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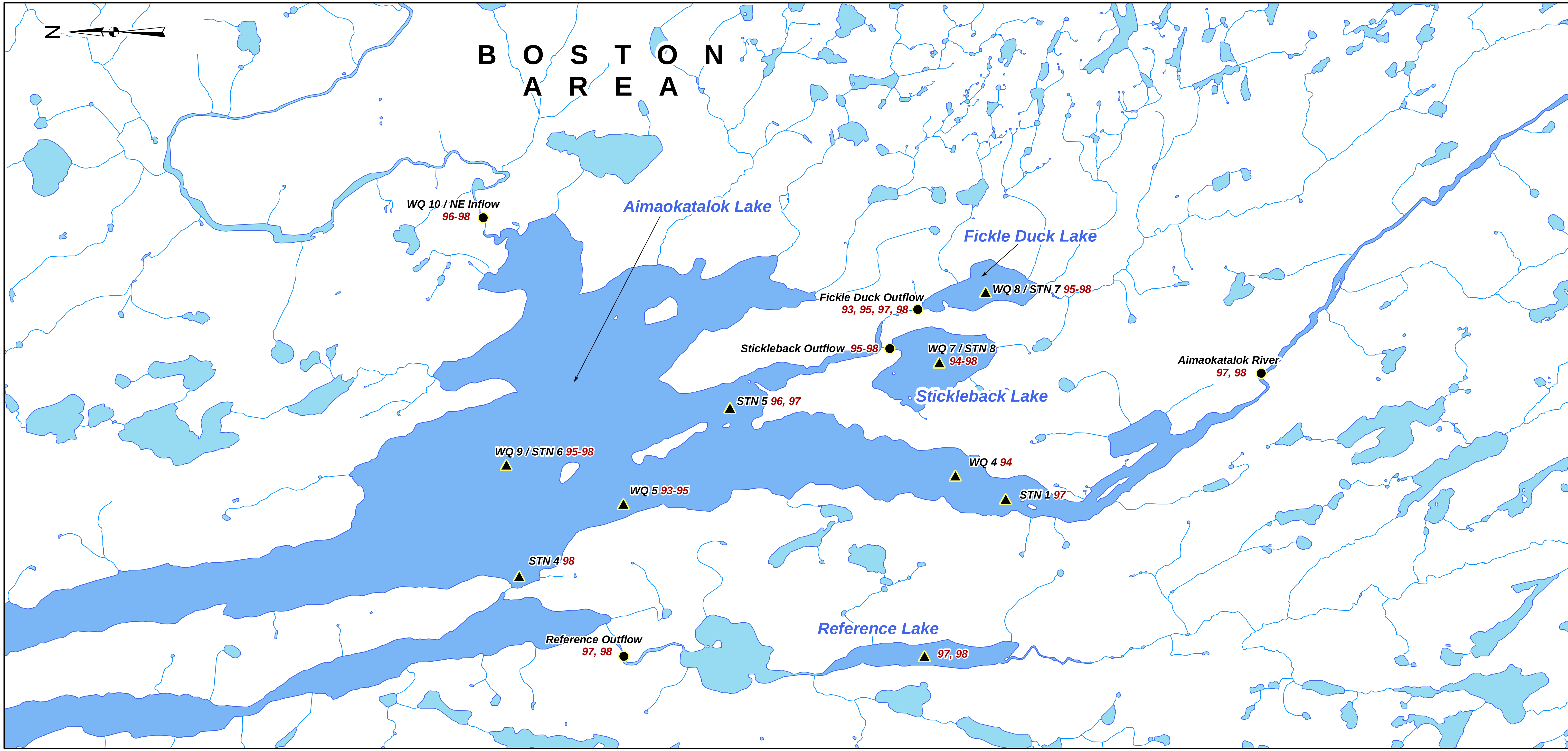

LEGEND

▲	Phytoplankton sampling locations	WQ X / STN X	Sampling stations names from Rescan reports
●	Periphyton sampling locations	95-97	Consecutive years of sampling at station
	Rivers		
	Study areas		
	Waterbodies		

DRAFT

REFERENCE

Sources: Data Obtained from the Government of Canada, Natural Resources Canada, Centre for Topographic Information
Projection: UTM Zone 13N Datum: NAD 83

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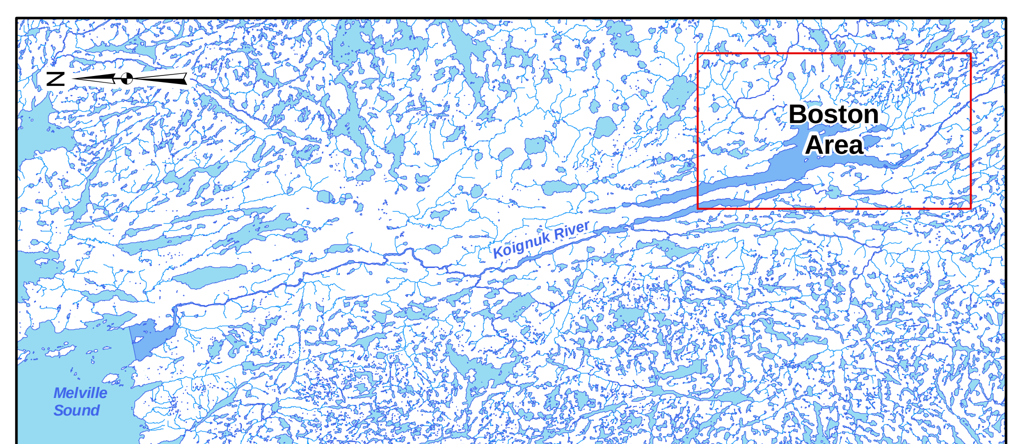

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Boston Project Data Compilation

TITLE

Phytoplankton and Periphyton Sampling Locations, 1993 - 1998

Golder Associates
Edmonton, Alberta

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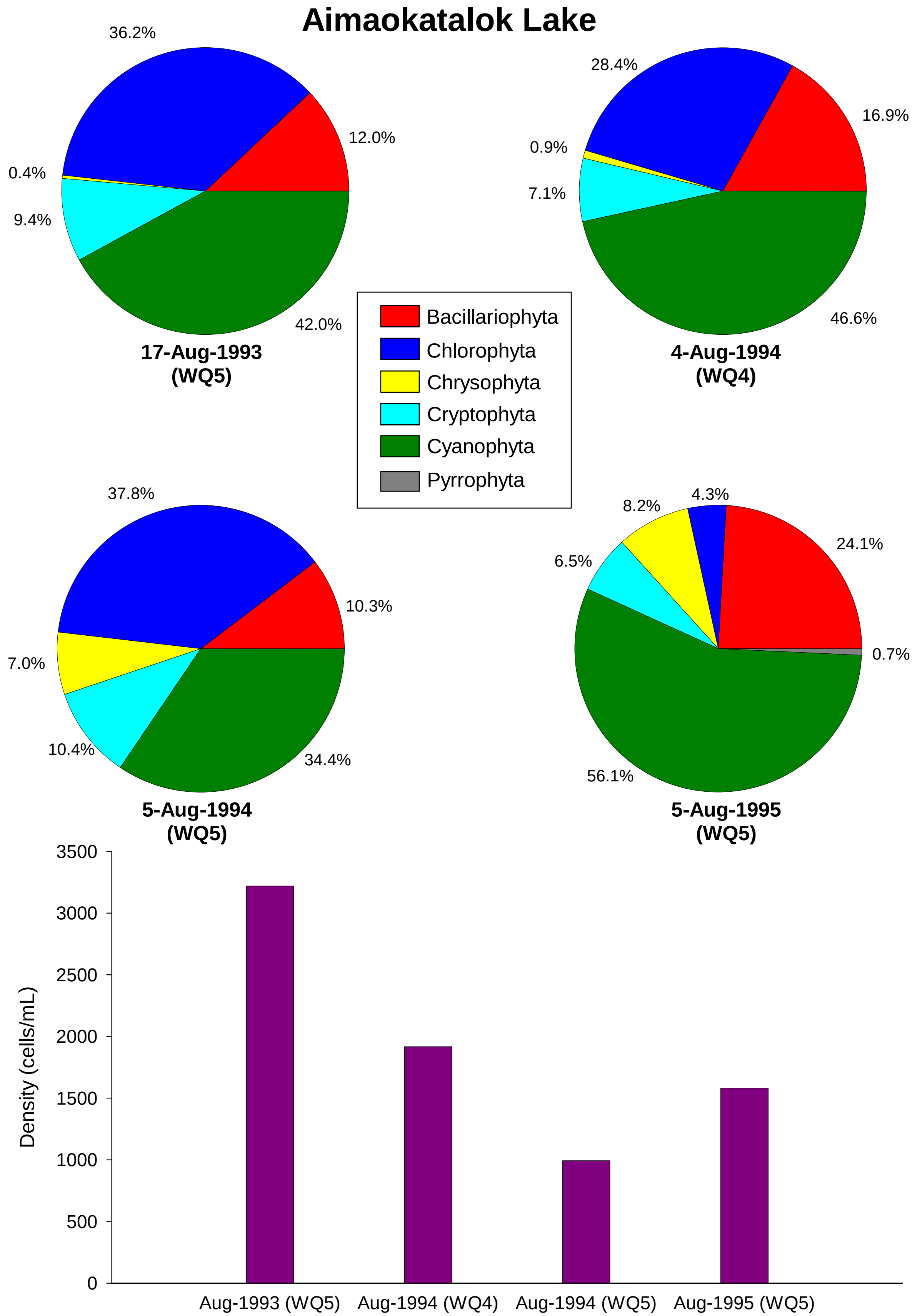


Figure 5.2 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of phytoplankton in Aimaokatalok Lake, 1993 to 1998.

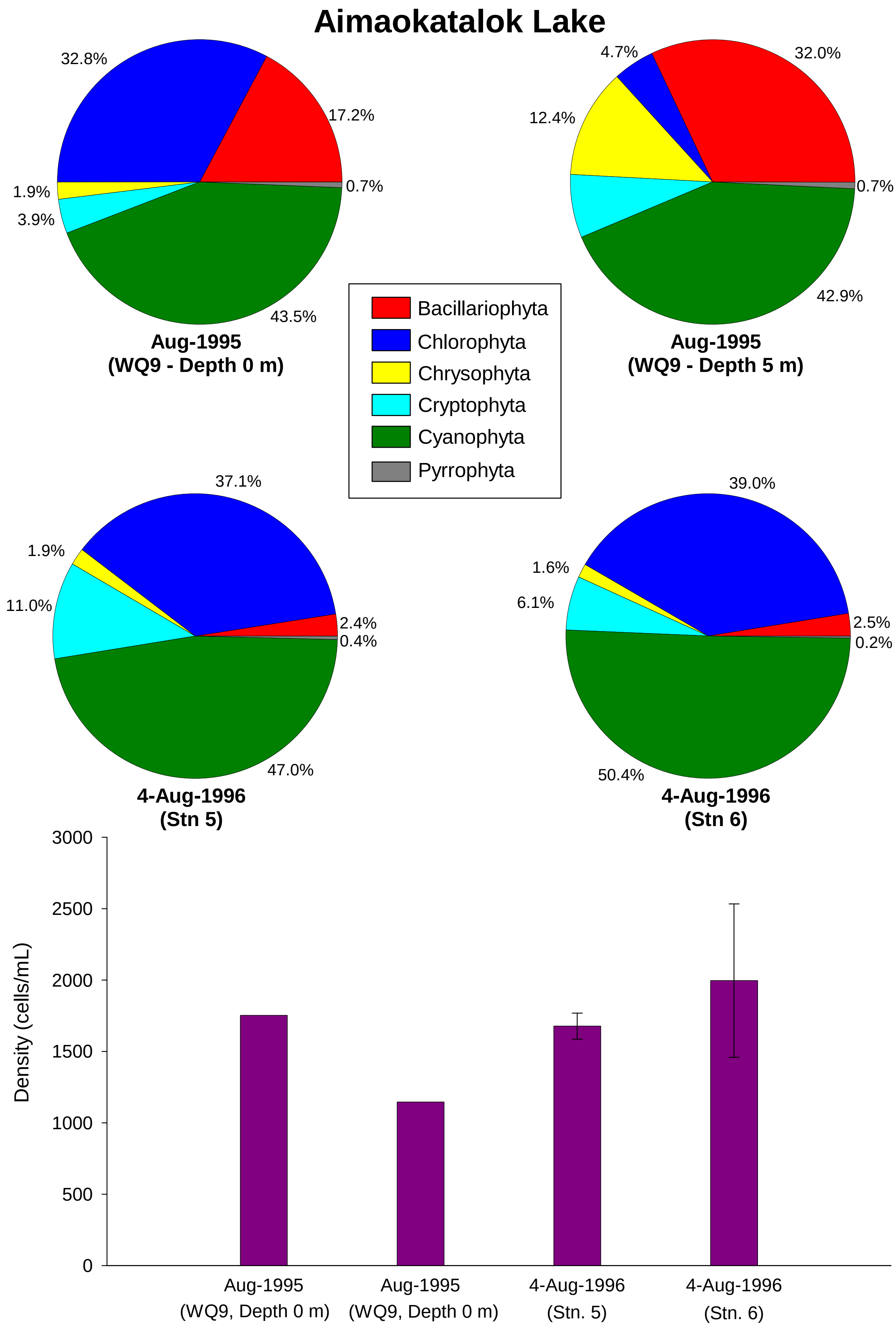


Figure 5.2 (continued). Relative abundance of major taxonomic groups and mean total density (± 1 SE) of phytoplankton in Aimaokatalok Lake, 1993 to 1998.

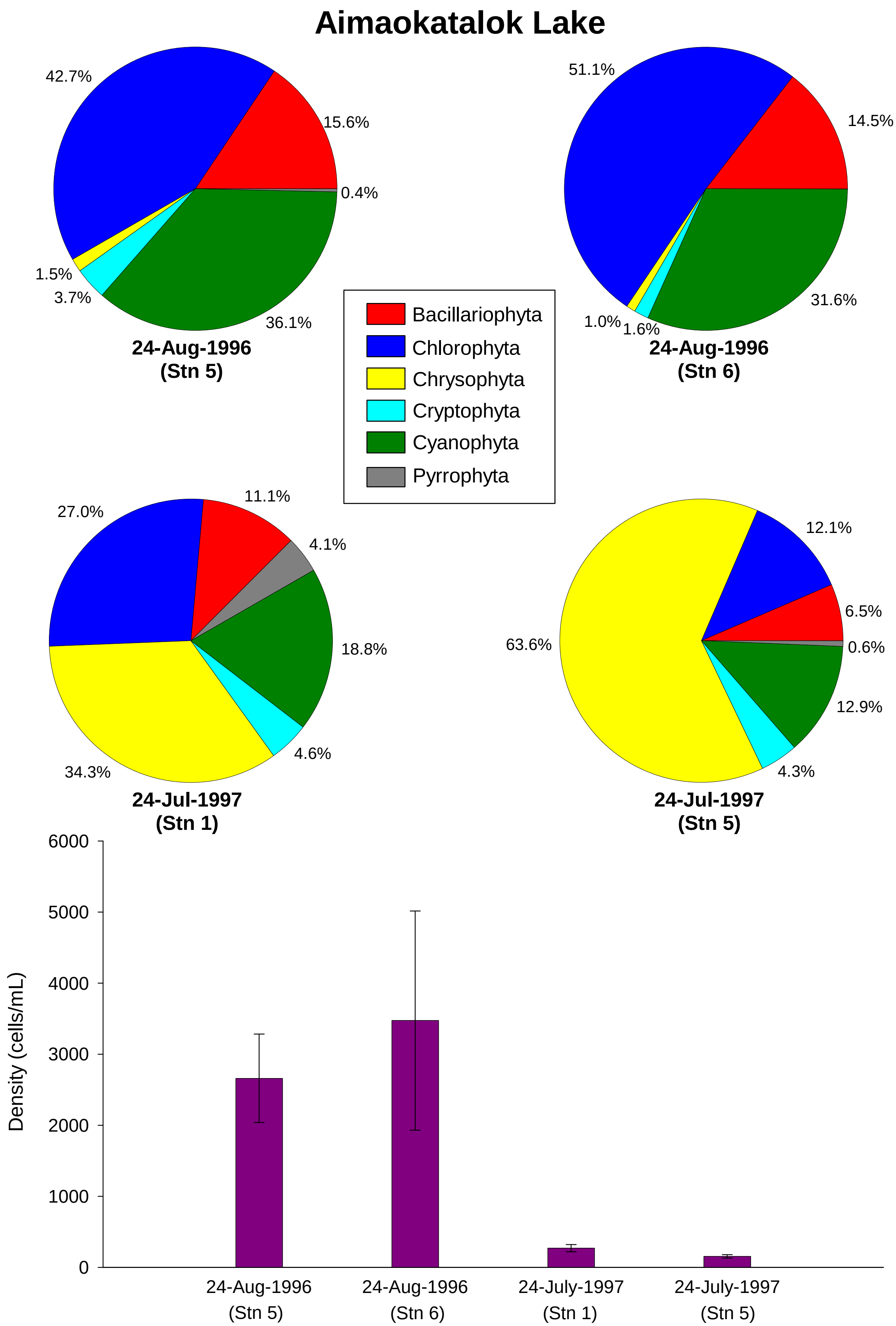


Figure 5.2 (continued). Relative abundance of major taxonomic groups and mean total density (± 1 SE) of phytoplankton in Aimaokatalok Lake, 1993 to 1998.

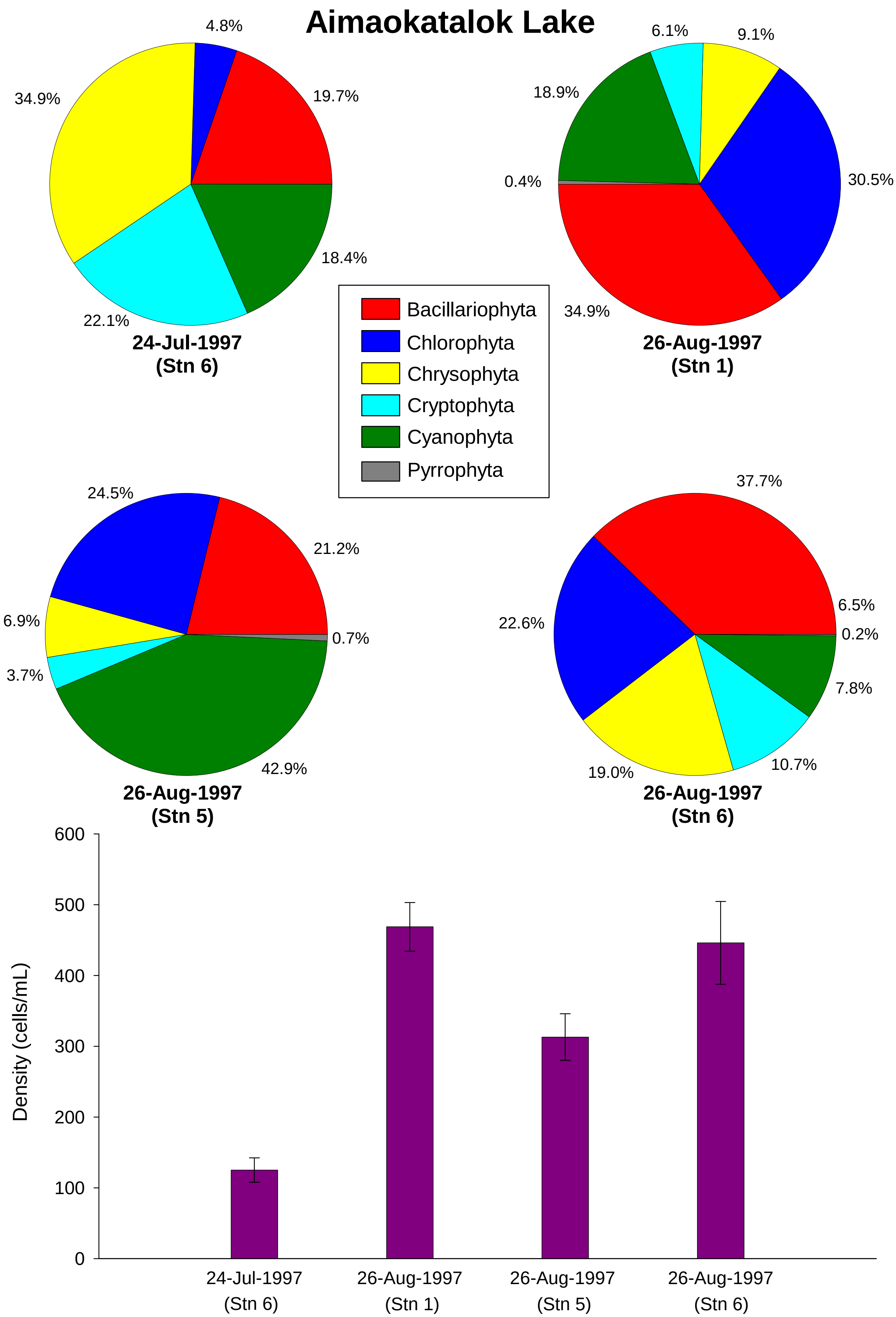
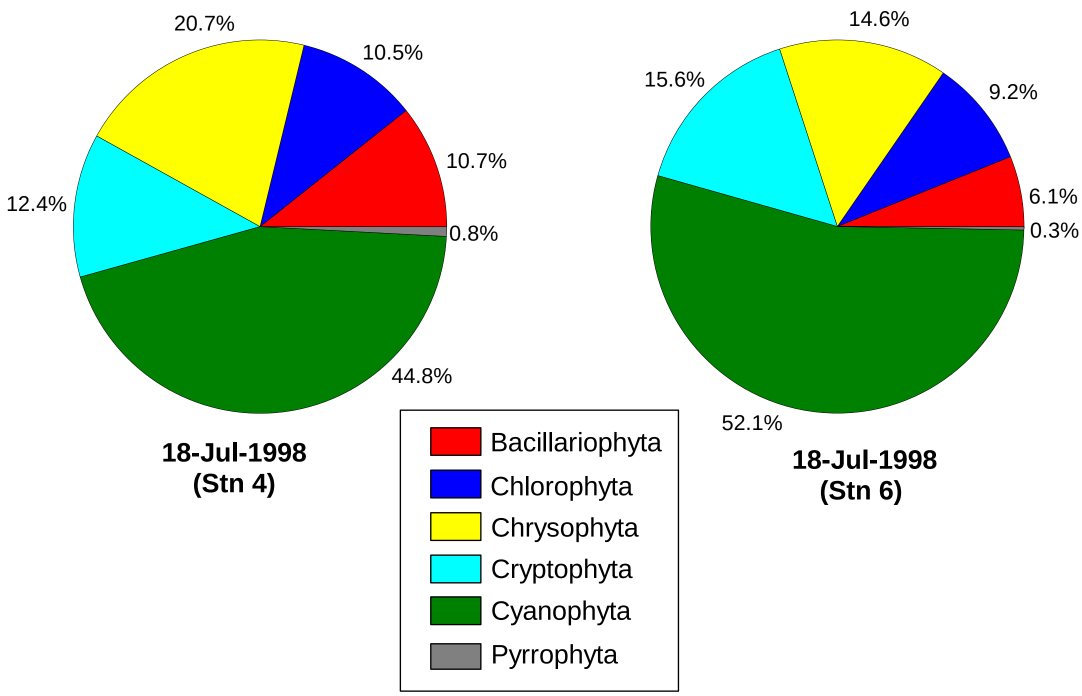


Figure 5.2 (continued). Relative abundance of major taxonomic groups and mean total density (± 1 SE) of phytoplankton in Aimaokatalok Lake, 1993 to 1998.

Aimaokatalok Lake



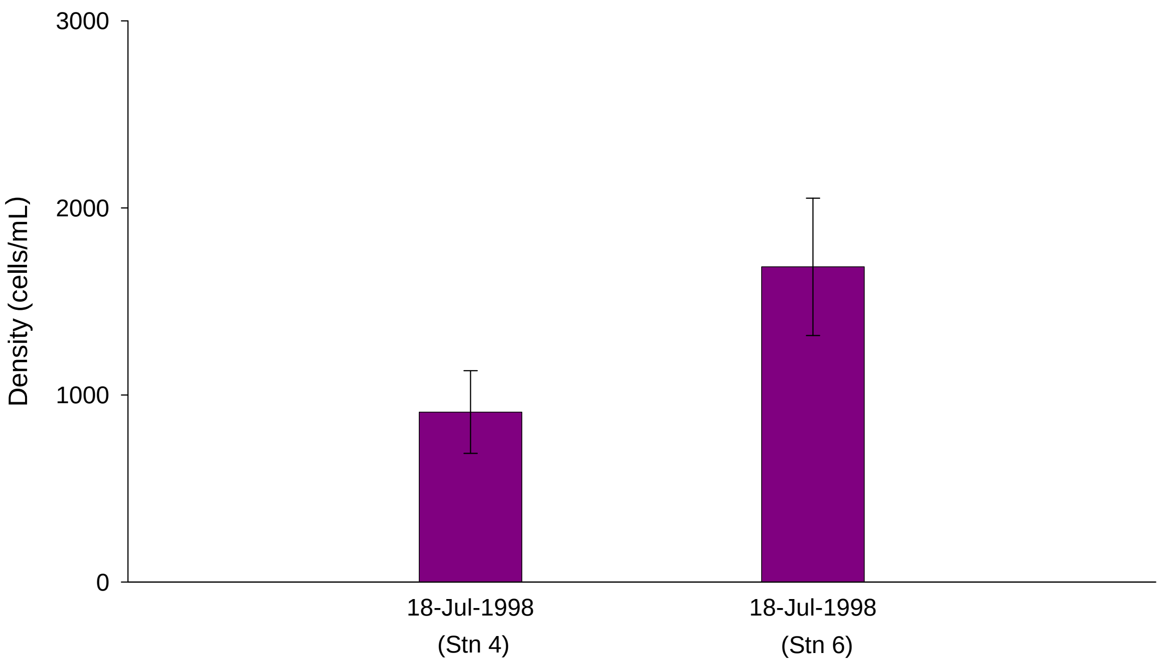


Figure 5.2 (continued). Relative abundance of major taxonomic groups and mean total density (± 1 SE) of phytoplankton in Aimaokatalok Lake, 1993 to 1998.

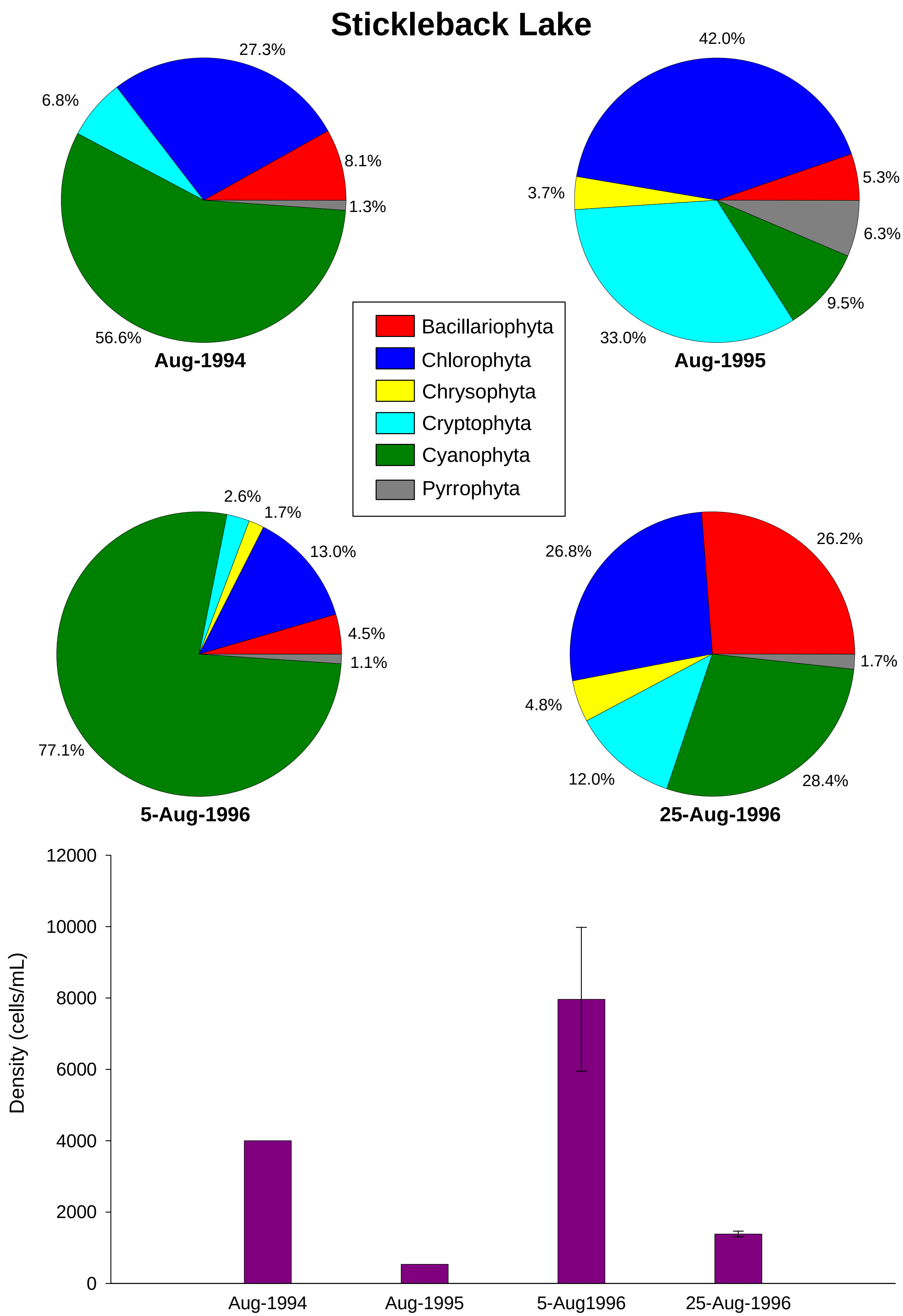


Figure 5.3 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of phytoplankton in Stickleback Lake, 1994 to 1998.

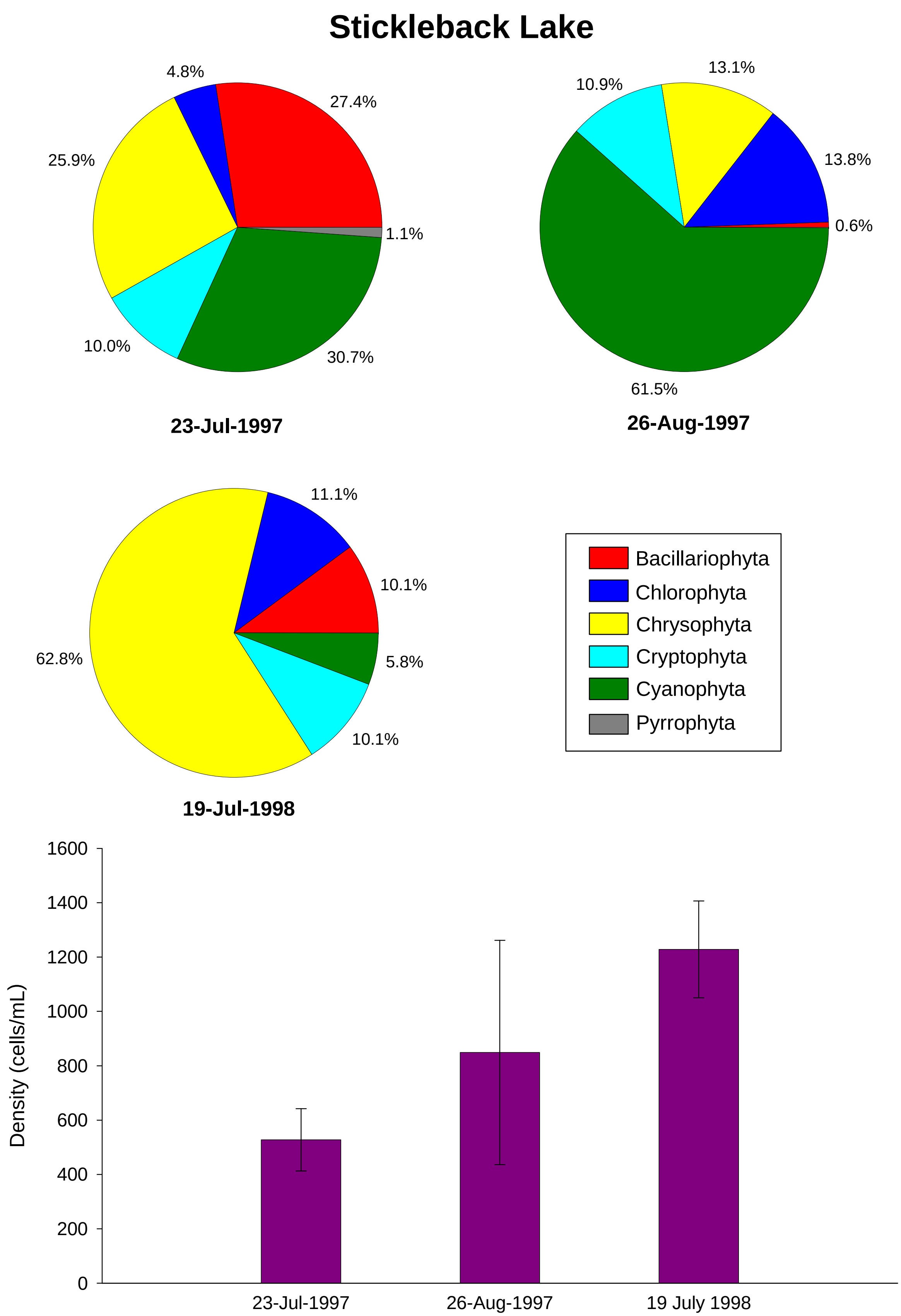


Figure 5.3 (continued). Relative abundance of major taxonomic groups and mean total density (± 1 SE) of phytoplankton in Stickleback Lake, 1994 to 1998.

5.1.4 Fickle Duck Lake

Six phytoplankton sampling sessions were conducted on Fickle Duck Lake during the summer: once in 1995 and 1998 and twice in 1996 and 1997. Mean total algal cell numbers (±1 SE) ranged from 53 ± 19 cells/mL on 23 July 1997 to 3901 ± 829 cells/mL on 5 Aug 1996 (Figure 5.4; Appendix B2).

Phytoplankton communities in Fickle Duck Lake were typically dominated by Cyanophyta, which contributed between 22.5 and 76.8% towards the mean total number of cells enumerated per sample. The major contributor of this group was *Anacystis* spp. Bacillariophyta, Chlorophyta, and Chrysophyta also were abundant on some sampling dates (Figure 5.4; Appendices B1 and B2). The major contributors to these three groups were *Asterionella formosa*, *Crucigenia* spp., and *Dinobryon* spp., respectively.

5.1.5 Reference Lake

Three phytoplankton sampling sessions were conducted on Reference Lake during the summer, including twice in 1997 and once in 1998. Mean total algal cell numbers (±1 SE) ranged from 172 ± 59 cells/mL on 23 July 1997 to 15 883 ± 11 471 cells/mL on 27 Aug 1996 (Figure 5.5; Appendix B2).

Phytoplankton communities in Reference Lake were typically dominated by Cyanophyta, which contributed between 30.4 and 98.6% towards the mean total number of cells enumerated per sampling session. The major contributors of this group included *Aphanizomenon flos-aquae*, *Anabaena* spp., and *Lyngbya limnetica*. In July 1997, phytoplankton communities also had significant contributions of Chlorophyta (green algae) and Chrysophyta (golden-brown algae). The major components of these groups included *Dinobryon* spp., *Ochromonas* spp., and *Crucigenia* spp., respectively (Figure 5.5; Appendices B1 and B2).

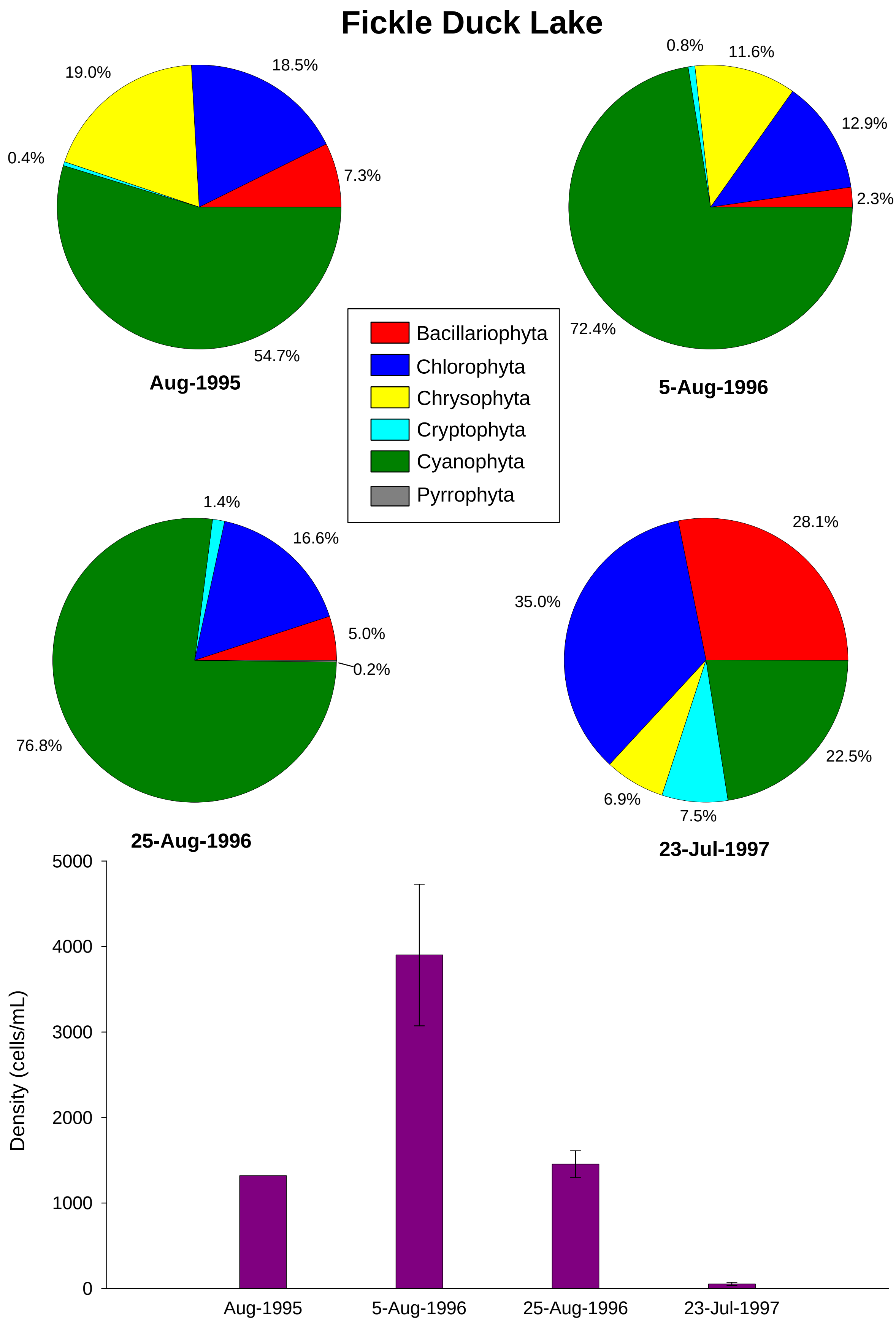
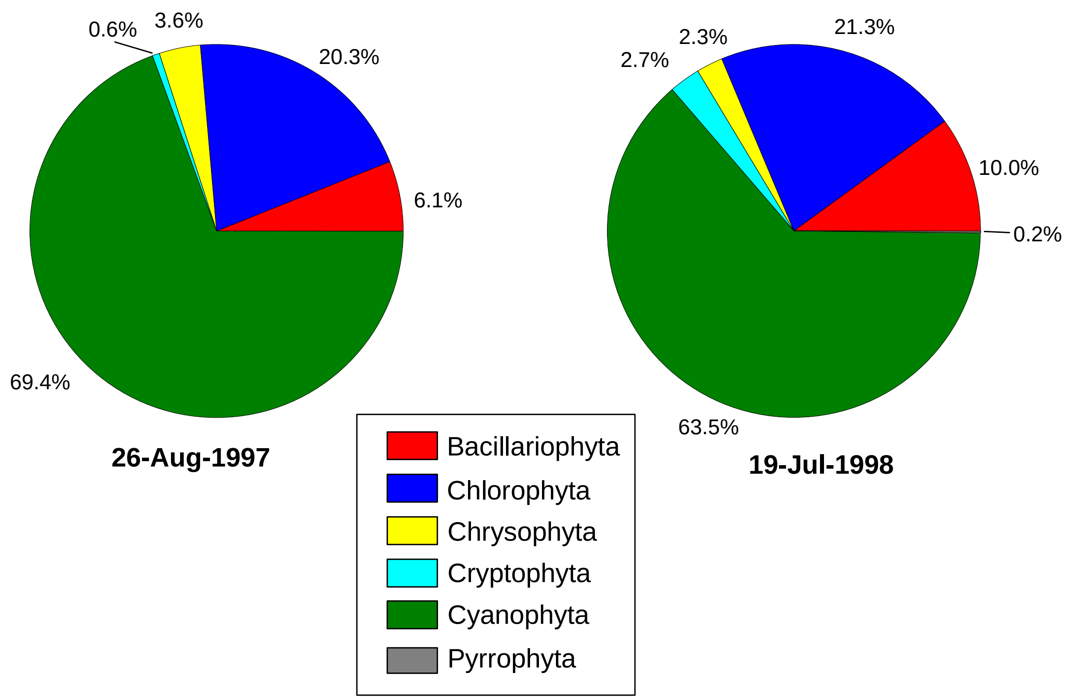


Figure 5.4. Relative abundance of major taxonomic groups and mean total density (± 1 SE) of phytoplankton in Fickle Duck Lake, 1995 to 1998.

Fickle Duck Lake



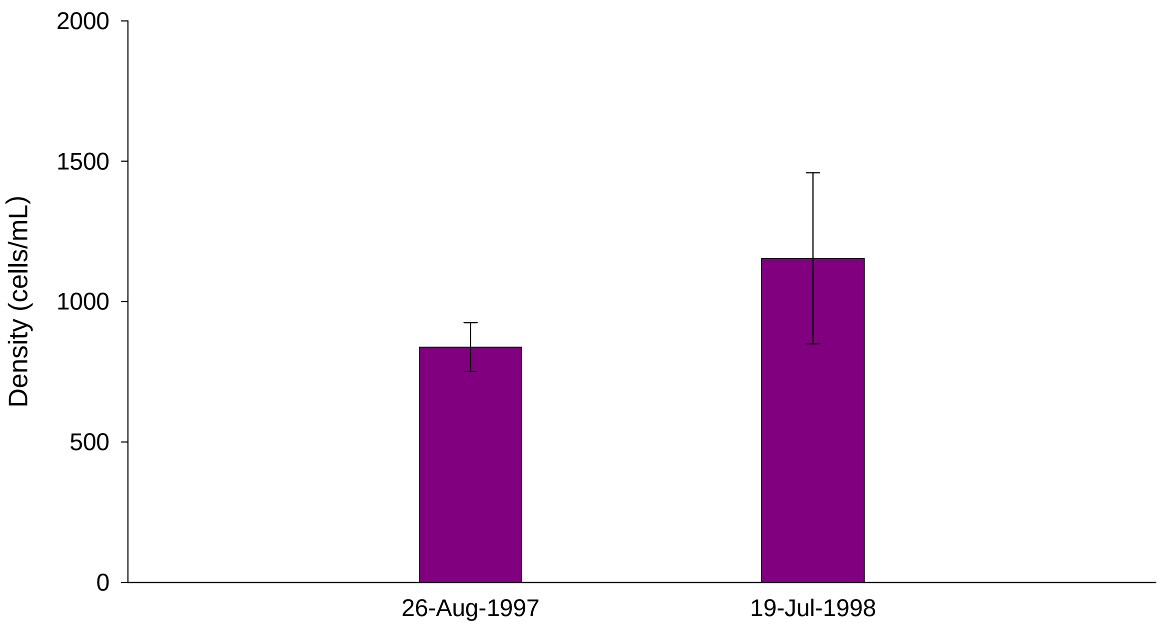


Figure 5.4 (continued). Relative abundance of major taxonomic groups and mean total density (± 1 SE) of phytoplankton in Fickle Duck Lake, 1995 to 1998.

