT	Site 8 July 13
1982	GN		508	1361	F	M	13	OT	Site 8 July 13
1982	GN		406	680	M	IM	8	OT	Site 8 July 13
1982	GN		419	822	M	IM			Site 8 July 13
1982	GN		375	539	F	IM			Site 8 July 13
1982	GN		337	482	M	IM	6	OT	Site 8 July 13

Appendix Table II continued.—Lake char individual data, Atlin Lake.

Year	Method	Set	Length	Weight	Sex	Maturity	Age	Structure	Comments
1982	GN		533	1871	M	M	14	OT	Taku Aug 9
1982	GN		432	1106	M	M	8	OT	Scotia Bay Aug 9
1982	GN		483	1162	F	M	11	OT	Scotia Bay Aug 9
1982	GN		483	1503	M	M	11	OT	Site 1 Aug 10
1982	GN		508	1701	F	IM	13	OT	Site 1 Aug 10
1982	GN		432	1729	F	M	8	OT	Site 1 Aug 10
1982	GN		457	1049	F	M	10	OT	Site 1 Aug 10
1982	GN		445	1077	M	IM	9	OT	Site 1 Aug 10
1982	GN		375	567	M	IM	6	OT	Site 1 Aug 10
1982	GN		438	1134	M	M	9	OT	Site 2 Aug 10
1982	GN		457	1304	M	M	10	OT	Site 2 Aug 10
1982	GN		584	2353	M	M	15	OT	Site 4 Aug 10
1982	GN		584	2268	F	M	15	OT	Site 4 Aug 10
1982	GN		483	1134	M	IM	11	OT	Sucker Bay Aug 11
1982	GN		724	4536	M	M	18	OT	Sucker Bay Aug 11
1982	GN		438	964	M	IM	10	OT	Sucker Bay Aug 11
1982	GN		356	595	F	IM	7	OT	Site 7 Aug 12
1982	GN		493	624	F	IM	12	OT	Site 7 Aug 12
1982	GN		597	2268	F	M	16	OT	Site 7 Aug 12
1982	GN		495	1304	M	M	11	OT	Site 8 Aug 13
1982	GN		457	1020	F	NR	10	OT	Site 8 Aug 13
1982	GN		432	907	F	NR	9	OT	Site 8 Aug 13
1982	GN		508	1389	F	NR	12	OT	Site 8 Aug 13
1982	GN		483	1361	F	SP	11	OT	Scotia Bay Oct 13
1982	GN		521	1418	F	SP	15	OT	Site 1 Oct 13
1982	GN		432	1021	F	SP	9	OT	Site 1 Oct 13
1982	GN		508	1474	M	SP	13	OT	Site 2 Oct 13
1982	GN		572	2041	F	SP	14	OT	Site 2 Oct 13
1982	GN		445	1134	M	NR	9	OT	Site 2 Oct 13
1982	GN		508	1616	M	M	13	OT	Site 2 Oct 13
1982	GN		546	1531	F	SP	14	OT	Site 2 Oct 13
1982	GN		495	1418	M	M	12	OT	Ck. mouth Site 8 Oct 15
1982	GN		432	1134	M	NR	9	OT	Ck. mouth Site 8 Oct 15
1982	GN		401	765	F	M	8	OT	Ck. mouth Site 8 Oct 15
1982	GN		432	1134	M	SP			Ck. mouth Site 8 Oct 15
1982	GN		400	680	M	SP			Ck. mouth Site 8 Oct 15
1982	GN		330	510	M	IM			Ck. mouth Site 8 Oct 15
1982	GN		330	539	M	IM	7	OT	Site 8 Oct 15
1982	GN		419	1134	F	SP			Site 8 Oct 15
1982	GN		521	1673	M	M			entr to Antler Bay Oct 16
1982	GN		521	1644	M	NR			entr to Antler Bay Oct 16
1982	GN		394	709	M	IM			entr to Antler Bay Oct 16
1982	GN		584	2211	F	SP			entr to Antler Bay Oct 16
1982	GN		508	1361	M	SP			entr to Antler Bay Oct 16

Appendix Table II continued.—Lake char individual data, Atlin Lake.

