An Investigation of the Physical Attributes, Chemical Properties, and Aquatic Biota of Kangaroo Lake

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Introduction

The Nature Conservancy requested that an analysis of water quality and aquatic biota be conducted on the north and south basins of Kangaroo Lake, located in Wisconsin's Door County. The Conservancy's primary objective is to compare the current aquatic state of the two basins to determine what, if any, differences exist between the undeveloped north basin and the nearly fully developed south basin.

Kangaroo Lake is located approximately one mile west of Baileys Harbor (see Figure 1) and is accessible via County Rte. E which crosses a causeway separating the north and south basins. The shores of the north basin are essentially development free (owned by the Conservancy). In contrast, the shores of the south basin are highly developed with privately owned homes, cottages and several small resorts. Two public access boat launches are located on the south basin, none on the north basin. Public access for small boats and canoes is available to both basins from the causeway.

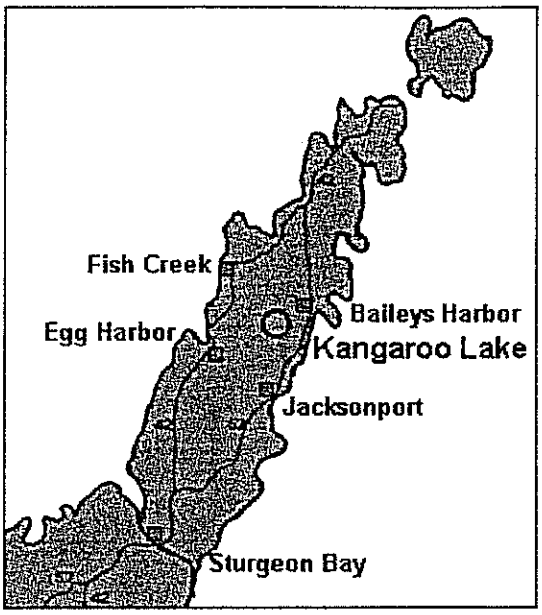


Figure 1 -- Door County, Wisconsin
Location of Kangaroo Lake

A University of Wisconsin – Green Bay graduate program team collected water, invertebrate, and macrophyte samples from, and made general morphology observations of, both basins on October 10, 1997. The collected samples were analyzed to determine:

1. Water physical and chemical properties including temperature, dissolved oxygen, alkalinity, pH, and specific conductivity

2. Light Attenuation and Secchi transparency

3. Chlorophyll a concentration

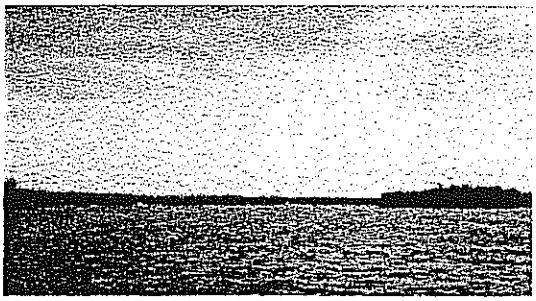
4. Zooplankton, invertebrate, and macrophyte diversity

In addition, the basin morphological features were documented.

The purpose of this report is to present the results of the analyses and observations, to compare the results from both basins, and to summarize the key findings from these comparisons.

Site Description

The two Kangaroo Lake basins are unique as far as their physical appearances are concerned. The south basin, much larger and deeper, has a shoreline that is almost completely developed (refer to Photograph 1). Property owners have protected their valuable shores by constructing breakwaters made of stone. As a result, the waters of the south basin probably receive significantly less allochthonous material due to lack of tree overhang. Minimal woody debris along the shallows also appears to be a consequence of this development. Bottom sediments in the shallow areas are composed of loose rocky material. Sparse stands of bulrush and cattail can be seen especially around the island and along portions of the eastern shoreline. Overall, little aquatic vegetation and waterfowl can be observed. On occasion one can catch a glimpse of a large submersed bed of aquatic vegetation several feet below the water's surface.



Photograph 1: Kangaroo Lake Shoreline

The north basin is significantly shallower than the southern basin, reaching a maximum depth of slightly over one meter. The bottom sediments are comprised of compacted cement-like marl (refer to Photograph 2). Under these conditions emergent stands of bulrush

Photograph 2: North basin bottom sediments Kangaroo Lake

submersed plant species are found in this well-lit basin. After bulrushes, cattails and lilypads are fairly common especially along the western shoreline. The interface between land and water is quite different in the northern basin as compared to the southern basin. No human development has occurred in this basin and therefore species of birch, aspen and cedar extend their limbs over the shoreline waters. The bottom material in these areas has a sandier composition with deeply embedded woody debris present. In addition, the northern basin appears to provide a more appealing stopping ground for coots and seagulls.

Photograph 3: North basin reed beds
Kangaroo Lake

Methods

Data was collected on several common lake characteristics to determine the effects of shoreline development in the northern and southern basins of Kangaroo Lake. This projects was done in coordination with Mike Grimm of the Nature Conservancy.

The lake characteristics examined and the instruments used are as follows:

Dissolved Oxygen, Alkalinity and pH

- Location of sample sites is indicated on Figure 2
- Van Dorn samplers were used to obtain water samples at 2 depth intervals in the north basin (0.25 m and 0.75 m) and 3 intervals (surface, 1m and 3m) in the south basin
- Dissolved oxygen was fixed immediately following sampling procedure
- Dissolved oxygen and alkalinity titrations were performed in the lab later the same day
- pH values were determined on each sample using an electrometric pH meter.

Conductivity and Temperature

- Recorded using a Yellow Springs Instruments model 33 meter
- Readings taken at various depth intervals based on the maximum depth of the basin (see Table 1 in the appendix)

Lake Clarity

- Determined using a standard Secchi Disc.
- Readings taken at the same sites as dissolved oxygen and alkalinity

Light Attenuation

- Recorded using a Yellow Springs Instruments LiCor Meter
- Readings taken at various depth intervals based on the maximum depth of the basin (see Table 1 in the appendix)

Macrophytes

- Collected throughout both basins using a vegetation rake with a handle approximately 12 feet long
- Macrophytes were also obtained by hand in shallower regions

Chlorophyll

- Samples were taken at the same sites as dissolved oxygen and alkalinity (see Figure 2)
- One sample taken at 1 meter was obtained from the north basin while an integrated sample from 1m and 2.5 m was obtained from the south basin

