Littoral Zone Macrophytes As Swan Habitat and Food:

Baseline Surveys of Plant Abundance and Species Composition

As Data for Potential Reintroduction

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Abstract

In this study, a baseline survey was done to look at the total belowground biomass, total aboveground biomass, species composition and species diversity of macrophytes in Brown Lake, Kickapoo Lake, and the connecting channel habitat. The purpose of the survey is to determine which habitat is best suited for the introduction of trumpeter swans, *Cygnus buccinator*. Based on the results, it is predicted that when the swans are introduced in May, early in the summer, the lack of submerged macrophytes will lead them to a habitat with abundant belowground biomass (tubers and seeds). Such an environment is found in Brown Lake. However, once the weather warms up and the plants emerge, the swans will likely move to areas with abundant, easily accessible submerged macrophytes. The lake channel will most likely be the habitat of choice at this time due to the abundance of macrophytes and relatively shallow depth of the water. The species composition of the 3 habitats was also calculated and results were compared to look at the prevalence of such favored macrophyte species as *Potamogeton* spp., *Elodea,* and *Chara* spp. Species diversity and evenness were also calculated in the 4 habitats. Brown Lake and Kickapoo Lake were found to have similar diversities (Kickapoo being slightly higher), and identical evenness indices. Each end of the channel habitat was found to have lower diversity and evenness as compared to the values for the lakes. All of the data obtained in this survey will provide baseline data for future experiments which will examine the effects of trumpeter swan herbivory on the macrophyte species composition and species diversity of the swan habitat.

Introduction

Conservation and restoration programs have been successful in increasing the existing populations of trumpeter swans (*Cygnus buccinator)* in North America. However, the populations are still in danger due to loss of wintering habitats, concentration of wintering flocks at few sites, lead poisoning, and lack of migration among certain wild and restored flocks (Mitchell 1994). Losses of large numbers of swans are not easily repaired due to the slow population growth of the species. This slow growth is primarily due to delayed maturation, single broods, highly variable production, and high winter mortality (Mitchell 1994). Current restoration programs are in the process of finding habitats that will be suitable for the reintroduction of trumpeter swans in N, NE, and SW Michigan, NW Minnesota, and N and central Wisconsin (Beaulieu 1992). However, it must first be determined if sites that fulfill the habitat and food requirements of the species are available in these areas.

Trumpeter swans use a variety of breeding and wintering habitats that provide open water, access to food and minimal disturbance. For nesting, swans tend to avoid areas with acidic, stagnant or eutrophic water. They are most productive in freshwater marshes, ponds, and lakes with 100 m of room for take off, accessible forage, shallow water (< 1.2 m), plenty of emergent vegetation, muskrat nest, an island or other structure to build the nest on, and low human disturbance (Mitchell 1994). Productivity is greatest in habitats that are abundant in macrophytes (Squires 1991) and invertebrate populations (Lockman et al. 1987). During the winter months, swans ideally inhabit ponds, lakes, and reservoirs with > 100 m of open water, banks with little or no shrubbery, depth < 1.3 m, abundant and diverse aquatic vegetation, no wire fences or powerlines, no lead, and little or no human disturbance (Lockman et al. 1987).

The feeding habits of trumpeter swans have been studied in previous experiments. In general, swans are herbivorous and feed on emergent and submerged vegetation (Squires 1991). Occasionally, they will also feed on fish and fish eggs (Hampton 1981). The trumpeter swan diet consists primarily of leaves, stems, roots and tubers of submerged, floating, and emergent plants (Mitchell 1994). Previous experiments have also determined the specifics of the seasonal eating habits of trumpeter swans. The studies show that the dominant foods in the swan diet (comprised >10 % of diet in at least one season) are *Chara* spp. (eaten in proportion to its availability), *Elodea canadensis*, *Potamogeton* spp., and *Potamogeton pectinatus* tubers (Anderson and Squires 1994). During the summer, the swans were found to feed primarily on *Potamogeton* foliage and nesting swans were found to prefer *Potamogeton* spp. (Anderson and Squires 1994). The studies also showed that swans avoid eating *Ceratophyllum demersum*, and *Myriophyllum exalbescens* (Anderson and Squires 1994).

Not only is the species composition of vegetation an important factor, but also the availability of the food. Changes in the macrophyte abundance in swan habitats (such as macrophyte loss due to eutrophication and recovery through human intervention) have been found to cause changes in swan population densities (Mitchell and Perrow 1996).

The possibility exists for future reintroduction of trumpeter swans to one or more lakes on the property of the University of Notre Dame Environmental Research Center (UNDERC). Efforts have already been made in neighboring areas such as Wisconsin's Vilas County. However, such attempts at reintroduction were not successful due to high levels of human disturbance (M. Mossman, Wisc. DNR, *pers. comm.*). This makes reintroduction at UNDERC ideal due to restricted human access to the area.

A preliminary survey of macrophyte abundance and species composition was performed on 2 of the lakes at UNDERC as well as the connecting channel. This was done in order to determine if the littoral zones of these lakes would provide suitable feeding and nesting resources for the swans. Following the introduction of the swans, this preliminary data can serve as the baseline data for potential future studies which will look at the effects of trumpeter swan feeding and nesting on the macrophyte characteristics of particular lakes.

Materials and Methods

Preparation of Sampling Sites

Brown and Kickapoo Lakes and the connecting channel, which are located on the UNDERC property in Michigan's Gogebic County, were selected for study. Three transects were established in each littoral zone of the lakes as well as in each end of the connecting channel (see Figs. 1 and 2). Both the lakeward and shore ends of the transects were permanently marked. Transects in the channel were established at 100 m intervals, the first being 100 m from the entrance to the lake. The cross-channel transects were also permanently marked.

