An Inventory and Assessment of the Aquatic Resources of Wallingford Pond, Wallingford, Vermont.

Vermont Agency of Natural Resources
Department of Environmental Conservation

Biomonitoring and Aquatic Studies Section

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For
The United States Forest Service - Green Mountain National Forest

October 1998

This was a cooperative project between the State of Vermont and the United States Forest Service and was funded in part by a grant from the USDA Forest Service, Green Mountain National Forest.

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Executive Summary

This report is a summation and assessment of the Vermont Agency of Natural Resources monitoring information collected at Wallingford Pond during 1996 and 1997. Included are the results for water chemistry, contaminants in fish tissue, benthic macroinvertebrates, phytoplankton, and aquatic macrophytes.

- Wallingford Pond, in the Otter Creek drainage basin, is an 86-acre body of water situated at an elevation of 2,165 feet (660 meters) in Rutland County, in the town of Wallingford. The pond is surrounded by the Green Mountain National Forest (GMNF). The forested drainage area is 1,470 acres. With the exception of several campsites along the shoreline, the watershed is currently relatively undisturbed. Primary bedrock formations in the watershed include gneiss, quartzite, and calc-silicate granulite. Historical uses of the pond include industrial water supply for the Seward Cheese Plant in East Wallingford.

- The pond has three basins, two of which thermally stratify, creating a true profundal zone at depths greater than 5 m. Maximum depth is 8.5 m. Dissolved oxygen concentrations as low as 0.05 mg/l were observed in the hypolimnion.

- Wallingford Pond is a tannic soft water lake with limited buffering capacity and is considered sensitive to acidification due to its low acid neutralizing capacity. Mean color and alkalinity are 110 Co-Pt units and 4.8 mg/l respectively. **Table S1** summarizes chemical results.

- Although total dissolved aluminum concentrations as high as 140 ug/l were observed, organic acids in this tannic pond will minimize the toxic effects of aluminum to the aquatic biota at these concentrations.

- Mercury was measured in the filets of yellow perch (yp), chain pickerel (cp), and small mouth bass (smb). Average concentrations in yp and cp were higher than statewide averages for those species. A composite sample of cp had mercury concentrations greater than 1 ppm and a 300 mm (~12 inch) yellow perch collected from Wallingford Pond in 1996 had the highest muscle tissue mercury concentration at 0.98 ppm, of over 207 yellow perch samples collected and analyzed from a wide range of lakes across Vermont.

Table S1: Water Quality Summary for Wallingford Pond, 1988 - 1997.

Parameter	Epilimnion				Hypolimnion (n=1)
	n	mean	median	range	
Temperature, C	5	-	-	9.5 - 20.5	7.3
Secchi, M	5	2.0	2.0	1.9 - 2.3	NA
pH, Standard Units	6	6.72	6.65	6.53 - 7.01	6.35
Alkalinity, mg/l	6	4.8	4.83	3.14 - 6.27	9.88
Conductivity, µs/cm	5	21.7	23.3	15.9 - 24.1	28.6
Color, Co-Pt units	3	110	114	75 - 140	161
Dissolved Cl, mg/l	4	0.29	0.29	0.23 - 0.33	0.33
Dissolved NO3, mg/l	4	< 0.02	< 0.02	< 0.02	< 0.02
Dissolved SO4, mg/l	4	2.93	2.55	2.70 - 3.93	2.41
Dissolved Ca, mg/l	5	2.55	2.67	2.68	2.96
Dissolved Mg, mg/l	5	0.66	0.65	0.54 - 0.72	0.67
Dissolved Na, mg/l	5	0.61	0.62	0.55 - 0.62	0.64
Dissolved K, mg/l	5	0.33	0.33	0.22 - 0.47	0.41
Dissolved Al, µg/l	4	91	93	74 - 105	140
Dissolved Si, mg/l	1	2.58	--	--	--
Calcite Sat Index	5	3.42	3.33	3.21 - 3.94	3.48
Dissolved Oxygen, mg/l	1	9.0	--	--	< 0.5

- The macrophyte community contains at least six species listed as rare in Vermont, as well as a diverse population of more common species. *Potomageton epihydrous*, *Eleocharis* sp. and two *Scirpus* sp. were the most common plants throughout the lake. *Isoetes tuckermanii* (very rare-S1), *Littorella americana* (rare-S2), *Eleocharis ovata* (very rare-S1), *Eleocharis olivacea* (very rare-S1), *Myriophyllum alterniflorum* (rare-S2), and *Sparganium fluctuans* (rare-S2) are known historically from the pond (Vermont Nongame and Natural Heritage Program, 1992) but were not identified during the course of this project.

- Macroinvertebrate sampling in 1996 covered all major habitats, including the littoral, sublittoral, and profundal zones. Ephemeroptera (mayfly) and Diptera (flies) were the most common orders, followed by Crustacea and Mollusca. The pond supports several species of Crustacea and Mollusca that are probably very close to the edge of their tolerance range for acidity. DEC has no records of the crayfish *Orconectes virilis*, the fingernail clam *Musculium partumeium*, and the Unionid mussel *Pyganodon cataracta* (the eastern floater) occurring at lower pH and alkalinities than those at Wallingford Pond. Only three species, *Chaoborus punctipennis*, *Zalutschia sp.*, *Chironomus sp.*, all tolerant of low dissolved oxygen, were found in the profundal zone. The sublittoral zone at approximately 4 meters, dominated by the same three species, also showed indications of dissolved oxygen stress within the benthic community.

Table S2. Percent composition of major macroinvertebrate groups from three littoral zone habitats (< 2.0m), the sublittoral zone (4 - 5m), and the profundal zone (> 7m).

Habitat	Rocky / Woody Debris			Macrophyte Beds			Mud / Sand Bottom			Sublit 4.2m	Prof 8.0m
Season	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Summer	Summer
Coleoptera	2	1	2	8	1	0	1	1	2	0	0
Diptera	50	47	30	47	63	24	20	70	54	97	100
Ephemeroptera	20	15	24	7	0	6	58	4	5	0	0
Trichoptera	4	3	6	9	8	11	7	1	4	0	0
Odonata	0.3	0	0.3	0.5	0	4	4	2	0	0	0
Crustacea	12	24	34	22	12	27	1	10	21	0	0
Mollusca	5.8	4	4	1	0	1	7	8	12	1	0
Oligocheata	3	4	0.3	0.5	12	24	0.5	2	2	2	0
Other	3	2	0	5	4	3	2	2	0	0	0

- The phytoplankton assemblage of Wallingford Pond was characterized from a summer composite sample which represents the average phytoplankton characteristics of the pond over the compositing period. Density estimates were dominated by four taxa, which make up 70 percent of the total algal cell density: *Cryptomonas erosa*, *Oscillatoria tenuis*, *Rhodomonas minuta*, and an unidentified flagellated taxon. Biovolume estimates are dominated by five taxa which make up 90% of the total volume: *Cryptomonas erosa*, *Oscillatoria tenuis*, *Peridinium cinctum*, *Cyclotella compta*, and *Glenodinium sp.* **Table S3** summarizes the density and volume characteristics by taxonomic group.

Table S3: Wallingford Pond summer composite phytoplankton assemblage reported as density in algal cells per ml and volume reported as cubic microns of algal material per cubic meter of water.