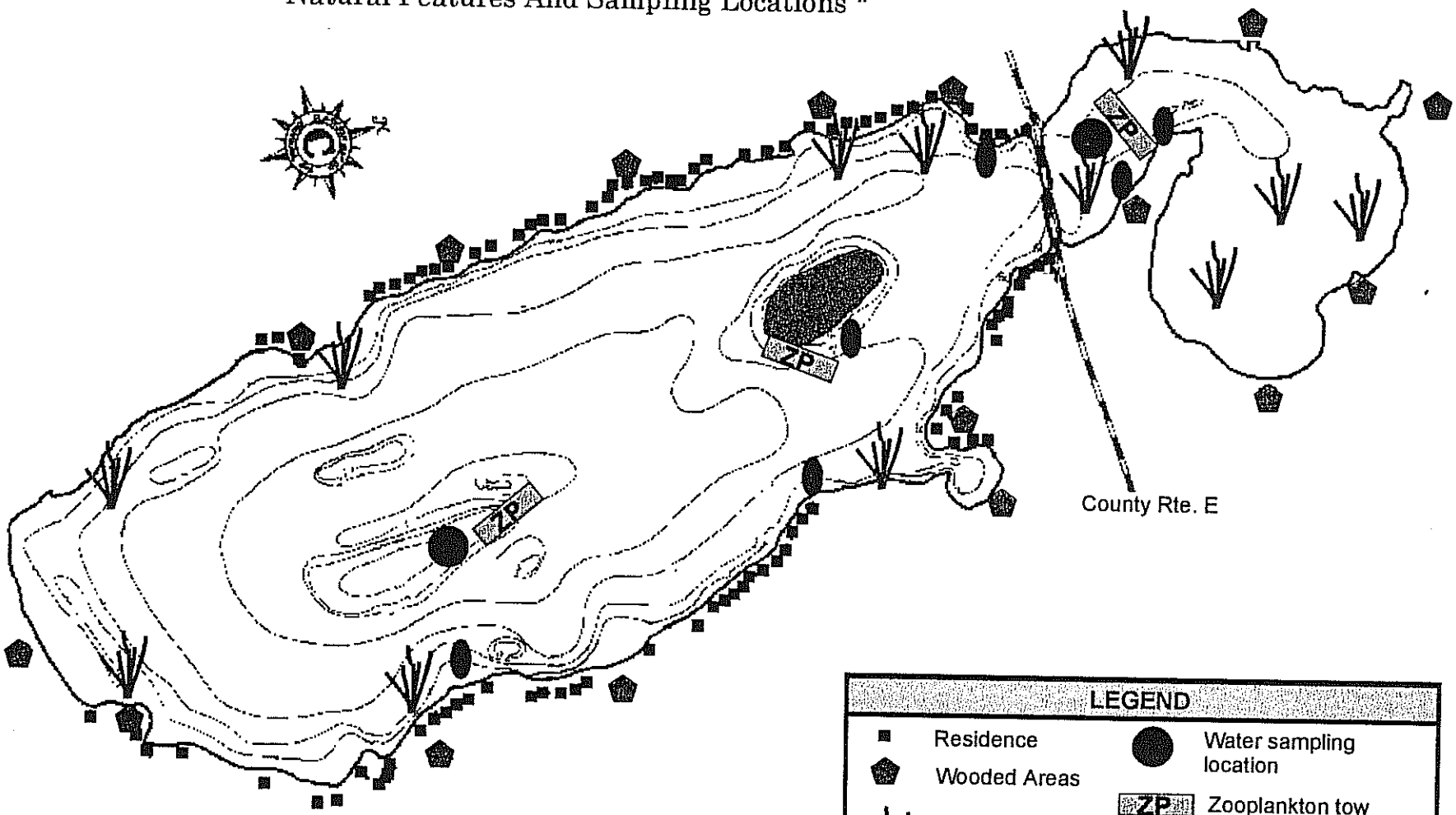
Zooplankton

- A 4.5" diameter zooplankton net was towed a linear distance of approximately 50 feet in the areas of the lake as designated on Figure 2.
- In the north basin, one tow in the deepest part of the lake was completed
- In the south basin, one tow occurred in the deepest part of the lake and a separate tow was taken through emergent vegetation.

Invertebrates

- Captured using two varieties of kick-nets lowered over the side of the boat. The smaller net was used to stir up the bottom sediments while the larger net retrieved the organisms as they were separated from the rocks and aquatic vegetation
- Sampling was concentrated in areas with an abundance of both emergent and submergent vegetation (see Figure 2 for locations)
- Specimens were preserved in 70% ethyl alcohol and later identified in the lab using Hilsenhoff's Aquatic Insects of Wisconsin (Hilsenhoff, 1995).

Figure 2
Kangaroo Lake
Natural Features And Sampling Locations *



* Basin features obtained from Door County Map number 1130, The Clarkson Company: Kaukauna, Wisconsin 54310

Results

The results from the measurements and sampling we performed are included in the following pages. The raw data and information regarding the calculations used in this analysis are included in Appendix A.

This section includes results of the following items:

Chemical and Physical Properties

Dissolved Oxygen
Temperature
pH
Specific Conductance
Alkalinity
Light Intensity and Attenuation

Aquatic Biota

Macrophytes
Chlorophyll a
Zooplankton
Invertebrates

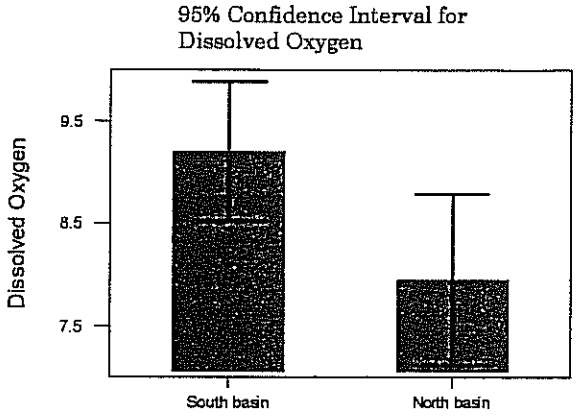
Dissolved Oxygen

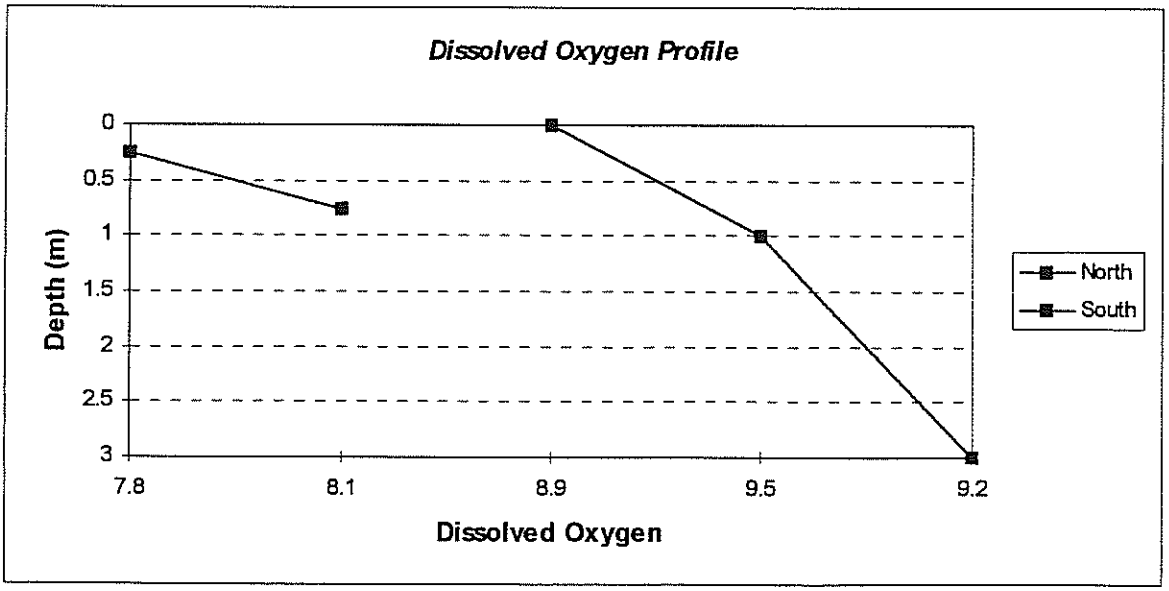
The measurement of dissolved oxygen provides valuable information about the biological and biochemical processes occurring in a lake. Oxygen is added to the system from the atmosphere and as a byproduct of photosynthesis. Oxygen is removed from the system through respiration and the breakdown of inorganic matter.

Detailed measurements of dissolved oxygen can be found in the Appendix A, Table 1. Average dissolved oxygen for the lake are shown below with a 95% confidence interval. The profile for the lake is shown in the chart at the bottom. These results indicate that there are differing amounts of dissolved oxygen in the two basins.

