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Hydroacoustic Survey and Point Sampling of Macrophytes In Diamond Lake 2009

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A Report to the
Partners for Umpqua Rivers
Roseburg, OR

And the
Umpqua National Forest
Roseburg, OR

By

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ABSTRACT

MaxDepth Aquatics, Inc. was contracted to conduct a hydroacoustic survey of macrophyte distribution in Diamond Lake in 2009. The survey essentially repeated surveys conducted in 2002 and 2007, allowing for a detailed assessment of conditions in 2009 and comparisons among previous years. In addition, Portland State University was contracted to conduct a depth stratified random point sample survey of macrophyte species presence and absence. The point sample survey was similar to surveys conducted in 2005 and 2007. The results of the 2009 hydroacoustic survey showed that macrophytes were widely distributed throughout the lake at depths less than 8 meters, although some shorter aggregations of macrophytes were found at depths down to 14 meters. Average canopy height corresponded closely to macrophyte density in 2009. The recent survey showed that macrophytes had extended deeper throughout the lake compared to 2002 and 2007 and that canopy height had increased substantially in some locations. The 2009 distribution showed that recolonization of the near shore areas was proceeding, albeit at a relatively slow pace since the lake drawdown completed in 2006. The maximum density of macrophytes in 2009 was found between 4 to 6 meters. Five macrophyte species, one macroalgal species, and filamentous algae were present in the 2009 random point survey. The occurrence rates of the macrophytes *Elodea canadensis*, *Ceratophyllum demersum*, and *Potamogeton praelongus* in 2009 were similar to 2005 and 2007 while *Potamogeton pusillus* occurrence increased and *Myriophyllum verticillatum* decreased. Macrophytes were present in a few samples greater than 9 meters; however, biomass, as measured by the fullness of a sampling rake, was highest between 2 and 6 meters. The comparison of the grab sampling conducted in August with the hydroacoustic survey in early September showed poor correspondence in macrophyte density obtained by the two methods. This is likely due to differences in spatial scales of collected samples (10 m^2 grid for hydroacoustics compared to < 1 m^2 grab samples), comparison of a continuous analytic tool (hydroacoustic) versus an ordinal ranking of density (rake), and possibly some changes in the macrophytes community between the two sampling dates.

INTRODUCTION

The distribution and composition of macrophyte species within a lake are determined by a number of factors including depth and water clarity. Diamond Lake is a relatively shallow (maximum depth 14.8 m; mean depth 6.9 m) productive lake in the south central Oregon Cascade Range. The lake has experienced several significant shifts in water clarity and water levels due to the invasion and eradication of a non native fish species (Eilers et al. 2007). The first reported investigation of the macrophytes in the lake was conducted during a relatively clear water era by Lauer et al. (1979) in which they reported depth of macrophyte distribution and general species composition. They reported a well defined macrophyte community from about 2 to 8 meters with three distinct bands: (1) *Elodea canadensis* from 2 to 4 meters; (2) *Potamogeton praelongus* and *E. canadensis* co-dominated from 4 to 6 meters; and (3) *Nitella* dominated from 6 to 8 meters. A survey conducted during an era with low water clarity in 2005 indicated that coontail (*Ceratophyllum demersum*) dominated the biomass from 3 to 7 meters while *E. canadensis* and whorled milfoil (*Myriophyllum verticillatum*) dominated the biomass in shallower water (Sytsma and Pfauth 2006). *E. canadensis*, *C. demersum*, and *P. prealongus* were the most commonly encountered species. A survey conducted in 2007 under vastly improved water clarity conditions and a year after a 2.4 meter lake drawdown indicated that the same three species were most commonly encountered; however, *E. canadensis* replaced much of the *C. demersum* biomass in deeper water (Sytsma and Miller, unpublished data). The first quantitative measurement of the distribution of macrophytes in Diamond Lake was conducted in 2002 (Eilers and Gubala 2003), which was repeated in 2007 (Eilers 2007).

The summer 2009 survey work which was conducted after several years of improved water clarity that is reported here consists of two complimentary efforts: grab samples collected by Portland State University to describe macrophyte species occurrence and depth distributions, and hydroacoustic analysis by MaxDepth Aquatics, Inc. to describe the spatial extent of the macrophytes and the relative density.

METHODS

GRAB SAMPLE SURVEYS

Macrophyte samples were collected at 107 sites on August 17-19, 2009 (Figure 1). Sites were randomly selected with GIS prior to sampling within five, 3-meter depth strata derived from a bathymetric map provided by Eilers and Gubala (2003). A differentially corrected Trimble Pro-XRT GPS receiver was used to navigate to sample sites. Thirty-two samples were collected from each of the three shallowest strata (0-3, 3-6, and 6-9 meters). These 96 samples were collected by lowering a double-sided thatch rake attached to a rigid pole to the sediment surface, twisting the rake, and retrieving macrophytes attached to the rake to the boat. Sample depth measured with the rigid pole was recorded at each site. An additional 11 samples were collected from water deeper than 9 meters by dragging a thatch rake along the bottom with a rope for approximately 5 meters. Depth was not measured at these sites. Measured depths of the 2009 samples ranged from 0.5-9 meters and consisted of 96 samples distributed evenly across the range (Figure 2). Samples collected during 2005 and 2007 surveys were shallower (0-7.5 meters) and the 2007 samples were slightly biased towards deeper water. Presence of macrophytes, macroalgae, or filamentous algae on each rake sample was recorded at each site during each survey. The dominant species in a sample was noted if present. Total sample biomass was estimated semi-quantitatively from the coverage of rake tines with macrophytes. Rake tines fully covered with macrophytes was defined as rake-fullness of one. The probability of macrophyte species occurrence, or coverage, within the random sample frame was estimated as the number of sites a species was found divided by the number of locations sampled. Errors associated with the coverage estimates were calculated according to Zar (1999) and are based on 95% certainty that the true coverage is with the error estimate.

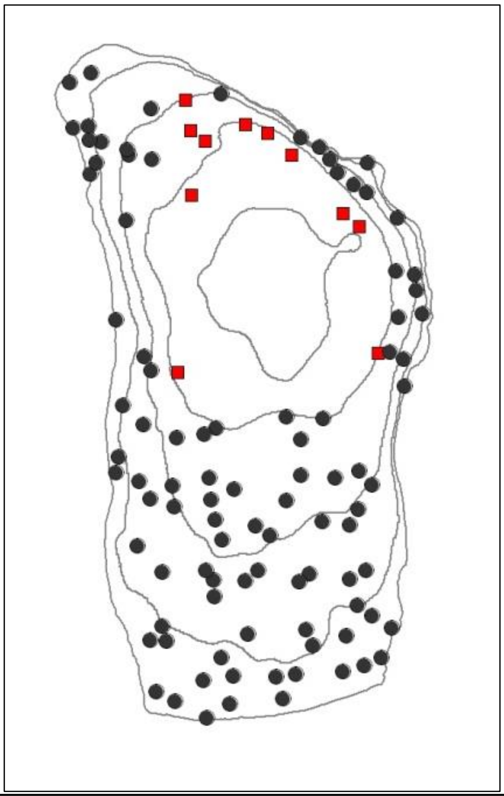


Figure 1. Diamond Lake macrophyte sample sites visited during the 2009 survey. Black circles were sampled with a thatch rake attached to a pole, red squares were sampled with a thatch rake attached to a rope.

