

Biological Control of Eurasian Watermilfoil

Fourth Status Report for 2001-2004

BY

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TO

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Deliverable A-2. Report of results from 2002.

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Content: Processing and analysis of 2002 samples will be completed and the results will be summarized in a multi-page progress report that will be submitted to the MnDNR. Results from all data collected will be analyzed and interpreted.

Introduction

Eurasian watermilfoil (*Myriophyllum spicatum* L.) is an exotic aquatic weed that often interferes with recreation (Smith and Barko 1990), inhibits water flow, impedes navigation, (Grace and Wetzel 1978) and will displace other aquatic macrophytes (Madsen et al. 1991). It was first reported in Minnesota in 1987 and occurred in over 140 Minnesota waterbodies by fall 2002 (Exotic Species Program 2003).

Recent work on the biological control of Eurasian watermilfoil has focused on the indigenous milfoil weevil, *Euhrychiopsis lecontei* (Dietz) (= *Eubrychiopsis lecontei*). This work suggests that *E. lecontei* is the most promising control agent (Creed and Sheldon 1995, Sheldon and Creed 1995, Creed 1998, Newman and Biesboer 2000). The weevil is native to Minnesota and Wisconsin (Newman and Maher 1995, Jester et al. 1997) and is highly specific to watermilfoils (Solarz and Newman 2001). Sheldon and O'Bryan (1996), Newman et al. (1996, 1997), Mazzie et al. (1999) and Newman et al. (2001b) describe the life history and development times of the weevil.

Although declines of milfoil in several lakes have been related to the occurrence of *E. lecontei* (Sheldon and Creed 1995, Lillie 1996, Creed 1998, Newman and Biesboer 2000), it is clear that at many sites in Minnesota, weevil densities do not get high enough to effect control (Newman et al. 1996, Newman et al. 1998, Newman and Biesboer 2000). Fish predation may be one factor limiting populations in some lakes (Sutter and Newman 1997, Newman and Biesboer 2000, Ward 2002). Identification and amelioration of factors limiting the milfoil weevil is essential for operational biological control of Eurasian watermilfoil (Newman et al. 1998). Getsinger et al. (2002) provide a good overview of the potential use of the weevil for control of milfoil.

The aim of this project is to attempt to detect milfoil declines and assess milfoil weevil populations, identify and manipulate factors that may be limiting control agent densities and identify and manipulate factors that may limit the effectiveness of milfoil control agents (plant community response). This report summarizes our methods and results through 2002.

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Methods

Semi-permanent Transect Sites:

During the summers of 1993 and 1994, we initiated selection of semi-permanent sampling sites, which can be repeatedly sampled at fixed locations (Newman and Ragsdale 1995). The sites were Lake Auburn (Carver Co.; T116N; R24W; S10), Otter Lake (Anoka and Ramsey Co.; T30-31N; R22W; S3-4, S35-36), Cedar Lake (Hennepin Co.; T29N; R24W; S29) and Smith's Bay of Lake Minnetonka (Hennepin Co.; T117N; R23W; S10,11). At each site, 5 transects, 30 m apart, were run from near shore (0.5 m depth) toward the plant limit. At Lake Auburn and Cedar Lake, the transects extended to 50 m from the shoreward starting point, in approximately 2.5 m depth at Auburn and 5 m depth in Cedar. Semipermanent stations were marked along the transect at 10 m intervals with fluorescent floats that were attached to bricks and suspended 0.5-1m beneath the surface. At Otter Lake, the transects were extended 100 m from shore, in approximately 2 m depth. At Smith's Bay, transects were started 100 m from shore and run to 4.5 m depth, approximately 0.8 km from shore, with 5 sampling stations along each transect approximately geometrically spaced. Distances from shore determined from GPS data were: 100m, 200m, 370m, 585m and 805m. These stations were marked with floating milfoil buoys.

In summer 1996, we noticed a dense population of weevils at Cenaiko Lake (Anoka Co.; T31N; R24W; S26). We therefore sampled this lake in July and September as a new site to be regularly sampled. We ran 3 or 4 transects, west to east across the north end of the lake, with sampling stations every 30 m. This resulted in 25-32 samples on each date (21-30 with plants; deep stations were deleted from the analysis). At Lake Auburn transects were sampled at 10 m intervals (stations), resulting in 6 samples per transect, or 30 samples. At Otter Lake samples were taken at each 20m sampling station, resulting in 5-6 samples per transect or 27 samples. At Cedar (30) and Smiths Bay (25), all stations were sampled, however, several stations in Cedar Lake were deeper than the plant limit (>7m) and these are excluded if no plants occurred there during the season. In 1997 sampling occurred twice: in late June to early July and in mid-September. In 1998, three lakes (Auburn, Cenaiko and Smith's Bay) were sampled thrice, in June, late-July or early August and in September. Otter and Cedar were sampled in June and September. Samples were alternately taken 2m from each side of each station on successive sampling dates to minimize sampling disturbance. In 1999, two lakes (Cenaiko, and Smith's Bay) were sampled thrice, in June, late-July or early August and in late August. Auburn and Cedar were sampled in June and late August and Otter was sampled in June and early August. In 2000, four lakes were sampled three times (Auburn, Cenaiko, Otter and Smith's Bay), in June, July and August and Cedar Lake was sampled twice, in June and August. Twenty-four to thirty samples were collected at each lake on each date. In 2001, four lakes (Auburn, Cenaiko, Otter and Smith's Bay) were sampled three times, in June, late July and late August. Cedar was sampled in June and August. In 2002 all 5 lakes were sampled twice, in early (late June or early July) and late (late August or early September) summer. Twenty to thirty samples were collected at each lake on each date.

At each sampling station, plant biomass and invertebrate samples were taken from 0.1 m² quadrats (all plant material was clipped at sediment interface and immediately placed in a sealable bag underwater). Sediment cores were also collected at shallow, medium and deep stations along 3 transects at each site.

A set of water column parameters were measured in the open water (>5.5m depth and >100 m from the bed) at each site on each sampling date. Secchi depth and surface conductivity were measured and a water sample (combined surface and Secchi depth sample) was collected for pH, alkalinity and chlorophyll a determination. A light (Photosynthetically Active Radiation = PAR, Li-Cor LI-189 with LI-192SA quantum sensor), temperature and oxygen (YSI 50B) profile was taken at 0.5 m depth increments from surface to bottom.

Alkalinity was determined by titration. For chlorophyll, 500 ml of water were filtered through a 1.2 mm glass fiber filter, the filter was placed on dry ice and returned to the laboratory and frozen until analysis. Chlorophyll was extracted with buffered acetone and measured spectrophotometrically (APHA 1989). Sediment cores were stored on ice and returned to the laboratory. Within 48 hr the top 15 cm of sediment was homogenized. A 5 ml sediment subsample was dried at 105 °C for 24-48 hrs and then weighed to obtain bulk density (g dry mass ml⁻¹). The dried sediment was then ashed at 550 °C for 4 hrs to obtain percent organic matter ([AFDM dry mass⁻¹] X 100). Pore water was extracted from the remaining sediment by centrifugation, acidified to < pH 2 and stored in the refrigerator. In 2001 and 2002 we further extracted the spun sediment with 2M KCl (shaken for 1 hr) to determine exchangeable nitrogen. The remaining spun sediment was either processed immediately or was frozen for later analysis. The extract was filtered and acidified. Within seven days, the NH₃ concentration was determined for both pore water and KCl extracted fractions by selective electrode (APHA, 1989). These results should allow us to evaluate McComas's (1999) hypothesis that nuisance levels of milfoil should only appear in sediments with high total nitrogen (e.g., > 3 mgN/L), whereas native plants should dominate in lower nitrogen sediments.

Biomass samples were rinsed of invertebrates and invertebrates were picked (endophytic and external on milfoil and from the wash water) from all samples; weevils and Lepidoptera were enumerated. Milfoil stems were counted and the average maximum stem length

determined. Plants were separated, identified to species, spun for 15 sec in a salad spinner and wet mass was recorded. These samples were dried (105 °C for 48h) and weighed or were frozen for later dry mass determination.

Because the relatively infrequent sampling of these sites (2 or 3 times per summer) does not provide very good resolution of weevil population dynamics, we initiated a biweekly weevil survey in Lake Auburn 1998 and in 1999 added Cenaiko and Smiths Bay to our weevil surveys. In 2000 we added Otter to our survey sites and we conducted bi-weekly surveys at Auburn, Cenaiko, Otter and Smith's Bay in 2000, 2001 and 2002. For each survey, 5-8 stems (top 50 cm) of milfoil were collected at each of 15-18 stations every other week (at Cenaiko we often were unable to find milfoil at some stations). At sites with lower densities of weevils we have been collecting 7 or 8 stems to increase our power to detect weevils. Weevils and lepidoptera were removed from the samples, which were scanned at 8X magnification, and enumerated by life stage. Results were expressed as numbers per basal stem. Single weevil surveys were also conducted during 2002 in Bald Eagle (Ramsey Co.), Calhoun, Cedar, Centerville (Anoka Co.), Independence (Hennepin Co.), Peltier (Anoka Co.), Schultz (Dakota Co.) and Vadnais (Ramsey Co.) to correlate weevil density with fish density (see below).

Survey Sites:

In 2001 and previous years, we conducted broader scale (whole lake or bay) surveys of plants in August at 5 sites: Lake Calhoun Hennepin Co.; T28-29N; R24W; S4,5,32,33), Lake Harriet (Hennepin Co.; T28N; R24W; S8,9,16,17), Lake of the Isles (Hennepin Co.; T29N; R24W; S32,33) and Shady Island (Hennepin Co.; T117N; R23W; S26) and Grays Bay (Hennepin Co.; T117N; R22W; S8) in Lake Minnetonka. In 2002 we sampled Calhoun, Cedar, Harriet and Isles, plus Centerville, Schultz and Vadnais. Weevil surveys were conducted on all of the lakes (except Isles, which had little milfoil by August) in 2002 to relate weevil density to sunfish abundance (see below). At each lake, plant community structure was determined with plant hook surveys along 5-15 transects and water quality was recorded. .

To quantitatively determine the extent of milfoil coverage, a set of 5-15 transects, perpendicular to shore, was located around the lake or bay in a stratified random manner (i.e., 1 transect located within each 1/10 of the lake shoreline circumference) in August. Along each transect, observations were made from shore (0.5 m depth) to the plant limit at 5 to 6 stations, at 7.5, 15, 30, 60, or 90m intervals to the depth of the plant limit. At steeper transects the shorter intervals were used, at long and gently sloping transects, the longer intervals were used. Transects were laid with a measuring rope and marked with jugs attached to bricks; the shoreward and offshore positions were recorded with a GPS unit. At each observation point, visible milfoil (% coverage) and other plant occurrence was recorded, plant height determined and plant disk (depth at which a Secchi disk disappears; Crowell et al. 1994) was measured within a 1m² area around the marker jug. Depth was recorded by dropping a plant hook vertically; plant species found on the plant hook or the jug rope and brick were also recorded and milfoil was examined for weevils and given a weevil damage rating (0-5). These data provide an estimate of milfoil and other plant coverage and frequency of occurrence around the lake as well as a relative estimate of weevil damage or occurrence.

Semi-quantitative estimates of plant density and weevil abundance were determined along a stratified subset of 5 of the transects with modification of a grapple hook method of Jessen and Lound (1962). At each sampling point 3 or 4 grapple throws were collected and rated for plant occurrence and density on a scale of 0-5 (Jessen and Lound 1962); these data provide species occurrence and relative density estimates for each species. The milfoil collected on each throw was scanned for the presence of weevils and visually assigned a damage rating (0-5). Thus for these 5 transects, we have both visual estimates of plant occurrence and density as well as the semiquantitative plant hook estimates.

Localized sites at Calhoun, Harriet and Isles were sampled quantitatively for milfoil, invertebrates and site characteristics in 2001 and 2002. At Calhoun, Lake of the Isles and Harriet, 5 transects with 5 stations on each transect were sampled twice in 2001 (June and August) and once in 2002 (August). At each station 0.1m² quadrat samples were taken for

plants and invertebrates. Sediment cores were sampled at the intermediate depth station along each transect. Open-water water quality samples were taken and processed in the same manner as the permanent transect sites. Samples were processed as above for plant mass by species, weevil abundance, and sediment characteristics.

Relationship of Weevil and Sunfish Densities:

Because previous research suggested that high sunfish densities were limiting weevil populations, we selected a set of lakes for which recent DNR fish population assessment were conducted and conducted single weevil surveys in late July or August. These lakes were Bald Eagle (Ramsey Co.), Calhoun, Cedar, Centerville (Anoka Co.), Independence (Hennepin Co.), Peltier (Anoka Co.), Schultz (Dakota Co.) and Vadnais (Ramsey Co.). At each lake, 5 transects were established around the lake and 4 stations (from shore to deep edge of the bed) on each transect were sampled for herbivores by collecting 8 milfoil stems (top 50 cm). These plants were processed and herbivores enumerated as done for other weevil surveys. At five of these lakes we also conducted plant community surveys (see above) to see if declines in milfoil were related to weevil or sunfish density.

The DNR fisheries survey results for trapnet catches of all sunfish (bluegill, pumpkinseed, bluegill X pumpkinseed hybrids and green sunfish) were used to estimate relative sunfish density (mean catch per overnight trapnet set). Most fisheries assessments were conducted in 2002, but assessments on Independence and Vadnais were conducted in 2001 and Calhoun and Cedar in 2000. Regression of our single-sample summer weevil density estimates with sunfish abundance was used to determine if there is an among-lake relationship of weevil density with sunfish density. To increase sample size, we also obtained DNR fisheries population assessments for the lakes on which we have been conducting regular bi-weekly weevil surveys. Fisheries assessments were available for Auburn in 2000, Cenaiko in 1998 and 2002 and Otter in 2001 and 2002. For these lakes we used average summer weevil densities for the year in which the fisheries assessment was conducted.

Weevil Introduction/Manipulation:

Previously we conducted small scale augmentations in caged fish enclosures and enclosures (Ward 2002). To provide a more realistic assessment of the feasibility of stocking or augmenting weevil populations we stocked weevils into two lakes with low weevil populations and different sunfish densities in 2002: Harriet and Hiawatha. Based on prior DNR fisheries assessments, Harriet was considered a high sunfish lake (340/trapnet) and Hiawatha a low sunfish lake (11/trapnet). An herbivore (weevil) stem survey (5 transects, 4 stations) was conducted prior to stocking to determine weevil abundance (no weevils were found in these surveys).

In mid-July, two contiguous plots were chosen in each lake and plant biomass and herbivore densities were determined with quantitative 0.1 m² quadrat samples from 4 stations (shallow to deep) on three transects in each plot (12 samples per plot). Adult weevils and associated meristems (including eggs and larvae) were collected from Otter Lake and 2000 adult weevils were stocked into one randomly selected plot in each lake. Biweekly weevil (herbivore) stem surveys (12 stations per plot) were conducted to monitor weevil populations and in mid-September, 12 quadrat samples were collected from each plot to determine plant biomass and areal herbivore densities.

Effects of plant community:

To test the hypothesis that plant competition may be important in the reestablishment of Eurasian watermilfoil after a decline (or reduction due to weevil damage) we established plots in Otter Lake (good water clarity and healthy native plant community) and in Lake Auburn (poor water clarity with community dominated by Eurasian watermilfoil and coontail) for plant

community manipulation experiments. Initial experiments were conducted in 1998-1999.

We established a new set of plant manipulation plots in Otter Lake and Lake Auburn in 2001 and in Cedar (good clarity but low diversity) in 2002. At each lake we established 20 plots marked by 2m x 2m PVC quadrats. The plots were sampled in early June for plant biomass (2 0.1-m² quadrat samples per plot) prior to manipulation. After initial sampling, the randomly assigned manipulation was applied to the plot by divers using SCUBA who manually removed vegetation within the area delineated by the 2x2 PVC quadrat. Harvested vegetation was not retained but allowed to float away. In five plots no plants were removed, in 5 plots all plants were removed and in the other plots either all native plants or all Eurasian watermilfoil was removed. Several times each summer, visual surveys (means of 16 0.5x0.5 cells) of plant coverage were conducted and in September, two biomass samples were taken from each plot. Otter Lake and Lake Auburn were re-sampled for biomass in June and September 2002 and visual surveys were conducted several times during the summer to further follow community changes. The duplicate biomass samples within plots were averaged and statistical analyses were conducted on the replicate plots. We also collected sediment cores from each plot in Otter Lake in September 2001 and 2002 and from each plot in Cedar and Auburn in September 2002.

Results and Discussion

Semi-permanent transect sites:

Milfoil biomass in Cedar Lake remained high during 2002, similar to 1997-2001 (Table 1). Milfoil biomass at Lake Auburn continued to increase from the low densities of 1998-1999 (Fig. 1) to around 1800 g wet/m² (250 g dry) during 2002. Nevertheless, milfoil remained below the very high densities found from 1995-1997.

Milfoil in Smith's Bay started at a moderate density in June 2002 (137 g/m² dry), but increased to a relatively high density of 250 g dry/m² by August, the highest density since 1998 (Fig. 1, Table 1). The higher milfoil density was mainly due to high densities at the deepest three stations (>200 g dry/m²); density at the two shallowest stations remained low even in August. Milfoil remained suppressed at Otter Lake with a peak of 28 g dry/m² in June declining to 13 g/m² in August. This was a continuation of the decline and suppression that started after June 2000 when milfoil biomass was 330 g dry/m². This three-year decline is clearly associated with weevils (see below). Changes in milfoil biomass at our sites (Fig. 1) are not due to regional changes; there was little concordance among the sites.

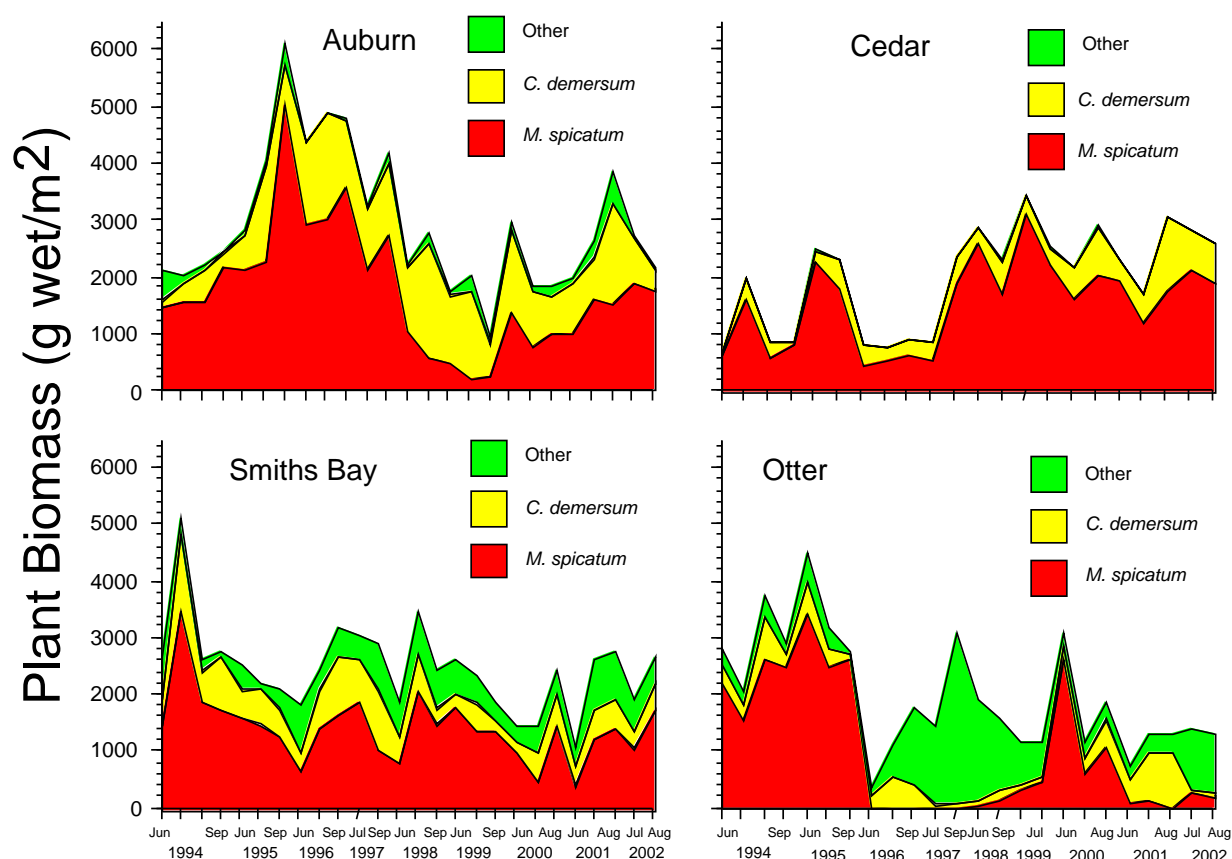


Fig. 1. Total plant biomass (Eurasian watermilfoil, coontail and other non-milfoil biomass; g wet/m²) at the four permanent transect sites from May 1994 - August 2002.

Non-milfoil biomass was generally lower at all lakes in 2002, with the exception of Otter Lake (Table 2). The contribution of the non-milfoil plant community remained low at Cedar Lake and declined at Lake Auburn; Eurasian watermilfoil contributed 63 to 76% of the biomass at Auburn and Cedar (Table 3). Native plant biomass also decreased somewhat at Smith's Bay and Eurasian watermilfoil composed 44-52% of plant biomass, an increase from 2001 but still much less than 1998-1999. With the continued suppression of milfoil at Otter Lake, its contribution was steady at 26% of plant biomass, an increase from 2001 but much lower than 1999-2000. Eurasian watermilfoil biomass remained high at Cedar Lake and contributed 65% of the plant biomass there and coontail composed over 90% of the non-milfoil biomass. Coontail was also the dominant native plant at Lake Auburn. It should be noted that as in previous years, at the shallowest station at Smith's Bay, northern watermilfoil was common and native plants dominated the Eurasian watermilfoil which composed <10% of total dry plant mass. The total number of species in each lake remained moderate in Auburn (6 in June and August) and low at Cedar (2-4 species) and remained relatively high at Smith's Bay (11 species); the number of species increased at Otter with the continued milfoil suppression to 13-16 species (Table 3). Similar trends were seen for numbers of species per sample with 3 or more per sample at Otter and Smith's Bay, 2.2-2.3 at Auburn and < 2 per sample at Cedar Lake (Table 2).

Table 1. Biomass \pm 1SE (g wet/m²) of Eurasian watermilfoil at the four sampling sites in 1994-2002. n = number of samples. Dry biomass (g/m² \pm 1SE) is presented for 1995-2002.

