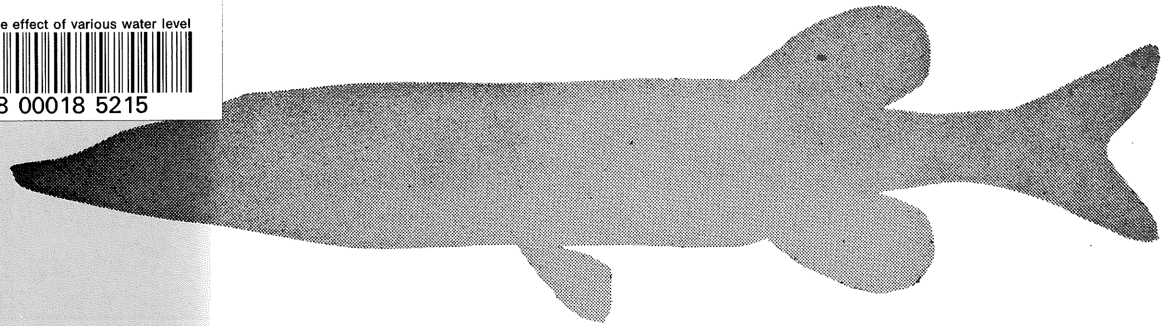

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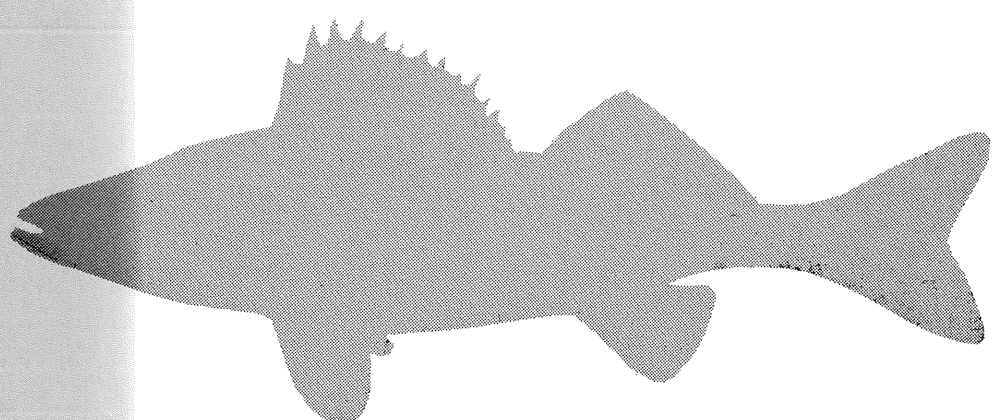



MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FISH AND WILDLIFE
SECTION OF FISHERIES



Department of the Army Corps of Engineers, St. Paul District
Contract No. DACW 37-77-C-0150 - State of Minnesota Department of Natural Resources

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FINAL REPORT

# THE EFFECT OF VARIOUS WATER LEVEL REGIMES ON FISH PRODUCTION IN THE LEECH LAKE RESERVOIR CASS COUNTY, MINNESOTA

By

Dwight E. Wilcox

December, 1979

Department of the Army Corps of Engineers, St. Paul District
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## INTRODUCTION

The objective of this study was to determine the effects of various operating water level regimes on Leech Lake on northern pike (Esox lucius) and walleye (Stizostedion vitreum) and to recommend a range of water levels for optimum production

Emphasis was placed on the relationships between water levels and the accessibility of spawning sites during the spawning period. While other factors such as temperature, food supply, and predation also affect production, these factors do not come into play unless reproduction occurs. For reproduction to occur the species considered must have available spawning sites meeting their specific requirements and access to these sites when they are ready to spawn.

Northern pike and walleye are most vulnerable to water level changes or inadequate water levels during their spawning, incubation and fry development periods in the early spring. Low water levels can prevent access to spawning areas or drops in water level may expose eggs or fry. High water levels can make spawning sites unusable by inundating them to depths beyond which the species spawn. It has been shown in Ball Club and Rainy Lakes (Johnson 1956, Chevalier 1977) that year class strength of these species can be related to water levels or changes in water levels.

Leech Lake is one of Minnesota's major walleye waters and supports a large sport fishery of about 225,000 fishing trips per year. Walleyes are the principal species in the catch with an annual harvest of about 210,000 pounds. The catch rate averages about 0.12 fish per man hour. Northern pike rank next with an annual harvest of about 160,000 pounds at a catch rate averaging about 0.08 pike per man hour. An additional harvest of about 107,000 pounds of other species are also taken by angling each year. These are principally trophy muskellunge (Esox masquinongy), perch (Perca flavescens) rock bass (Ambloplites ruspestris) and bullhead (Ictalurus sp.) (Schupp 1972). The sport fishery contributes an estimated $2,300,000 annually to the tourism based economy of the area (U.S. Fish and Wildlife Service 1977).

In addition to the sport fishery, the Leech Lake Indian Band conducts a commercial fishery for whitefish (Coregonus clupeaformis) and tullibee (Coregonus artedi). Gillnetting by Band members for all other species, for personal use only, is also permitted. This harvest of walleye and northern pike is estimated at 12,000 to 15,000 pounds annually (Strand 1979).

The total annual yield of fish from Leech Lake is about 5.0 lbs. per acre which is close to the theoretical optimum yield of 5.7 lbs. per acre (Ryder et al. 1974) for a lake of these physical and chemical characteristics (table 1).

TABLE 1. Physical and chemical characteristics of Leech Lake, August 1976[a]

| Measurements | |
|---|---|
| Water area | 112,835 acres |
| Mean depth | 18.4 ft. |
| Maximum depth | 177.5 ft. |
| Transparency, (Secchi disc) | 4.9-13.4 ft. |
| Total dissolved solids | 172.9 ppm |
| Total alkalinity | 136.5 ppm |
| Theoretical optimal yield | 5.7 lb/acre |
| Actual yield | 5.0 lb/acre |

[a]Schupp 1978

## DESCRIPTION OF LAKE

Leech Lake is Minnesota's fourth largest lake, excluding Lake Superior (Minnesota Conservation Department 1968, Figure 1). In its original state, it covered 106,000 acres with a water level about 1292 mean sea level (m.s.l.). Federal Dam which regulates the lake level was built on the Leech Lake River in 1884 and has been rebuilt twice since then. The dam raised the lake about 2 feet, increasing it to its present size of about 112,000 acres.

Leech Lake lies over three glacial zones which give the lake its unique diversity and characteristics. Steamboat Bay is in an arm of the sand outwash that underlies Bemidji, Cass, and Winnibigoshish Lakes. The major portion of the lake overlies glacial till plains while the south shore is butted against an end moraine, a portion of the St. Croix moraine system (Oakes and Bidwell 1968).

The northern and eastern bays are generally euthrophic and shallow, having a maximum depth of 15 ft., with gradually sloped basins, and sand or muck bottom materials (Schupp 1978). There are extensive floating bogs in these bays, with edges that provide excellent spawning sites for northern pike. Northern pike and bullheads are abundant in these bays with lesser populations of perch, walleye and centrarchids also present.