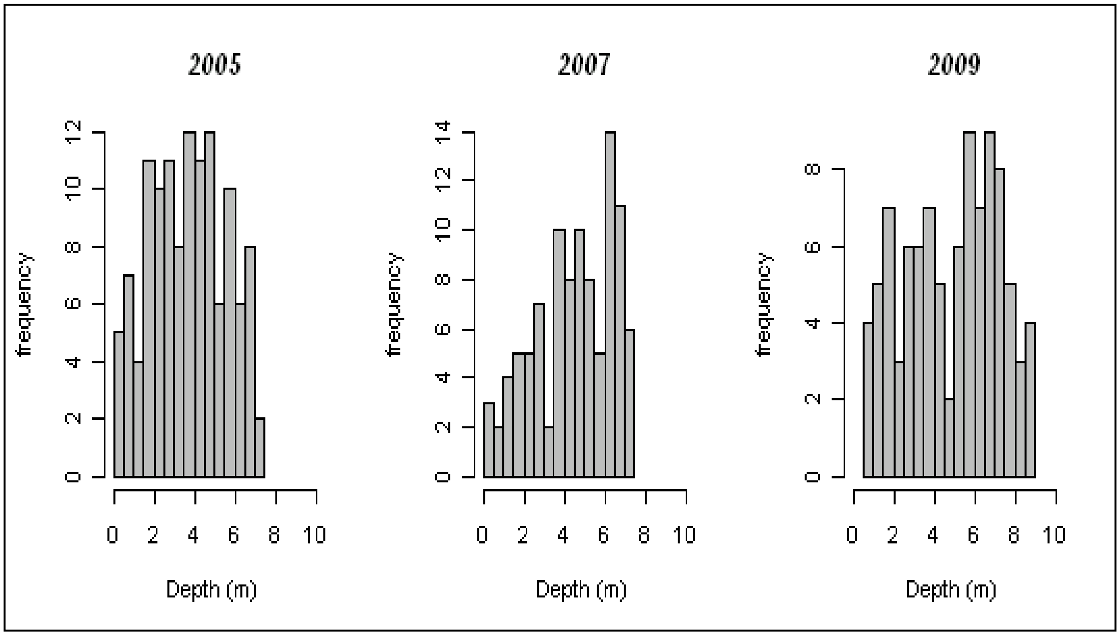


Figure 2. Histograms of macrophyte sample depths during 2005, 2007, and 2009 surveys.

HYDROACOUSTIC SURVEYS

The hydroacoustic survey was conducted from September 4-6, 2009. The survey was conducted using a BioSonics digital echosounder equipped with a 200 KHz split-beam transducer. Positioning was determined with a Trimble AG132 DGPS receiver. The boat speed was maintained at a nominal 9 kph and was routed along transects with 75-m spacing for areas with a depth less than about 9 m. Spacing between transects was expanded in the deeper waters as macrophytes became sparse (Figure 3). The data were processed using BioSonics Visual Analyzer 4.1 software. The data were processed in 10-m grid cells and maps were generated using Surfer software (Golden Software, Golden, CO). Survey points were provided to MaxDepth Aquatics by Portland State University staff containing the results of the community composition survey. In addition to location information, the data included depth at the site, fullness of the rake sample, relative abundance of seven macrophyte taxa. These points were overlaid and compared to macrophyte height and density values from the 10-m grids generated from the hydroacoustic data.

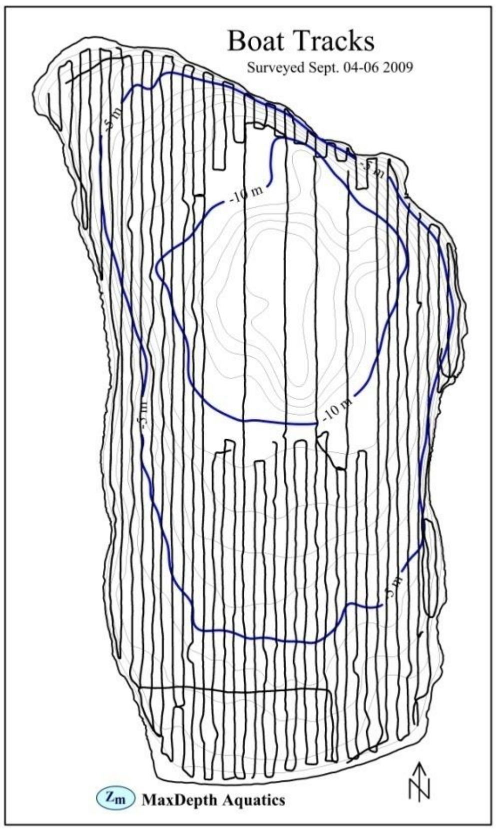


Figure 3. Boat tracks documenting hydroacoustic sampling coverage in Diamond Lake in 2009.

RESULTS

GRAB SAMPLE SURVEYS

Macrophytes, the macroalgal species *Nitella*, or an unidentified filamentous algal species were present in 86% of the samples collected in the 0-9 meter sampling area (Figure 4). Since the samples were randomly selected, the proportion of sites with a species present approximates the spatial coverage of the species. *Elodea canadensis* (Canadian waterweed) was present at the greatest proportion of sites, followed by *Ceratophyllum demersum* (coontail), *Potamogeton praelongus* (whitestem pondweed), and *Potamogeton pusillus* (small pondweed). *Myriophyllum verticillatum* (whorl-leaf watermilfoil) was present at too few sites (n=4) to estimate of coverage. At least one of the five macrophyte species was present at 73% of the sample sites. Coverage of each macrophyte species in 2009 was similar to coverage in 2005 and 2007 with the exception of small pondweed which increased to 30% coverage during the 2009 survey from 8% in 2007 and 7% in 2005.

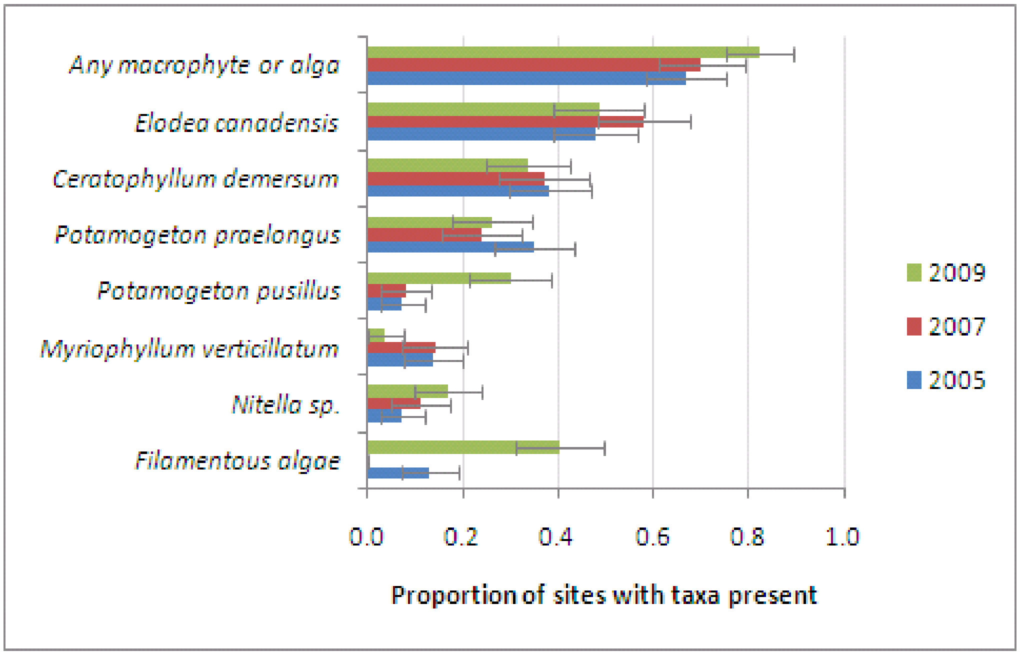


Figure 4. Proportion of sampling sites with taxa by survey year. Error bars represent the 95% confidence intervals of estimates.

