Southeast Wisconsin's
Pewaukee Lake
Aquatic Plant Survey 2004

Wisconsin Lutheran College, Biology Dept.
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Prepared by
Pamela Iwen and
Robert C. Anderson, PhD

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Executive Summary

An aquatic plant survey based of Pewaukee Lake, Waukesha County, Wisconsin was conducted during the July and August of 2004. Sampling involved rake pulls along 48 equally spaced transects around the perimeter of this 2,500 acre lake. Fourteen species of plants were collected with Eurasian water milfoil dominating the samples. Sago (*Potamogeton pectinatus*), coontail (*Ceratophyllum demersum*) and eel grass (*Vallisnera americana*) were the most abundant native species. Similar distributions of species were found in the east and west basins of the lake. Greatest density and number of species occurred at the five foot depth with very few plants found at the eleven foot depth. Comparisons to a 2002 survey (Koch & Anderson 2003) showed that there has been a dramatic decline in aquatic plant diversity and density in 2004. This decline may be due to decreased water clarity resulting from an extensive algal bloom in late summer of 2002 through 2003. It was also noted that near shore samples taken in areas with natural bank vegetation had greater diversity of submerged aquatic plants and a lower density of Eurasian water milfoil.

Introduction

Aquatic plants play a vital role in a lake ecosystem. They are responsible for replenishing oxygen content through photosynthesis, converting inorganic nutrients into organic materials used as food and providing essential habitat for many organisms (SEWRPC 2003). Aquatic insects live among the leaves of plants and fish hide amid the plant beds.

Aquatic insects and fish depend upon the diversity of the plants. Certain insects are able to thrive better on finely-dissected leaves found on coontail (*Ceratophyllum demersum*) or water milfoil (*Myriophyllum sibiricum*), while others prefer the flat leaves of eel grass (*Vallisnera americana*) or the broad leaves of large leaf pondweed (*Potamogeton amplifolius*) (Cheruvelil 2002). If one species of plant were to become dominant, the lake ecosystem may be thrown off-balance. Once introduced, an exotic species, such as Eurasian water milfoil (*Myriophyllum spicatum*), has been known to over take many areas of a lake. It has the ability to grow up to the water's surface and form a canopy, thereby limiting the amount of sunlight that reaches the native aquatic plants on the bottom of the lake (Boylen et al. 1999). The decrease in light caused by the canopy not only reduces its competition, it also encourages its own stem elongation (Barko & Smart 1981). In this manner Eurasian water milfoil can severely reduce native plant diversity as well as reducing light and oxygen in the water column (AERF 2005). A reduced variety of aquatic plants can cause a domino effect in a lake's ecosystem. Fewer aquatic insects inhabit beds composed of one plant species, as opposed to a diverse plant bed (Cheruvelil 2002). As a result, the fish that feed on the aquatic insects are also impacted.

Pewaukee Lake in Waukesha County, Wisconsin, recently contained large canopies of Eurasian water milfoil and experienced nuisance algae blooms. The purpose of this study is to examine the current condition of Pewaukee Lake's aquatic plant population.

Methods

During the months of July and August of 2004, aquatic plants were sampled at 48 transects around Pewaukee Lake (Figure 1). The transects were established by the Wisconsin Department of Natural Resources (WDNR) for Pewaukee Lake plant surveys (SEWRPC 2003).

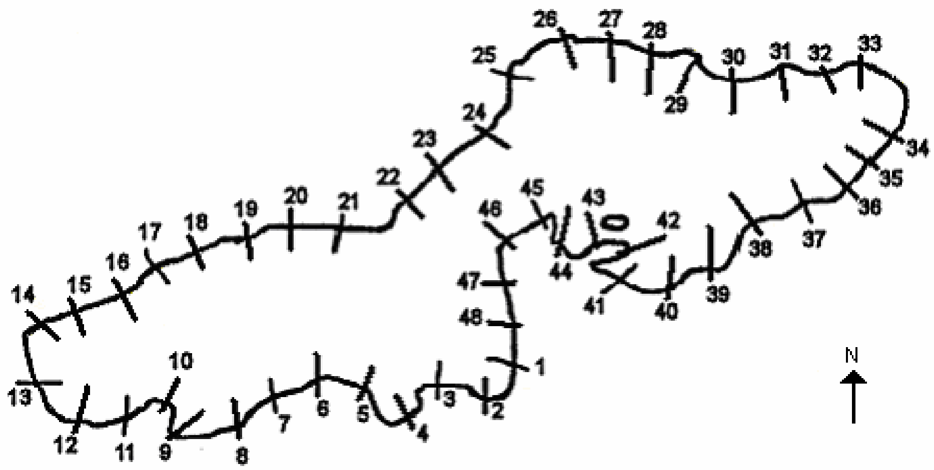


Figure 1: Location of transects on Pewaukee Lake, WI.

At each transect, a rake was used to collect four samples from the end of the boat at depths of 1.5, 5, 9, and 11 feet (Jessen & Lound 1962). All plants were identified in the field using Borman et al. (1997). At each depth, the plants were given a density rating, based on the amount found on each rake pull. The density rating could range from 0 (indicating none found on any rake pulls) to 5 (indicating a rake-full found on all four rake pulls). All plant density ratings and substrate types were recorded.

The frequency and average density were calculated to show the abundance of each submerged plant species. Frequency was used to indicate how often a species was found at each transect. Average density shows the quantity of each species found at all transects.

On each sampling day, the temperature, dissolved oxygen, pH, and conductivity were measured with a DataSonde 4 Hydrolab unit. At that time, the water clarity was measured with a Secchi disc. The time, weather, and lake conditions were also noted.

Results

A total of fourteen species of aquatic plants were found in samples collected from Pewaukee Lake, WI during July and August of 2004 (Table 1).

Table 1: Aquatic plant species found in Pewaukee Lake, in August of 2004; and their relative abundance.

Aquatic Plant Species	Relative Abundance
Coontail - *Ceratophyllum demersum*	abundant
Muskgrass - *Chara vulgaris*	moderate
Elodea - *Elodea canadensis*	very sparse
Eurasian water milfoil - *Myriophyllum spicatum*	very abundant
Bushy Pondweed - *Najas flexilis*	moderate
Large Leaf Pondweed - *Potamogeton amplifolius*	very sparse
Curly Leaf Pondweed - *Potamogeton crispus*	sparse
Sago - *Potamogeton pectinatus*	abundant
Flatstem Pondweed - *Potamogeton zosteriformis*	sparse
Variable Pondweed - *Potamogeton gramineus*	moderate
Eel Grass - *Vallisneria americana*	abundant
Water Star Grass - *Zosterella dubia*	moderate
Yellow Water Lilly - *Nuphar variegatum*	very sparse
White Water Lilly - *Nymphaea tuberosa*	very sparse

Overall, Eurasian water milfoil, *Myriophyllum Spicatum,* was the most abundant species found throughout the lake (Figure 2 & 1A). The five-foot depth supported the most diverse group of aquatic plants.