The main lake is mesotrophic with a maximum depth of 40 feet, and an average depth of 20 feet (Schupp 1978). The bottom and shoal water areas are predominately glacial till. The abundant coarse gravel and rubble shoals provide excellent walleye spawning sites. Walleye, perch, tullibee, whitefish, suckers, and rock bass are the principal species in this area.

Kabekona and Walker bags are morphometrically oligotrophic in nature with abrupt deep basins having maximum depths of 100 feet or more. Because their chemical fertility is high they are classed as mesotrophic. Shorelines and shoal areas in Walker Bay are predominately coarse gravel and rubble with some boulder present. Similar shoreline and shoals are present in Kabekona Bay. Muck bottom and shallow weedy bays are also present. Tullibee, whitefish, walleyes and panfish are the principal species in these waters.

The present operational plan of the Leech Lake Reservoir was arranged between the Minnesota Department of Natural Resources, and the U.S. Corps of Engineers in the early 1960's to provide optimal fish and wildlife benefits. Basically the plan of operation is to maintain a summer level of 1294.5 m.s.l. to 1294.9 m.s.l. through September, then to begin draw down, lowering the lake level to 1293.2 m.s.l. by March 1. This provides storage for the spring runoff that will return the lake to the normal level.

The spring level is usually attained. However, the summer level has fluctuated from 1292.7 m.s.l. to 1297.9 m.s.l. about its desired stage of 1294.5 m.s.l. to 1294.9 m.s.l. (Corps of Engineers 1977).

The minimum and maximum discharge range is determined by lake level. However, within the given range, the rate is determined by current water conditions and water demands throughout the Mississippi River watershed (Westerberg 1962).

Federal Dam has an operational range of 1292.7 m.s.l. to 1297.9 m.s.l. which inundates 106,000 to 165,000 acres. The lake is usually maintained at a summer level above 1294 m.s.l. which inundates about 112,000 acres.

## METHODS

Field work was conducted on Leech Lake from April through September in 1978 and in April and May in 1979. Emphasis was placed upon six activities: (1) sampling a variety of vegetation types in potential northern pike spawning areas for eggs to determine spawning site characteristics and preference by northern pike for particular habitat types; (2) searching potential northern pike spawning areas for fry and fingerlings to relate hatching success to vegetation types; (3) mapping and evaluating habitat types in randomly selected sample sites to estimate the total amount and quality of available northern pike spawning area, and determining what effects changing water levels had on these areas; (4) mapping the entire shoreline of Leech Lake recording shoreline and bottom material, and estimating total walleye spawning acreage and the effects of fluctuating water levels on these spawning areas; (5) monitoring the effects of wind on lake level; (6) taking aerial photographs of selected sample sites for comparison with field examinations to determine feasibility of using aerial photography as a tool for evaluation of northern pike spawning areas.

Egg collections were made to gather information to determine spawning site preference by northern pike. In 1978, thirty-three potential northern pike spawning areas representative of all types of spawning sites were sampled for eggs. Thirty-four sites were sampled in 1979

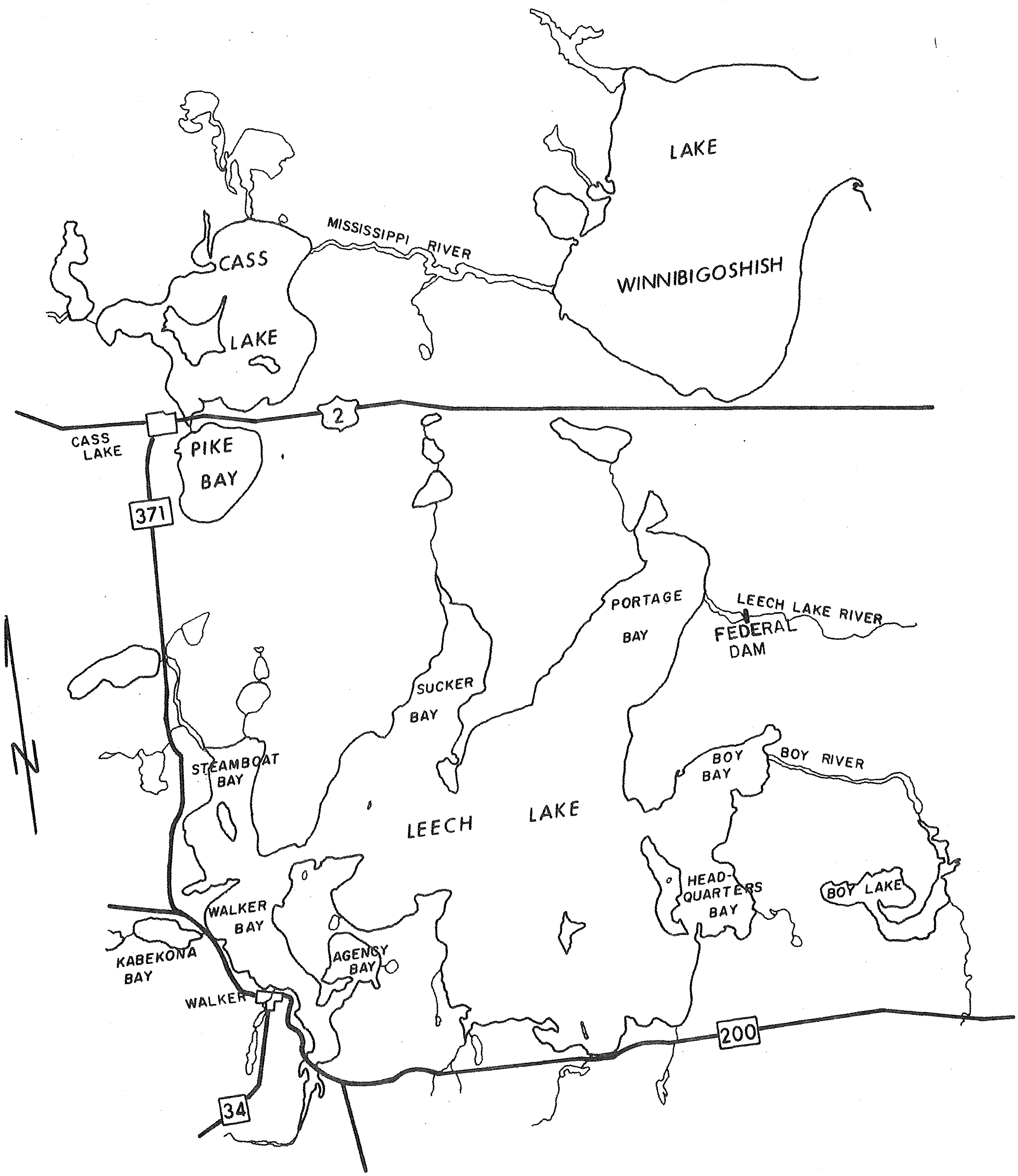



Figure 1. Leech Lake area, Cass and Beltrami Counties, Minnesota.