None of the macrophyte species collected were known non-native species; however, the non-native species *Potamogenton crispus* (curly leaf pondweed) was observed during the 2007 survey (Sytsma and Miller, unpublished data) and has been noted as present in the lake by the US Forest Service prior to 2005 (Sytsma and Pfauth 2006).

Macrophytes were present in samples with depths ranging from 0.8 meters to greater than 9 meters (Table 1). *E. canadensis*, the non-vascular *Nitella sp.* and filamentous algae were the only species present at sites deeper than 8 meters. The depth distribution of species presence skewed slightly deeper after the increase in water clarity during the 2009 and 2007 surveys than in 2005 prior to the clarity increase (Figure 5).

Table 1. Macrophyte, macroalgae and filamentous algae presence, dominance, and depth ranges in Diamond Lake during 2009 based on 107 random samples.

Taxon	Sites Present	Sites Dominant	Min Depth	Max Depth
Elodea canadensis	52	13	1.2	> 9.0
Ceratophyllum demersum	36	18	0.8	7.5
Potamogeton pusillus	32	3	1.7	7.7
Potamogeton praelongus	28	6	2.2	6.7
Myriophyllum sp.	4	1	1.7	3.4
Nitella sp.	18	4	1.2	> 9.0
Filamentous Algae	43	11	0.8	> 9.0

Rake fullness, a surrogate for total sample biomass, was highest from 2 to 7 m and exhibited high variance between samples (Figure 6). Only one full rake sample was collected from a site deeper than 7 m and no full rake samples were collected deeper than 8 m. This pattern was similar to, but slightly deeper than patterns of total macrophyte wet weight measured during the 2005 and 2007 surveys (Figure 7). Interestingly, the dominance of wet weight biomass by *C. demersum* in 2005 was replaced by dominance by *E. canadensis* in 2007 (Figure 7).

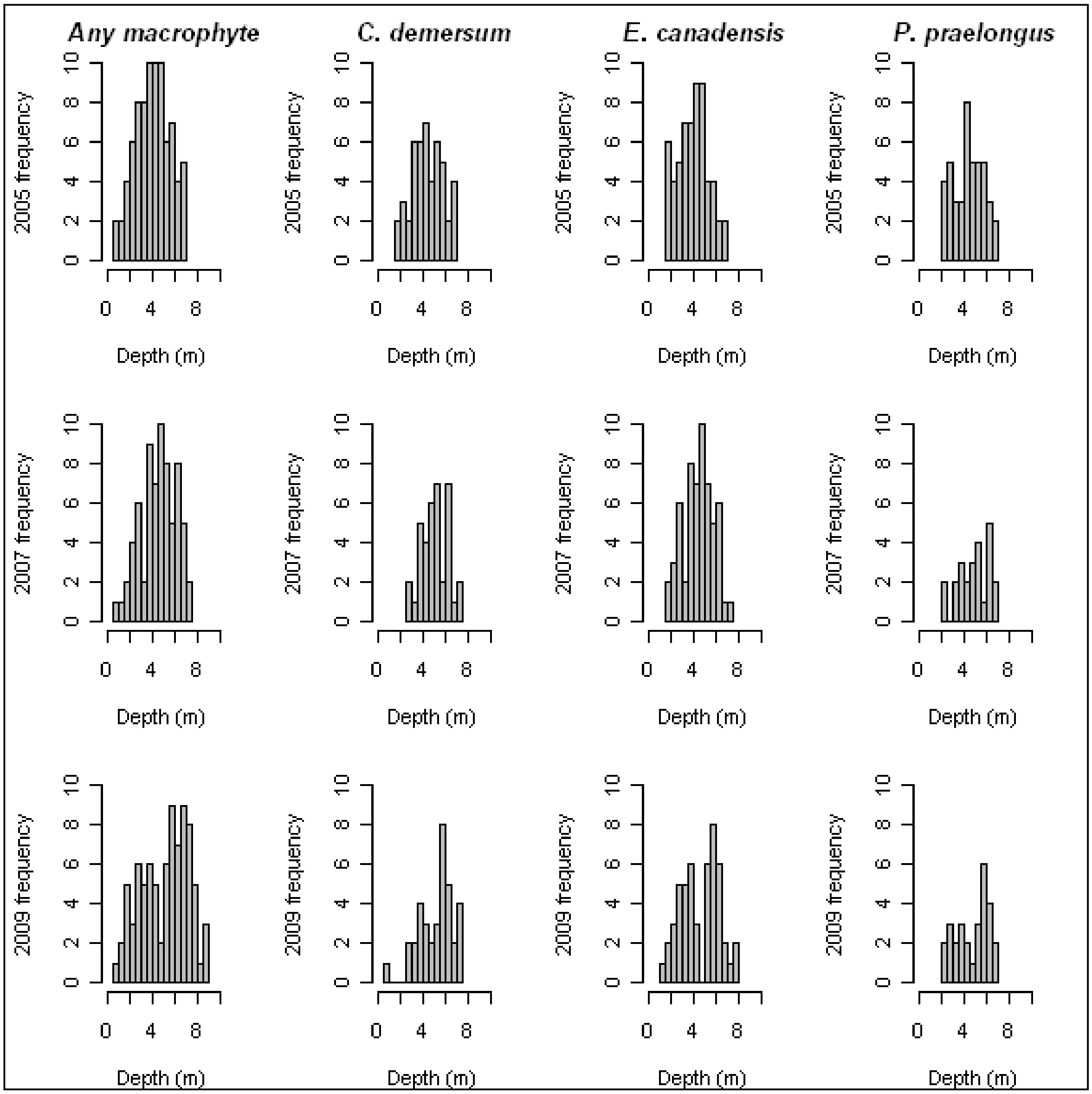


Figure 5. Histograms of the most common macrophyte species occurrence by depth during the 2005, 2007, and 2009 surveys.

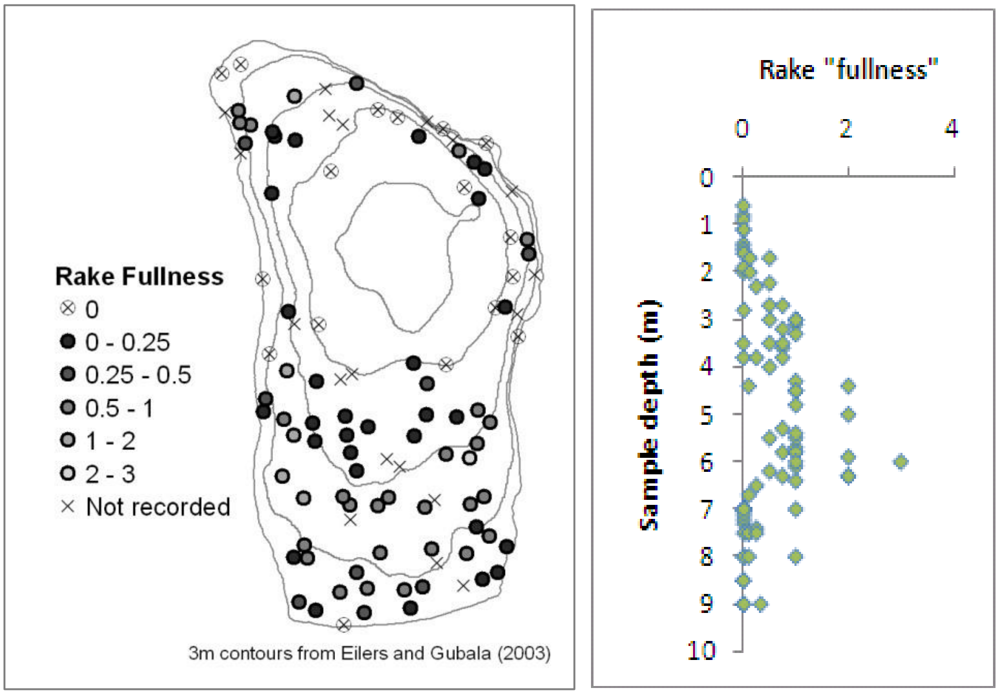


Figure 6. “Fullness” of 2009 thatch rake samples by location (left panel) and by depth (right panel).

