UPL-056

Current Status of Lake Amacoy, WI

Final Report

Wisconsin DNR Lakes Planning Grant

Submitted to:

Rusk County Land Conservation Department

by:

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INTRODUCTION

Lake Amacoy is a small, relatively shallow and productive lake located in Rusk County, Wisconsin. Lakeshore property owners have been concerned with maintaining water quality in the lake that is suitable for recreational activities, including boating, fishing and swimming. In order to evaluate the current status of Lake Amacoy, the Rusk County Land Conservation Department applied for and received funding from the Wisconsin Department of Natural Resources (DNR) as part of the Lakes Planning Grant Program in 1991. The purpose of the grant was to determine: 1) the present status of nutrient conditions and algal populations; 2) whether inlet streams associated with agricultural activities account for the observed levels of algal nutrients; and 3) whether there is evidence of bacterial contamination in Lake Amacoy.

In order to accomplish these objectives, we sampled Lake Amacoy and its inlet streams during spring and summer in 1991 and 1992. The purpose of the sampling was to determine the current trophic condition (levels of algal nutrients and algal populations) of the lake. Evaluation of the trophic condition or status of the lake involved several steps including the measurement of thermal structure, oxygen distributions, lakewater transparency, the chemical analysis of water samples and microscopic analysis of algal samples. This report summarizes the results of sampling during both years.

Watershed and lake description

The Lake Amacoy watershed is approximately 1800 hectares (4787 acres including the lake and 4512 acres excluding the lake). Roughly 31% of the watershed is used for agriculture and there are six active farms. Wetland (24%) and forest (31%) also comprise significant portions of the watershed. Approximately 39% of the watershed is covered by sandy soils and the remainder by more poorly-drained, hydric soils (USDA - Soil Conservation Service).

Relatively little of the watershed surface area is covered by commercial or residential development. There are only 60 residences in the watershed and about half are located around the lake. Some of the residences are used only in the summer months.

Lake Amacoy has a surface area of 112 hectares. It is a drainage lake having two main inlets and an outlet that drains into the Chippewa River. The lake is relatively small compared to the surface area of the watershed. The watershed is 16 times the surface area of the lake.

The largest inlet to the lake enters on the north shore (site INL-1 on Figure 1). This stream drains wetland areas prior to entering the lake, but it is influenced by runoff from most of the watershed area (Figure 2). A second inlet (INL-2) enters the lake through a culvert under Highway 40 along the western shore of the lake. The flow of this stream is small, but it directly drains an animal feedlot. A third inlet appeared on U.S. Geological Survey quadrangle maps and other maps from the 1970's and before. This inlet formerly entered the lake at the southern end near site A2-T (Figure 1), but there is no existing inlet at that site. We could not determine from field inspection whether water drains into the lake via a subsurface pipe or whether drainage was routed away from the lake.

The outlet from the lake is on the northeastern side and it drains into the nearby Chippewa River. Because of the proximity of the lake to the Chippewa River, the river would flood periodically and reverse the flow of water back into the lake. Before 1970, flooding occurred every three or four years and it affected Highway 40. Consequently, a flood gate was constructed on the outlet to prevent flood waters from entering the lake and impacting the roadway. However, placement of the gate also resulted in raising the lake level by almost 0.5 m, which resulted in many changes along the shoreline. Many flooded trees are still evident along the shores.

During the first year of the present study (1991), the flood gates failed and waters from the Chippewa River entered the lake. This event occurred before sampling began. It appeared to change conditions in the lake and lakeshore residents commented on the increase in brown color of the water and the greater apparent clarity due to lower concentrations of algae than they observed in other years. These observations raised the question of whether periodic flooding from the Chippewa River might have a beneficial effect on the lake. Unfortunately, only limited data from prior years were available from WI DNR to examine the possible influence of river flooding on the dynamics of Lake Amacoy and this question is examined later in this report.

Lake Amacoy is relatively shallow and there is little surface relief in the area immediately around the lake. Although most of the lake has a depth greater than 3 m (roughly 10 feet; see Figures 1 and 3), the lake only reaches a measured maximum depth of 7 m. The lake is roughly ovoid in

Lake Amacoy

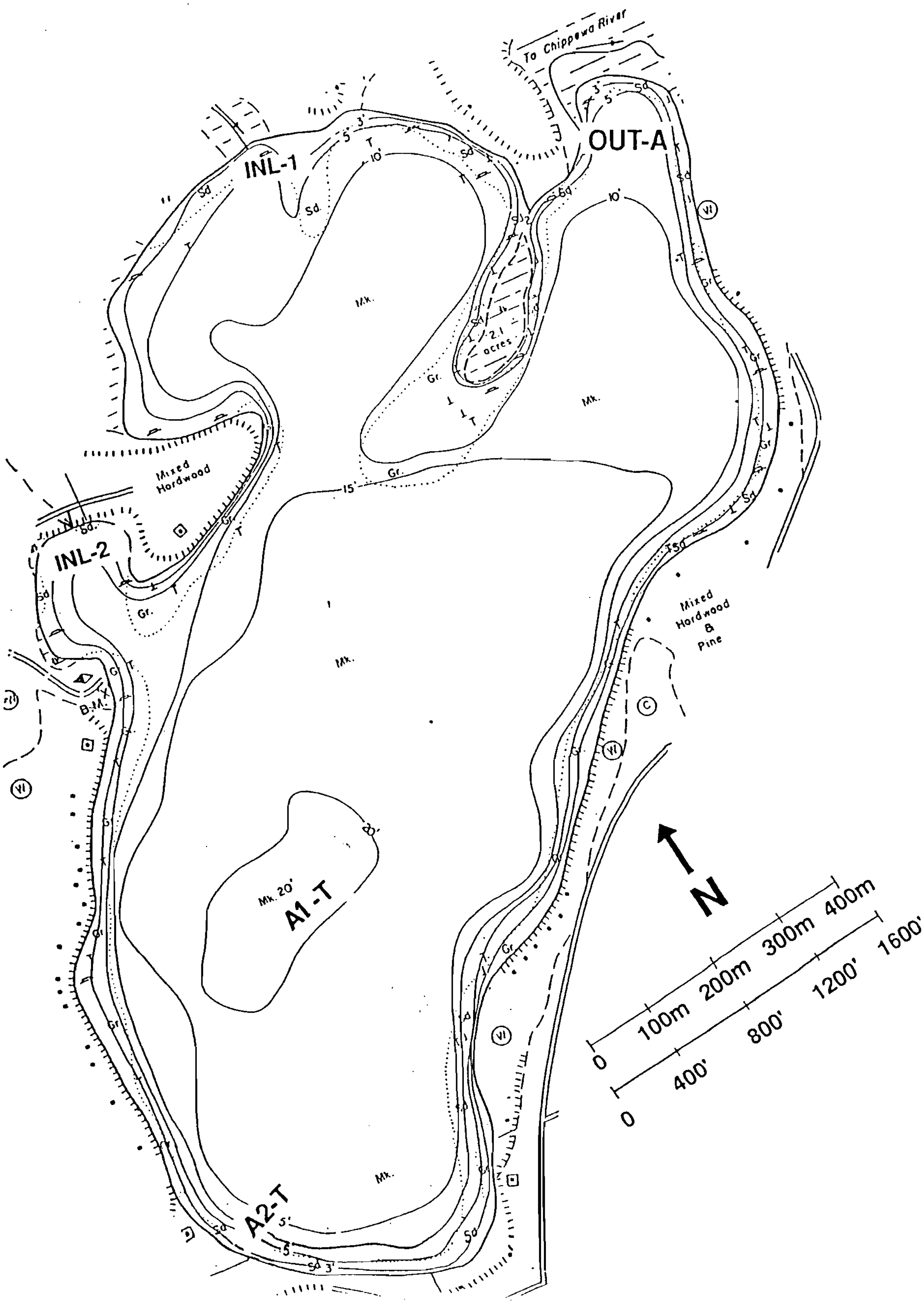


Figure 1.

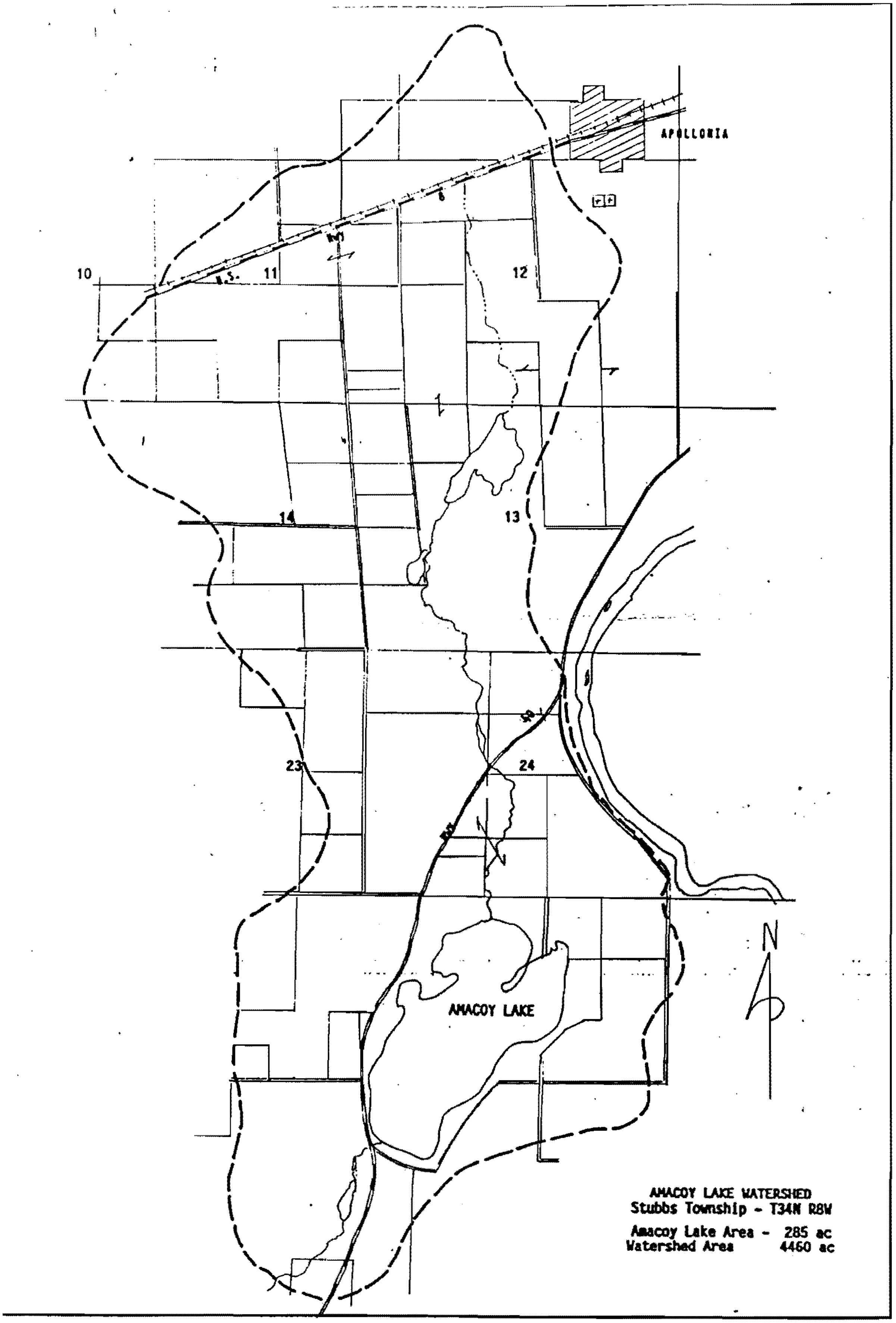

APOLLONIA
10
11
12
13
14
23
24
AMACOY LAKE
AMACOY LAKE WATERSHED
Stubbs Township - T34N R8W
Amacoy Lake Area - 285 ac
Watershed Area 4460 ac
N

Figure 2.

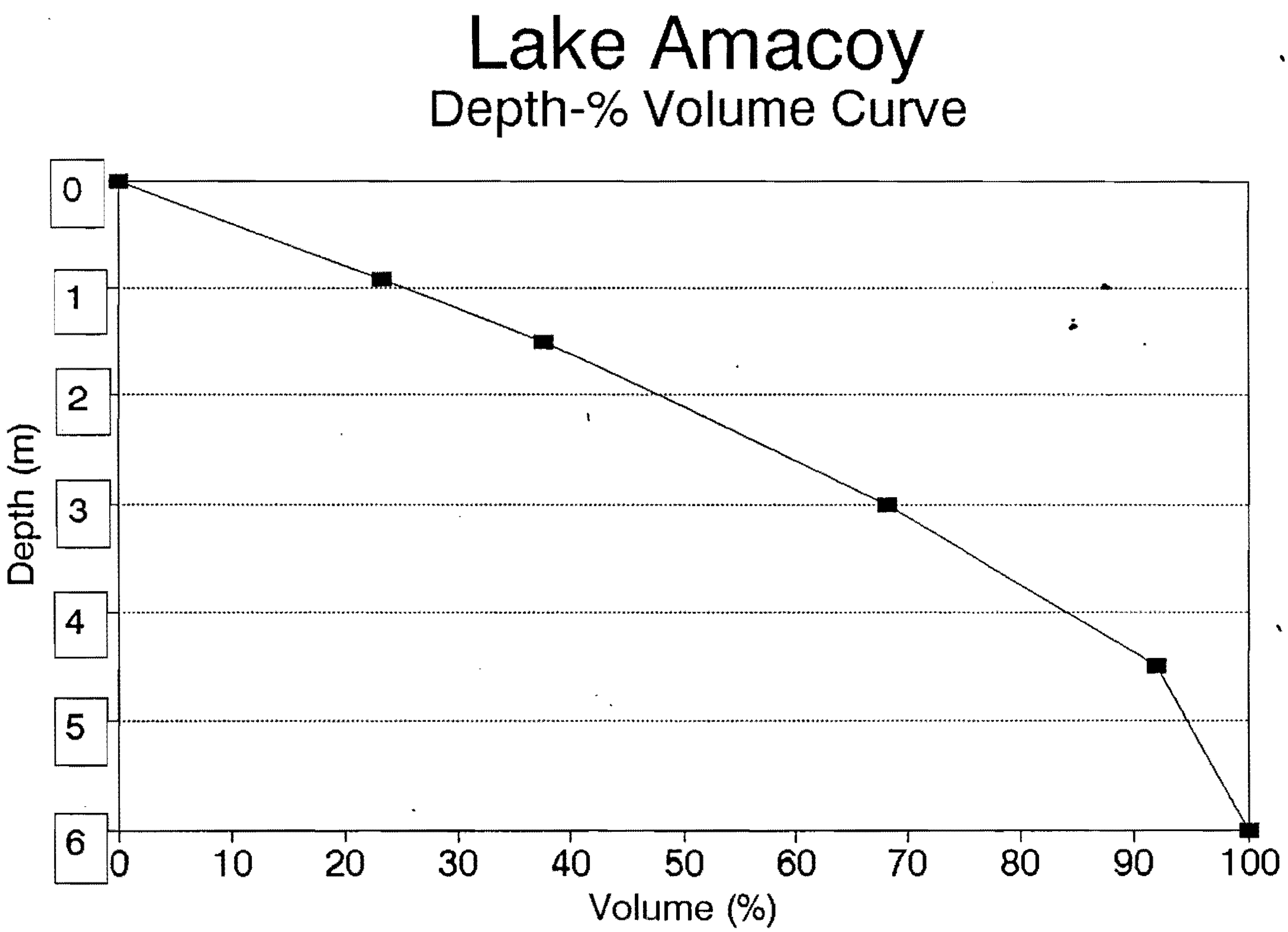

Lake Amacoy
Depth-% Volume Curve
Depth (m)
0
1
2
3
4
5
6
0
10
20
30
40
50
60
70
80
90
100
Volume (%)

Figure 3.

shape, with two small, shallow embayments. Further morphometric features of the lake and its watershed are given in Table 1.

