Distribution and Biomass of Macrophytes In Six Large Beds Adjacent to Streams with High Nutrient Loading (Conesus Lake, Summer 2001)

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by
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EXECUTIVE SUMMARY

1. The distribution and abundance of macrophytes were determined for six large beds located near streams draining sub-watersheds known to deliver high amounts of nutrients into Conesus Lake. The comprehensive goals of the study were to better understand the pattern of rooted macrophyte growth near streams and to gather baseline data in preparation for a proposed long-term monitoring program of areas associated with streams targeted for best management practices.

2. Five of the six beds were dominated by Eurasian watermilfoil (*Myriophyllum spicatum*) particularly at depths of two and three meters. The one exception was a long, narrow bed along the Graywood region that was dominated by coontail (*Ceratophyllum demersum*).

3. There were statistically significant differences in macrophyte biomass at different depths, with the highest biomass occurring at two or three meters. In all six beds, Eurasian milfoil was present at depths near 1 m yet other species were well represented. At a depth of four meters, macrophyte populations were patchy and sparse and coontail was often the dominant species.

4. Statistically significant differences in macrophyte biomass relative to transect distance from stream were found in four of the six beds. Transects nearest the stream typically had the lowest biomass. The lack of a statistical pattern at the Graywood and Long Point sites may be due to the influence of more than one stream in these areas.

5. The highest biomass of Eurasian watermilfoil was observed in the beds near Sand Point Gully, McPhersons Point (North Gully) and Sutton Point, and the lowest were in the Long Point Cove and Cottonwood Gully. This pattern was consistent with total phosphorus loading data collected by SUNY Brockport in 2001 (regression R^2= 0.56) but the relationship was not statistically significant at the $p= 0.05$ level ($p=0.14$).

6. The Graywood Gully bed was the largest in total surface area (36,147 m^2 or 8.93 acres) and estimated dry weight biomass (14, 603 kg). The smallest beds were North Sutton Point (8593 m^2, 4017 kg) and Cottonwood Gully (9387 m^2, 3504 kg). Annual loading of total phosphorus was significantly related to standing crops for the six beds (regression $R^2 = 0.65$, $p = 0.046$).

6. Direct comparisons with summer 2000 estimates for the McPhersons Point and the Sand Point beds showed that surface area had increased by 3 and 10% and total biomass by 54 and 46% respectively. This trend is consistent with our observation that macrophyte biomass was generally higher during the 2001 summer season than in 2000 and similar with values recorded for 1999.

8. Compared to nine previous years going back to 1967, the maximum average macrophyte biomass in 2001 was moderate.

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Figure Legends

Figure 1. Locations of macrophyte beds surveyed during this study.

Figure 2. Relationship of macrophyte dry weight calculated from wet weight by two different procedures. One procedure uses a standard conversion factor of 0.10, which represents an average wet to dry weight ratio for all species (Forest 1978, personal communication). The second procedure uses species-specific conversion factors determined by Bosch *et al.* (2000) and in this study from bulk samples. Each point is an individual quadrat sample. The dashed line represents a one to one correspondence between the two methods. Points above the dashed line indicate an underestimate of the standard method relative to the species-specific method.

Figure 3. Macrophyte dry weight for transects in each of the six macrophyte beds studied. The corresponding numerical data are presented in Table 3. The location of each transect relative to the nearby stream is presented in Table 1 and Table 3. The dry weights were determined directly or by using species-specific wet weight to dry weight conversion factors. ND: no data.

Figure 4. The average percent of the total weight of each quadrat comprised by Eurasian watermilfoil. Locations where plants were absent or that were dominated by coontail (*Ceratophyllum demersum*) are identified. ND : no data.