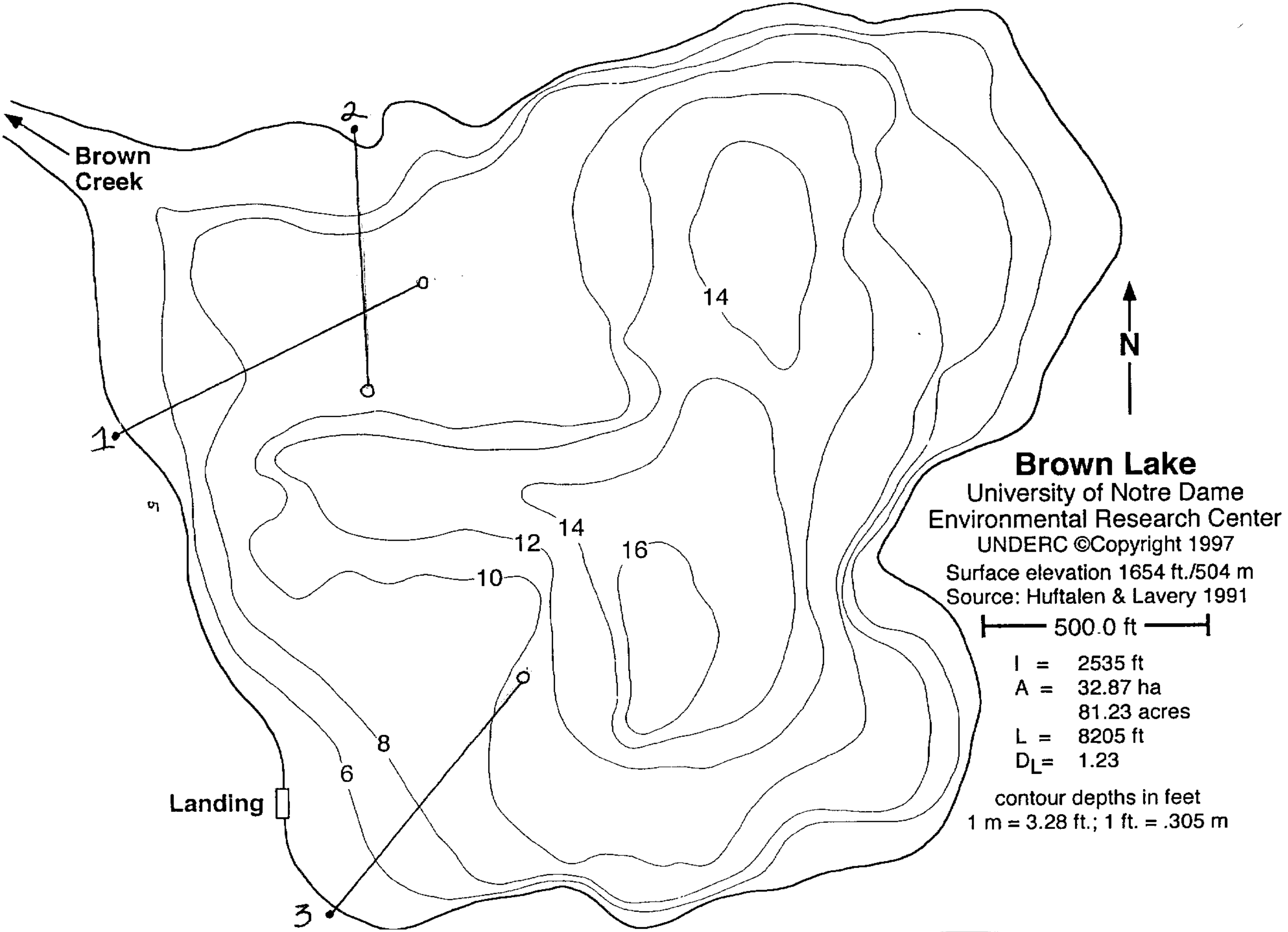

Figure 1: Map of Brown Lake
Map indicates sampled transects which are labeled with transect number. Transects were chosen early in the summer based on the abundance of submerged macrophytes. Both lakeward and shore ends of each transect were permanently marked.

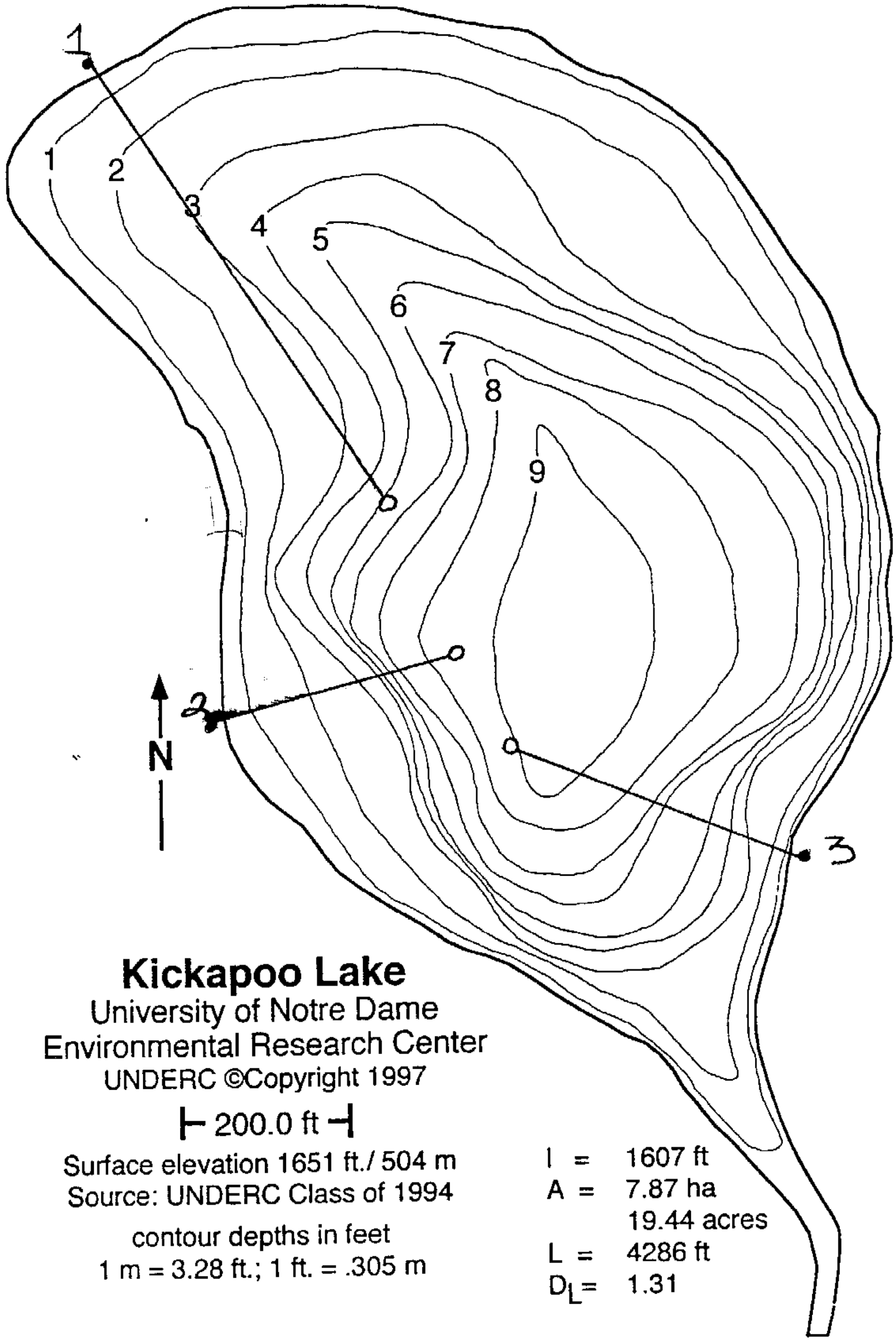

Figure 2: Map of Kickapoo Lake

Map indicates sampled transects which are labeled with transect number. Transects were chosen early in the summer based in the abundance of submerged macrophytes. Both lakeward and shore ends of each transect were permanently marked.