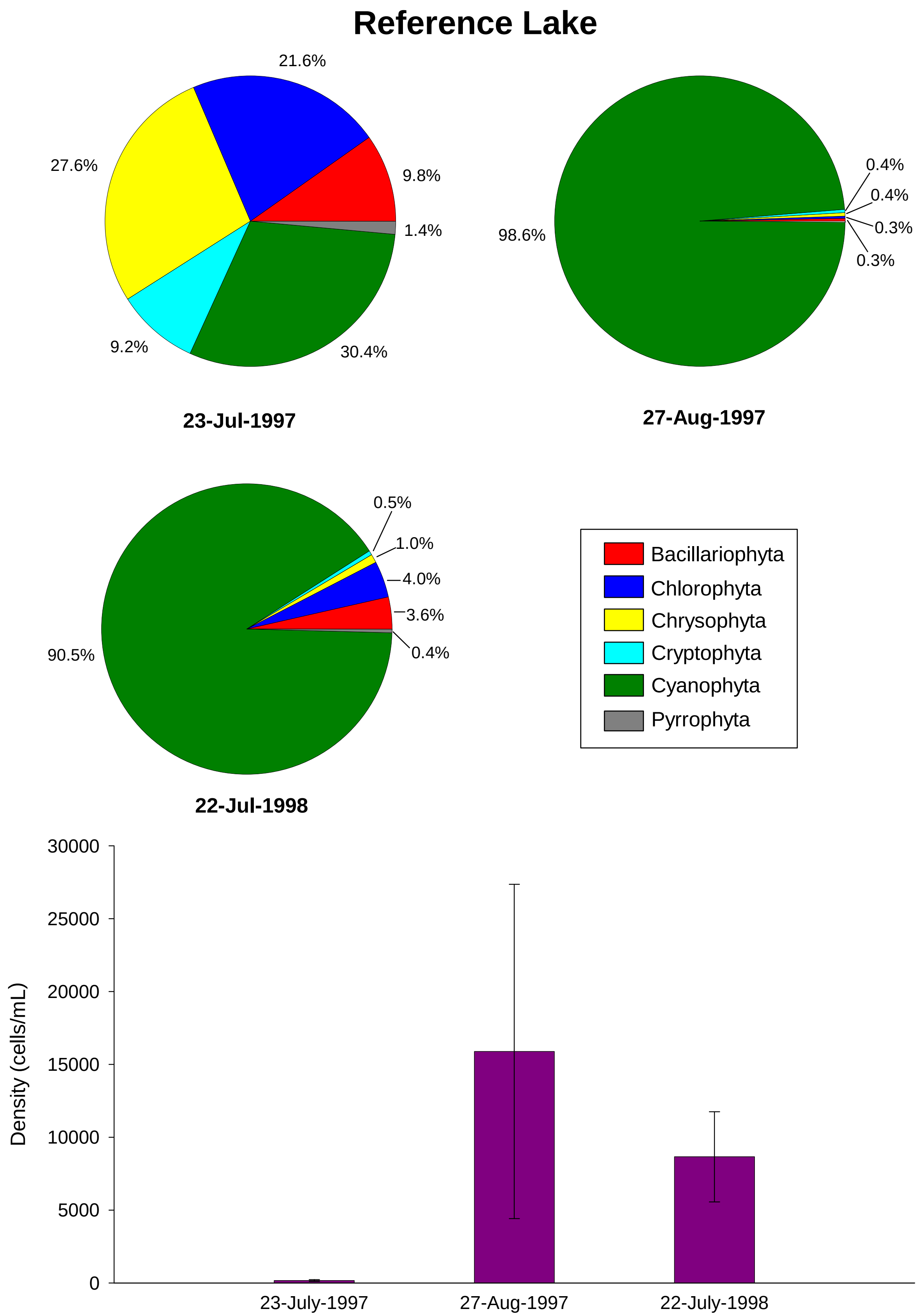


Figure 5.5 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of phytoplankton in Reference Lake, 1997 to 1998.

5.1.6 Summary

The phytoplankton samples obtained from the Boston area lakes did not reveal any uncommon or rare species. The phytoplankton communities (i.e., taxonomic composition) of the four lakes showed little differentiation and were similar in many respects to the communities of many other small lakes in the Arctic and sub-Arctic (Moore 1978a, 1978b; RL&L 1997, 1998, and 1999). In general, phytoplankton within the Boston area lakes were numerically dominated by the Cyanophyta species, *Anacystis* spp. and *Lyngbya limnetica*. However, in several of the lakes *Crucigenia* spp. (Chlorophyta), *Asterionella formosa* (Bacillariophyta), and *Dinobryon* spp. (Chrysophyta) each made significant contributions to phytoplankton abundance.

For the Boston area lakes, a comparison of phytoplankton abundance suggested that Reference Lake was the most productive and Aimaokatalok Lake was the least productive (Table 5.2). The concentration of chlorophyll *a* is typically a better measure of productivity than phytoplankton cell abundance; however, these data were only collected during two sampling sessions from each lake. Based on the chlorophyll *a* data, Reference Lake appears to be nearly twice as productive as the other three lakes, with Fickle Duck Lake being the least productive (Table 5.2).

Table 5.2 Summary of Phytoplankton Abundance in Boston Area Lakes, 1996 to 2000

Waterbody	Number of Sampling Sessions	Mean Abundance (cells/mL)	Mean Chlorophyll *a* (ug/L) in 1997	Mean Chlorophyll *a* (ug/L) in 1998
Aimaokatalok Lake	17	1 354	0.35	1.56
Stickleback Lake	7	2 355	0.76	1.40
Fickle Duck Lake	6	1 454	0.65	1.12
Reference Lake	3	8 237	1.24	3.61

The numerical dominance by Cyanophyta among the four Boston area lakes suggested that this group was able to take advantage of environmental conditions and substantially increase its population. Indeed, many species of Cyanophyta exhibit rapid population increases when conditions are suitable (Hoogenhout and Amez 1964). Cyanophyta can regulate their buoyancy (Reynolds 1975) and thus maintain themselves near the surface where incident light is greatest. Large concentrations of algae near the surface also can effectively shade other algae in the deeper waters (Fogg 1966), thereby inhibiting production of those species that cannot regulate their buoyancy and move toward the surface. Through their ability to fix atmospheric nitrogen, Cyanophyta can flourish during periods when concentrations of available dissolved nitrogen are low (Dugdale and

Dugdale 1962). Water quality results included in this compilation report (see Section 3) indicated that nitrate + nitrite nitrogen levels were low throughout all sampling sessions. The low available nitrogen levels may be a limiting factor for groups other than Cyanophyta.

5.2 PERIPHYTON IN STREAMS

Periphyton is the algae, bacteria, fungi, and associated materials that surround solid surfaces in aquatic systems (Lock et al. 1984). The periphytic algal community is often monitored or assessed because of the following: 1) minimal sampling effort is required, 2) algae are numerically abundant, diverse, and easy to identify, and 3) periphytic algae form part of the lower trophic food chain level (i.e., convert sunlight into biological tissues), upon which other aquatic life forms depend. The information presented is based on data from annual data reports (Rescan 1993, 1994, 1995, 1997, and 1999a).

5.2.1 Methods

Periphyton samples were collected from five streams within the Boston area (Figure 5.1). Two to five sampling sessions were conducted on each waterbody between 1993 and 1998 (Table 5.3). Periphyton samples were not collected in 1994.

Table 5.3 Periphyton Sampling Schedule in Boston Area Lakes, 1993 to 1998

Waterbody	Date					
	1993	1994	1995	1996	1997	1998[a]
Stickleback Outflow			Aug	25 Aug	21 July & 24 Aug	26 June to 30 July
Fickle Duck Outflow	17 Aug		Aug		25 Aug	26 June to 31 July
Aimaokatalok NE Inflow				5 Aug	25 Aug	28 June to 31 July
Aimaokatalok River					24 Aug	27 June to 1 Aug
Reference Outflow					25 Aug	28 June to 1 Aug

[a] In 1998, artificial substrate samplers were used. The date range indicates the period the samplers were in the water.

To collect periphyton samples, an attempt was made to use Plexiglas plate artificial substrate samplers (100 cm^2); however, drastic changes in water levels occasionally resulted in artificial substrate samplers not being recovered. When artificial substrate samplers were not available, instantaneous samples for periphyton were obtained from rocks. Regardless of substrate, periphyton samples were collected either by using a modified syringe-brush or by scraping a known surface area of rock with a plastic spatula and ruler. Surface areas sampled were cleaned with a fine-bristled brush and rinsed using a wash bottle. The samples were transferred in 500-mL jars and preserved in Lugol's iodine solution. Genera and, where possible, species were identified and enumerated by Fraser Environmental Services, in accordance with procedures described in Rescan (1995). Again, Rescan reports identified Cryptophyta and Pyrrophyta as members of the same phylum; however, recent literature (Wehr et al. 2002) makes a distinction between the two taxonomic groups, treating both Cryptophyta and Pyrrophyta as two distinct phyla. For this report, Cryptophyta and Pyrrophyta were analyzed as two separate phyla.

Chlorophyll *a* samples were obtained by gently scraping a known surface area of an artificial substrate into a plastic wide-mouth jar using filtered stream water and a brush. Filtered stream water was added to keep the sample moist and in suspension. Jars were kept cold and in the dark until returned to the field laboratory, where the samples were gently shaken and filtered onto 47 mm diameter membrane filters with a pore size of 0.45 µm. Filters were carefully folded in half, wrapped in aluminum foil, and frozen until analysed by the fluorometric method described in Parsons et al. (1984). Chlorophyll *a* samples were collected only in summer 1998.

5.2.2 Stickleback Outflow

Five periphyton sampling sessions were conducted on Stickleback Outflow during the summer, including once in 1995 and 1996, twice in 1997, and once in 1998. Mean total algal cell numbers (±1 SE) ranged from $133 \times 10^3 \pm 44 \times 10^3$ cells/cm^2 in 1998 to 1196×10^3 cells/cm^2 in a single sample from August 1995 (Figure 5.6; Appendices B3 and B4).

Bacillariophyta (diatoms) contributed between 17.3 and 68.1% towards the total mean number of cells enumerated in each sample (Figure 5.6; Appendix B4). Cyanophyta, also known as cyanobacteria and colloquially referred to as blue-green algae, were also common (contributed betweem 23.7 and 58.9% to total cell numbers). The major components of Bacillariophyta were *Fragilaria* spp., *Navicula* spp., and *Synedra* spp., whereas Cyanophyta were mainly represented by *Lyngbya limnetica* in 1995 and *Anacystis* spp. in 1996 to 1998.

5.2.3 Fickle Duck Outflow

Four periphyton sampling sessions were conducted on Fickle Duck Outflow during the summers of 1993, 1995, 1997, and 1998. Mean total algal cell numbers (±1 SE) ranged from $371 \times 10^3 \pm 127 \times 10^3$ cells/cm^2 in August 1997 to 3933×10^3 cells/cm^2 in a single sample from August 1995 (Figure 5.7; Appendix B4).

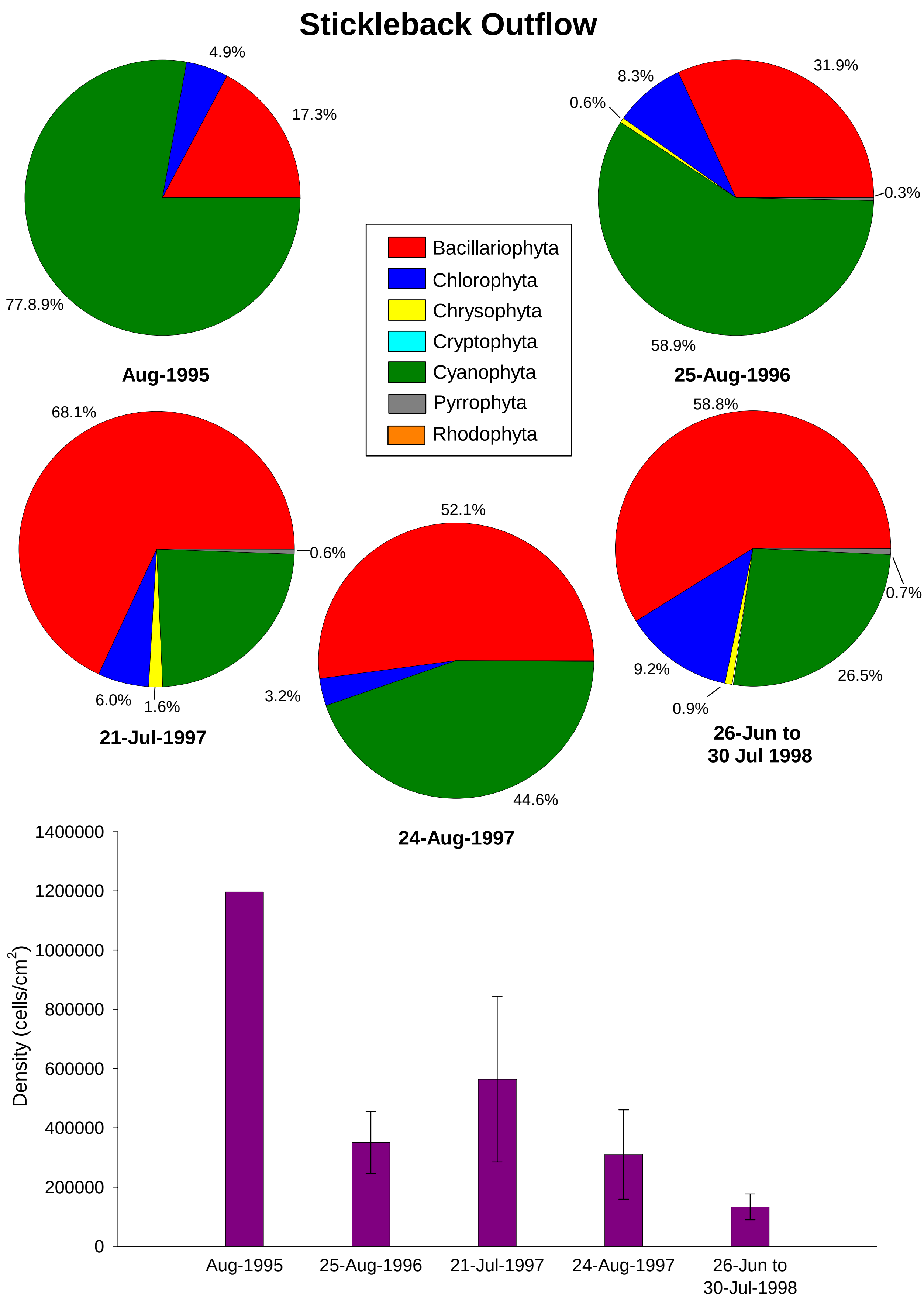


Figure 5.6 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of periphyton in Stickleback Outflow, 1995 to 1998.

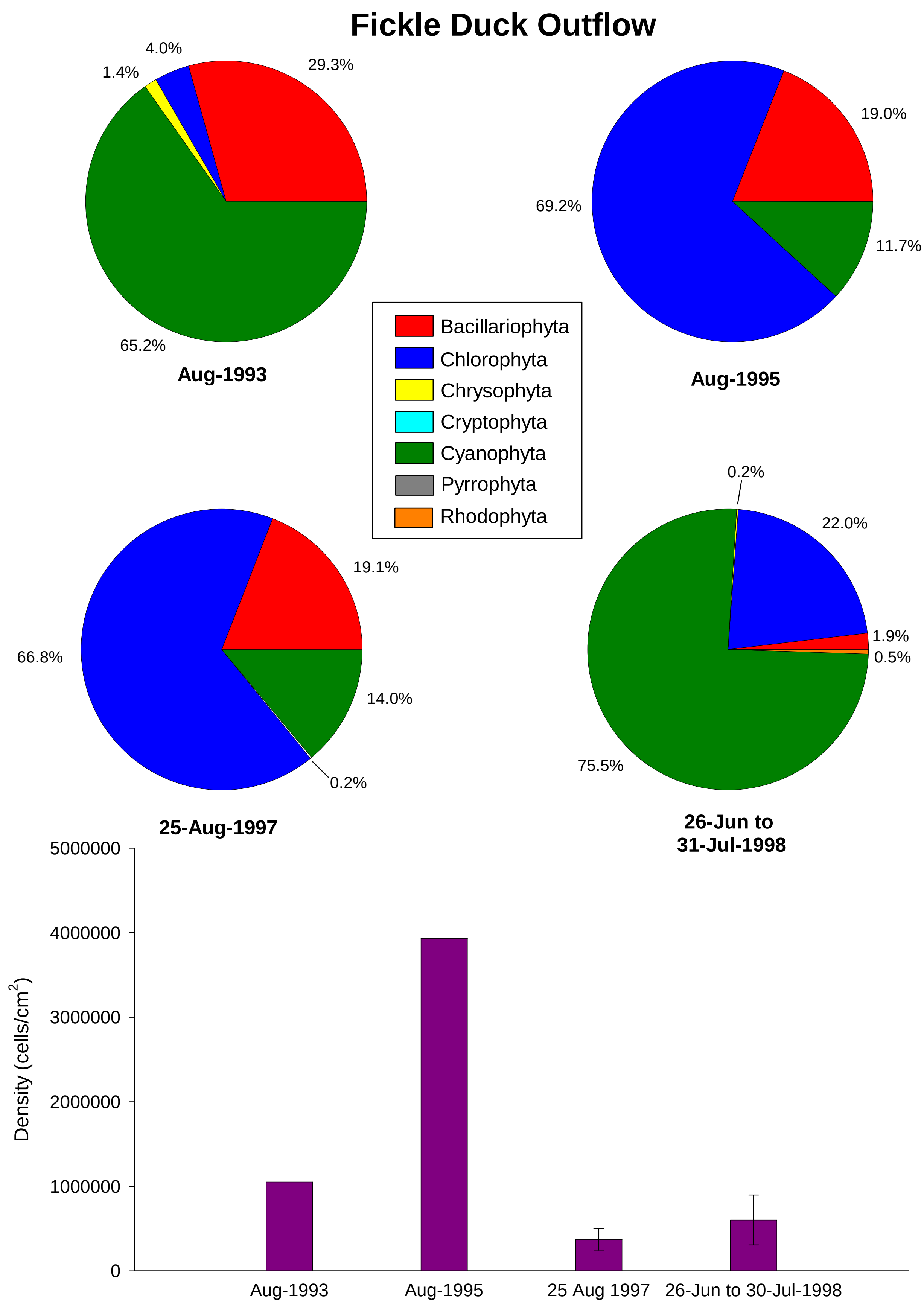


Figure 5.7 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of periphyton in Fickle Duck Outflow, 1993 to 1998.

In 1993 and 1998, the periphyton algal community of Fickle Duck Outflow was dominated by Cyanophyta (65.2 and 75.5%, respectively), whereas in 1995 and 1997 Chlorophyta (green algae) were dominant (69.2 and 66.8%, respectively). In years when Cyanophyta dominated, Chlorphyta formed a relatively small portion of the community and *vice versa*. Bacillariophyta also made significant contributions towards the total mean cell count in the sample, ranging from 1.9 to 29.3% (Figure 5.7; Appendices B3 and B4). Major contributors to Chlorophyta were *Stigeoclonium* spp. in 1995 and *Tetraspora* spp. in 1997 and 1998. Cyanophyta were comprised largely of *Agmenellum* spp. in 1993 and an unidentified species in 1998. The major component of the Bacillariophyta was *Tabellaria flocculosa*.

5.2.4 Aimaokatalok NE Inflow

Three periphyton sampling sessions were conducted on Aimaokatalok NE Inflow, one each during the summers of 1996, 1997 and 1998. Mean total algal cell numbers (±1 SE) ranged from 121 x 10^3 cells/cm^2 in 1997 to 987 x 10^3 ± 150 x 10^3 cells/cm^2 in 1998 (Figure 5.8; Appendix B4).

The periphyton algal community of Aimaokatalok NE Inflow was dominated by Cyanophyta (57.5 to 74.3% of total cell numbers) (Figure 5.8; Appendices B3 and B4); this group was comprised largely of *Gomphosphaeria nagelianum*.

5.2.5 Aimaokatalok River

Two periphyton sampling sessions were conducted on the Aimaokatalok River, including once during the summers of 1997 and 1998. Mean total algal cell numbers (± 1 SE) ranged from 26 x 10^3 ± 2 x 10^3 cells/cm^2 in 1997 to 582 x 10^3 ± 82 x 10^3 cells/cm^2 in 1998 (Figure 5.9; Appendices B3 and B4).

The periphyton community in the Aimaokatalok River was dominated by three taxonomic groups: Bacillariophyta (29.4 and 48.7% of total cell numbers), Chlorophyta (24.4 and 39.5%) and Cyanophyta (11.8 and 45.7%) (Figure 5.9; Appendices B3 and B4). The major contributor to the Bacillariophyta was *Tabellaria flocculosa*. Chlorophyta were comprised largely of *Ankistrodesmus falcatus* and an unidentified unicellular species. Cyanophyta were mainly represented by *Gomphosphaeria nagelianum*.

5.2.6 Reference Outflow

Two periphyton sampling sessions were conducted on Reference Outflow during the summers of 1997 and 1998. Total algal cell numbers (±1 SE) ranged from

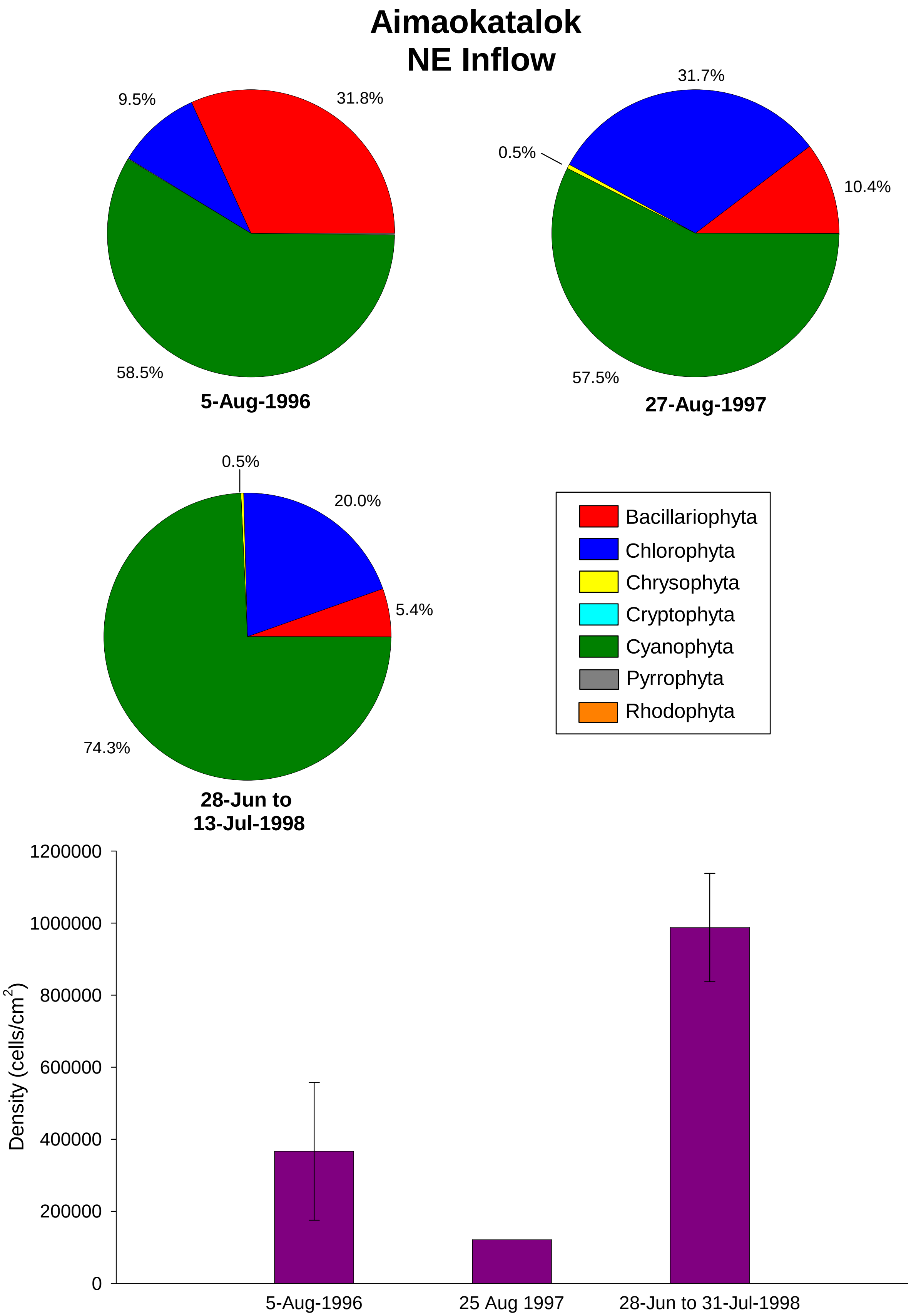


Figure 5.8 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of periphyton in Aimaokatalok NE Inflow 1996 to 1998.

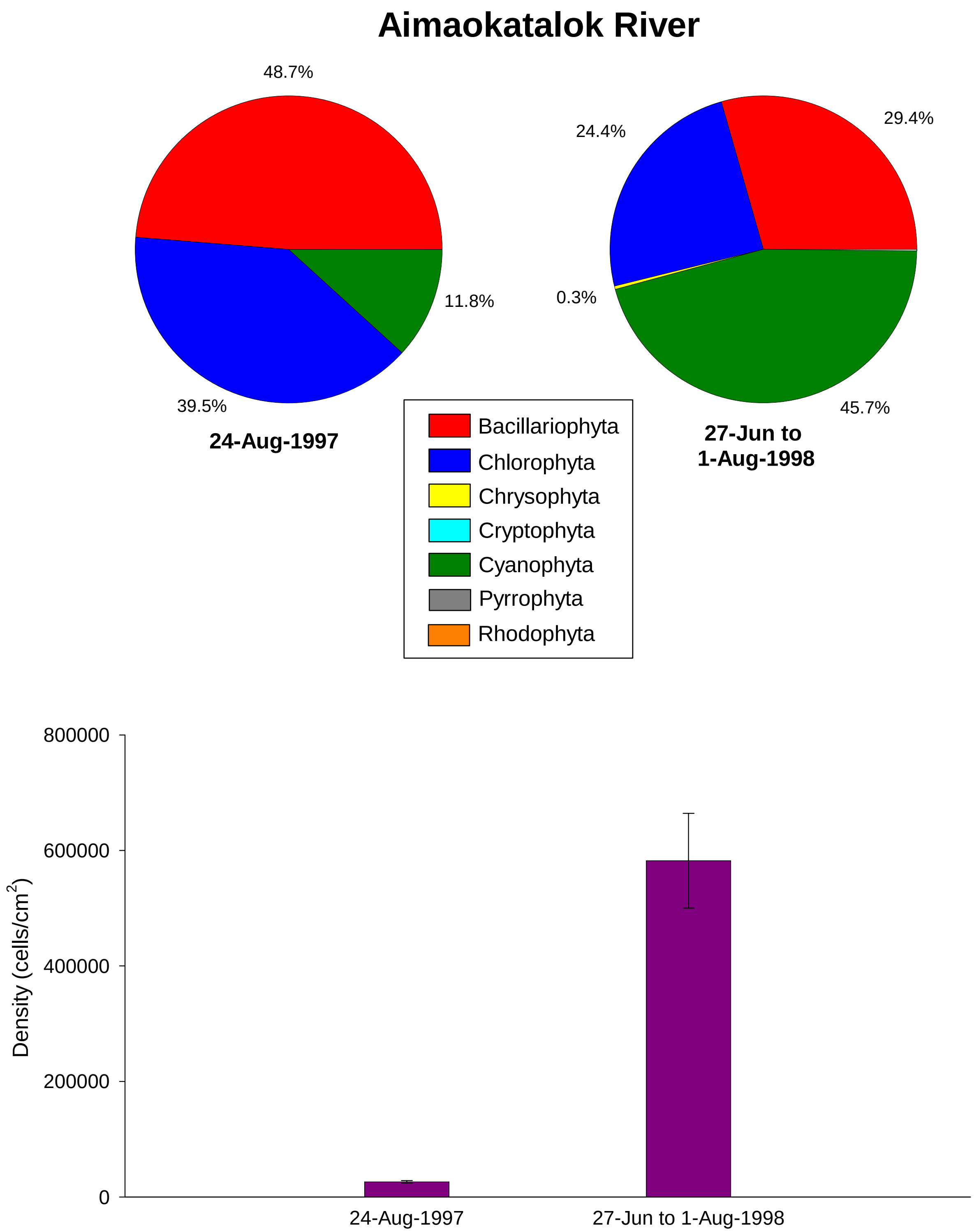


Figure 5.9 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of periphyton in Aimaokatalok River, 1997 to 1998.

175 ± 66 x 10^3 cells/cm^2 in 1998 to 247 ± 82 x 10^3 cells/cm^2 in 1997 (Figure 5.10; Appendices B3 and B4).

The periphyton community in Reference Outflow was equally dominated by three taxonomic groups: Bacillariophyta (18.9 and 42.0% of total cell numbers), Chlorophyta (20.5 and 23.6%) and Cyanophyta (36.6 and 56.7%) (Figure 5.10; Appendices B3 and B4). The major contributor to the Bacillariophyta was *Diatoma elongatum*. Chlorophyta were comprised largely of *Tetraspora* spp. and *Oedogonium* sp. Cyanophyta were mainly represented by *Clastidium setiferum* and *Gomphosphaeria nagelianum.*

5.2.7 Summary

For the Boston area streams, a comparison of mean periphyton abundance suggested that Fickle Duck Outflow was the most productive and Reference Outflow was the least productive stream (Table 5.4). Based on chlorophyll *a* concentrations, which is a biomass estimate of live algae, Reference Outflow was the most productive, whereas Fickle Duck Outflow was the least productive. The discrepancy between the results based on cell abundance and chlorophyll *a* concentrations was likely related to the relatively small cell size of Cyanophyta, which could greatly contribute to high numerical abundance (cells/cm^2) without an associated increase in algal biomass.

Table 5.4 Summary of Periphyton Abundance in Boston Area Streams, 1993 to 1998

Waterbody	Number of Sampling Events	Mean Abundance (cells/cm^2)	June 1998 Chlorophyll *a* (µg/cm^2)	July/Aug 1998 Chlorophyll *a* (µg/cm^2)
Stickleback Outflow	5	510 784	-	49.76
Fickle Duck Outflow	4	1 489 118	124.08	88.74
Aimaokatalok NE Inflow	3	491 534	51.94	370.88
Aimaokatalok River	2	304 172	199.54	49.38
Reference Outflow	2	210 974	371.65	95.02

Similar to the phytoplankton (see Section 5.1), the numerical dominance by Cyanophyta (mainly *Gomphosphaeria nagelianum and Lyngbya limnetica*) among the five Boston area streams suggested that this group was able to take advantage of environmental conditions and substantially increase its population. In contrast to the phytoplankton, Bacillariophyta (mainly *Tabellaria flocculosa)* and Chlorophyta made significant contributions to periphyton communities, and typically co-dominated along with Cyanophyta. The co-dominance of several taxonomic groups makes the assessment of water quality difficult. As Cyanophyta can fix atmospheric nitrogen, the incomplete dominance of this

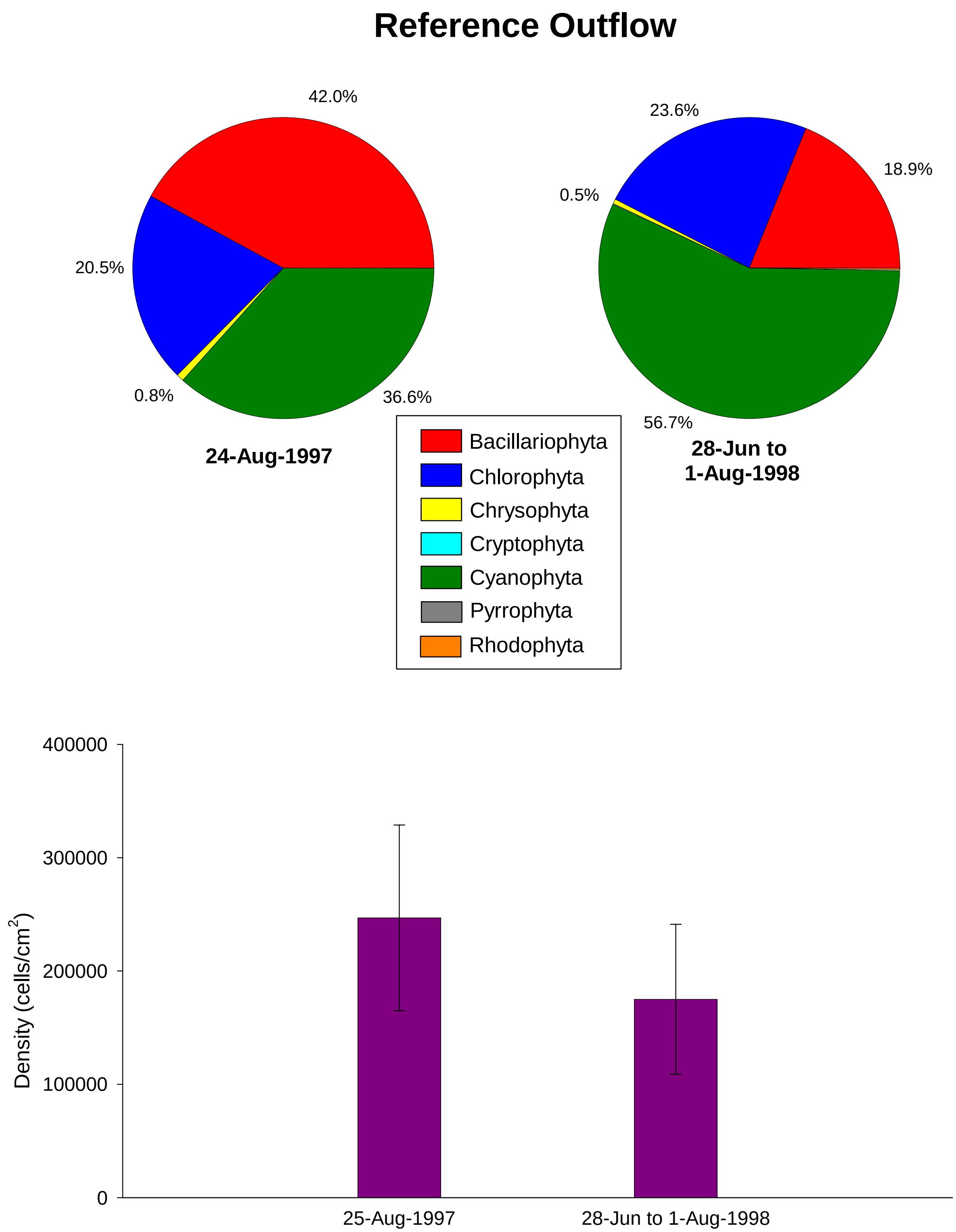


Figure 5.10 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of periphyton in Reference Outflow, 1997 to 1998.

group generally suggested that nitrogen levels were not the single limiting factor. The dominant periphyton taxa were those that form filaments or gelatinous bags and are able to attach to substrata in flowing waters. The above observations were consistent with those made in other streams of the Arctic and sub-Arctic (RL&L 1997, 1998, and 1999).

6 SECONDARY PRODUCERS

6.1 ZOOPLANKTON IN LAKES

In general, zooplankton are small animals that inhabit the water column of lakes. Zooplankton consume phytoplankton and other organic matter. Zooplankton are an important food source for large invertebrates and fish. The information presented is based on data from annual data reports (Rescan 1993, 1994, 1995, 1997, 1998, and 1999a).

6.1.1 Methods

Zooplankton samples were collected from four lakes within the Boston area between 1993 and 1998 (Figure 6.1) (Rescan 1993, 1994, 1995, 1997, 1998, and 1999a). Three to 13 sampling sessions were conducted on each lake. Zooplankton samples were not collected in 1994 (Table 6.1).

Table 6.1 Zooplankton Sampling Schedule in Boston Area Lakes, 1993 to 1998

Waterbody	Sampling Station	Date					
		1993	1994	1995	1996	1997	1998
Aimaokatalok Lake	WQ5	Aug		2 Aug			
	Stn 1					24 Jul	
	Stn 4						18 July
	Stn 5				4 & 24 Aug	24 Jul & 25 Aug	
	WQ9/Stn 6				4 & 24 Aug	24 Jul & 25 Aug	18 July
Stickleback Lake		Aug		3 Aug	4 & 25 Aug	23 Jul & 25 Aug	19 July
Fickle Duck Lake				3 Aug	5 & 25 Aug	23 Jul & 26 Aug	19 July
Reference Lake						23 Jul & 27 Aug	22 July

Zooplankton samples were collected with a 118 µm mesh net with an opening diameter of 30 cm. Triplicate zooplankton samples were collected during each sampling session, except for 1993 when only single samples were collected. At each site, samples were collected from the entire water column beginning at a depth 2 m above the bottom sediments. At each site, a single haul was collected by vertically raising the net at a constant speed of 0.5 m/s. Each sample was transferred to a clean 500-mL plastic bottle, preserved with 10% formalin, and labeled. All samples were submitted to Applied Technical Services, Victoria, BC, for taxonomic identification and enumeration.

Although all zooplankton abundance data had been reported by Rescan in terms of number of animals per cubic metre (i.e., standardized to account for depth differences, between vertical hauls and net diameter), data from 1995 and 1996 (Rescan 1996, 1997) appeared to be in an unconverted form (i.e., number of animals per sample), as confirmed with Applied Technical Services, who performed the original analysis. To allow comparisons of zooplankton abundance, the zooplankton data from 1995 and 1996 were converted into animals/m^3 by applying the same conversion factors that were used in 1997 (Rescan 1998). Additionally, all 1993 data were excluded from the summary calculations of zooplankton abundance for Aimaokatalok and Stickleback lakes. Due to the large number of rotifers collected in 1993 compared to other years, and the lack of identification further than the phylum Rotifera, we were not confident that these samples were processed properly.

6.1.2 Aimaokatalok Lake

Thirteen zooplankton sampling events were conducted on Aimaokatalok Lake during summer, including one each in 1993 and 1995, four in 1996, five in 1997 and two in 1998. Mean total numbers (±1 SE) ranged from 1816 ± 115 animals/m^3 on 24 July 1997 to 72 596 ± 7735 animals/m^3 on 6 August 1996 (Figure 6.2; Appendices C1 and C2).

At most sites and times cyclopoid copepods (Cyclopoida) dominated the zooplankton community of Aimaokatalok Lake, contributing between 23.3 and 86.9% towards the total number of animals recorded per sample. The major contributors to Cyclopoida were juvenile *Lichomolgidae* nauplii, which are parasites. The second most abundant group were Rotifera (wheel-animals), contributing between 9.5 and 66.3%, largely dominated by *Kellicottia longispina* and *Trichocerca* sp. In August 1996, large numbers (up to 26 453 animals/m^3) of Cladocera (water fleas, mostly *Daphnia longiremis*) were found at several sites (Figure 6.2; Appendices C1 and C2).

6.1.3 Stickleback Lake

Seven zooplankton sampling sessions were conducted on Stickleback Lake, including once during 1993 and 1995, twice in 1996 and 1997, and once in 1998. Mean total numbers (±1 SE) ranged from 1127 ± 124 animals/m^3 on 25 August 1996 to 911 697 animals/m^3 in a single sample from August 1993 (Figure 6.3; Appendices C1 and C2).

Cyclopoid copepods contributed the most (between 21.3 and 98.5%) towards total numbers in most years (except for the 1993 sample, which was composed

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LEGEND

- ▲ Zooplankton sampling locations
- ● Drift sampling locations
- Rivers
- Study area waterbodies
- Waterbodies

WQ X / STN X Sampling station names from Rescan Reports

95-97 Consequtive years of sampling at station

REFERENCE

Sources: Data Obtained from the Government of Canada, Natural Resources Canada, Centre for Topographic Information
Projection: UTM Zone 13N Datum: NAD 83

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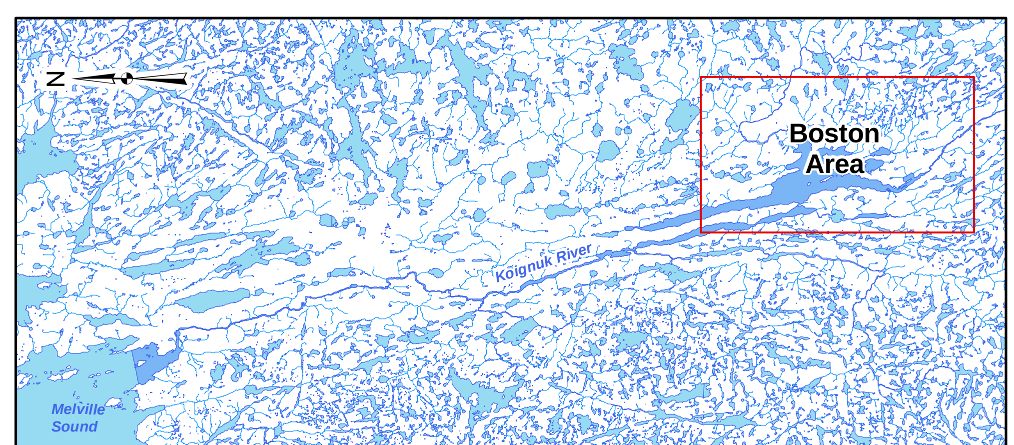

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Boston Project Data Compilation

TITLE

Zooplankton and Macroinertebrate Drift Sampling Locations, 1993 - 1998

PROJECT No.06-1373-028			SCALE AS SHOWN	REV. 0
DESIGN	JP	22 April 2008		
GIS	RC	22 April 2008		
CHECK	JP	14 May 2008		
REVIEW	GA	16 May 2008		

Golder Associates
Edmonton, Alberta

FIGURE: 6.1

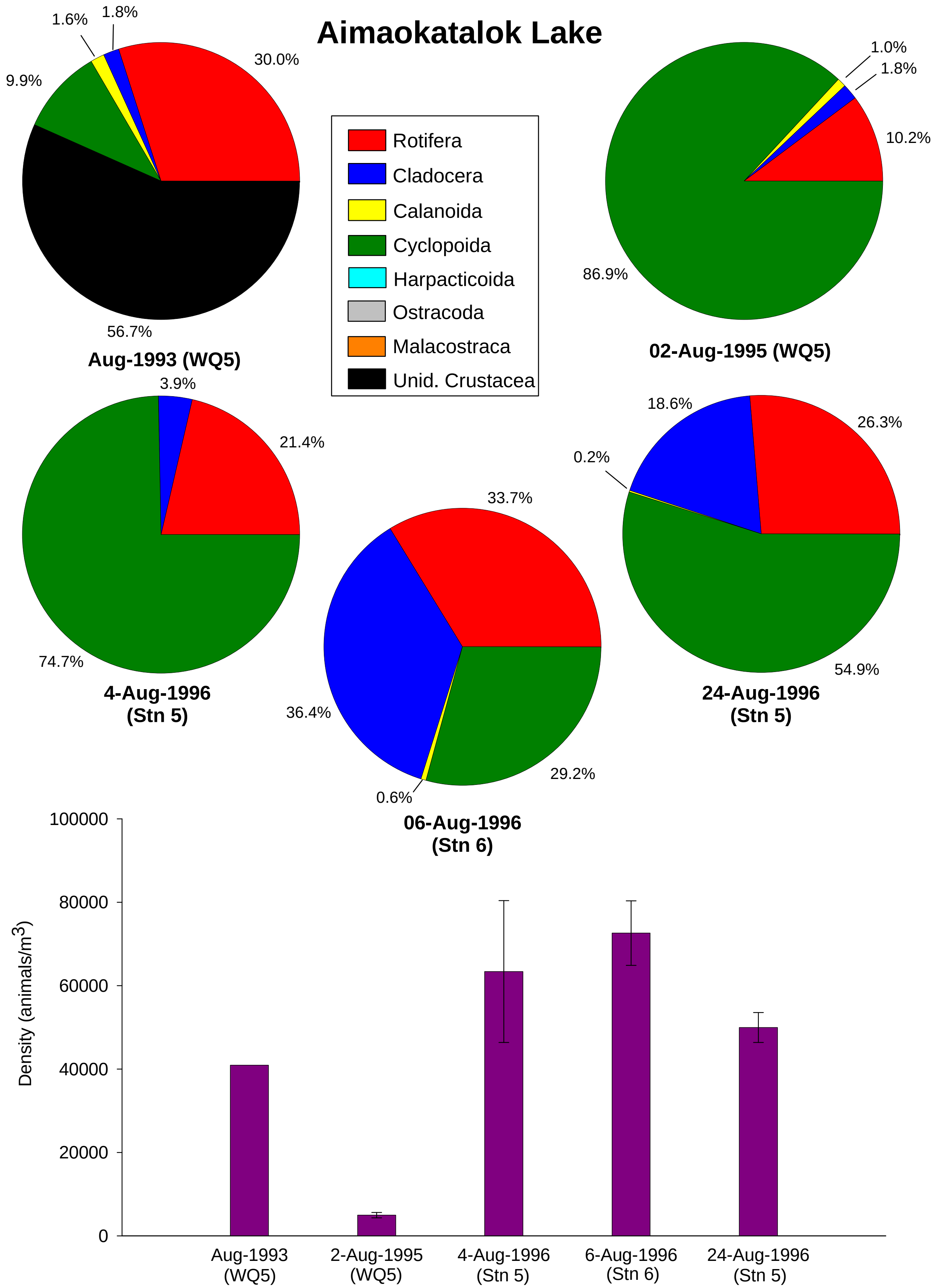

Figure 6.2 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of zooplankton in Aimaokatalok Lake, 1993 to 1998.

