



Table 4.2-2
Water Quality Monitoring Parameters (Seawater)
with Applicable Detection Limits

Parameter	Detection Limit (mg/L, unless otherwise stated)
Physical Tests	
pH	0.01 pH Units
Conductivity	2 µmhos/cm
Total Dissolved Solids (TDS)	10
Total Suspended Solids (TSS)	1
Hardness (as CaCO ₃)	0.05
Turbidity	0.1 NTU
Dissolved Anions	
Alkalinity	1
Acidity	1
Chloride	50
Fluoride	0.02
Sulphate	10
Dissolved Metals	
Aluminum	n/a
Antimony	0.0002
Arsenic	0.0001
Barium	n/a
Beryllium	n/a
Boron	n/a
Cadmium	0.0002
Calcium	0.5
Chromium	0.001
Cobalt	0.00005
Copper	0.00005
Iron	0.01
Lead	0.00005
Magnesium	0.5
Manganese	0.00005
Molybdenum	0.001
Nickel	0.00005
Selenium	0.0005
Silver	0.001
Uranium	0.00005
Vanadium	n/a
Zinc	0.0005

Table 4.2-3
Physical Parameters for Lakes and Marine Sites
in the Doris Property Area (1998)

Parameter	Wolverine Lake	Patch Lake	Ogama Lake	Doris Lake	Tail Lake	Windy Lake	Pelvic Lake	Hope Bay (Stations 1-3)	Roberts Bay (Stations 1-5)
pH (pH units)	7.42-7.46	7.51-7.52	7.19-7.38	7.34-7.35	7.34-7.39	7.69-7.73	7.08-7.19	7.56-7.87	7.77-7.95
Total Suspended Solids (mg/L)	1-5	<1-1	<1-1	3-5	b/d	<1-1	<1-5	2-66	<2-32
Turbidity (NTU)	1.1-1.2	0.8-0.9	4.1-4.5	4.3-4.5	0.8-0.9	0.3-0.4	6.0-6.3	0.5-1.5	0.3-1.0

Note: Data presented are ranges from the entire water column. If no range is given, all values were the same.
b/d = below detection limit

4.2.1.2 *Results and Discussion*

All of the raw data for water quality analyses conducted on Doris Property lakes and marine sites are presented in Appendix 4.2-1. Selected parameters are summarized and discussed in the following sections.

4.2.1.2.1 Physical Parameters and Nutrients

Data on key water quality parameters including pH, total suspended solids (TSS) and turbidity for all lakes and marine sites in Hope Bay and Roberts Bay are summarized in Table 4.2-3.

The pH in all the lakes and marine sites was neutral to slightly basic, with values ranging from 7.08 to 7.73 and 7.56 to 7.95, respectively. Conductivity was somewhat elevated with values ranging from 243 to 647 $\mu\text{mhos/cm}$ in the lake samples (Wolverine Lake), and from 15300 to 41700 $\mu\text{mhos/cm}$ in the marine samples (Roberts Bay, Station 1). Total dissolved solids (TDS) fluctuated quite substantially. Lake TDS values varied from 136 to 366 mg/L (Wolverine Lake). TDS values in the marine samples ranged from 11900 to 28100 mg/L (Roberts Bay). The values measured for hardness in the lake samples ranged from 43.5 to 119 mg CaCO_3/L , while hardness values in marine samples varied from 2030 to 5240 mg CaCO_3/L .

The total suspended solids (TSS) concentration in lakes ranged from below the detection limit (<1.0 mg/L) to 5.0 mg/L measured in Wolverine, Doris and Pelvic lakes. The TSS in marine samples ranged from below the detection limit (<2.0 mg/L) to 66 mg/L measured in Roberts Bay. With respect to turbidity, lake samples ranged in value from 0.3 to 6.3 NTU (Pelvic Lake), while marine samples ranged in value from 0.3 to 1.5 NTU (Roberts Bay).

4.2.1.3 *Metal Concentrations - Lakes*

Data for total metal concentrations in lakes are presented in Appendix 4.2-1. Table 4.2-4 summarizes total metal concentrations for metals of environmental concern measured in Doris Property lakes in 1998, along with Canadian Federal Water Quality Guidelines for freshwater aquatic life (CCREM, 1987). Total

Table 4.2-4
Total Metal Concentrations in Doris Property Lakes (1998)
and CCREM Guidelines for Freshwater Aquatic Life

Total Metal (mg/L)	Wolverine Lake	Patch Lake	Ogama Lake	Doris Lake	Tail Lake	Windy Lake	Pelvic Lake	CCREM Guidelines
Aluminum	0.012-0.016	0.030-0.032	0.216-0.227	0.008-0.013	0.047-0.051	0.009-0.010	0.093-0.095	0.005-0.10 ²
Arsenic	0.0008	0.0005	0.0008	0.0004	0.0004	0.0005-0.0006	0.0005	0.05
Cadmium	b/d	b/d	b/d	b/d	b/d	b/d	b/d	0.001 ³
Chromium	b/d	b/d	0.002	b/d	b/d	b/d	0.002	0.002
Copper	0.002-0.003	0.003-0.006	0.006-0.007	0.002-0.004	0.004-0.007	0.002	0.013-0.014	0.002 ³
Iron	0.30-0.32	0.04	0.20-0.23	0.02-0.03	0.12-0.13	<0.01-0.01	0.08-0.11	0.3
Lead	b/d	<0.001-0.002	b/d	<0.001-0.004	0.001	<0.001-0.001	0.001-0.002	0.001 ³
Nickel	0.002	b/d	0.003	b/d	0.001	b/d	0.002	0.025 ³
Zinc	0.011-0.013	b/d	0.011-0.015	b/d	0.007	b/d	0.010-0.012	0.03

¹: Concentrations presented as ranges for all sampling periods; where only one value is given, all concentrations were same.

²: The CCREM guideline for Al is 0.005 mg/L for waters with pH <6.5 and 0.1 mg/L for waters with pH >6.5.

³: CCREM guideline for waters with a hardness of 0-60 mg/L (CaCO₃).

b/d = below detection limit

concentrations of most metals of environmental concern were low and close to or below their respective detection limits at most sites (*e.g.* cadmium, chromium, lead, nickel). Therefore, most metals in the lakes were found to exist at levels well below the recommended CCREM criteria.

Total aluminum concentrations ranged from 0.008 to 0.227 mg/L (Ogama Lake). The pH of all Doris Property lakes was above 6.5 so the 0.100 mg/L CCREM criterion was applicable. Ogama Lake was the only sample to exceed the CCREM guideline for aluminum. The samples from Pelvic Lake (0.093 to 0.095 mg/L) approached, but did not exceed, the guideline value.

Total arsenic concentrations ranged from 0.0004 to 0.0008 mg/L (Wolverine and Ogama lakes). These values are well below the CCREM criterion for arsenic of 0.05 mg/L.

Total cadmium concentrations were below the detection limit in all lakes and total chromium concentrations were below the detection limit in all but two lakes (Ogama and Pelvic lakes). In the two lakes that had detectable chromium, the total chromium concentration was 0.002 mg/L which equals the CCREM criterion for chromium.

Concentrations of total copper ranged from 0.002 to 0.014 mg/L (Pelvic Lake). Thus, the CCREM criterion for copper of 0.002 mg/L was equaled or exceeded in all lakes. The concentration of total iron varied from below the detection limit (<0.01 mg/L) to 0.32 mg/L (Wolverine Lake). The CCREM criterion for iron was equaled or exceeded only by the samples collected from Wolverine Lake (0.30 to 0.32 mg/L).

A maximum total lead concentration of 0.004 mg/L was measured in Doris Lake. The other lakes had total lead concentrations that ranged from below the detection limit to 0.002 mg/L. As a result, the lead guideline was equaled or exceeded by the majority of lake samples. Wolverine and Ogama lakes were the only sites not to exceed the lead criterion of 0.001 mg/L.

Three of the lakes had total nickel concentrations below the detection limit and the remaining lakes had values that ranged from 0.001 to 0.003 mg/L. Therefore, the CCREM nickel criterion was not exceeded by any of the samples.

Table 4.2-5
Dissolved Metal Concentrations for
Hope Bay and Roberts Bay (1998)¹

Dissolved Metal (mg/L)	Hope Bay (Stations 1-3)	Roberts Bay (Stations 1-5)
Aluminum	n/a	n/a
Arsenic	0.0003-0.009	0.0006-0.0009
Cadmium	0.00002-0.00004	0.00003-0.00016
Chromium	b/d	b/d
Copper	0.00049-0.00064	0.00037-0.00102
Iron	b/d	b/d
Lead	<0.00005-0.00007	<0.00005-0.00013
Nickel	0.00047-0.00061	0.00049-0.00081
Zinc	<0.0005-0.0008	<0.0005-0.0017

¹: Concentrations are presented as ranges for all stations sampled.
n/a = not analyzed
b/d = below detection limit

Total zinc concentrations were generally low. Three of the lakes had total zinc concentrations below the detection limit and the remaining lakes had values that ranged from 0.007 to 0.015 mg/L. None of the samples exceeded the CCREM zinc guideline of 0.025 mg/L.

4.2.1.4 Metal Concentrations – Marine Sites

Dissolved metal concentrations at the marine sites in Hope Bay and Roberts Bay are presented in Appendix 4.2-1. Results for a select group of key metals of environmental concern are presented in Table 4.2-5. Detection limits for most metals were lower than those for freshwater samples because of the preconcentration step necessary to remove the seawater matrix.

Dissolved metal concentrations tended to be low, especially for chromium and iron which had concentrations below the detection limit. Aluminum was not analyzed in the seawater samples.

Dissolved arsenic concentrations ranged from 0.0003 to 0.0009 mg/L in Hope Bay (Station 1, 5 m depth) and from 0.0006 to 0.0009 mg/L in Roberts Bay (Stations 1, 2, 3). Concentrations for dissolved cadmium ranged from 0.00002 to 0.00004 mg/L in Hope Bay (Station 1, 5 m depth) and from 0.00003 to 0.00016 mg/L in Roberts Bay (Station 4, 1 m depth).

Dissolved copper concentrations in Hope Bay varied from 0.00049 to 0.00064 mg/L. The range was much wider in Roberts Bay, with values ranging from 0.00037 to 0.00102 mg/L.

The concentrations of dissolved lead were quite low, ranging from below the detection limit (<0.00005 mg/L) at both sites to 0.00007 mg/L in Hope Bay (Station 1, 5 m depth) and to 0.00013 mg/L in Roberts Bay (Station 4, 1 m depth).

Dissolved zinc concentrations were also low, ranging from below the detection limit (<0.00005 mg/L) at both sites to 0.00008 mg/L in Hope Bay (Station 1, 5 m depth) and to 0.00017 mg/L in Roberts Bay (Station 4, 1 m depth).

Overall, these data indicate that most metals exist at very low dissolved concentrations in both Hope Bay and Roberts Bay, as would be expected in a non-polluted marine environment.

4.2.2 Streams

In 1998, stream samples were only collected from the Koignuk River. The sampling location is shown in Figure 4.2-1.

4.2.2.1 Methods

Sampling methods in streams were similar to those described in Section 4.1.2.1. Water quality samples were analyzed for physical parameters, dissolved ions, nutrients and total metals. Detection limits for the various parameters analyzed are the same as those provided in Table 4.1-2. Table 4.2-6 summarizes the sampling schedule for the Doris Property streams.

Table 4.2-6
Water Quality Sampling Locations and
Dates for Doris Property Streams (1998)

Sampling Location	Sampling Date
Koignuk River	June 3, 1998 ¹
	August 3, 1998

¹: replicate samples taken

4.2.2.2 Results and Discussion

All of the raw data for water quality analyses conducted on samples collected from the Koignuk River in 1998 are presented in Appendix 4.2-2. Selected parameters are summarized and discussed in the following sections.

4.2.2.2.1 Physicals Parameters and Nutrients

Key water quality data related to physical parameters and nutrients are summarized in Table 4.2-7. The pH of the Koignuk River was slightly acidic in both sampling periods, ranging from 6.79 to 6.88. Conductivity varied from 65 μ mhos/cm in August to 90 μ mhos/cm in June. Total dissolved solids also varied dramatically between June and August. TDS values decreased from 74 mg/L in June to 48 mg/L in August. A similar trend was observed for hardness, which ranged from 22.3 to 22.7 mg CaCO_3 /L in June and dropped to 13.7 mg CaCO_3 /L in August.

Table 4.2-7
Physical Parameters and Nutrients Data
for Doris Property Streams (1998)¹

Parameter	Koignuk River
pH (pH units)	6.79-6.88
TSS (mg/L)	2.0-14.0
Turbidity (NTU)	3.2-36.3
Dissolved Nitrate (mg/L)	0.001
Total Phosphorous (mg/L)	0.051-0.057

¹: Concentrations were presented as ranges for all sampling periods; where only one value is given, all concentrations were the same.

Total suspended solids (TSS) and turbidity varied dramatically between the June and August sampling periods. Values for TSS varied from 12.0 to 14.0 mg/L in June, decreasing to 2.0 mg/L in August. Turbidity values changed even more significantly; turbidity in June ranged from 35.5 to 36.3 NTU, while in August turbidity was measured at 3.2 NTU.

4.2.2.2.2 Metals

Table 4.2-8 presents total metal concentrations for key metals of environmental concern along with Canadian Federal Water Quality Guidelines for freshwater aquatic life (CCREM, 1987).

Table 4.2-8
Total Metal Concentrations in Doris Property Streams (1998)
and CCREM Guidelines for Freshwater Aquatic Life¹

Total Metal (mg/L)	Koignuk River	CCREM Guidelines
Aluminum	0.100-1.400	0.005-0.10 ²
Arsenic	0.0003-0.0004	0.05
Cadmium	b/d	0.001 ³
Chromium	<0.001-0.003	0.002
Copper	0.001-0.020	0.002 ³
Iron	0.14-1.20	0.3
Lead	b/d	0.001 ³
Nickel	<0.001-0.002	0.025 ³
Zinc	b/d	0.03

¹: Concentrations presented as ranges for all sampling periods; where only one value is given, all concentrations were same.

²: CCREM guideline for Al is 0.005 mg/L for waters with pH <6.5 and 0.1 mg/L for waters with pH >6.5.

³: CCREM guideline for waters with a hardness of 0-60 mg/L (CaCO₃).
b/d = below detection limit

Total metal concentrations were generally low, with cadmium, lead and zinc concentrations being below their respective detection limits in both June and August. Thus, total metal concentrations for cadmium, lead and zinc were well below the CCREM guidelines for these metals.

The concentration of total arsenic changed only slightly from June to August, varying from 0.0003 to 0.0004 mg/L. This range is over two orders-of-magnitude

WATER QUALITY

less than the CCREM criterion of 0.05 mg/L. Chromium and nickel also changed only slightly between the two sampling periods. Chromium ranged from below the detection limit (<0.001 mg/L) in August to 0.003 mg/L in June, while nickel varied from below the detection limit (<0.001 mg/L) in August to 0.002 mg/L in June. The total chromium concentrations in June slightly exceeded the CCREM guideline for chromium of 0.002 mg/L, while total nickel concentrations were well below the criterion value of 0.025 mg/L.

Total aluminum concentrations ranged from 0.100 mg/L in August to 1.400 mg/L in June. As a result, the CCREM guideline for aluminum was exceeded by all samples from the Koignuk River. Total copper concentrations varied from 0.003 to 0.020 mg/L in June and decreased to 0.001 mg/L in August. The June samples exceeded the CCREM criterion for copper of 0.002 mg/L. The concentrations of total iron ranged from 0.14 in August to 1.20 mg/L in June. Both of the June samples exceeded the CCREM guideline for iron of 0.30 mg/L.

In summary, total metal concentrations in the Koignuk River tended to be low. In most cases, metal concentrations were well below their CCREM criteria. The only metal to exceed the guideline value in both sampling periods was aluminum. The other metals that exceeded their respective CCREM criteria (chromium, copper, iron) only did so in June.