Table 1. Morphometric features of Lake Amacoy.

Latitude	45°24'0"
Longitude	91°18'45"
Elevation	324 m
Watershed area	18.0 km^2
Lake area	112. ha
Maximum depth	7 m
Mean depth	3.7 m
Relative depth	0.51%
Shoreline length	5890 m
Shoreline development	5.14

METHODS

Lake sampling and sample analysis

Lake Amacoy was sampled four times in each of two years to characterize summertime conditions. The lake was sampled in May, June, July and August in 1991 and 1992. In addition, the inlet streams and the lake outlet were sampled on the same dates. The lake also was sampled in October 1992 to extend our observations.

For each sampling date, temperature and oxygen profiles were determined for the deep site on the lake (A1-T, Figure 1). These measurements were made using a YSI temperature/dissolved oxygen meter. The probe was calibrated on each day of sampling and the results also were compared to dissolved oxygen titrations for selected dates and depths. Lakewater transparency was measured on each sampling date using a Secchi disc. Surface water samples were collected by grab sampling and an opaque Kemmerer water bottle was used to collect samples at depth.

A 1.5 m vertical integrated sample was collected at the surface of the lake on each sampling date. A portion of the sample was examined prior to preservation to aid in identification. The samples were preserved with Lugol's solution and were concentrated by a standard sedimentation procedure. Algal cells were counted for the August samples in both years using a standard counting procedure using an inverted microscope. All algal sample analysis was done by Dr. Lloyd Ohl, a phycologist in the Department of Biology, University of Wisconsin - Eau Claire.

Water samples were placed in coolers and chilled during transport back to the laboratory. Sample preservation followed protocols used by the WI DNR for lake sampling and monitoring programs. The samples were cooled to approximately 4° C, packed in styrofoam coolers with ice and shipped via overnight mail to the State Lab of Hygiene. All chemical analysis was done at the State Lab following standard protocols used in the analysis of water and methods used for all WI DNR lake sampling programs. Therefore, the analytical data from this study can be compared with data from other lakes monitored by WI DNR. The total list of parameters measured over the two-year period is found in Table 2.

Table 2

Sampling and analysis schedule for Lake Amacoy, 1991 and 1992

	Monthly (May - August)	August - A1-T (0 m)	August - A1-T (5.5 m)
Temperature	X	X	X
Dissolved oxygen	X	X	X
pH	X	X	X
Alkalinity	X	X	X
Total phosphorus	X	X	X
Soluble P	X	X	X
Total nitrogen	X	X	X
Nitrate - N		X	X
Ammonia - N		X	X
Chlorophyll *a*		X	
Algal sample collected	X		
Algal sample analyzed		X	
Coliform bacteria	X (inlets, outlet and A2-T)		

Data analysis

Analytical data were reported from the State Lab of Hygiene to Dan Ryan at the WI DNR office in Spooner. Copies of the data reports were sent to UW-EC where the data were entered into a spreadsheet (Quattro Pro) for further analysis. Temperature, oxygen and Secchi disc measurements also were entered into the same database.

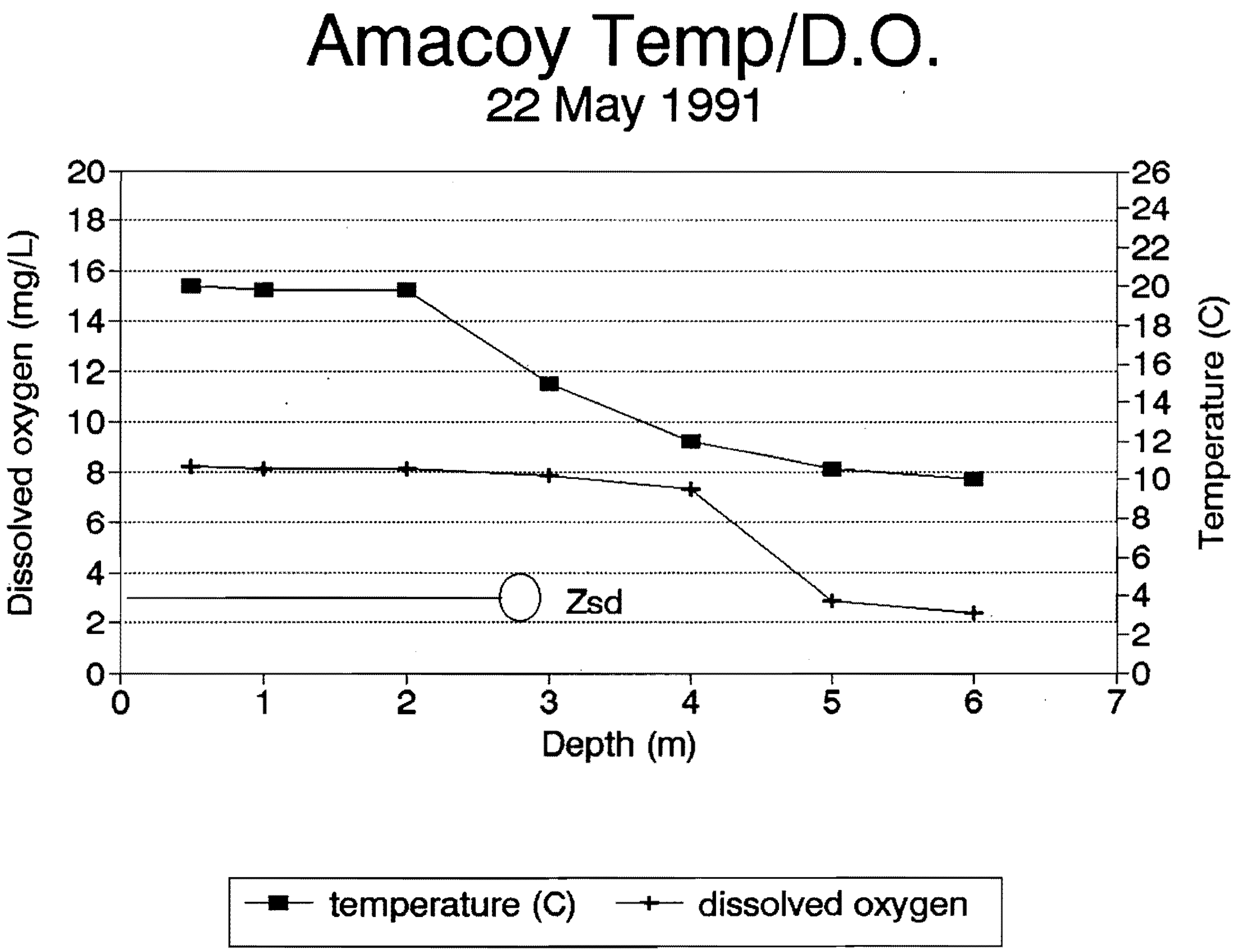

Amacoy Temp/D.O.
22 May 1991
Dissolved oxygen (mg/L)
Temperature (C)
Zsd
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
1
3
5
7
temperature (C)
dissolved oxygen

Figure 4.