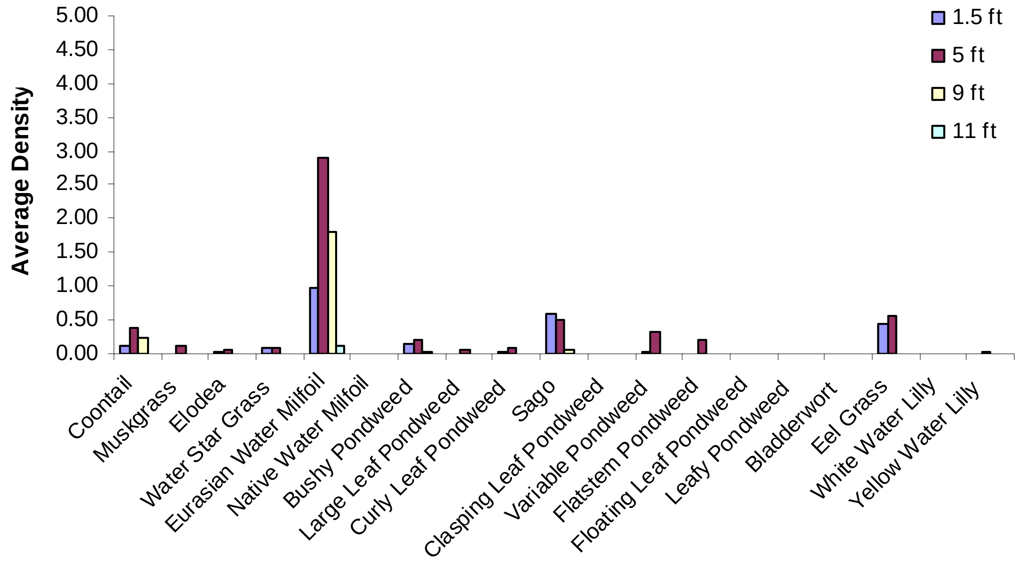


Figure 2: Average density of aquatic plants per depth in Pewaukee Lake, WI, from August 2004.

Despite the fact that the east basin originated as a marsh, the aquatic plant community found throughout Pewaukee Lake was not that dissimilar in the summer of 2004. Most of the plant species in Pewaukee Lake were found with comparable densities in either basin of the lake (Figure 3).

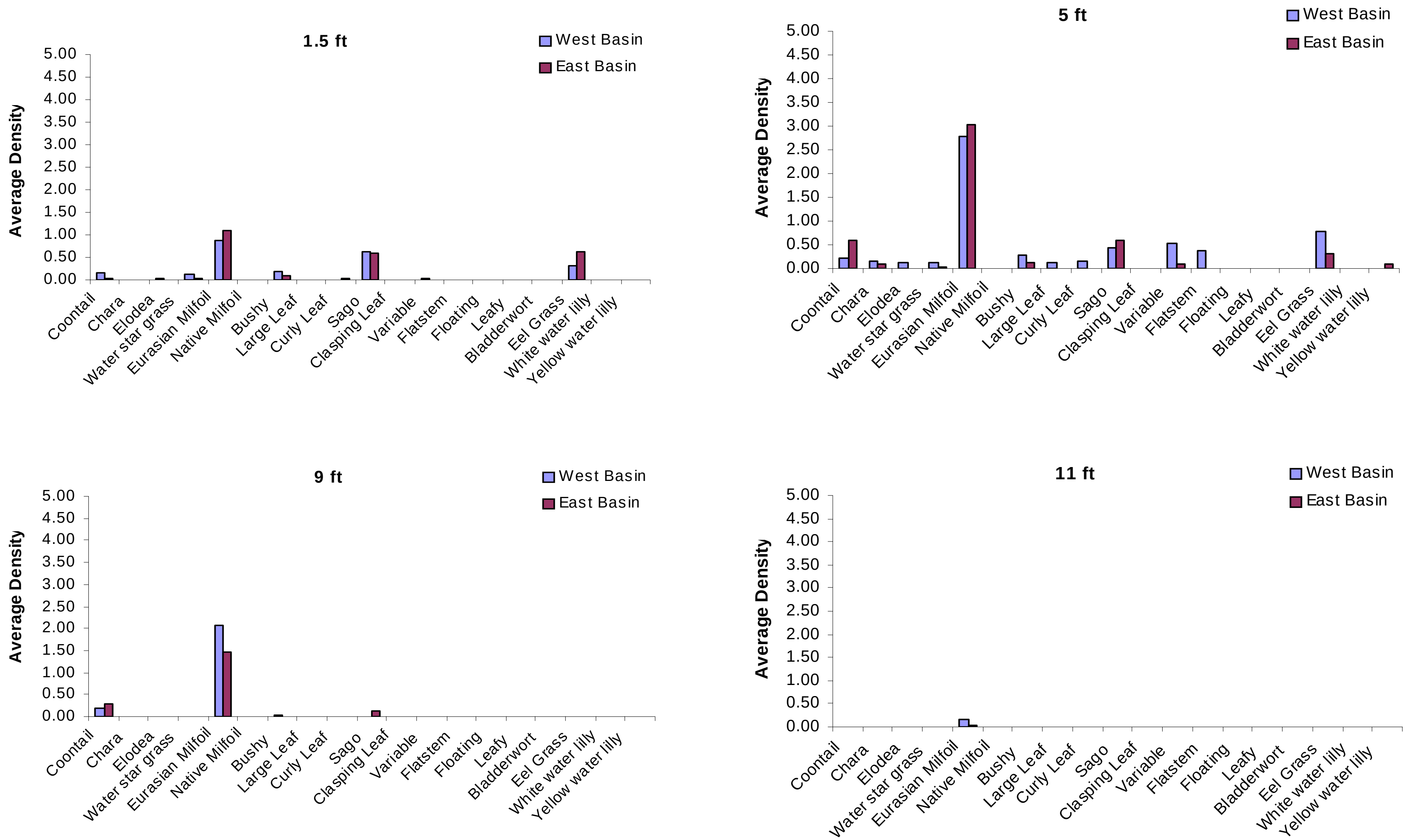


Figure 3: Average density of aquatic plants at various depths from the west and east basins of Pewaukee Lake, WI.

In order to provide a more detailed picture of the abundance of aquatic plants in Pewaukee Lake in 2004, specific areas of the lake were chosen for comparisons (Figure 4).