Average Dissolved Oxygen	
North basin	7.95 mg/l
South basin	9.20 mg/l

Percent O_2 Saturation	
North basin	77.1%
South basin	91.2%

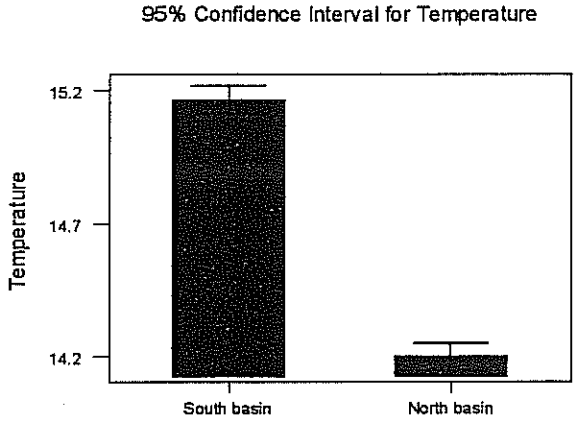




Temperature

Temperature is a factor influenced by solar radiation input. In turn, temperature affects other lake properties and the biota in the lake. Below is the average temperature for each basin along with its 95% confidence interval. Although the chart indicates a significant difference in temperatures between the basins, the raw data showed almost no variation (see Appendix A, Table 1) making these results suspect. With only a one degree difference in temperature, there was no sizable difference in temperature between the two basins.

Average Temperature	
North basin	14.2 °C
South basin	15.2 °C

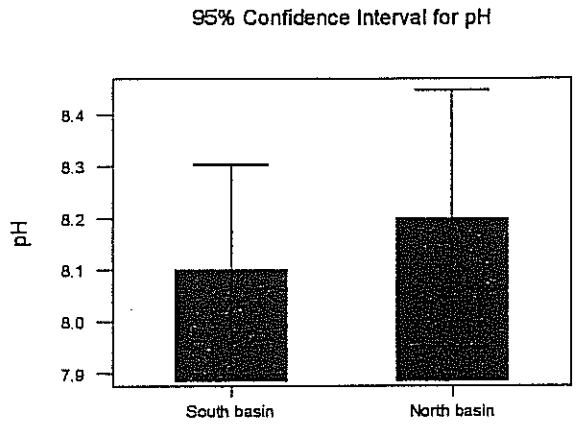


pH

pH is measured on a scale of 0 -14, with 0 - 7 representing an acid condition and 7-14 representing increasing alkalinity. An increasing amount of H+ or OH- ions causes the pH to move from the neutral reading of 7.

Below is the average pH for each basin along with the 95% confidence interval (refer to Appendix A, Table 1 for data). There was effectively no difference in pH between the basins. These results indicate a slightly alkaline state existing in both basins.

Average pH	
North basin	8.2
South basin	8.1

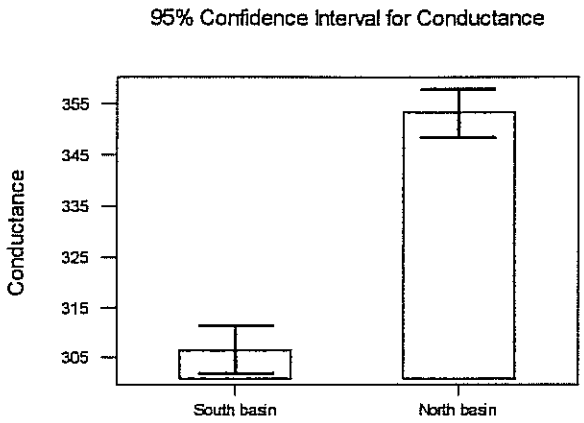


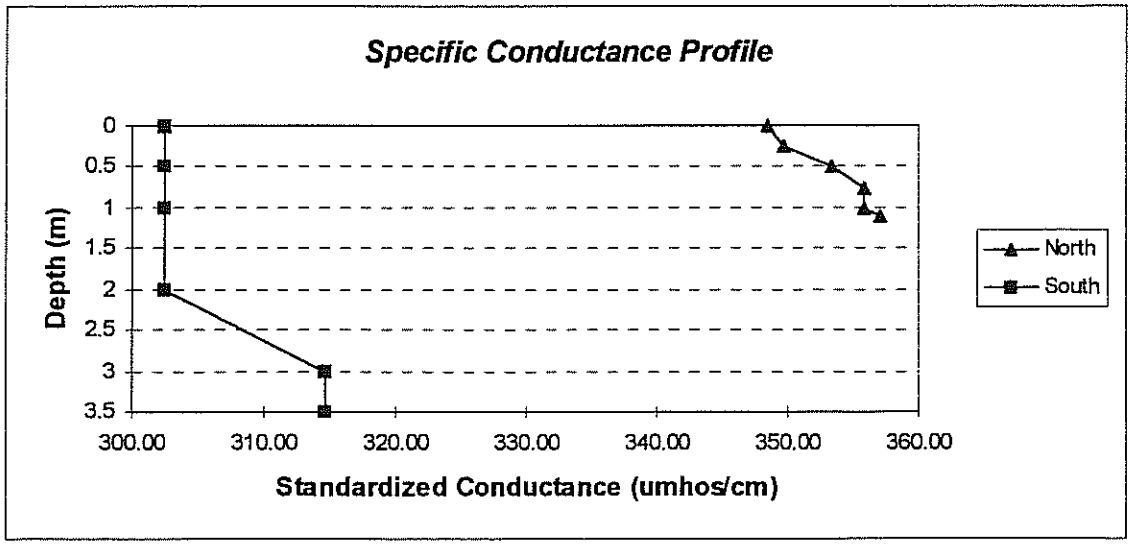
Specific Conductance

Conductance is a measurement of ion concentration. Fewer dissolved electrolytes leads to greater resistance. This measurement is affected by temperature therefore the values reported here have been standardized to 25 ^{o}C.

Detailed measurements of conductance can be found in the Appendix A, Table 1. Average conductance for the lake are shown below with a 95% confidence interval on these values. The profile for the lake is shown in the chart at the bottom. These results indicate that the north basin has a higher conductance than the south basin.

Average Conductance	
North basin	353.40 µmhos/cm
South basin	306.53 µmhos/cm



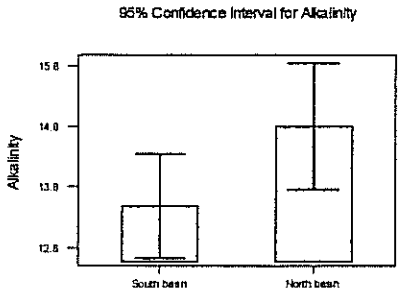


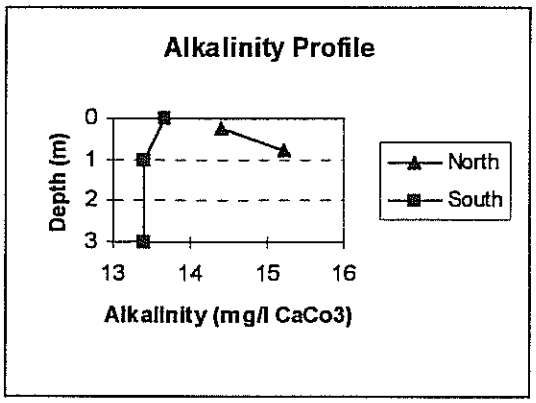
Alkalinity

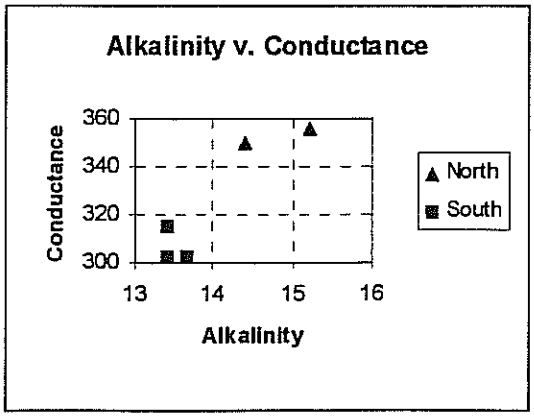
Alkalinity measurements denote the buffering capacity of the lake caused by dissolved substances that neutralize protons. It is an indicator of the amount of $CaCO_3$ in the water and may be composed of free CO_2, HCO_3^-, or $CO_3^=$. However, the pH obtained for Kangaroo Lake indicates that HCO_3^- is the primary constituent. Additionally, the fertility of a lake is related to the amount of phosphorous and nitrogen which are correlated with the availability of $CaCO_3$.