Belowground Biomass Sampling Protocol

When each transect was sampled, rope was run from the pipe on shore to the anchored bottle. A PVC pipe marked off in 0.1 m intervals was used to determine the depth along the transect. 15 cm cores were taken at 0.25, 0.50, 0.75, and 1.00 m along each lake transect. Three cores were taken at each depth making 36 cores/lake and a total of 72 cores. Each core was rinsed in a 2 mm sieve and the contents were placed in labeled Ziploc bags.

Analysis of Core Samples

The cores that were obtained from Brown and Kickapoo Lakes were sifted through in search of tubers and/or seeds. Similar tubers and seeds in each core were placed together, blotted dry, and weighed to the nearest 0.001 g. At least one of each type of tuber or seed was placed in a numbered specimen vial with 80% ethanol to preserve for possible identification. Data for each core were placed in pre-made data sheets (see Fig. 3).

Aboveground Biomass Sampling Protocol

Macrophyte samples were collected beginning June 30, 1997. This was done to ensure that all or most of the plant species had been given enough time to emerge. Samples were taken while snorkeling, using 0.25 m^2 quadrats to establish the macrophyte sampling sites along the transects. In the open lakes, three samples were taken at 0.5, 1.0, 1.5, and 2.0 m along each of the 3 transects. The quadrat was placed in the macrophyte stand and average canopy depth was measured using a piece of Styrofoam connected to a weighted rope marked off in 0.1 m intervals. All submerged aboveground biomass was then collected by hand and placed in labeled Ziploc bags.

Macrophyte samples were taken in a similar manner along the channel transects. However, only 6 samples were taken at each transect, 3 along the shore line and 3 in the middle of the channel. Average canopy depth was also measured in the channel samples and all aboveground biomass was collected by hand and placed in labeled Ziploc bags. The overall number of samples collected was 36 samples/lake along with 18 samples/channel for a total of 108 macrophyte samples.

Data Sheet for Sediment Cores

Transect number: ________ Date: ____________

Depth: _________ Lake: ____________

Sample: ______

Core Depth: _______

Species A: _______________________ Vial #: ________

Obs # Tubers: ___________

Fresh weight: ___________

Species B: _______________________ Vial #: ________

Obs # Tubers: ___________

Fresh weight: ___________

Species C: _______________________ Vial #: ________

Obs # Tubers: ___________

Fresh weight: ___________

Species D: _______________________ Vial #: ________

Obs # Tubers: ___________

Fresh weight: ___________

Species E: _______________________ Vial #: ________

Obs # Tubers: ___________

Fresh weight: ___________

Figure 3: Sample Data Sheet for Sediment Cores
For each core the date, lake, transect number, depth, and sample were recorded along with the fresh weights of the observed belowground biomass.

Analysis of Macrophyte Samples

The obtained macrophyte samples were then sorted by species, rinsed, and the roots removed. If a species was unknown, a small amount was placed in a Ziploc bag labeled with spp. A, B, C, etc. and a number. These specimens were later pressed, dried, and identified using the Fasset taxonomic guide. The separated plants were placed in labeled paper bags (lunch bag size). If a very large amount of one species was present, the sample was divided between 2 labeled bags. The plants were then dried for approximately 15-20 hours at 45 - 50° C. Once the samples were completely dry, the dry weights of the individual species were measured (to 0.001 g) and recorded in data sheets (see Fig. 4). The dry weights of the individual species were then used to calculate their relative abundance by weight in each sample.

Analysis of Results

The data obtained for both below and aboveground biomass were entered into the statistical program Systat so that means could be calculated and graphs could be generated. Lists were then made of the different species that were found in each of the habitats and species diversity and evenness were calculated for each habitat using the Shannon-Weiner Index.

Results

Belowground Biomass

The mean value for belowground biomass at each depth were averaged for all transects to determine mean total belowground biomass for all sampled depths in each of the lakes. Table 1 indicates the results for both Brown and Kickapoo. The data indicate that at the lower depths of 0.25 and 0.5 m, Brown had much more belowground biomass than Kickapoo. However, at 0.75 and 1.0 m, Kickapoo was found to have more belowground biomass than Brown. The values for 1.0 m were quite close, but with the 95% confidence intervals included, the value for Kickapoo was still slightly higher.

Aboveground Biomass

The mean value for aboveground biomass at each depth were averaged for all transects to determine the mean total aboveground biomass at all sampled depths in

Data Sheet for Submerged Plant Samples

Transect #: ____________ Date: ________________

Depth: ____________ Lake: ________________

Sample: _______

Average canopy depth: ______________

Species A: __________________________ Bag #: ________

Dry weight: ____________

Relative abundance by weight: ____________

Species B: __________________________ Bag #: ________

Dry weight: ____________

Relative abundance by weight: ____________

Species C: __________________________ Bag #: ________

Dry weight: ____________

Relative abundance by weight: ____________

Species D: __________________________ Bag #: ________

Dry weight: ____________

Relative abundance by weight: ____________

Species E: __________________________ Bag #: ________

Dry weight: ____________

Relative abundance by weight: ____________

Figure 4: Sample Data Sheet for Submerged Plant Samples
For each macrophyte sample the date, lake, transect number, depth, and sample were recorded along with the individual species names and dry weights.

Lake	0.25 m (+/- 95% CI)	0.50 m (+/- 95% CI)	0.75 m (+/- 95% CI)	1.00 m (+/- 95% CI)
Brown	0.337 g (+/- 0.71 g)	0.434 g (+/- 0.81 g)	0.0122 g (+/- 0.019 g)	0.0338 g (+/- 0.024 g)
Kickapoo	0.0392 g (+/- 0.045 g)	0.0599 g (+/- 0.080 g)	0.0727 g (+/- 0.10 g)	0.0614 g (+/- 0.066 g)

Table 1 : Average Belowground Biomass Values for Sampled Depths (fresh weights)

Data from all sediment cores were averaged to find average total belowground biomass at each sampled depth for both of the lakes.

both lakes and in both ends of the channel. Figure 5 shows a comparison between Brown Lake and Kickapoo Lake of the results for each of the sampled depths. The data indicate that the values for aboveground biomass at 0.5 m and 2.0 m are much different between the 2 lakes with Brown having more aboveground biomass at 0.5 m and Kickapoo having more at 2.0 m. The data for the depths 1.0 m and 1.5 m indicate that the values for the 2 lakes are not statistically different due to the overlapping confidence intervals.

