Historical Trends of Macrophyte Diversity and Biomass in Conesus Lake (Summer 2012)

Report Submitted to
The Livingston County Planning Department

by

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Table of Contents

List of Tables

List of Figures

I. Summary

- There were two principal goals for the macrophyte monitoring program in 2012. One goal was to continue monitoring the biomass of Eurasian watermilfoil in four macrophyte beds that have been sampled since 2000, initially as part of the U.S.D.A. watershed study. The second goal was to survey the species diversity and relative abundance of the macrophyte community lake-wide and to compare its current state to trends identified in 1968 and 1999.

- At the Sutton Point, Sand Point, and Cottonwood Gully long-term monitoring sites, the surface area of coverage and the standing crop of the milfoil-dominated zone remained low or continued to decrease when compared to 2009, even in sites that had already undergone significant reductions of milfoil biomass from 2004-2008 in response to watershed management. At the North Gully site, where in 2008 the stream channel was redirected to drain away from the macrophyte bed, the surface area of the milfoil dominated zone and the total milfoil standing crop were about 40% lower than in 2009.

- Most of the macrophyte species that are currently abundant in Conesus Lake were abundant in previous surveys, going back even to W.C. Muenschner's survey in 1927. The one exception is in the dominance of the invasive Eurasian watermilfoil, which had colonized the lake by the late 1960's and ultimately supplanted the native Northern milfoil and displaced the dominant Water stargrass in most of the lake.. This shift in the community is reflected in all of the community metrics tested. The Simpson's Diversity Index in 2012 was 0.32 with milfoil representing more than 43% of the dry weight, compared to an Simpson's Index of 0.43 and 14% dry weight for 1968. A Proportional Community Similarity Index of only 37.5% between 1968 and 2012 is also an indication of a shift in species dominance.

- Presently milfoil is especially dominant near the mouths of some streams, where it represents 84.3% of the biomass in the 2-3 m depth zone. In areas more removed from the influence of these streams, milfoil is only 43.8% of the biomass and many of the native macrophytes are found in much greater abundance. This observation offers some hope that continuing nutrient management will not only reduce the dominance of Eurasian milfoil, as we have already documented in the long-term monitoring sites, but also restore diversity in the macrophyte community that was lost with the spread of this invasive.

II. Introduction

The submerged macrophyte community of Conesus Lake is one of the most extensively studied in the Finger Lakes region. W.C. Muenschner (1927) first described this varied flora in a study that also included Silver Lake. Muenschner judged several species to be predominant in both lakes, including *Ceratophyllum* (Coontail), *Elodea* (Waterweed), *Heteranthera* (Water stargrass), *Myriophyllum* (probably *M. sibiricum*, Northern watermilfoil), *Naja*s (Slender naiad) and 10 species of *Potamogeton* (Pondweeds).

Geneseo Professor Herman Forest and his co-workers conducted the first quantitative studies of the macrophyte community in Conesus Lake in 1967-1970. Forest and colleagues (1971, 1978) duplicated Muenschner's transects and sampled extensively throughout the lake, describing a diverse assemblage dominated by the very same species described by Muenschner in 1927. In 1999, Bosch and colleagues (1999) conducted the first a lake-wide survey of macrophytes since Forest's work in the 1970's, also duplicating some of the Muenschner/Forest transects. Based on readings of Forest's earlier reports and on observations in the unpublished data, Bosch *et al.* (2001) noted that Forest had doubts about the identity of the dominant milfoil in the lake and suspected the native Northern milfoil had been widely displaced by the invasive Eurasian watermilfoil. However, at the time of Forest's work a clear morphological distinction between the Northern milfoil and the invasive Eurasian milfoil had not been made. In time Aiken and his colleagues (1979, 1980) described ways to distinguish the two species on the basis of size and number of leaflets. Relying on these studies, Bosch and his colleagues (1999) identified *M. spicatum* as the overwhelmingly dominant macrophyte in Conesus Lake, A lake-wide search for the native Northern milfoil in 2005 uncovered a small relic population adjacent to Camp Stella Maris, but subsequent attempts to find more plants were unsuccessful (Bosch, unpublished data).

One of the most important results of the Bosch (1999) study was finding that the largest and most dense milfoil-dominated macrophyte beds were located near streams that drained primarily agricultural watersheds. This observation was part of the rationale for the U.S.D.A. watershed management project (2003-2009), which among many other questions tested the possibility that nutrient management at the watershed level could reduce milfoil biomass downstream along the lake littoral (Makarewicz *et al.,* 2009). The results of the project demonstrated the benefits of agricultural management in terms of stream water quality and in reducing plant growth along the lake coastal zone (e.g. Makarewicz *et al*., 2009, Bosch *et al.* 2009a, b). Monitoring of the Conesus Lake macrophyte beds has continued In recent years at Sutton Point Gully, Sand Point Gully and Cottonwood Gully, as well as North Gully, which served as a reference site for the U.S.D.A. project. In the winter 2008, the North Gully stream channel was diverted to direct runoff into the open water and away from the macrophyte bed south of McPhersons Point (North Gully Cove). Initial studies by Bosch and colleagues (2008, 2009, 2010) found no evidence that diversion of the stream had reduced milfoil or algal growth in North Gully Cove.

For the monitoring program in 2012 we examined the biomass of Eurasian watermilfoil in four macrophyte beds that have been sampled since 2000, initially as part of the U.S.D.A. watershed study. Our goal was to determine if the milfoil dominated areas had continued to decrease, following a pattern that started during the U.S.D.A. funded watershed project. For the North Gully Cove macrophyte bed, we were interested in discovering whether there was any sign of reduced milfoil biomass after the diversion of the North Gully Stream. A second goal of this season's monitoring was to survey the species diversity and relative abundance of the submerged macrophyte community lake-wide and to compare the current state to trends identified in 1968 and in 1999, the when the last two comprehensive surveys were carried out.

III. Methods

Macrophyte Biomass in Long-Term Monitoring Sites

Samples were collected in late July and August near the peak of the macrophyte growing season. Replicate benthic quadrats were taken by S.C.U.B.A. divers at depths of 2, 3 and 4 m along three historical transects at Sutton Point, North, Gully Cove, Sand Point and Cottonwood Gully. The methods and transect sites are described in detail by Bosch *et al.* (2009). Quadrat samples were sorted and weighed by species to the nearest 0.1 g. The blotted wet weight (WW) was converted to dry weight (DW) using species-specific conversions (Bosch *et al.* 2009). A conversion factor of 0.10 DW/WW was used when conversion data for individual species were not available.

The surface area of each macrophyte bed and of the milfoil-dominated section (>50% of plants) within each bed was determined by mapping with a Trimble Ranger GPS unit. The GPS unit was operated on board a pontoon boat while the boat closely followed a snorkeler who swam the perimeter of the bed and of the milfoil dominated zone. In cases where the inner shallow margin of the distribution was patchy, observations were made directly from a boat. GPS data was loaded into ArcGIS 10 and used to determine the surface areas (in meters squared) of both the entire weed bed and the milfoil-dominated zones.

Lake-Wide Survey of Macrophyte Biodiveristy

We surveyed the diversity and relative composition of the macrophyte community at ten different sites spread widely in Conesus Lake (**Figure 1**). At each location replicate samples (n=3) were taken from depths of 1-4 m using a large, 1 m wide, weighted metal rake. A backing of wire mesh was attached to the rake to keep plants from slipping through the collector while it was dragged along the bottom or lifted on board. Rake sampling was used extensively by Forest for surveys of macrophyte diversity and relative abundance. While direct hand collection by S.C.U.B.A. divers might be preferable, we observed that plants were reliably sampled by the rake method and saw no evidence of any major bias in collection.

The ten collection sites for the biodiversity survey have been sampled previously by W.C. Muenschner (1927), and subsequently in the 1960's and 70's by Herman Forest and colleagues. Some of the data gathered by Forest and colleagues have been published (Forest and Mills 1971, Forest *et al.,* 1978) but much remains unpublished. Professor Forest left most of his records with us (I.B.) upon his retirement, and they are now in the keeping of the Biology department at SUNY Geneseo. Bosch *et al.* (1999) compiled some of the unpublished Forest data as part of a report on long-term trends of macrophyte biomass and dominance in Conesus Lake. A portion of the archived data was also used in the present study (see data in **Appendix I**). Specifically, we compared data from 1968 and 2012 (**Appendix II**) to investigate changes in species richness, the Simpson's Index of Diversity, and the Proportional Index of Community Similarity of the macrophyte community.