Detailed measurements of alkalinity can be found in the Appendix A, Table 1. Average alkalinity for the lake are shown below with its 95% confidence interval. The profile for the lake is shown in the chart at the bottom. These results indicate that the alkalinity in the north basin is slightly higher than the alkalinity in the south basin. The Alkalinity v. Conductance plot shows the expected high correlation between alkalinity and specific conductance.

Average Alkalinity	
North basin	14.8 mg/l $CaCO_3$
South basin	13.5 mg/l $CaCO_3$







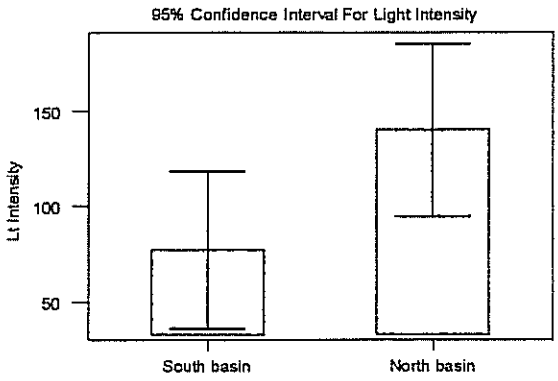
Light Intensity and Attenuation

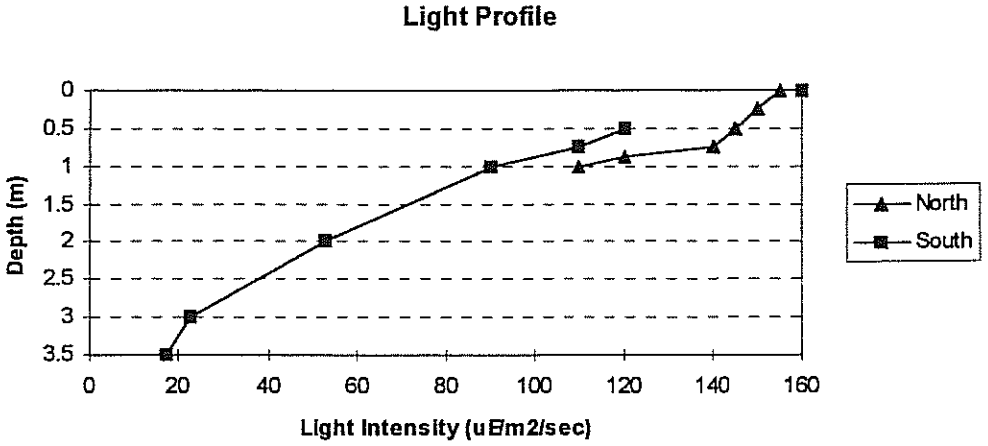
Various measurements of the light available in the lake are represented here. The Secchi readings are a measurement of light transparency. In the north basin, the disc could be seen to the bottom of the lake due to the shallow depth.

Secchi Transparency Averages	
North basin	1.09 m (bottom)
South basin	2.02 m

Light intensity as measured from the LiCor meter is shown below with a 95% confidence interval. The corresponding light profile is shown in the chart at left. Detailed measurements of light intensity can be found in the appendix, Table 1. These results show a significant difference in light intensities between the basins.

Light Intensity Averages	
North basin	140.0 $\mu E/m^2/sec$
South basin	77.1 $\mu E/m^2/sec$





The amount of light and the depth of its penetration are important factors in photosynthesis by phytoplankton and macrophytes. The depth of the photic zone where these biota exist is affected by light attenuation. As shown in Appendix Table 2, the depth of the photic zone in the north basin was calculated as 13.43 m. This calculated depth exceeds the actual basin depth indicating both the shallow depth of this basin and the low level of light attenuation. The condition is similar in the south basin where the calculated photic zone was 7.23 m, below the actual basin depth of approximately 4 m. This circumstance indicates a favorable environment for phytoplankton and macrophytes throughout the water column.

Light attenuation calculations (see the appendix, Table 2) indicate that background factors are the major contributor to the extinction of light in both basins. These background factors include dissolved matter, suspended particles, and the water itself. Chlorophyll was a minor contributor. Extinction due to background factors was higher in the south basin.

Light Attenuation	
North basin	0.343 µE/m/sec
South basin	0.647 µE/m/sec

% Extinction Due to Background	
North basin	67.3%
South basin	85.5%

Depth of Photic Zone	
North basin	13.43 m
South basin	7.23 m

Aquatic Biota

Macrophytes, zooplankton and invertebrate specimens were collected in each basin. These specimens were later identified as indicted in the appendix A, Tables 4, 5, and 6. The purpose of this effort was to identify species diversity. However, since the sampling of the biota was carried out over a single day a more complete picture of the lake biota could be obtained by extending the collection period throughout the year.

Macrophytes

Macrophytes were collected at numerous locations in each basin. The results of this effort can be seen in Table 4 in Appendix A. As indicated in Figure 3, six species were found in the north basin and eight species were found in the south basin.

Chlorophyll a Concentration

Sampling of phytoplankton did not occur during this investigation. However, water samples were taken to measure the amount of chlorophyll in the basins. The calculations used to obtain the results below can be found in Table 3 in Appendix A. The data suggests a somewhat higher concentration of chlorophyll a in the north basin.

Chlorophyll a Concentrations	
North basin	5.618 µg / l
South basin	4.604 µg / l

Zooplankton

Zooplankton were collected in each basin. Species were identified and counted using a Sedwick-Rafter Cell. Calculations were completed for abundance and biomass as shown in Appendix A, Table 5.

In Figure 3, it can be seen that more species were identified in the north basin.

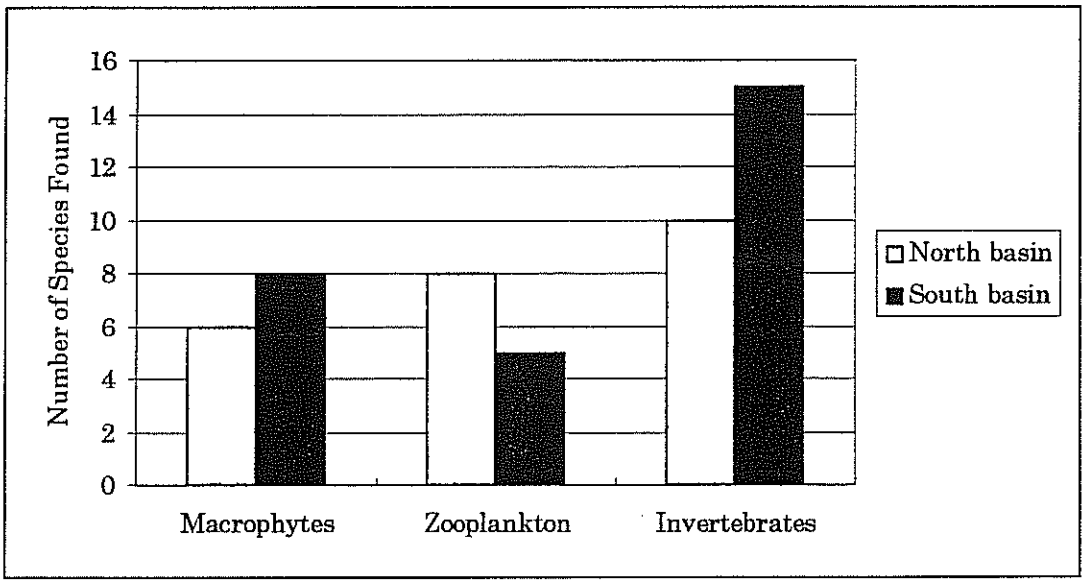
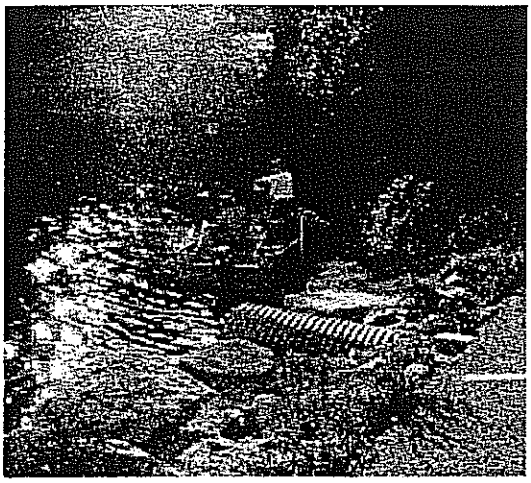


Figure 3 – Species Diversity

Aquatic Invertebrates

Our intent was to collect approximately 100 specimens from each of the north and south basins. This proved to be a more difficult task than anticipated. The southern basin of Kangaroo Lake had a lower overall abundance of aquatic invertebrates however their diversity was higher (see Figure 3). The opposite was true for the northern end. A majority of the specimens collected in the southern basin were found near a culvert that joined the waters of the northern and southern basins (refer to Photograph 4). There were very few adequate habitats for the invertebrates in the southern basin due to the high amount of developed shoreline.