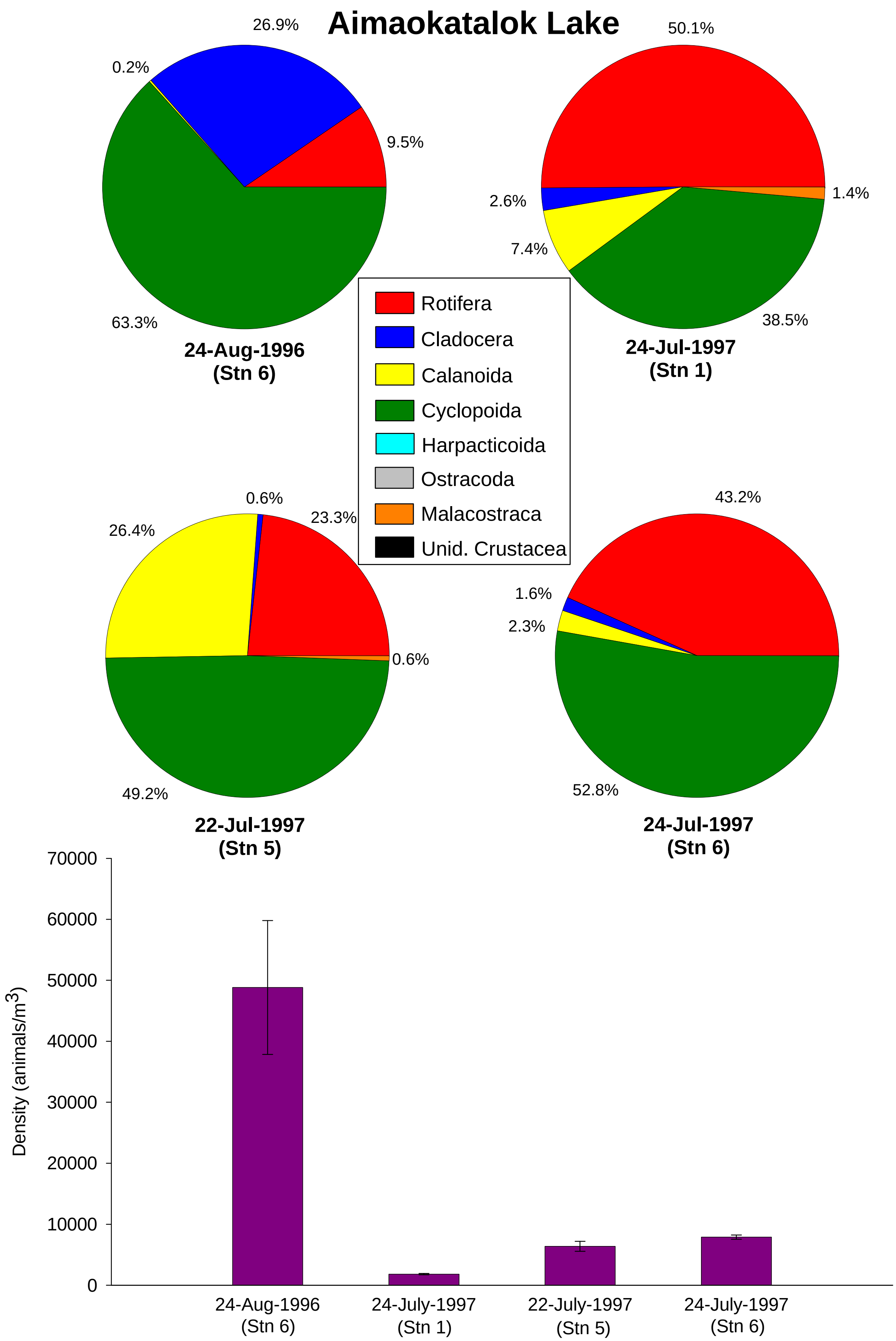

Figure 6.2 (continued). Relative abundance of major taxonomic groups and mean total density (± 1 SE) of zooplankton in Aimaokatalok Lake, 1993 to 1998.

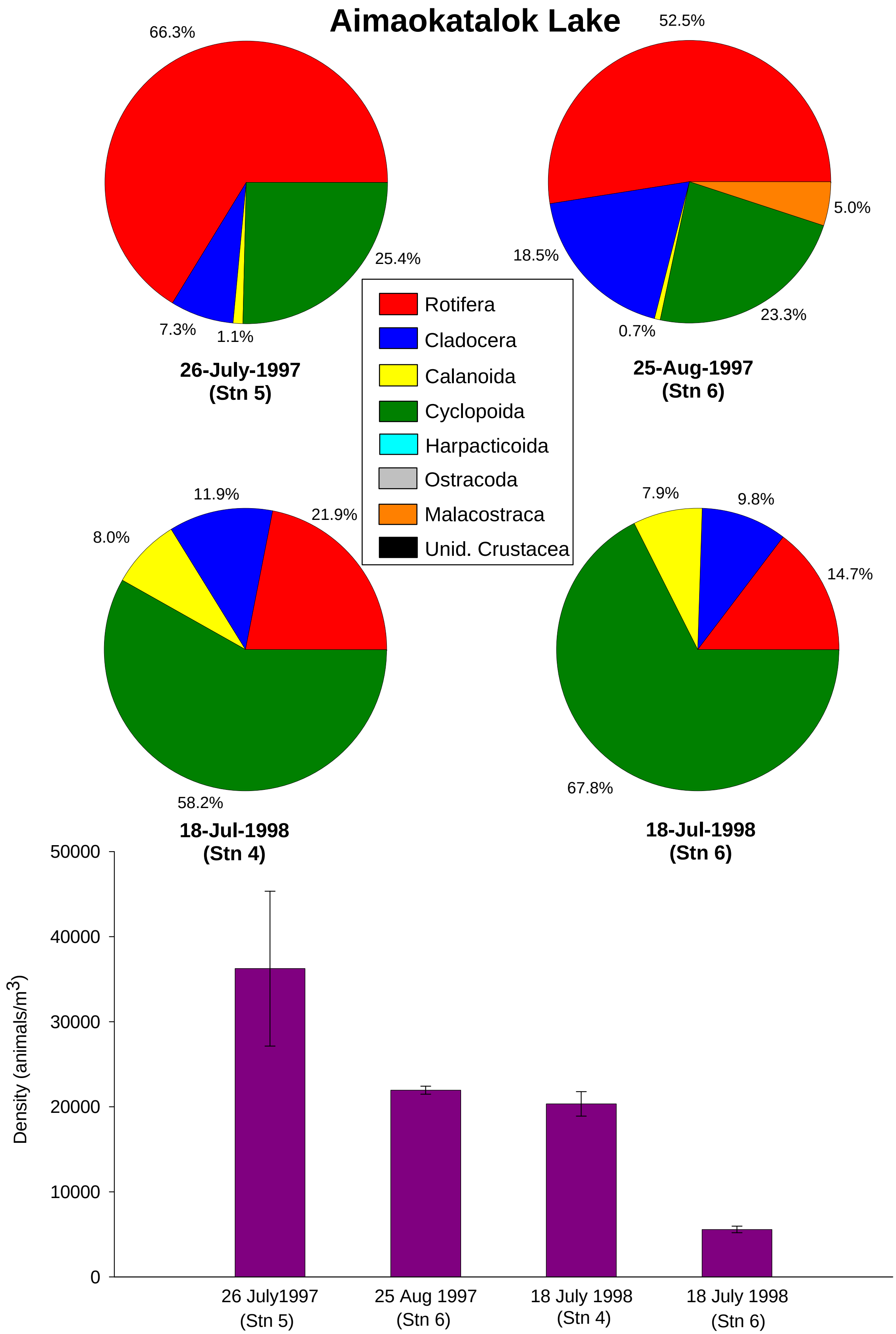

Figure 6.2 (continued). Relative abundance of major taxonomic groups and mean total density (± 1 SE) of zooplankton in Aimaokatalok Lake, 1993 to 1998.

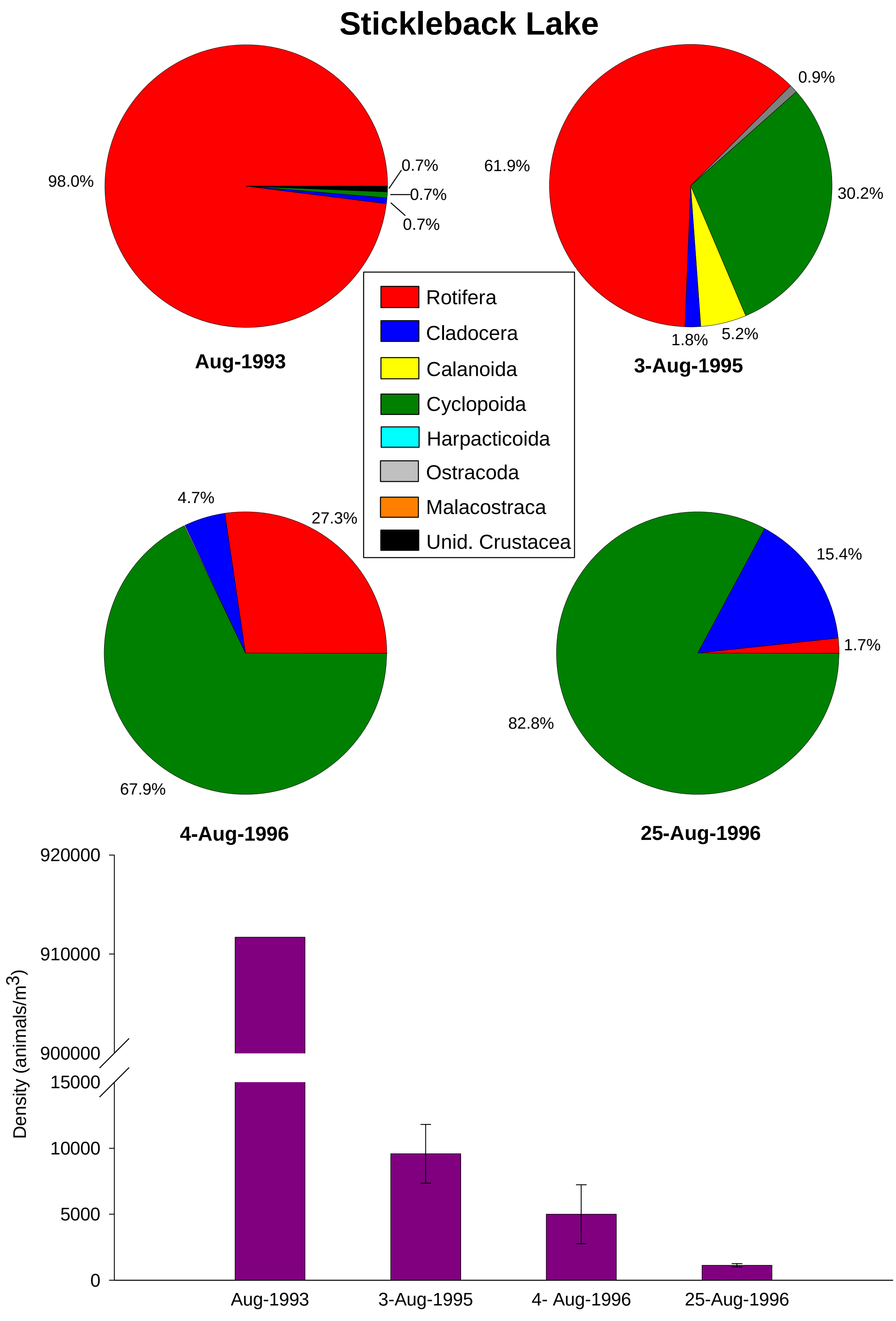

Figure 6.3 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of zooplankton in Stickleback Lake, 1993 to 1998.

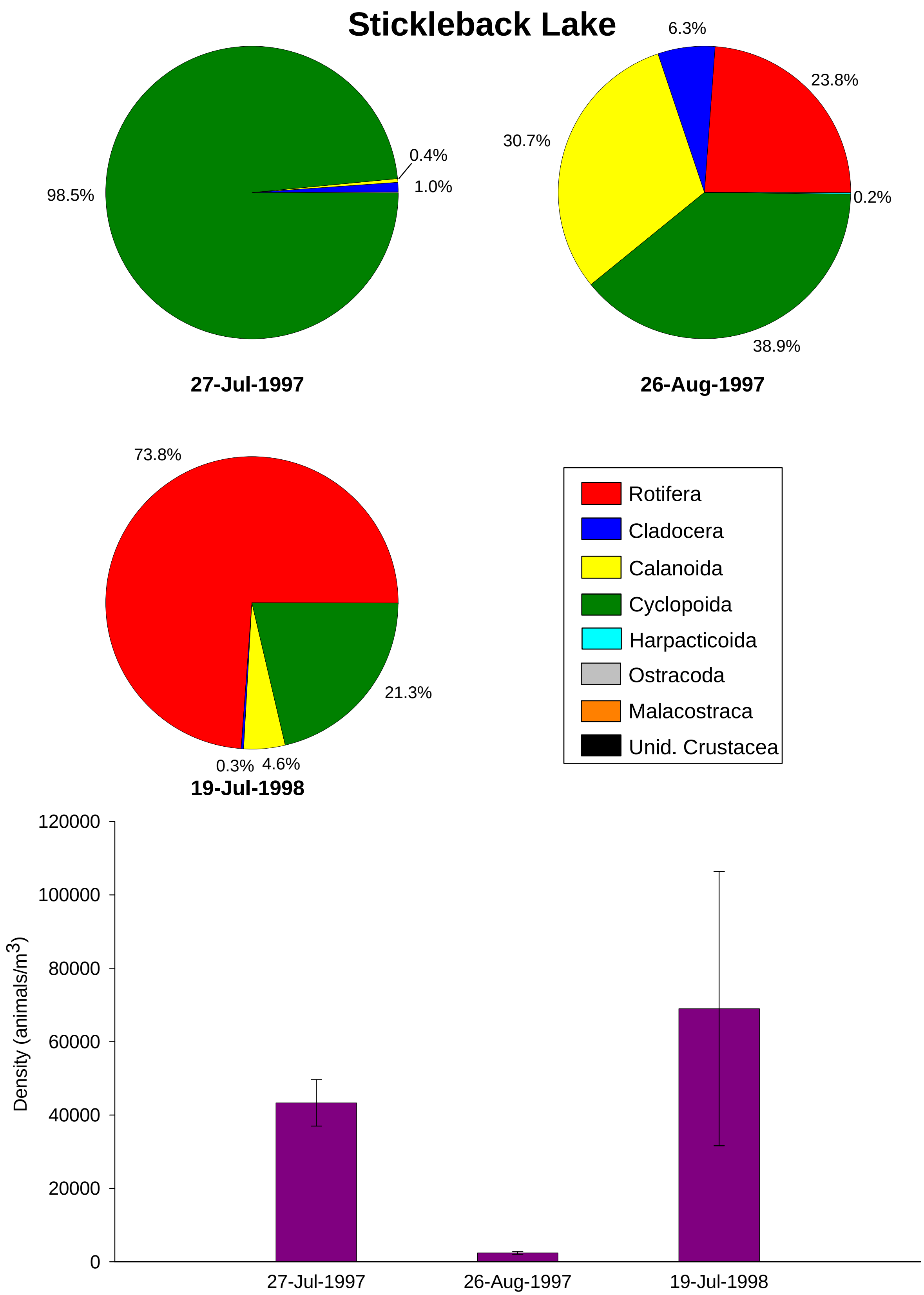

Figure 6.3 (continued). Relative abundance of major taxonomic groups and mean total density (± 1 SE) of zooplankton in Stickleback Lake, 1993 to 1998.

almost exlusively by Rotifera). Rotifers varied greatly in abundance, from 19 animals/m^3 in August 1996 to 893 584 animals/m^3 in August 1993. The major contributors to the cyclopoids were immature copepodites (the most abundant species of adult size was *Cyclops scutifer*), whereas *Kellicottia longispina* dominated the rotifers (Figure 6.3; Appendices C1 and C2).

6.1.4 Fickle Duck Lake

Six zooplankton sampling sessions were conducted on Fickle Duck Lake, including once during 1995, twice in 1996 and 1997, and once in 1998. Mean total abundance (±1 SE) ranged from 16 124 ± 2234 to 153 408 ± 17 981 animals/m^3 (Figure 6.4; Appendices C1 and C2).

Rotifera dominated the zooplankton community in Fickle Duck Lake, contributing between 30.8 and 91.8% towards the total mean animal count per sample (Figure 6.4; Appendices C1 and C2). The major contributors in this group were *Kellicottia longispina* and *Asplanchna* spp. In 1995, immature calanoid copepodites (Calanoida) of *Diaptomus* spp. and *Epischura nevadensis* contributed 46.9% of the zooplankton community, but were much less common in other years.

6.1.5 Reference Lake

Three zooplankton sampling sessions were conducted on Reference Lake, including twice in 1997 and once in 1998. Mean total numbers (±1 SE) ranged between 2001 ± 455 animals/m^3 in July 1997 and 16 589 ± 7293 animals/m^3 in August 1997 (Figure 6.5; Appendices C1 and C2).

In July 1997, the zooplankton of Reference Lake was dominated by calanoid copepods, which contributed 53.1% of the total mean animal count in the sample (Figure 6.5; Appendices C1 and C2); the major contributors within this major taxonomic group were adults and copopodites of *Leptodiaptomus pribilofensis.* In August of 1997 and July of 1998, Rotifera contributed 88.8 and 66.9%, respectively, to the total animal count, dominating the zooplankton community of Reference Lake. This major taxonomic group was represented primarily by *Kellicottia longispina*.

6.1.6 Summary

The zooplankton samples obtained from the Boston area lakes did not reveal any uncommon or rare species. The zooplankton communities (i.e., taxonomic composition) among the four waterbodies showed little differentiation and were

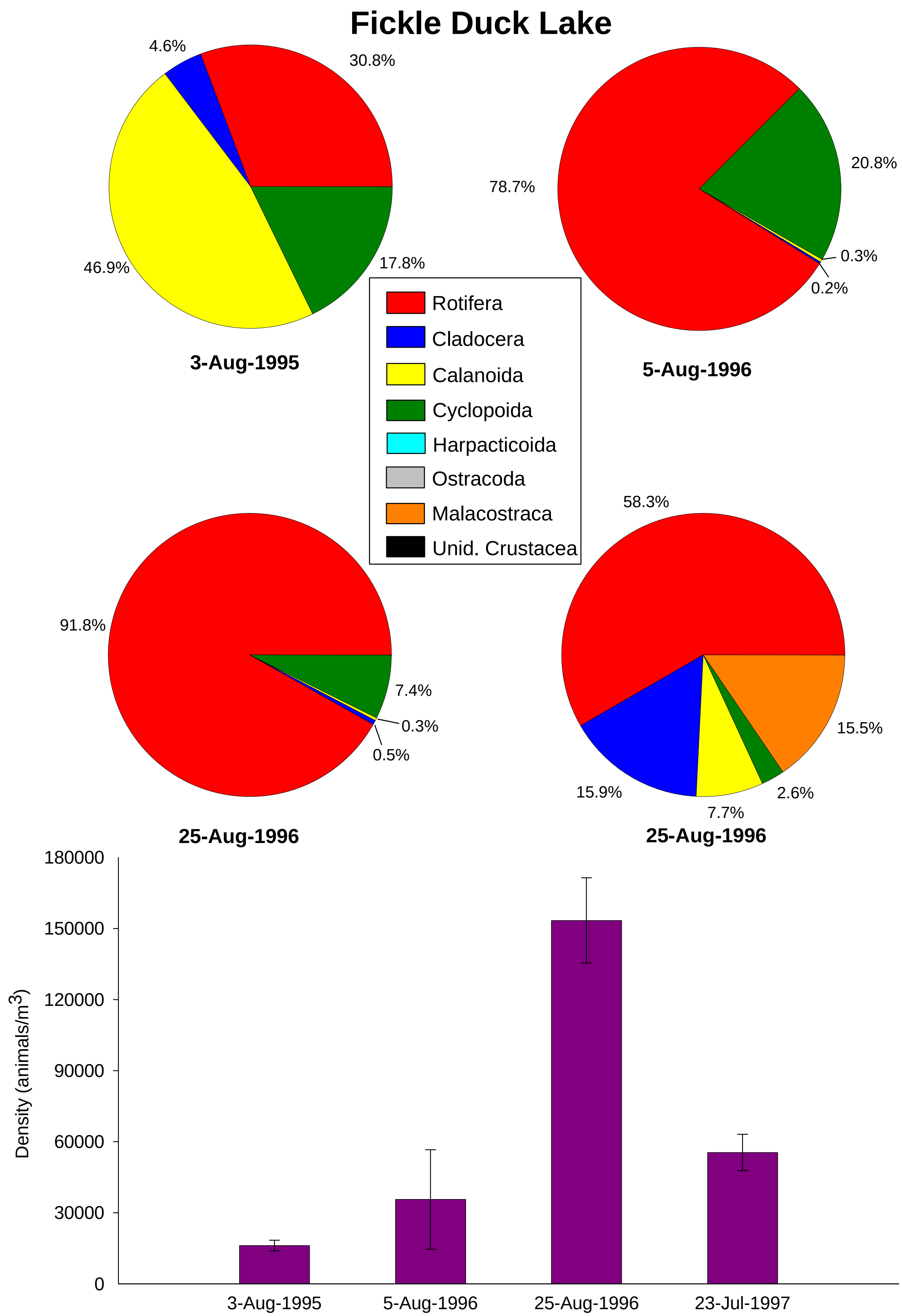

Figure 6.4 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of zooplankton in Fickle Duck Lake, 1995 to 1998.

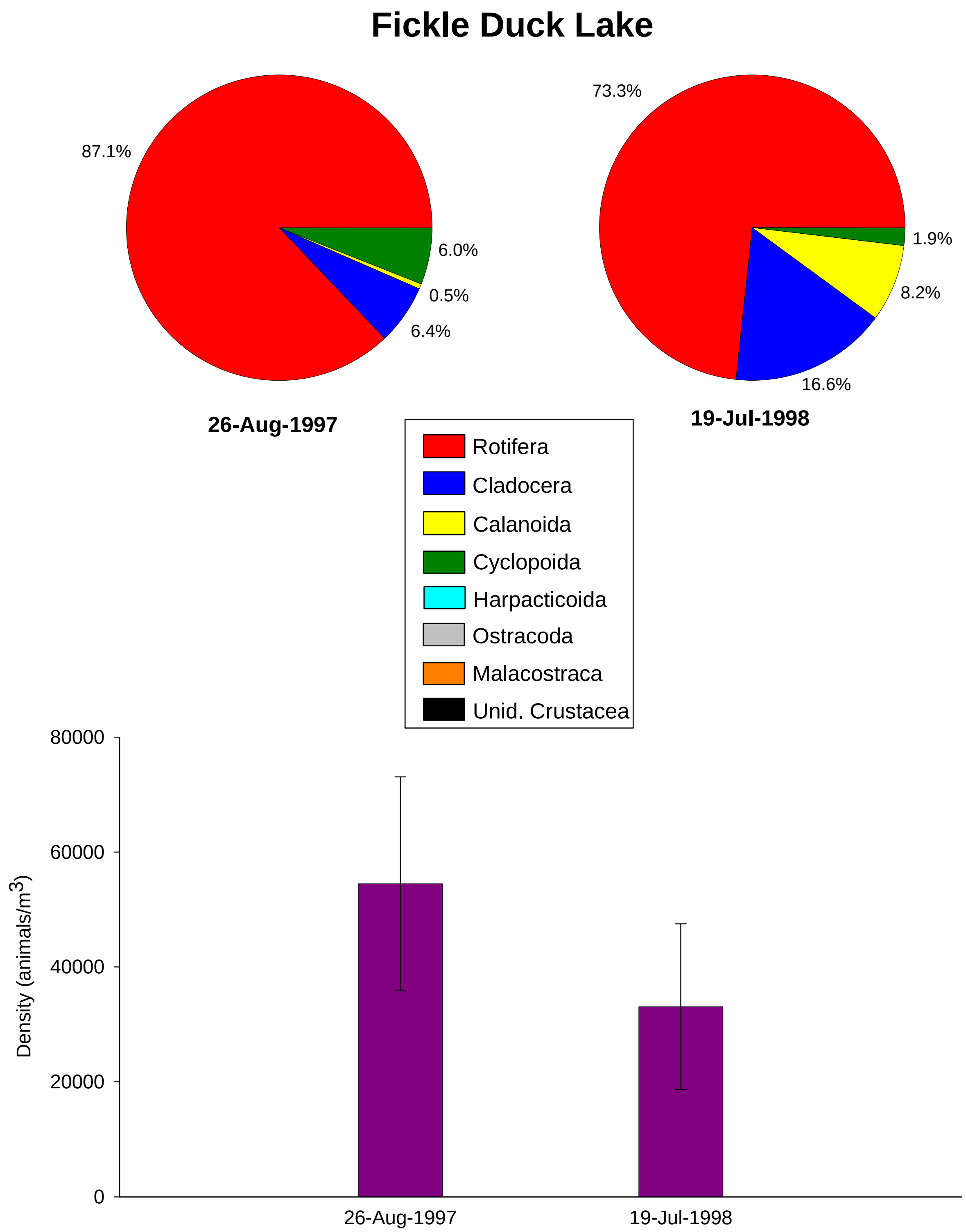

Figure 6.4 (continued). Relative abundance of major taxonomic groups and mean total density (± 1 SE) of zooplankton in Fickle Duck Lake, 1995 to 1998.

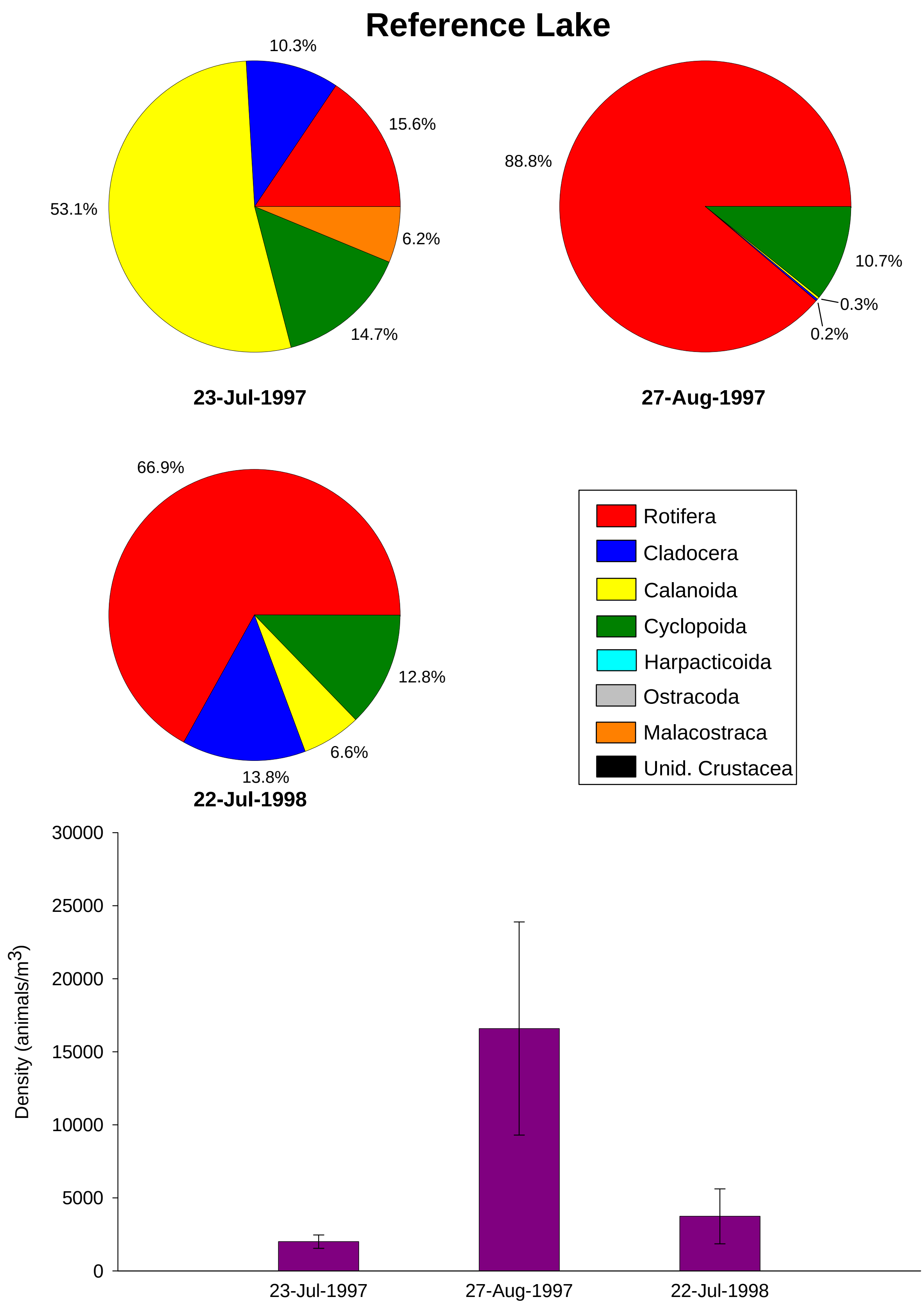

Figure 6.5 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of zooplankton in Reference Lake, 1997 to 1998.

similar in many respects to the communities of many other small lakes in the Arctic and sub-Arctic (Moore 1978a, and 1978b; RL&L 1997, 1998, and 1999).

In general, zooplankton communities within the Boston area lakes were numerically dominated by the rotifer *Kellicottia longispina*. It should be pointed out, however, that the numbers of rotifers reported were likely underestimated, because the mesh size of the zooplankton net was 118 µm (i.e., smaller rotifers could pass through the mesh). Among Copepoda, cyclopoid nauplii, copopodids and adult *Cyclops scutifer* were the most abundant. *Daphnia longiremis* was the most numerous cladoceran, but as a group, Cladocera were not abundant.

A comparison of mean zooplankton abundance indicated that Fickle Duck Lake was the most productive and Reference Lake was the least productive; mean total numbers among all sampling sessions in these two lakes were 58 018 animals/m^3 in Fickle Duck Lake and 7442 animals/m^3 in Reference Lake (Table 6.2). This observation may be somewhat misleading because biomass data, often reported as wet weight/m^3, were not reported by Rescan. In terms of biomass, large zooplankton species can dominate zooplankton communities, while remaining numerically subdominant. For example, Cladocera invariably dominated the biomass of eight study lakes near Rankin Inlet, Nunavut, and six lakes near Lupin, Nunavut, despite being overwhelmingly outnumbered by small-sized Rotifera (RL&L 1997, 1998, and 1999). Among zooplankton communities, Rotifera have small sized species relative to other groups, Copepoda have moderately sized species, and Cladocera have species that are large in size (particularly *Daphnia* spp.).

Table 6.2 Summary of Zooplankton Abundance in Boston Area Lakes, 1993 to 1998

Lake	Number of Sampling Events	Mean Total Density (animals/m^3)	Mean Number of Rotifera (animals/m^3)	Mean Number of Cyclopoida (animals/m^3)	Mean Number of Cladocera (animals/m^3)	Ratio of Rotifera to Cladocera	Ratio of Rotifera to Cyclopoida
Aimaokatalok[a]	13	28 323	8 579	14 094	5 110	1.68	0.61
Stickleback[a]	7	21 734	9 808	10 920	762	12.87	0.90
Fickle Duck	6	58 018	46 311	4 483	2 570	18.20	10.33
Reference	3	7 442	5 847	850	235	24.88	6.88

[a] 1993 data were not included due to potentially inaccurate identification and enumeration.

In the presence of sufficient food and the absence of zooplankton-feeding predators, zooplankton communities tend to be dominated by large-sized species (Lynch et al. 1977a; Vanni 1986a, and 1986b), although the species of certain genera such as *Daphnia* (large) and *Kellicottia* (small) may coexist in the absence of predators by partitioning an adequately diverse food source (Kerfoot and DeMott 1980). Many investigators have shown that a shift from large to small species is related to the presence of abundant fish or large invertebrate predators (Brooks and Dodson 1965; Hrbacek and Novotna-Dvorakova 1965; Anderson and Raasveldt 1974; Anderson 1980). Conversely, the decline or removal of fish may promote a return to large zooplankton species (Shapiro and Wright 1984). However, other studies have shown that the type and concentration of food available or a combination of a number of environmental factors in addition to food and/or predators may determine the size structure of zooplankton communities (Lynch 1977b, and 1980; Vanni 1986a, and 1986b). Based on the above, the presence of large numbers of moderately-sized zooplankton (i.e., Copepoda) relative to small-sized zooplankton (i.e., Rotifera), suggested that Aimaokatalok Lake may have lower predation pressure than Stickleback, Fickle Duck, and Reference lakes (Table 6.2).

Although the presence of large numbers of zooplankton-feeding predators (particularly cisco and whitefish species) is the most obvious explanation for the apparent shift from large to small body size in the zooplankton, other causes are possible. Large year-to-year fluctuations do occur in many small lake zooplankton communities, and it would be necessary to collect fish, zooplankton, and other limnological data consistently over a period of several years to be able to determine the causes of community structure changes and to ascertain the permanent or cyclical nature of these changes. For example, high flushing rates in small waterbodies are known to have an impact on community structure and abundance (Soballe and Kimmel 1987). In the Boston area lakes, flushing may reduce overall abundance without affecting zooplankton species composition. The strong winds reported in the Boston area (Klohn-Crippen 1995; Rescan 1997) and the morphology of the studied waterbodies (i.e., elongated and narrow basins) suggested that winds likely influenced the distribution of zooplankton, with some species likely affected more than others (Teraguchi et al. 1983). This wind factor may explain the considerable differences in abundance of certain species between different stations in the same waterbody or between years.

6.2 BENTHIC INVERTEBRATES IN LAKES

Benthic (bottom-dwelling) invertebrates (also termed macroinvertebrates because of their large size; some species can reach a few centimetres in length) are an important link in aquatic food webs. Most benthic invertebrates are herbivores, detritivores or filter feeders and derive much of their energy from aquatic plants and organic materials. Some benthic macroinvertebrates are predacious, generally feeding upon other invertebrates. Many fish species, including early life history stages of piscivorous species, feed upon benthic macroinvertebrates. The information presented is based on data from annual data reports (Rescan 1993, 1994, 1995, 1997, 1998, and 1999a).

6.2.1 Methods

Benthic macroinvertebrates samples were collected from four lakes within the Boston area (Figure 6.6) (Rescan 1993, 1994, 1995, 1997, 1998, 1999a). Three to 18 sampling events were conducted on each lake between 1993 and 1998 (Table 6.3).

Table 6.3 Benthic Invertebrate Sampling Schedule in Boston Area Lakes, 1993 to 1998

Waterbody	Sampling Station	Date					
		1993	1994	1995	1996	1997	1998
Aimaokatalok Lake	WQ3	Aug					
	WQ4		Aug				
	WQ5		Aug	2 Aug			
	Stn 1					24 Jul & 26 Aug	17 Jul
	Stn 4						17 Jul
	Stn 5				4 & 24 Aug	24 Jul & 26 Aug	17 Jul
	Stn 6				4 & 24 Aug	24 Jul & 26 Aug	17 Jul
Stickleback Lake			Aug	3 Aug	5 & 25 Aug	23 Jul & 26 Aug	19 Jul
Fickle Duck Lake				3 Aug		23 Jul & 26 Aug	19 Jul
Reference Lake						23 Jul & 27 Aug	22 Jul

Benthic macroinvertebrate samples were collected using an Ekman grab with a sampling area of 0.0225 m^2. Except for 1993 and 1994 when only single samples were collected, triplicate samples were collected during each sampling event from 1995 to 1998. For Stickleback, Fickle Duck, and Reference lakes, sample collections were taken from shallow (littoral zone) locations that were generally less than 3.0 m in depth. Sample locations in Aimaokatalok Lake were taken from both shallow (up to 6.5 m in depth) and deep (10 to 29 m in depth) locations. Deep sampling locations included WQ5 and Station 6. Shallow sampling locations included WQ3, WQ4, Station 1, Station 4, and Station 5. Each replicate sample was sieved over 0.493 mm mesh, transferred to a clean 500-mL plastic bottle, preserved with 10% formalin, and labeled. All samples were submitted to Applied Technical Services in Victoria, BC for taxonomic identification and enumeration. Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) are taxa of interest due to their sensitivity to pollution and their use as a biomonitoring index (Rosenberg and Resh 1993). However, because of their low abundance in Boston area lakes, they were treated as one taxonomic group and were not evaluated separately when calculating relative abundances.

Benthic macroinvertebrate results from 1995 sampling appear to have been reported as the number of individuals/sample, even though the appendix indicates

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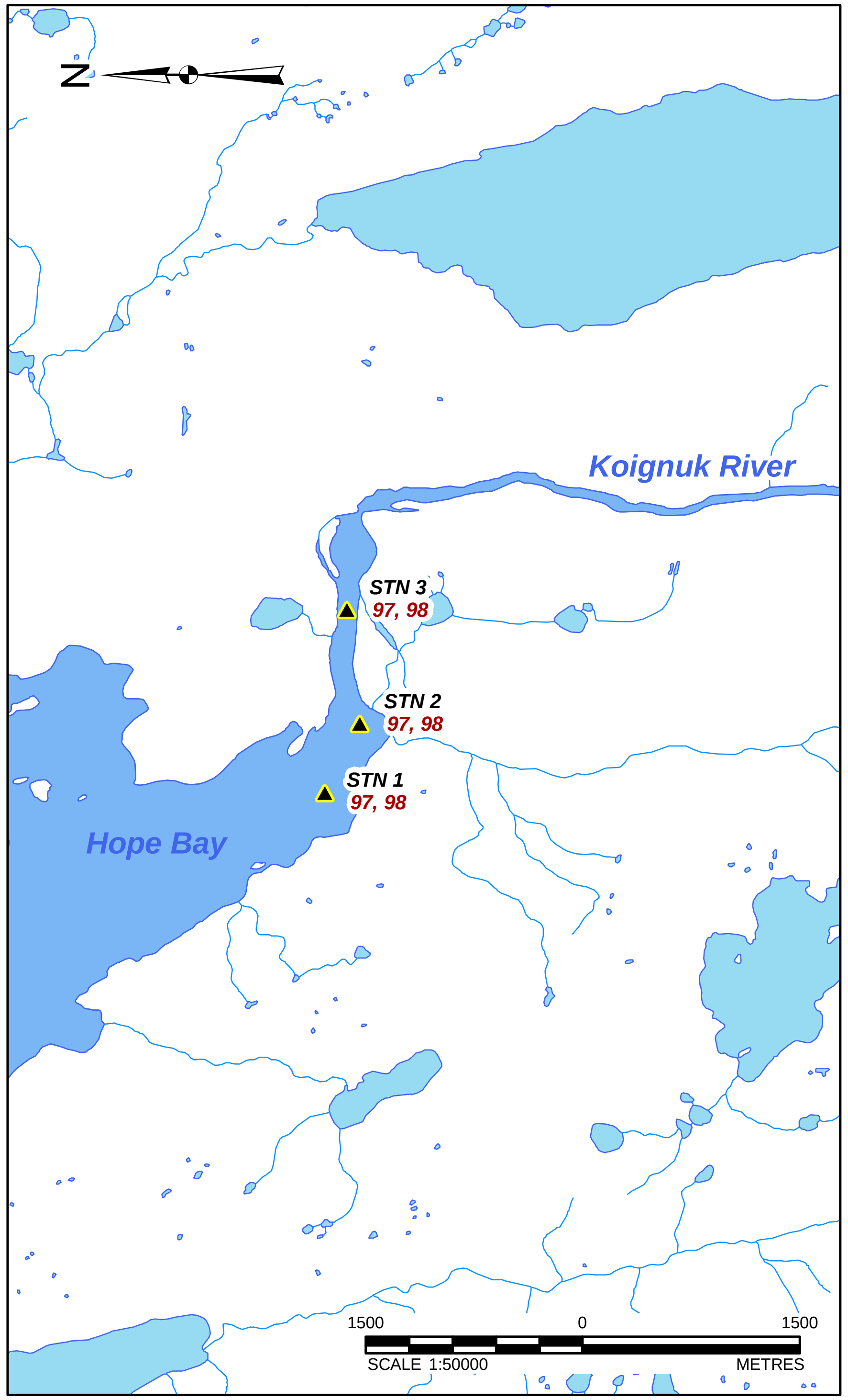

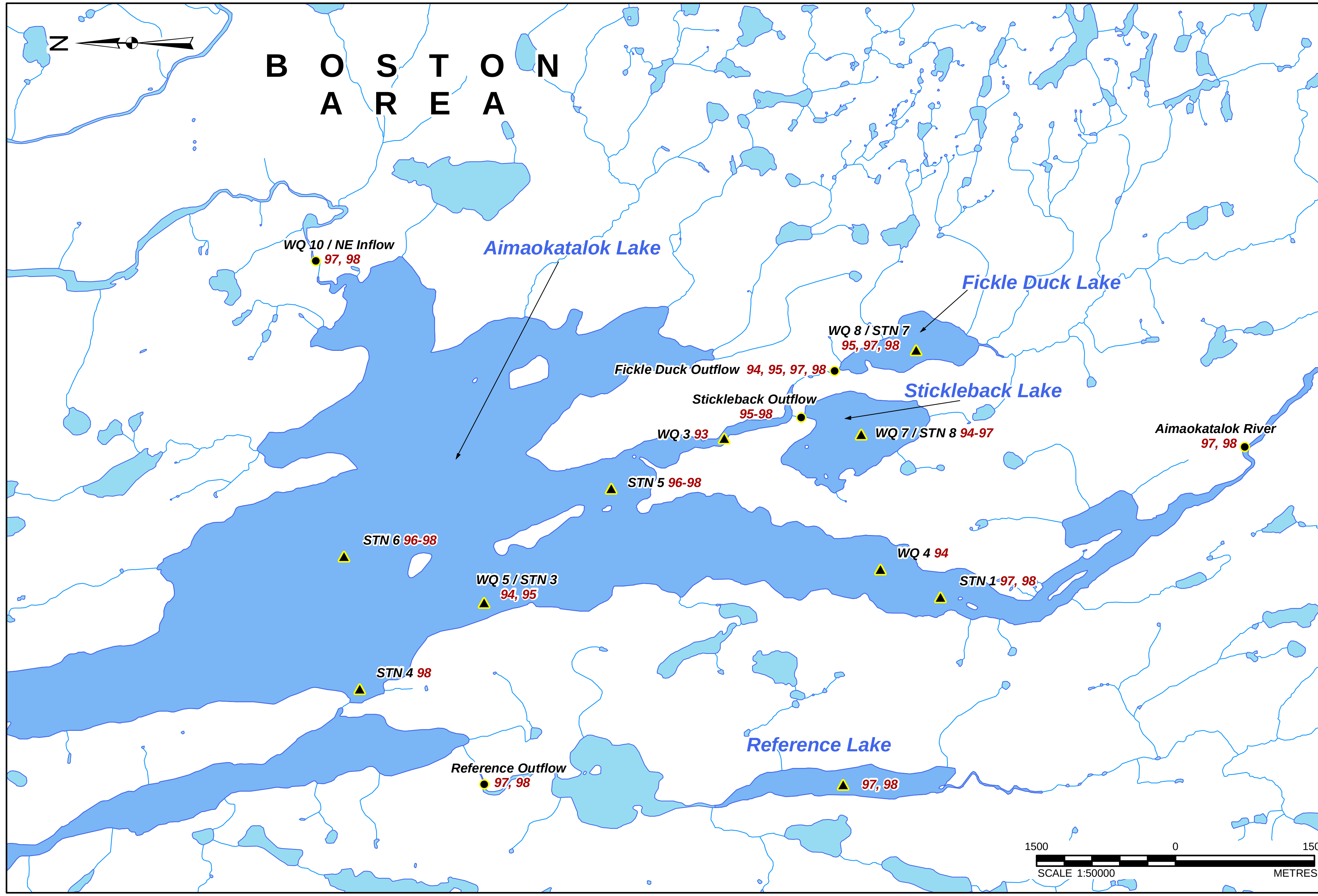

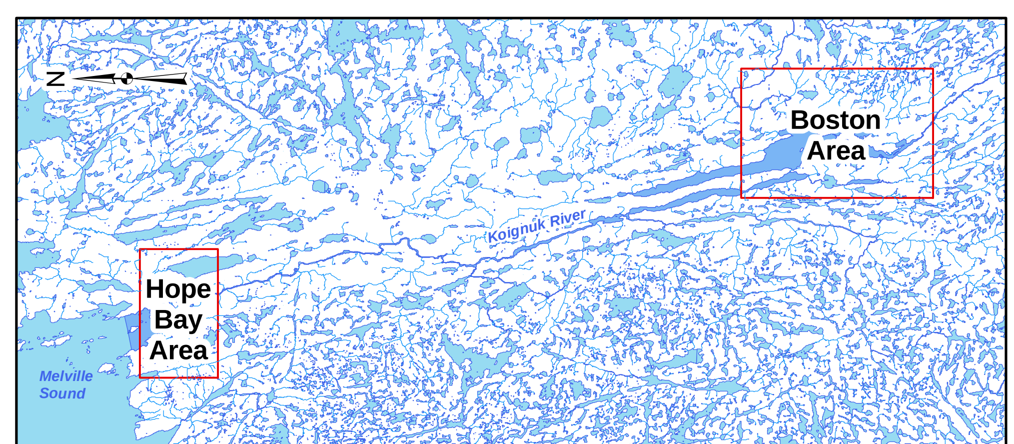

LEGEND

▲	Lake/marine sampling locations	*WQ X / STN X*	Sampling station names from Rescan Reports
●	Stream sampling locations	*95-97*	Consequtive years of sampling at station
	Rivers		
	Study area waterbodies		
	Waterbodies		

REFERENCE

Sources: Data Obtained from the Government of Canada, Natural Resources Canada, Centre for Topographic Information
Projection: UTM Zone 13N Datum: NAD 83

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MIRAMAR HOPE BAY LTD.

