LPL 081

Norman Rockwell: *Along the Trout Stream (1920)*

# BEAR LAKE
# Oneida County, Wisconsin
# Fish Survey, Septic Leachate Survey, and Sedimentation Study, 1992

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**Bear Lake, Oneido County, Wisconsin**
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## SUMMARY

Bear Lake is a 312 acre mesotrophic lake in Oneida County, Wisconsin. Bear Lake is managed for walleyes and has a macrophyte community that covers roughly 90% of the lake area although plants are not considered a major nuisance. The Bear Lake District has sponsored numerous projects funded entirely by the District and also in conjunction with the WDNR. The objectives of the previous studies and projects have been to evaluate existing conditions and to improve problems areas associated with stunted sunfish, low walleye population, sedimentation concerns, and watershed development and pollution inputs.

This report presents results from a spring fyke net fish survey, a septic leachate survey, and a sedimentation survey.

The spring fyke net survey results were compared to the last spring fyke net survey in 1980. Conclusions were that walleyes have not changed, white suckers are declining, but perch and northern pike are increasing. It appears that the fish community is adjusting to stunted panfish removal efforts conducted in 1985, 86, 87, 88, 89 and 1991. Scat netting found fertilized walleye eggs in spawning areas, but fyke netting found no evidence of natural walleye reproduction.

A septic leachate survey was conducted almost 10 years to the day of the last septic leachate survey. Results from 1992 did not indicate any septic system problems. Areas of groundwater inflow were characterized in our 1992 study. We found that the conductivity reading described inflow areas delineated from a groundwater using wells. We conclude that conductivity surveys are as good as extensive groundwater studies using wells for finding areas of groundwater.

Three sets of sediment traps were deployed in Bear Lake over the summer of 1992. One set was lost, but the other two were recovered. Sediment traps were set in bays because these are the areas that have the greatest accumulation of organic sediment. Sediment traps were left in place for 108 days. When recovered we found a sediment accumulation in the traps of 3 inches. This equates to a sedimentation rate of 9 inches per year. This is not a new sediment deposition, but rather a resuspended deposition rate. Phosphorus content in the resuspended sediment was low. We concluded our method of evaluating sedimentation rates in shallow bays was not valid, but it did characterize resuspension.

## 1. RECAP OF PAST PROJECTS

The Bear Lake Protection and Rehabilitation District was formed in 1977. Fish stocking and lake and fish surveys had been conducted prior to 1977 by WDNR, but detailed studies began after 1977. A summary of Bear Lake Studies and projects over the years is shown in Table 1.

Table 1. List of projects that have occurred on Bear Lake over the years. Specific stocking records are at WDNR-Woodruff.

| Year | Project | Sponsoring Group |
|---|---|---|
| 1930s-present | Walleye stocking | WDNR |
| 1964 | Fish cribs | WDNR |
| 1977 | Formation of Lake District | Bear Lake Dist, WDNR |
| 1977 | Bear Lake Limnological Study | Northern Lake Service |
| 1978 | Bear Lake Feasibility Study | WDNR |
| 1982 | Septic leachate survey | Swanson Environmental |
| 1982 | Gamefish survey, Bear Lake | WDNR |
| 1984 | Summary of existing conditions and implementation manual | Blue Water Science |
| 1985-present | Water Quality monitoring (twice a year) | UW-Stevens Point |
| 1985,1986, 1987,1988 | Sunfish and bullhead removal using fyke nets | Bear Lake District and Blue Water Science (nets loaned by WDNR) |
| 1987 | Walleye stocking | WDNR |
| 1988 | Autumn shocking survey | WDNR |
| 1989 | Walleye stocking | WDNR |
| 1989 | Autumn shocking survey | WDNR |
| 1989-present | Septic tank maintenance program | Bear Lake District |
| 1989-present | Walleye spawning bed rejuvenation | Bear Lake District and Blue Water Science |
| 1991 (this study) | Nutrient budget, aquatic plant survey, zooplankton evaluation, panfish evaluation | Blue Water Science, Bear Lake District, WDNR |

As often happens, when a study is conducted to address certain question, other questions arise. Beginning in 1991, the Bear Lake District started a 3 year program to answer some questions that had arisen from the lake users. A 1991 study evaluated panfish, repeated a macrophyte survey, performed watershed land use analysis, and did lake modeling. This report summarizes results form the second year of the three year comprehensive lake management plan.

In this second phase, we evaluated gamefish, conducted a septic leachate survey, and set out sediment traps to try to gather information on sedimentation rates.

## 2. EXISTING CONDITIONS AND OBJECTIVES OF THIS STUDY

Bear Lake is a 312 acre mesotrophic lake in Oneida County, Wisconsin. General Lake characteristics are shown in Table 2.

Table 2. Bear Lake Characteristics

Area (Lake): 312 acres ( 126 ha)
Mean depth: 8.4 feet ( 2.6 m)
Maximum depth: 23 feet ( 7 m)
Volume: 2,620.8 acre-feet ( 327.6 Ha-M)
Littoral area: 12 %
Fetch: 1.2 mile ( 1.9 km)
Watershed area: 840 acres ( 340 ha)
Watershed: Lake surface ratio 2.6:1
Estimated average water residence time 2.98 years
Public accesses (#): 1
Inlets: 1 Outlets: 1

Land Use (percentage/area):

| | Forest | Wetlands | Urban-Res |
|---|---|---|---|
| Percentage | 69 | 26 | 5 |
| Acres | 580 | 219 | 41 |

| Development (Homes): | Seasonal | Permanent | Total |
|---|---|---|---|
| | 85 | 11 | 96 |

Spring and fall averages for epilimnetic water for several water quality parameters is shown in Table 3.

Table 3. Epilimnetic Spring and Fall Data for Bear Lake 1985-91 (Analysis by UW-Stevens Point).

| Parameter | Units | Mean | n | Min | Max |
|---|---|---|---|---|---|
| Total phosphorus | ppb | 18 | 15 | 8 | 35 |
| Soluble Reactive P | ppb | 8 | 15 | 2 | 25 |
| Chlorophyll a | ppb | 9* | 2 | | |
| Secchi disk | m | 3.8** | 10 | 2.3 | 5.1 |
| Total Kjeldahl N | ppm | 0.6 | 15 | 0.2 | 2.2 |
| Nitrite + Nitrate-N | ppm | 0.5 | 15 | 0.01 | 0.2 |
| Ammonia-N | ppm | 0.1 | 15 | 0.01 | 0.2 |
| Alkalinity | ppm | 32 | 15 | 22 | 44 |
| Color | Pt-Co Units | 18 | 15 | 2.3 | 80 |
| pH | SU | 7.5 | 15 | 6.8 | 8.3 |
| Chloride | ppm | 1.3 | 15 | 1 | 3 |
| Conductivity | umhos/cm | 68 | 15 | 54 | 83 |

TN:TP ratio 61:1

* Chlorophyll reading for June and July of 1991.
** 3.8m = 12.5 feet

Because Bear Lake is mesotrophic and not eutrophic, watershed inputs are not currently a problem (McComas 1993) and questions that lake users have about Bear Lake relate primarily to in-lake conditions. This study attempts to address several of these questions.

The objectives of this study were to design sampling programs to address questions posed by lake users. These questions were brought up at the Annual Lake District meeting, the Annual Lake Association meeting and by concerned residents that spoke to Lake District President, Dale Jalinski, over the course of the year(s).

The questions posed and the way they were addressed in this study are listed below:

1. What is the status of walleye, northern pike, yellow perch, and white sucker? The feeling is that summer panfish removal project results do not give the full picture. Approach: *We conducted a spring fyke net survey to examine gamefish and perch and suckers. We could then compare results to the last WDNR spring fyke net survey conducted in 1980.*

2. What is status of septic tank systems? Are they polluting the lake? Approach: *We conducted a septic leachate survey around Bear Lake and compared results to a survey conducted in 1982.*

3. Bear Lake has a tremendous accumulation of soft sediments. What is the sedimentation rate in Bear Lake? Approach: *Place sediment traps in Bear Lake and measure sedimentation rate.*

## 3. METHODS

### Fish Survey

The 1992 Bear Lake fish survey had several tasks:

1. Perform scat netting on walleye spawning beds to see if fertilized eggs are present
2. Sample dissolved oxygen in the pore water of spawning beds to see if eggs can survive
3. Deploy fyke nets for spring fish survey
4. Collect scale samples from walleye for age determination

1. Scat netting: Scat netting is a method to sample walleye eggs or other fish eggs deposited in sand, cobble, or even muck and vegetation. The scat net is a flat net with a mesh of about 2 millimeters (we used window screen) stretched over a rectangle frame measuring about 18 inches wide by 10 inches deep (we used a dip net that was bent into the shape of a rectangle and replaced the net with the screen material). The scat net is used like a sweep net. The net is swept over walleye spawning habitat and eggs are collected on the net. All eggs observed in the Bear Lake study were counted and returned to the lake.

2. Spawning Bed Pore Water Dissolved Oxygen: At several walleye spawning sites, interstitial water (pore water) was analyzed for dissolved oxygen and conductivity. A 1.5-inch inside-diameter PVC pipe was driven 6-inches into the gravel-cobble substrate at several locations at a spawning site. Pipes were left inplace for 5 to 30 minutes, then a YSI oxygen/temperature meter and a YSI Conductivity meter probe were lowered into the pipe, below the surface of the substrate to make temperature, oxygen, and conductivity measurements.

3. Fyke Net Deployment: Six Wisconsin DNR style fyke nets were deployed from April 28 to April 31, 1992 on Bear Lake. WDNR style fyke nets consists of a square frame followed by four hoops with 2 throats. A 0.75 inch mesh (bar length) was used. Two of the nets were dipcoated, the other four were untreated.

We intended to fish for four days, but ice was still on Bear Lake on April 27. When we first set the nets on April 28, ice was still present on shaded shorelines. Because the state Walleye opener was May 2, nets were removed May 1. Fyke net locations were similar to sets in 1980 (shown in Figure 1).

All fish were measured except for bluegill and perch which were subsampled and measured. Any fin clipped walleyes were noted.

4. Scales Samples from Walleyes: Scale samples were collected from all walleyes. Scales were read under a Nikon stereoscope. Edges of scales were counted as a ring, the center was not counted.

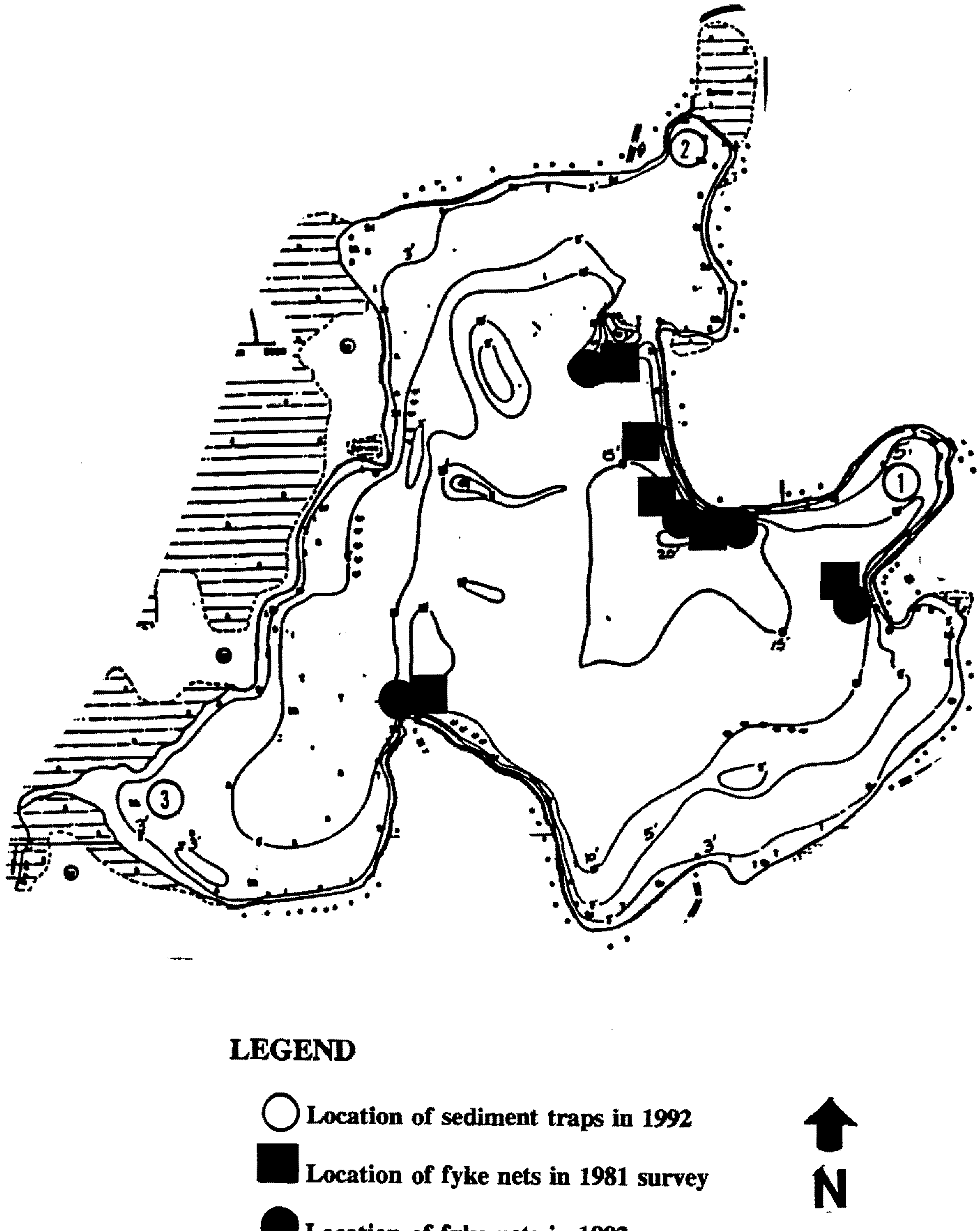



Figure 1. Locations of fyke nets for Spring fish surveys in 1981 and 1992, and sediment trap locations.