INTRODUCTION

Conesus Lake, the westernmost of the Finger Lakes of New York, has a rich and diverse macrophyte flora that was first characterized by W.C. Muench in 1927. Quantitative studies of macrophytes in the lake were first undertaken by SUNY Geneseo Professor Herman Forest and his co-workers beginning in 1967-1970 and continued sporadically until 1991. Forest (1971, 1978, unpublished data) described a diverse, lake-wide assemblage dominated by a variety of species which included eelgrass (*Vallisneria americana*), coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*) water stargrass (*Zosterella dubia*), slender naiad (*Najas flexilis*) and several pond weeds (*Potomogetum* spp.) Two forms of the genus *Myriophyllum* were also found but Forest did not distinguish between the two forms in his collections since at the time the taxonomy of *Myriophyllum* was a matter of great controversy among experts. In time Aiken and his colleagues (1979, 1980) and others were able to distinguish the two forms as species. Relying on these studies, Bosch and his colleagues (2000, 2001) identified *M. spicatum* as the overwhelmingly dominant macrophyte in Conesus Lake and quantified standing crops in twelve large beds distributed throughout the lake. These beds were invariably located in the proximity of streams and drainage pipes, including several which deliver high loads of nutrients from the watershed into the lake (Makarewicz *et al.*, 1986, 1991, 2001, 2002).

Conclusive evidence that nutrient loading by streams is directly responsible for the local enrichment of macrophyte growth in Conesus Lake is still lacking. Bosch and his students (Johnson *et al.*, 2001) compared event phosphorus loading determined by Makarewicz and colleagues (2000) to macrophyte biomass for six beds studied during the summer 2000 and found a significant loading effect ($R^2 = 0.95$; $p < 0.01$). Unfortunately, their analysis was based on a limited number of quadrat samples and nutrient measurements and therefore was susceptible to random error. More extensive measurements are needed before a better understanding of the relationship between stream loading and macrophyte growth in Conesus Lake is obtained.

In this study we increased the number of quadrats sampled and conducted transect surveys to specifically explore the ecological relationship between Eurasian watermilfoil growth and nutrient loading by streams. Our results improve the understanding of macrophyte growth patterns in Conesus Lake and provide a baseline for future monitoring of several areas in the lake that in recent years have experienced excessive plant growth.

PROCEDURES AND MATERIALS

Our study of macrophyte biomass and distribution was carried out from June to September, 2001 in Conesus Lake (Lat 42° 47' N; Long 77° 43' W). Detailed accounts of our methods are provided in earlier reports (Bosch *et al.* 2000, Bosch *et al.* 2001). Here we provide a general description of the procedures used for this project.

The six macrophyte beds selected (**Figure 1**) are associated with streams that drain sub-watersheds known to deliver high amounts of nutrients into the lake (Makarewicz *et al.* 2001, 2002) These sites have been identified for long-term monitoring as part of a proposed manipulation study that will test the efficacy of agricultural best management practices in reducing soil and nutrient loss from watersheds and in alleviating nuisance plant growth in downstream habitats.

To determine the pattern of marcrophyte growth relative to distance from each stream, three or four transects were established at each site, approximately perpendicular to the shoreline (**Table 1**). One transect was positioned at the edge of the bed closest to the stream. The other transects were positioned incrementally about 50 m along the length of the bed. With the exception of McPhersons Point all of the beds surveyed were located north of the stream (i.e. windward).

Along each transect line, 2-4 (usually three) replicate quadrat samples were collected at depths of one, two, three and four meters by S.C.U.B.A. or by snorkeling in the shallower depths. Approximately 210 quadrat samples were collected for this study. The quadrat was a PVC (0.5 inch outer diameter) square with sides of 0.5 m which were held together by PVC elbows. Plants rooted or attached within the quadrat were pulled, placed inside a collection bag, and brought back to the laboratory for analysis. In the laboratory, samples were drained of water, vigorously blotted dry with paper towels and allowed to dry for about 5 minutes on a bed of absorbent paper towels. The wet weight of samples sorted by individual species was determined to the nearest 0.1 g with an electronic scale.