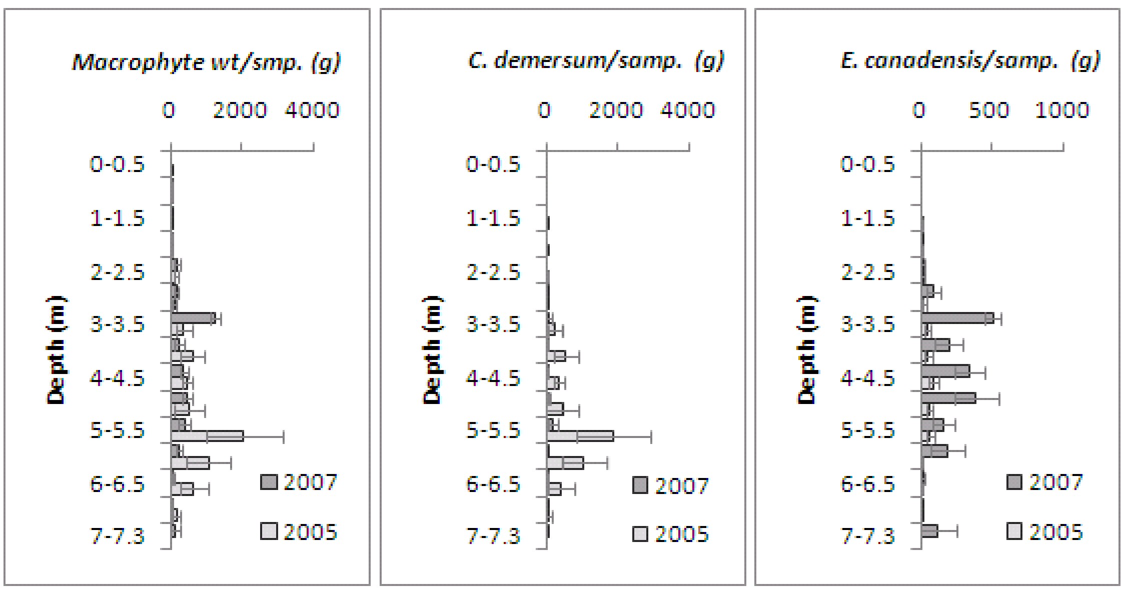


Figure 7. Average wet weight and standard errors of macrophyte samples collected during the 2005 and 2007 surveys grouped by half-meter depth bins. Note the different scales on the x-axes.

HYDROACOUSTIC SURVEYS

The distribution and canopy height of macrophytes surveyed in 2009 are shown in Figure 8. Average canopy height varied greatly as a function of site depth and showed a peak at about 4.5 meters (Figure 9). The volume of the water column with the maximum volumetric representation of macrophytes was slightly less, peaking at about 4.2 meters. Maximum canopy height was about 4 meters in length and minimum detectable height was about 0.2 meters. The canopy height of the macrophytes present in the deep waters seldom exceeded 0.4 meters (Figure 9).

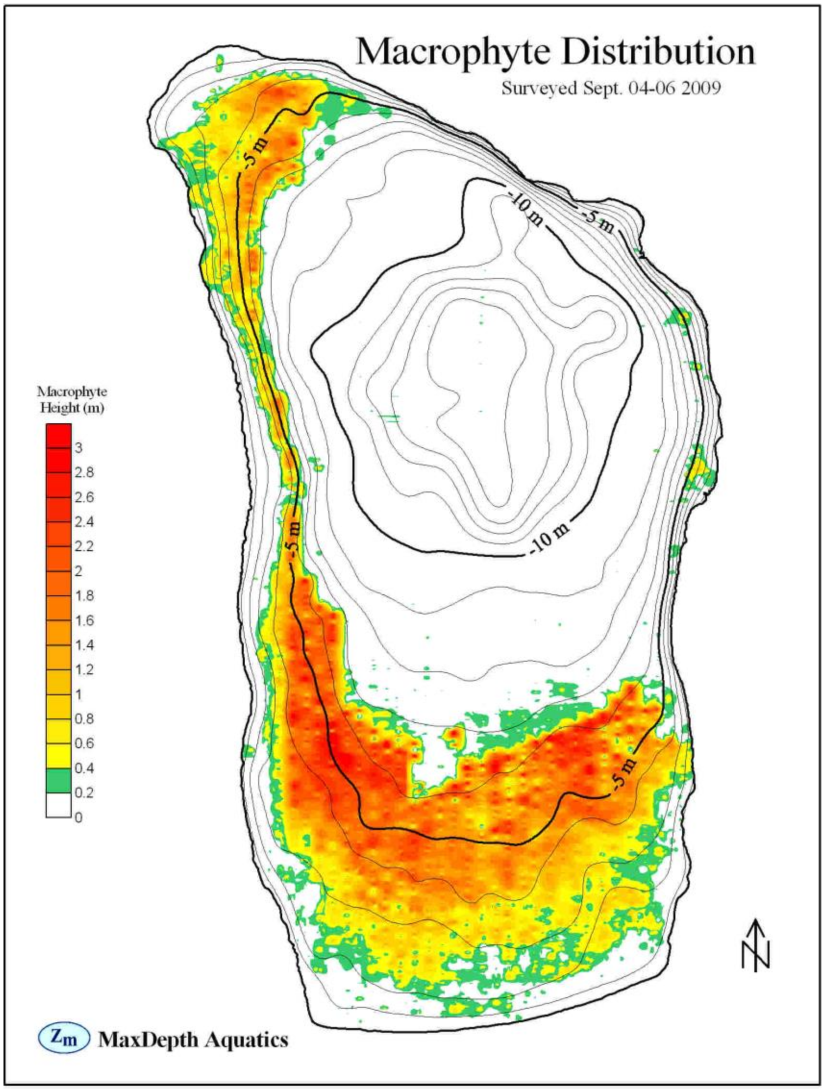


Figure 8. Macrophyte distribution and canopy height based on the 2009 hydroacoustic survey.

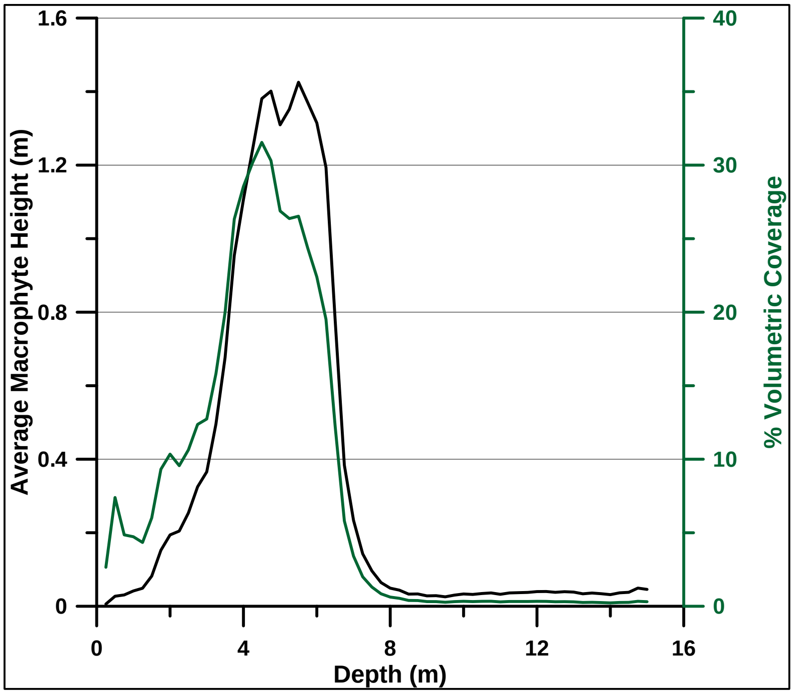


Figure 9. Average macrophyte canopy height and percent density of macrophytes within the water column as a function of depth of water.