## Septic Leachate Survey and Groundwater Inflow Survey

To evaluate potential nutrient inputs from septic tank systems, a septic leachate survey was conducted. The method is to motor around the shoreline of the lake extending a conductivity probe as close to shore as possible. If septic tank effluent is coming into Bear Lake, the salt content in the inflow (from urine and from detergents) will be recorded on a conductivity meter. For this study we used a YSI Conductivity meter. We used the center of the lake as background to get a baseline conductivity reading, and then we headed around the shoreline recording changes in conductivity. A conductivity less than background usually indicates a spring (area of groundwater inflow).

## Sedimentation Survey

To evaluate sedimentation in shallow bays, we deployed sediment traps in three locations (shown in Figure 1). The intent was to get a sediment accumulation rate in these shallow bays. The sediment traps consisted of two upright plastic bottles and one inverted plastic bottle taped to a PVC stake. The stake was inserted into the sediments and the top of the bottles were 1-foot off the bottom. Sediment traps were placed on April 29, 1992 and were removed on August 16, 1992. Contents of the bottles were analyzed for total phosphorus, total suspended solids, and total volatile solids.

Sediment traps were placed in 5-feet (Station 1 and 2) and 3-feet (Station 3) of water.

## 4. RESULTS

### Fish Survey

A spring fish survey was conducted April 28-31, 1992 using 6 fyke nets set for three days (18 lifts). We also conducted scat netting around walleye spawning areas looking for fertilized walleye eggs, we characterized spawning bed dissolved oxygen conditions, and we took walleye scale samples. Fyke net locations and spawning bed investigation sites have been shown in Figure 1. The total number of fish captured in the fyke net survey is shown in Table 4. A summary of fish length distribution for major species that were captured is shown in Figure 2.

Table 4. Total number of fish captured and the fish per net for the April 28-31, 1992 Bear Lake fish survey.

| Species | Total Number of Fish | Fish/Net (18 nets) |
|---|---|---|
| Bluegill | 271 | 15.1 |
| Pumpkinseeds | 128 | 7.1 |
| Yellow Bullheads | 343 | 19.1 |
| Largemouth Bass | 6 | 0.3 |
| Northern Pike | 75 | 4.2 |
| Walleye | 64* | 3.6 |
| Black Crappie | 165 | 9.2 |
| Rock Bass | 15 | 0.8 |
| Yellow Perch | 1531 | 85 |
| White Sucker | 136 | 7.6 |

* Average weight = 1.7 lbs
  based on 64 fish

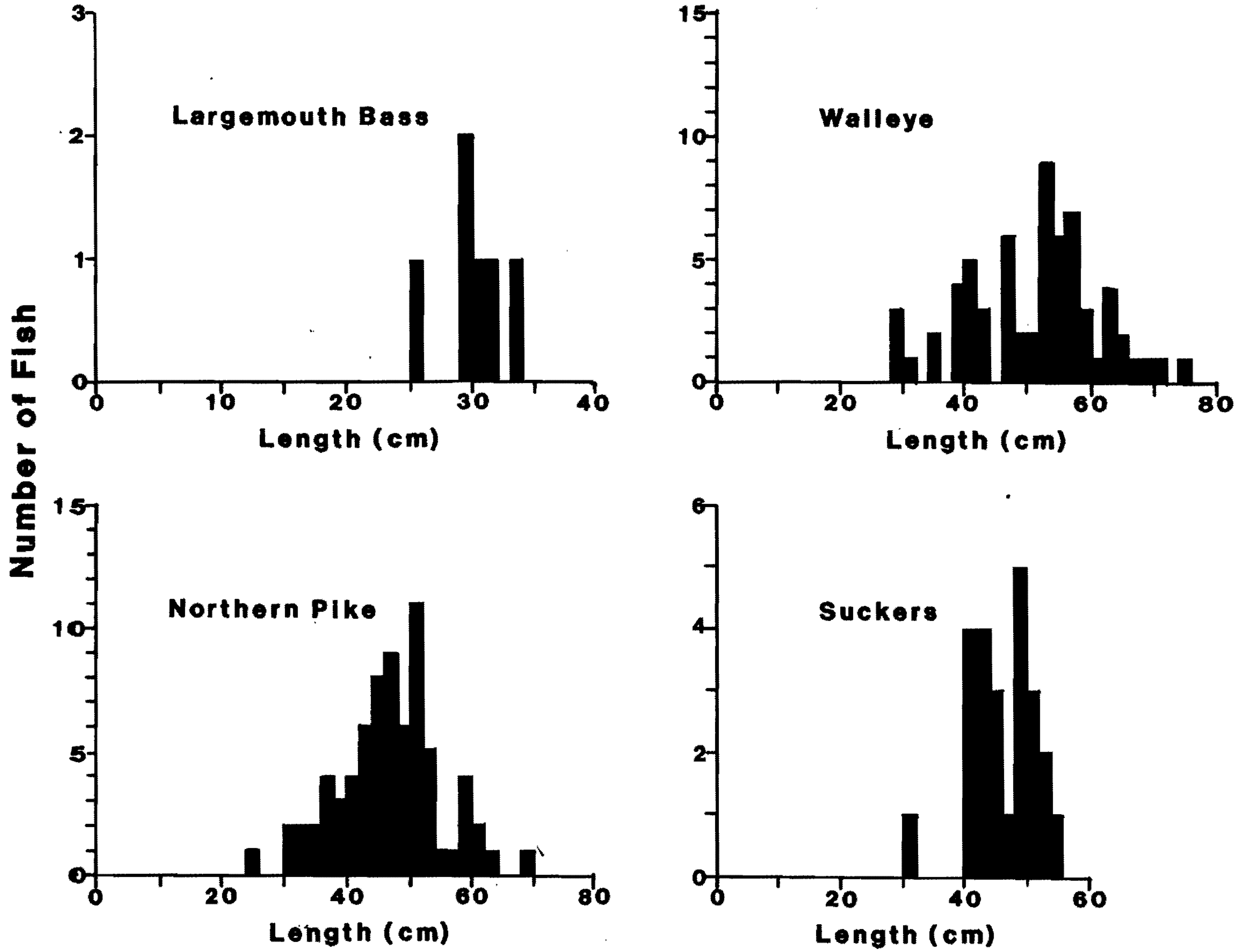



Figure 2. Fish length distribution for April 28- May 1, 1992. Bear Lake fish fyke net survey.

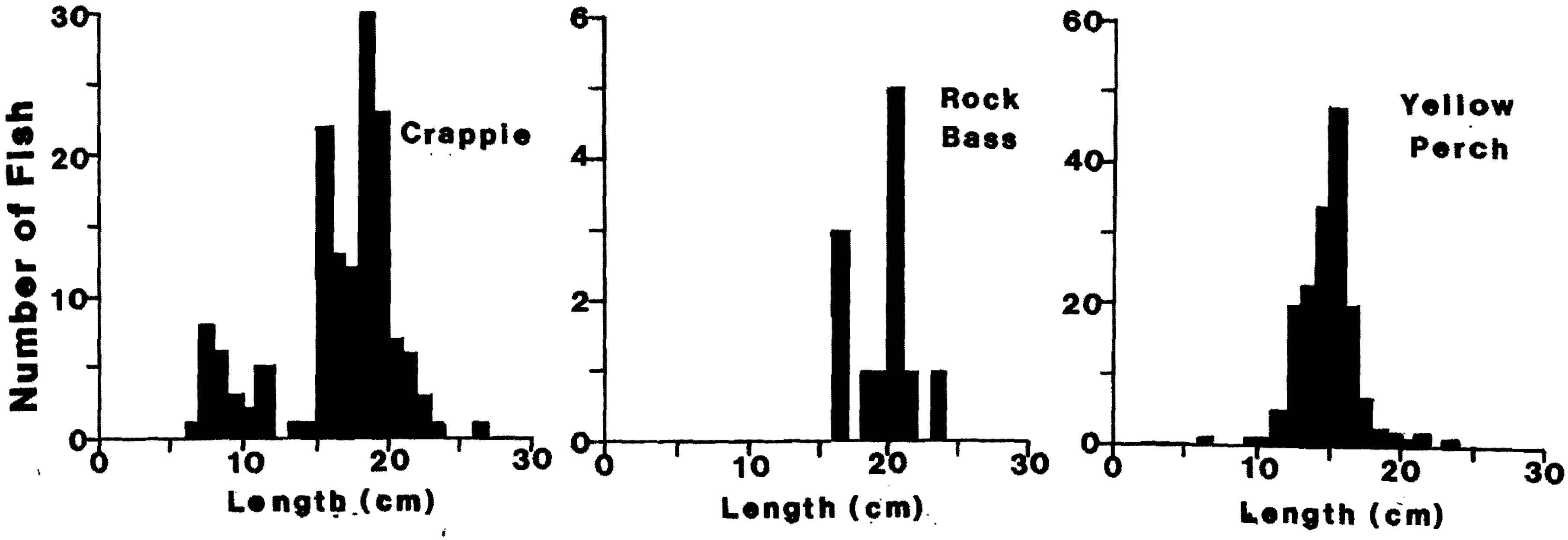



Figure 2. Concluded.

The main objective of this study was to evaluate the walleye population. Results showing individual walleye lengths and weights is shown in Table 5. Length distribution for other fish species are shown in Table 6.

Table 5. Walleye length distribution Bear Lake, April 28-May 1, 1992 fyke net survey.

| Length (cm) | Males | | Females | | Undetermined | |
|---|---|---|---|---|---|---|
| | Number | Average Weight (lbs) | Number | Average Weight (lbs) | Number | Average Weight (lbs) |
| 0.0-1.9 | | | | | | |
| 2.0-3.9 | | | | | | |
| 4.0-5.9 | | | | | | |
| 6.0-7.9 | | | | | | |
| 8.0-9.9 | | | | | | |
| 10.0-11.9 | | | | | | |
| 12.0-13.9 | | | | | | |
| 14.0-15.9 | | | | | | |
| 16.0-17.9 | | | | | | |
| 18.0-19.9 | | | | | | |
| 20.0-21.9 | | | | | | |
| 22.0-23.9 | | | | | | |
| 24.0-25.9 | | | | | | |
| 26.0-27.9 | | | | | | |
| 28.0-29.9 | 2 | 0.5 | | | 1^a | 0.5 |
| 30.0-31.9 | | | | | | |
| 32.0-33.9 | 1 | 0.7 | | | | |
| 34.0-35.9 | 1^b | 1 | | | 1^b | 1 |
| 36.0-37.9 | | | | | | |
| 38.0-39.9 | 4^c | 1.3 | | | | |
| 40.0-41.9 | 5 | 1.8 | | | | |
| 42.0-43.9 | 2 | 2 | | | 1 | 1.7 |
| 44.0-45.9 | | | | | | |
| 46.0-47.9 | 5 | 2 | | | 1 | 2.2 |
| 48.0-49.9 | 1 | 2.1 | 1 | 3.3 | | |
| 50.0-51.9 | 1 | 3 | 1 | 3.6 | | |
| 52.0-53.9 | 6 | 3.2 | 3 | 3.7 | | |
| 54.0-55.9 | 4^d | 3.6 | 2 | 3.9 | | |
| 56.0-57.9 | 4 | 3.7 | 3^e | 3 | | |
| 58.0-59.9 | 1 | 3.9 | 1 | 5.5 | | |
| 60.0-61.9 | | | | | 1 | 4.4 |
| 62.0-63.9 | 2 | 5.6 | 1 | 6 | 1 | 4.6 |
| 64.0-65.9 | | | 2^g | 5.5 | | |
| 66.0-67.9 | | | 1 | 6.9 | | |
| 68.0-69.9 | | | 1 | 7.6 | | |
| 70.0-71.9 | | | 1^f | 6.5 | | |
| 72.0-73.9 | | | | | | |
| 74.0-75.9 | | | 1 | 8.7 | | |
| TOTALS | 39 | | 18 | | 6 | |