5. Sediments

5. SEDIMENTS

5.1 Boston Property

Sediment sampling locations for the Boston Property lakes are shown in Figure 4.1-1. Samples were collected during the open water season in July, 1998 from four stations in Aimaoktak Lake (Stations 1, 4, 5 and 6) and from single stations in each of Stickleback and Trout lakes. A sample was also taken from the Boston Reference Lake.

5.1.1 Methods

Sediment sampling techniques were the same as those used during the 1997 survey and are described fully in Rescan (1997). Sediment samples were examined for various properties (texture, approximate grain size, *etc.*). Sediment color was determined using the Rock-Color Chart (supplied by the Geological Society of America). The Rock-Color Chart has been in use since 1948 and uses Munsell color chips. Sediment samples were also examined for visible biological material and detritus. All observations were recorded on a Sediment Description Sheet. Note that samples were not subjected to chemical analysis (metals, organic carbon, *etc.*) as was the case during the 1997 program.

5.1.2 Results and Discussion

Sediment Description Sheets are presented in Appendix 5.1-1. Photographic records of sediments samples are available upon request.

5.1.2.1 Sediment Descriptions

Sediment texture in Boston Property lakes exists as fine to medium sands, occasionally mixed with clay, or as homogeneous clay. Sediments profiles were usually comprised of two or three distinct horizons.

Surficial sediment color, based on Munsell color chips, was dominated by yellowish orange/brown to olive brown shades (10YR 6/6, 10YR 5/4, 5Y 5/6, 5Y 4/4) in most lakes, with generally gray, medium gray or olive gray shades (N5, 5Y 3/2, 5Y 4/1) below the surface.

SEDIMENTS

Biological material was evident in some of the sediment grabs and consisted mostly of plants and occasionally snails and other invertebrates. No true sediment sample was obtained from Stickleback Lake as the bottom of the lake was completely covered by plant material.

5.2 Doris Property

No sediment samples were collected from the Doris Property lakes in 1998. Samples were collected in July from marine sites in Hope Bay (Stations 1, 2 and 3) and Roberts Bay (Stations 1, 2, 3, 4 and 5). Sampling locations are shown in Figure 4.2-1.

5.2.1 Methods

Sediment samples were collected in the same manner as described in Section 5.1.1.

5.2.2 Results and Discussion

Sediment Description Sheets are presented in Appendix 5.2-1. Photographic records of sediments samples are available upon request.

5.2.2.1 Sediment Descriptions

Hope Bay

Hope Bay sediments consisted of mostly homogeneous clay, clay mixed with sand, or homogeneous sand mixed with coarse sand. Where stratification was evident, the sediment profile consisted of two rather indistinct horizons; an overlayer and an underlayer.

Sediment color ranged from light olive brown (5Y 5/6) to moderate olive brown (5Y 4/4) on surficial sediments and from medium gray (N5) to medium dark gray (N4) in subsurface material. Multicolored sand was present in both surficial and subsurface materials.

Biological material consisted of grass and other organic materials. Clams and snails were observed at Stations 2 and 3.

Roberts Bay

Roberts Bay sediments were composed of predominantly homogeneous clay or homogeneous fine sand. Stratification, when evident, consisted of two rather indistinct horizons; an overlayer and an underlayer. Overlayer horizons were occasionally marked with mottles.

Surficial sediments ranged in color from light olive brown (5Y 5/6) to light olive gray (5Y 5/2). Subsurface sediments ranged in color from medium light gray (N6) to dark gray (N3). Surficial mottles ranged in color from dark gray (N3) to moderate brown (5YR 3/4).

Biological material and detritus was practically nonexistent. Mussels and shells were observed in the sample from Station 1 and two small clams were observed in the sample from Station 4.

6. Physical Characteristics

6. PHYSICAL CHARACTERISTICS

Dissolved oxygen/temperature profiles and Secchi depths were measured at lakes within both the Boston and Doris properties in 1998, and at three stations in Hope Bay, and at five stations in Roberts Bay. Under ice dissolved oxygen/temperature profiles were measured at some lakes within the Boston and Doris properties during the winter of 1998.

6.1 Methods

Table 6.1-1 lists the sampling times and locations for all dissolved oxygen/temperature profiles and Secchi depths (open water season only) measured in 1998. Secchi depths and dissolved oxygen/temperature profiles were measured at designated lake site locations within the Boston Property once during the open-water season and once during the ice-covered season. Lakes within the Doris Property were measured one time during the ice-covered season. In addition, marine physical characteristics were measured at three stations in Hope Bay, and at five stations in Roberts Bay one time during the open water season. Sampling locations corresponded to the water quality and aquatic biology stations indicated in Figure 4.1-1 in Chapter 4 (Water Quality) of this report. A list of all sampling locations and dates is provided in Table 6.1-1.

Secchi depth and dissolved oxygen/temperature profile were obtained as described in Rescan (1998). Weather observations including percent cloud cover and wind speed and direction were also recorded on all sampling days.

6.2 Results and Discussion

The results from the dissolved oxygen/temperature profiles and Secchi depths measured in 1998 for all sites are presented as follows:

PHYSICAL CHARACTERISTICS

Table 6.1-1
Sampling Locations and Dates for Physical Characteristics for
Hope Bay Belt Property Waters, 1998

Location	Date (under ice)	Date (open water)
<u>Freshwater Stations</u>		
Aimaoktak Lake, Stn 1		17-July-98
Aimaoktak Lake, Stn 4	22-April-98	18-July-98
Aimaoktak Lake, Stn 5		17-July-98
Aimaoktak Lake, Stn 6	22-April-98	18-July-98
Stickleback Lake		19-July-98
Trout Lake		19-July-98
Boston Reference Lake	22-April-98	22-July-98
Windy Lake	26-April-98	
Doris Lake	24-April-98	
Patch Lake	24-April-98	
Tail Lake	24-April-98	
Pelvic Lake	24-April-98	
Wolverine Lake	24-April-98	
Ogama Lake	24-April-98	
<u>Marine Stations</u>		
Hope Bay, Stn 1		21-July-98
Hope Bay, Stn 2		21-July-98
Hope Bay, Stn 3		21-July-98
Roberts Bay, Stn 1		20-July-98
Roberts Bay, Stn 2		20-July-98
Roberts Bay, Stn 3		20-July-98
Roberts Bay, Stn 4		21-July-98
Roberts Bay, Stn 5		21-July-98

6.2.1 Dissolved Oxygen/Temperature Profiles

Dissolved oxygen, temperature, and depth data are provided in Appendix 6.2-1 for all profiles measured in 1998. Profiles are presented graphically in Appendix 6.2-2.

6.2.1.1 *Boston Property Lake Sites*

For the under-ice dissolved oxygen/temperature profiles, Aimaoktak Lake and Boston Reference Lake were inversely stratified, with surface waters being colder than deeper waters. Shallow water temperatures were approximately 0.2°C, while bottom waters had temperatures of approximately 2.0°C. Dissolved oxygen concentrations were greater in Aimaoktak Lake compared to Boston Reference Lake. Shallow dissolved oxygen concentrations ranged from approximately 8 to 17 mg/L, and bottom water dissolved oxygen concentrations approached 2 mg/L. At the deepest spot in Aimaoktak Lake, dissolved oxygen concentrations remained greater than 6 mg/L at depths of 24 m or shallower.

During July of 1998, all of the shallow lakes had homogeneous water columns. Stickleback, Trout, and Boston Reference lakes had uniform distributions of dissolved oxygen and temperature with depth, with water temperatures ranging from approximately 14 to 15°C and dissolved oxygen concentrations ranging from approximately 8.5 to 10.0 mg/L.

For the deepest spot in Aimaoktak Lake (Station 6, 29 m), a thermocline existed at approximately 8.5 m depth, with water temperatures dropping steadily below that depth. Surface water temperature was approximately 10.8°C, whereas waters were approximately 8.0°C at depth (29 m). The bottom waters were at 8.0°C, indicating that Aimaoktak Lake could not have been continuously stratified during the open water season. As well, bottom water dissolved oxygen concentrations were approximately 10.5 mg/L and were fairly uniform with depth, indicating a well-oxygenated water column.

6.2.1.2 *Doris Property Lake Sites*

Inverse stratification, with surface waters being colder than deeper waters, was also present for all lakes measured during the winter of 1998. Shallow water temperatures were slightly above 0°C. Bottom water temperatures were at approximately 2.0°C in all of the lakes measured.

Dissolved oxygen concentrations varied among lakes. Patch, Tail, and Ogama lakes had bottom water dissolved oxygen concentrations of greater than 8.0 mg/L. Windy and Doris lakes had high oxygen concentrations of greater than 8.0 mg/L until just above the water-sediment interface, where dissolved oxygen

PHYSICAL CHARACTERISTICS

concentrations reached values around 2.0 mg/L. Shallow water dissolved oxygen concentrations ranged from 6 to 16 mg/L.

6.2.1.3 Marine Sites

For Hope Bay on July 21, surface water temperatures decreased with distance away from the Koignuk River mouth, and ranged from approximately 11.4 to 9.0°C. Bottom waters ranged from approximately 7°C near the river mouth to nearly 0°C at Station 1. Dissolved oxygen concentrations ranged from approximately 5 to 11 mg/L and increased with depth due to decreasing temperature.

The outer stations in Roberts Bay had strong thermoclines at approximately 2 to 3 m depth on July 20. Surface temperatures were around 10°C, while bottom water temperatures declined to around 7°C. Surface dissolved oxygen concentrations were approximately 10 to 12 mg/L, and bottom water dissolved oxygen concentrations were approximately 14 mg/L or greater. The stations near the mouth of Little Roberts Outflow were extremely shallow and had water temperatures of 9°C and dissolved oxygen concentrations of 11 to 12 mg/L.

6.2.2 Secchi Depth

Table 6.2-1 presents the Secchi depth and calculated euphotic zone depth for all waterbodies sampled in 1998.

For the Boston Property lakes, Secchi depths ranged from 1.5 to 2.7 m in late July of 1998. The resulting euphotic zone depths were between 6.1 and 11.0 m depth. Stickleback Lake had similar water clarity to Aimaoktak Lake. Trout and Boston Reference lakes had lower water column transparencies compared to Stickleback and Aimaoktak lakes.

The marine sites had very transparent water columns, with euphotic zone depths ranging from 15.0 to 30.0 m depth. The exception was Station 5 in Roberts Bay, which had a euphotic zone depth of 4.9 m. Station 5 in Roberts Bay is located at the outlet of Little Roberts Outflow.

Table 6.2-1
Secchi Depth (D_s), Extinction Coefficient (k'), and Depth of the Euphotic Zone for Boston Property Lakes and Marine Sites, 1998

Site	D_s (m)	k' (m^{-1})	Base of Euphotic Zone (m) ¹
<u>Boston Property Lakes</u>			
Aimaoktak Lake, Stn 1	>bottom		
Aimaoktak Lake, Stn 4	2.6	0.65	10.6
Aimaoktak Lake, Stn 5	2.5	0.68	10.1
Aimaoktak Lake, Stn 6	2.7	0.63	11.0
Stickleback Lake	2.6	0.65	10.6
Trout Lake	1.6	1.06	6.5
Boston Reference Lake	1.5	1.13	6.1
<u>Marine Sites</u>			
Hope Bay, Stn 1	6.5	0.26	26.5
Hope Bay, Stn 2	3.7	0.46	15.0
Hope Bay, Stn 3	>bottom		
Roberts Bay, Stn 1	7.5	0.23	30.0
Roberts Bay, Stn 2	7.0	0.24	28.8
Roberts Bay, Stn 3	6.4	0.27	25.6
Roberts Bay, Stn 4	>bottom		
Roberts Bay, Stn 5	1.2	1.42	4.9

1: defined as 0.1% of surface irradiance.

7. Primary Producers

7. PRIMARY PRODUCERS

Both lake primary producers (phytoplankton) and stream primary producers (periphyton) were examined in Boston Property waters during the 1998 open water season.

7.1 Lake Primary Producers - Phytoplankton

Samples for phytoplankton taxonomic analysis, enumeration and biomass were collected one time from Boston Property lake sites during the open water season of 1998.

7.1.1 Methods

Table 7.1-1 presents all sampling dates and locations when samples for phytoplankton biomass and taxonomy were obtained. Sampling locations are indicated on the map presented in Figure 4.1-1 of Chapter 4 (Water Quality).

Table 7.1-1
Sampling Locations and Dates for Phytoplankton
Samples, Boston Property Lake Sites, 1998

Lake Site	Date
Aimaoktak Lake, Stn 4	18-Jul-98
Aimaoktak Lake, Stn 6	18-Jul-98
Stickleback Lake	19-Jul-98
Trout Lake	19-Jul-98
Boston Reference Lake	22-Jul-98

7.1.1.1 *Phytoplankton Biomass-Chlorophyll a*

Samples for chlorophyll *a* were collected in triplicate at 1 m depth and processed as described in Rescan (1998) at all locations and on all sampling dates indicated in Table 7.1-1. Samples were filtered in the field, frozen, and were sent to the University of British Columbia for analysis by the fluorometric method of Parsons *et al.* (1984).

PRIMARY PRODUCERS

7.1.1.2 Phytoplankton Identification and Enumeration

Phytoplankton taxonomic samples were collected in triplicate at one metre depth using a Go-Flo water sampling bottle as described previously (Rescan 1998). Taxonomic identification and enumeration was conducted by Fraser Environmental Services as in previous years.

7.1.1.3 Diversity Indices

Shannon and Simpson diversity indices were calculated for the phytoplankton samples as described in Rescan (1998). The taxonomic level of genus was used as in previous years.

7.1.2 Results and Discussion

*7.1.2.1 Phytoplankton Biomass-Chlorophyll *a**

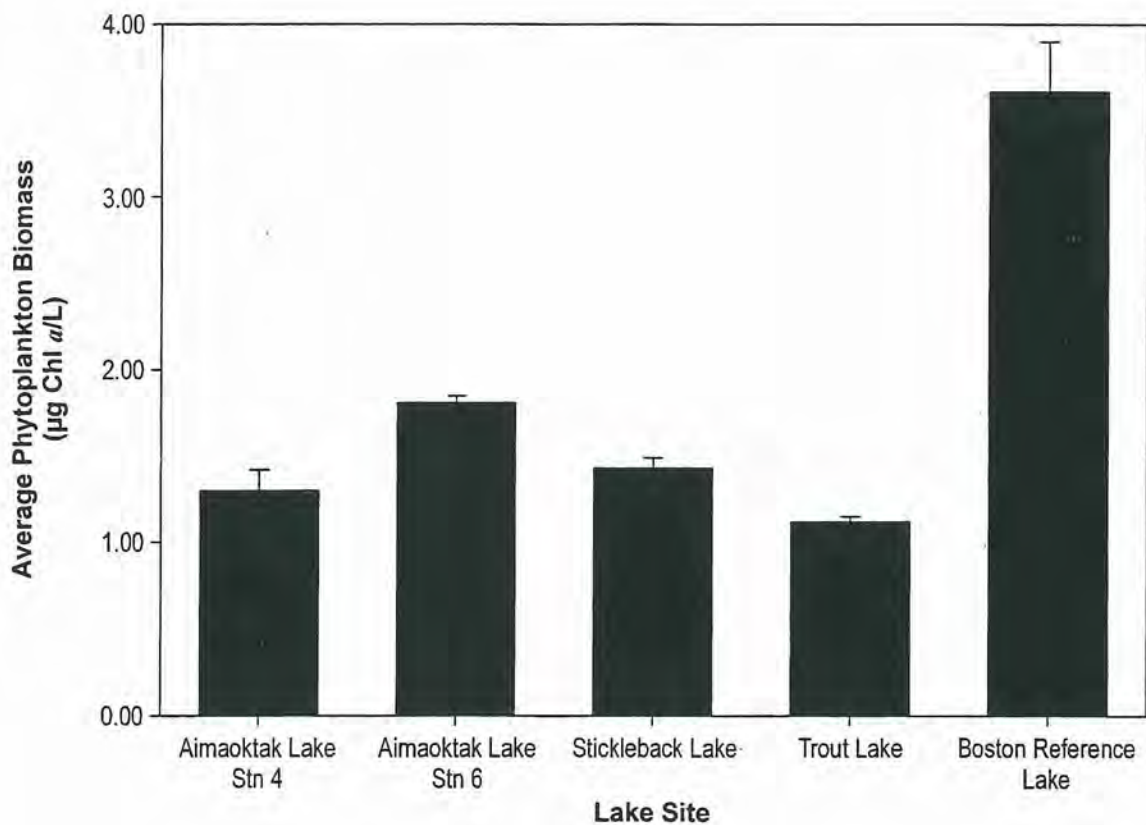
All chlorophyll *a* data are presented in Appendix 7.1-1.