Our results are reported as dry weight biomass. To convert samples from wet weight to dry weight we used factors determined in an earlier study for individual species

(See **Table 2**; Bosch *et al.* 2000). The conversion factor for Eurasian milfoil was determined in this study by drying pre-weighed samples (n=18) for at least 48 hours then weighing them a second time. The resulting average factor of 0.179 (dry wt./wet wt.) was used to calculate milfoil dry weight in other bulk samples. This number differs significantly from the standard 0.10 factor used by Forest and his colleagues (personal communication) and by our group for the purpose of comparison in earlier reports (Bosch *et al.* 2000, 2001). The standard factor underestimates biomass considerably (See **Figure 2**) primarily because the wet to dry conversion used for the dominant Eurasian watermilfoil is 0.10 compared to the 0.18 used in this study. Here we report the dry weights determined by species-specific factors, except when comparing our results to biomass trends in earlier studies.

In addition to the transect studies, we mapped the distribution and calculated the surface area of each bed using global positioning systems. The margin of each bed was tracked visually by a swimmer. Corresponding GPS coordinates were recorded from a closely trailing boat every few seconds using a Trimble Model TSC1 global positioning unit (Trimble Navigation Ltd.). This system uses multiple satellites in combination with ground-based U.S. Coastguard transmitters to obtain global positions that are accurate to less than a meter. ArcView software (Esri Inc.) was used to superimpose the graphical data on a high-resolution topographic map of Conesus Lake and the surrounding watershed.

Statistical analyses of the biomass distribution patterns were carried out using the statistical software package SPSS (SPSS Inc. 1996). To test for the relationship between biomass and distance from stream, for differences in biomass among the different beds, and for the relationship between stream loading and biomass, we used only data from the 2 and 3 m collections. This approach allowed us to focus the analysis on the zones dominated by Eurasian watermilfoil and to avoid the confounding effect of high variability in the transitional zones at the 1 and 4 m depths.

RESULTS AND DISCUSSION

The average and standard deviation of the dry weight at four depths, along 3-4 transects, for each of six beds is shown in **Table 3** and a graphical representation of the

Our analysis revealed statistically significant differences in macrophyte biomass between transects at four of the six beds (Single Factor ANOVA for each bed $p < 0.036$). The two beds for which no significant changes with distance were observed were Long Point Cove ($p = 0.19$) and Graywood ($p=0.55$). These are the only two beds that are subject to runoff from more than one major stream or rivulet. The Long Point Cove bed is bounded in its northern margin by Long Point Gully and in its southern margin by an unnamed stream. The Graywood bed lies to the north of Graywood Gully, and is subject to inputs from another stream and a large drainage pipe along its northern expanse. Multiple points of nutrient loading probably account for the lack of a significant pattern of biomass change with distance from the main streams in Long Point Cove and Graywood.

Areas nearest to streams typically had the lowest macrophyte biomass. This was true for all four sites in which significant distance effects on biomass were found (Sand Pt., McPhersons Pt., Cottonwood Gully, and Sutton Pt.). The highest biomass was found in transects taken near the middle of each bed, often more than 100 m away from the stream source. One possible explanation for this pattern is that despite the high nutrients available to plants, areas immediately adjacent to streams are not ideal for plant growth due to some combination of increased sedimentation, turbidity and water movement.

Differences Between Beds

The dry weight biomass of macrophytes in the 2-3 m zone of the six beds studied is shown in **Table 3**. The mean biomass of pooled samples from 2 and 3 m are shown in **Table 4** along with GPS estimates of surface area, perimeter and estimates of total macrophyte dry weight in each of the beds. Overall there were statistically significant differences in average biomass between the beds (Single factor ANOVA $p = 0.04$ for pooled 2 and 3 m samples). The highest average biomass was found off Sand Point Gully and the lowest in Long Point Cove. Further analyses revealed that the six beds fell into three statistical groupings, with the Sand Point Gully, Sutton Point and McPhersons Point beds having a significantly higher biomass than Cottonwood Gully and Long Point Gully (Least Significant Difference post-hoc test). The biomass of the Graywood bed was not statistically different from that of the other groups.