Examples of echograms from the hydroacoustic survey reveal the range of some of the displays of macrophyte assemblages observed in Diamond Lake in 2009 (Figures 10-14). An echogram of a mixed community assemblage found in a depth from about 4 m to 7 m illustrates the transition from high, dense canopy to short, sparse macrophytes is typical of what was observed in this depth range (Figure 10). A contrasting transition was observed from the shoreline to a depth of 5 m, whereby macrophytes were usually sparse or absent at depths less than 2 m, a feature attributed to the effects of ice action (Figure 11). In substantial portions of the southern end of the lake where gradients in depth were very gradual, long-stranded foliage of 3 m in length was common (Figure 12). In slightly shallower depths, communities of *E. canadensis* or *C. demersum* were so dense that it was difficult to achieve bottom-lock with the echosounder. In these cases, the echogram displayed oscillating waves of macrophytes with no visual record of the substrate (Figure 13). In the deepest areas of the lake, short aggregations of macrophytes were observed widely scattered over the substrate. We sent down divers in October, 2007 and confirmed that these images were macrophytes that appeared to consist of intertwined *Elodea* and *Ceratophyllum* (Figure 14).

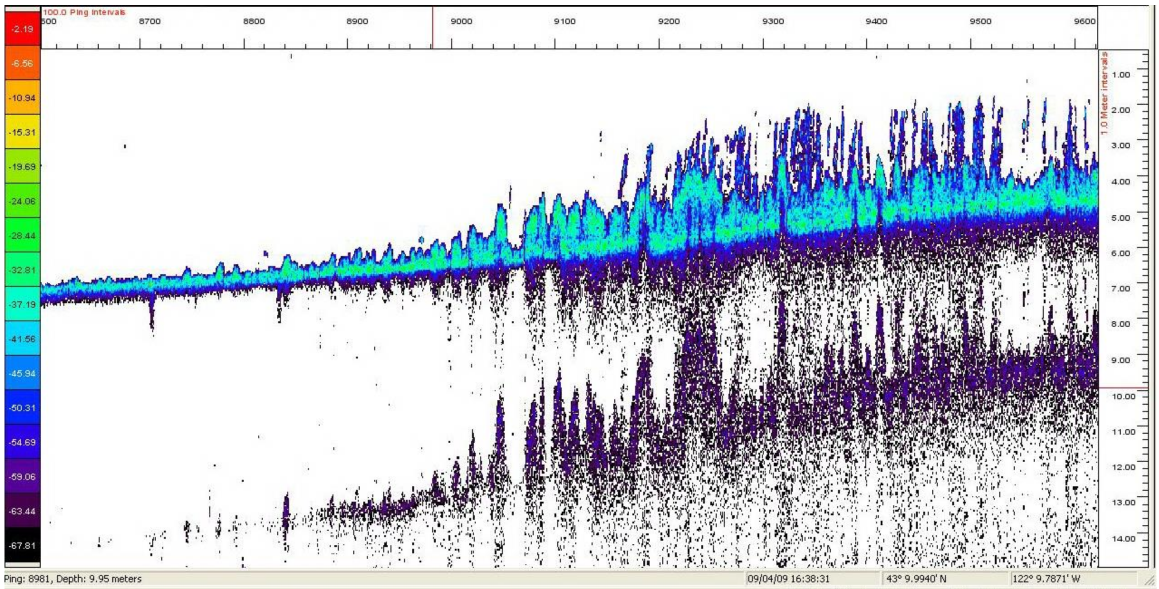


Figure 10. Echogram of a mixed community of macrophytes from about 4 m to 7 m depth with greatest density from about 4 to 5 m. Vertical scale is on the right.

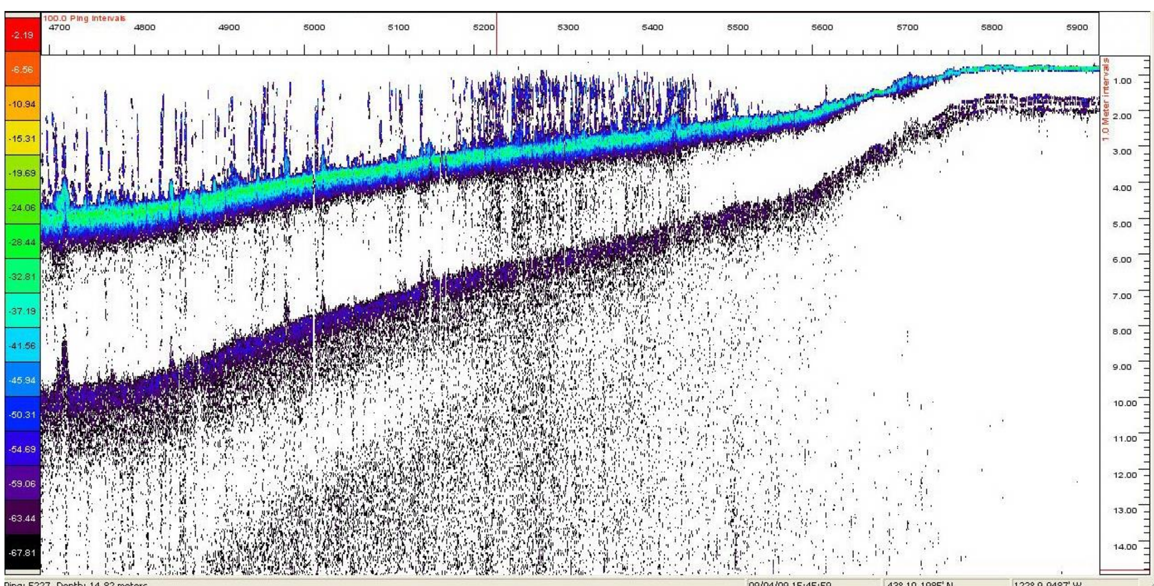


Figure 11. Echogram of macrophytes from shoreline to about 5 m showing the near absence of macrophytes from 2 m in depth to shore.

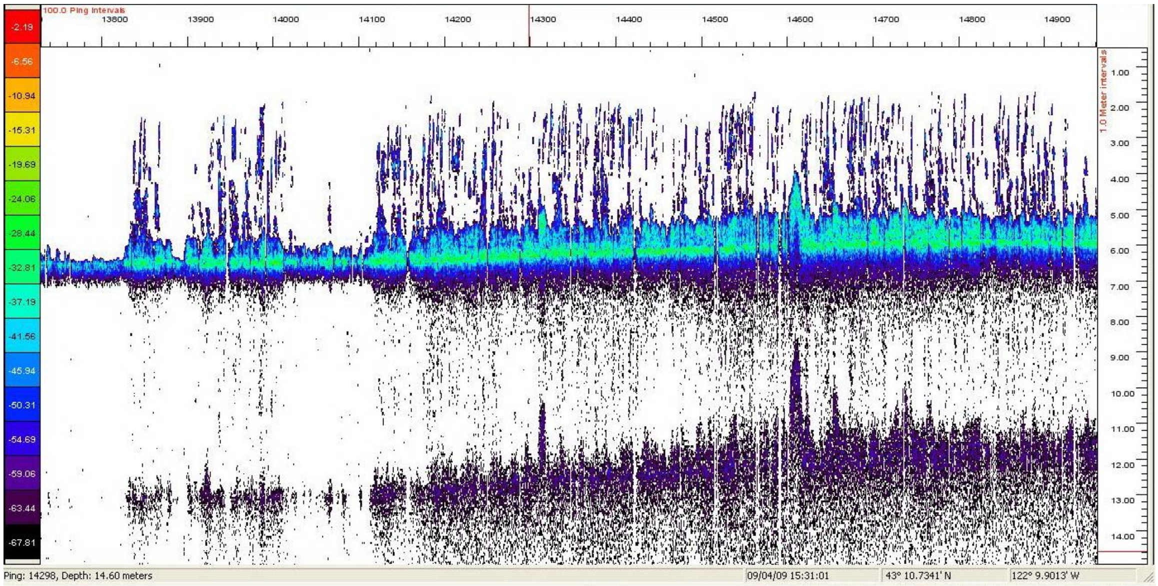


Figure 12. Echogram of a transect of tall macrophytes (typical of a *Potamogeton praelongus* community) extending from about 5 m depth to less than 2 m from the surface.

