Winslow Homer: *Eight Bells*, 1886

Evaluating Influence of Carp on Aquatic Plants and Benthic Invertebrates Using Carp Exclosures in Cedar Lake, Polk and St. Croix Counties, WI

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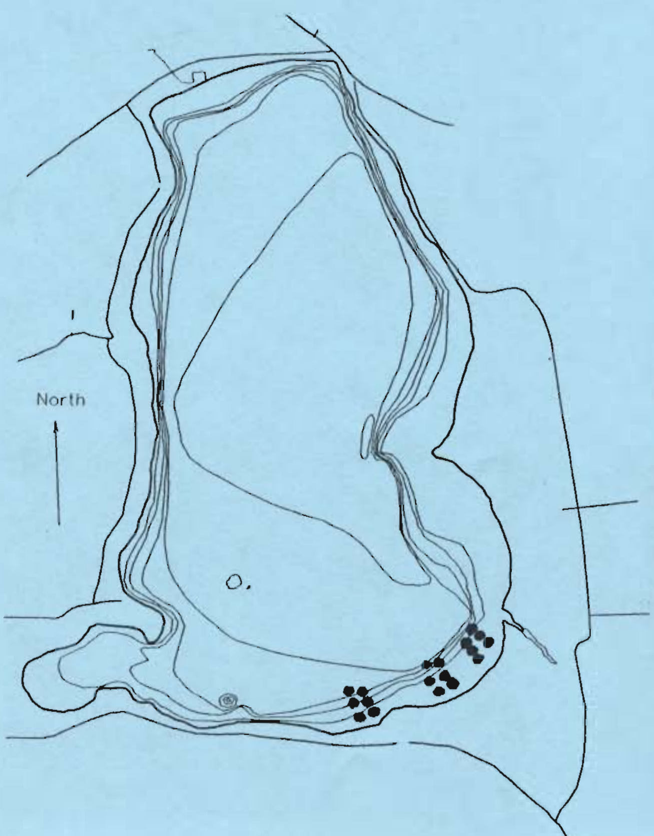
Evaluating Influence of Carp on Aquatic Plants and Benthic Invertebrates Using Carp Exclosures

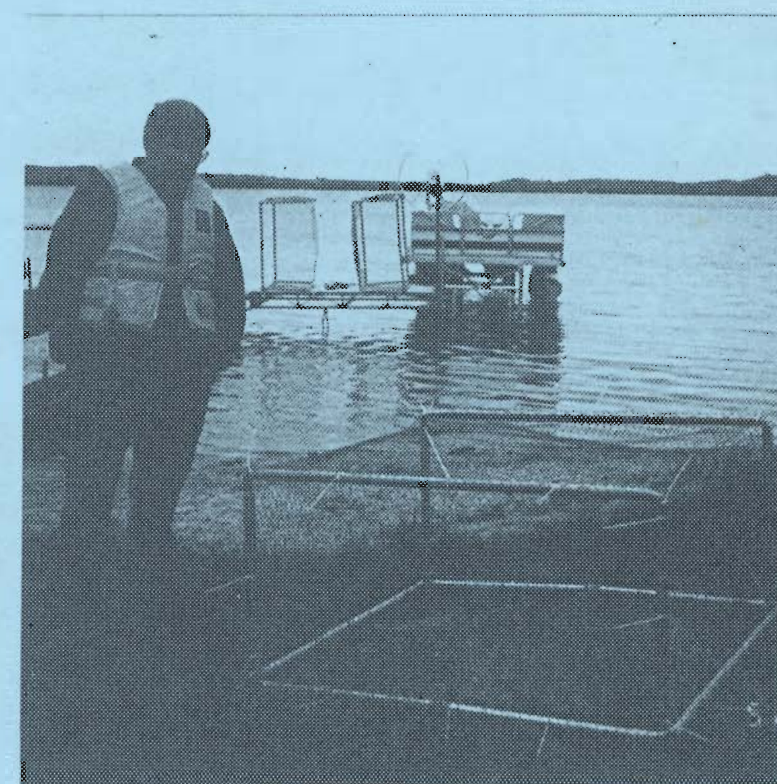
Summary

Reason for the Project: A Cedar Lake Management Plan was completed in 1989 and it identified carp as a major source of phosphorus to Cedar Lake. We thought carp may also have adverse impacts on aquatic plants and aquatic insects. We designed an experiment to examine the carp impacts on plants and aquatic insects.

Experimental Set-Up: We built 18 small cages and set them on the lake bottom in May, 1997. The cages were designed to keep carp away from the plants and insects living in the sediments inside the caged area. We did some initial sampling in June and sampled the aquatic plants inside the cages and areas outside the cages in early September. We compared the amount of aquatic plants and number of aquatic insects inside and outside of the cages.



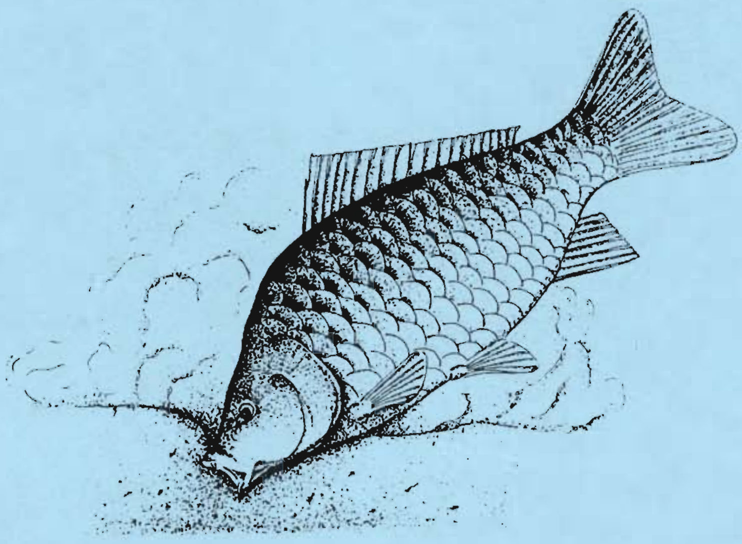
Exclosures were placed in three areas on the south side of Cedar Lake. Locations are shown above.



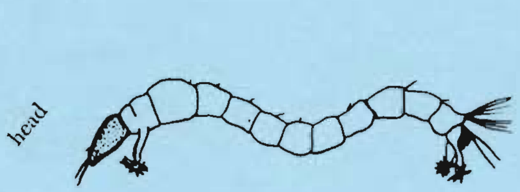
Lake District President, Jack Hayes, stands next to one of the eighteen "exclosures" that were placed in Cedar Lake in the 1997 summer.

What We Are Trying to Find Out: Because the cages will keep carp out of the area they cover, carp should have no impacts on plants and insects inside the caged area. If there are more plants and insects inside the cages compared to outside of the cages, it may that carp were not able to uproot plants or feed on the insects.