Although the Sand Point and Sutton Point beds had the highest biomass per unit area, their total surface area was relatively small (**Table 4**). Consequently the calculated values of standing crop (i.e. total biomass) for these two beds were the second and third lowest among the six. In contrast, the Graywood Gully, McPhersons Point and Long Point beds had large surface areas, and their standing crops were 2 - 3.5 times greater despite their more moderate biomass per unit area. Overall the two largest bed in terms of standing crop were Graywood and McPhersons Point, which have a large area and sustain biomass values that are moderately high.

To examine the relationship between Eurasian watermilfoil biomass and stream nutrient loading, we compared the data collected in this study to the estimates of annual loading of total phosphorus reported by Makarewicz and his colleagues (Makarewicz *et al.* 2002). The Graywood bed, which is dominated by coontail, was excluded from this analysis. The relative magnitude of the watermilfoil biomass corresponded consistently to the magnitude of the loading values. The strength of the regression was moderate ($R^2 = 0.56$) and significant at the $p= 0.14$ level but not at the $p= 0.05$ level, possibly due to the relatively small number of beds used in the analysis.

The relationship between annual loading of total phosphorus and standing crops in all six beds was also examined. The linear regression was significant ($p = 0.046$), with a high R^2 of 0.67.

Inter-Annual Trends

Direct comparisons between measurements taken in August 2001 and August 2000 at the McPhersons Point and Sand Point Gully beds revealed that bed surface area had increased by 3 and 10% and standing crops by 54 and 46% respectively. The large increases in standing crop are due to significant increases in average quadrat biomass in 2001 compared to 2000.

A long-term record is not available for any of the six beds studied. Therefore we examined trends in macrophyte biomass by comparing the two highest biomass averages (based on 3 replicate quadrats) recorded in 2001 to maximum values reported for other parts of the lake in nine previous years, dating back to 1967 (**Table 5**). The numbers indicate that the maximum averages for 2001 were comparable to those of 1999 but apparently higher than summer 2000 maxima. The last three years, including 2001, can still be considered moderate compared to the maximum macrophyte biomass reported for 1967 through 1970 (Forest and colleagues 1971, 1978). This observation does not contradict the general public perception that the current "weed" problems in Conesus Lake are unprecedented. It appears that since the early 1970's Eurasian watermilfoil has become the dominant macrophyte species in Conesus Lake. The exceptionally dense growth of this species and the thick tangles it forms near the surface are readily visible to the casual observer and severely impair recreational use of the lake.

SUMMARY AND CONCLUSIONS

In addition to providing a baseline for future monitoring of the six beds studied, this work improves our understanding of macrophyte growth patterns within beds and in different areas of the lake. The results reveal that differences in macrophyte biomass exist relative to depth, distance along shore from stream sources, and between different beds. Along the Graywood Gully area and in Long Point Cove, the growth of macrophytes may be influenced by more than one stream and there were no statistically significant patterns of macrophyte distribution with distance from stream.

There was no direct relationship between the surface area of a bed and its biomass per unit area. The highest biomass per unit area occurred in some of the smaller beds. The Graywood and McPhersons Point beds, with large surface area and moderate to high biomass per unit area, had the largest standing crops of macrophytes.

There was a moderately consistent relationship between the biomass per unit area in each bed and the annual loading of total phosphorus by its associated stream. A sample size of more than six beds should likely yield a more robust correspondence in future studies. Annual loading of total phosphorus strongly and significantly influenced standing crop in this sample of six beds.

The maximum average macrophyte biomass recorded in the summer 2001 was higher than that reported for the summer 2000, but comparable to 1999 values. Overall the last three years were moderate compared to the records from 1967 to 1970. This observation does not contradict public perception that current "weed" problems in Conesus Lake are unprecedented. It is the combination of moderate biomass and dominance by Eurasian watermilfoil that is responsible for the deterioration of water quality in the lake.

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Table 1. Locations and dates of transect surveys of macrophyte beds carried out in 2001.