The Simpson's Index of Diversity is widely used in the ecological literature. The metric provides a single value that incorporates the species richness and the relative abundance of species in a community:

$$\mathbf{D = 1- \sum \frac{n(n-1)}{N(N-1)}}$$

n= the total number of organisms of one species

N= the total number of organisms of all species

The value of D ranges from 0-1 with a 1 representing infinite diversity and a 0 representing no diversity. Statistical comparisons of the Simpson's index in two communities can be made using a t-test with calculated variance in the data:

$$\mathbf{s^2 = 4[p_i^3 - (p_i^2)^2]/N}$$

where p_i is the proportion of the number of organisms in the i^{th} species (n_i) to the total number of organisms in the sample (N). Therefore, $p_i = n_i/N$

We also compared the species composition of the lake between 1968 and 2012 using the Proportional Index of Community Similarity:

$$\mathbf{PSI = \sum min\ (p_i, q_i)}$$

The values ***pi*** and ***qi*** represent the proportion of each species in the two communities. A comparison of two communities yields a PSI value between 0 and 100%, with a 100% representing two identical communities and a 0% representing two communities having no species in common.

IV. Results and Discussion

Trends in Macrophyte Biomass in Long Term Monitoring Sites

A compilation of the biomass data collected in 2012 is provided in **Appendix III.** While quadrat biomass data generally increased slightly (**Figure 1**), there were marked decreasing trends in the amount of surface area covered by milfoil (**Table 1, Figure 2**) even while the size of the whole beds remained fairly constant or increased in the last 3 years. At Sutton Point and North Gully, the surface area of the milfoil beds decreased by more than 40% since 2009 (**Table 2, Figure 3**). Multiplying bed surface by average quadrat biomass showed that the standing crop of milfoil in 2012 was 1785 Kg dry weight at Sutton Point and 3,844 Kg at North Gully (**Figure 4**). By comparison, the highest milfoil standing crop estimates since 2000 was 4,017 Kg for the Sutton Point bed and 11,834 Kg for the North Gully bed, both in 2001 (**Table 1**). In 2002 the two watersheds were designated as reference sites for the U.S.D.A. watershed management study (Makarewicz *et al*., 2009). However, changes in land use and other forms of management were later implemented at each site. In the Sutton Point watershed, landowners converted acreage from corn production to alfalfa/grass starting with 37% in 2003 and reaching 63% in 2007. The shift in crop plantings was associated with reductions of 39% in nitrate loading from Sutton Point Gully (Makarewicz *et al*. 2009). In the North Gully system, diversion of the North Gully stream channel completed in early 2008 redirected part of the stream effluent into open water away from North Gully Cove and its macrophyte bed. Bosch and colleagues (2008, 2009, 2010) saw no initial reductions in macrophyte biomass that could be attributed to the stream diversion, but by 2012 we may be seeing evidence of the long-term effects of the project.

At the Cottonwood Gully and Sand Point Gully beds, milfoil coverage and standing crops were also low in 2012 (**Table 1, Figure 3, 4**). Bed surface areas were 53% lower and 43% lower than the average for 2000-2009, (**Table 2, Figure 5**). The only break in this trend was in 2010 for Cottonwood Gully, where milfoil surface coverage increased by 45%. Nevertheless, the average standing crop for Cottonwood between 2010-2012 was 931 Kg, well below the 2001-2008 average of 1893 Kg (Figure 5) and a milfoil standing crop of 352 Kg in 2012 was the lowest recorded at Cottonwood Gully since monitoring began in 2000. The Cottonwood Gully and Sand Point watersheds were both experimental sites for the U.S.D.A. funded project. Agricultural best management practices established in these watersheds in 2003 produced significant reductions in nitrogen and/or phosphorus loading (Makarewicz *et al.*, 2009) and by 2004 the milfoil biomass had already decreased significantly in both sites (Bosch *et. al.,* 2009). Thus, a strong case can be made that the declining milfoil standing crops over the past three years (**Figure 5**) are a continuation of improvement generated by BMPs established in the watersheds as part of the U.S.D.A. project.

Lake-Wide Macrophyte Diversity and Relative Composition

In 108 rake samples taken over depths of 1-4 m at 10 transects spread throughout the lake (**Figure 1**) we documented a total of 16 species of submerged macrophytes (**Table 3, Appendix III**). The most common species in order of biomass were Eurasian Watermilfoil, Coontail, Sago Pondweed and Water Stargrass. With the exception of Eurasian watermilfoil, these same species were identified as the most abundant in the lake by Muenschner in 1926 and by Herman Forest and colleagues in work carried out between 1968-1977 (Forest *et al.,* 1978). When Muenschner sampled in 1926, the common milfoil was most likely Northern milfoil (*Myriophillum sibiricum, sometimes synonymous with M.exalbescens*). Careful reading of comments by Forest and colleagues (1971,1978) and unpublished data indicates that by the late 1960's and 70's Eurasian watermilfoil was well established in Coneus Lake. By the time of the survey by Bosch and colleagues in1999 , Eurasian watermilfoil was the only milfoil species readily encountered. A systematic survey of the lake conducted by our group in the summer 2005 yielded only a few plants identifiable as Northern milfoil at 1.5-2 m off Camp Stella Maris (Unpublished data). However, no specimens of *M. sibiricum* have been found since, even at the Stella Maris site.

We identified the ditch grass *Rupia sp.* in our survey (2 samples, 1.3% of total DW collected). However, ditch grass closely resembles Sago pondweed (*Potamogeton pectinatus*) and our identification is therefore tentative. We are more confident about the new record of Waterthread pondweed (*P. diversifolius*). This species is widespread in New York State but it is never locally abundant (New York Natural Heritage Program Plant Guide). Although it was present in 10 of our rake samples it made up only 0.5 % of all DW collected. It is quite possible that due to its low biomass the species was simply overlooked in previous surveys.

An interesting pattern of community level organization emerged in our comparison of Simpson's Index of Diversity between Forest's 1968 data and the 2012 rake collections (**Table 4**). We found that while the number of species (i.e. species richness) in our samples was significantly higher than in the 1968 samples (9.6 vs. 4.25; p =0.001, Paired two-tailed T-test), the average Simpson's Index of Diversity was higher in 1968 (0.435 vs. 0.321; p =0.13, Paired two-tailed T-test), though it was not significantly different from 2012. The Simpson's Index incorporates species richness and relative abundance of species (i.e. Evenness) into its biodiversity value and assigns very high importance to abundant species. Consequently, if one or two species have a very high proportional weight the index remains low even with a relatively high number of species. In the Conesus Lake data we noted that in 2012 Eurasian watermilfoil made up 43.8% of the biomass and it was the dominant plant at all of the sites surveyed. In1968 Eurasian watermilfoil made up only 13.5% of the total weight of macrophytes. While Waterstargrass made up a large proportion of the biomass lake-wide, it was only dominant at only two sites sampled. For example at Pebble Beach in 1968, Waterstargrass and *Chara* made up 88 % of the biomass biomass and the Simpson's Index was a low 0.13. Overall in 1968 there was much greater evenness in species representation at the individual sites, whereas Eurasian watermilfoil was dominant at all of the sites in 2012, accounting for the lower average Simpson's Index value.

To examine more closely the shifts in community structure between 1968 and 2012 we used the proportional weight of individual species in the biodiversity collections to determined the Proportional Index of Community Similarity for the whole lake (**Table 5**). The calculated index was 32% out of a maximum of 100%. A 32% similarity index is low given the apparent stability of the species composition in the macrophyte community (**Table 3**). However a brief look at the data shows that a major shift in relative species abundance took place in Conesus Lake and that shift could account for the differences in the proportional index (**Figure 6**). Specifically, the relative biomass of Water stargrass was 52.4% in 1968 and only 3.8% in 2012. The Common waterweed (*Elodea canadensis*) also experienced proportional declines, from 8.7 to 0.6%. In the 2012 samples, Water stargrass and Common waterweed were displaced by Eurasian watermilfoil, which increased in proportional biomass from 13.9% to 42.9%. It is not surprising that the invasion and subsequent spread of Eurasian watermilfoil since the 1960's may have caused a decrease in other species, particularly those that occupy similar depth zones. We have already discussed the apparent extirpation of Northern milfoil from Conesus Lake. According to data collected by Forest and colleagues (**Appendix I, unpublished**), large beds consisting primarily of Water stargrass at depths of 2-4 m were present in different parts of Conesus Lake, and an especially prominent assemblage occurred near the Inlet stream. Those stands of Water stargrass have been displaced, particularly in areas near streams where nutrient loading is high (Bosch 1999). To our knowledge at least two moderately-sized beds assemblages of Water stargrass remain in Conesus Lake, one at Sand Point-Vitale Park and the other near Camp Stella Maris, which is also where we located a relic population of Northern milfoil in 2005 (Bosch, unpublished).