**Total weight captured:**

| | |
|---|---|
| Males | 99.0 lbs |
| Female | 81.3 lbs |
| Undetermined | 14.4 lbs |

a = 1 undetermined 0.5 lbs clipped fin
b = clipped fin
c = 1 male 1.5 clipped fin
d = 1 male 3.5 lbs clipped fin
e = 1 female no weight clipped fin
f = 1 female 6.5 lbs clipped fin
g = 1 fish no weight

Table 6. Species length distribution for Bear Lake spring survey 1992.*

| Length (cm) | Northern Pike | Largemouth Bass | Crappie | Rock Bass | Yellow Perch | White Sucker |
|---|---|---|---|---|---|---|
| not measured | | | 13 | | 1359 | 109 |
| 4.0-5.9 | | | | | | |
| 6.0-7.9 | | | 9 | | 1 | |
| 8.0-9.9 | | | 11 | | 1 | |
| 10.0-11.9 | | | 8 | | 6 | |
| 12.0-13.9 | | | 1 | | 43 | |
| 14.0-15.9 | | | 23 | | 82 | |
| 16.0-17.9 | | | 29 | 3 | 27 | |
| 18.0-19.9 | | | 53 | 2 | 5 | |
| 20.0-21.9 | | | 13 | 6 | 3 | |
| 22.0-23.9 | | | 4 | 1 | 1 | |
| 24.0-25.9 | 1 | 1 | | | | |
| 26.0-27.9 | | | 1 | | | |
| 28.0-29.9 | | 2 | | 1 | | |
| 30.0-31.9 | 2 | 2 | | | | 1 |
| 32.0-33.9 | 2 | 1 | | | | |
| 34.0-35.9 | 2 | | | | | |
| 36.0-37.9 | 4 | | | | | |
| 38.0-39.9 | 3 | | | | | |
| 40.0-41.9 | 4 | | | | | 4 |
| 42.0-43.9 | 6 | | | | | 4 |
| 44.0-45.9 | 8 | | | | | 3 |
| 46.0-47.9 | 9 | | | | | 1 |
| 48.0-49.9 | 6 | | | | | 5 |
| 50.0-51.9 | 11 | | | | | 3 |
| 52.0-53.9 | 5 | | | | | 2 |
| 54.0-55.9 | 1 | | | | | 1 |
| 56.0-57.9 | 1 | | | | | |
| 58.0-59.9 | 5 | | | | | |
| 60.0-61.9 | 2 | | | | | |
| 62.0-63.9 | 1 | | | | | |
| 64.0-65.9 | | | | | | |
| 66.0-67.9 | | | | | | |
| 68.0-69.9 | 1 | | | | | |
| 70.0-71.9 | | | | | | |
| 72.0-73.9 | | | | | | |
| 74.0-75.9 | | | | | | |
| TOTALS | 74 | 6 | 165 | 13 | 1528 | 133 |

* 271 bluegills and 128 pumpkinsedd sunfish were trapped but not measured.

Walleye age determination based on scale readings, and total lengths for an age class is shown in Table 7. Few walleyes were found in I-II year class. Growth rates were similar to what was found in 1980.

Table 7. Age and average walleye total lengths for an age class from 1992 spring fyke net survey are compared to age and average walleye total lengths for an age class from 1980 spring fyke net survey. Length is in inches. Number of fish for each age class is in parentheses.

| Age | 1980 | | | 1992 | | |
|---|---|---|---|---|---|---|
| | Walleye(M) | Walleye(F) | Walleye (Combined) | Walleye(M) | Walleye(F) | Walleye (Combined) |
| I | -- | -- | -- | -- | -- | -- |
| II | -- | -- | -- | 9.1(1) | -- | 9.1(1) |
| III | 11.4(3) | -- | 11.4(3) | 11.4(3) | -- | 11.4(3) |
| IV | 14.3(6) | -- | 14.3(6) | 14.5(7) | -- | 14.5(7) |
| V | 16.1(37) | -- | 16.1(37) | 16.5(8) | -- | 16.5(8) |
| VI | 18.0(42) | 18.4(17) | 18.1(59) | 18.2(3) | -- | 18.2(3) |
| VII | 19.8(23) | 20.1(12) | 19.9(35) | 20.1(3) | 20.3(2) | 20.2(5) |
| VIII | 21.3(3) | 21.3(5) | 21.3(8) | 21.2(3) | 21.3(1) | 21.2(4) |
| IX | 22.1(3) | 23.0(11) | 22.8(14) | 22.4(2) | 22.4(3) | 22.4(5) |
| X | -- | 24.3(5) | 24.3(5) | -- | 25.2(2) | 25.2(2) |
| XI | -- | 26.2(4) | 26.2(4) | -- | 26.0(1) | 26.0(1) |
| XII | -- | -- | -- | -- | 27.6(1) | 27.6(1) |
| XIII | -- | 28.4(4) | 28.4(4) | -- | -- | -- |
| Total Number of Fish Captured | | | 175 | | | 40* |

* 2 fish were not added into age determination. Their lengths were 53 cm and 75 cm, also.

White suckers seem to have declined in the last 30 years. As with walleyes, few young suckers were found (Figure 2). The three suckers that we made age determinations for were four and five years old.

Table 8. Age and length of three white suckers that were captured in 1992. Length is in cm.

| Age | Length |
| --- | --- |
| IV | 45(1);46(1) |
| V | 49(1) |

Another project that was conducted along with fyke netting was walleye spawning bed investigation. We used scat netting to look for fertilized walleye eggs and we performed some water quality monitoring of the interstitial pore water at spawning locations. Results are summarized in Table 9.

Table 9. Scat netting results, and spawning bed pore water quality results for spring 1992.

| Location | Water Depth | Number of Eggs | Water Temp C | Cond. uS | Open Water DO mg/l | Pore Water DO mg/l | Pore Water Cond uS |
|---|---|---|---|---|---|---|---|
| April 29 | | | | | | | |
| Island Stat. | 18-24" | 10 | 9 | 40 | 9.4 | 7.0 | -- |
| Island Stat. | 6" | 100 | 9 | 40 | 9.4 | 7.0 | -- |
| Ruth's Point | 6-24" | 0 | 9 | 43 | 9.2 | 7.4 | -- |
| Webers | 6-24" | 2 | 9 | -- | -- | -- | -- |
| April 30 | | | | | | | |
| Island Stat. | 6-12" | 50-60 | 11 | 45 | 10.6 | 6.0 | 60 |
| Shaefers | 6-18" | 10-20 | -- | -- | -- | -- | -- |
| Ruth's | 6-18" | 2 | 10.5 | 40 | 9.2 | 6.0 | 90 |
| Bremer's | 6-12" | 20-40 | -- | -- | -- | -- | -- |

Results indicated that the island shoreline produces the most walleye eggs. Ruth's point, which is the shoreline along Sunset Resort, has excellent rock rubble substrate but low eggs counts. We don't know why. In the 1950's and 1960's walleyes were frequently seen on these beds (R. Van Prooien, personal communication). Pore water is different than open-lake water but should not inhibit egg hatching (based on our sample results--Table 9). Reasons for a lack of walleye spawning success do not appear to be to poor water quality or a lack of suitable spawning substrate.

## Septic Leachate Survey and Groundwater Inflow Survey

A septic leachate survey and groundwater inflow study was conducted on Bear Lake on August 15, 1992. For the survey we used a YSI (Yellow Springs Instruments) Conductivity Meter with the probe attached to a 8-feet pole. We proceeded around the shoreline in a boat and measured conductivity. The objective was to detect either an increase or decrease in conductivity as we went around the lake. We assumed an increase in conductivity could maybe be an indicator of septic tank effluent entering the lake. We assumed a decrease in conductivity reflected groundwater inputs from groundwater that had a relatively short conduct time with the soil.

Results are shown in Figure 3. Open water conductivity was 56 umhos/cm and nearshore background was 59 umhos/cm. Several areas around the lake had below background conductivity readings. These may be areas of groundwater inflow. Several areas showed a conductivity reading of 1 or 3 umhos/cm above background. These maybe areas of septic tank effluent inputs. We did not perform any water testing. Typically, phosphorus measurements taken from suspected plumes are inconclusive.

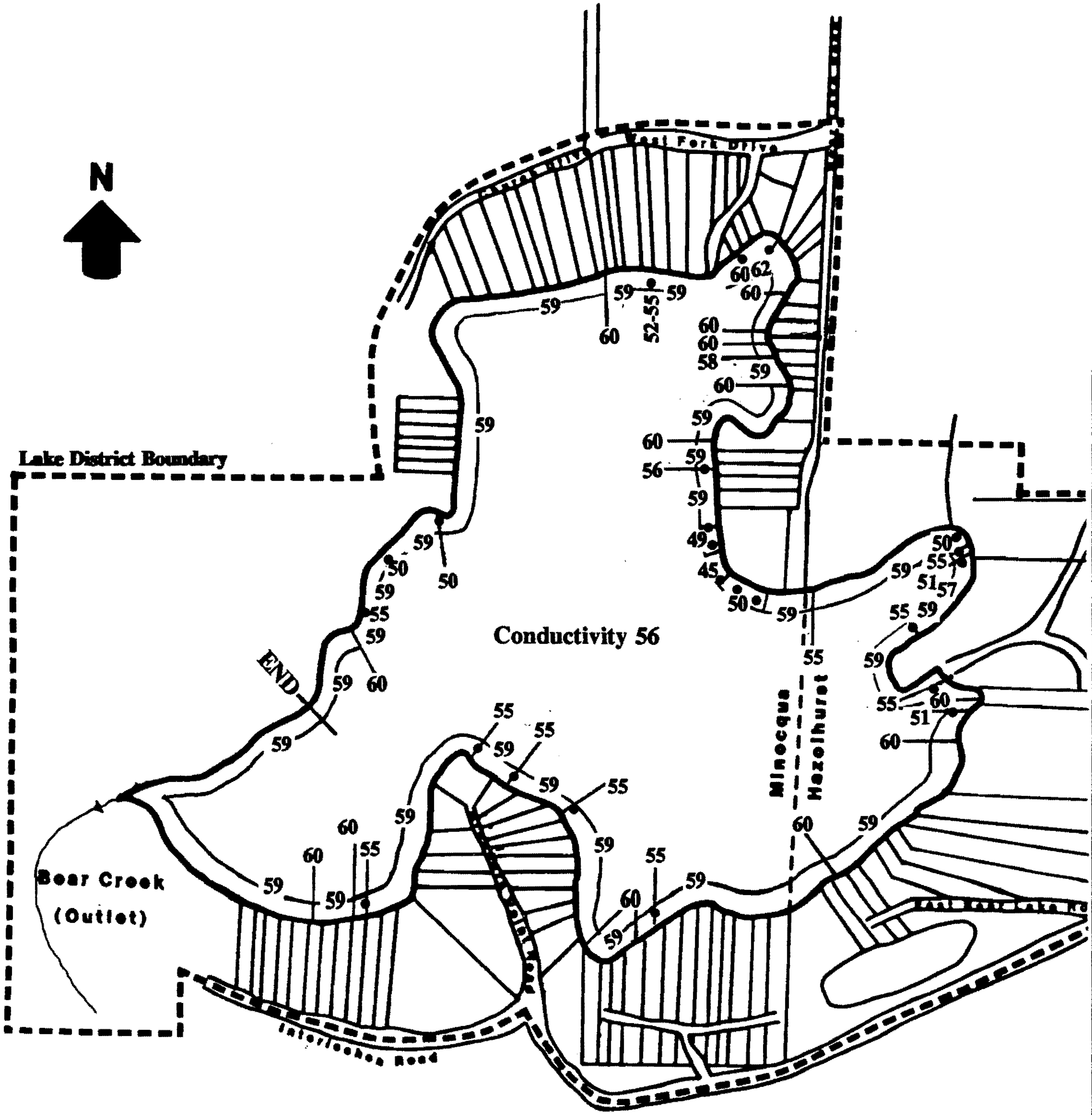



Figure 3. Results of septic leachate for Bear Lake, August 15, 1992.