What We Found: More plants were growing inside the cages and than outside. It's possible that he cages kept carp out and that's why there were more plants inside the cages. The dominant aquatic insects found in the lake sediments both inside and outside the cages were midges (an example of a midge is shown below).



Carp seem to uproot plants in search of food. They ingest sediments but really they are looking for aquatic insect larvae that are in the sediments. Over centuries they apparently have discovered that there are more insect larvae in plant root systems than in the open lake sediment areas. Therefore, carp seem to seek out aquatic plant beds and search for food. It is in this feeding process that plants are uprooted as a by-product of their hunt for juicy aquatic invertebrates.



Of the sediment samples from Cedar Lake we examined, the aquatic invertebrates were dominated by midges (like the one shown above). They are less than ½- inch long and there were several hundred in a sample the size of a coffee cup.

Conclusions

Did we see any impact of carp on the aquatic plants or invertebrates based on results from our study? The answer is maybe with the aquatic plants, and there is a question mark with any impacts on the invertebrates.

Results from the invertebrate testing were inconclusive. At the June collection, cages had only been in the lake for a month, probably not long enough to be impacted by carp. The September sample date was about one week too late. The abandoned exoskeletons of millions of larval aquatic insects indicated there had been a hatch. The number of organisms in the sediment sample was low in the September analysis and there was not much difference between the inside and outside of the cages.

However plant results may have showed something. At the two shallow depths, we found more plant biomass and more plant species inside the cages than outside. Was this because carp were keeping the biomass down in areas outside the cages? That is one explanation. We did not rule out the factor that the cages were acting as a wave break and may have allowed plants to become established inside the cages. However, lake residents have stated that lush vegetation has grown in these shallow waters in the past. It appears plants can grow there, and sediment fertility is high enough to support plants as well. It appears we can make a case for carp limiting aquatic plant growth in Cedar Lake.

Evaluating Influence of Carp On Aquatic Plants and Benthic Invertebrates Using Carp Exclosures

Introduction

The Cedar Lake Management Plan (completed in 1989 by Buzz Sorge and Marty Engel -- WDNR) identified the carp population as a major source of phosphorus to Cedar Lake. In addition, carp can also have adverse impacts on aquatic plants and aquatic invertebrates. This study examined carp impacts on plants and invertebrates by looking at differences between open lake bottom areas and bottom areas excluded using exclosures underwater cages (exclosures).

Carp have been shown to add phosphorus to lake water as well as hinder aquatic plant growth. Was this the case in Cedar Lake?

The goal of this project was to evaluate the impact of carp activities on aquatic plants and aquatic invertebrates. We used small cages (exclosures) that excluded carp from bottom areas of Cedar Lake. We then compared differences between areas where carp had been excluded and areas where they had full access. Other studies have demonstrated adverse carp impacts on aquatic plants (Cahn 1929; Threinen and Helm 1954; Tyron 1954; King and Hunt 1967; Winkelman 1995) and on aquatic benthic invertebrates (Wilcox and Hornback 1991; Tatrai et al 1994). The long range goal for Cedar Lake is to improve water transparency and reduce phosphorus concentrations. It has been hypothesized that the carp populations may be a significant phosphorus source (Sorge and Engel 1989) and if they are found to be a factor adversely impacting aquatic plants, then there is additional support for carp control programs.

Methods

Exclosures

We installed 1.2 meter^2 (four feet by four feet) exclosures on three transects at three depths in Cedar Lake. Locations are shown in Figure 1. At each depth on a transect we used two exclosures and marked an area on the bottom that served as a control. There were nine sites on a transect and a total of 27 sample sites for all three transects. An exclosure was constructed by draping ½-inch mesh metal netting (chicken wire), over a frame made of 1-inch diameter metal conduit. Exclosures were four feet long, four feet deep, and two feet high. An exclosure was anchored on diagonal corners with 0.5-inch diameter rebar that was pounded into the sediment. Placement was made by scuba divers in deeper water (7 feet). Transect locations (Figure 1) were based on an earlier aquatic plant survey (Konkel and Borman 1996) that delineated plant species composition and sediment type.

We used an experimental approach that has been used since the 1950s . . . carp exclosures.

Aquatic Plants

Aquatic plant growth was observed over the summer growing season. In early September, aquatic plants were collected at all the sites, dried at 105°C for 24 hours and weighed. Stem densities and species composition were noted as well. A 0.10m^2 quadrat was used for making stem density measurements and collecting plant material for dry weight determinations.

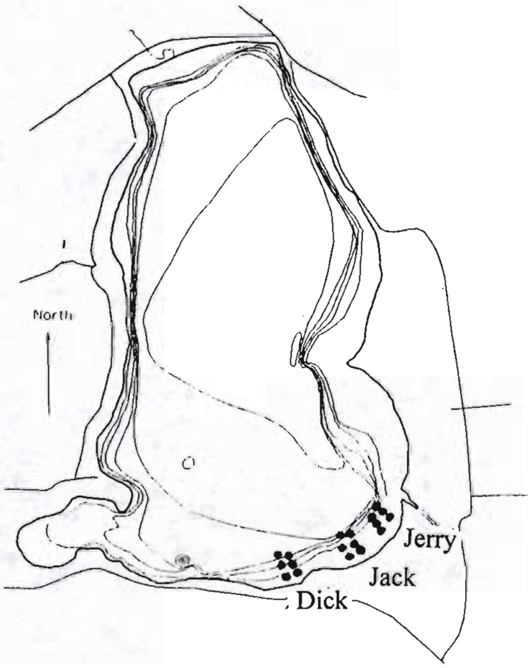
Aquatic Invertebrates

Aquatic invertebrates were sampled on two of the three transects. Duplicate samples were collected at each exclosure and control on two occasions - early summer (June 27) and late summer (Sept 9 & 15). A previous review of benthic biomass sampling (Timms 1995) recommended two sample dates. Samples were hand collected using a one liter glass jar and sieved through a 0.5 mm sieve.

Soils

Lake sediment chemistry was characterized at 9 sites using standard agricultural soil test methods. We collected duplicate samples at three depths on each transect. There were three transects.

A summary of sampling parameters to be collected are shown in Table 1. Photos of exclosures are shown in Figures 2 through 5.



We named the three transects after the names of the homeowners whose lot was the reference point for the transects.

Figure 1. Location of exclosures in Cedar Lake, Wisconsin.

Table 1. Data collection summary.