Year	Method	Set	Length	Weight	Sex	Maturity	Age	Structure	Comments
1982	GN		521	1814	F	SP			Site 6 Oct 16
1982	GN		368	652	F	SP			Site 6 Oct 16
1982	GN		584	2722	F	SP			Site 6 Oct 16
1982	GN		521	2098	F	SP			Site 6 Oct 16
1982	GN		495	1588	F	SP			Site 6 Oct 16
1982	GN		381	709	F	SP			Site 5 Oct 16
1982	GN		387	680	U	IM			Site 5 Oct 16
1982	GN		432	907	M	SP			Site 5 Oct 16
1982	GN		305	255	U	IM			Site 5 Oct 16
1982	GN		445	964	F	M			Site 5 Oct 16
1982	GN		533	1559	F	SP	13	OT	4th of July Oct 17
1982	GN		394	652	F	IM	7	OT	4th of July Oct 17
1982	GN		476	1162	M	SP	11	OT	4th of July Oct 17
1982	GN		381	624	M	IM	8	OT	4th of July Oct 17
1982	GN		373	624	M	IM	6	OT	4th of July Oct 17
1982	GN			3345	M	M	18	OT	Taku Aug 31
1982	GN		546	1843	F	M	12	OT	Taku Aug 31
1982	GN		572	2494	F	M	14	OT	Taku Aug 20
1982	GN		521	1474	M	M	12	OT	Taku Aug 20
1982	GN		572	2835	F	M	14	OT	Taku Aug 20
1982	GN		508	1644	M	M	12	OT	Taku Aug 20
1982	UN		508	2381	M	M			Taku-spot check
1982	UN		521	1588	F	M			Taku-spot check
1982	UN		724	6152	F	M			Taku-spot check
1982	UN		508	1871	M	M			Taku-spot check
1982	UN		508	1588	F	M			Taku-spot check
1982	UN		597	2353	M	M			Taku-spot check
1982	UN			13608		NR			Taku-spot check
1982	UN		738	6067	M	M			Sucker Bay-spot check
1982	UN		533	2325	F	M			Sucker Bay-spot check
1982	UN		508	1899	F	M			Sucker Bay-spot check
1982	UN		508	1814	F	M			Sucker Bay-spot check
1982	UN			7711		NR			Taku-spot check
1982	UN		508	2495	F	M			Taku-spot check
1982	UN		483	2268	F	M			Taku-spot check
1982	UN		559	2183	F	M			Taku-spot check
1982	UN		521	1474	M	SP			Taku-spot check
1982	UN		508	1474	M	M			Taku-spot check
1982	UN		609	3232	F	M			Taku-spot check
1982	UN		508	1474	M	M			Taku-spot check
1982	UN		533	1588	F	M			Taku-spot check
1982	UN		457	1134	M	M			Taku-spot check
1982	UN		559	1814	F	M			Taku-spot check
1982	UN		483	1191	F	SP			Taku-spot check

Appendix Table II continued.—Lake char individual data, Atlin Lake.

Year	Method	Set	Length	Weight	Sex	Maturity	Age	Structure	Comments
1990	UN	1	530		F	M	12	B	Taku Island
1990	UN	1	570		F	M	18	B	Taku Island
1990	UN	1	920		F	M	27	B	Taku Island
1990	UN	1	870		F	M	26	B	Taku Island
1990	UN	1	890		M	M	21	B	Taku Island
1990	UN	1	560		F	M	16	B	Taku Island
1990	UN	1	500		M	M	13	B	Taku Island
1990	UN	1	500		M	M	23	B	Taku Island
1990	UN	2	1020	10000		NR			
1990	UN	2	540			NR	10	B	
1990	UN	2	690			NR	13	B	
1990	UN	2	495			NR	9	B	
1992	GNS	1	670	3000	M	M	11	FR	
1992	GNS	1	500	1100	F	MT	14	FR	
1992	GNS	1	600	1860	F	MT	15	FR	
1992	GNS	1	790	4800	F	MT	17	FR	
1992	GNS	1	350	360	F	IM	4	FR	
1992	GNS	1	250	140	M	IM	3	FR	
1992	GNS	1	410	580	M	IM	8	FR	
1992	GNS	2	450	825	F	MT	9	FR	
1992	GNS	2	460	830	M	MT	8	FR	
1992	GNS	2	210	80	F	IM	2	FR	
1992	GNS	2	370	455	F	IM	6	FR	
1992	GNS	2	400	515	M	IM	7	FR	
1992	GNS	3	500	1080	F	MT	11	FR	
1992	GNS	3	470	980	F	MT	11	FR	
1992	GNS	3	120	20	F	IM	1	FR	
1992	GNS	3	140	30	F	IM	1	FR	
1992	GNS	3	210	93	F	IM	2	FR	
1992	GNS	3	210	90	F	IM	3	FR	
1992	GNS	3	290	230	F	IM	3	FR	
1992	GNS	3	310	280	F	IM	3	FR	
1992	GNS	3	300	245	F	IM	3	FR	
1992	GNS	3	330	380	F	IM	4	FR	
1992	GNS	3	210	87	M	IM	2	FR	
1992	GNS	3	230	120	M	IM	2	FR	
1992	GNS	3	330	280	M	IM	4	FR	
1992	GNS	3	370	475	M	IM	6	FR	
1992	GNS	3	410	600	M	IM	6	FR	
1992	GNS	4	800	5500	F	M	15	FR	
1992	GNS	4	560	1500	F	MT	12	FR	
1992	GNS	4	570	1750	M	MT	13	FR	
1992	GNS	4	305	250	F	IM	4	FR	
1992	GNS	4	360	375	F	IM	5	FR	

Appendix Table II continued.—Lake char individual data, Atlin Lake.

Year	Method	Set	Length	Weight	Sex	Maturity	Age	Structure	Comments
1992	GNS	4	360	400	F	IM	6	FR	
1992	GNS	4	390	510	F	IM	7	FR	
1992	GNS	4	350	400	F	IM	8	FR	
1992	GNS	4	410	700	F	IM	8	FR	
1992	GNS	4	430	680	F	IM	9	FR	
1992	GNS	4	320	300	M	IM	5	FR	
1992	GNS	4	335	305	M	IM	6	FR	
1992	GNS	4	335	330	M	IM	6	FR	
1992	GNS	4	360	380	M	IM	6	FR	
1992	GNS	4	370	410	M	IM	7	FR	
1992	GNS	4	390	490	M	IM	8	FR	
1992	GNS	4	410	650	M	IM	10	FR	
1992	GNS	4	510	1375	M	IM	10	FR	
1992	GNS	5	490	1300	F	M	10	FR	
1992	GNS	5	490	1120	M	M	9	FR	
1992	GNS	5	630	2000	F	MT	13	FR	
1992	GNS	5	720	3600	M	MT	14	FR	
1992	GNS	6	540	1600	F	M	11	FR	
1992	GNS	6	610	2500	F	M	12	FR	
1992	GNS	6	640	3000	M	M	14	FR	
1992	GNS	6	440	850	F	MT	9	FR	
1992	GNS	6	530	1800	F	MT	13	FR	
1992	GNS	6	420	760	M	MT	7	FR	
1992	GNS	6	480	1220	M	MT	12	FR	
1992	GNS	6	770	4000	M	MT	15	FR	
1992	GNS	6	390	540	F	IM	5	FR	
1992	GNS	6	390	540	F	IM	6	FR	
1992	GNS	6	400	575	F	IM	6	FR	
1992	GNS	6	260	125	M	IM	4	FR	
1992	GNS	6	460	910	M	MT		FR	
1992	GNS	6	490	1270	M	IM	8	FR	
1992	GNS	6	550	1480	M	IM	11	FR	
1992	GNS	6	510	1225	M	IM	11	FR	