Taxonomic Group	Density (#/ml)	% Density	Volume (μ^3/m^3)	% Volume
Cryptomonas/ Rhodomonas	372	42.5	135,465	42.5
Blue-green	140	16	83,550	26
Diatoms	91	10.4	32,504	10.2
Green	173	19.8	12,680	4
Other	99	11.3	54,841	17.3
Total	875		319,040	

- Concurrent monitoring activities proposed or ongoing for Wallingford Pond include:

  1) Phytoplankton, and sediment nutrients and metals were collected as part of an on-going Paleolimnology and Bioassessment of Vermont and New Hampshire Lakes Project funded by USEPA and conducted by Vermont and New Hampshire State Environmental Departments. The sediment cores were sectioned in the field into one centimeter slices and will be examined by the New Hampshire Department of Environmental Services. The cores will be analyzed for total phosphorus, aluminum, cadmium, calcium, chromium, copper, iron, manganese, sodium, lead, nickel and potassium.

  2) Mercury will be collected from sediment-core samples in 1999 as part of the Assessment of Mercury in Hypolimnetic Lake-Bed Sediments of Northern New England, with an emphasis on Vermont and New Hampshire Project (Kamman and Estabrook 1997). It is anticipated these cores will be dated to determine if significant changes in sediment mercury have occurred between pre-settlement and the present.

Recommendations

Wallingford Pond supports a rich and diverse aquatic community, including several rare species of aquatic plants and several species of aquatic invertebrates at the extreme range of their tolerance to acidic conditions. Except for a “rough” access road leading to the shoreline, the pond appears to be minimally impacted by human activity. The Vermont Department of Environmental Conservation is currently evaluating the biological characteristics of Wallingford Pond as an example of the least-disturbed conditions for a body of water with similar physical and chemical characteristics, and as a research site for studying the dynamics of mercury in the aquatic environment. **As such, the protection of the current relatively primitive condition of Wallingford Pond should be given high priority.** Future use of the pond should be managed to minimize potential disturbance. Consideration should be given to the intensity of future use and the maintenance of appropriate buffers around the perimeter of the pond.

The evaluation of mercury dynamics in the pond should be continued. Levels of mercury in fish suggest that concentrations are higher than statewide averages. **Further assessment of the potential health effects related to mercury in fish tissue should be given a high priority.**

Erosion from the current access area was observed. **Efforts to stabilize and curtail use of this access area should be given a high priority.**

Additional macroinvertebrate and macrophyte inventories should be conducted to assess the current status of rare animals and plants. Water quality and biological monitoring should be conducted at a minimum of every five years or in conjunction with land disturbance activities occurring in the watershed.

Acknowledgments

This study was a collaboration between the GMNF and the State of Vermont. It would not have been possible without the support of the GMNF, especially Soil Scientist Nancy Burt and Fishery Biologist Steve Roy. They have been responsible for developing the Challenge Cost-Share Agreements that permit the State of Vermont to conduct water quality and biological assessment studies on GMNF lands. Steve Roy was the Project Coordinator, as he often is, on these cooperative projects. In addition to their assistance, help was also received from the Manchester District Office fish crew whose team leader was Scott Wixsom.

The entire staff of the VT DEC’s Biomonitoring and Aquatic Studies Section greatly assisted with all facets of this project from sample collections to the final report. Heather Pembrook did much of the final editing and table presentation. Section Supervisor, Douglas Burnham is gratefully acknowledged for his review and the time and effort he puts into the staff workplans that allows special studies like this to proceed. The VT DEC’s Reginald A. LaRosa Laboratory under the direction of Dr. Gerald Divincenzo deserve thanks for the analytical testing. Neil Kamman of the VT DEC’s Lakes and Ponds Section provided the basis for **Figure 1** and the macrophyte and phytoplankton information assembled in the appendices. This information was generated for the Paleolimnology and Bioassessment of Vermont and New Hampshire Lakes Project and coordinated by Neil Kamman.

Introduction

The Vermont Department of Environmental Conservation (VT DEC) initially monitored Wallingford Pond in the summer of 1988 to document its chemical and biological status. At that time, baseline water chemistry and an inventory of macroinvertebrates and macrophytes was established. Periodic monitoring was recommended if activities were to occur within the drainage that would have the potential to affect water quality. In 1996, VT DEC recommended further assessment of Wallingford Pond for the following reasons:

- The Green Mountain National Forest (GMNF) planned to conduct a fish community survey in 1996;
- Increasing concerns regarding elevated mercury in fish collected from Vermont water bodies;
- Future activities being considered by GMNF within this watershed including primary road reconstruction, additional snowmobile corridors, recreational improvements to include primitive camping, and a nearby timber sale;
- It is located in Management Area 8.1;
- Current efforts by VT DEC to establish a biological database on reference quality lakes like Wallingford Pond, to define the natural biological potential of Vermont lakes.

In 1996, VT DEC entered into a cooperative agreement with the GMNF to assess the ecological conditions of Wallingford Pond. The assessment would include the collection of new data as well as the evaluation of other existing applicable data and information. The primary objectives of the assessment are:

1. Describe the chemical, physical, and biological status of Wallingford Pond;

2. Make recommendations to the GMNF pursuant to future activities in the Wallingford Pond watershed;

The field element of this project was carried out cooperatively by the GMNF and the VT DEC.

The GMNF was responsible for:

1. Fish surveys and collections of specimens for mercury analysis.

The VT DEC was responsible for:

1. Macroinvertebrate sampling from three littoral habitat types on a seasonal basis, and sampling the sublittoral and profundal macroinvertebrate communities once in the summer.

2. Seasonal water chemistry sampling in conjunction with the bioassessment.

3. Six analyses from 15 fish for the presence of mercury in filets.

In addition, the VT DEC compiled and reviewed historical information available on Wallingford Pond. This includes a 1973 fishery assessment by the Vermont Department of Fish and Game and macrophyte inventories conducted by the Vermont Non-Game and Natural Heritage Program and VT DEC. Concurrent monitoring activities proposed or ongoing for Wallingford Pond include:

- 1) Phytoplankton, and sediment nutrients and metals were collected as part of an on-going Paleolimnology and Bioassessment of Vermont and New Hampshire Lakes Project, funded by USEPA and conducted by Vermont and New Hampshire State Environmental Departments. The sediment cores were sectioned in the field into one centimeter slices and will be analyzed by the New Hampshire Department of Environmental Services. The cores will be analyzed for total phosphorus, aluminum, cadmium, calcium, chromium, copper, iron, manganese, sodium, lead, nickel, and potassium.

- 2) Mercury will be collected from sediment-core samples in 1999 as part of the Assessment of Mercury in Hypolimnetic Lake-bed Sediments of Northern New England, with an Emphasis on Vermont and New Hampshire Project (Kamman and Estabrook 1997). It is anticipated these cores will be dated to determine if significant changes in sediment mercury have occurred between pre-settlement and the present.