Boston Project Data Compilation

TITLE

Benthic Invertebrate Sampling Locations, 1993 - 2000

Golder Associates
Edmonton, Alberta

PROJECT No.06-1373-028			SCALE AS SHOWN	REV. 1
DESIGN	JP	22 April 2008		
GIS	RC	22 April 2008		
CHECK	JP	14 May 2008		
REVIEW	GA	21 May 2008		

FIGURE 6.6

that the data are individuals/m^2. To allow comparisons between years, results from 1995 were divided by 0.0225 m^2 to account for the area sampled by the Ekman grab.

6.2.2 Aimaokatalok Lake

Eighteen benthic macroinvertebrate summer sampling events were conducted on Aimaokatalok Lake; these included one in 1993 and 1995, two in 1994, four in 1996, six in 1997, and four in 1998. Mean total numbers (±1 SE) from the shallow locations ranged from 193 ± 104 animals/m^2 on 26 August 1997 to 19 378 animals/m^2 in a single sample from 1993. Mean total number of benthic macroinvertebrates from the deep locations ranged from 104 ± 15 animals/m^2 in July 1998 to 3437 animals/m^2 (no SE was not calculated because only one sample was collected) in August 1994 (Figure 6.7; Appendices C3 and C4).

Shallow Locations

Three taxa dominated the benthos at shallow depths in Aimaokatalok Lake. Chironomidae (midges) were well represented during most sampling sessions; this taxon contributed between 10.2 and 92.3% to total numbers. Several species contributed to the abundance of Chironomidae, none being clearly dominant across years and sites. Pelecypoda (clams), represented by Sphaeriidae (*Pisidium* spp. and *Sphaerium* spp.), were generally low in abundance from Station 1 and WQ 3 in the southern arm of Aimaokatalok Lake (0.0 to 13.6%), but typically more abundant at other shallow stations (11.4 to 57.1%). Nematoda (round worms) had high contributions to total number (up to 45.9%) in most years, except for 1997 (0.0 to 7.7%) (Figure 6.7; Appendices C3 and C4). Nematodes are typically not identified to lower taxonomic levels.

Deep Locations

Chironomidae dominated the benthos of Aimaokatalok Lake at depths greater than 10 m (Figure 6.7; Appendices C3 and C4). This taxon contributed between 10.2 and 71.5% to total mean number of animals among the sample dates and locations. Several species contributed to the abundance of Chironomidae, none being clearly dominant. With the exception of being absent from Station 6 on 18 July 1998, Pelecypoda had large contributions to the benthic community of Aimaokatalok Lake (21.6 to 60.0%). The exclusive contributors to Pelecypoda were *Pisidium* spp. and *Sphaerium* spp.

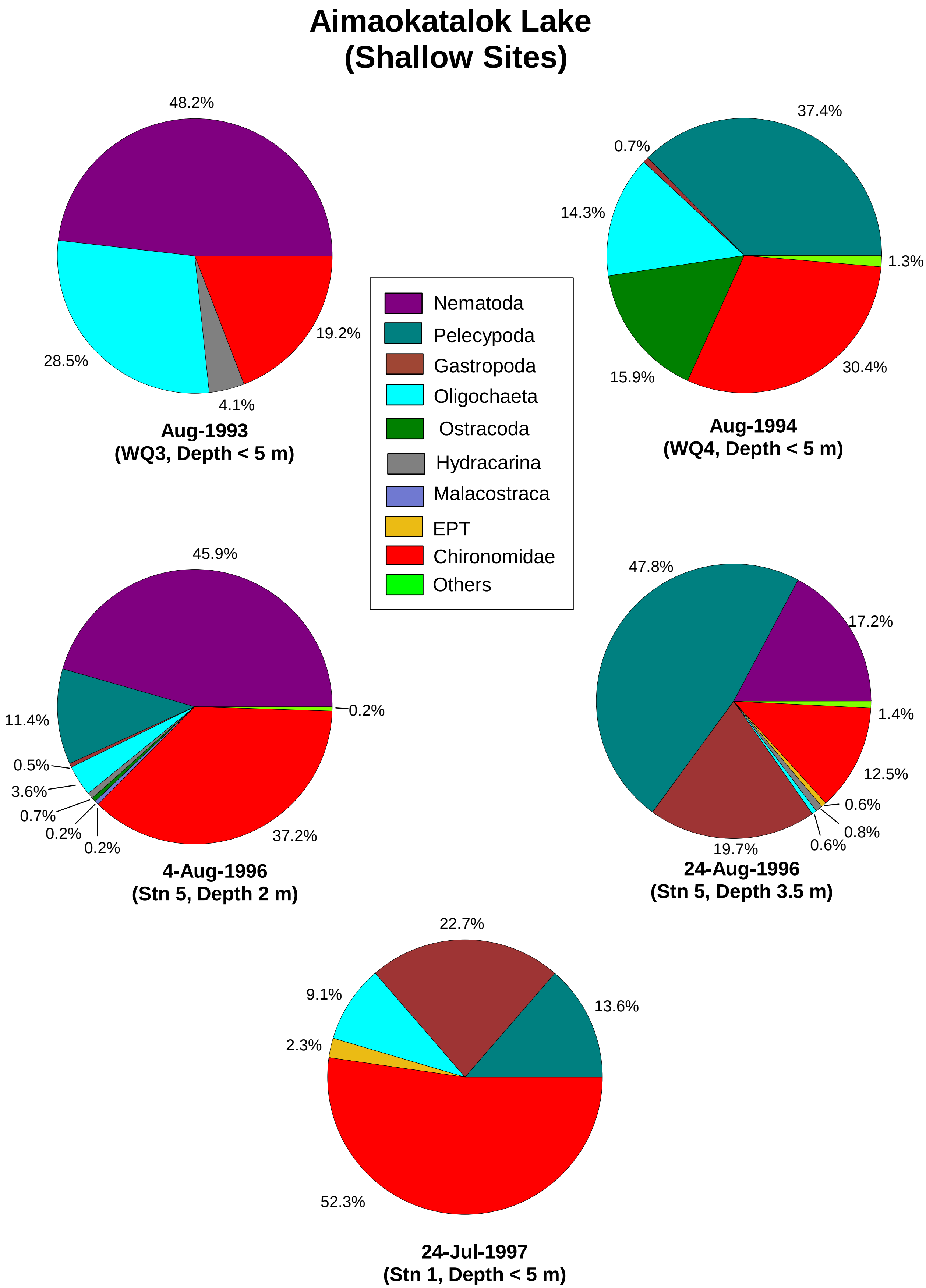


Figure 6.7. Relative abundance of major taxonomic groups and mean total density (± 1 SE) of benthic invertebrates in Aimaokatalok Lake, 1993 to 1998.

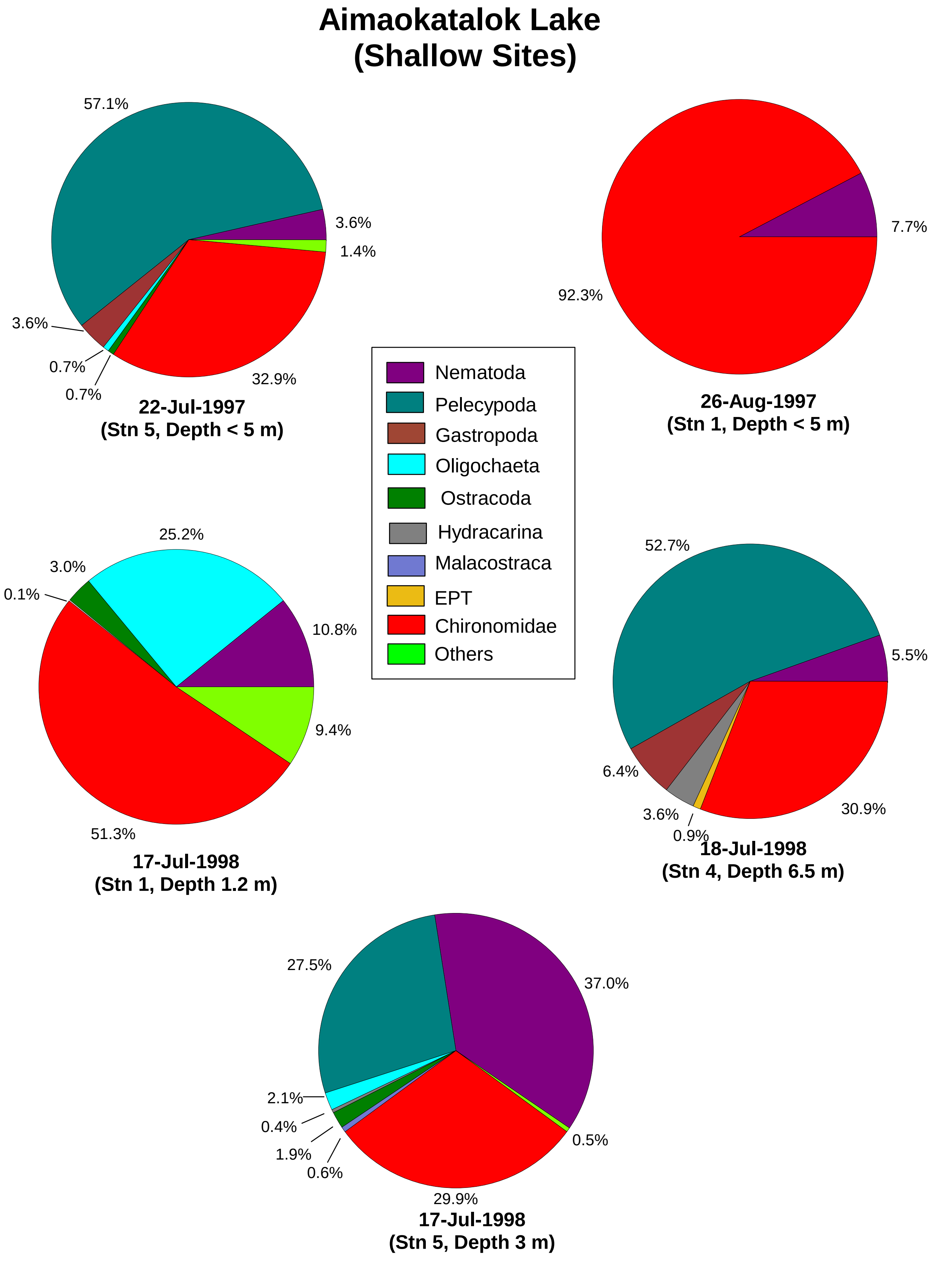


Figure 6.7 (continued). Relative abundance of major taxonomic groups and mean total density (± 1 SE) of benthic invertebrates in Aimaokatalok Lake, 1993 to 1998.

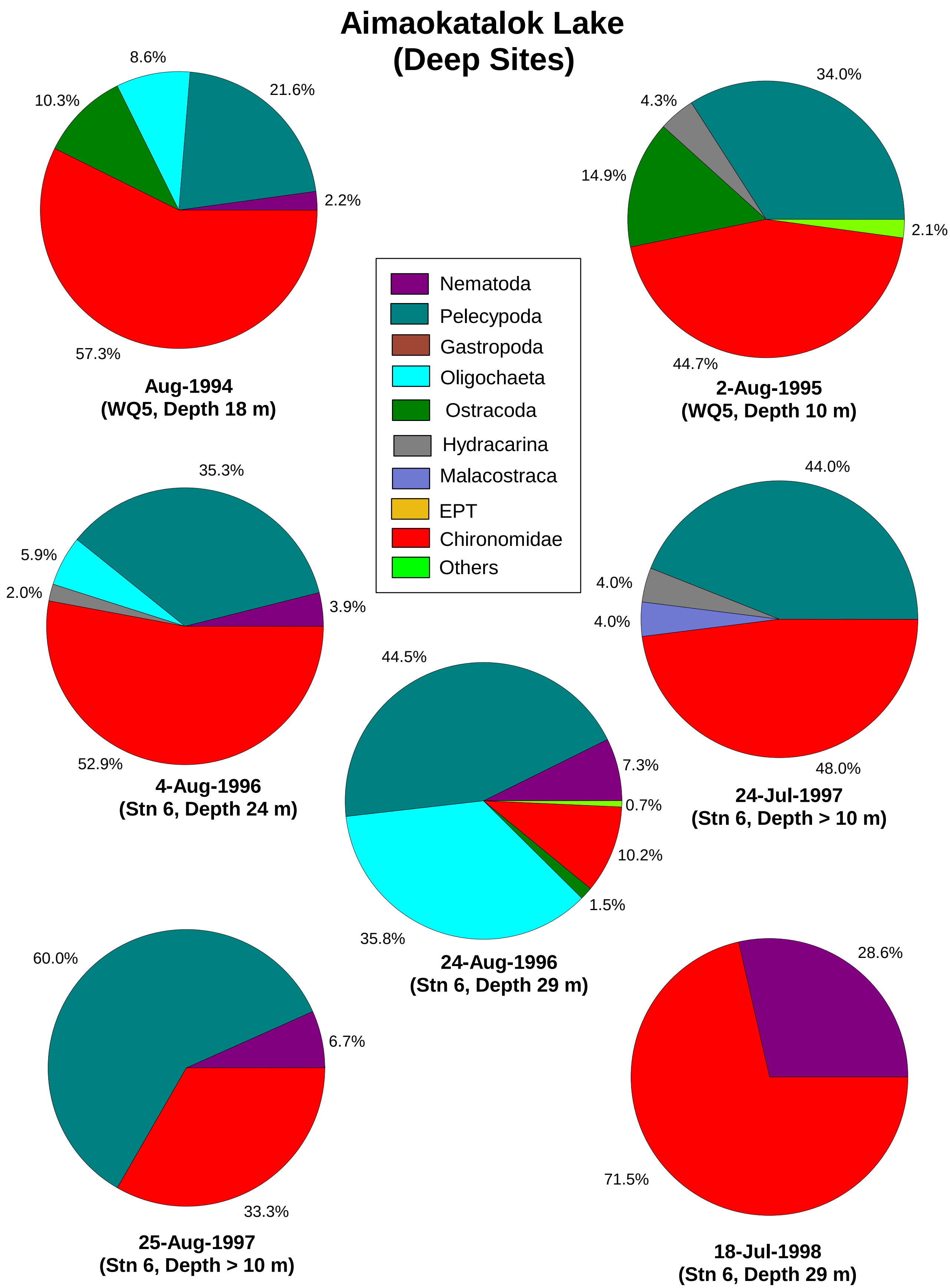


Figure 6.7 (continued). Relative abundance of major taxonomic groups and mean total density (± 1 SE) of benthic invertebrates in Aimaokatalok Lake, 1993 to 1998.

Aimaokatalok Lake

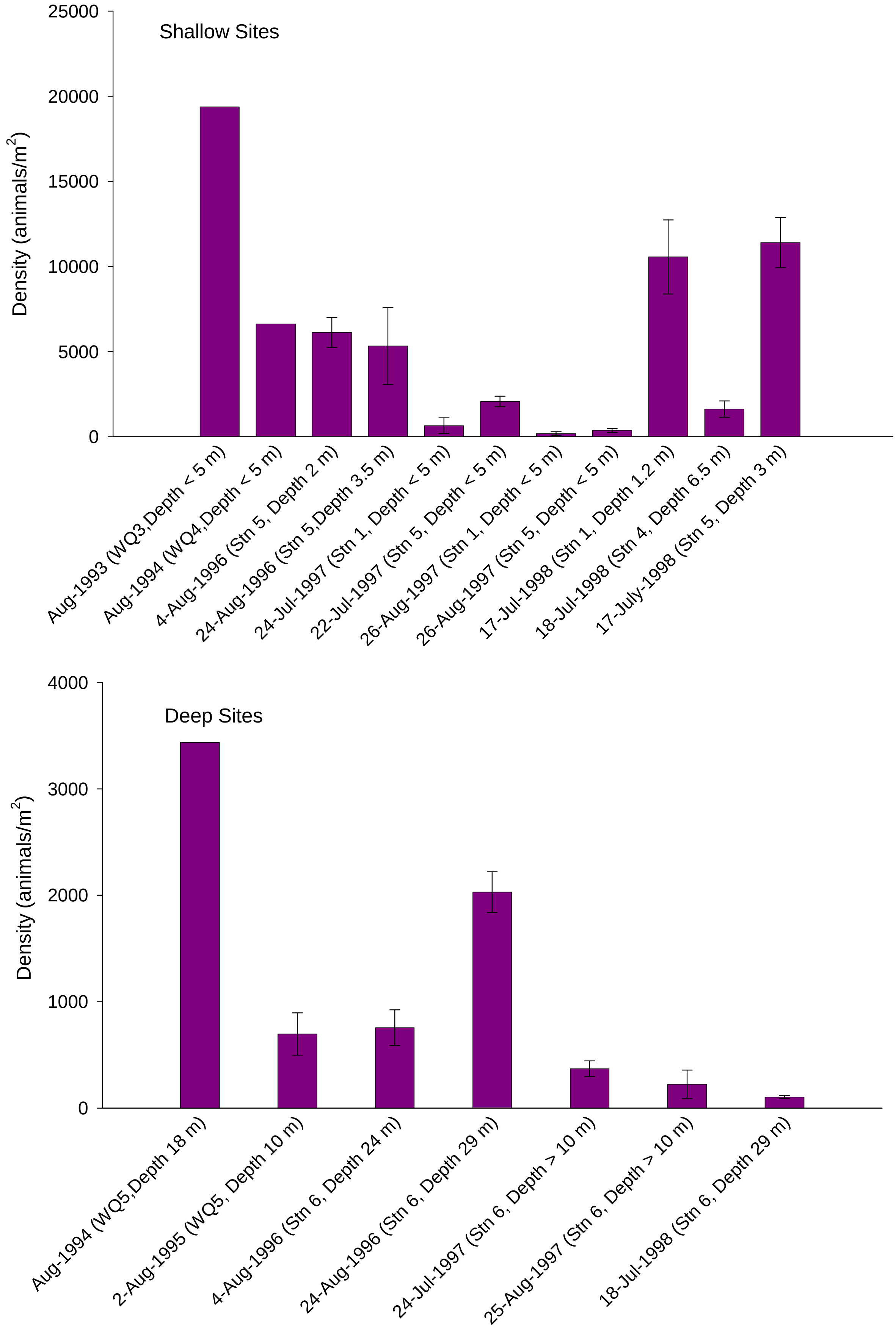


Figure 6.7 (continued). Relative abundance of major taxonomic groups and mean total density (± 1 SE) of benthic invertebrates in Aimaokatalok Lake, 1993 to 1998.

6.2.3 Stickleback Lake

Seven benthic macroinvertebrate sampling sessions were conducted on Stickleback Lake in the summer; these included one session in 1994 and 1995, two in 1996 and 1997, and one in 1998. Samples were collected from shallow locations (water depths were 2.6 m or less). Mean total numbers (± 1 SE) ranged from 3185 ± 1095 animals/m^2 in late August 1997 to 41 226 ± 5241 animals/m^2 in early August 1996 (Figure 6.8; Appendices C3 and C4).

Overall, Chironomidae contributed the most (12.8 to 47.9%) to total mean numbers of benthic invertebrates within Stickleback Lake. Nematoda were well represented in the samples (0.5 to 64.0%), particularly during 1996. Ostracoda (seed shrimp) displayed contrasting results to Nematoda, having high abundances in most years (10.2 to 39.1%), except 1996 (1.9 and 3.3%).

6.2.4 Fickle Duck Lake

Benthic invertebrate sampling sessions on Fickle Duck Lake were conducted once in 1995, twice in 1997 and once in 1998. During all sessions, samples were collected from shallow waters (less than 3.0 m). Mean total numbers (±1 SE) were between 2637 ± 928 animals/m^2 in August 1997 and 5896 ± 1129 animals/m^2 in August 1995 (Figure 6.9; Appendices C3 and C4).

Chironomidae dominated the benthos of Fickle Duck Lake (contributed between 57.4 and 80.7% to the total mean animal count). Pelecypoda were second in abundance at 0.8 to 37.1% of total numbers (Figure 6.9; Appendices C3 and C4). The major contributors for the Chironomidae were *Zalutschia* spp., *Procladius* spp., and *Tanytarsus* spp. Pelecypoda were composed almost exclusively of *Sphaerium* spp.

6.2.5 Reference Lake

The benthic community of Reference Lake was sampled twice in 1997 and once in 1998, in water 2.5 m deep. Mean total numbers (±1 SE) were between 4237 ± 948 in July 1997 and 6163 ± 347 animals/m^2 in July 1998 (Figure 6.10; Appendices C3 and C4).

Chironomidae, which contributed between 28.3 and 82.4% to the total mean animal count, dominated the benthos of Reference Lake. Pelecypods were second

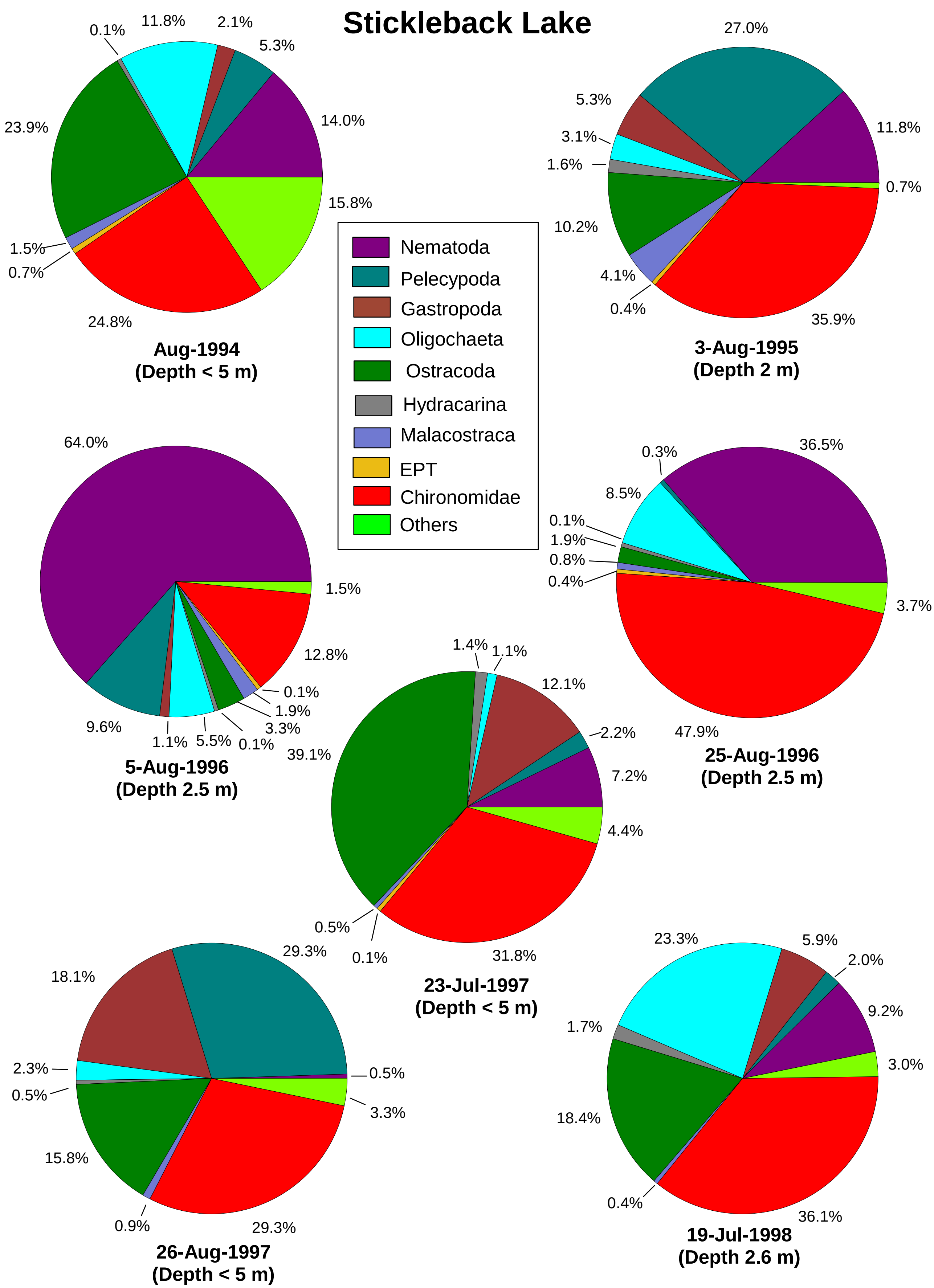


Figure 6.8 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of benthic invertebrates in Stickleback Lake, 1994 to 1998.

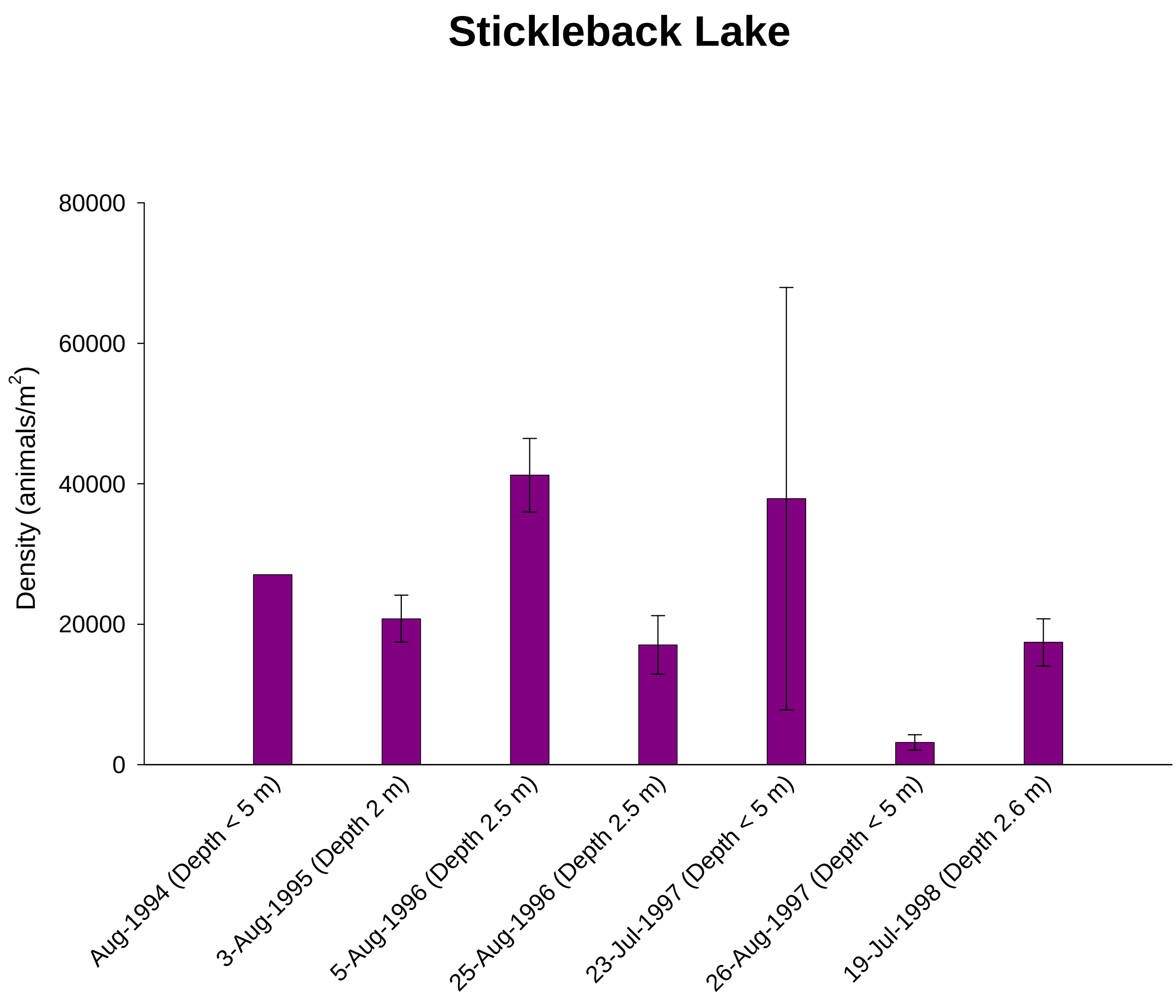


Figure 6.8 (continued). Relative abundance of major taxonomic groups and mean total density (± 1 SE) of benthic invertebrates in Stickleback Lake, 1994 to 1998.

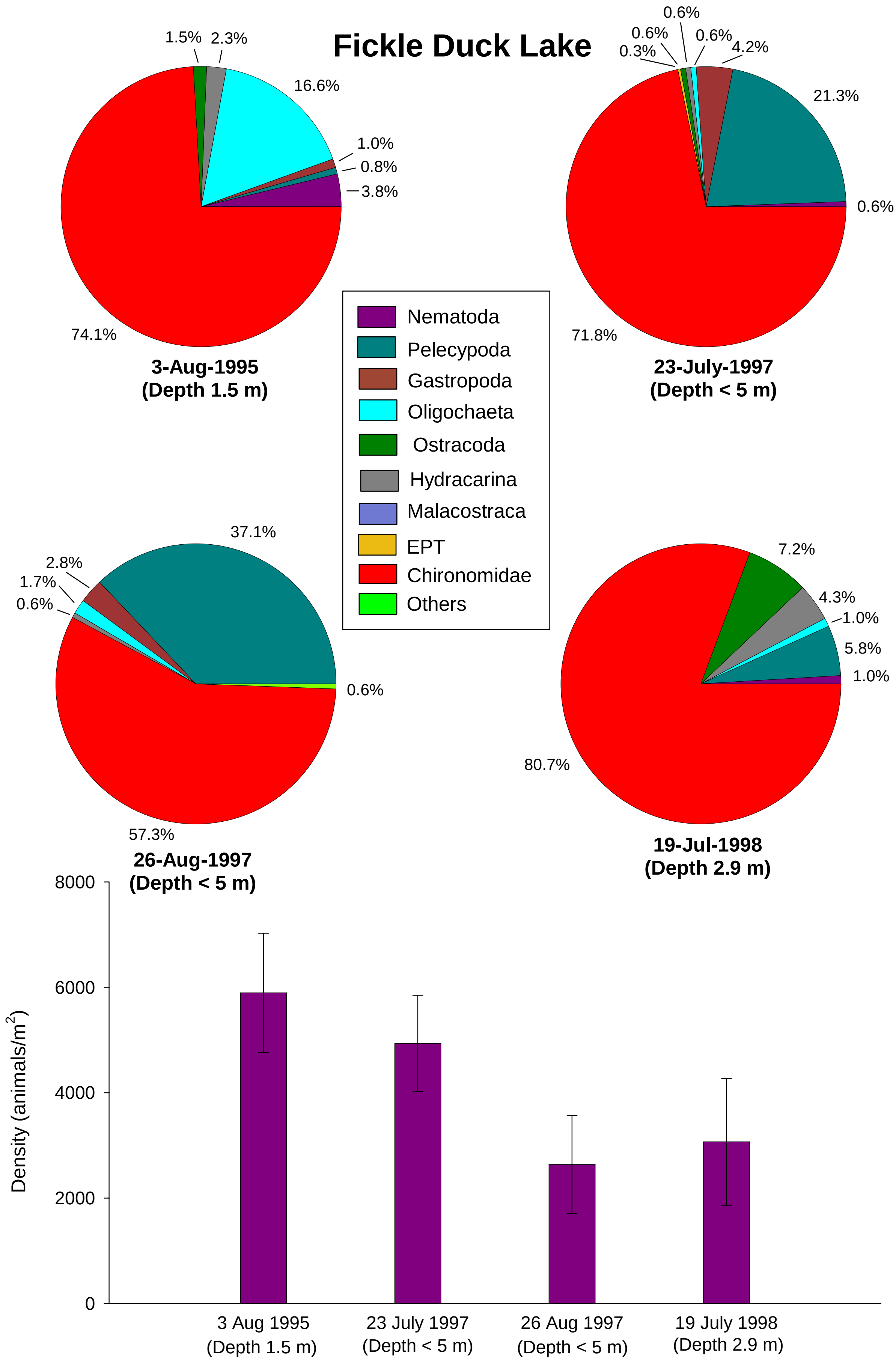


Figure 6.9 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of benthic invertebrates in Fickle Duck Lake, 1995 to 1998.

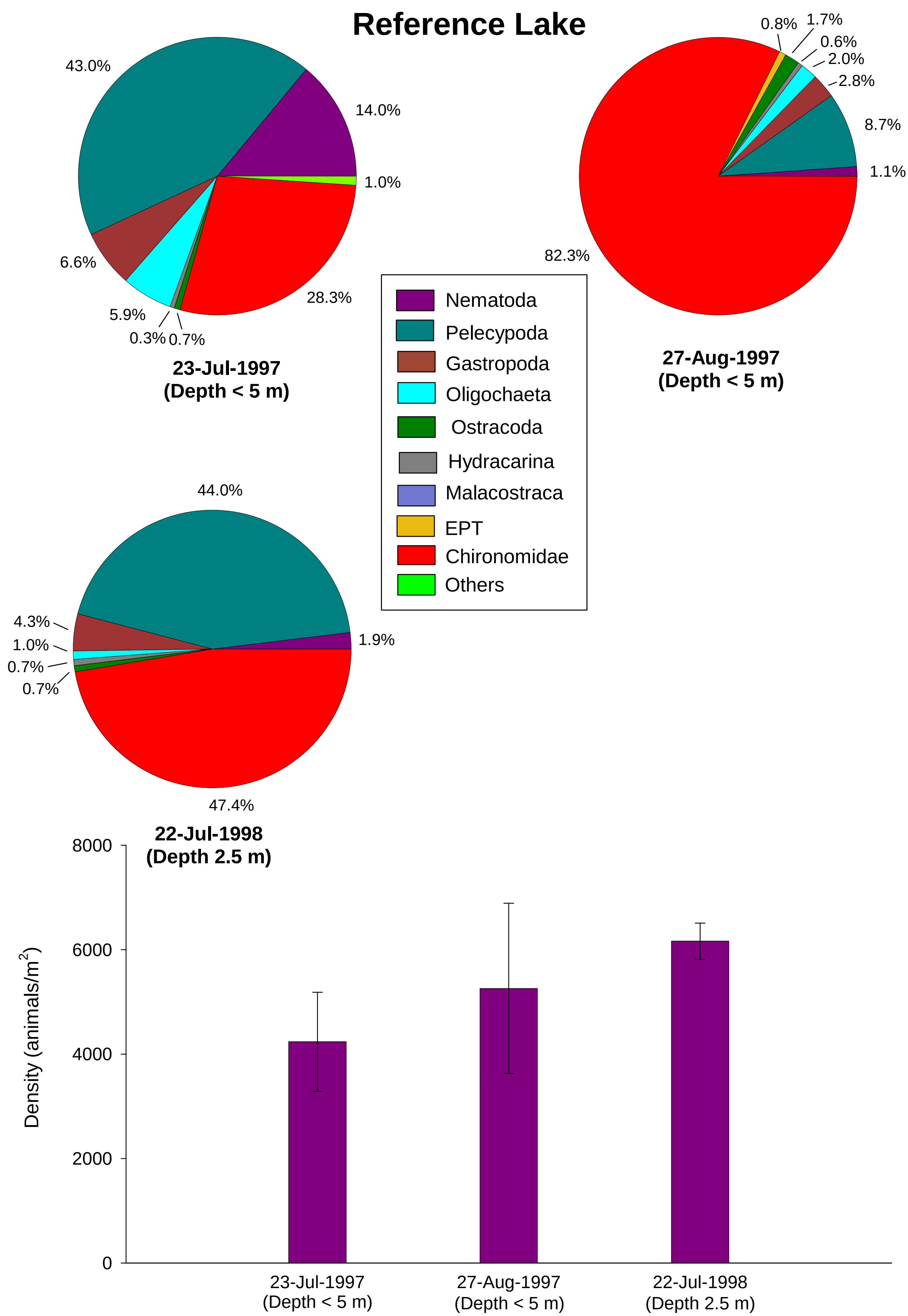


Figure 6.10 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of benthic invertebrates in Reference Lake, 1997 to 1998.

in abundance at 8.7 to 44.0% of total numbers (Figure 6.10; Appendices C3 and C4). The major contributors for the Chironomidae were *Psectrocladius* spp. and *Procladius* spp. Pelecypoda were comprised exclusively of *Sphaerium* spp.

6.2.6 Summary

Chironomidae and Pelecypoda, and to a lesser extent Nematoda and Oligochaeta, dominated the benthos of the Boston area lakes. Differences in composition and abundance of the benthos could largely be ascribed to physical characteristics among the sampling locations. The benthic invertebrate communities of the four lakes were similar in many respects to the communities of many other small lakes in the Canadian Arctic and sub-Arctic (RL&L 1997, 1998, and 1999).

A comparison of mean benthic macroinvertebrate abundance suggests that Stickleback Lake was the most productive and that the deep areas of Aimaokatalok Lake were the least productive (Table 6.4). Deep-water habitats in Aimaokatalok Lake had reduced abundances of benthic invertebrates, but the proportion of Chironomidae remained similar to shallow habitats. Deep-water habitats can become oxygen depleted and primarily support taxa that can tolerate low oxygen levels (e.g., certain Chironomidae and Oligochaeta). Anoxia of the profundal zone was not recorded in the study lakes (see Section 3.0) and probably was not a factor in benthic macroinvertebrate production. Oxic conditions are common to Arctic and sub-Artic lakes and likely reflect the short open water season (resulting in low productivity), low nutrient loading, and windy conditions that tend to keep the lakes from stratifying (RL&L 1999).

Table 6.4 Summary of Benthic Invertebrate Abundance in the Boston Area Lakes, 1993 to 1998

Lake	Sample Depth (m)	Number of Sampling Events	Mean Total Density (animals/m^2)	Mean Number of Chironomidae (animals/m^2)	Contribution of Chironomidae to Total (%)
Aimaokatalok (shallow)	≤ 6 and 5	11	5 851	1 752	36.8
Aimaokatalok (deep)	> 10	7	1 088	459	45.4
Stickleback	≤ 2.6	7	23 596	6 722	31.2
Fickle Duck	≤ 3.0	4	4 134	2 975	71.0
Reference	≤ 2.5	3	5 220	2 815	52.6

Although Chironomidae contributed a majority (i.e., more than 50% of total numbers) of the benthic community only in Fickle Duck and Reference lakes, they were the most numerically abundant taxonomic group in all Boston area lakes (Table 6.4). The family Chironomidae is an ecologically important group of aquatic insects, often occurring in high densities and diversity. Indeed, the number of chironomid species present, and their densities, often account for at least half of the total macroinvertebrate species diversity and abundance in most systems. The actual number of chironomid species present in a system is the result of the complex of physical, chemical, biological, and biogeographic conditions (Coffman and Ferrington 1996).

6.3 DRIFT ORGANISMS IN STREAMS

Benthic macroinvertebrates can actively or passively enter the water column. This behaviour is known as drift (Resh and Rosenberg 1984). Also included in the drift can be pelagic forms or invertebrates (e.g., zooplankton) that are entrained from lakes, back-eddies, and calm side-channels of flowing waters. Drift organisms are an important part of the food chain, particularly because they are easily observed and available to fish and other potential predators. The information presented is based on data from annual data reports (Rescan 1998 and 1999a).

6.3.1 Methods

Drift samples were collected from five streams within the Boston area (Figure 6.6) (Rescan 1998 and 1999a). Up to four sampling sessions were conducted on each stream between 1997 and 1998 (Table 6.5).

Table 6.5 Drift Sampling Schedule in Boston Area Streams, 1997 to 1998

Stream	Date Sampled	
	1997	1998
Aimaokatalok NE Inflow	22 July & 24 August	27 June & 31 July
Aimaokatalok River		27 June & 31 July
Stickleback Outflow	21 July	26 June & 30 July
Fickle Duck Outflow	21 July & 25 August	26 June & 30 July
Reference Outflow	21 July & 25 August	27 June & 01 August

Two replicate drift samples were collected with a cone-shaped net (0.5 mm mesh size) that featured an opening aperture frame of 0.14 m^2. Soak time for the samplers was approximately 24 h. Water flow rates were measured in the streams during sampling, and the average flow rate was used to standardize data to volume (animals/1000 m^3). Each sample was transferred to a clean 500-mL plastic bottle, preserved with 10% formalin, and labeled. All samples were submitted to Applied Technical Services, Victoria, BC, for taxonomic identification and enumeration. Drift samples were also collected in 1996 for Stickleback Outflow and Fickle Duck Outflow; however, these data could not be standardized for volume because flow data were not provided. Therefore, these were not used for further analysis.

As mentioned in the lake section, percentage contribution of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) (EPT) was also calculated because these taxonomic groups are a common biomonitoring index (Rosenberg and Resh 1993). Presence of these taxa may indicate that these are healthy waterbodies.