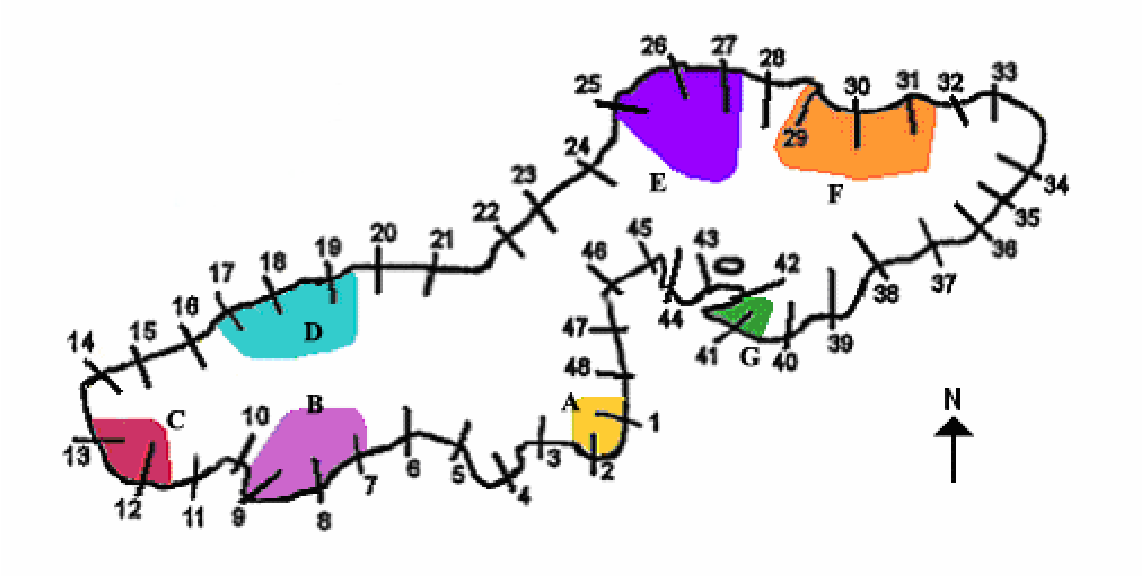


Figure 4: Map of Pewaukee Lake, indicating seven areas of focus.

The plant found in the highest density around the lake is Eurasian milfoil, except at the 1.5 ft depth at areas C and E. These areas, which have a natural shoreline, do not support higher densities of Eurasian milfoil until the 5ft depth. The 9 ft depth supported mainly Eurasian milfoil, except in areas A and E where coontail and sago were also found.

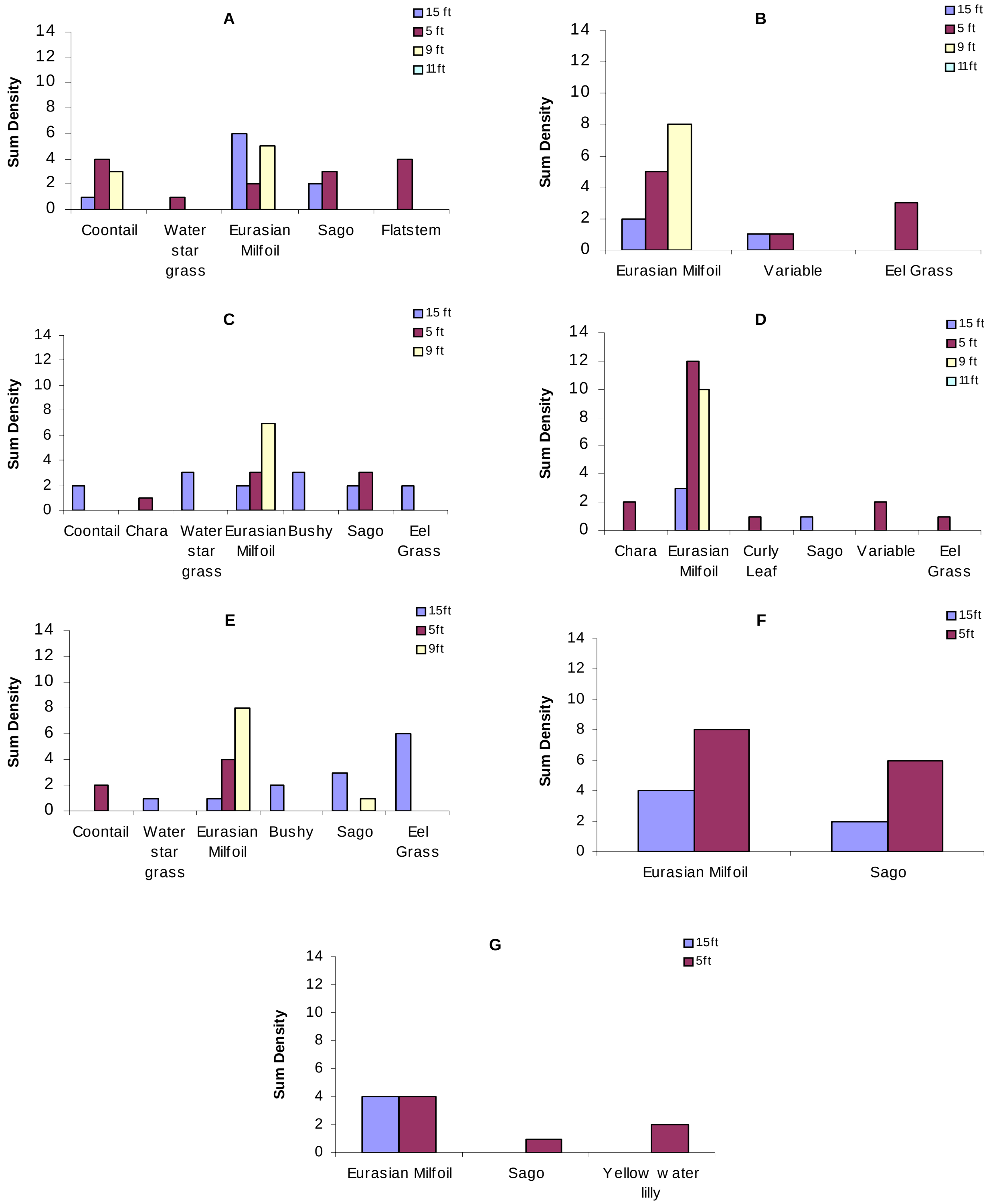


Figure 5: Sum density of aquatic plants by depth at various areas in Pewaukee Lake, WI. during the summer of 2004. The depths not shown did not occur in that area.

In August, the recorded temperature in the deepest point of the lake showed a decrease in temperature at about ten meters (Table 1A). The dissolved oxygen concentrations showed a significant decrease at a depth of nine meters, and dropped to nearly zero mg/L at twelve meters (Figure 6).

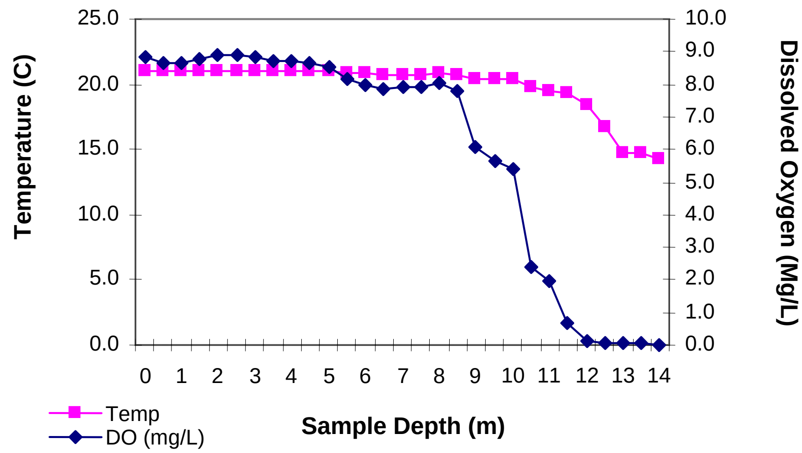


Figure 6: Temperature (C) and dissolved oxygen (mg/L) readings at the deepest point of Pewaukee Lake, WI, from August 26, 2004; taken with the Data Sonde 4 Hydrolab.