Figure 7.1-1 presents the average phytoplankton biomass concentrations (as chlorophyll *a*) measured at all Boston Property lake sites in 1998. It appeared that phytoplankton biomass concentrations were greatest in Boston Reference Lake (average concentration of 3.61 µg/L) compared to the other lakes sampled. All other lake sites had average chlorophyll *a* concentrations ranging from 1.12 to 1.81 µg chl *a*/L.

7.1.2.2 Phytoplankton Abundance

Results from the taxonomic analysis and enumeration are given in Appendix 7.1-2.

Figure 7.1-2 presents the average phytoplankton abundance measured for all Boston Property lakes in July of 1998. Similar to the biomass results, it appeared that Boston Reference Lake had the greatest abundance of phytoplankton compared to the other lakes. Average phytoplankton abundances ranged from 908 to 8,657 cells/mL.

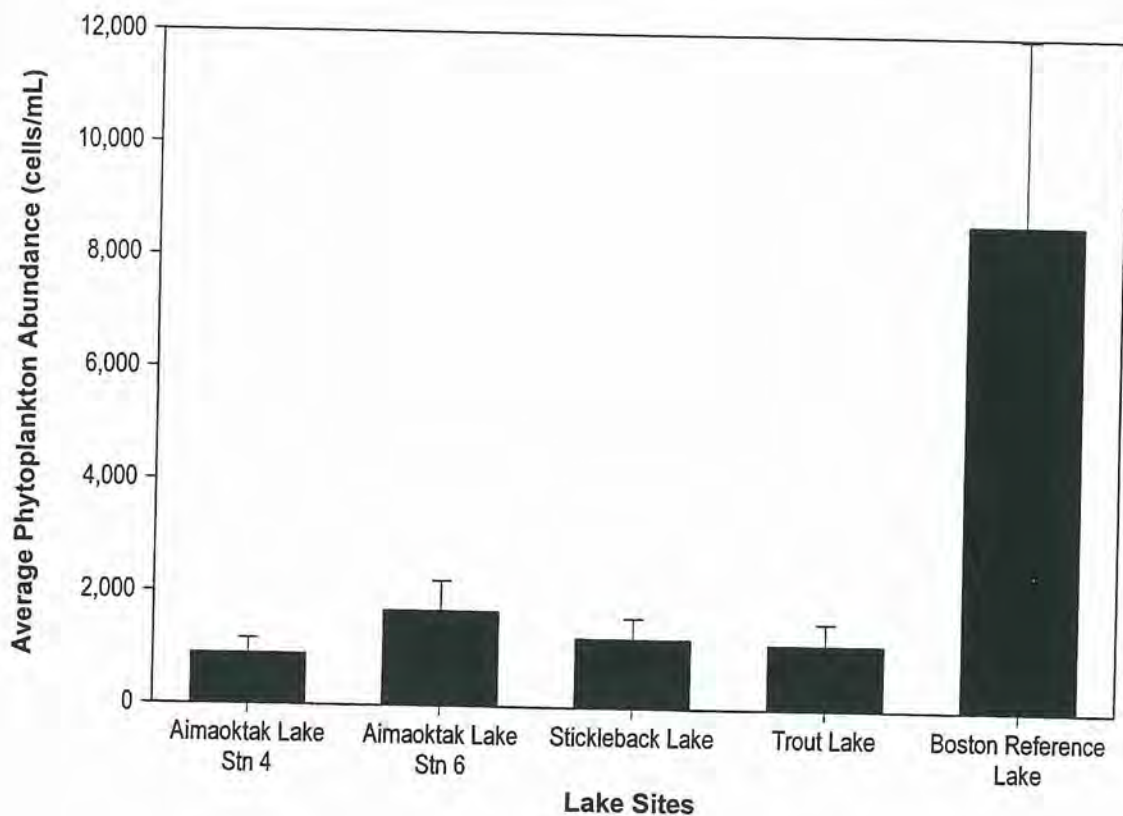


Note: Error Bars Represent Standard Error

**Average Phytoplankton Biomass
for Boston Property Lake Sites,
July 1998**

FIGURE 7.1-1





Note: Error Bars Represent Standard Error

Average Phytoplankton Abundance
for Boston Property Lake Sites,
July 1998



FIGURE 7.1-2



7.1.2.3 *Phytoplankton Taxonomic Composition*

Figure 7.1-3 presents the average taxonomic composition of the phytoplankton assemblages sampled in July of 1998. Cyanobacteria were the predominant organisms at all lake sites with the exception of Stickleback Lake. Cyanophyta comprised between 45 to 91% of the assemblages in Aimaoktak (Spyder), Trout, and Boston Reference lakes. At Stickleback Lake, phytoplankton assemblages were predominated by Chrysophyta (63%). The assemblage at Boston Reference Lake was strongly dominated by cyanobacteria (91%).

7.1.2.4 *Phytoplankton Diversity*

Table 7.1-2 presents the average Shannon and Simpson diversity indices for the phytoplankton assemblages sampled in July of 1998. All assemblages were quite diverse, with between 30 and 40 genera comprising the assemblages. Shannon diversity index values ranged from 1.75 to 2.53, and Simpson diversity index values ranged from 0.67 to 0.88. The assemblage sampled in Boston Reference Lake was the least diverse, with all other lakes having similarly diverse assemblages.

Table 7.1-2
Average Diversity Indices for Phytoplankton Assemblages,
Boston Property Lake Sites, 1998

Lake Site	S	S (90%)	Max. Dom.	Shannon Diversity Index	Simpson Diversity Index
Aimaoktak Lake, Stn 4	40	15	33	2.50	0.84
Aimaoktak Lake, Stn 6	33	14	20	2.53	0.88
Stickleback Lake	30	22	40	2.47	0.80
Trout Lake	36	14	29	2.43	0.84
Boston Reference Lake	39	9	48	1.75	0.67

S: The number of genera per site

S(90%): The number of genera contributing to 90% of the abundance

Max. Dom.: The maximum dominance accounted for by a single genus as a percentage

PRIMARY PRODUCERS

7.2 Stream Primary Producers-Periphyton

Samples for periphyton taxonomic analysis and enumeration were collected one time, and samples for periphyton biomass were collected two times from Boston Property streams during the open water season of 1998.

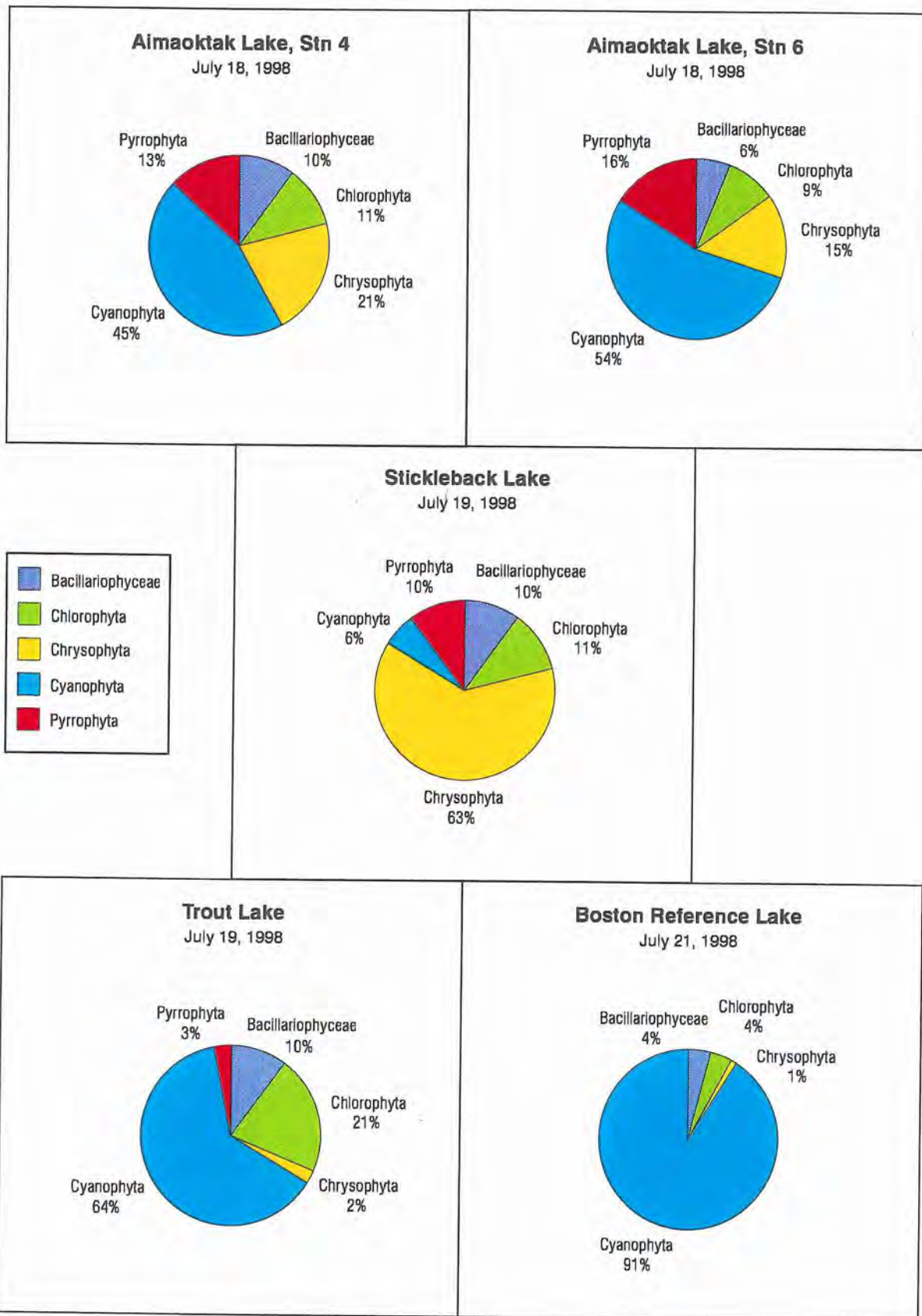
7.2.1 Methods

Table 7.2-1 presents all sampling dates and locations when samples for periphyton biomass and taxonomy were obtained. Sampling locations are indicated on the map presented in Figure 4.1-1 of Chapter 4 (Water Quality).

Artificial substrate samplers were used to collect periphyton samples as in previous years (Rescan 1998). However, due to the early timing of the spring field trip, artificial substrate samplers were not placed in the streams in June. To procure some information, instantaneous samples for periphyton biomass were collected in early July when the substrate samplers were immersed. These data are included in the appendices, but are not presented in the report. Data from instantaneous methods could be useful in the future for specialized monitoring purposes, but should not be used for baseline or effects monitoring. As well, data obtained from instantaneous methods should not be compared with data obtained from substrate samplers.

Table 7.2-1
Sampling Locations and Dates for
Periphyton Samples, Boston Property Streams, 1998

Stream Site	Sampler Immersion Dates
NE Aimaoktak Inflow	June 28-Jul 31, 1998
Aimaoktak River	June 27-Aug 1, 1998
Stickleback Outflow	June 26-Jul 30, 1998
Trout Outflow	June 26-Jul 31, 1998
Boston Reference Outflow	June 28-Aug 1, 1998



**Average Taxonomic Composition
of Phytoplankton Assemblages,
Boston Property Lakes, July 1998**

FIGURE 7.1-3

*7.2.1.1 Periphyton Biomass-Chlorophyll *a**

Samples for periphyton chlorophyll *a* were collected from three individual substrate samplers as described in Rescan (1998) at all locations and on all sampling dates indicated in Table 7.2-1. Samples were filtered in the field, frozen, and were sent to the University of British Columbia for analysis by the fluorometric method of Parsons *et al.* (1984).

7.2.1.2 Periphyton Identification and Enumeration

Samples for periphyton taxonomic identification and enumeration were collected from three individual substrate samplers (the same samplers as the biomass samples were collected from) as described in Rescan (1998). Taxonomic identification and enumeration was conducted by Fraser Environmental Services as in previous years.

7.2.1.3 Diversity Indices

Shannon and Simpson diversity indices were calculated for the periphyton samples as described in Rescan (1998). The taxonomic level of genus was used as in previous years.

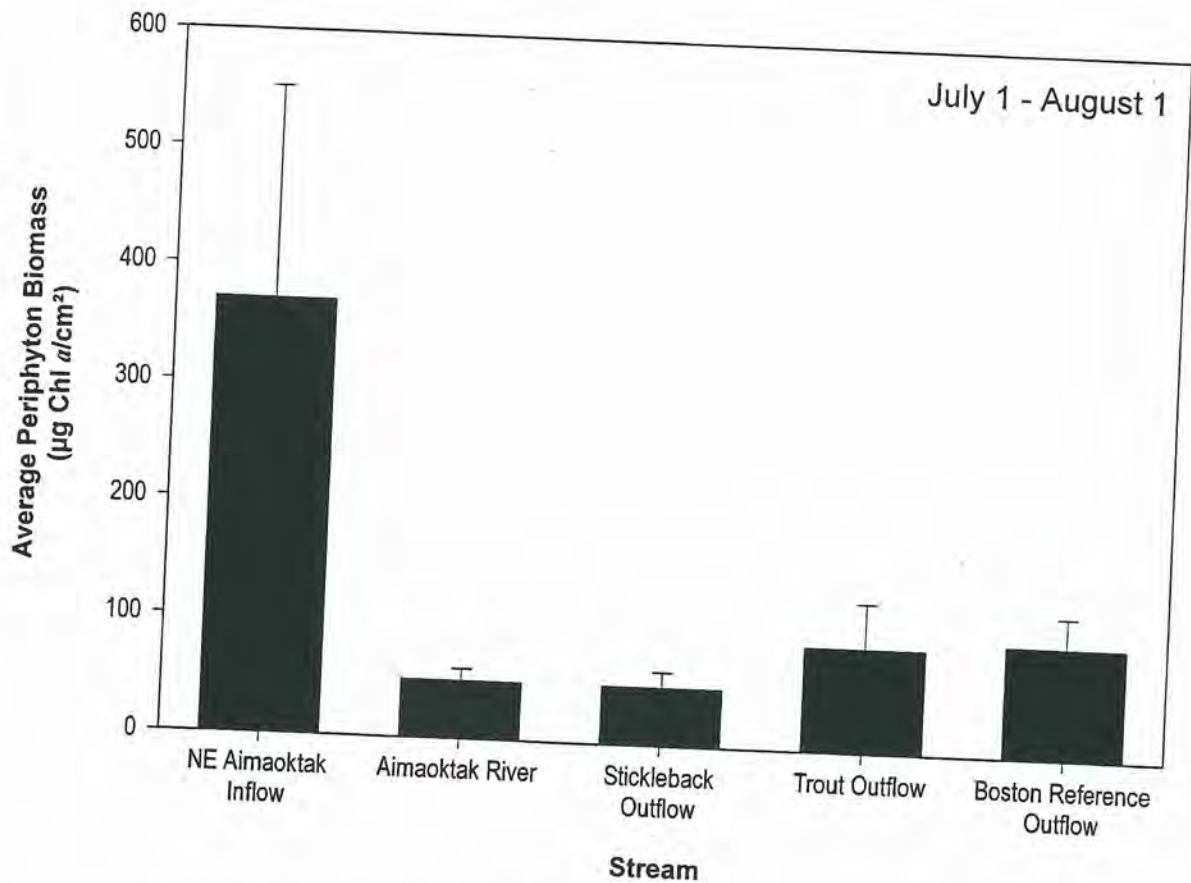
7.2.2 Results and Discussion

*7.2.2.1 Periphyton Biomass-Chlorophyll *a**

All periphyton chlorophyll *a* data are presented in Appendix 7.2-1.