Appendix Table III.—Lake char per-net summary, Atlin Lake 1982.

Date	Location	LT Catch	Biomass	LT CPE	LT BPE
1982/05/15	Taku	3	10205	9.1	31.0
1982/06/05	Scotia Bay	1	2693	3.0	8.2
1982/07/05	Taku	2	3033	6.1	9.2
1982/07/06	Site 1	4	5896	12.1	17.9
1982/07/07	Site 3	2	6011	6.1	18.2
1982/07/10	Scotia Bay	2	3459	6.1	10.5
1982/07/12	Site 6	4	7739	12.1	23.5
1982/07/12	Site 5	3	11539	9.1	35.0
1982/07/12	Site 7	1	142	3.0	0.4
1982/07/13	Site 8	9	14284	27.3	43.3
1982/08/09	Taku	1	1871	3.0	5.7
1982/08/09	Scotia Bay	2	2268	6.1	6.9
1982/08/10	Site 1	6	7626	18.2	23.1
1982/08/10	Site 2	2	2438	6.1	7.4
1982/08/10	Site 4	2	4621	6.1	14.0
1982/08/11	Sucker Bay	3	6634	9.1	20.1
1982/08/12	Site 7	3	3487	9.1	10.6
1982/08/13	Site 8	4	4620	12.1	14.0
1982/10/13	Scotia Bay	1	1361	3.0	4.1
1982/10/13	Site 1	2	2439	6.1	7.4
1982/10/13	Site 2	5	7796	15.2	23.6
1982/10/15	Site 8 Ck mouth	6	5641	18.2	17.1
1982/10/15	Site 8	2	1673	6.1	5.1
1982/10/16	Entr to Antler Bay	5	7598	15.2	23.0
1982/10/16	Site 6	5	8874	15.2	26.9
1982/10/16	Site 5	5	3515	15.2	10.7
1982/10/17	4th July	5	4621	15.2	14.0
1982/08/31	Taku	2	5188	6.1	15.7
1982/08/20	Taku	4	8447	12.1	25.6

Appendix IV.—Atlin Lake char gillnet CPE in 1955

Material in Withler (1956) appears to indicate that that two gangs were set on two consecutive nights at each station, in July and September. Experimental gillnet gangs utilized by British Columbia Provincial fisheries agencies have typically been built to the current length of 91 m and depth of 2.4 m since the year 1950 or earlier (D. Coombes, BC Ministry of Fisheries, Inventory Section, personal communication).

Assuming a standard single gang length of 91 m and an overnight soak time of 12 hr, the total catch of 83 lake trout in 12 gangs in July 1955 implies a mean CPE of 15.2. The total of 51 lake trout captured in 12 gangs in September 1955 gives a mean CPE of 9.3. The pooled mean CPE for both months would thus be 12.3.

For 6 MELP standard overnight gillnet sets made in Atlin Lake in 1992, mean CPE was 16.0 (median 17.5; range 4.5 to 25.5).

It should be emphasized that the 1955 CPE estimates are highly speculative, based only on what appear to be the most likely values for net length and soak time.

Appendix V.—Atlin Lake char gillnet CPE in 1982

Expressed in units of fish per 100m of net per 24 hr of soak, estimated mean CPE of lake char for 29 gillnet sets made during 1982 was 10.0 (median 9.1; range 3.0 to 27.3) (Figure 12). For 6 MELP standard overnight gillnet sets made in Atlin Lake in 1992, mean CPE of lake char was 16.0 (median 17.5; range 4.5 to 25.5). Comparability of the 1982 and 1992 relative abundance estimates is constrained by differences in gillnet configuration, including mesh sizes and filament differences, and net width or height (reportedly 1.25 m in 1982, versus 2.4 m in 1992).