Sampling Date	Auburn	n	Cedar	n	Otter	n	Smith's Bay	n
5/19-6/3/94	1474 \pm 326	10	610 \pm 289	18	2208 \pm 332	21	1470 \pm 320	14
7/1-7/11/94	1570 \pm 297	16	1642 \pm 523	18	1589 \pm 231	27	3478 \pm 399	16
8/12-8/19/94	1581 \pm 224	15	601 \pm 207	15	2626 \pm 472	14	1886 \pm 328	16
9/14-9/21/94	2205 \pm 350	19	824 \pm 188	24	2510 \pm 557	9	1767 \pm 386	14
6/07-6/27/95	1999 \pm 324	30	2307 \pm 631	23	3444 \pm 336	27	1618 \pm 289	25
dry	280 \pm 43		245 \pm 67		312 \pm 33		158 \pm 28	
7/31-8/15/95	2277 \pm 417	19	1821 \pm 797	10	2526 \pm 385	15	1481 \pm 245	25
dry	267 \pm 46		172 \pm 79		171 \pm 29		149 \pm 28	
9/18-9/29/95	5044 \pm 752	17	479 \pm 173	17	2629 \pm 323	18	1281 \pm 178	25
dry	551 \pm 94		37 \pm 13		194 \pm 23		113 \pm 15	
6/12-6/24/96	2959 \pm 402	30	568 \pm 200	30	21 \pm 8	27	665 \pm 144	25
dry	306 \pm 40		59 \pm 24		2 \pm 1		46 \pm 10	
7/30-8/9/96	3035 \pm 619	27	665 \pm 219	30	1 \pm 1	27	1415 \pm 256	25
dry	390 \pm 82		62 \pm 20		0 \pm 0		176 \pm 36	
9/12-9/19/96	3622 \pm 469	30	574 \pm 174	30	0 \pm 0	27	1656 \pm 393	25
dry	361 \pm 49		50 \pm 14		0 \pm 0		156 \pm 40	
6/27-7/17/97	2134 \pm 321	30	1906 \pm 341	28	24 \pm 22	26	1880 \pm 327	25
dry	294 \pm 46		210 \pm 40		3 \pm 3		296 \pm 55	
9/8-9/18/97	2786 \pm 400	30	2646 \pm 502	29	4 \pm 4	27	1055 \pm 170	25
dry	321 \pm 49		271 \pm 55		0 \pm 0		100 \pm 18	
6/8-6/18/98	1080 \pm 168	30	1690 \pm 360	31	79 \pm 52	27	815 \pm 164	25
dry	130 \pm 18	30	213 \pm 52	31	7 \pm 4	27	105 \pm 21	25
7/27-8/3/98	581 \pm 133	30					2103 \pm 475	25
dry	67 \pm 16	30					286 \pm 65	25
9/8-9/16/98	530 \pm 76	30	3146 \pm 514	29	181 \pm 44	27	1487 \pm 338	25
dry	48 \pm 7	30	367 \pm 63	29	15 \pm 4	27	172 \pm 40	25
6/15-6/22/99	202 \pm 50	30	2238 \pm 393	28	355 \pm 113	27	1806 \pm 289	25
dry	24 \pm 7	30	252 \pm 50	28	25 \pm 8	27	155 \pm 32	25
7/29-8/3/99					483 \pm 101	27	1358 \pm 289	25
dry					36 \pm 8	27	189 \pm 44	25
8/23-8/25/99	253 \pm 83	30	1632 \pm 237	30			1362 \pm 320	25
dry	25 \pm 9	30	105 \pm 15	30			106 \pm 26	25
6/6-6/23/00	1392 \pm 263	30	2045 \pm 321	29	2652 \pm 340	27	981 \pm 318	25
dry	208 \pm 39	30	219 \pm 38	29	331 \pm 42	27	109 \pm 37	25
7/11-7/19/00	783 \pm 200	30			607 \pm 82	27	501 \pm 150	25
dry	115 \pm 32	30			45 \pm 7	27	77 \pm 22	25
8/23-8/29/00	1007 \pm 152	30	1988 \pm 305	29	1098 \pm 136	27	1474 \pm 346	25
dry	91 \pm 14	30	175 \pm 28	29	90 \pm 14	27	162 \pm 40	25
6/18-6/25/01	1022 \pm 199	30	1213 \pm 267	29	116 \pm 34	27	408 \pm 107	25
dry	109 \pm 21	30	111 \pm 26	29	9 \pm 3	27	31 \pm 8	25
7/17-7/30/01	1641 \pm 279	30			138 \pm 58	25	1211 \pm 290	25
dry	232 \pm 45	30			6 \pm 3	27	168 \pm 43	25
8/23-8/30/01	1549 \pm 289	30	1798 \pm 398	25	24 \pm 11	27	1438 \pm 381	25
dry	158 \pm 33	30	162 \pm 41	25	2 \pm 1	27	160 \pm 43	25
6/2-7/8/02	1886 \pm 339	30	2123 \pm 468	21	302 \pm 87	30	1067 \pm 245	25
dry	254 \pm 46	30	231 \pm 52	21	28 \pm 7	30	137 \pm 36	25
8/8-9/6/02	1776 \pm 273	30	1910 \pm 294	32	205 \pm 49	30	1746 \pm 346	25
dry	222 \pm 37	30	149 \pm 23	32	13 \pm 3	30	246 \pm 47	25

Table 2. Mean number of species per sample (Spp/S) \pm 1SE and non-milfoil biomass (B; g wet/m²) at the 4 sampling sites in 1994-2002. Number of samples is given in Table 1.

Sampling Date	Auburn		Cedar		Otter		Smith's Bay	
	Spp/S	B	Spp/S	B	Spp/S	B	Spp/S	B
5/19-6/3/94	3.80 \pm 0.47	670	1.33 \pm 0.28	75	4.76 \pm 0.19	600	3.29 \pm 0.22	1231
7/1-7/11/94	3.63 \pm 0.29	444	1.83 \pm 0.28	370	4.37 \pm 0.29	520	3.75 \pm 0.35	1604
8/12-8/19/94	3.00 \pm 0.28	647	1.53 \pm 0.26	282	5.57 \pm 0.39	1126	3.13 \pm 0.42	765
9/14-9/21/94	3.11 \pm 0.37	268	1.46 \pm 0.19	54	4.89 \pm 0.61	431	3.50 \pm 0.39	975
6/07-6/27/95	2.23 \pm 0.22	822	1.43 \pm 0.20	214	4.70 \pm 0.21	1065	3.64 \pm 0.30	877
7/31-8/15/95	3.37 \pm 0.26	1789	1.70 \pm 0.15	516	4.27 \pm 0.30	642	2.68 \pm 0.24	703
9/18-9/29/95	2.18 \pm 0.18	1058	1.41 \pm 0.17	337	2.44 \pm 0.34	135	2.80 \pm 0.20	856
6/12-6/24/96	2.93 \pm 0.24	1450	2.10 \pm 0.22	248	5.19 \pm 0.25	434	4.32 \pm 0.36	1159
7/30-8/9/96	2.78 \pm 0.31	1186	1.43 \pm 0.18	270	4.19 \pm 0.20	1171	3.88 \pm 0.41	1017
9/12-9/19/96	2.50 \pm 0.20	1166	1.57 \pm 0.16	307	3.93 \pm 0.28	1798	3.88 \pm 0.32	1531
6/27-7/17/97	2.97 \pm 0.14	1435	1.82 \pm 0.14	460	4.31 \pm 0.29	1516	4.16 \pm 0.39	1162
9/8-9/18/97	2.63 \pm 0.17	1500	1.59 \pm 0.09	235	4.81 \pm 0.26	3180	3.64 \pm 0.27	1863
6/8-6/18/98	2.43 \pm 0.18	1158	1.74 \pm 0.81	637	5.37 \pm 0.24	1835	5.32 \pm 0.43	1038
7/27-8/3/98	2.97 \pm 0.23	2197					5.00 \pm 0.44	1385
9/8-9/16/98	2.40 \pm 0.12	1258	1.62 \pm 0.12	296	4.74 \pm 0.39	1423	4.32 \pm 0.38	969
6/15-6/22/99	3.07 \pm 0.16	1806	1.86 \pm 0.13	326	4.52 \pm 0.31	825	4.60 \pm 0.37	810
7/29-8/3/99					5.33 \pm 0.30	720	3.72 \pm 0.31	973
8/23-8/25/99	1.93 \pm 0.13	679	1.37 \pm 0.09	570			2.92 \pm 0.33	534
6/6-6/23/00	3.17 \pm 0.19	1597	1.62 \pm 0.10	919	4.33 \pm 0.28	471	3.44 \pm 0.39	458
7/11-7/19/00	2.70 \pm 0.20	1090			4.59 \pm 0.24	595	4.48 \pm 0.45	949
8/23-8/29/00	2.30 \pm 0.12	852	1.62 \pm 0.10	354	4.33 \pm 0.21	778	4.00 \pm 0.36	979
6/18-6/25/01	2.77 \pm 0.21	971	1.52 \pm 0.11	495	4.44 \pm 0.23	628	4.00 \pm 0.35	663
7/17/-7/30/01	2.40 \pm 0.11	996			3.04 \pm 0.24	1189	3.96 \pm 0.32	1387
8/23-8/30/01	2.80 \pm 0.16	2314	1.80 \pm 0.08	1303	3.81 \pm 0.27	1293	3.60 \pm 0.28	1342
6/2-7/8/02	2.17 \pm 0.11	861	1.67 \pm 0.11	738	3.53 \pm 0.26	1128	3.28 \pm 0.26	858
8/8-9/6/02	2.30 \pm 0.14	398	1.53 \pm 0.12	709	4.53 \pm 0.25	1094	3.12 \pm 0.19	928

Table 3. Percentages of total plant wet biomass that was Eurasian watermilfoil (± 1 SE) and total number of species (N) collected at each site. These are the average percentage found in the samples and are thus not equal to total mean milfoil biomass/plant biomass.

Sampling Date	Auburn	N	Cedar	N	Otter	N	Smith's Bay	N
5/19-6/3/94	65% \pm 10%	9	67% \pm 11%	4	80% \pm 6%	9	64% \pm 10%	8
7/1-7/11/94	79% \pm 6%	9	67% \pm 9%	4	75% \pm 5%	9	72% \pm 6%	11
8/12-8/19/94	74% \pm 6%	9	61% \pm 13%	3	75% \pm 6%	11	81% \pm 5%	11
9/14-9/21/94	91% \pm 6%	9	87% \pm 5%	4	83% \pm 6%	11	71% \pm 8%	9
6/07-6/27/95	72% \pm 7%	7	82% \pm 7%	3	79% \pm 4%	9	61% \pm 5%	10
7/31-8/15/95	58% \pm 7%	7	58% \pm 6%	2	80% \pm 7%	9	63% \pm 6%	11
9/18-9/29/95	81% \pm 7%	5	38% \pm 5%	2	95% \pm 1%	6	63% \pm 7%	10
6/12-6/24/96	70% \pm 7%	7	57% \pm 7%	5	7% \pm 5%	9	33% \pm 6%	10
7/30-8/9/96	56% \pm 8%	7	59% \pm 9%	5	0.1% \pm 0.1%	10	56% \pm 7%	11
9/12-9/19/96	69% \pm 6%	8	73% \pm 6%	4	0% \pm 0%	9	49% \pm 7%	10
6/27-7/17/97	53% \pm 13%	10	82% \pm 9%	3	1.2% \pm 2.3%	12	54% \pm 14%	12
9/8-9/18/97	60% \pm 13%	8	88% \pm 9%	2	0.2% \pm 0.3%	13	40% \pm 14%	11
6/8-6/18/98	42% \pm 5%	11	79% \pm 5%	4	4% \pm 2%	15	37% \pm 6%	15
7/27-8/3/98	24% \pm 4%	12					49% \pm 8%	16
9/8-9/16/98	34% \pm 4%	7	82% \pm 6%	4	20% \pm 5%	13	50% \pm 8%	13
6/15-6/22/99	14% \pm 4%	7	82% \pm 6%	3	30% \pm 6%	13	61% \pm 7%	12
7/29-8/3/99					40% \pm 5%	14	53% \pm 8%	13
8/23-8/25/99	36% \pm 7%	6	85% \pm 6%	2			61% \pm 8%	12
6/6-6/23/00	43% \pm 6%	9	75% \pm 7%	5	81% \pm 5%	12	49% \pm 9%	13
7/11-7/19/00	37% \pm 6%	9			53% \pm 4%	15	40% \pm 8%	15
8/23-8/29/00	55% \pm 6%	6	77% \pm 6%	3	63% \pm 5%	9	50% \pm 8%	13
6/18-6/25/01	52% \pm 6%	10	77% \pm 6%	2	20% \pm 5%	15	35% \pm 8%	14
7/17-7/30/01	56% \pm 6%	5			9% \pm 4%	11	42% \pm 7%	14
8/23-8/30/01	40% \pm 6%	5	59% \pm 8%	2	5% \pm 3%	12	42% \pm 8%	12
6/2-7/8/02	65% \pm 6%	6	63% \pm 9%	2	26% \pm 5%	13	44% \pm 8%	11
8/8-9/6/02	76% \pm 5%	6	73% \pm 7%	4	26% \pm 5%	16	52% \pm 8%	11

Water clarity in 2002 was slightly better than 2001 but similar to previous years (Table 4). Sediment pore water ammonium levels were higher than in 2001, but lower than 1998-1999 in most lakes (Table 4). Sediment pore water ammonium levels increased in Otter Lake and nutrient depletion would not appear to be the cause of the milfoil decline there.

Generally, exchangeable N concentrations were similar among the four lakes. Total exchangeable N generally decreased over the summer with highest levels in June or early July. A more complete assessment of the relationship of sediment characters and plant biomass, along with the exchangeable N results, is provided in a later section on plant-sediment relationships.

In summary, there was the continued persistence of dense milfoil at Cedar Lake, a continued increase in milfoil at Auburn, a low density of milfoil at the shallowest stations in Smiths Bay but relatively high densities at the deeper stations, and continued suppression of milfoil at Otter Lake associated with high weevil densities (see below). Abundance of native plants remained high at Otter Lake and moderate at Smith's Bay, but low at Auburn and Cedar where coontail was the dominant native plant.

Weevil densities (N/m^2) were very low ($<1.5/m^2$) at Cedar and at Auburn in June (Table 5). Surprisingly, weevil densities at Auburn increased dramatically in fall to $19/m^2$ (Table 5). This increase, verified by bi-weekly surveys (see below), was likely not due to an increase in local densities over the summer but probably resulted from recruitment from elsewhere in the lake, or perhaps another lake. Weevil densities on an areal basis were moderate at both Otter Lake and Smith's Bay, but were higher on a per stem basis. *Acentria* and *Parapoynx* were found at very low densities in Auburn, Cedar and Smith's Bay. Moderate densities ($3-5/m^2$) were found at Otter Lake, mostly associated with other plants.

Table 4. Sediment characteristics (bulk density, percent organic matter, sediment pore water ammonium and water column characteristics in 1995-2002 at the four permanent transect sites. Sediment samples were collected from shallow, moderate and deep stations along transects 1, 3 and 5 (n=9). Secchi depth (SD), chlorophyll a (Chl-a; pooled surface and SD sample) and light and temperature profiles were taken in deep water > 100 m from the plant bed. Temperature is at 1m depth and 10% PAR depth is the depth at which light intensity was 10% of surface light (presented as the range which encompassed the 10% value).

Lake/Date	Bulk Dens. (g dm/ml)	NH ₄ (mg/L)	% Organic	Chl-a (mg/m ³)	SD (m)	Temp (°C 1m)	10% PAR Depth (m)	Plant Limit (m)
Auburn								
6/15/95	0.60	3.96	11.34	9.5	2.3	20.7	2.5-3.0	3.0
2se	0.15	0.91	3.73					
8/1/95	0.49	4.00	10.69	13.9	1.4	26.0	1.5-2.0	3.0
2se	0.18	1.24	4.39					
9/26/95	0.45	4.40	12.67	8.0	2.0	14.8	2.5	3.0
2se	0.13	1.96	4.05					
6/13/96	0.41	3.08	16.0	2.9	4.2	25.1	3	3.0
2se	0.11	1.66	8.6					
7/31/96	0.42	5.81	13.6	12.8	2.4	23.3	1-1.5	3.0
2se	0.17	1.52	4.7					
9/12/96	0.38	2.68	13.7	8.8	2.4	21.2	2.5-3.0	3.0
2se	0.14	0.95	4.3					
6/23/97	0.59	1.93	25.6	11.2	1.2	24.5	2.0	3.4
2se	0.22	0.56	16.8					
9/8/97	0.48	4.42	12.3	16.6	1.4	22.4	1.5-2.0	3.4
2se	0.14	1.46	3.3					
6/8/98	0.23	11.82	11.9	14.4	1.9	18.8	1.5-2.0	
2se	0.08	4.07	4.4					
7/28/98	0.45	20.09	9.5	41.2	0.7	25.7	0.5-1.0	
2se	0.27	3.68	4.3					
9/9/98	0.44	37.72	11.9	36.4	1.1	21.9	1.0-1.5	
2se	0.15	12.57	4.6					
6/22/99	0.50	2.79	13.6	9.4	1.8	22.4	2.0	
2SE	0.16	1.06	3.8					
8/23/99	0.44	10.98	11.6	11.0	1.5	23.1	1.0-1.5	
2SE	0.12	1.81	4.2					
6/19/00	0.51	2.36	11.1	5.9	2.1	20.4	2.5-3.0	
2se	0.14	0.51	4.0					
7/17/00	0.57	4.61	10.2	5.3	2.5	25.3	2.5-3.0	
2se	0.22	1.54	3.6					
8/28/00	0.53	7.75	11.8	5.3	2.3	24.3	3.0	
2se	0.14	1.58	3.9					
6/15/01	0.50	0.98	11.2	6.7	2.9	21.5	3	
2se	0.18	0.38	4.2					
7/17/01	0.57	3.72	25.7	7.2	1.8	27.9	2.5	
2se	0.26	1.92	30.5					
8/29/01	0.47	5.46	10.9	0.8	1.7	24.3	2-2.5	
2se	0.18	1.11	3.8					
6/27/02	0.53	6.61	18.8	-	1.6	26.2	2-2.5	
2se	0.12	3.25	6.3					
9/6/02	0.62	5.14	19.7	17.1	2.6	21.0	2.5	
2se	0.22	-	10.4					

Table 4 Continued

Cedar								
6/28/95	0.62	3.90	13.73	10.2	4.5	24.0	4.5	4.0
2se	0.36	1.63	6.00					
8/3/95	0.45	7.27	16.41	16.3	1.2	26.7	1.0-1.5	3.1
2se	0.33	1.39	7.40					
9/28/95	0.43	6.06	21.56	27.5	0.8	14.8	1.0-1.5	3.1
2se	0.36	1.98	7.38					
6/18/96	0.57	3.78	13.3	1.1	5.5	24.6	3.5-4.0	6.5
2se	0.38	1.34	6.3					
8/1/96	0.42	3.86	19.0	4.5	1.9	23.8	2.5-3.0	3.1
2se	0.38	1.59	7.5					
9/16/96	0.41	5.12	18.5	5.3	2.8	20.1	2-2.5	3.1
2se	0.37	1.63	6.9					
7/8/97	0.54	3.97	12.89	9.6	2.5	21.0	3.0-4.0	6.0
2se	0.40	2.87	5.97					
9/11/97	0.42	5.69	15.76	0.8	3.7	22.0	3.0-3.5	6.4
2se	0.33	2.26	6.31					
6/18/98	0.31	4.01	18.35	2.1	4.7	22.6	4.5-5.0	
2se	0.30	1.99	5.27					
7/24/98*	N.A.	N.A.	N.A.	1.3	4.7	26.0	4.5-5.0	
9/16/98	0.29	34.77	18.68	6.9	2.6	23.4	2.5-3.0	
2se	0.30	18.72	4.78					
6/23/99	0.51	4.68	16.15	5.3	2.6	25.6	3.5	
2SE	0.36	1.68	8.79					
8/24/99	0.36	12.35	12.14	17.6	1.6	22.9	2.0-2.5	
2SE	0.34	3.87	3.37					
6/23/00	0.32	2.29	18.28	5.1	3.3	23.1	3.0-3.5	
2se	0.25	1.42	4.77					
8/8/00	0.52	4.15	16.89	4.3	1.6	25.9	3.5-4.0	
2se	0.40	3.91	8.43					
6/19/01	0.60	3.83	22.49	15.0	1.9	22.9	3	
2se	0.43	2.14	16.81					
8/30/01	0.45	2.87	14.92	15.8	1.8	24.7	3-3.5	
2se	0.40	0.74	5.99					
7/8/02	0.51	6.11	30.7	-	1.9	28.3	3.5	
2se	0.28	2.51	11.6					
8/30/02	-	-	-	-	2.2	24.6	2.5-3.0	
2se	-	-	-					
Otter								
6/26/95	0.42	3.27	20.26	5.6	3.0	30.0	3.5-4.0	4.0
2se	0.18	1.43	7.23					
8/10/95	0.39	4.66	24.44	12.5	2.5	24.7	1.5-2.0	4.0
2se	0.26	1.77	9.49					
9/30/95	0.38	2.76	25.07	3.7	1.1	14.5	1.0-1.5	4.0
2se	0.26	1.34	11.34					
6/20/96	0.47	4.86	23.5	8.5	1.9	21.1	1.5-2.0	3.5
2se	0.34	1.67	10.2					
8/6/96	0.27	3.54	27.5	4.8	2	26	2-2.5	4.0
2se	0.16	0.88	8.6					
9/17/96	0.33	3.77	24.9	8.0	1.5	17.9	1.5-2.0	4.0
2se	0.24	1.76	9.5					
7/2/97	0.33	1.89	26.42	9.9	1.3	21.1	2.0-2.5	3.5
2se	0.21	1.09	8.17					
9/15/97	0.29	5.88	27.47	4.8	2.1	21.0	2.0-2.5	3.5
2se	0.16	2.61	9.52					
6/10/98	0.18	10.51	24.24	2.9	2.6	17.8	4.5-5.0	
2se	0.11	3.55	8.54					
9/10/98	0.24	27.47	24.36	1.6	4.0	21.1	3.5-4.0	
2se	0.11	9.40	7.55					
6/21/99	0.24	3.37	27.31	15.5	2.7	24.5	2.5	
2SE	0.07	0.83	8.34					
7/29/99	0.22	9.58	25.37	13.4	2.1	26.4	2.0	
2SE	0.12	3.02	8.61					

Table 4 Continued

Otter continued

7/11/00	0.47	2.69	21.36	6.9	2.5	26.7	1.5-2.0
2se	0.32	1.63	9.13				
8/29/00	0.25	3.16	29.84	4.5	2.9	23.7	2.0-2.5
2se	0.13	1.69	9.13				
6/21/01	0.34	2.55	25.25	3.2	2.9	22.5	2.5
2se	0.20	1.07	10.83				
7/18/01	0.36	3.64	27.71	3.2	2.1	27.8	2.0-2.5
2se	0.21	1.38	9.70				
8/28/01	0.35	2.77	23.05	5.1	2	24.9	2.5-3.0
2se	0.19	1.13	8.12				
6/26/02	0.34	5.86	19.5	-	2.6	24.8	2-2.5
2se	0.20	4.74	12.1				
9/5/02	0.70	6.92	40.2	6.1	2.3	23.7	2.5-3.0
2se	0.50	3.31	14.1				

Smith's

6/29/95	0.59	5.18	11.81	4.0	3.9	23.7	5.0	5.0
2se	0.25	3.40	4.62					
8/16/95	0.28	4.06	12.86	7.5	2.1	24.9	3.5-4.0	5.0
2se	0.14	0.97	3.71					
9/18/95	0.31	4.25	12.50	10.7	2.1	14.7	2.5	5.0
2se	0.15	0.77	3.98					
6/24/96	0.36	1.13	13.9	3.7	3.7	20.6	3.5-4.0	5.0
2se	0.22	0.32	4.7					
8/8/96	0.37	2.61	17.6	1.3	3.4	24.4	4.5-5.0	5.0
2se	0.21	1.01	5.3					
9/19/96	0.32	2.43	19.1	3.2	3.5	20.1	3.0-3.5	5.0
2se	0.18	0.90	14.3					
7/15/97	0.34	2.44	9.29	1.6	3.5	22.2	4.5-5.0	5.0
2se	0.17	0.80	3.48					
9/18/97	0.31	2.94	14.10	5.3	2.4	20.9	2.5-3.0	5.0
2se	0.17	1.21	4.74					
6/15/98	0.35	3.35	11.50	1.6	3.6	21.0	4.0-4.5	
2se	0.19	1.98	4.22					
8/4/98	0.34	9.32	11.76	4.0	2.9	23.6	3.5-4.0	
2se	0.16	3.27	3.59					
9/15/98	0.30	26.00	13.55	4.3	2.7	22.5	3.0-3.5	
2se	0.14	5.87	3.40					
6/16/99	0.34	2.21	12.71	4.3	3.7	20.8	4.0	
2SE	0.18	0.40	4.08					
8/4/99	0.37	11.54	10.32	4.8	2.6	26.1	4.5-5	
2SE	0.22	8.83	3.84					
8/25/99	0.30	9.71	10.63	7.2	2.9	24.7	4.0	
2SE	0.16	3.24	3.52					
6/20/00	0.39	2.03	11.06	4.3	3.2	19.9	4.0-4.5	
2se	0.16	0.62	3.17					
7/18/00	0.38	4.00	9.91	4.5	1.9	24.3	4.5-5.0	
2se	0.20	1.13	4.71					
8/23/00	0.42	3.02	12.90	4.3	3.2	23.9	4.0	
2se	0.24	0.82	4.69					
6/22/01	0.33	1.93	12.52	2.1	2.9	20.8	4.0-4.5	
2se	0.19	0.81	4.47					
7/24/01	0.38	2.42	13.57	14.4	2.3	26.9	4	
2se	0.24	1.37	5.15					
8/23/01	0.37	3.30	12.93	3.5	3.4	24.7	4.0-4.5	
2se	0.24	1.16	4.29					
7/2/02	0.38	4.41	24.2	-	3.1	26.1	4.5	
2se	0.12	1.73	20.0					
8/8/02	0.62	3.48	17.5	5.1	2.2	23.7	3	
2se	0.24	1.06	10.6					

Table 5. Density ($N/m^2 \pm 2$ SE and N per stem ± 2 SE) of *Euhrychiopsis lecontei* larvae, pupae and adults, *Acentria ephemerella* and *Parapoynx* at the four permanent transect sites, 1994-2002. *Parapoynx* were not enumerated before 1996. A stem is a basal milfoil stem emerging from the sediment; estimates per stem do not include samples without milfoil and because caterpillars occurred often without milfoil, per stem estimates are not reported for them.