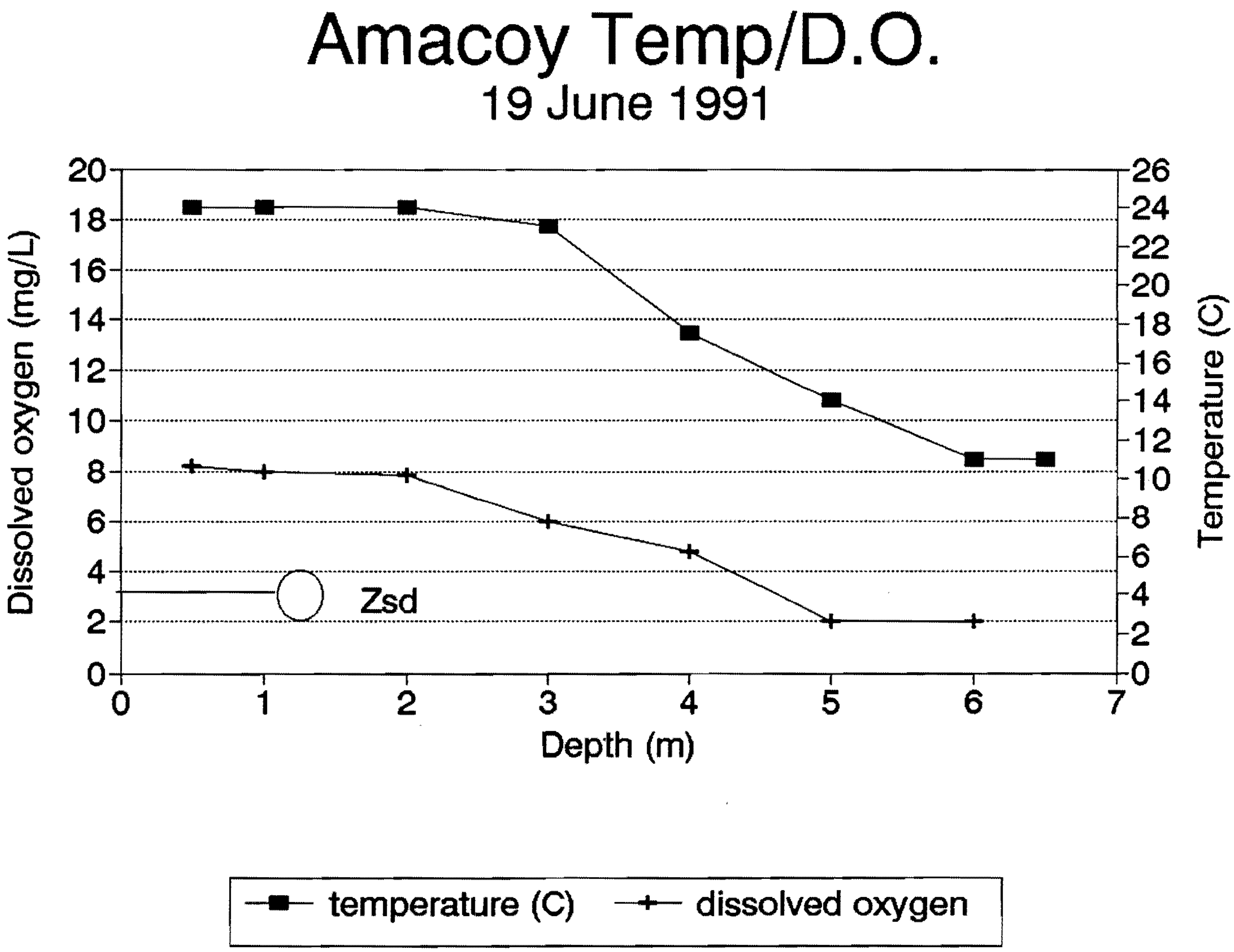
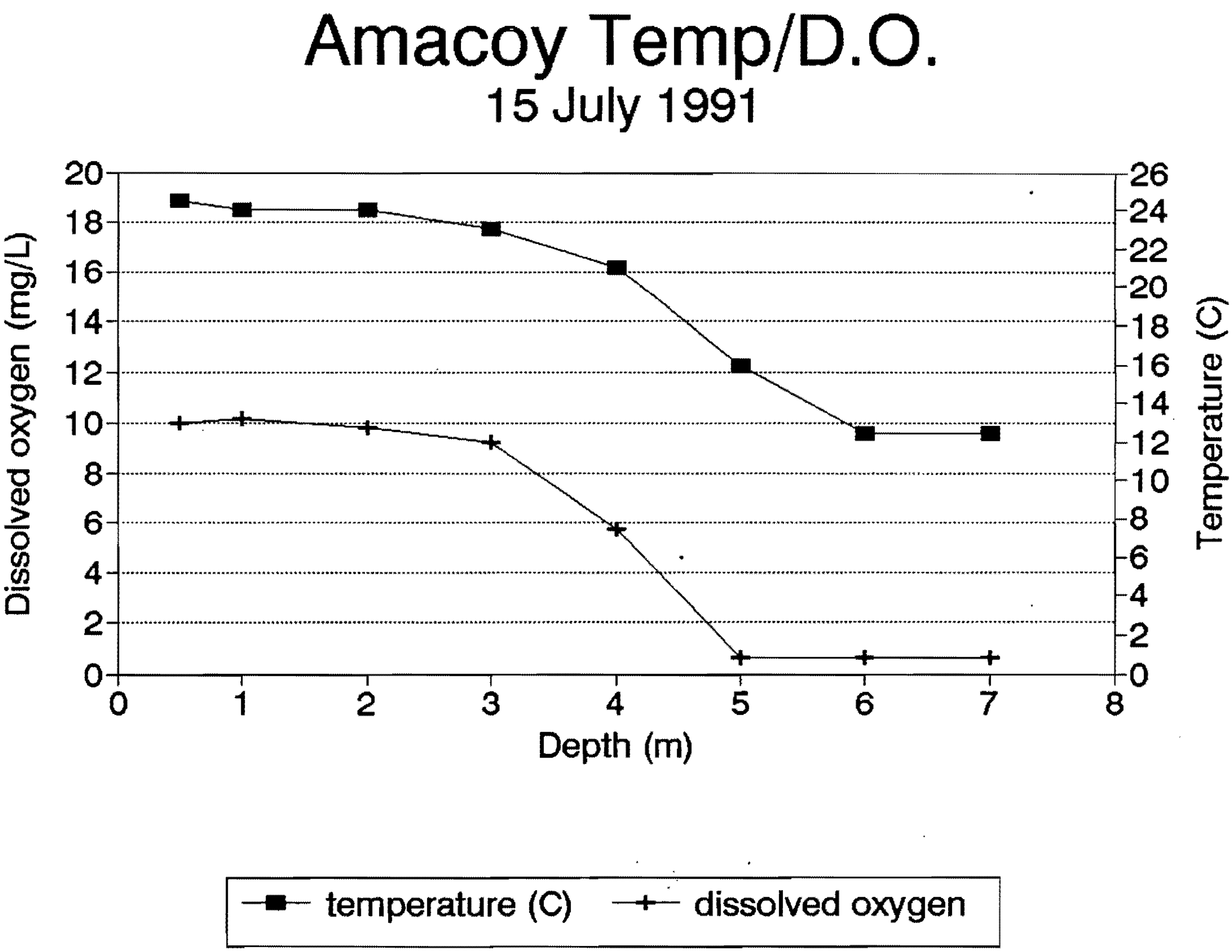
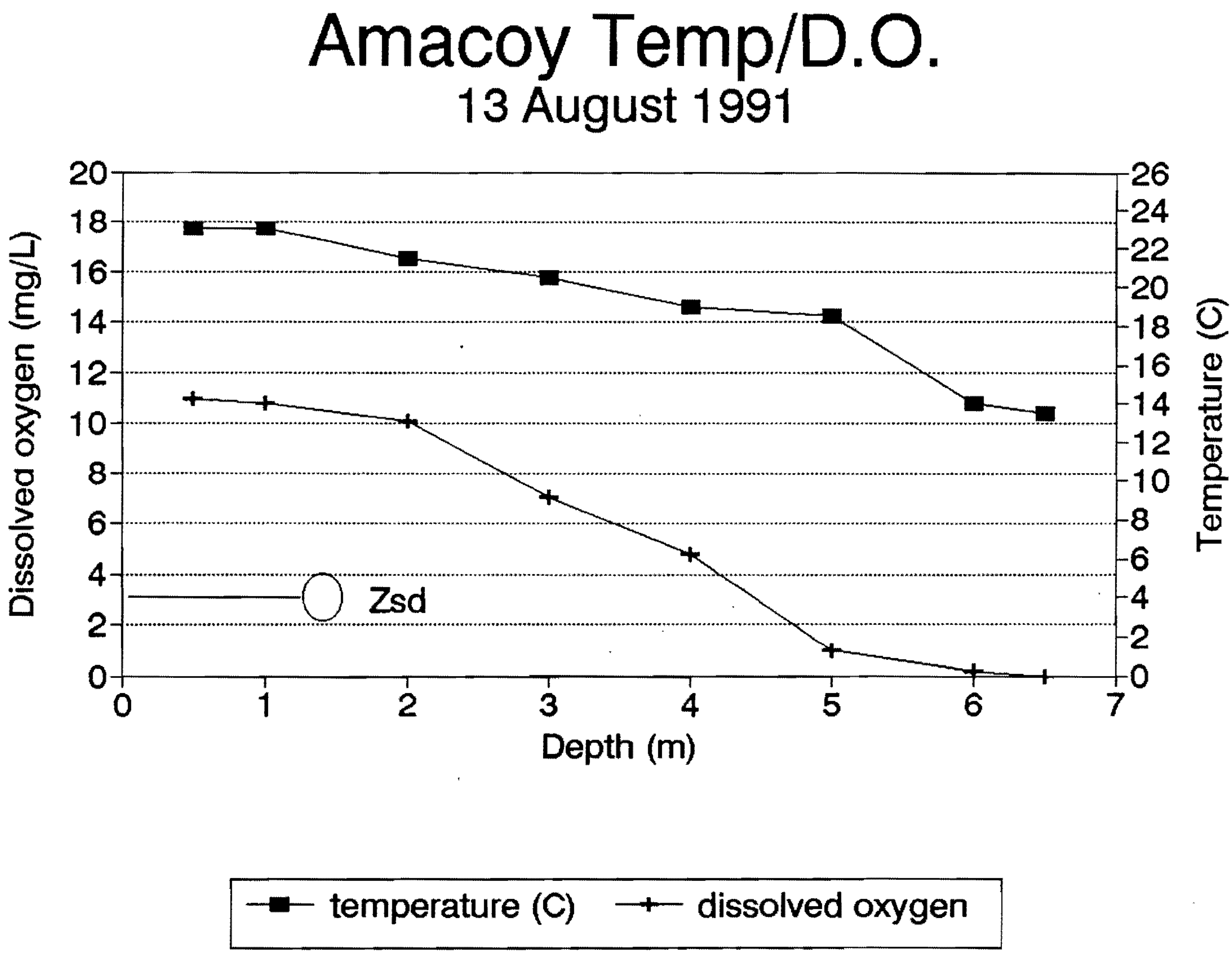

Amacoy Temp/D.O.
19 June 1991
Dissolved oxygen (mg/L)
Temperature (C)
Zsd
Depth (m)
temperature (C)
dissolved oxygen
0
2
4
6
8
10
12
14
16
18
20
22
24
26
1
3
5
7

Figure 5.



Amacoy Temp/D.O.
15 July 1991
Dissolved oxygen (mg/L)
Temperature (C)
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
0 1 2 3 4 5 6 7 8
temperature (C)
dissolved oxygen

Figure 6.



Amacoy Temp/D.O.
13 August 1991
Dissolved oxygen (mg/L)
Temperature (C)
Depth (m)
Zsd
20
18
16
14
12
10
8
6
4
2
0
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0
1
2
3
4
5
6
7
temperature (C)
dissolved oxygen

Figure 7.

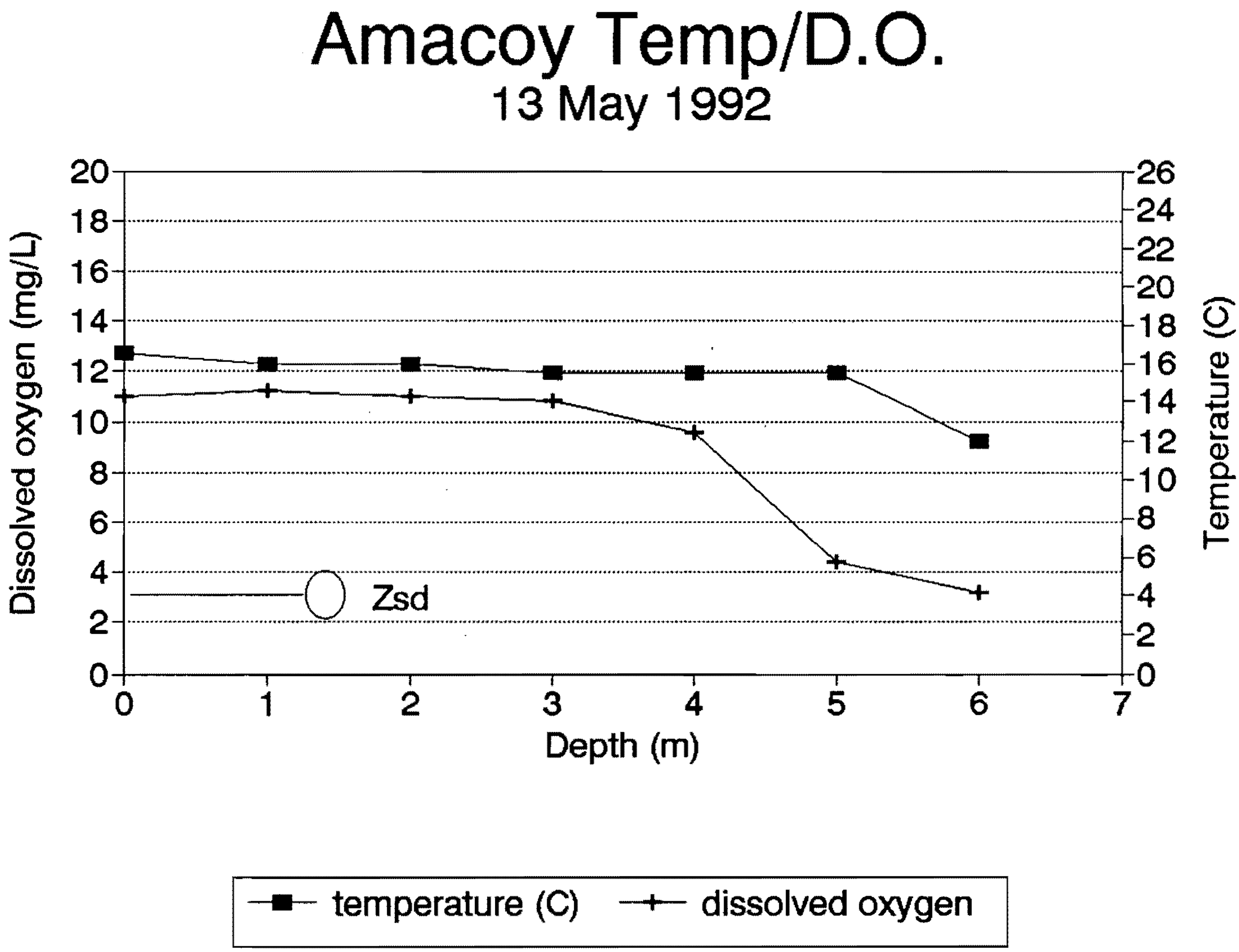

Amacoy Temp/D.O.
13 May 1992
Dissolved oxygen (mg/L)
Temperature (C)
Depth (m)
Zsd
temperature (C)
dissolved oxygen

Figure 8.

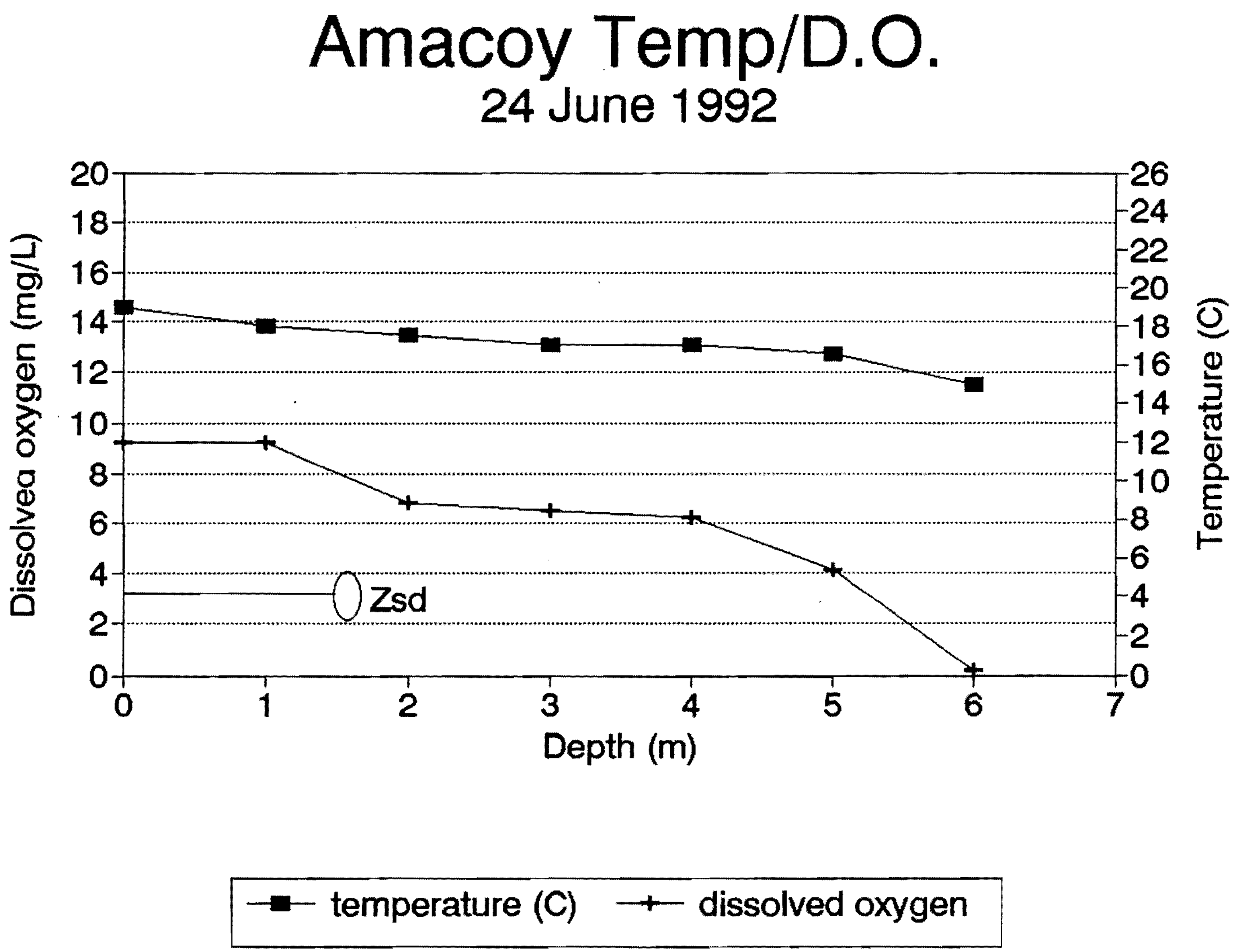
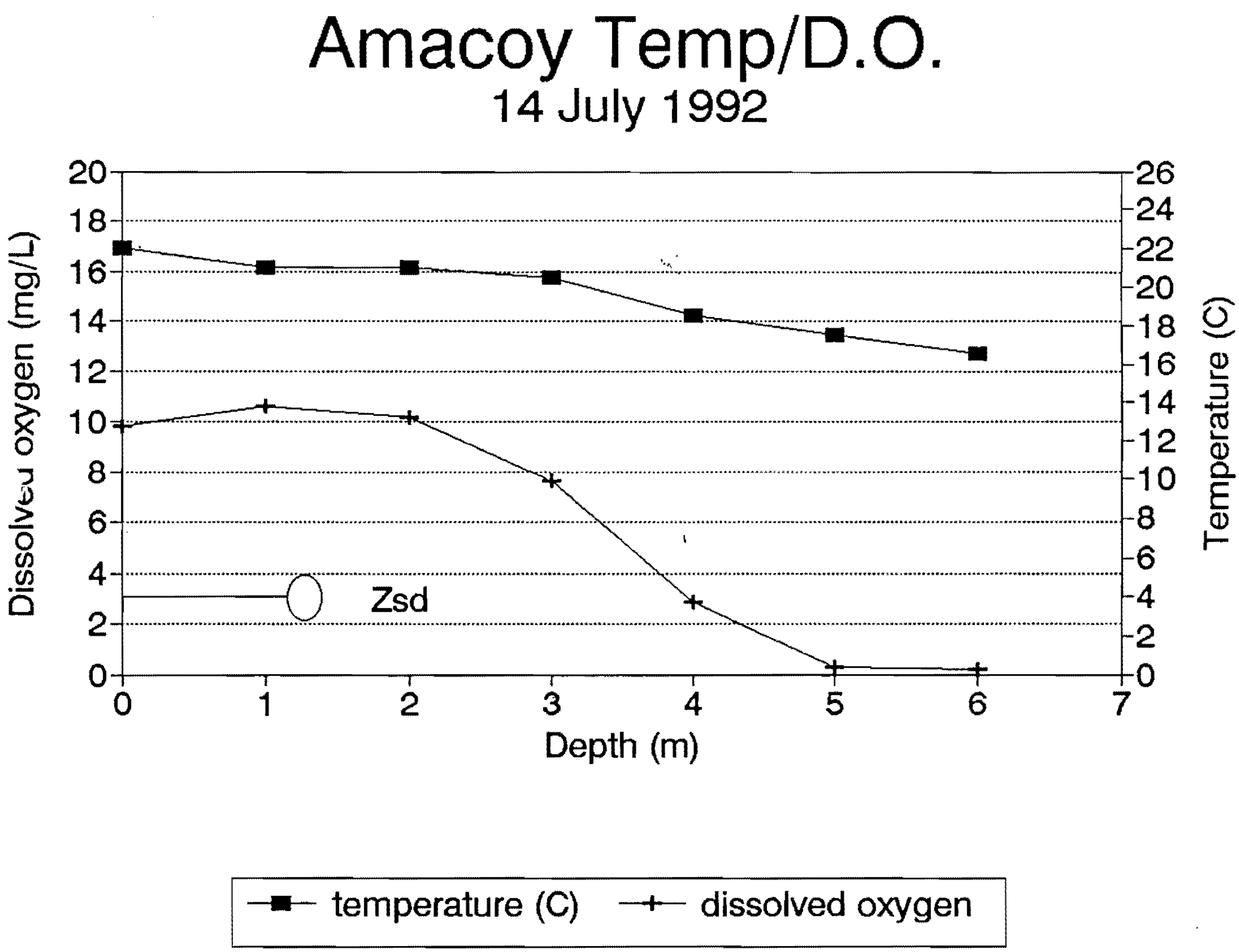