## Sedimentation Study

Sediment traps were placed in three bays in Bear Lake in the summer of 1992 for a total of 100 days (from April 29-August 16, 1992. Location of the sediment traps was shown in Figure 1-- page 7a.). The amount of the sediment recovered in the traps was unexpectedly high (Figure 4) about three inches in each bottle. Contents of the sediment traps were analyzed for total phosphorus and solids and results are shown in Table 10.

Table 10. Laboratory results from sediment traps on bulk sediments (Average sedimentation was 3 inches over 108 days. Sediment trap diameter was 2.25 inches).

| | Sample 2<br>5 feet | Sample 3a<br>3 feet | Sample 3b<br>3 feet |
|---|---|---|---|
| Total Phosphorus (mg/L) | 17.3 | 7.02 | 11.7 |
| Suspended Solids (mg/L) | 12,900 | 9,460 | 13,020 |
| Volatile Suspended Solids (mg/L) | 8,060 | 6,390 | 8,910 |

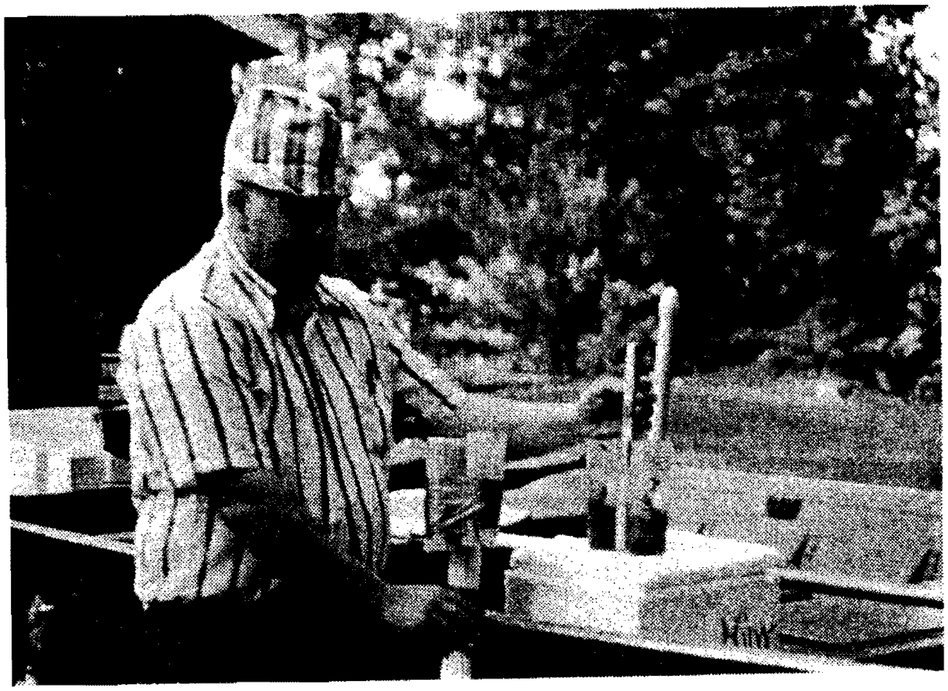
From the laboratory results, total phosphorus that was resuspended and captured in the bottle was calculated on a square meter of lake bottom and results are shown in Table 11. Also the percent volatile solids is given in Table 11. Volatile solids are an approximate measure of organic matter.

Table 11. Sediment trap results for phosphorus and volatile suspended solids. Data have been derived from results in Table 10.

| | Sample 2 | Sample 3a | Sample 3b |
|---|---|---|---|
| Total resuspended phosphorus ($mg/m^2/day$) | 12 | 5 | 8 |
| Percent volatile solids (%) | 63 | 68 | 68 |
| Water depth at sample site (feet) | 5 | 3 | 3 |

Calculations for Sediment Trap Phosphorus

The resuspended phosphorus concentration was estimated from the following criteria: Average depth of sediments in the trap was 3.0 inches. Bottle diameter was 2.25 inches. Total volume of sediment was 3.0 inches x surface area of trap opening (3.95 $inches^2$)= 11.85 cubic inches. The trap volume of 11.5 cubic inches can be converted to 194 milliliters. Multiplying the volume (194ml) by concentration (17.3mg/l) gives us a phosphorus mass (3.4mg-phosphorus). This amount of phosphorus was deposited in the sediment trap with a surface opening of 25.4 $cm^2$ (based on 2.5 inch diameter opening). 25.4 $cm^2$ = 0.00254$m^2$. To get a phosphorus load for a square meter, we multiply 1/0.000254$m^2$ x 3.4mg-phosphorus + 1339mg-phosphorus/108 days/$m^2$ = 12mg-P/$m^2$/day. Similar calculations were made for samples 3a and 3b.



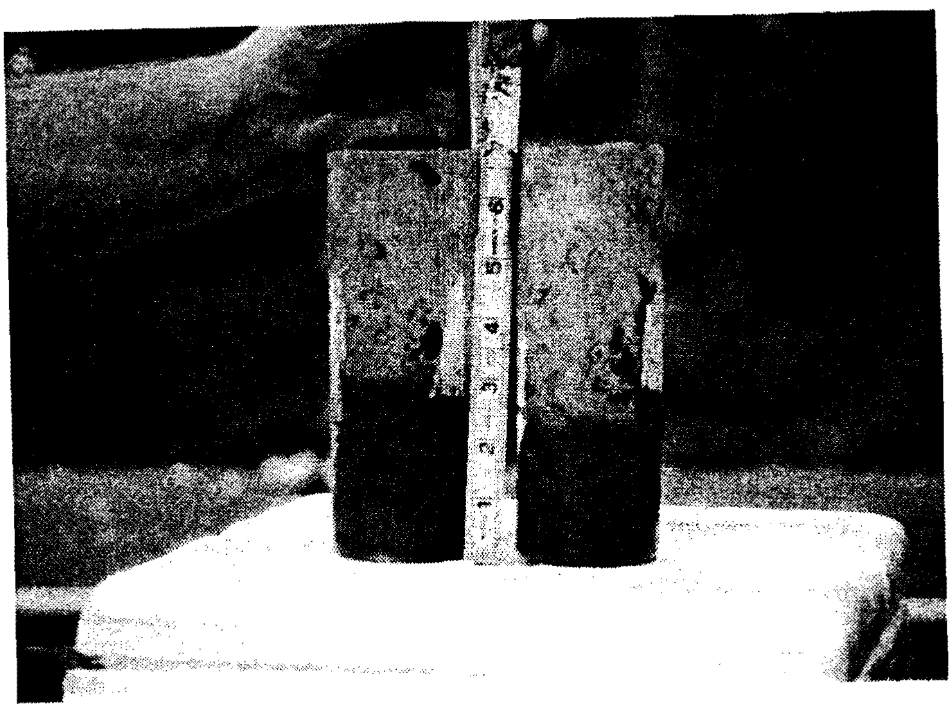


Figure 4. Photographs of sediment traps contents.

## 5. DISCUSSION

**Bear Lake's Dynamic Fish Community *(based on comparisons to other Bear Lake surveys)***

The Bear Lake District has been tracking sunfish populations since panfish removal efforts started in 1985. From 1985 through 1991 a total of 10,290 pounds of sunfish and 2,338 pounds of bullheads were removed. A summary is shown in Table 12.

Table 12. Pounds of fish removal from 312 acre Bear Lake since 1985.

| | Bluegill | Pumpkinseed | Bullheads | Total Pounds | Pounds Per Acre |
|---|---|---|---|---|---|
| 1985** | ? | ? | 0 | 688* | 2.2 |
| 1986*** | 1,397 | 1,471 | 483 | 3,351 | 10.7 |
| 1987*** | 1,148 | 1,146 | 376 | 2,670 | 8.6 |
| 1988*** | 939 | 947 | 767 | 2,653 | 8.5 |
| 1989**** | 443 | 571 | 321 | 1,335 | 4.3 |
| 1991***** | 995 | 545 | 391 | 1,931 | 6.2 |
| Total | 4,922 | 4,680 | 2,338 | 12,628 | 40.5 |

* estimate of Bluegills and Pumkinseeds pounds removed.
** 4 days, 6 nets, bullheads were not removed
*** 10 days, 10 nets, major removal effort
**** 6 days, 6 nets, this was intended as a sampling year not a fullblown fish removal year
***** 5 days, 10 nets
++ Total number of fish removed since 1985: 151,654

We have kept records for all fish captured during the early summer fyke netting and those results are shown in Table 13.

Table 13. Number of gamefish and panfish caught for every fyke net set.

| Date | Walleye | Northern Pike | Largemouth Bass | Yellow Perch | Bluegill | Pumpkinseed | Bullhead |
|---|---|---|---|---|---|---|---|
| 1985* | 0.3 | 0.2 | 1.9 | 3.4 | 131 | 187 | -- |
| 1986 | 0.3 | 0.4 | 2.1 | 1.2 | 246 | 145 | 19 |
| 1987 | 0.5 | 0.6 | 0.9 | 1.0 | 240 | 116 | 17 |
| 1988 | 0.1 | 0.5 | 1.7 | 0.4 | 188 | 91 | 40 |
| 1989* | 0.2 | 0.6 | 4.0 | 0.4 | 169 | 110 | 35 |
| 1991* | 0.2 | 1.4 | 3.5 | 0.4 | 343 | 81 | 28 |

* netting conducted for one week period.
Other years netting was conducted for 2 weeks.

Fish sampling in the spring has been less frequent, but it goes back further to 1959. Some changes in the fish community appear to have taken place over this time period (Table 14). Since 1959, walleyes have decreased as have white suckers, where as bluegill, yellow perch, crappie, and bullheads have increased. Northern pike may have increased also. However, this Table may not show the whole picture. Summer fyke netting results indicate largemouth bass are increasing. And the startling increase in perch appears to be recent (1992). The 1991 summer fyke survey did not show an increase in perch.

I think the Bear Lake fish community is still changing. With the recent increase in yellow perch, it may be possible that walleye recruitment will increase in the future. This is something to watch.

Table 14. Number of each species per lift found in Bear Lake during 1959, 1980, and 1992 surveys.

| | 1959[1] | 1980[2] | 1992[3] |
|---|---|---|---|
| Walleye (total) | 46 | 9.6 | 3.6 |
| (males) | -- | 7.1 | 2.3 |
| (females) | -- | 2.5 | 1.3 |
| Northern Pike | present | 1.3 | 4.2 |
| White Sucker | 143 | 29.2 | 7.7 |
| Bluegill | 0 | A | 15.1 |
| Yellow Perch | 0.5 | B | 85 |
| Crappie | ? | B | 9.2 |
| Bullhead | 1.5 | B | 19.1[C] |
| Rock Bass | 0.1 | B | 0.8 |
| Muskie | present | 0 | 0 |
| Smallmouth Bass | present | B | 0 |

[A]numerous 3.0-inch bluegills
[B]not mentioned
[C]Yellow bullhead

[1]1959: April 27-30, 1959; 20 lifts
[2]1980: April 23-26, 1980; 24 lifts
[3]1992: April 28-May 1, 1992; 18 lifts

**Prey Fish Availability**

Something else appears to have been happening in the Bear Lake fish community since 1980. A cursory look at the data seemed to indicate more gamefish in 1992 than in 1985 or 1980, and that a higher percentage of prey fish are now vulnerable to predation than in 1980 or 1985. The ramifications, if true, are that gamefish may be able to exert some control over the panfish and that with reduced panfish numbers, more young gamefish may survive through the tough first year into a size that then allows them to counter an abundance of prey.

To test the idea that more prey fish are vulnerable now compared to 1980 or 1985 we needed some way to quantify prey vulnerability. As a foundation, we employed techniques used by Lawrence (1958) and Hambright et al (1991), and modified those approaches to get a prey vulnerability index.

To establish a prey vulnerability index, we need several measurements. One measurement is how large of a prey fish a gamefish can shallow. To do this we have converted gamefish total lengths to mouth widths (also referred to as gape width). Next we have converted prey fish total lengths to body depths. Then we have made the assumption that any prey fish with a body depth less than the mouth width of a gamefish is vulnerable to ingestion.

Literature data have been used to express the total length verses mouth width (gamefish) and total length verses body depth (prey fish). Graphical representations predator mouth widths are shown in Figures 5 and 6. The relationship between prey depth and total length is shown in Figure 7. Equations that describe the graph lines are shown in Table 15. Charts that display total length verse game fish mouth widths and prey body depths is shown in Table 16.