Date	Topic	Number of Samples	Comments
May 16	Cage placement	6	Jerry - 2 in shallow water; Jack - 2 in shallow, 2 - in mid. depth
May 18	Cage placement	12	Rest of the cages were placed.
June 27	Benthic invertebrates, all stations	36	See if species composition and biomass are different between control and exclosures in early summer and late summer [biomass in g/m^2, species richness in #/m^2]
Sept 9	Benthic invertebrates	30	All samples collected except Jerry - deep.
Sept 9,15	Collect rest of invertebrate samples	6	See if species composition and biomass are different between control and exclosures in early summer and late summer [biomass in g/m^2, species richness in #/m^2]
Sept 9, 15	Aquatic plants (Jerry & Dick - deep collected on 9.15)	54	See if species composition and biomass are different between controls and exclosures [biomass in g/m^2, species richness in #/m^2]
Sept 9, 15	Sediment chemistry (Jerry & Dick - deep collected on 9.15)	18	Relate sediment chemistry to water depth and to plant species distribution
Sept 15	Cage removal	18	recycled at Gary's Scrap Metal USA

Figure 2. A total of eighteen exclosures were placed in Cedar Lake. An example of an exclosure is shown above. Chicken wire was attached to the 1-inch diameter conduit with cable ties (bottom photo).

Figure 3. The south side of Cedar Lake is shallow. Exclosures were placed in 1.5 feet of water (top) and two feet of water (bottom). Exclosures were placed in Cedar Lake on May 16 and May 18, 1997.

Figure 4. In September, aquatic plants were subsampled inside the cages and outside by setting a square frame (quadrat) on the bottom and counting and collecting plants within the square. The quadrat is shown sitting on top of an exclosure in the top photo. A quadrat is shown sitting on the lake bottom in the bottom photo.

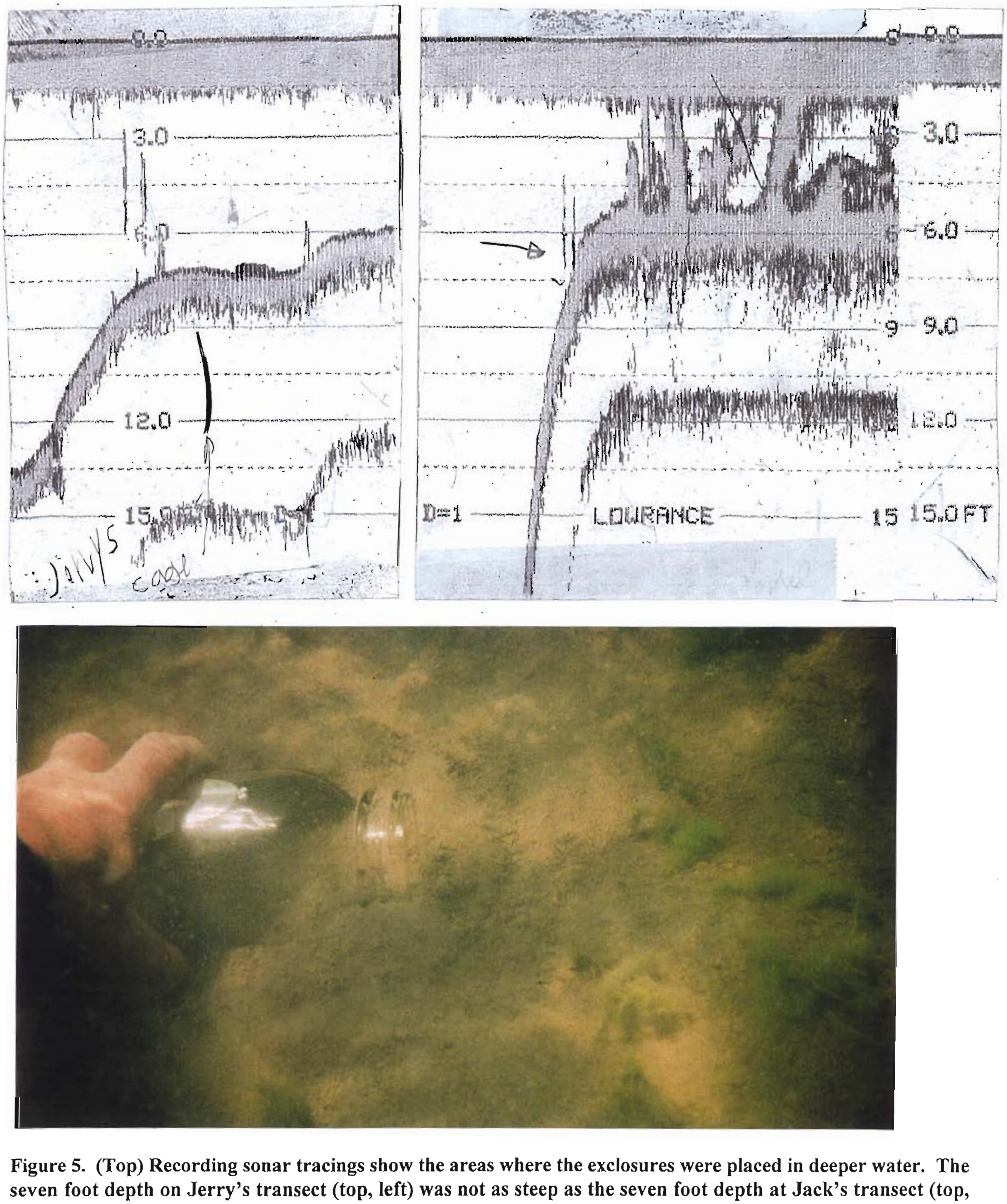


Figure 5. (Top) Recording sonar tracings show the areas where the exclosures were placed in deeper water. The seven foot depth on Jerry's transect (top, left) was not as steep as the seven foot depth at Jack's transect (top, right).
(Bottom) Invertebrate samples were collected using a glass jar and collecting sediments to a depth of 8 cm (3 inches).

Results

Aquatic Plants

We found more aquatic plants and more species of aquatic plants inside the cages compared to outside of the cages. Results are shown in Tables 2 and 3. The biomass (the weight) of aquatic plants was more than twice as much inside the cages compared to outside for the 1.7-foot water depth and nearly double the biomass at the 2.2-foot depth location.

The plant species found inside and outside of the cages are listed in Table 4. Water celery was dominant in the shallow water at Jack's transect (Figure 6) otherwise nitella, chara, naiads, elodea, claspingleaf pondweed, coontail, stringy pondweed, and sago pondweed (line drawing examples are shown in Figure 7) were found as well as filamentous algae (shown in Figure 8).

The different kinds of plant species found at the three depths are summarized in Table 5. More plant species were found inside the cages compared to the exposed lake bed (Table 5).

Most of the aquatic plants were found in the two shallow water depths. Light penetration was not very good at the 7-foot depth. Cages at 7-feet had very little plant growth inside, as well as having practically no attached growth on the chicken wire (Figure 9).

Table 2. Aquatic plant (dry weight in grams) for 0.1 m^2 quadrat. Exclosures were planed in Cedar Lake on May 16 and May 18, 1997 and samples were collected from the exclosures on September 9 and 15, 1997.

