Baseline Limnological Data and Bathymetry of Nansen Lake, Cranberry Bog and Ziesnis Bog

BIOS 569 - Practicum in Aquatic Ecology

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ABSTRACT

This study was intended to be descriptive in quality. Its chief concern was the investigation of two bodies of water recently acquired by the University of Notre Dame Environmental Research Center, and a third bog that had been little studied in the past. Cranberry Bog and Nansen Lake are located on the newly attained western edge of the property. After travel to the lakes was made possible, measurements of various physical, chemical, and biological data were undertaken to establish a beginning to our knowledge of the character of these bodies of water. Sonar was used to map the bathymetry of these and several other lakes on the property. Access to the sites was improved.

Another facet of the study that did not meet with the same degree of success was an attempt to monitor diel vertical migrations in the cladoceran Daphnia. This undertaking involved twenty-four hour sampling periods at meter depth intervals in the deepest part of the Bog. It was hoped that a pattern of migration would be established in Cranberry and Ziesnis Bogs. Comparison of the migration patterns of the animals in the two lakes would be of significance to the predation avoidance hypothesis because Ziesnis contained no planktivorous fish; Cranberry did. Unfortunately this facet never came to fruition due to significant problems with the sampling technique and equipment.

INTRODUCTION

Over the ten week period beginning in mid-May and extending to the end of July, 1991, descriptive research was conducted on the University of Notre Dame Environmental Research Center's property. By its completion, the study included work on several lakes. Three of these, Nansen Lake, Ziesnis Bog and Cranberry Bog had previously not had any formal extensive research performed on them; consequently, little was known about these habitats.

The intent of the research was two-fold; both facets were of an observational or descriptive nature. Dini (1989) has performed an extensive study on the adaptive significance of the diel migration of daphnids. His study was conducted on the UNDERC properties during the summers of 1985-1989. He determined that the potential for diel migratory behavior lies in the genome of the daphnid. He explored one potential explanation for this behavior known as the predation avoidance hypothesis. A simplified summary of this hypothesis suggests that the migration downward in the water column during the daylight hours is a response to visual predation by fish. The lower, darker waters provide a safety zone for the microcrustaceans. At night, when the light intensity is low in the upper waters, the zooplankton ascend to feed on the phytoplankton, which are more abundant in the upper water.

Dini has shown that under conditions of high fish planktivory, non-migrating individuals would be eliminated by visual predators in the daylight, giving a competitive advantage to the migrating animals. In lakes with low fish planktivory, there was found to be a high variability in migratory behavior.

This study was to have compared the variability in diel migration of daphnids in Ziesnis Bog, which is believed to be fishless, with the diel migration of daphnids in Cranberry Bog, which is known to contain fish. The presence or absence of zooplanktivores was to be considered as a possible reason for behavior patterns of the microcrustacean, in accordance with the predation avoidance hypothesis. It was understood that the ultimate answer to the question of variability in diel migrations is likely to be a synthesis of complex, multi-factor hypotheses, rather than a simple, single factor hypotheses hinging on one variable, such as fish predation. The proximity and similar nature of the two bogs, however, provide an opportunity to investigate the role of fish predation and the viability of the predation avoidance hypothesis in a natural setting.

A second important aim of the study was to gather baseline limnological data. These investigations were principally focused on Cranberry Bog and Nansen Lake because of the lack of data existing on the two lakes located on recently acquired land. Data was also obtained from Ziesnis Bog and several other lakes and bogs on the property. Bathymetric maps were constructed for several bodies of water that had previously been unmapped. The acquisition of baseline data on these lakes is significant in that they provide an index of limnological conditions on bodies of water that have remained relatively undisturbed by man.

Comparison with lakes suspected to be affected by the activities of man may prove useful.

STUDY SITE, MATERIALS, AND METHODS

The study site was the lakes of the UNDERC property, with special emphasis on Cranberry Bog and Nansen Lake, which are located on the recently acquired western edge of the property. The first task was to find the lakes. This was done with the aid of Eileen Perkins, teaching assistant for the course. A veteran explorer of the property, Ms. Perkins lead us to Cranberry, then Nansen with little misdirection. Even though it had been a relatively dry spring, the road leading into the lakes was impassable during the first few weeks of the program. The road was choked with fallen trees and other natural refuse throughout its entire length. This made early attempts at investigation of lakes with any instruments, especially boats, impractical. The groundskeepers assisted Mark Lavery and myself in clearing the road and it was soon passable with four wheel drive vehicles. The main road lead directly to Cranberry Bog, allowing us to drive equipment to within sixty yards of the shore of the bog. The path that branched off the main road and lead to Nansen Lake was not driveable, therefore a three-quarter mile hike was required for access to the lake.

Ziesnis Bog was easily accessible, located one hundred yards to the west of the main road leading north out of the compound.

As the summer progressed, efforts were made to improve the accessibility of the lakes. Periodic maintenance of the path to Nansen was required in order for the lake to remain passable, especially in a particularly low, wetland area of the trail. The main road leading to Cranberry was fortified by the addition of crushed stone in areas. A bog walk was constructed from the edge of dry land to the edge of Cranberry bog, in order to reduce destruction to the bog mat occasioned by frequent trips to and from the water's edge. The construction of the walk involved gathering of cedar logs and purchase of rough cut 2"x6"x8' cedar planks. The logs were cut to 2.5-3 foot lengths and placed at four foot intervals from the edge of the water to the edge of the mat. The planks were nailed in place on top of the logs, providing a 20 to 24 inch walking platform.

While the boats were left at the respective lakes, all other equipment was carried to the lakes on every visit. This equipment included a Van Dorn sampler. This was used to obtain water samples from discreet depths in the lake. The water samples obtained from this sampler were used to measure pH and sometimes conductivity in the field, and water was bottled for further chemical analysis in the lab. Analysis in the lab include tests for total acidity in mg/l phenolphthalein acidity as $CaCO_3$, orthophosphate concentration in mg/ l PO_4^{3-}, nitrate concentration expressed in mg/l NO_3^--N, color, both true and apparent, expressed in Platinum-Cobalt units, and sulfide in mg/l H_2S. All these parameters with the exception of sulfide, were tested using the Hach DR/2000 spectrophotometer. The procedures can be found in the Hach DR/2000 Spectrophotometer Handbook. The procedure of the sulfide test was to place pre-treated pads in the cap of a reaction vessel. A water sample was then placed in the bottle and a bicarbonate reagent in the form of an Alka-Seltzer tablet was added. The color of the pad was then compared with known standards to determine a sulfide level. Precaution was taken with samples to be tested for sulfide concentration because of the possibility of contamination of sample with oxygen; this was a difficult problem, and many samples were probably contaminated. This concern was also considered when testing pH and acidity.

Samples were also obtained using the Van Dorn for the analysis of chlorophyll-A concentrations. Again, special precautions were taken with these samples. They were stored in a cooler, or insulated in some manner so they would not be affected by sunlight or a temperature change before analysis could begin. The sample was filtered with a suction apparatus. The volume of the sample filtered was recorded. The filters were then placed in film canisters and frozen. On the day before the evening appointed for work with the spectrophotometer, the filters were dissolved in 50 ml of methanol. A reagent was then added to the extract and the sample was placed in the spectrophotometer with the appropriate light setting and the proper light filter was selected. An initial reading was recorded and thirty seconds later a second reading was recorded. The micrograms/liter of chlorophyll-A was computed by taking the difference of the two numbers, multiplying by a factor determined by the scale of the light setting and the percent light filtration, and dividing by the volume of sample originally filtered.

The Van Dorn sampler also was used in an attempt to collect biological data. The sampler was lowered to the depth desired and the sample was collected. The entire contents of the Van Dorn was then filtered through a plankton net in order to reduce the amount of water in the sample while retaining the zooplankton. The concentrated sample was then placed in a jar containing a ten percent formalin solution. Some difficulties were discovered with this method, so the Van Dorn was modified. Fins were attached in the vertical plane, and the sampling method was altered. The Van Dorn was lowered to the desired depth and immediately swung the length of the boat in hopes of obtaining a sample truly isolated to the depth desired. The fins were to direct the motion of the sampler in a horizontal linear manner. This method proved less effective in practice than it had been hoped. A further discussion of the results of the biological sampling is found in the results and discussion sections.

A plankton net was used both in the manner explained above and for vertical plankton tows. The net had a radius of 14.75 cm. at its mouth. The mesh size was 64 microns.

Another instrument used was a Hach portable pH meter. The meter was calibrated with buffer solutions and, when functioning properly, the instrument gave instant pH readings by placing the probe in the sample. A Hach conductivity meter was also used. Conductivity was displayed as μ mho/cm.

An oxygen-temperature probe was used. The probe was calibrated and lowered to the desired depth where the oxygen concentration could be read in parts per million and the temperature could be read in degrees centigrade.

A light probe and Sechi disk were used to determine light levels. Light was recorded in units of micro einsteins. Sechi depths are recorded in meters.

In order to monitor diel migrations of microcrustaceans, a 24 hour sampling must be performed. It would obviosly be most desirable to take the 24 hour at the lakes to be compared over the same 24 hour period. Due to lack of available manpower, this proved to be impossible. The dates for the sampling were made as close as possible. The sampling of Nansen Lake occured on the 17-18 of June 1991; the sampling of Cranberry Bog occured on the 22-23 of the same month. The procedure was as follows: At the approach of every even numbered hour with the exception of 2:00 AM and 2:00 PM, the boat was positioned at the deepest point in the lake and anchored. Biological samples were then taken at every meter and placed in labelled jars. The jars were then safely stored for lab analysis. A Sechi disk reading was then recorded, if visible, and a light reading with the light meter was recorded at each meter of depth. A terrestrial light reading was also recorded. The air temperature and conditions were noted, and the water temperature and dissolved oxygen were recorded. In some cases the pH was recorded over the 24 hour period, but the data was not consistent due to a malfunctioning probe.

Bathymetric maps were constructed and converted into the appropriate format. This was done for the following bodies of water: Cranberry Bog, Nansen Lake, Ziesnis Bog, Bog Pot Lake, Brown Lake, Hummingbird Bog, Morris Lake, the northeast bay of Tenderfoot Lake, Tender Bog, and Ward Lake. In conjunction with Mark Lavery, a system for consistent mapping of the lakes was developed using a Tournament sonar unit and a trolling motor. Details of the mapping protocol are available and included in Appendix 1.

RESULTS

The results for the biological aspect of the study, in which the question of the predation avoidance hypothesis' relevance to daphnid migration was to be addressed, were not conclusive. Some limited information was attained however. It was established that daphnid assemblages existed in both Cranberry and Ziesnis Bogs through examination samples obtained through horizontal plankton net tows. Unfortunately, when using this method of sampling, we did not seek to establish a a qualitative measure of population, and therefore did not record the horizontal distance of the tow.