The northern basin provided potentially better shoreline habitat for many of these invertebrates. Twice as many aquatic invertebrates were collected in the northern basin in the same amount of time spent collecting in the southern basin.



Photograph 4: Culvert near invertebrate sampling area (Kangaroo Lake)

Using Hilsenhoff's biotic index (Hilsenhoff, 1987), tolerance values were assigned to each genus. This value was derived by averaging the values for all species of a given genus represented in the index. The invertebrate sampling results with the assigned tolerance values are included in the appendix, Table 6.

In general, the genera collected in both basins of Kangaroo Lake had relatively high tolerance values indicating that the invertebrates would be able to withstand a fairly significant amount of organic pollution in the lake. Those orders which are extremely sensitive to organic pollution, such as the Plecoptera, were not found in either basin.

Comparison With Previous Results

Measurements of water clarity (Secchi Disc transparency), Chlorophyll a concentrations, and temperature were obtained during the spring, summer, and fall seasons of 1993, '94, and '95 in the south basin and in 1995 in the north basin. These data are attached as Appendix B.

A comparison of these data at comparable seasonal dates with our October 1997 data is shown below.

Basin	Date	Chlor a (µg/l)	Secchi Disc (m)	Avg. Temp. (oC)
South	10/10/97	4.60	2.02	15
	10/30/95	7.25	1.37	6
	10/3/94	8.69	1.37	10
	11/3/93	14.70	1.22	3
North	10/10/97	5.62	1.09 (bottom)	14
	10/30/95	2.52	0.91	5

At these particular seasonal dates, a general temporal trend of decreasing chlorophyll a concentration and increasing water clarity (Secchi depth) is suggested by the data for the south basin. Overall, these two trends are consistent and suggest that the concentration of chlorophyll a could be a significant contributor to water clarity in the south basin. The inverse is indicated by the comparable data from the north basin where the Secchi depth data indicates that water clarity between 1995 and 1997 increased along with an increase in chlorophyll a. This could imply that background factors, such as dissolved and suspended particulates, were dominant during the 1995 sampling period. However, Secchi depth in the north basin may not be valid because of the shallow lake depth.

Calculation of the Wisconsin Trophic State Index (TSI) (Lillie, et. al., 1993), using both Chlorophyll a concentrations and Secchi depth readings at comparable seasonal dates produced the results shown in Figure 4. The south basin exhibits a

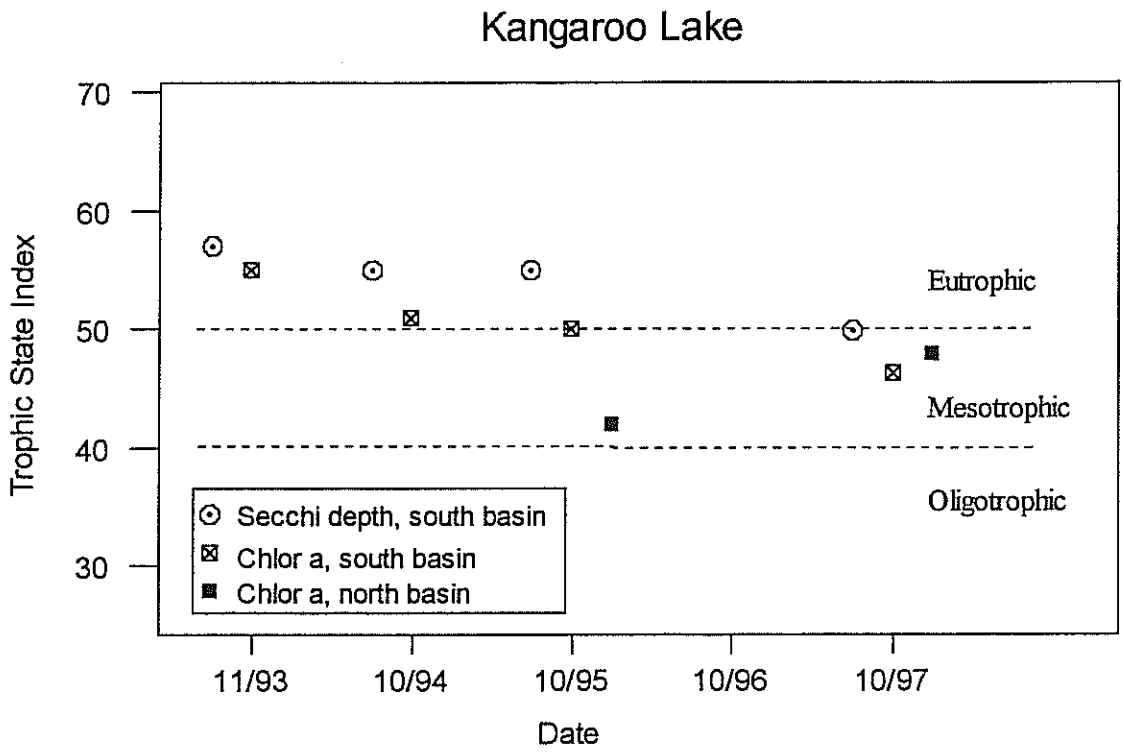


FIGURE 4

definite trend changing trophic states from eutrophic in October 1993 to marginally mesotrophic in October 1997 based on Chlorophyll a and Secchi depth TSI's. The north basin shows an opposite trend with the Chlorophyll a TSI increasing between October 1995 and October 1997, however the trophic state remained in the mesotrophic range. No Secchi depth TSI's were calculated for the north basin due to the shallow depth previously described.

The temperature profiles for all the sample dates indicate that neither of the basins achieve stratification during the seasons sampled. This indication of

continuous mixed state is most likely attributable to the large surface-area-to-depth ratios of both of the basins (i.e. promotes a wind effect contributing to mixing).

The above assessment should be viewed as an observation only because of the small set of data samples compared. Additional data would be needed to derive conclusive comparisons but the trends appear to be reasonable.

Summary & Conclusions

The following presents a brief summary of the findings from the October 10, 1997 Kangaroo Lake sampling project. Further details are contained in the *Results* section of this report.

⇒ The measurements of dissolved oxygen indicate a slightly higher amount in the south basin. However, this value represents an average for all depths and may simply be a larger value due to the greater depth of the south basin. Additionally, comparison of one sample is not adequate to determine if a true difference exists between the basins.

⇒ Both basins exhibited non-stratified temperature profiles suggesting that both were in a mixed state. Previous data from 1993, '94, and '95 verify this finding and show that this mixed state persists from late spring through late fall (larger surface area-to-depth ratio allowing for wind mixing effect).

⇒ pH levels in both basins are in the mid-range suggesting that the water in the basins is in a medium hardness category. The levels suggest that CO2 concentration is primarily in the form of HCO3.

⇒ Conductance and alkalinity measurements showed higher values in the north basin. However, similar to dissolved oxygen analyses, further samples are required to detect a "real" difference.

⇒ Light extinction rate was higher (for comparable depth) in the south basin. Since Chlorophyll a concentration was higher in the north basin, this higher extinction rate is attributed to higher background factors (dissolved and suspended particulates) in the south basin.