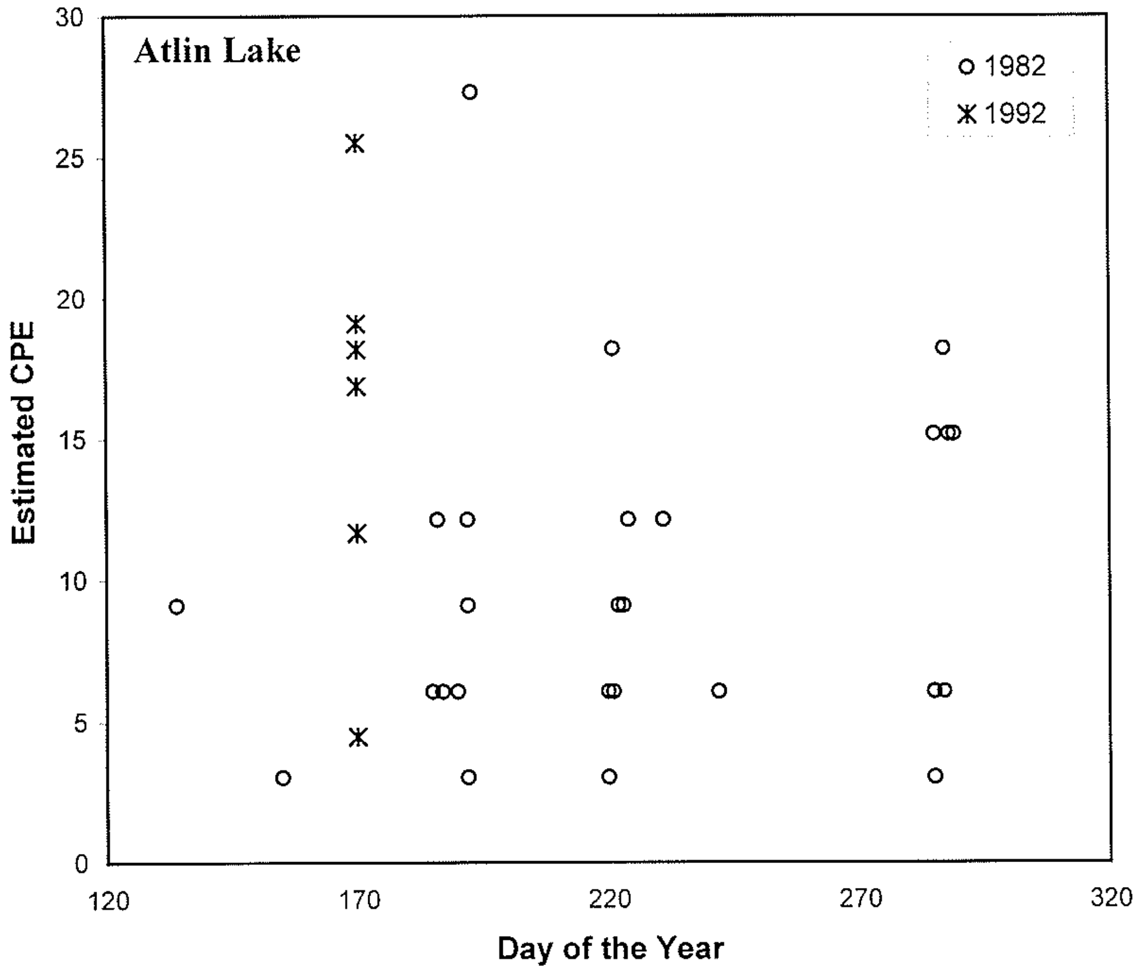

Figure 12.—Lake char CPE (unit is number of char captured per 100 m of net per 24 hr soak time) plotted versus day of the year (January 1 is day 1) for Atlin Lake gillnet sets, 1982 and 1992. Gillnets differed in mesh sizes, filament type and width between 1982 and 1992.

Size-Specific Numerical Abundance

Of primary interest is whether available data reveal any evidence of declining abundance of large or old char at Atlin Lake. Because of doubts about age determination discussed elsewhere, this discussion focuses on length. The upper panel of Figure 13 depicts a comparison of length-stratified relative abundance from 1982 and 1992 gillnetting. Only for the 500 - 599 mm category is char CPE much higher in 1982; relative abundance appears similar for the 800 - 899 length class and higher in 1992 for the two intervening categories (Figure 13). In short, the data do not suggest a consistent decline in population density of large char. However, the validity of the summary is seriously constrained by the differences in seasonal timing and gillnet construction between 1982 and 1992.

One potential method of circumventing the possible difference in effective effort between 1982 and 1992 due to net configuration and seasonality would be to compare the proportion of the pooled catch in each length category between years, as in the lower panel of Figure 13. The flaw in this approach is that the estimated proportion of large fish in the catch is derived not only from the abundance of large fish but also from the abundance of small fish. Even if the actual abundance of large fish remained constant between two years, their proportional representation in a particular year would be lower if for any reason smaller fish were more abundant in that year. Interestingly, the proportion of fish of fork length greater than 600 mm is relatively similar in 1992 and 1982 (Figure 13). The two years' sample proportions differ mainly in the distribution among size categories of char less than 600 mm. Char less than 400 mm made up 46.5 % of the catch in 1992, and only 16.6 % of the catch in 1982; char 400 - 600 mm represented 72.9 % of the sample in 1982 and only 39.4 % in 1992.

Examination of Figure 13 reveals another important difference between the size-structured catch data in 1982 and 1992. The conventional interpretation of this type of gillnet length frequency histogram ("catch curve") is that as size increases along the x-axis, abundance first increases due to increasing vulnerability to the gear, peaks at the size category for which fish are assumed to be fully vulnerable ("recruited") to the gear, and then declines due to mortality. The 1982 data suggest full recruitment at the 400 - 499 mm category, while in 1992 full recruitment appears to occur in the 300 - 399 mm length class. Again, this difference may result from dissimilarity of the sampling gear or methods, or from a relatively radical change in the population size structure. The data do not allow distinction between these possibilities although the former explanation seems more plausible given the smaller meshes used in 1992. Regardless of the cause, between-year comparison of the proportional representation of size classes of fish would only be valid if the catchability for each size class was similar in the two years, which does not appear to be the case.