In previous studies we documented the presence of several large macrophyte beds near the mouth of streams where extensive shoals and high stream nutrient input seem to favor the dominance of Eurasian watermilfoil (Bosch *et al*., 1999, 2001). Eurasian watermilfoil competes very effectively for nutrients in the sediment by means of root uptake, and in the water by foliar uptake. High nutrient availability such as that found near streams results in rapid and luxuriant growth of milfoil, culminating in the formation of a canopy that absorbs much of the surface light and shades potential competitors.

To further test the hypothesis that nutrient loading by streams favors the local dominance of milfoil we compared the relative biomass of macrophyte species in the 2012 quadrat collections taken near streams to that of rake samples taken in areas away from streams. The results, shown in Table **6 A-B**, are consistent with the hypothesis that streams favor milfoil dominance. In samples taken at depths of 2-3 m near streams, milfoil made up an average of 84.3% of the biomass compared to only 43.8% of the biomass in “non-stream” samples. There is greater macrophyte species diversity away from streams, and several species including Coontail, Sago pondweed,and the aforementioned Water stargrass, enjoy a greater representation.

V. Conclusions

The results of our survey at the North Gully, Sutton Point Gully, Sand Point Gully, and Cottonwood Gully long-term monitoring sites indicate that dominance of Eurasian watermilfoil continues to abate. Specifically, the surface area and total standing crops of milfoil have decreased markedly since 2009, while the overall size of the macrophyte bed has changed very little. For the Sand Point Gully, Sutton Point Gully and Cottonwood Gully sites these results appear to be a continuation of a trend that was first described as part of the U.S.D.A. watershed management project (Bosch *et al*., 2009). The reduction of the milfoil bed in North Gully is a more recent phenomenon, which may be an indication that the stream diversion project completed in winter 2008 is finally having a positive influence on the water quality of the local area.

Lake-wide, the species composition of the macrophyte community in Conesus Lake seems to be very stable, having changed only slightly since the first survey conducted by W.C. Muenschner (1927). It is virtually the same as that documented by Professor Herman Forest during his extensive studies in Conesus lake in the 1960’s and ‘70s. The one exception is the invasion and subsequent spread to all parts of the lake by Eurasian watermilfoil, which we surmise may have begun in the late 1960’s. Since that time, the species has established itself as the dominant macrophyte, outcompeting the formerly abundant Water stargrass and Common waterweed. With the shift to milfoil dominance, the overall species diversity index and the species evenness of the macrophyte community has declined.

The greatest diversity of macrophytes in Conesus Lake may still be found in nearshore areas that are somewhat removed from the fertilizing effect of major streams. In places such as Pebble Beach Cove, Sand Point near Vitale Park, and the Conesus Inlet, the relative biomass of milfoil is nearly half that of the streamside macrophyte beds and native species such as Water stargrass, Sago pondweed, Common waterweed and Wild celery are better represented. Makarewicz and colleagues (2009) documented reductions in stream nutrient loading from U.S.D.A. project watersheds and in a recent report describe reductions in dissolved nutrients and in phytoplankton (chl a) biomass in the offshore regions of Conesus Lake (Makarewicz *et al*., 2012). Our observation of losses in milfoil standing crop are consistent with the trends of declining nutrient inputs and decreased nutrient availability in Conesus Lake. All things considered it appears that the ecosystem may be beginning to recover after years of increasingly eutrophic conditions.

VI. Acknowledgements

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VIII. Tables and Figures

Table 1. Long-term record of dry weight biomass, bed surface area and total biomass (i.e. standing crop) in the milfoil-dominated zone for the four study sites.

Location	Year	Average Biomass grams . m^2	Surface Area m^2	Standing Crop Kg DW
Sutton Point	2000	184 ± 43	---	---
	2001	467 ± 183	8,592	4,017
	2002	71 ± 40	3,688	262
	2003	138 ± 92	11,819	1,631
	2004	227 ± 77	11,909	2,703
	2005	197 ± 90	11,995	2,349
	2006	364 ± 208	7,438	2,707
	2007	295 ± 94	10,973	3,232
	2008	190 ± 106	5,985	1,201
	2009	224 ± 112	13,802	1,201
	2010	135 ± 47	7,390	998
	2012	270 ± 57	6,610	1785
North Gully	2000	262 ± 134	23,192	6,192
	2001	459 ± 202	25,783	11,834
	2002	151 ± 74	12,004	1,813
	2003	304 ± 176	19,760	6,007
	2004	186 ± 57	30,099	5,598
	2005	188 ± 105	21,798	4,098
	2006	230 ± 100	22,560	5,178
	2007	225± 70	27,850	6,266
	2008	266 ± 167	11,855	3,149
	2009	286 ± 108	24,267	6,874
	2010	265 ± 175	13,325	3,531
	2012	272 ± 153	14,133	3,844
Sand Point Gully	2000	212 ± 29	9,535	2, 021
	2001	484 ± 300	9,781	4,730
	2002	325 ± 82	7,354	2,390
	2003	290 ± 126	5,310	1,540
	2004	131 ± 34	8,474	1,110
	2005	191 ± 96	8,349	1,595
	2006	230 ± 92	9,775	2,246
	2007	112 ± 111	9,684	1,084
	2008	201 ± 71	6,022	1,147
	2009	222 ± 111	6,564	1,457
	2010	205 ± 19	4,939	1,012
	2012	301 ± 146	3,846	1,158
Cottonwood	2000	193 ± 85	---	
	2001	373 ± 168	9,387	3,501
	2002	316 ± 134	7,360	2,326
	2003	146 ± 43	3,750	548
	2004	234 ± 41	9,205	2,154
	2005	273 ± 81	6,880	1,878
	2006	283 ± 61	5,605	1,589
	2007	155 ± 140	8,100	1,253
	2008	-	-	-
	2009	135 ± 78	4,860	657
	2010	252 ± 90	7,077	1,783
	2012	154 ±107	2,283	352

Table 2. Changes in milfoil cover in square meters over the last four seasons in the U.S.D.A. macrophyte bed monitoring sites. The milfoil-dominated zone usually encompasses the 2-3 m sampling depths.

Site	Year	Bed Surface Area sq. m	Milfoil Dominated sq. m	Milfoil Percent of Bed Area	Change in Milfoil Area vs. 2009
Sutton Point	2009	14,434	13,802	96	-
Gully	2010	11,179	7,390	66	-46.45
	2012	14,512	6,610	46	-52.11
North Gully	2009	27,877	24,267	87	-
	2010	29,421	13,325	45	-45.09
	2012	26,812	14,133	53	-41.76
Sand Point	2009	8,347	6,564	79	-
Gully	2010	10,185	4,939	48	-24.76
	2012	10,234	3,846	38	-41.41
Cottonwood	2009	8,091	4,860	60	-
Gully	2010	7,440	7,077	95	45.61
	2012	11,483	2,283	20	-53.03

Table 3. List of submerged macrophyte species collected in Conesus Lake by Muenschner in 1926 as reported by Forest and collegues (1978), in 1968 and later as reported by Forest and colleagues (1978), and by Bosch and colleagues in 1999 and 2012. With the exception of two species that are patchily distributed, all of the macrophytes in the recent surveys have been identified previously in Conesus Lake.

Species Name	Common Name	1926 *Muenschner*	1968 and later *Forest*	1999 *Bosch*	2012 *Bosch*
*Myriophyllum spp**	Northern/Eurasian milfoil	✔	✔	✔	✔
Ceratophyllum demersum	Coontail	✔	✔	✔	✔
Vallisneria americana	Wild Celery/Eel grass	✔	✔	✔	✔
Najas flexilis	Slender naiad	✔	✔	✔	✔
Heteranthera dubia	Water stargrass	✔	✔	✔	✔
Potamogeton diversifolius	Water thread pondweed				✔
P. zosteriformis	Flat Stem pondweed		✔		✔
P. pectinatus	Sago Pondweed	✔	✔	✔	✔
P. nodosus	Long Leaf		✔	✔	✔
P. gramineus	Variable Pondweed		✔		✔
Elodea canadensis	Waterweed	✔	✔	✔	✔
Ruppia sp.	Ditch Grass				✔
P. crispus	Curly Leaf Pondweed	✔	✔	✔	✔
Chara sp.	Musk Grass		✔	✔	✔
P. Illinoensis (as angustifolious)	Illinois Pondweed		✔		✔
Racunculus longirostris	Water Crowfoot		✔	✔	✔

****The dominant northern watermilfoil in the lake (*M. sibiricum*) has been replaced by Eurasian watermilfoil (*M. spicatum*)**

Table 4. Comparison of species richness and Simpson's Index of Diversity for areas sampled in 1968 and 2012. Data were compiled for all depths sampled at each transect and all three transects from the Inlet were combined for the analysis. Species richness was higher in 2012, but that may be an artifact of identification. Despite the greater species richness, 2012 samples generally had the lower diversity due to the recent dominance of milfoil in Conesus Lake.