The samples collected during the 24 hour sampling period at Cranberry Bog were analyzed and discredited as probably invalid do to problems with sampling technique. This determination was made in conjunction with the assistant director, Dr. Berg. After thourough examination of samples from 8 depths for both the 12:00 AM and 12:00 PM sampling periods, along with analysis of samples from other selected times and depths, it was apparent that no discernable migration pattern would be established from the samples collected. Examination of samples from Nansen Lake indicated the same difficulties. In addition to abscence of pattern, it was noted that zooplankton numbers of all kind were remarkably small. This made examination of even the few samples analyzed a long and tedious process. The following is a list of families of zooplankton found and individuals recorded from a count of an <u>entire</u> sample from the 12:00PM sampling:

.5 m - (1) Dioptomid

1.5 m - (1) Dioptomid
2.5 m - (1) Dioptomid, (1) Bosminid, (1) Daphnid
3.5 m - none
4.5 m - (1) Dioptomid, (2) Bosminids
5.5 m - (1) Bosminid, (1) Daphnid
6.5 m - (1) Macrothricid, (1) Bosminid, (1) Dioptomid
7.5 m - none

It is apparent that these numbers are probably not representative of the actual conditions in the bog. This issue will be addressed in the Discussion section. The zooplankters were not keyed out further as effort was concentrated on developing a more effective trapping system.

Vertical plankton tows were taken to get a rough estimate of daphnid populations in Cranberry and Ziesnis Bogs. A plankton net towed vertically through 6.5 meters of water and having a circular area of $\pi \times (14.75\text{cm})^2$. Therefore, the volume of water sampled was 443950 cm^3. The daphnid counts from three samples of this size taken on June 29 from Cranberry Bog averaged 514 individuals per sample. The volume contained by a Van Dorn sampler is only 2500 cm^3. A simple ratio of animals counted to volume of water, reveals that if the Van Dorn samplers were porportional to the tow samples (a questionable assumption), the 2500 cm^3 would contain approximately 2.5 daphnids.

Ziesnis Bog planktonic tow samples were taken on July 17. The tows contained an average of 570 daphnids per sample.

Minnow trapping and personal observations of potentially zooplanktivorous fish populations in the three lakes revealed that Nansen Lake had a very high zooplanktivore population, while lower levels existed in Cranberry Bog. No evidence of fish population was found in Ziesnis Bog.

Total acidity was was found to be 5.8 mg/l phenophthalein acidity as $CaCo_3$ at a .5m smple, comparable to the value of 6.0 mg/l recorded for Cranberry on the same date at the same depth. Ziesnis' total acidity was recorded at a higher level of 28.5 mg/l $CaCO_3$ on July 1, 1991.

Sulfide was detectable to the nose in samples taken within 1m of the bottom in all three lakes, but sample contamination with oxygen by the time they could be processed in the lab made results unattainable or suspect. Lack of oxygen in the hypolimnion of all three of the lakes suggests hydogen sulfide is present.

Orthophosphate and nitrates were low in all three lakes. Readings ranged between 0.0 mg/l and 0.4 mg/l PO_4^{3-}, and 0.0 and 0.2 mg/l N-NO_3/l for Ziesnis Bog. In Nansen Lake the range was .03-.06 mg/l PO_4^{3-} and .02-.03 mg/l N-NO_3/l. Cranbery ranged between .01-.04 mg/l PO_4^{3-} and .01-.05 mg/l N-NO_3/l. These numbers are all low, as would be expected for undisturbed lakes in this region.

Color was measured in Platinum-Cobalt units. Nansen was found to be the most highly colored with a true color of 169 Pt-Co units and an apparent color of 191 Pt-Co units. Ziesnis had an apparent color of 141 Pt-Co units and a true color of 107 Pt-Co units. Cranberry was the least colored of the three lakes with readings of 119 Pt-Co units apparent color and 87 Pt-Co units true color.

The results of the bathymetric mapping are located in Appendix 2.

Pertinent physical and chemical data are located in the graphs in Figures 1-5.

FIGURE 1

****INSERT FIG. 1 HERE (NANSEN 1)****

FIGURE 2

****INSERT FIG. 2 HERE (CRAN 1)****

FIGURE 3

****INSERT FIG. 3 HERE (CRAN 2)****

FIGURE 4

****INSERT FIG. 4 HERE (ZIES 1)****

FIGURE 5

****INSERT FIG. 5 HERE (ZIES 2)****

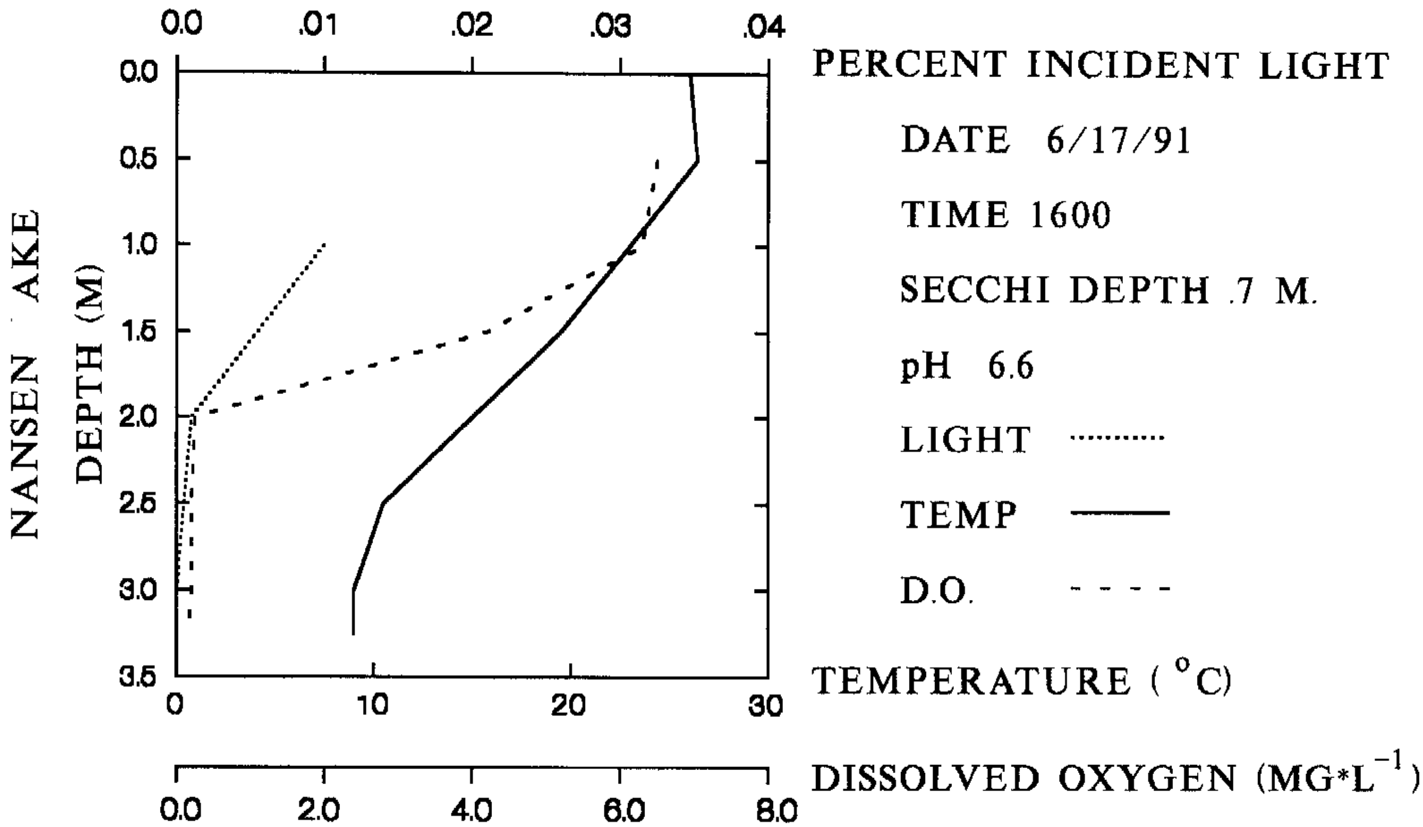
DISCUSSION

The primary difficulty encountered this summer was with the zooplankton trapping methods. As shown earlier, the volume of water contained in a sample collected by a Van Dorn may not be sufficient to trap a desirable number of zooplanktors. This however may not be the biggest problem. It has been suggested that the major flaw in this method may be slightly more complex than the simple factor of volume. It involves the hydrodynamics of the Van Dorn. When the Van Dorn is lowered in the conventional manner, the cylinder is in a horizontal position, with both ends open to the water. It has been suggested by Drs. Berg and Carlton that the continual eddies that form inside the sampler as it is being lowered serve to mix the water inside the sampler with all the water it passes through on its way down to the desired depth. The result is that rather than a discreet sample from the depth to which it is lowered, the Van Dorn traps an integrated sample containing water from the entire length of its descent.

If this were the only problem, it could conceivably be solved by using a Kemmer Sampler, which lowers the cylinder vertically oriented in the water, or by allowing the Van Dorn to equilibrate at the desired depth. Another problem is probable however. Even if the Van Dorn is lowered and allowed to equilibrate, there may be a tendency for the microcrustaceans to avoid the trap due to the fact that they may sense and avoid the large white cylinder.

One attempt made to overcome the problem of integrated samples and zooplankton avoidance was to add large fins to the sides of the sampler. Three plastic fins were positioned on the body of the sampler in an attepmpt to make it more hydrodynamically stable (see figure 6). These additions were to take advantage of a new sampling procedure. The sampler was lowered to the desired depth, and upon reaching this depth was dragged the length of the boat, and the messenger was then released to close the trap. In theory, the sampler would move horizontally through the water and trap a sample containing water from only the desired depth. The motion would also not allow for time for the animals to avoid the trap. Unfortunately, the results were not realized in practice. The sampler would often twist when being lowered, especially to lower depths, and

FIG. 1



0.0
.01
.02
.03
.04
PERCENT INCIDENT LIGHT
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
NANSEN AKE
DEPTH (M)
DATE 6/17/91
TIME 1600
SECCHI DEPTH .7 M.
pH 6.6
LIGHT
TEMP
D.O.
0
10
20
30
TEMPERATURE (°C)
0.0
2.0
4.0
6.0
8.0
DISSOLVED OXYGEN (MG*L^-1)