Discussion

The purpose of this study was to evaluate the current condition of the plant population in Pewaukee Lake. In past years, the plant diversity in Pewaukee Lake has decreased as the result of the introduction of Eurasian water milfoil (*Myriophyllum spicatum*), an invasive species (SEWRPC 2003). Eurasian water milfoil has been the dominant macrophyte since the late 1960s. From 1990 to 1997, Eurasian water milfoil experienced a decline in abundance; however, in 2000, it rebounded and was responsible for causing nuisance conditions in Pewaukee Lake (SEWRPC 2003). This study documents a dramatic decrease of submerged aquatic plants from 2002 to 2004. In fact, the frequencies of most of the aquatic plants, including Eurasian water milfoil, throughout Pewaukee Lake have decreased since 2002 (Figure 7 & 2A).

Taking a closer look at the east basin of Pewaukee Lake, both the north shore and the south shore show lower densities of plants present in August of 2004 than there were in August of 2002 (Figure 8). However, sago (*Potamogeton pectinatus*), which was not found in the east basin in August during the 2002, was found along the north and south shores in 2004. This shows that not all of the aquatic plant species in Pewaukee Lake are experiencing a decline.

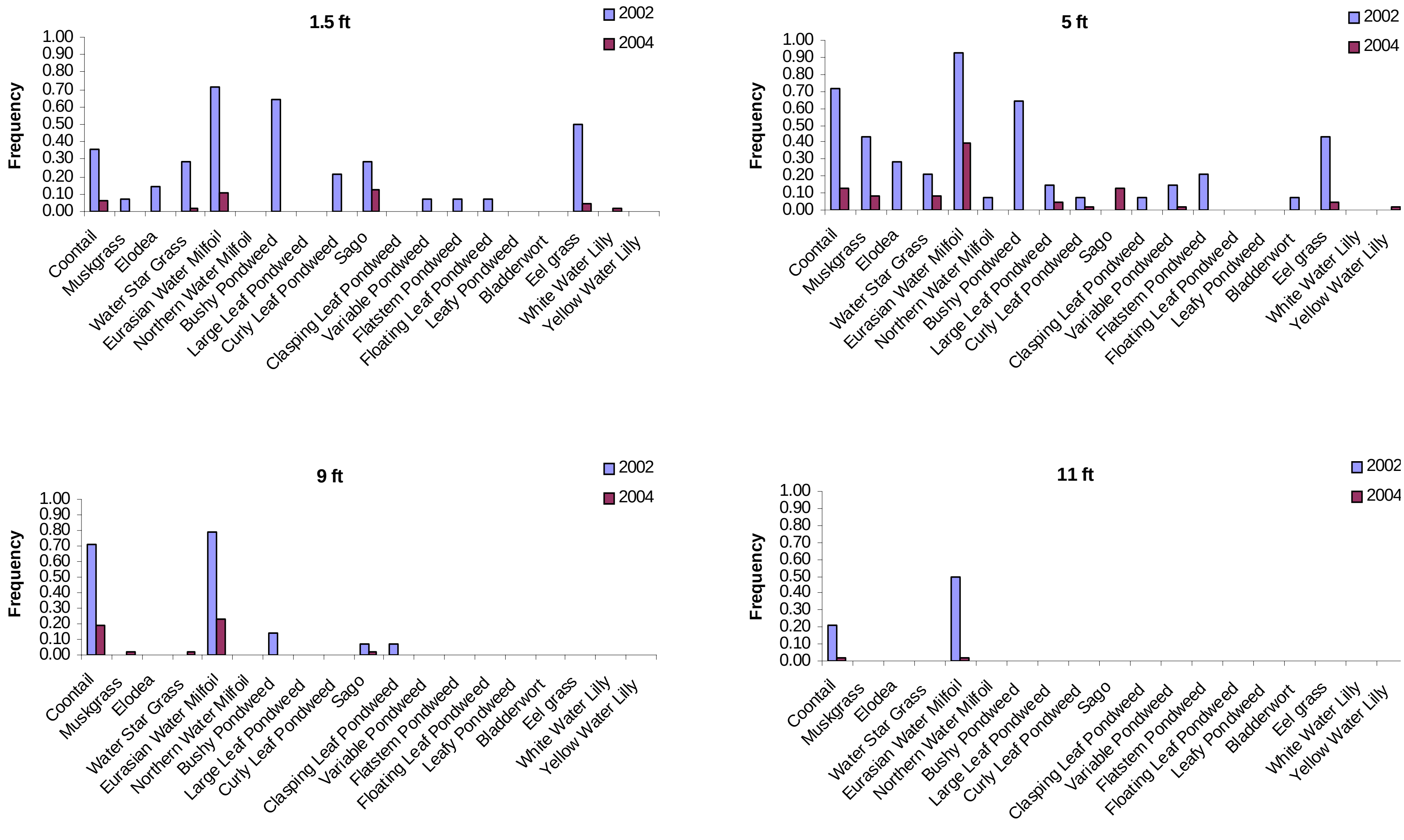
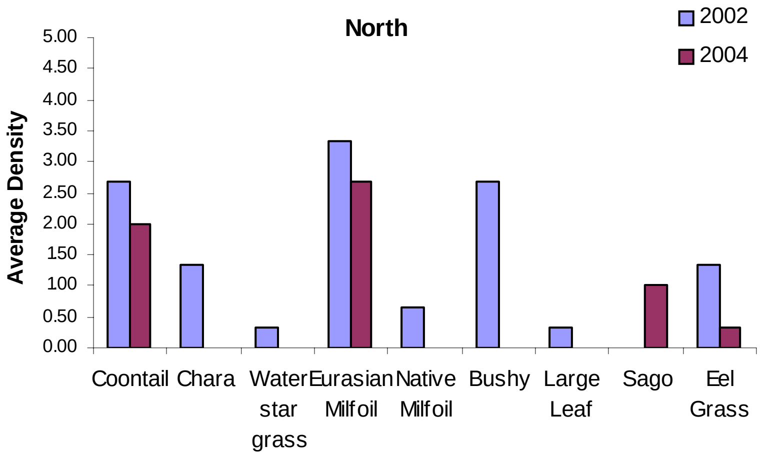


Figure 7: Average frequency of aquatic plants at various depths in Pewaukee Lake, WI; from August 2002 and August 2004.