Figure 6 compares the mean aboveground biomass values for the 2 depths sampled in the channel (shore and mid-channel). The confidence intervals indicate that the values for each end of the channel are very different at both of the sampled depths, with the Brown-end of the channel having more aboveground biomass at both depths. Within each individual end of the channel, no significant distinctions can be made between the amount of aboveground biomass at the depths along the shore compared to that in the middle of the channel. Therefore, there is low variation in aboveground biomass in the channel.

Species Composition

Figure 7 is a list of all the submerged macrophyte species that were collected in Brown and Kickapoo Lakes as well as both ends of the connecting channel. The mean percent abundance of each macrophyte species collected was then used to generate graphs depicting the abundance of each species at each depth in the lakes and channel. Figure 8 shows the overall species composition of Brown Lake and Figure 9 is the breakdown of Brown species' abundance at each of the 4 sampled depths. The same was done for Kickapoo Lake in Figures 10 and 11. The graphs of abundance at individual depths have been modified to focus mainly on the macrophyte species that are of importance for trumpeter swan herbivory.

The macrophyte species breakdown was also determined for each end of the channel at both of the sampled depths. The results are represented in Figures 12 and 13. Once again, in the generation of the graphs, focus was placed on the submerged macrophyte species of particular importance to the swans.

Species Diversity

The Shannon-Weiner Index was used to calculate the species diversity and species evenness of Brown and Kickapoo Lakes as well as in the connecting channel (see Figure 14). Based on the index, Brown Lake and Kickapoo Lake have relatively

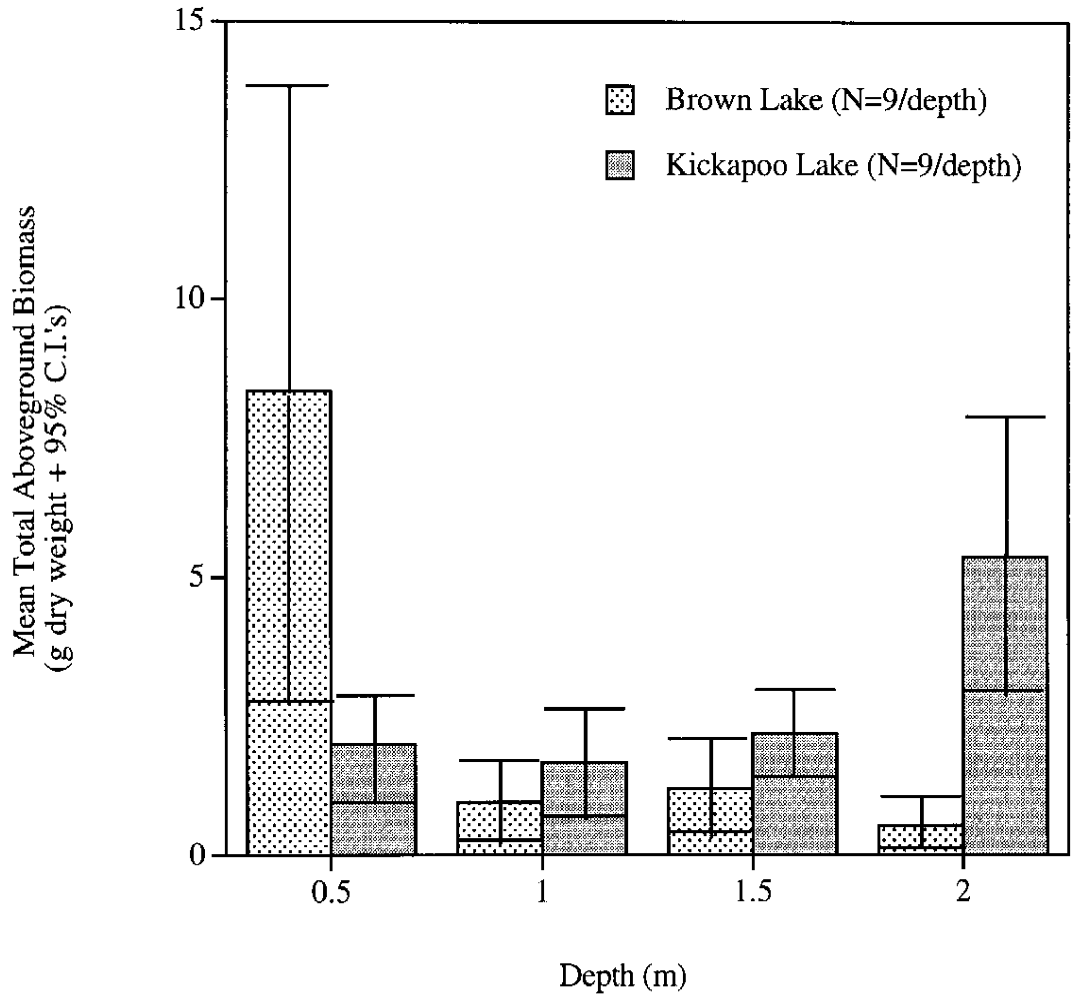

Figure 5: Bar Graph of Total Aboveground Biomass at Sampled Lake Depths
All macrophyte mass data were combined and averaged to obtain average total aboveground biomass at all sampled depths for the 2 lakes.