FIG. 2

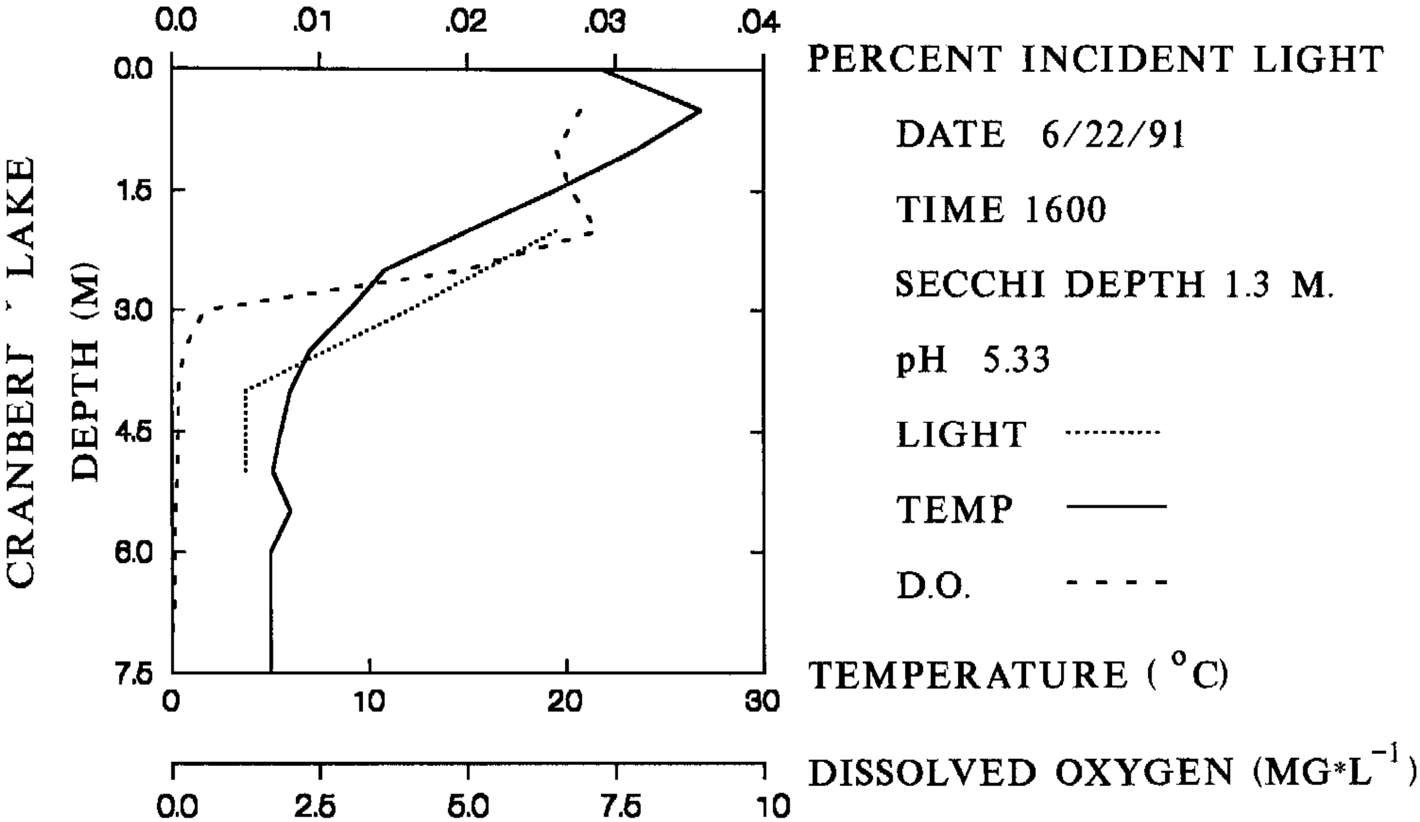
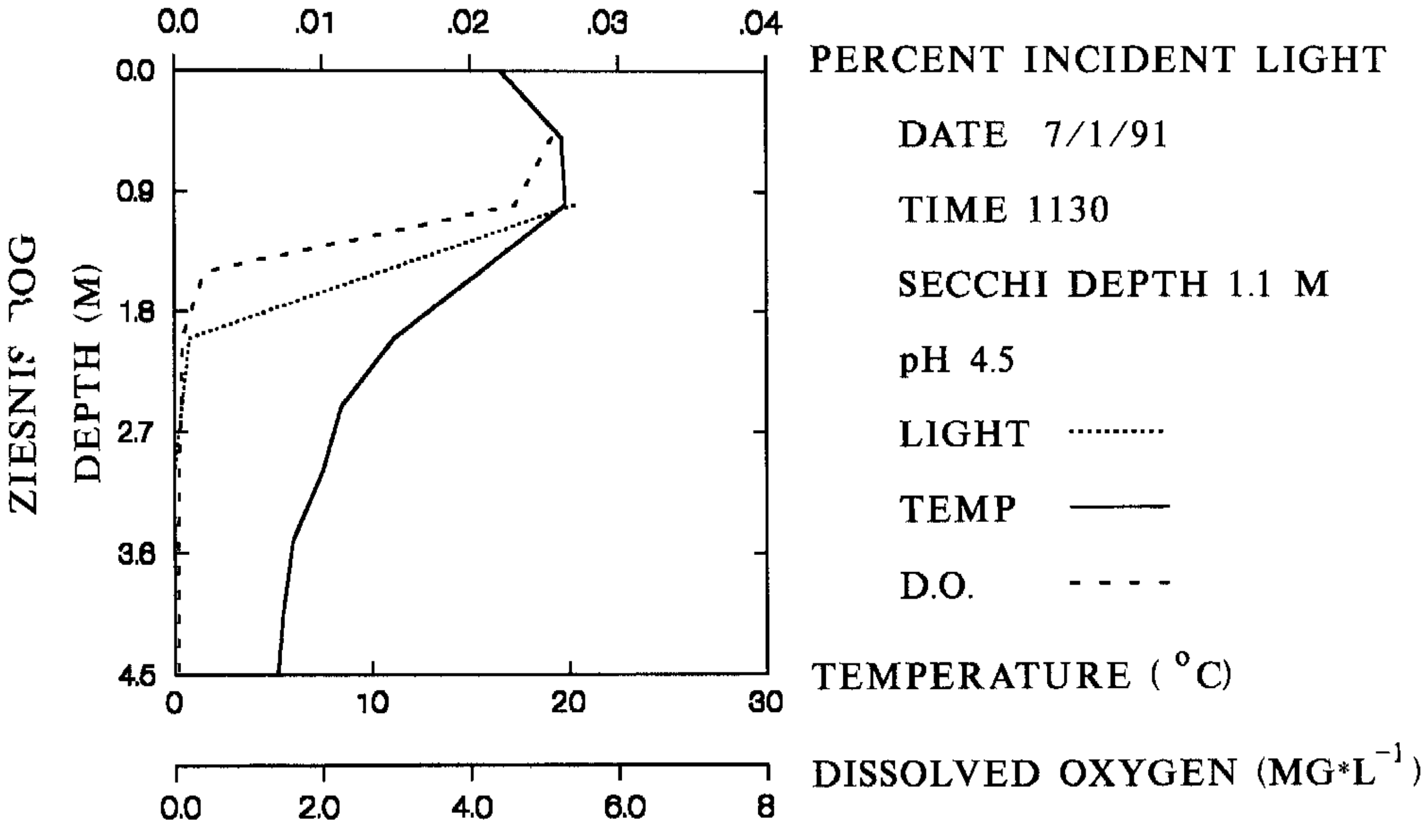

0.0
.01
.02
.03
.04
PERCENT INCIDENT LIGHT
DATE 6/22/91
TIME 1600
SECCHI DEPTH 1.3 M.
pH 5.33
LIGHT
TEMP
D.O.
CRANBERI ' LAKE
DEPTH (M)
0.0
1.5
3.0
4.5
6.0
7.5
0
10
20
30
TEMPERATURE (°C)
DISSOLVED OXYGEN (MG*L-1)
0.0
2.5
5.0
7.5
10

FIG. 5



0.0
.01
.02
.03
.04
PERCENT INCIDENT LIGHT
DATE 7/1/91
TIME 1130
SECCHI DEPTH 1.1 M
pH 4.5
LIGHT
TEMP
D.O.
ZIESNIS BOG
DEPTH (M)
0.0
0.9
1.8
2.7
3.6
4.5
0
10
20
30
TEMPERATURE (°C)
DISSOLVED OXYGEN (MG*L^-1)
0.0
2.0
4.0
6.0
8