6.3.2 Aimaokatalok NE Inflow

Four drift sampling sessions were conducted on Aimaokatalok NE Inflow, including two in both 1997 and 1998. Mean total drift numbers (±1 SE) ranged from 196 ± 102 animals/1000 m^3 on 22 July 1997 to 16 175 ± 2076 animals/1000 m^3 on 28 June 1998 (Figure 6.11; Appendices C5 and C6).

Chironomidae (midges) dominated the drift samples in all sampling sessions, contributing 40.6 to 51.7% to the total mean number of animals enumerated. The July 1997 samples had a considerable proportion (37.0%) of Simulidae (black flies), whereas the August 1997 samples had large proportions of Ostracoda (seed shrimp; 25.3%), Hydracarina (water mites; 16.7%) and Copepoda (copepods; 12.7%). EPT taxa contributed 9.3 and 7.5% to the total mean number of individuals in the June and July 1998 samples, respectively (Figure 6.11; Appendices C5 and C6). The Chironomidae were primarily represented by Orthocladiinae species, whereas the Copepoda were well represented by Cyclopoida species and the Simulidae were represented by *Simulium* spp.

6.3.3 Aimaokatalok River

Two drift sampling sessions were conducted on Aimaokatalok River in 1998. Mean total numbers (±1 SE) of drifting benthic invertebrates were 12 447 ± 3072 animals/1000 m^3 in June and 13 896 ± 394 animals/1000 m^3 in July (Figure 6.12; Appendices C5 and C6).

In June and July 1998, Chironomidae dominated the drift of the Aimaokatalok River, contributing 39.0 and 53.0% to total mean numbers, respectively. Cladocera (water fleas) also made up a significant proportion (11.0%) of the June drift, but was absent from the July sample. EPT taxa contributed 11.4% to total mean numbers in June 1998 and 8.4% in July 1998 (Figure 6.12;

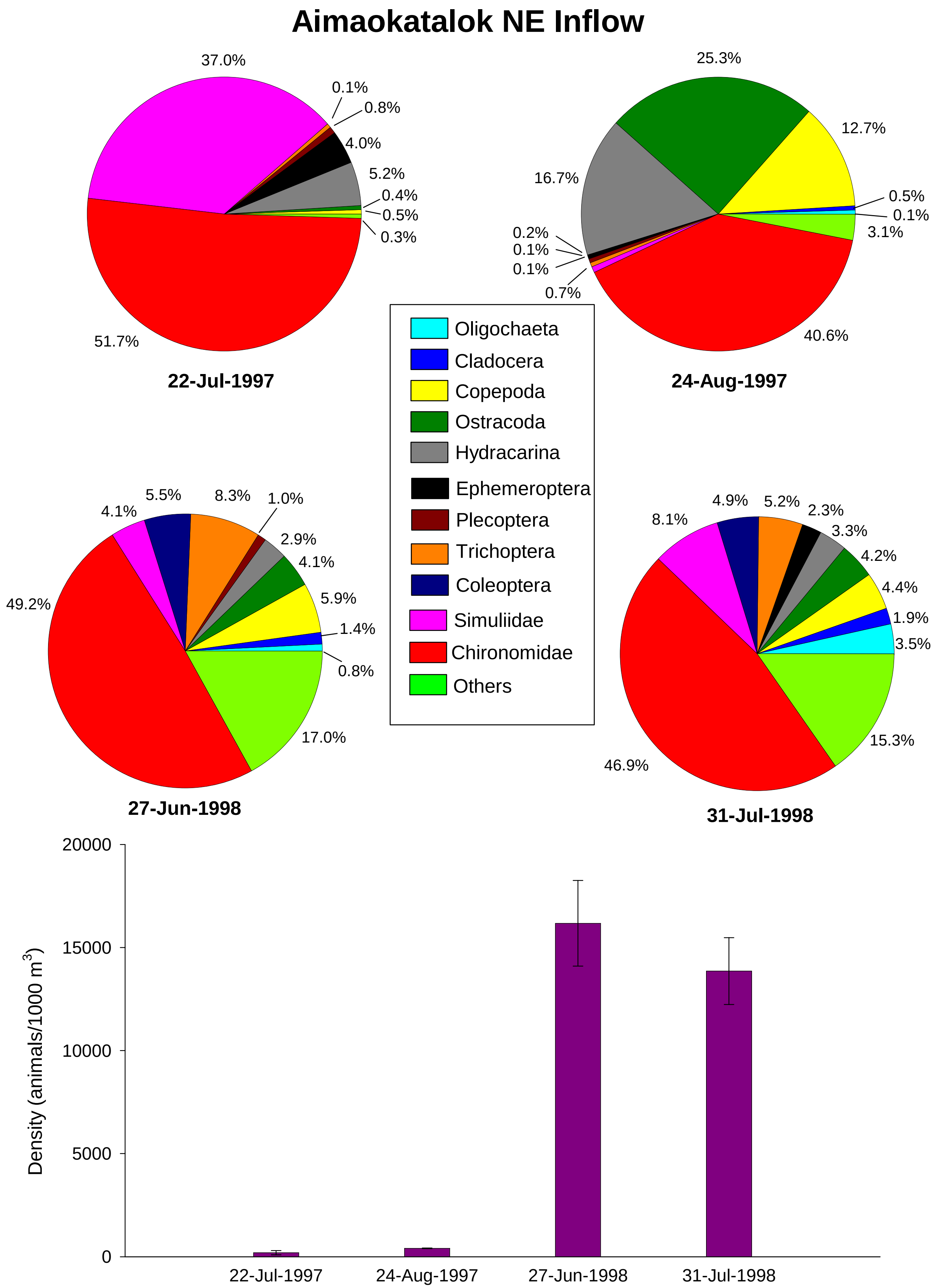


Figure 6.11 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of drifting invertebrates in Aimaokatalok NE Inflow, 1997 and 1998.

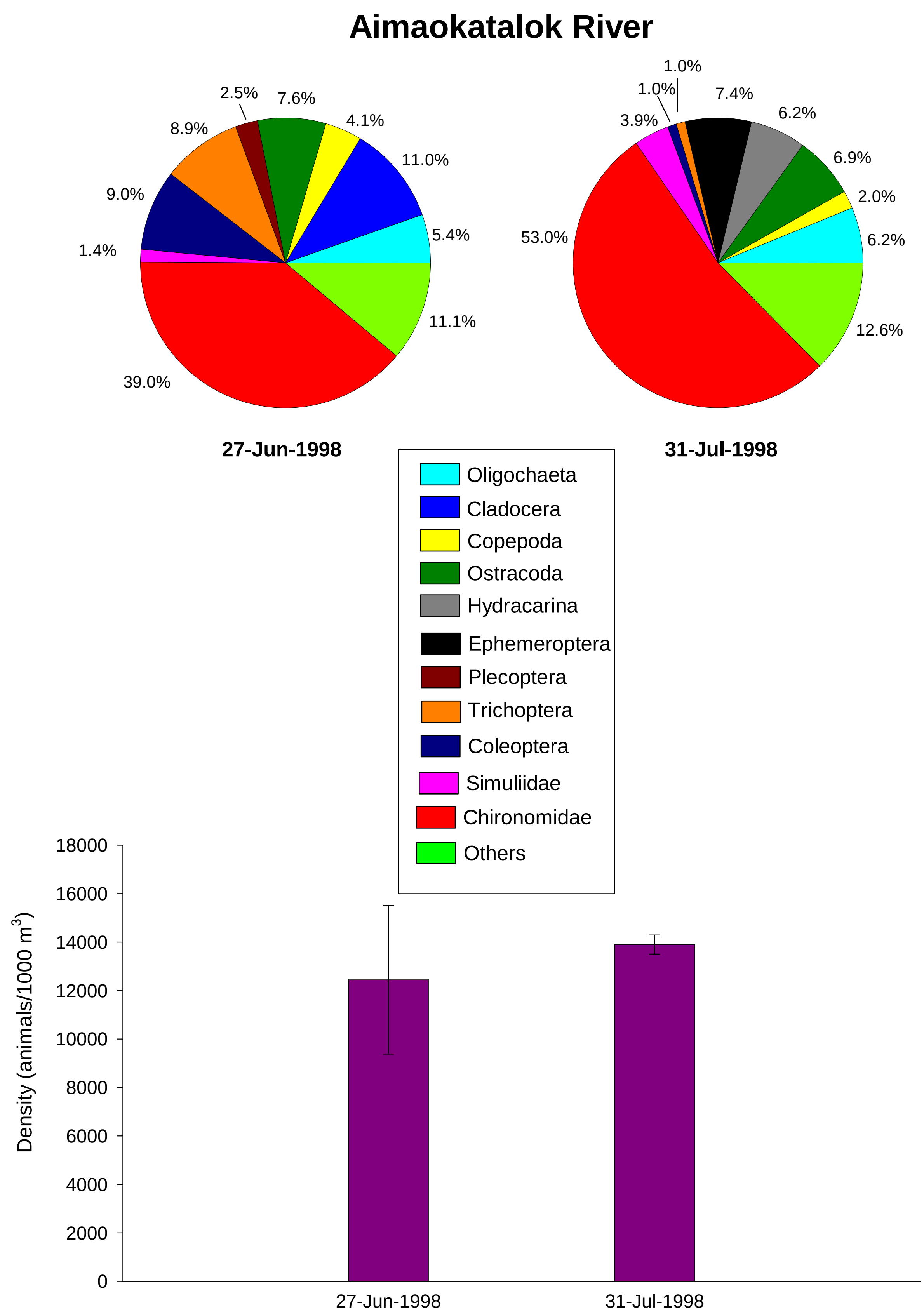


Figure 6.12 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of drifting invertebrates in Aimaokatalok River, 1998.

Appendices C5 and C6). The major contributors of the Chironomidae were members of the Orthocladiinae sub-family.

6.3.4 Stickleback Outflow

Three sampling sessions were conducted in Stickleback Outflow, including one in July 1997 and two in 1998 during June and July. There was no flow in the stream in August 1997, preventing sampling. Mean total numbers (±1 SE) ranged from 9733 ± 3196 animals/1000 m^3 in June 1998 to 160 784 ± 70 693 animals/1000 m^3 in July 1997 (Figure 6.13; Appendices C5 and C6).

In July 1997, Ostracoda and Hydracarina dominated the drift of Stickleback Outflow; these groups contributed 51.8 and 44.8% to total mean numbers, respectively. In 1998, the June drift community was dominated by Chironomidae (46.5% of total mean numbers), whereas the July drift was dominated by both Chironomidae and Ostracoda (37.1 and 35.6% of total mean numbers, respectively). EPT taxa contributed less than one percent to total mean abundances in July 1997, 9.0% in June 1998, and 3.7% in July 1998 (Figure 6.13; Appendices C5 and C6). Ostracoda was primarily represented by *Cypria* spp., and Chironomidae were mainly represented by members of the Tanytarsini and Orthocladiinae subfamilies.

6.3.5 Fickle Duck Outflow

Drift net sampling in Fickle Duck Outflow was conducted only in July and August in 1997 and in June and July in 1998. Mean total number (± 1 SE) of organisms collected ranged from 833 ± 375 animals/1000 m^3 in July 1997 to 13 996 ± 4459 animals/1000 m^3 in July 1998 (Figure 6.14; Appendices C5 and C6).

Chironomidae dominated the drift community during both July and August sampling sessions in 1997 and during the June sampling session in 1998, contributing 41.8, 51.6 and 48.8% to the total mean count in the samples, respectively (Figure 6.14; Appendices C5 and C6). Simuliidae and Ostracoda also contributed a substantial portion of the drift in July 1997 (22.3 and 16.9% of the total mean count, respectively). Hydracarina contributed 29.7% of the total mean count of the drift in August 1997. In the July 1998 sampling session, Chironomidae and Ostracoda contributed a large portion of the drift (23.0 and 23.2% of total mean count, respectively). EPT taxa contributed only 2.6% towards total mean abundance in July 1997, 0.7% in August 1997, 9.5% in June 1998, and 22.6% in July 1998. Chironomidae were largely represented by

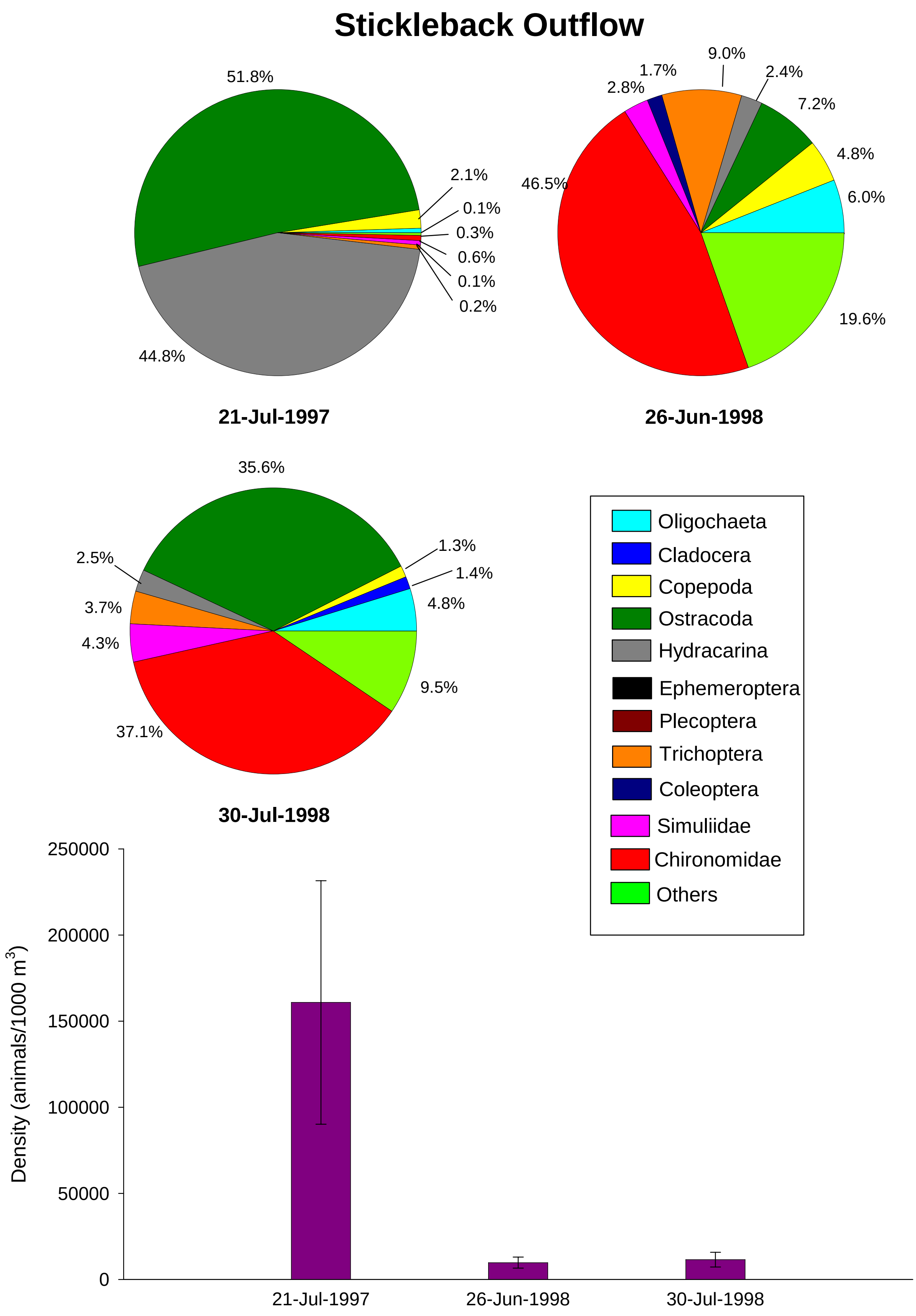


Figure 6.13 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of drifting invertebrates in Stickleback Outflow, 1997 to 1998.

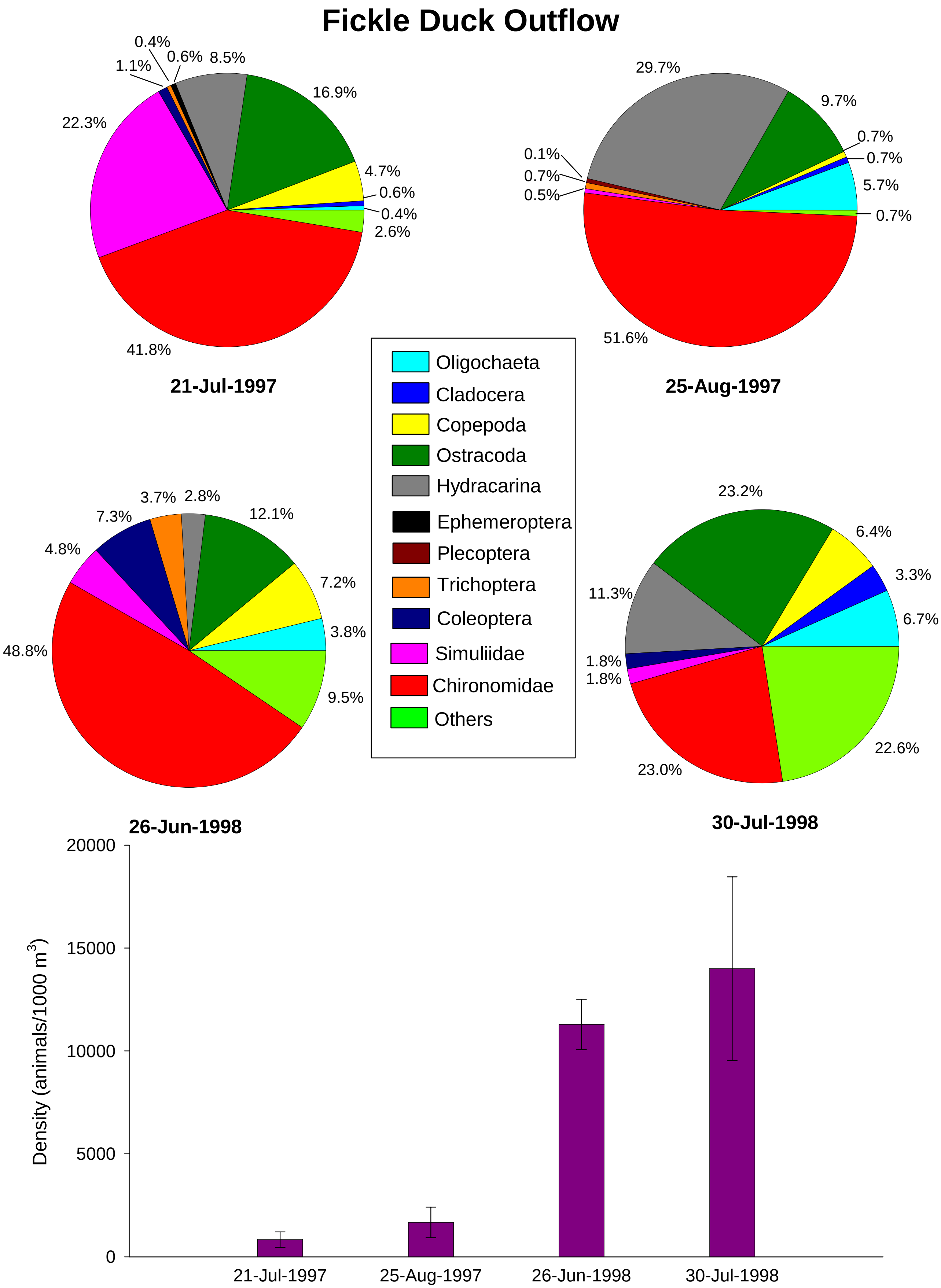


Figure 6.14 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of drifting invertebrates in Fickle Duck Outflow, 1997 to 1998.

species of the Orthocladiinae and Tarytarsini subfamilies. Simuliidae were represented by *Simulium* spp. and Ostracoda were mainly represented by *Cadona*, *Cypria*, and *Cypris* spp.

6.3.6 Reference Outflow

Drift net drift sampling in Reference Outflow was conducted in July 1997, August 1997, June 1998 and August 1998. Mean total numbers (±1 SE) ranged from 381 ± 224 in August 1997 to 13 533 ± 2317 animals/1000 m^3 in August 1998 (Figure 6.15; Appendices C5 and C6).

Chironomidae dominated the drift of Reference Outflow in all sampling sessions, contributing 41.2 to 83.5% towards total mean numbers (August 1997 and August 1998, respectively) (Figure 6.15; Appendices C5 and C6). In July 1997, Simulidae also made up a large portion of the drift (24.7% of total numbers). In June and August 1998, Cladocera also contributed a significant amount to the drift (13.8 and 10.1%, respectively). EPT taxa contributed less than one percent towards total mean abundances in all four sampling events. The Chironomidae were represented by Orthocladinae, Tanytarsini, and unidentified species. Simulidae were mainly represented by unidentified species and the Cladocera were represented by a variety of species.

6.3.7 Summary

For the Boston area streams, a comparison of mean total drift abundance suggests that Stickleback Outflow was highly productive, and that Reference Outflow was the least productive (Table 6.6). Chironomidae (midges), Simuliidae (black flies), and Ostracoda (seed shrimp) dominated the drift of the Boston area streams. EPT taxa were present in low abundances in most streams. The presence of these taxa is not currently indicative of the health of the streams; however, if the EPT taxa were absent in future sampling events this may indicate worsening health of the ecosystems.

Table 6.6 Summary of Drift Abundance in Boston Streams, 1997 to 2000

Stream	Number of Sampling Events	Mean Drift Numbers[a] (animals/1000 m^3)
Aimaokatalok NE Inflow	4	7 659
Aimaokatalok River	2	13 171
Stickleback Outflow	3	60 675
Fickle Duck Outflow	4	6 947
Reference Outflow	4	5 890

[a] All sampling events combined.

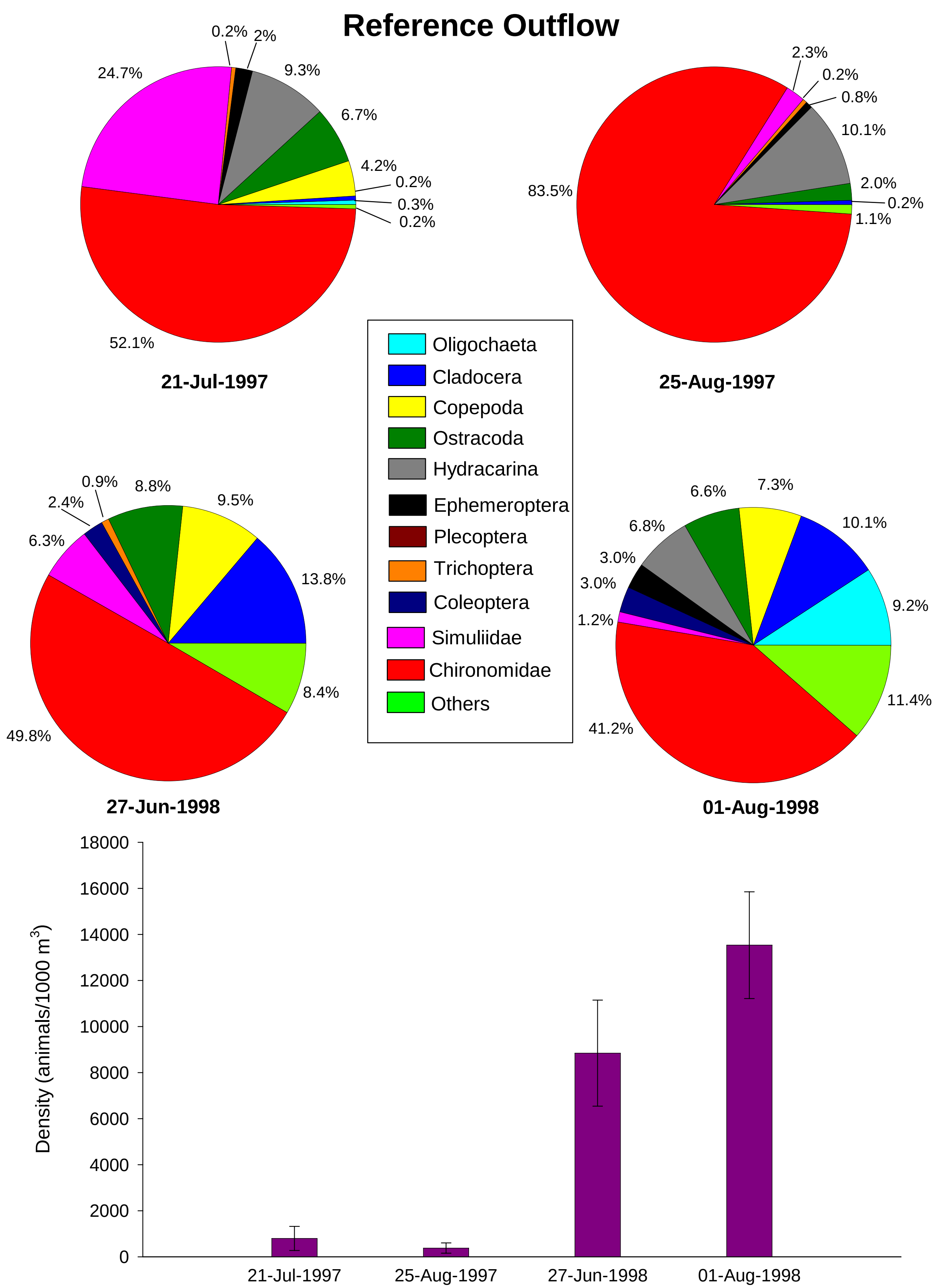


Figure 6.15 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of drifting invertebrates in Reference Outflow, 1997 to 1998.

Differences in composition and abundance of drift organisms could largely be ascribed to physical and energetic characteristics among the study streams. For example, the very high numbers of drift encountered in Stickleback Outflow in July 1997 may be due to the low flow rates encountered at this site (Rescan 1998). Zooplankton were abundant in most of the Boston Area streams, which may be an artifact of positioning the drift nets in close proximity to the lake and/or high flushing rates of the lake. Abundant zooplankton present within the drift of streams suggests that they may be an important prey item for stream resident predators.

6.4 BENTHIC INVERTEBRATES IN STREAMS

Stream benthic macroinvertebrates are adapted to living in flowing waters. Thus, the species encountered in streams are typically different than those from lake environments (see Section 6.2). Stream invertebrates are an important part of the food chain, particularly if they are located within fish feeding and rearing habitats. The information presented is based on data from annual data reports (Rescan 1994, 1995, 1997, 1998, and 1999a).

6.4.1 Methods

Benthic samples were collected from five streams within the Boston area (Figure 6.6) (Rescan 1994, 1995, 1997, 1998, and 1999a). Two to five sampling sessions were conducted on each stream between 1995 and 1998 (Table 6.7).

Artificial substrate samplers (Hester and Dendy 1962) were used to collect stream invertebrates. The artificial substrate samplers consisted of eight 0.064 m^2 plates stacked 0.5 cm apart. Five samplers were set in each stream sampling site to facilitate the collection of a minimum of three replicate samplers at the time of retrieval. Among the study sites, the artificial substrate samplers were placed, exposed, and collected in conditions as nearly identical as possible to reduce site-to-site variability. Invertebrates were allowed to colonize the artificial substrates for approximately 33 to 35 days; however, deployment dates for the 1998 survey were the only ones reported by Rescan (1998). For the sample from Fickle Duck Outflow in 1994, a Hess sampler with a sampling area of 0.09616 m^2 was used to collect benthic invertebrates (Rescan 1995).

Once again, percentage contribution of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) (EPT) was also calculated because these taxonomic groups are a common biomonitoring index (Rosenberg and Resh 1993). Presence of these taxa may indicate that these are healthy waterbodies.

Table 6.7 Benthic Invertebrate Sampling Schedule in Boston Area Streams, 1995 to 1998

Stream	Date Sampled				
	1994	1995	1996	1997	1998
Aimaokatalok NE Inflow				25 August	28 June to 31 July
Aimaokatalok River				24 August	27June to 1 August
Stickleback Outflow		1 August	5 August	21 July + 25 August	26 June to 30 July
Fickle Duck Outflow	August	1 August		25 August	26 June to 31 July
Reference Outflow				25 August	28 June to 1 August

Prior to sampler removal, a sieve (mesh size not reported) was placed on the downstream side of the sampler to prevent possible loss of organisms. Organisms were then gently brushed from the sampler onto a sieve, transferred to a clean 500-mL plastic bottle, preserved with 10% formalin, and labeled. The 1995, 1996 and 1997 samples were submitted to Biologica (Victoria, BC), whereas the 1998 samples were submitted to Applied Technical Services (Victoria, BC) for taxonomic identification and enumeration.

6.4.2 Aimaokatalok NE Inflow

Two benthic invertebrate sampling sessions were conducted on the Aimaokatalok NE Inflow, including one in August 1997 and one in July 1998. Mean total numbers (±1 SE) were 301 ± 202 animals/m^2 in August 1997 and 2522 ± 500 animals/m^2 in 1998 (Figure 6.16; Appendices C7 and C8).

Chironomidae dominated the benthic invertebrate community of Aimaokatalok NE Inflow in 1997, contributing 70.7% to the total mean number of animals enumerated (Figure 6.16; Appendices C7 and C8). The second most abundant group was EPT taxa at 17.4%. The 1998 sampling session was co-dominated by ‘other’ benthic invertebrates, Ostracoda, and Chironomidae, each contributing 40.0, 35.5, and 21.9%, respectively. No particular taxa were identified as the major contributor to Chironomidae, whereas *Candona* sp. was the dominant Ostracoda. EPT taxa contributed less than 1% towards total mean abundance in 1998. The ‘other’ benthic invertebrates were comprised of *Valvata sincera sincera* (Gastropoda) and *Physa* spp. (Pelecypoda).

6.4.3 Aimaokatalok River

Two benthic invertebrate sampling sessions were conducted on the Aimaokatalok River, including one in August 1997 and one in July 1998. Mean total numbers

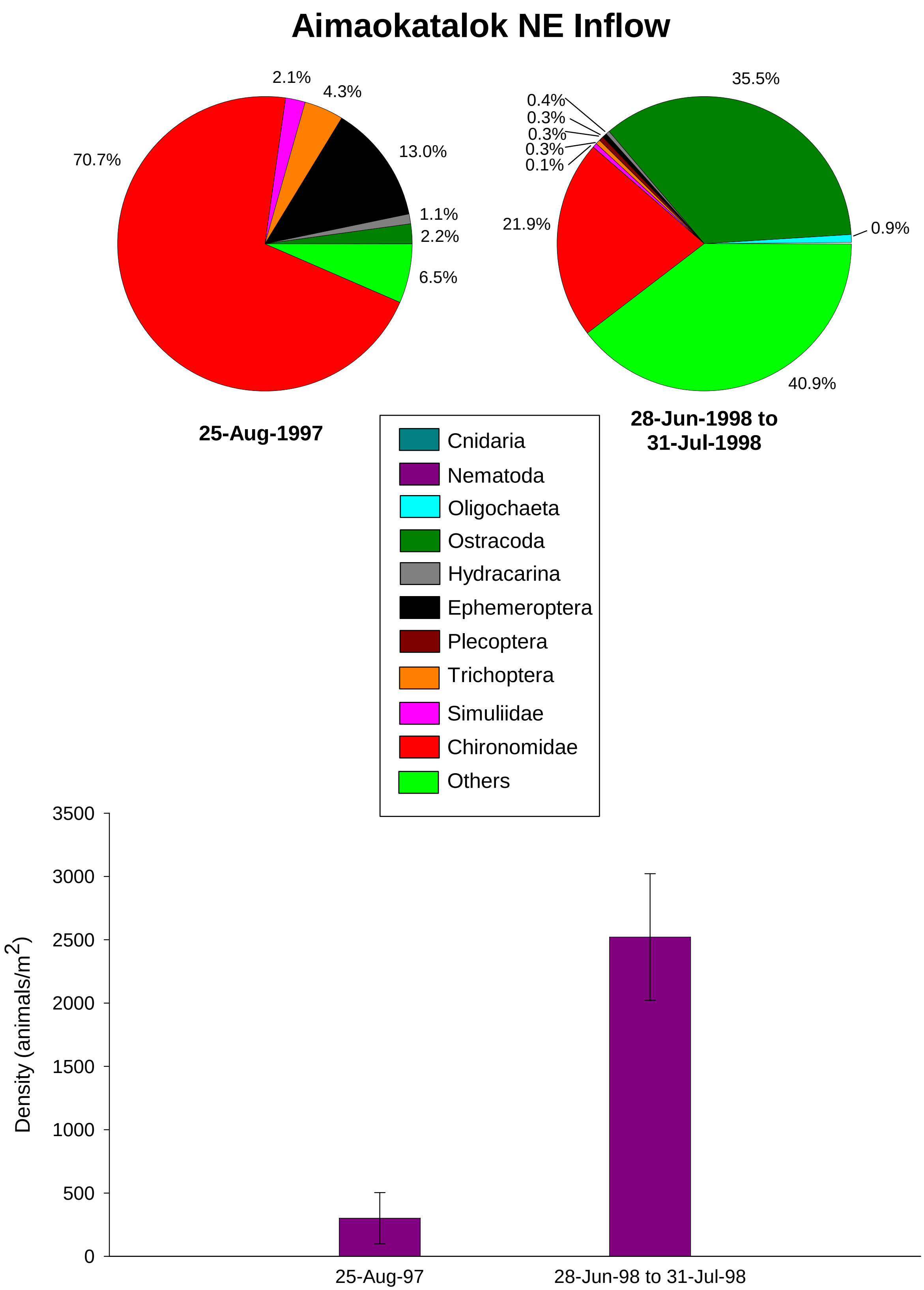


Figure 6.16 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of benthic invertebrates in Aimaokatalok NE Inflow, 1997 to 1998.

(±1 SE) were 529 ± 152 animals/m^2 in August 1997 and 870 ± 57 animals/m^2 in 1998 (Figure 6.17; Appendices C7 and C8).

Dominant taxa differed between sampling years. In August 1997, EPT taxa contributed 49.4% towards mean abundance (with Trichoptera at 43.2%) while Ostracoda contributed 39.5%. In 1998, however, Chironomidae was dominant with 67.6% of total mean abundance. EPT taxa contributed less than 1% towards total mean abundance (Figure 6.17; Appendices C7 and C8). The ostracods were dominated by *Candona* spp., whereas the chironomids were comprised of numerous taxa.

6.4.4 Stickleback Outflow

Five benthic invertebrate sampling sessions were conducted on the Stickleback Outflow, including one in each of 1995 and 1996, two in 1997, and one in 1998. Mean total invertebrate numbers (±1 SE) ranged from 258 ± 20 animals/m^2 in August 1997 to 10 003 ± 3717 animals/m^2 in 1998 (Figure 6.18; Appendices C7 and C8).

The benthic invertebrate community of Stickleback Outflow varied considerably among sampling events. For example Ostracoda dominated the benthic invertebrate samples in 1995 and 1998, contributing 78.9 and 83.3%, respectively, towards the total mean number of animals enumerated (Figure 6.18; Appendices C7 and C8). However, Ostracoda only contributed between 0.2 and 17.3% in samples from other years. Chironomidae dominated the sample in 1996, contributing 73.2% to total numbers. In the two samples in 1997, ‘other’ benthic invertebrates were the most numerous, contributing 22.0 and 27.8% to total numbers. The Ostracoda were represented by a number of different genera such as *Cypridopsis* spp. and *Cypris* spp., *Cyprois marginata*. Chironomidae were represented primarily by *Tanytarsus* spp. In the 1996 samples the ‘other’ benthic invertebrates comprised of large numbers of the *Grensia praeterita* (Trichoptera), and *Gammarus lacustris* (Malacostraca). EPT were present in greatest abundance in 1997 and 1998, contributing 10.4 and 13.9% to total mean abundance, respectively.

6.4.5 Fickle Duck Outflow

Four invertebrate sampling sessions were conducted on the Fickle Duck Outflow, including one in August of 1994, 1995, and 1997, and one in July 1998. Mean total numbers (±1 SE) on these dates ranged from 1088 ± 262 animals/m^2 in August 1997 to 13 457 ± 5655 animals/m^2 in 1998 (Figure 6.19; Appendices C7 and C8).

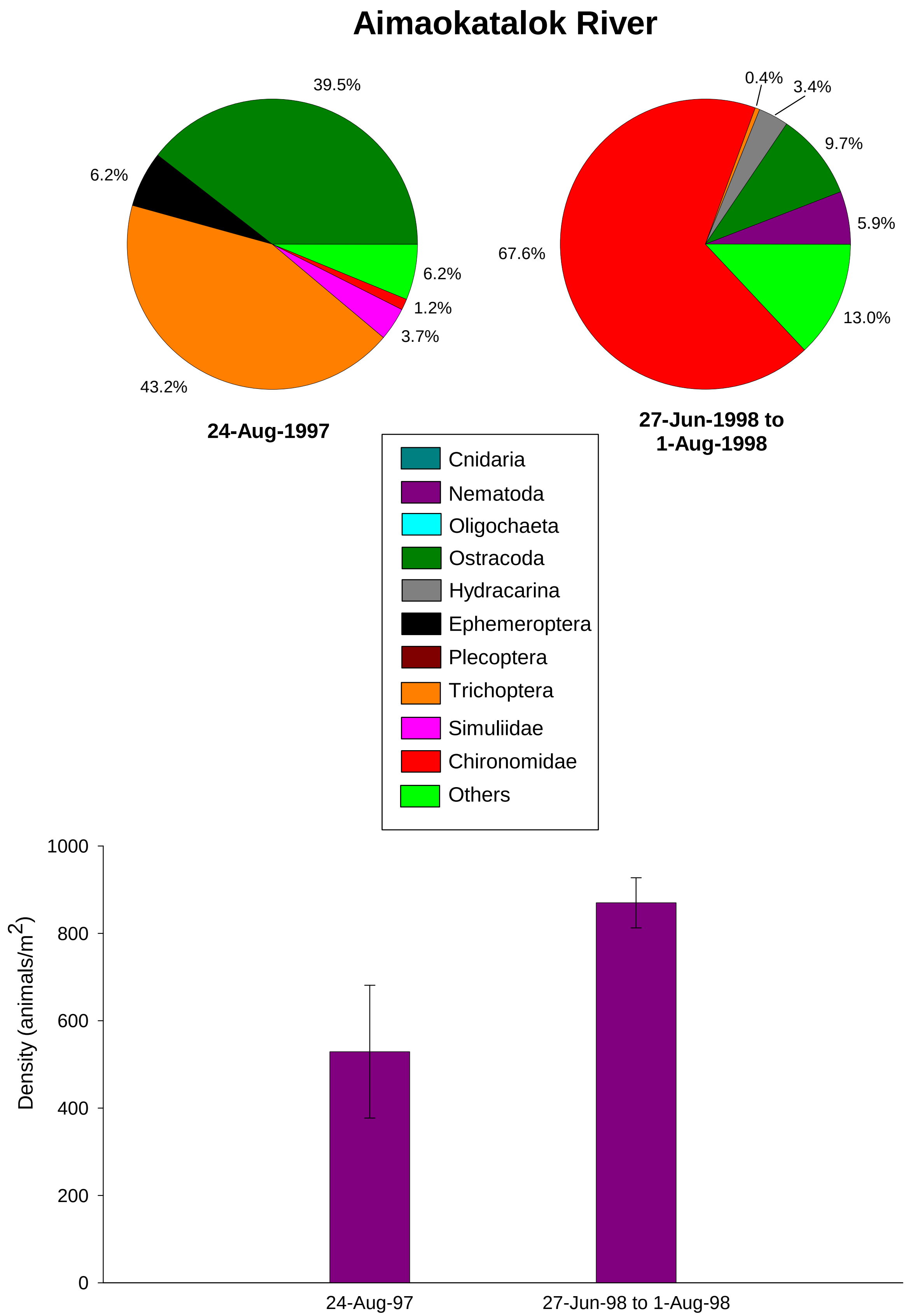


Figure 6.17 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of benthic invertebrates in Aimaokatalok River, 1997 to 1998.

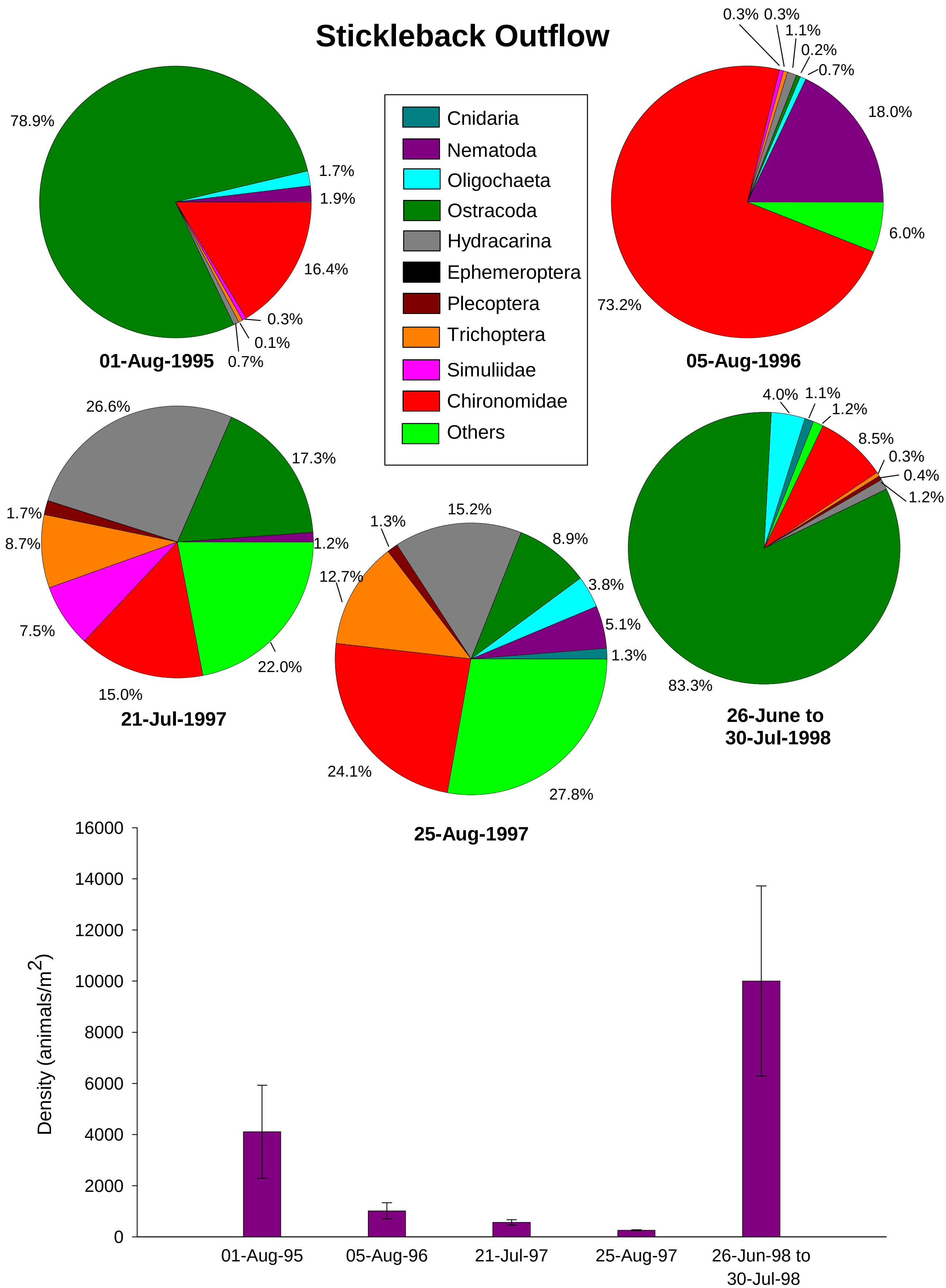


Figure 6.18 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of benthic invertebrates in Stickleback Outflow, 1995 to 1998.