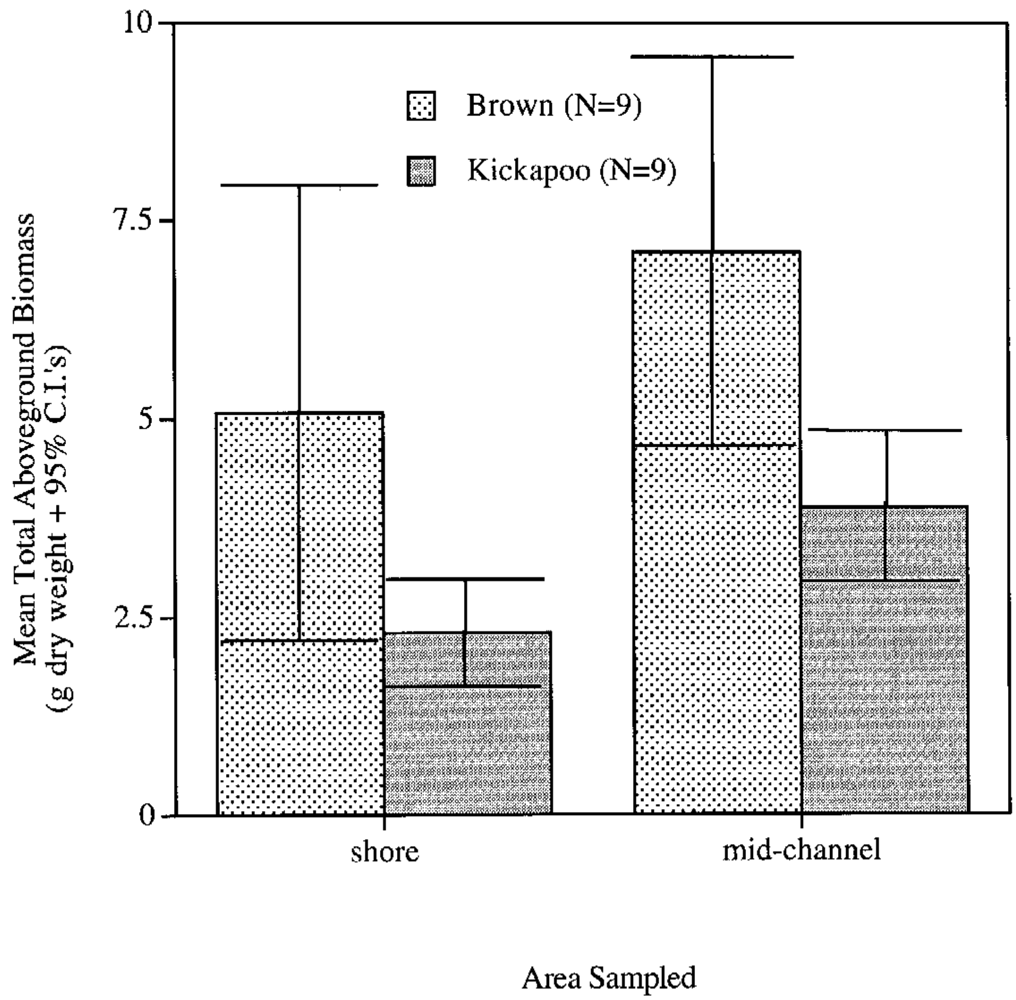

Figure 6: Bar Graph of Total Aboveground Biomass at Sampled Channel Depths
All macrophyte mass data were combined and averaged to obtain average total aboveground biomass at all sampled depths in the channel.

Macrophyte Species Found in Brown Lake

Ceratophyllum demersum
Chara vulgaris
Elodea canadensis
Lemna trisulca
Littorela americana
Potamogeton amplifolius
Vallisneria americana

Macrophyte Species Found in Kickapoo Lake

Ceratophyllum demersum
Chara vulgaris
Elodea canadensis
Myriophyllum spp.
Potamogeton amplifolius
Potamogeton robbinsii
Sparganium spp.
Utricularia spp.

Macrophyte Species Found in Brown Channel

Ceratophyllum demersum
Elodea canadensis
Potamogeton filiformis
Potamogeton robbinsii
Sparganium spp.

Macrophyte Species Found in Kickapoo Channel

Ceratophyllum demersum
Elodea canadensis
Potamogeton amplifolius
Potamogeton robbinsii
Sparganium spp.
Utricularia spp.

Figure 7: List of Macrophyte Species
Similar submerged macrophyte species were found in all sampled habitats. However, some differences were seen, not only among habitats, but within habitats as well.

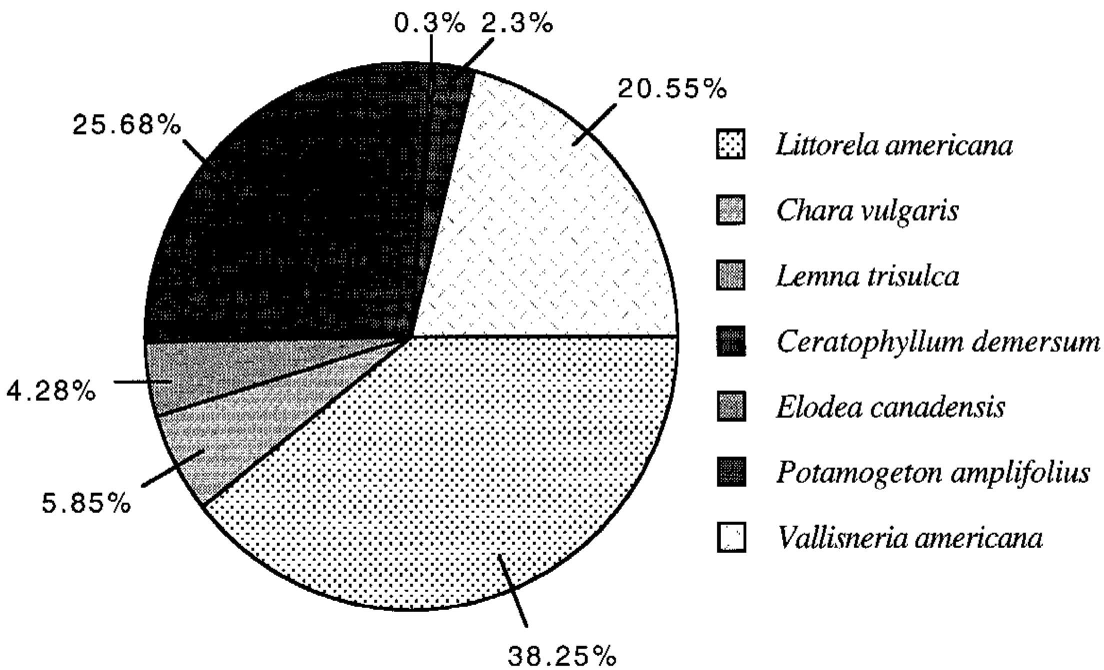

Figure 8: Submerged Macrophyte Species Composition of Brown Lake
All percent abundance values for each macrophyte species were averaged to obtain a profile of species composition for Brown Lake. Included are all obtained macrophyte species.