FIG. 3

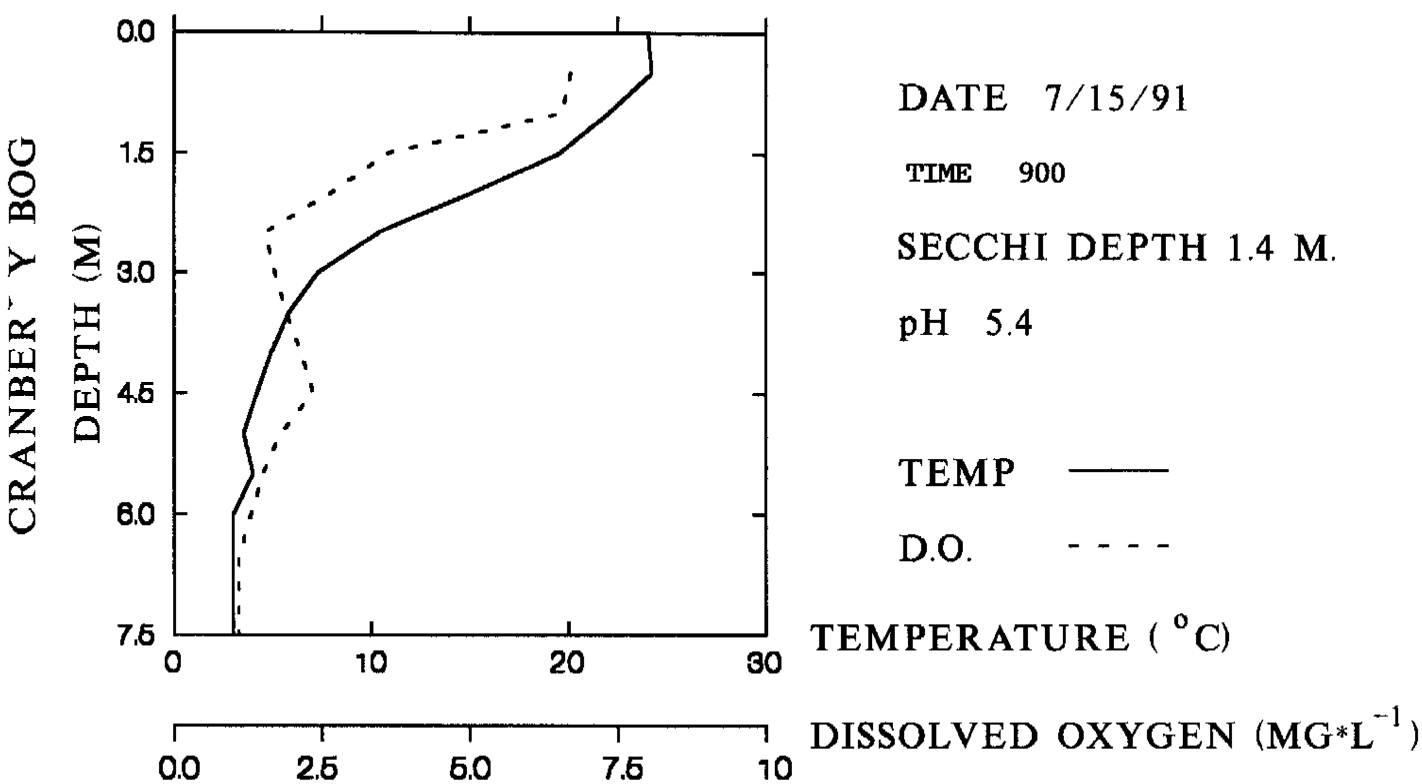
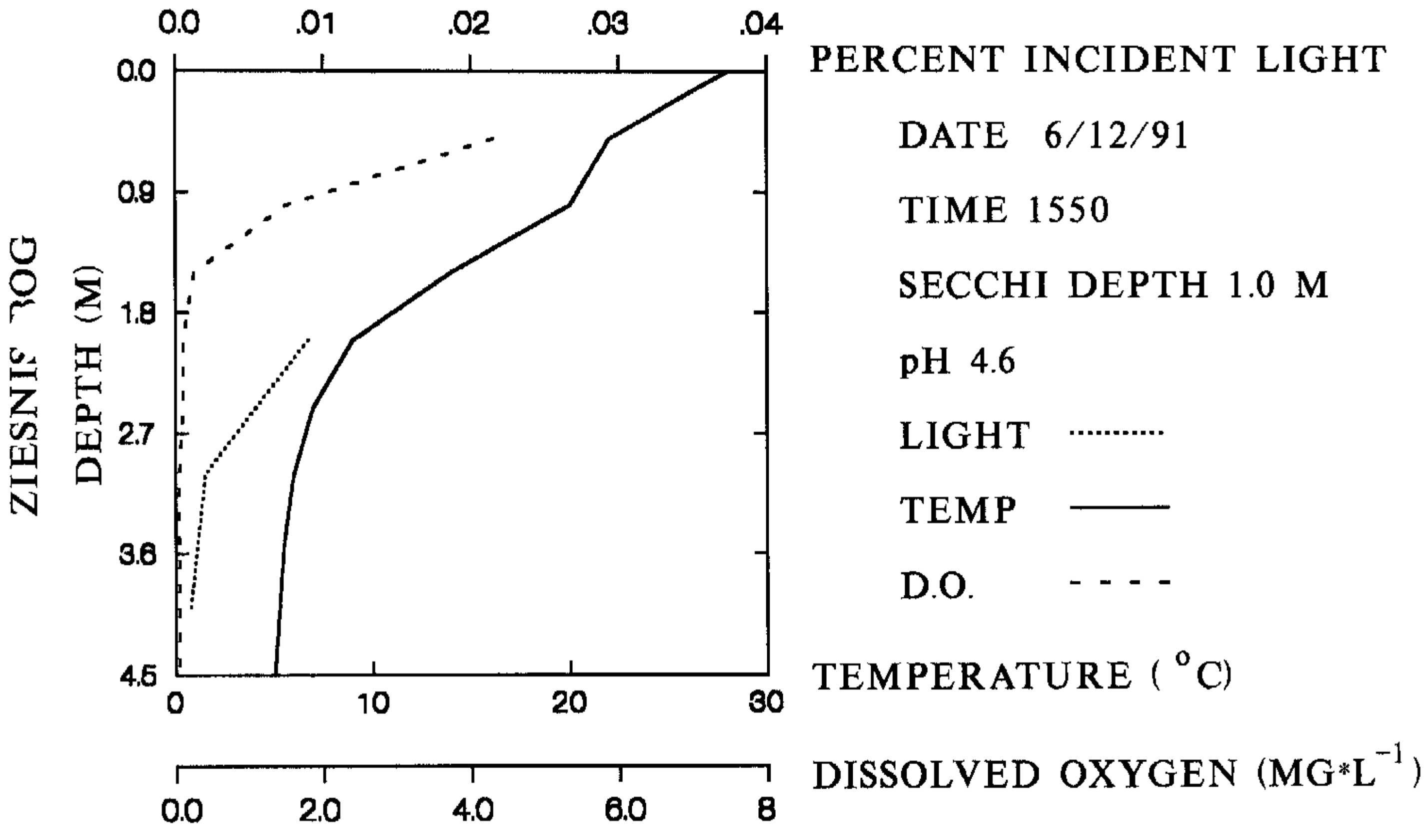

CRANBER` Y BOG
DEPTH (M)
0.0
1.5
3.0
4.5
6.0
7.5
0
10
20
30
TEMPERATURE (°C)
0.0
2.5
5.0
7.5
10
DISSOLVED OXYGEN (MG*L⁻¹)
DATE 7/15/91
TIME 900
SECCHI DEPTH 1.4 M.
pH 5.4
TEMP
D.O.

FIG. 4


ZIESNIS BOG
DEPTH (M)
PERCENT INCIDENT LIGHT
0.0
.01
.02
.03
.04
0.0
0.9
1.8
2.7
3.6
4.5
DATE 6/12/91
TIME 1550
SECCHI DEPTH 1.0 M
pH 4.6
LIGHT
TEMP
D.O.
TEMPERATURE (°C)
0
10
20
30
DISSOLVED OXYGEN (MG*L⁻¹)
0.0
2.0
4.0
6.0
8

would not come around and move through the water in the desired trajectory by the time the top of the rope had been relayed from one end of the boat to the other.

It is recommended that in the future, a Schindler trap be used for work dealing with zooplankton trapping and population estimates. Unfortunately, this summer, we could not obtain access to one of these traps.

Though statistically unsupportable, I found it interesting to compare the average number of daphnids found in Cranberry and Ziesnis Bogs. Cranberry, which had the higher apparent zooplanktivore activity had the lower daphnid population, while Ziesnis which had no zooplanktivore activity, had a higher daphnid population. These initial finding are consistent with evidence discussed by Dini and Carpenter (1988) who observed that in manipulated lakes, daphnids were larger and more abundant in reduced planktivory lakes. Elser and Carpenter (1988) also showed that in Tuesday Lake, when planktivory was reduced, the daphnid populations increased. Size selectivity has been well documented in discussions of zooplanktivory. What would be more interesting would be a study attempting to document variability in migrations of zooplankton according to varying levels of fish predation on the zooplankton. This was one of the aims of our study that was not realized due to lack of avilability of initial information about our sites, and lack of time once this information was gathered. Now that something is known about these habitats, it would be interesting to conduct an experiment correlating levels of zooplanktivory with size, type, and behaviour, specifically migratory behavior, of the zooplankton assemblages in Nansen, Cranberry and Ziesnis. The range of zooplanktivory could be characterized as extremely high in Nansen, moderate in Cranberry, and for all practical purposes, non-existent in Ziesnis (at least judging from observations made in the summer of 1991).

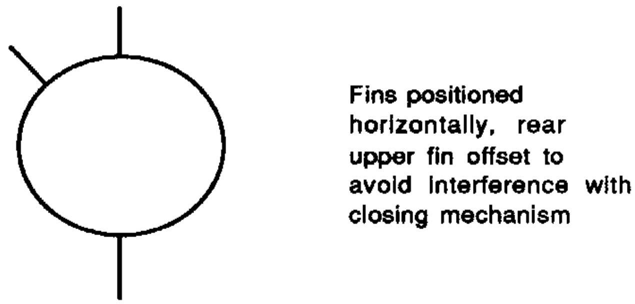
Though Cranberry and Ziesnis are easily characterized as typical bog lakes, Nansen is rather different. It is a highly stained shallow lake. There is an extensive sphagnum mat colonizing the perimeter of the lake, yet the water is not as acidic as one would expect for bog type water. One reason for this may be there is an inflow and outflow at the south and north ends of the lake, respectively.

Figure 1 is a graph depicting some physical and chemical parameters of Nansen Lake on June 17, 1991. The temperature gradient reveals a fairly typical temperature profile, with a warm upper layer (22° C), a 2 meter metalimnion, and relatively cool lower waters. The lake is shallow enough so that the lowest waters are considerably warmer than 4° C, even at this early sampling date. Dissolved oxygen remains relatively high until about 2m of depth, where light levels become low enough to prohibit most photosynthetic production of oxygen. I would suggest that high levels of microbial decomposition drain oxygen levels below 2m. Nansen is a highly productive lake, as shown by its total chlorophyll content. On June 12, 1991 total chlorophyll was recorded at 24.5 mg/m^3. This is at the high end of the spectrum of the lakes on the property tested by Elser in 1987. This value falls in between the the two highest levels he presented; Moccasin Lake was reported at 20.6 mg/m^3, while Morris was the highest at 25.0 mg/m^3. Chlorophyll contents in Cranberry and Ziesnis bogs were lower at 5.09 mg/m^3 and 13.2 mg/m^3, respectively. These fall in the expected range of lakes on the property; Elser found a range of 1.68-25.0 mg/m^3 (Elser, 1987).

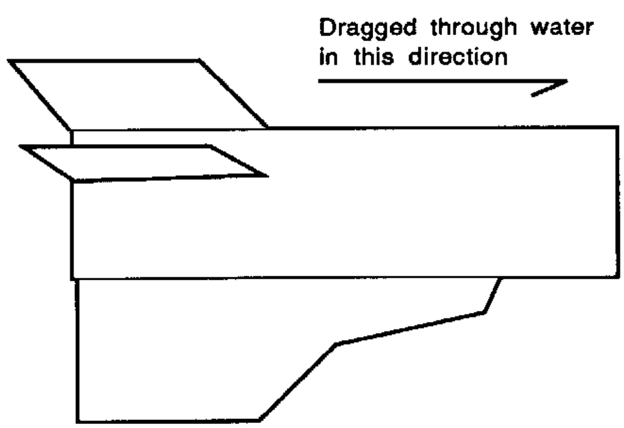
Comparison of the two sampling dates of Cranberry Bog, 6/22/91 and 7/15/91 rreveal similar temperature regimes (Figs.2,3). The earlier oxygen profile contains an oxygen maximum at a depth of about 2m, while the later sampling shows a more regular decline. This oxygen maximum may be a result of the late hour at which the profile was taken, after photosyntesis had occured all day. The later sample was taken earlier in the morning. Comparisons of two sampling dates for Ziesnis Bog (Figs. 4,5), 6/12/91 and 7/1/91, reveals a cooler upper water temperature for the second date. Again, I think the difference is a reflection of varied time of smapling on the particular day, rather than resulting from the long term change. The cooler profile was taken in the morning, while the 6/12 profile was taken later in the afternoon. This would also explain the deeper light penetration in the 6/12 profile. The furthest separated complete profiles for Nansen Lake are over a 5 day period; no substantial changes from 6/12 to 6/17 were noted.

Mapping of the lakes revealed several interesting features. Cranberry consists of a double basin probably formed by two proximate glacially formed kettle basins. Sonar gave an initial reading of about 11 feet in Nansen, but when allowed to sit in one place for a short period, would penetrate depths of up to 30 feet. The bottom muds are floculent and apparently very deep.