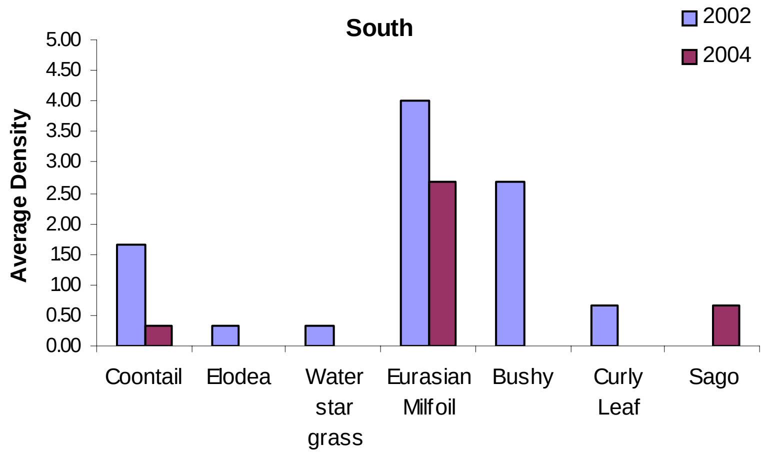


Figure 8: Average density of aquatic plants at the 5 ft depth along the north and south shores of the east basin of Pewaukee Lake, WI, from August 2002 and August 2004.

In order to get a better understanding of the aquatic plant decline sample transects from 2002 and 2004 in the areas specified in Figure 4 were compared (Figures 9 - 12). At the 1.5 ft depth, the aquatic plant diversity and density decreased, except in Area A. Area E had the highest diversity at the 1.5 ft depth in 2002; however, in 2004, sago was the only aquatic plant species found in that area at that depth (Figure 9). Other than Eurasian milfoil, sago and eel grass were the species most commonly found in the 1.5 ft depth around Pewaukee Lake in 2004. At the 5 ft depth a decrease in diversity was seen from 2002 to 2004 in areas B, C, D and E (Figure 10). In area A no plants were found at this depth in either year. In Areas C and E, only one of the species found in 2002 was also found in 2004. Also, in 2002, dense canopies of Eurasian water milfoil were present at the 5 ft depth in Area E; but in 2004 no Eurasian water milfoil was found in the samples at that depth (Koch & Anderson 2003). Conversely, Areas F and G did experience an increase in plant density and diversity from 2002 to 2004. In 2004, sago was found in both areas F and G, but it was not present in either area in 2002.

What would allow sago to thrive in the east basin, while most other plants experience a decline? Unlike most other species, sago thrives in lower dissolved oxygen concentrations and the sediment in the east basin is highly organic. As the organic material in the sediment decomposes it uses oxygen and may deplete dissolved oxygen level in and near the sediment (Koch & Anderson 2003; SEWRPC 2003). The growth and senescence of Eurasian water milfoil canopies can be responsible for causing low levels of dissolved oxygen in the sediment (AERF 2005). The conditions during the summer of 2004 may have provided sago the competitive advantage to extend beyond the sediment into oxygenated areas closer to the water surface. The elongation of the terminal shoots in sago is promoted by anaerobic conditions. This growth allows it to extend above the other plant species into the oxygenated water above (Summers & Jackson 1994 and Summers et al. 2000).

At the 9 ft depth, the plant species that were present with low densities in 2002 were no longer present in 2004 (Figure 11). Eurasian milfoil is still the dominant species in all areas. In 2002, Areas A and D were the only areas to support aquatic plants (Eurasian milfoil and coontail) at the 11 ft depth; however, in 2004, only Area A supported low densities of aquatic plants at that depth (Figure 12).

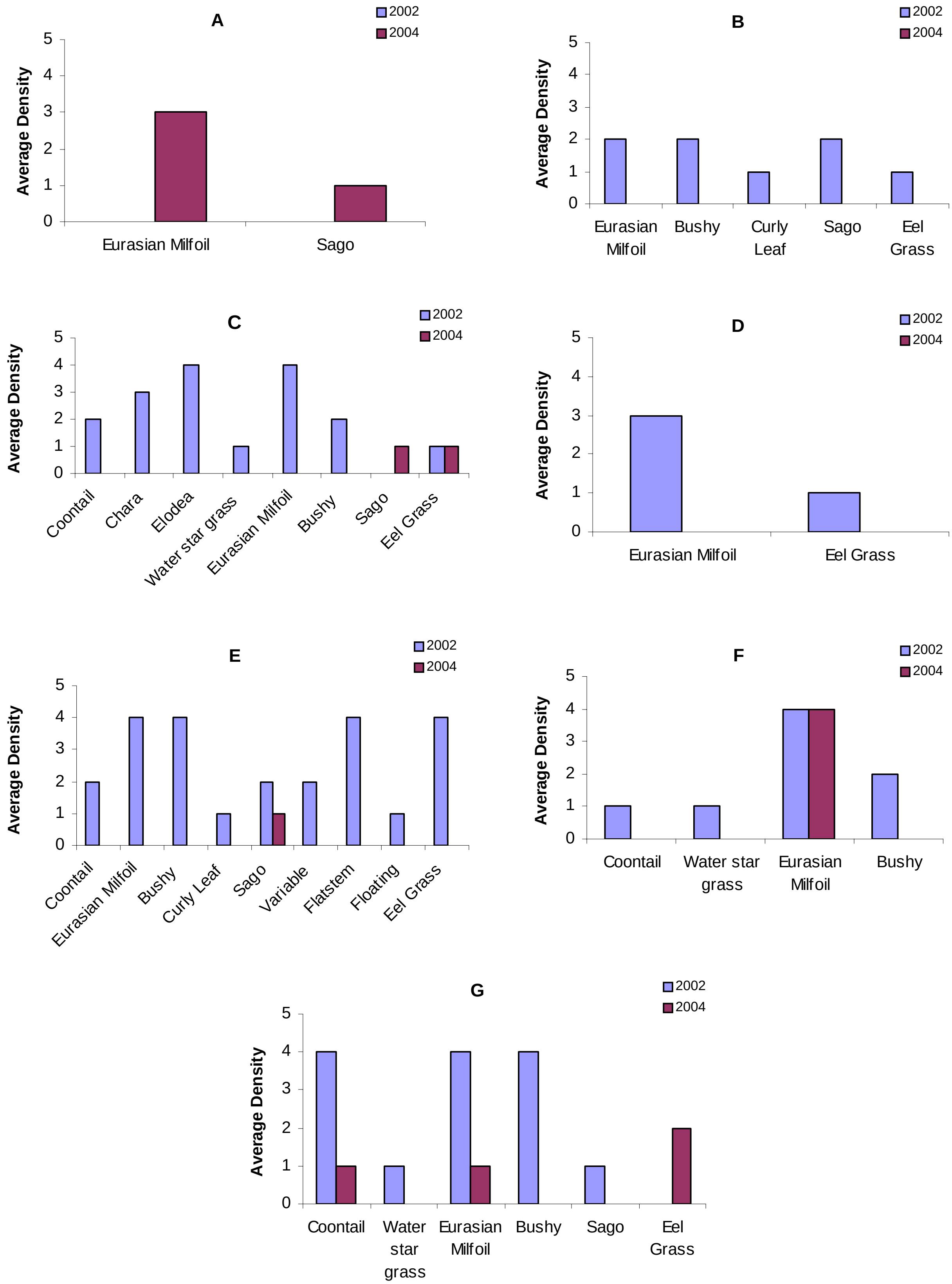


Figure 9: The 2002 and 2004 average density of aquatic plants at the 1.5 ft depth from specific areas in Pewaukee Lake, WI.