Site	Year	# of Species	Index of Diversity	Variance
Cottonwood E	1968	3	0.36	0.00005
Cottonwood W	1968	3	0.64	0.00021
Eagle E	1968	4	0.51	0.00041
Eagle W	1968	5	0.5	0.00013
Inlet	1968	6	0.48	0.00001
Pebble Beach	1968	6	0.13	0.00001
Sand N	1968	5	0.35	0.00005
Wilkin's Creek	1968	2	0.51	0.00004
Cottonwood-E	2012	9	0.21	0.00002
Cottonwood-W	2012	9	0.31	0.00002
Eagle Point-E	2012	11	0.33	0.00004
Eagle Point-W	2012	8	0.5	0.00012
Inlet	2012	9	0.34	0.00004
Pebble Beach	2012	7	0.39	0.00003
Sand-N	2012	12	0.3	0.00007
Wilkin's Creek	2012	12	0.19	0.00003

Table 5. The Proportional Index of Community Similarity for 1968 and 2012 with data from all biodiversity survey sites compiled. The Index was fairly low due primarily to the shift in dominance from Water stargrass (*Heteranthera dubia*) in 1968 to Eurasian watermilfoil (*Myriophyllum spicatum*) in 2012.

Species	% of DW Collected 1968	% of DW Collected 2012	Low %
Coontail	6.22	14.41	6.22
Curly Leaf Pondweed	0.08	2.44	0.08
Eel Grass/Wild Celery	11.79	7.16	7.16
Flat Stem Pondweed	0.00	0.22	0.00
Long Leaf Pondweed	0.00	0.40	0.00
Milfoill	13.86	42.89	13.86
Muskgrass	0.00	12.84	0.00
Sago Pondweed	1.09	6.69	1.09
Slender naiad	0.00	1.54	0.00
Common Waterweed	8.73	0.57	0.57
Water stargrass	52.35	3.76	3.76
Crowsfoot	0.00	0.02	0.00
Variable Pondweed	0.00	0.46	0.00
Illinois Pondweed	0.00	0.13	0.00
Chara	5.33	0.00	0.00
Water thread Pondweed	0.00	5.65	0.00
Unknown sp.	0.00	0.04	0.00
	Proportional Index		32.75

Table 6. Comparison of species composition in areas near the mouths of streams (A) and in areas further away from streams (B). We included the Conesus Inlet area as a "non-stream" site because nutrient concentrations in inlet drainage are generally much lower than those of streams draining primarily agricultural watersheds.

A.

Near-Stream Sites					# >50 g
		Total g DW	**% of**	**# of quad**	**DW/**
Species Name	**Common Name**	**in 80 sq. m**	**Total DW**	**present**	**sq. m**
Myriophyllum spicatum	Eurasian milfoil	17131.8	84.3	72	57
Ceratophyllum demersum	Coontail	2449.0	12.1	45	14
Vallisneria Americana	Wild Celery/Eelgrass	458.0	2.3	25	4
Najas flexilis	Slender naiad	145.0	0.7	10	0
Heteranthera dubia	Water stargrass	71.0	0.3	9	0
Potamogeton diversifolius	W.thread pondweed	41.0	0.2	5	0
P. zosteriformis	Flat Stem pondweed	12.0	0.1	5	0
P. pectinatus	Sago Pondweed	10.0	0.0	4	0
	Total g DW. In Quadrats	**20317.8**	**100.0**		

B.

Sites not near streams		**Total g DW**	**% of**	**# rake**
		in 94 Rake	**Total**	**samples**
Species Name	**Common Name**	**Samples**	**DW**	**present**
Myriophyllum spicatum	*Eurasian milfoil*	*954.8*	*43.8*	*53*
Ceratophyllum demersum	*Coontail*	*659.5*	*27.6*	*55*
Potamogeton pectinatus	*Sago Pondweed*	*183.1*	*7.7*	*19*
Heteranthera dubia	*Water stargrass*	*180.6*	*7.6*	*13*
Chara sp.	*Musk Grass*	*77.9*	*3.2*	*6*
P. crispus	*Curly Leaf Pondweed*	*75.0*	*3.1*	*17*
Vallisneria americana	*Wild celery/eelgrass*	*74.5*	*3.1*	*52*
Ruppia sp.	*Ditch Grass*	*29.8*	*1.2*	*2*
P. diversifolius	*Water thread pondweed*	*11.1*	*0.5*	*10*
P. gramineus	*Variable Pondweed*	*10.6*	*0.4*	*2*
Najas flexilis	*Slender naiad*	*10.5*	*0.4*	*12*
Elodea canadensis	*Waterweed*	*8.1*	*0.3*	*7*
P. illinoensis	*Illinois Pondweed*	*6.8*	*0.3*	*1*
P. zosteriformis	*Flat Stem pondweed*	*5.2*	*0.3*	*7*
Racunculus longirostris	*Water Crowfoot*	*2.0*	*0.1*	*3*
P. nodosus	*Long Leaf*	*1.7*	*0.1*	*2*
P. vaseyi	*Vasey's Pondweed*	*0.1*	*0.01*	*1*
	Total g DW Rake samples	**2389.7**	**100.00**	

Figure 1. Map of Conesus Lake showing U.S.D.A. the four stream sites and ten other transect sites where biodiversity surveys were conducted in 1968 and again in 2012.

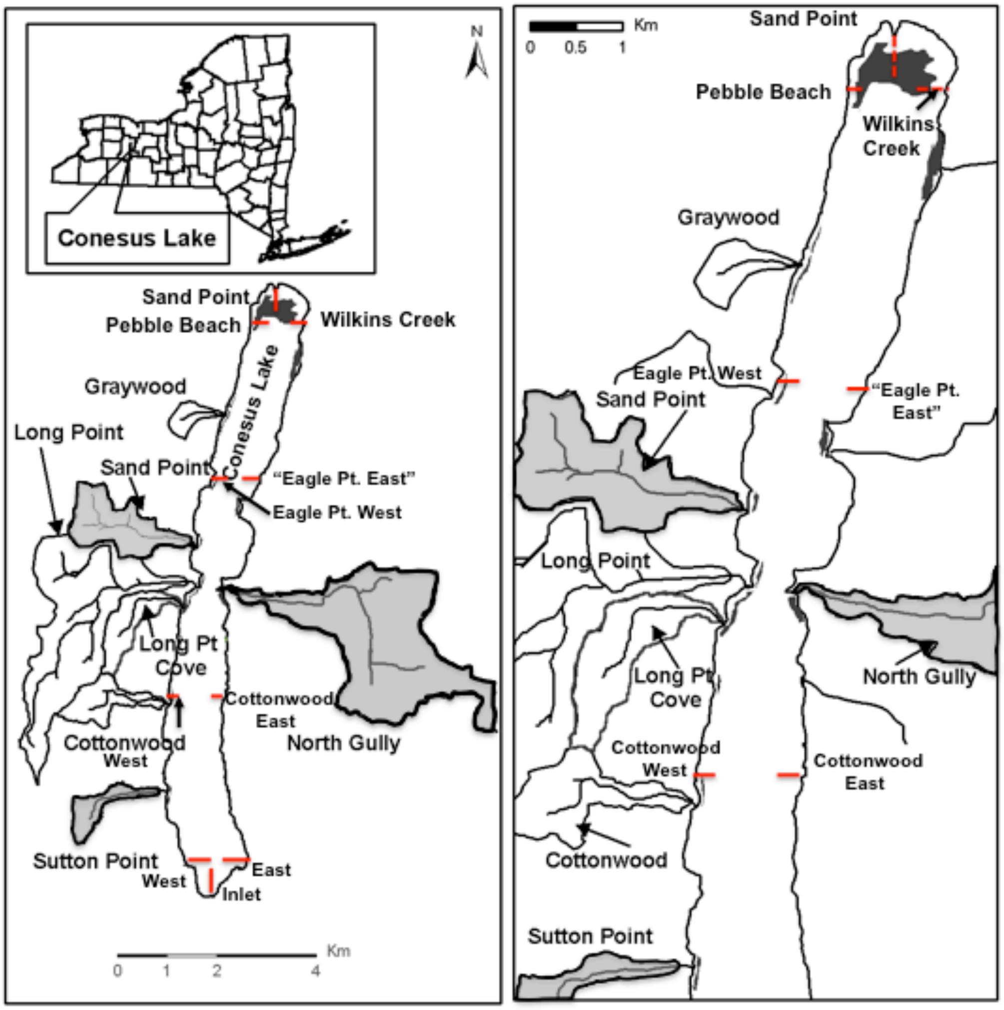


Figure 2. Multi year trend in quadrat biomass in the milfoil dominated zones at 4 of the U.S.D.A. study sites