Amacoy Temp/D.O.
24 June 1992
Dissolvea oxygen (mg/L)
Temperature (C)
Depth (m)
Zsd
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12
14
16
18
20
0
2
4
6
8
10
12
14
16
18
20
22
24
26
temperature (C)
dissolved oxygen

Figure 9.



Amacoy Temp/D.O.
14 July 1992
Dissolved oxygen (mg/L)
Temperature (C)
Depth (m)
Zsd
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12
14
16
18
20
22
24
26
temperature (C)
dissolved oxygen

Figure 10.

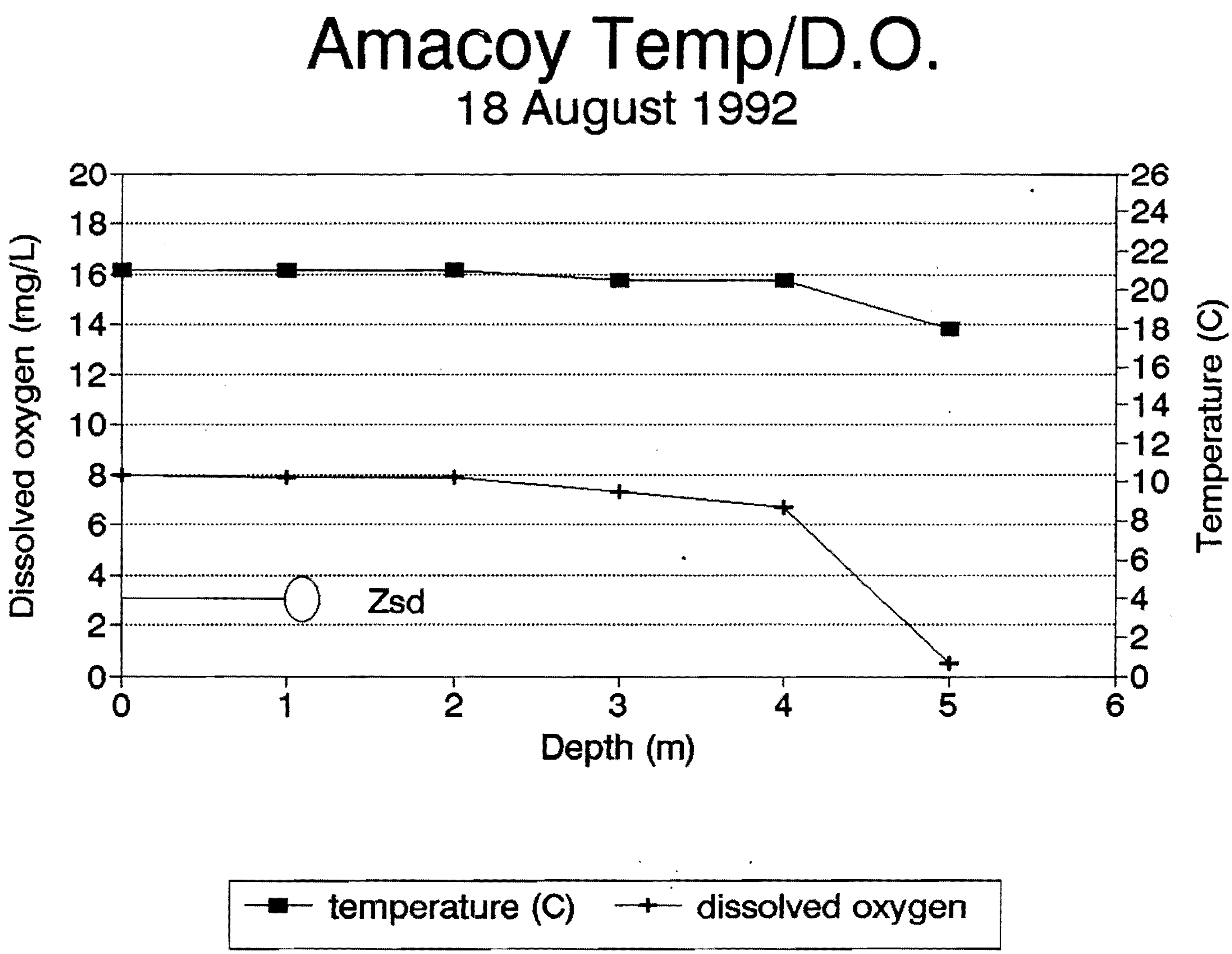

Amacoy Temp/D.O.
18 August 1992
Dissolved oxygen (mg/L)
Temperature (C)
Zsd
Depth (m)
0
1
2
3
4
5
6
0
2
4
6
8
10
12
14
16
18
20
22
24
26
temperature (C)
dissolved oxygen

Figure 11.

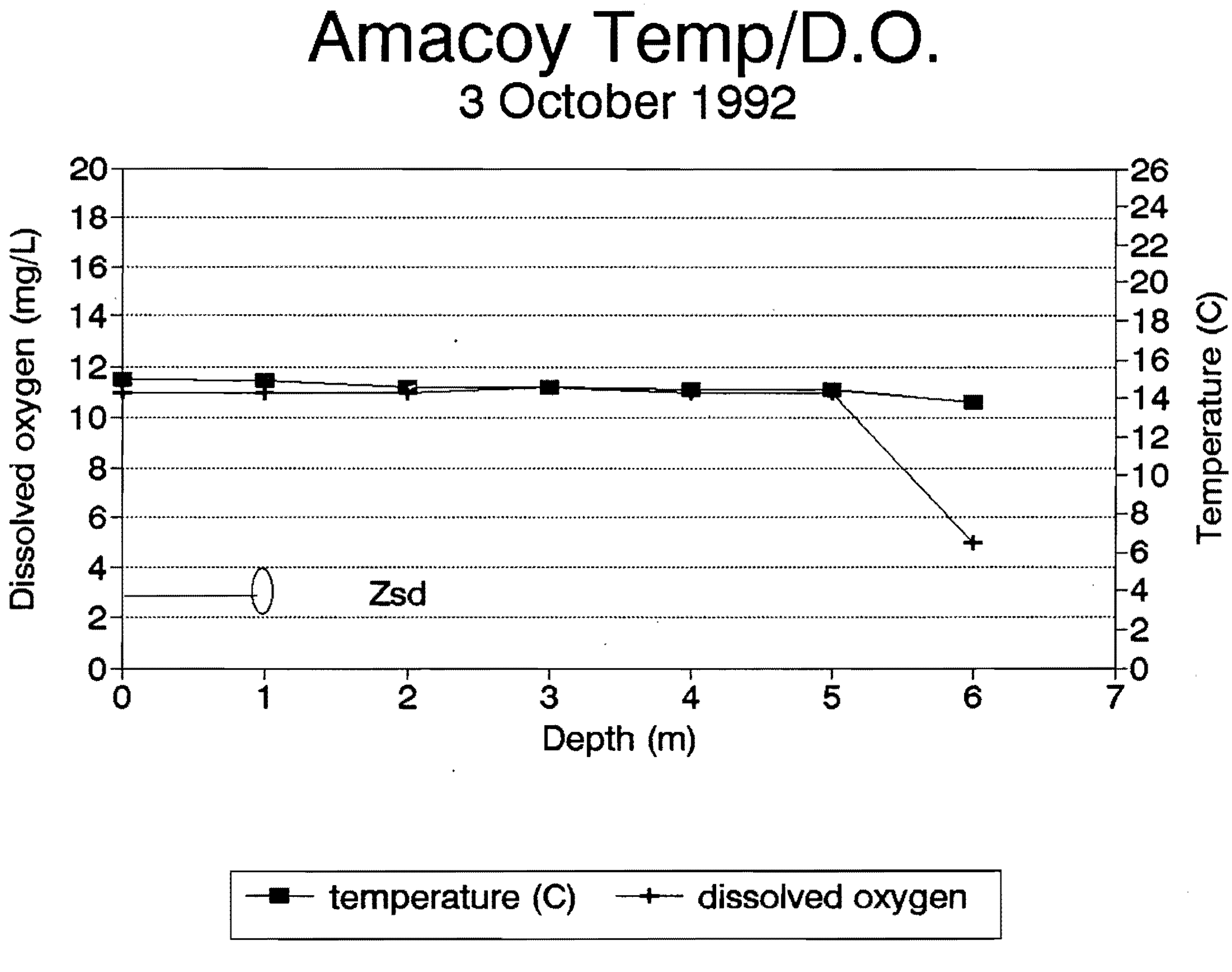

Amacoy Temp/D.O.
3 October 1992
Dissolved oxygen (mg/L)
Temperature (C)
Zsd
Depth (m)
temperature (C)
dissolved oxygen
20
18
16
14
12
10
8
6
4
2
0
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0
1
2
3
4
5
6
7

Figure 12.

RESULTS AND DISCUSSION

Lake and stream sampling

The proposed sampling program identified in Table 2 was completed in both years. The mechanism of sample collection and shipping to the State Lab worked well, with only two minor exceptions in 1991, when one sample was lost by the State Lab and the first series of phosphorus analyses was done with lower precision than desired. Nonetheless, subsequent samples and analyses provided an excellent evaluation of conditions in the lake.

Lake stratification, circulation and transparency

Two unusual events occurred during the sampling period. First, as mentioned previously, the Chippewa River backed up into Amacoy Lake in 1991. This event occurred prior to any sampling, and as a consequence, the impact of the river on the lake can only be inferred. Second, the summer of 1992 was one of the coolest on record. After some warm weather in May, air temperatures were very cool during June and July 1992. The constrast between the years can been seen by comparing departures of air temperatures from the average conditions observed in 1951-1980. While air temperatures were 5.2° F higher than normal in June 1991, they were roughly 5° F cooler than average in July 1992 (NOAA 1992).

Lake Amacoy circulates completely in spring and fall and it stratifies for weeks to months in summer. The duration of stratification varies as a function of spring and summer climatic conditions. Because of the exposure of the basin and the lake's shallow depth, stratification can be disrupted by summer storms. The lake also stratifies under ice. Deeper waters in the lake are prone to low oxygen concentrations during periods of stratification in summer or winter (WI DNR file data for 1975-77).

Given the shallowness of the lake and its exposure to wind action, the lake circulates for several weeks in spring resulting in relatively warm temperatures in deeper waters. Stratification may occur quickly as it did in 1991 and persist (Figures 4-7) or it may be temporary and slight as occurred during the unusually cool summer of 1992 (Figures 8-11). While the water column warmed quickly in May 1992, little further warming occurred in June or July. Oxygen began declining at 2-3 m in the water column during summer and concentrations fell to very low levels below 5 m by July of each summer. A similar pattern was found by WI DNR in 1976 (Figure 12). Water column temperatures in 1976 and 1991 were significantly higher than in 1992.