⇒ Macrophyte diversity was higher in the south basin. This may be attributable to the environment in the south basin but more likely is due to the larger size of the south basin and our sampling technique.

⇒ Zooplankton diversity was higher in the north basin. This was the only diversity category where the north basin showed an increase over the south basin. This may be related to a particular zooplankton growth cycle peaking in the north basin at the time of our sampling. Additional samples could verify the diversity values.

⇒ Invertebrate diversity was higher in the south basin whereas abundance was higher in the north basin. However, overall diversity and abundance were relatively low in both basins. This is attributed to the type of bottom structure and the shoreline development (in the south basin).

⇒ Calculated values of the Wisconsin Trophic State Index (TSI) based on both Chlorophyll a and Secchi depth suggest that the basins are in the mesotrophic range. Comparison with previous TSI's calculated in 1993, '94, and '95 indicate that the south basin may be changing form eutrophic state to the mesotrophic state whereas the north basin remains mesotrophic.

Quantitative comparisons to determine the impact of the anthropogenic and natural effects on the physical and chemical properties of the water and aquatic biota in the two basins will require considerably more data than obtained during this study. Temporal variation requiring seasonal and annual data are needed to "track" the changes in all the parameters measured to separate long term variances from short term perturbations.

Works Cited

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Hilsenhoff, William L. (1987). An Improved Biotic Index of Organic Stream Pollution. The Great Lakes Entomologist 20(1):31-39.

Lillie, R. A. et. al. (1993) Trophic State Index Equations and Regional Predictive Equations For Wisconsin Lakes. Research Management Findings. Wisconsin Department of Natural Resources. No. 35.

Appendix A

Contents

Table 1 -- Water Physical and Chemical Properties

Kangaroo Lake, Door County, Wisconsin
October 10, 1997

Lake Section	Z (m)	Dissolved Oxygen (mg/l)	Alkalinity (mg/l $CaCO_3$)	pH	Temp. (^oC)	Standardized Conductance (μmohs/cm)	Light Intensity ($\mu E/m^2/sec$)
North	0.00				14.2	348.4	155.0
	0.25	7.8	14.40	8.1	14.2	349.7	150.0
	0.50				14.2	353.4	145.0
	0.75	8.1	15.20	8.3	14.2	355.9	140.0
	1.00				14.2	355.9	110.0
	1.09				14.2	357.1	
South	0.00	8.9	13.65	8.1	15.2	302.5	160.0
	0.50				15.2	302.5	120.0
	1.00	9.5	13.40	8.1	15.2	302.5	90.0
	2.00				15.2	302.5	53.0
	3.00	9.2	13.40	8.1	15.2	314.6	22.5
	3.50				15.0	314.6	17.2

Table 2 – Light Attenuation Calculations

Kangaroo Lake, Door County, Wisconsin
October 10, 1997

Light Extinction	North	South
$Epar = \frac{\ln I_0 - \ln I_z}{z}$	$\frac{\ln(155) - \ln(110)}{1m} = 0.343$	$\frac{\ln(160) - \ln(17.2)}{3.5\ m} = 0.637$

Background Extinction	North	South
Eb = Epar - Kc(Chlor)	0.343 - 0.02(5.618) = 0.231	0.637 - 0.02(4.604) = 0.545

% Contribution of background factors to total extinction	North	South
Eb / Epar	0.231 / 0.343 = 0.673	0.545 / 0.637 = 0.855

Depth of Photic Zone	North	South
$z = \frac{\ln(100) - \ln(1)}{Epar}$	$\frac{\ln(100) - \ln(1)}{0.343} = 13.43\ m$	$\frac{\ln(100) - \ln(1)}{0.637} = 7.23\ m$

Table 3 – Chlorophyll Data

Kangaroo Lake, Door County, Wisconsin
October 10, 1997

Basin	UV Spect. Rdg. - E	UV Meter Setting
North	0.0297 Absorption/ Turbidity	@ 750 nm
	0.0593 "	@ 664 nm
	0.0441 "	@ 647 nm
	0.0415 "	@ 630 nm
South	0.0243 Absorption/ Turbidity	@ 750 nm
	0.0485 "	@ 664 nm
	0.0353 "	@ 647 nm
	0.0334 "	@ 630 nm

Calculations: Chlorophyll a (mg/l) = (Ca)(v) / (V)(Z)

Where: Ca = 11.85E - 1.54E - 0.08E
v = 8 ml
V = 0.9 l
Z = 1

Results: North basin Chlorophyll a 5.618 µg/l
South basin Chlorophyll a 4.604 µg/l

Table 4 -- Aquatic Plants

Kangaroo Lake, Door County, Wisconsin
October 10, 1997

Genus/species	Common Name	North	South
Chara vulgaris	Chara	✓	✓
Nuphar variegatum	Yellow Pond Lily		✓
Scirpus acutus	Hardstem Bulrush	✓	✓
Myriophyllum exalbescens	Water Milfoil	✓	✓
Potamogeton crispis	Curly Pondweed	✓	✓
Potamogeton pectinatus	Sago Pondweed		✓
Najas flexlis	Bushy Pondweed	✓	
Utricularin vulgaris	Bladderwort		✓
Typhaceae angustifolia	Narrow Leaved Cattail	✓	✓

Table 5 -- Zooplankton Diversity

Kangaroo Lake, Door County, Wisconsin
October 10, 1997

North Basin

Zooplankton species	Average # / cell	Abundance (# / liter)	Biomass (mg C / m^3)
Bosmina	0.92	1.07	0.91
Chydorous bicornutus	0.02	0.02	0.02
Cyclops	0.11	0.13	0.56
Diaptomous	0.15	0.175	1.75
Keratella cochlearis	0.04	0.05	0.0018
Nauplius	0.02	0.02	0.01
Polyarthra	0.02	0.02	0.0006
Rotifer x.	0.06	0.07	(*)

South Basin

Zooplankton species	South (vegetation)			South (open water)		
	Average # / cell	Abundance (# / liter)	Biomass (mg C / m^3)	Average # / cell	Abundance (# / liter)	Biomass (mg C / m^3)
Bosmina	0.02	0.05	0.04	0.10	0.45	0.38
Diaptomous	0.02	0.05	0.5	0.45	2.01	20.1
Nauplius	0.13	0.30	0.15	0.00	n/a	n/a
Polyarthra	0.02	0.05	0.0015	0.00	n/a	n/a
Rotifer x.	0.10	0.23	(*)	0.00	n/a	n/a

* This species represented an unidentified Rotifer. The dry weight could not be obtained to calculate the biomass.

Table 6 -- Invertebrate Diversity

Kangaroo Lake, Door County, Wisconsin
October 10, 1997

			North		South	
Order	**Family**	**Genus**	**Quantity Collected**	**Tolerance Value ***	**Quantity Collected**	**Tolerance Value ***
Amphipoda	Gammaridae	Crangonyx	18	8	3	8
Coleoptera	Gyrinidae	Dineutus			3	
		Gyrinus			5	
Coleoptera larva	Elmidae	Stenelmis			10	5
Diptera	Chironomidae		1	6.6		
Ephemeroptera	Caenidae	Caenis	10	7	1	7
	Ephemeridae	Hexagenia			2	6
	Heptageniidae	Stenacron			1	7
		Stenonema			3	3.38
Isopoda	Asellidae	Lirceus	20		2	
Lepidoptera (non-aquatic)			4		1	
Mollusca (snails)			21			
Odonata	Aeshnidae	Basiaeschna			2	6
	Coenagrionidae	Amphiagrion	23	8		
		Coenagrion			2	8
	Corduliidae	Epitheca	6	7	1	7
	Gomphidae	Hagenius	1	1		
Sponge			1			
Trichoptera	Helicopsychidae	Helicopsyche			3	3
	Leptoceridae	Nectopsyche			2	3

* Tolerance values are indicated per individual.