An alternative possibility is to include only size categories which appear fully recruited in 1982 and 1992, e.g. catch of fork length ≥ 400 mm (Figure 14). Char 400 - 499 mm constitute a much higher proportion of the recruited catch in 1982 than in 1992, while the larger size classes are a larger proportion of the recruited catch in 1992 than in 1982. The data offer no means of assessing whether gillnet differences in 1982 and 1992 also altered the catchability of large char. But the gillnet samples do not suggest a decline between 1982 and 1992 in the abundance of very large Atlin Lake char (≥ 600 mm FL) *as a proportion of char of FL ≥ 400 mm*. However, the data cannot be used to assess whether char ≥ 400 mm FL were as abundant in 1992 as in 1982, either in absolute terms or relative to the abundance of smaller char in those years.

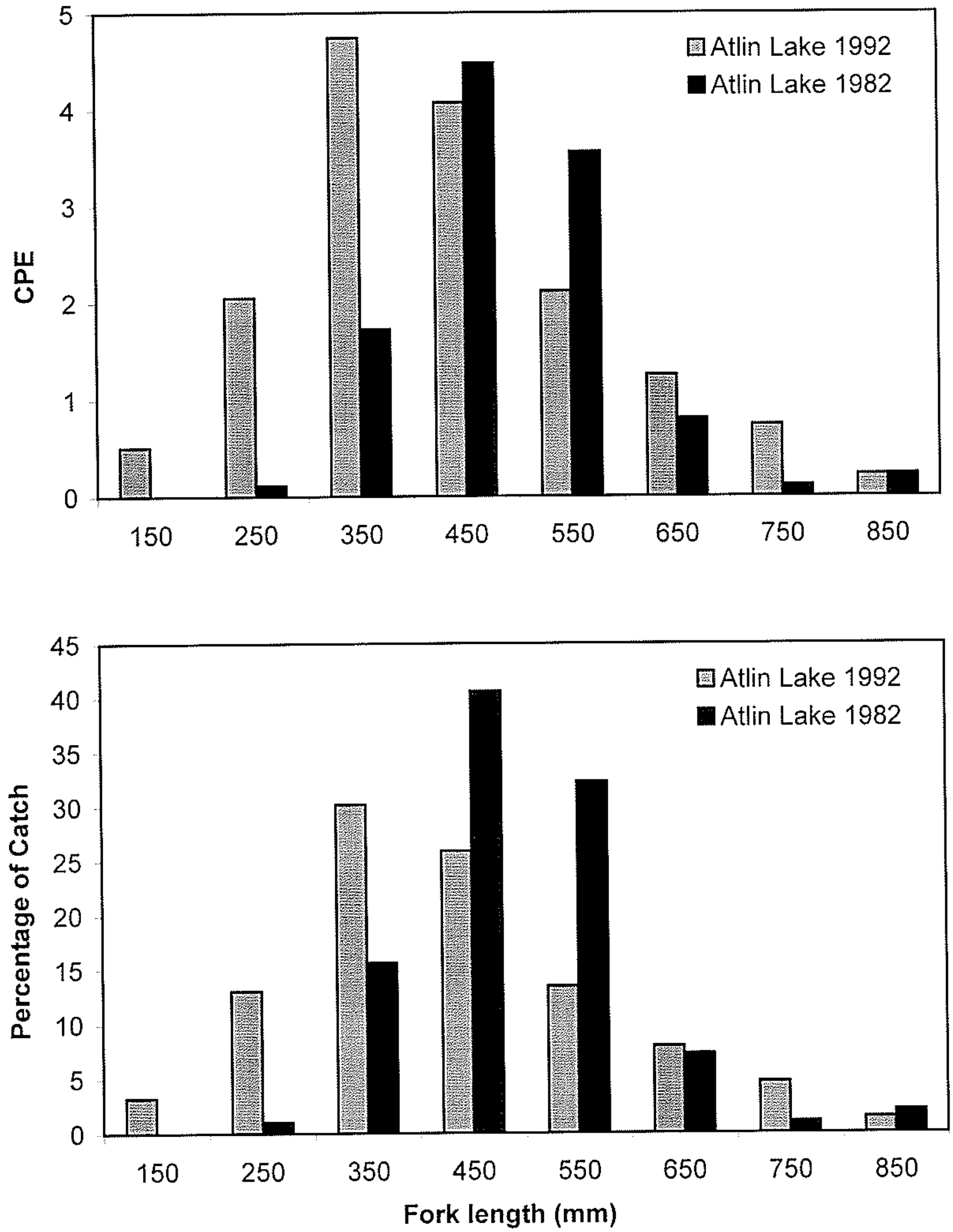

Figure 13.—Lake char CPE (upper panel) and percentage of all catch (lower panel), by length category, for pooled gillnet sets made in Atlin Lake in 1982 and 1992. Fork length category labels are the bin midpoints.