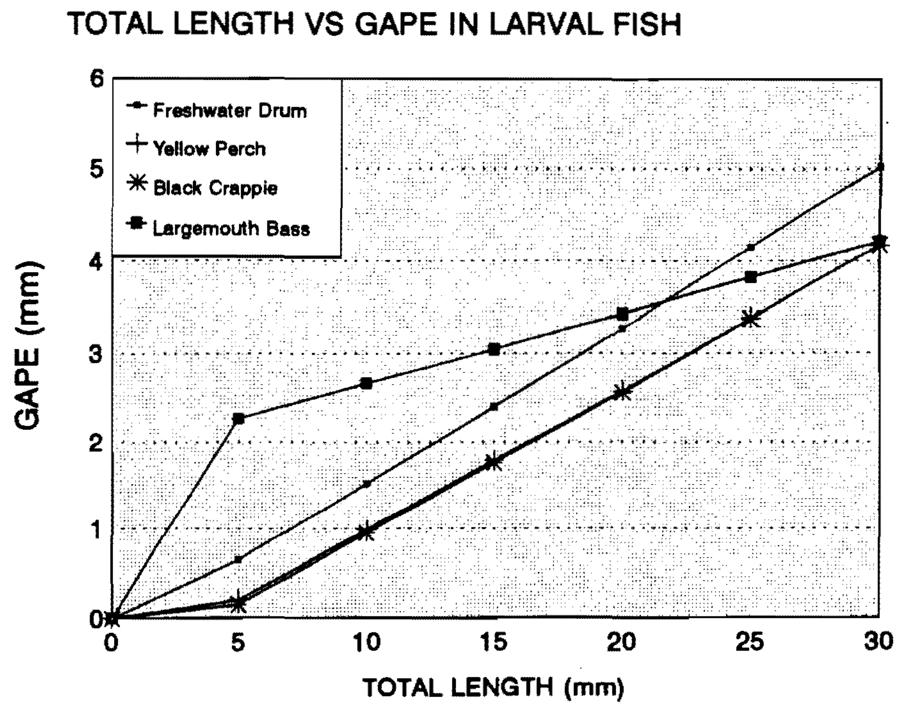



Figure 5. The gape or mouth width for four species of larval fish as a function of fish total length. The assumption is that a predator can shallow any prey with a body depth less than its mouth width.

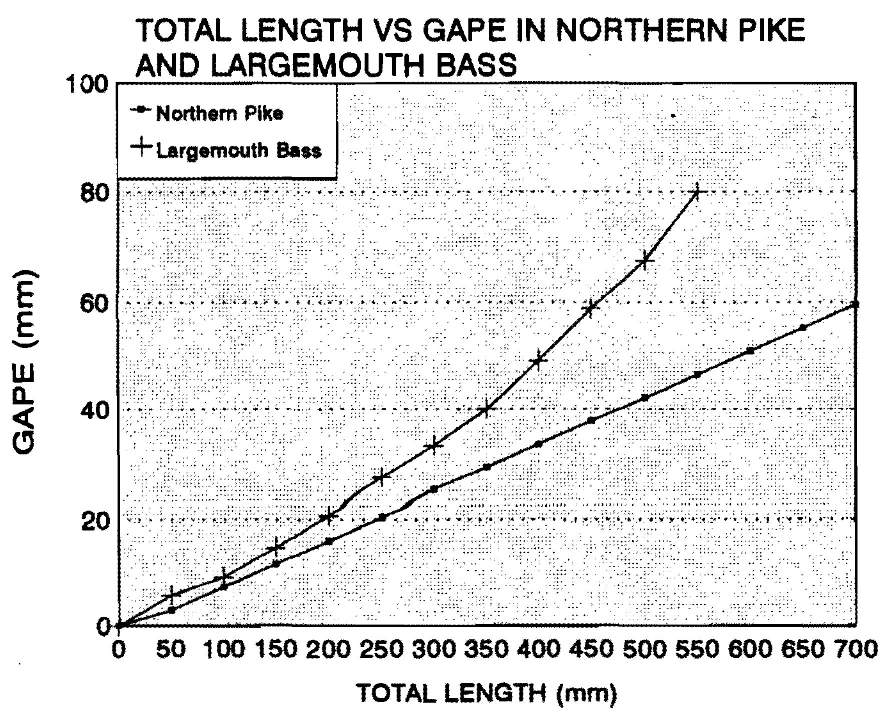



Figure 6. The gape or mouth width for northern pike and largemouth bass as a function of fish total length. The assumption is that a predator can shallow any prey with a body depth less than its mouth width.

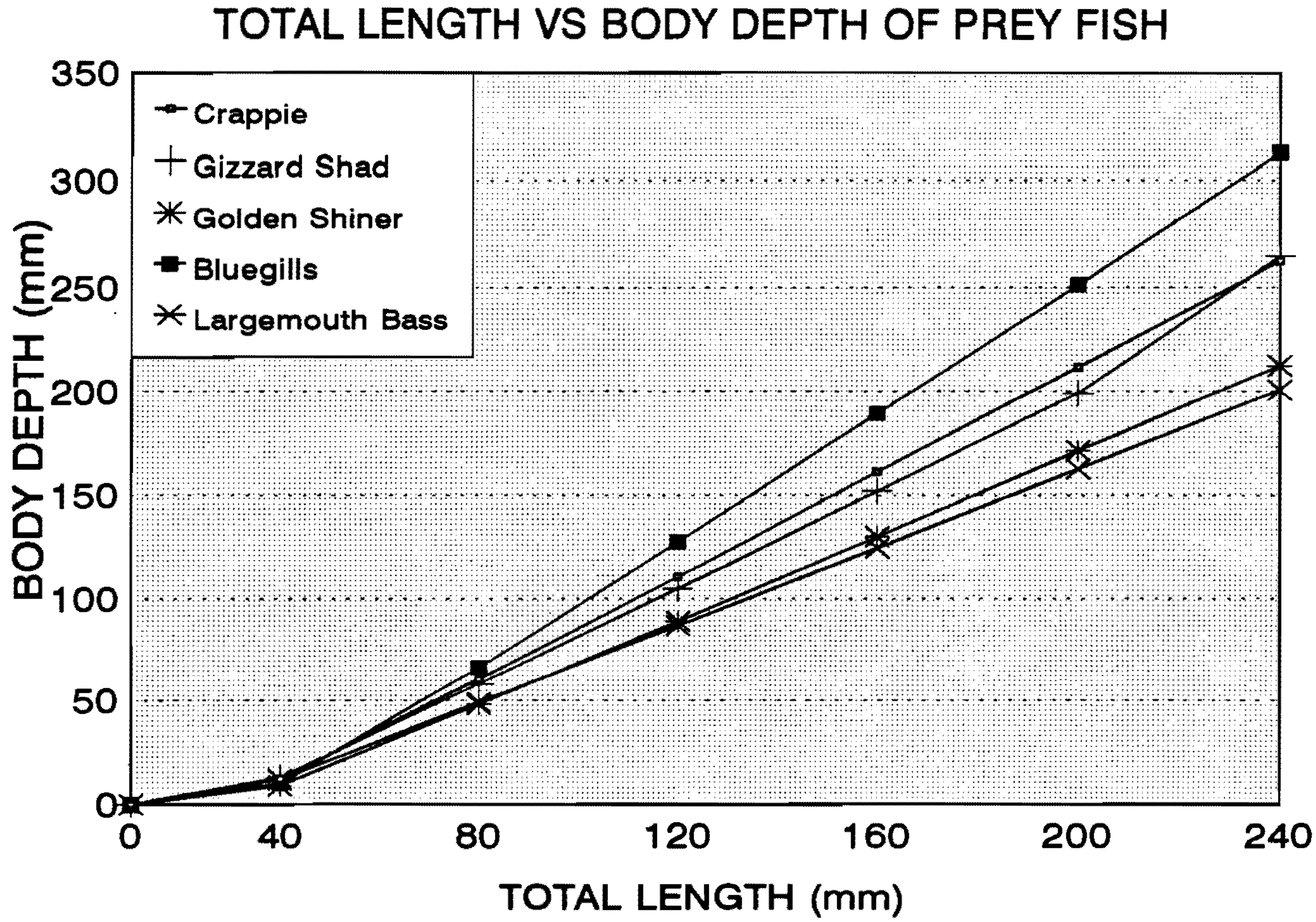



Figure 7. The body depth for several species of prey fish as a function of fish total length. The assumption is any prey fish with a body depth less than the mouth width of a predator is vulnerable to predator.

Table 15. Gape, mouth widths, and body depths as a function of total length for selected prey and gamefish (predator fish).

LARVAL GAMEFISH MOUTH WIDTHS (OR GAPE)

Total length=mm except for yellow perch

| | | | | |
|---|---|---|---|---|
| Freshwater drum | gape(mm)=0.175L - 0.228 | $r^2$=0.92 | n=132 | Schael et al 1991 |
| Yellow perch | gape(mm)=0.159L - 0.597 | $r^2$=0.94 | n=287 | 0-24 mm |
| Black crappie | gape(mm)=0.161L - 0.656 | $r^2$=0.75 | n=162 | 0-30 mm |
| Yellow perch L=cm | gape(mm)=1.53L - 0.52 | $r^2$=0.98 | n=238 | Arts & Evens 1987 |
| Largemouth Bass 0-100 mm | mouth width=0.0775L + 1.88 | | | Lawrence 1957 |

ADULTS GAMEFISH MOUTH WIDTHS

Total length=mm

| | | | |
|---|---|---|---|
| Walleye | mouth width(mm)=15.43Ln(TL)-61.43 | $r^2$=0.99 derived from Knight et al 1984 | |
| Northern pike | mouth width(mm)=0.087TL - 1.38 | $r^2$=0.98 n=34 Hambright et al 1991 | |
| Largemouth Bass | mouth width(mm)=0.111TL - 1.88 | Lawrence 1957 | 100-199 |
| | mouth width(mm)=0.129TL - 5.16 | " " | 200-299 |
| | mouth width(mm)=0.137TL - 7.96 | " " | 300-399 |
| | mouth width(mm)=0.196TL - 29.41 | " " | 400-499 |
| | mouth width(mm)=0.248TL - 56.36 | " " | 500-599 |

PREY BODY DEPTHS

Total Length(TL)=mm

| | | |
|---|---|---|
| Bluegill | body depth(mm)=0.418TL - 7.98 | |
| Redear | body depth(mm)=0.346TL - 2.08 | |
| Green | body depth(mm)=0.372TL - 4.36 | |
| Crappie | body depth(mm)=0.3151TL - 5.38 | $r^2$=1.00 n=31 Hambright et al |
| Gizzard shad | body depth(mm)=0.294TL - 4.59 | |
| Goldfish | body depth(mm)=0.385TL - 8.50 | |
| Golden shiner | body depth(mm)=0.257TL - 4.71 | |
| Largemouth Bass | body depth(mm)=0.237TL - 3.16 | (0-299 mm) |
| Yellow Perch | body depth(mm)=0.271TL - 1.15 | $r^2$=0.99 Knight et al 1984 |

Table 16. Gamefish conversion chart.

| Mouth Widths (mm) | Walleye Total (mm) | Walleye Length (inches) | Walleye Weight (pounds) | Largemouth Bass Total (mm) | Largemouth Bass Length (inches) | Largemouth Bass Weight (pounds) | Northern Pike Total (mm) | Northern Pike Length (inches) | Northern Pike Weight (pounds) |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | | | | 40 | 1.6 | - | 73 | 2.9 | - |
| 10 | 100 | 3.9 | - | 107 | 4.2 | - | 130 | 5.1 | - |
| 15 | | | | 152 | 6 | - | 188 | 7.4 | - |
| 20 | 200 | 7.8 | - | 197 | 7.8 | - | 246 | 9.7 | - |
| 25 | 275 | 10.8 | - | 234 | 9.2 | - | 303 | 12 | - |
| 30 | 375 | 14.8 | 1.5 | 273 | 10.8 | - | 360 | 14.2 | - |
| 35 | 525 | 20.7 | 2.8 | 314 | 12.3 | 1 | 418 | 16.5 | - |
| 40 | 700 | 27.6 | 8 | 350 | 13.8 | 1.9 | 476 | 18.7 | - |
| 45 | | | | 387 | 15.2 | 2.3 | 533 | 21 | 2 |
| 50 | | | | 405 | 16 | 2.7 | 590 | 23.2 | 2.7 |
| 55 | | | | 431 | 17 | 3.1 | 648 | 25.5 | 3.6 |
| 60 | | | | 456 | 18 | 3.5 | 705 | 27.8 | 4.9 |
| 65 | | | | 482 | 19 | 4.5 | 763 | 30 | 5.8 |
| 70 | | | | 510 | 20.1 | 5.4 | 820 | 32.3 | 8.2 |
| 75 | | | | 530 | 20.9 | 6.3 | 878 | 34.6 | 10.6 |
| 80 | | | | 550 | 21.7 | 7.2 | 935 | 36.8 | 13.4 |