FIGURE 6: Modifications to Van Dorn



Front View



Side View

Appendix 1: Mapping Procedure

Need: paper, pencils, clipboard, compass, sonar, trolling motor with battery

1. Orient yourself such that transects can be made N-S and E-W.
2. Reset the trip log on the sonar, this should be done after each transect.
3. Goto the Navigate screen, be sure that the trip odometer reads zero.
4. Note distance from shore and take depth reading.
5. Start the transect:
   A) one person should write the depth at each 100th mi. and make notes of land marks and how they relate to the transect.
      eg. just exited the bay (.005mi transect 2 S-N) or passing the point (.1mi. transect 2 N-S), so that relative sizes of lake features and orientations will be taken into account when drawing the map.
   B) the person driving the boat should 1) locate destination before starting a transect (where the transect should end if you travel in a straight line in the chosen direction).
6. Troll at maximum speed (of the trolling motor) and keep a straight course (N-S or E-W).
7. Multiple parallel transects should be made in each direction (note the distance between the transects) and then multiple parallel transects should be made perpendicular to these.
8. Label each transect!! Be sure to note which way the transect is going. eg N to S or S to N.
9. Before leaving the lake make a rough sketch of the lakes perimeter marking distinctive features and be sure to draw were each transect went, this will aid in the recreation of the lake back in the lab.

Drawing the Map

Need: Graph paper, pencils, calculator, ruler or straight edge.

1. Take the longest transect and calculate how many squares must represent a unit length (eg. 2 squares = 1/100 mi) in order for it to fit on the paper.
2. Plot the transects on the graph paper. (eg. at the first square depth = 2', put a 2 on that line) then move two more squares along that transect and record the next depth from the transect. When all the transects are

plotted on the paper it will have just #'s in straight lines going across it. Where N-S and E-W transects intersect, the depths should be the same, if they are not, look to see if one is off center, it is possible that you have oriented them incorrectly, (slid them to fit together).

3. From your rough sketch, notes, and the transects that you have drawn you can now draw an accurate shoreline of the lake.
4. Look at the #'s on the page and attempt to get a feel of how the bottom of the lake must look. Group the common #'s , determine a contour interval eg. if the lake is shallow you may want to go by one foot intervals whereas if the lake is deep you would have too many lines if you did this so choose a large contour interval, maybe 3 feet. This will give one third the # of contour lines and make it easier to read.
5. Begin to draw contour lines from the shore (shallowest) to the middle (deepest). If you chose a contour interval of 2 feet you would draw the line such that the depths of 2 feet or less were to the out side of the contour. When this line is finished you would then draw the 4 foot contour, this line would include values of 4 or less. NOTE : Contours lines NEVER cross other contours and ALWAYS are complete, enclose the space.
6. If the depth decreases within a larger depth just draw another contour. Eg. in the middle of the 8 foot contour there is a depth of 6 feet but this depth could not be included in the 6 foot contour because it is surrounded by 8 foot water.
7. The finished map should have a size scale (eg. 2 squares = 1/100 mi.), contour interval (C.I. = 2 feet), show direction (North is that way), Lakes name.

Scanning the map

Need: Tracing paper, fine tiped black pen, Apple scanner, Apple Scan, Canvas 2.1, patience, time.

1. Trace the contours only onto tracing paper with a very fine black pen.
2. Allow the scanner to warm up for 10 minutes.
3. In Apple Scan scan the map at 75pt. resolution then adjust the threshold to be sure that all the contours are visible.
4. From the FILE menu select New then rescan the map.
5. Save the map as a "tiff" file.
6. Exit Apple Scan and open Canvas 2.1.
7. Open your file and select the magnifying tool and zoom in on the lake.
8. Select the pencil tool.
9. You must make each contour continuous, only one dot wide and it can not touch another contour. If you click on a dot with the pencil it disappears and you can dots with it. This process is very time consuming!!
   -at diagonals if the corners are touching the line is continuous.
10. Once the map is finally clean with no labels **SAVE** this "bit mapped image".
11. Select the arrow tool and click on the map.
12. Goto EFFECTS and select Autotrace (Smooth Polygon), this gives a "Draw"

image.

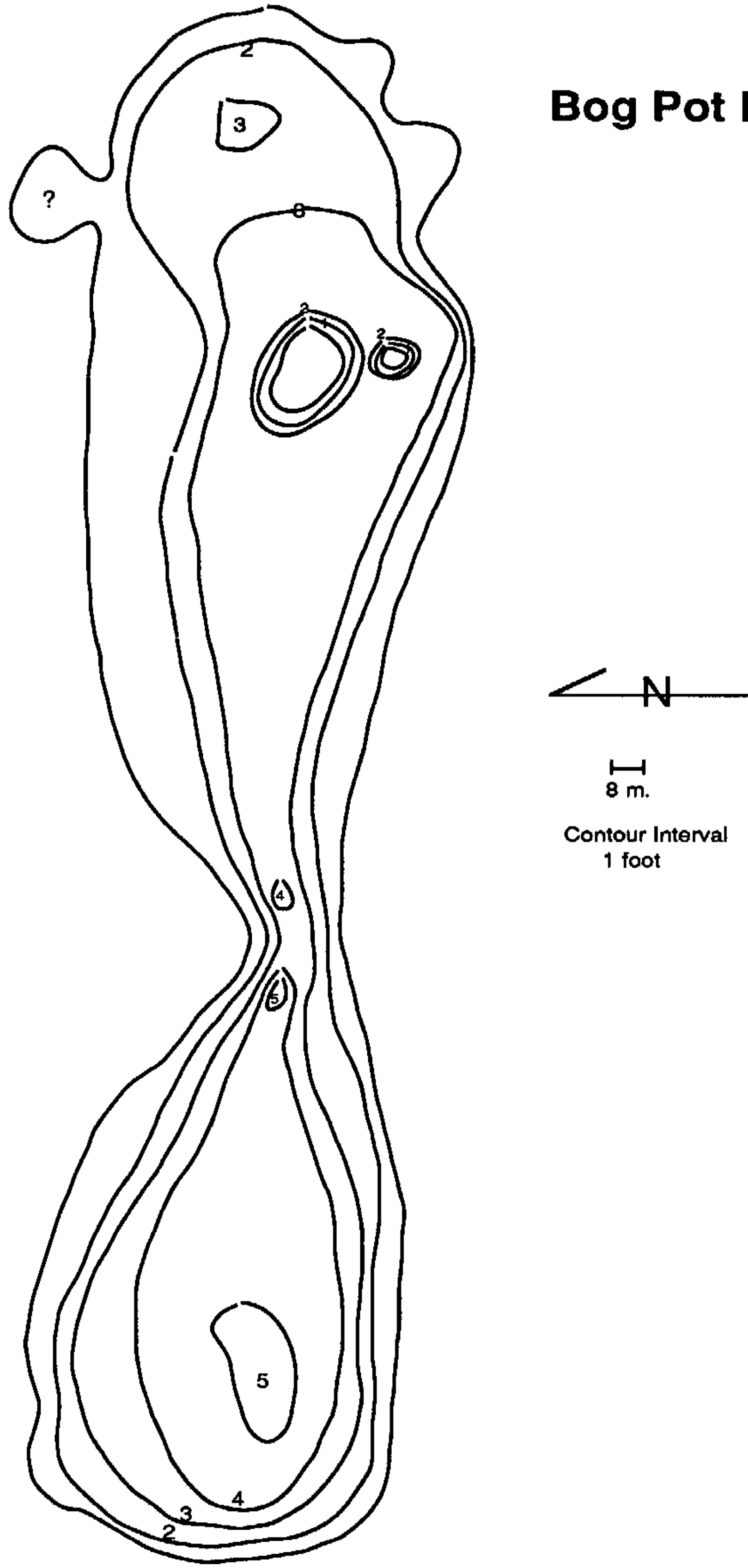
13. Immediately!! go to OBJECT and select Group. Do not click on the map!
14. Goto EDIT. Select Copy.
15. Goto layers (bottom left corner) and select Layer manager. Make a new layer called "Contours", select that layer.
16. Goto EDIT. Select Paste.
17. Make the old layer invisible.
18. Goto LAYOUT select Drawsize and make sure only one page is selected by clicking on the upper left box.
19. Click on the map and drag it onto the page. Then scale it to the page by clicking on the bottom right "tie" dot and holding down the shift key then dragging to enlarge or shrink. The shift key moves an object in a scaled manner, if you don't hold it down the lake will be squished or stretched.
20. When the lake is oriented and scaled as you want it:
    Make a new layer, via layer manager called "Labels".
21. Label contours, direction, title, contour interval. Scale on this "Labels layer"

Note: you now have a layer that has contours and one that has labels

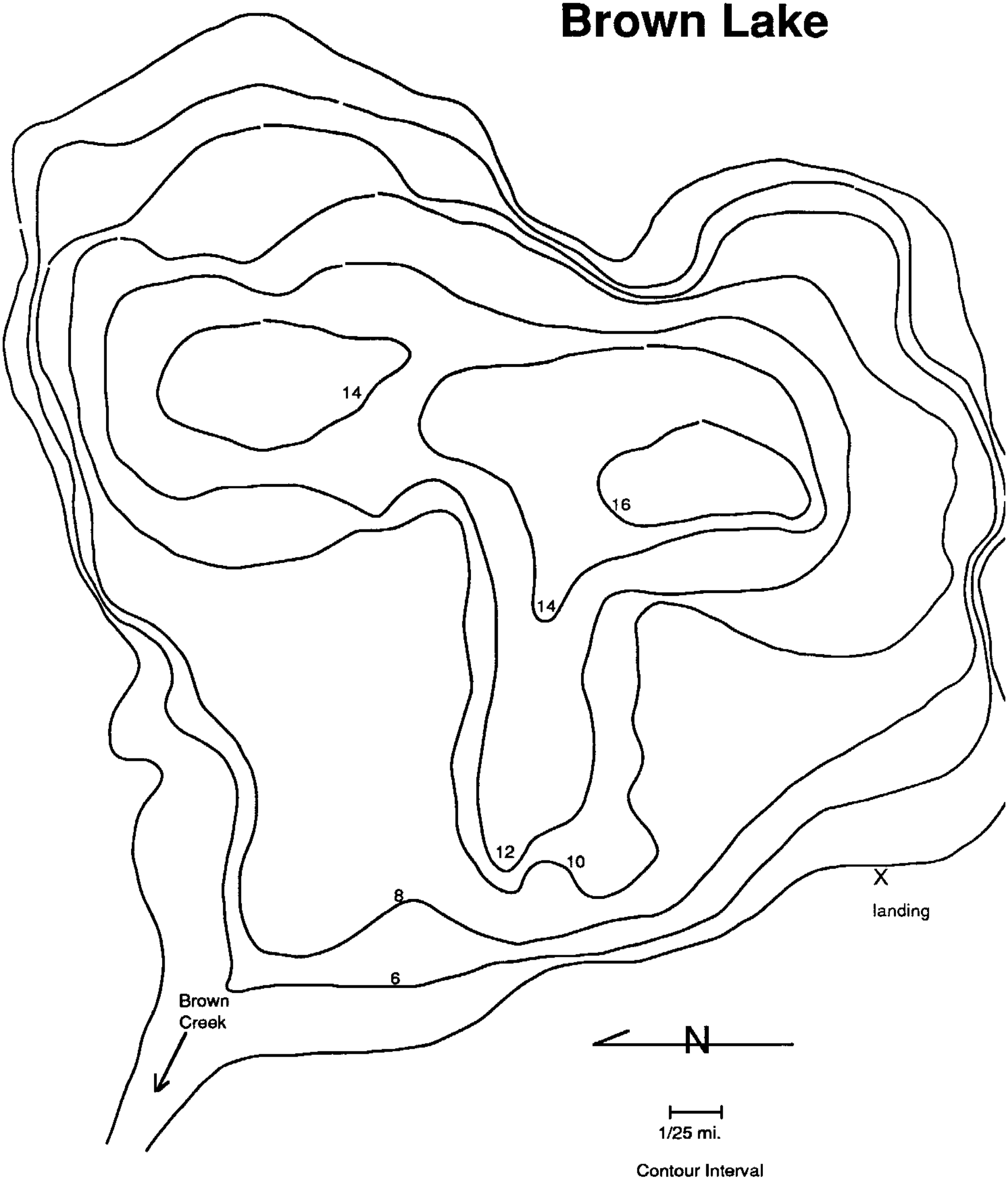
22. Delete the first layer. Be Sure You Don't Delete your "Contour" layer or our "Labels" layer.
23. **SAVE** your finished Map on multiple disks under a name other than your cleaned Draw image, this will allow you to retrace if there is a problem.