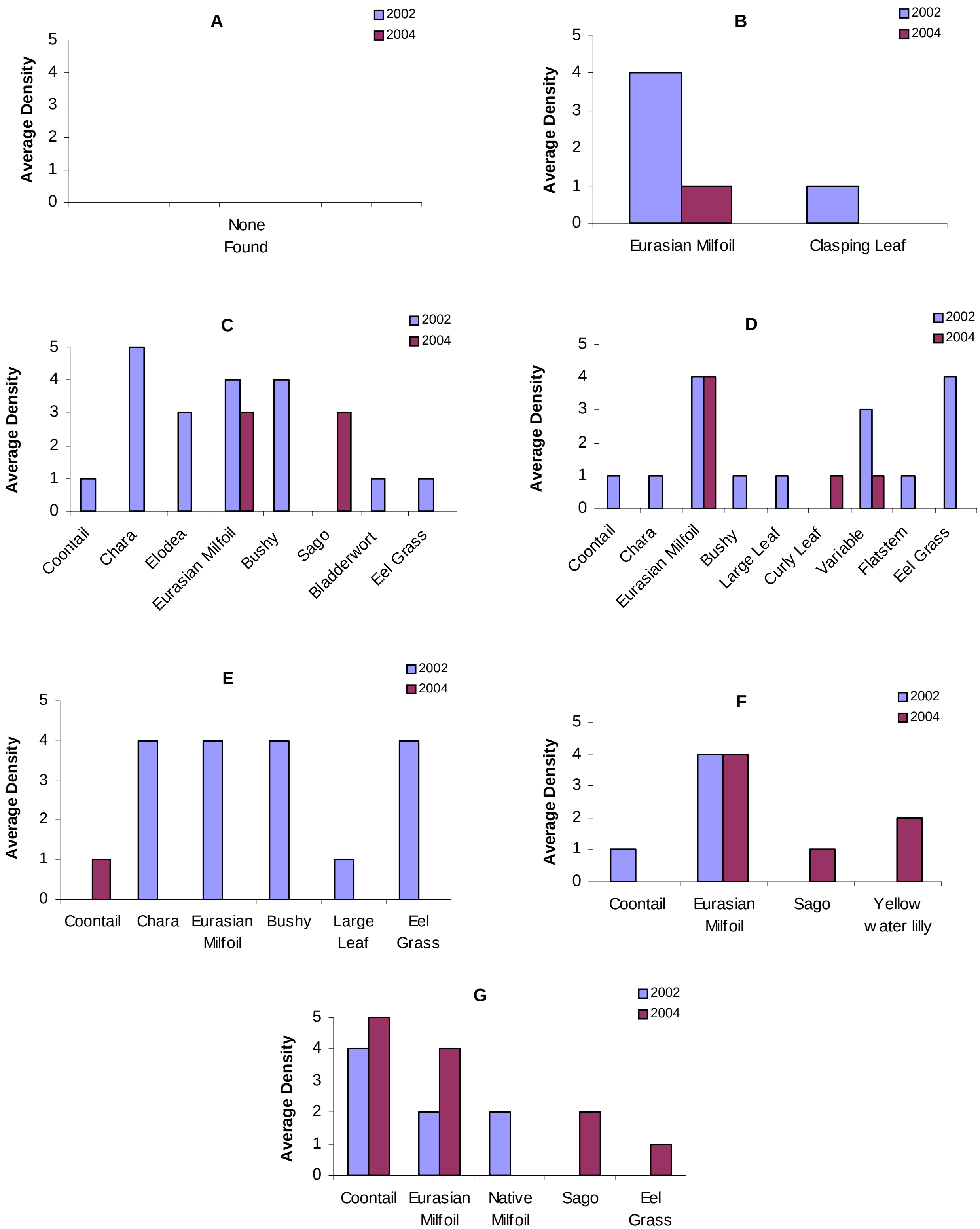


Figure 10: The 2002 and 2004 average density of aquatic plants at the 5 ft depth from specific areas in Pewaukee Lake, WI.

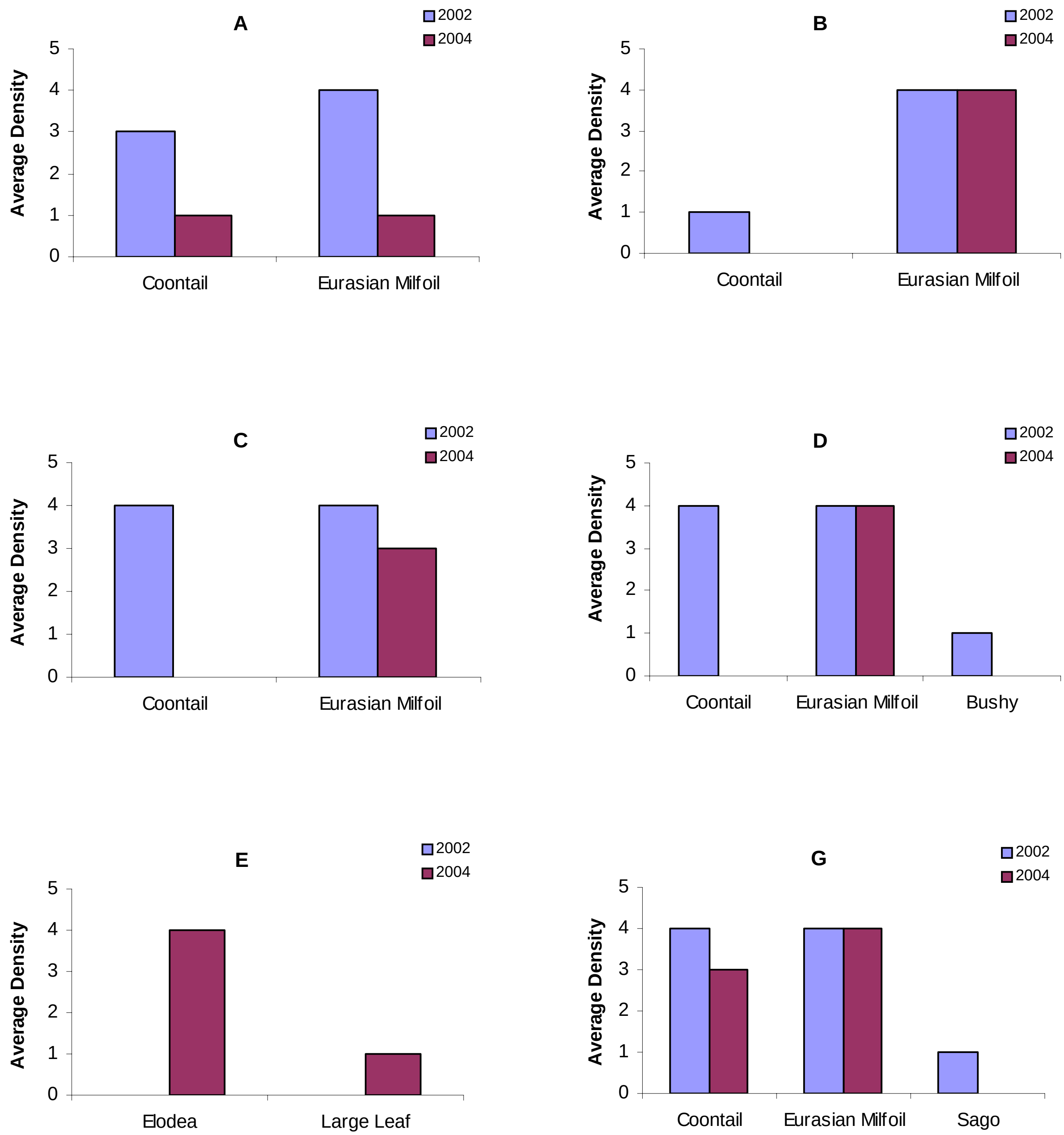


Figure 11: The 2002 and 2004 average density of aquatic plants at the 9 ft depth from various areas in Pewaukee Lake, WI. The 9 ft depth was not found in Area F.