Lake and Basin Description

Wallingford Pond is situated at an elevation of 2,165 feet (660 meters) in Rutland County, in the town of Wallingford. The pond is surrounded by the GMNF and is accessed via a four-wheel drive road that begins at the terminus of Forest Road 20. This one-mile drive into the pond is rough and not maintained. The last one-quarter mile of the road is a source of considerable erosion and sedimentation funneling into the lake access.[1] The pond is unusually shaped and consists of three distinct bays **(Figure 1).** The southern arm is the deepest section of the lake having a maximum depth of 8.5 meters. It is connected to the rest of the lake by a narrow, shallow channel. Wallingford Pond is 86 acres and is one of the largest totally undeveloped water bodies in southern Vermont. The unregulated outlet is located on the north side of the largest and most northerly arm and flows into Fowler Brook that leads into Mill Brook and eventually into the Otter Creek drainage. Historically, the presently free-flowing outlet was controlled by two, 1-foot wide flash boards. This impounded water was used at the Seward Cheese Plant in East Wallingford (Vermont Fish and Game 1973). A large pile of rocks next to the outlet in a thicket of trees is a reminder of past uses of Wallingford Pond. The physical characteristics of the pond and basin are summarized in **Table 1**.

Table 1. Physical Characteristics of Wallingford Pond.

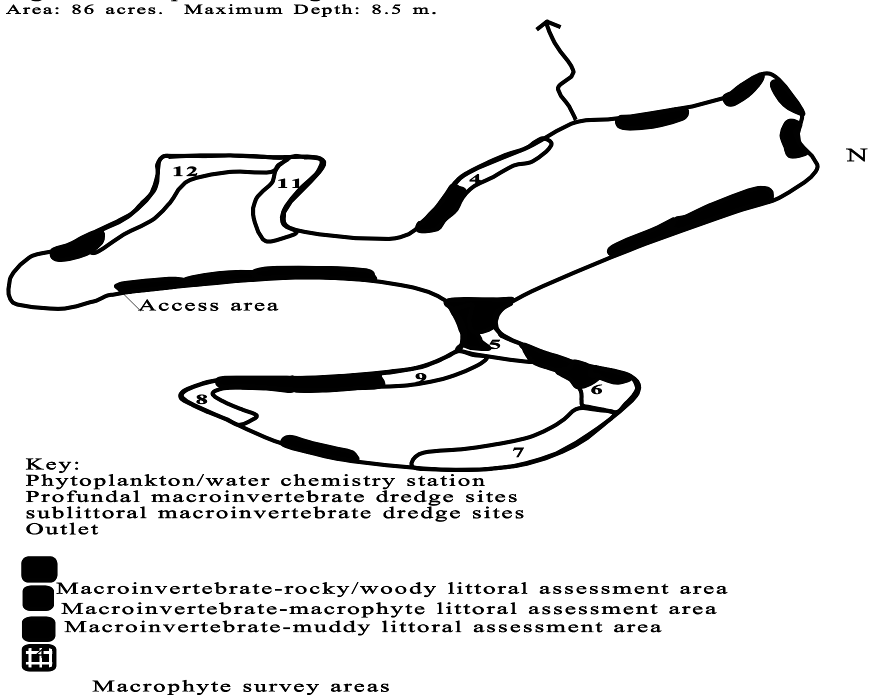
Elevation (feet)	Drainage Area (acres)	Surface Area (acres)	DA/SA	Maximum Depth (m)	Topography[1]	Bedrock Type[2]
2165	1470	86	17	8.5	Mod	I

[1] Mod = moderate relief.
[2] I = low to no buffering capacity and expected to have been impacted from acid precipitation.

[1] The road not only causes erosion problems, but possibly promotes heavy use of the lake by campers who would not otherwise haul in their gear and equipment for extended stays.

The watershed is predominantly forested and free of shoreline disturbances other than the boat launch and clearings for campsites. Some areas of the pond are bordered by adjacent wetlands. The northern bay has a small sandy white beach next to a campsite. The bedrock consists of gneiss, quartzite and calc-silicate granulite which is the most common bedrock type in south-central Vermont (Doll 1961).

Figure 1. Map of Wallingford Pond
Area: 86 acres. Maximum Depth: 8.5 m.



Lake Sampling Methods

Water Chemistry

The pond was sampled six times between the summer of 1988 and late spring of 1997. The samples were collected from a canoe using a 1.2-liter acrylic Kemmerer bottle at the deepest region of the lake. The epilimnion was sampled 1 meter below the surface, and the hypolimnion was sampled 1 to 2 meters from the bottom. Lake water was transferred into
two 1-liter Nalgene high density polyethylene (HDPE) bottles and upon return to the vehicle, placed in a cooler with ice for transport to the VT DEC Laboratory in Waterbury, VT. In-situ measurements include Secchi disk transparency, field pH, and temperature profiles from the surface to the bottom at one meter intervals. In-situ data and weather observations were entered onto a field sheet.

Upon return to the laboratory the samples were logged into the Laboratory Management System and each lake sample was issued a unique five digit number for sample tracking. The samples were then processed within the holding time following collection. One of the two 1-liter bottles was filtered through a Gelman Supor-450 0.45 micron filter into a one liter side-arm flask using a Doerr electric vacuum pump. Prior to filtration, all filtration apparatus including the filters were thoroughly rinsed with deionized water. The filters were soaked, then pre-rinsed with approximately 25 ml of sample. Stringent rinsing protocols with both deionized water and the filtered sample all but eliminate the possibility of contamination. The filtered liter was split into aliquots for base cations, anions and aluminum and preserved if required. The remaining liter bottle was used for pH, alkalinity, apparent color (TC) and conductance.

All field and laboratory procedures are consistent with the VT DEC Field Methods Manual (VT DEC 1989) and VT DEC Laboratory Quality Assurance Plan (VT DEC, 1992 and revisions). The analytical procedures are presented in **Appendix 1** along with the reference source. The methods used are consistent with the US EPA Quality Assurance Plan for the Long-term Monitoring Project (Morrison 1991).[2]

Macroinvertebrates

The aquatic macroinvertebrates of Wallingford Pond were surveyed to determine the current species composition of the lake. Macroinvertebrate species composition is often strongly influenced by the physical/chemical habitat type found within the lakes. For this reason, the various macro-habitats within the littoral zone were differentiated and sampled separately, as were the sublittoral and profundal zones. The littoral zone habitats were sampled on a seasonal basis to ensure a more complete species list, and to compare species composition changes over the course of a year. The sublittoral and profundal zones were sampled once coinciding with summer stratification.

[2] The VT DEC is a participant in this project. The objectives are to detect and measure trends in the chemistry of low alkalinity surface waters such as Wallingford Pond.

Littoral Zone

The littoral zone is defined as that area between the shoreline and the far edge of macrophyte growth. The occurrence of macroinvertebrates depends greatly on littoral zone habitat. Therefore, for each of the three habitat types, a composite sample from a minimum of three sites was collected, at least one within each bay. The habitat types selected for assessment were:

-Rocky/Cobble and Large Woody Debris
-Macrophyte Beds
-Fine Organic and Inorganic Material and Leaves

All habitats were qualitatively sampled by two people for approximately 15 minutes per site. Thus, each habitat was sampled a minimum of 1.5 person hours per season. The macroinvertebrates were collected with a 500 micron mesh sweep net, forceps or strainers. All samples were preserved in the field using 75 percent ethyl alcohol (ETOH). The littoral zone sampling methods were recently developed by the VT DEC to better assess lake-wide macroinvertebrate communities and are consistent with methodologies used by VT DEC to assess macroinvertebrate communities across a broad range of lakes types and sizes.