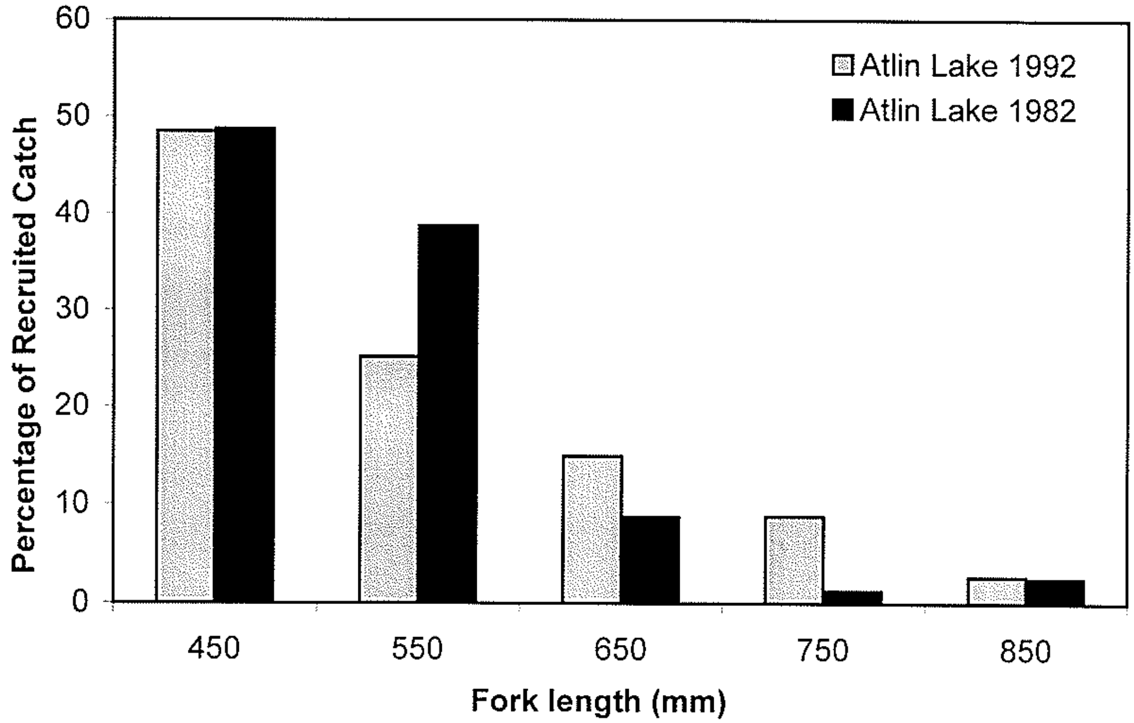

Figure 14.—Percentage of recruited catch (fork length ≥ 400 mm), by length category, for pooled gillnet sets made in Atlin Lake in 1982 and 1992. Fork length category labels are the bin midpoints.

Appendix Table VI.—Thermal profiles, Atlin Lake July 1955.

Data recovered from Figure of Withler 1956. Three stations were sampled by bathythermograph on 7-July and 30-July 1955. Profiles for 18-July were estimated by linear interpolation of temperature-at-depth for each station. Temperatures in bold font are > 8°C.

Depth		7-July-1955				18-July-1955 (interpolated)				30-July-1955			
ft	m	Stn 1	Stn 2	Stn 3	Date Mean	Stn 1	Stn 2	Stn 3	Date Mean	Stn 1	Stn 2	Stn 3	Date Mean
0	0.0	5.6	6.7	8.8	7.0	7.5	8.9	10.0	8.8	9.4	11.1	11.3	10.6
5	1.5	5.5	6.2	8.6	6.8	7.4	8.6	9.8	8.6	9.3	10.9	11.1	10.4
10	3.0	5.4	5.9	8.3	6.5	7.3	8.3	9.6	8.4	9.3	10.8	10.9	10.3
15	4.6	5.4	5.7	8.2	6.4	7.3	8.2	9.5	8.4	9.3	10.7	10.8	10.3
20	6.1	5.4	5.7	8.1	6.4	7.3	8.2	9.5	8.3	9.3	10.7	10.8	10.3
25	7.6	5.4	5.7	8.1	6.4	7.3	8.1	9.4	8.3	9.3	10.6	10.8	10.2
30	9.1	5.3	5.7	8.1	6.4	7.3	8.1	9.4	8.3	9.3	10.5	10.7	10.2
35	10.7	5.3	5.5	8.1	6.3	7.3	7.9	9.4	8.2	9.3	10.4	10.6	10.1
40	12.2	5.3	5.3	8.1	6.2	7.3	7.8	9.3	8.1	9.3	10.3	10.4	10.0
45	13.7	5.2	5.1	8.1	6.1	7.2	7.6	9.3	8.0	9.2	10.2	10.4	9.9
50	15.2	5.2	4.9	8.1	6.0	7.1	7.6	9.2	8.0	9.1	10.2	10.4	9.9
55	16.8	5.2	4.7	8.1	6.0	6.9	7.5	9.2	7.9	8.7	10.2	10.4	9.8
60	18.3	5.2	4.6	8.0	5.9	6.6	7.4	9.2	7.7	8.1	10.2	10.3	9.5
65	19.8	5.2	4.3	7.9	5.8	6.1	7.1	9.1	7.5	7.1	10.0	10.3	9.1
70	21.3	5.2	4.1	7.9	5.7	5.5	6.8	9.1	7.1	5.9	9.4	10.2	8.5
75	22.9	5.1	4.1	7.9	5.7	5.3	6.3	9.0	6.9	5.6	8.6	10.1	8.1
80	24.4	5.0	4.0	7.8	5.6	5.1	6.0	8.9	6.7	5.2	8.0	10.0	7.7
85	25.9	4.9	3.9	7.8	5.5	4.9	5.7	8.8	6.5	4.8	7.5	9.9	7.4
90	27.4	4.7	3.9	7.7	5.4	4.6	5.5	8.7	6.3	4.4	7.1	9.7	7.1
95	29.0	4.6	3.8	7.8	5.4	4.4	5.4	8.6	6.1	4.1	6.9	9.4	6.8
100	30.5	4.7	3.7	7.8	5.4	4.3	5.2	8.4	6.0	3.9	6.7	9.1	6.6
105	32.0	4.7	3.6	7.8	5.4	4.2	5.1	7.9	5.7	3.7	6.6	8.0	6.1
110	33.5	4.7	3.3	7.7	5.3	4.2	4.9	7.6	5.6	3.6	6.4	7.6	5.9

Appendix Table VII.—Characteristics of char lakes used to estimate THV - harvest relationship.