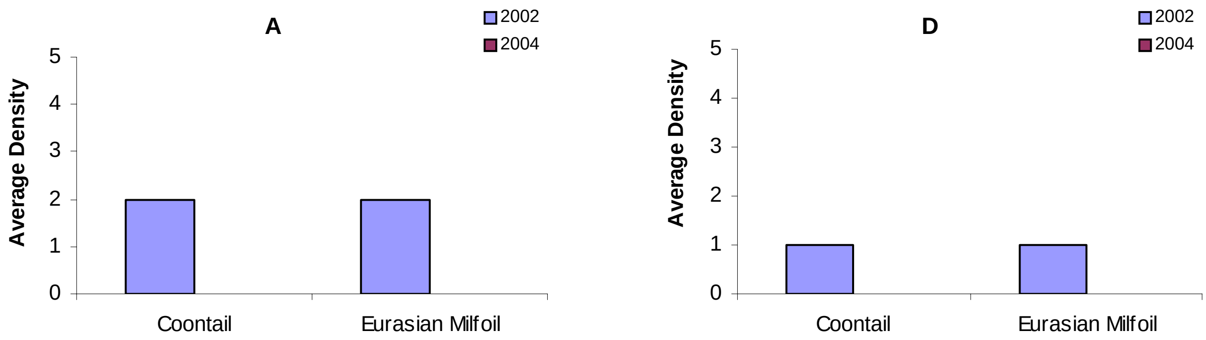


Figure 12: The 2002 and 2004 average density of aquatic plants at the 11 ft depth from various areas in Pewaukee Lake, WI. The 11 ft depth was not found in Areas B, C, E, F and G.

Temperature is a primary growth limiting factor for Eurasian water milfoil. In the spring, the plant elongates from shoots that were formed in the fall. This initial growth can occur earlier than in native plants, because it is tolerant of low water temperatures (AERF 2005 and Barko & Smart 1981). It is possible that the spring water temperatures in Pewaukee Lake in 2004 did not provide this advantage. This however would not explain the decline in other plant species that was also observed in the summer of 2004. Therefore a more plausible explanation may be that the burdensome algae bloom experienced in Pewaukee Lake in the summer of 2002 which continued into 2003 (SEWRPC 2003) may have caused the macrophyte decline. Thick algae blooms can limit the amount of light that reaches the lake bottom. Light availability is often considered the most crucial environmental factor limiting plant growth (Hoyer and Canfield 1997). As a result of reduced water clarity, submerged plants may not receive enough light which could lead to a die off (Scheffer 1999; Hoyer & Canfield 1997 and LMCD 2005). The algae blooms may have been the key factor leading to the decreased frequency and density of plants, including Eurasian water milfoil observed in Pewaukee Lake in the summer of 2004.

While examining the decline in submerged aquatic plant density and diversity throughout Pewaukee Lake, two areas of interest came to view. As previously mentioned, the five-foot depth in Pewaukee Lake sustains the highest diversity of plant species, except in Area C and Area E in 2004 (Figure 5). In those areas, the 1.5-foot depth has the highest diversity and Eurasian water milfoil was found in low frequencies and low densities. Area C and Area E happen to be positioned along natural shorelines, which are considered environmentally sensitive areas in Pewaukee Lake (SEWRPC 2003). The native plants in these areas are effectively out-competing Eurasian water milfoil. This may be due to the lack of stress that shoreline development tends to place on an ecosystem (SEWRPC 2003).

Measuring and evaluating changes in submerged lake plant communities is very complex and involves many factors that act concurrently and perhaps synergistically. The annual changes in aquatic plant abundance and diversity noted in this study indicate the importance of regular monitoring of lake plant communities. Through annual monitoring a better understanding of natural fluctuations in plant communities can be developed. This knowledge will assist lake managers in making decisions on the most effective methods for controlling excessive plant growth.

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Appendix A

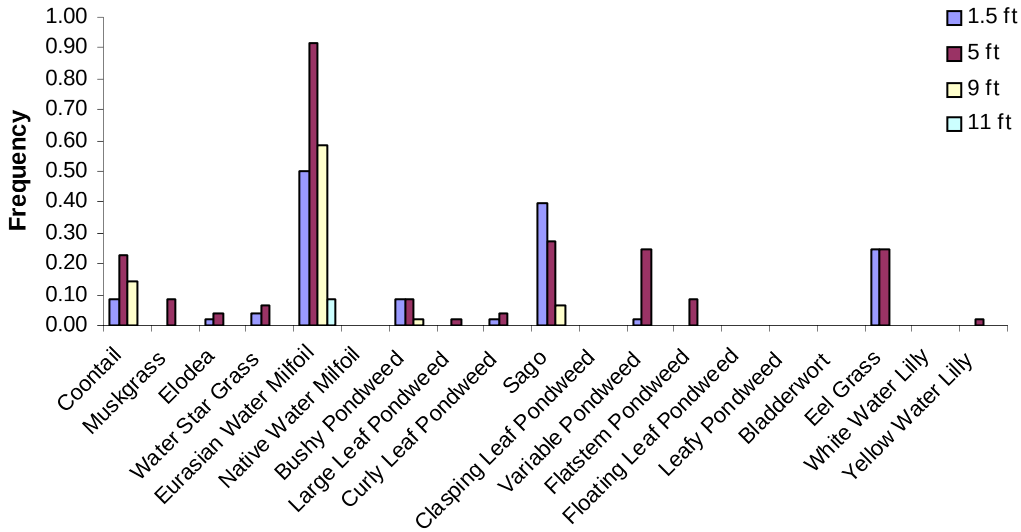

Figure 1A: Frequency of aquatic plants per depth in Pewaukee Lake, WI, from August 2004.

Table 1A: Hydrolab data taken at various locations in Pewaukee Lake during summer 2004.