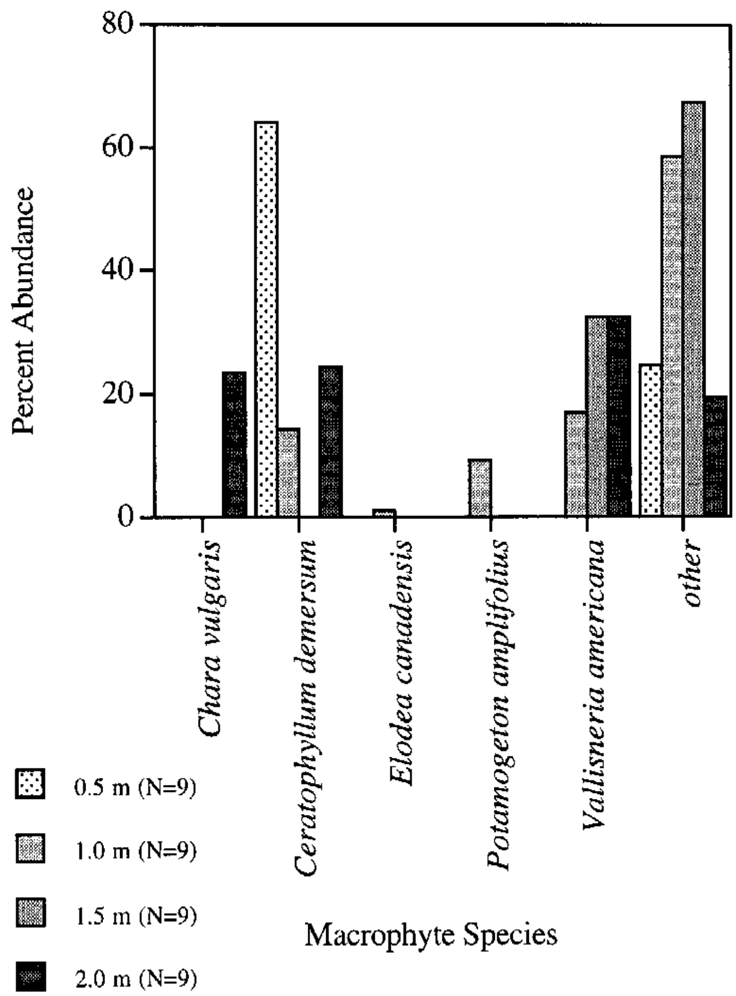

Figure 9: Species Abundance at Each Sampled Depth in Brown Lake

Percent abundance values for each macrophyte species were averaged for each depth sampled to obtain a graph of species abundance for each depth sampled in Brown Lake. Included only are species of importance to trumpeter swan herbivory.

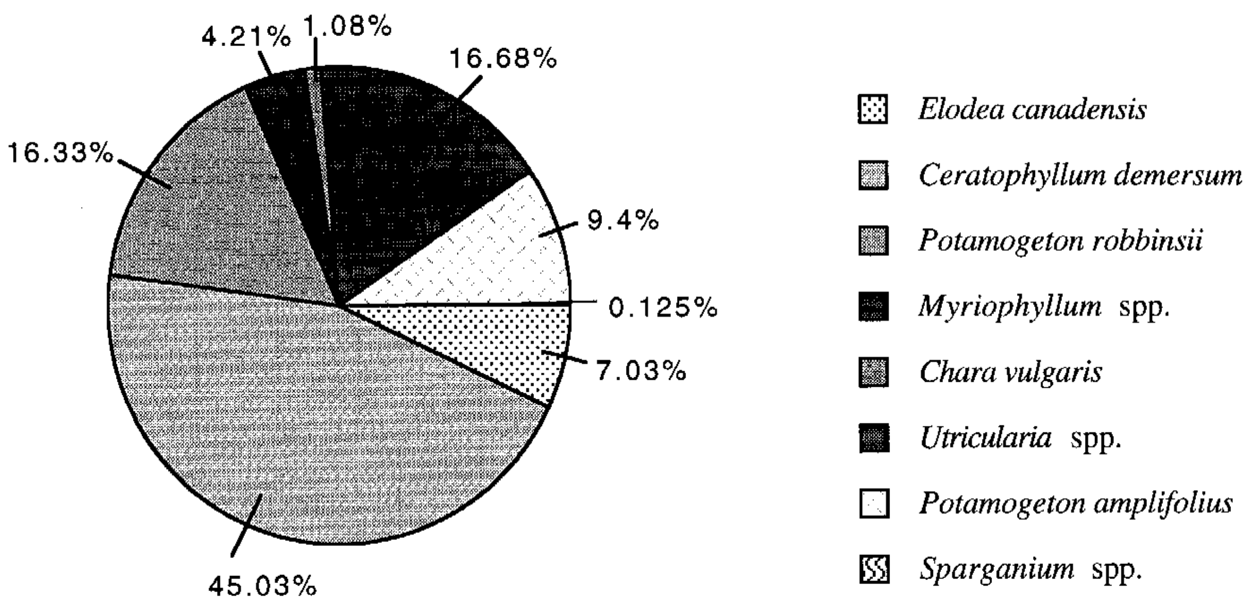

Figure 10: Submerged Macrophyte Species Composition of Kickapoo Lake
All percent abundance values for each macrophyte species were averaged to obtain a profile of species composition for Kickapoo Lake. Included are all obtained macrophyte species.

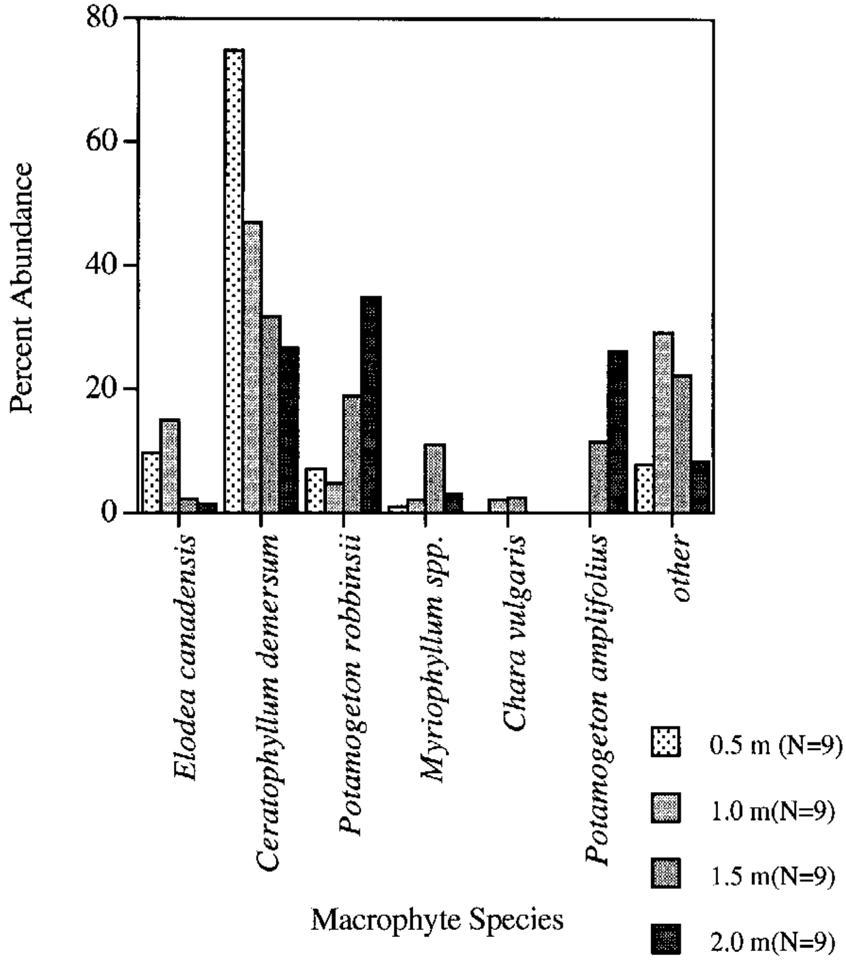

Figure 11: Species Abundance at Each Sampled Depth in Kickapoo Lake

Percent abundance values for each macrophyte species were averaged for each depth sampled to obtain a graph of species abundance for each depth sampled in Kickapoo Lake. Included only are species of importance to trumpeter swan herbivory.