(Figure 2). The sites chosen for egg sampling were limited to areas accessible by truck since ice at that time was too thin for walking and the areas were not yet accessible by boat. Because of the access problem, sampling could not be random. However, the sites that were sampled were typical of all vegetation types present in Leech Lake. A 10 inch diameter, fine wire mesh dip net was used to collect eggs by passing it through the vegetation in an down and up, scallop type motion (Smith and Franklin, 1958). All vegetation types in a potential spawning area were sampled by at least ten passes of the net. Each pass covered approximately 2 square feet and was about 5 feet from previous locations. The average number of eggs was calculated. Data was recorded on the survey form shown as explained in appendix, A4-A5.

Searches for northern pike fry and fingerlings were made on foot and by boat at 32 sites (Figure 2). Each site was visually examined and sampled with nets for 15 minutes. The number of young seen or captured and the type of vegetation in which they were found was recorded. Eighteen of these sites were the same as those used for the egg collections. However, when only small numbers of fry were found in areas known to have had substantial egg deposition, 14 additional sites that were previously inaccessible, were examined to determine whether the number of fry observed was a function of the productivity of the area or more related to observational or capture difficulties.

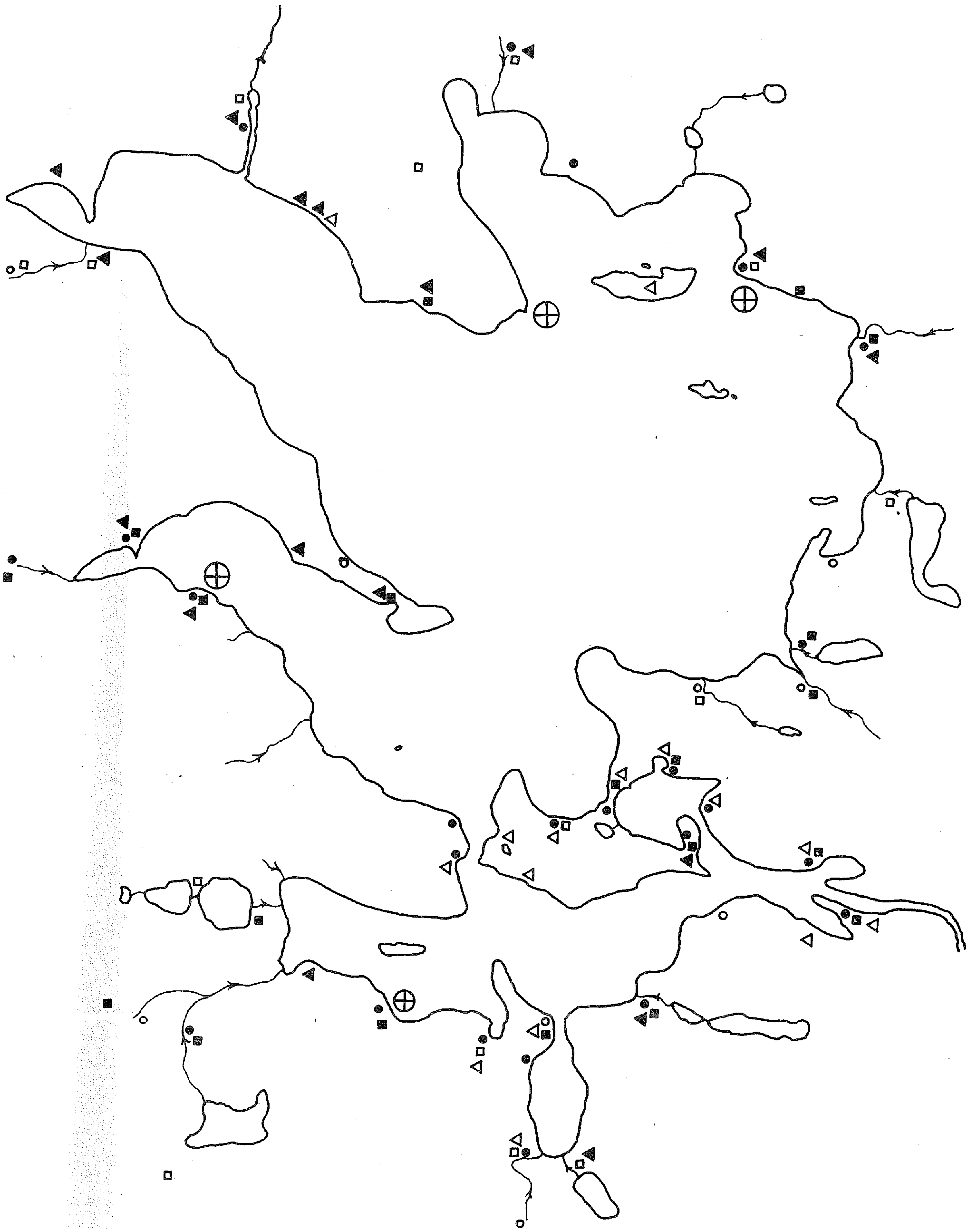
A detailed survey of Leech Lake's type 3,4 and 5 wetlands (Shaw and Fredine, 1977) was performed to determine how different water levels might affect potential northern pike spawning areas. An inventory of these type wetlands on Leech Lake was made using the results of University of Minnesota aerial-photograph analysis (Minor and Meyer 1978). All areas identified as sedge meadows (Sm), phragmites (Ph) or cattails (Tm) and greater than two acres were considered as potential spawning areas. Areas of two acres or larger were selected since the University vegetation maps were limited to areas of this size. Other vegetation types identified on the maps did not provide minimum spawning requirements for northern pike. From these areas, 62 sites were randomly selected. The shoreline of each wetland that was greater than 50 acres and contained potential northern pike spawning areas was divided into one-quarter mile segments. Depending on the total acreage of the wetland, one, two, or three sites for sampling were randomly chosen from a table of random numbers from among the quarter mile segments of each wetland area. Of the wetland areas smaller than 50 acres, 15 were randomly selected. The complete shoreline of these smaller wetlands was examined. Locations of the sampling sites are shown in Figure 3. Base maps of the selected sample sites were prepared prior to field examination from aerial photographs enlarged to 1:3168 scale and traced onto tagboard. During field examination, plant and bottom materials of the spawning sites were located and noted on the base map. Then each area was rated according to its value as a spawning site.

A habitat evaluation system was developed to provide a standard, systematic comparison and rating of habitat types on the sample sites. (see appendix A8-A19). Numeric values were assigned to key characteristics arbitrarily, based on the number of eggs found by egg sampling on Leech Lake for this project

Figure 2. Location of sites examined for northern pike spawning use and location of staff gauges.