Prey fish conversion chart.

| Body Depth (mm) | Bluegill mm (inches) | Pumpkinseed mm (inches) | Crappie mm (inches) | Yellow Perch mm (inches) | Golden shiner mm (inches) | Gizzard shad mm (inches) | Largemouth Bass mm (inches) |
|---|---|---|---|---|---|---|---|
| 0 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| 5 | 31 (1.2) | 31 (1.2) | 33 (1.3) | 27 (1) | 38 (1.5) | 33 (1.3) | 34 (1.4) |
| 10 | 43 (1.7) | 43 (1.7) | 49 (1.9) | 41 (1.6) | 57 (2.3) | 50 (2.0) | 56 (2.2) |
| 15 | 55 (2.2) | 55 (2.2) | 65 (2.5) | 60 (2.3) | 77 (3.0) | 67 (2.6) | 77 (3.0) |
| 20 | 67 (2.6) | 67 (2.6) | 81 (3.2) | 78 (3.1) | 96 (3.8) | 84 (3.3) | 98 (3.8) |
| 25 | 79 (3.1) | 79 (3.1) | 96 (3.8) | 98 (3.8) | 116 (4.6) | 101 (4.0) | 119 (4.7) |
| 30 | 91 (3.6) | 91 (3.6) | 112 (4.4) | 115 (4.5) | 135 (5.3) | 118 (4.6) | 140 (5.5) |
| 35 | 103 (4.0) | 103 (4.0) | 128 (5.0) | 133 (5.3) | 155 (6.1) | 135 (5.3) | 161 (6.3) |
| 40 | 115 (4.5) | 115 (4.5) | 144 (5.7) | 152 (6.0) | 174 (6.8) | 152 (6.0) | 182 (7.2) |
| 45 | 127 (5.0) | 127 (5.0) | 160 (6.3) | 170 (6.7) | 193 (7.6) | 169 (6.6) | 203 (8.0) |
| 50 | 139 (5.5) | 139 (5.5) | 176 (6.9) | 189 (7.4) | 213 (8.4) | 186 (7.3) | 224 (8.8) |
| 55 | 151 (5.9) | 151 (5.9) | 192 (7.5) | 207 (8.2) | 232 (9.1) | 203 (8.0) | 245 (9.7) |
| 60 | 163 (6.4) | 163 (6.4) | 207 (8.2) | 226 (8.9) | 252 (9.9) | 220 (8.6) | 266 (10.5) |
| 65 | 175 (6.9) | 175 (6.9) | 223 (9.4) | 244 (9.6) | 271 (10.7) | 237 (9.3) | 288 (11.3) |
| 70 | 187 (7.3) | 187 (7.3) | 255 (10.0) | 263 (10.3) | 291 (11.4) | 254 (10.0) | 309 (12.2) |
| 75 | 199 (7.8) | 199 (7.8) | 271 (10.7) | 281 (11.1) | 310 (12.2) | 271 (10.7) | 330 (13.0) |
| 80 | 210 (8.3) | 210 (8.3) | 287 (11.3) | 299 (11.8) | 330 (13.0) | 289 (11.3) | 351 (13.8) |
| 85 | 222 (8.8) | 222 (8.8) | 287 (11.3) | 318 (12.5) | 349 (13.7) | 305 (12.0) | 372 (14.6) |
| 90 | 234 (9.2) | 234 (9.2) | 303 (11.9) | 336 (13.2) | 369 (14.5) | 322 (12.7) | 393 (15.5) |

Results of gamefish mouth width distributions for Bear Lake summer fyke netting are shown in Figure 8. Several differences are found between 1985 and 1991. One difference is the number of gamefish sampled. More gamefish were sampled in 1991 than in 1985. Even though there were more lifts in 1991 (50) compared to 1985 (24) the number per lift is still greater. For both years largemouth bass were more numerous than northern pike.

The gamefish mouth width distribution appeared to increase for largemouth bass from 1985 to 1991 (Figure 8). The stunted sunfish in Bear Lake are around four inches long which equates to a body depth of about 35 mm. With more gamefish in 1991 in a size class that could eat the stunted sunfish, maybe gamefish could start exerting some control over sunfish.

We believe we have a way to look at this. We looked at total lengths for all preyfish (bluegill, pumpkinseed, crappie, yellow perch) and converted total lengths to body depths. We took all gamefish (northern pike, largemouth bass, and walleye) total lengths and converted them to mouth widths. Results are shown in Figure 9.

We have set-up an arbitrary scale called "gamefish coverage". We have assumed a gamefish can ingest a prey that has a body depth less than its mouth width.

Apparently the condition in Bear Lake in 1985 was the preyfish community was largely safe from gamefish predation. Predators were small and there were not very many of them. From 1985 to 1989, June fish removal with fyke nets occurred. The areas under the curves changed. In 1991, gamefish numbers increased (in terms of number per lift) and they were larger.

What does this mean? Because gamefish in 1991 were more numerous and bigger than 1985, more preyfish were vulnerable to be ingested. This gamefish coverage number is a way to quantify this observation.

The gamefish coverage percentage is a relative indicator. All it indicates is the overlap of gamefish mouth widths with prey body depths. However it does seem to have some value. It will indicate if there is a stunted fish population (low overlap percentage or coverage) and should indicate a well balanced fish community. As more lake surveys are evaluated for gamefish coverage classification schemes can be set.

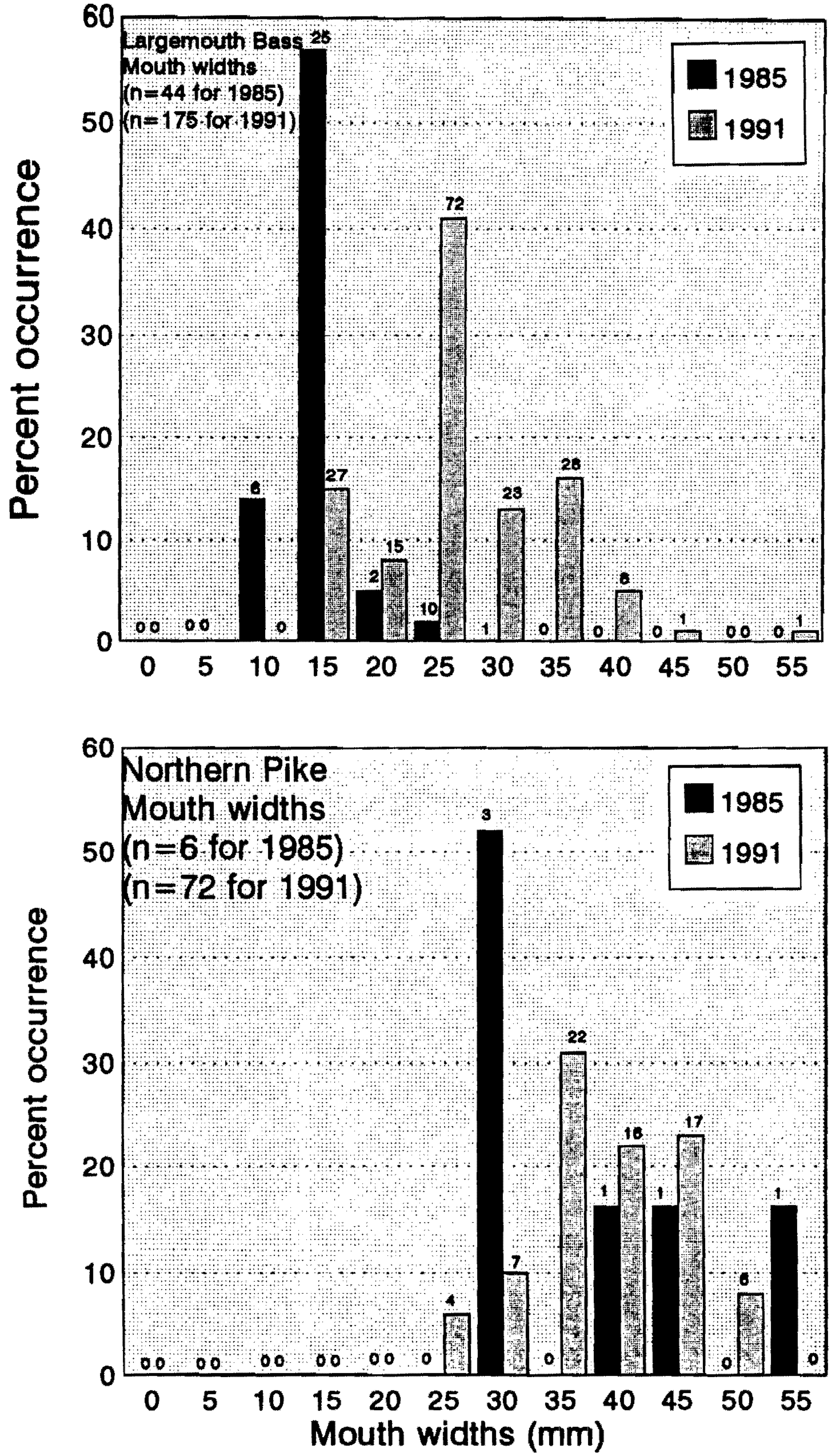



Figure 8. Frequency distribution of gamefish mouth widths for June fyke netting on Bear Lake. Numbers on top of bars indicate number of fish. Number of lifts in 1985 was 24 and in 1991 it was 50.

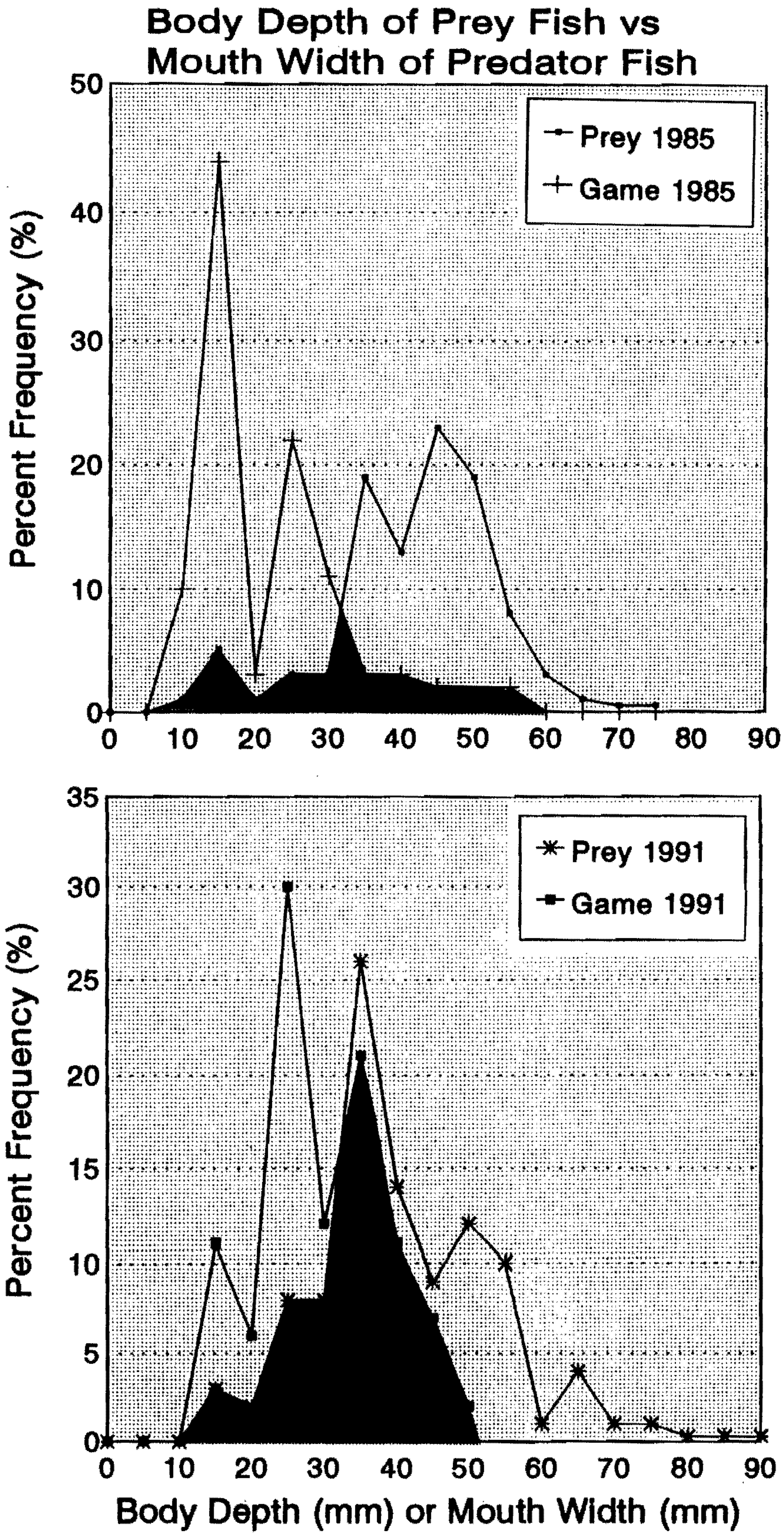
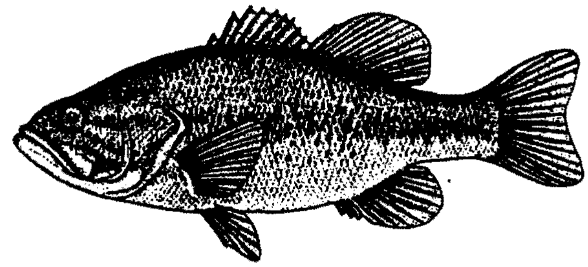
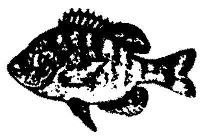



Figure 9. Prey body depth and gamefish (predator) mouth width distributions for Bear Lake based on June fyke net results for 1985 and 1991. The shaded area is the area that gamefish "cover" preyfish.