Cedar	Weevil	Larvae	Pupae	Adults	Total <i>E.l.</i>	<i>Acentria</i>	<i>Parapoynx</i>
Date	n	N/m^2	N/m^2	N/m^2	N/m^2	N/m^2	
May-94	11	5.5 ± 10.9	0.0 ± 0.0	0.9 ± 1.8	6.4 ± 10.9	0.0 ± 0.0	
per stem	0	—	—	—	—		
Jul-94	14	4.3 ± 8.6	1.4 ± 2.9	1.4 ± 2.9	7.1 ± 14.3	0.0 ± 0.0	
	0	—	—	—	—		
Aug-94	11	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	
Sep-94	17	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	
Jun-95	18	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	
Aug-95	10	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	
Sep-95	17	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	
Jun-96	29	0.3 ± 0.7	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.7	0.0 ± 0.0	0.0 ± 0.0
per stem	25	0.010 ± 0.020	0.000 ± 0.000	0.000 ± 0.000	0.010 ± 0.020		
Aug-96	21	0.0 ± 0.0	0.5 ± 1.0	0.5 ± 1.0	1.0 ± 1.9	0.0 ± 0.0	0.0 ± 0.0
per stem	21	0.000 ± 0.000	0.002 ± 0.004	0.002 ± 0.004	0.004 ± 0.008		
Sep-96	23	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
per stem	24	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000		
Jul-97	28	0.0 ± 0.0	0.0 ± 0.0	0.4 ± 0.7	0.4 ± 0.7	0.4 ± 0.7	0.0 ± 0.0
per stem	28	0.000 ± 0.000	0.000 ± 0.000	0.002 ± 0.003	0.002 ± 0.003		
Sep-97	26	0.8 ± 1.1	0.0 ± 0.0	0.4 ± 0.8	1.2 ± 1.3	0.0 ± 0.0	0.0 ± 0.0
per stem	26	0.012 ± 0.016	0.000 ± 0.000	0.002 ± 0.003	0.013 ± 0.019		
Jun-98	31	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
per stem	30	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000		
Sep-98	28	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.4 ± 0.7	0.0 ± 0.0
per stem	24	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000		
Jun-99	26	1.9 ± 2.5	0.0 ± 0.0	0.38 ± 0.77	2.3 ± 2.6	0.0 ± 0.0	0.0 ± 0.0
per stem	24	0.011 ± 0.013	0.000 ± 0.000	0.003 ± 0.006	0.013 ± 0.013		
Aug-99	27	0.7 ± 1.5	0.0 ± 0.0	0.0 ± 0.0	0.7 ± 1.5	0.0 ± 0.0	0.0 ± 0.0
per stem	26	0.002 ± 0.004	0.000 ± 0.000	0.000 ± 0.000	0.002 ± 0.004		
Jun-00	26	7.7 ± 6.8	0.8 ± 1.5	0.4 ± 0.8	8.8 ± 7.8	0.0 ± 0.0	0.0 ± 0.0
per stem	25	0.035 ± 0.031	0.003 ± 0.005	0.001 ± 0.002	0.039 ± 0.034		
Aug-00	27	3.3 ± 3.2	0.0 ± 0.0	0.0 ± 0.0	3.3 ± 3.2	0.7 ± 1.0	0.0 ± 0.0
per stem	25	0.023 ± 0.023	0.000 ± 0.000	0.000 ± 0.000	0.023 ± 0.023		
Jun-01	28	0.0 ± 0.0	1.1 ± 2.1	2.1 ± 4.3	3.2 ± 6.4	0.0 ± 0.0	0.0 ± 0.0
per stem	20	0.000 ± 0.000	0.017 ± 0.033	0.033 ± 0.067	0.050 ± 0.100		
Aug-01	24	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
per stem	12	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000		
Jul-02	18	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
per stem	16	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000		
Aug-02	29	1.4 ± 1.3	0.0 ± 0.0	0.0 ± 0.0	1.4 ± 1.3	0.0 ± 0.0	0.3 ± 0.7
per stem	23	0.010 ± 0.010	0.000 ± 0.000	0.000 ± 0.000	0.010 ± 0.010		

Table 5. Continued.

Auburn	Weevil	Larvae	Pupae	Adults	Total <i>E.l.</i>	<i>Acentria</i>	<i>Parapoynx</i>
Date	n	N/m ²	N/m ²	N/m ²	N/m ²	N/m ²	
May-94	9	27.8 ± 27.4	1.1 ± 2.2	6.7 ± 8.8	35.6 ± 36.5	1.1 ± 2.2	
per stem	9	0.134 ± 0.103	0.002 ± 0.004	0.018 ± 0.020	0.154 ± 0.106		
Jul-94	16	58.8 ± 21.1	12.5 ± 9.6	31.3 ± 14.0	102.5 ± 36.7	6.3 ± 7.7	
per stem	16	0.217 ± 0.092	0.034 ± 0.034	0.084 ± 0.036	0.335 ± 0.127		
Aug-94	15	8.7 ± 7.5	2.0 ± 2.9	3.3 ± 3.7	14.0 ± 9.5	0.7 ± 1.3	
per stem	15	0.031 ± 0.025	0.003 ± 0.005	0.008 ± 0.008	0.042 ± 0.030		
Sep-94	18	1.7 ± 3.3	2.2 ± 2.6	7.8 ± 7.8	11.7 ± 11.8	3.9 ± 3.3	
per stem	18	0.002 ± 0.004	0.006 ± 0.008	0.014 ± 0.012	0.022 ± 0.019		
Jun-95	30	6.0 ± 4.0	0.7 ± 0.9	1.0 ± 1.1	7.7 ± 2.7	0.3 ± 0.7	
per stem	21	0.070 ± 0.043	0.003 ± 0.006	0.011 ± 0.015	0.085 ± 0.056		
Jul-95	15	2.0 ± 2.1	0.7 ± 1.3	5.3 ± 5.5	8.0 ± 3.8	0.0 ± 0.0	
per stem	14	0.006 ± 0.009	0.000 ± 0.000	0.032 ± 0.039	0.038 ± 0.042		
Sep-95	16	2.5 ± 2.2	3.1 ± 3.5	3.8 ± 4.0	9.4 ± 3.4	1.3 ± 1.7	
per stem	11	0.140 ± 0.194	0.049 ± 0.090	0.103 ± 0.180	0.292 ± 0.385		
Jun-96	30	31.0 ± 17.8	2.0 ± 2.0	0.0 ± 0.0	33.0 ± 19.5	0.3 ± 0.7	0.0 ± 0.0
per stem	27	0.729 ± 1.179	0.080 ± 0.148	0.000 ± 0.000	0.809 ± 1.326		
Jul-96	25	9.2 ± 15.2	3.6 ± 2.6	12.8 ± 6.3	25.6 ± 17.9	1.6 ± 1.5	0.8 ± 1.1
per stem	23	0.029 ± 0.043	0.020 ± 0.021	0.048 ± 0.027	0.096 ± 0.061		
Sep-96	30	6.7 ± 4.3	2.3 ± 1.6	3.0 ± 2.7	12.0 ± 6.5	0.7 ± 0.9	5.7 ± 4.4
per stem	29	0.048 ± 0.053	0.007 ± 0.005	0.011 ± 0.010	0.065 ± 0.055		
Jun-97	30	35.7 ± 19.6	0.3 ± 0.7	4.3 ± 5.9	40.3 ± 24.3	0.7 ± 1.3	0.0 ± 0.0
per stem	27	0.201 ± 0.126	0.001 ± 0.003	0.022 ± 0.027	0.224 ± 0.144		
Sep-97	30	0.3 ± 0.7	0.0 ± 0.0	1.7 ± 1.4	2.0 ± 1.5	1.7 ± 2.7	2.3 ± 2.8
per stem	29	0.001 ± 0.001	0.000 ± 0.000	0.007 ± 0.007	0.008 ± 0.008		
Jun-98	27	1.0 ± 1.1	0.0 ± 0.0	0.3 ± 0.7	1.3 ± 1.3	1.0 ± 2.0	0.0 ± 0.0
per stem	27	0.005 ± 0.005	0.000 ± 0.000	0.001 ± 0.003	0.006 ± 0.006		
Jul-98	28	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.7 ± 1.0	0.0 ± 0.0
per stem	24	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000		
Sep-98	30	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.7
per stem	28	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000		
Jun-99	27	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.7	0.0 ± 0.0
per stem	19	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000		
Aug-99	27	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
per stem	19	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000		
Jun-00	26	0.8 ± 1.1	0.0 ± 0.0	1.5 ± 1.4	2.3 ± 2.0	0.0 ± 0.0	0.0 ± 0.0
per stem	23	0.004 ± 0.005	0.000 ± 0.000	0.007 ± 0.007	0.010 ± 0.009		
Jul-00	28	1.6 ± 2.5	0.4 ± 0.8	3.6 ± 3.6	5.4 ± 5.5	0.0 ± 0.0	0.0 ± 0.0
per stem	21	0.009 ± 0.014	0.004 ± 0.008	0.027 ± 0.025	0.039 ± 0.038		
Aug-00	28	1.1 ± 2.1	0.0 ± 0.0	2.1 ± 2.4	3.2 ± 4.4	0.0 ± 0.0	2.1 ± 3.1
per stem	27	0.011 ± 0.022	0.000 ± 0.000	0.024 ± 0.028	0.035 ± 0.047		
Jun-01	29	0.3 ± 0.7	2.4 ± 2.6	0.7 ± 1.0	3.4 ± 2.7	0.0 ± 0.0	0.0 ± 0.0
per stem	24	0.003 ± 0.006	0.023 ± 0.029	0.008 ± 0.012	0.034 ± 0.030		
Jul-01	30	0.7 ± 0.9	0.3 ± 0.7	1.0 ± 1.1	2.0 ± 1.5	0.0 ± 0.0	0.0 ± 0.0
per stem	25	0.011 ± 0.015	0.002 ± 0.003	0.007 ± 0.008	0.019 ± 0.016		
Aug-01	30	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	2.3 ± 4.0	5.0 ± 6.0
per stem	19	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000		

Table 5. Continued.

Auburn Cont:

Weevil		Larvae	Pupae	Adults	Total <i>E.l.</i>	<i>Acentria</i>	<i>Parapoynx</i>
Date	n	N/m ²	N/m ²	N/m ²	N/m ²	N/m ²	
Jun-02	30	0.37±0.7	0.07±0.0	0.37±0.7	0.77±0.9	0.07±0.0	0.07±0.0
per stem	29	0.003±0.006	0.000±0.000	0.001±0.002	0.004±0.006		
Sep-02	27	4.87±3.3	3.07±3.3	11.97±7.6	18.97±11.5	3.07±2.6	0.47±0.0
per stem	27	0.021±0.015	0.009±0.010	0.045±0.028	0.076±0.044		

Otter

May-94	20	12.5± 10.2	0.0± 0.0	0.0± 0.0	12.5± 10.2	0.5± 1.0	
per stem	20	0.047±0.038	0.000±0.000	0.000±0.000	0.047±0.038		
Jul-94	24	0.4± 0.9	0.0± 0.0	0.4± 0.9	0.8± 1.2	0.0± 0.0	
	24	0.001±0.002	0.000±0.000	0.001±0.003	0.002±0.003		
Aug-94	14	0.0± 0.0	0.0± 0.0	0.0± 0.0	0.0± 0.0	1.4± 2.9	
	14	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
Sep-94	8	0.0± 0.0	1.3± 2.5	2.5± 3.3	3.8± 3.7	6.3± 5.3	
	7	0.000±0.000	0.003±0.007	0.013±0.022	0.016±0.021		
Jun-95	27	5.9± 5.1	2.6± 3.3	3.3± 3.4	11.9± 9.0	0.4± 0.7	
	26	0.033±0.030	0.021±0.034	0.022±0.020	0.076±0.071		
Aug-95	15	0.0± 0.0	0.0± 0.0	0.7± 1.3	0.7± 1.3	0.0± 0.0	
	1	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
Sep-95	18	0.6± 1.1	0.0± 0.0	1.1± 2.2	1.7± 2.4	0.0± 0.0	
	1	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
Jun-96	25	0.0± 0.0	0.0± 0.0	0.0± 0.0	0.0± 0.0	0.8± 1.6	0.8±1.6
	5	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
Aug-96	26	0.0± 0.0	0.0± 0.0	0.0± 0.0	0.0± 0.0	0.8± 1.1	2.3± 2.0
	2	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
Sep-96	27	0.0± 0.0	0.0± 0.0	0.0± 0.0	0.0± 0.0	4.4± 3.6	100.4±24.5
	0	-	-	-	-		
Jul-97	26	0.4±0.8	0.0±0.0	0.0±0.0	0.4±0.8	6.2± 3.9	20.8±20.5
	3	0.083±0.167	0.000±0.000	0.000±0.000	0.083±0.167		
Sep-97	27	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	1.5±1.8	30.0±13.8
	1	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
Jun-98	27	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	1.1±1.6	0.4±0.7
	13	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
Sep-98	27	4.1±4.3	0.0±0.0	1.9±3.0	5.9±5.1	0.0±0.0	4.4±5.4
	16	0.206±0.219	0.000±0.000	0.049±0.084	0.255±0.223		
Jun-99	22	1.4±2.0	0.0±0.0	0.0±0.0	1.4±2.0	0.0±0.0	0.0±0.0
	20	0.030±0.050	0.000±0.000	0.000±0.000	0.030±0.050		
Jul-99	26	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	26	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
Jun-00	27	14.4±14.8	4.8±4.3	4.8±3.9	24.1±20.4	0.0±0.0	0.4±0.7
	27	0.092±0.093	0.029±0.037	0.028±0.027	0.150±0.131		
Jul-00	27	1.1±1.6	0.0±0.0	0.7±1.5	1.9±3.0	0.0±0.0	0.0±0.0
	27	0.019±0.030	0.000±0.000	0.015±0.030	0.033±0.059		
Aug-00	27	4.1±4.8	0.0±0.0	1.5±1.4	5.6±5.7	1.9±1.5	3.3±2.4
	27	0.064±0.074	0.000±0.000	0.011±0.012	0.076±0.083		

Table 5. Continued.
Otter Continued:

Weevil		Larvae	Pupae	Adults	Total <i>E.l.</i>	<i>Acentria</i>	<i>Parapoynx</i>
Date	n	N/m ²	N/m ²	N/m ²	N/m ²	N/m ²	N/m ²
Jun-01	27	1.1±2.2	0.4±0.7	2.2±3.3	3.7±4.3	4.1±3.6	0.7±1.5
per stem	21	0.024±0.034	0.005±0.010	0.083±0.131	0.111±0.134		
Jul-01	25	0.0±0.0	0.0±0.0	0.8±1.6	0.8±1.6	0.4±0.8	13.2±9.5
per stem	4	0.000±0.000	0.000±0.000	0.250±0.500	0.250±0.500		
Aug-01	23	5.7±6.6	0.0±0.0	0.4±0.9	6.1±7.4	2.6±3.8	27.0±11.6
per stem	0	.-	.-	.-	.-		
Jun-02	27	1.1±1.2	0.7±1.5	0.7±1.0	1.5±1.8	3.3±2.4	3.0±2.8
per stem	20	0.078±0.109	0.007±0.013	0.006±0.009	0.091±0.109		
Sep-02	26	1.5±1.8	0.4±0.8	0.8±1.1	2.7±2.1	2.7±2.4	5.0±5.0
per stem	26	0.038±0.046	0.005±0.010	0.019±0.027	0.063±0.051		
Smith's Bay							
Jun-94	13	3.8± 5.3	0.0± 0.0	0.8± 1.5	4.6± 6.6	0.0± 0.0	
per stem	12	0.020±0.030	0.000±0.000	0.005±0.010	0.025±0.040		
Jul-94	11	12.3± 13.0	6.9± 8.0	1.5± 2.1	20.8± 20.9	0.8± 1.5	
	13	0.064±0.083	0.038±0.052	0.006±0.009	0.108±0.137		
Aug-94	16	18.0± 15.0	3.1± 4.0	1.9± 2.7	23.1± 20.2	0.6± 1.3	
	15	0.104±0.079	0.019±0.022	0.010±0.015	0.133±0.109		
Sep-94	14	0.0± 0.0	1.4± 2.9	2.1± 2.3	3.6± 4.5	0.0± 0.0	
	14	0.000±0.000	0.003±0.006	0.013±0.020	0.016±0.022		
Jun-95	25	0.4± 0.8	0.0± 0.0	0.8± 1.1	1.2± 1.3	0.0± 0.0	
	14	0.001±0.003	0.000±0.000	0.027±0.048	0.028±0.047		
Aug-95	25	4.0± 4.3	1.2± 1.8	0.4± 0.8	5.6± 5.3	0.0± 0.0	
	9	0.080±0.096	0.000±0.000	0.007±0.015	0.087±0.107		
Sep-95	25	0.8± 1.1	2.0± 3.3	0.8± 1.1	3.6± 5.0	0.0± 0.0	
	15	0.010±0.014	0.025±0.039	0.013±0.019	0.048±0.061		
Jun-96	25	4.8± 5.8	0.0± 0.0	0.0± 0.0	4.8± 5.8	5.2± 8.8	0.0± 0.0
	20	0.037±0.043	0.000±0.000	0.000±0.000	0.037±0.043		
Aug-96	25	12.4± 10.0	1.2± 1.8	2.0± 2.0	15.6± 10.5	0.0± 0.0	1.6± 2.5
	24	0.107±0.084	0.006±0.008	0.015±0.015	0.127±0.087		
Sep-96	25	1.2± 1.8	2.0± 2.0	2.8± 3.4	6.0± 5.3	0.8± 1.1	0.0± 0.0
	24	0.005±0.007	0.009±0.009	0.014±0.015	0.028±0.022		
Jul-97	25	5.2±4.3	0.4±0.8	4.0±3.7	9.6±6.9	0.0± 0.0	0.8±1.6
	21	0.049±0.053	0.003±0.005	0.043±0.049	0.094±0.094		
Sep-97	25	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.4±0.8	0.0± 0.0
	21	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
Jun-98	25	7.2±7.2	0.4±0.8	0.0±0.0	7.6±7.6	1.2±1.8	0.0±0.0
	21	0.052±0.054	0.002±0.005	0.000±0.000	0.054±0.055		
Aug-98	25	1.2±1.8	0.0±0.0	0.8±1.1	2.0±2.0	0.0±0.0	0.0±0.0
	20	0.017±0.023	0.000±0.000	0.002±0.005	0.019±0.023		
Sep-98	25	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.4±0.8
	19	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
Jun-99	22	0.9±1.3	0.0±0.0	0.9±1.3	1.8±2.1	0.9±1.3	0.0±0.0
	22	0.047±0.091	0.000±0.000	0.047±0.091	0.094±0.182		
Jul-99	25	2.4±4.8	0.8±1.1	1.2±1.3	4.4±4.9	0.0±0.0	1.2±1.5
	21	0.000±0.000	0.002±0.003	0.014±0.024	0.017±0.024		
Aug-99	23	0.9±1.2	0.0±0.0	0.9±1.2	1.7±2.0	0.0±0.0	0.0±0.0
	22	0.005±0.007	0.000±0.000	0.007±0.010	0.012±0.015		

Table 5. Continued.
Smith's Bay Continued:

	Weevil	Larvae	Pupae	Adults	Total <i>E.l.</i>	<i>Acentria</i>	<i>Parapoynx</i>
Date	n	N/m ²	N/m ²	N/m ²	N/m ²	N/m ²	N/m ²
Jun-00	22	3.6±4.1	0.9±1.8	1.8±1.7	6.4±5.5	1.4±2.0	0.0±0.0
	20	0.027±0.035	0.007±0.014	0.008±0.009	0.042±0.042		
Jul-00	24	0.0±0.0	0.0±0.0	0.8±1.7	0.8±1.7	0.0±0.0	0.0±0.0
	19	0.000±0.000	0.000±0.000	0.009±0.018	0.009±0.018		
Aug-00	23	1.3±1.4	0.0±0.0	0.0±0.0	1.3±1.4	0.0±0.0	1.7±2.4
	21	0.009±0.010	0.000±0.000	0.000±0.000	0.009±0.010		
Jun-01 per stem	25	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.4±0.8	0.0±0.0
	13	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
Jul-01 per stem	24	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	17	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
Aug-01 per stem	20	0.0±0.0	0.0±0.0	0.5±1.0	0.5±1.0	0.0±0.0	0.0±0.0
	14	0.000±0.000	0.000±0.000	0.002±0.005	0.002±0.005		
Jul-02 per stem	25	5.6±4.8	0.8±1.1	1.6±2.2	4.0±5.0	0.0±0.0	0.0±0.0
	19	0.117±0.210	0.001±0.002	0.113±0.210	0.231±0.420		
Aug-02 per stem	24	1.4±2.5	0.1±0.0	0.9±1.2	2.2±2.7	0.5±0.8	0.1±0.0
	19	0.004±0.009	0.000±0.000	0.009±0.012	0.013±0.014		

Cenaiko Lake

Milfoil biomass rebounded in 2002 at Cenaiko Lake (Fig. 2), to 68g/m² in June and 27 g/m² in August when it composed 37% of total plant biomass (Table 6). Native plant biomass decreased relative to previous years and the total number of species decreased. The increase in milfoil biomass was likely due to low herbivore densities. No weevils were found in biomass samples in 2002 continuing several years of very low weevil densities (Table 7; see also bi-weekly weevil survey results below). *Acentria* and *Parapoynx* were also found at low densities. The decrease in native plants did not appear due to water clarity, which was better than in 2000-2001 (Table 8). Sediment nutrients and organic matter remained low but similar to previous years (Table 8). Exchangeable N was lower than most lakes (0.005-0.019 mg N/g dry sed; see below), but generally above a revised threshold for nuisance milfoil growth presented by McComas (0.01 ppt, Steve McComas, personal communication). The lower nitrogen content would be expected to favor native plants over milfoil. A more detailed analysis of sediment and plant relationships is presented in the later section on plant-sediment relationships.