Appendix B

Trophic State Index calculations for October 10, 1997

and

Previous data collected for Kangaroo Lake

Wisconsin Trophic State Index Calculations

Kangaroo Lake, Door County, Wisconsin
October 10, 1997

	Using Secchi Depth	Using Chlorophyll a
Formula	WTSI = 60 - (14.4 ln SD)	WTSI = 34.8 + (7.56 ln Chlor a)
North basin	n/a	34.8 + 7.56 (1.73) = 47.88
South basin	60 - 14.4 (0.703) = 49.88	34.8 + 7.56 (1.53) = 46.37

Kangaroo Lake

1993

Door County
TSI Volunteer(s): Paul G. Mahlberg
Site: Deep Hole (South Lobe)

STORET #: 153121
Waterbody #: 0098600
Surface area: 1123 acres
Lake depth: 12 feet
Lake type: mixed drainage
Georegion: Southeast

Date	SD	CHL	TP	TSI (SD)	TSI(CHL)	TSI(TP)
02-Jun-93	5	4.21	12	54	46	47
21-Jun-93	5	7.59	13	54	50	48
14-Jul-93	4.5	6.72	11	55	49	47
13-Aug-93	4.5	4.92*	12	55	47	47
07-Sep-93	4	8.46	11	57	51	47
03-Nov-93	4	14.7	14	57	55	49
16-Jun-93	3.5			59		
10-Jul-93	4.75			55		
19-Jul-93	5.5			53		
04-Aug-93	4.5			55		
17-Aug-93	5.5			53		
03-Sep-93	3.5			59		

* low absorbance; result approximate

Date: 02-Jun-93	
Depth	Temp.
1.0	58.0
3.0	57.0
8.5	56.0

Date: 21-Jun-93	
Depth	Temp.
1.0	65.0
3.0	65.0
8.5	65.0

Date: 14-Jul-93	
Depth	Temp.
1.0	73.0
3.0	73.0
9.0	73.0

Date: 13-Aug-93	
Depth	Temp.
1.0	77.0
3.0	77.0
9.0	73.0

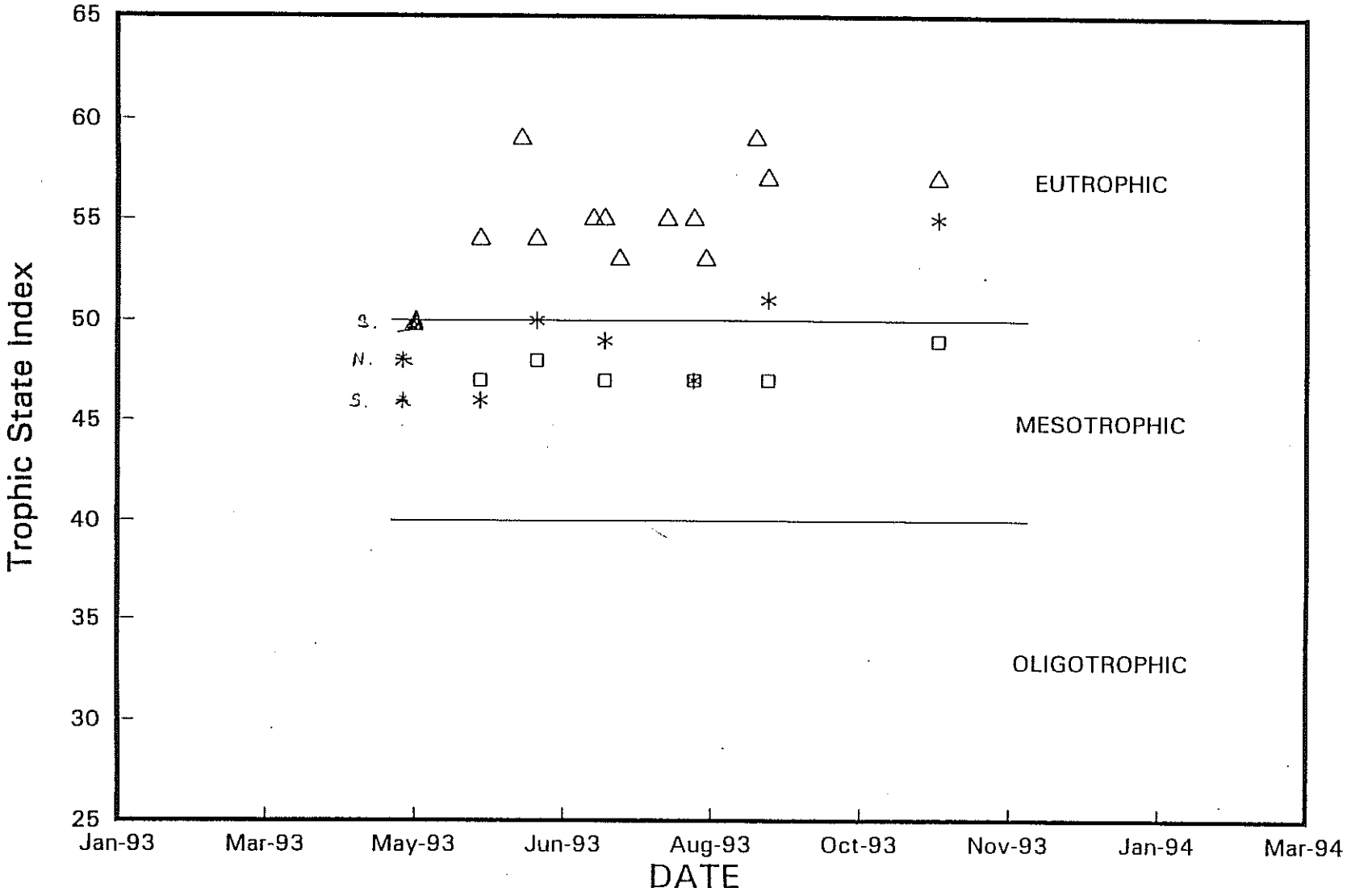
Date: 07-Sep-93	
Depth	Temp.
1.0	69.0
3.0	69.0
9.0	68.0

Date: 03-Nov-93	
Depth	Temp.
1.0	40.0
3.0	38.0
9.0	38.0

SD=Secchi depth in feet; CHL=chlorophyll-a in ug/L (micrograms per liter);
TP=Total phosphorus in ug/L; Temp.=temperature in degrees Fahrenheit;

The average Secchi depth was 4.52 feet.
The average chlorophyll concentration was 7.77 ug/L.
The average surface total phosphorus was 12.17 ug/L.
The TSI values ranged from 46 to 59.
The lake remained mixed through the summer.

Kangaroo Lake - 1993



□ T. Phos. * Chl a △ Secchi Depth

Kangaroo Lake 1994

Door County
TSI Volunteer(s): Paul G. Mahlberg
Site: Deep Hole
South Lobe)

STORET #: 153121
Waterbody #: 0098600
Surface area: 1123 acres
Lake depth: 12 feet
Lake type: mixed drainage
Georegion: Southeast

Date	SD	CHL	TP	TSI (SD)	TSI(CHL)	TSI(TP)
15-May-94	4.5	10.4	11	55	53	47
13-Jun-94	4.5	7.8	16.0	55	50	50
20-Jul-94	4.5	9.8	13.0	55	52	48
08-Aug-94	4.5	9.02	17	55	51	50
03-Oct-94	4.5	8.69	13	55	51	48

Date: 15-May-94

Depth	Temp.
1.0	55.0
3.0	54.0
9.0	54.0

Date: 13-Jun-94

Depth	Temp.
1.0	68.0
3.0	67.0
9.5	67.0

Date: 20-Jul-94

Depth	Temp.
1.0	74.0
3.0	74.0
9.5	72.0

Date: 08-Aug-94

Depth	Temp.
1.0	70.0
3.0	70.0
9.5	69.0

Date: 03-Oct-94

Depth	Temp.
1.0	
9.5	50.0

SD=Secchi depth in feet; CHL=chlorophyll-a in ug/L (micrograms per liter);
TP=Total phosphorus in ug/L; Temp.=temperature in degrees Fahrenheit;

The average Secchi depth was 4.5 feet.
The average chlorophyll concentration was 9.14 ug/L.
The average surface total phosphorus was 14 ug/L.
The TSI values ranged from 47 to 55.
The lake is mixed.