Sublittoral Zone

The sublittoral zone is defined as that area of the lake bottom below the area of macrophyte growth, but above the thermocline. The preferred bottom type for sampling is fine organic muck (gytta). An Ekman dredge (15 x 15 cm) was used to collect the sample and then rinsed through a # 30 (560 µ mesh size) sieve bucket. A single Ekman dredge grab from three separate sublittoral zones was composited into a single sample. The sample was preserved in the field using 75 percent ETOH. The sublittoral method employed was Method 4.4.5 (VT DEC 1989).

Profundal Zone

The profundal zone is defined as that area of the lake bottom below the thermocline. The preferred bottom type for sampling is fine organic muck (gytta). An Ekman dredge (15 x 15 cm) was used to collect the sample and then rinsed through a # 30 (560 µ mesh size) sieve bucket. Three Ekman dredge samples were collected and composited. One sample was taken from the northern most bay; two samples were collected from the larger, deeper southern bay. The eastern bay was not sampled as it lacked a true profundal zone. Samples were preserved in the field using 75 percent ETOH. The profundal method employed was Method 4.4.5 (VT DEC 1989).

Laboratory Protocols

Upon return to the VT DEC Laboratory, the macroinvertebrate samples were logged into a notebook and given a unique sequential number beginning with the last two numbers of the calendar year. This number is used by the staff biologists for sample tracking.

The samples were rinsed of ETOH through a # 30 sieve and spread evenly over a 12 inch x 18 inch white gridded (24 squares) enamel tray. A small amount of water was added to allow the sample to be evenly spread. Care was taken to avoid adding too much water as this causes the macroinvertebrates to float freely around the tray. Beginning with a randomly selected grid number, all macroinvertebrates from one quarter of the tray were picked and sorted into major groups. If less than 300 aquatic organisms were found, additional squares were picked until 300 were processed. A random number approach was used to determine the initial square picked. The total number of squares picked was recorded along with the analyst's name. All picked samples were checked by a second analyst for completeness prior to discarding. The second analyst was also responsible for examining the entire tray for different or uncommon taxa not previously encountered in the sample. These animals were picked out and recorded as present, but not included as part of the community analysis.

Fish Contaminants

Total mercury was analyzed from three species of fish collected from Wallingford Pond on July 18 and October 8, 1996 by staff from the Manchester District of the GMNF. The fish were collected by gill nets and the lengths were recorded in the field. Whole fish were wrapped in aluminum foil and placed in plastic bags and transported on ice to the Manchester District Office and frozen. Fish were later transported on ice in a cooler to the VT DEC Laboratory and stored at -20 °C until processed. Fish filets were prepared in the laboratory on a glass cutting board using a stainless steel knife. A 2 to 4 inch fillet from each fish was homogenized in a tissue grinder. Chain pickerel and smallmouth bass fillets were analyzed with the skin removed and yellow perch, with the skin intact. The samples were then frozen until analysis. Section 2.4.2 (Mercury Preparation for Fish Tissue) and Section 2.5.8 (Mercury Determination in Fish Tissue) of Appendix A of the VT DEC Laboratory Quality Assurance Plan are the Standard Operating Procedures (SOP's).

Macrophytes

The littoral zone macrophyte community was semi-quantitatively surveyed for its species composition. Species were identified in the field or brought back to the laboratory for accurate identification. The Braun-Blanquet scale was used to determine semi-quantitative percent estimates of macrophyte cover, by species, for subsections of the littoral zone with similar species associations. The average percent cover was then calculated for the entire littoral zone. Macrophyte survey methods are outlined in Methods 4.3.1 (VT DEC 1989).

Phytoplankton

Phytoplankton was collected three times over the summer of 1996. The samples were depth-integrated hose samples collected at the stations marked on **Figure 1**. The hose was lowered to twice the depth of the secchi disk reading, or at least one meter above the bottom. A 100 ml sample was collected and preserved in Lugol's solution at 2.5 ml per 100 ml. At the end of the field season, the individual samples were composited into a representative whole-lake sample. Phytoplankton methods are outlined in Method 4.1.1 (VT DEC 1989).

Results and Discussion

Water Chemistry

The water chemistry of Wallingford Pond was sampled six times beginning on July 20, 1988. In comparison to other GMNF ponds, Wallingford Pond appears to have greater buffering capacity and has a higher alkalinity than most ponds. The Calcite Saturation Index (CSI) is computed from the pond's pH, alkalinity, and calcium levels and is used to determine a waterbody's sensitivity to acid deposition (Conroy et al. 1974). The mean of the five CSI's calculated for epilimnion samples between 1988 and 1996 is 3.42, a value that suggests this pond is sensitive to acidification. Many GMNF lakes including Little (Woodford), Bourn, Branch, Haystack and Moses Ponds are acidic with CSI's greater than 6.00. Clearly, many of the water bodies within the GMNF boundaries have been affected by both natural and anthropogenic acidification processes to a greater extent than Wallingford Pond (Kellogg et al. 1996). The mean alkalinity in the epilimnion is 4.80 mg/l $CaCO_3$, ranging from the minimum of 3.14 mg/l collected on May 23, 1996 to 6.27 mg/l collected on October 10, 1996. The alkalinities for most Vermont lakes show this seasonal pattern with increasing alkalinities as the open water season progresses. The spring snow melt from the watershed delivers a considerable acid load from the accumulated snow pack that depresses the lake pH, alkalinity and often the base cations especially the calcium ions. In time, these parameters recover and often achieve maximum values associated with the fall turn-over. This occurs when slightly more buffered hypolimnetic waters mix freely with less buffered epilimnetic surface waters.

The epilimnetic pH levels ranged from 6.53 to 7.01 and are near neutral. Levels of base cations suggest adequate buffering exists to prevent further acidification from occurring. This is verified by reviewing the CSI's which ranged from 3.21 to 3.94. These values are considered susceptible, but not imminently threatened by acidification.

Wallingford Pond is highly stained, resulting in a tea color due to dissolved organic humic matter. This humic matter originates from the breakdown of organic material of both terrestrial and aquatic origin. The carbonaceous material readily binds with inorganic monomeric aluminum (the most toxic form of aluminum) to form organic monomeric aluminum complexes, a considerably less toxic form of aluminum. The true color (TC) values are generally very high (75-161 Pt-Co units). Although the mean total aluminum concentration approaches 100 ug/l, aluminum toxicity is not considered a threat to the fish community due to aluminum's ability to bind with organic material rendering it less toxic.

Vermont Fish and Game historical records and a dissolved oxygen (DO) sample collected by VT DEC on August 12, 1996 suggests less than 1 ppm DO can be expected below 5 meters. This severe oxygen depletion occurs during the summer stratification period. The warm summer epilimnion temperatures and the low DO in the hypolimnion may preclude salmonids from inhabiting this pond. **Table 2** presents all water chemistry results collected to date by the VT DEC.