Figure 7.2-1 presents the average periphyton biomass as chlorophyll *a* for the Boston Property streams sampled in 1998.

Biomass concentrations ranged from approximately 30 to 540 $\mu\text{g chl } a/\text{cm}^2$. Biomass concentrations appeared to be greatest in the NE Inflow of Aimaoktak (Spyder) Lake compared to other streams. Periphyton biomass concentrations were similar among the other Boston Property streams.



Note: Error Bars Represent Standard Error



Average Periphyton Biomass for
Boston Property Streams, 1998

FIGURE 7.2-1



7.2.2.2 *Periphyton Abundance*

Results from the taxonomic analysis and enumeration are provided in Appendix 7.2-2.

Figure 7.2-2 presents the average periphyton densities measured in the Boston Property Streams in 1998.

Densities ranged from approximately 20,000 to 1,200,000 cells/cm². It appeared that the NE Aimaoktak Inflow, Trout Outflow, and the Aimaoktak River had greater periphyton densities compared to the other two streams. Stickleback Outflow appeared to have the lowest periphyton density among the streams sampled.

7.2.2.3 *Periphyton Taxonomic Composition*

Figure 7.2-3 presents the average taxonomic composition of the periphyton assemblages sampled from Boston Property streams in 1998. The percentages reflect the proportion of each phyla as measured by cell numbers.

Periphyton assemblages were dominated by cyanobacteria (Cyanophyta) at all stream sites, constituting 58 to 78% of the assemblages by numbers. The second most dominant phylum was Chlorophyta (green algae), which constituted 21 to 33% of the assemblages.

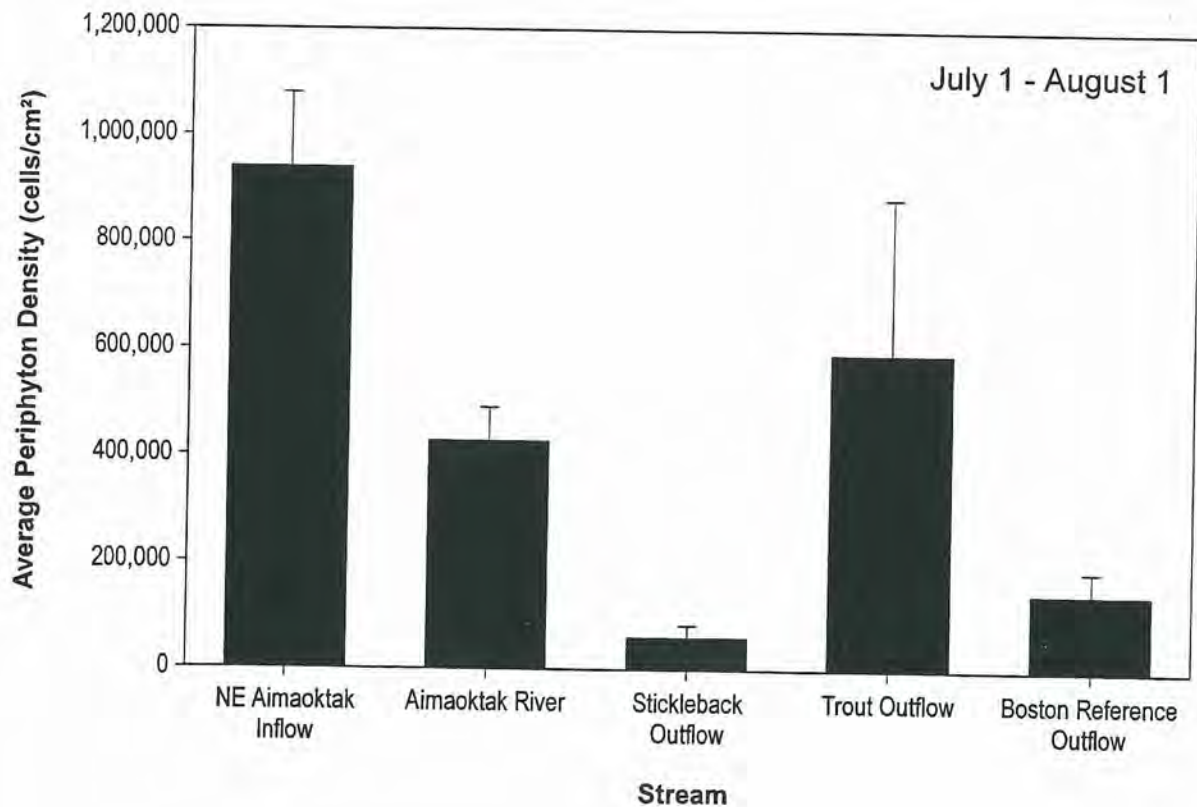
The taxonomic composition of all periphyton assemblages was in general similar among stream sites.

7.2.2.4 *Periphyton Diversity*

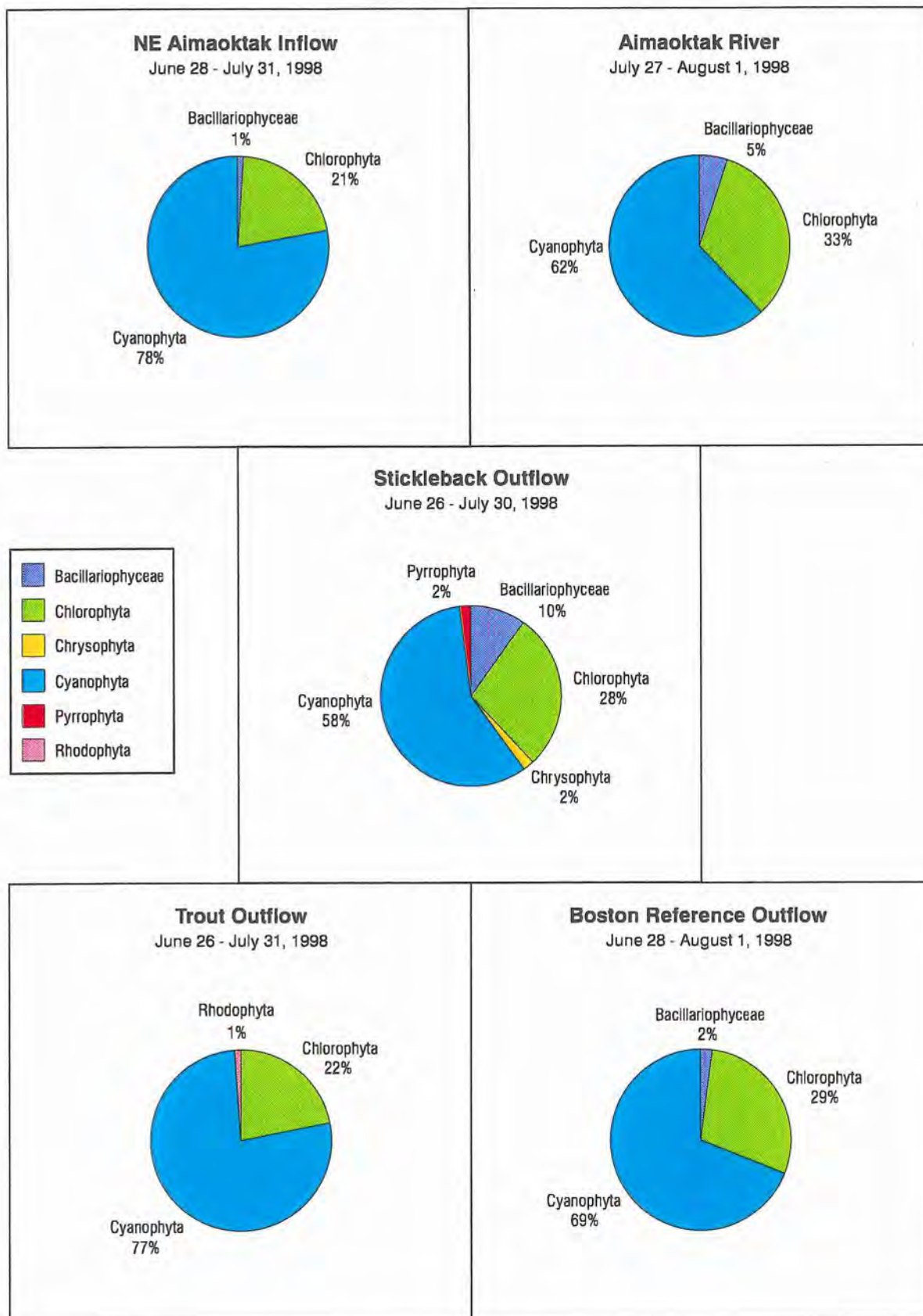
Table 7.2-2 presents the average Shannon and Simpson diversity indices for periphyton assemblages measured in Boston Property streams in 1998.

Periphyton assemblages were generally quite diverse, with between 17 and 31 genera comprising the assemblages. Assemblages in the Aimaoktak River appeared to be the most diverse among the streams sampled. Shannon diversity indices ranged from 1.59 to 2.43, and Simpson diversity indices ranged from 0.62 to 0.86.

Simp.
Periphyton



Note: Error Bars Represent Standard Error



**Average Taxonomic Composition
of Periphyton Assemblages,
Boston Property Streams, 1998**

FIGURE 7.2-3

Table 7.2-2
Average Diversity Indices for Periphyton Assemblages,
Boston Property Streams, 1998

Stream	S	S (90%)	Max. Dom.	Shannon Diversity Index	Simpson Diversity Index
NE Aimaoktak Inflow	25	9	59	1.67	0.62
Aimaoktak River	31	13	26	2.43	0.86
Stickleback Outflow	23	10	48	1.96	0.73
Trout Outflow	17	6	53	1.59	0.63
Boston Reference Outflow	25	11	42	2.08	0.74

S: The number of genera per site

S(90%): The number of genera contributing to 90% of the abundance

Max. Dom.: The maximum dominance accounted for by a single genus as a percentage

8. Secondary Producers

8. SECONDARY PRODUCERS

The following chapter presents the methods and results for the secondary producers sampling program in 1998. Zooplankton, lake benthos, larval drift, stream benthos, and marine benthos were all examined in 1998.

8.1 Lake Secondary Producers-Zooplankton

Zooplankton assemblages were examined one time during the open water season in Boston Property lakes.

8.1.1 Methods

Table 8.1-1 lists all sampling dates and locations for the zooplankton program. Sampling locations are indicated on Figure 4.1-1 in Chapter 4 of this report.

Table 8.1-1
Sampling Locations and Dates for Zooplankton
Program, Boston Property Lake Sites, 1998

Lake Site	Date
Aimaoktak Lake, Stn 4	18-Jul-98
Aimaoktak Lake, Stn 6	18-Jul-98
Stickleback Lake	19-Jul-98
Trout Lake	19-Jul-98
Boston Reference Lake	22-Jul-98

8.1.1.1 Zooplankton Identification and Enumeration

Samples for zooplankton taxonomic samples were collected in triplicate using vertical hauls on each of the sampling dates indicated in Table 8.1-1. Samples were collected and preserved as described in Rescan (1998). An internally mounted flowmeter was used to determine the volume of water passing through the net for each tow. Taxonomic identification and enumeration was conducted by Applied Technical Services as in previous years.

SECONDARY PRODUCERS

8.1.1.2 Zooplankton Diversity Indices

Shannon and Simpson diversity indices were calculated for zooplankton assemblages as described in Rescan (1998). The taxonomic level of genus was used as in previous years.

8.1.2 Results and Discussion

8.1.2.1 Zooplankton Abundance

All results from the taxonomic identification and enumeration are presented in Appendix 8.1-1.

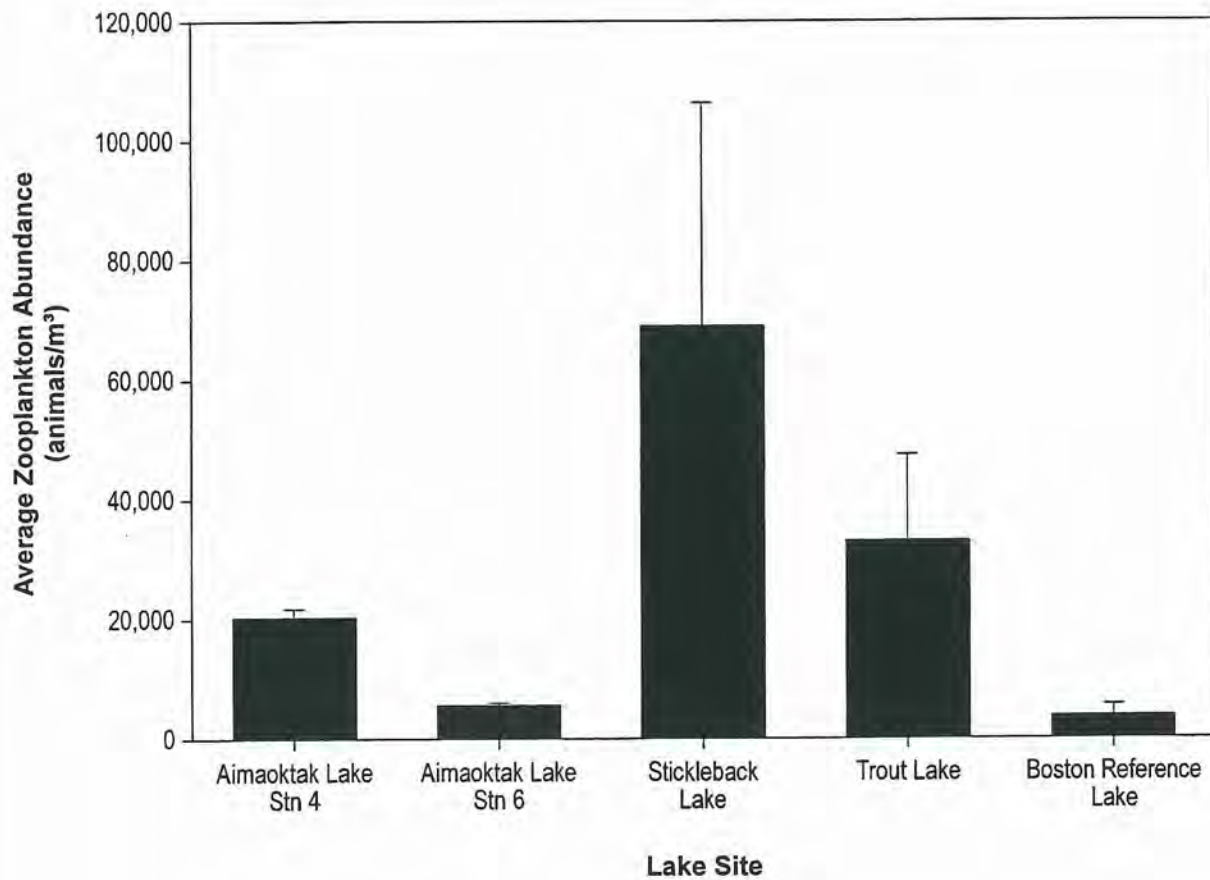
Figure 8.1-1 presents the average zooplankton abundance for all lake sites sampled within the Boston Property in July, 1998. Average zooplankton abundances ranged from 3,735 to 68,987 animals/m³. It appeared that abundances in Stickleback Lake were high compared to some of the other lake sites. There appeared to be differences in abundance between stations in Aimaoktak Lake, with Station 4 having a greater abundance of zooplankton than Station 6. Boston Reference Lake had a relatively low abundance of zooplankton, similar to Station 6 in Aimaoktak Lake.

8.1.2.2 Zooplankton Taxonomic Composition

Figure 8.1-2 presents the average taxonomic composition of the zooplankton assemblages sampled during the open water season (July) of 1998. Rotifers were dominant in assemblages in Stickleback, Trout, and Boston reference lakes, comprising from 67 to 74% of the assemblages. For Aimaoktak Lake, cyclopoid copepods were dominant, comprising 58 and 68% of the assemblages at stations 4 and 6, respectively.

8.1.2.3 Zooplankton Diversity

Table 8.1-2 presents the average Shannon and Simpson diversity indices for the zooplankton assemblages that were sampled in Boston Property lakes in July, 1998.