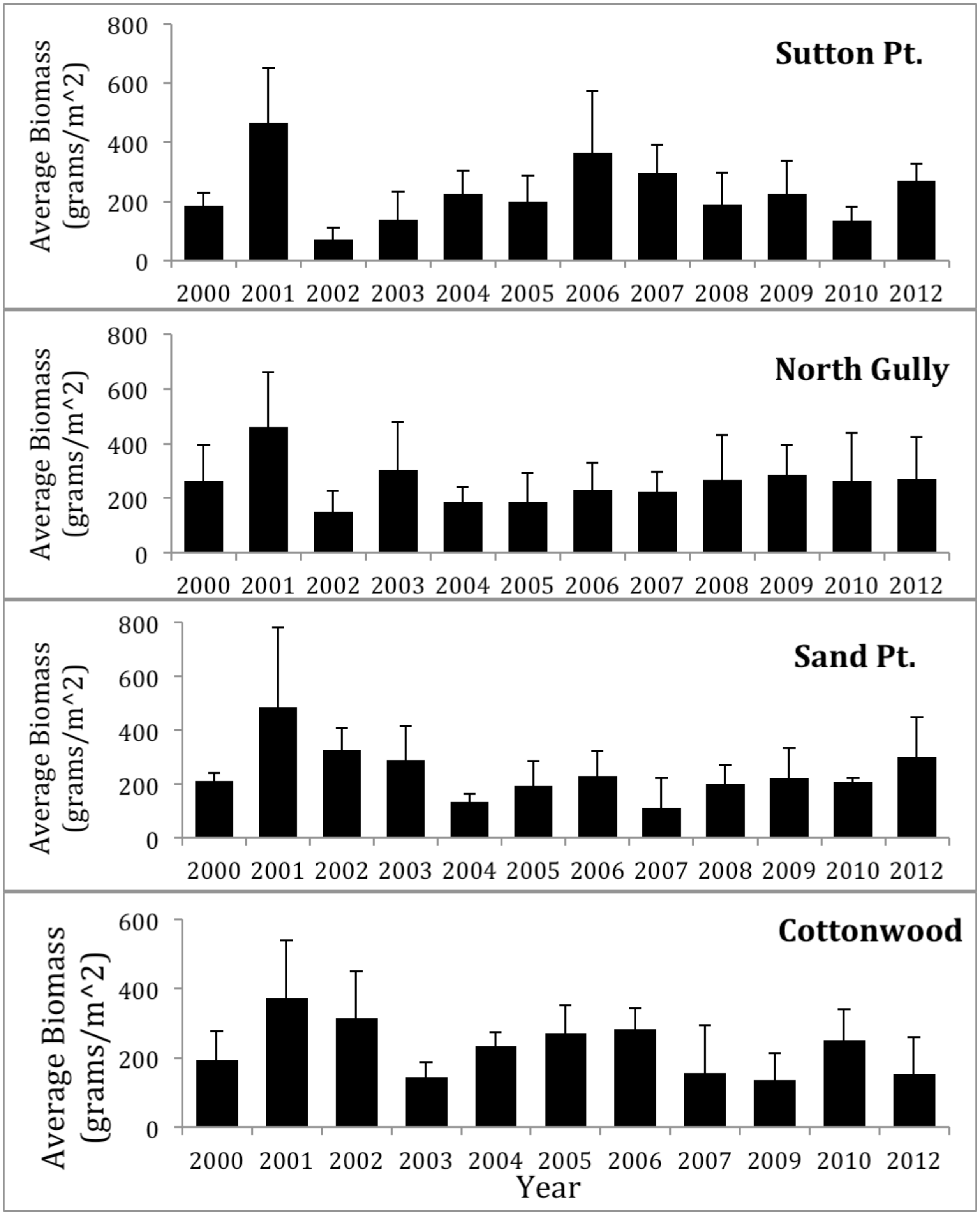


Figure 3 Multi year trend in area of the milfoil-dominated zones (Milfoil >50% of plants) at the four long-term monitoring sites.

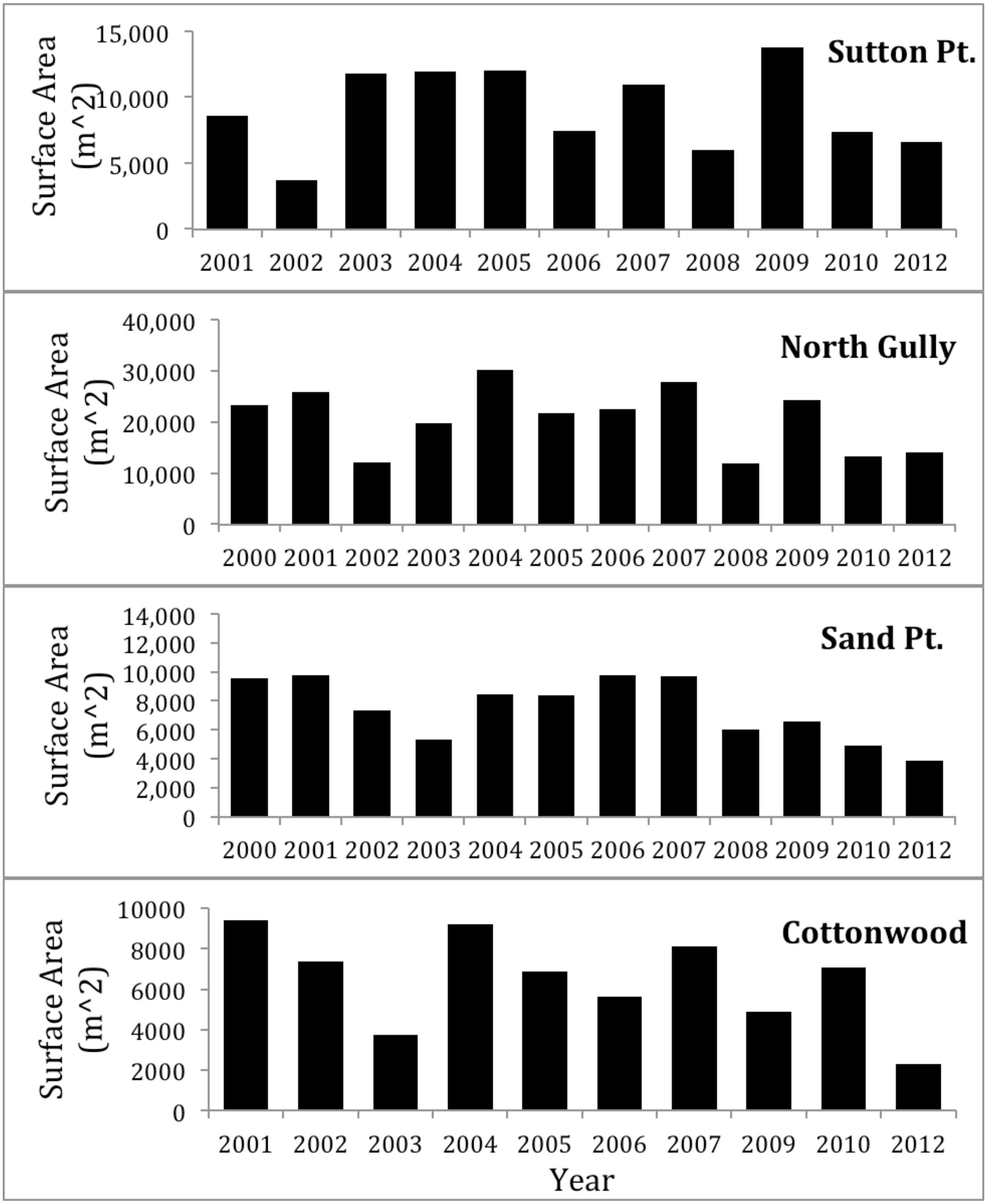


Figure 4. Multi year trend in standing crop of the milfoil dominated zones at the four long-term monitoring sites. Standing crop is calculated by multiplying the average macrophyte density in the 2-3 m quadrats x the surface area covered.