Self-Help Lake Monitoring 1995 Annual Report

KANGAROO LAKE

Door County
WATERBODY NUMBER : 98600

LAKETYPE :stratified drainage
DNR DISTRICT :LM
DNR REGION : NE
GEOREGION : Southeast

GROUP	SITE	VOLUNTEER NAME	VOL. ID
699	Deep Hole	R.J. POPLAWSKI	699

GROUP	DATE	SD(ft)	SD(m)	CHL	TP	TSI(SD)	TSI(CHL)	TSI(TP)
699	5/30/95	4.50	1.37			55		
699	6/6/95	4.00	1.22			57		
699	6/13/95	3.50	1.07			59		
699	6/20/95	5.00	1.52			54		
699	6/27/95	5.50	1.68			53		
699	7/3/95	6.00	1.83			51		
699	7/10/95	6.00	1.83			51		
699	7/19/95	5.50	1.68			53		
699	7/26/95	4.50	1.37			55		
699	8/2/95	3.50	1.07			59		
699	8/8/95	4.50	1.37			55		
699	8/24/95	4.00	1.22			57		
699	8/31/95	4.00	1.22			57		
699	9/17/95	4.00	1.22			57		

DATA SUMMARY:

Average SD(ft):	4.61
Minimum SD(ft):	3.5
Maximum SD(ft):	6
Average Chl:	0
Minimum Chl:	0
Maximum Chl:	0
Average TP:	0
Minimum TP:	0
Maximum TP:	0

DATE	VOLUNTEER COMMENTS
8/2/95	Cloudy.
9/17/95	Cloudy.

GROUP	SITE	VOLUNTEER NAME	VOL. ID
558	Site 1-South	PAUL MAHLBERG	558

GROUP	DATE	SD(ft)	SD(m)	CHL	TP	TSI(SD)	TSI(CHL)	TSI(TP)
558	4/19/95	5.00	1.52	2.44	10	54	41	46
558	5/17/95	5.50	1.68	2.37	13	53	41	48
558	6/27/95	5.00	1.52	5.2	11	54	47	47
558	7/24/95	3.75	1.14	.11	13	58	18	48
558	8/28/95	3.50	1.07	2.56	14	59	42	49
558	10/30/95	4.50	1.37	7.25	10	55	50	46

DATA SUMMARY:

Average SD(ft):	4.54
Minimum SD(ft):	3.5
Maximum SD(ft):	5.5
Average Chl:	3.32
Minimum Chl:	.11
Maximum Chl:	7.25
Average TP:	11.83
Minimum TP:	10
Maximum TP:	14

DATE : 4/19/95

DEPTH	TEMP.	D.O.
3	43.00	

DATE : 5/17/95

DEPTH	TEMP.	D.O.
1	58.00	
3	58.00	
6	57.00	
9	57.00	
12	56.00	

DATE : 6/27/95

DEPTH	TEMP.	D.O.
1	80.00	
3	80.00	
6	80.00	
9	79.00	
12	78.00	

SD = Secchi disk depth measured in feet & converted to meters; Chl = Chlorophyll a in micrograms per liter (ug/L); TP = Total phosphorus in ug/L, surface sample only; TSI(SD), TSI(CHL), TSI(TP) = Trophic state index based on SD, Chl, or TP respectively; Depth measured in feet; Temp. = Temperature in degrees Fahrenheit; D.O. = Dissolved oxygen in parts per million.

Self-Help Lake Monitoring 1995 Annual Report

KANGAROO LAKE

Door County
WATERBODY NUMBER : 98600

LAKETYPE :stratified drainage
DNR DISTRICT :LM
DNR REGION : NE
GEOREGION : Southeast

DATE : 7/24/95

DEPTH	TEMP.	D.O.
1	77.00	
3	76.00	
6	76.00	
9	76.00	
12	76.00	

DATE : 8/28/95

DEPTH	TEMP.	D.O.
1	78.00	
3	78.00	
6	77.00	
9	77.00	

DATE : 10/30/95

DEPTH	TEMP.	D.O.
1	43.00	
3	43.00	
6	43.00	
9	43.00	
12	43.00	

DATE	LAB/Self-Help COMMENTS
4/19/95	S.disk hit bottom, pls disregard TSI(SD). Chl approximate, low absorbance.
5/17/95	Chl approximate, low absorbance.
6/27/95	Chl approximate, low absorbance.
7/24/95	Chl approximate, low absorbance. Technical difficulty with sampling.
8/28/95	Chl approximate, low absorbance.

GROUP	SITE	VOLUNTEER NAME	VOL. ID
558	Site 2-North	PAUL MAHLBERG	558

GROUP	DATE	SD(ft)	SD(m)	CHL	TP	TSI(SD)	TSI(CHL)	TSI(TP)
558	4/19/95	4.00	1.22	2.37	9	57	41	45
558	5/17/95	4.00	1.22	2.25	10	57	41	46
558	6/27/95	4.00	1.22	3.72	15	57	45	49
558	7/24/95	4.00	1.22	.42	12	57	28	47
558	8/28/95			7.2	12		50	47
558	8/29/95	3.00	0.91			61		
558	10/30/95	3.00	0.91	2.52	7	61	42	43

DATA SUMMARY:

Average SD(ft):	3.67
Minimum SD(ft):	3
Maximum SD(ft):	4
Average Chl:	3.08
Minimum Chl:	.42
Maximum Chl:	7.2
Average TP:	10.83
Minimum TP:	7
Maximum TP:	15

DATE : 4/19/95

DEPTH	TEMP.	D.O.
3	46.00	

DATE : 5/17/95

DEPTH	TEMP.	D.O.
3	59.00	

DATE : 6/27/95

DEPTH	TEMP.	D.O.
3	81.00	

DATE : 7/24/95

DEPTH	TEMP.	D.O.
3	79.00	

DATE : 8/28/95

DEPTH	TEMP.	D.O.
1	79.00	
3	78.00	

DATE : 10/30/95

DEPTH	TEMP.	D.O.
1	41.00	
3	41.00	

SD = Secchi disk depth measured in feet & converted to meters; Chl = Chlorophyll a in micrograms per liter (ug/L); TP = Total phosphorus in ug/L, surface sample only; TSI(SD), TSI(CHL), TSI(TP) = Trophic state index based on SD, Chl, or TP respectively; Depth measured in feet; Temp. = Temperature in degrees Fahrenheit; D.O. = Dissolved oxygen in parts per million.

KANGAROO LAKE

Door County
WATERBODY NUMBER : 98600

LAKETYPE :stratified drainage
DNR DISTRICT :LM
DNR REGION : NE
GEOREGION : Southeast

DATE	LAB/Self-Help COMMENTS
4/19/95	Chl approximate, low absorbance.
5/17/95	S.disk hit bottom, pls disregard TSI(SD). Chl approximate, low absorbance.
6/27/95	S.disk hit bottom, pls disregard TSI(SD). Chl approximate, low absorbance.
7/24/95	S.disk hit bottom, pls disregard TSI(SD). Chl approximate, low absorbance. Technical difficulty with sample collection.
8/28/95	S.disk hit bottom, pls disregard TSI(SD).
10/30/95	S.disk hit bottom, pls disregard TSI(SD). Chl approximate, low absorbance.

SD = Secchi disk depth measured in feet & converted to meters; Chl = Chlorophyll a in micrograms per liter (ug/L); TP = Total phosphorus in ug/L, surface sample only; TSI(SD), TSI(CHL), TSI(TP) = Trophic state index based on SD, Chl, or TP respectively; Depth measured in feet; Temp. = Temperature in degrees Fahrenheit; D.O. = Dissolved oxygen in parts per million.