	Shallow Water Location (1.7')			Mid Water Location (2.2')			Deep Water Location (7')		
	Jerry	Jack	Dick	Jerry	Jack	Dick	Jerry	Jack	Dick
Cages A1	38.09	54.62	16.11	0.37	1.53	5.89	0.10	0	0
Cages A2	22.26	29.56	2.65	9.44	7.58	4.00	0	0	0
Cages B1	61.96	18.82	4.09	4.59	9.69	11.01	0	0	0
Cages B2	0	44.97	23.43	38.89	27.35	1.79	0	0.36	0
Open water	0	27.32	3.82	5.49	4.95	6.65	0	0	0
Open water	0	23.75	0	8.92	0	9.59	0	0	0

Table 3. Averages of Cedar Lake aquatic plant dry weights (g/0.1m^2).

Water Depth (ft)	Within Exclosure (g/0.1m^2)	n	Exposed Lake Bed (g/0.1m^2)	n
1.7	26.38	(12)	9.15	(6)
2.2	10.15	(12)	5.94	(6)
7.0	0.08	(12)	0	(6)

Table 4. Aquatic plant occurrence and densities in Cedar Lake. Results are shown as stems/0.1m². Filamentous algae is shown by abundance with X = low abundance. A and B samples are from within the cages and C is open water.

JACK	Shallow (1.7 feet)						Mid (2.2 feet)						Deep (7.0 feet)					
Species	A1	A2	B1	B2	C1	C2	A1	A2	B1	B2	C1	C2	A1	A2	B1	B2	C1	C2
Filamentous algae								X	X	X	X							
Naiads							2		4	4								
Chara										1								
Nitella																		
Water celery	10	9	9	15	15	11		3										
Northern watermilfoil																		
Elodea			3															
Sago pondweed							3		1	5								
Claspingleaf pondweed																		
Stringy pondweed																		
Coontail																2		
Dry wt of plants (g / 0.1m²)	54.6	29.6	18.8	45.0	27.3	23.8	1.5	7.6	9.7	27.4	5.0	0	0	0	0	0.4	0	0

JERRY	Shallow (1.7 feet)						Mid (2.2 feet)						Deep (7.0 feet)					
Species	A1	A2	B1	B2	C1	C2	A1	A2	B1	B2	C1	C2	A1	A2	B1	B2	C1	C2
Filamentous algae	XX	XX	XX				X	X	X	XX	X	X						
Naiads			14				1			10								
Chara							1	1		1								
Nitella										1								
Water celery																		
Northern watermilfoil																		
Elodea																		
Sago pondweed									2		3	5						
Claspingleaf pondweed																		
Stringy pondweed																		
Coontail								1					1					
Dry wt of plants (g / 0.1m²)	38.1	22.3	62.0	0	0	0	0.4	9.4	4.6	18.9	5.5	8.9	0.1	0	0	0	0	0

DICK	Shallow (1.7 feet)						Mid (2.2 feet)						Deep (7.0 feet)					
Species	A1	A2	B1	B2	C1	C2	A1	A2	B1	B2	C1	C2	A1	A2	B1	B2	C1	C2
Filamentous algae	X	X	X	X	X		X	X	X	X	X	X						
Naiads																		
Chara	1	2		1			2	1	2	1								
Nitella																		
Water celery																		
Northern watermilfoil																		
Elodea																		
Sago pondweed									3	3	1	2						
Claspingleaf pondweed			2															
Stringy pondweed				3														
Coontail																		
Dry wt of plants (g / 0.1m²)	16.1	2.7	4.1	23.4	3.8	0	5.9	4.0	11.0	1.8	6.7	9.6	0	0	0	0	0	0

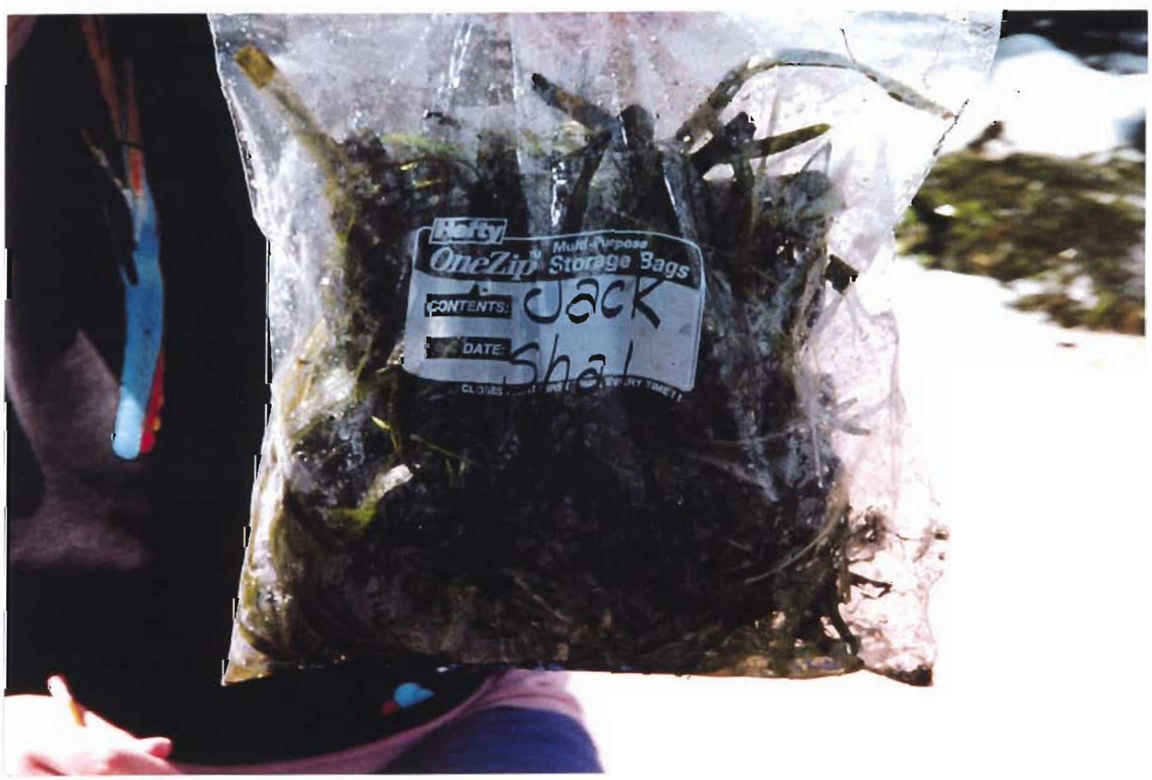


Figure 6. Water celery was the dominant plant on Jack's transect at the 1.7-foot deep location. It did not show up at the other two transects. Here we have collected a sample and this was sent to the lab for controlled drying and weighing.