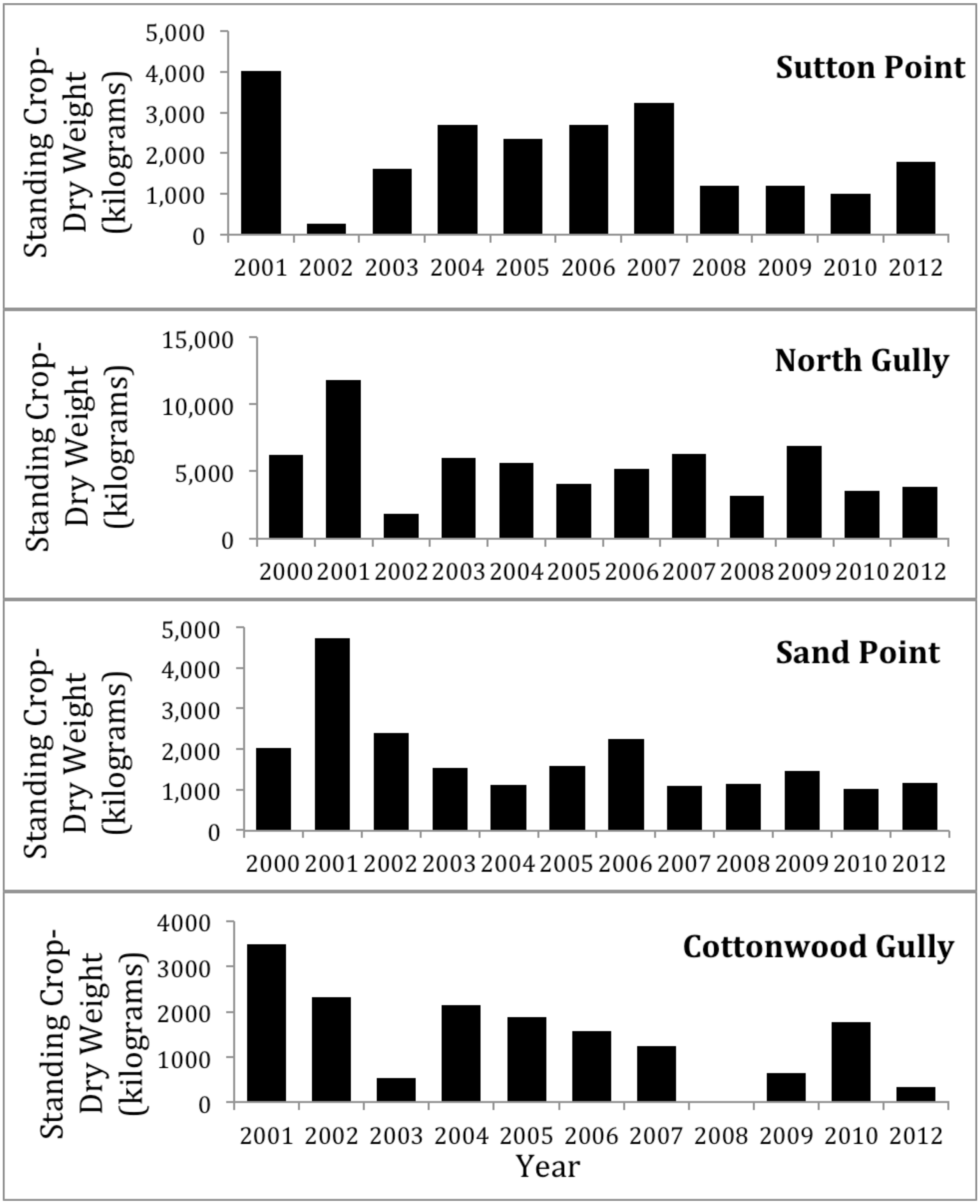


Figure 5. Change in milfoil dominance. Average values for quadrat biomass, surface area of milfoil dominated region and standing crop of milfoil dominated region are compared for 2010-12 and 2000-2009.

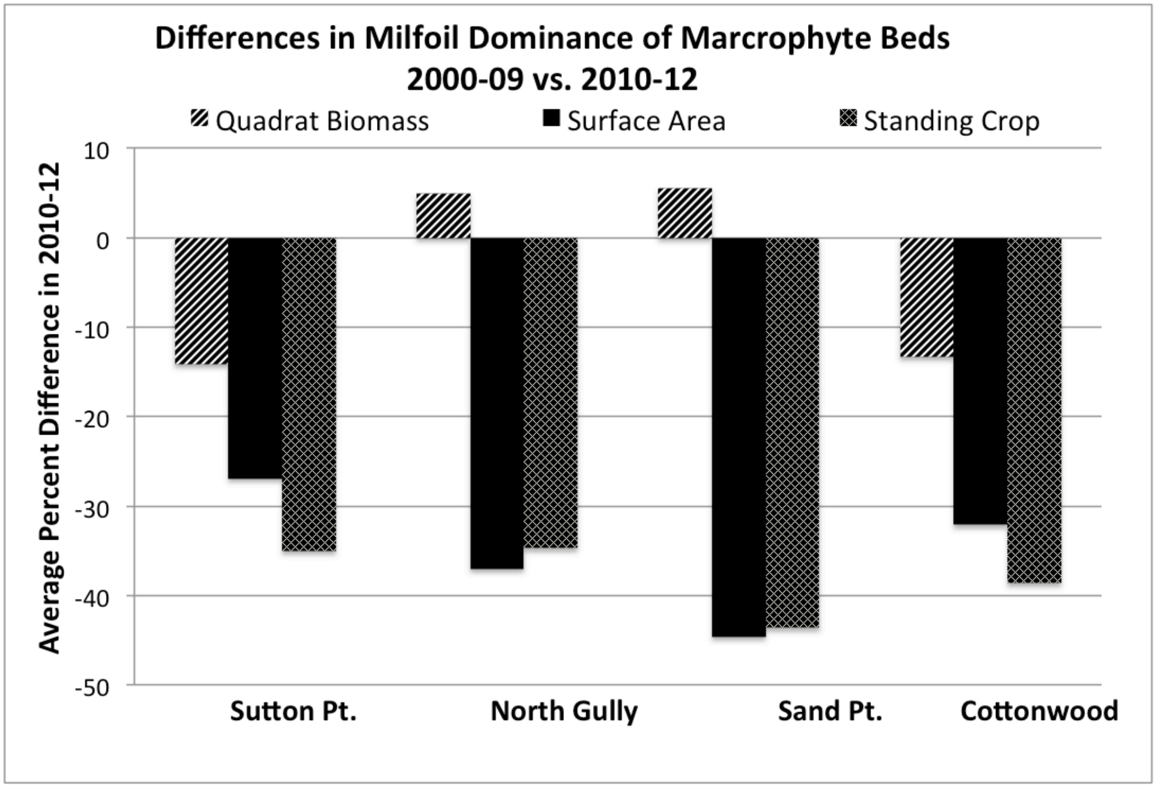
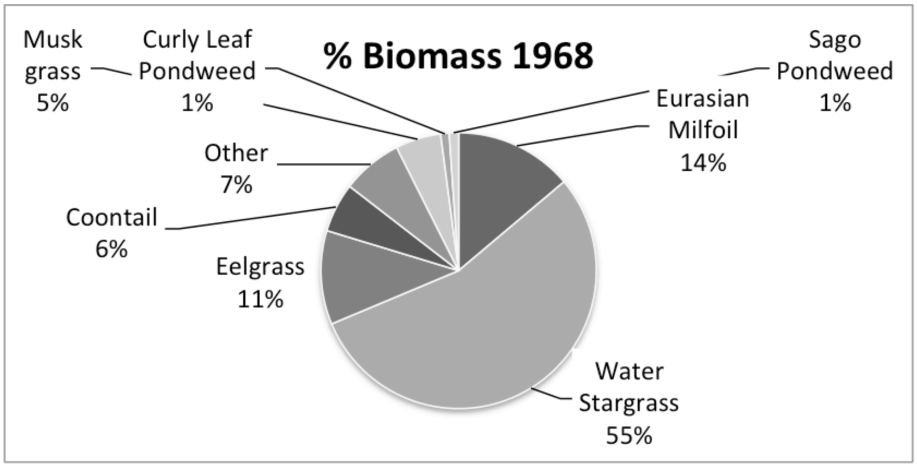
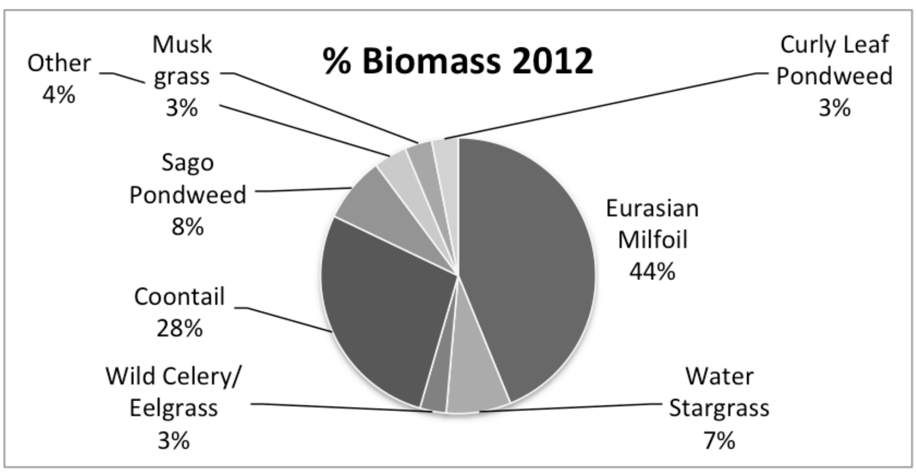