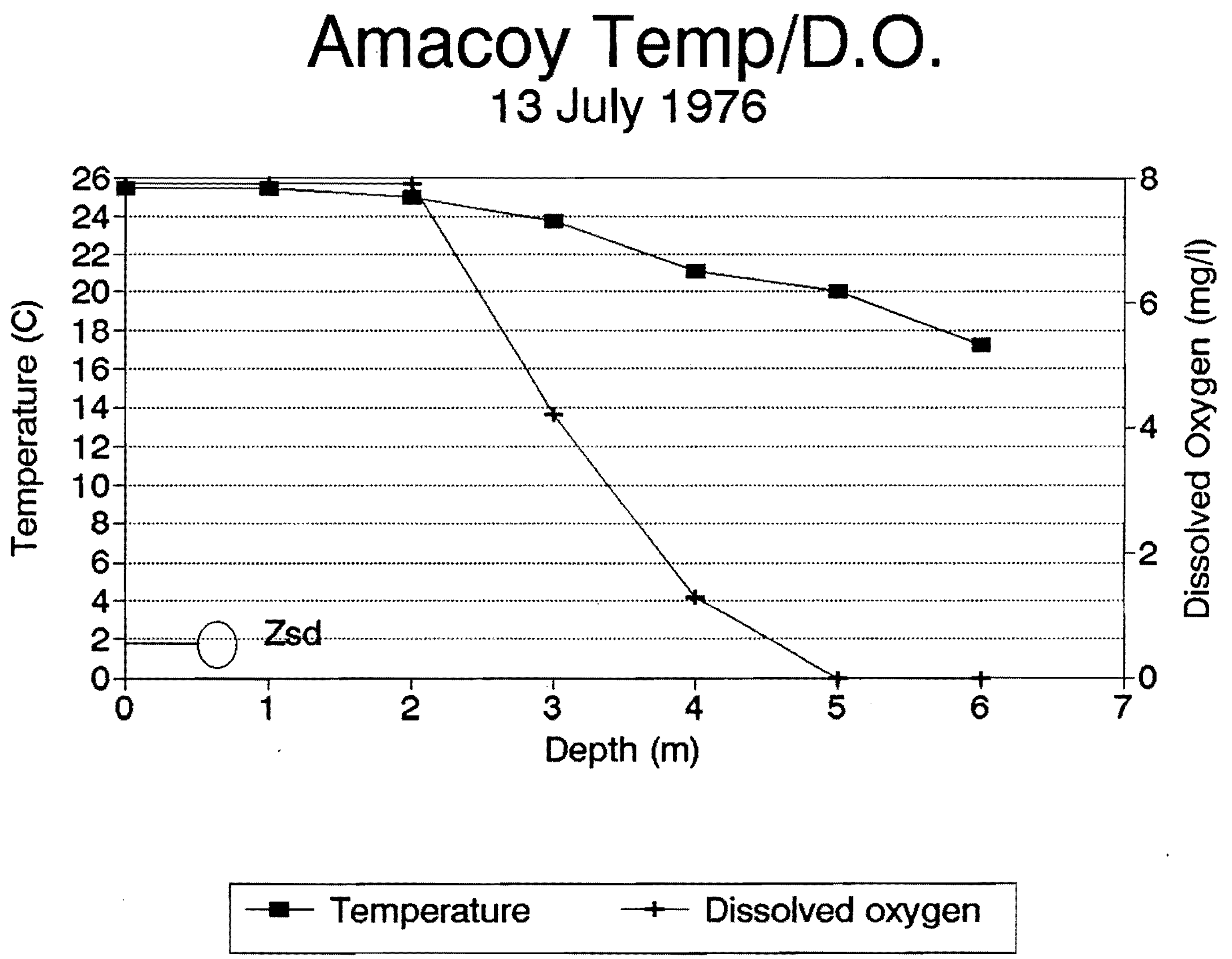
Surface water oxygen was supersaturated during some samplings related to productive algal blooms commonly observed in July and August. These periods also were associated with an increase in surface water pH (Figure 13).

Lakewater transparency was low and normally between 1 and 1.5 meters, with the exception of May 1991 when it was nearly 3 m. The transparency of the water column was affected by two primary factors: the brown-stain of the water and the varying concentrations of algae on the date of sampling. Comparable lakewater transparencies also were found by DNR in the mid-1970's.

Surface water nutrient concentrations

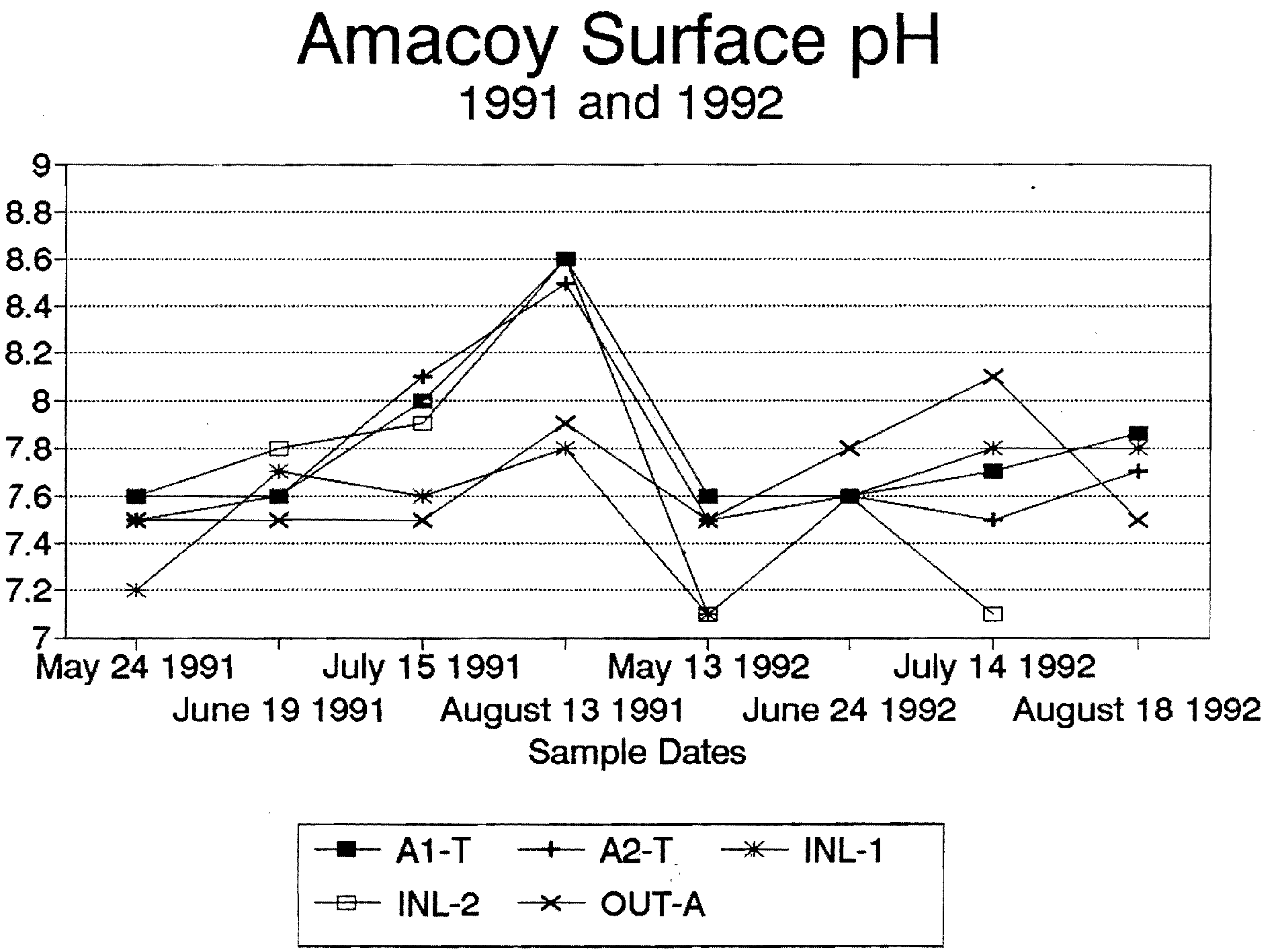
Nutrient concentrations in the lake were relatively high in the major inlet stream (INL-1). Total phosphorus for this inlet normally ranged from 20 to 70 µg/l (Figure 14). Phosphorus concentrations were lowest near the center of the lake at site A1-T, where they ranged from 20 to 35 µg/l. The outlet and site A2-T were normally intermediate. The second, small inlet (INL-2) running under Highway 40 had the highest concentrations during periods when it was flowing. Similar patterns were found for total nitrogen at the sites (Figure 15).

The August sampling included a deeper water sample collected at approximately 5.5 m in the middle of the lake at site A1-T. Nutrient concentrations were higher in the deep water sample than in the surface sample during both years of sampling due to sedimentation and mineralization within the water column, and the likely release of nutrients from sediments. Total phosphorus, soluble P, total nitrogen, nitrate and ammonia increased with depth. The increase was more dramatic in 1991 than in 1992 due to the more intense and longer period of stratification.



Amacoy Temp/D.O.
13 July 1976
Temperature (C)
Dissolved Oxygen (mg/l)
Depth (m)
Zsd
26
24
22
20
18
16
14
12
10
8
6
4
2
0
8
6
4
2
0
0
1
2
3
4
5
6
7
Temperature
Dissolved oxygen

Figure 13.



Amacoy Surface pH
1991 and 1992
9
8.8
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
7
May 24 1991
June 19 1991
July 15 1991
August 13 1991
May 13 1992
June 24 1992
July 14 1992
August 18 1992
Sample Dates
A1-T
A2-T
INL-1
INL-2
OUT-A

Figure 14.

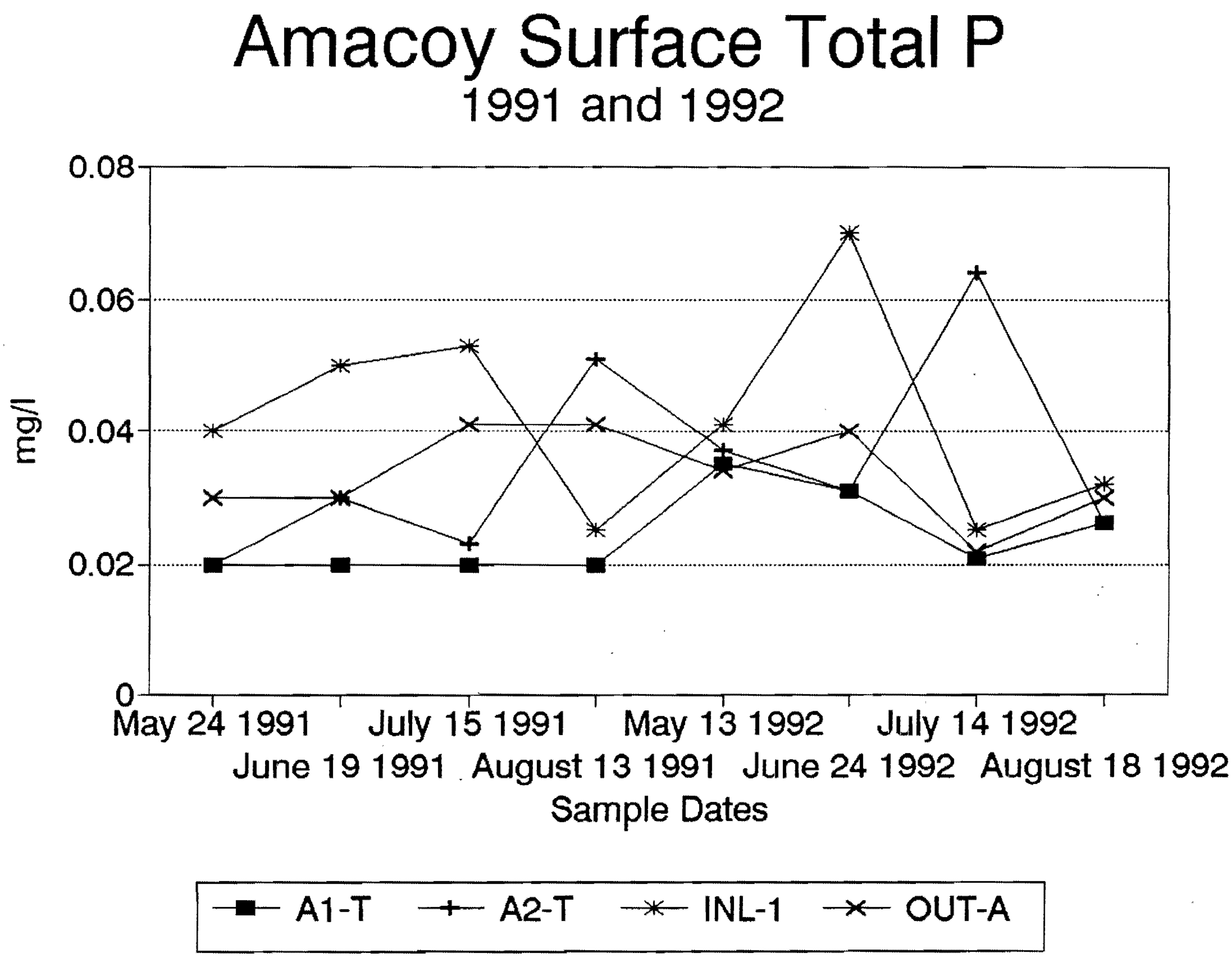
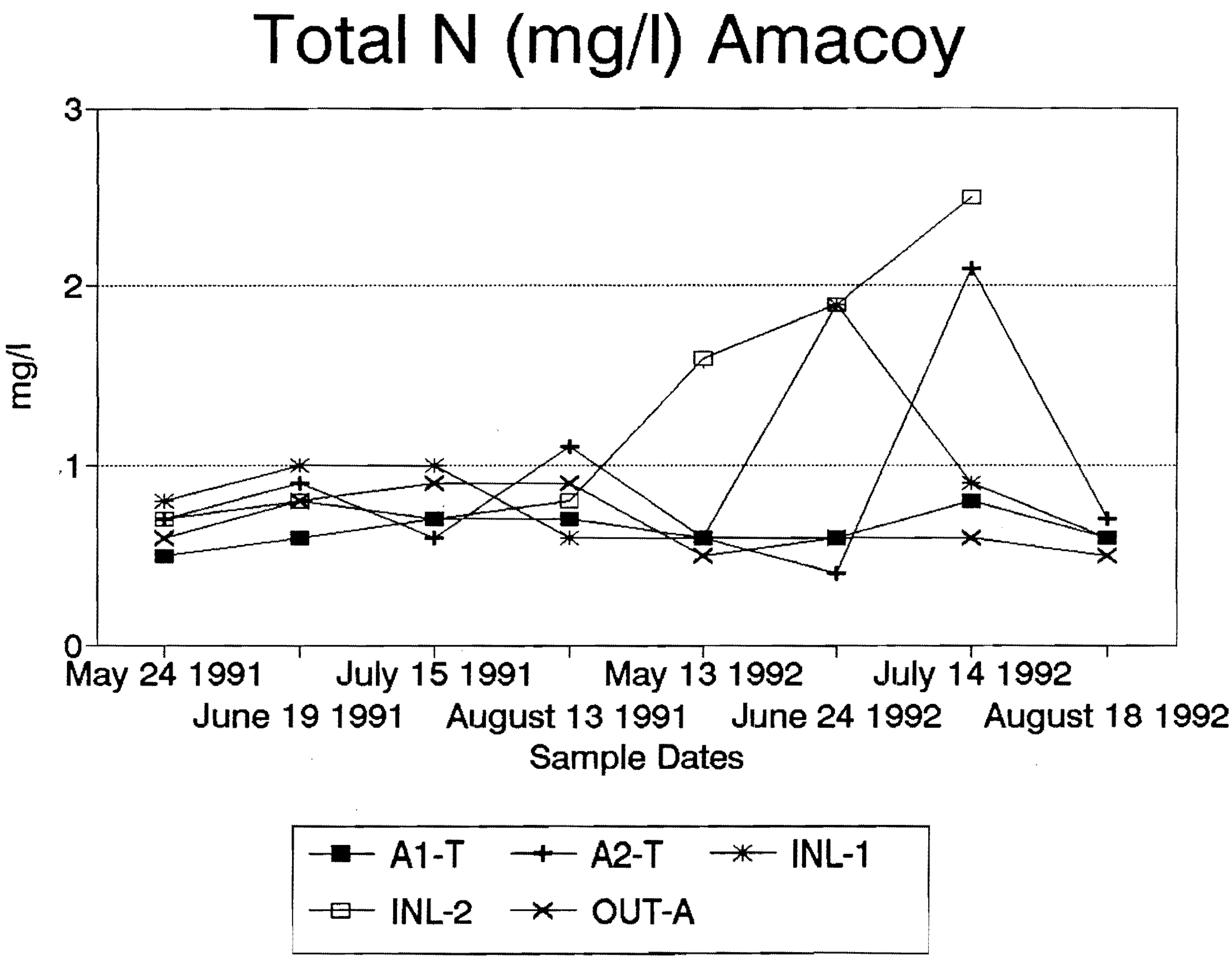