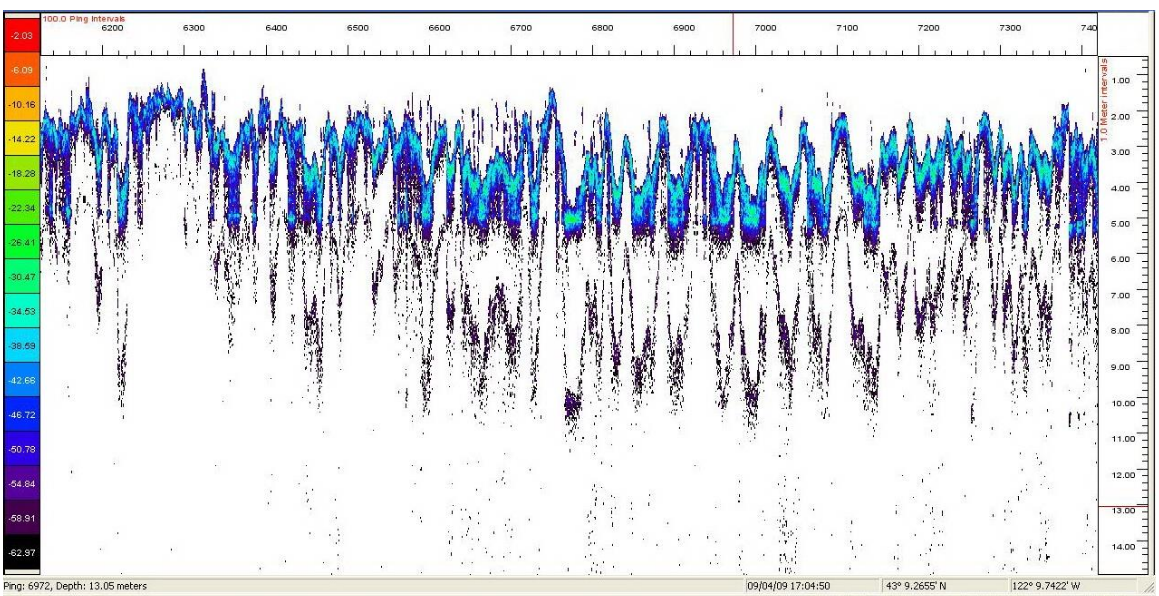


Figure 13. Echogram of an extremely dense macrophyte community (such as what might be found for *E. canadensis* or *C. demersum*) occurring in the range of about 3 to 5 m. The macrophytes are so dense that it is interfering with the echosounder to achieve bottom-lock on the substrate.

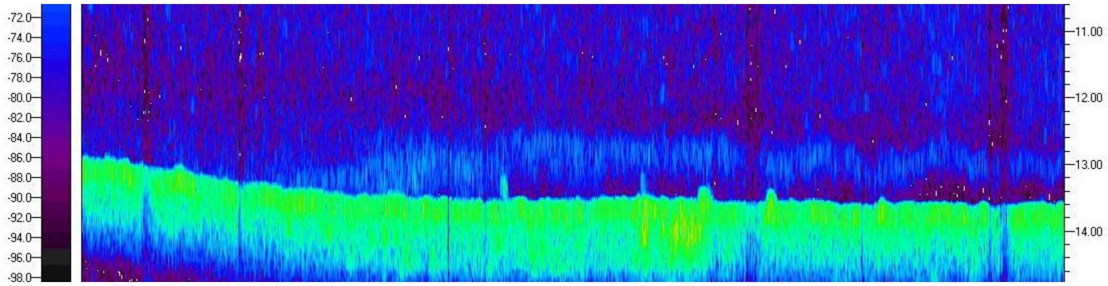


Figure 14. Echogram of a deep-water transect showing small aggregations of macrophytes up to 40 cm in height at a depth of about 13.5 m.

A comparison of macrophyte distribution and canopy height among the three survey years shows that canopy height in 2009 is greater than during the two previous surveys (Figure 15). Macrophyte distribution in 2009 is most similar to that in 2002, although there are several differences worth noting in addition to the greater canopy height in 2009. First is that the shallow areas less than 3 meters depth had greater coverage in 2002 compared to 2009. This is reflected in the overall decline in macrophyte coverage of the lake from 41 percent in 2002 to 33.4 percent in 2009. Second, there appears to have been some moderately large open zones of little macrophyte coverage in the south-eastern portion of the lake in 2002 compared to almost continuous coverage throughout those areas in 2009. There are small, sparsely distributed areas of macrophytes present in the deep waters (> 8 m) in 2009 and none reported in 2002.

The survey showing the least resemblance to the others is the survey in 2007, which displayed little growth of macrophytes in areas of the lake less than 3 meters in depth. The 2007 survey also displayed shorter average canopy height and extensive areas of patchy distribution compared to the largely continuous zones of macrophyte growth observed in 2009. Only 27.8 percent of the lake substrate was covered with macrophytes in 2007. A map of the differences between the 2007 and 2009 surveys highlights areas of the lake showing the fastest response to the return of normal lake stage, which was achieved in spring 2007 (Figure 16).