As discussed below in the section of sunfish-weevil relationships, an increase in sunfish density since 1998 may be suppressing weevil and lepidopteran densities and allowing milfoil to once again dominate. Unless weevil densities increase in 2003 we predict a major increase in milfoil biomass at Cenaiko.

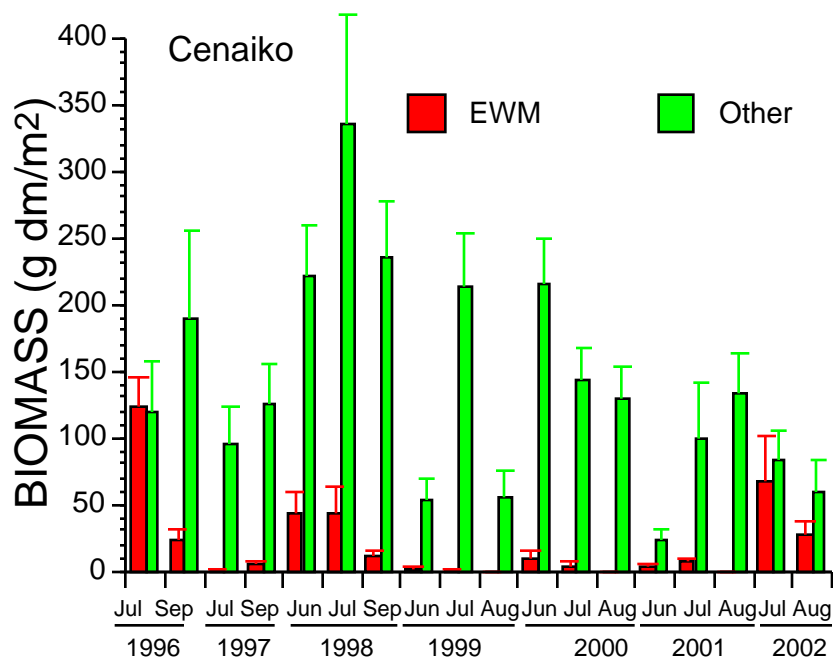


Fig. 2. Dry biomass of milfoil (EWM) and non-milfoil plants at Cenaiko Lake, 1996-2002. Milfoil was present but not found in August 1999 samples and was 0.01g/m² in August 2001. N = 17-27 samples on each date.

Table 6. Biomass (g dry/m²) of all plants (Total), Eurasian watermilfoil (MSP), the dominant plants (coontail (CRT), *Zosterella (= Heteranthera) dubia* (ZOS), *Potamogeton zosteriformis* (PZS), *Chara* (CHA) and *Potamogeton amplifolius* (PAM)), non-milfoil biomass (NAT), total (TN) and mean number of species (N Sp) and mean percentage of biomass that was Eurasian watermilfoil in Cenaiko Lake 1999-2002. N=17-27 samples per date. In July and August 2001, *Potamogeton nodosus* was present at densities of 36 and 19 g dry/m² and in August 2002 at 7 g/m². In 2002 *P. pectinatus* was present at 1-2 g/m².

Date	Total	MSP	CRT	PZS	ZOS	CHA	PAM	TN	N Sp.	NAT	%MSP
6/24/99	53.7	1.3	32.2	0.2	3.0	0.5	12.3	11	1.9	52.4	7.9%
1 S.E.	17.0	0.9	12.0	0.2	2.5	0.4	10.7		0.2	17.1	5.2%
8/2/99	214.6	1.1	124.5	0.0	26.7	0.0	34.1	10	2.6	213.5	1.0%
1 S.E.	40.1	0.8	37.5	0.0	9.7	0.0	23.6		0.2	40.2	0.7%
8/26/99	55.0	0.0	30.2	0.1	5.0	0.0	6.7	5	1.5	55.0	0.0%
1 S.E.	20.1	0.0	20.1	0.1	3.4	0.0	4.4		0.1	20.1	0.0%
6/29/00	225.9	10.0	123.9	0.0	16.3	46.0	19.8	9	2.1	215.9	3.1%
1 SE	34.1	5.2	31.2	0.0	8.2	21.1	14.3		0.2	33.1	1.7%
7/20/00	146.8	3.7	86.4	0.0	19.5	14.5	18.3	8	2.4	143.2	8.4%
1 SE	23.6	2.2	22.5	0.0	10.1	9.4	11.8		0.3	24.1	5.1%
8/30/00	134.5	0.1	89.4	34.5	0.0	8.0	1.7	8	1.8	129.4	0.1%
1 SE	22.0	0.1	23.5	14.9	0.0	7.3	1.5		0.2	22.8	0.1%
6/26/01	25.5	2.8	17.2	0.6	0.0	0.0	0.6	7	1.4	22.7	3.5%
1 SE	8.5	2.8	7.9	0.3	0.0	0.0	0.6		0.4	8.0	3.3%
7/30/01	105.4	6.8	59.5	0.0	0.0	0.0	0.0	7	1.1	98.6	7.1%
1 SE	43.1	4.0	26.1	0.0	0.0	0.0	0.0		0.3	42.6	4.4%
8/27/01	133.6	0.0	98.8	1.0	0.0	0.0	8.8	6	1.0	133.6	4.0%
1 SE	29.6	0.0	27.3	0.5	0.0	0.0	6.4		0.1	29.6	4.0%
7/1/02	152.4	67.7	74.6	4.0	0.0	0.0	0.0	5	2.2	84.8	19.4%
1 SE	44.5	34.3	21.8	3.2	0.0	0.0	0.0		0.2	20.7	8.7%
8/27/02	87.8	26.9	51.3	0.1	0.0	0.0	0.0	6	1.8	60.9	36.8%
1 SE	21.1	11.3	22.5	0.1	0.0	0.0	0.0		0.2	22.0	11.3%

Table 7. Density ($N/m^2 \pm 2$ SE and N per stem) of *Euhrychiopsis lecontei* (*E.l.*) larvae, pupae and adults, and *Acentria ephemerella* and *Parapoynx* sp. at Cenaiko Lake in 1996-2002.

Densities per stem were only calculated for samples with Eurasian watermilfoil and because the caterpillars often occurred in samples with no milfoil their densities per stem were not calculated. A stem is a basal milfoil stem emerging from the sediment. Samples with no plants were not included in herbivore density estimates.

Date	Weevil n	Larvae N/m ²	Pupae N/m ²	Adults N/m ²	Total <i>E.l.</i> N/m ²	<i>Acentria</i> N/m ²	<i>Parapoynx</i> N/m ²
7/22/96	29	48.6± 25.2	22.8± 10.8	31.7± 13.6	103.1± 41.9	18.3± 7.7	1.0± 1.5
per stem	26	0.923±1.292	0.337±0.458	0.381±0.280	1.640±1.972		
9/5/96	21	2.9± 2.4	1.0± 1.3	4.3± 4.3	8.1± 5.6	31.9± 20.2	0.0± 0.0
per stem	8	0.229±0.259	0.008±0.017	0.417±0.516	0.654±0.721		
7/16/97	26	1.5±1.8	0.0±0.0	0.0±0.0	1.5±1.8	8.8±5.8	0.0±0.0
per stem	3	0.389±0.401	0.000±0.000	0.000±0.000	0.389±0.401		
9/17/97	24	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	32.1±19.6	1.7±2.0
per stem	6	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
6/16/98	25	0.4±0.8	0.0±0.0	0.0±0.0	0.4±0.8	17.6±9.1	0.4±0.8
per stem	15	0.004±0.009	0.000±0.000	0.000±0.000	0.004±0.009		
7/29/98	25	0.0±0.0	0.0±0.0	0.8±1.6	0.8±1.6	1.6±1.5	0.4±0.8
per stem	12	0.000±0.000	0.000±0.000	0.019±0.037	0.019±0.037		
9/14/98	25	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	6.4±4.5	21.6±19.8
per stem	3	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
6/24/99	26	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	16.9±10.3	0.0±0.0
per stem	3	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
8/2/99	24	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	2.0±1.1	0.0±0.1
per stem	3	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
8/26/99	23	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	6.5±5.4	0.0±0.0
per stem	0	-	-	-	-		
06/29/00	22	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	69.1±43.2	0.0±0.0
per stem	6	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
07/20/00	22	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	32.0±16.1	3.0±5.0
per stem	7	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
08/30/00	21	0.5±1.0	0.0±0.0	0.0±0.0	0.5±1.0	12.9±9.4	4.3±8.6
per stem	7	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
6/26/01	20	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	3.5±4.9	0.0±0.0
per stem	1	0.000±.	0.000±.	0.000±.	0.000±.		
7/30/01	21	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	4.8±4.3	0.0±0.0
per stem	3	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
8/27/01	19	0.5±1.1	0.0±0.0	0.0±0.0	0.5±1.1	0.0±0.0	0.0±0.0
per stem	0	-	-	-	-		
7/1/02	15	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	5.3±5.1	0.0±0.0
per stem	7	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		
8/27/02	16	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	1.3±1.7	0.6±1.2
per stem	8	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000		

Table 8. Sediment characteristics (bulk density, percent organic matter, sediment pore water ammonium and water column characteristics in 1996-2001 at Cenaiko Lake. Sediment samples were collected from shallow, moderate and deep stations along transects 1, 2 and 3 (n=9).

Date	Bulk Dens. (g dm/ml)	NH ₄ (mg/L)	% Organic	Chl-a (mg/m ³)	SD (m)	Temp (°C 1m)	10% PAR Depth (m)	Plant Limit (m)
7/22/96	1.23	0.60	1.5%	1.34	5.0	25.4	4.5-5.0	3.4
2se	0.22	0.54	0.5%					
9/5/96	1.22	0.67	2.4%	5.61	4.0	25.7	5.0	3.4
2se	0.23	0.40	1.1%					
7/16/97	1.10	1.63	2.5%	4.54	2.3	27.6	3.5	3.0
2se	0.20	0.67	0.6%					
9/17/97	0.96	2.87	2.5%	1.60	2.3	21.3	2.0-2.5	3.0
2se	0.18	1.65	0.5%					
6/16/98	0.98	2.37	2.2%	2.41	3.8	23.7	5.5-6.0	3.4
2se	0.18	0.66	0.5%					
7/29/98	0.97	4.98	2.3%	2.41	4.4	25.9	4.5-5.0	3.4
2se	0.16	2.31	0.7%					
9/14/98	1.12	6.08	1.7%	3.21	3.0	23.8	3.5-4.0	3.2
2se	0.12	4.90	0.5%					
6/24/99	1.12	1.12	1.76%	1.3	2.7	24.3	3.5-4.0	
2SE	0.24	0.24	0.82%					
8/2/99	1.14	2.09	1.29%	3.5	2.7	27.4	3.0-3.5	
2SE	0.17	0.78	0.40%					
8/26/99	1.22	4.20	1.30%	2.1	3.1	24.3	3.0-3.5.0	
2SE	0.14	1.27	0.45%					
6/29/00	1.08	1.11	2.31%	2.14	2.3	23.5	3.5	
2se	0.27	0.73	0.41%					
7/20/00	1.13	4.09	3.01%	3.47	1.6	23.2	2.0-2.5	
2se	0.35	.	1.57%					
8/30/00	1.25	3.27	2.43%	2.94	1.4	23.1	4.5-5.0	
2se	0.26	2.41	0.70%					
6/26/01	1.05	1.45	3.69%	4.3	1.3	25.2	2.5	
2se	0.28	0.75	3.66					
7/30/01	1.27	2.07	1.80%	4.5	0.9	26.9	1.5	
2se	0.23	0.65	0.59					
8/27/01	1.26	3.92	1.70%	17.6	2.3	25.6	4.5	
2se	0.21	2.08	0.60					
7/1/02	1.42	2.39	5.3	-	1.2	29.0	1.5-2.0	
2se	0.63	1.63	4.2					
8/27/02	1.51	2.57	7.8	4.0	3.8	24.6	4	
2se	0.24	1.41	2.2					

Bi-weekly weevil surveys

Weevil densities at Lake Auburn were low in spring 2002 and no weevils were found in late June through July; low densities were found in August, but in late September the number of adults and total weevils increased dramatically to 0.27 adults/stem and 0.33 total weevils/stem (Table 9). This increase was reflected in our biomass samples and suggests that weevils recruited from elsewhere in September. No *Acentria* and few *Parapoynx* were found. Densities at Cenaiko Lake remained low, never exceeding 0.02/stem, and well below densities in 2000 and early 2001. Densities of *Acentria* and *Parapoynx* were also very low (Table 9). More sunfish were noted at Cenaiko in 2001 and 2002 than in previous years and may have contributed to low herbivore density.

Weevil densities were higher at Smith's Bay with > 0.1 per stem found on half the sample dates and 0.34/stem in mid June (Table 9). A few *Acentria* were found in June, but not on any other dates and no *Parapoynx* were collected. Weevil densities remained high at Otter Lake with > 0.4 /stem through mid July and the population persisted at > 0.1 per stem through August (Table 9; Fig 3). These densities are, however, about half the densities found in 2001. *Acentria* and *Parapoynx* were rare and when present, < 0.025 /stem (except for *Parapoynx* in early June). The persistently higher adult populations (per stem) in 2000-2003 rival those seen at Cenaiko during the major decline (Newman and Biesboer 2000). Weevil damage was clearly responsible for the milfoil decline and continued suppression at Otter during 2000-2002. The low densities of caterpillars at Otter in May through August (always < 0.07 /stem) suggests they were not instrumental in the milfoil decline. Although the number of observations is low, it appears that the caterpillars are not common in lakes or years with low weevil densities, further suggesting that sunfish may be limiting populations of potential control agents.

Overall, low weevil density in Auburn and Cenaiko allowed continued increases in milfoil biomass. The moderate density at Smith's Bay continued to suppress milfoil in the shallowest station but not at the deeper stations. The relatively high and persistent density of milfoil weevils at Otter continued the suppression of milfoil there, however there was some increase in milfoil biomass associated with weevil densities that were lower than in 2001.

Table 9. Density of weevil life stages (per stem), total weevils per stem and density of the caterpillars *Acentria* (Acent) and *Parapoynx* (Parap) from the bi-weekly weevil surveys.

Lake	Date	Eggs	Larvae	Pupae	Adults	Total	Acent	Parap
Cenaiko								
	5/16/00	0.1952	0.0229	0.0000	0.0000	0.2181	0.2762	0.0000
	5/30/00	0.0397	0.0159	0.0069	0.0000	0.0625	0.1905	0.0000
	6/13/00	0.1190	0.0883	0.0488	0.0756	0.3318	0.1584	0.0000
	6/29/00	0.2476	0.0556	0.0397	0.0238	0.3667	0.0508	0.0000
	7/11/00	0.3214	0.0347	0.0208	0.1141	0.4911	0.1141	0.0000
	7/24/00	0.7393	0.0208	0.0069	0.1181	0.8851	0.0417	0.0000
	8/10/00	0.5417	0.0917	0.0000	0.0167	0.5667	0.0083	0.0000
	8/24/00	0.0822	0.0519	0.0065	0.0652	0.2058	0.0465	0.0000
	9/7/00	0.0278	0.0324	0.0379	0.0866	0.1847	0.1554	0.0000
	9/20/00	0.0000	0.0694	0.0000	0.0478	0.1173	0.0556	0.0000
	10/3/00	0.0000	0.0368	0.0000	0.0083	0.0451	0.0000	0.0000
	5/21/01	0.0833	0.0000	0.0000	0.0000	0.0833	0.8068	0.0000
	6/6/01	0.6893	0.0000	0.0000	0.1857	0.8750	0.1250	0.0000
	6/18/01	0.0500	0.0000	0.0000	0.0000	0.0500	0.0000	0.0000
	7/3/01	0.0343	0.0000	0.0000	0.0000	0.0343	0.0100	0.0000
	7/19/01	0.0000	0.1268	0.0000	0.0000	0.1268	0.0250	0.0000
	7/30/01	0.0000	0.0000	0.0000	0.0125	0.0125	0.0250	0.0000
	8/15/01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	8/27/01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	9/5/01	0.0104	0.0000	0.0000	0.0000	0.0104	0.0625	0.0000
	9/18/01	0.0000	0.0000	0.0000	0.0000	0.0000	0.1472	0.0000
	5/24/02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0625	0.0000
	6/3/02	0.0208	0.0000	0.0000	0.0000	0.0208	0.0046	0.0139
	6/17/02	0.0000	0.0196	0.0000	0.0000	0.0196	0.0000	0.0000
	7/1/02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	7/16/02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	7/29/02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	8/13/02	0.0000	0.0069	0.0000	0.0069	0.0139	0.0228	0.0000
	8/26/02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	9/10/02	0.0000	0.0069	0.0000	0.0139	0.0208	0.0000	0.0000
Auburn								
	5/19/00	0.0267	0.0267	0.0000	0.0000	0.0533	0.0000	0.0000
	6/1/00	0.0000	0.0218	0.0000	0.0079	0.0298	0.0000	0.0000
	6/15/00	0.0139	0.0278	0.0000	0.0000	0.0417	0.0000	0.0000
	6/27/00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	7/10/00	0.0000	0.0000	0.0069	0.0347	0.0417	0.0000	0.0000
	7/25/00	0.1528	0.0000	0.0069	0.0556	0.2153	0.0000	0.0000
	8/9/00	0.0368	0.0515	0.0515	0.0294	0.1691	0.0000	0.0000
	8/28/00	0.0000	0.0000	0.0000	0.0074	0.0074	0.0000	0.0000
	9/12/00	0.0000	0.0208	0.0062	0.0123	0.0394	0.0000	0.0149
	9/28/00	0.0000	0.0000	0.0000	0.0139	0.0139	0.0000	0.0000
	5/10/01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	5/24/01	0.2562	0.0139	0.0000	0.0309	0.3009	0.0000	0.0000
	5/30/01	0.1847	0.0000	0.0000	0.0000	0.1847	0.0000	0.0000
	6/13/01	0.0069	0.0139	0.0139	0.0308	0.0655	0.0000	0.0000
	6/28/01	0.0278	0.0139	0.0000	0.0000	0.0417	0.0000	0.0000
	7/9/01	0.0278	0.1389	0.0139	0.0139	0.1944	0.0000	0.0000
	7/23/01	0.0000	0.0123	0.0270	0.0139	0.0532	0.0000	0.0000
	8/8/01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	8/20/01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	9/11/01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	9/27/01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 9. Continued.

Lake	Date	Eggs	Larvae	Pupae	Adults	Total	Acent	Parap
Auburn Continued								
	5/22/02	0.0185	0.0000	0.0000	0.0000	0.0185	0.0000	0.0000
	6/13/02	0.0074	0.0000	0.0000	0.0000	0.0074	0.0000	0.0000
	6/26/02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	7/11/02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	7/22/02	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	8/7/02	0.0000	0.0000	0.0000	0.0208	0.0208	0.0000	0.0000
	8/21/02	0.0185	0.0417	0.0024	0.0062	0.0688	0.0000	0.0000
	9/4/02	0.0000	0.0000	0.0000	0.0417	0.0417	0.0000	0.0000
	9/20/02	0.0000	0.0208	0.0417	0.2708	0.3333	0.0000	0.0069
Otter								
	6/5/00	0.1940	0.1321	0.0500	0.0821	0.4583	0.0250	0.0000
	6/22/00	0.1395	0.2027	0.0580	0.0804	0.4806	0.0268	0.0089
	7/5/00	0.0000	0.0403	0.0079	0.0079	0.0575	0.0000	0.0000
	7/18/00	0.0000	0.0074	0.0074	0.0000	0.0147	0.0000	0.0000
	8/2/00	0.0218	0.0000	0.0069	0.0218	0.0506	0.0069	0.0000
	8/16/00	0.0074	0.0147	0.0000	0.0000	0.0221	0.0000	0.0000
	8/29/00	0.0000	0.0441	0.0074	0.0515	0.1029	0.0000	0.0000
	9/13/00	0.0000	0.0394	0.0278	0.0231	0.0903	0.0000	0.0000
	9/26/00	0.0000	0.0069	0.0764	0.1042	0.1875	0.0000	0.0000
	5/21/01	0.3268	0.0000	0.0000	0.1250	0.4518	0.0000	0.0000
	6/4/01	0.2225	0.0000	0.0000	0.1789	0.4015	0.0417	0.0147
	6/21/01	0.5345	0.0407	0.0000	0.0663	0.6415	0.0074	0.0000
	7/5/01	0.4117	0.1354	0.0851	0.1634	0.7955	0.0202	0.0000
	7/16/01	0.1119	0.0000	0.0000	0.2608	0.3727	0.0000	0.0000
	8/1/01	0.1027	0.0469	0.0000	0.1007	0.2502	0.0000	0.0000
	8/13/01	0.1507	0.0306	0.0000	0.0512	0.2324	0.0000	0.0000
	8/28/01	0.0515	0.1922	0.0000	0.0221	0.2658	0.0074	0.0000
	9/5/01	0.1128	0.1553	0.0131	0.1063	0.3875	0.0378	0.0069
	9/17/01	0.0278	0.2750	0.0486	0.2935	0.6449	0.0069	0.1918
	10/2/01	0.0193	0.0432	0.0288	0.1211	0.2124	0.0455	0.0481
	5/21/02	0.0179	0.0000	0.0000	0.0625	0.0804	0.0238	0.0000
	6/2/02	0.5218	0.1862	0.0147	0.1183	0.8646	0.0000	0.0715
	6/17/02	0.0981	0.2302	0.0591	0.0757	0.4631	0.0083	0.0000
	7/3/02	0.1759	0.2037	0.0208	0.1319	0.5324	0.0000	0.0069
	7/16/02	0.1911	0.0000	0.0000	0.2444	0.4355	0.0000	0.0069
	7/29/02	0.0294	0.0296	0.0000	0.0795	0.1459	0.0000	0.0131
	8/13/02	0.0964	0.0182	0.0000	0.0339	0.1484	0.0000	0.0000
	8/26/02	0.0672	0.0389	0.0000	0.0546	0.1607	0.0000	0.0000
	9/9/02	0.0208	0.0069	0.0000	0.0208	0.0486	0.0000	0.0000

Table 9. Continued.