KEY:

| 1978 | 1979 | |
|---|---|---|
| ● | ■ | Eggs collected in area |
| ○ | □ | No eggs collected in area |
| ◐ | ◩ | Only adults seen in area |
| ▲ | | Fry or fingerlings observed in area |
| △ | | No fry or fingerlings observed in area |
| ⊕ | | Staff gauge |



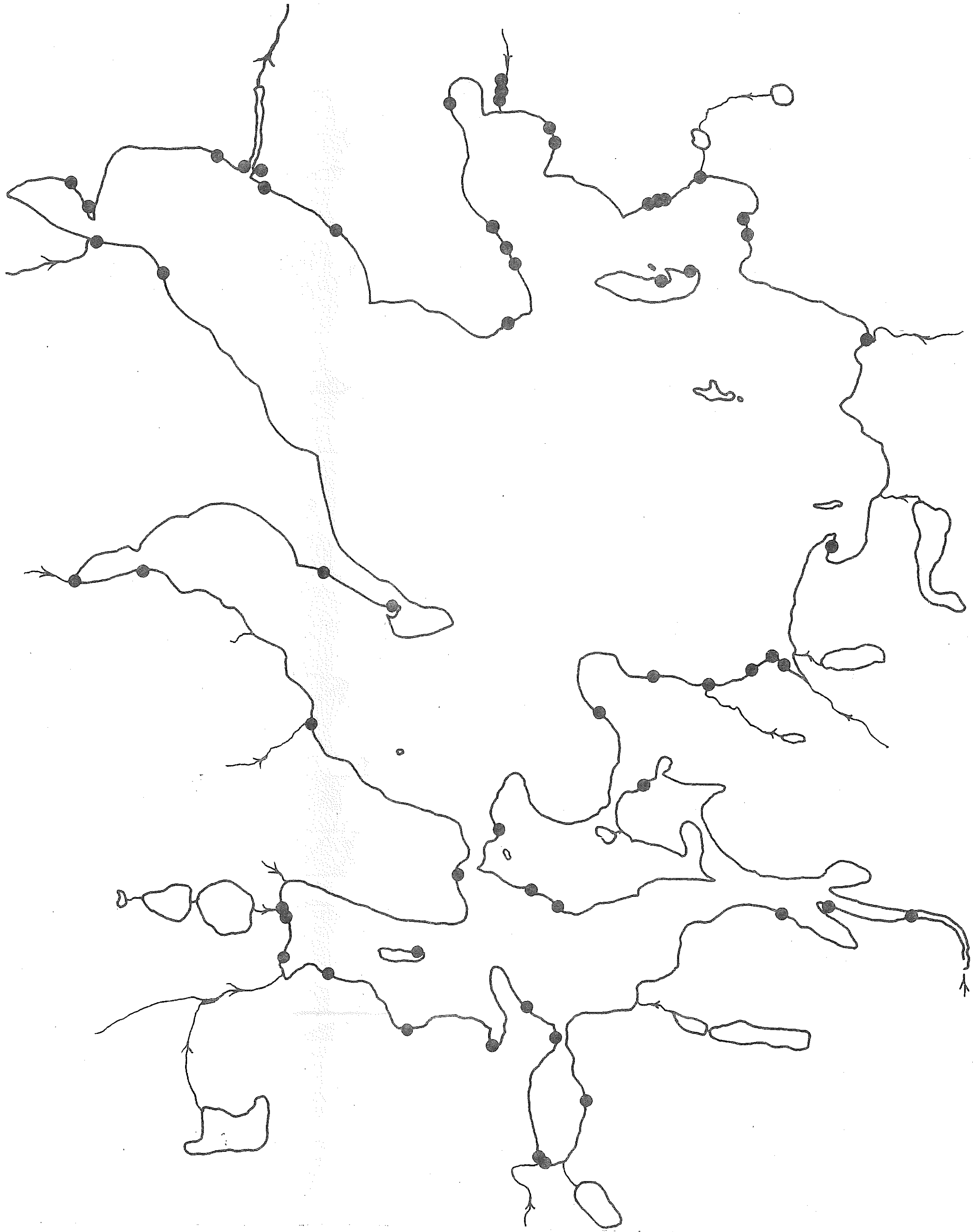


Figure 3. Locations of northern pike spawning area selected for sampling sites.

and findings from previous studies (Forney 1968, Bryan 1967, Smith and Franklin 1958, Fabricus and Gustafson 1958, Johnson 1956, Clark 1950, Carbine 1941, McNamara 1935).

The evaluation system was divided into two sections measuring the quality and the quantity of spawning sites. The quality of the habitat type was rated by assigning values to these characteristics: kind of vegetation; vegetation density; accessibility; substrate; protection and current. The quantity of spawning area at different water levels was estimated by the following measurements: the minimum and maximum water level at which potential spawning habitat was available; the optimum water level; and the average width of the area available for spawning.

A graph was drawn in the field to give a general pictorial approximation of the effects of different water levels on the area of the spawning site (Figure 4, Appendix pp A17-19).

Each sample site was divided into habitat types, based on the habitat evaluation system developed for the study. A habitat type was defined as a section of shoreline consisting at least 100 feet and being different from the adjacent habitats by at least two points in one of the following categories; kind of vegetation, density, access, or substrate.

The composition of a particular wetland area was estimated from the findings of the sample sites surveyed within the wetland. The shoreline of each habitat type, sample site, and corresponding wetland area from which the sample was taken was measured from aerial maps with a Hewlett-Packard digitizer. This electronic device is much more precise than a map wheel, especially when measuring irregular shorelines such as those found in the spawning areas. The overall composition of the wetland area was then estimated by direct proportion from the ratio of the shoreline length of each habitat type to the shoreline length of the respective sample site as follows:

$$\frac{L1}{L2} : \frac{L4}{L3}$$

where:

- L1 = shoreline length of a single habitat type within a sample site
- L2 = shoreline length of an entire sample site
- L3 = shoreline length of the wetland area
- L4 = estimated shoreline length of similar habitat types within the wetland area

therefore:

$$L4 = \frac{L1 \times L3}{L2}$$

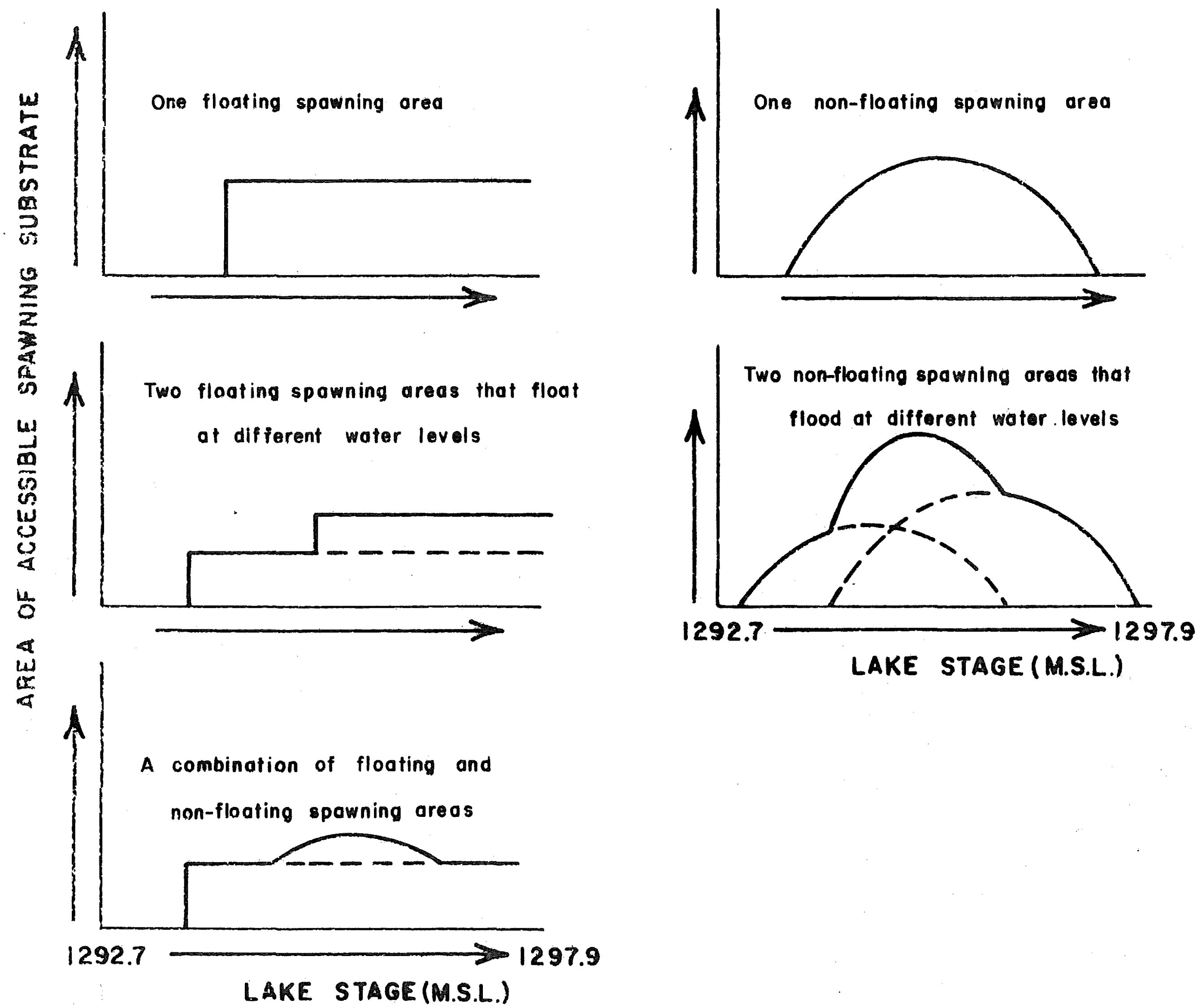



Figure 4. Schematic diagram of combinations of non-floating and floating wetland types on Leech Lake used to determine available area within operational limits of the dam.

The effect of different water levels on the amount of usuable spawning acreage in potential spawning sites was estimated from the simple area formula (Area = width x length). Two derivations of this formula were developed to apply to floating and non-floating habitats incorporating the above ratio.

(1) In floating habitat types, once the minimum water level was attained to allow fish access to potential spawning beds, the acreage available for spawning was best estimated by:

$$A_R = W \times L4$$

where:

$A_R$ = the area accessible for spawning at a lake stage of R

R = the lake stage
W = the average width of area available for spawning

If the water level was below the minimum necessary to make this site float, the area accessible to the fish for spawning was negligible. In floating habitat types, there was no maximum water level within the usual operating levels since the bog rose with the water level and the accessible area used for spawning remained constant.

(2) If the spawning site was a non-floating habitat type, the width of the spawning band is best estimated by the simple parabolic curve:

$$y = a(x_1 - x_0)^2 + b$$

substituting variables as applicable to this study:

$$W_R = \frac{W}{(D1 - D2)^2} \times (R - D2)^2 + W$$

where:

$W_R$ = width of spawning substrate accessible at lake stage of R
R = lake stage
D1 = minimum water level at which spawning substrate is accessible
D2 = optimum water level for maximum accessible spawning area
W = optimum width of area accessible for spawning

After substituting $W_R$ into the area formula, the best estimate of the area accessible for spawning is:

$$A_R = W_R \times L4$$

It was assumed the spawning materials were anchored on a shore with a constant slope.

In some cases the spawning site was described as a combination of floating and non-floating habitat types (Figure 4). When this occured the additional habitat was evaluated and treated as a separate spawning site.

The areas of the floating and non-floating habitat types were summed at one-half foot intervals from 1292.0 m.s.l. to 1297.0 m.s.l., to obtain the total accessible potential spawning area available within the operating range of Federal Dam.

The potential northern pike spawning area on tributaries to Leech Lake was estimated by interpretation of aerial prints and maps. To determine the distance from the lake the fish must travel, streams were measured on aerial photographs to the uppermost available spawning site using the shortest path following the stream channel. The maximum distance found was 7.25 miles. Steamboat, Shingobee, Boy, and Kabekona Rivers were also measured, but only to 7.25 miles above their mouths so that the maximum distance travel in rivers was the same as that traveled in streams. The length of the streams' and rivers' edge with potential spawning area within 7.25 miles from the lake was measured next. This included breaks in the bog, small drainages, islands and lake shores. To estimate the total acreage of available spawning material in tributaries, this length was multiplied by 6.7 feet, the average width of northern pike spawning sites on Leech Lake proper.

Later in the summer, a simple visual survey of the complete shoreline of Leech Lake was performed. The shoreline was divided into sections, according to the shoreline and bottom materials observed. Individual sections were relatively distinct because of minimal gradation between obviously different habitats, such as rocks or sand or sand to sedge mats. Each section was located on blue-line aerial prints and the bottom or shoreline materials present was recorded.

Northern pike spawning areas were rated on a scale of one to three, based upon vegetation and substrate characteristics. (See: Definition of qualitative and quantitative terms pages A9-10). Good northern pike spawning habitat was rated three, and was predominantly sedge (*Carex sp.*), terrestrial grasses or other vegetation types with high density and clean stable, vegetative substrate. Fair northern pike spawning habitat was rated two, and was characterized by phragmites, (*Phragmites sp.*), burreed (*Sparganium sp.*), or cattails (*Typha sp.*) with moderate density and stable vegetative substrate. However, some loose muck, sand or debris may be present. Poor northern pike spawning habitat was rated one and included all other shoreline types.

Walleye spawning habitat was rated on a scale of one to three based upon the size and amount of rocks ( 6-12 inches in diameter) and rubble ( 1 to 6 inches in diameter) present at each site. Good walleye spawning areas were rated three if they had abundant rocks and rubble, that covered at least 50 percent of the bottom. Fair spawning habitat was rated two. It was characterized by materials mostly bigger than twelve inches or smaller than one inch, yet with some intermediate sizes. These materials covered at least 25 percent of the bottom. Poor spawning habitat was rated a one and included all other shoreline types.

If the site rated two or three for walleye spawning habitat, the minimum water level that permitted use of the spawning site and the average distance the spawning bed extended into the lake was estimated. The shoreline length of each section was measured with the digitizer. The effect of changing water levels on the acreage of potential walleye spawning sites was estimated by the following formula:

$$A_R = W \times \frac{D1}{(1296 - D)} \times L1$$

where:

$A_R$ = potential spawning area at a lake stage of R
R = the lake stage
D = minimum water level with spawning material available
L1 = shoreline length of a single habitat type
W = width of potential spawning substrate
D1 = depth of water over potential spawning sites

The factor $\frac{D1}{(1296-D)}$ estimates the fraction of the total width of the spawning area that is available.