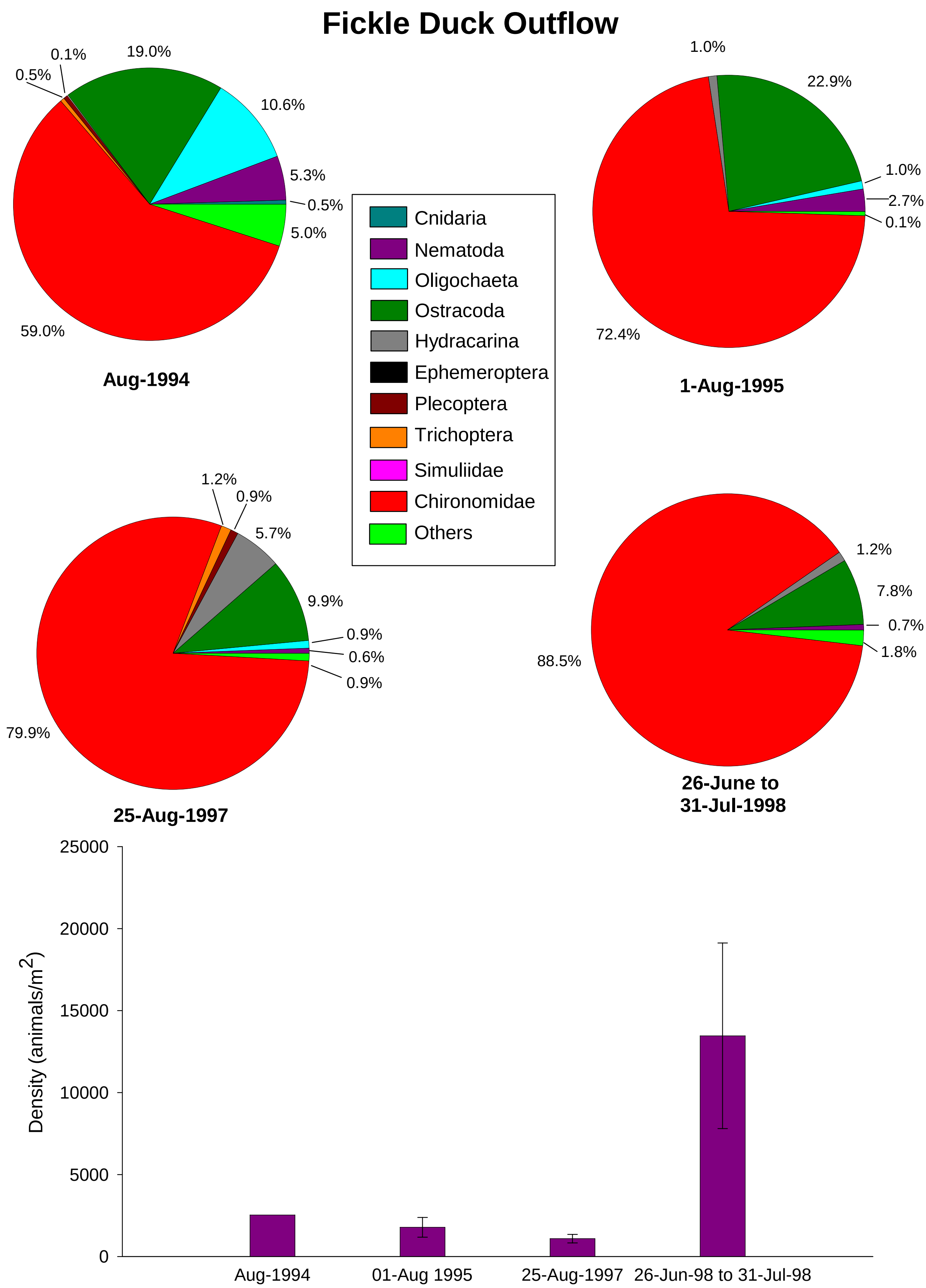


Figure 6.19 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of bethic invertebrates in Fickle Duck Outflow, 1994 to 1998.

The benthic invertebrate community of Fickle Duck Outflow was dominated by Chironomidae, which contributed between 59.0 and 88.5% to total mean numbers (Figure 6.19; Appendices C7 and C8). In 1995, Ostracoda, represented largely by *Cypridopsis* spp., formed a considerable part (22.9%) of the benthic community. Unidentified chironomids, unidentified Tanytarsini, *Corynoneura* spp., and *Stempellinella* spp. were the main contributors to Chironomidae. EPT taxa contributed small percentages towards total mean abundances in 1994 (0.6%) and 1997 (2.1%), and were absent from the outflow in 1995 and 1998 (Appendices C7 and C8).

6.4.6 Reference Outflow

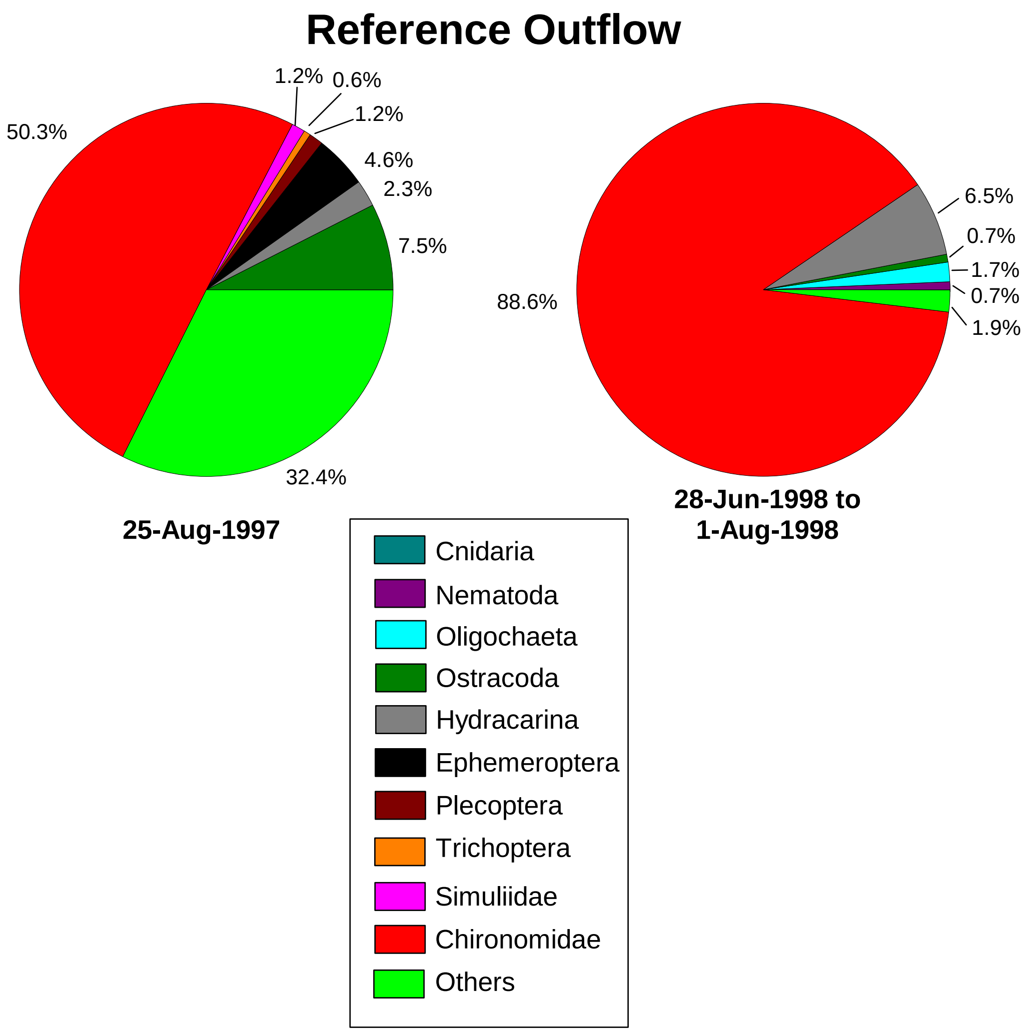
Retrieval of the artificial substrates from Reference Outflow was conducted on 25 August 1997 and 1 August 1998. Mean total numbers (±1 SE) on these dates were 565 ± 105 animals/m^2 and 38 880 ± 20 748 animals/m^2, respectively (Figure 6.20; Appendices C7 and C8).

The benthic invertebrate community of Reference Outflow was comprised largely of Chironomidae, which contributed 50.3 and 88.6% to total mean numbers in 1997 and 1998, respectively (Figure 6.20; Appendices C7 and C8). EPT taxa contributed small percentages towards total mean abundance in both years: 6.4% in 1997 and 0% in 1998. In 1997, 'other' benthic invertebrates (largely the gastropod *Valvata sincera sincera*) represented a considerable proportion (38.7%) of the benthic community. The major contributors to the chironomids were unidentified Diamesinae, unidentified Tanytarsini, *Cricotopus* spp. and *Rheotanytarsus* spp. (Appendices C7 and C8).

6.4.7 Summary

For the Boston area streams, a comparison of mean total benthic abundance suggested that Reference Outflow was the most productive, and Aimaokatalok River was the least productive (Table 6.8). Chironomidae, Ostracoda, and 'other' invertebrates (e.g., Gastropoda) dominated the benthic communities of the Boston area streams. EPT were common in a few streams, contributing towards almost half of the total mean abundance of invertebrates on one sampling occasion. Once again, as discussed in the drift invertebrates portion, absence of these taxa from future sampling events may indicate worsening health of the ecosystems.

Differences in composition and abundance of benthic organisms could largely be ascribed to physical and energetic characteristics among the study streams, as well as seasonality. For example, the low numbers of benthos encountered



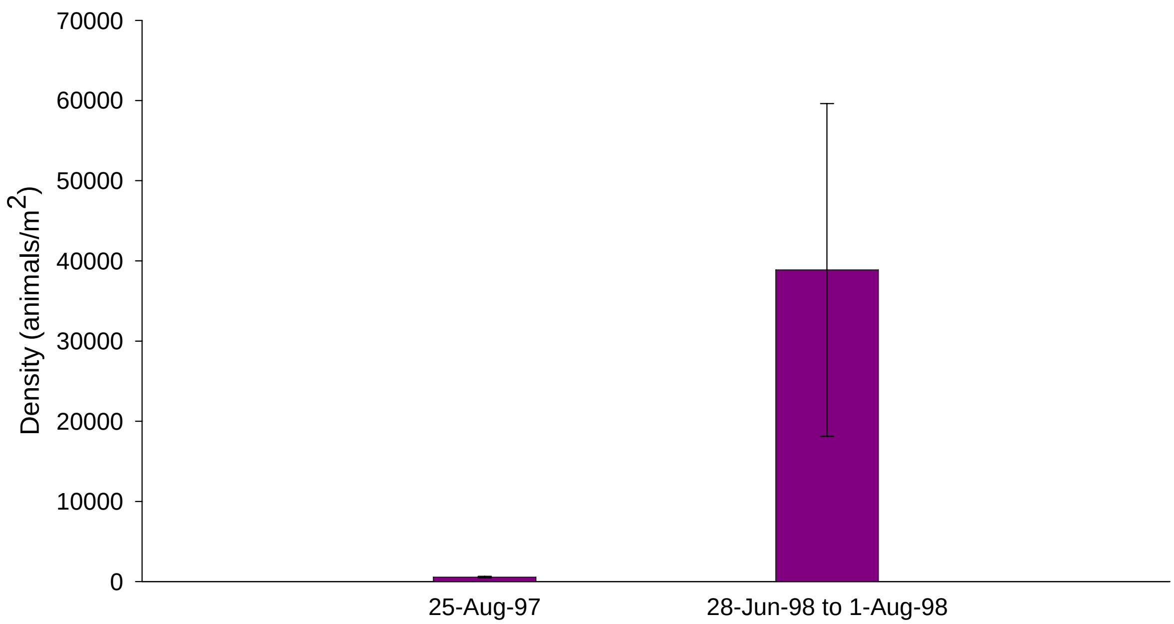


Figure 6.20 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of benthic invertebrates in Reference Outflow, 1997 to 1998.

in Aimaokatalok River may be due to the higher velocities encountered in that system. Similarly, higher abundances of benthos in the outflow systems might be attributed to the effect of a lake located immediately upstream. All streams sampled featured high proportions (at least 68% of total numbers) of Chironomidae on at least one sampling date. The dominance of chironomids among all of the Boston area streams suggested that this group was able to take advantage of existing conditions and maintain the high population densities.

Table 6.8 Summary of Benthic Invertebrate Abundance in Boston Area Streams, 1995 to 1998

Stream	Number of Sampling Events	Mean Number of organisms (per m^2)
Aimaokatalok NE Inflow	2	1 411
Aimaokatalok River	2	700
Stickleback Outflow	5	3 190
Fickle Duck Outflow	4	4 712
Reference Outflow	2	19 722

6.5 MARINE BENTHIC INVERTEBRATES

As with freshwater invertebrates, benthic forms of marine invertebrates are an important link in food webs. Most marine invertebrates are herbivores, detritivores or filter feeders and derive much of their energy from aquatic plants and organic materials. Some benthic macroinvertebrates are predacious, generally feeding upon other invertebrates. Many fish and mammal species feed upon marine invertebrates. The watersheds of the Boston area empty into Hope Bay via the Koignuk River.

6.5.1 Methods

Benthic marine invertebrate samples were collected from three sites within Hope Bay (Figure 6.6). A single sampling session was conducted at each site on 21 July 1998. Triplicate benthic invertebrate samples were collected at each study location and during each sampling session with an Ekman grab sampler (0.0232 m^2). Two different water depths were sampled; Station 1 was approximately 8 m, and Station 2 and Station 3 were approximately 3.6 m deep. Each replicate sample was sieved over 493 µm mesh, transferred to a clean 500-mL plastic bottle, preserved with 10% formalin, and labeled. All samples were submitted to Applied Technical Services, Victoria, BC, for taxonomic identification and enumeration.

6.5.2 Hope Bay

Mean total numbers (±1 SE) of benthic marine invertebrates inhabiting Hope Bay ranged from 1652 ± 456 animals/m^2 to 3417 ± 427 animals/m^2. The site with the greatest depth also had the largest benthic invertebrate density (Figures 6.21; Appendices C9 and C10).

Station 1 – Moderate Depth

Polychaeta (lugworms, tube worms, and marine bristle worms) and Chironomidae (midges) dominated the moderate depth (i.e., 8 m deep) benthic community of Hope Bay, contributing 59.2 and 19.5% towards total numbers, respectively (Figure 6.21; Appendices C9 and C10). The polychaetes were represented mainly by *Nephthys cornuta* and *Pholoe minuta*, whereas the chironomids were comprised of a dozen taxa approximately equivalent in abundance.

Station 2 – Shallow

Nematoda (nematodes), Polychaetea, and Chironomidae dominated the benthic community at Station 2 in Hope Bay (Figure 6.21; Appendices C9 and C10). Nematoda contributed 44.4% to total mean number of animals and typically are not identified to lower taxonomic levels. The proportions of polychaetes within the benthos was 25.1%, and this group was composed largely of *Laonice cirrata*. Chironomids contributed 22.4% of the total mean benthos numbers, but were found almost exclusively within a single replicate; *Rheotanytarsus* spp., *Cricotopus* spp., and *Eukiefferiella* spp. were the species commonly encountered.

Station 3 – Shallow

Nematoda and Polychaetea dominated the benthic community at Station 3 in Hope Bay (Figure 6.21; Appendices C9 and C10). Nematodes contributed 51.7% to the total mean number of benthic invertebrates. Polychaetes contributed 35.4% to total mean number of benthic invertebrates. The main contributors to this major taxonomic group were *Mediomastus* spp. and *Laonice cirrata*.

6.5.3 Summary

Benthic marine invertebrate samples were collected from three sites (two at shallow depths, one at a moderate depth) within Hope Bay. A single sampling session was conducted at each site on 21 July 1998.

Polychaeta (lugworms, tube worms, and marine bristle worms), Nematoda and Chironomidae dominated the benthos of Hope Bay. The composition of benthic

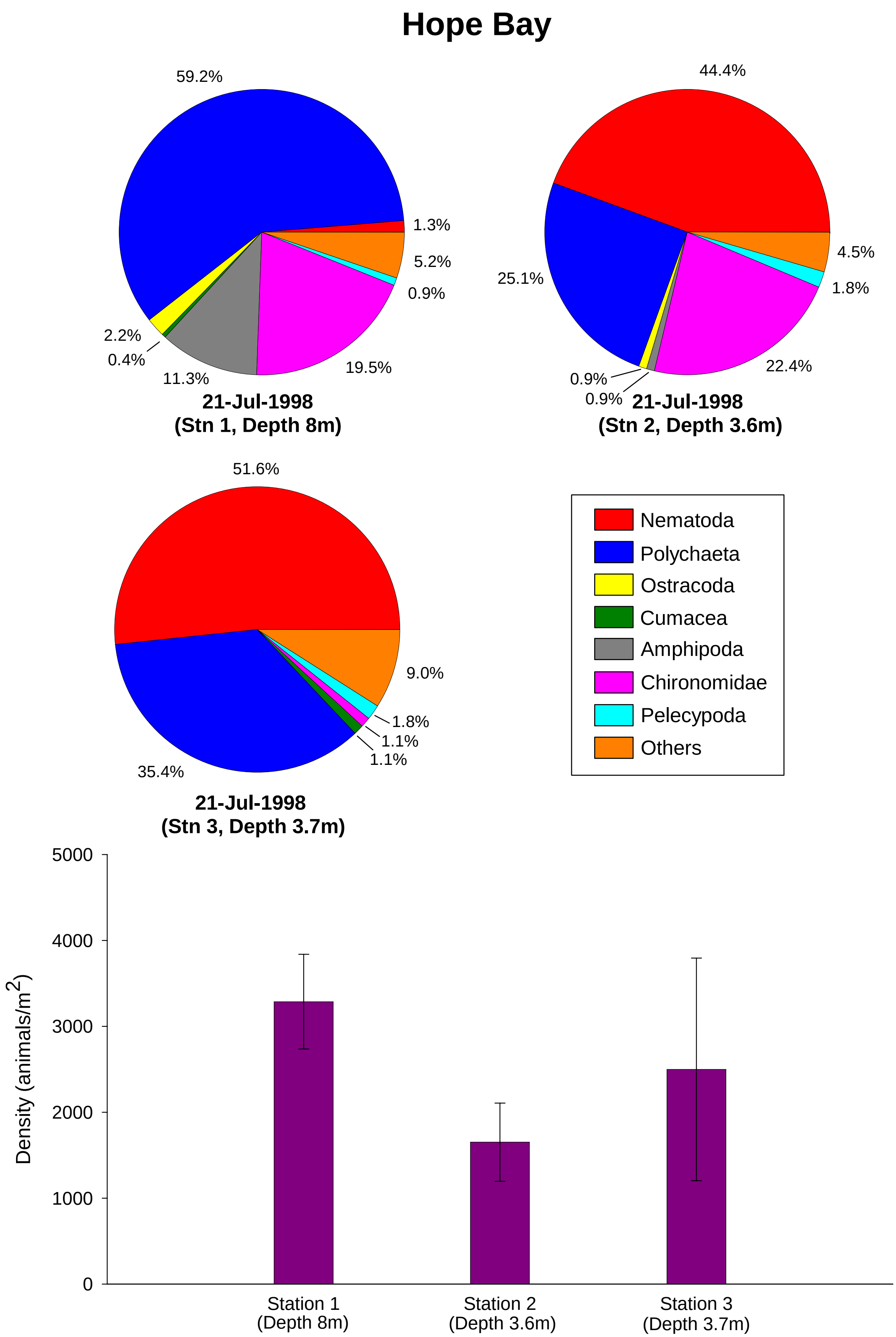


Figure 6.21 Relative abundance of major taxonomic groups and mean total density (± 1 SE) of benthic invertebrates in Hope Bay, 1998.

communities within Hope Bay were typical for the Arctic and Antarctic regions of the world (Hickman 1973; Johannesson et al. 2000). Differences in composition and abundance of the benthos among the three stations could be ascribed to physicochemical (e.g., water depth, salinity) characteristics at the sampling locations.

A comparison of mean benthic macroinvertebrate abundance among the three Hope Bay stations indicated that greater faunal densities correspond with increased water depth (Table 6.9). Increased invertebrate abundances at greater depths were also observed in nearby Roberts Bay samples (RL&L/Golder 2002). Additionally, substantial differences in the abundances of several taxonomic groups were observed between the two depths. For example, Amphipoda were located almost exclusively at the deeper location (Table 6.9). Additionally, a greater diversity and abundance of Polychaeta existed at greater depths.

Table 6.9 Summary of Benthic Invertebrate Abundance in Hope Bay, 1998

Location	Sample Depth (m)	Number of Sampling Events	Mean Total Density (animals/m^2)	Mean Number of Amphipoda (animals/m^2)	Mean Number of Polychaeta Taxa	Mean Number of Polychaeta (animals/m^2)
Station 1	8	1	3417	385	10	2025
Station 2	3.6	1	1652	15	3	415
Station 3	3.7	1	2628	0	4	930

The taxonomic Class Polychaeta (within the phylum Annelida) is an ecologically important group of primarily marine worms. More than 10 000 species of these worms exist in nature, displaying an enormous size range (less than 1 mm to 3 m). There are two general forms of polychaetes: those that are free living (Errantia) and those that are sedentary tube dwellers (Sedentaria). The actual number and type of polychaete species present in a system is the result of the complex of physical, chemical, biological and biogeographic conditions (Hickman 1973).

7 FISH POPULATIONS

7.1 LAKE COMMUNITIES

7.1.1 Methods

Field Methods

Fish sampling techniques used in the Boston area lakes between 1993 and 1997 included gill nets, minnow traps, and angling. The primary fish capture method was gill netting (all years), with considerably lesser amounts of angling (1995 and 1997), and minnow trapping (1995). All surveys were conducted during August. The waterbodies sampled during the 1993 to 1997 period included Aimaokatalok (Spyder), Fickle Duck (Trout), and Stickleback lakes (Figure 7.1). Fickle Duck Lake was sampled only twice during this period (1995 and 1996), whereas Stickleback Lake was sampled four times (1993, 1994, 1995 and 1997), and Aimaokatalok Lake was sampled each year. Detailed descriptions of fish capture methods are provided below.

Fish surveys conducted in the Boston area lakes in 1993, 1994 and 1995 used gill nets with a variety of mesh sizes, and the nets were deployed at the surface and on the bottom. In 1993, gill net set duration was 7.5 hours; however, information on mesh and net size was not provided in Rescan (1993). In 1994, both a sinking gill net gang (15.2 m long by 1.8 m deep, with a mesh size of 89 mm) and a floating gang (three 15.2 m long by 1.8 m deep panels comprised of 38, 64, and 89 mm mesh sizes) were used. Each net was set for 16 hours. In 1995, gill nets consisted of three panels, each 15.2 m long by 2.4 m deep, with 38, 64, and 89 mm mesh sizes. These nets were deployed near the surface in all but one site, which was on Aimaokatalok Lake.

Surveys conducted in 1996 involved setting two gill nets at each sampling site. The nets were positioned perpendicular to shore and parallel to each other. One net consisted of three panels with 19, 25, and 38 mm mesh sizes and a total length of 45.7 m. The other net consisted of four panels with 51, 64, 89, and 127 mm mesh sizes and a total length of 61.0 m. Gill net depths were not specified. Fish mortality was minimized by setting gill nets for a maximum of eight hours and checking each net hourly.

In 1997, both standard gill net gangs and index gill nets were used. The standard gill net gangs consisted of seven panels with 19, 25, 38, 51, 64, 76 and 89 mm mesh sizes. Each panel was 15.0 m long by 2.44 m deep. The total net area of each gang was 256 m^2. Index gill nets consisted of three panels of 38 mm mesh.

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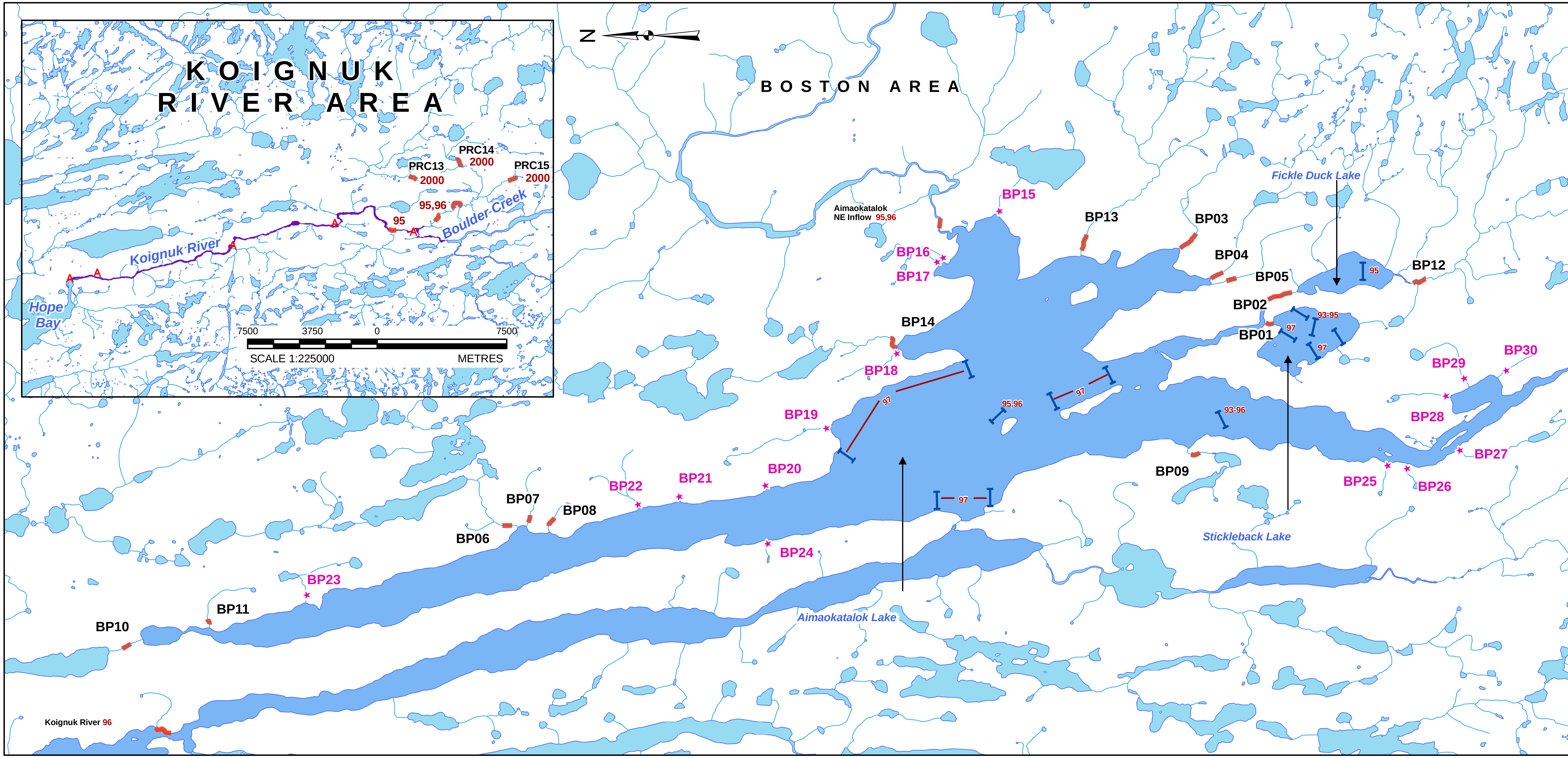


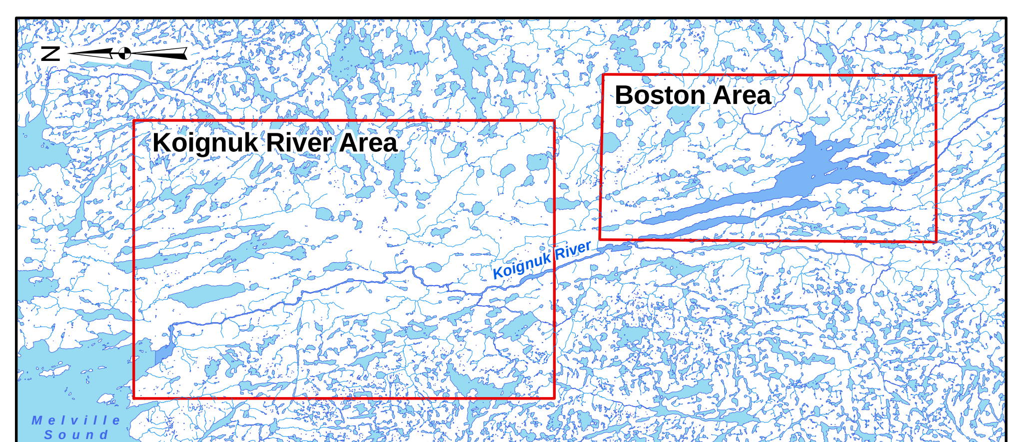
LEGEND

- Electrofishing and Habitat Survey
- ★ Habitat Assessment Only (1997)
- Gill Net Locations
- Koignuk River Habitat Survey (1998)
- A Angling
- Streams
- Study Area Waterbodies
- Waterbodies

93-96 Years of Sampling at Station
Note: All BPxx sites were sampled in 1997

REFERENCE

Sources: Data Obtained from the Government of Canada, Natural Resources Canada, Centre for Topographic Information
Projection: UTM Zone 13N Datum: NAD 83
This map is for information purposes only. Golder Associates Ltd. does not accept any liability arising from its misuse or misrepresentation.



2000 0 2000
SCALE 1:550000 METRES

MIRAMAR HOPE BAY LTD.

Boston Project Data Compilation

TITLE

Fish and Habitat Sampling Locations, 1993 - 2000

Golder Associates
Edmonton, Alberta

PROJECT No.06-1373-028			SCALE AS SHOWN	REV. 0
DESIGN	JP	30 Apr. 2008		
GIS	RC	05 May 2008		
CHECK	JP	14 May 2008	FIGURE: 7.1	
REVIEW	GA	20 May 2008		

Each panel was 15.0 m long by 2.44 m deep. The total net area was 110 m^2 per gang. Index gangs were deployed in what was termed as "rounds." In a round, three to four index nets were set in succession for approximately one-hour sessions. They were then retrieved in the order of setting and re-deployed upon completion of fish sampling.

Minnow traps were used only in 1995. They were made of galvanized metal with a wire mesh of 6.5 mm (diagonal measure). The traps were baited with salmon eggs and left submerged for 22 or 23 hours at each deployment site.

Fish life history information was collected from all fish captured. From 1993 to 1995, fish were identified to species, measured (fork length and/or total length in mm), weighed (g), and sampled for ageing structures; sex was determined through internal examination. In 1996, live fish were identified to species and measured (fork length in mm). In 1997, live fish were identified to species, measured (fork length in mm), weighed (g), sampled for ageing structures (left pectoral fin clips) and released. Fish larger than 300 mm in fork length were marked in 1997 with a uniquely numbered Floy™ anchor tag to assess their movements through subsequent recaptures. Additional data were collected from accidental and euthanized mortalities. These included sex and maturity, reproductive status, stomach contents, collection of otoliths (for ageing), and muscle, liver and/or kidney tissues for metal analysis.

Data Analysis

Data analysis and presentation varied considerably between the five annual data reports. As a result, all raw data have been consolidated into one table (Appendix D7) and submitted to a thorough QA/QC procedure. In cases where fish length did not correspond to its weight (i.e., Fulton's condition factor less than 0.5 or greater than 2.0), both length and weight data were eliminated from life history analyses (these data are reported in quotation marks in Appendix D7). As fish length data in 1994 were recorded only as total length (instead of fork length), they were converted to fork length using linear regression of species specific total length and fork length data collected in 1995. Subsequent to filtering out data errors, the raw data were used to calculate life history statistics that included:

- length-frequency distributions;
- length-weight relationships;
- mean, standard deviation, and range of length, weight, age and condition factor data;
- age-specific mean length and weight;
- size characteristics for separate sex and maturity categories; and

- diet analyses.

The multi-year data collected from each lake were combined during analyses to increase the sample size for each species.

As an index of relative abundance, catch-per-unit-effort (CPUE) values were presented only for 1997 surveys because of the consistent sampling methods (index gill nets) used during this year. Inconsistent mesh sizes used during 1993 to 1996, as well as the lack of detailed catch and effort information in the early data reports, did not allow for proper CPUE comparisons. The CPUE values for 1997 gill netting data are reported as number of fish captured per 100 m^2 of net set for 24 hours.

7.1.2 Aimaokatalok Lake

The catch rates, length-frequency distributions, size and age statistics, age-specific lengths and weights, diet, and sex/maturity data for fish species sampled in Aimaokatalok Lake during 1993 to 1997 are summarized in Appendices D1 to D6; data from individual fish are presented in Appendix D7. Gill netting was the main capture method used in Aimaokatalok Lake; however, angling and minnow traps were also used occasionally to capture fish.

7.1.2.1 Species Composition and Relative Abundance

In total, 260 fish were caught in Aimaokatalok Lake using gill nets during 1993 to 1997 (Table 7.1). They included lake trout (*Salvelinus namaycush*), lake whitefish (*Coregonus clupeaformis*), cisco (*Coregonus* sp.), and Arctic grayling (*Thymallus arcticus*). Lake trout was the predominant species in the overall catch (51.2%), followed by lake whitefish (41.9%) and cisco (6.5%). Arctic grayling was represented by only one individual captured in 1994. In 1993 and 1994, fish sampling occurred at only one location near the south end of the lake. In 1995 and 1996, fish sampling was conducted at two sites (in the south arm and the middle basin). In 1997, three new sampling locations were assessed (all within the middle basin of the lake).

Although lake trout dominated the catch in 1995 and 1996, lake whitefish outnumbered lake trout in 1994 and 1997. Cisco were captured only in 1997, likely as a result of the increased sampling effort in 1997 relative to the other years. This more intensive sampling effort, combined with the change in capture methods (use of index gangs), contributed to the large increase in the total number of fish caught in 1997 (62% of the total five-year catch). The CPUE values for lake trout, lake whitefish, and cisco caught in the index nets in 1997 were 35, 61, and

10 fish/100 m^2/24 h, respectively (Appendix D2). The overall CPUE values for the small and large mesh standard gangs (55 and 72 fish/100m^2/24 h, respectively) were lower than the overall CPUE value for index nets (106 fish/100m^2/24 h).

Table 7.1 Number and Percent Composition of Fish Captured by Gill Nets in Aimaokatalok Lake, 1993 to 1997

Species	1993		1994		1995		1996		1997		1993-1997	
	n	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
Lake trout	*7*	53.8	*20*	45.5	*23*	82.1	*13*	92.9	*70*	43.5	***133***	**51.2**
Lake whitefish	*6*	46.2	*23*	52.3	*5*	17.9	*1*	7.1	*74*	46.0	***109***	**41.9**
Cisco	*0*	0.0	*0*	0.0	*0*	0.0	*0*	0.0	*17*	10.5	***17***	**6.5**
Arctic grayling	*0*	0.0	*1*	2.3	*0*	0.0	*0*	0.0	*0*	0.0	***1***	**0.4**
Total	***13***	**100**	***44***	**100**	***28***	**100**	***14***	**100**	***161***	**100**	***260***	**100**

Fish marked with Floy tags during the 1997 survey included 60 lake trout and 30 lake whitefish. None of the marked fish were subsequently recaptured.

Angling in Aimaokatalok Lake resulted in the capture of two lake trout in 1995 and 30 lake trout in 1997 (Appendix D1). Ninespine stickleback (*Pungitius pungitius*) (n = 75) were also captured in Aimaokatalok Lake using minnow traps in 1995 (total sampling effort of 46 h).

7.1.2.2 Life History Data

Lake Trout

Size Distribution

The length-frequency distribution of the measured lake trout catch in Aimaokatalok Lake (*n* = 160) was widespread, ranging from 113 to 905 mm in fork length (Figure 7.2; Appendix D4). The mean fork length was 527 mm (Appendix D3). Although the overall length distribution of the catch was widespread, most lake trout (59%) were within the 440 to 610 mm size-class.

Length-Weight Relationship

The length-weight regression equation for lake trout from Aimaokatalok Lake (all sampling years and methods combined) was as follows:

log Weight (g) = -4.890 + 2.969 log Fork Length (mm) (n=153; r^2=0.973)

The mean condition factor was 1.08; condition factors for individual fish ranged from 0.67 to 1.97 (Appendix D3).

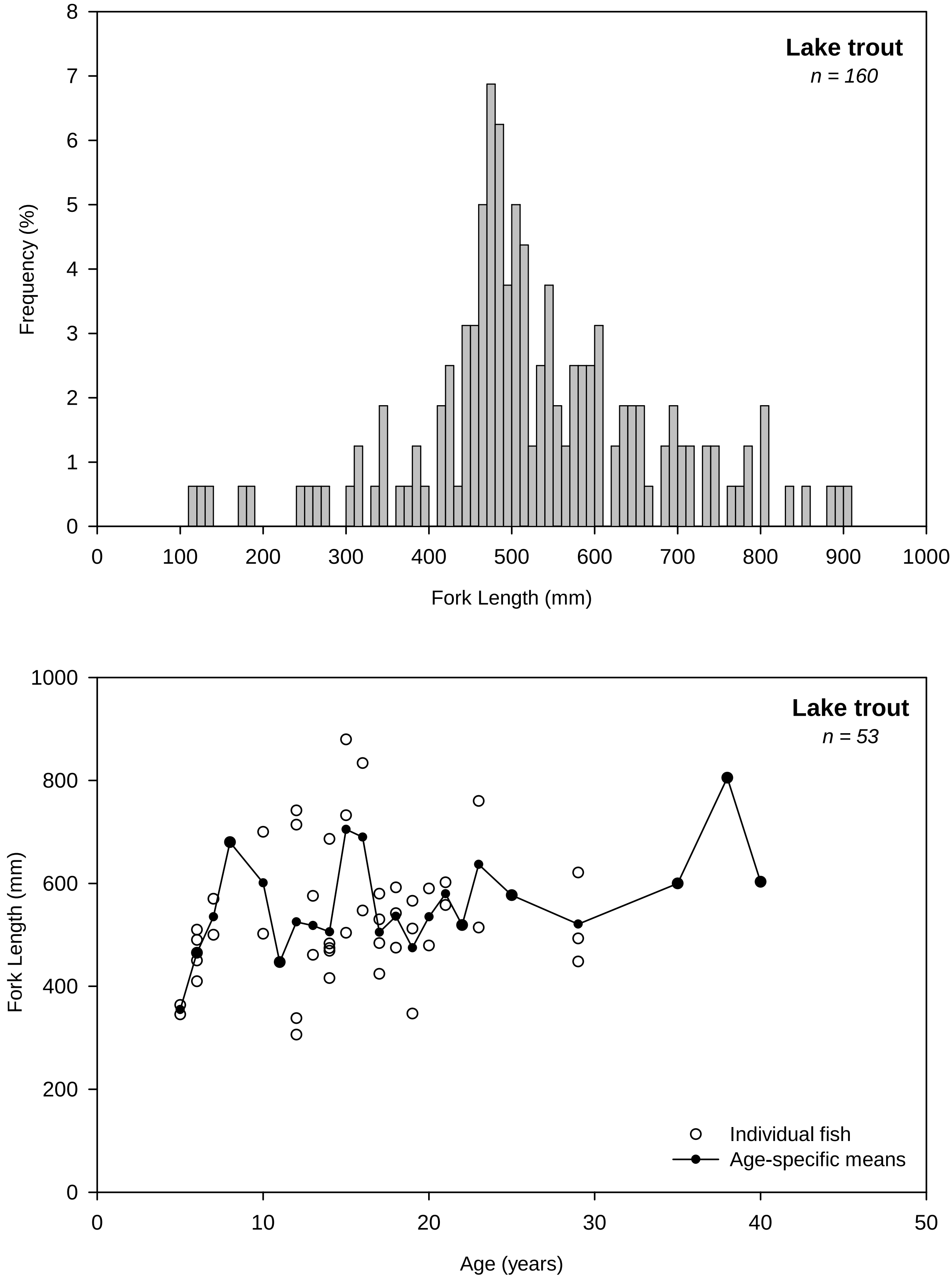


Figure 7.2 Length frequency distribution and age-length relationship for lake trout captured in Aimaokatalok Lake, 1993 to 1997.

Age and Growth

The age-length relationship for lake trout sampled in 1993-1997 is illustrated in Figure 7.2. Age-classes between 5 and 40 years were represented in the sample of 53 fish; the mean age was 16.4 years (Appendices D3 and D5). Mean length-at-age data were highly variable, likely because of the small sample size of aged fish (i.e., most age-specific means were based on one or two fish).

Sex and Maturity

Sex and maturity characteristics were determined for 42 lake trout from Aimaokatalok Lake (Appendix D6). Of these, 25 were females (15 mature and 10 immature) and 17 were males (eight mature and nine immature).

The largest immature female was 461 mm in fork length and the smallest mature female was 469 mm, suggesting that females reach maturity at an approximate length of 460-470 mm. Within the sample of males, the largest immature fish was 602 mm in fork length and the smallest mature individual was 448 mm in fork length. This large discrepancy in the size-at-maturity of males may indicate that some males remain immature despite their large size.

Diet

Nineteen lake trout captured in Aimaokatalok Lake during August 1997 were examined for stomach contents (Appendix D7). Of these, 11 (58%) had empty stomachs. Within the stomachs of eight fish that contained food items, unidentified fish remains were recorded in six of the stomachs and dipteran larvae were recorded in two stomachs. On the average, the non-empty stomachs were 30% full, ranging from 5 to 75% in stomach capacity of individual fish.

In addition to the above, qualitative data on lake trout diet in Aimaokatalok Lake were reported in Rescan (1994). The list of stomach contents included blackflies (*Simulium* sp.), mosquitoes (Culicidae), shrimp (*Mysis relicta*), amphipods (*Hyalella azteca*), isopods (*Lireus* sp.), nematodes, orb snail (*Valvata sincera heliocoidea*), lake whitefish (*Coregonus clupeaformis*), and stickleback (Gasteroidae).

Lake Whitefish

Size Distribution

Lake whitefish caught in Aimaokatalok Lake between 1993 and 1997 (n = 107) ranged from 172 to 538 mm in fork length (mean of 430 mm) (Figure 7.3). Most (72%) of the catch was composed of fish larger than 400 mm in fork length, with 18% of the catch exceeding 500 mm in fork length. Fish smaller than 240 mm in fork length contributed only 3% of the catch.

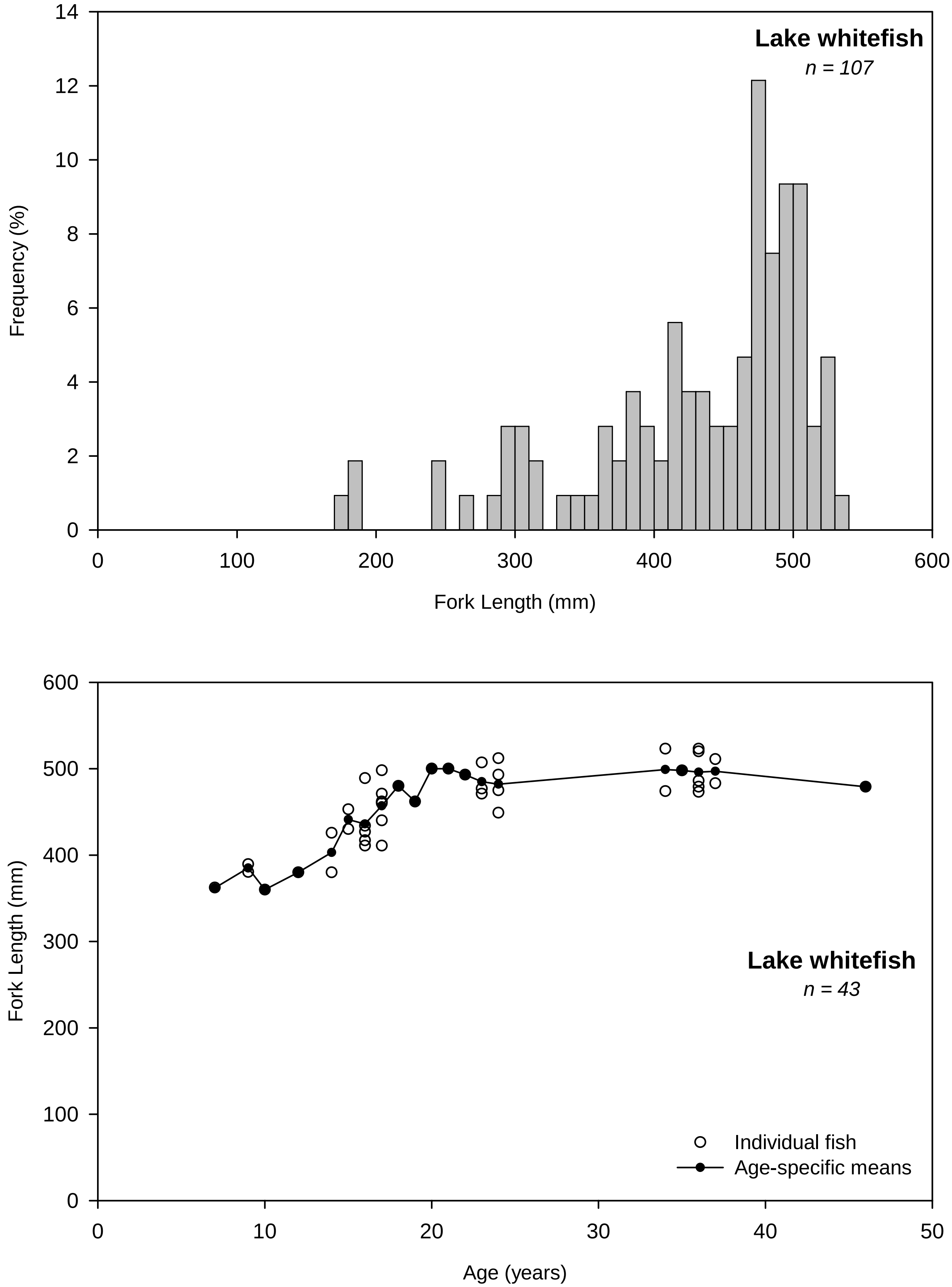


Figure 7.3 Length frequency distribution and age-length relationship for lake whitefish captured in Aimaokatalok Lake, 1993 to 1997.