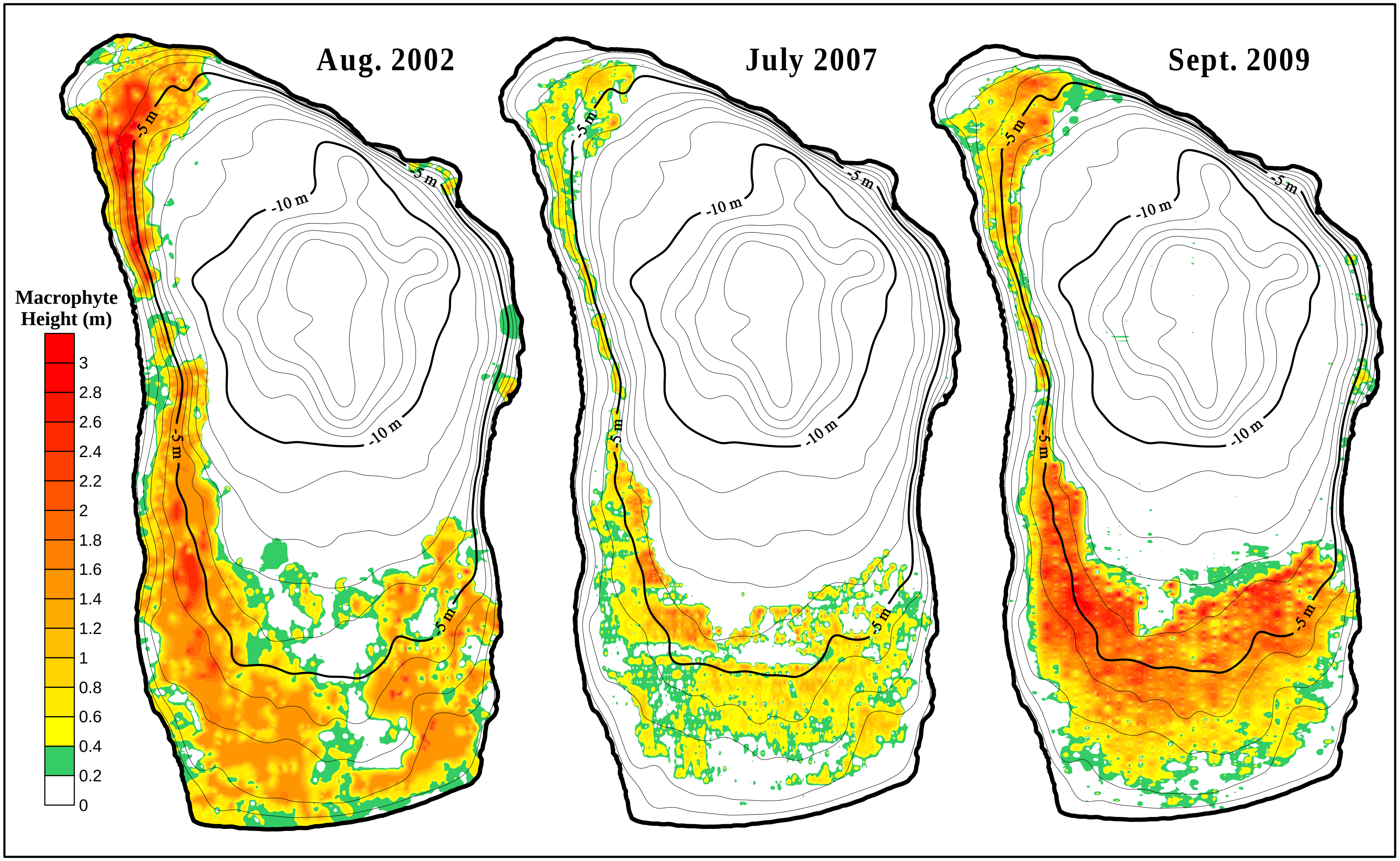
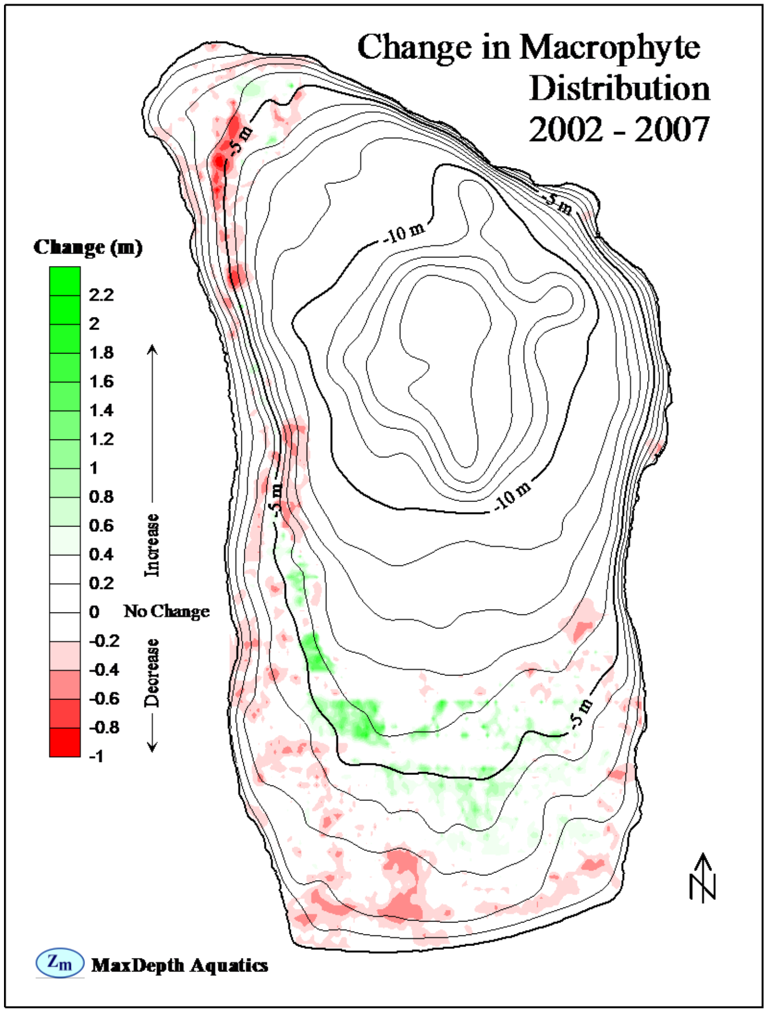


Figure 15. Comparison of hydroacoustic surveys of macrophyte distribution and canopy height from 2002, 2007 and 2009.



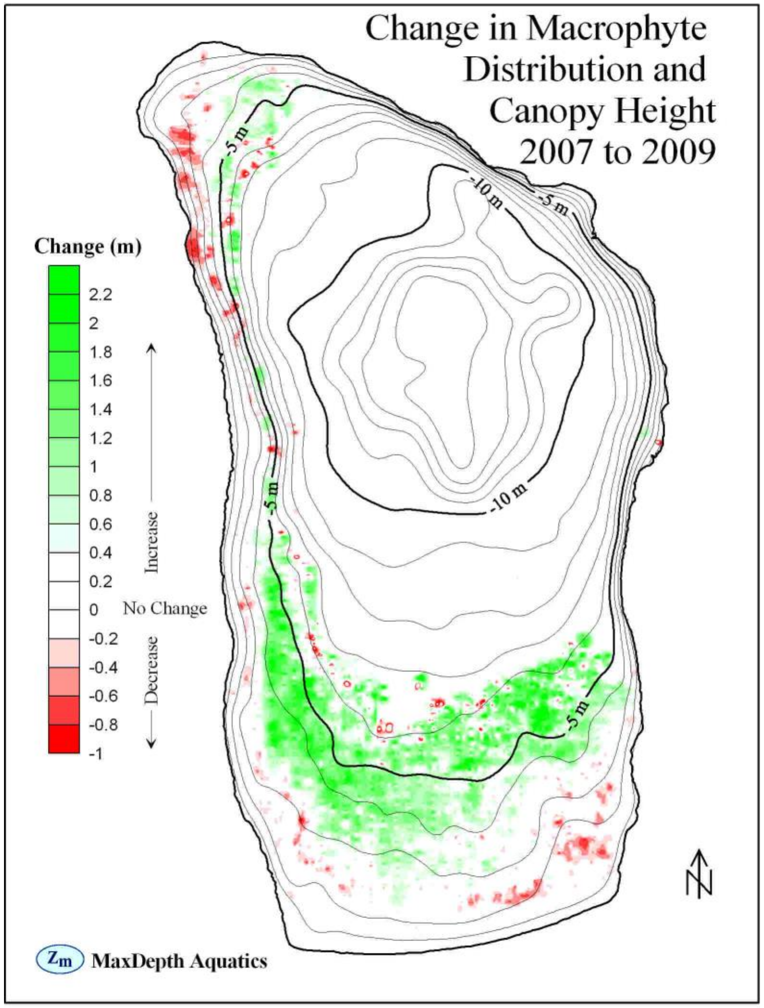


Figure 16. Difference maps comparing macrophyte distribution and canopy height between the surveys in 2002 and 2002 (left) and 2007 and 2009 (right).