Figure 6. Comparison of dominant species composition in 1968 and 2012 based on lake -wide surveys. Water stargrass was a dominant species in 1968, whereas Eurasian watermilfoil is dominant in 2012





Appendix I. Previously unpublished data from quadrat collections taken by Herman Forest in 1968. Dr. Forest's field records are kept by the Biology department at SUNY Geneseo

Site	Quadrat Number	Species	KG DW	Species KG DW	Dry Wt. (g/m^2)
Cottonwood E	1.	Water Celery	0.04	0.26	258
		Water Celery	0.11		
		Water Celery	0.04		
		Water Celery	0.04		
		Water Celery	0.04		
	2.	Elodea	0.20	0.20	198
	3.	Milfoil	0.29	0.40	404
		Milfoil	0.11		
Cottonwood W	1.	Coontail	0.09	0.21	207
		Coontail	0.12		
	2.	Water Celery	0.04	0.11	114
		Water Celery	0.04		
		Water Celery	0.04		
	3.	Milfoil	0.23	1.15	1149
		Milfoil	0.04		
		Milfoil	0.23		
		Milfoil	0.64		
Eagle Point E	1.	Coontail	0.09	0.09	89
	2.	Water Celery	0.04	0.10	96
		Water Celery	0.04		
	3.	Elodea	0.02		
	4.	Milfoil	0.18	0.39	390
		Milfoil	0.21		
Eagle Point W	1.	Coontail	0.09	0.18	178
		Coontail	0.09		
	3.	Water Celery	0.04	0.15	152
		Water Celery	0.04		
		Water Celery	0.04		
		Water Celery	0.04		
	4.	Sago Pondweed	0.36	0.36	360
	5.	WaterStarGrass	1.44	1.46	1462
		WaterStarGrass	0.02		

Appendix I Continued

Site	Quadrat Number	Species	KG DW	Species KG DW	Dry Wt. (g/m^2)
Inlet	1.	Coontail	0.74	1.43	1425
		Coontail	0.69		
	2.	Curly-leaf pondweed	0.02	0.02	16
	3.	Water Celery	0.07	2.83	2830
		Water Celery	0.40		
		Water Celery	0.40		
		Water Celery	0.20		
		Water Celery	0.77		
		Water Celery	0.19		
		Water Celery	0.56		
		Water Celery	0.24		
	4.	Milfoil	0.05	0.56	555
		Milfoil	0.03		
		Milfoil	0.24		
		Milfoil	0.24		
	5.	Water Stargrass	4.01	13.91	13911
		Water Stargrass	1.41		
		Water Stargrass	4.01		
		Water Stargrass	2.69		
		Water stargrass	1.79		
	6.	Waterweed	0.25	2.17	2168
		Waterweed	0.02		
		Waterweed	0.15		
		Waterweed	1.75		
Pebble Beach Cove	1.	Chara	0.93	1.75	1755
		Chara	0.83		
	2.	curly leaf	0.01	0.01	11
	3.	Water Celery	0.01	0.07	71
		Water Celery	0.06		
	4.	milfoil	0.02	0.32	324
		milfoil	0.30		
	5.	Water stargrass	1.47	1.47	1475
	6.	Waterweed	0.03	0.03	25
Sand Point Vitale Park	1.	coontail	0.15	0.15	150
	2.	Water Celery	0.03	0.10	96
		Water Celery	0.04		
		Water Celery	0.03		
	3.	Milfoil	0.04	1.37	1375
		Milfoil	1.33		
	4.	Water stargrass	0.11	0.39	386
		Water stargrass	0.27		
	5.	Waterweed	0.66	0.66	660
Wilkin's Creek	1.	Water Celery	0.11	0.26	264
		Water Celery	0.15		
	2.	milfoil	0.28	0.37	366
		milfoil	0.08		

Appendix II. Collections made in June and July 2012 for biodiversity analysis. Samples were gathered by dragging a large metal rake over the bottom.

Site	Species	Kg Dry Weight by Species	% by Weight
Cottonwood-E	Coontail	0.49	30
	Curly Leaf Pondweed	0.10	6
	Eel Grass	0.08	5
	Flat Stem Pondweed	0.02	1
	Long Leaf Pondweed	0.00	0
	Eurasian Watermillfoil	0.38	23
	Muskgrass	0.25	15
	Sago	0.29	18
	Slender Naiad	0.02	1
	TOTAL	**1.63**	
Cottonwood-W	Water Weed	0.00	0
	Coontail	0.08	1
	Eel Grass	1.39	17
	Flat Stem Pondweed	0.19	2
	Eurasian Watermillfoil	4.17	50
	Muskgrass	1.30	16
	Sago Pondweed	0.88	11
	Slender Naiad	0.29	3
	Water Stargrass	0.06	1
	TOTAL	**8.36**	
Eagle Point-E	Water Weed	0.00	0
	Coontail	0.35	10
	Crowsfoot	0.00	0
	Curly Leaf Pondweed	0.17	5
	Eel Grass	0.09	3
	Long Leaf Pondweed	0.01	0
	Eurasian Watermillfoil	1.70	49
	Muskgrass	0.90	26
	Sago Pondweed	0.18	5
	Slender Naiad	0.05	1
	Water Thread Pondweed	0.02	1
	TOTAL	**3.47**	
Eagle Point-W	Coon Tail	0.29	13
	Crowsfoot	0.00	0
	Curly Leaf Pondweed	0.08	4
	Eel Grass	0.01	1
	Eurasian Watermillfoil	1.58	68
	Muskgrass	0.33	14
	Sago Pondweed	0.02	1
	Slender Naiad	0.00	0
	TOTAL	**2.33**	

Appendix II Continued

Site	Species	Kg Dry Weight by Species	% by Weight
Inlet	Canadian Waterweed	0.13	0
	Coon Tail	1.37	47
	Curly Leaf Pondweed	0.20	7
	Eel Grass	0.06	2
	Flat Stem Pondweed	0.00	0
	Eurasian Watermillfoil	0.93	32
	Sago Pondweed	0.07	2
	Water Thread Pondweed	0.10	4
	Water Stargrass	0.04	1
	TOTAL	**2.90**	
Pebble Beach	Coon Tail	0.19	7
	Curly Leaf Pondweed	0.01	0
	Eel Grass	0.01	0
	Eurasian Watermillfoil	1.21	46
	Sago Pondweed	0.13	5
	Unknown	0.01	0
	Water Thread Pondweed	1.07	41
	TOTAL	**2.62**	
Sand Point-Vitale Pk	Coon Tail	0.44	25
	Curly Leaf Pondweed	0.02	1
	Eel Grass	0.02	1
	Flat Stem Pondweed	0.02	1
	Long Leaf Pondweed	0.06	3
	Eurasian Watermillfoil	0.10	6
	Muskgrass	0.12	7
	Sago Pondweed	0.00	0
	Slender Naiad	0.00	0
	Variable Pond Weed	0.11	6
	Water Thread Pondweed	0.04	2
	Water Stargrass	0.81	47
	TOTAL	**1.73**	
Wilkin's Creek	Canadian Water Weed	0.00	0
	Coon Tail	0.23	28
	Curly Leaf Pondweed	0.00	0
	Ditch Grass	0.01	2
	Eel Grass	0.05	6
	Illinois Pondweed	0.03	4
	Long Leaf Pondweed	0.02	3
	Eurasian Watermillfoil	0.16	20
	Muskgrass	0.16	19
	Sago Pondweed	0.03	4
	Slender Naiad	0.00	0
	Water thread Pondweed	0.11	13
	TOTAL	**0.82**	

Appendix III.A. Dry weight biomass in 2012 for study sites at Sand Point Gully (A), Cottonwood Gully (B), Sutton Point Gully (C) and North Gully (D). Quadrats were taken at depths of 2, 3, and 4 m ion 2012. The blotted wet weight was converted to dry weight using species-specific DW/WW data reported by Bosch *et al*. In 1999.