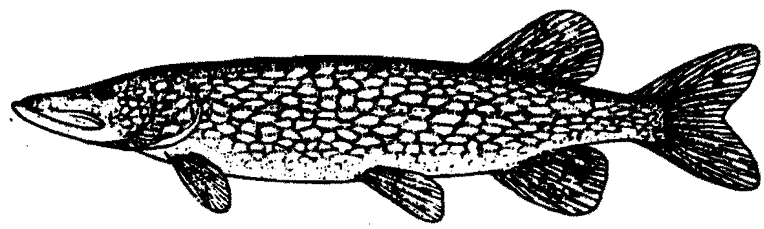
In summary, the idea behind gamefish mouth widths and prey body depths is to develop a technique where a lake manager can take fish survey results, make some graphs and quantify with one number the relative condition of the fish community. As example, a stunted sunfish community is dominated by four inch fish. It takes a 12 inch bass, 16 inch pike, or a 21 inch walleye to eat a stunted sunfish. If the gamefish community does not have enough fish that big, then the stunted sunfish will continue to be numerous. A representation of the prey body depth and gamefish mouth width is shown in Figure 10. In this case a yellow perch is shown as well. A 5.3 inch yellow perch is equivalent to a 4.0 inch bluegill.



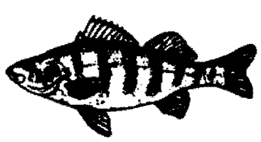
Largemouth Bass, 12.3 inches
3-4 years old, 1 pound



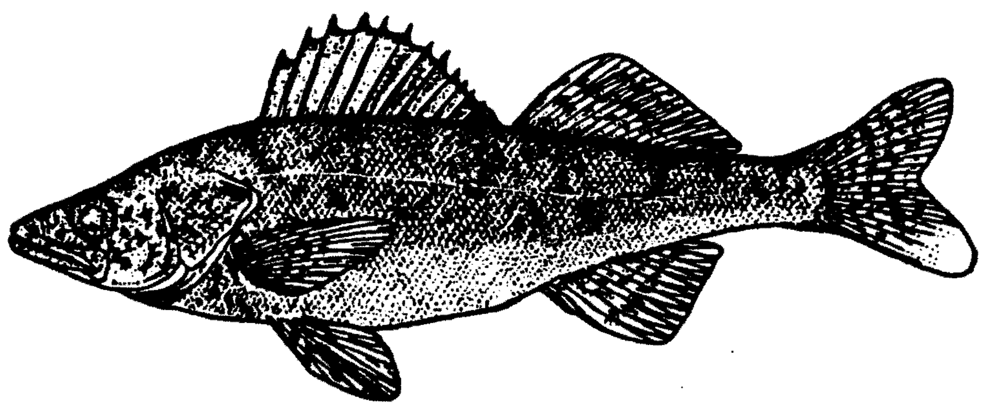
Bluegill sunfish, 4 inches
1-2 years old



Northern Pike, 16.5 inches
6-7 years old, 1.5 pounds



Yellow perch, 5.3 inches
2 years old



Walleye, 21 inches
8 years old, 3 pounds

Figure 10. Relationship (to scale) of predator fish and prey fish in Bear Lake. For gamefish to control stunted sunfish (4 inches), a bass has to be 12.3 inches, a pike, 16.5 inches and a walleye, 21 inches. This is based on the predator mouth width to prey body depth relationship. A 5.3 inch perch is equivalent to a 4 inch bluegill in regard to what can be swallowed by a gamefish.

## Impact of On-site Systems on Bear Lake and Groundwater Inflow

In 1977 Northern Lake Service conducted a groundwater survey on Bear Lake. Their results indicated that at the time of the survey groundwater was not a big influence on the water quality of the lake. Northern Lake Service also concluded that of the eight sites that were studied four flowed into the lake and four flowed away from the lake (Figure 11). All four that flow toward the lake had higher conductivity values and higher concentration of chlorides then the values that were found in the lake. They concluded that this meant that humans had influenced the groundwater. However nutrient and bacterial testing showed no major onsite problems. Our conclusion after conducting our survey is that septic tank systems are not a problems in 1992.

The methods they used were to collect water samples monthly from the 15 wells that were placed around the lake. The wells were placed, one near the lake, and one away from the lake. There was no off site location of wells at A and B because of the rocky terrain. Only one well was placed at the outflow. Three deep wells were placed next to sample sites A, E, and G. These deep wells were used to determine vertical groundwater flow.

In the following year, Wisconsin Department of Natural Resources (WDNR) interpreted the results from the Northern Lake Service to show that there were five sources of groundwater entering the lake and four spots where water was leaving the lake (Figure 12). The groundwater that was entering the lake was good quality and the nutrient concentration was low (0.04mg/l). It was stated that because of the long water residence time, any major changes in the groundwater quality could have a longterm effect on the lake water quality.

When the Blue Water Science conductivity survey is compared to what the WDNR groundwater survey found, the conductivity survey is very close to what was found with an extensive well installation and monitoring program.

We conclude that with cautiously interpreting conductivity surveys, that general areas of groundwater inflow can be determined. When looking at WDNR input arrows and comparing with conductivity readings, there is some overlap of areas of predicted inflows. Conductivity readings show broad areas of inflow (by looking at elevated or depressed conductivity compared to open water (background) readings. I believe in many cases, groundwater enters a lake as a diffuse front, so WDNR arrows probably indicate a diffuse inflow area and not a point source inflow. In this respect a conductivity survey can give an indication of groundwater inflow. It does not allow us to determine areas of outflow. However, a conductivity survey is very inexpensive and quick and probably can be used as a lake management tool. One component that is missing from these types of groundwater studies is the magnitude of groundwater inflow. Inexpensive techniques for determining the volume of groundwater inflow is not available (seepage meters generally are not satisfactory). However, some promising techniques that Blue Water Science is developing may soon be mainstream (flow velocity measurements, etc.).

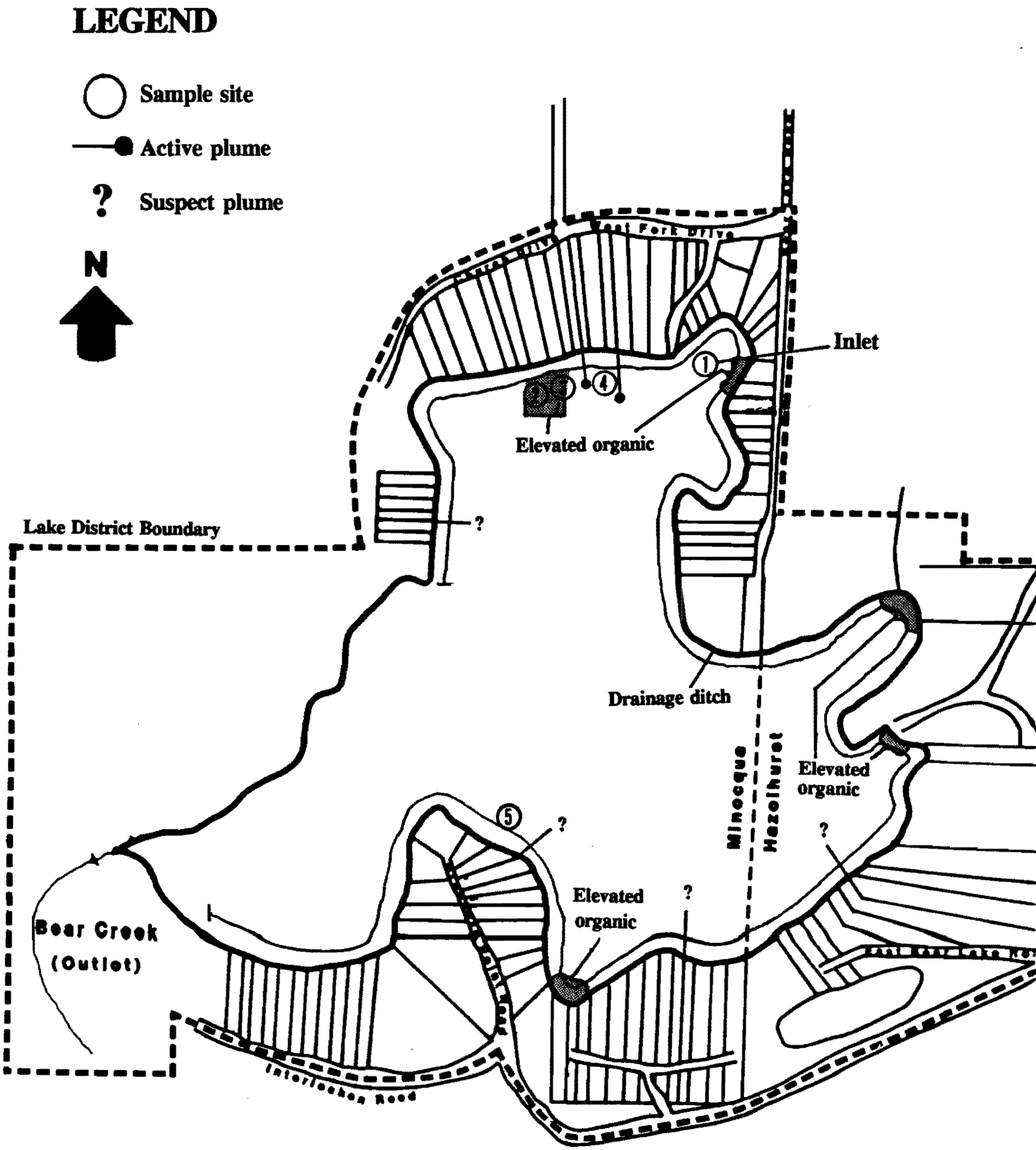



Figure 11. Septic Leachate survey from August 17-19, 1982 using the fancy septic leachate rig an ENDECO Septic Snooper ™ Model 2100 (Fluorometer and conductivity meters). Survey was conducted by Swanson Environmental, Inc