Lake Smith's	Date	Eggs	Larvae	Pupae	Adults	Total	Acent	Parap
	5/25/00	0.2867	0.0267	0.0000	0.0000	0.3133	0.0000	0.0000
	6/8/00	0.2095	0.1429	0.0095	0.0000	0.3619	0.0000	0.0000
	6/21/00	0.2519	0.0824	0.0429	0.0167	0.3938	0.0583	0.0000
	7/3/00	0.0810	0.0369	0.0000	0.0000	0.1179	0.0000	0.0000
	7/19/00	0.0167	0.0250	0.0111	0.0417	0.0944	0.0000	0.0000
	8/4/00	0.2604	0.0702	0.1339	0.0274	0.4919	0.0000	0.0000
	8/15/00	0.0472	0.0750	0.0074	0.0389	0.1685	0.0000	0.0000
	8/23/00	0.0919	0.1100	0.0726	0.0871	0.3361	0.0085	0.0000
	9/6/00	0.0250	0.0880	0.0000	0.0591	0.1721	0.0000	0.0000
	9/19/00	0.0000	0.0167	0.0000	0.0167	0.0333	0.0000	0.0000
	5/15/01	0.0000	0.0000	0.0000	0.0083	0.0083	0.0000	0.0000
	5/31/01	0.0241	0.0000	0.0000	0.0333	0.0574	0.0000	0.0000
	6/11/01	0.2287	0.0083	0.0000	0.0095	0.2466	0.0000	0.0000
	6/25/01	0.0222	0.0000	0.0000	0.0274	0.0496	0.0000	0.0000
	7/10/01	0.0000	0.0482	0.0240	0.0000	0.0722	0.0000	0.0000
	7/23/01	0.0000	0.0639	0.0307	0.0000	0.0946	0.0000	0.0000
	8/8/01	0.0250	0.1480	0.0194	0.0083	0.2008	0.0000	0.0000
	8/24/01	0.0148	0.0917	0.0083	0.0000	0.1148	0.0000	0.0000
	9/13/01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	6/5/02	0.1790	0.0000	0.0000	0.0079	0.1870	0.0102	0.0000
	6/18/02	0.2113	0.1247	0.0000	0.0000	0.3360	0.0000	0.0000
	7/2/02	0.0676	0.0475	0.0079	0.0119	0.1349	0.0000	0.0000
	7/19/02	0.0111	0.0000	0.0083	0.0194	0.0389	0.0000	0.0000
	8/1/02	0.0167	0.0400	0.0000	0.0328	0.0894	0.0000	0.0000
	8/12/02	0.0000	0.0398	0.0000	0.0083	0.0481	0.0000	0.0000
	8/28/02	0.0083	0.0824	0.0000	0.0324	0.1231	0.0000	0.0000
	9/10/02	0.0000	0.0000	0.0000	0.0102	0.0102	0.0000	0.0000

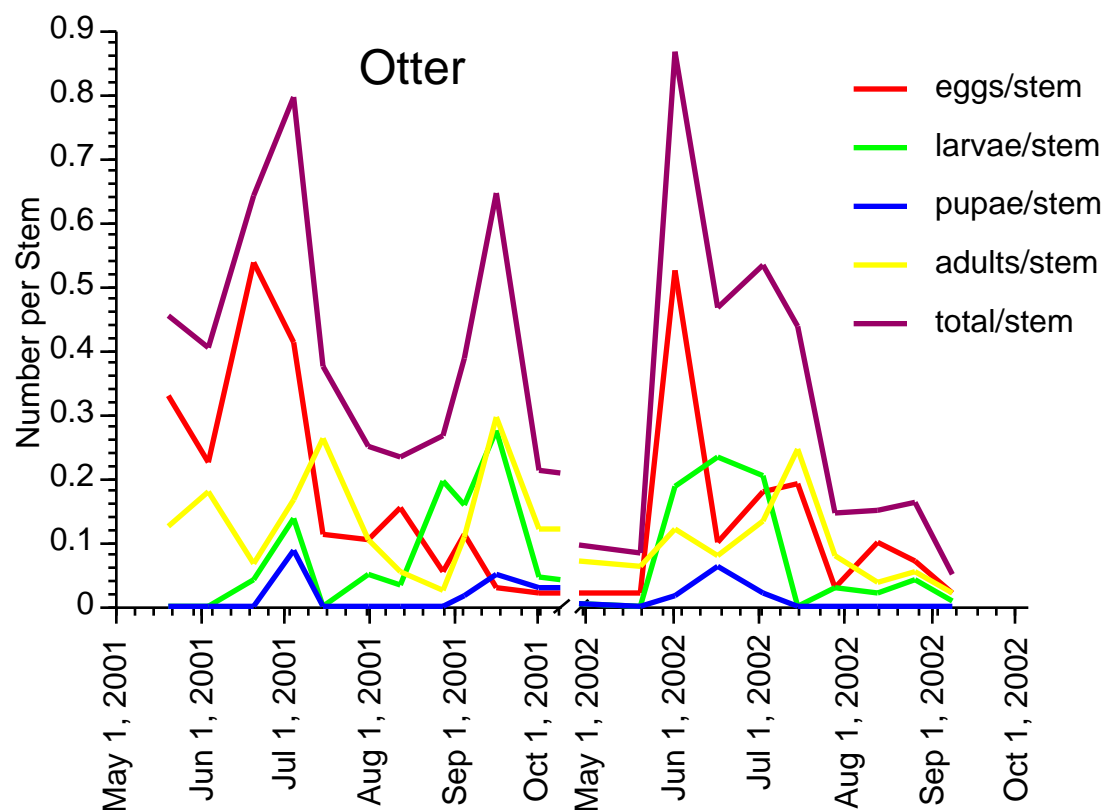


Fig. 3. Biweekly density (number per milfoil stem) of weevil life stages at Otter Lake in 2001-2002.

Minneapolis survey lakes:

Milfoil biomass increased in the three Minneapolis lakes in 2002 (Table 10 and Table 1). Although milfoil increased from 2001 at Lake-of-the-Isles, it was still quite low, 25g dry/m². The low densities in 2001 and 2002 are likely due to poor water clarity (Table 11). Just prior to sampling in 2002, milfoil was much more dense (Ward, personal observation), but it declined with a rapid decrease in clarity. Most of the non-milfoil biomass was coontail and the relatively low average contribution of milfoil (32% of biomass) was due to many samples that contained only coontail. Sediment pore water ammonium was moderate (Table 11) and exchangeable N levels were well above those expected for nuisance milfoil (> 0.01 mg N/g sediment). Milfoil continued to increase at Lake Calhoun from very low levels in 1999-2000 (Table 10). Milfoil biomass was 180 g/m² and composed 94% of total plant biomass. Pore water ammonium increased in 2002 (Table 11), but exchangeable N was well above levels for nuisance milfoil in June 2001 and almost as high in 2002. Milfoil biomass remained high at Harriet and by September increased to 340 g/m². Milfoil composed 86-96% of total plant biomass at Harriet. Pore water ammonium was moderate (3 mg N/L) but exchangeable N was > 0.01 mg N/g. As noted previously, milfoil biomass increased somewhat at Cedar (Table 1; 150-230 g/m²) and composed 63-73% of total plant biomass (Table 3). Few other plants were collected and coontail composed most of the non-milfoil biomass.

Table 10. Total plant and milfoil biomass (g dry/m²) and mean percent of plant biomass that was Eurasian watermilfoil at Minneapolis Chain of Lakes lakes in summer 1999-2002. N = 20 samples at all sites. See Tables 1-3 for Cedar results.

Lake	Date	Total Plant Biomass (g/m ²)	Milfoil Biomass (g/m ²)	% Milfoil (of biomass)	Secchi Depth (m)
Lake of the Isles	9/14/95	62.5	58.3	90.1%	0.5
	SE	20.6	22.6	5.0%	
	8/30/96	199.7	169.2	74.6%	1.1
	SE	74.0	74.1	10.1%	
	8/14/97	31.9	9.9	22.4%	1.4
	SE	10.4	5.3	8.6%	
	8/31/98	28.2	14.0	36.9%	0.3
	1 SE	4.7	6.1	12.2%	
	8/16/99	51.8	49.3	88.3%	0.5
	1SE	14.8	14.5	4.4%	
	6/28/00	265.4	252.9	88.9%	2.3
	1 SE	45.6	46.9	3.7%	
	8/16/00	195.4	192.7	97.7%	2.2
	1 SE	17.6	17.8	1.1%	
	6/27/01	22.0	4.5	30.0%	1.6
	1 SE	7.1	1.8	8.2%	
	9/7/01	16.0	3.0	18.6%	0.8
1 SE	8.9	2.2	7.9%		
7/9/02	37.7	24.9	32.4%	1.1	
1 SE	9.4	9.0	9.1%		
Calhoun	9/16/99	41.6	8.1	10.8%	1.6
	1 SE	10.7	3.9	5.5%	
	6/26/00	22.7	10.8	38.3%	3.1
	1 SE	11.3	5.6	13.5%	
	8/18/00	12.5	10.9	56.5%	1.8
	1 SE	4.0	4.1	10.0%	
	6/28/01	99.8	98.1	81.0%	3.2
	1 SE	24.9	25.0	7.1%	
	9/6/01	142.1	121.9	73.3%	2.3
	1 SE	30.5	31.3	8.4%	
7/26/02	181.4	179.5	94.1%	2.8	
1 SE	26.4	26.6	4.3%		
Harriet	9/23/99	180.2	168.3	87.9%	2.6
	1 SE	27.6	26.8	5.2%	
	6/30/00	332.1	215.0	61.5%	1.6
	1 SE	53.2	37.8	5.7%	
	8/22/00	106.0	90.7	78.0%	2.3
	1 SE	18.9	19.5	5.9%	
	7/2/01	311.1	259.4	74.1%	2.5
	1 SE	46.4	45.9	6.9%	
	9/12/01	170.5	149.6	83.7%	3.0
	1 SE	25.7	23.6	5.3%	
	7/11/02	252.9	237.3	86.1%	2.2
1 SE	42.3	44.0	5.0%		
9/14/02	354.8	337.3	95.5%	2.9	
1 SE	43.6	42.0	1.8%		

Table 11. Sediment characteristics (bulk density, percent organic matter, sediment pore water ammonium concentrations) and water column characteristics at Minneapolis Chain of Lakes lakes in summer 1999-2002. Nine sediment samples from the shallow, intermediate and deep stations were collected at each lake.

Lake/Date	Bulk Dens. (g dm/ml)	NH ₄ (mg/L)	% Organic	Chl-a (mg/m ³)	SD (m)	Temp (°C 1m)	10% PAR Depth (m)	Plant Limit (m)
Calhoun								
9/24/97				7.2	3.1	18.9	2.5-3.0	4.7
9/4/98				3.7	3.0	23.7	3.5-4.0	4.1
9/21/99				17.1	1.6	18.5	2.0	3.8
6/26/00	0.75	2.00	6.17	4.3	3.1	21.4	3.5-4	
2se	0.32	1.08	2.60					
8/18/00	0.65	1.15	0.17	8.6	1.8	24.3	3.5-4	2.4
2se	0.38	0.33	0.03					
6/28/01	0.68	1.31	6.0	19.8	3.2	26.1	3.5	
2se	0.31	1.02	2.4					
9/6/01	0.68	2.96	7.6	3.5	2.3	22.9	5	
2se	0.40	1.58	3.2					
7/26/02	0.74	6.62	15.3	.	2.8	25.2	3.5	
2se	0.37	4.33	14.3					
8/23/02	.	.	.	11.2	2.2	22.1	3-3.5	
2se	.	.	.					
Lake of the Isles								
9/14/95	1.45	5.21	1.8	57.4	0.5	20.3	0.5-1.0	0.5
2se	0.36	4.36	1.1					
8/30/96	0.28	9.30	10.0	6.9	1.1	24.6	1.5-2.0	2.0
2se	0.08	5.32	6.7					
8/13/97	0.71	8.48	16.2	26.2	1.4	22.5	1.0-1.5	3.7
2se	0.58	0.88	20.0					
8/31/98	0.25	29.33	23.9	54.3	0.3	24.3	0.5-1.0	3.3
2se	0.28	19.07	19.0					
8/16/99	0.15	0.54	24.2	83.7	0.5	22.5	0.5-1.0	3.0
2se	0.05	0.56	12.5					
6/28/00	0.72	0.57	41.1	8.8	2.3	22.9	1.5-2.0	
2se	0.87	0.23	13.3					
8/16/00	0.51	1.13	26.1	15.8	2.2	25.7	2.5-3.0	4.0
2se	0.39	1.09	12.8					
6/29/01	0.95	2.55	16.8	49.5	1.6	26.3	2.0-2.5	
2se	0.49	1.96	14.1					
9/7/01	0.53	3.42	27.6	42.8	0.8	23.5	1.0-1.5	
2se	0.44	1.38	15.8					
7/9/02	0.60	2.66	42.1	.	1.1	28.4	1.0-1.5	
2se	0.66	2.03	55.7					
8/22/02				82.3	0.7	22.7	1	
Harriet								
10/9/97				4.5	> 5.4	17.3	3.0-3.5	5.2
9/23/98				3.7	2.6	20.3	4.0-4.5	5.0
9/24/99				7.5	2.6	17.5	3.5	4.0
6/30/00	0.74	3.74	7.69	6.1	1.6	22.8	2.5-3	
2se	0.42	1.43	3.87					
8/22/00	0.76	6.72	.	8.3	2.3	23.1	3.5-4	4.1
2se	0.48	1.59	.					
7/2/01	0.94	3.59	7.0	9.1	2.5	23.4	2.5-3.0	
2se	0.44	2.31	3.6					
9/12/01	0.78	2.13	7.3	4.0	3.6	21.5	4.5-5.0	
2se	0.44	1.21	3.7					
7/11/02	1.23	3.28	6.1	7.4	2.2	25.4	3.5	
2se	0.44	1.64	1.1					
9/14/02	2.9	23.1	4	

Plant coverage and occurrence (Table 12) showed trends similar to biomass. Milfoil coverage and density increased in Lake Calhoun to levels similar to 1998. The number of other species found decreased. Very little weevil damage was noted. Milfoil coverage and density also increased in Cedar Lake and was the highest recorded in whole lake surveys from 1999-2002. Coontail was the second most common plant. Milfoil coverage increased at Lake Harriet but density was similar to previous years; coontail was also the second most common plant and the total number of species collected declined from higher numbers in 2000-2001 (Table 12). Visible milfoil and occurrence increased at Lake-of-the-Isles but density remained similar to 2001. Coverage and density were lower in 2001-2002 than in 2000, probably due to poorer clarity (Table 11).

Table 12. Estimates of plant coverage and occurrence for the whole-lake surveys (Calhoun, Cedar, Harriet, Isles, Centerville, Schultz and Vadnais). Estimates of visual milfoil cover (% Vis MSP Cov), percent visual occurrence, occurrence on the drop hook and mean weevil damage rating (0-5) for the whole lake estimates were based on n = 66-82 stations at each of the Minneapolis lakes and 25-30 stations at Centerville, Schultz and Vadnais. Jessen and Lound (1962) relative density ratings (0-5) were determined from a subset of 5-6 transects (n=24-29 stations). Relative density is the mean for all stations sampled. Species abbreviations are given in Appendix I.

Cedar Lake Date	n	% Vis MSP Cov Mean ± 1S.E.	% Occurrence (Visual) Spp.% Occ. ±1S.D.	% Occurrence (Drop Hook) Spp.% Occ. ±1S.D.	Density Rating n = 26 Spp.Density ± 2S.E.
9/27/99	75	50.1 ± 4.2%	MSP 78.7 ± 4.7% NMP 13.3 ± 3.9%	MSP 90.7 ± 3.4% CRT 25.3 ± 5.0% NMP 6.7 ± 2.9%	MSP 3.96 ± 0.46 CRT 1.50 ± 0.60 NMP 0.12 ± 0.23 PRI 0.04 ± 0.08 DRC 0.04 ± 0.08

Cedar Lake Date	n	Mean ± 1S.E.	Spp.% Occ. ±1S.D.	Spp.% Occ. ±1S.D.	Spp.Density ± 2S.E.
8/9/00	72	44.3 ± 4.7%	MSP 68.1 ± 5.5% CRT 9.7 ± 3.5% NMP 15.3 ± 4.2% PAM 1.4 ± 1.4% PEC 1.4 ± 1.4%	MSP 87.5 ± 3.9% CRT 23.6 ± 5.0% NAJ 1.4 ± 1.4% NMP 6.9 ± 3.0% PAM 1.4 ± 1.4% PCR 1.4 ± 1.4% CHA 1.4 ± 1.4%	MSP 3.58 ± 0.61 CRT 1.29 ± 0.53 NMP 0.38 ± 0.38 NAJ 0.08 ± 0.17 CHA 0.04 ± 0.08

Cedar Lake Date	n	% Vis MSP Cov Mean ± 1S.E.	% Occurrence (Visual) Spp.% Occ. ± 1S.D.	% Occurrence (Drop Hook) Spp.% Occ. ± 1S.D.	Density Rating n = 24 Spp.Density ± 2S.E.
8/21/01	75	36.3 ± 4.2%	MSP 66.7 ± 5.4% NMP 16.0 ± 4.2% CRT 9.3 ± 3.4% PEC 1.3 ± 1.3% PRI 1.3 ± 1.3% PZS 1.3 ± 1.3%	MSP 81.3 ± 4.5% CRT 34.7 ± 5.5% NMP 5.3 ± 2.6% CHA 1.3 ± 1.3% PEC 1.3 ± 1.3% PRI 1.3 ± 1.3%	MSP 2.83 ± 0.71 CRT 0.71 ± 0.52 NMP 0.08 ± 0.17

Weevil Damage Rating: 0.24

Cedar Lake Date	n	% Vis MSP Cov Mean ± 1SE	% Occurrence (Visual) Spp. % Occ. ± 1 SD	% Occurrence (Drop Hook) Spp. % Occ. ± 1 SD	Density Rating n = 18 Spp. Density ± 2SE
8/26/02	68	56.6% ± 4.6%	MSP 77.9 ± 0.1 CRT 19.1 ± 0.0 PAM 5.9 ± 0.0 NMP 4.4 ± 0.0 PPR 4.4 ± 0.0 PCR 1.5 ± 0.0	MSP 83.6 ± 0.0 CRT 47.1 ± 0.1 PAM 4.4 ± 0.0 PPR 4.4 ± 0.0 NMP 2.9 ± 0.0	MSP 4.44 ± 0.29 CRT 2.00 ± 0.76 PAM 0.28 ± 0.56

Weevil Damage Rating: 0.31

Table 12 Continued

Lake Calhoun		% Vis MSP Cov	% Occurrence (Visual)		% Occurrence (Drop Hook)		Density Rating n = 27	
Date	n	Mean ± 1SE	Spp.	% Occ. ± 1 SD	Spp.	% Occ. ± 1 SD	Spp.	Density ± 2SE
9/4/98	63	30.7 ± 4.4%	MSP	87.3 ± 4.2%	MSP	76.2 ± 5.4%	MSP	3.67 ± 0.49
			PEC	17.5 ± 4.8%	CRT	50.8 ± 6.3%	CRT	3.07 ± 0.53
			PRI	14.3 ± 4.4%	PEC	12.7 ± 4.2%	PCR	0.48 ± 0.38
			CRT	11.1 ± 4.0%	PRI	3.2 ± 2.2%	PEC	0.48 ± 0.43
			PCR	7.9 ± 3.1%	PZS	1.6 ± 1.6%	PRI	0.41 ± 0.36
			NAJ	6.3 ± 3.1%			NAJ	0.33 ± 0.34
			ELD	1.6 ± 1.6%			ELD	0.04 ± 0.07
			HET	1.6 ± 1.6%			HET	0.04 ± 0.07

Weevil Damage Rating: 0.698±0.133

Lake Calhoun		% Vis MSP Cov	% Occurrence (Visual)		% Occurrence (Drop Hook)		Density Rating n = 25	
Date	n	Mean ± 1SE	Spp.	% Occ. ± 1 SD	Spp.	% Occ. ± 1 SD	Spp.	Density ± 2SE.
9/16/99	74	45.0 ± 4.5%	MSP	87.3 ± 3.9%	MSP	76.2 ± 5.0%	MSP	1.84 ± 0.75
			PEC	17.5 ± 4.4%	CRT	50.8 ± 5.8%	CRT	3.32 ± 0.47
			PRI	14.3 ± 4.1%	PEC	12.7 ± 3.9%	PRI	0.20 ± 0.23
			CRT	11.1 ± 3.7%	PRI	3.2 ± 2.0%		
			PCR	7.9 ± 3.1%	PZS	1.6 ± 1.5%		
			NAJ	6.3 ± 2.8%				
			ELD	1.6 ± 1.5%				
			HET	1.6 ± 1.5%				

Weevil Damage Rating:

Lake Calhoun		% Vis MSP Cov	% Occurrence (Visual)		% Occurrence (Drop Hook)		Density Rating n = 26	
Date	n	Mean ± 1S.E.	Spp.	% Occ. ± 1S.D.	Spp.	% Occ. ± 1S.D.	Spp.	Density ± 2S.E.
8/17/00	73	6.8 ± 2.0%	MSP	26.0 ± 5.1%	MSP	24.7 ± 5.0%	MSP	1.62 ± 0.70
			PEC	1.4 ± 1.4%	CRT	11.0 ± 3.7%	PEC	0.04 ± 0.08
			PRI	2.7 ± 1.9%	NAJ	2.7 ± 1.9%	PZS	0.12 ± 0.17
			NAJ	1.4 ± 1.4%	PRI	2.7 ± 1.9%	CRT	2.00 ± 0.63
			CHA	1.4 ± 1.4%	PZS	1.4 ± 1.4%	ELD	0.04 ± 0.08
							PCR	0.38 ± 0.35
							NAJ	0.31 ± 0.29
							PRI	0.12 ± 0.17
							HET	0.08 ± 0.15
							CHA	0.42 ± 0.32
							VAL	0.04 ± 0.08
							ZPA	0.15 ± 0.31

Lake Calhoun		% Vis MSP Cov	% Occurrence (Visual)		% Occurrence (Drop Hook)		Density Rating n = 26	
Date	n	Mean ± 1S.E.	Spp.	% Occ. ± 1S.D.	Spp.	% Occ. ± 1S.D.	Spp.	Density ± 2S.E.
8/17/01	66	31.3 ± 4.9%	MSP	39.4 ± 6.0%	MSP	56.1 ± 6.1%	MSP	2.62 ± 0.62
			PEC	7.6 ± 3.3%	CRT	15.2 ± 4.4%	NAJ	0.54 ± 0.40
			CRT	3.0 ± 2.1%	PEC	7.6 ± 3.3%	CRT	0.46 ± 0.28
			PCR	3.0 ± 2.1%	PRI	6.1 ± 2.9%	PRI	0.27 ± 0.38
			NAJ	1.5 ± 1.5%	NAJ	3.0 ± 2.1%	PCR	0.19 ± 0.19
			PZS	1.5 ± 1.5%	PZS	3.0 ± 2.1%	PEC	0.15 ± 0.24
					PCR	1.5 ± 1.5%	PZS	0.15 ± 0.24
					PFO	1.5 ± 1.5%	PPR	0.12 ± 0.23
							CHA	0.08 ± 0.11
							HET	0.04 ± 0.08
							PFO	0.04 ± 0.08