The areas of potential walleye spawning habitat were summed at one-foot intervals from 1288.0 m.s.l. to 1296.0 m.s.l. to obtain the total potential spawning area available within the operating range of the dam.

Based upon observations, the maximum elevation for potential walleye spawning area was 1296.0 m.s.l. In most walleye spawning areas, there was an abrupt ice ridge that rose from 1296.0 m.s.l. to about 1297 m.s.l. Above 1297.0 m.s.l. the shoreline habitat was typically a terrestrial environment. It was assumed that walleye spawning materials were evenly distributed over a constant slope.

Data from previous investigations were examined to determine changes in walleye and northern pike population structures. Extensive surveys of the fish population of Leech Lake were made by the Minnesota Department of Natural Resources in 1936, 1943, 1950, and 1976. The surveys made in 1950 and 1976 used current Minnesota DNR standard lake surveying methods but the earlier surveys used somewhat different techniques, and the data are not directly comparable with current surveys. Differences in mesh sizes of sampling gear, net dimensions, time length of net sets, and fish measurements had to be equated with current standards by rough estimates and, as a result, can be used only for general comparison. In 1936 only 1½ and 2 inch mesh (bar measure) gill nets were used, so no conversion could be made. In 1943 the nets used were 100 ft. in length, 5 feet deep, of the mesh size used in 1950 and 1976, and the catches were expressed in approximately 12 hour periods. Nets used in 1950 and 1976 were 250 feet in length, 6 feet deep with 50 foot sections of 3/4, 1, 1¼, 1½, and 2 mesh (bar measure) set for 24 hours. To compare 1943 netting results with the 1950 and 1976 catches, the following conversion was applied: 1943 catch per set x 2 (for hours of set) x 2.5 (for length of net) x 1.2 (for depth of net) (Strand 1976). Length and age frequencies were calculated for all years with data available. Composite length and age frequencies were made by compiling all available data to form mean frequencies which were used as a standard to compare with individual years to determine strong and weak year classes.

Simple staff gauges were placed around the lake to measure the effects of wind on the accessibility of spawning sites. (Figure 2). Daily records of water level were kept by local property owners.

Aerial photographs were taken to determine their value as a tool to evaluate northern pike spawning habitat. Twenty-five sites were selected to include most habitat types on Leech Lake. Photographs of these sites were taken at a scale of 1:9600 using color-infrared 35 mm slide film during "leaf-on" condition. After processing, slides were projected onto a rear-projection screen, enlarged and vegetation maps were made by tracing outlines of vegetation types. Interpretation of vegetation type, vegetation density, accessibility, substrate and water depth was attempted.

## FINDINGS

### Northern Pike

The northern pike spawning season on Leech Lake normally begins in mid-April and continues through early May. The kind of vegetation, vegetation density, access, substrate, protection and current were the principal factors determining the quality and use of potential spawning sites.

The distribution and abundance of northern pike eggs in spawning sites showed that there was an apparent preference for sites with certain vegetation characteristics. Seven general vegetation types were identified as the principal spawning areas used (Figure 5).

"Grassy" type vegetation contained the highest density of eggs. Similar observations were made by Smith and Franklin (1958) and Carbine (1941). The most abundant grassy-type vegetation was sedge. There were two types of sedge spawning sites, floating and non-floating. However, this did not have a noticeable effect on whether the area was used as a spawning site if the area was flooded by water 3 to 36 inches deep. The presence of other plants, usually phragmites or cattails, did not effect the density of eggs found, unless the second plant constituted more than 75 percent of the vegetation in the spawning site. This was because the general "grassy" characteristic of sedge was dominant even when only small amounts were present.

Terrestrial grasses did not greatly contribute to the acreage of spawning areas on Leech Lake because of normal dam operations. During the summer months the water level was higher than that during the spring spawning season and as a result, terrestrial grasses could not establish themselves in areas accessible to northern pike during the normal spawning time. When terrestrial grasses were available, egg deposition was heavy.

Vegetation types that contained less than 25 percent sedge were used for spawning to a lesser degree.

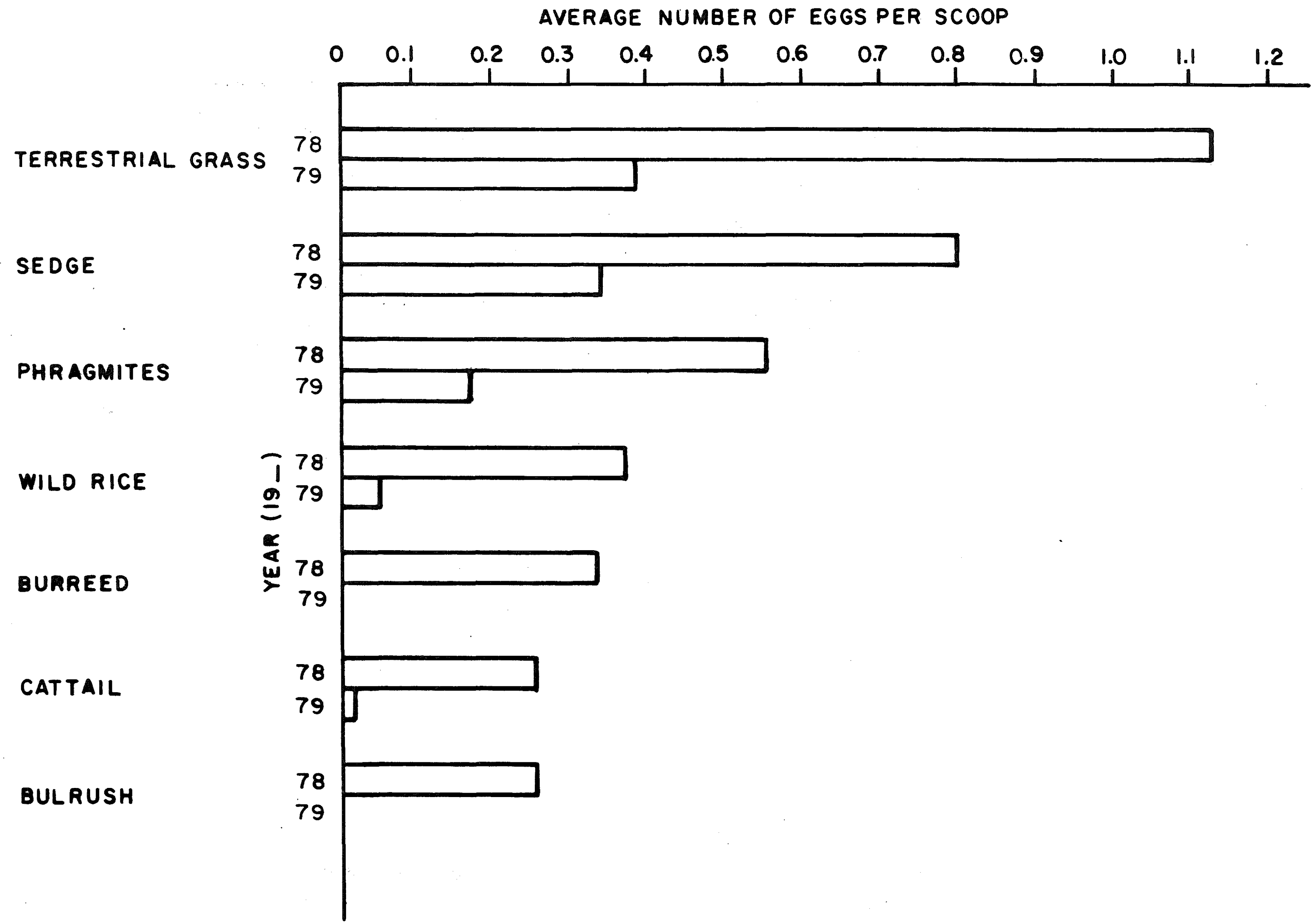



Figure 5. Average number of northern pike eggs per scoop in several vegetation types in 1978 and 1979.