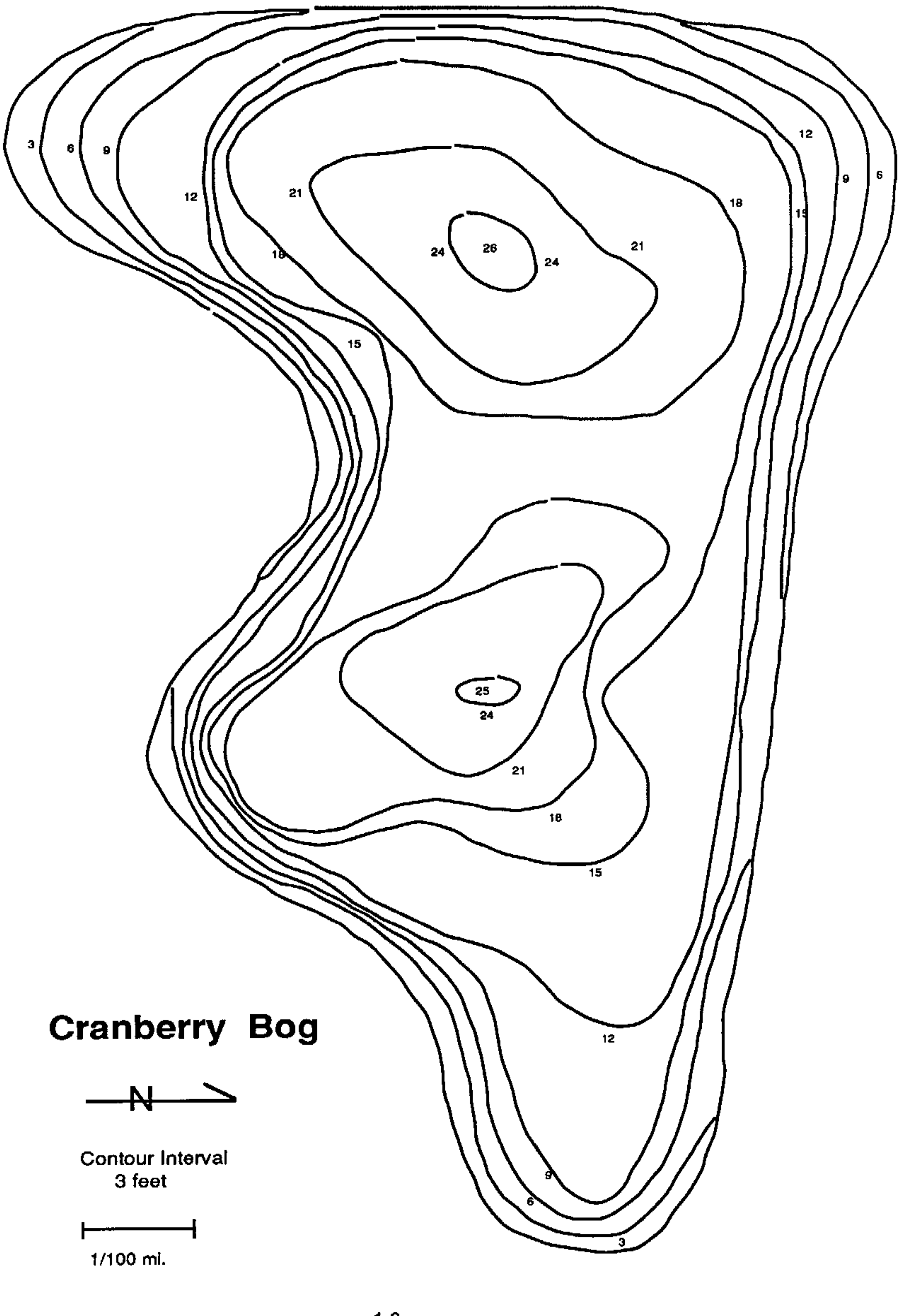
Appendix 2: Bathymetric Maps

Bog Pot Lake

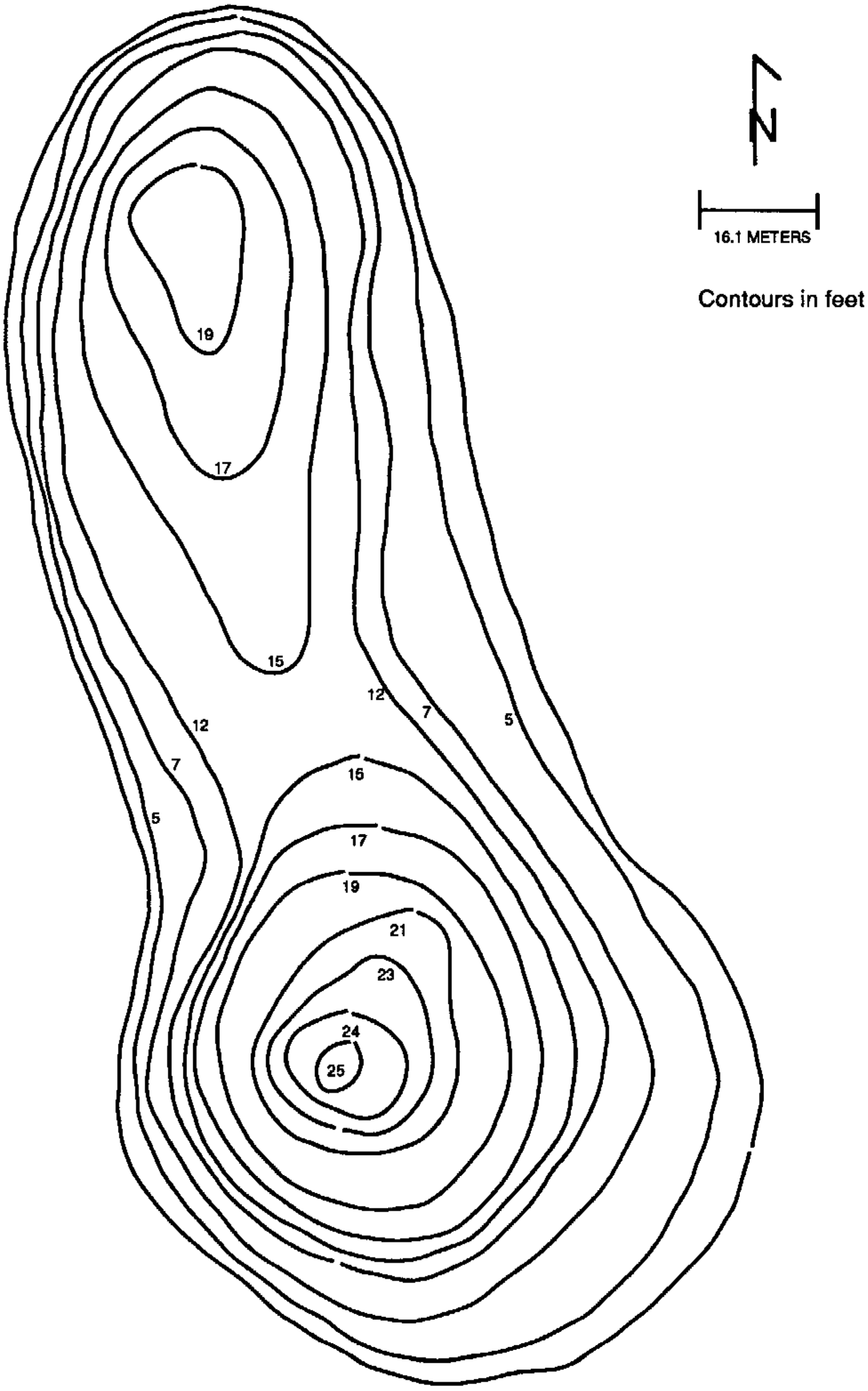


Brown Lake

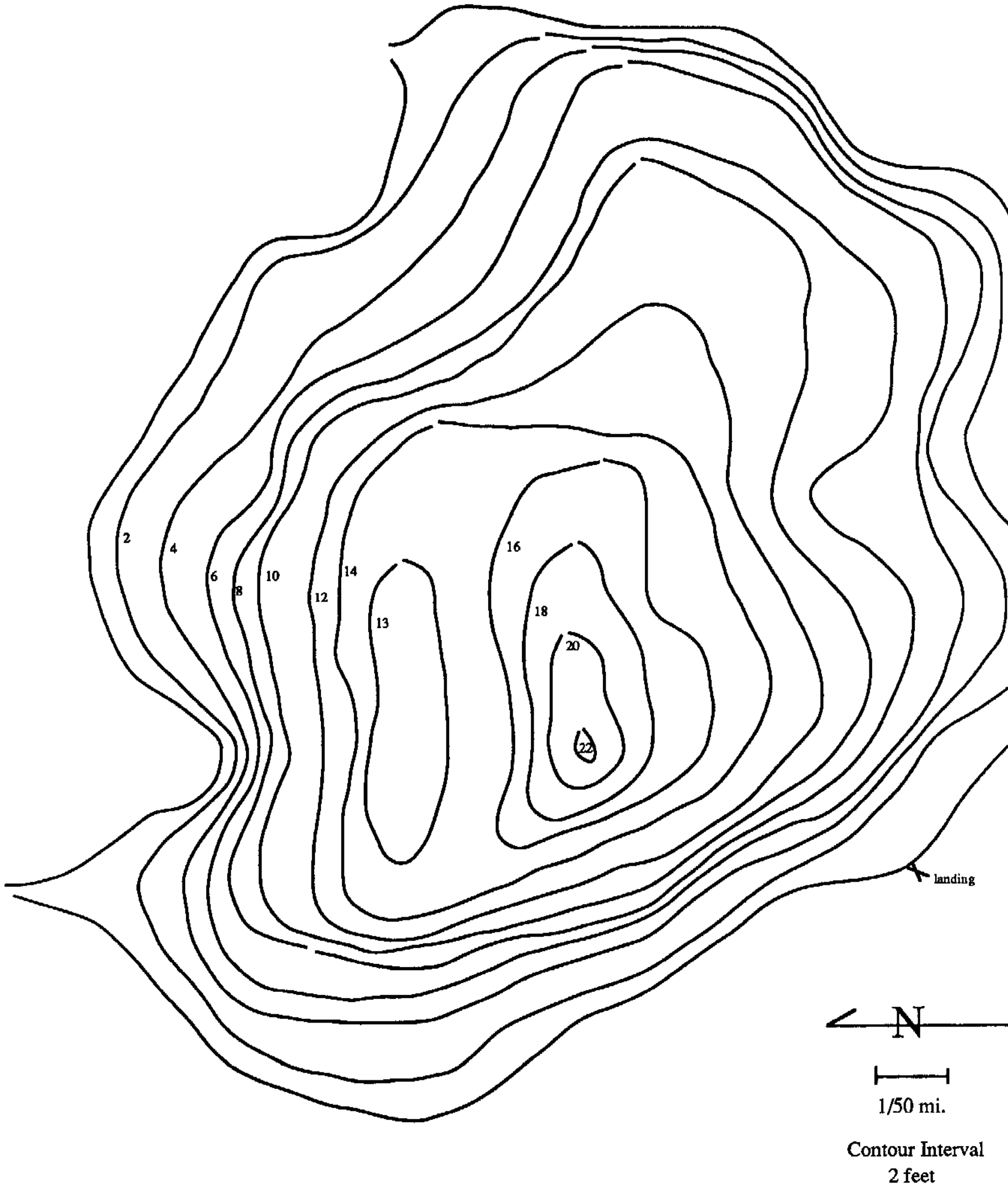

14
16
14
12
10
8
6
X
landing
Brown
Creek
N
1/25 mi.
Contour Interval
2 feet


Cranberry Bog
N
Contour Interval
3 feet
1/100 mi.
3
6
9
12
15
18
21
24
26
25

Hummingbird Bog

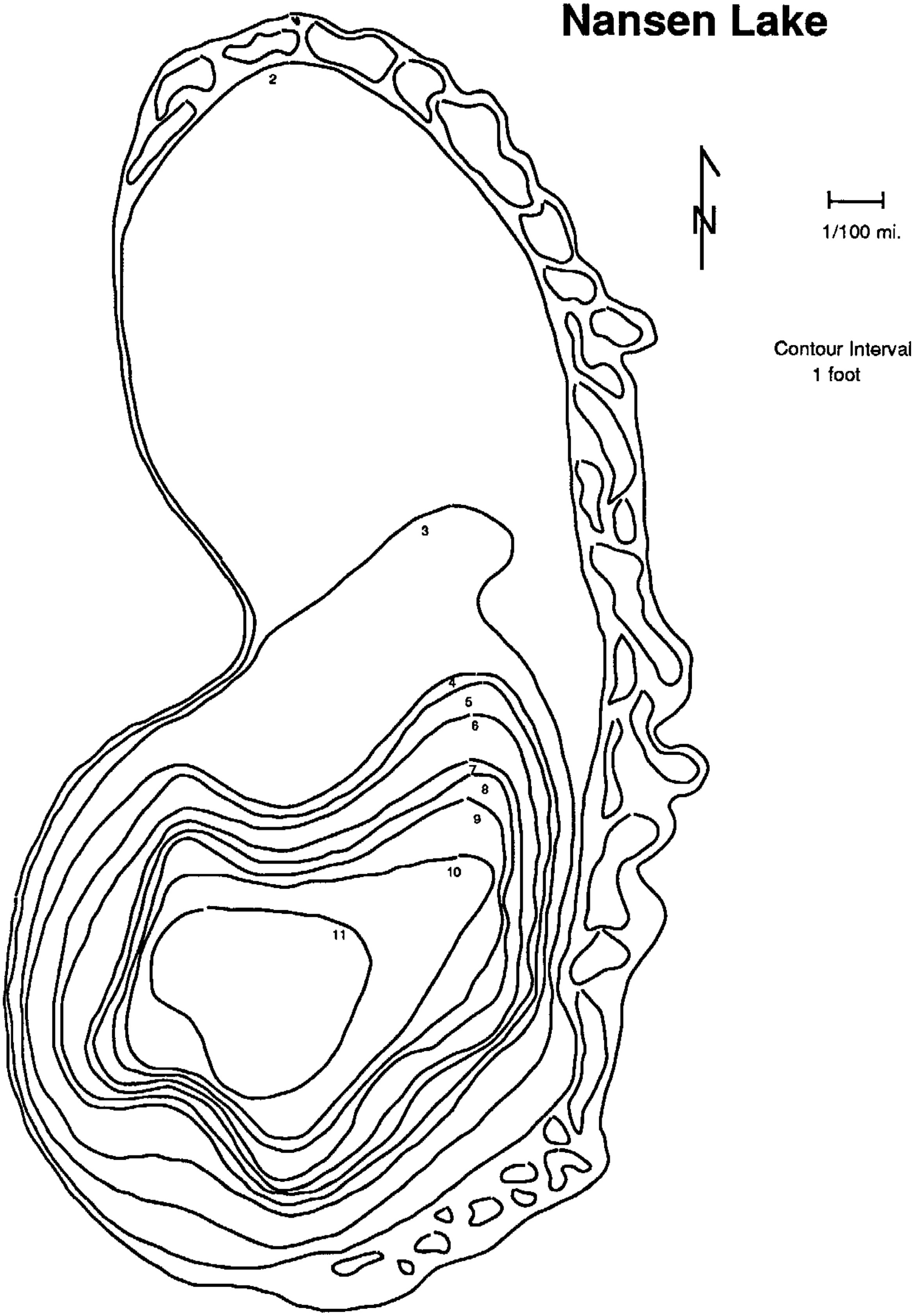


Morris Lake

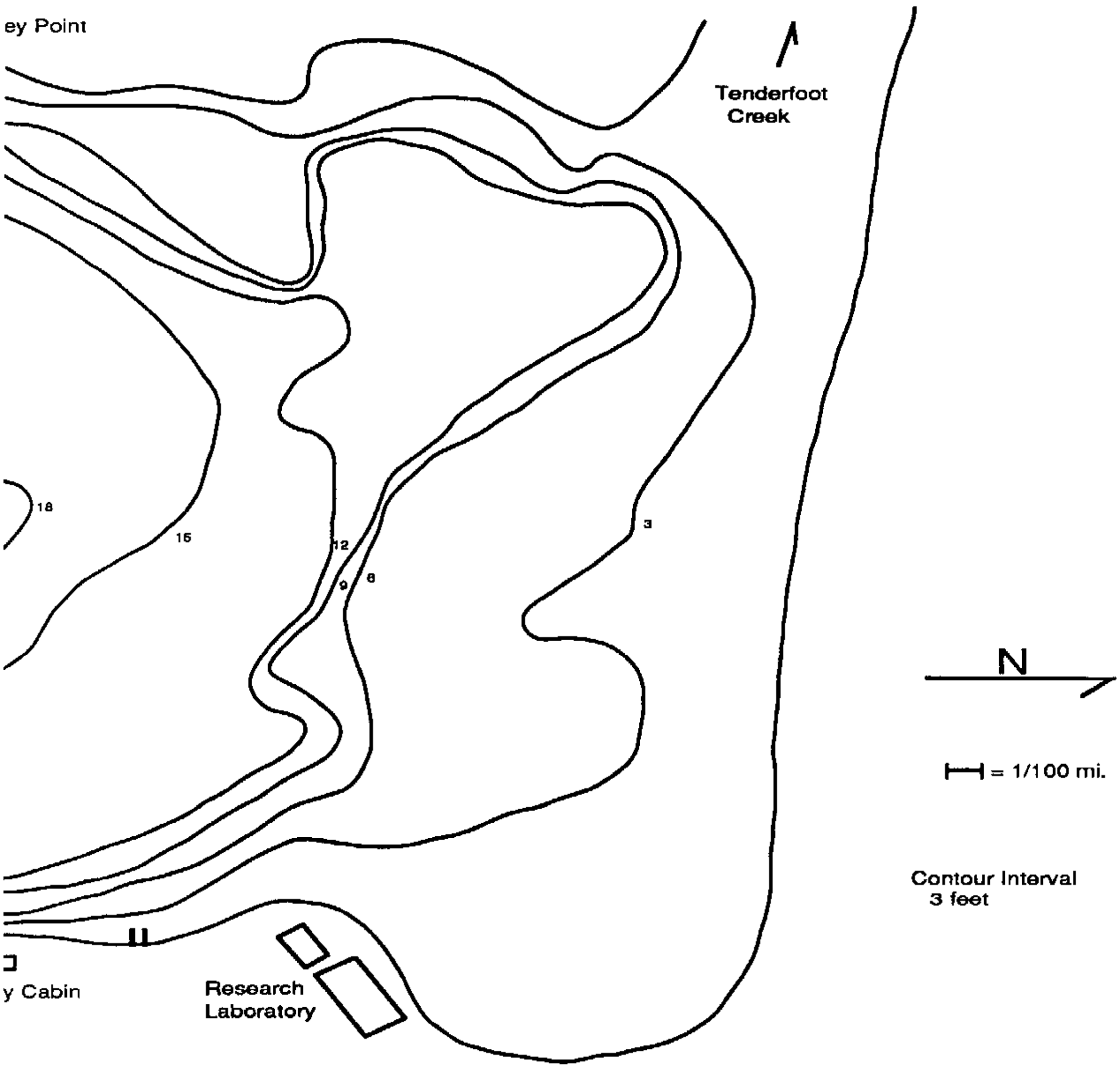


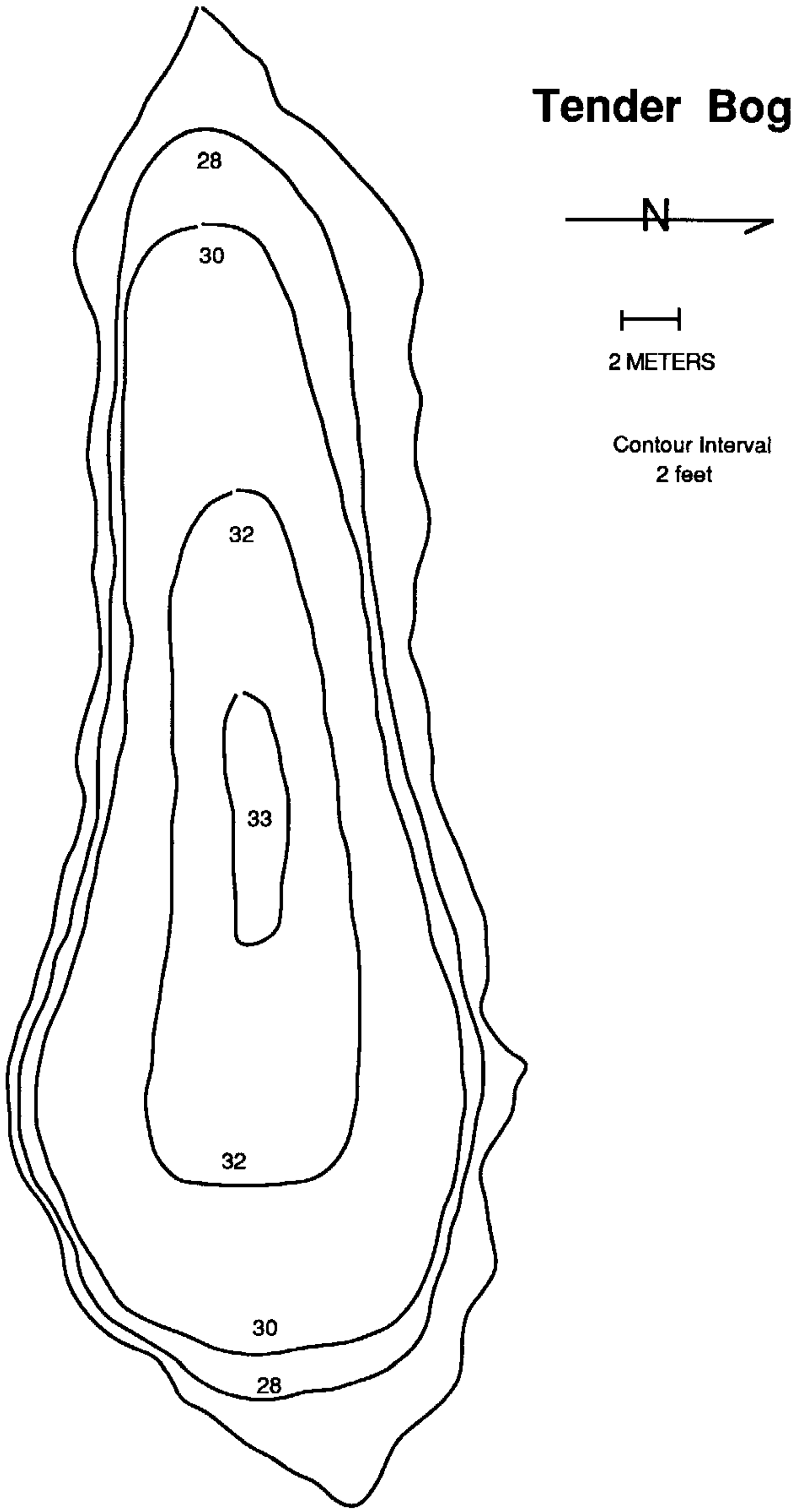
2
4
6
8
10
12
14
13
16
18
20