Location	Transect #	Dates of Survey	Coordinates in Minutes (42° N, 77° W)	Meters From Stream (m)
North Sutton Point	1	7/25, 7/30	44.537, 43.525	0
	2	7/25, 7/30	44.555, 43.524	100 N
	3	7/25, 7/30	44.573, 43.529	200 N
Cottonwood Gully	1	7/25, 8/8	45.441, 43.550	0
	2	8/6, 8/8	45.496, 43.551	102 N
	3	7/25, 8/8	45.544, 43.526	190 N
McPhersons Point	1	7/26, 7/30	46.692, 42.867	10 S
	2	7/26, 7/30	46.654, 42.865	78 S
	3	7/26, 7/30	46.611, 42.849	156 S
Long Point Cove	1	7/30, 8/2	46.496, 43.398	0
	2	7/30, 8/2	46.550, 43.356	100 N
	3	7/30, 8/2	46.581, 43.350	157 N
Sand Point Gully	1	7/30, 8/2	47.173, 43.226	5 N
	2	7/30, 8/2	47.242, 43.196	73 N
	3	8/1	47.210, 43.196	137 N
	4	7/30, 8/1	47.298, 43.215	242 N
Graywood Gully	1	8/3, 8/7	48.619, N.A.	0
	2	8/3, 8/7	48.619, N.A.	100 N
	3	8/3, 8/7	48.619, N.A.	157 N

Table 2. Factors used to convert individual species wet weights to dry weights. The conversion factor used for the dominant Eurasian watermilfoil was 0.18 (Dry wt/Wet wt.). The 0.10 conversion factor utilized in previous studies would underestimate total biomass (See Figure 2).

Species	Common Name	Sample Size	Dry /Wet Weight Ratio	Standard Deviation
Myriophyllum spicatum (stem)	Eurasian milfoil	8	0.1062	0.0315
Myriophyllum spicatum (leaf)	Eurasian milfoil	8	0.2079	0.0333
Myriophyllum spicatum (bulk)	Eurasian milfoil	18	0.1795	0.0321
Vallisneria americana	Eel-grass	8	0.0366	0.0029
Ceratophyllum demersum	Coontail	7	0.1048	0.0181
Zosterella dubia	Water stargrass	8	0.1060	0.0312
Potomogeton crispatus	Curly-leaf pondweed	8	0.0773	0.0021
Elodea canadiensis	Common waterweed	8	0.0663	0.0117

Table 3. Macrophyte biomass (dry weight mean + standard deviation) in multiple transects taken from the six macrophyte beds. Each biomass value is the average of three replicate quadrats. The distance of each transect along shore north (N) or south (S) of each stream was determined from GPS coordinates.

Location		Meters from stream	Depth 1 m	2 m	3 m	4 m
No. Sutton Point	#1	0	310 ± 122	370 ± 164	473 ± 145	5 ± 9
	#2	100 N	162 ±165	688 ± 156	339 ± 18.2	0
	#3	200 N	103 ± 7.2	---	---	---
Cottonwood Gully	#1	0	305 ± 64	337 ± 160	254 ± 69	0
	#2	102 N	263 ± 119	254 ± 33	264 ± 81	1 ± 2
	#3	190 N	169 ± 101	621 ± 73	510 ± 131	0
McPhersons Point	#1	10 S	59 ± 5	219 ± 67	381 ± 133	124 ± 160
	#2	78 S	232 ± 127	618 ± 61	383 ± 86	23 ± 39
	#3	156 S	303 ± 174	749 ± 109	403 ± 175	2 ± 3
Long Point Cove	#1	0	330 ± 19	261 ± 125	201 ± 125	40.3 ± 46
	#2	100 N	450± 95	453 ± 216	347 ± 183	34 ± 7
	#3	157 N	644 ± 162	342 ± 280	214 ± 66	15 ± 8
Sand Point Gully	#1	5 N	216 ± 26	160 ± 68	242 ± 77	304 ± 263
	#2	73 N	298 ± 18	1159 ± 489	787 ± 150	3 ± 5
	#3	137 N	283 ± 66	402 ± 40	315 ± 236	57 ± 15
	#4	242 N	122 ± 35	---	206 ± 43	53 ± 41
Graywood Gully	#1	0	497 ± 205	453 ± 57	433 ± 178	124 ± 142
	#2	100 N	271 ± 48	559 ± 326	302 ± 146	---
	#3	157 N	381 ± 150	406 ± 81	271 ± 18	253 ± 77

Table 4. Perimeter, surface area and total dry weight in each of the six macrophyte beds surveyed. The total dry weight was calculated by multiplying the surface area of each bed times the average quadrat biomass for 2 and 3 m samples combined.