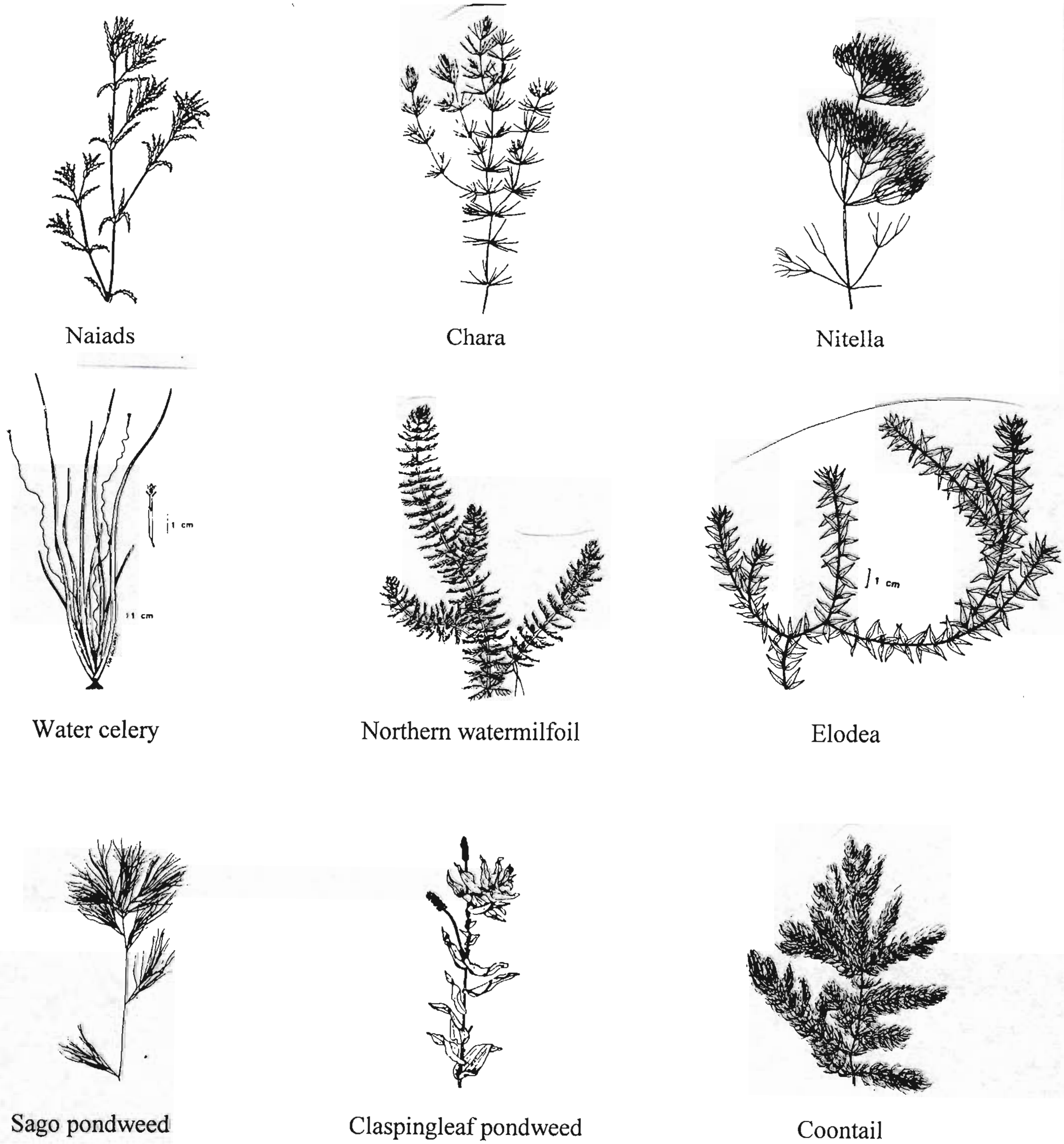


Figure 7. Examples of the types of plants found in the study.

Table 5. Number of plant species found in cages and in open water.

Water Depth (ft)	Within Exclosure	n	Exposed Lake Bed	n
1.7	7	(12)	2	(6)
2.2	7	(12)	2	(6)
7.0	1	(12)	0	(6)

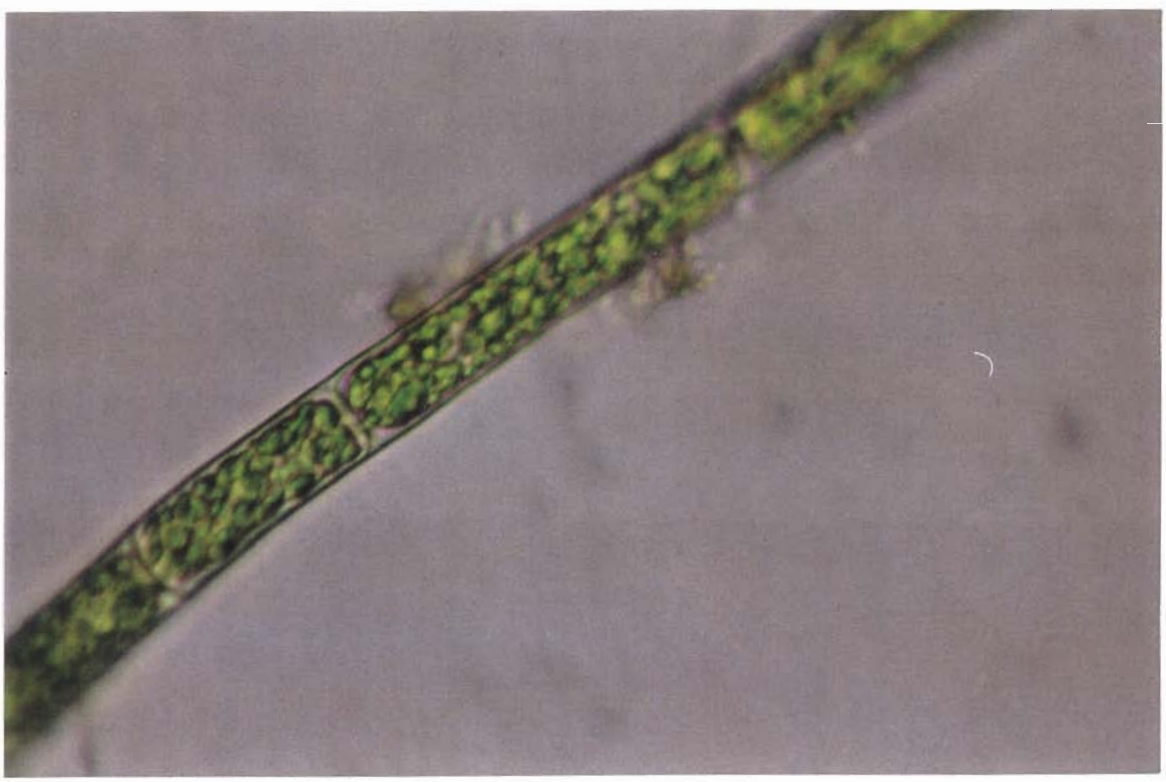


Figure 8. Filamentous algae represented a significant amount of plant biomass at several locations, especially on Jerry's transect. Here is a magnified photo of the filamentous algae found growing on the sediment surface. It is in the green algae family, but the species was not identified.