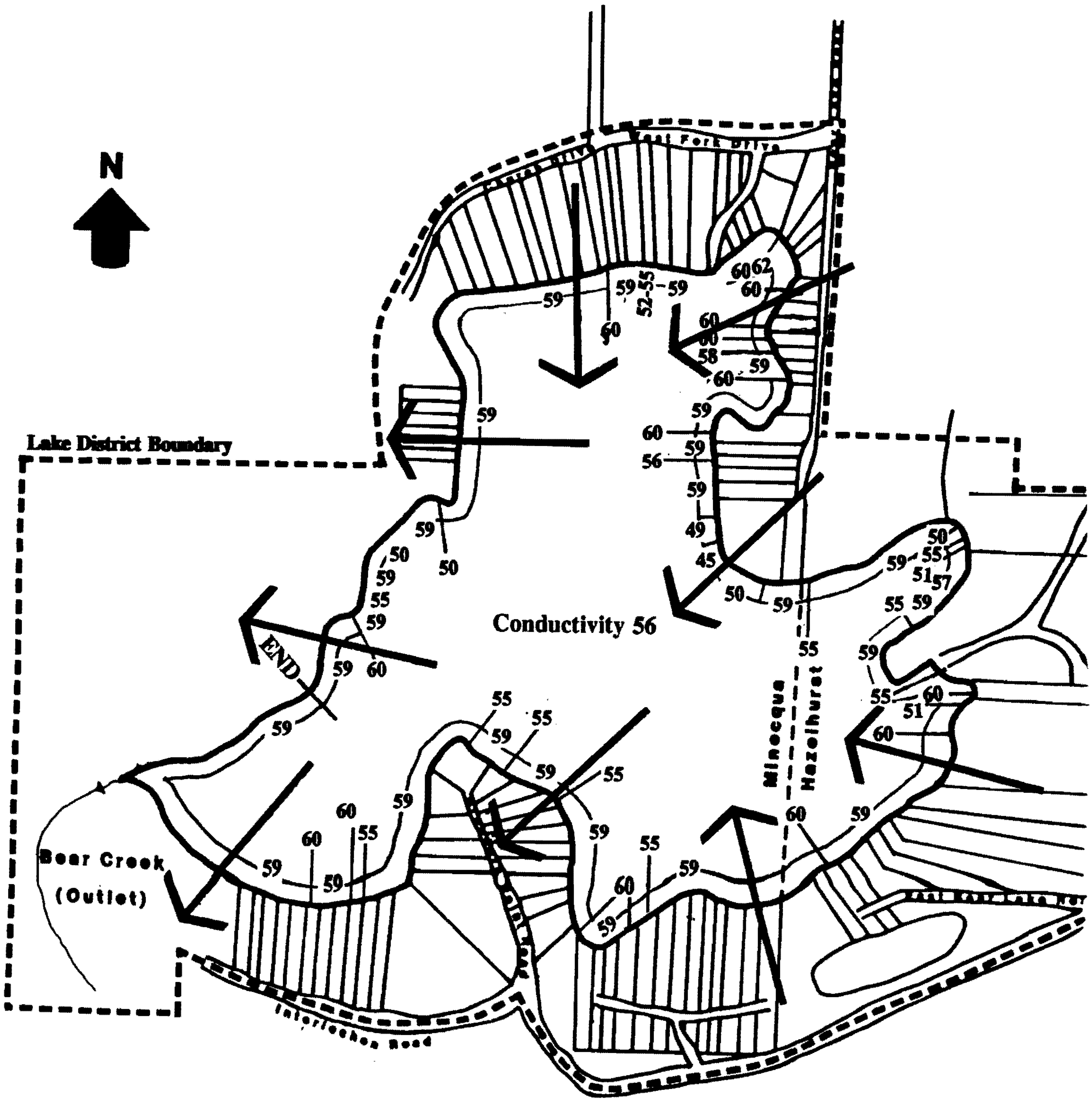



Figure 12. Areas of inflow and outflow as determined by the WDNR 1978 are shown with large arrows. These roughly correspond to areas of changes in conductivity indicating areas of groundwater inflow.

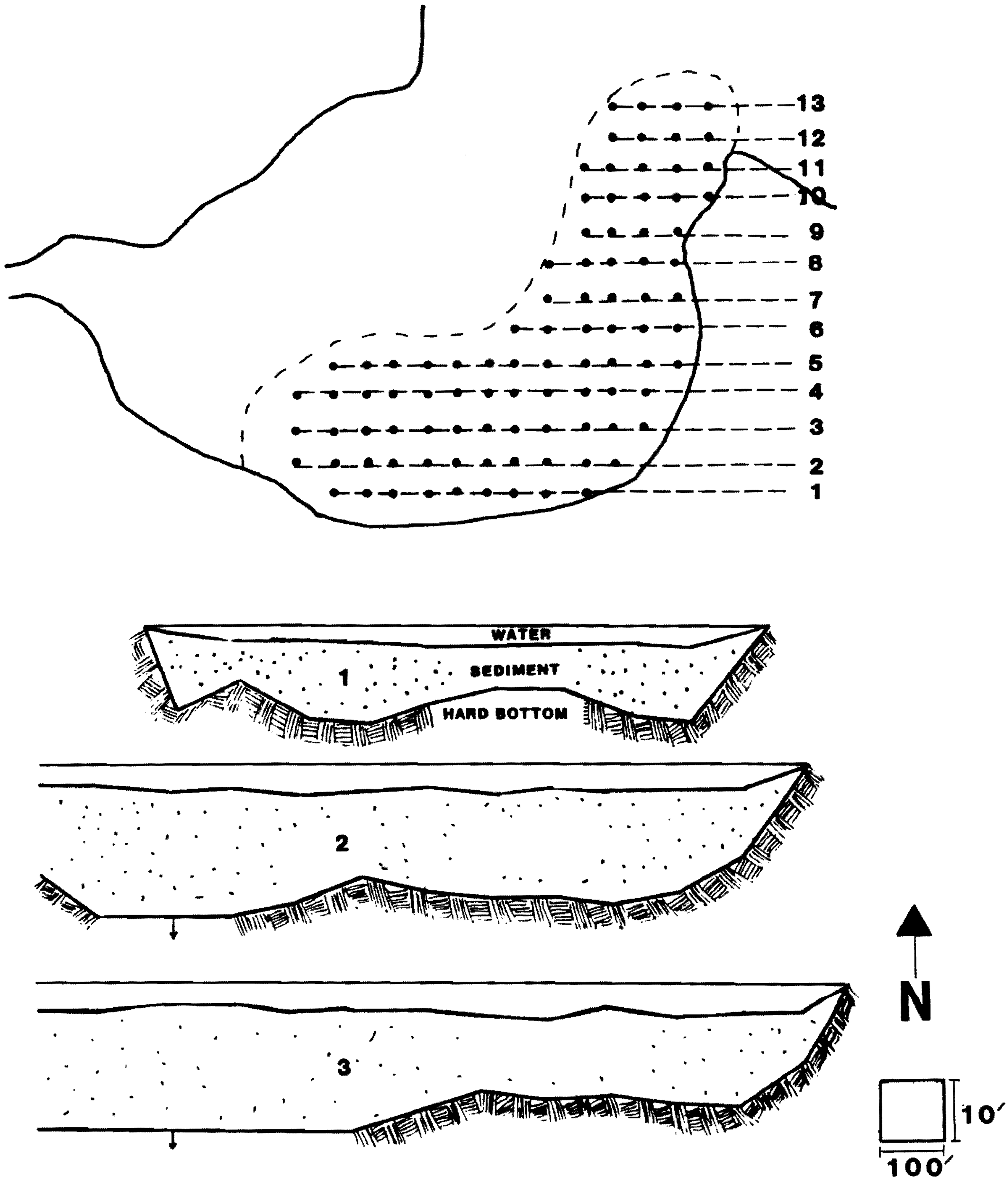
## Sedimentation and Resuspension in Bear Lake

Sedimentation is the build-up of material, usually gravel, plants, and other organic matter, in a lake or river basin. This build up has been happening on Bear Lake for about the last 10,000 years, since the last glacier receded.

In 1978 a soft sediment survey was conducted in the southern bay of Bear Lake to determine the depths of the soft sediments. It was determined at the time that the depths of the sediments ranged from several feet to greater than 23 feet (the length of the probe was 23 feet). It was not, nor could it be now, determined the exact rate at which the sediments are being deposited on the bottom of Bear Lake. Of the several methods for determining the general rate of sedimentation one is to use radioactive isotope markers that are found in the sediments. Another approach is to use sediment traps that are placed in the water for a given period of time. When these traps are removed the rate of sedimentation can be determined. Although we tried sediment traps, they did not work. The next try could be radioactive markers.

Transect locations for the Bear Lake soft sediment survey are shown in Figure 13. During each transect the depth of the soft sediments were measured. The results are shown in Figure 13 as sediment/water cross-sections.

Because erosion sources are not evident and because water clarity is good (low algae) sedimentation rates are expected to be low.




↓ indicates soft sediments are deeper than 26 feet

Figure 13. Soft sediment depths in the southwest bay of Bear Lake. (Modified from Northern Lake Service. 1978. Northern Lake Service Report is in Appendix A)

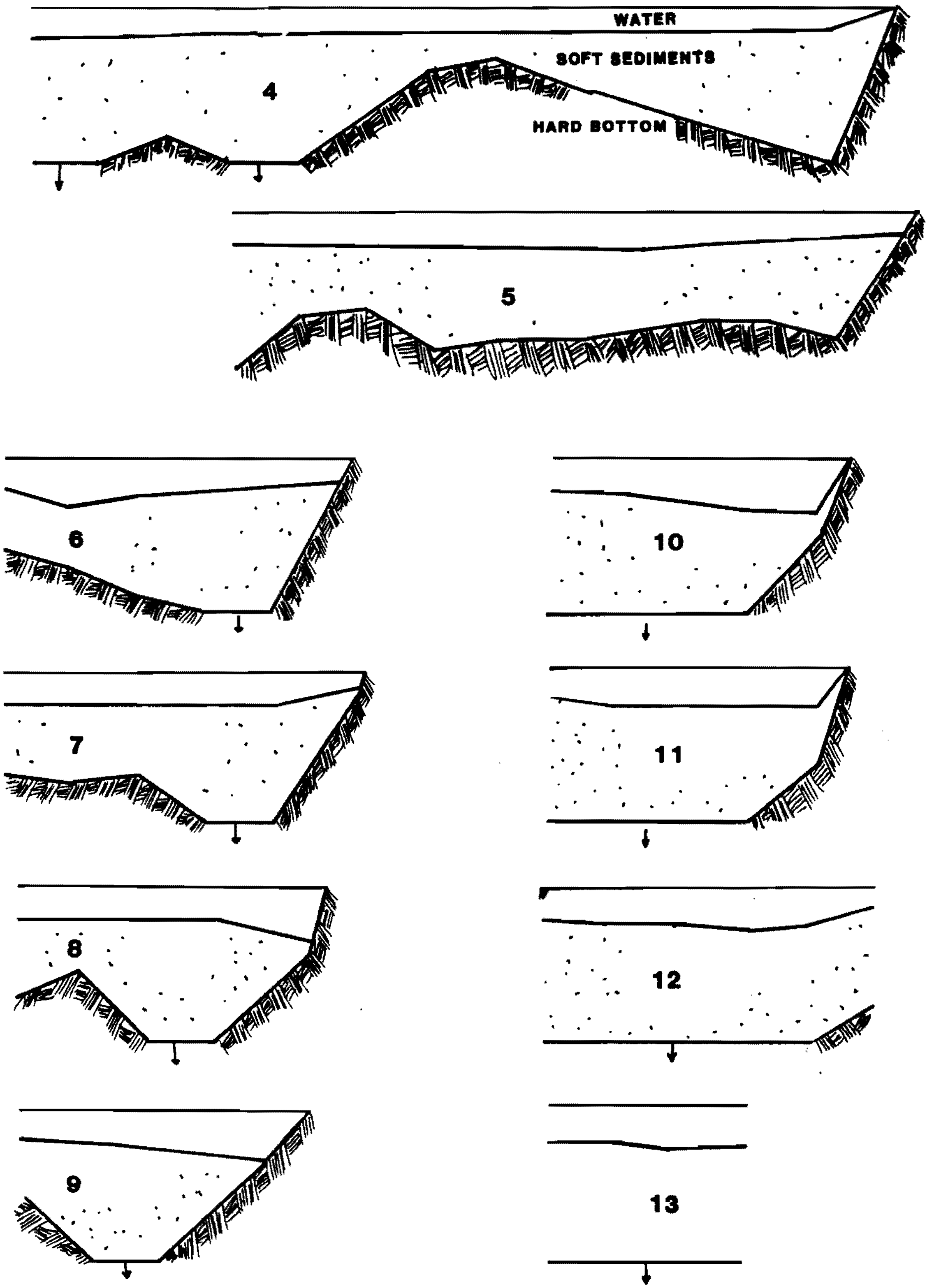



Figure 13. Concluded.

## 6. FUTURE PROJECTS

From a phosphorus viewpoint, Bear Lake is in good shape, the question is can it be maintained. From a fishery viewpoint, Bear Lake is changing, apparently for the better.

Future projects should emphasize lake protection from excessive phosphorus and monitoring of the fish community, especially the sunfish can and bluegill.

It is also time for the Bear Lake District to prepare short term (1 year plans) and long term plans (10 years plan). Bear Lake has accumulated a lot of important information that could be of value to other lake associations and lake districts.

In addition, the Bear Lake District should consider a variety of maintenance projects. Will spot dredging be feasible? Is stocking adult walleye feasible? Is the aquatic plant community in need of maintenance or does it harbor an essential aquatic invertebrate community (an invertebrate study would be beneficial) that maintains clear water?

A comprehensive plan with both a technical and a non-technical component would be appropriate.