Amacoy Surface Total P
1991 and 1992
0.08
0.06
0.04
0.02
0
mg/l
May 24 1991
June 19 1991
July 15 1991
August 13 1991
May 13 1992
June 24 1992
July 14 1992
August 18 1992
Sample Dates
A1-T
A2-T
INL-1
OUT-A

Figure 15.



Total N (mg/l) Amacoy
mg/l
3
2
1
0
May 24 1991
June 19 1991
July 15 1991
August 13 1991
May 13 1992
June 24 1992
July 14 1992
August 18 1992
Sample Dates
A1-T
A2-T
INL-1
INL-2
OUT-A

Figure 16.

Surface water algal populations

Surface water blooms of blue-green bacteria were noted on sampling dates in July and August in 1991, but with lesser frequency in 1992. Plankton samples were counted for the August sampling date in each year (the raw data are included as Appendix 1). These samples reflect the difference in the composition of the algal populations between the two years. During 1991, the algal sample was dominated by blue-green bacteria (Cyanophyta), but it also had a high percentage of green algae (Chlorophyta, Figure 16).

During 1992, the algal sample indicated a high population of green algae and diatoms (Bacillariophya, Figure 17), with a much lower percentage of blue-green bacteria. The total number of cells in the sample from 1992 was somewhat, but not substantially, lower than it was in 1991. However, even though populations of blue-green bacteria were lower in 1992, lakewater transparency remained low and Secchi disc measurements were similar to those in 1991, because of the continuing high productivity of Lake Amacoy.

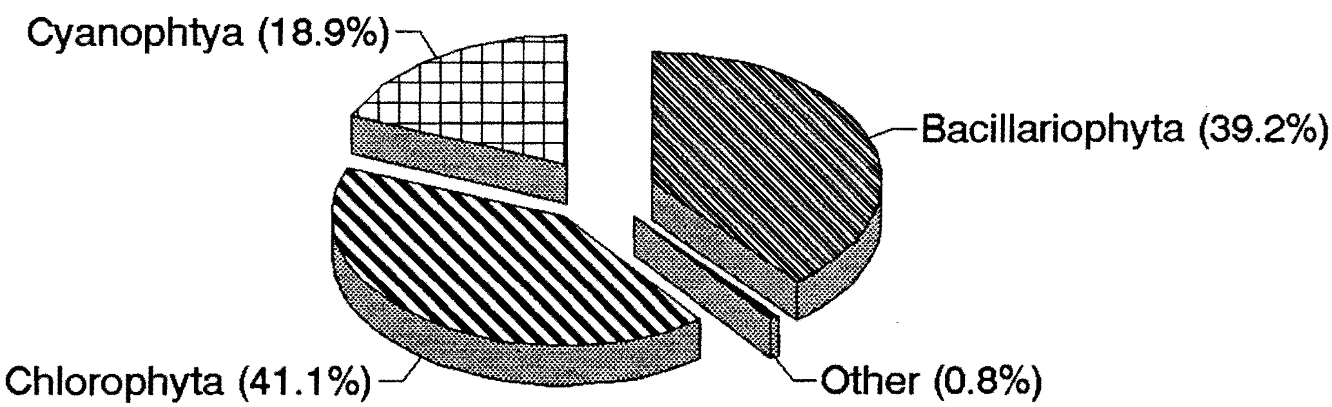
Current trophic status evaluation

There are several ways to evaluate the trophic status of a lake. In the last decade, most summary evaluations of lake trophic status have made using the Trophic State Index (TSI) concept developed by Carlson (1977). This method involves the scaling of separate measures of lakewater transparency, total phosphorus concentrations and chlorophyll *a* concentrations (a measure of algal biomass) to produce summary estimates of algal populations and lake trophic status.

Before summarizing calculations of TSI values, it is useful to consider other physical and chemical characteristics of Lake Amacoy. The lake is shallow and its surface area is small in relation to the size of the watershed. Both of these factors contribute to high natural productivity. Evidence of this high productivity was found in rapid oxygen depletion in deeper waters during periods of circulation, low transparency in surface waters and relatively high concentrations of algal nutrients.

Chlorophyll *a* values and total phosphorus concentrations are often highly correlated with lakewater transparency, but water color and suspended inorganic particles can influence the relationships (cf. Carlson

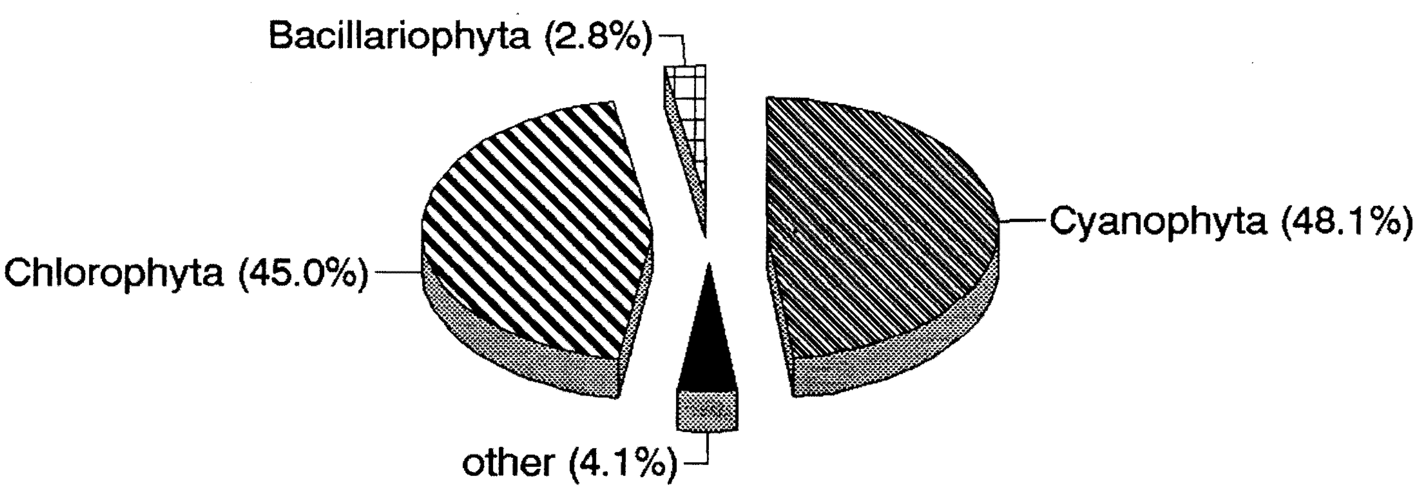
Amacoy Lake
Phytoplankton - August 1992



Total number of cells = 4021/ml

Figure 17.

Amacoy Lake
Phytoplankton - August 1991



Total number of cells = 4633/ml

Figure 18.

1980). In order to assess this possible influence, we took additional samples from the lake and measured turbidity and dissolved color. Although the lakewater had a slight yellow-brown color, the measured color was only 20-25 PCU for surface samples even in spring 1991 following the flooding of the lake with some water from the Chippewa River. Measured turbidity was generally low, except during algal blooms, and microscopic evaluations of particles determined that most of the particulates were algal cells. Therefore, inorganic particles and dissolved color had a minor influence on the relationships of transparency and nutrient concentrations or algal biomass.

The basic relationship between lakewater transparency and total phosphorus concentrations can be summarized as every doubling of total phosphorus leads to a halving of transparency. For example, if total phosphorus increased from 12 to 24 µg/l, Secchi disc transparency would decrease from approximately 4 to 2 m. Similarly, approximately a three-fold increase in measured chorophyll *a* (hereafter chl *a*) produces the same reduction in transparency. This relationships were scaled by Carlson (1977) such that TSI values ranged from 0 to 100 and a decrease in transparency or a doubling of phosphorus resulted in an increase of 10 TSI units. He also considered lakes having TSI from 0 - 40 to be oligotrophic, those from 40 to 50 to be mesotrophic and those lakes with TSI > 50 to be eutrophic.

For a sense of scale, a lake on the eutrophic border of TSI = 50, would have a transparency of 2 m, total phosphorus of 24 µg/l and chl *a* of 6.4 µg/l. During 1991, total P was approximately 20 ug/l throughout the summer at the mid-lake site. Higher concentrations were found at the southern shoreline site (A2-T), particularly during a blue-green bacterial bloom in August when total P was 51 µg/l. In 1992, total P ranged from 21 - 35 µg/l at mid-lake. A similar range was found at the shoreline site, except for the July sampling, when total P was 64 µg/l, also associated with a windswept accumulation of an algal bloom along the southern shore. These measurements indicate that Lake Amacoy is eutrophic.

Transparency and chl *a* also indicate the lake is eutrophic. As mentioned earlier, transparency was normally only 1 to 1.5 m. Chl *a* was only measured on the August samples for the mid-lake site, but was 16 and 21.4 µg/l in 1991 and 1992, respectively. Both measurements indicate high algal production. The results of calculations of the Trophic State Index are shown in Figure 18.

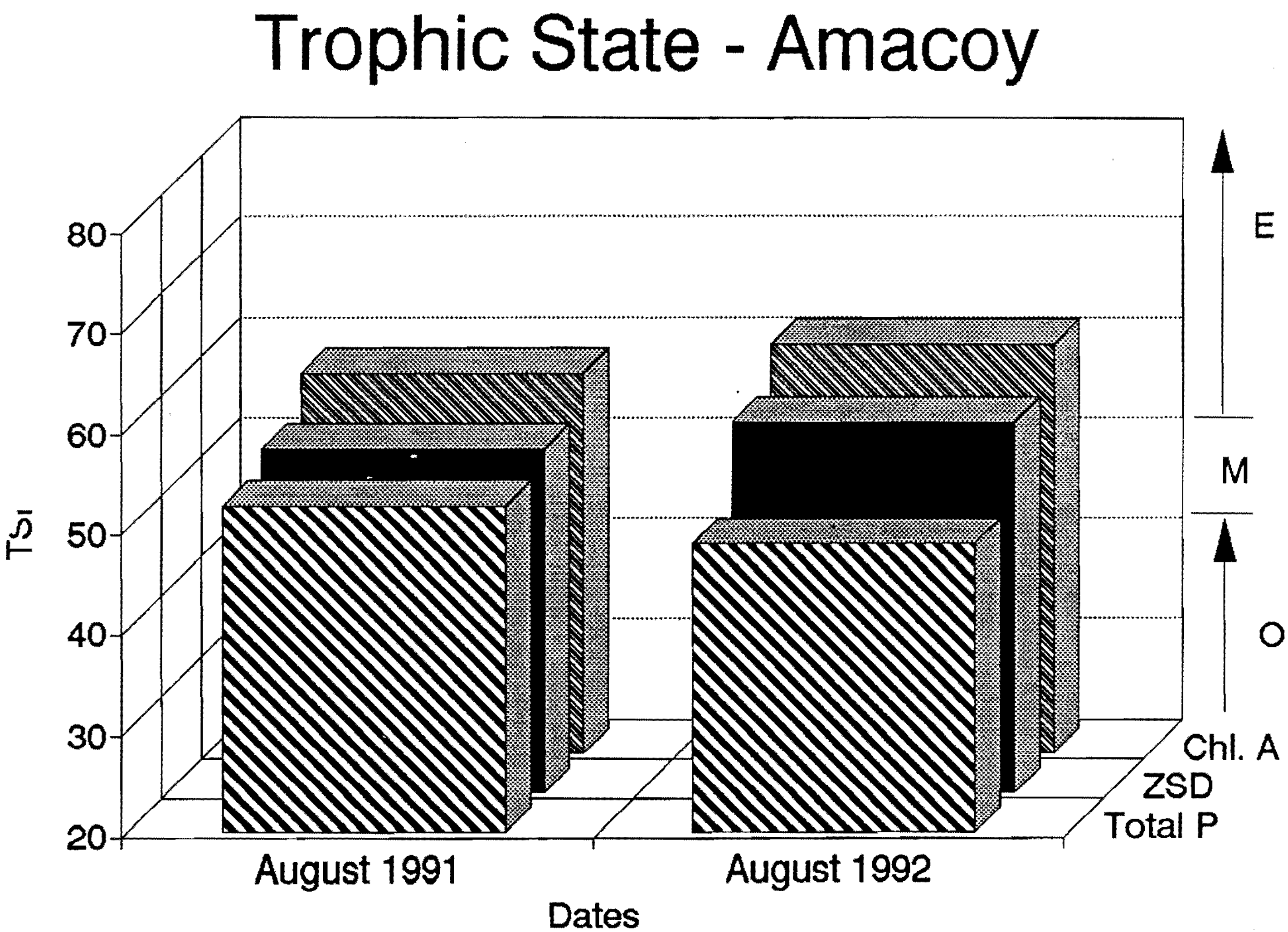

Trophic State - Amacoy
80
70
60
50
40
30
20
TSI
E
M
O
Chl. A
ZSD
Total P
August 1991
August 1992
Dates

Figure 19.