Macrophyte Bed	Perimeter (m)	Calculated Area (m^2)	Mean Dry Wt. (g/m^2)	Total Dry Wt. (kg)
North Sutton Point	---	8592.84	467	4016.6
Cottonwood Gully	865	9387.34	373	3501.5
McPhersons Point	830	25783.24	459	11834.3
Long Point Cove	1340	26498.19	303	8026.5
Sand Point Gully	659	9781.71	484	4730.7
Graywood Gully	1897	36147.73	412	14897

Table 5. Comparison of highest average macrophyte biomass values reported for Conesus Lake in ten different years. The 2001 values were high compared to maximum values from 2000, but comparable to those of 1999, and moderate overall. A conversion factor of 0.10 was used to change wet weight values to dry weight in this comparison.

Date	Location	Depth	Maximum Average Dry Weight (g/m^2)
July, 1967	Unknown	1 m	1060
Sept. 1968	North End	4 m	1470
Sept. 1969	Wilkins Creek	3 m	1860
Aug. 1970	Wilkins Creek	3 m	1407
Aug. 1978	North End	3 m	260
Aug. 1984	Wilkins Creek	4 m	601
Aug. 1985	South End	4 m	1400
Aug. 1999	Wilkins Creek	2 m	687 ± 267
Aug. 1999	North End	3 m	827 ± 296
Aug. 2000	Wilkins Creek	1.5 m	419 ± 133
Aug. 2000	North End	3.5 m	513 ± 11.9
Aug. 2001	Sutton Point	2 m	688 + 156
Aug. 2001	Sand Point Gully	2 m	644 + 271

Figure 1. Locations of macrophyte beds surveyed during this study.