**Average Zooplankton Abundance
for Boston Property Lake Sites,
July 1998**

FIGURE 8.1-1

SECONDARY PRODUCERS

Assemblages consisted of between 8 and 10 genera. Average Shannon diversity indices ranged from 0.44 to 1.40, and average Simpson diversity indices ranged from 0.18 to 0.69. Stickleback Lake had the least diverse assemblage, with copepods being responsible for 90% of the abundance. Aimaoktak Lake (Station 4) and Trout Lake both had high diversity assemblages.

Table 8.1-2
Average Diversity Indices for Zooplankton
Assemblages, Boston Property Lakes, 1998

Lake Site	S	S (90%)	Max. Dom.	Shannon Diversity Index	Simpson Diversity Index
Aimaoktak Lake, Stn 4	10	4	45	1.40	0.69
Aimaoktak Lake, Stn 6	9	4	67	1.08	0.51
Stickleback Lake	8	2	90	0.44	0.18
Trout Lake	8	4	45	1.38	0.66
Boston Reference Lake	9	4	50	1.27	0.63

S: The number of genera per site.

S(90%): The number of genera contributing to 90% of the abundance.

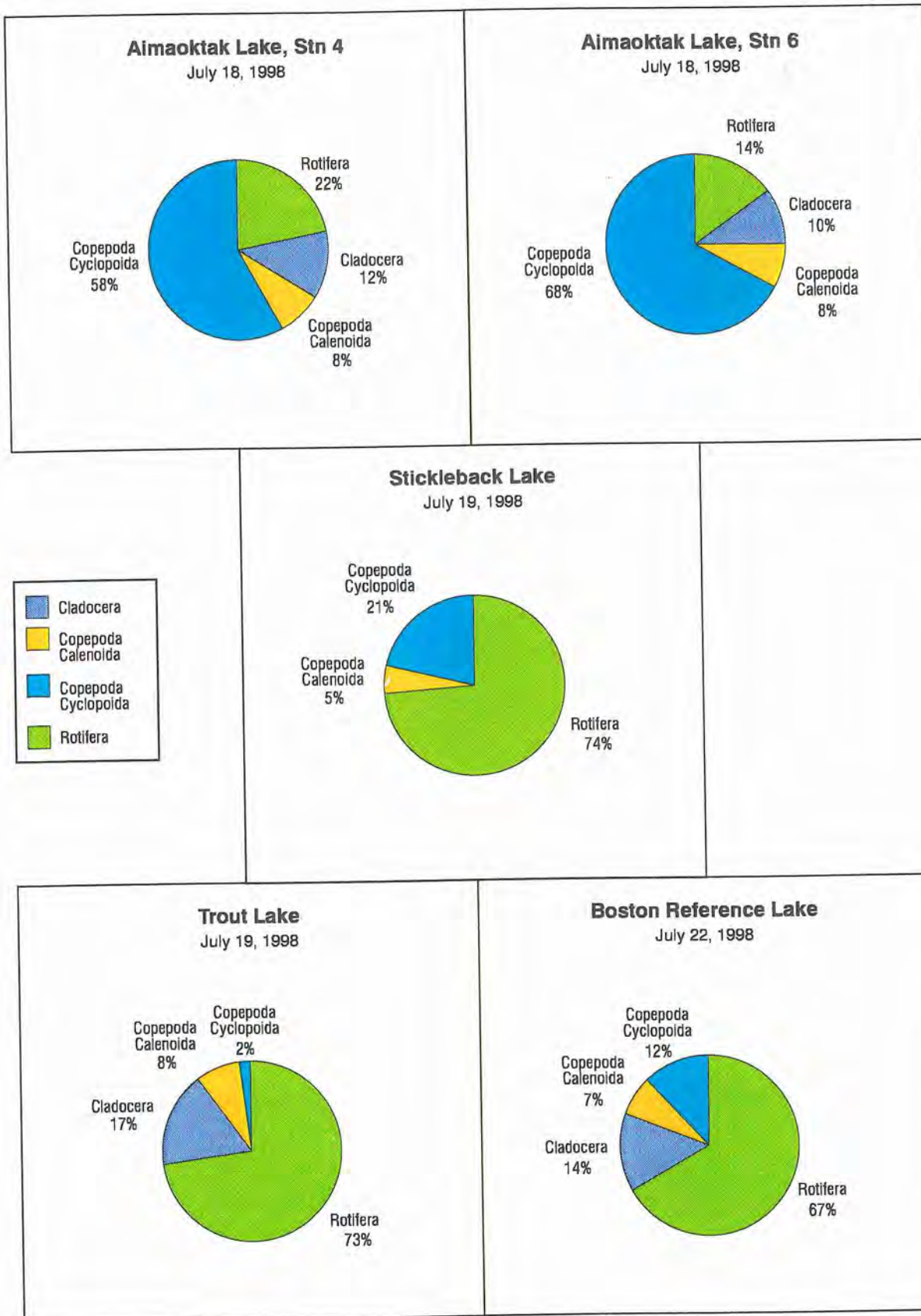
Max. Dom.: The maximum dominance accounted for by a single genus as a percentage.

8.2 Lake Secondary Producers – Lake Benthos

Lake benthic organisms in the Boston Property lakes were examined one time during the open water season in 1998.

8.2.1 Methods

Table 8.2-1 lists all sampling dates, locations and sampling depths for all lake benthos samples collected. Sampling locations are indicated on Figure 4.1-1 in Chapter 4 of this document.



**Average Taxonomic Composition of
Zooplankton Assemblages,
Boston Property Lakes, 1998**

FIGURE 8.1-2

Table 8.2-1
Sampling Locations and Dates for
Lake Benthos Program, Boston Property Lake Sites, 1998

Lake Site	Sampling Date	Sample Depths	Depth Strata ¹
Aimaoktak Lake, Stn 1	17-Jul-98	n=3 @ 1.2 m	Shallow
Aimaoktak Lake, Stn 4	18-Jul-98	n=3 @ 6.5 m	Mid
Aimaoktak Lake, Stn 5	17-Jul-98	n=3 @ 3.0 m	Shallow
Aimaoktak Lake, Stn 6	18-Jul-98	n=3 @ 29.0 m	Deep
Stickleback Lake	19-Jul-98	n=3 @ 2.6 m	Shallow
Trout Lake	19-Jul-98	n=3 @ 2.9 m	Shallow
Boston Reference Lake	22-Jul-98	n=3 @ 2.5 m	Shallow

1: Shallow = 0-5 m; Mid=5-10 m; Deep=10+ m.

8.2.1.1 Lake Benthos Identification and Enumeration

Lake benthos samples were collected during a one-time survey in July, 1998, using methods described previously in Rescan (1998). Triplicate samples were collected at the designated lake site or at the deepest part of the lake. Samples were preserved as described in Rescan (1998), and sent to Applied Technical Services for enumeration and identification.

8.2.1.2 Lake Benthos Dipteran Community Diversity

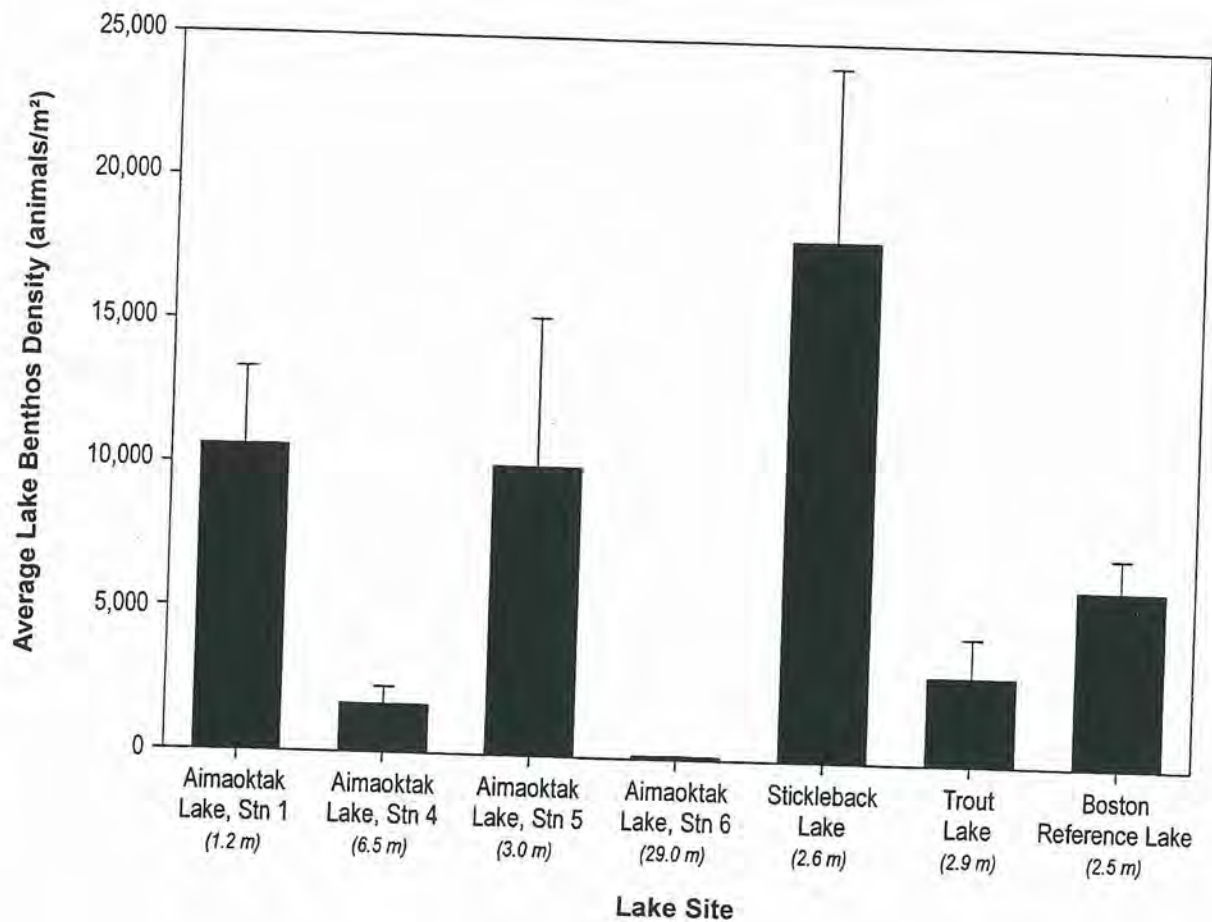
Both the Shannon and Simpson diversity indices were determined for the dipteran communities at all lake sites as described previously in Rescan (1998).

8.2.2 Results and Discussion

8.2.2.1 Lake Benthos Density

Results of the taxonomic identification and enumeration are given in Appendix 8.2-1.

Figure 8.2-1 presents the average lake benthos density for all lake sites that were sampled within the Boston Property in July, 1998. Average lake benthos densities ranged from 104 to 18,102 animals/m². Of the shallow benthos communities, Stickleback and Aimaoktak lakes appeared to have greater densities than Trout and Boston Reference lakes. The deepest community (29 m) had the lowest benthos density.



Note: Error Bars Represent Standard Error
Sample Depth is Indicated in Parentheses

**Average Lake Benthos Density for
Boston Property Lakes, July 1998**



FIGURE 8.2-1



8.2.2.2 *Lake Benthos Taxonomic Composition*

Figure 8.2-2 presents the average taxonomic composition of the lake benthos communities sampled within the Boston Property in July, 1998.

The composition of lake benthos organisms varied among sites in Aimaoktak Lake. Station 1 (1.2 m depth) was dominated by Diptera (55%), with Annelida (25%) also being important. Station 5 (3.0 m depth) was dominated by Diptera, Mollusca, and Nematoda almost equally. The mid-depth station, Station 4, had a community consisting of predominantly Mollusca (55%) and Diptera (30%). The deep community at Station 6 was strongly dominated by Diptera (71%).

The lake benthos community (2.6 m depth) in Stickleback Lake consisted primarily of Diptera (36%), Annelida (23%), and Ostracoda (18%). The community (2.9 m) in Trout Lake was strongly dominated by Diptera (81%). Boston Reference Lake had a benthos community (2.5 m depth) co-dominated by Diptera (48%) and Mollusca (47%).

8.2.2.3 *Lake Benthos Dipteran Community Diversity*

Table 8.2-2 presents the average Shannon and Simpson diversity indices for the lake benthos dipteran communities sampled in July, 1998. The dipteran communities consisted of 1 to 9 genera. Shannon diversity indices ranged from 0.23 to 1.78, and Simpson diversity indices ranged from 0.17 to 0.79.

In general, the shallow communities were more diverse than the deeper communities. The deepest community (29 m, Station 6, Aimaoktak Lake) had much lower diversity indices than more shallow communities. Dipteran communities in Stickleback, Trout, and Boston Reference lakes exhibited similar diversities. The community with the highest diversity was at Station 1 in Aimaoktak Lake (1.2 m), which was also the shallowest community.

SECONDARY PRODUCERS

Table 8.2-2
Average Diversity Indices for Lake Benthos Dipteran
Communities, Boston Property Lake Sites, 1998

Lake Site	Depth (m)	S	S (90%)	Max. Dom.	Shannon Diversity Index	Simpson Diversity Index
Aimaoktak Lake, Stn 1	1.2	9	6	34	1.78	0.79
Aimaoktak Lake, Stn 4	6.5	4	3	64	0.99	0.53
Aimaoktak Lake, Stn 5	3.0	5	3	56	1.12	0.60
Aimaoktak Lake, Stn 6	29.0	1	1	83	0.23	0.17
Stickleback Lake	2.6	8	5	48	1.50	0.69
Trout Lake	2.9	8	5	49	1.54	0.69
Boston Reference Lake	2.5	7	4	36	1.56	0.75

S: The number of genera per site.

S(90%): The number of genera contributing to 90% of the abundance.

Max. Dom.: The maximum dominance accounted for by a single genus as a percentage.

8.3 Stream Secondary Producers-Larval Drift

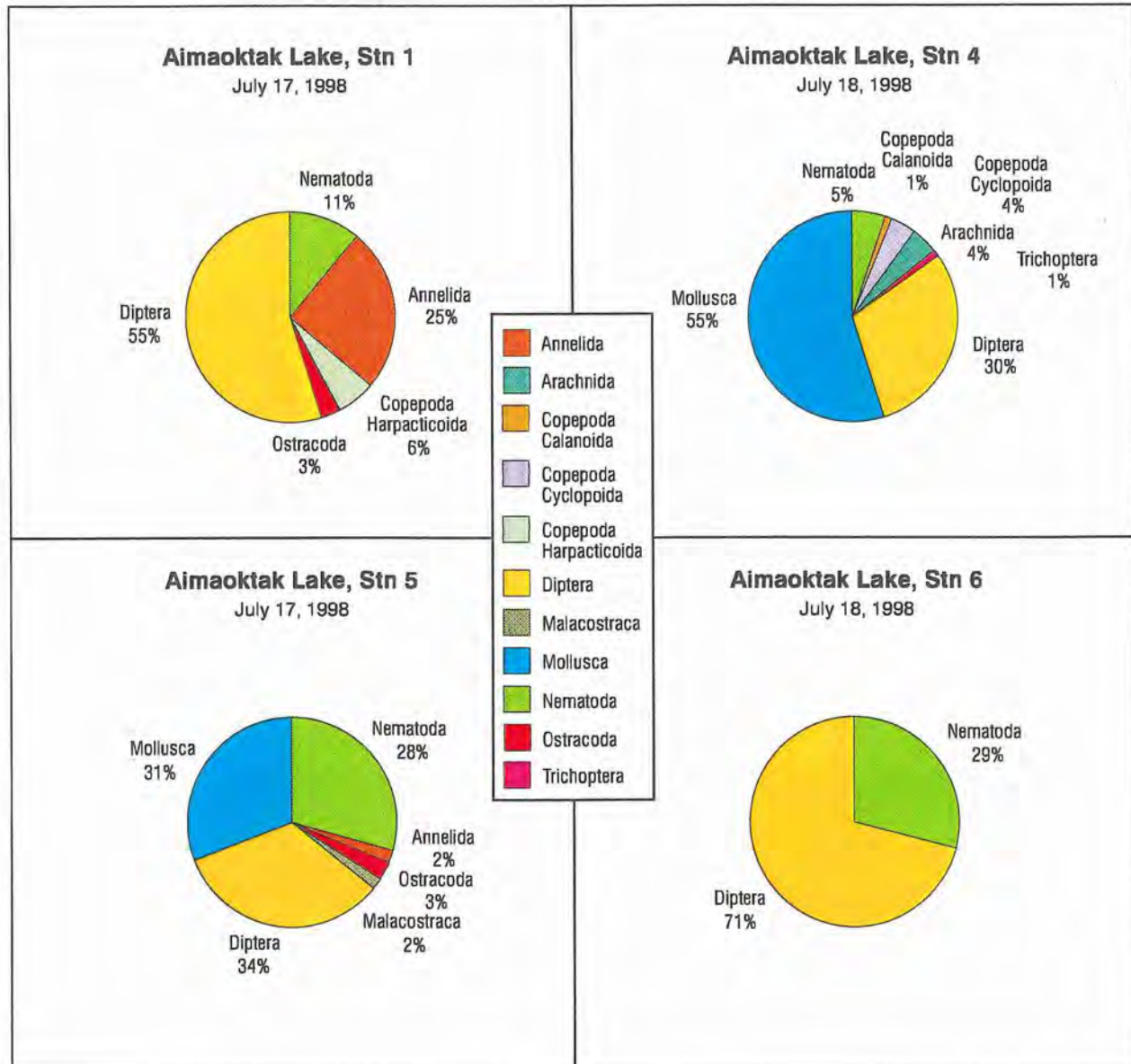
Larval drift communities were examined in Boston Property streams two times during the open water season of 1998.