Table 2. Chemistry of Wallingford Pond (1988-1997)

Date	**07/20/88**	**05/23/96**	**08/13/96**	**08/13/96**	**09/17/96**	**10/10/96**	**06/11/97**	**MEANS ***
Type	KEMM	KEMM	KEMM	KEMM	KEMM	KEMM	KEMM	--
Depth m	--	0.5	1.0	7.0	1.0	1.0	1.0	--
Temp °C	25.0	16.6	20.5	7.3	16.0	9.5	20.5	--
Secchi m	2.3	2.1	1.9	1.9	2.0	2.0	--	2.0
pH Std. U	7.01	6.57	6.93	6.35	6.58	6.72	6.53	6.72
pH-field	6.84	6.58	6.61	6.49	6.67	--	6.70	6.68
Alk mg/l	4.51	3.14	5.15	9.88	5.75	6.27	4.00	4.80
Cond µs/cm	--	15.9	23.3	28.6	24.1	24.1	21.0	21.7
DC Pt-Co	--	75	140	161	114	--	--	110
TC Pt-Co.	30	65	>70	>70	>70	>70	--	--
DCL mg/l	--	0.30	0.23	0.33	0.28	0.33	--	0.29
DNO3 mg/l	--	<0.01	<0.02	<0.02	<0.02	<0.02	--	--
DSO4 mg/l	--	3.93	2.40	2.41	2.69	2.70	--	2.93
DCa mg/l	2.67	1.99	2.55	2.96	2.68	2.68	--	2.51
DMg mg/l	0.65	0.54	0.65	0.67	0.72	0.72	--	0.66
DNa mg/l	0.64	0.55	0.62	0.64	0.62	0.62	--	0.61
DK mg/l	0.47	0.33	0.20	0.41	0.34	0.32	--	0.33
DAl µg/l	--	104	105	140	74	82	--	91
DSi mg/l	--	2.58	--	--	--	--	--	2.58
CSI	3.21	3.94	3.25	3.48	3.33	3.36	--	3.42

*averages based on epilimnion samples only

Macroinvertebrates - Littoral Zone

In 1988, VT DEC conducted macroinvertebrate sampling at Wallingford Pond, documenting the presence of acid-sensitive species in the Crustacea, Mollusca, and Ephemeroptera orders from a single summer sampling event. In 1996, sampling was conducted seasonally and all taxa were collected from three littoral zone habitat types. The habitat samples were then processed separately allowing for a more detailed examination of preferred habitat for each taxon. The additional, more comprehensive sampling effort was conducted to provide a more complete taxa list as well as assess the effect of seasonality and habitat on the community composition. The community level biometrics are presented in **Tables 3-5** by habitat type and season. **Appendix 2** provides a complete taxa list of all the macroinvertebrates collected in 1988 and 1996 from the different habitats and by season. Clearly, the 1996 efforts were by far more successful in documenting not only the acid-sensitive species, but also producing a significantly more comprehensive taxa list.

The same two species of Crustacea were collected in 1988 and 1996. These were the scud *Hyalella azteca* and the crayfish *Orconectes virilis*. *H. azteca* was found to be common both years, while *O. virilis* was very rare in both years. *H. azteca* had been reported in 16 of 25 other low alkalinity lakes in Vermont (Fiske 1987), and is able to tolerate alkalinity as low as 1.0 mg/l, and pH levels as low as 5.18 (Levi Pond in Groton, VT.) It does not appear to be immediately threatened in Wallingford Pond with a mean alkalinity of 4.80, and pH of 6.68. *O. virilis* however is probably on the edge of its tolerance limit of pH and alkalinity, since it has only been found in waterbodies with much higher pH's and alkalinities (VT DEC monitoring data).

Mollusca taxa from the order Gastropoda were found in 1996 which were not found in 1988. All the additional taxa are small species that were probably overlooked in the 1988 collection. In 1996, samples were collected by rinsing and brushing debris or sweeping through muds and macrophyte beds. The small species found using this method of collection were *Ferrissia californica, Pseudosuccinea columella, Gyraulus parvus, Micromenetus dilatus,* and *Promenetus exacuous.* Two larger gastropods, *Helisoma anceps* and the introduced *Campeloma decisa,* were found both years. These species are near their pH and alkalinity limits in Wallingford Pond. Curiously, *C. decisa* has not spread throughout the pond since documented in 1988 and still is only found near the boat access in the west bay. This gastropod, though native to New England, is often found in the vicinity of boat access sites and is possibly introduced via boats.

Three Bivalvia species were found both years. Two fingernail clams *Pisidium sp.,* and *Musculium partumeium*, and the large mussel *Pyganodon cataracta*, the eastern floater. *Pisidium sp.* has been observed in many other low alkalinity/pH lakes in Vermont, and is able to tolerate pH's down to the lower 5's and alkalinities <1 mg/l (Fiske 1987). Both *M. partumeium,* and *P. cataracta*, however appear to be at the edge of their tolerance limits of pH and alkalinity. *M. partumeium* has not been recorded in a lower pH/alkalinity lake, and *P. cataracta* has not been found in lakes with pH's less then 6.5, or alkalinities less then 4.0 (VTDEC monitoring data).

The 1996 survey found six additional species of Ephemeroptera (mayfly), attributable to seasonal sampling. Of the mayfly taxa, most notable, primarily for their value as food for fish and intolerance to harsh environmental conditions, are *Hexagenia sp.* and *Arthroplea bipunctata*. Both species are sensitive to low D.O. and pH. The *Leptophlebidae* (mayfly) family seems to be the most tolerant of low pH and was found in 22 of 25 low alkalinity lakes down to a pH of 4.66 in Branch Pond (Fiske 1987) .

Table 3 compares the macroinvertebrate community metrics from the three littoral habitat types on a seasonal basis. Overall relative abundance was apparently highest in the rocky/woody debris in the summer. Taxa richness tended to be highest in the spring for all habitat types due to the collections of mature aquatic insect larvae and nymphs before their hatches. This is especially pronounced in the orders Ephemeroptera, Trichoptera, and Odonata. The macrophyte beds tended to have the fewest number of taxa in all seasons. The rocky/woody debris habitat tended to be the most taxa rich and consistent between seasons. The Ephemeroptera-Coleoptera-Trichoptera-Odonata (ECTO) taxa index was generally highest in the spring and lowest in the summer months. The number of Crustacea and Mollusca taxa was consistent across all habitats and seasons, with the exception of a low number of taxa found in the macrophyte beds during the summer sampling. The spring sample in the mud/sand habitat had the highest percent dominance and lowest Hilsenhoff's Bio Index (BI) value. The sample was dominated by a large proportion of Ephemeroptera (58%), specifically *Eurylophella bicolor* and *Leptophlebia sp.*.These two species have low tolerance values in calculating BI. This index is a measure of a communities' tolerance to organic enrichment. Since two species of tolerant Ephemeroptera dominated this site, a low BI resulted.

Table 3. Macroinvertebrate community metrics from three littoral zone habitats.

Habitat	Rocky / Woody Debris			Macrophyte Beds			Mud / Sand Bottom		
Season	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
Relative Abundance	377	1064	329	209	432	445	203	429	188
Richness	36	32	31	29	21	29	36	31	28
ECTO	13	7	12	10	6	12	17	11	9
Crustacea-Mollusca	4	4	5	4	1	3	5	5	6
%dominance	16	24	34	21	25	27	43	39	21
BI(0-10)	6.41	6.79	6.53	6.64	7.07	7.44	3.8	6.64	6.5

Table 4 compares the percent composition of the major groups from the three littoral zones on a seasonal basis. The Coleoptera reached their greatest percent composition in the macrophyte zone during the spring representing eight percent of the community. The order having the greatest percent composition in all seasons and habitats was the Diptera, reaching 70% in the mud/sand in the summer and was comprised chiefly of Chironomidae larvae. This only failed to be the case in the mud/sand zone during the spring when 58 percent of the community was Ephemeroptera resulting in a low BI and the high ECTO Index as observed in **Table 3**. The Ephemeroptera and the Crustacea tended to be the second most dominant orders

with the exception of the Oligochaeta during the summer and fall in the macrophyte zone. The remaining orders were consistently low in percent composition with the exception of the mollusca in the mud/sand habitat.