Other regional lakes have been sampled over the same time period for similar parameters and the samples were analyzed by the State Lab, except in the case of Pine Lake, where they were done by a private, certified laboratory. The results were summarized as TSI values for mid-lake stations in mid-August. We can then compare the Island Chain of Lakes (1991 values), Pine Lake (also 1991) and the two years of data for Lake Amacoy. Of the lakes, Pine Lake had the lowest P concentrations and was by far the most transparent. Clear Lake was the most transparent lake in the Island Chain, but it has higher P and algal biomass and lower transparency than Pine Lake. Lake Amacoy had greater algal biomass than the other lakes and the lowest transparency. It was the most eutrophic of the six lakes (Figure 19). This state was due to greater nutrient concentrations resulting from a large watershed area being loaded to a shallow lake with relatively low water color.

Nutrient and bacterial loading from the watershed

Developing a detailed hydrologic and nutrient budget was beyond the scope of this study and it would have required much greater sampling intensity. Nonetheless, we sampled inlet streams and can make some observations on levels of nutrients coming from the watershed of Lake Amacoy. Much of the drainage from the watershed enters the lake at site INL-1 on the northern shore. Nutrient concentrations at this inlet are higher than at the mid-lake site. Based on its size and nutrient concentrations, it is likely that the bulk of nutrient loading to the lake enters at this inlet. The sources of nutrients in the watershed that contribute to the inlet are unknown, but it is likely that natural loading rates are relatively high and some contribution is expected from agricultural activities. Further analysis of the source of nutrients draining into the lake via INL-1 is warranted.

Fecal coliform concentrations at INL-1 were often higher than at the southern shoreline or at the outlet, but concentrations never exceeded 60 colonies/100 ml sample and only two samples were > 20 colonies/100 ml. The major inlet does not appear to be a significant source of bacterial loading to the lake.

The second, smaller inlet (INL-2) does not contribute a large volume, but during periods of when it flowed into the lake, nutrient concentrations were elevated. During the first year of the study, flow at the inlet was diverted by construction along Highway 40. When the culvert

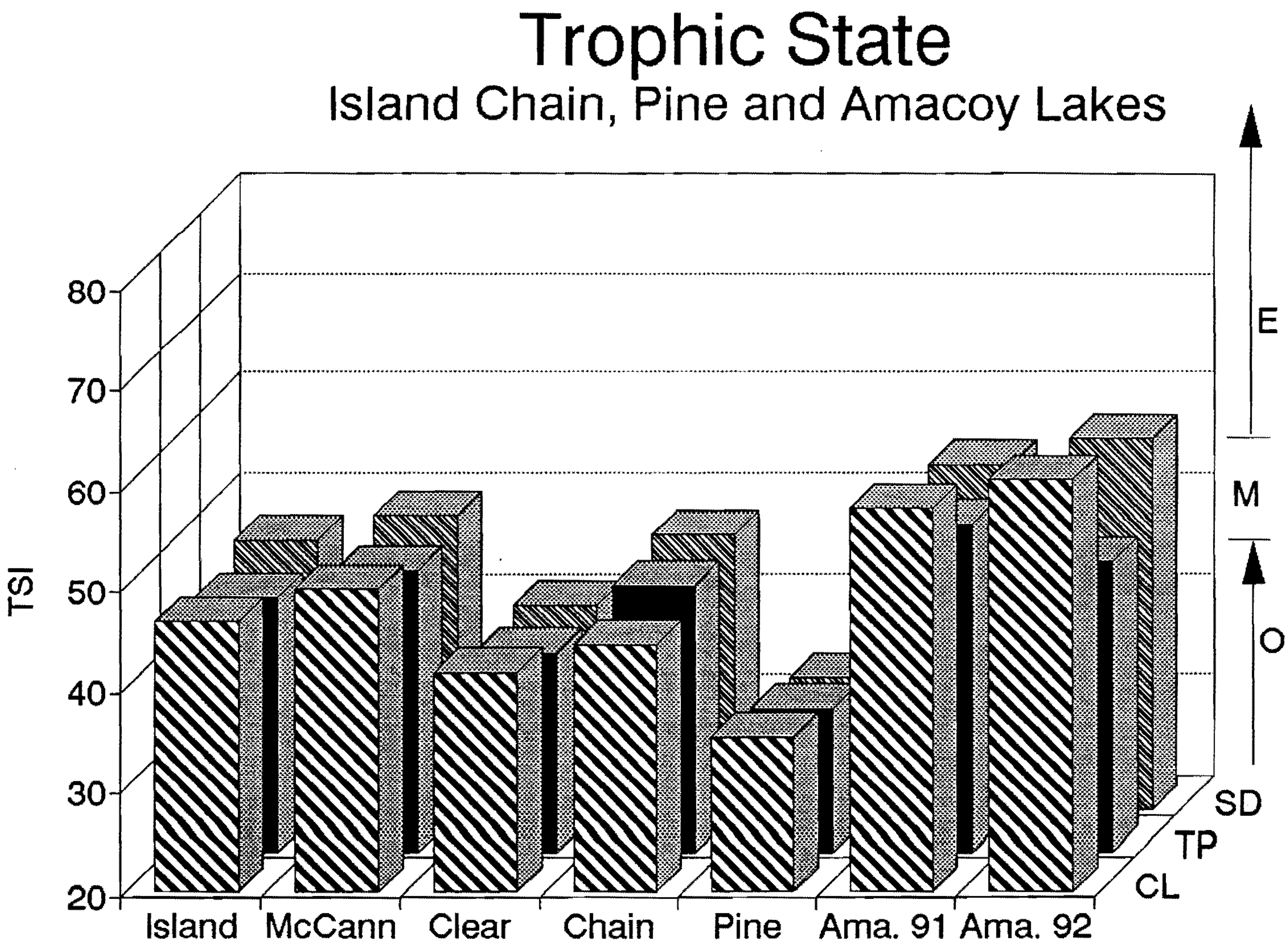

Trophic State
Island Chain, Pine and Amacoy Lakes
TSI
80
70
60
50
40
30
20
Island
McCann
Clear
Chain
Pine
Ama. 91
Ama. 92
SD
TP
CL
E
M
O

Figure 20.

under the road was opened and drainage from a nearby barnyard began to enter the lake, total phosphorus and bacterial concentrations increased substantially (Figures 20 and 21; see also Figure 15). No flow occurred at the site on the August sampling in 1992, but levels of nutrients and bacteria were particularly high for all other sample dates that year. Although INL-2 does not contribute a large volume of water to the lake, nutrient and bacterial loading are high and they appear to be associated with barnyard runoff. Immediate steps should be taken to address the problem of barnyard runoff directly entering Lake Amacoy. Bacterial levels in the immediate area of this small inlet would exceed NR 102 WI Administrative Code standards for recreational use of 200/100 ml for geometric means of multiple samples and greatly exceed standards for drinking water.

What is the influence of the Chippewa River on Lake Amacoy?

Prior to the installation of flood gates to protect the highway, the Chippewa River periodically backed up into the lake. This flooding undoubtedly influenced conditions in the lake, but it did not occur during all years and the amount of water entering the lake certainly varied from year to year. Did this flooding have a beneficial or detrimental affect on the lake because of the quality of the entering water? Two main factors might determine the response of the lake to the entry of water from the Chippewa River. First, could the entering river waters change nutrient concentrations in the lake? Second, did the river waters change the light environment and thereby influence the populations of algae that developed over the course of the summer. Both of these questions are significant and complex. Moreover, flooding of the lake occurred before we began the study, consequently we have no data available from before and after the flooding to address either question.

Water from the river has higher color than water entering Lake Amacoy from either of the inlets. Therefore, during periods following entry of river water, the lake should have higher dissolved color. This increased color would change the light environment and decrease the penetration of light into the water column. An increase in dissolved color might effectively reduce the production of algae by changing the light environment, but it also would alter the thermal regime and likely result in greater oxygen depletion in deeper waters. While it may be obvious that flooding would change the light environment, the influence on algal growth is more difficult to estimate.

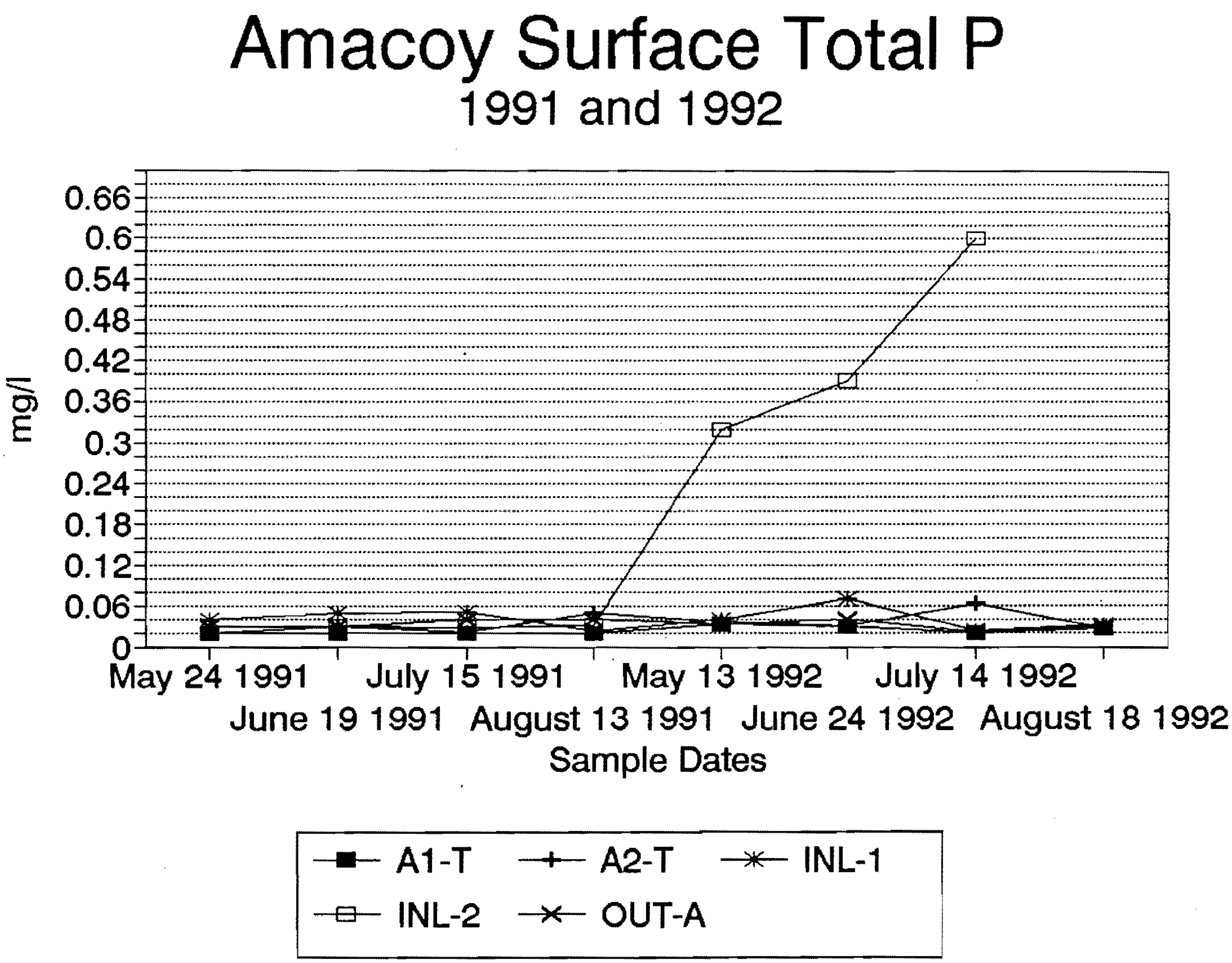
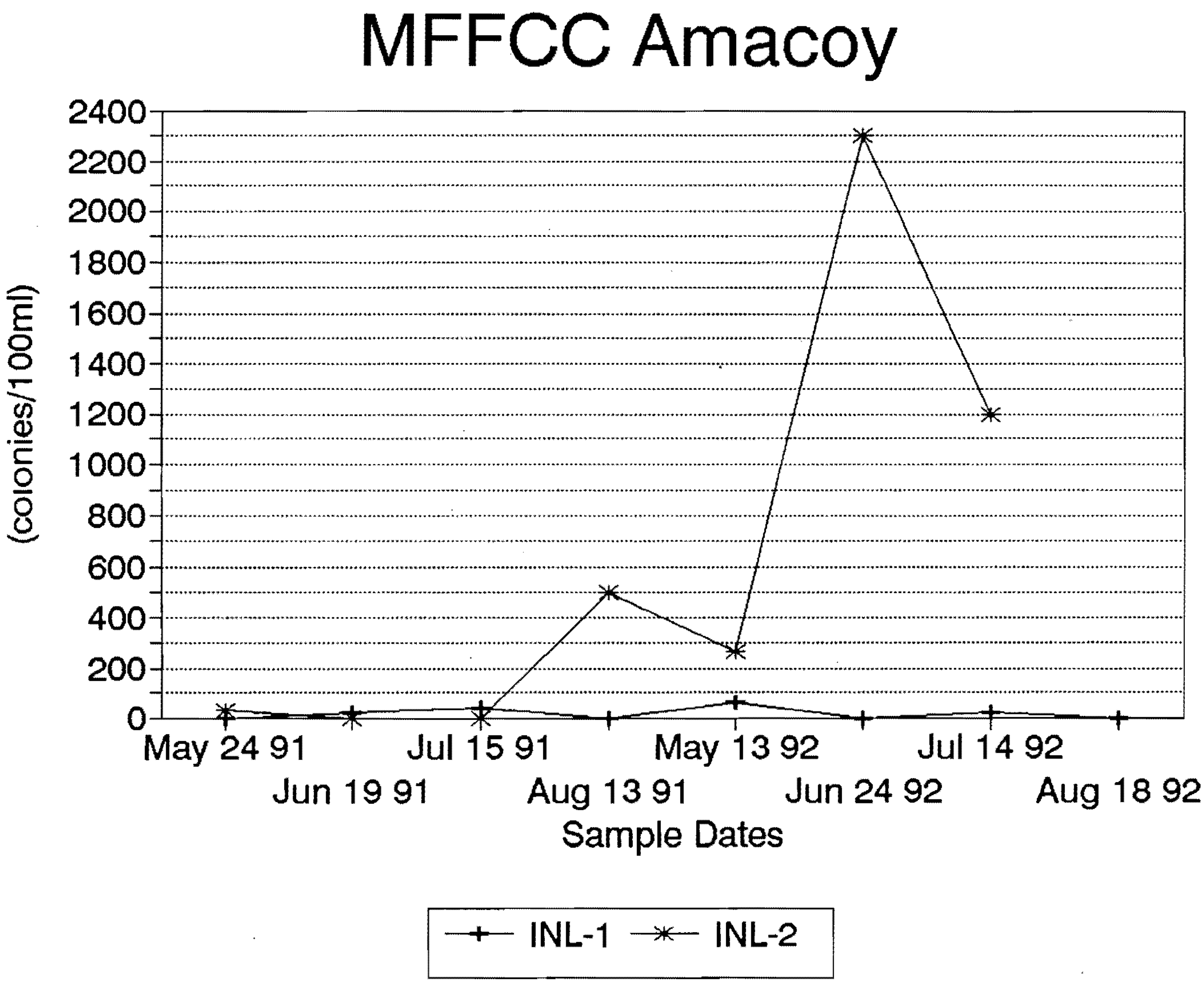