Weevil Damage Rating: 0.2

Calhoun		% Vis MSP Cov	% Occurrence (Visual)		% Occurrence (Drop Hook)		Density Rating n = 25	
Date	n	Mean ± 1S.E.	Spp.	% Occ. ± 1S.D.	Spp.	% Occ. ± 1S.D.	Spp.	Density ± 2S.E.
8/20/02	68	52.2 ± 4.0%	MSP	80.9 ± 0.0	MSP	71.4 ± 0.1	MSP	3.16 ± 0.71
			CRT	7.5 ± 0.0	CRT	19.0 ± 0.0	CRT	0.16 ± 0.19
			PRI	6.9 ± 0.0	PRI	4.8 ± 0.0	NAJ	0.04 ± 0.08
			VAL	2.9 ± 0.0	NAJ	1.6 ± 0.0	PRI	0.28 ± 0.29
			PEC	1.5 ± 0.0			VAL	0.04 ± 0.08
			PIL	1.5 ± 0.0				

Weevil Damage Rating: 0.15

Table 12 Continued

Lake Harriet Date	n	% Vis MSP Cov Mean ± 1 S.E.	% Occurrence (Visual) Spp. % Occ. ± 1 S.D.	% Occurrence (Drop Hook) Spp. % Occ. ± 1 S.D.	Density Rating n = 29 Spp. Density ± 2S.E.
10/9/97	72	52.2 ± 3.8%	MSP 87.5 ± 3.9% CRT 8.3 ± 3.3% HET 1.4 ± 1.4% PRI 1.4 ± 1.4%	MSP 86.1 ± 4.1% CRT 40.3 ± 5.8% PRI 1.4 ± 1.4% PZS 1.4 ± 1.4%	MSP 4.41 ± 0.36 CRT 2.21 ± 0.49 PRI 0.17 ± 0.14 ELD 0.03 ± 0.07 NAJ 0.03 ± 0.07 PEC 0.03 ± 0.07

Weevil Damage rating 0.507±0.072

Lake Harriet Date	n	% Vis MSP Cov Mean ± 1SE	% Occurrence (Visual) Spp. % Occ. ± 1 SD	% Occurrence (Drop Hook) Spp. % Occ. ± 1 SD	Density Rating n = 27 Spp. Density ± 2SE
9/23/98	73	59.2 ± 4.2%	MSP 84.9 ± 4.2% CRT 8.2 ± 3.2% PRI 6.8 ± 3.0% NAJ 1.4 ± 1.4% PZS 1.4 ± 1.4%	MSP 82. ± 4.5% CRT 39.7 ± 5.7% PRI 6.8 ± 3.0% NAJ 5.7 ± 2.7% PEC 1.4 ± 1.4% PZS 1.4 ± 1.4%	MSP 3.81 ± 0.68 CRT 2.07 ± 0.55 PRI 0.26 ± 0.31 PZS 0.19 ± 0.26 NAJ 0.15 ± 0.18 PEC 0.07 ± 0.10 HET 0.04 ± 0.07

Weevil Damage Rating: 0.493±0.088

Lake Harriet Date	n	% Vis MSP Cov Mean ±1S.E.	% Occurrence (Visual) Spp. % Occ. ± 1S.D.	% Occurrence (Drop Hook) Spp. % Occ. ±S.D.	Density Rating n = 29 Spp. Density ±2S.E.
9/24/99	71	71.9 ± 2.8%	MSP 79.2 ± 4.8% CRT 11.1 ± 3.7%	MSP 93.1 ± 3.0% CRT 59.7 ± 5.8%	MSP 3.86 ± 0.44 PZS 0.03 ± 0.07 CRT 3.14 ± 0.46

Lake Harriet Date	n	% Vis MSP Cov Mean ±1S.E.	% Occurrence (Visual) Spp. % Occ. ±1S.D.	% Occurrence (Drop Hook) Spp. % Occ. ±1S.D.	Density Rating n = 25 Spp. Density ±2S.E.
8/21/00	66	36.8 ± 4.2%	MSP 71.2 ± 5.6% CRT 24.2 ± 5.3% NAJ 1.5 ± 1.5% PZS 3.0 ± 2.1% PEC 3.0 ± 2.1%	MSP 74.2 ± 5.4% CRT 62.1 ± 6.0% NAJ 1.5 ± 1.5% PZS 1.5 ± 1.5%	MSP 3.56 ± 0.54 PEC 0.12 ± 0.13 PZS 0.08 ± 0.16 CRT 3.20 ± 0.60 NAJ 0.12 ± 0.24 PRI 0.04 ± 0.08 CHA 0.04 ± 0.08

Lake Harriet Date	n	% Vis MSP Cov Mean ± 1SE	% Occurrence (Visual) Spp. % Occ. ± 1 SD	% Occurrence (Drop Hook) Spp. % Occ. ± 1 SD	Density Rating n = 20 Spp. Density ± 2SE
8/14/01	71	46.4 ± 4.7%	MSP 54.9 ± 5.9% CRT 14.1 ± 4.1% HET 1.4 ± 1.4% PEC 1.4 ± 1.4%	MSP 81.7 ± 4.6% CRT 60.6 ± 5.8% PRI 1.4 ± 1.4%	MSP 3.65 ± 0.55 CRT 3.05 ± 0.59 HET 0.10 ± 0.14 NAJ 0.05 ± 0.10 PRI 0.05 ± 0.10 PZS 0.05 ± 0.10

Weevil Damage Rating: 0.01

Lake Harriet Date	n	% Vis MSP Cov Mean ± 1SE	% Occurrence (Visual) Spp. % Occ. ± 1 SD	% Occurrence (Drop Hook) Spp. % Occ. ± 1 SD	Density Rating n = 20 Spp. Density ± 2SE
8/19/02	n=66.	62.1 ± 4.6%	MSP 83.3 ± 0.0 CRT 10.6 ± 0.0	MSP 75.8 ± 0.1 CRT 34.8 ± 0.1	MSP 3.40 ± 0.70 CRT 2.15 ± 0.71 PRI 0.05 ± 0.10

Weevil Damage Rating: 0.36

Table 12 Continued

Lake of the Isles	% Vis MSP Cov	% Occurrence (Visual)		% Occurrence (Drop Hook)		Density Rating	
Date	n	Mean ± 1 S.E.	Spp.	% Occ. ± 1 S.D.	Spp.	% Occ. ± 1 S.D.	Spp. Density ± 2S.E.
8/13/97	72	15.4 ± 3.5%	MSP	31.9 ± 5.5%	MSP	59.7 ± 5.8%	CRT 2.48 ± 0.37
			CRT	26.4 ± 5.2%	CRT	62.5 ± 5.7%	MSP 1.84 ± 0.53
			PZS	1.4 ± 1.4%	NAJ	2.8 ± 1.9%	PZS 0.04 ± 0.08
					PZS	2.8 ± 1.9%	

Lake of the Isles	% Vis MSP Cov	% Occurrence (Visual)		% Occurrence (Drop Hook)		Density Rating	
Date	n	Mean ± 1SE	Spp.	% Occ. ± 1 SD	Spp.	% Occ. ± 1 SD	Spp. Density ± 2SE
8/31/98	73	8.5 ± 2.0%	MSP	28.8 ± 5.3%	MSP	56.2 ± 5.8%	CRT 2.85 ± 0.60
			CRT	15.1 ± 4.2%	CRT	39.7 ± 5.7%	MSP 2.81 ± 0.69
					CHC	2.7 ± 1.9%	NAJ 0.08 ± 0.15
					NAJ	2.7 ± 1.9%	CHC 0.04 ± 0.08
					PEC	1.4 ± 1.4%	PCR 0.04 ± 0.08
							PEC 0.04 ± 0.08

Weevil Damage Rating: 1.411±0.320

Lake of the Isles	% Vis MSP Cov	% Occurrence (Visual)		% Occurrence (Drop Hook)		Density Rating	
Date	n	Mean ±1S.E.	Spp.% Occ. ±1S.D.	Spp.% Occ. ±1S.D.	Spp.% Occ. ±1S.D.	Spp.Density ± 2S.E.	
8/17/99	72	21.2 ± 2.8%	MSP	22.2 ± 4.9%	MSP	72.2 ± 5.3%	MSP 3.69 ± 0.57
			CRT	1.4 ± 1.4%	CRT	40.3 ± 5.8%	PEC 0.04 ± 0.08
							CRT 2.88 ± 0.52
							NAJ 0.04 ± 0.08
							CHA 0.04 ± 0.08

Lake of the Isles	% Vis MSP Cov	% Occurrence (Visual)		% Occurrence (Drop Hook)		Density Rating	
Date	n	Mean ±1S.E.	Spp.% Occ. ±1S.D.	Spp.% Occ. ±1S.D.	Spp.% Occ. ±1S.D.	Spp.Density ± 2S.E.	
8/14/00	82	50.7 ± 4.4%	MSP	82.2 ± 14.2%	MSP	87.7 ± 13.6%	MSP 3.73 ± 0.49
					CRT	24.7 ± 14.8%	CRT 1.58 ± 0.58
							PCR 0.23 ± 0.26
							NAJ 0.04 ± 0.08
							PRI 0.04 ± 0.08

Lake of the Isles	% Vis MSP Cov	% Occurrence (Visual)		% Occurrence (Drop Hook)		Density Rating	
Date	n	Mean ±1S.E.	Spp.% Occ. ±1S.D.	Spp.% Occ. ±1S.D.	Spp.% Occ. ±1S.D.	Spp.Density ± 2S.E.	
8/15/01	82	3.9 ± 1.4%	MSP	7.3 ± 2.9%	MSP	25.6 ± 4.8%	CRT 2.88 ± 0.56
			CRT	7.3 ± 2.9%	CRT	36.6 ± 5.3%	MSP 1.65 ± 0.68
					NAJ	1.2 ± 1.2%	NAJ 0.08 ± 0.15
					PCR	1.2 ± 1.2%	PCR 0.08 ± 0.15
							PFO 0.04 ± 0.08
							PRI 0.04 ± 0.08

Weevil Damage Rating: 0.15

Lake of the Isles	% Vis MSP Cov	% Occurrence (Visual)		% Occurrence (Drop Hook)		Density Rating	
Date	n	Mean ±1S.E.	Spp.% Occ. ±1S.D.	Spp.% Occ. ±1S.D.	Spp.% Occ. ±1S.D.	Spp.Density ± 2S.E.	
8/22/02	70	17.3 ± 3.6%	MSP	39.0 ± 0.1	MSP	55.7 ± 0.1	MSP 2.90 ± 0.79
			CRT	19.5 ± 0.0	CRT	40.0 ± 0.1	CRT 1.67 ± 0.68
			BRA	1.2 ± 0.0	CHA	1.4 ± 0.0	CHA 0.05 ± 0.10
			PEC	1.2 ± 0.0			

Weevil Damage Rating: 0.06

Table 12 Continued

Centerville		% Vis MSP Cov		% Occurrence (Visual)		% Occurrence (Drop Hook)		Density Rating		n = 20
Date	n	Mean	1S.E.	Spp.% Occ.	±1S.D.	Spp.% Occ.	±1S.D.	Spp.Density	± 2S.E.	
8/14/02	35	0.3	±0.2%	MSP	8.6 ± 0.0	MSP	71.4 ± 0.1	MSP	3.25 ± 0.66	
				CRT	2.9 ± 0.0	CRT	71.4 ± 0.1	CRT	1.65 ± 0.57	
				LTR	2.9 ± 0.0	CHA	22.9 ± 0.1	PCR	0.05 ± 0.10	
				PEC	2.9 ± 0.0	PCR	2.9 ± 0.0	CHA	0.80 ± 0.64	
Weevil Damage Rating:		0.79				PEC	2.9 ± 0.0			
Schultz		% Vis MSP Cov		% Occurrence (Visual)		% Occurrence (Drop Hook)		Density Rating		n = 24
Date	n	Mean	1S.E.	Spp.% Occ.	±1S.D.	Spp.% Occ.	±1S.D.	Spp.Density	± 2S.E.	
9/3/02	25	16.6	±4.4%	MSP	80.8 ± 0.1	MSP	84.6 ± 0.1	MSP	2.46 ± 0.58	
				CRT	69.2 ± 0.1	CRT	100.0 ± 0.0	PEC	0.04 ± 0.08	
				PEC	30.8 ± 0.1	PAM	30.8 ± 0.1	CRT	3.38 ± 0.66	
				PAM	23.1 ± 0.1	PEC	19.2 ± 0.1	PAM	0.83 ± 0.62	
				NAJ	3.8 ± 0.0	NAJ	7.7 ± 0.1			
						PCR	7.7 ± 0.1			
Vadnais		% Vis MSP Cov		% Occurrence (Visual)		% Occurrence (Drop Hook)		Density Rating		n = 31
Date	n	Mean	1S.E.	Spp.% Occ.	±1S.D.	Spp.% Occ.	±1S.D.	Spp.Density	± 2S.E.	
8/16/02	34	22.4	±3.8%	MSP	55.9 ± 0.1	MSP	82.4 ± 0.1	MSP	2.65 ± 0.48	
				CRT	38.2 ± 0.1	CRT	82.4 ± 0.1	PEC	0.58 ± 0.40	
				PEC	26.5 ± 0.1	PEC	38.2 ± 0.1	PZS	0.90 ± 0.40	
				VAL	23.5 ± 0.1	VAL	35.3 ± 0.1	CRT	2.97 ± 0.51	
				PRI	11.8 ± 0.1	PZS	23.5 ± 0.1	NMP	0.03 ± 0.06	
				PZS	8.8 ± 0.0	PPR	20.6 ± 0.1	NAJ	0.10 ± 0.19	
				PPR	5.9 ± 0.0	PRI	5.9 ± 0.0	PRI	0.10 ± 0.14	
				NAJ	2.9 ± 0.0	NAJ	2.9 ± 0.0	PPR	0.29 ± 0.19	
Weevil Damage Rating:		0.49		NMP	2.9 ± 0.0	NMP	2.9 ± 0.0	VAL	0.87 ± 0.55	

It should be noted that we expected that alum treatments in the Minneapolis Chain-of-Lakes would eventually enhance native plant communities. Although we predicted that Eurasian watermilfoil would initially be enhanced by better water clarity, we expected that better water clarity would favor the native plants after several years, reducing the competitive advantage Eurasian watermilfoil appears to have in lower light environments. To date we have no indication that alum treatments have enhanced the native plant communities. Eurasian watermilfoil remains dominant in Cedar Lake, 6 years after treatment in 1996. The number of plant species remains low and the better clarity appears to have reduced seasonal fluctuations in milfoil biomass. Eurasian watermilfoil increased and also remains dominant in Harriet and Calhoun, although the alum treatments are likely too recent to have resulted in a longer term shift in plant community composition. However, it should also be noted that there are few milfoil weevils in any of these lakes and a shift to native communities may not occur without some additional factor, such as herbivory, limiting Eurasian watermilfoil.

Coverage and density of milfoil was generally lower at the three additional lakes surveyed, Centerville, Schultz and Vadnais (Table 12), but relative densities were moderate (2.5-3.25). Coontail was the dominant native plant in these lakes. Poor clarity and high chlorophyll (Table 13) probably limited coverage and plant growth in these lakes, although weevils (see below) may also be a factor.

Table 13. Water column characteristics at additional survey lakes in summer 2002 and sediment characteristics (bulk density, percent organic matter, sediment pore water ammonium concentrations) at a subset of these lakes.

Lake/Date	Bulk Dens. (g dm/ml)	NH ₄ (mg/L)	% Organic	Chl-a (mg/m ³)	SD (m)	Temp (°C 1m)	10% PAR Depth (m)
Bald Eagle 8/5/02				53.4	0.8	24.7	0.5-1.0
Centerville 8/14/02	1.00	10.20	13.5	39.0	1.1	25.9	1.5
2se	0.61	.	7.4				
Independence 7/31/02				38.2	1.0	26.5	1.0-1.5
Peltier 7/30/02				85.3	0.8	25.1	1.0
Schultz 9/3/02				20.0	2.0	24.4	2.0
Vadnais 8/7/02	1.40	1.24	7.5	15.2	1.7	23.5	2
2se	0.23	.	5.8				

Surveys of weevils and fish

To attempt to detect additional declines and to determine if agent and perhaps milfoil density may be related to fish density, we also conducted weevil surveys on 6 new lakes along with Cedar Lake and Calhoun in August. These lakes had DNR fish surveys conducted in 2000, 2001 or 2002 (Table 14). A range of weevil densities was found; generally lakes with high fish densities had low weevil densities and lakes with high weevil densities had low sunfish densities (Table 14). There was a significant ($p = 0.05$) regression of adult weevil density on $\ln(\text{sunfish/trapnet})$:

$$\text{Adults/stem} = 0.16 - 0.034 \ln(\text{sunfish/trapnet}), r^2 = 0.49$$

Abundance of sunfish that results in zero weevils can be predicted from the converse regression, which gave an intercept of 4.36, or 78 sunfish per trapnet. The regression of sunfish on total weevil abundance was marginally significant ($p=0.1$).

To increase sample size we included lakes for which fisheries surveys were available and for which we had weevil surveys during the same year. For Cenaiko Lake in 1998 we had one weevil survey from September, one week prior to the fisheries survey. For Lake Auburn in 2000, Cenaiko in 2002 and Otter Lake in 2001 and 2002 we averaged our bi-weekly weevil surveys to provide an average summer density. We then used the combined data set to determine the relationship between weevil density and sunfish relative abundance (Fig. 4). Cenaiko Lake in 1998 was determined to be an outlier (weevil density was much higher than all other sites, Table 14) and was dropped from the regressions (Fig. 4). The regressions of total weevil density and adult weevil density on $\ln(\text{sunfish/trapnet})$ were highly significant ($p=0.003$ and $p=0.001$, respectively). The equations for fish abundance on weevil density are provided because they can be used to predict the sunfish density resulting in zero weevils.

$$\ln(\text{sunfish/trapnet}) = 4.35 - 6.12(\text{TotalWeevils/stem}), r^2 = 0.61$$

$$\ln(\text{sunfish/trapnet}) = 4.38 - 22.94(\text{AdultWeevils/stem}), r^2 = 0.71$$

These regressions suggest that sunfish density explains 61 and 71% of the variation in total weevil and adult weevil density, respectively, among lakes and support our experimental observations that sunfish predation is an important factor limiting weevil density (and thus milfoil control) in Minnesota lakes. The stronger relationship between sunfish and adult densities is intuitively appealing as sunfish prey primarily on adults (Sutter and Newman 1997) and thus indirectly limit total weevil densities. The high density of weevils in Cenaiko in 1998 is consistent with the other results and suggests that at some low fish density, fish are not limiting weevil populations; modelling suggests that with low adult mortality, fall densities can be very high. The intercepts suggest that weevil populations would be below detection with about 80 sunfish per trapnet. A density of more than 40 sunfish per trapnet would result in weevil densities less than 0.1/stem and likely be limiting to milfoil control.

Table. 14. Results of mid-summer 2002 weevil surveys (number per stem) at lakes with a range of fish densities. Fish densities are the mean number of sunfish (bluegill, pumpkinseed, hybrid and green sunfish) per trapnet set based on MN DNR fisheries surveys (2000-2002; Date provided). Below these results are results of historical fish surveys that correspond to weevil surveys from the same year in our regularly sampled lakes (summer-long average of bi-weekly weevil surveys, except Cenaiko when only one weevil survey was conducted in September 1998, one week prior to the fish survey).

Lake/Date	Date	Fish Density	Eggs	Larvae	Pupae	Adults	Total
Calhoun	7/24/00	241	0	0	0	0	0
Cedar	7/17/00	101	0	0.005	0	0	0.005
Bald Eagle	7/8/02	64	0	0	0	0.008	0.008
Peltier	8/5/02	60	0.042	0	0	0	0.042
Schultz	8/1/02	55	0	0	0	0.013	0.013
Centerville	7/29/02	35	0.218	0.066	0.019	0.042	0.346
Independence	7/23/01	28	0	0	0	0.014	0.014
Vadnais	7/16/01	20	0.169	0.013	0.025	0.113	0.319
Historical surveys							
Auburn	6/19/00	113	0.023	0.015	0.007	0.016	0.061
Cenaiko	9/9/98	5	0.856	1.978	0.156	0.611	3.600
Cenaiko	9/4/02	25	0.002	0.004	0.000	0.002	0.008
Otter	7/30/01	2	0.205	0.088	0.015	0.137	0.444
Otter	6/10/02	6	0.135	0.079	0.011	0.091	0.320

There was no clear relationship between weevil density and milfoil relative density (Tables 12 and 14), however, without several years of data it is difficult to tell if weevil densities had recently increased or if milfoil density was increasing or decreasing. Followup surveys in 2003 should allow us to determine if milfoil weevil densities remain high in Centerville and Vadnais and if milfoil density declines if weevil densities remain high.

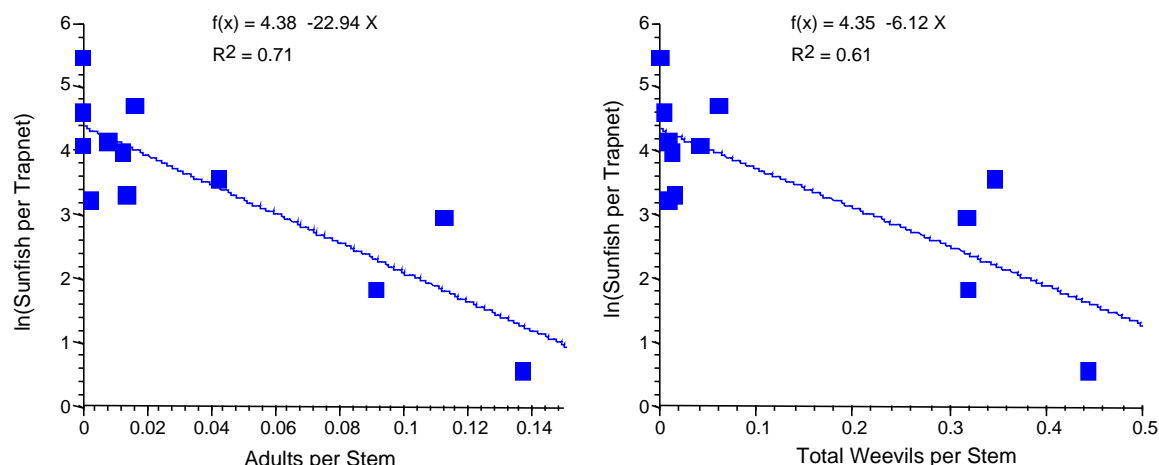


Figure 4. Regression of sunfish trapnet catch on weevil density. Cenaiko Lake 1998 weevil densities were very high (Table 14) and were outliers and were dropped from the analysis.

Relationship of plant community to sediment characteristics:

McComas (1999) proposed that sediment nitrogen may be a good predictor of nuisance levels of Eurasian watermilfoil; high nitrogen sites should support dense growths of milfoil while lower nitrogen sites would be more amenable to native plants that are adapted to lower nitrogen levels. At low nitrogen sites, Eurasian watermilfoil should not reach nuisance levels. Recently, McComas (2003) updated his predictions and predicted that nuisance milfoil should occur in sediments with > 6ppm exchangeable ammonia. This prediction was based on a volume basis (mg/cm³, McComas, personal communication). In 2001 we started measuring exchangeable (KCL extractable ammonium) N from the sediments because pore water ammonium is rapidly influenced by short term plant uptake and may not reflect longer term nitrogen availability. We have now analysed all the sediment samples from 2001-2002 for exchangeable N and present some preliminary analyses. Although our measures based on dry mass (mg N/g dm sediment) are not directly comparable to McComas's, they should provide some basis for testing his hypothesis and an assessment of possible N limitation of milfoil at our sites (Table 15).