The “rake fullness” ranking from the community composition survey by PSU was compared to the density and the canopy height measured with hydroacoustics. The results show poor correspondence between the two methods (Figures 17 and 18). The intensity of the lack of agreement is displayed in the extremes of the plot whereby the rake sample recorded a positive sample of macrophytes in several cases where the hydroacoustic data set showed no macrophytes present. Conversely, there were several cases where the rake sample showed no macrophytes present, whereas the hydroacoustic data set recorded macrophytes present. Even in cases where both methods recorded macrophytes present, there was little correspondence between the nature of the hydroacoustic signal and the “fullness” of the rake samples. The comparison of depth recorded at the rake sample site and the average depth within the 10-m grid derived from the hydroacoustics showed generally close agreement, indicating that the positional information of the sites appeared to be reasonably close (Figure 19). The likely reason for the poor fit between the two methods can be explained by high degree of spatial variability in macrophyte density and canopy height, as is evident in Figures 4-7. Each grid cell created from the hydroacoustic data represents the average macrophyte coverage within 100 square meters while each rake grab represents the average macrophyte coverage in less than 1 square meter. The lack of correspondence between the two methods precluded further utilization of the combined data sets for displaying macrophyte taxa spatially.

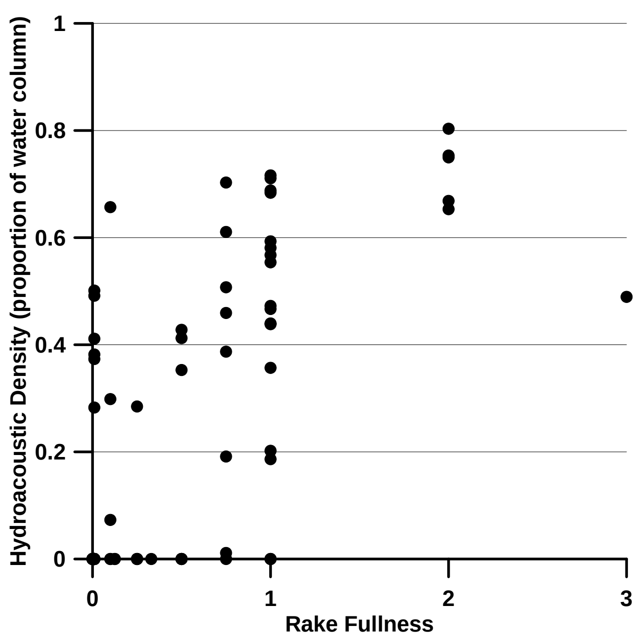


Figure 17. The degree of macrophytes retrieved from the bottom as expressed by “rake fullness” versus the density of macrophytes within the same 10 m grid based on the hydroacoustic survey.

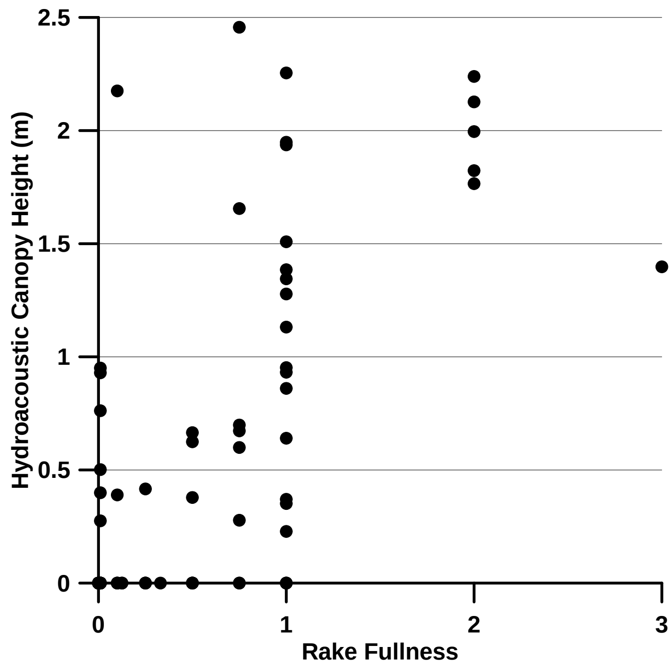


Figure 18. The degree of macrophytes retrieved from the bottom as expressed by "rake fullness" versus the canopy height of macrophytes within the same 10 m grid based on the hydroacoustic survey.

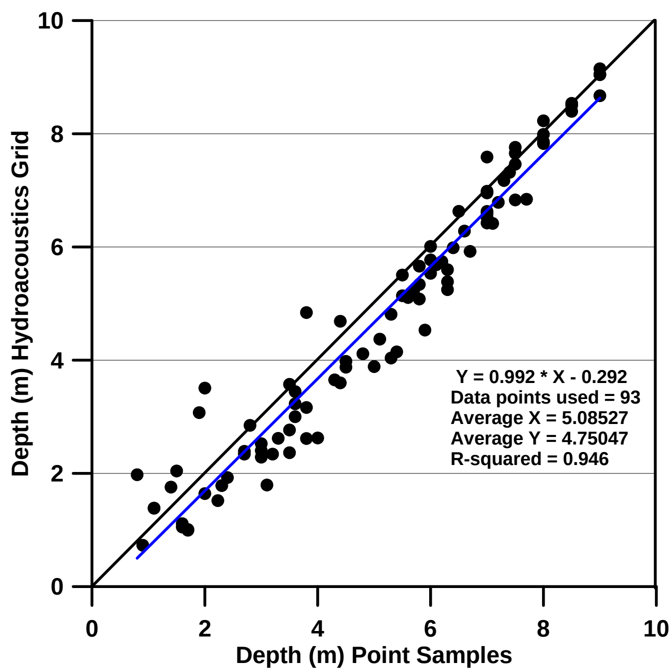


Figure 19. Depth at the point of collection of the macrophyte sample versus the average depth within the 10m grid derived from the hydroacoustic survey.

DISCUSSION

The increased distribution and canopy height of the macrophytes in 2009 compared to 2007 reflects a moderately fast recovery of the macrophyte community to the perturbations associated with the drawdown and rotenone treatment in 2006. Maximum canopy height is now greater than recorded for any of the macrophyte surveys and the growth of macrophytes into the deep waters reflects the increased transparency in Diamond Lake following the treatment (Eilers 2008). The macrophyte recolonization of the substrate exposed during the treatment is considerably slower than the recolonization of the deeper waters. This likely reflects the loss of organic matter in the shallow areas as the lake was drawn down in addition to likely compaction of the exposed sediments.

A possible expansion of macrophytes down to 14 m reflects something not observed in Diamond Lake prior to 2007. Light has now become sufficient to allow growth of macrophytes at all depths in Diamond Lake, however growth of many macrophytes are inhibited by increasing hydrostatic pressure. Even with adequate light, most macrophytes are restricted to depths of less than 10 m (Wetzel 2001). It is possible that the macrophytes observed at 14 m were not rooted, but represent plants that became uprooted from shallower sites and were transported to depth in entangled masses. Algae are not inhibited to the same degree as aquatic angiosperms with respect to hydrostatic pressure. Thus, it is not surprising to see that the taxa present below 8 m were *Nitella*, a macroalga, and an unidentified filamentous alga. Low densities of filamentous algae are unlikely to be identified using hydroacoustics and even high densities of algae are poor targets for hydroacoustics if the algae are largely prostrate. It may be that filamentous algae now extend below depths of 9 meters throughout Diamond Lake.

The most significant change in species composition observed during the three grab sample surveys was a decrease in *C. demersum* biomass and an increase in *E. canadensis* biomass between 2005 and 2007. Changes in biomass may have been due to differences in how the two species obtain nutrients or their competitive abilities at different light levels. Over the period from 2005 to 2007 nutrient levels in the water column decreased while light levels increased. *C. demersum* is a non-rooted macrophyte and is therefore reliant on nutrients in the water column. *E. canadensis* is rooted and obtains nutrients from the sediment.

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