Table 4. Percent composition of major macroinvertebrate groups from three littoral zone habitats.

Habitat	Rocky / Woody Debris			Macrophyte Beds			Mud / Sand Bottom		
Season	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
Coleoptera	2	1	2	8	1	0	1	1	2
Diptera	50	47	30	47	63	24	20	70	54
Ephemeroptera	20	15	24	7	0	6	58	4	5
Trichoptera	4	3	6	9	8	11	7	1	4
Odonata	0.3	0	0.3	0.5	0	4	4	2	0
Crustacea	12	24	34	22	12	27	1	10	21
Mollusca	5.8	4	4	1	0	1	7	8	12
Oligocheata	3	4	0.3	0.5	12	24	0.5	2	2
Other	3	2	0	5	4	3	2	2	0

Table 5. Percent composition of macroinvertebrate functional groups from three littoral zone habitats.

Habitat	Rocky / Woody Debris			Macrophyte Beds			Mud / Sand Bottom		
Season	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
Collector-Gatherers	44	38	51	51	56	60	66	22	55
Collector-Filterers	21	10	6	2	1	0	4	44	18
Predators	12	28	20	28	39	15	20	22	19
Shredder-	2	2	2	1	1	1	2	0	0

Habitat	Rocky / Woody Debris			Macrophyte Beds			Mud / Sand Bottom		
Detritis									
Shredder-Herbivore	4	4	2	14	3	15	1	1	0
Scrapper	17	9	18	0.5	0	1	5	6	7

Table 5 compares the percent composition of the functional groups from the three littoral zones on a seasonal basis. The collector-gatherers (deposit feeders) were generally the most dominant in percent composition, regardless of the habitat or season, and ranged from 22 to 66 percent. The exception is the mud/sand habitat in the summer dominated by the collector-filterer group. Examples of collector-gatherers include many Diptera from the order Chironomidae, and *Hyalella azteca*. Predators were the second most dominant functional group and ranged from 12 to 39 percent and were represented by the Chironomidae, Coleoptera, Megaloptera, and Hirudinea. Shredder-herbivores were only important in the macrophyte beds indicating that filamentous algae were not a prevalent food source in the lake. The scraper functional group was important in the rocky/woody debris habitat across all seasons indicating that diatom type periphyton is an important food source in these areas. The rocky/woody debris habitat tended to have the most diverse representation of functional feeding groups in all seasons.

<u>Macroinvertebrates - Sublittoral and Profundal Zones</u>

The macroinvertebrate biometrics of density/m^2, taxa richness, BI, and percent dominance, along with percent composition of the functional groups and taxa are reported in **Table 6**. Densities ranged from 2850/m^2 in the profundal to 5050/m^2 in the sublittoral zone. Richness ranged from 3 in the profundal to 7 in the sublittoral zone. The BI was 7.16 in the profundal zone and 6.58 in the sublittoral zone. Both areas were dominated by *Chaoborus punctipennis* and to a lesser extent, the two Chironomidae *Zalutschia sp.* and *Chironomus sp.* These three species are considered relatively tolerant to low D.O. conditions. The richness declines from seven taxa in the sublittoral to three in the profundal, suggesting that the profundal zone is a more stressful environment than the sublittoral zone. This is indeed the case. Two D.O. vertical profiles were conducted at the deep hole in the south bay by VT Fish and Game in 1971 and VT DEC in 1996. Surface D.O.'s were 9 ppm, at 5 meters 0.55 ppm and at 7 meters only 0.05 ppm was reported. The functional group composition is representative of three dominant taxa. *C. punctipennis (predator)*, *Zalutschia sp.* (detritus-shredder), and *Chironomus sp.* (collector-gatherer).

Table 6. Percent composition of the functional groups and dominant species for the sublittoral and profundal zones.

Biometric	Sublittoral (4.2m)	Profundal (8.0m)
Density/m2	5,050	2,850
Richness	7	3
Bio Index	6.58	7.16
% Dominance	45	68
Diptera *Chaoborus punctipennis*	45	68
Chironomus sp.	11	7
Zalutschia sp.	39	24
Microtendipes sp.	1	0
Nanocladius sp.	1	0
Bivalvia *Pisidium sp.*	1	0
Oligocheata *Tubificidae unid*	2	0
% Collector-Gatherer	15	7
% Collector-Filterer	1	0
% Predator	46	68
% Shredder-Detritus	39	25

Fish Contaminants

Mercury levels from the four yellow perch samples ranged from 0.21 to 0.98 mg/kg wet weight (ww). The average mercury concentration from 241 yellow perch from 27 Vermont lakes is 0.32 mg/kg ww. Smallmouth bass and chain pickerel are among the species which accumulate mercury at the highest concentrations. Mean mercury levels for these two species from 13 Vermont lakes are 0.75 and 0.66 mg/kg ww respectively. The 5-fish composite for chain pickerel from Wallingford Pond had a mean concentration of 1.08 mg/kg ww. The single smallmouth bass sampled showed a concentration of 0.71 mg/kg ww (**Table 7**). These levels of mercury in fish suggest that further evaluation of the health risks associated with the consumption of fish from Wallingford Pond may be appropriate.

Table 7. Mercury levels in fish from Wallingford Pond.

Species	Date Collected	Number of Fish in Sample	Total Length (mm)	Mercury (mg/kg,ww)
Chain Pickerel	07/18/96	5	457	1.08
Smallmouth Bass	10/08/96	1	332	0.71
Yellow Perch	07/18/96	2	252	0.49
Yellow Perch	07/18/96	5	148	0.21
Yellow Perch	10/08/96	1	300	0.98
Yellow Perch	10/08/96	1	289	0.36

Macrophytes

Wallingford Pond supports a healthy and diverse plant population including some rare plants. *Potomageton epihydrous*, *Eleocharis* sp. and two *Scirpus* sp. were the most common plants throughout the lake. *Isoetes tuckermanii* (very rare-S1), *Littorella americana* (rare-S2), *Eleocharis ovata* (very rare-S1), *Eleocharis olivacea* (very rare-S1), *Myriophyllum alterniflorum* (rare-S2), and *Sparganium fluctuans* (rare-S2) are known historically from the pond. (Vermont Nongame and Natural Heritage Program 1992). Macrophyte sampling areas are shown in **Figure 1**. Species composition, abundance and the Braun-Blanquet Cover Index are presented in **Appendix 3.** The categories and associated Braun-Blanquet Values are presented in **Appendix 4.**

Phytoplankton

The total number/ml, percent density, biological volume and percent biological volumes are presented in **Appendix 5**. As indicated in the methods section, the numbers reported in **Appendix 5** represent a whole lake annual mean value. Analysis was conducted on a composite of samples collected at different locations on the lake on three dates over the open water season.

Density estimates are dominated by four taxa, which make up 70% of the total algal cell density: *Cryptomonas erosa*, *Oscillatoria tenuis*, *Rhodomonas minuta,* and an unidentified flagellated taxon.