8.3.1 Methods

Table 8.3-1 lists all sampling dates and locations for all larval drift samples collected. Sampling locations are indicated on Figure 4.1-1 in Chapter 4.

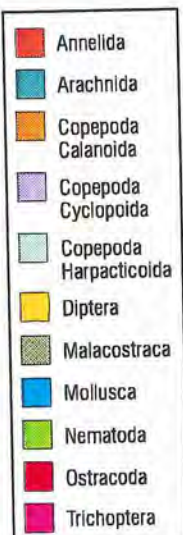
Table 8.3-1
Sampling Locations and Dates for Larval Drift Program,
Boston Property Streams, 1998

Stream Site	Dates of Net Installation	Dates of Net Installation
NE Aimaoktak Inflow	June 27, 1998	July 31, 1998
Aimaoktak River	June 27, 1998	July 31, 1998
Stickleback Outflow	June 26, 1998	July 30, 1998
Trout Outflow	June 26, 1998	July 30, 1998
Boston Reference Outflow	June 27, 1998	August 1, 1998

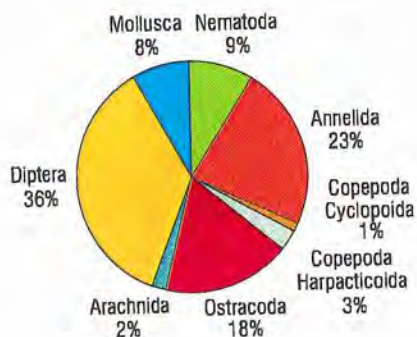


**Average Taxonomic Composition
of Lake Benthos Communities,
Boston Property Lakes, July 1998**

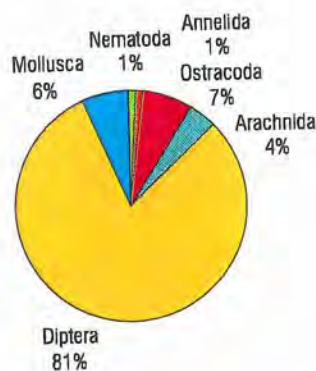
FIGURE 8.2-2a

**Stickleback Lake**

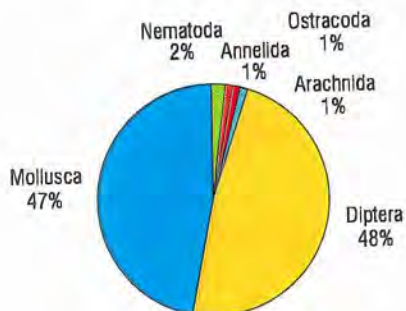
July 19, 1998

**Trout Lake**

July 19, 1998

**Boston Reference Lake**

July 22, 1998



**Average Taxonomic Composition
of Lake Benthos Communities,
Boston Property Lakes, July 1998**

FIGURE 8.2-2b

8.3.1.1 Larval Drift Identification and Enumeration

Samples for larval drift organisms were collected on two separate occasions from Boston Property streams in 1998. Two nets were installed per stream, and allowed to soak for 24 hours before retrieval. Water volume passing through the nets was calculated by measuring stream flows across the net mouth upon installation and retrieval as described in Rescan (1998). Sample retrieval, processing and handling followed methods outlined in Rescan (1998), and all samples were sent to Applied Technical Services for enumeration and identification.

8.3.1.2 Larval Drift Dipteran Community Diversity

Both the Shannon and Simpson diversity indices were determined for the drift dipteran communities at all stream sites as described previously in Rescan (1998).

8.3.2 Results and Discussion

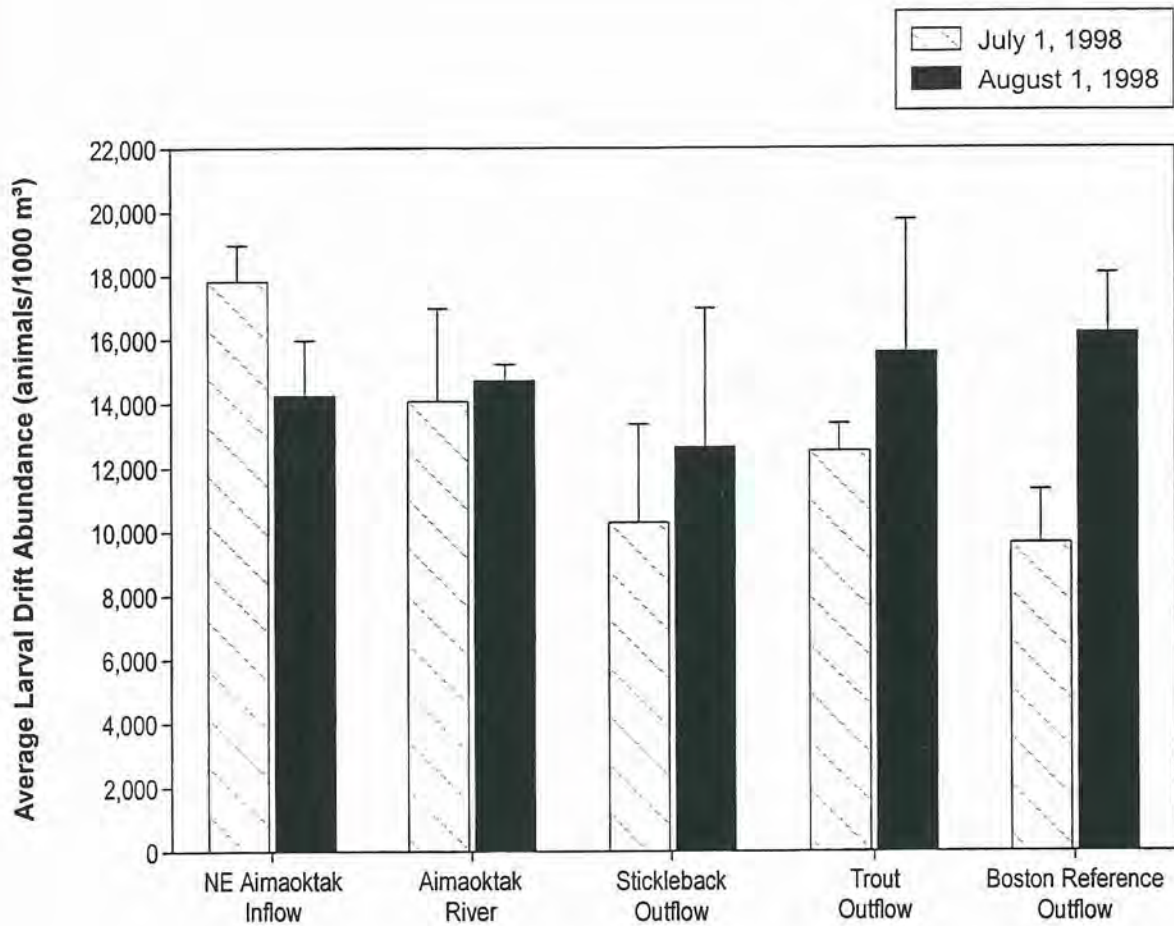
8.3.2.1 Larval Drift Abundance

Results from the taxonomic identification and enumeration are presented in Appendix 8.3-1.

Figure 8.3-1 presents the average larval drift abundance for all Boston Property streams sampled in 1998. Average abundances ranged from 9,634 to 17,826 animals/1000 m³. All streams had fairly similar abundances of drift organisms, and there were no major differences in abundances between sampling dates.

8.3.2.2 Larval Drift Taxonomic Composition

Figure 8.3-2 presents the average taxonomic composition for the larval drift communities for all streams sampled within the Boston Property in 1998. Overall, Diptera were the most prevalent organisms present in communities from all sampling locations and from all sampling dates. Ostracoda were important during the second sampling period in Stickleback and Trout outflows.



Note: Error Bars Represent Standard Error

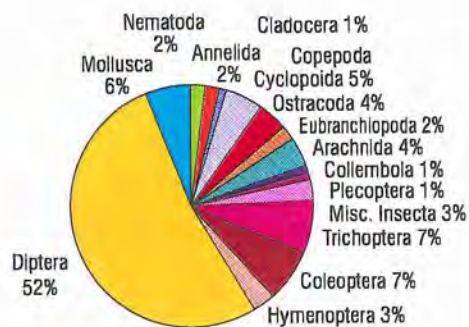
Average Larval Drift Abundance for
Boston Property Streams, 1998

FIGURE 8.3-1

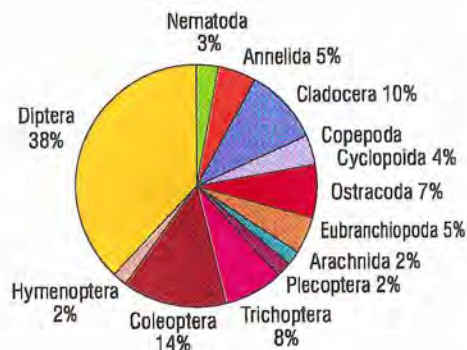


NE Aimaoktak Inflow

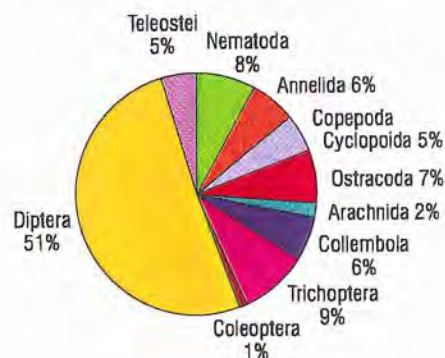
June 27 - June 28, 1998

**Aimaoktak River**

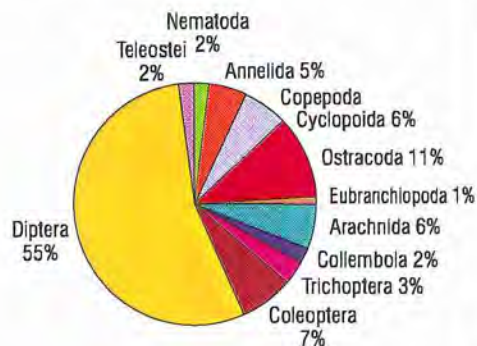
June 27 - June 28, 1998

**Stickleback Outflow**

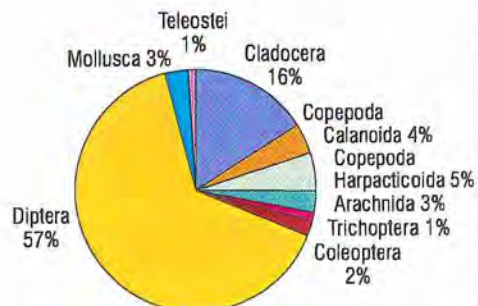
June 26 - June 27, 1998

**Trout Outflow**

June 26 - June 27, 1998

**Boston Reference Outflow**

June 27 - June 28, 1998

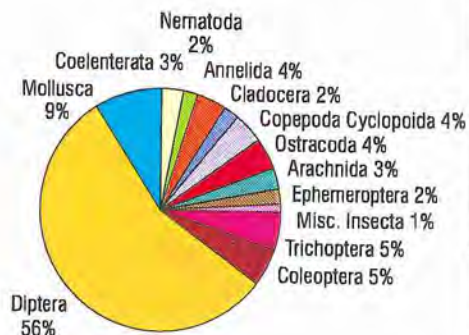


**Average Taxonomic Composition
of Larval Drift Communities,
Boston Property Streams, 1998**

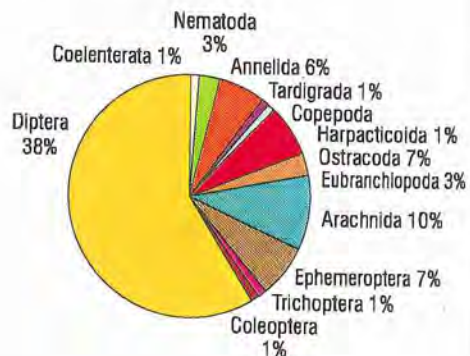
FIGURE 8.3-2a

NE Aimaoktak Inflow

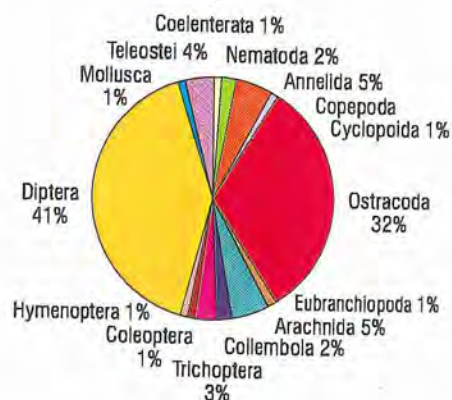
July 31 - August 1, 1998

**Aimaoktak River**

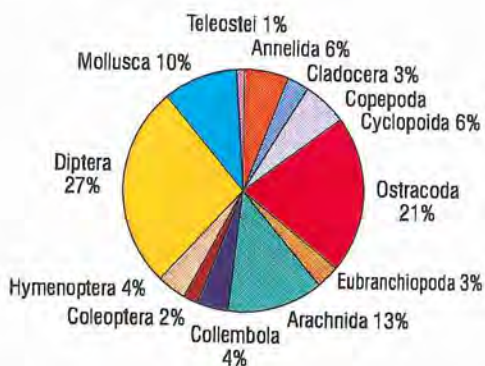
July 31 - August 1, 1998

**Stickleback Outflow**

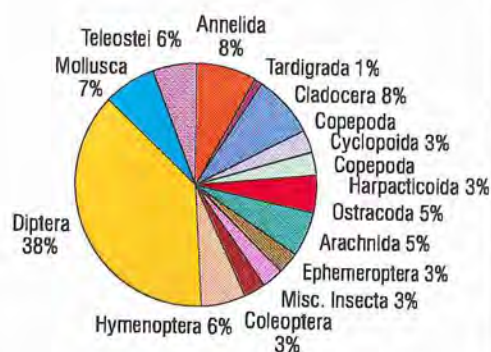
July 30 - July 31, 1998

**Trout Outflow**

July 30 - July 31, 1998

**Boston Reference Outflow**

July 30 - July 31, 1998



**Average Taxonomic Composition
of Larval Drift Communities,
Boston Property Streams, 1998**

FIGURE 8.3-2b

8.3.2.3 Larval Drift Dipteran Community Diversity

Table 8.3-2 presents the average Shannon and Simpson diversity indices for the drift dipteran communities for all streams sampled within the Boston Property in 1998.