7/8/2004	Location: Transect # 26 (5 ft)			
Depth (m)	Temp. ©	DO	pH	SpC
0.5	21.63	7.51	8.27	0.7362
1	21.58	7.39	8.28	0.736
1.5	21.56	7.13	8.28	0.7358

7/14/2004	Location: Transect # 40 (9 ft)			
Depth (m)	Temp. ©	DO	pH	SpC
0	23.95	7.54	8.27	0.7302
0.5	23.97	7.23	8.28	0.7311
1	23.97	6.98	8.29	0.7305
1.5	23.97	6.94	8.29	0.7304
2	23.96	6.83	8.29	0.7306
2.5	23.96	6.17	8.28	0.7307

8/5/2004	Location: Transect # 13 (9 ft)			
Depth (m)	Temp. ©	DO	pH	SpC
0	23.4	7.85	8.26	0.709
0.5	23.4	7.54	8.33	0.7091
1	23.36	7.45	8.34	0.7079
1.5	22.94	7.41	8.31	0.7005
2	22.84	7.01	8.3	0.7001

8/12/2004	Location: Transect # 48 (9 ft)			
Depth (m)	Temp. ©	DO	pH	SpC
0	20.46	6.93	8.24	0.7266
0.5	200.47	6.85	8.3	0.7264
1	20.46	6.6	8.33	0.7261
1.5	20.46	6.5	8.33	0.7255
2	20.45	6.62	8.34	0.7262
2.5	20.42	6.44	8.34	0.7262
3	20.4	6.4	8.34	0.7258

8/19/2004	Location: Transect # 38 (9 ft)			
Depth (m)	Temp. ©	DO	pH	SpC
0	21.08	8.43	8.32	0.7249
0.5	21.04	8.18	8.4	0.7244
1	20.9	8.01	8.43	0.7241
1.5	20.81	7.89	8.43	0.7236
2	20.77	6.49	8.37	0.7243

8/26/2004	Location: Deepest point in lake			
Depth (m)	Temp. ©	DO	pH	SpC
0	21.02	8.83	8.32	0.7339
0.5	21.01	8.62	8.33	7.339
1	21	8.67	8.33	7.341
1.5	21.03	8.79	8.35	0.7341
2	21.06	8.88	8.35	0.7342
2.5	21.05	8.87	8.35	0.7341
3	21.04	8.83	8.35	0.7344
3.5	21.02	8.74	8.35	0.7343
4	21.02	8.72	8.35	0.7345
4.5	21.01	8.66	8.35	0.7345
5	20.95	8.51	8.34	0.7347
5.5	20.9	8.18	8.32	0.735
6	20.84	7.97	8.3	0.7353
6.5	20.78	7.83	8.29	0.7358
7	20.75	7.9	8.28	0.7359
7.5	20.74	7.89	8.28	0.7358
8	20.79	8.01	8.28	0.7358
8.5	20.76	7.82	8.28	0.7359
9	20.42	6.05	8.14	0.7385
9.5	20.39	5.64	8.13	0.7388
10	20.37	5.42	8.11	0.739
10.5	19.73	2.42	7.8	0.7443
11	19.46	1.98	7.95	0.7424
11.5	19.28	0.68	7.74	0.7469
12	18.45	0.14	7.69	0.7491
12.5	16.69	0.09	7.47	0.7645
13	14.79	0.07	7.34	0.7801
13.5	15.29	0.04	7.34	0.782
14	14.34	0.01	7.28	0.7948
14.5	14.46	0	7.29	0.7935

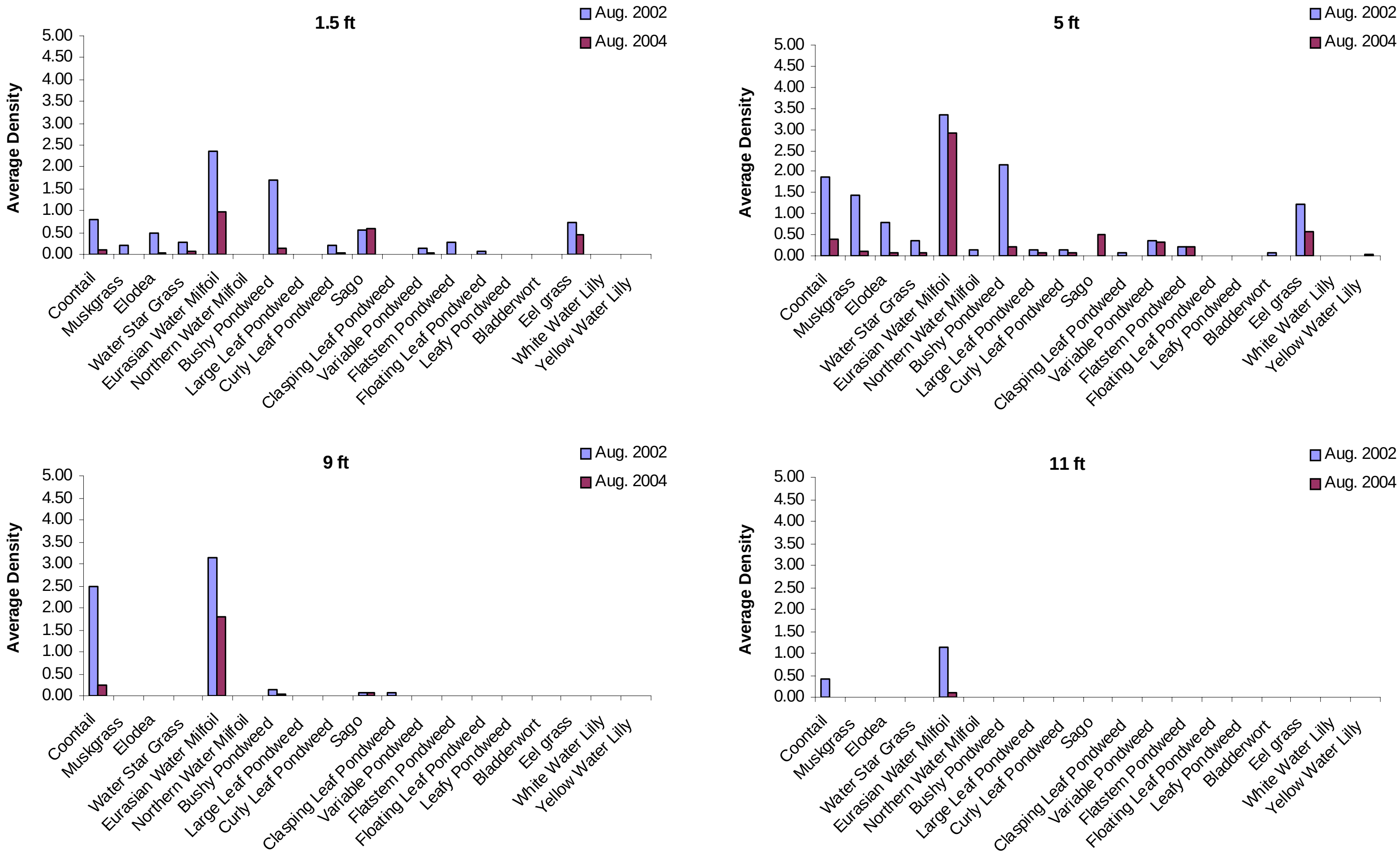

Figure 2A: Average density of aquatic plants at various depths in Pewaukee Lake, WI; from August 2002 and August 2004.