Length-Weight Relationship

The length-weight regression equation for lake whitefish caught in Aimaokatalok Lake (all sampling years combined) was as follows:

log Weight (g) = -5.702 + 3.313 log Fork Length (mm) (n = 105; r^2 = 0.96)

The mean condition factor was 1.33; condition factors for individual fish ranged from 0.74 to 1.94 (Appendix D3).

Age and Growth

The age-length relationship for lake whitefish sampled in 1993-1997 is illustrated in Figure 7.3. Within the aged sample of 43 fish, age-classes from 7 to 46 years were represented, and the mean age was 22.2 years (Appendices D3 and D5). Although data were limited for younger age-classes, fish between ages 7 and 18 exhibited steady annual growth of approximately 11 mm in fork length. Older age-classes did not appear to grow as fast and reached an asymptotic size of about 500 mm in fork length.

Sex and Maturity

Sex and maturity characteristics were determined for 44 lake whitefish from Aimaokatalok Lake (Appendix D6). Of these, 23 were females (18 mature and five immature) and 21 were males (13 mature and eight immature).

The largest immature female was 379 mm in fork length and the smallest mature female was 411 mm in fork length. Within the sample of males, the largest immature fish was 437 mm in fork length and the smallest mature individual was 413 mm in fork length. The youngest ages recorded for mature fish were 15 years for females and 16 years for males. These data suggest that both sexes reach sexual maturity around age 15 at an approximate fork length of 410 to 430 mm.

Diet

Only qualitative data were available for lake whitefish diet (Rescan 1994). Listed food items included orb snails (*Valvata sincera helicoidea*), fingernail clams (*Pisidium casertanum*), fingernail clams (*Sphaerium nitidum*), freshwater shrimp (*Mysis relicta*), aquatic mites (*Lebertia sp.*), caddisflies (Trichoptera), mayflies (Ephemeroptera), and unidentified fish eggs.

Cisco

Size Distribution

Cisco were captured in Aimaokatalok Lake only in August 1997 (*n* = 17). They ranged from 92 to 348 mm in fork length (Figure 7.4), with a mean of 207 mm. Most (53%) of the catch was comprised of fish within a relatively narrow size-class of 170 to 209 mm in fork length.

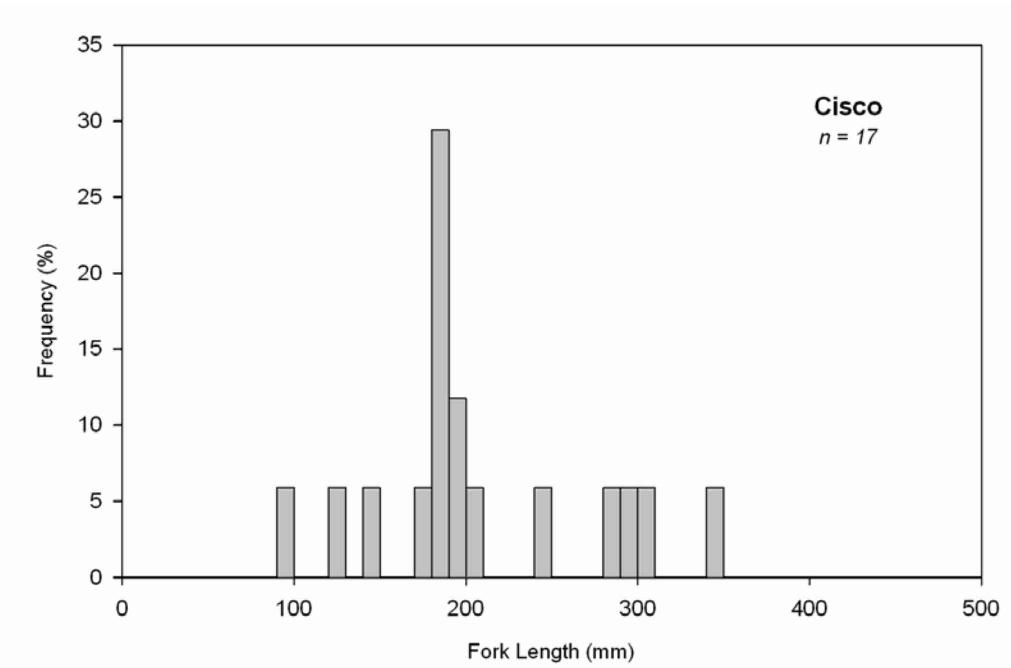


Figure 7.4 Length-Frequency Distribution of Cisco Captured in Aimaokatalok Lake, 1997

Length-Weight Relationship

The length-weight regression equation for cisco caught in Aimaokatalok Lake was as follows:

log Weight (g) = -5.389 + 3.166 log Fork Length (mm) ($n = 17$; $r^2 = 0.994$)

The mean condition factor was 0.99; condition factors for individual fish ranged from 0.85 to 1.26 (Appendix D3).

Sex and Maturity

Sex and maturity characteristics were determined for 11 cisco captured in Aimaokatalok Lake (Appendix D6). Of these, three were females (two mature and one immature) and eight were males (two mature and six immature).

The largest immature female was 305 mm in fork length and the smallest mature female was 198 mm in fork length. This large discrepancy in size-at-maturity data and the small size of two females reported in ripe spawning condition (198 and 205 mm in fork length) suggested that one part of the cisco catch in Aimaokatalok Lake may have been comprised of least cisco (*Coregonus sardinella*) that were misidentified as cisco (*Coregonus artedi*).

Within the sample of males, the largest immature fish was 287 mm in fork length and the smallest mature individual was 293 mm in fork length. These data suggested that cisco males reach sexual maturity at an approximate size of 290 mm in fork length.

Arctic Grayling

Only one Arctic grayling was caught in Aimaokatalok Lake. This fish was a six-year old male with a total length of 340 mm and a weight of 400 g (Appendix D7).

7.1.3 Stickleback Lake

Gill nets were set in Stickleback Lake during 1993, 1994, 1995, and 1997; however, no fish were captured despite the large amount of effort exerted. Minnow traps deployed for 22 h in 1995 captured 19 ninespine stickleback, indicating that it is likely the only fish species that inhabits this lake. Ninespine stickleback were also reported as observed in Stickleback Lake during 1993, 1994, and 1997 (Appendix D1).

7.1.4 Fickle Duck Lake

The catch rates, length-frequency distributions, size and age statistics, age-specific lengths and weights, diet, and sex/maturity data for fish species sampled in Fickle Duck Lake during 1995 and 1996 are summarized in Appendices D1 to D6; data from individual fish are presented in Appendix D7.

7.1.4.1 Species Composition and Relative Abundance

Arctic grayling was the only fish species captured in gill nets in Fickle Duck Lake during the 1995 to 1996 period (Appendix D1). Unlike Aimaokatalok Lake, Fickle Duck Lake did not appear to support lake trout, lake whitefish or cisco populations. Based on minnow trap catches, ninespine stickleback also inhabits this waterbody (three individuals were caught in July 1995).

Although Rescan (1997) presented tissue results for lake trout captured in Fickle Duck Lake in 1996, the same report stated that only Arctic grayling were captured in this lake. As such, it remains unclear which part of the report is in error; however, subsequent sampling in Fickle Duck Lake by Golder Associates Ltd. has confirmed that lake trout and present in the lake (Golder 2008).

In total, eight Arctic grayling were captured in gill nets; four were caught in 1995 and four were caught in 1996.

7.1.4.2 Life History Data

Arctic Grayling

Size Distribution

The sample of Arctic grayling from Fickle Duck Lake (n = 8) ranged between 224 and 407 mm in fork length, with a mean of 323 mm (Appendix D3). Only four fish were weighed; they ranged from 600 to 900 g, with a mean weight of 750 g.

Length-Weight Relationship

The length-weight regression equation for the sampled Arctic grayling was as follows:

log Weight (g) = -5.340 + 3.216 log Fork Length (mm) ($n = 4$; $r^2 = 0.998$)

The mean condition factor was 1.63; condition factors for individual fish ranged from 1.60 to 1.65 (Appendix D3).

Age and Growth

Age was determined for only two Arctic grayling from Fickle Duck Lake. One was an eight-year old female with a fork length of 335 mm. The other was a 12-year old male with a fork length of 380 mm.

7.1.5 Summary

In total, 300 fish representing four species were captured in gill nets or angled in three Boston area lakes during fisheries surveys conducted between 1993 and 1997 (Table 7.2). The captured species included lake trout (56% of the total catch), lake whitefish (38%), cisco (6%), and Arctic grayling (0.3%). Ninespine stickleback were also present in all lakes, as recorded from observations and minnow trap catches; however, numeric counts of these catches were not always reported.

Table 7.2 Summary of Fish Species Composition in Gill Net Catches of Boston Area Lakes, 1993 to 1997

Lake	Total Catch	Dominant Species (% of total catch)		Co-dominant Species (% of total catch)		Other Species (% of total catch)	
Aimaokatalok	292	Lake Trout	(56.2)	Lake whitefish	(37.6)	Cisco Arctic grayling	(5.9) (0.3)
Fickle Duck	8	Arctic grayling	(100.0)				
Stickleback	0						
Total	**300**						

The fish populations in Aimaokatalok Lake included lake trout, lake whitefish, cisco, Arctic grayling and ninespine stickleback. In Fickle Duck Lake, only Arctic grayling and ninespine stickleback were caught, and in Stickleback Lake only ninespine stickleback were caught. Considering that Fickle Duck and Stickleback lakes are similar in size and depth, the presence of Arctic grayling in Fickle Duck Lake is suspect. The presence of lake trout in Fickle Duck Lake has been confirmed in 2006 (Golder 2006), which suggests that lake trout may have been reported as Arctic grayling in error.

7.2 STREAM COMMUNITIES

7.2.1 Methods

Field Methods

Fish sampling techniques used in streams within the Boston area (including the Koignuk River) included backpack electrofishing, angling, minnow trapping, and gill netting (only in the Koignuk River). The primary fish capture method was backpack electrofishing. Stream surveys were conducted from June to August during the 1993-2000 period. Sampled watercourses included Fickle Duck and Stickleback outflows, Aimaokatalok NW Inflow, as well as several small inflows to Aimaokatalok Lake and one to Fickle Duck Lake (Figure 7.1; Appendix D8). The Koignuk River, Boulder Creek (tributary to the Koignuk River) and three small streams where permanent road crossings were proposed (PRC13, PRC14, and PRC15) were also sampled. Detailed descriptions of fish capture methods are provided below.

Backpack electrofishing was conducted by a two-person crew using either a gas-powered Smith-Root™ model 15A POW (Programmable Output Waveforms) or model 15C backpack electrofisher. Working in an upstream direction, both single and double pass electrofishing were used on accessible portions of selected streams (Rescan 1993, 1994, 1995, 1997, 1998, and 2001).

Surveyed sections varied between years. Data recorded during backpack electrofishing events included location, effort, amperage, voltage, water temperature, and habitat conditions; however, this data set was not complete for all sites. After the electrofishing survey, a habitat assessment of the surveyed stream section was also conducted (see Section 8). All stream site reference numbers (e.g., BP01, BP02, etc.; Figure 7.1) are based on Rescan (1998) designations, with the exception of the PRC sites, which were reported in Rescan (2001).

Fish life history data were collected from the captured fish. Live fish were identified to species, measured (fork length or total length in mm), weighed (g), and released. Due to large catches of ninespine stickleback in some years, the numbers of captured fish were only estimated and life history data (e.g., length) were not recorded. Additional data were collected from accidental and euthanized mortalities; these included sex and maturity, reproductive status, and collection of otoliths (for ageing).

Data Analysis

The presentation of fish population data for Boston area streams varied considerably between the six annual data reports in which they were discussed. To facilitate data presentation in this report, all data were consolidated into one table (Appendix D10) and analyzed for life history characteristics based on multi-year catches combined. Where data were available, mean fork length, weight, condition factor, and age (with corresponding standard deviations and ranges) were calculated for each stream and each species on a yearly basis (Appendix D9). The multi-year data collected from each stream were also combined to maximize the sample sizes.

As an index of relative abundance, catch-per-unit-effort (CPUE) values are presented in Appendix D8 as fish captured or observed per minute of active sampling (fish/min). Although some previous data reports had recorded CPUE differently (e.g., as fish/300 m/hour; Rescan 1997), data on distance sampled were not consistently reported in all years. To allow use of a common unit for comparisons, some of the CPUE data presented in Appendix D9 were calculated or changed to fish caught per minute of sampling, without considering the distance sampled.

7.2.2 Aimaokatalok NE Inflow

The Aimaokatalok NE Inflow originates from a chain of lakes east of Aimaokatalok Lake and drains into the northeast part of the middle basin of Aimaokatalok Lake. It is the second largest inflow into Aimaokatalok Lake after the Aimaokatalok River. Sampling of this inflow occurred during August 1995 and July 1996. High flows and turbid water conditions did not allow assessment in 1997. Where reported, the electrofished stream sections ranged from 150 to 300 m in length and both one-pass and two-pass (1996 only) electrofishing methods were used.

In total, 39 fish were captured in Aimaokatalok NE Inflow during backpack electrofishing surveys in August 1995 and August 1996 (Appendix D8). They included 34 lake trout and five Arctic grayling. Ninespine stickleback were also caught in this stream in 1996; however, they were not enumerated because of time constraints and the large numbers caught (Rescan 1997). In 1995, only Arctic grayling were reported from minnow trapping and electrofishing effort, whereas in 1996 only lake trout were caught by electrofishing. The electrofishing CPUE value was 0.5 fish/min in 1995 and 3.3 fish/min in 1996.

The Arctic grayling caught in 1995 (n = 5) were all juveniles and were not measured. The lake trout catch in 1996 (n = 34) ranged from 52 to 82 mm fork length, with a mean of 64 mm (Appendix D9). The entire catch consisted of juvenile fish, suggesting that Aimaokatalok NE Inflow is used during summer for Arctic grayling and lake trout rearing.

7.2.3 Stickleback Outflow (BP01)

The Stickleback Outflow drains out of Stickleback Lake and into the southern portion of Aimaokatalok Lake. This stream has no observable spawning, overwintering, or adult holding habitat and there are no barriers to fish migration. Sampling was conducted by backpack electrofishing during August 1993 and June 1997 (Figure 7.1). Minnow traps were used in August 1994 and August 1995. The electrofished stream section was only 12 m in length in 1993; it was 175 m long in 1997.

Only two fish species were captured in Stickleback Outflow. The catch was dominated by ninespine stickleback, whereas lake trout were represented by a single fish (fry) caught in a minnow trap in 1994 (Appendix D8). Not all ninespine stickleback were counted in 1994 due to large catches.

In total, over 140 ninespine stickleback and one lake trout fry were captured in Stickleback Outflow. Electrofishing catches of ninespine stickleback were much higher in August 1993 (n = 31 or 12.4 fish/min) than in June 1997 (n = 2 or 0.3 fish/min), suggesting a seasonal difference in use by ninespine stickleback. Only two ninespine stickleback were measured; they were caught near the inflow to Aimaokatalok Lake in 1997 and were 59 and 61 mm in total length (Appendix D8); the size of the single lake trout fry was not reported.

7.2.4 Fickle Duck Outflow (BP02)

The Fickle Duck Outflow drains into the southern portion of Aimaokatalok Lake. This stream has no observable spawning, overwintering, or adult holding habitat, and there are no barriers to fish migration. Sampling was conducted using backpack electrofishing in August 1993, July 1995, and June 1997. Minnow traps were used in August 1994 and August 1995. The length of the electrofished stream section was 20 m in 1993 and 80 m in 1997.

Similar to Stickleback Outflow, only two fish species were captured in Fickle Duck Outflow. The catch was dominated by ninespine stickleback, and lake trout were represented by a single fish caught in a minnow trap in 1994 (Appendix D8). Not all ninespine stickleback were counted in 1994 due to large catches.

In total, over 166 ninespine stickleback and one lake trout fry were captured in Fickle Duck Outflow. The electrofishing catch of ninespine stickleback was much higher in July 1995 (n = 40 or 33 fish/min) than in August 1993 (n = 2 or 0.3 fish/min) and June 1997 (n = 2 or 0.4 fish/min). Only two ninespine stickleback were measured (61 and 69 mm in total length; Appendix D8); the size of the single lake trout fry was not reported.

7.2.5 Small Tributaries to Aimaokatalok Lake (B03 to B30)

In total, 12 small tributaries to Aimaokatalok Lake were sampled by backpack electrofishing in June 1997 (BP03 to BP14; Figure 7.1). An additional 16 streams (BP15-BP30) were assessed as not having fish habitat, or as having barriers preventing fish movement from Aimaokatalok Lake. Details on the streams where fish sampling occurred are reported below.

Stream BP03

Stream BP03 flows into the southeast basin of Aimaokatalok Lake. A 350 m stream section was electrofished on 15 June 1997. The total catch consisted of five ninespine stickleback and one Arctic grayling adult. The Arctic grayling was captured in a small pool immediately downstream of the marshy area and the ninespine stickleback were caught at the mouth of the creek. The ninespine stickleback ranged from 43 to 50 mm in total length, with a mean length of 47 mm (Appendix D9). The Arctic grayling was a mature male, 358 mm in fork length and 460 g in weight. The overall CPUE value was 0.6 fish/min (Appendix D8).

Stream BP04

Stream BP03 drains a series of small ponds and flows into the southeast basin of Aimaokatalok Lake. This stream was sampled by backpack electrofishing on 16 June 1997. No fish were captured during sampling. The surveyed section of the stream was in flood, flowing over terrestrial grasses and organic matter. Potential spawning, rearing, adult feeding, or overwintering habitat was not present within the stream. A low-laying marshy area likely acted as a barrier to large-bodied fish accessing the upstream ponds (Rescan 1998).

Stream BP05

Stream BP05 is located immediately southwest of Stream BP04 and flows into the southeast basin of Aimaokatalok Lake. An 80 m stream section was electrofished on 16 June 1997. Two ninespine stickleback and one Arctic grayling were captured (CPUE of 0.6 fish/min; Appendix D8). The ninespine stickleback were 49 and 54 mm in total length, whereas the Arctic grayling was an immature male, 224 mm in fork length and 102 g in weight (Appendix D9).

The surveyed section of the stream was in flood, flowing for the most part over terrestrial grasses and organic matter, and it is likely that this stream is ephemeral. There was no observable spawning, rearing, overwintering, or adult feeding habitat present. The fish were caught near the mouth of the stream.

Stream BP06

Stream BP06 drains a series of small ponds into the northern arm of Aimaokatalok Lake. It was sampled by backpack electrofishing on 16 June 1997, resulting in no fish captures. The surveyed section of the stream flowed through series of rock shelves, pools, and riffles. The substrate was composed largely of organic matter as the stream flowed through terrestrial grasses and shrubs. The stream provided potential rearing habitat, but not spawning, overwintering, or adult feeding habitat. A rock shelf at the mouth of the stream probably acts as a fish barrier, preventing movement into BP06 or the upstream ponds.

Stream BP07

Stream BP07 is located immediately south of Stream BP06 and drains a marshy area into the northern arm of Aimaokatalok Lake. It was sampled by backpack electrofishing on 16 June 1997, resulting in no fish captures. The stream flowed over terrestrial grasses and organic matter. There was no observable spawning, overwintering, or adult feeding habitat present, and there was no potential rearing habitat within the channel.

Stream BP08

Stream BP08 is located immediately south of Stream BP07 and drains into the northern arm of Aimaokatalok Lake. It was sampled by backpack electrofishing on 16 June 1997, resulting in no fish captures. The stream flowed over terrestrial grasses and organic matter. There was no spawning, overwintering, rearing, or adult feeding habitat within the channel.

Stream BP09

Stream BP09 is located on the west side of Aimaokatalok Lake, and drains a series of small ponds into the southern arm of Aimaokatalok Lake. It was sampled by backpack electrofishing on 16 June 1997, resulting in no fish captures. As the stream was in flood stage, much of the stream was flowing through terrestrial grasses; however, the central channel had a substrate consisting of fines, cobble and boulders. Of all the streams assessed, this stream had the best potential as spawning and rearing habitat for Arctic grayling; however, a rock shelf at the mouth of the stream likely acted as a migration barrier for fish movements, especially during low water levels.

Stream BP10

Stream BP10 drains a small lake into the northern tip of Aimaokatalok Lake. A 150 m section was electrofished on 17 June 1997, when the stream was in flood. The stream was composed of a series of deep pools connected by "riffles over terrestrial grasses" (Rescan 1998). The stream then changed to a marshy area of indistinct channels 200 m upstream, which most likely acted as a migration barrier. In total, one mature Arctic grayling, one mature lake trout and one ninespine stickleback were caught (overall CPUE of 1.2 fish/min; Appendix D8). The Arctic grayling was 415 mm in fork length and weighed 826 g. The lake trout was 733 mm in fork length and weighed 4050 g. The ninespine stickleback had a total length of 54 mm.

Stream BP11

Stream BP11 flows into the northern arm of Aimaokatalok Lake. A 160 m stream section was electrofished on 17 June 1997. Seven ninespine stickleback were captured (CPUE of 2 fish/min; Appendix D8). They ranged from 47 to 55 mm in total length (Appendix D9). The surveyed section of the stream was in flood, flowing for the most part over terrestrial grasses and organic matter. There was no observable spawning, rearing, overwintering, or adult feeding habitat present.

The fish were caught near the mouth of the stream, suggesting they originated in Aimaokatalok Lake.

Stream BP12 (Fickle Duck Inflow)

Although Rescan (1998) designated Stream BP12 as Stickleback Inflow, the location of this site on the accompanying map clearly shows that it flows into Fickle Duck Lake. It was assumed that the map was correct and the site has been renamed to Fickle Duck Inflow in this report.

Stream B12 drains a series of small lakes and marshy areas southeast of Fickle Duck Lake. It was sampled on 17 June 1997. The surveyed section of stream consisted of a series of pools connected by riffles and runs. Run sections were lined by undercut banks. Although the stream was in flood stage, the central channel was underlain by fines, cobble, and boulders. Two ninespine stickleback were captured (CPUE of 0.4 fish/min; Appendix D8). They were 57 and 71 mm in total length (Appendix D9).

Stream BP13

Stream BP13 drains a series of small lakes into the east part of the middle basin of Aimaokatalok Lake. It was sampled by backpack electrofishing on 17 June 1997, resulting in no fish captures. The stream was a series of small pools connected by riffles flowing over terrestrial grasses and organic matter. There was no spawning, overwintering, rearing, or adult feeding habitat in the channel.

Stream BP14

Stream BP14 drains a series of small lakes into the northeast part of the middle basin of Aimaokatalok Lake. It was sampled by backpack electrofishing on 17 June 1997, resulting in no fish captures; however, one juvenile Artic grayling was observed. The surveyed section of the stream was steep in gradient and flowed over terrestrial grasses and a set of rapids. Poor spawning, rearing, and adult feeding habitat was located with the channel. There was no overwintering habitat.

Streams BP15 to BP30

Based on helicopter reconnaissance surveys, streams BP15 to BP30 were determined to have no suitable fish habitat and were not sampled for fish. All of these streams were ephemeral in nature, draining melt water into Aimaokatalok Lake.

7.2.6 Koignuk River

The Koignuk River extends from a chain of lakes west of Aimaokatalok Lake, then converges with the outflow of Aimaokatalok Lake and flows north into Hope Bay. The Koignuk River features mainly rock/cobble substrate with numerous gravel bars. Sampling took place in 1995, 1996, and 1998 and included backpack electrofishing (1995 and 1996), angling (1995 and 1998), and gill netting (1998). Backpack electrofishing was done downstream of the Boulder Creek confluence in 1995 and in the upstream reach in 1996. In 1998, angling was conducted at five locations along the lowermost 25-km section of the river (Figure 7.1).

In total, 46 fish were caught using all three capture methods. Eighteen fish were caught by electrofishing, 27 were caught by angling, and one was caught in a gill net (Appendix D8). The catch was comprised of 30 lake trout, 10 Arctic grayling, four ninespine stickleback, one lake whitefish (caught in the gill net) and one Greenland cod (*Gadus ogac*). Observations of slimy sculpin were also reported in 1998 (Rescan 1999).

Within the sample of 26 lake trout that were measured, fork lengths ranged from 46 to 795 mm (Appendix D9). Lake trout captured by backpack electrofishing on 8 August 1996 (n = 14) ranged between 46 and 72 mm in fork length (likely young-of-the-year or yearlings). Lake trout captured by angling (n = 12) ranged from 322 to 795 mm in fork length; the largest fish weighed 5850 g. Ages were determined for nine of these fish and ranged from 10 to 25 years.

Arctic grayling (n = 7) ranged from 293 to 383 mm in fork length (mean of 347 mm). They ranged from four to 10 years in age. All Arctic grayling were caught by angling. The heaviest fish weighted 570 g.

One lake whitefish was caught using a gill net drifted through a scour pool located about 1.25-km upstream from the Koignuk River mouth in August 1998. This fish was 173 mm in fork length and weighed 51 g. One Greenland cod (467 mm in length and 1180 g in weight) was also angled at this site, indicating that this marine species can occasionally use freshwater habitats.

7.2.7 Tributaries to Koignuk River

Boulder Creek

Boulder Creek is approximately 13-km long and drains a series of lakes into the Koignuk River (Figure 7.1). Near its confluence with the Koignuk River, Boulder Creek features suitable spawning habitat for Arctic grayling and possibly for lake trout. Backpack electrofishing in this stream was conducted on 3 August 1995. During 440 s of electrofishing, seven juvenile Arctic grayling were caught (CPUE = 1.0 fish/min; Appendix D8). The sizes of these fish were not reported. Water depth in the sampled area ranged from <0.3 to 1.0 m.

Backpack electrofishing was also conducted in this stream on 10 August 1996. Lake trout were the only fish species caught during this survey (n = 26). They were all juveniles within two distinct size-classes; 21 fish were between 48 and 62 mm in fork length (likely young-of-the-year fish) and three ranged from 102 to 116 mm in fork length (likely yearlings).

Stream PRC13

Stream PRC13 (a tributary to Boulder Creek) was sampled at a proposed crossing for an all-weather road. Backpack electrofishing was conducted on 29 August 2000, when a 100 m long section was sampled. Only three ninespine stickleback were captured. They ranged from 24 to 33 mm in total length.

Stream PRC14

Stream PRC14 (a tributary to Boulder Creek) was sampled at a proposed crossing for an all-weather road. Backpack electrofishing was conducted on 25 June 2000 along a 300 m long section. Sixteen ninespine stickleback were captured. They ranged from 26 to 69 mm in total length.

Stream PRC15

Stream PRC15 (a tributary to Boulder Creek) was sampled at a proposed crossing for an all-weather road. Backpack electrofishing was conducted on 29 August 2000 along a 175 m long stream section. Three ninespine stickleback and one Arctic grayling were captured. The ninespine stickleback ranged from 28 to 33 mm in total length. The Arctic grayling was 55 mm in fork length (likely a y-o-y fish).

7.2.8 Summary

Streams in the Boston area, excluding the lower sections of the Koignuk River, were inhabited by at least three fish species (lake trout, Arctic grayling, and ninespine stickleback). Two additional species (Greenland cod and lake whitefish) were present in the lower section of the Koignuk River. Slimy sculpin were also observed but not captured.

Ninespine stickleback was the most common species (74%) in the total catch of more than 471 fish. This species was also most widely distributed among the sampled streams; it was recorded in 11 of the 13 stream sites sampled for fish. Lake trout was second in abundance (20% of the total catch) and was recorded at six sites. Arctic grayling contributed 6% to the total catch and were recorded at seven sites. Juveniles and adults were present in the catch of both lake trout and Arctic grayling.

7.3 FISH TISSUES

To provide baseline data on metal concentrations in fish tissues, dorsal muscle and liver samples were collected from lake trout, lake whitefish, and Arctic grayling from Aimaokatalok and Fickle Duck lakes (Figure 7.1). In total, 236 tissue samples were collected and analyzed. Table 7.3 shows the distribution of the samples in terms of species, tissue types, lakes, and sampling years. Preliminary analyses of small numbers of fish tissue samples were carried out in 1993, 1994, and 1996 (Rescan 1993, 1994, and 1997); however, most (70%) of the samples were collected in 1995 and 1997 (Rescan 1995 and 1998). The data for all individual samples are included in Appendix D11.

Table 7.3 Number of Fish Tissue Samples Analyzed for Metal Concentrations, Boston Area Lakes, 1993 to 1997

Lake	Species	1993		1994		1995		1996		1997	
		Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle
Aimaokatalok	Lake trout	3	3	11	11	25	25	3	3	25	25
	Lake whitefish	3	3	11	11	5	5	-	-	24	24
	Arctic grayling	-	-	1	1	-	-	-	-		
Fickle Duck	Lake trout[a]	-	-	-	-	-	-	3	3	-	-
	Arctic grayling	-	-	-	-	4	4	-	-	-	-

[a] The tissue results for lake trout from Fickle Duck Lake were presented in Rescan (1997); however, the same report stated that only Arctic grayling were captured in this lake.

Because most of the analyzed metal constituents are not potential contaminants associated with the Boston Project, they are not included in the detailed analyses, but are presented in Appendices D11 to D13. Metal constituents that were deemed to be suitable indicators included aluminum, arsenic, cadmium, copper, lead, mercury, nickel, selenium, and zinc. These metals were included because they are of potential concern in gold mining developments and from a human consumption perspective. The following sections briefly outline the significance of these constituents to aquatic environments and human health.

Aluminum

The availability of aluminum to aquatic organisms has been correlated with the pH of the aquatic environment (Holtze and Hutchinson 1989); however, it is unclear at what pH threshold or concentration aluminum becomes toxic to fish. Aluminum can be acutely toxic at high exposure levels, but it does not bioaccumulate in aquatic organisms (Neville 1985).

Arsenic

Arsenic is more common in the earth's crust than is mercury or cadmium, and is more toxic to plants than to animals (Demayo et al. 1979). It does not appear to biomagnify through different trophic levels. Demersal (bottom dwelling) fish species are more likely to accumulate arsenic than pelagic (open-water) species (Demayo et al. 1979). Arsenic concentrates mainly in the liver and is a cumulative toxin (Falk et al. 1973). Background concentrations of arsenic in most aquatic organisms generally are less than 1 µg/g wet weight (Eisler 1988) or less than 5 µg/g dry weight (assuming 80% moisture content). The Canadian Food Inspection Agency guideline indicates that arsenic levels in fish tissues should not exceed 3.5 µg/g wet weight (http://www.inspection.gc.ca/english/anima/fispoi/manman/samnem/app3e.shtml).

Cadmium

Cadmium is a relatively rare element and is most often associated with copper, lead, and zinc. In sufficient concentrations, cadmium is toxic to plants and animals (Health Canada 1992). The rate of cadmium uptake in aquatic organisms is generally faster in hard waters, although cadmium toxicity decreases in hard water (Reeder et al. 1979). Cadmium does not bioaccumulate in the food web (Reeder et al. 1979). Cadmium concentrations exceeding 3 µg/L in water lead to high mortality of aquatic organisms, reduced growth, and inhibited reproduction (Eisler 1985a). The main sources of cadmium pollution are industrial and municipal wastes. Other anthropogenic sources of cadmium include smelter dusts and fumes, and fossil fuel incineration products (Health Canada 1992).

Copper

In contrast to the non-essential trace metals (e.g., arsenic, cadmium, mercury, and lead), copper is an essential element with important biochemical functions; however, excessive amounts of copper are toxic to freshwater fish (Forstner and Wittman 1979). The toxicity of copper varies not only with the species of fish, but also with ambient water characteristics such as pH and alkalinity. Copper is not considered to be a cumulative systematic poison as most of it is excreted from the body (Falk et al. 1973). The main areas of the body where it concentrates are liver, muscle, and brain tissues (Demayo and Taylor 1981).

Lead

Lead is the most common of the heavy metals and is toxic to all forms of life. Lead does not appear to bioaccumulate. In aquatic ecosystems, lead concentrations are generally higher in benthic organisms and lower in organisms at higher trophic levels. Lead tends to deposit in bone (hard tissue) as a cumulative toxin (Falk et al. 1973). It is more toxic in soft water than in hard water (Demayo et al. 1980). Solid and liquid wastes account for a large percentage of the lead discharged into the Canadian environment, usually into landfills, but lead has been dispersed more widely in the general environment though atmospheric emissions (Health Canada 1992). The federal guidelines state that lead levels should not exceed 0.5 µg/g wet weight in fish tissues (http://www.inspection.gc.ca/english/anima/fispoi/manman/samnem/app3e.shtml).

Mercury

Mercury is a toxic element, which, in fish tissue, is most commonly present in the form of methyl mercury. Under anaerobic conditions in sediments, inorganic mercury can be processed by microorganisms into organic mercury compounds (most commonly in the form of methyl mercury). Methyl mercury can readily associate with suspended and organic matter and be taken up by aquatic organisms. It has a high affinity for lipids and is distributed to the fatty tissues of living organisms (Health Canada 1992). As such, methyl mercury bioaccumulates in the food chain and tissues of the top predators may contain mercury levels that are unacceptable for human consumption (Health Canada 1992). The average proportion of methyl mercury to total mercury increases from 10% in the water column to 15% in phytoplankton, 30% in zooplankton, and 90% or more in fish (Huckabee et al. 1979; Morel et al. 1998). High levels of mercury are common in reservoirs as flooded terrestrial vegetation, which is rich in organic material, decomposes and stimulates the production of methyl mercury. Environmental conditions can influence the rate of methylation; these environmental conditions include water temperature, pH, dissolved oxygen, and sediment chemistry (Rudd and Turner 1983). Mercury may enter the water column from three principal sources: 1) by direct deposition from the atmosphere, 2) in runoff from the drainage basin, or 3) by solubilization or suspension from the benthic sediments. Erosion of mercury-bearing rocks is the ultimate geological source of mercury, and also contributes to mercury loads in rivers. Long-term daily ingestion of mercury has been found to cause the onset of neurological symptoms (Health Canada 1992). The maximum allowable level of mercury in muscle tissue of fish sold in Canada for human consumption is 0.5 µg/g wet weight (http://www.inspection.gc.ca/english/anima/fispoi/manman/samnem/app3e.shtml).

Nickel

The toxicity of nickel increases with decreasing water hardness and increasing acidity (CCREM 1996). Nickel toxicity also increases when it is present with copper, likely as a result of synergism (Taylor et al. 1979). Nickel does not biomagnify in the food web (Taylor et al. 1979). Hutchinson et al. (1975) reported that nickel concentrations were highest in plants and lowest in top predators. Bowen (1966) considered 1 µg/g (dry weight) of nickel in fish tissue to be in the range of natural background levels. Nickel concentrations tend to be highest in the vicinity of nickel smelters, sewage outfalls, coal ash disposal basins, and heavily populated areas (Eisler 1998). In fish, signs of nickel poisoning include rapid opercular and mouth movements, and surfacing. Loss of equilibrium and convulsions occur prior to death (Khangarot and Ray 1990).

Selenium

Selenium is an essential nutrient in low concentrations (Eisler 1985b); however, it is also a toxicant for humans and animals at concentrations slightly higher than those required (Chen 2000). Selenium is a naturally occurring trace element found commonly in rocks and soil, particularly in deposits of coal and other fossil fuels (Lemly and Smith 1987). Selenium is usually present in water as selenate or selenite; however, the elemental form may be carried in suspension (Health Canada 1992). Anthropogenic sources of selenium include irrigation waters from seleniferous soils, municipal and industrial wastewaters, fuel (coal and oil) combustion, mining, smelting, and refining (Nagpal and Howell 2001; Health Canada 1992). Selenium has been found to bioaccumulate within the food chain (Nagpal and Howell 2001; Lemly and Smith 1987). In aquatic environments, organisms accumulate selenium from both water and food. Most selenium (90%) that enters an aquatic ecosystem is taken up by organisms or bound to particulate matter, which results in its deposition and accumulation in the top layer of sediments and detritus. Toxic effects of selenium include mortality of juvenile and adult fish and reproductive effects (Lemly and Smith 1987). Selenite tends to be more toxic at early life history stages (i.e., eggs and juveniles) and these effects are more pronounced when water temperature is elevated. Selenium concentrations greater than 0.005 mg/L in water can be bioconcentrated in food chains and cause toxicity and reproductive failure in fish (Lemly and Smith 1987). Juvenile and adult fish usually require higher concentrations of selenium in water before mortality occurs. Signs of selenium toxicity include losses of equilibrium, lethargy, muscle spasms, liver degeneration, reduction in erythrocytes and blood haemoglobin, and an increase in white blood cells (Eisler 1985b). Lemly and Smith (1987) provided selenium levels of concern for fish and wildlife. They suggested that concentrations in water should not exceed 2 to 5 µg/L to protect fish and waterfowl. For food ingested by fish, they suggested that concentrations of 5 µg/g (dry weight) could cause toxic effects. Reproductive failure was found to occur in fish when concentrations exceeded 12 µg/g (dry weight) in whole body residue, 16 µg/g in visceral residue, and 8 µg/g in skeletal muscle residue.

Zinc

Zinc primarily affects gill epithelial tissues. In excessive amounts, it can cause outright mortality or induce stress that leads to death (Falk et al. 1973). Zinc, however, is essential for plant and animal health. Zinc toxicity increases with increasing pH and decreasing water hardness. Zinc concentrations are usually greater in omnivorous than in piscivorous species, and greater in benthic invertebrates than in fish (CCME 2007).

7.3.1 Methods

Field Methods

Tissue samples were collected opportunistically from fish mortalities encountered during the gill netting surveys of the Boston area lakes. Most fish were captured during the lake survey programs in 1995 and 1997. All fish selected for tissue analyses were identified to species; most were measured for fork length (mm), weighed (g), examined for sex, maturity, and reproductive status, and dissected for ageing structures (otoliths) and tissues. Length, weight and age data were not reported for fish sampled in 1996.

A minimum of 100 g of muscle tissue was collected from each fish, as well as the complete liver (without the bile gland). Samples were individually stored in plastic Whirl-Pac bags and frozen until analysis.

Laboratory

Analyses for fish collected in 1997 were conducted by Analytical Services Laboratories Ltd. in Vancouver, BC. The 1995 samples were analyzed by Elemental Research Inc. laboratory in North Vancouver, BC. The laboratories used for analyses of the 1993, 1994, and 1996 samples were not specified. The detection limits and methods used for metal analyses are listed for each sampling year in Table 7.4.

All results are reported as micrograms per gram on a ‘wet weight’ basis. The results from 1996 were reported in Rescan (1997) as ‘µg/g dry weight’; however, the magnesium concentrations in muscle tissues indicated that they were likely based on wet weight. As such, this report assumes the 1996 values to be based on wet weight (same as reported in all other years).

Table 7.4 Detection Limits (µg/g wet weight) and Methods Used to Analyze Fish Tissues for Metals Concentrations, Boston Area Lakes, 1993 to 1997

	1993	1994	1995		1996	1997	
	Det. Limit	Det. Limit	Det. Limit	Method	Det. Limit	Det. Limit	Method
Aluminum						5	ICP
Arsenic		0.01	0.05	ICPMS	0.05	0.05	HVAAS
Barium						0.5	ICP
Beryllium						0.2	ICP
Cadmium	0.006	0.0008 - 0.0021	0.005	ICPMS	0.02	0.02	ICP
Calcium						10	ICP
Chromium						0.5	ICP
Cobalt						0.5	ICP
Copper			0.01	ICPMS	0.1	0.5	ICP
Iron						1	ICP
Lead	0.04		0.002	ICPMS	0.05	0.05	GFAAS
Magnesium					1	0.05	ICP
Manganese					0.1	0.2	ICP
Mercury		0.008 - 0.013	0.005	ICPMS	0.005	0.005	CVAAS
Molybdenum						1	ICP
Nickel	0.2		0.05	ICPMS	0.2	1	ICP
Selenium					0.2	0.1 - 0.3	HVAAS
Silver	0.01	0.0014 -0.0038	0.005		0.01	0.1	ICP
Tellurium		0.002 - 0.0038	0.005 -0.009		0.2		
Zinc			0.01	ICPMS	0.1	0.3	ICP

Notes:

CVAAS = Cold Vapor Atomic Absorption Spectrophotometry.

GVAAS = Graphite Furnace Atomic Absorption Spectrophotometry.

HVAAS = Hydride Vapor Atomic Absorption Spectrophotometry.

ICP = Inducively Coupled Argon Plasma / Atomic Emission Spectrophotometry.

ICPMS = Inducively Coupled Argon Plasma / Mass Spectrometer.

Detection limits for 1993 and 1994 were inferred from the data, as laboratory detection limits were not reported.

Data Analyses

To allow statistical analyses of all sample data, metal constituent values that were below analytical detection limits were replaced with values that equaled one half the detection limit (Helsel and Hirsch 1992). As concentration of mercury in fish tissues tends to increase with increasing fish size and age (Bodaly et al. 1984), mercury concentrations were described in relation to fork length and age of fish. Mercury concentrations were presented on the dependent axis (Y) and the fork length and age of the fish on the independent axis (X). Because growth of fish (irrespective of age, weight, or length) is curvilinear, it would be inappropriate to apply linear regression techniques against non-linear data without first transforming the data. As such, length, age, and mercury data were transformed into logarithmic values prior to calculating the regression equations and the associated r^2 values.

7.3.2 Aimaokatalok Lake

The following discussion is based on muscle and liver tissues collected from 67 lake trout, 43 lake whitefish, and one Arctic grayling in Aimaokatalok Lake. Lake trout captured for tissue analyses in Aimaokatalok Lake ranged from 170 to 880 mm in fork length and from five to 40 years in age (Table 7.5). Lake whitefish ranged from 172 to 523 mm in fork length and from 10 to 46 years in age. The single Arctic grayling had a total length of 340 mm and weighed 400 g; its age was not determined.

Table 7.5 Fork Length, Weight and Age of Lake Trout and Lake Whitefish Sampled for Metal Concentrations in Aimaokatalok Lake, 1993-1997

Species	n	Fork Length (mm)			Weight (g)			Age (years)		
		Mean	SD[a]	Range	Mean	SD[a]	Range	Mean	SD[a]	Range
Lake trout	67[b]	550	129	170-880	1976	1329	35-7100	17	8	5-40
Lake whitefish	43[c]	450	64	172-523	1260	441	45-2100	26	10	10-46
Arctic grayling	1	340[d]	-	-	400	-	-	-	-	-

[a] Standard deviation.
[b] Length/weight reported for 64 fish; age determined for 43 fish.
[c] Age determined for 29 fish.
[d] Total length; fork length not reported.