Drift dipteran communities were comprised of between 7 to 15 genera. Average Shannon diversity indices ranged from 1.59 to 2.48, and average Simpson diversity indices ranged from 0.77 to 0.90. Drift dipteran communities were the most diverse in the NE Aimaoktak Inflow, however, all communities exhibited high diversity index values.

Table 8.3-2
Average Diversity Indices for Larval Drift Dipteran
Communities, Boston Property Streams, 1998

Stream	Date	S	S (90%)	Max. Dom.	Shannon Diversity Index	Simpson Diversity Index
NE Aimaoktak Inflow	June 27	15	12	19	2.48	0.90
	July 31	11	10	17	2.32	0.89
Aimaoktak River	June 27	8	7	29	1.86	0.80
	July 31	12	9	20	2.27	0.88
Stickleback Outflow	June 26	6	5	31	1.59	0.77
	July 30	7	6	29	1.78	0.81
Trout Outflow	June 26	8	6	23	1.85	0.83
	July 30	7	6	27	1.82	0.82
Boston Reference Outflow	June 27	11	8	27	2.01	0.84
	August 1	7	5	30	1.62	0.77

S: The number of genera per site.

S(90%): The number of genera contributing to 90% of the abundance.

Max. Dom.: The maximum dominance accounted for by a single genus as a percentage.

8.4 Stream Secondary Producers –Stream Benthos

Stream benthos were examined in streams within the Boston Property one time during the open water season of 1998.

SECONDARY PRODUCERS

8.4.1 Methods

Table 8.4-1 lists all sampling dates and locations for all stream benthos samples collected. Sampling locations are indicated on Figure 4.1-1 in Chapter 4.

Table 8.4-1
Sampling Locations and Dates for Stream
Benthos Program, Boston Property Streams, 1998

Stream Site	Dates of Sampler Immersion
NE Aimaoktak Inflow	June 28 – July 31, 1998
Aimaoktak River	June 27 – August 1, 1998
Stickleback Outflow	June 26 – July 30, 1998
Trout Outflow	June 26 – July 31, 1998
Boston Reference Outflow	June 28 – August 1, 1998

8.4.1.1 Stream Benthos Identification and Enumeration

Stream benthos samples were collected using Hester-Dendy artificial substrate samplers and processed as described in Rescan (1998). A Hester-Dendy multiple plate sampler was used which consisted of nine 75 x 76 mm plates, for an available surface area of 0.0912 m² (the top and bottom outer surfaces were not sampled; hence, there were sixteen available sides). Samplers were placed and left in the stream sites during the time period that most closely resembled the sampling time corresponding to the second sampling period of 1997. Triplicate samples were retrieved and processed as described in Rescan (1998), and sent to Applied Technical Services for enumeration and identification.

8.4.1.2 Stream Benthos Dipteran Community Diversity

Both the Shannon and Simpson diversity indices were determined for the dipteran communities for all stream sites as described previously in Rescan (1998).

8.4.2 Results and Discussion

8.4.2.1 Stream Benthos Density

Results of the stream benthos taxonomic analyses are provided in Appendix 8.4-1.

Figure 8.4-1 presents the average stream benthos density for all streams sampled within the Boston Property in 1998. Average stream benthos densities ranged from 1,067 to 38,946 animals/m². It appeared that Aimaoktak River had the lowest stream benthos densities (this is the largest, fastest flowing water of all of the streams). Stream benthos densities at all other sites were fairly similar. There was very large variability in the three replicates collected from Boston Reference Outflow.

8.4.2.2 Stream Benthos Taxonomic Composition

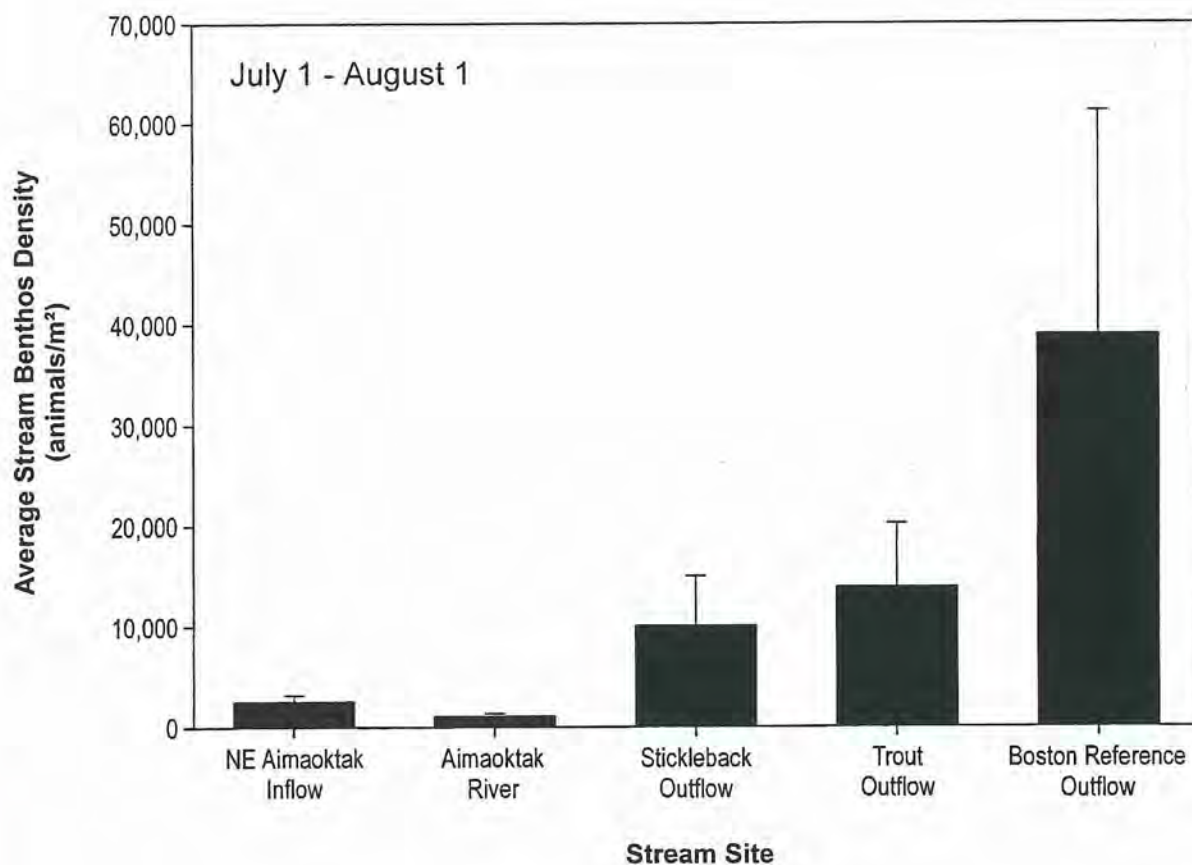
Figure 8.4-2 presents the average taxonomic composition of stream benthos communities for locations sampled in 1998.

Trout Outflow (86%), Boston Reference Outflow (88%), and Aimaoktak River (56%) has stream benthos communities dominated by Diptera. Stickleback Outflow was strongly dominated by Ostracoda (83%). The NE Aimaoktak Inflow was co-dominated by Mollusca (40%) and Ostracoda (35%).

8.4.2.3 Stream Benthos Dipteran Community Diversity

Table 8.4-2 lists the average Shannon and Simpson diversity indices for the stream benthos dipteran communities sampled in 1998.

The stream benthic communities were comprised of between 3 to 8 genera. Shannon diversity indices ranged from 0.50 to 1.40, and Simpson diversity indices ranged from 0.22 to 0.68. Boston Reference Outflow had the least diverse dipteran stream benthos community, and Aimaoktak River and NE Aimaoktak Inflow had the greatest diversity of dipteran stream benthos communities.



Note: Error Bars Represent Standard Error

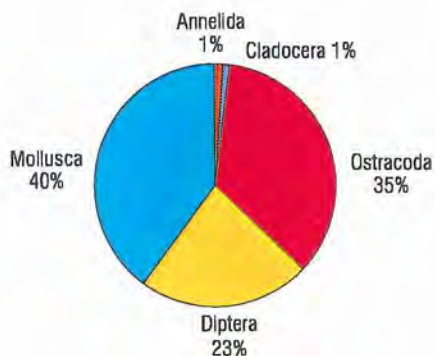
Average Stream Benthos Density for
Boston Property Streams, 1998

FIGURE 8.4-1

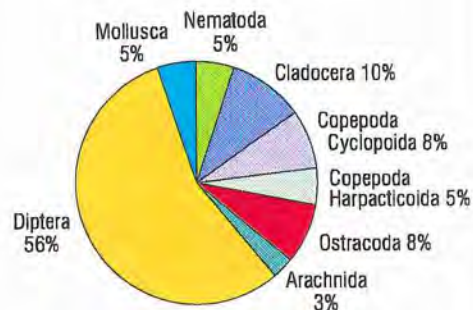


NE Aimaoktak Inflow

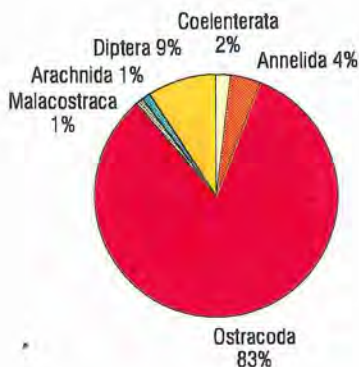
July 3 - July 31, 1998

**Aimaoktak River**

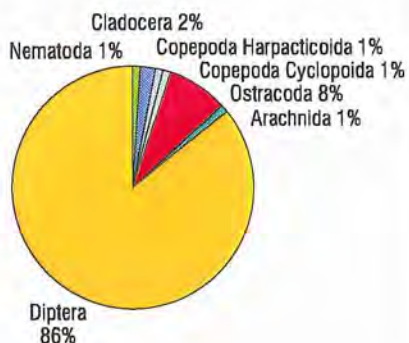
July 3 - August 1, 1998

**Stickleback Outflow**

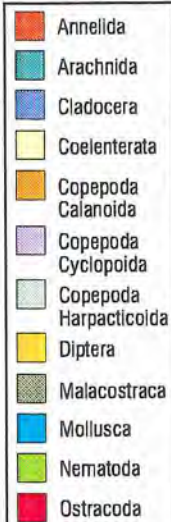
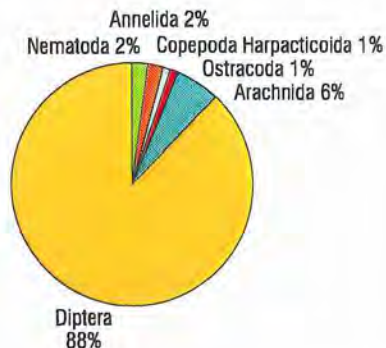
July 3 - July 30, 1998

**Trout Outflow**

July 3 - July 31, 1998

**Boston Reference Outflow**

July 3 - August 1, 1998



**Average Taxonomic Composition
of Stream Benthos,
Boston Property Streams, July 1998**

FIGURE 8.4-2



Table 8.4-2
Average Diversity Indices for Stream Benthos
Dipteran Communities, Boston Property Streams, 1998

Stream Site	S	S (90%)	Max. Dom.	Shannon Diversity Index	Simpson Diversity Index
NE Aimaoktak Inflow	7	5	50	1.40	0.65
Aimaoktak River	5	4	46	1.36	0.68
Stickleback Outflow	3	2	78	0.65	0.35
Trout Outflow	7	3	53	1.21	0.59
Boston Reference Outflow	8	2	88	0.50	0.22

S: The number of genera per site.

S(90%): The number of genera contributing to 90% of the abundance.

Max. Dom.: The maximum dominance accounted for by a single genus as a percentage.

8.5 Marine Secondary Producers-Marine Benthos

Marine benthic communities were examined in Hope Bay and in Roberts Bay one time during the open water season of 1998.

8.5.1 Methods

Table 8.5-1 lists all sampling dates, locations and sampling depths for all marine benthos samples collected. Sampling locations are indicated on Figure 4.1-1 in Chapter 4 of this document.

Table 8.5-1
Sampling Locations and Dates for
Marine Benthos Samples, Hope Bay and Roberts Bay, 1998

Marine Site	Sampling Date	Sample Depths	Depth Strata ¹
Hope Bay, Stn 1	21-Jul-98	n=3 @ 8.0 m	Mid
Hope Bay, Stn 2	21-Jul-98	n=3 @ 3.5 m	Shallow
Hope Bay, Stn 3	21-Jul-98	n=3 @ 3.7 m	Shallow
Roberts Bay, Stn 1	20-Jul-98	n=3 @ 16.0 m	Deep
Roberts Bay, Stn 3	20-Jul-98	n=3 @ 10.4 m	Deep
Roberts Bay, Stn 5	21-Jul-98	n=3 @ 1.2 m	Shallow

1: Shallow = 0-5 m; Mid=5-10 m; Deep=10+ m.

SECONDARY PRODUCERS

8.5.1.1 Marine Benthos Identification and Enumeration

Marine benthos samples were collected during a one-time survey in 1998, using a Ponar grab sampler and methods described previously in Rescan (1998). Triplicate samples were collected at the designated sites. Samples were preserved as described in Rescan (1998), and sent to Applied Technical Services for enumeration and identification.

8.5.1.2 Marine Benthos Diversity-Polychaetes and Molluscs

Both the Shannon and Simpson diversity indices were determined for the polychaete and mollusc communities at all sites as described previously in Rescan (1998).

8.5.2 Results and Discussion

8.5.2.1 Marine Benthos Density

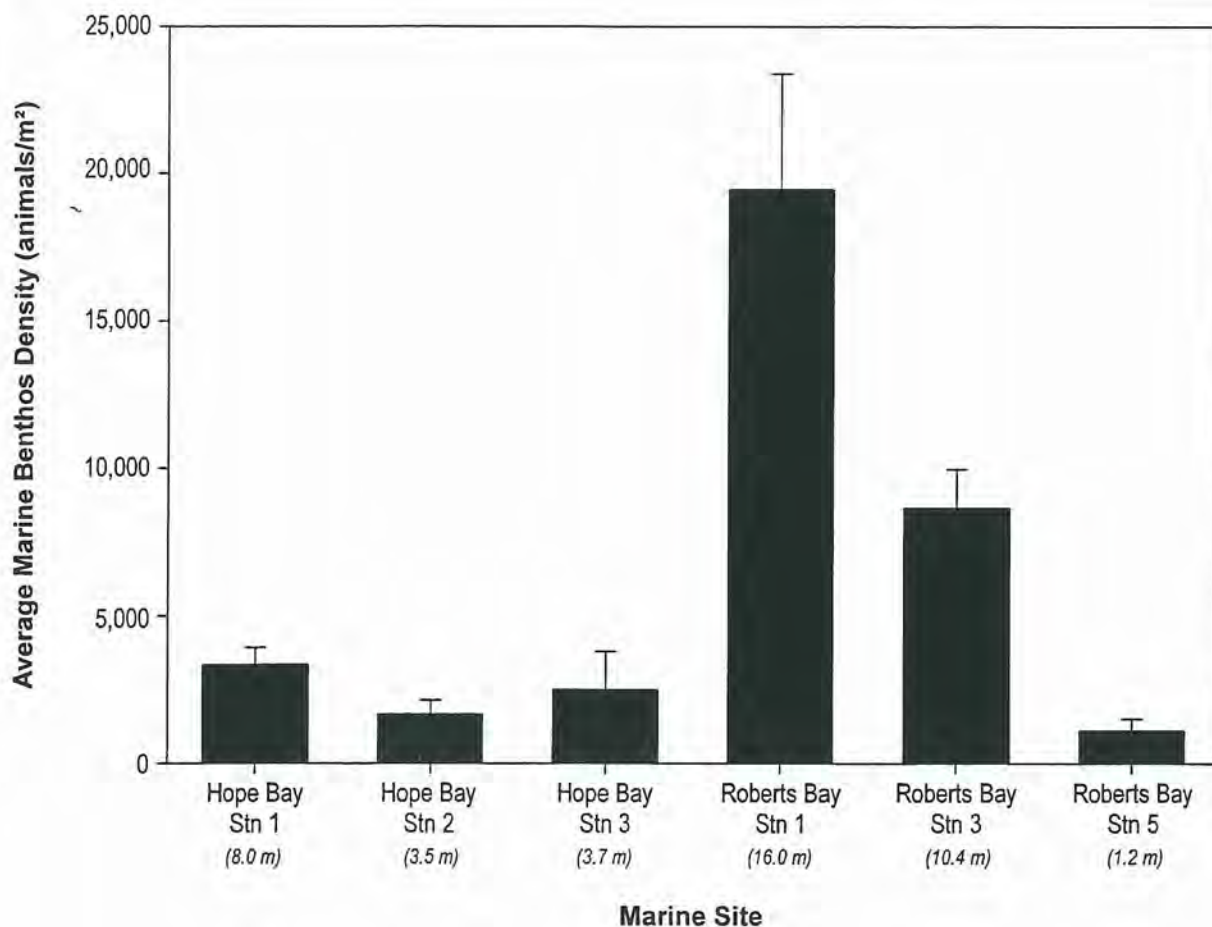
Results from the taxonomic identification and enumeration of the marine benthos samples are given in Appendix 8.5-1.