Figure 9. Some of the cages had things growing on them and some cages did not. In shallow water filamentous algae was growing on the chicken wire of the cages (top photo), where as in deeper water, we did not see any algae growth. However at the 7-foot depth we found freshwater sponges growing on the chicken wire (bottom photo) but not on the shallow water cages.

Results (continued)

Aquatic Invertebrates

Aquatic invertebrates serve several functions in lake systems. They shred plant material and help decompose dead plants. They also scrape algae off of plant leaves and stems. Aquatic invertebrates also serve as prey for fish, and are part of the lake food chain.

Carp will ingest sediments and then use their gillrakers to filter the benthic invertebrates (larval aquatic insects that live in the sediments). Results of the invertebrate analyses from inside and outside of the cages are shown in Tables 6 and 7. The key to the invertebrate labels is shown Tables 6 and 7 and line drawings of representative members of a group are shown in Figure 10.

We sampled invertebrates on two dates. We found the June sample date had more organisms present than the September sample date. Small chironomids were the dominant group in June.

Group averages for each sample date are listed in Table 8. For June, results are mixed. There does not appear to be a pattern between samples from inside or outside of the cages although more amphipods were found in the two shallow water sites compared to the deeper water sites and in greater numbers inside the cages compared to outside. For some of the other groups, more organisms were found in the areas outside the cage than inside. Cages were in place for about a month.

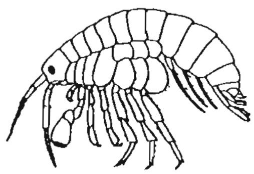
September was the next sample date. When we visited the lake in September we found thousands of exoskeltons washing up on shore. It was obvious there recently had been significant emergence of aquatic larval insects. Sample results show greatly reduced numbers of organisms both inside and outside of the cages compared to June (Table 8). The September results show a decrease in overall numbers, but any influence from fish predation is masked due to the emergence.

Table 6. Invertebrates found Cedar Lake sediments on June 27, 1997. Results are shown in number/m².

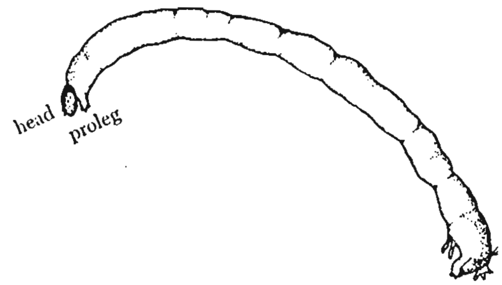
Case	Location	Amph m²	Chiron lgm	Chiron smm	Dipter m²	Ephem m²	Gastro m²	Hirud m²	Odon m²	Oligo m²	Trich m²
	Shallow										
1	control 1 - Jk	0	1504	752	752	0	0	0	0	752	15040
2	control 2 - Jk	0	1504	3008	752	0	0	0	0	1504	6768
3	control 1 - Jy	752	1504	40608	752	752	0	752	0	4512	752
4	control 2 - Jy	1504	3760	51136	752	0	0	0	0	2256	2256
5	cage A1 - Jk	18800	3760	3760	752	752	752	0	0	1504	2256
6	cage A2 - Jk	752	1504	5264	0	0	0	0	0	752	1504
7	cage B1 - Jk	0	0	0	0	0	0	0	0	3008	3760
8	cage B2 - Jk	752	0	0	0	0	0	0	0	1504	752
9	cage A1 - Jy	3008	2256	54144	0	0	0	0	752	1504	1504
10	cage A2 - Jy	7520	4512	138368	0	752	0	0	0	1504	752
11	cage B1 - Jy	3008	2256	49632	0	0	0	0	0	1504	1504
12	cage B2 - Jy	0	0	5264	0	0	0	0	0	0	7520
	Mid										
13	control 1 - Jk	0	3760	49632	0	752	0	0	0	3008	752
14	control 2 - Jk	0	3008	72944	752	0	0	0	0	3008	4512
15	control 1 - Jy	2256	752	24816	752	0	0	0	0	4512	752
16	control 2 - Jy	1504	1504	36848	752	0	0	752	0	6768	1504
17	cage A1 - Jk	6016	8272	46624	752	0	0	0	0	752	752
18	cage A2 - Jk	752	4512	43616	752	0	0	0	0	0	0
19	cage B1 - Jk	0	2256	27824	0	0	0	0	0	0	0
20	cage B2 - Jk	8272	4512	42112	752	0	0	0	0	752	0
21	cage A1 - Jy	9024	11280	66928	752	0	0	0	0	752	12784
22	cage A2 - Jy	2256	1504	25568	752	0	0	2256	0	0	4512
23	cage B1 - Jy	7520	3008	55648	752	0	0	0	1504	2256	6016
24	cage B2 - Jy	8272	752	57904	0	0	0	0	0	3008	6016
	Deep										
25	control 1 - Jk	1504	752	59408	3008	0	0	21808	0	3760	3008
26	control 2 - Jk	0	752	12784	0	0	0	11280	0	1504	3008
27	control 1 - Jy	752	0	0	0	0	0	752	0	2256	752
28	control 2 - Jy	0	0	3008	0	0	0	0	0	6768	752
29	cage A1 - Jk	0	752	10528	0	0	0	3008	0	15792	4512
30	cage A2 - Jk	1504	752	5261	0	0	0	752	0	5264	3008
31	cage B1 - Jk	752	752	9024	0	0	0	9024	0	2256	0
32	cage B2 - Jk	0	752	3008	0	0	0	752	0	3760	2256
33	cage A1 - Jy	0	0	0	0	0	2256	752	0	2256	0
34	cage A2 - Jy	0	0	0	0	0	0	0	0	1504	752
35	cage B1 - Jy	752	0	3760	0	0	0	0	0	1504	1504
36	cage B2 - Jy	0	0	3008	0	0	0	0	0	6768	752

Table 7. Invertebrates found Cedar Lake sediments on September 9 & 15, 1997. Results are shown in number/m^2.