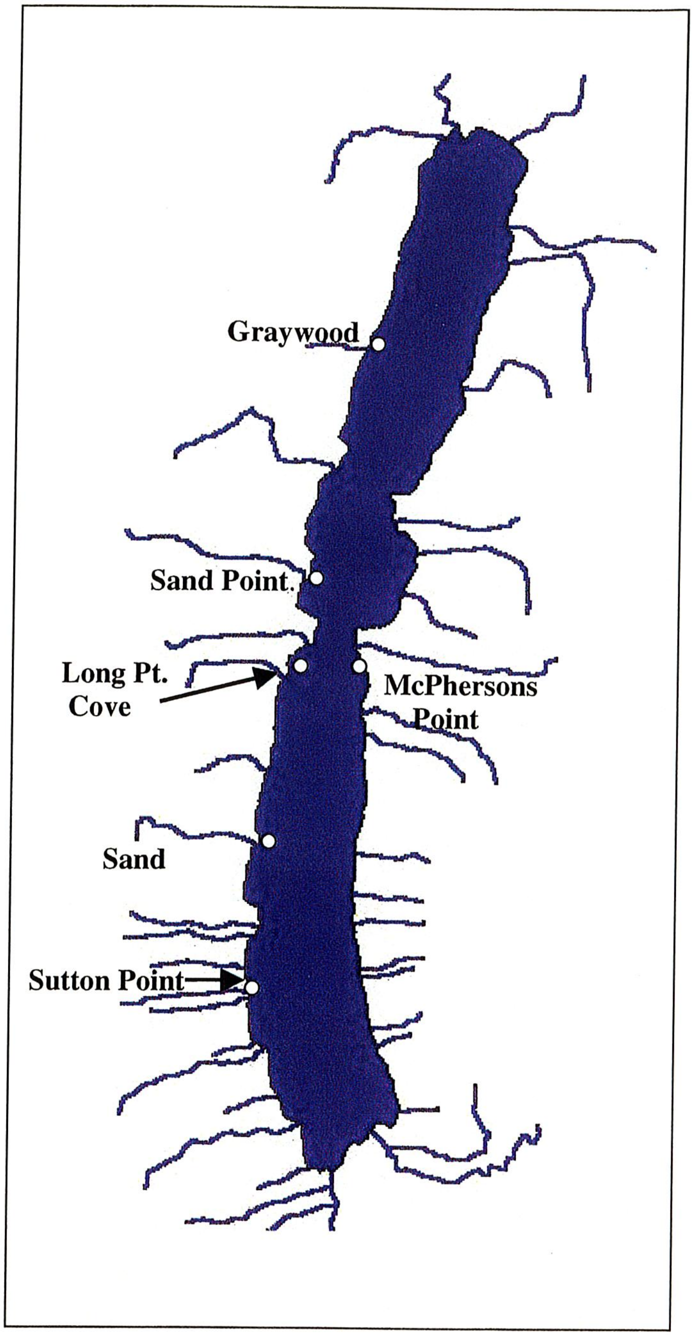

Figure 2. Relationship of macrophyte dry weight calculated from wet weight by two different procedures. One procedure uses a standard conversion factor of 0.10, which represents an average wet to dry weight ratio for all species (Forest 1978, personal communication). The second procedure uses species-specific conversion factors determined by Bosch et al (1999) and in this study from bulk samples. Each point is an individual quadrat sample. The dashed line represents a one to one correspondence between the two methods. Points above the dashed line indicate an underestimate of the standard method relative to the species-specific method.

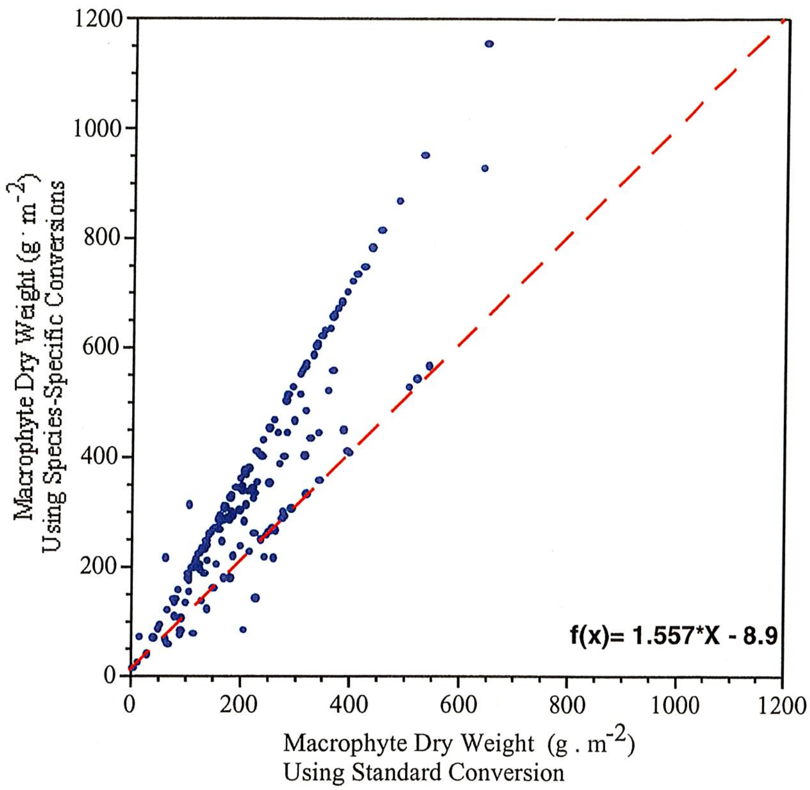

Figure 3. Macrophyte dry weight for three transects in each of the six macrophyte beds studied. The corresponding numerical data are presented in Table 3. The location of each transect relative to the nearby stream is presented in Table 1 and Table 3. The dry weights were determined directly or by using species-specific wet weight to dry weight conversion factors. ND: no data.