Phragmites was common throughout Leech Lake, primarily in brakes, and mixed with sedge. It can best be described as stick-like. Large numbers of eggs were found in some phragmites stands but not in others. It appeared, for no apparent reason, to be an all or none situation, with heavy egg deposition or none at all. The literature reviewed makes no reference to similar observations. If similar egg deposition in phragmites are found in other waters, more detailed investigation of possible causes might be warranted.

Cattails and burreed were also common throughout Leech Lake, usually growing in the margin between open water and other types of vegetation. Cattails and burreed usually grew as one-to two-inch diameter stalks. Small numbers of eggs were found occassionally in this type vegetation.

It was observed that dense wild rice stands, rooted in a firm bottom, close to the shoreline, and flooded by less than three feet of water, closely resembled sedge type vegetation and had similar egg deposition.

Rice debris, at the time of northern pike spawning, was piled in windrows on the margins of the lake. It had a grassy appearance, but was rapidly decomposing and easily moved by wind and ice which destroyed the windrows. These are undesirable conditions for egg deposition and survival. Rice debris was not observed to be extensively used for spawning. Use was light even when more desirable substrate was not available.

No eggs were found in bulrush stands. However, a few eggs were found in windrows of bulrush debris on the shoreline when no other vegetation was available. These windrows were later destroyed by wave action prior to the hatch of the eggs.

Vegetation density was a very important characteristic in determining the value of a potential spawning site. Egg deposition was observed to be higher in areas of greater vegetation density than in comparable sites with lesser vegetation. Heavy plant density is an innate condition with sedge under most circumstances. In other plant types such as phragmites, cattail, burreed and bulrush, where the individual plants normally grow further apart, the amount of egg deposition in the site increased with increased crowding of plants. It was important, therefore, to evaluate this characteristic properly so that even with less desirable vegetation types or other characteristics, a site may be of good quality because it had a highly desirable and compensating plant density.

Accessibility describes the ease of northern pike entry into a potential spawning area. If an area was not accessible to northern pike at water levels between 1292.7 m.s.l. to 1297.9 m.s.l. it was not considered a potential site. If it was accessible, the minimum and maximum water level at which access could be made was recorded.

Egg collections showed that between comparable areas, sites with more points of access had greater egg deposition. In non-floating spawning areas, accessibility was usually good because rising water levels would flood the entire site giving access to all inundated materials. In floating spawning areas, access was limited by two factors: (1) very dense vegetation or, (2) the site floated above the water surface. This prevented fish access to all but the periphery of the vegetation. However, most floating sites have non-restrictive vegetation density and float 3 to 20 inches below the water surface with small, frequent channels leading from the lake throughout the spawning site allowing excellent accessibility.

There were some spawning sites in small bays, isolated from the main lake by an incomplete or temporary ice ridge or sand bar. In most of these sites there was a channel through the barrier. The main factors affecting accessibility were whether the channel was open or whether the lake was high enough to flood over the ridge. During the spring there was enough flow to keep the channel open, but during the drier summer months the flow slowed or stopped and longshore currents filled in the channel blocking passage back to the lake, stranding whatever fish remained. This stranding was usually temporary. With occasional rains through the summer, the lake level would rise or the flow would increase to reopen the channel allowing emigration.

There were several potential spawning areas that had permanent barriers that isolated them from the lake at all water levels (Table 2). It would not appear to be worthwhile to reopen these sites since there are an abundance of other suitable sites available in the lake and along the tributaries.

Table 2. Location of potential northern pike spawning areas separated from lake permanent barriers, Leech Lake, Minnesota, 1978.

| Twp. | R. | Sec. | Shoreline Identification number[a] |
|---|---|---|---|
| 141N | 29W | SW ¼ NE ¼ S. 3 | 227 |
| 142N | 30W | NE ¼ SW ¼ S. 22 | 270 |
| 142N | 30W | SE ¼ SE ¼ S. 27 | 257 |
| 142N | 30W | SE ¼ SW ¼ S. 27 | 262 |
| 142N | 31W | SE ¼ SW ¼ S. 2 | 300 |
| 142N | 31W | NE ¼ SW ¼ S. 26 | 405 |
| 142N | 31W | SE ¼ NW ¼ S. 26 | 408 |
| 142N | 35W | NW ¼ NE ¼ S. 35 | 401 |
| 143N | 28W | SE ¼ S. 5 | 184-188 |
| 143N | 31W | SW ¼ NE ¼ S. 25 | 79 |
| 144N | 28W | E ½ S. 20 | 152 |
| 144N | 29W | SE ¼ S. 24 | 142 |
| 144N | 29W | E ½ S. 24 | 143 |

[a]Blueline Maps

It was observed that areas with clean, well-vegetated, stable and aerated substrate had heavier egg deposition than comparable areas without these qualities. This preference was especially noticeable in areas with loose muck that could smother eggs or in decomposing wild rice debris that could cause an oxygen deficit.

Protection of a site from wind action is important during the later stages of spawning and incubation. During and after ice break-up, strong winds can cause mortalities to eggs or fry in unprotected areas because of wave action or ice movement. Harbored bays and tributaries provide the best protection, but in many cases a band of vegetation such as cattails, burreed, or bulrush can dissipate much of the wave energy before it reaches the spawning site. However, these sites are still susceptible to ice movement.

Areas with moving water either along tributaries or with longshore currents appeared to have heavier egg deposition than comparable areas without currents because spawning sites with a current in the vicinity tended to attract more adult fish than similar habitat without a current.

Northern pike fry or fingerlings were found in 17 of the 33 sites examined (Figure 2). In areas exposed to waves, less than 2 young were seen. In a few protected bays or stream outlets, 4 to 25 young were seen. The differences in the numbers was probably a function of visibility rather than a real difference in the productive potential of the site. Visibility was much better in protected areas where the surface was less affected by the wind. Because of this, no evaluation of the sites could be made from the fry and fingerling collections.

There are 251 miles of shoreline on Leech Lake. This consists of 92 miles of dense vegetation and 56 miles of rocks and rubble, 37 miles of pure sand, 23 miles of moderately dense vegetation, 18 miles of shore with phragmites or cattails in a firm sand substrate, 14 miles of rubble and gravel and 11 miles of boulders or ice ridges (Figure 6). A detailed description of the shoreline habitat is shown by maps (appendix) and Table 3.