Table 15. Sediment bulk density (g/mL), % organic matter, pore water NH₄⁺ (mgN/L), total exchangeable N (mg N/ g dry sediment) and the KCL extracted N (ppm, less pore water) (2SE).

Lake	Date	Density	% Organic	NH ₄	Exch N	KCL ext N
Auburn	6/15/01	0.50	11.23	0.98	0.073	72.85
	2SE	0.18	4.23	0.38	0.021	20.81
	7/17/01	0.57	25.69	3.72	0.040	38.67
		0.26	30.49	1.92	0.018	17.55
	8/29/01	0.47	10.90	5.46	0.047	42.99
		0.18	3.77	1.11	0.018	15.47
	6/27/02	0.53	18.83	6.61	0.052	47.34
		0.12	6.27	3.25	0.031	25.97
	9/6/02	0.62	19.70	5.14	0.033	32.77
		0.22	10.41	.	0.013	12.67
Calhoun	6/28/01	0.68	6.02	1.31	0.025	24.57
		0.31	2.37	1.02	0.013	12.67
	9/6/01	0.68	7.57	2.96	0.007	4.82
		0.40	3.22	1.58	0.003	2.12
	7/26/02	0.74	15.31	6.62	0.019	18.30
	0.37	14.30	4.33	0.016	16.07	

Table 15 Continued

Lake	Date	Density	% Organic	NH ₄	Exch N	KCL ext N
Cedar	6/19/01	0.60	22.49	3.83	0.102	96.36
	2SE	0.43	16.81	2.14	0.095	88.26
	8/30/01	0.45	14.92	2.87	0.027	23.79
		0.40	5.99	0.74	0.014	12.57
	7/8/02	0.51	30.67	6.11	0.059	49.40
		0.28	11.62	2.51	0.031	28.67
Cenaiko	6/26/01	1.05	3.69	1.45	0.019	18.22
		0.28	3.66	0.75	0.020	19.22
	7/30/01	1.27	1.80	2.07	0.012	11.83
		0.23	0.59	0.65	0.006	6.31
	8/27/01	1.26	1.70	3.92	0.005	4.83
		0.21	0.60	2.08	0.001	0.89
	7/1/02	1.42	5.32	2.39	0.011	10.85
		0.63	4.23	1.63	0.008	7.57
	8/27/02	1.51	7.83	2.57	0.005	4.76
		0.24	2.23	1.41	0.004	3.80
Centerville	8/14/02	1.00	13.49	10.20	0.011	8.56
		0.61	7.42	.	.	9.67
Hiawatha	7/18/02	1.57	3.44	3.55	0.005	4.43
		0.07	1.87	1.80	0.002	2.27
	9/12/02	1.55	3.10	.	0.005	3.92
		0.10	1.19	.	0.001	2.76
Harriet	7/2/01	0.94	7.01	3.59	0.013	11.65
		0.44	3.56	2.31	0.008	6.96
	9/12/01	0.78	7.29	2.13	0.014	12.89
		0.44	3.65	1.21	0.009	9.06
	7/18/02	1.23	6.08	3.28	0.012	11.77
		0.44	1.08	1.64	0.017	16.44
Isles	6/29/01	0.95	16.78	2.55	0.033	32.09
		0.49	14.10	1.96	0.025	24.87
	9/7/01	0.53	27.60	3.42	0.057	49.24
		0.44	15.76	1.38	0.038	33.55
	7/9/02	0.60	42.14	2.66	0.016	15.58
		0.66	55.71	2.03	0.021	21.12
Otter	6/21/01	0.34	25.25	2.55	0.182	177.64
		0.20	10.83	1.07	0.103	100.28
	7/18/01	0.36	27.71	3.64	0.045	41.15
		0.21	9.70	1.38	0.021	20.02
	8/28/01	0.35	23.05	2.77	0.068	63.58
		0.19	8.12	1.13	0.036	33.27
	6/26/02	0.34	19.50	5.86	0.062	60.68
		0.20	12.14	4.74	0.034	33.36
	9/5/02	0.70	40.18	6.92	0.029	28.00
		0.50	14.08	3.31	0.023	23.13
	Smith's Bay	6/22/01	0.33	12.52	1.93	0.027
0.19			4.47	0.81	0.013	12.52
7/24/01		0.38	13.57	2.42	0.088	84.26
		0.24	5.15	1.37	0.064	62.66
8/23/01		0.37	12.93	3.30	0.020	16.02
		0.24	4.29	1.16	0.009	6.67
7/2/02		0.38	24.17	4.41	0.043	39.76
		0.12	20.03	1.73	0.020	18.54
8/8/02		0.62	17.46	3.48	0.012	11.15
		0.24	10.55	1.06	0.006	5.46
Vadnais		8/16/02	1.40	7.54	1.24	0.004
	0.23		5.81	.	.	1.35

Mean total exchangeable N (mg N/g dry sediment) ranged from 0.005 (occasions at Cenaiko, Hiawatha and Vadnais) to > 1 mg/g (Otter and Cedar in 2001). Almost all values were above the threshold of approximately 0.001 mg/g, which is not surprising as all sites have supported nuisance growths of Eurasian watermilfoil. Preliminary correlation analyses on selected lakes suggest that: 1) exchangeable N is highly positively correlated with sediment organic matter, and negatively correlated with bulk density, 2) there is no consistent relationship with pore water ammonium (which is more immediately affected by plant density), and 3), exchangeable N is typically lower at the shallowest stations (which also have higher bulk density and lower percent organics) compared to deeper stations.

Analyses of plant biomass samples collected at the same location as the sediment cores (generally 9 samples per lake on each date) were used to assess the relationship of sediment characteristics to milfoil and native plant biomass. No clear and consistent relationships have been found with plant biomass (Eurasian or nonmilfoil plants).

Several confounding factors need to be considered in further analyses. First, if weevils are controlling milfoil then the nuisance milfoil may not exist where it otherwise would. For example, McComas (pers. com.) determined that nuisance milfoil should occur in most of Otter Lake but did not in 2002, likely due to weevil impacts. Second, shallower sites appear to have lower exchangeable N, related to less organics and higher bulk density at these higher energy sites. These shallow sites also tend to have more species and greater abundance of native plants. It is unclear how much of this difference is due to depth vs sediment. Third, preliminary analyses suggest that Eurasian watermilfoil is negatively correlated with bulk density but a positive relationship with exchangeable N is not as strong. Partial correlations may be needed to separate these effects.

In summary, additional analyses of sediment characteristics in predicting species composition and nuisance levels of milfoil are needed. A more complete analysis will be provided in our final report.

Effects of plant community:

We established a new set of plant manipulation plots in Otter Lake and Lake Auburn in 2001. At Lake Auburn, the community was dominated by coontail and Eurasian watermilfoil (MSP) (Table 16). The plant removals were successful at manipulating the plant community; total plant biomass was reduced in the remove-all treatment and milfoil biomass was reduced in the remove- MSP treatment. Overall, treatments resulted in significant changes in total dry biomass, EWM biomass, the percentage of EWM and coontail, and mean number of species (ANOVA, all $p < 0.1$), but no significant changes in non-EWM biomass, coontail biomass or the mean number of nonwatermoil species were detected. Coontail biomass increased (but not significantly) with removal of EWM and EWM increased substantially in both the control and remove native treatments. In September, total biomass was lower in Remove all than in the Control and Remove Native treatments (Tukey's HSD, $p < 0.05$) These results suggest that coontail was able to quickly colonize and take advantage of removal of MSP and that proportional representation of MSP was reduced through the summer in the plots from which it was removed, however, MSP continued to dominate in the control plots and the remove natives plots. In the lower diversity and poorer water clarity system of Lake Auburn, Eurasian watermilfoil retained dominance in the control or when natives were removed, but coontail was able to become dominant where Eurasian watermilfoil was removed, even in the remove-all treatment.

Table 16. Mean biomass \pm 2SE (g dryt/m²) of all plants (Total), Eurasian watermilfoil (MSP), all other plants (NAT) and the most common plants (coontail (CRT), flatstem pondweed (PZS), sago pondweed (PEC; now *Stuckenia pectinata*) and *Nymphaea* (NMP)) by treatment for the plant community manipulation at Lake Auburn 2001-2002. The percent of total plant biomass composed by MSP and percent of native plant mass composed of CRT along with the mean number of non-MSP species per sample (Spec) are also given. Treatments were: No removal (Contr), Remove all plants (Remall), remove Eurasian watermilfoil (RemMSP) and remove all plants except MSP (Remnat). Plant manipulations occurred just after the initial sampling in June 2001. n = 5 plots per treatment.

Treat	Total	MSP	CRT	PZS	PEC	NMP	NAT	%MSP	%CRT	Spec.
6/13/01										
Contr	178.9 55.3	102.3 75.7	67.2 50.4	0.0 0.0	0.0 0.0	9.4 18.8	68.8 57.7	49.5% 25.8%	95.9% 8.3%	1.0 0.3
Remall	239.4 53.8	118.0 83.5	101.0 45.8	0.1 0.2	0.0 0.0	20.3 32.4	121.4 72.2	45.6% 26.4%	91.1% 9.6%	1.3 0.2
RemMSP	198.3 38.8	88.0 38.2	109.7 67.0	0.6 1.3	0.0 0.0	0.0 0.0	110.3 68.1	43.3% 23.5%	99.8% 0.4%	1.1 0.2
Remnat	253.8 84.2	145.9 94.9	94.2 65.4	0.0 0.0	0.0 0.0	13.7 12.4	107.9 60.4	47.1% 23.5%	86.2% 13.1%	1.3 0.2
9/21/01										
Contr	291.8 126.6	196.5 150.3	82.2 63.8	0.0 0.0	3.2 4.2	9.9 13.1	95.3 55.3	59.6% 24.6%	77.6% 19.9%	1.6 0.4
Remall	104.8 34.0	5.7 8.0	91.0 40.4	0.3 0.6	0.0 0.0	7.8 13.5	99.1 40.7	11.3% 19.9%	93.2% 8.2%	1.3 0.2
RemMSP	200.1 74.6	17.5 15.8	179.3 72.3	1.2 2.4	0.2 0.4	1.9 3.8	182.6 71.3	11.5% 10.6%	97.7% 3.5%	1.4 0.6
Remnat	293.0 106.8	194.2 157.1	75.7 91.0	0.0 0.0	0.3 0.4	22.8 27.5	98.8 83.7	60.6% 34.0%	72.4% 22.8%	1.4 0.5
6/13/02										
Contr	145.0 53.9	66.4 62.4	71.1 64.8	0.0 0.0	0.0 0.0	7.5 15.0	78.6 77.5	45.2% 38.0%	96.1% 7.8%	1.2 0.4
Remall	154.6 72.7	64.9 39.6	88.1 80.4	0.2 0.3	0.0 0.0	0.0 0.0	89.8 79.1	51.4% 28.2%	95.5% 9.0%	1.3 0.4
RemMSP	230.7 124.7	94.5 76.9	136.0 106.0	0.1 0.3	0.0 0.0	0.0 0.0	136.2 105.8	40.4% 14.9%	98.3% 3.3%	1.4 0.2
Remnat	133.3 77.6	86.6 58.1	46.7 27.2	0.1 0.1	0.0 0.0	0.0 0.0	46.7 27.2	50.0% 23.1%	99.4% 1.2%	1.1 0.4
9/20/02										
Contr	428.8 176.6	348.4 189.1	80.4 83.0	0.0 0.0	0.0 0.0	0.0 0.0	80.4 83.0	70.6% 33.2%	100.0% 0.0%	0.9 0.2
Remall	231.8 90.5	82.6 73.5	137.7 103.1	0.0 0.0	0.0 0.0	11.4 14.5	149.2 98.5	42.9% 35.6%	78.8% 23.2%	1.3 0.2
RemMSP	219.1 123.5	123.0 129.5	96.1 61.0	0.0 0.0	0.0 0.0	0.0 0.0	96.1 61.0	46.7% 35.5%	100.0% 0.0%	0.9 0.2
Remnat	167.6 124.2	101.6 111.2	64.4 46.4	0.0 0.0	0.0 0.0	1.6 3.2	66.0 46.3	49.2% 23.8%	97.5% 5.0%	1.1 0.5

In June 2002 biomass was lower at all plots than in June 2001, probably due to weather. However, MSP had partly recovered in the remove all and remove EWM plots (Table 16). To examine the longer term effects of the manipulation repeated measures ANOVA (treatments with repeated samples over time) was used with the post manipulation (Sep 2001, June 2002, Sep 2002) data. Total biomass and EWM biomass both varied significantly by treatment ($p < 0.01$), date ($p < 0.1$) and the treatment by date interaction ($p < 0.1$), however, no significant effects were found for coontail, non-EWM biomass, percentage milfoil or number of species. Although the mean number of non-EWM species declined throughout the experiment there was no treatment effect or treatment by time interaction. Eurasian watermilfoil maintained its dominance in the control and recovered in the remove milfoil plots. Surprisingly, it did not increase its dominance in the remove natives plots and remained at its lowest density in the remove all plots.

In September 2002 total biomass and EWM biomass were significantly related to pore water NH_4 (lower due to use) but there were no significant differences in exchangeable N with treatment and neither pore water or exchangeable N were significant covariates.

In this low clarity system, dominated by Eurasian watermilfoil and coontail, milfoil recovered from removal within a year and plants other than coontail failed to increase where Eurasian watermilfoil was reduced. This was not entirely due to a total lack of propagules, as *Stuckenia pectinata*, *Potamogeton zosteriformis* and *Nymphaea* were found at low levels in many plots, but clearly, environmental conditions, Eurasian watermilfoil and coontail prevented them from establishing significant populations after removal of some or all plants.

Otter Lake had a much more diverse plant community (Table 17) with 3 to 6 species (2-4 non-EWM species) per sample commonly collected. Date was a more significant factor in Otter Lake; total plant biomass declined significantly from June to September ($p < 0.001$) and this was primarily due to a significant decline in Eurasian watermilfoil from over 36 g/m^2 to less than 1 g/m^2 in September 2001. Non-Eurasian watermilfoil biomass also decreased significantly due to our removal treatments. No significant differences in plant biomass due to treatment were found in 2001 with the exception of a significant increase in *Potamogeton richardsonii* in the remove MSP plots (Tukey's HSD, $p < 0.05$). The decline in milfoil was likely due to weevil damage (see above). It should be noted that the removal plots were distant from our regular transect sites and illustrate the lake-wide decline of Eurasian watermilfoil associated with weevil damage. The percent contribution of Eurasian decreased and the percent coontail increased from June to September and the mean number of species also decreased over time (all $p < 0.05$) but no significant treatment effects were found for these variables. No significant differences among treatments in sediment nitrogen (pore water or exchangeable N), bulk density or percent organic matter were found for the September 2001 sediment cores.

Eurasian watermilfoil biomass remained suppressed in all treatments in 2002, again due to suppression by milfoil weevils. Milfoil was apparently too rare to support detectible weevil populations, but low densities of *Acentria* ($0.3 \pm 0.5 / \text{m}^2$) and *Paraponyx* ($4.3 \pm 2.9 / \text{m}^2$) were found in June, probably associated with native plants. Perhaps because of the low Eurasian density, few significant treatment effects were noted. Other than a significant decline of Eurasian watermilfoil and percent milfoil between June and September and a significant increase in total and non-watermilfoil species during the same time, the only treatment effect was for Chara, due mainly to its abundance in remove all plots in June. Repeated measures analyses of all post removal samples (Sep 2001, June 2002 and Sep 2002) also revealed few significant treatment effects. Coontail showed a marginal treatment effect ($p = 0.1$); it was higher in remove MSP plots, and total biomass and Chara showed date by time interactions. Most other measures showed no effects or a significant date effect (MSP, %MSP, Elodea, non-EWM biomass, number of species). Native plant biomass had apparently reached an equilibrium prior to the removals and the suppression of Eurasian watermilfoil by milfoil weevils eliminated it as a competitive factor after June 2001.

Analysis of sediment in September 2001 and 2002 showed no overall effects of treatment on sediment N, but pore water ammonium was significantly lower in 2002. Further analyses with sediment N as a covariate will be explored.

Table 17. Mean biomass \pm 2SE (g dryt/m²) of all plants (Total), Eurasian watermilfoil (MSP), all other plants (NAT) and the most common plants (coontail (CRT), *Elodea* (ELD), *Najas* (NAJ), flatstem pondweed (PZS), sago pondweed (PEC), *Potamogeton richardsonii* and *praelongus* (PRI) and *Chara* (CHA)) by treatment for the plant community manipulation at Otter Lake 2001-2002. The percent of total plant biomass composed by MSP and CRT along with the mean number of non-EWM species per sample (Spec) are also given. Treatments were: No removal (Contr), Remove all plants (Remall), remove Eurasian watermilfoil (RemMSP) and remove all plants except MSP (Remnat). Plant manipulations occurred just after the initial sampling in June 2001. n = 5 plots per treatment.

Treat	Total	MSP	CRT	ELD	PZS	NAJ	PEC	PRI	CHA	NAT	%Spec	%CRT	Spec
6/7/01													
Contr	144.2 60.6	43.2 39.9	24.5 31.8	34.2 30.0	14.3 14.8	2.2 3.2	0.0 0.0	5.3 3.4	20.5 25.6	97.5 90.5	36.9% 32.3%	13.3% 10.3%	4.8 0.2
Remall	114.7 74.1	37.3 22.5	10.1 8.4	18.3 25.7	11.2 11.8	35.9 55.2	0.0 0.0	1.9 2.4	0.1 0.1	77.4 71.8	41.7% 29.1%	8.1% 4.2%	3.8 1.1
RemMSP	114.2 55.4	36.4 32.0	18.8 15.7	32.7 42.9	21.7 14.2	3.1 5.7	0.0 0.0	0.0 0.0	1.5 2.5	77.8 71.7	40.8% 32.1%	14.2% 7.8%	3.8 0.7
Remnat	192.7 128.0	130.2 120.2	13.6 18.4	19.6 33.4	15.4 19.0	1.1 1.1	0.0 0.0	0.0 0.0	12.7 25.1	62.5 65.9	68.2% 25.0%	7.9% 8.2%	4.1 0.2
9/20/01													
Contr t	60.4 37.5	0.3 0.6	12.0 11.3	16.2 22.1	2.2 2.2	13.1 13.5	0.7 1.4	1.1 2.2	11.7 23.4	60.1 37.5	0.4% 0.7%	28.0% 17.2%	3.7 0.7
Remall	15.7 11.9	0.3 0.6	5.5 6.4	5.2 6.4	1.7 2.2	1.6 2.0	0.0 0.0	0.4 0.8	0.0 0.0	15.4 12.0	2.0% 4.1%	25.5% 21.0%	3.0 0.7
RemMSP	53.6 43.4	0.1 0.1	14.1 10.2	15.0 8.1	4.0 2.5	13.1 16.1	3.5 7.0	3.0 5.5	0.1 0.2	53.5 43.3	0.1% 0.1%	26.8% 14.5%	3.5 1.6
Remnat	41.3 28.1	0.2 0.4	2.6 1.7	9.9 9.4	2.5 3.8	14.2 15.7	4.3 7.9	1.2 1.0	3.8 7.6	41.1 28.1	0.5% 1.0%	11.5% 13.0%	3.6 0.9
6/11/02													
Contr	73.9 39.3	12.4 17.7	3.2 3.3	56.3 36.1	0.0 0.1	0.4 0.8	0.0 0.0	0.3 0.6	1.3 1.7	61.5 34.6	16.5% 19.1%	11.7% 19.3%	1.9 0.8
Remall	121.0 50.9	9.6 18.7	9.2 18.4	45.5 38.0	0.0 0.0	14.4 28.8	0.0 0.0	0.0 0.0	37.5 20.1	111.4 58.5	9.8% 18.4%	5.4% 10.7%	2.0 0.8
RemMSP	70.1 25.7	0.4 0.8	17.8 34.1	29.6 23.8	1.9 3.5	18.6 22.8	0.0 0.0	0.0 0.0	1.5 2.3	69.7 26.2	0.7% 1.3%	10.7% 19.3%	2.2 1.0
Remnat	88.7 33.6	2.4 2.1	2.7 3.3	61.5 41.2	0.7 0.9	9.5 16.6	0.0 0.0	0.5 1.0	9.2 18.4	86.3 34.2	3.6% 3.9%	1.7% 1.7%	2.4 1.0
9/13/02													
Contr	97.9 71.4	0.1 0.1	4.2 4.3	64.4 71.6	5.7 8.0	4.9 4.3	8.1 16.2	4.1 7.4	6.1 7.5	97.8 71.4	0.2% 0.3%	5.5% 7.0%	4.1 1.0
Remall	68.5 57.3	0.1 0.1	5.7 7.0	27.0 35.3	0.3 0.3	15.8 31.1	0.0 0.0	6.8 8.9	6.4 11.4	68.4 57.3	2.3% 4.5%	12.2% 19.4%	2.8 0.7
RemMSP	113.9 68.0	0.1 0.1	8.9 6.8	75.4 40.7	0.2 0.3	24.9 41.3	0.2 0.4	0.0 0.0	0.0 0.0	113.8 68.0	0.0% 0.1%	7.3% 5.5%	3.6 1.2
Remnat	145.1 68.7	0.5 1.0	0.6 0.5	105.3 74.7	1.0 2.0	18.4 33.6	0.0 0.0	0.6 1.2	14.7 28.7	144.6 68.8	1.0% 2.1%	0.3% 0.3%	4.2 1.1

At Cedar Lake, removal manipulations were initiated in June 2002. Eurasian watermilfoil and coontail were the dominant taxa followed by some *Nymphaea* (Table 18). Removals were successful and reducing total biomass and number of milfoil stems (both $p < 0.1$) and milfoil biomass ($p < 0.05$) in remove-all and remove-EWM plots (ANOVA of differences) but no reductions in natives were seen in September in the remove native plots. This is probably due to rapid colonization by the unrooted coontail and by new shoots of *Nymphaea* from tubers (plants were pulled with roots but tubers were not removed from the plots). No treatment effects were found for native plant biomass, percentage of milfoil or coontail or number of species. No differences in sediment were noted. Sampling in 2003 will determine if the plant community returns to the premanipulation dominance by milfoil and coontail.

Table 18. Mean biomass \pm 2SE (g dryt/m²) of all plants (Total), Eurasian watermilfoil (MSP), all other plants (NAT) and the most common plants (coontail (CRT), and *Nymphaea* (NMP)) by treatment for the plant community manipulation at Cedar Lake 2002. The percent of total plant biomass composed by MSP and CRT along with the mean number of species (Spec) and non-MSP species per sample (NSpec) are also given. Treatments were: No removal (Contr), Remove all plants (Remall), Remove Eurasian watermilfoil (RemMSP) and Remove all plants except MSP (Remnat). Plant manipulations occurred just after the initial sampling in June 2002. n = 5 plots per treatment.