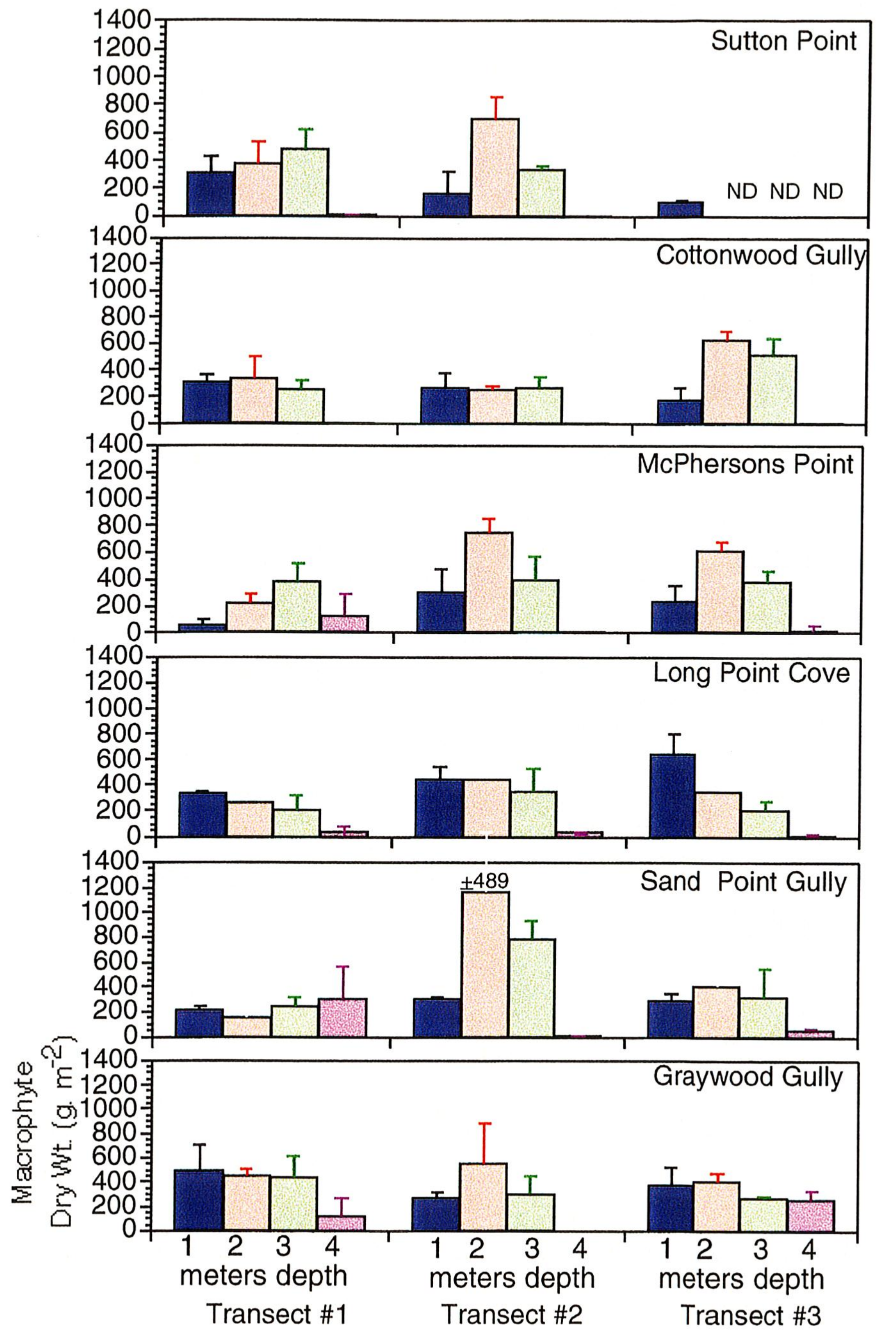

Figure 4. The average percent of the total weight of each quadrat comprised by Eurasian watermilfoil. Locations where plants were absent or that were dominated by coontail (*Ceratophyllum demersum*) are identified. A: Sutton Point, B: Cottonwood Gully, C: McPhersons Point, D: Long Point Cove, E: Sand Point, F: Graywood Gully; ND : no data.