Data from Table 2 of Payne et al (1990). **THV/Area** and **Mean Depth** were calculated from the presented data. Asterisked values in the **Yield** column indicate a discrepancy (unknown reason) between the displayed yield and the value of **Harvest /Area**.

Lake / Water	Harvest (kg/yr)	Area (ha)	Yield (kg/ha/yr)	Volume (cu hm)	July THV (cu hm)	THV /Area (m)	Mean Depth (m)
Superior	1,895,500	8,241,400	0.23	12,230,000	1,011,766	12.3	148.4
Michigan	3,248,900	5,801,600	0.56	4,908,000	471,483	8.1	84.6
Huron	1,499,700	4,165,900	0.36	2,791,000	264,505	6.3	67.0
Great Slave	1,003,200	2,538,200	0.40	1,574,000	114,102	4.5	62.0
Ontario	311,600	1,947,700	0.16	1,637,000	118,290	6.1	84.0
Georgian Bay	660,100	1,375,200	0.48	660,000	102,290	7.4	48.0
Erie	50,000	623,700	0.08	151,700	19,822	3.2	24.3
Reindeer	278,600	556,900	0.50	94,700	25,866	4.6	17.0
North Channel (Huron)	254,800	455,000	0.56	88,000	21,672	4.8	19.3
Nipigon	130,900	448,100	0.29	221,500	24,638	5.5	49.4
Lake of the Woods	7,800	356,900	0.02	28,200	947	0.3	7.9
Wollaston	159,200	206,200	0.77	42,500	11,785	5.7	20.6
La Ronge	64,000	130,700	0.49	17,700	2,865	2.2	13.5
Cree	100,600	115,200	0.87	17,200	4,472	3.9	14.9
Amisk	13,400	32,100	0.42	4,200	895	2.8	13.1
Opeongo	4,005	5,894	0.68	755	112	1.9	12.8
Chiblow / Denman	1,570	2,675	0.59	621	62	2.3	23.2
Flack	1,285	951	1.30	198	27	2.8	20.8
Bone	256	121	* 3.00	9	1	0.7	7.4
Christman	94	59	* 1.00	4	1	0.8	6.8
Atlin	**N/A**	**63,455**	**N/A**	**54,368**	**9,003[13]**	**14.2**	**85.6**

[13]This Atlin Lake THV estimate was derived from the arithmetic mean temperature profile for July 1955.

Appendix VIII.—Skeena Region lake surface water TDS and [P_{total}].