Biovolume estimates are dominated by five taxa which make up 90% of the total volume: *Cryptomonas erosa*, *Oscillatoria tenuis*, *Peridinium cinctum*, *Cyclotella compta*, and G*lenodinium sp.*

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Appendix 1. Analytical Methods for the Wallingford Pond Assessment Study.

Parameter	Method/Equipment	Method Reference	Reference #
pH, field	Beckman 21 meter with temperature compensation. Sample placed in 30ml plastic beaker and analyzed.	U.S. EPA, 1983 Method 150.1	1
pH, lab (stirred)	Cole Palmer DigipHase meter, Ross combination electrode model 81-02.	U.S. EPA, 1983 Method 150.1	1
Gran Alkalinity	Titration with 0.020 N H_2SO_4 to pH 3.5, with a minimum of 17 points used for Gran plot calculation.	Pfeiffer and Festa, 1980	2
Conductivity	YSI model 32 with two cells, one for samples <20 µmhos, another for samples >20 µmhos.	U.S. EPA, 1983 Method 120.1	1
Cl^-, SO_4^{2-}, NO_3^-	Dionex Ion Chromatograph 2000 with integrator; manual injection, 3 to 6 calibration standards with an independent check sample run after every 10 samples.	Pfaff, Brockhoff and O'Dell U.S. EPA, 1989 Method 300.0	3
Ca, Mg, Na, K	Perkin Elmer 3030B; 5 calibration standards; acetylene flame for Mg, Na and K, nitrous oxide flame for Ca, 1 out of every 10 samples is a duplicate or spike. Lanthanum added to base cations.	U.S. EPA, 1983 Method 215.1 (Ca) Method 242.1 (Mg) Method 273.1 (Na) Method 258.1 (K)	1
Al, total dissolved	Perkin Elmer 3030B, Perkin Elmer 5100 PC and OHGA 600 furnace with autosampler.	U.S. EPA, 1983 Method 202.1	1
Color	True color is filtered through 0.45-µm filter and measured at 420 nm on a spectrophotometer. Bauch and Lomb Spectronic 100	Black & Christman, 1963.	4
	Apparent color is unfiltered and measured on a Taylor color comparator.	U.S. EPA, 1983 Method 110.2	1
Temperature	Cole-Parmer thermistor (Model 8402-00) with weighted cable.	APHA, 1992 Section 2550B	5
Secchi Disk Transparency	Secchi Disk with calibrated line.	U.S. EPA, 1989 Section 11.0	6

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Appendix 2. Macroinvertebrate taxa collected from Wallingford Pond. (The 1988 data was a composite of all littoral habitats from one sampling date.)

	1988	1996				
Habitat Type	Littoral	Rocky Littoral	Macrophyte Beds	Muddy Littoral	Sublittoral Zone	Profundal Zone
Coleoptera *Dubiraphia sp.*				*sum, fall*		
Scirtes sp.				*spr.*		
Macronychus glabratus	*sum*	*spr,sum,fall*		*spr*		
Stenelmis bicarinata	*sum*	*fall*				
Dineutus sp.	*sum*		*sum*			
horni			*spr*			
Gyrinus sp.	*sum*		*sum*	*sum*		
analis			*spr*			
Tropisternus sp.			*sum*			
Diptera *Probezzia sp.*				*fall*		
Bezzia sp.		*spr, fall*		*spr*		
Chaoborus punctipennis					*sum*	*sum*
Ablabesmyia sp.		*sum*	*spr, sum*	*spr, sum*		
Asheum sp.		*spr,sum,fall*	*spr., fall*			
Cladotanytarsus sp.		*spr.*		*fall*		
Clinotanypus sp.				*sum, fall*		
Corynoneura sp.		*spr.,sum*	*spr.*	*spr.*		
Cricotopus tremulus		*spr.*				
revesus		*spr.*				
sylvestris			*spr.*			
Cricotopus sp.		*sum.*	*spr,sum,fall*			
Chironomus sp.					*sum*	*sum*
Dicrotendipes sp.		*spr., sum*		*sum, fall*		
Endochironomus sp.	*sum*	*spr,sum,fall*	*spr,sum,fall*			
Glypotendipes sp.		*spr, fall*	*spr, fall*			

	1988	1996				
Habitat Type	Littoral	Rocky Littoral	Macrophyte Beds	Muddy Littoral	Sublittoral Zone	Profundal Zone
Diptera *Labrundinia sp.*			*sum*			
Microtendipes sp.		*fall*		*fall*	*sum*	
Nilotanypus sp.				*sum*		
Nanocladius sp.				*spr.*	*sum*	
Pagastia sp.				*fall*		
Parachironomus sp.		*fall*	*sum*			
Polypedilum sp.						
illionoense		*sum*		*spr., fall*		
convictum			*sum*			
Psectrocladius sp.		*spr.,sum*	*spr,sum,fall*	*spr,sum,fall*		
Pseudochironomus sp.		*spr,sum,fall*		*sum,fall*		
Procladius sp.		*spr.*	*sum,fall*	*spr.,sum*		
Pagastiella sp.				*sum*		
Paratanytarsus sp.		*sum*	*spr,sum*	*sum*		
Paratedipes sp.				*spr*		
Phaenopsectra sp.		*sum*		*spr*		
Synorthocladius sp.		*spr*				
Stempellina sp.		*fall*				
Stenochironomus sp.		*sum*				
Thienemannemyia sp.		*spr,sum,fall*	*spr,fall*	*spr,fall*		
Tanytarsus sp.		*spr,sum,fall*	*sum*	*sum,fall*		
Trichotanypus sp.				*fall*		
Zalutschia sp.				*spr*	*sum*	*sum*
Zavrelia sp.				*spr.,sum*		
Scathophagidae uid.			*fall*			
Tabanus sp.	*sum*					
Ephemeroptera *Baetidae imm.*	*sum*					

	1988	1996				
Habitat Type	Littoral	Rocky Littoral	Macrophyte Beds	Muddy Littoral	Sublittoral Zone	Profundal Zone
Arthroplea bicarinata			*spr*	*spr*		
Caenis sp.		*sum*	*spr.,fall*	*spr,sum,fall*		
Ephemerella sp.				*fall*		
Eurylophella sp.				*fall*		
temporalis			*fall*			
bicolor		*spr,fall*	*spr*	*spr*		
Hexagenia sp.				*spr,sum*		
Leptophlebiidae imm.		*sum*	*fall*	*sum,fall*		
Leptophlebia sp.		*spr,fall*		*spr*		
Heptageniidae imm.	*sum*	*sum,fall*				
Stenacron sp.	*sum*					
interpuctatum		*spr,sum,fall*		*spr*		
Trichoptera *Ceraclea sp.*		*spr*				
Cyrnellus sp.	*sum*	*spr,sum,fall*				
Helicopsyche borealis		*spr*				
Hydatophylax sp.		*fall*	*spr*			
Hydroptila sp.			*fall*			
Grammotaulis sp.				*spr*		
Lype sp.		*spr, fall*				
Limnephilus sp.			*fall*	*spr*		
Lepidostoma sp.			*sum*			
Mollana blenda	*sum*					
Mystacides sp.	*sum*	*spr,fall*		*spr,fall*		
Nectopsyche sp.		*spr*				
Oxyethira sp.			*sum,fall*	*fall*		
Oecetis sp.		*spr,fall*	*spr,fall*	*spr,sum*		
Phryganea sp.			*fall*			
Ptilostomis sp.		*sum*	*spr,fall*			