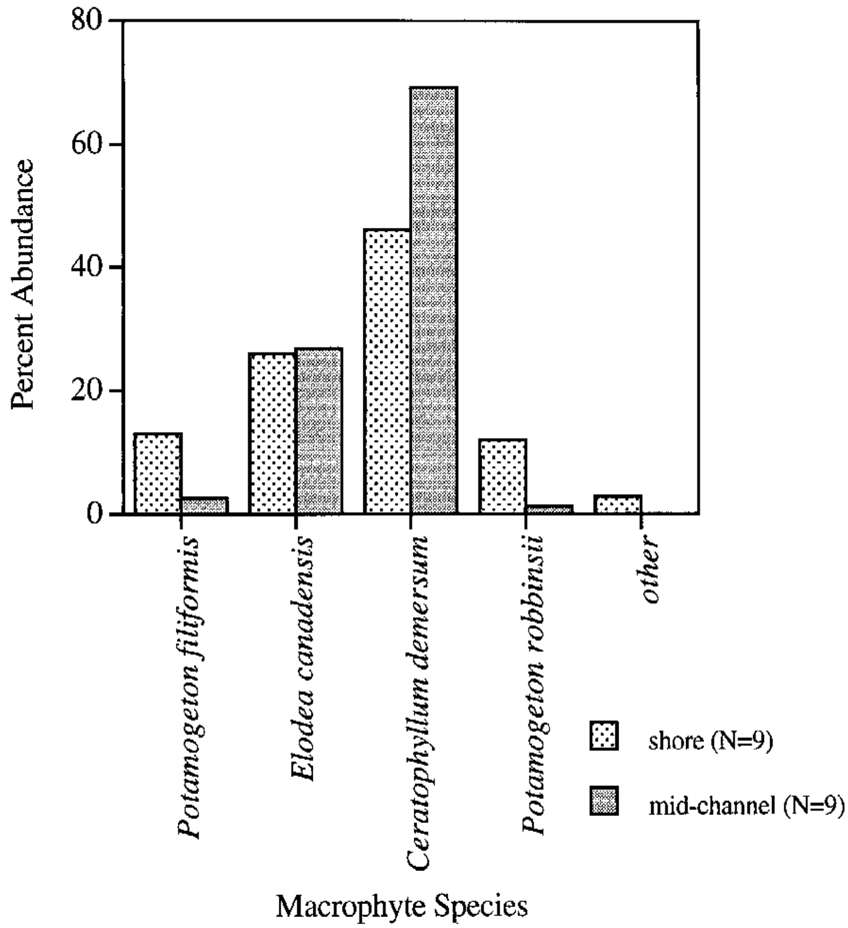

Figure 12: Species Abundance at Each Depth in Brown-End of Channel

Percent abundance values for each macrophyte species were averaged for each depth sampled to obtain a graph of species abundance for each depth sampled in Brown Channel. Included only are species of importance to trumpeter swan herbivory.

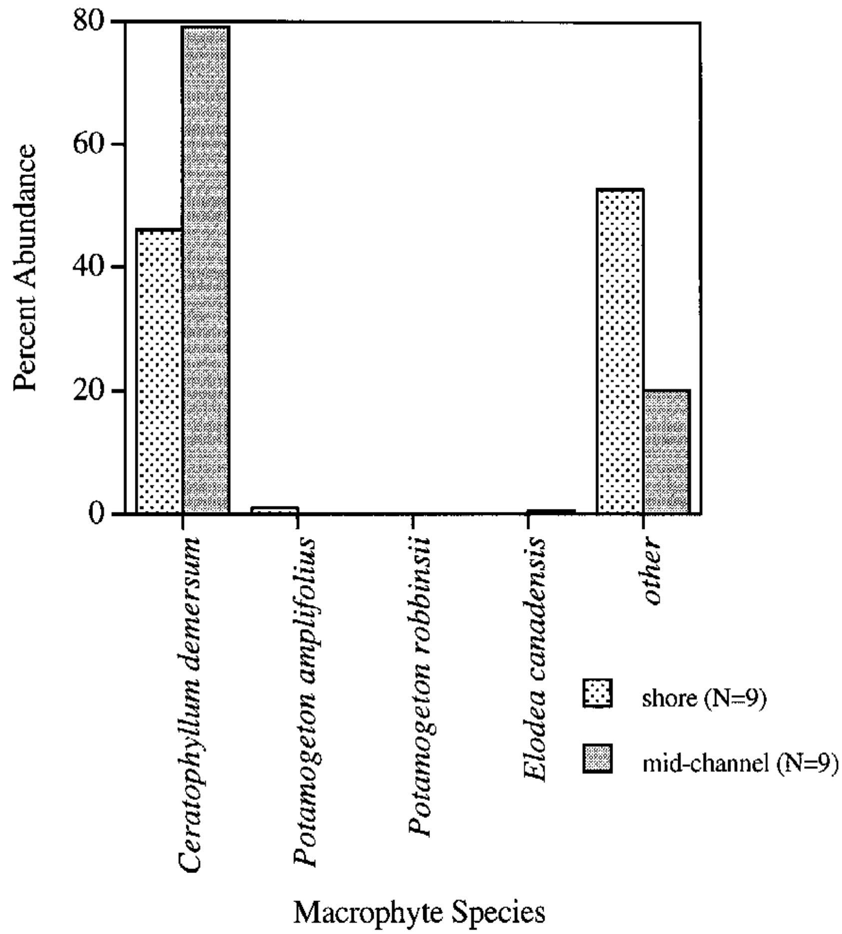

Figure 13: Species Abundance Each Depth Sampled in Kickapoo-End of Channel

Percent abundance values for each macrophyte species were averaged for each depth sampled to obtain a graph of species composition for each depth sampled in Kickapoo Channel. Included only are species of importance to trumpeter swan herbivory.