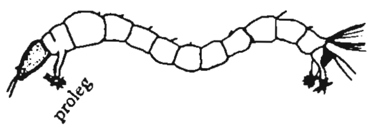
Case	Location	Amph m^2	Chiron lgm	Chiron smm	Coleop m^2	Gastro m^2	Hirud m^2	Oligo m^2	Trich m^2
	Shallow								
1	control 1 - Jk	3008	0	0	0	0	0	6768	752
2	control 2 - Jk	752	0	752	0	0	0	2256	752
3	control 1 - Jy	0	0	0	0	0	0	2256	1504
4	control 2 - Jy	752	0	0	0	0	0	3008	752
5	cage A1 - Jk	752	752	1504	0	0	1504	4512	0
6	cage A2 - Jk	0	0	752	0	0	1504	2256	0
7	cage B1 - Jk	0	0	0	0	752	2256	9024	0
8	cage B2 - Jk	1504	0	0	0	0	752	15792	1504
9	cage A1 - Jy	1504	0	752	0	0	0	752	0
10	cage A2 - Jy	1504	0	0	0	0	0	0	0
11	cage B1 - Jy	2256	0	2256	0	0	0	752	0
12	cage B2 - Jy	0	0	0	0	0	0	2256	0
	Mid								
15	control 1 - Jk	752	0	0	0	0	0	2256	1504
14	control 2 - Jk	0	0	2256	752	0	0	0	752
15	control 1 - Jy	3008	0	0	0	0	0	0	0
16	control 2 - Jy	8272	0	0	0	0	0	0	752
17	cage A1 - Jk	7520	0	752	0	0	752	0	752
18	cage A2 - Jk	0	0	0	0	0	752	0	0
19	cage B1 - Jk	2256	0	752	0	0	0	0	752
20	cage B2 - Jk	752	752	0	0	0	0	0	0
21	cage A1 - Jy	4512	0	0	0	0	0	1504	0
22	cage A2 - Jy	752	0	0	0	0	0	752	0
23	cage B1 - Jy	6768	0	1504	0	0	4512	3008	4512
24	cage B2 - Jy	0	0	1504	0	0	0	752	0
	Deep								
25	control 1 - Jk	0	0	0	0	0	0	4512	0
26	control 2 - Jk	3008	0	1504	0	0	752	1504	0
27	control 1 - Jy	0	0	0	0	0	0	752	0
28	control 2 - Jy	1504	0	2256	0	0	0	1504	0
29	cage A1 - Jk	0	0	0	0	0	0	752	0
30	cage A2 - Jk	0	0	0	0	0	0	3760	752
31	cage B1 - Jk	0	0	752	0	0	0	5264	1504
32	cage B2 - Jk	0	0	0	0	0	0	1504	0
33	cage A1 - Jy	0	0	0	0	0	0	6016	0
34	cage A2 - Jy	0	0	0	0	0	0	4512	0
35	cage B1 - Jy	0	0	0	0	0	0	5264	0
36	cage B2 - Jy	0	0	0	0	0	0	6016	0



Amph = Amphipods (scuds)



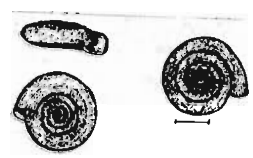
Chiron lgm = Chironomidae (large) (large midge larvae)



Chiron smm = Chironomidae (small)(midge larvae)

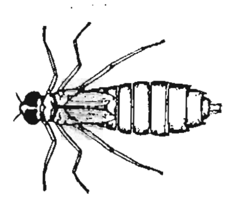
Dipter = Diptera (fly larvae)

Ephem = Ephemeroptera (mayfly larvae)

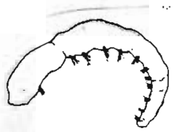


Gasto = Gastropoda (snails)

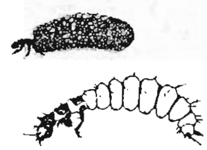
Hirud = Hirudinea (leeches)



Odon = Odonata (dragonfly larvae)



Oligo = Oligochaeta (worms)



Trich = Trichoptera (caddis flies)

Figure 10. Examples of the types of larvae found in the study.

Table 8. Averages of benthic invertebrates from Cedar Lake from two collection periods -- June and September, 1997.

June Averages

	Amph m²	Chiron lgm	Chiron smm	Dipter m²	Ephem m²	Gastro m²	Hirud m²	Odon m²	Oligo m²	Trich m²
Shallow										
control (n=4)	564	2068	23876	752	188	0	188	0	2256	6204
cage (n=8)	4230	786	32054	94	188	94	0	94	1410	2444
Mid Depth										
control (n=4)	940	2256	46060	564	188	0	188	0	4324	1880
cage (n=8)	5264	4512	45778	564	0	0	282	188	940	3760
Deep										
control (n=4)	564	376	18800	752	0	0	8460	0	3572	1880
cage (n=8)	376	376	4324	0	0	282	2858	0	4888	1598

September Averages

	Amph m²	Chiron lgm	Chiron smm	Coleop m²	Gastro m²	Hirud m²	Oligo m²	Trich m²
Shallow								
control (n=4)	1128	0	188	0	0	0	3572	940
cage (n=8)	940	94	658	0	94	752	4418	188
Mid Depth								
control (n=4)	3008	0	564	188	0	0	564	752
cage (n=8)	2820	94	564	0	0	752	1504	752
Deep								
control (n=4)	1128	0	940	0	0	188	2068	0
cage (n=8)	0	0	94	0	0	0	4136	282

Results (concluded)

Lake Soil Analysis

In the plant growing zone of the lake (the littoral zone) lake sediments really act like soils in that the sediments supply nutrients to rooted plants. We wanted to check the fertility of the lake "soils" in the areas we were conducting our experiments to see if they were fertile enough to support aquatic plant growth.

The question would arise if plants weren't growing in an area was it because the carp were keeping them down or was it the soils were too infertile to support plant growth.

We took replicate soil samples from three depths on each of the three transects for a total of eighteen samples. Soil analysis results (Table 9 and Figure 11) indicated that the lake soils at all the experimental locations were fertile enough to support rooted aquatic plant growth. This is based on the range of results found by McComas and Stuckert (1998) for other lakes where we have tested soils the same way. The range of fertility levels that supported plant growth from other lakes was similar to the range of fertility found in Cedar Lake.

Table 9. Replicate soil sample results from three depths on three transects in Cedar Lake.