Amacoy Surface Total P
1991 and 1992
0.66
0.6
0.54
0.48
0.42
0.36
0.3
0.24
0.18
0.12
0.06
0
mg/l
May 24 1991
June 19 1991
July 15 1991
August 13 1991
May 13 1992
June 24 1992
July 14 1992
August 18 1992
Sample Dates
A1-T
A2-T
INL-1
INL-2
OUT-A

Figure 21.



MFFCC Amacoy
(colonies/100ml)
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
May 24 91
Jun 19 91
Jul 15 91
Aug 13 91
May 13 92
Jun 24 92
Jul 14 92
Aug 18 92
Sample Dates
INL-1
INL-2

Figure 22.

The question of whether the river might have a beneficial affect on the lake due to a combination of increased flushing rate and the entry of water of lower nutrient concentrations is very difficult to address given available information on the Chippewa River. I contacted a number of different sources to obtain data on nutrient concentrations in the Chippewa River. These potential sources included the WI DNR (Northwest: Larry Prem and Dan Ryan; and West Central Districts: Buzz Sorge), WI DNR personnel in Madison who are responsible for data in STORET, Robert Ramharter of WI DNR who was responsible for the Flambeau Mine Project Environmental Impact Statement, the U.S. Geological Survey and Northern States Power. I was looking for information along the stretch of river near Lake Amacoy and in spite of the number of contacts, I could not find extensive information on the Chippewa River in the relevant reach.

There is a U.S.G.S. gauging station on the Chippewa River near Bruce, but this station records only discharge measurements. There are some limited analyses of other parameters for the site from the mid-1960's, but no data were available for phosphorus concentrations. Similarly, during the Flambeau Mine Project EIS phase, extensive measurements were made on the Flambeau and Chippewa Rivers, but these measurements did not include analyses of nutrients (WI DNR 1990, 1992).

Two sites near Lake Holcombe have data records from the mid-1970's (WI DNR 1980) and there is recent data for the outlet from that flowage (NSP and WI DNR file data). These sites are a considerable distance downstream from Lake Amacoy and additional sources of nutrients along the river are unknown, so they may not provide a reliable indicator of nutrient concentrations near Lake Amacoy.

Some data were available for a site near the headwaters of the river in Sawyer County (WI DNR 1980). These data also were from the mid-1970's and are a considerable distance from the area near Lake Amacoy. The data showed a large variation in total phosphorus, however 8 of 11 measurements were < 40 µg/l and 5 of 11 were between 20 and 30 µg/l. The latter measurements were similar to the concentrations measured for the mid-lake site in Amacoy during 1991 and 1992 and lower than concentrations measured at the main inlet (INL-1). Measurements of phosphorus from the 1970's were not done with the same level of precision as the current analayses and there are several possible sources of nutrients and a large contributary watershed before the Chippewa River reaches the area of Lake Amacoy. Consequently, it is not possible to consider whether the river might have a beneficial impact on the lake by reducing nutrient concentrations by an input of relatively lower nutrient water during high water periods. In addition, most of the flooding periods are likely to occur in spring and few measurements were available for this period.

Given the observations of lakeshore residents that transparency of Lake Amacoy was better following the flooding of the Chippewa River in early 1991 than in other years and the very skimpy records of data on the river, the question of whether lake flushing caused by the river has a positive impact on the lake cannot be addressed at present. My observations of the lake in 1991 and 1992 also suggest the possibility that the river can have a beneficial impact on conditions in the lake, but it should not be viewed as a solution to the relatively high nutrient loadings currently received by the lake.

The question of the impact of flooding should be addressed by specific sampling and analysis of the river during relevant time periods. This analysis should involve a careful comparison of conditions in the lake and the river prior to and during the flooding interval, as well as observations on conditions in the lake after flooding. These analyses also should be combined with further analysis of the loading of nutrients from the watershed of the lake to determine whether nutrient sources in the watershed can be controlled, which also would result in improved conditions in the lake.

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NOAA (National Oceanic and Atmospheric Administration). 1991 and 1992. Climatological Data. Wisconsin. Volume 96 Numbers 5-8 and Volume 97 Numbers 5-8.

Executive Summary

Lake Amacoy is a small, relatively shallow and productive lake located in Rusk County, Wisconsin. Lakeshore residents have been concerned with maintaining water quality that is suitable for recreational activities, including boating, fishing and swimming. In order to evaluate the current status of the lake, the Rusk County Land Conservation Department applied for and received funding from the Wisconsin Department of Natural Resources (DNR) as part of the Lakes Planning Grant Program in 1991. The purpose of the grant was to determine: 1) the present status of nutrient conditions and algal populations; 2) whether inlet streams,which might be associated with agricultural activities, accounted for the observed levels of algal nutrients; and 3) whether there is evidence of bacterial contamination in Lake Amacoy.

In order to accomplish these objectives, we sampled Lake Amacoy and its inlet streams during May - August 1991 and 1992. The purpose of the sampling was to determine the current trophic condition (levels of nutrients and algal populations) of the lake. Evaluation of the trophic status of the lake included the measurement of thermal structure, oxygen distributions, lakewater transparency, chemical analysis of water samples and microscopic analysis of algal samples.

The summer of 1992 was cool and the lake responded with cooler surface water temperatures than observed in 1991 or found in previous studies by the DNR. The lake received floodwaters from the Chippewa River during the spring of 1991, which resulted in more darkly colored water and the highest transparencies during the study period.

Nutrient concentrations were relatively high in the major inlet stream (INL-1). The sources of these nutrients are unknown and may include contributions from agricultural practices in the drainage system of the main inlet. The highest concentrations of nutrients (but a relatively small volume of inflowing water) entered the lake via a small inlet (INL-2) running under Highway 40. This inlet was connected directly to a cattle feedlot and concentrations of coliform bacteria reached high levels when the inlet was flowing.

Nutrient concentrations in the lake were relatively high and they promoted algal growth that reduced the transparency of the water column. Surface water blooms of blue-green bacteria were noted on sampling dates in July and August 1991. Surface blooms also were observed in 1992, but with lesser frequency likely due to the cooler surface water temperatures.

All measures of lake trophic status (transparency, chlorophyll *a* concentrations as indicators of algal biomass, and total phosphorus concentrations) indicate the lake is eutrophic. Compared with several other lakes in the area, e.g. the Island Chain of Lakes, Amacoy is productive and subject to more frequent algal blooms.

Given the observation of lakeshore residents that transparency improves when the Chippewa River floods the lake, we considered whether future lake management might involve manipulation of the floodgates to allow more frequent entry of water from the river. Unfortunately, no prior data were available from DNR or other sources to evaluate the nutrient concentrations in the Chippewa River during periods of flooding and whether allowing entry of river water would result in flushing the lake with water of lower nutrient concentrations.

In order to maintain or improve the water quality in Lake Amacoy, several steps are suggested. First, immediate steps should be taken to address the problem of barnyard runoff directly entering Lake Amacoy at inlet INL-2. This runoff represents excess nutrient addition and also may be a health hazard for human contact. Samples collected at the inlet would exceed State Standards for recreational use and greatly exceed Standards for drinking water. Lakeshore residents drawing water directly from the lake for human consumption, especially those residents near one of the inlets, should have the water tested by the County Health Department for levels of bacteria.

Second, given the relatively high nutrient loading from the main inlet, sampling should be conducted on its drainage to determine if animal feedlots or other practices are contributing to nutrient loading of the lake or whether natural sources predominate. Significant reduction in current nutrient loading is unlikely unless some point sources or a number of diffuse, non-point sources are identified. Nonetheless, best management practices should be used in the watershed to protect the quality of the lake.

Third, because of the uncertainty about nutrient concentrations in the Chippewa River near Lake Amacoy, nutrient samples should be collected at the river during high water periods when entry into the lake might occur. Based on comparison of in-lake and inlet concentrations of nutrients and river water concentrations, the correct course of action in allowing or preventing river water into the lake can be determined.

Appendix 1.

Raw data on Phytoplankton Counts

Amacoy Lake

August 1991 and August 1992

AMACOY LAKE
13 August 1991

Phytoplankton from 100 ml of lake water was preserved by settling in 1 % Lugol's sol'n which was then; concentrated to 20 ml prior to counting. Ten ml of the concentrated plankton were added to a plankton counting chamber and enumerated using a Wild inverted microscope at 400X. Due to number of plankters present field counts (area 0.01525 mm) were utilized instead of strip counts. In all instances forty fields were counted.

TAXON	Colonies/ml	Cells/ml	NOTES
BACILLARIOPHYTA			
Melosira granulata	16	98	
Synedra tenera		16	
Tabellaria fenestrata	16	16	
CHLOROPHYTA			
Ankistrodesmus falcatus		180	
Chlamydomonas sp.		869	
Micractinium pusillum	16	393	
Scenedesmus quadricauda	16	64	
Selenastrum bibrainum	16	590	
Xanthidium subhastiferum		16	
EUGLENOPHYTA			
Trachlemonas sp.		16	
IRYSOPHYTA			
Chroomonas nordstedtii		98	
CRYPTOMONADALES			
Cryptomonas erosa		16	
CYANOPHYTA (Cyanobacteria)			
Anabaena circinalis	229		av. length 0.138 mm
Anabaena limnetica	197		av. length 0.374 mm
Anabaena planctonica	131		av. length 0.284 mm
Anabaena spiroides v. *crassa*	147		av. length 0.131 mm
Aphanocapsa elachista	410		fragmented?
Aphanocapsa pulchra	262		
Aphanothece sp.	16		fragmented?
Aphanizomenon flos-aquae	820		av. length 0.112 mm
Coeleosphaerium naegelianum	33		
Lyngbya birgei	16		av. length 0.2 mm

AMACOY LAKE
8 August 1992

Phytoplankton from 100 ml of lake water was preserved by settling in 1 % Lugol's sol'n which was then concentrated to 20 ml prior to counting. Ten ml of concentrated plankton were added to a plankton counting chamber and counted using a Wild inverted microscope at 400X. One strip (area 1.25 mm^2) was counted.

TAXON	Colonies/ml	Cells/ml	Notes
BACILLARIOPHYTA			
Fragilaria crotonensis	24	704	
Stephanodiscus niagarae		8	
Synedra delicatissima		8	
Tabellaria fenestrata	107	852	
CHLOROPHYTA			
Chlamydomonas spp.		90	
Coelastrum microporum	8	262	
Geminella mutabalis	33	746	
Sphaerocystis schroeteri	24	459	
Spondylosium pulchrum	24	82	
Staurastrum sp.		8	
PYRROPHYTA			
Ceratium hirundinella		8	
CHRYSOPHYTA			
Chroomonas nordstedtii		24	
CYANOPHYTA			
Anabaena circinalis	33		av. length 0.311 mm
Anabaena limnetica	90		av. length 0.08 mm
Anabaena spiroides	90		av. length 0.117 mm
Aphanocapsa elachista	98		
Aphanocapsa pulchra	24		
Aphanothece spp.	106		
Aphanozomenon flos-aquae	106		av. length 0.03 mm
Coeleosphaerium naegelianum	164		
Gomphosphaeria lacustris	33		
Lyngbya spp.	16		av. length 0.122

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