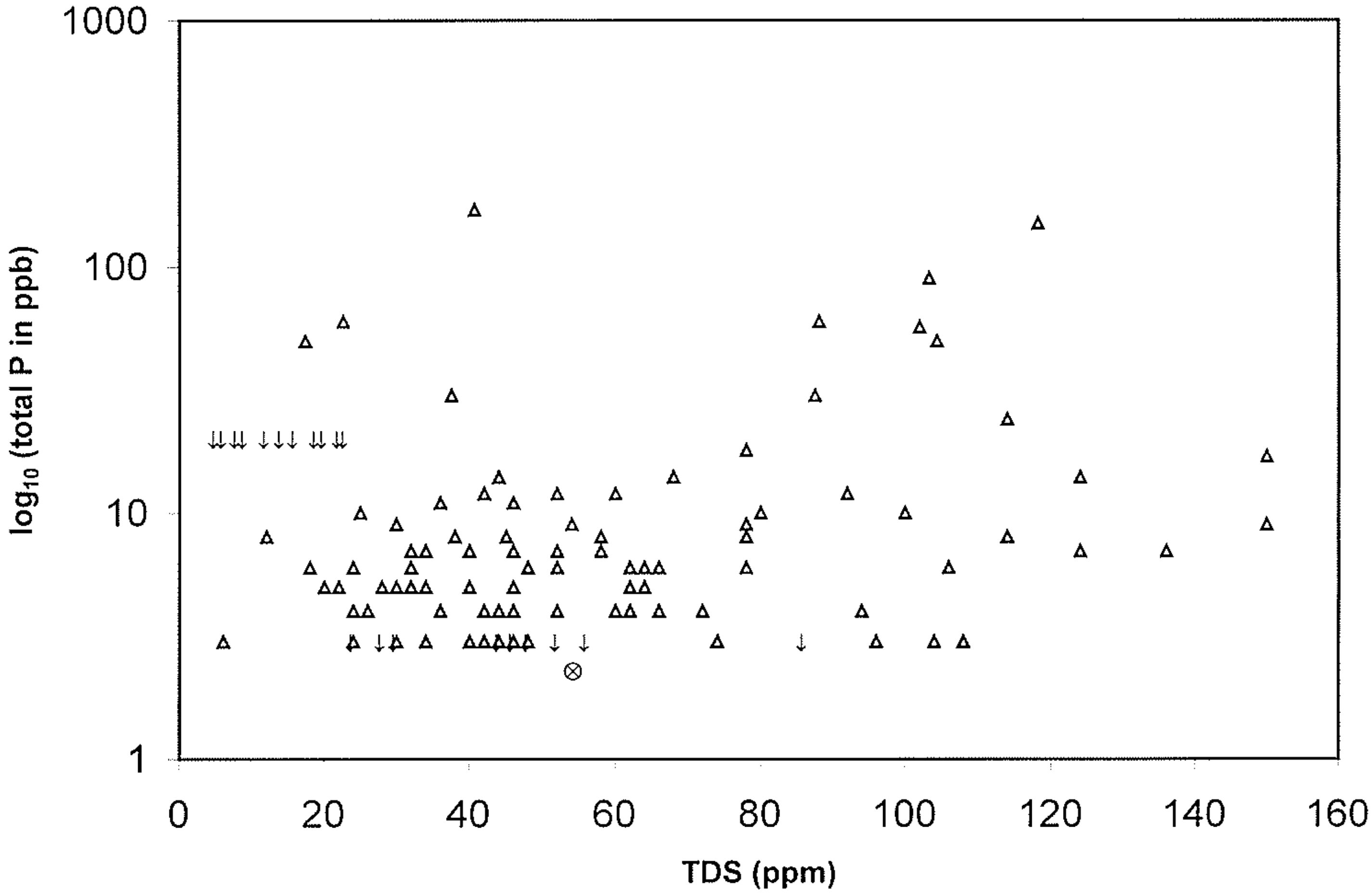

Figure 15.—Skeena Region lake surface water TDS and [P_{total}]. The plot symbol '⊗' depicts the mean values of these parameters for Atlin Lake (Kirkland and Gray 1986). Open triangles depict observed values for other Skeena Region lakes, while the symbol '↓' depicts lakes for which TDS was measured but total [P_{total}] was below the indicated value (reported detection limit).

Appendix IX.—Skeena Region lake surface water TDS and [N_{total}].

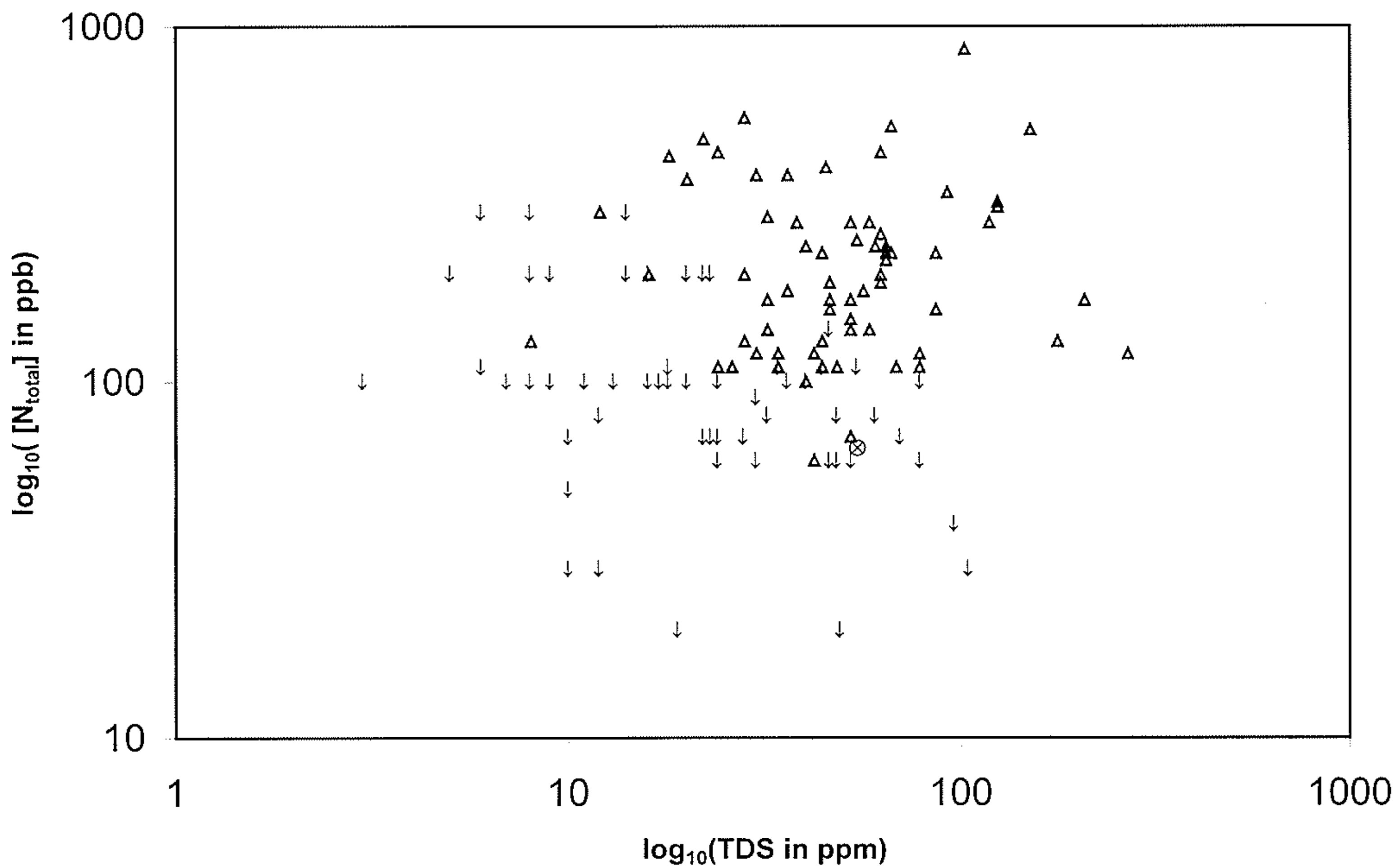

Figure 16.—Skeena Region lake surface water TDS and [N_{total}]. The plot symbol '⊗' depicts the mean values of these parameters for Atlin Lake (Kirkland and Gray 1986). Open triangles depict observed values for other Skeena Region lakes, while the symbol '↓' depicts lakes for which TDS was measured but [N_{total}] was below the indicated value (reported detection limit).