The concentrations of 20 different elements in individual tissue samples are presented in Appendix D11. Mean metal concentrations (including standard deviation, range, and number of samples below analytical detection limits) are provided for each species, sampling year and tissue type in Appendix D12. The average concentrations of some of the potentially toxic trace metals in Aimaokatalok Lake (i.e., aluminum, arsenic, cadmium, copper, lead, mercury, nickel, selenium, and zinc) are summarized in Table 7.6.

Aluminum

All lake trout and lake whitefish muscle and liver tissue samples contained aluminum levels below the detection limit (<5 µg/g). The single Arctic grayling was not sampled for aluminum (Table 7.6).

Table 7.6 Metal Concentrations in Lake Trout, Lake Whitefish and Arctic Grayling Tissues from Aimaokatalok Lake, 1993-1997

Species	Tissue	Parameter	Metal Concentrations (µg/g wet weight)								
			Al[c]	As	Cd	Cu	Pb	Hg	Ni[d]	Se	Zn
Lake trout	Muscle *n=67*	*n < D.L.*[a]	*25*	*50*	*56*	*25*	*31*	*1*	*17*	*3*	*0*
		Mean	2.50	0.03	0.01	0.33	0.04	0.51	0.10	0.19	3.63
		SD[b]	0.00	0.02	0.004	0.17	0.05	0.28	0.15	0.05	1.32
		Minimum	2.50	0.01	0.001	0.18	0.002	0.01	0.01	0.04	2.20
		Maximum	2.50	0.13	0.02	1.44	0.37	1.44	0.91	0.36	8.10
	Liver *n=67*	*n < D.L*	*25*	*49*	*25*	*4*	*31*	*0*	*24*	*14*	*0*
		Mean	2.50	0.04	0.04	9.58	0.03	1.01	0.05	0.64	20.64
		SD	0.00	0.05	0.04	8.44	0.02	0.71	0.05	0.64	14.64
		Minimum	2.50	0.01	0.01	0.25	0.004	0.05	0.02	0.05	1.70
		Maximum	2.50	0.31	0.16	34.1	0.08	3.48	0.32	2.77	46.20
Lake whitefish	Muscle *n=43*	*n < D.L*	*24*	*23*	*40*	*24*	*27*	*0*	*4*	*0*	*0*
		Mean	2.50	0.04	0.01	0.31	0.02	0.19	0.07	0.23	3.38
		SD	0.00	0.02	0.004	0.29	0.01	0.11	0.05	0.06	1.08
		Minimum	2.50	0.01	0.001	0.12	0.003	0.03	0.01	0.14	2.28
		Maximum	2.50	0.10	0.01	2.09	0.05	0.48	0.18	0.34	8.86
	Liver *n=43*	*n < D.L*	*24*	*28*	*19*	*7*	*27*	*0*	*4*	*4*	*0*
		Mean	2.50	0.07	0.06	2.93	0.02	0.80	0.08	0.57	16.42
		SD	0.00	0.08	0.07	3.18	0.01	0.96	0.04	0.63	18.92
		Minimum	2.50	0.03	0.01	0.25	0.01	0.13	0.02	0.05	1.90
		Maximum	2.50	0.43	0.30	11.80	0.05	5.72	0.15	2.35	93.20
Arctic Grayling	Muscle *n=1*	*n < D.L.*	n/a	*1*	*1*	*0*	*0*	*1*	*0*	*0*	*0*
		Mean	n/a	0.01	0.001	0.29	0.01	0.004	0.01	0.10	3.28
	Liver *n=1*	*n < D.L*	n/a	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
		Mean	n/a	0.01	0.04	3.30	0.01	0.12	0.07	0.42	21.10

[a] Number of samples below detection limit.
[b] Standard deviation.
[c] Aluminum was analyzed only in 1997; therefore *n*=25 for lake trout, 24 for lake whitefish and 0 for Arctic grayling.
[d] Nickel values were calculated for only 1993 to 1996 data (42 lake trout and 19 lake whitefish) because of very high detection limits used in 1997 (1 µg/g).

Arsenic

The maximum arsenic levels in lake trout from Aimaokatalok Lake (0.13 µg/g in muscle and 0.31 µg/g in liver tissues) were recorded from a single fish caught in 1994 (410 mm in fork length). Mean concentrations were similar in muscle and liver tissues (0.03 and 0.04 µg/g). The percentages of samples below the detection limit were 74% for muscle and 73% for liver.

In lake whitefish, the mean concentrations of arsenic were greater in liver than in muscle tissues (0.07 and 0.04 µg/g, respectively). The highest arsenic level (0.43 µg/g) was recorded in a lake whitefish liver sample. More than half of lake whitefish samples (53% muscle and 65% liver samples) were below the detection limit.

Arsenic concentrations were below detection limits in both muscle and liver tissues of the single Arctic grayling sampled.

Cadmium

Mean cadmium concentrations were higher in liver tissues than in muscle of both lake trout (0.04 and 0.01 µg/g, respectively) and lake whitefish (0.06 and 0.01 µg/g, respectively). The maximum cadmium concentration (0.30 µg/g) was recorded in a lake whitefish liver sample; the maximum concentration recorded in the muscle tissues (0.02 µg/g in a lake trout) was considerably lower.

Cadmium concentrations in the single Arctic grayling were 0.001 and 0.04 µg/g in its muscle and liver tissues, respectively.

Copper

Mean copper concentrations were higher in liver than in muscle tissues of both lake trout (9.58 and 0.33 µg/g, respectively) and lake whitefish (2.93 and 0.31 µg/g, respectively). The maximum copper concentration (34.1 µg/g) was recorded in a lake trout liver sample; the maximum concentration recorded in the muscle tissues (2.09 µg/g in a lake whitefish) was considerably lower.

Copper concentrations in the single Arctic grayling were of 0.29 and 3.30 µg/g in its muscle and liver tissues, respectively.

Lead

Almost half (46%) of both muscle and liver tissue samples collected from lake trout in Aimaokatalok Lake had lead concentrations below the detection limit. Mean lead concentrations were similar in both tissues (0.04 µg/g in muscle and 0.03 µg/g in liver). The maximum lead concentration (0.37 µg/g recorded in a lake trout muscle sample) was below the federal guideline for human consumption (0.5 µg/g).

Mean lead concentrations in lake whitefish tissue samples (0.02 µg/g for both muscle and liver) were lower than in lake trout tissues. The maximum recorded concentration (0.05 µg/g) was about 10 times lower than the federal guideline for human consumption.

The single Arctic grayling contained 0.01 µg/g of lead in both muscle and liver tissues.

Mercury

Total mercury concentrations in lake trout muscle tissues ranged from 0.01 to 1.44 µg/g. The mean concentration was 0.51 µg/g. Almost half (45%) of the tested lake trout ($n = 67$) muscle tissues exceeded the federal guideline for human consumption (0.5 µg/g).

Mercury levels in lake trout liver tissues were higher than in muscle tissues and ranged from 0.05 to 3.48 µg/g.; the mean concentration was 1.01 µg/g. Most (76%) of the tested lake trout liver tissues exceeded the federal guideline for human consumption.

Lake whitefish mercury concentrations were lower than in lake trout, with mean concentrations of 0.19 and 0.80 µg/g in muscle and liver samples, respectively. Whereas none of the lake whitefish muscle samples exceeded the federal guidelines for human consumption, almost half (47%) of liver samples exceeded the guideline. The maximum mercury level recorded in lake whitefish from Aimaokatalok Lake was 5.72 µg/g in a liver sample.

Because mercury is known to bioaccumulate in fish, mercury concentrations in muscle and liver tissues were regressed against age and fork length to determine the strength of these relationships and to allow comparisons with future monitoring studies (Figure 7.5). The correlation coefficients for lake trout (r^2 between 0.32 and 0.68) were generally lower than those determined for lake whitefish (between 0.35 and 0.82). Mercury concentrations in lake trout tissues appeared to be better correlated with fork length than with age, an opposite relationship was recorded for lake whitefish (i.e., age was a better indicator of mercury levels than fork length).

The single Arctic grayling had a mercury concentration of <0.008 and 0.12 µg/g in muscle and liver tissues, respectively.

Nickel

Mean nickel concentrations are presented here only for the 1993 to 1996 data (42 lake trout and 19 lake whitefish) because of the very high detection limit (1 µg/g) used for nickel analyses in 1997. The 1997 samples were excluded from the calculations because assigning 0.5 µg/g as the value of half detection limit would skew the “real” values, which were generally less than 0.1 µg/g.

AIMAOKATALOK LAKE

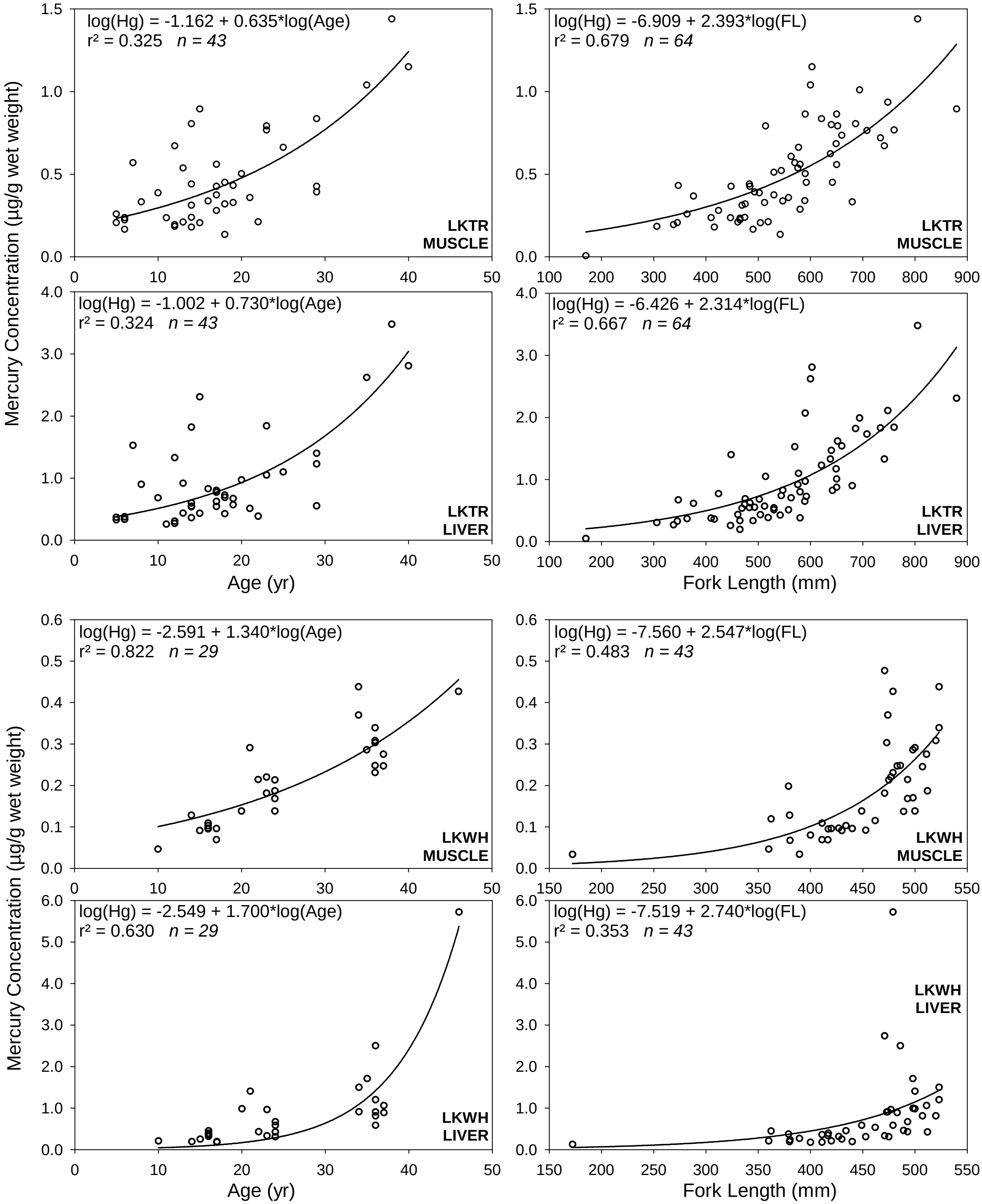


Figure 7.5 Mercury concentrations in lake trout (LKTR) and lake whitefish (LKWH) muscle and liver tissues from Aimaokatalok Lake, 1993 to 1997.

The maximum nickel concentrations recorded in lake trout from Aimaokatalok Lake were 0.91 µg/g in muscle and 0.32 µg/g in liver tissues. Mean nickel concentration in lake trout muscle tissue (0.10 µg/g) was twice as high as in the liver (0.05 µg/g).

In lake whitefish, the maximum nickel concentrations were 0.18 µg/g in muscle and 0.15 µg/g in liver tissues. The mean concentrations were similar in both muscle and liver tissues (0.07 and 0.08 µg/g, respectively).

The single Arctic grayling had a nickel concentration of 0.01 and 0.07 µg/g in muscle and liver tissues, respectively.

Selenium

Selenium levels in lake trout muscle tissues ranged from 0.04 to 0.36 µg/g; the mean concentration was 0.19 µg/g. In lake trout liver tissues, mean selenium concentration (0.64 µg/g) and the maximum recorded level (2.77 µg/g) were much higher than in muscle tissues.

Lake whitefish selenium concentrations were similar to those recorded in lake trout, with mean concentrations of 0.23 and 0.57 µg/g (muscle and liver samples, respectively). The highest selenium concentration in lake whitefish was 2.35 µg/g (in liver).

The single Arctic grayling had a selenium concentration of 0.10 and 0.42 µg/g in muscle and liver tissues, respectively.

Zinc

Zinc concentrations in lake trout muscle tissues ranged from 2.20 to 8.10 µg/g. The mean concentration in muscle tissues (3.63 µg/g) was approximately six times lower than in liver tissues (20.64 µg/g). Zinc concentrations ranged from 1.70 to 46.20 µg/g in lake trout liver tissues.

Lake whitefish zinc concentrations were similar to those recorded in lake trout, with mean levels of 3.38 and 16.42 µg/g (muscle and liver samples, respectively).

The highest zinc levels recorded in lake whitefish were 93.20 µg/g in liver and 8.86 µg/g in muscle tissues; these maximum values were reported for the same fish (172 mm in fork length) captured in 1994.

The single Arctic grayling had a zinc concentration of 3.28 and 21.10 µg/g in muscle and liver tissues, respectively.

7.3.3 Fickle Duck Lake

Tissue samples from Fickle Duck Lake were collected in 1995 and 1996. The 1995 samples were limited to muscle and liver tissues from four Arctic grayling, whereas muscle and liver tissues were collected from three lake trout in 1996 (Appendices D11 and D12). The tissue results for lake trout from Fickle Duck Lake were presented in Rescan (1997); however, the same report stated that only Arctic grayling were captured in this lake. As it was not possible to ascertain which part of the report (Rescan 1997) was correct, the lake trout results are presented here at face value (i.e., as lake trout from Fickle Duck Lake).

The Arctic grayling ranged from 335 to 380 mm in fork length and from 8 to 12 years in age. Fish sizes and ages were not reported for the lake trout sample (Table 7.7).

Table 7.7 Fork Length, Weight and Age of Fish Sampled for Metal Concentrations in Fickle Duck Lake, 1995 to 1996

Species	n	Fork Length (mm)			Weight (g)			Age (years)		
		Mean	SD[a]	Range	Mean	SD[a]	Range	Mean	SD[a]	Range
Arctic Grayling	4	358	19	335-380	750	129	600-900	10	3	8-12
Lake Trout	3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

[a] Standard deviation.

The concentrations of metal elements in individual tissue samples are presented in Appendix D11. Mean metal concentrations (including standard deviation, range, and number of samples below analytical detection limits) are provided for each tissue type in Appendix D13. The average concentrations of some of the potentially toxic trace metals (i.e., arsenic, cadmium, copper, lead, mercury, nickel, and zinc) are summarized in Table 7.8. The tissue samples collected from Fickle Duck Lake were not analyzed for aluminum.

Arsenic

Arsenic levels in lake trout tissues ranged from 0.06 to 0.91 µg/g. Mean concentrations were higher in liver tissues (0.66 µg/g) than in muscle tissues (0.08 µg/g). Arsenic levels were considerably lower in Artic grayling tissues, with seven out of the eight samples (muscle and liver) below the detection limit. The only sample above the detection limit was a liver sample with an arsenic concentration of 0.19 µg/g.

Table 7.8 Metal Concentrations in Lake Trout and Arctic Grayling Tissues from Fickle Duck Lake, 1995 to 1996

Species	Tissue	Parameter	Metal Concentrations (µg/g wet weight)							
			As	Cd	Cu	Pb	Hg	Ni	Se	Zn
Lake Trout	Muscle *n=3*	*n < D.L.*[a]	*0*	*3*	*0*	*3*	*0*	*3*	*0*	*0*
		Mean	0.08	0.01	0.27	0.03	0.03	0.10	0.47	3.20
		SD[b]	0.03	0.00	0.05	0.00	0.02	0.00	0.06	0.17
		Minimum	0.06	0.01	0.22	0.03	0.01	0.10	0.40	3.00
		Maximum	0.11	0.01	0.30	0.03	0.04	0.10	0.50	3.30
	Liver *n=3*	*n < D.L*	*0*	*0*	*0*	*2*	*0*	*3*	*0*	*0*
		Mean	0.66	0.05	36.47	0.04	0.24	0.10	2.73	46.23
		SD	0.21	0.03	7.79	0.02	0.32	0.00	0.61	4.18
		Minimum	0.52	0.02	27.70	0.03	0.02	0.10	2.20	41.50
		Maximum	0.91	0.08	42.60	0.06	0.61	0.10	3.40	49.40
Arctic Grayling	Muscle *n=4*	*n < D.L.*	*4*	*2*	*0*	*0*	*0*	*3*	*0*	*0*
		Mean	0.03	0.004	0.63	0.03	0.06	0.03	0.32	5.13
		SD	0.00	0.00	0.39	0.02	0.03	0.02	0.05	1.00
		Minimum	0.03	0.003	0.39	0.01	0.03	0.03	0.25	3.80
		Maximum	0.03	0.01	1.21	0.05	0.10	0.06	0.36	6.00
	Liver *n=4*	*n < D.L*	*3*	*0*	*0*	*0*	*3*	*4*	*0*	*0*
		Mean	0.07	0.02	1.81	0.02	0.02	0.03	1.05	19.95
		SD	0.08	0.01	0.30	0.00	0.03	0.00	0.05	1.14
		Minimum	0.03	0.01	1.52	0.01	0.003	0.03	0.99	18.90
		Maximum	0.19	0.03	2.09	0.02	0.06	0.03	1.11	21.40

[a] Number of samples below detection limit.
[b] Standard deviation.

Cadmium

Although all lake trout muscle tissue samples contained cadmium levels below the detection limit, all liver samples had detectable levels. Mean cadmium concentration in the liver was 0.05 µg/g, and the highest level was 0.08 µg/g.

Two of the four Arctic grayling muscle tissue samples contained cadmium levels below the detection limit, whereas all liver samples were above detectable levels. The mean cadmium concentration in liver tissues was 0.02 µg/g, and the maximum was 0.03 µg/g.

Copper

Copper concentrations in lake trout ranged from 0.22 to 42.60 µg/g. Mean concentrations were considerably higher in liver tissues (36.47 µg/g) than in muscle tissues (0.27 µg/g). All copper concentrations were above the detection limit.

For Arctic grayling, the mean copper concentration in liver tissue (1.81 µg/g) was considerably lower than in lake trout liver tissue. Mean copper concentration in Arctic grayling muscle tissue was 0.63 µg/g.

Lead

Most (88%) of lake trout tissue samples were below the detection limit (>0.05 µg/g) used for lead in 1996. With much lower detection limits used in 1995, lead concentrations in Arctic grayling tissues were all above detection limit and ranged from 0.01 to 0.05 µg/g.

Mercury

Total mercury concentrations in lake trout muscle tissues ranged from 0.01 to 0.04 µg/g (mean of 0.03 µg/g). The maximum mercury concentration recorded was well below the federal guideline for human consumption (0.5 µg/g).

Mercury concentrations in lake trout liver tissues ranged from 0.02 to 0.61 µg/g; mean of 0.24 µg/g). The maximum mercury concentration found in liver tissues was slightly higher than the federal guideline for human consumption (0.5 µg/g).

The maximum mercury concentration recorded in Arctic grayling (0.10 µg/g, in muscle) was considerably lower than the federal guideline (0.5 µg/g).

Nickel

All lake trout tissue samples collected from Fickle Duck Lake were below the detection limit (0.2 µg/g) used for nickel in 1996. The maximum nickel concentration in Arctic grayling (0.06 µg/g) was recorded in a muscle sample in 1995, when lower detection limits were used.

Selenium

Selenium concentrations in lake trout muscle samples ranged from 0.40 to 0.50 µg/g (mean of 0.47 µg/g). Lake trout liver samples had considerably higher selenium concentrations, ranging from 2.20 to 3.40 µg/g (mean of 2.73 µg/g).

Arctic grayling muscle tissue had selenium concentrations ranging from 0.25 to 0.36 µg/g (mean of 0.32 µg/g). Selenium concentrations were greater in liver tissues, ranging from 0.99 to 1.11 µg/g (mean of 1.05 µg/g).

Zinc

All tissue samples collected from Fickle Duck Lake had detectable zinc concentrations. Mean concentrations of zinc in lake trout tissues were considerably higher in liver tissue (46.23 µg/g) than in the muscle tissue (3.20 µg/g). The maximum zinc concentration was 49.40 µg/g in liver tissue.

Mean zinc concentrations in Arctic grayling were also higher in liver tissue (19.95 µg/g) than in the muscle tissue (5.13 µg/g). The maximum zinc concentration was 21.40 µg/g (in liver).

7.3.4 Summary

Fish tissue (dorsal muscle and liver) samples were collected from 70 lake trout, 43 lake whitefish and five Arctic grayling to provide baseline data on metal concentrations in Aimaokatalok and Fickle Duck lakes. Samples were collected every year from 1993 to 1997; however, most (70%) of the samples were collected in 1995 or 1997.

Analyses of fish tissues indicated generally low levels of metal accumulation; however, exceedences of the federal guidelines for human consumption were noted for mercury. In lake trout, approximately 43% of muscle tissues and 74% of liver tissues exceeded the federal food consumption guideline of 0.5 µg/g for mercury. For lake whitefish, none of the muscle samples, but 43% of liver samples exceeded the guideline. Consistent with bioaccumulation up the food chain, older and larger fish had greater concentrations of mercury in their tissues, and these fish were most likely to have mercury concentrations above the federal guideline.

None of the fish samples from Aimaokatalok or Fickle Duck lakes exceeded the federal food consumption guidelines for arsenic and lead (3.5 and 0.5 µg/g, respectively).

8 FISH HABITAT ASSESSMENT

8.1 LAKES

Fish habitat information for Boston area lakes is limited to bathymetric surveys of Aimaokatalok and Stickleback lakes conducted in 1993 and 1994 (already presented in Section 2). Data on lake substrates and characteristics of the litoral zones were not included in the previous reports.

8.2 STREAMS

8.2.1 Methods

Stream habitat surveys were conducted in the Boston area in 1996, 1997, and 2000 (Rescan 1997, 1998, 1999a and 1999b). This involved aerial assessments and detailed ground surveys carried out in conjunction with fish surveys. The classification system used in collecting Arctic stream habitat data, including substrate assessment, is provided in Appendix E1. This system allowed the observer to visually quantify habitat units and quality using such key variables as water depth, velocity, and substrate type.

Most streams were sampled during freshet (June-July), others were sampled during lower flows (August), and a few were sampled during both periods. Where streams were sampled in more than one year, it is unknown whether the assessments were done at the same locations from year to year, as site coordinates were provided only for the 1996 survey. The site numbers assigned to streams in 1997 were used in this report to reference streams assessed by air and ground between 1996 and 2000 (streams not sampled in 1997 were assigned their original designations).

Aerial surveys in 1996 and 1997 were conducted to determine the overall importance of lake inflow and outflow streams as fish habitat and to add streams not delineated on the topographical maps. Streams were labelled as either ephemeral or permanent, and reference photographs were taken of streams exhibiting very poor habitat. All other streams were given an identification number, photographed, and measured for approximate length using GPS waypoints. Some streams were assessed from the air in both 1996 and 1997, and some were ground surveyed in 1997 after an initial aerial assessment was done in 1996.

In 2000, aerial surveys were conducted to determine potential fish habitat at proposed permanent road stream crossings initially identified on 1:50,000 topographic maps. After the assessments, streams identified as potentially containing suitable fish habitat were surveyed.

In 1996, habitat was characterized during ground surveys using several criteria, including average water velocity, percent of runs/riffles/pools, bank vegetation, stream bank and substrate composition, and mean wetted width. Habitat was classified in three 100 m sections for each stream. Velocity was measured using the timed float method. The average of five wetted width measurements was calculated to determine the mean stream width. The remaining habitat parameters were visually estimated.

Methodology used for stream habitat surveys conducted in 1997 and 2000 were similar. Within each segment surveyed, instream habitat units (i.e., pools, runs, flats, riffles, cascades, and rapids) were quantified as a percentage of each surveyed segment. A series of habitat measurements was then collected for each habitat unit and averaged for the entire survey section. These parameters included the following:

- survey length;
- gradient;
- mean channel width;
- mean depth, maximum pool depth, and maximum riffle depth;
- streambed material composition (percent organic matter, silt, sand, small gravel, large gravel, cobble, boulder, and bedrock);
- total cover for fish, and percent from pools, boulders, cutbanks, macrophytes, and overhanging vegetation;
- streambed compaction and embeddedness;
- water temperature, colour, and stream stage; and
- bank height, stability, substrate composition, and vegetative cover.

Stream habitat suitability for spawning, rearing, adult feeding, overwintering, and migration was qualitatively classified using a numerical scale of 0 to 4. Within this system, 0 = no fish habitat present, 1 = poor, 2 = fair, 3 = good, and 4 = excellent (Appendix E1).

Since the assessment methodology and habitat descriptions were similar and most detailed in 1997 and 2000, where possible discussion of stream habitat is primarily based on the survey data and descriptions from these two years

(Rescan 1998 and 2001). Stream habitat data were collected for five streams in 1996, and at a less detailed level than in the other years surveyed. Three of these streams were only sampled in 1996.

8.2.2 Aimaokatalok NE Inflow

The Aimaokatalok NE Inflow is a long stream relative to most of the other streams sampled. It extends from a chain of lakes to the east, and drains into the northeast portion of Aimaokatalok Lake (Figure 7.1). It is the second largest inflow into Aimaokatalok Lake after the Aimaokatalok River. Habitat sampling of this stream was conducted in 1996 and 2000. High, turbid water conditions did not allow assessment in 1997.

Fish habitat was assessed over three 100 m sections on 7 July 1996 and one 750 m section on 26 June 2000 (Appendix E2). Average velocity was measured at 0.61 m/s during the 1996 survey, and the surveyed section had an average channel width of 12.4 m. The surveyed section in 2000 had a gradient of 2%, and the channel had an average width 20 m. Instream habitat was characterized by a series of rapids, runs, and pools, with rapids and best quality runs (depth greater than 0.75 m) dominating the surveyed section. Some riffle, chute and flat habitats were also noted in the 2000 survey.

Cobble, boulder, and bedrock were the predominant substrates within the stream sections surveyed. Boulders provided most (85%) of the instream cover. Overall spawning, rearing, adult feeding, and migration habitat was considered excellent, whereas overwintering habitat was generally poor (Appendix E2). Electrofishing surveys resulted in the capture of lake trout, Arctic grayling, and ninespine stickleback (Appendix D8).

8.2.3 Aimaokatalok River

The Aimaokatalok River is the largest inflow to Aimaokatalok Lake and flows into the southern end of the lake (Figure 7.1). Habitat sampling was conducted at three 100 m sections at this site on 9 August 1996 (Appendix E2). The wetted channel width ranged from 9.6 to 30.7 m, with an average of 15.7 m. The average velocity was 0.58 m/s. The instream habitat consisted mainly of runs and pools, with riffles also present. Boulder and cobble were the main substrate within the surveyed section. Bank vegetation consisted of grass and willow (Appendix E2). Fish sampling was not conducted at this site.

8.2.4 Stickleback Outflow

The Stickleback Outflow drains into the southern portion of Aimaokatalok Lake. This stream was surveyed 15 June 1997 and was found to be in flood and covered by sheets of ice (Plate 1 in Appendix E). The stream was flowing over terrestrial grasses and organic matter. The 175 m stream section that was surveyed had an average width of 4.5 m and average depth of 0.35 m (Appendix E2). The instream habitat was composed of riffles (90%) and pools (10%). The substrate was composed of organic matter (95%) and sand (5%). Instream cover was provided by aquatic vegetation (90%) and pools (10%). There was no observable spawning, overwintering, or adult rearing habitat. Of the habitat present, the rearing habitat was rated as good, while the migration habitat was rated as poor. There were no barriers to fish migration present. The electrofishing survey in 1997 resulted in the capture of two ninespine stickleback. Minnow traps set in 1994 and 1995 resulted in the catch of many ninespine stickleback and one juvenile lake trout (Appendix D8).

8.2.5 Fickle Duck Outflow

The Fickle Duck Outflow drains into the southern portion of Aimaokatalok Lake. Habitat sampling of this stream was conducted on 7 July 1996 and 15 June 1997. Fish habitat was assessed over three 100 m sections in 1996 and only one 80 m section in 1997 (Appendix E2). Average velocity was 0.65 m/s during the 1996 survey. The surveyed sections of stream channel were 0.7 m to 4.8 m wide, averaging 2.3 m in 1996 and 6.5 m in 1997. Average water depth was 0.55 m in 1997. In 1997, the stream was in flood, flowing over terrestrial grasses and organic matter (90%), with a narrow strip of cobble substrate (10%) in the centre of the channel (Plate 2 in Appendix E). Instream habitat was characterized entirely by riffles (Appendix E2). Instream cover was provided entirely by aquatic vegetation. There was no observable overwintering habitat due to shallow depths. Spawning habitat was rated as poor, whereas rearing and adult feeding habitats were rated as fair, and migration habitat was considered good (Appendix E2). Similar to Stickleback Outflow, only two fish species were captured in Fickle Duck Outflow. The catch was dominated by ninespine stickleback, with lake trout represented by a single juvenile caught in a minnow trap (Appendix D8).

8.2.6 Fickle Duck Inflow (Site BP12)

This inflow stream drains a series of small lakes and marshy areas into Fickle Duck Lake. A 210 m stream section was assessed for fish habitat in June 1997. The stream was found to be in flood, overflowing the banks and flowing through terrestrial grasses (Plate 3 in Appendix E). The surveyed section was composed of a series of good quality pools (20%) connected by riffles (55%) and runs (20%). The run sections were lined with cutbanks. Rapids were also present (5%). Average stream width of the surveyed section was 6.2 m and average depth was 0.65 m. The substrate in the areas where the stream was flowing over terrestrial vegetation were composed of organic matter (60%), whereas the central channel was underlain with silt (15%), cobble (10%), boulder (10%), and sand (5%). Instream cover was provided by aquatic vegetation (40%), cutbanks (25%), pools (25%) and boulders (10%). This stream was persistent into late summer. Whereas rearing habitat was rated as good, both adult feeding and migration habitat were rated as fair. Spawning and overwintering habitat were rated as poor. An electrofishing survey resulted in the capture of two ninespine stickleback (Appendix D9).

8.2.7 Small Tributaries to Aimaokatalok Lake (B03 to B30)

Eleven small tributary inflows to Aimaokatalok Lake were assessed for fish habitat on 15 to 17 June 1997. Streams BP03, BP04, BP05, and BP13 flowed into the east side of the lake (Figure 7.1). Streams BP06, BP07, BP08, BP10, and BP11 flowed into the northern arm of the lake. Stream BP09 was the only inflow that flowed into the west side of the lake. Stream BP14 flowed into a small inlet on the north side of Aimaokatalok Lake, west of the Aimaokatalok NE Inflow .

Stream BP03

Stream BP03, which enters Aimaokatalok Lake from the southeast, was surveyed over a distance of 350 m. It drains a series of small ponds through a low, marshy area before entering Aimaokatalok Lake. The stream was in flood at the time of the survey, flowing over terrestrial grasses and organic matter (Plate 4 in Appendix E). The average wetted width was 3.3 m, and the average depth was 0.4 m (Appendix E2). Instream habitat was dominated by riffle habitat (80%), but also contained good quality pools (10%) and poor quality runs (10%). The substrate was 90% organic matter, 5% sand, and 5% boulder. Instream cover was provided by aquatic vegetation (65%), pools (20%), cutbanks (10%), and boulders (5%). There was no observable spawning, overwintering, or migration habitat. Rearing habitat was rated as good and adult feeding was rated as poor (Appendix E2). The total electrofishing catch consisted of five ninespine stickleback and one Arctic grayling (Appendix D8).

Stream BP04

This stream, which enters Aimaokatalok Lake from the southeast, was surveyed over a distance of 95 m. The stream was in flood at the time of the survey, draining a series of small ponds through a low marshy area before entering Aimaokatalok Lake. The stream flowed, for the most part, over terrestrial grasses and organic matter. The average wetted width was 8.5 m, and the average depth was 0.35 m (Appendix E2). Instream habitat was dominated by riffles (95%) and the substrate was composed entirely of organic matter. Instream cover was provided by aquatic vegetation. There was no observable spawning, adult feeding, overwintering, or migration habitat, and rearing suitability was rated as fair at the time of the survey (Appendix E2). The low marshy area provided a barrier to Arctic grayling migration. No fish were captured during an electrofishing survey.

Stream BP05

This inlet stream flows into Aimaokatalok lake from the southeast, just west of Stream BP04. An 80 m section of this stream was sampled. It was in flood, draining a low marshy area into Aimaokatalok Lake. The stream flowed for the most part over terrestrial grasses and organic matter. Average stream width was 7.5 m and average depth was 0.25 m. The stream was dominated by riffles (95%) and the substrate was composed entirely of organic matter. With no persistent source of water, this stream is most likely ephemeral. Instream cover was provided by aquatic vegetation. There was no observable spawning, adult feeding, overwintering, or migration habitat. Rearing suitability was rated as fair at the time of the survey (Appendix E2). An electrofishing survey resulted in the capture two ninespine stickleback and one Arctic grayling near the mouth of the stream (Appendix D8).

Stream BP06

Stream BP06 drains a series of small lakes into the northern arm of Aimaokatalok Lake. When surveyed, the stream was found to be in flood and the 150 m stream section that was surveyed flowed through a stepped series of rock shelves, pools, and riffles. A rock shelf present at the mouth of the stream likely provided a barrier to fish migration (Plate 5 in Appendix E). The substrate of the surveyed section was composed of fines (5% sand, 5% silt) and bedrock (10%), but mostly (80%) organic matter (where the stream overflowed its banks). Average stream width was 8.3 m and average depth was 0.35 m. The stream was dominated by riffles (75%), but also contained good quality pool (15%) and poor quality run (10%) habitat. Instream cover was provided mainly by aquatic vegetation (55%) and pools (35%), whereas boulders (5%) and cutbanks (5%) provided the remainder. There was no observable spawning, adult feeding, overwintering, or migration habitat. Rearing suitability was rated as fair at the time of the survey (Appendix E2). An electrofishing survey resulted in no fish captures.

Stream BP07

This stream drains a marshy area into the northern arm of Aimaokatalok Lake. The stream was in flood, flowing over terrestrial grasses and organic matter. Within the 50 m surveyed section, the average stream width was 0.6 m and average depth was 0.15 m. The stream was dominated by riffles (95%) and the substrate was composed entirely of organic matter. Instream cover was provided by aquatic vegetation. There was no observable spawning, rearing, adult feeding, overwintering, or migration habitat within the channel (Appendix E2). An electrofishing survey resulted in no fish captures.

Stream BP08

This stream was in flood, draining melt water from a snow deposit into the northern arm of Aimaokatalok Lake. The 110 m surveyed stream section flowed over terrestrial grasses and organic matter. Average stream width was 5.3 m and average depth was 0.25 m. The stream was dominated by riffles (90%) and also contained poor quality pools (10%). The substrate was mostly organic matter. Instream cover was provided by aquatic vegetation (80%) and pools (20%). There were no observable adult feeding, overwintering, or migration habitat within the channel. Spawning and rearing habitat were rated as poor. An electrofishing survey resulted in no fish captures.

Stream BP09

This stream was in flood, draining a series of small lakes into the northern arm of Aimaokatalok Lake. The 95 m surveyed stream section flowed over terrestrial grasses and organic matter (80%); however the central channel was composed of small gravel (7.5%), cobble (5%), sand (5%), and boulders (2.5%) (Appendix E2). Average stream width was 4.2 m and average depth was 0.30 m. The stream was dominated by riffles (75%) and also contained intermediate and poor quality pool habitat (7.5 and 2.5%, respectively). Instream cover was provided by aquatic vegetation (80%), cutbanks (10%), pools (7.5%), and boulders (2.5%). This stream featured good spawning and rearing habitat; however, a migration barrier was present where the stream flowed over a rock shelf before entering Aimaokatalok Lake (Plate 6 in Appendix E). An electrofishing survey resulted in no fish captures.

Stream BP10

This stream was found to be in flood, draining a small lake into the northern tip of Aimaokatalok Lake. The 150 m surveyed section of stream was composed of a series of deep pools connected by riffles over terrestrial grasses (Plate 7 in Appendix E). This habitat disappeared 200 m upstream in a marshy area of indistinct channels. In the surveyed section average stream width was 3.2 m and average depth was 0.35 m (Appendix E2). The stream section was dominated by riffles (70%) and also contained intermediate and good quality pools (10 and 15%, respectively). The substrate in the riffle sections was composed of organic matter, whereas the pools were underlain with silt. Instream cover was mostly provided by aquatic vegetation (70%), whereas pools provided some additional cover (30%). There was no observable spawning or overwintering habitat, and the marshy area most likely provided a migration barrier. Both rearing and adult feeding habitat were present at the time of the survey (rated as fair and good, respectively; Appendix E2). An electrofishing survey resulted in the capture of one mature Arctic grayling, one mature lake trout and one ninespine stickleback (Appendix D8).

Stream BP11

This stream was in flood, draining melt water from a snow deposit into the northern tip of Aimaokatalok Lake. The 160 m surveyed stream section flowed, for the most part, over terrestrial grasses and organic matter. Average stream width of the surveyed section was 0.7 m and average depth was 0.35 m Appendix E2). This stream section was dominated by riffles (85%), but also consisted of poor quality run (10%) and poor quality pool habitat (5%). The substrate was composed entirely of organic matter. Instream cover was provided by flooded vegetation. There was no observable spawning, rearing, adult feeding, overwintering, or migration habitat within the channel (Appendix E2). It was suspected that the stream flowed subsurface in the summer. An electrofishing survey resulted in the capture of seven ninespine stickleback (Appendix D8). The fish were caught near the mouth of the creek, suggesting they originated in Aimaokatalok Lake.

Stream BP13

This stream was in flood, draining a series of small pools through a marshy area into the eastern side of Aimaokatalok Lake. The 225 m section of surveyed stream was comprised of a series of good quality pools (20%) connected by riffles (80%) flowing over terrestrial grasses and willows (Appendix E2). Average stream width in the surveyed section was 3.2 m and average depth was 0.65 m. The substrate was composed mainly of organic matter (75%), but also consisted of silt (15%), cobble (5%), and boulder (5%). Instream cover was largely provided by aquatic vegetation (70%), whereas pools and boulders also provided some additional cover (25% and 5%, respectively). There was no observable overwintering or migration habitat within the channel. Rearing, adult feeding, and spawning habitat were ranked as good, fair, and poor, respectively (Appendix E2). An electrofishing survey resulted in no fish captures.

Stream BP14

This stream was in flood, draining a series of small ponds and lakes from the north into the central part of Aimaokatalok Lake. The 310 m section of surveyed stream had a steep gradient and flowed for the most part over terrestrial grasses and willows (Plate 8 in Appendix E). The stream consisted of pools (30%) connected by riffles over terrestrial grasses (40%) (Appendix E2). Also present were rapids (20%) and some poor quality run habitats (10%). Average stream width of the surveyed section was 3.1 m. Instream cover was largely provided by aquatic vegetation (65%), whereas pools (15%), boulders (10%), and overhanging vegetation (10%) provided addition cover. There was no observable migration or overwintering habitat within the channel. Spawning and adult feeding were ranked as poor, whereas rearing habitat was rated as fair (Appendix E2). An electrofishing survey resulted in no fish captures; however, one juvenile Arctic grayling was observed.

Streams BP14 to BP30

Streams that were aerially assessed in 1996 and 1997, and found to be either ephemeral, draining melt water, or considered to be poor fish habitat are indicated as BP15 to BP30 in Figure 7.1. In June 1997, 16 streams were assessed as not possessing fish habitat or having barriers to fish migration for fish colonization from Aimaokatalok Lake. Helicopter surveys showed that all of these streams were ephemeral, draining melt water into Aimaokatalok Lake. Stream BP15 drained a small lake into Aimaokatalok Lake; however, it had no distinct channel and provided no fish habitat. Streams BP16 to BP23 carried melt water and had no distinct channels or fish habitat. Streams BP24 to BP26 had low flows and steep gradients, but did not persist beyond the spring freshet. Streams BP27 to BP30 had no distinct channels and no fish habitat present.

Additional sites assessed in 1996 included three small inflows into Fickle Duck Lake and two inflows into Stickleback Lake. All of these sites were assessed as melt-water channels that did not contain fish habitat.

8.2.8 Koignuk River

The Koignuk River extends from a chain of lakes west of Aimaokatalok Lake, before converging with the Aimaokatalok Outflow and running north into Hope Bay. In the upper portion of the river, a habitat survey of this stream was conducted on 9 August 1996. Fish habitat was assessed over two 100 m sections at a site located approximately 12-km downstream of Aimaokatalok Outflow (Figure 8.1). Average velocity was measured at 1.16 m/s and the stream channel was 21.8 to 33.2 m wide, averaging 25.5 m (Appendix E2). Channel depth was not recorded. Instream habitat was characterized by rapids, runs, and pools, with rapids and best quality runs (depth greater than 0.75 m) being most prominent in the surveys. Cobble and boulder were the predominant substrates within the sections surveyed and the bank vegetation consisted of both willows and grasses (Appendix E2). At the time of the habitat sampling, electrofishing surveys resulted in the capture of 14 lake trout and an uncounted number of ninespine stickleback.

Habitat assessments also took place in the lower 25.5 km of the Koignuk River on 13 to 20 August 1998. The resulting habitat mapping data are presented in Figure 8.1. The surveyed section was divided into four reaches. The lowest reach had a low gradient (0.08%) channel of riffle/run flowing over marine sediments, sand, gravel, and boulders and was 11.5-km in length. There were also a few constrictions where the river flowed over bedrock. The second reach was 12-km in length, flowing through a low gradient channel (0.17%) of riffle/run habitat with fines, gravel, boulders, and bedrock substrate. The third reach had a total length of only 1.4-km and had a high gradient (1.56%) series of rapids, waterfalls, and runs underlain by fines, gravel, boulders, and bedrock. Within this section was a 10 m high waterfall, which provided a definite barrier to fish migration. An aerial survey of the fourth reach (14.3-km in length) revealed that it had a low gradient channel (0.13%) characterized by deep runs, pools, flats, and occasional bedrock outcrops.

Angling surveys in the lower 25-km section of the river in 1998 resulted in the capture of 13 lake trout, seven Arctic grayling and one Greenland cod. Gill net sets in 1998 resulted in the capture of one lake whitefish (Appendix D8).

8.2.9 Tributaries to Koignuk River

Boulder Creek

Boulder Creek is a long (approximately 13-km), wide stream, which drains a series of lakes into the Koignuk River (Figure 7.1). Three 100 m sections of Boulder Creek were surveyed on 10 August 1996. The headwaters of Boulder Creek were slow moving with mud/cobble substrate, but the creek became faster and had a rocky substrate near the confluence with the Koignuk River. This rock/gravel section provided suitable spawning habitat for Arctic grayling and lake trout. The surveyed sections had an average velocity of 0.45 m/s and an average width of 10.2 m. These sections were composed of cobble/boulder substrate with run, rapid, and pool habitat (Appendix E2). An electrofishing survey at the time of the habitat survey resulted in the capture of 26 juvenile lake trout. An electrofishing survey of this stream in 1995 resulted in the capture of seven Arctic grayling.