22
landing
N
1/50 mi.
Contour Interval
2 feet

Nansen Lake



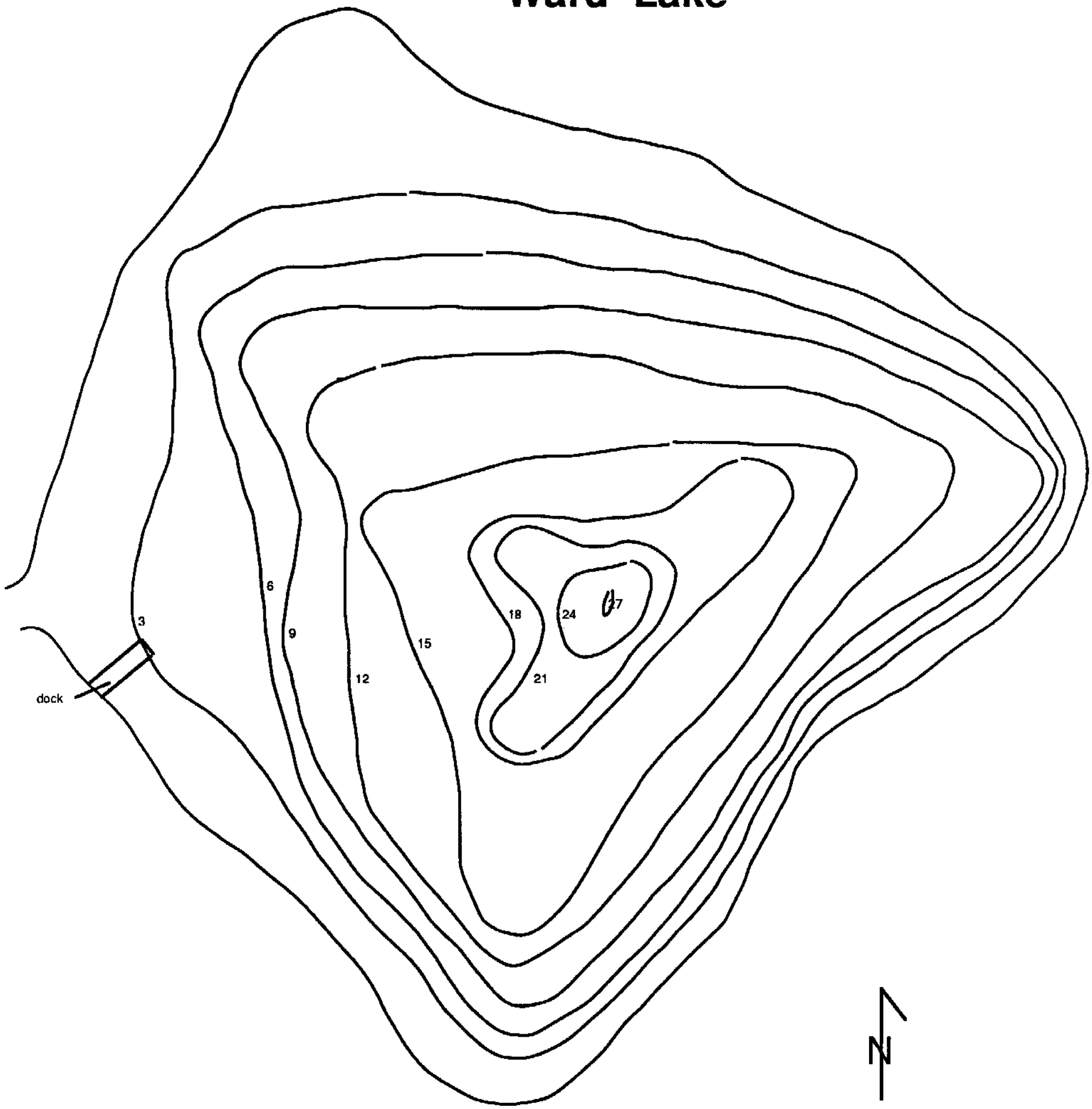
Northeast Bay,Tenderfoot Lake





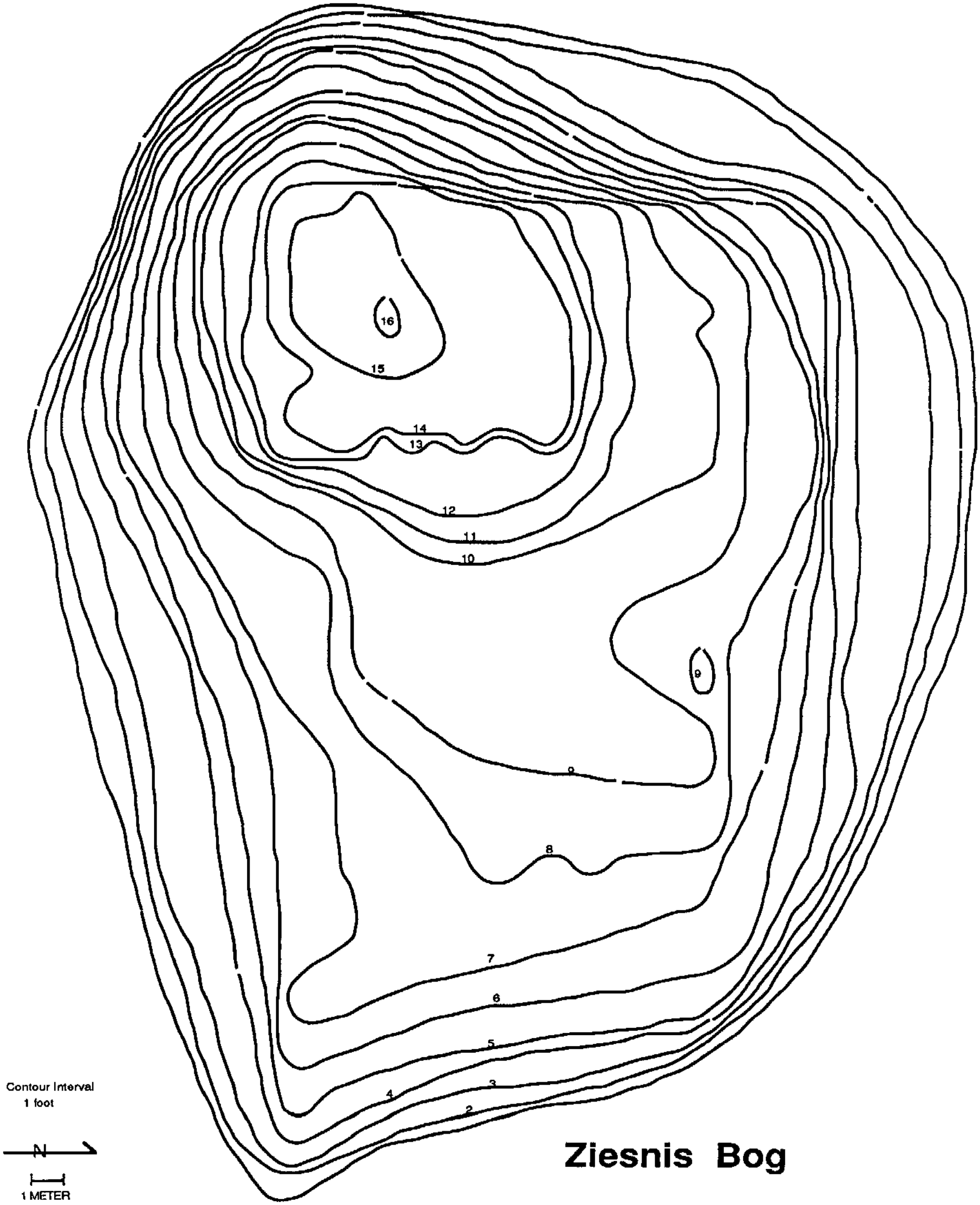
Tender Bog
N
2 METERS
Contour Interval
2 feet
28
30
32
33
32
30
28

Ward Lake



Contour Interval
3 feet

1/100 mi.


16
15
14
13
12
11
10
9
9
8
7
6
5
4
3
2
Contour Interval
1 foot
N
1 METER

Ziesnis Bog

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References Cited

Dini, M.L. 1989. The Adaptive Significance of Diel Vertical Migration in Daphnia. PhD Dissertation, University of Notre Dame.

Dini, M.L. and S.R. Carpenter. 1988. Variability in Dahnia behavior following fish community manipulations. J. Plankton Research. 10:621-635.

Elser, J.J. and S.R. Carpenter. 1988. Predation driven dynamics of zooplankton and phytoplankton communities in a whole lake experiment. Oecologia. 76:148-154.

Elser, J.J. 1987. Evaluation of size related changes in chlorophyll-specific light extinction in some north temperate lakes. Archiv Fur Hydrobiologie. 11:171-182.