	Field Id	Exch NH_4 (ppm)	Bray P (ppm)	Olsen P (ppm)	Exch K (ppm)	Mang (ppm)	Iron (ppm)	Sulfur (ppm)	Zinc (ppm)	Copper (ppm)	Boron (ppm)	Cations (ppm)			Org Mat	pH	CEC (meg/ 100g)
												Calcium (Ca)	Magnes (Mg)	Sodium (Na)			
Shallow																	
Jerry	1	2.8	7.0	4.8	20	10.6	24.2	36.5	0.28	0.26	0.29	1920	47.5	10	0.90	7.7	10.09
	2	2.6	7.2	5.9	24	12.4	22.6	34.3	0.30	0.30	0.28	1960	55.0	16	0.86	7.6	10.39
Jack	1	5.2	9.5	6.7	22	6.0	20.0	16.9	0.30	0.26	0.12	1400	42.5	60	0.78	7.4	7.67
	2	3.9	9.3	1.6	15	4.6	16.8	15.4	0.28	0.30	0.09	1080	30.0	6	0.48	7.6	5.72
Dick	1	1.1	7.4	3.6	20	6.2	18.4	30.7	0.28	0.24	0.23	1320	37.5	12	0.70	7.6	7.02
	2	2.0	8.5	4.3	28	6.8	22.2	23.5	0.30	0.30	0.21	1120	35.0	22	0.68	7.6	6.06
Mid																	
Jerry	1	2.9	10.1	6.7	33	17.2	33.8	36.0	0.34	0.26	0.53	1680	42.5	16	1.08	7.5	8.91
	2	2.2	11.0	6.7	30	18.0	29.6	49.9	0.32	0.24	0.50	1600	45.0	4	1.06	7.5	8.47
Jack	1	4.2	10.3	6.3	23	8.0	20.6	38.2	0.22	0.28	0.35	2200	47.5	40	1.16	7.5	11.63
	2	3.4	10.5	4.5	25	7.8	15.4	39.3	0.26	0.22	0.42	1800	40.0	22	1.10	7.5	9.49
Dick	1	2.0	12.0	10.1	40	9.2	21.2	38.4	0.34	0.26	0.51	1360	40.0	24	1.14	7.3	7.34
	2	2.0	10.8	8.5	28	8.0	18.4	38.0	0.30	0.26	0.49	1320	37.5	4	1.04	7.4	7.00
Deep																	
Jerry	1	9.3	7.0	11.0	24	28.6	50.0	25.0	0.34	0.26	0.34	2080	60.0	26	1.3	7.7	11.08
	2	7.4	7.0	10.0	22	28.0	55.0	22.0	0.32	0.24	0.35	2040	45	46	1.0	7.6	10.83
Jack	1	2.8	10.6	3.4	13	4.7	22.0	39.3	0.26	0.26	0.26	920	32.5	26	0.70	7.6	5.02
	2	2.8	8.9	3.6	11	5.0	17.0	46.6	0.26	0.24	0.23	1040	32.5	20	0.64	7.7	5.59
Dick	1	1.1	18.0	13.0	32	13.6	30.8	35.0	0.32	0.32	0.46	920	42.0	34	1.0	7.4	5.18
	2	2.7	14	11	34	9.7	26.0	48.0	0.32	0.32	0.48	1000	50	52	1.0	7.3	5.73

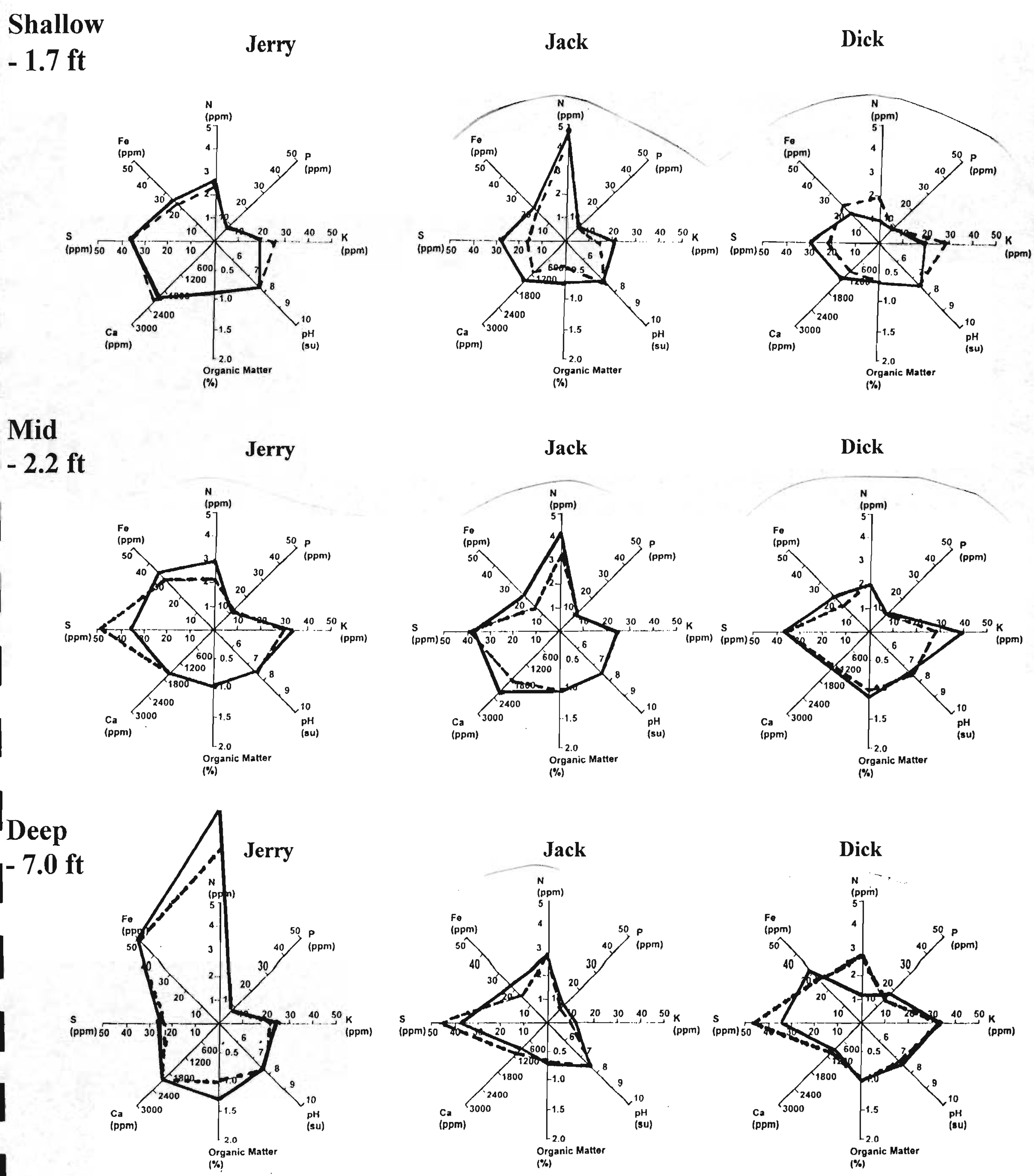


Figure 11. Soil sample results for eight parameters for each of the eighteen Cedar Lake soil samples are shown above. Concentrations are shown on the spokes of the "fertility wheel". Two analysis (replicates) for each sample location are shown with the dashed and solid lines.

Discussion and Conclusions

Did we see any impact of carp on the aquatic plants or invertebrates based on results from our study? The answer is maybe with the aquatic plants, and there is a question mark with any impacts on the invertebrates.

Results from the invertebrate testing were inconclusive. At the June collection, cages had only been in the lake for a month, probably not long enough to be impacted by carp. The September sample date was about one week too late. The abandoned exoskeletons of millions of larval aquatic insects indicated there had been a hatch. The number of organisms in the sediment sample was low in the September analysis and there was not much difference between the inside and outside of the cages.

However plant results may have showed something. At the two shallow depths, we found more plant biomass and more plant species inside the cages than outside. Was this because carp were keeping the biomass down in areas outside the cages? That is one explanation. We did not rule out the factor that the cages were acting as a wave break and may have allowed plants to become established inside the cages. However, lake residents have stated that lush vegetation has grown in these shallow waters in the past. It appears plants can grow there, and sediment fertility is high enough to support plants as well. It appears we can make a case for carp limiting aquatic plant growth in Cedar Lake.

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