Figure 8.5-1 presents the average marine benthos densities for all sites sampled within Hope Bay and Roberts Bay in 1998. The density of marine benthic communities at the three Hope Bay sites were all similar, with average densities ranging from 1,667 to 3,346 animals/m². Average densities were greatest at the deepest site sampled in Roberts Bay, which had an average density of 19,451 animals/m².

8.5.2.2 Marine Benthos Taxonomic Composition

Figure 8.5-2 presents the average taxonomic composition of the marine benthos communities sampled in 1998.

Stations 2 and 3 in Hope Bay were dominated by both Nematoda and Polychaeta, with Diptera being important at Station 2 as well. At Station 1 in Hope Bay, Nematoda were much less prevalent, and Polychaeta and Diptera were the dominant types of organisms.



Note: Error Bars Represent Standard Error
Sample Depth is Indicated in Parentheses

**Average Marine Benthos Density
for Hope Bay and Roberts Bay,
July 1998**



FIGURE 8.5-1

SECONDARY PRODUCERS

In Roberts Bay, Polychaeta were important at all three stations sampled, comprising between 32 and 53% of the communities. Cumacea were important at Station 1 (21%), Amphipoda at Station 3 (33%), and Bivalvia at Station 5 (41%) in Roberts Bay.

8.5.2.3 Marine Benthos Diversity-Polychaetes and Molluscs

Table 8.5-2 presents the average Shannon and Simpson diversity indices for both the polychaete and mollusc communities in Hope Bay and Roberts Bay for 1998.

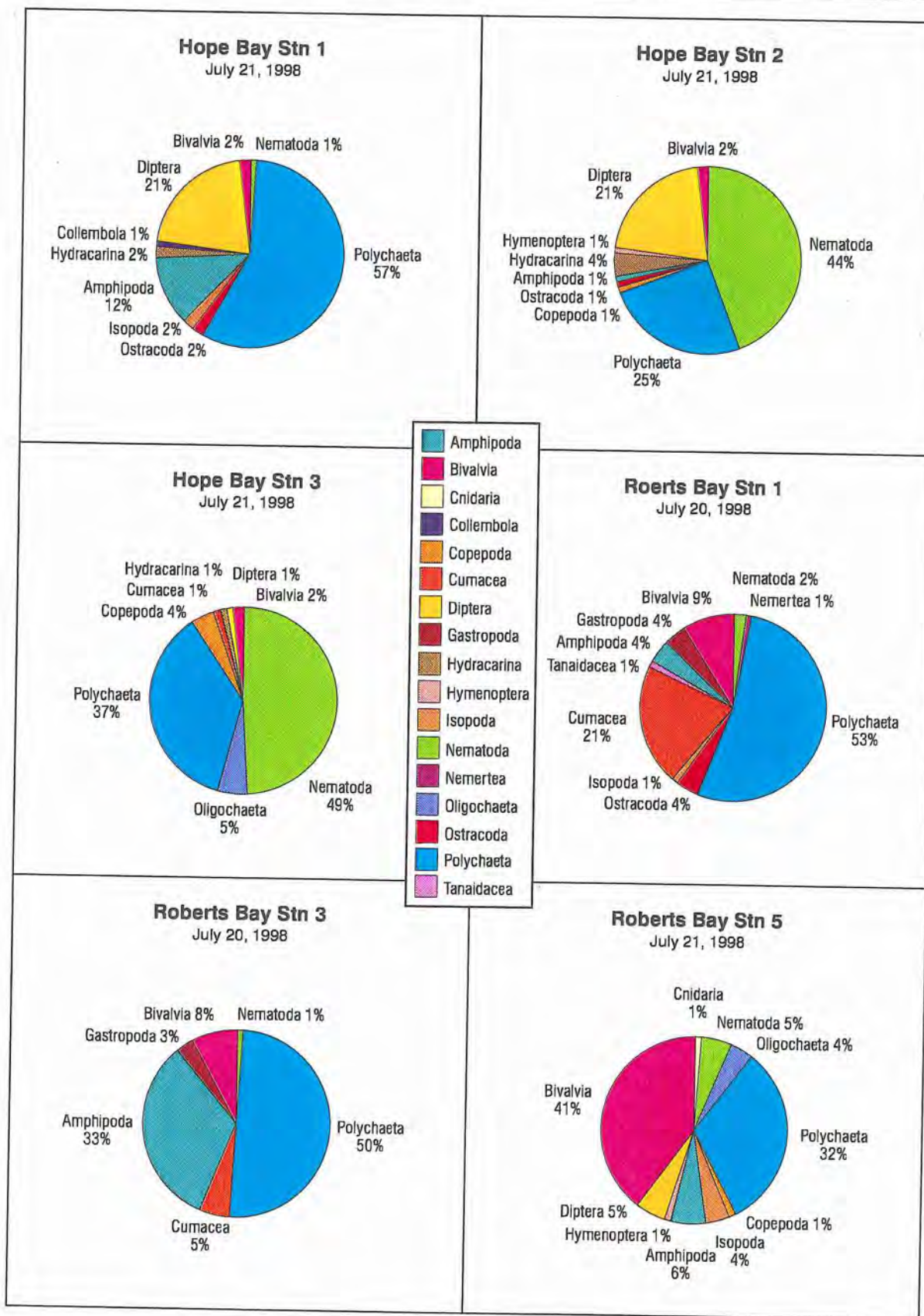
Table 8.5-2
Average Diversity Indices for Marine Benthos Polychaete and Mollusc Communities, Hope Bay and Roberts Bay, 1998

Marine Site	Depth (m)	S	S (90%)	Max. Dom.	Shannon Diversity Index	Simpson Diversity Index
<u>Polychaete Community</u>						
Hope Bay, Stn 1	8.0	6	4	58	1.20	.60
Hope Bay, Stn 2	3.5	2	1	91	0.12	0.14
Hope Bay, Stn 3	3.7	2	2	66	0.71	0.47
Roberts Bay, Stn 1	16.0	11	4	77	0.97	0.39
Roberts Bay, Stn 3	10.4	5	3	66	0.91	0.46
Roberts Bay, Stn 5	1.2	2	2	48	0.47	0.26
<u>Mollusc Community</u>						
Hope Bay, Stn 1	8.0	1	1	33	0.00	0.00
Hope Bay, Stn 2	3.5	1	1	33	0.00	0.00
Hope Bay, Stn 3	3.7	1	1	33	0.00	0.00
Roberts Bay, Stn 1	16.0	8	6	34	1.74	0.78
Roberts Bay, Stn 3	10.4	4	3	49	1.19	0.65
Roberts Bay, Stn 5	1.2	1	1	67	0.00	0.00

S: The number of genera per site.

S(90%): The number of genera contributing to 90% of the abundance.

Max. Dom.: The maximum dominance accounted for by a single genus as a percentage.



**Taxonomic Composition of
Marine Benthos Communities,
Hope Bay and Roberts Bay, 1998**

FIGURE 8.5-2

For the polychaete community, communities consisted of from 2 to 11 genera. Average Shannon diversity indices ranged from 0.12 to 1.20, and average Simpson diversity indices ranged from 0.14 to 0.60. The deeper depths tended to have more diverse polychaete communities. The least diverse community was found at Station 2 in Hope Bay, where the polychaete community was represented by only one genus.

For the mollusc community, from 1 to 8 genera comprised the communities. Where only one genus existed, the calculated diversity was zero. The only stations in which more than one mollusc genus was present were stations 1 and 3 in Roberts Bay. These two stations had average Shannon diversity indices of 1.19 and 1.74, and average Simpson diversity indices of 0.65 and 0.78. Station 1 in Roberts Bay had the most diverse community of molluscs compared to all other marine sites sampled.

9. Fish Communities

9. FISH COMMUNITIES

In August, 1998, a synoptic fish community survey was conducted in Pelvic Lake and a stream fish survey and habitat inventory were conducted in the Koignuk River on the Doris Property of the Hope Bay Belt area. In the following sections, the methods, results, and brief discussions of these surveys are presented.

9.1 Lake Communities

Fish community data were collected in Pelvic Lake during the period August 13 to 20, 1998. Keys to the fish names and raw data are contained in Appendices 9-1 to 9-3. Pelvic Lake is situated 5 km west of the Doris Lake exploration zone (Figure 1-1). Morphologically, Pelvic Lake resembles the other lakes of the Doris Property survey conducted in 1997 (Rescan 1998). Primarily because Pelvic Lake is not adjacent to any of the exploration zones, it was selected to serve as the regional reference lake for both the Doris and Boston properties.

9.1.1 Methods

9.1.1.1 *Fish Community Survey*

The Pelvic Lake fish community was surveyed between August 15 to 17, 1998, using index gill net gangs (Figure 9.1-1). Each gang consisted of three panels of 3.8 cm (1.5") mesh. Each panel measured 15.0 m long by 2.44 m deep for an area of 36.6 m² and a total area of 109.8 m² per gang. Index gangs were deployed in what are termed "rounds". During a round, three to four index gangs were set in succession and soaked for 60 minutes. The gangs were then retrieved in order of setting and the captured fishes were sampled. Once the fishes were sampled, the gangs were re-deployed for another round.

All captured fishes were identified to species, measured for fork length (mm), weighed (gm), sampled for ageing structures, and released. Left pectoral fins were used for ageing structures. In addition, all fishes over 300 mm were marked with a uniquely numbered Floy anchor tag. For mortalities, sex, maturity, and reproductive status were recorded, and otoliths and stomachs were removed for ageing and content analysis, respectively. In addition, myomere (muscle tissue)

FISH COMMUNITIES

and livers were removed from mortalities for trace metal analysis, on an opportunistic basis.

9.1.1.2 Analysis of Data

Catch per unit effort (CPUE), biomass per unit effort (BPUE), condition factor (CF), and population estimates were calculated. As well, basic descriptors such as mean size (*i.e.*, fork length and weight), length frequency distributions, and average-length-at-age distributions were calculated for species present in sufficient numbers.

Average CPUE was calculated from index gill net data. CPUE standardizes the catch data so that direct comparisons can be made between sampling periods. CPUE was calculated using the following equation:

$$\text{CPUE} = \# \text{ of fish in gang} \times [(100/\text{total gang area}) \times (24/\text{set time})]$$

The result of this expression is the number of fish per 100 m² of gill net soaking for 24 hr.

Average BPUE was also calculated from the index gill net data. CPUE standardizes the catch data so that direct comparisons can be made between sampling periods. The fish mass in each gang was summed and BPUE calculated using the following equation:

$$\text{BPUE} = \text{Kilograms of fish in gang} \times [(100/\text{total gang area}) \times (24/\text{set time})]$$

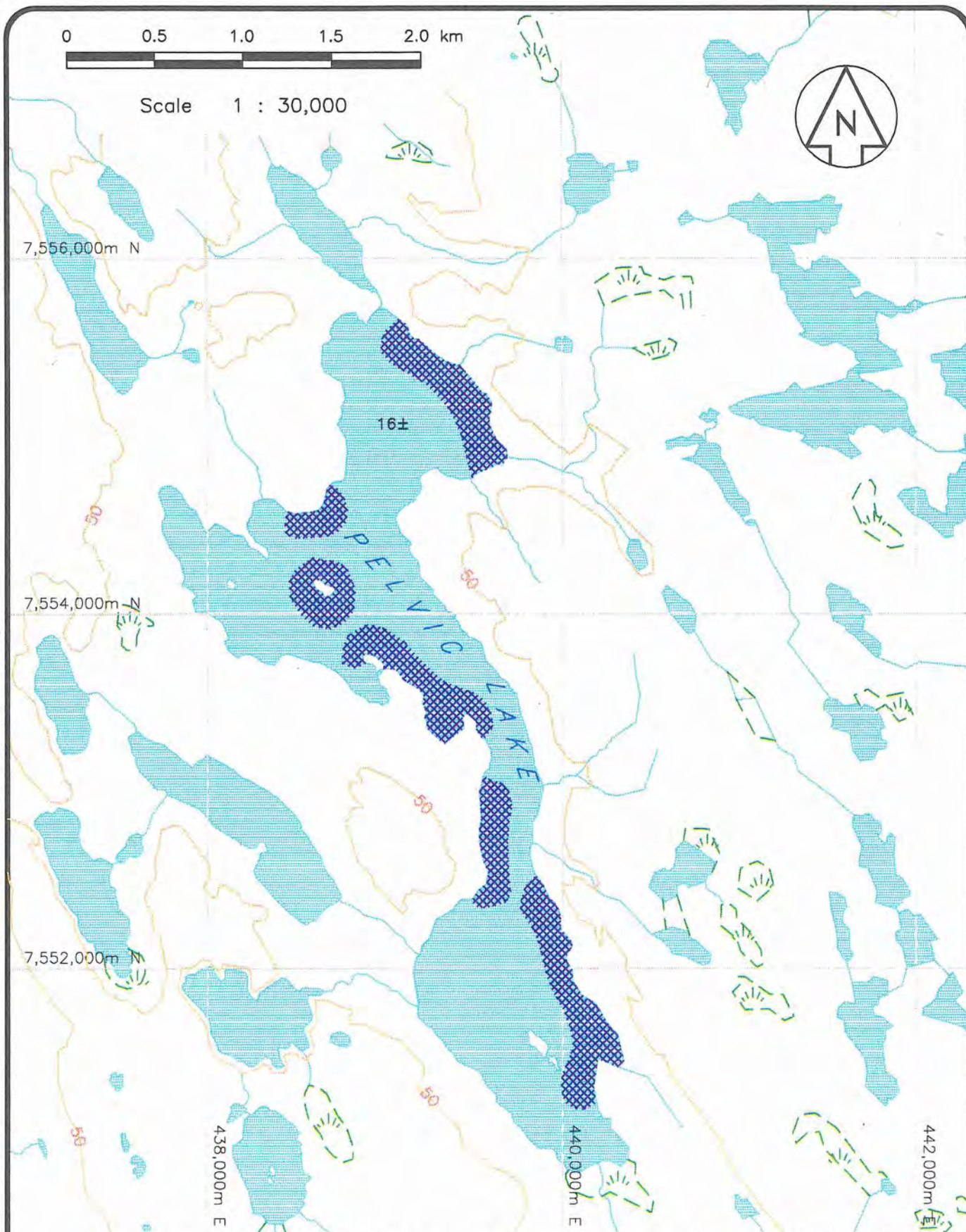
The result of this expression is the kilograms of fish per 100 m² of gill net soaking for 24 hr.

Fish condition factor (CF) was calculated following the allometric condition factor method outlined in Ricker (1975). The equation used was:

$$\text{CF} = [(\text{weight in gm}) \times 10^5] / (\text{fork length in mm})^3$$

This method of expressing fish condition was used in previous data reports (Rescan 1996, 1998). It is used here to provide continuity with the previous data reports and provide a morphological rather than condition comparison with other fish populations within the watershed.

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Index Gill Net Survey Locations in Pelvic Lake
15 to 17 August, 1998



Figure 9.1-1