	1988	1996				
Habitat Type	Littoral	Rocky Littoral	Macrophyte Beds	Muddy Littoral	Sublittoral Zone	Profundal Zone
Polycentropus sp.		*spr,sum,fall*	*spr,sum,fall*			
Trichoptera *Psilotreta sp.*				*spr,fall*		
Phylocentropus sp.				*spr,sum,fall*		
Triaenodes sp.				*sum*		
Megaloptera *Nigronia sp.*	*sum*	*spr,sum*				
Sialis sp.				*sum*		
Neuroptera *Sisyra sp.*	*sum*					
Lepidoptera *Nymphula sp.*				*sum*		
Pyralidae uid.			*fall*			
Odonata *Anisoptera* *Arigomphus sp.*				*sum*		
Basiaeschna janata	*sum*					
Dromogomphus sp.				*sum*		
Epicordulia priceps	*sum*					
Gomphus sp.				*sum*		
Libellula sp	*sum*			*spr*		
Tetragoneuria sp.	*sum*	*spr, fall*				
Odonata Zygoptera *Coenagrionidae uid.*			*fall*	*spr*		
Ischnura sp.			*spr*	*spr*		
Lestes sp.			*fall*			
Hemiptera *Buenoa sp.*		*sum*	*sum*			
Notonecta sp.			*spr,sum,fall*			
Trepobates sp.			*sum*			
Trichorixa sp.	*sum*					
Amphipoda *Hyalella azteca*	*sum*	*spr,sum,fall*	*spr,sum,fall*	*spr,sum,fall*		
Decapoda *Orconectes virilis*	*sum*			*spr*		
Gastropoda *Campeloma decisa*	*sum*	*spr,sum*		*spr,sum,fall*		

	1988	1996				
Habitat Type	Littoral	Rocky Littoral	Macrophyte Beds	Muddy Littoral	Sublittoral Zone	Profundal Zone
Ferrissia californica		*fall*	*spr,fall*	*fall*		
Gyraulus parvus		*sum*		*spr*		
Gastropoda *Helisoma anceps*	*sum*			*sum*		
Micromenetus dilatus				*fall*		
Pseudosuccinea columella			*spr,fall*			
Promenetus exacuous		*fall*				
Bivalvia *Musculium partumeium*	*sum*	*sum,fall*	*spr*	*spr,fall*		
Musculium sp.		*spr*				
Pisidium punctatum		*spr.,fall*		*sum,fall*		
Pisidium sp.	*sum*				*sum*	
Pyganodon cataracta	*sum*			*sum*		
Oligocheata *Lumbriculidae uid.*		*sum*	*fall*			
Naididae uid.		*spr,sum,fall*	*spr,sum,fall*	*spr,sum,fall*		
Tubificidae uid.			*fall*		*sum*	
Hirudinea *Erpobdella punctata*		*spr,sum,fall*				
Helobdella stagnalis		*spr,fall*				
Macrobdella decora			*spr*	*sum*		
Mooreobdella fervida	*sum*					
Oligobdella biannulata		*sum*				
Placobdella ornata			*spr*			
Hydrachnidia *Arrenurus sp.*			*spr*			
Limnochares sp			*fall*			
Unionicola sp				*spr*		

Appendix 3. Macrophyte Abundance by Pond Area

Area	***Species***	***Abundance***	***Braun/Blanquet Cover Index***
4	Nymphoides sp.	Occasional	2
4	Scirpus sp.	Uncommon	0
4	Equisetum sp.	Uncommon	0
4	Eriocaulon sp.	Occasional	2
4	Eleocharis sp.	Uncommon	0
5	Sparganium angustifolium	Common	3
5	Potamogeton natans	Scattered	1
5	Potamogeton epihydrous	Common	3
5	Utricularia vulgaris	Uncommon	0
5	Nuphar sp.	Uncommon	0
5	Scirpus sp.	Common-Abundant	3.5
5	Scirpus sp.	Common-Abundant	3.5
6	Scirpus sp.	Scattered	1
6	Equisetum sp.	Occasional	2
6	Sagitarius latifolia	Solitary	0
7	Sparganium angustifolium	Common	3
7	Utricularia vulgaris	Common	3
7	Potamogeton epihydrous	Common-Abundant	3.5
7	Potamogeton natans	Abundant	4
7	Equisetum sp.	Occasional	2
7	Eleocharis sp.	Common-Abundant	3.5
7	Sparganium sp.	Common-Abundant	3.5
7	Scirpus sp.	Abundant	4
7	Utricularia minor	Scattered	1
7	Potamogeton pusillus	Scattered	1
7	Najas sp.	Scattered	1
7	Nuphar sp.	Uncommon	0
8	Eleocharis sp.	Common	3
8	Scirpus sp.	Common	3
8	Sagitaria latifolia	Common	3
8	Potamogeton epihydrous	Common	3
8	Sparganium angustifolium	Common	3
8	Equisetum sp.	Common	3
8	Nuphar	Uncommon	0
9	Scirpus sp.	Scattered	1
9	Scirpus sp.	Scattered	1

Area	Species	Abundance	Braun/Blanquet Cover Index
9	Sparganium angustifolium	Scattered	1
9	Potamogeton epihydrous	Scattered	1
9	Nuphar	Scattered	1
9	Glyceria borealis	Scattered	1
11	Scirpus sp.	Common	3
11	Potamogeton pusillus	Common	3
11	Isoetes sp.	Common	3
11	Nymphoides sp.	Common	3
12	Potamogeton natans	Common	3
12	Sparganium angustifolium	Occasional	2
12	Nuphar sp.	Uncommon	0
12	Najas sp.	Abundant	4
12	Utricularia vulgaris	Abundant	4
12	Potamogeton epihydrous	Abundant	4

Appendix 4. Braun/Blanquet Cover Index

% Cover	Category	Braun/Blanquet Value
<1	Uncommon (sparse)	0
<5	Scattered	1
5-25	Occasional	2
25-50	Common	3
50-75	Abundant	4
>75	Very Abundant	5

Appendix 5. Phytoplankton Metrics

Species	Density (#/ml)	% Density	BioVol (u^3/m^3)	% BioVol
Cryptomonas erosa	256.06	29.25	133152.40	41.82
Oscillatoria tenuis	140.42	16.04	83550.64	26.24
Rhodomonas minuta	115.64	13.21	2312.82	0.73
Unidentified flagellate	107.38	12.26	2147.62	0.67
Chromulina sp.	57.82	6.60	1156.41	0.36
Cyclotella sp.	33.04	3.77	4212.64	1.32
Cyclotella stelligera	33.04	3.77	2271.52	0.71
Chlamydomonas sp.	24.78	2.83	8053.57	2.53
Glenodinium sp.	24.78	2.83	17346.15	5.45
Ankistrodesmus falcatus	24.78	2.83	619.51	0.19
Ochromonas sp.	8.26	0.94	702.11	0.22
Pinnularia sp.	8.26	0.94	3304.03	1.04
Dinobryon sertularia	8.26	0.94	982.95	0.31
Peridinium cinctum	8.26	0.94	34692.31	10.90
Cyclotella comta	8.26	0.94	18750.37	5.89
Navicula capitata	8.26	0.94	3964.84	1.25
Sphaerocystis schroeteri	8.26	0.94	1156.41	0.36