Treat	Total	MSP	CRT	NMP	NAT	%MSP	%CRT	Stems	Spec	NSpec
6/10/02										
Contr	187.1	109.9	70.0	5.3	77.2	58.2%	35.4%	182.0	2.3	1.3
	106.9	78.5	70.4	10.6	67.5	32.7%	25.9%	97.5	0.7	0.7
Remall	201.6	181.5	14.5	5.5	20.2	80.9%	16.2%	207.0	2.1	1.0
	120.0	121.9	17.2	11.0	22.2	17.7%	17.0%	111.4	0.6	0.7
RemMSP	167.9	124.8	37.3	5.8	43.1	78.7%	19.3%	204.0	1.7	0.7
	37.7	55.6	59.3	11.6	56.8	31.7%	32.7%	112.0	0.4	0.4
Remnat	139.0	127.7	11.3	0.0	11.3	93.4%	6.6%	171.0	1.4	0.4
	62.1	50.8	19.7	0.0	19.7	8.5%	8.5%	60.8	0.5	0.5
9/5/02										
Contr	319.9	222.4	97.5	0.0	97.5	76.0%	24.0%	189.0	1.8	0.8
	155.0	86.9	121.6	0.0	121.6	24.2%	24.2%	54.3	0.2	0.2
Remall	95.3	28.8	44.5	22.0	66.5	59.2%	31.4%	44.0	1.7	0.7
	103.1	40.4	65.6	44.0	68.3	33.7%	29.0%	36.2	0.6	0.6
RemMSP	87.7	45.7	38.3	3.7	42.0	73.5%	20.9%	84.0	1.5	0.5
	57.6	29.4	73.6	7.4	72.3	37.0%	37.6%	37.9	0.4	0.4
Remnat	219.2	170.5	30.3	18.4	48.7	82.4%	14.2%	137.0	1.4	0.4
	99.4	114.1	60.6	36.8	97.4	35.2%	28.4%	81.7	0.6	0.6

Weevil Introduction/Manipulation:

To determine if open lake weevil augmentation might be successful we stocked weevils into two city lakes: Hiawatha (low sunfish density) and Harriet (high sunfish density). In each lake a stocked area and an adjacent control area were sampled for plant biomass (12 samples

per treatment) and the stocked area was stocked with weevils (adults, associated meristems and any attached eggs and larvae, which were tied to individual plants). Biweekly weevil surveys were conducted (12 sample stations per treatment) and at the end of the summer, biomass was again determined. Harriet and Hiawatha each were stocked with 2000 adult weevils in mid-July.

No weevils were found in stem surveys prior to stocking and no weevils were found in biomass samples taken immediately prior to stocking at either lake (Table 19). Weevils were found at both lakes after stocking (Table 19 and 21).

At Harriet, there was a significant increase in weevil abundance (per m² and per stem) after stocking (Table 19; $p < 0.004$) but no difference among stocked and not-stocked plots, suggesting that stocking did enhance abundance. Weevil densities increased through early September to 0.1 per stem in Harriet (Table 21). However, even though the plots were $> 100\text{m}$ apart weevils moved and colonized the not-stocked plots. Although a few weevil juveniles have been found in previous years in Lake Harriet, all adults since 2000 have been *Phytobius*, suggesting that milfoil weevil populations were very low in Lake Harriet prior to stocking in 2002. *Acentria* and *Paraponyx* were not found at Harriet.

At Hiawatha, *Acentria* was present at low densities prior to stocking but no milfoil weevils were found (Table 19). Weevils appeared after stocking but densities were lower than Harriet and it was mid-September before weevils were common (Table 21). There was a significant increase in weevil abundance (per m² and per stem) after stocking (Table 19; $p < 0.1$) but no difference in weevil abundance between stocked and not stocked plots ($p > 0.8$). These results suggest substantial within-lake movement of weevils within a summer and indicate that control and treatment plots should be placed very far apart (opposite sides of the lake). It was somewhat surprising that adult weevil densities were similar in both lakes after stocking and total weevil densities were higher in Harriet than in Hiawatha because Harriet has a much high density of sunfish (over 320/trapnet set in 2000) than Hiawatha (11/trapnet set in 2001). However, poor water quality and clarity in Hiawatha may have limited weevil success in that lake.

Milfoil and total plant biomass was lower in Hiawatha than Harriet (perhaps due to clarity) and milfoil was more dominant in Harriet (Table 20). Significant declines of milfoil were not noted in either lake, but milfoil increased significantly more in the not-stocked plots compared to stocked plots at Harriet (Anova of differences; $p < 0.04$) while no significant change in non-milfoil biomass was detected ($p > 0.8$). Overall, milfoil increased over the summer at Harriet and there was a significant ($p < 0.07$) stocking by session interaction.

At Hiawatha, there was no effect of treatment on milfoil biomass and no change in milfoil biomass with treatment or date (all $p > 0.1$) although milfoil biomass decreased in stocked plots and increased in unstocked plots. There was a significant decrease in non-watermilfoil biomass over time ($p < 0.001$) and a significant decrease in number of species, both likely due to decreases in water clarity. Non-watermilfoil decreased marginally more in the non-stocked than stocked plots ($p = 0.11$).

These sites will be resampled in 2003 and unless weevil densities are high (> 0.5 per stem), they will be augmented with another stocking.

Table 19. Abundance of weevil stages (N/m^2 and number per milfoil stem $\pm 2SE$) and *Acentria* and *Parapoinx* before stocking (July) and after stocking (September) from biomass samples from stocked and non-stocked plots at Lakes Harriet and Hiawatha. $N = 12$ samples from each plot and date.

Harriet	Weevil	Larvae	Pupae	Adults	Total <i>E.l.</i>	<i>Acentria</i>	<i>Parapoinx</i>
	Date	N/m^2	N/m^2	N/m^2	N/m^2	N/m^2	N/m^2
	7/11/02 Stocked	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0
	per stem	0.000 \pm 0.000	0.000 \pm 0.000	0.000 \pm 0.000	0.000 \pm 0.000		
	Not Stocked	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0
	per stem	0.000 \pm 0.000	0.000 \pm 0.000	0.000 \pm 0.000	0.000 \pm 0.000		
	9/14/02 Stocked	5.8 \pm 8.3	1.7 \pm 2.2	4.2 \pm 4.6	11.7 \pm 13.2	0.0 \pm 0.0	0.0 \pm 0.0
	per stem	0.014 \pm 0.016	0.006 \pm 0.009	0.018 \pm 0.023	0.038 \pm 0.031		
	Not Stocked	5.0 \pm 6.7	2.5 \pm 3.6	5.8 \pm 5.8	13.3 \pm 9.0	0.0 \pm 0.0	0.0 \pm 0.0
	per stem	0.012 \pm 0.016	0.013 \pm 0.022	0.023 \pm 0.022	0.047 \pm 0.037		
Hiawatha	Weevil	Larvae	Pupae	Adults	Total <i>E.l.</i>	<i>Acentria</i>	<i>Parapoinx</i>
	Date	N/m^2	N/m^2	N/m^2	N/m^2	N/m^2	N/m^2
	7/18/02 Stocked	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	3.3 \pm 2.8	0.0 \pm 0.0
	per stem	0.000 \pm 0.000	0.000 \pm 0.000	0.000 \pm 0.000	0.000 \pm 0.000		
	Not Stocked	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	2.7 \pm 2.8	0.0 \pm 0.0
	per stem	0.000 \pm 0.000	0.000 \pm 0.000	0.000 \pm 0.000	0.000 \pm 0.000		
	9/12/02 Stocked	0.0 \pm 0.0	0.0 \pm 0.0	5.0 \pm 8.0	5.0 \pm 8.0	2.0 \pm 4.0	0.0 \pm 0.0
	per stem	0.000 \pm 0.000	0.000 \pm 0.000	0.050 \pm 0.083	0.050 \pm 0.083		
	Not Stocked	1.0 \pm 2.0	0.0 \pm 0.0	3.0 \pm 4.3	4.0 \pm 6.1	0.0 \pm 0.0	0.0 \pm 0.0
	per stem	0.009 \pm 0.019	0.000 \pm 0.000	0.056 \pm 0.079	0.065 \pm 0.087		

Table 20. Total plant biomass ($g\ dryt/m^2$), milfoil biomass (MSP), non-milfoil biomass and percent milfoil before (July) and 7 weeks after stocking weevils in stocked and non-stocked plots at Hiawatha and Harriet.

Session	Date	Trt	Total Biomass	MSP	NonMSP	%MSP
Hiawatha	7/18/02	Stocked	77 \pm 23	38 \pm 21	39 \pm 18	42.7 \pm 19.9%
	7/18/02	Not Stocked	99 \pm 40	18 \pm 16	81 \pm 40	19.0 \pm 16.2%
	9/12/02	Stocked	39 \pm 24	29 \pm 24	10 \pm 11	52.6 \pm 25.9%
	9/12/02	Not Stocked	37 \pm 15	22 \pm 14	15 \pm 8	55.0 \pm 20.0%
Harriet	7/11/02	Stocked	336 \pm 133	319 \pm 143	16 \pm 19	84.2 \pm 17.4%
	7/11/02	Not Stocked	170 \pm 84	155 \pm 85	14 \pm 10	88.0 \pm 11.0%
	9/14/02	Stocked	339 \pm 123	308 \pm 114	31 \pm 26	92.3 \pm 6.5%
	9/14/02	Not Stocked	371 \pm 128	367 \pm 126	4 \pm 3	98.7 \pm 1.2%

Table 21. Results of weevil surveys in stocked lakes Hiawatha and Harriet. Numbers are densities of weevil life stages (per stem), total weevils per stem and density (per stem) of the caterpillars *Acentria* (Acent) and *Parapoynx* (Parap). No weevils were found in mid-July prior to stocking.

Date	Treatment	Eggs	Larvae	Pupae	Adults	Total	<i>Acent</i>	<i>Parap</i>
Hiawatha								
7/30/02	stocked	0.000	0.000	0.000	0.013	0.013	0.009	0.000
7/30/02	notstocked	0.013	0.000	0.000	0.000	0.013	0.000	0.000
8/12/02	stocked	0.000	0.000	0.000	0.000	0.000	0.008	0.000
8/12/02	notstocked	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8/26/02	stocked	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8/26/02	notstocked	0.023	0.034	0.000	0.000	0.057	0.000	0.000
9/12/02	stocked	0.000	0.000	0.000	0.073	0.073	0.000	0.000
9/12/02	notstocked	0.000	0.000	0.000	0.072	0.072	0.000	0.000
Harriet								
7/24/02	stocked	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7/24/02	unstocked	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8/6/02	stocked	0.000	0.000	0.000	0.010	0.010	0.000	0.000
8/6/02	unstocked	0.104	0.000	0.000	0.000	0.104	0.000	0.000
8/19/02	stocked	0.031	0.000	0.021	0.014	0.066	0.000	0.000
8/19/02	unstocked	0.010	0.104	0.021	0.010	0.146	0.000	0.000
9/6/02	stocked	0.000	0.021	0.010	0.052	0.083	0.000	0.000
9/6/02	unstocked	0.063	0.000	0.000	0.045	0.107	0.000	0.000
9/17/02	stocked	0.000	0.021	0.000	0.021	0.042	0.000	0.000
9/17/02	unstocked	0.000	0.031	0.031	0.031	0.094	0.000	0.000

Summary:

Eurasian watermilfoil remained suppressed at Otter Lake, where milfoil weevil densities have remained high since the milfoil decline started in 2000. Eurasian watermilfoil remained suppressed at the shallowest stations at Smith's Bay, which have moderate weevil densities, but milfoil remained dense at deeper stations where weevils are rare. Eurasian watermilfoil continued to increase at Lake Auburn and Cernaiko Lake where weevil densities have decreased and remain low. Eurasian watermilfoil remained dominant at Cedar Lake where weevil densities have always been low. An analysis of lakes with a range of weevil and sunfish densities showed a strong negative relationship between weevil and sunfish densities. Sunfish densities > 40/trapnet may limit weevil populations and their ability to control Eurasian watermilfoil.

Weevil augmentation in two lakes resulted in establishment of low density weevil populations but limited effect on Eurasian watermilfoil. These sites will be followed in 2003 and may be re-augmented.

Plant removal experiments in three lakes were successful in manipulating the community but Eurasian watermilfoil and coontail generally dominated regardless of treatment.

Conclusions

- Milfoil declined dramatically during 2000-2001 at Otter Lake to 7% of total plant biomass. Suppression persisted through 2002 with relatively high weevil densities. In Smith's Bay, milfoil remained suppressed at the shallowest site with high non-milfoil biomass and moderate weevil densities, but remained dense at the deeper sites that show little evidence of weevil damage. Milfoil continued to increase at Lake Auburn from the very low densities of 1999. Milfoil density remained high at Cedar Lake and composed 65% of plant biomass.
- Bi-weekly weevil surveys showed that milfoil weevil densities were generally lower than in 2000 but higher than in 1998-1999. Milfoil weevils at Lake Auburn, Cernaiko and Smith's Bay were low to moderate and persisted throughout summer 2001. Weevils were abundant at Otter Lake in 2001. Weevil damage suppressed the high density of milfoil in early summer 2000 to $< 2 \text{ g dry/m}^2$ by August 2001.
- Milfoil coverage generally increased at Cedar, Isles and Harriet in the Minneapolis Chain of Lakes. Weevil densities were low to non-detectible in these lakes and water clarity appears to be the main limiting factor for milfoil coverage in Lake of the Isles.
- Comparison of milfoil weevil densities in 11 lakes with sunfish densities determined by DNR Fisheries assessments shows that weevil density decline significantly with increasing sunfish density. Sunfish densities greater than 40 may severely limit weevil populations and their ability to control Eurasian watermilfoil. These results confirm that fish predation is an important limiting factor in Minnesota lakes.
- Plant community manipulation experiments showed few clear significant effects. Although the manipulations altered community structure and abundance, milfoil and coontail remain dominant where not controlled by the milfoil weevil. The results do suggest that Eurasian watermilfoil is competing with the native plants and coontail. Continued investigation of these interactions is warranted.
- Augmentation of weevils into Hiawatha and Harriet resulted in establishment of weevil populations but the densities were relatively low and the effects on milfoil were limited. A higher weevil population developed in the high fish density lake (Harriet) than the low fish density lake (Hiawatha), but this may be due to poor clarity and environmental conditions in Hiawatha.
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Literature Cited

- APHA. 1989. Standard methods for the examination of water and wastewater. 17th ed. APHA-AWA-WPCF, Washington, DC.
- Best, E. P. H. and W. A. Boyd. 1999. A simulation model for the growth of the submersed aquatic macrophyte Eurasian watermilfoil (*Myriophyllum spicatum* L.). U.S. Army Engineer Research and Development Center Waterways Experiment Station, Vicksburg, MS. Technical Report A-99-3.
- Creed, R. P. 1998. A biogeographical perspective on watermilfoil declines: additional evidence for the role of herbivorous weevils in promoting declines? *Journal of Aquatic Plant Management* 36: 16-22.
- Creed, R. P., and S. P. Sheldon. 1995. Weevils and watermilfoil: did a North American herbivore cause the decline of an exotic plant? *Ecological Applications* 5: 1113-1121.
- Crowell, W., N. Troelstrup, L. Queen, and J. Perry. 1994. Effects of harvesting on plant communities dominated by Eurasian watermilfoil in Lake Minnetonka, MN. *Journal of Aquatic Plant Management* 32: 56-60.
- Exotic Species Program. 2003. Harmful exotic species of aquatic plant and wild animals in Minnesota: annual report for 2002. Minnesota Department of Natural Resources, St. Paul, MN.
- Getsinger, K.D., A. G. Poovey, W.F. James, R. M. Stewart, M.J. Grodowitz, M.J. Maceina, and R.M. Newman. 2002. Management of Eurasian watermilfoil in Houghton Lake, Michigan: workshop summary. Technical Report ERDC/EL TR-02-24, U.S. Army Engineer Research and Development Center, Vicksburg, MS. 88 pgs..
- Grace, J. B., and R. G. Wetzel. 1978. The production biology of Eurasian watermilfoil (*Myriophyllum spicatum* L.): a review. *J. Aquat. Plant Manage.* 16: 1-11.
- Jessen, R., and R. Lound. 1962. An evaluation of a survey technique for submerged aquatic plants. Minnesota Department of Conservation Division of Game and Fish Section of Research and Planning Fish and Wildlife Surveys Unit, Game Investigational Report No.6, St. Paul, Minnesota.
- Jester, L.L., M.A. Bozek, S.P. Sheldon. 1997. Researching the use of an aquatic weevil for biological control of Eurasian water milfoil in Wisconsin. *LakeLine* 17(3): 18-19; 32-34.
- Kitchell, J. F., J. F. Koonge, R. V. O' Neill, H. H. Jr. Shugart, J. J. Magnuson, and R. S. Booth. 1974. Model of fish biomass dynamics. *Transactions of the American Fisheries Society* 103:786-798.
- Lillie, R. A. 1996. A quantitative survey of the floating-leafed and submersed macrophytes of Fish Lake, Dane County, Wisconsin. *Trans. Wisc. Acad. Arts Lett.* 84: 111-125.
- Madsen, J. D., J. W. Sutherland, J. A. Bloomfield, L. W. Eichler, and C. W. Boylen. 1991. The decline of native vegetation under dense Eurasian watermilfoil canopies. *Journal of Aquatic Plant Management* 29: 94-99.
- Mazzei, K.C., R.M. Newman, A. Loos, and D.W. Ragsdale. 1999. Developmental rates of the native milfoil weevil, *Euhrychiopsis lecontei*, and damage to Eurasian watermilfoil at constant temperatures. *Biological Control* 16(2): 139-143.
- McComas, S. 1999. The role of lake soils in managing lakes. *Focus* 10,000 11(1): 7-9.
- McComas, S. 2003. Lake and pond management guidebook. Lewis Publishers, Boca Raton, FL.
- Newman, R.M. and D.D. Biesboer. 2000. A decline of Eurasian watermilfoil in Minnesota associated with the milfoil weevil, *Euhrychiopsis lecontei*. *Journal of Aquatic Plant Management* 38(2): 105-111.
- Newman, R.M. and L.M. Maher. 1995. New records and distribution of aquatic insect herbivores of watermilfoils (Haloragaceae: *Myriophyllum* spp.) in Minnesota. *Entomological News* 106: 6-12.
- Newman, R.M., K. L. Holmberg, D. D. Biesboer and B. G. Penner. 1996. Effects of the potential biological control agent, *Euhrychiopsis lecontei*, on Eurasian watermilfoil in experimental tanks. *Aquatic Botany* 53:131-150.
- Newman, R.M., M. E. Borman and S. W. Castro. 1997. Developmental performance of the weevil

- Euhrychiopsis lecontei* on native and exotic watermilfoil hostplants. *Journal of the North American Benthological Society* 16(3): 627-634.
- Newman, R.M., D.W. Ragsdale, and D. D. Biesboer. 2001a. Factors Influencing the Control of Eurasian Watermilfoil With Native Or Naturalized Insects. Fourth status report submitted for 1999-2001 to the Minnesota Department of Natural Resources, Ecological Services, St. Paul, MN.
- Newman, R. M., D. W. Ragsdale, A. Milles and C. Oien. 2001b. Overwinter habitat and the relationship of overwinter to in-lake densities of the milfoil weevil, *Euhrychiopsis lecontei*, a Eurasian watermilfoil biological control agent. *Journal of the Aquatic Plant Management* 39(1): 63- 66.
- Newman, R.M., D.C. Thompson and D.B. Richman. 1998. Conservation strategies for the biological control of weeds. Pages 371-396 in Barbosa, P. Conservation biological control. Academic Press, NY, NY.
- Olson, M. H., S. R. Carpenter, P. Cunningham, S. Gafny, B. R. Herwig, N. P. Nibbelink, T. Pellett, C. Storlie, A. S. Trebitz, and K. A. Wilson. 1998. Managing macrophytes to improve fish growth: A multi-lake experiment. *Fisheries* 23(2):6-12.
- Sheldon, S. P., and R. P. Creed. 1995. Use of a native insect as a biological control for an introduced weed. *Ecological Applications* 5: 1122-1132.
- Sheldon, S. P., and K. N. Jones. 2001. Restricted gene flow according to host plant in an herbivore feeding on native and exotic watermilfoils (*Myriophyllum*: Haloragaceae). *International Journal Of Plant Sciences* 162: 793-799.
- Sheldon, S. P., and L. M. O'Bryan. 1996. Life history of the weevil *Euhrychiopsis lecontei*, a potential biological control agent of Eurasian watermilfoil. *Entomological News* 107: 16-22.
- Smith, C. S., and J. W. Barko. 1990. Ecology of Eurasian watermilfoil. *J. Aquat. Plant Manage.* 28: 55-64.
- Solarz, S. L., and R. M. Newman. 1996. Oviposition specificity and behavior of the watermilfoil specialist *Euhrychiopsis lecontei*. *Oecologia* 106: 337-344.
- Solarz, S.L. and R.M. Newman. 2001. Variation in hostplant preference and performance by the milfoil weevil *Euhrychiopsis lecontei* Dietz exposed to native and exotic watermilfoils. *Oecologia* 126: 66-75.
- Sutter, T.J. and R.M. Newman. 1997. Is predation by sunfish (*Lepomis* spp.) a source of mortality for the Eurasian watermilfoil biocontrol agent *Euhrychiopsis lecontei*? *J. Freshwat. Ecol.* 12(2): 225-234.
- Ward, D.M. 2002. The impact of fish predation on Eurasian watermilfoil herbivores and indirect effects on the macrophyte community. MS Thesis, University of Minnesota, St. Paul, MN.

Appendix I. Key to plant abbreviations used in this report.

CHA	<i>Chara</i> spp. (muskgrass)
CRT	<i>Ceratophyllum demersum</i> (coontail)
ELD	<i>Elodea canadensis</i> (Canada waterweed)
HET	<i>Heteranthera dubia</i> (mud plantain) = <i>Zosterella dubia</i>
LMR	<i>Lemna minor</i> (lesser duckweed)
LTR	<i>Lemna trisulca</i> (star duckweed)
MGD	<i>Megalodonta beckii</i> (water marigold)
MSI	<i>Myriophyllum sibiricum</i> (northern watermilfoil)
MSP	<i>Myriophyllum spicatum</i> (Eurasian watermilfoil)
NAJ	<i>Najas</i> spp.
NMP	<i>Nymphaea</i> spp.
NUP	<i>Nuphar</i> spp.
PAM	<i>Potamogeton amplifolius</i> (largeleaf pondweed)
PBE	<i>Potamogeton berchtoldi</i> (Berchtolds' pondweed)
PCR	<i>Potamogeton crispus</i> (curled pondweed)
PDI	<i>Potamogeton diversifolius</i>
PEC	<i>Potamogeton pectinatus</i> (sage pondweed)
PFO	<i>Potamogeton foliosus</i> (leafy pondweed)
PGR	<i>Potamogeton gramineus</i> (variable pondweed)
PIL	<i>Potamogeton illinoensis</i> (Illinois pondweed)
PNA	<i>Potamogeton natans</i> (floating leaf pondweed)
PNO	<i>Potamogeton nodosus</i> (river pondweed)
PRI	<i>Potamogeton richardsonii</i> (claspingleaf pondweed)
PRO	<i>Potamogeton robbinsii</i> (Robins' pondweed)
PSP	<i>Potamogeton spirillus</i> (snailedseed pondweed)
PZS	<i>Potamogeton zosteriformis</i> (flatstem pondweed)
RAN	<i>Ranunculus</i> spp. (white water buttercup)
SPO	<i>Spirodela polyrhiza</i> (greater duckweed)
VAL	<i>Vallisneria americana</i> (wild celery)
UTV	<i>Utricularia vulgaris</i> (bladderwort)