A. Sand Point Gully

Transect	Depth (m)	Quad	Species	Dry Wt g/quad	Dry Wt g/m^2	Total Biomass gDW*m^2	DW Average STDEV	Transect Avg+STD DW 2-3 m
Sand Pt. North	4	1	Coontail	18	73	81		
	4		Millfoil	2	8			
	4	2	Coontail	9	36	36		
	4	3	Coontail	1	4	62	60	Sant Pt
	4		Millfoil	15	59		23	252
	3	1	Coontail	0	2	133		138
	3		Millfoil	33	132			
	3	2	Coontail	6	24	299		
	3		Millfoil	69	275			
	3	3	Coontail	1	3	269	234	
	3		Millfoil	66	266		89	
	2	1	Coontail	1	2	545		
	2		Millfoil	136	543			
	2	2	Milfoil	175	699	699		
	2		Water thread	0	2		519	
	2	3	Milfoil	78	313	314	194	
Sand Pt. Central	4	1	Coontail	12	50			
	4	2	Coontail	52	207		133	
	4	3	Coontail	36	143		79	
	3	1	Coontail	8	33	244		
	3		Milfoil	53	211			
	3	2	Coontail	4	16	155		
	3		Milfoil	35	139			
	3	3	Coontail	9	37	205	201	
	3		Milfoil	42	167		45	
	2	1	Coontail	0	1	237		
	2		Milfoil	59	235			
	2		Stargrass	0	1			
	2	2	Coontail	18	71	253		
	2		Milfoil	46	183			
	2	3	Coontail	6	22	244	245	
	2		Milfoil	55	222		8	
Sand Pt. South	4	1	Coontail	23	93	93		
	4		Coontail	10	39	39		
	4	2	Milfoil	1	4		125	
	4	3	Coontail	61	242	242	105	
	3	1	Coontail	1	5			
	3		Milfoil	43	174	178		
	3	2	Milfoil	29	117			
	3		Coontail	1	4	121	159	
	3	3	Milfoil	45	179	179	34	
	2	1	Coontail	13	52			
	2		Milfoil	64	256			
	2		Flat Stem	0	1			
	2		Waterthread	0	0			
	2		Coontail	1	5	309		
	2	2	Milfoil	125	501	501	403	
	2	3	Milfoil	99	397	397	74	

Appendix III.B. Cottonwood Gully

Transect	Depth (m)	Quad	Species	Dry Wt g/quad	Dry Wt g/m^2	Total Biomass $gDW*m^2$	DW Average STDEV	Transect Avg±STD DW 2-3 m
Cotton Pt. North	4	1	Milfoil	5	19	19	7	
	4	2	Milfoil	1	4	4		
	4	3	Milfoil	0	0	0		Cotton. Pt.
	3	1	Milfoil	66	265	271	295	154
	3		Eel Grass	0	1			107
	3		Coontail	1	5			
	3	2	Milfoil	52	206	206		
	3	3	Milfoil	102	408	408		
	2	1	Milfoil	75	301	301	207	
	2	2	Milfoil	63	250	250		
	2		Sago	0	1			
	2	3	Milfoil	67	266	268		
Cotton Pt. Center	4	1	Eel grass	1	4	4		
	4	2	Eel grass	0	0	0	3	
	4	3	Milfoil	1	3	3	2	
	3	1	Eel grass	3	12			
	3		Milfoil	63	254	266	166	
	3	2	Eel grass	8	33		141	
	3		Milfoil	8	32			
	3		Sago	0	1			
	3		Slender Niad	0	0	66		
	2	1	Eel grass	0	0			
	2		Milfoil	51	206	52	198	
	2	2	Slender Niad	1	3		194	
	2		Eel grass	1	3			
	2		Milfoil	103	412	418		
	2	3	Eel grass	1	2			
	2		Milfoil	29	116			
	2		Stargrass	2	7			
	2		Slender Niad	0	1	126		
Cotton Pt. South	4	1	Eel Grass	6	25	25	8	
	4	2		0	0	0	14	
	4	3		0	0	0		
	3	1	Eel Grass	10	41	41	45	
	3	2	Eel Grass	8	32	32	16	
	3	3	Eel Grass	13	51	63		
	3		Coontail	1	2			
	3		Flat Stem	2	8			
	3		SlenderNiad	1	2			
	2	1	Eel Grass	4	17	4	12	
	2	2	Milfoil	1	4	0	17	
	2		Sago	0	0			
	2		Curly Leaf	0	0			
	2	3	Eel Grass	2	7	32		
	2		Stargrass	6	25			

Appendix III.C. Sutton Point Gully

Transect	Depth (m)	Quad	Species	Dry Wt g/quad	Dry Wt g/m^2	Total Biomass gDW*m^2	DW Average STDEV	Transect Avg+STD DW 2-3 m
Sutton Pt. North	4	1	Milfoil	12	47	47		
	4	2	Milfoil	9	36	36	37	
	4	3	Milfoil	7	28	28	10	Sutton Pt.
	3		Milfoil	64	256			250
	3	1	Eel Grass	1	3	260		63
	3		Coontail	43	172			
	3	2	Eel Grass	4	15	187		
	3		Coontail	1	5		199	
	3	3	Milfoil	37	146	151	55	
	2	1	Eel Grass	0	1			
	2		Milfoil	67	267	267		
	2	2	Eel Grass	15	59		205	
	2		Milfoil	56	224	142	89	
Sutton Pt. Central	4	1	Coontail	7	27			
	4		Milfoil	5	19	47		
	4	2	Flat Stem	0	1			
	4		Coontail	35	139	140		
	4	3	Coontail	33	131		107	
	4		Stargrass	1	4	135	52	
	3	1	Eel grass	0	2			
	3		Coontail	1	4			
	3		Milfoil	42	169			
	3	2	Flat Stem	0	0	175	268	
	3		Eel grass	5	20		81	
	3		Coontail	2	9			
	3		Milfoil	73	292			
	3	3	Stargrass	1	4	324		
	3		Flat Stem	0	1			
	3		Coontail	0	1			
	3		Milfoil	75	302	304		
	2	1	Eel grass	0	1			
	2		Coontail	18	71			
	2		Milfoil	93	372	444	346	
	2		Sago	1	5		180	
	2	2	Eel grass	0	1			
	2		Coontail	4	15			
	2		Milfoil	109	435	456		
	2	3	Coontail	4	15			
	2		Milfoil	30	121			
	2		Stargrass	4	15			
	2		Sago	1	3	138		
Sutton Pt. South	4	1	Coontail	11	43			
	4	2	Coontail	11	42			
	4	3	Coontail	10	38			
	3	1	Milfoil	26	104			
	3		Coontail	1	3	107	344	
	3	2	Milfoil	94	376		212	
	3		Coontail	8	33	409		
	3	3	Milfoil	83	332			
	3		Coontail	46	183	515		
	2	1	Milfoil	21	83	83		
	2	2	Coontail	36	145	158	197	
	2		Stargrass	3	13		77	
	2		Sago	0	0			
	2	3	Coontail	56	223	236	236	

Appendix III.D. North Gully

Transect	Depth (m)	Quad	Species	Dry Wt g/quad	Dry Wt g/m^2	Total Biomass $gDW*m^2$	DW Average STDEV	Transect Avg±STD DW 2-3 m
No. Gully North	4	1	Milfoil	3	13	13	4	
	4	2	-	0	0	0	7	
	4	3	-	0	0	0		No. Gully
	3	1	Milfoil	98	391	393	322	272
	3		Stargrass	0	2		65	153
	3	2	Milfoil	77	308	308		
	3	3	Milfoil	66	264	264		
	2	1	Milfoil	59	235	235	301	
	2	2	Water Thread	1	5	413	98	
	2		Milfoil	102	408			
	2	3	Stargrass	0	1	255		
	2		Water Thread	3	13			
	2		Eel Grass	13	53			
	2		Milfoil	47	189			
No. Gully Central	4	1	Milfoil	3	12	12	10	
	4	2	Milfoil	5	19	19	9	
	4	3	Milfoil	0	0	0		
	3	1	Milfoil	70	278	278	315	
	3	2	Milfoil	53	214	226	112	
	3		Coontail	3	13			
	3	3	Milfoil	110	442	442		
	2	1	Milfoil	110	439	439	488	
	2	2	Milfoil	108	432	452	73	
	2		Water Thread	5	21			
	2	3	Milfoil	143	571	571		
	2		Stargrass	0	0			
	2		Algal Pond	0	0			
No. Gully South	4	1	Milfoil	12	48	48	18	
	4	2	Milfoil	1	5	5	26	
	4	3	Milfoil	0	0	0		
	3	1	Milfoil	31	126	126	161	
	3	2	Milfoil	60	240	240	68	
	3		Stargrass	0	1	118		
	3		Flat Stem	0	0			
	3		Eel Grass	0	0			
	3	3	Milfoil	29	117			
	2		Milfoil	86	342	342	316	
	2		Eel Grass	0	1		33	
	2		Milfoil	70	278	279		
	2		Stargrass	0	0			
	2		Milfoil	82	326	327		