Species Diversity: Shannon-Weiner Index

BROWN LAKE

species	avg. % abundance	pi	ln pi	(pi)(ln pi)
l. americana	38.25	0.392	0.934	0.367
c. vulgaris	5.85	0.0602	2.81	0.169
l. trisulca	4.28	0.044	3.12	0.137
c. demersum	25.68	0.264	1.33	0.351
e. canadensis	0.3	0.00309	5.78	0.0179
p. amplifolius	2.3	0.0237	3.74	0.0886
v. americana	20.55	0.211	1.56	0.329
Sums =	97.21	1		H = 1.46
				Hmax = 1.95
				E = 0.75

KICKAPOO LAKE

species	avg. % abundance	pi	ln pi	(pi)(ln pi)
e. canadensis	7.03	0.0704	2.65	0.187
c. demersum	45.03	0.451	0.796	0.359
p. robbinsii	16.33	0.163	1.81	0.295
myriophyllum	4.21	0.0421	3.17	0.133
c. vulgaris	1.08	0.0108	4.53	0.0489
utricularia	16.68	0.167	1.79	0.299
p. amplifolius	9.4	0.0941	2.36	0.222
sparganium	0.125	0.00125	6.68	0.00835
Sums =	99.89	1		H = 1.55
				Hmax = 2.08
				E = 0.75

BROWN-END of CHANNEL

species	avg. % abundance	pi	ln pi	(pi)(ln pi)
p. filiformis	7.8	0.078	2.55	0.199
e. canadensis	26.35	0.264	1.33	0.351
c. demersum	57.65	0.577	0.55	0.317
sparganium	1.45	0.045	4.23	0.0613
p. robbinsii	6.65	0.0665	2.71	0.18
Sums =	99.9	1		H = 1.11
				Hmax = 1.61
				E = 0.69

KICKAPOO-END of CHANNEL

species	avg. % abundance	pi	ln pi	(pi)(ln pi)
c. demersum	62.6	0.626	0.468	0.293
p. amplifolius	0.5	0.005	5.3	0.0265
utricularia	21.45	0.2145	1.54	0.33
p. robbinsii	0.1	0.001	6.91	0.00691
sparganium	14.95	0.1495	1.9	0.284
e. canadensis	0.4	0.004	5.52	0.0221
Sums =	100	1		H = 0.96
				Hmax = 1.79
				E = 0.54

Figure 14: Species Diversity

Species diversity and evenness were calculated for all four habitats using the Shannon-Weiner Index.

similar diversity indices with Kickapoo Lake having a slightly higher diversity. The evenness indices, on the other hand, were identical in the 2 lakes. In comparison to the lakes, the ends of the channel had lower indices of species diversity and evenness. Based on the channel data alone, the Brown-end of the channel was found to have both higher species diversity and species evenness than the Kickapoo-end.

Discussion

The purpose of this survey was to quantify and characterize the belowground and aboveground biomass in Brown and Kickapoo Lakes as well as to look at the diversity of the two sites. The results may be useful in predicting where the swans will go when introduced to the sites. The data can also provide the baseline data obtained prior to the introduction of the swans that can be used in future trumpeter swan herbivory studies.

At least two trumpeter swans, one male and one female, will be introduced to the Brown/Kickapoo/channel system in May of 1998. This time of the summer presents a problem for the herbivorous birds due to the fact that few, if any, submerged macrophytes are present in the lakes. The swans must therefore obtain their nourishment by eating belowground biomass such as macrophyte tubers and seeds. The data obtained in this survey indicate that Brown Lake contains higher levels of belowground biomass than Kickapoo Lake especially at the depths 0.25 m and 0.50 m. This is important because it will be easier for the swans to obtain the biomass from the sediment at the shallower depths. It therefore follows that the Brown Lake habitat would make a better habitat for the swans at that point in the summer due to the presence of larger amounts of belowground biomass for feeding.

By midsummer, the swans will have mated and the cygnets will have hatched by July. This will have marked a change from a dependence on belowground biomass to a dependence on the abundant aboveground biomass for both feeding and nourishment of the cygnets. Based on the values for mean total aboveground biomass alone, it is predicted that the swans will favor the channel habitat due to the dense amount of macrophytes in those areas, especially in the channel area exiting Brown Lake. The lakes themselves, however, contain decent amounts of submerged macrophytes that would be able support the swan population. The obtained data indicate that at 0.5 m Brown has more aboveground biomass than Kickapoo, while Kickapoo has more at 2.0 m. The two lakes were found to have similar amounts of submerged macrophytes at 1.0 m and 1.5 m. It follows again from this that the environment provided by Brown Lake might be more suitable for the swans due to the larger amounts of submerged macrophytes at shallow depths that will be accessible by foraging.

Macrophytes as Swan Habitat and Food

It is important, however, to note that high quantities of biomass alone are not indicative of a good swan habitat, nor can they necessarily predict in which areas the swans will tend to stay. The food preferences of the swans may also play a role as well. Experiments have been done in the past examining the dietary preferences of the trumpeter swan. The studies have shown that the swans tend to favor such macrophytes as *Chara* spp., *Elodea canadensis,* and *Potamogeton* spp while avoiding such species as *Ceratophyllum demersum* and *Myriophyllum exalbescens* (Anderson and Squires 1994).

Based on these data on trumpeter swan food preferences, the data obtained on macrophyte species composition must be reevaluated. Although the channel had higher amounts of macrophytes, the data indicate that much of that mass is attributed to *Ceratophyllum demersum,* a species that swans have been found to avoid. The species composition data for Brown Lake indicate an abundance of such desired species as *Chara* and *Vallisneria,* although much of it is found at larger depths which may be more difficult for the swans to reach. The species composition data for Kickapoo Lake indicate the presence of such desired species as *Potamogeton* spp., *Elodea* and *Chara,* much of which is at accessible depths. However, the data also indicate the presence of *Myriophyllum* spp. as well as *Ceratophyllum,* both of which are undesired species.

Problems also arise when considering the food preferences of trumpeter swans because certain species preferences have been found to be affected by water chemistry. Conditions that may affect the swans' diet preferences include whether the water is hard or soft. Experiments have shown that trumpeter swans tend to like *Chara* spp., yet other studies have also shown that this preference is limited to hard water environments. This information may not be applicable, therefore, to a lake such as Brown which is a soft water environment (A. Froelich, graduate student, UND, *pers. comm.*)

Due to the variability in trumpeter swan dietary preferences, only predictions can be made about what macrophyte species the swans will favor and what exact areas of the environment the swans will inhabit. These predictions can only be confirmed when the actual introduction takes place and the effects of swan herbivory are examined through the use of such tools as caging experiments. These types of experiments would not only shed light on which specific macrophytes the swans target when they graze, but effects of the grazing on the diversity of the environment may also be examined. In this baseline survey, the species diversities of the various lake/channel environments were calculated using the Shannon-Weiner Index. These data can be used as baselines for caging experiments with the prediction that macrophyte species diversity will increase in the areas that are accessible to the swan foraging, while the areas within the cages will show decreased species diversity. It can be speculated that the lack of foraging within the cages will result in the domination of one macrophyte species over the rest while selective foraging outside of the cages will allow for the growth of more diverse species that would never have been able to survive without the foraging.

Through this survey, potential swan habitats have been characterized by amount of biomass present, species composition of that biomass, and species diversity. The results indicate that both Brown, Kickapoo, and the connecting channel will make suitable habitats for the introduced trumpeter swans. However, the data do not provide definite answers as to the specific areas the swans will inhabit or the specific macrophyte species that the swans will favor in their grazing habits. The data can provide a baseline for future experiments to be done on the habitats which will eventually provide answers to the questions about trumpeter swan herbivory and the effects it has on the habitat environment.

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