Measurement of northern pike spawning area from maps of Leech Lake showed that there are 115 miles of shoreline with potential spawning area. Of this, 64 miles are good quality, 25 miles of fair quality, and 26 miles are poor quality, or have no permanent access.

A disparity between this study and previous investigations was in the amount of shoreline miles judged suitable for northern pike spawning. Previous surveys measured the shoreline that consisted of bogs, cane, or wild rice as 60 miles with a map wheel. In this study it was measured as 115 miles using a digitizer. Measurements of smooth, regular shorelines with a map wheel and a digitizer were similar (Table 4).

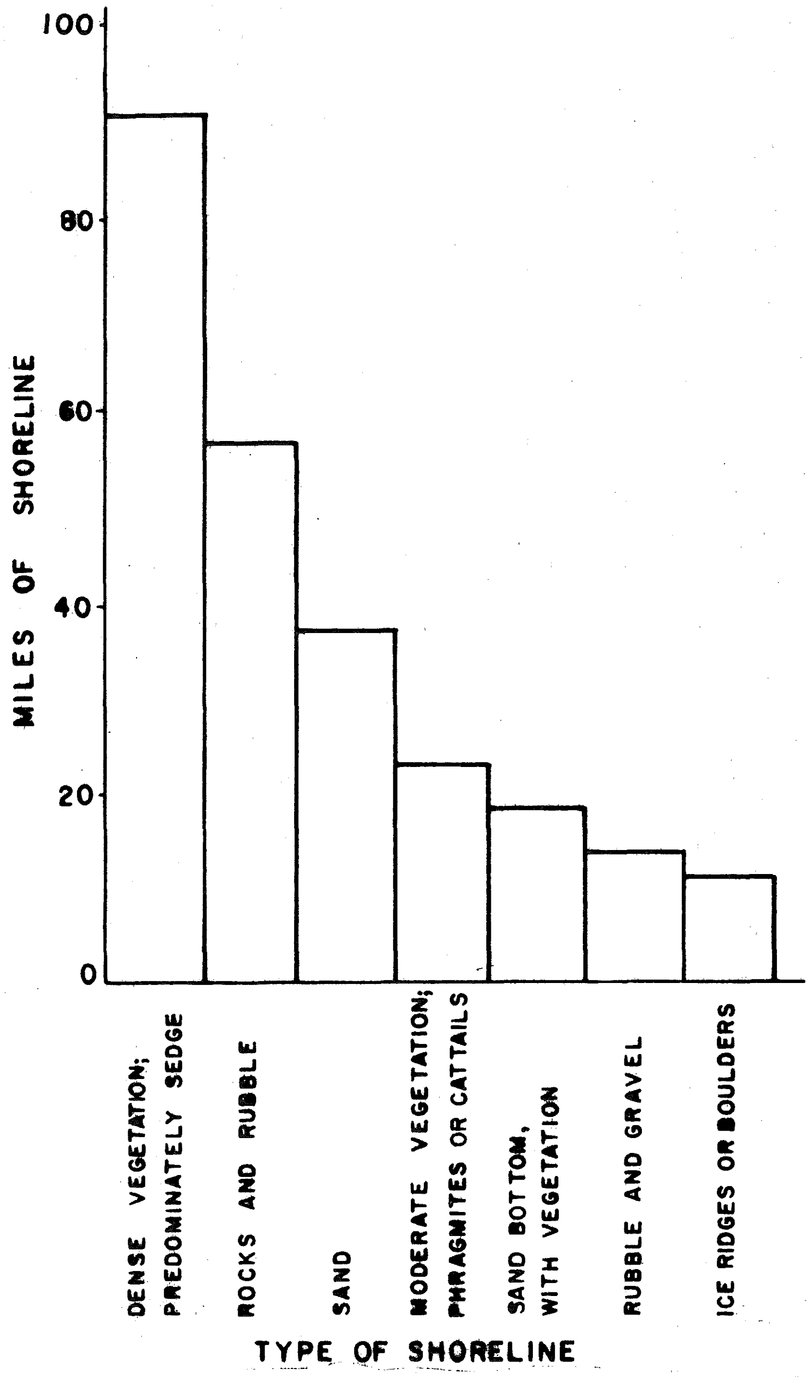



Figure 6. Shoreline miles of principal kinds of shoreline, Leech Lake, 1978-79.

| NO. | LEN. | W | N | SHORELINE TYPE | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | .80 | 1 | 1 | 2 | 3 | 4 | 5 | 0 | 0 |
| 2 | .17 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 3 | .45 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 4 | .14 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 5 | .24 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 6 | .22 | 2 | 1 | 2 | 3 | 11 | 0 | 0 | 0 |
| 7 | .05 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 8 | .11 | 3 | 1 | 2 | 3 | 0 | 0 | 0 | 0 |
| 9 | .05 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 10 | .53 | 3 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 11 | .08 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 12 | .15 | 3 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 13 | .29 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 14 | .11 | 1 | 3 | 8 | 0 | 0 | 0 | 0 | 0 |
| 15 | .04 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 16 | .09 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 17 | .43 | 3 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 18 | .14 | 1 | 3 | 10 | 0 | 0 | 0 | 0 | 0 |
| 19 | .30 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 20 | .05 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 21 | .22 | 1 | 2 | 6 | 11 | 0 | 0 | 0 | 0 |
| 22 | .21 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 23 | 1.44 | 1 | 3 | 6 | 8 | 10 | 11 | 0 | 0 |
| 24 | .29 | 3 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 25 | .54 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 26 | .09 | 1 | 3 | 1 | 8 | 10 | 0 | 0 | 0 |
| 27 | .25 | 1 | 2 | 8 | 10 | 0 | 0 | 0 | 0 |
| 28 | .17 | 1 | 2 | 6 | 0 | 0 | 0 | 0 | 0 |
| 29 | .07 | 3 | 1 | 3 | 0 | 0 | 0 | 0 | 0 |
| 30 | 1.19 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 31 | .83 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 32 | .86 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 33 | .26 | 1 | 2 | 6 | 8 | 0 | 0 | 0 | 0 |
| 34 | .90 | 1 | 3 | 10 | 11 | 0 | 0 | 0 | 0 |
| 35 | .17 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 36 | .22 | 1 | 3 | 10 | 12 | 0 | 0 | 0 | 0 |
| 37 | .22 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 38 | .15 | 1 | 3 | 6 | 7 | 11 | 0 | 0 | 0 |
| 39 | .62 | 1 | 2 | 5 | 6 | 7 | 11 | 0 | 0 |
| 40 | .64 | 1 | 2 | 6 | 7 | 0 | 0 | 0 | 0 |
| 41 | 1.03 | 1 | 3 | 10 | 0 | 0 | 0 | 0 | 0 |
| 42 | .10 | 1 | 2 | 6 | 11 | 0 | 0 | 0 | 0 |
| 43 | .10 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 44 | .11 | 1 | 2 | 5 | 6 | 0 | 0 | 0 | 0 |
| 45 | .27 | 1 | 2 | 5 | 6 | 0 | 0 | 0 | 0 |
| 46 | .24 | 1 | 3 | 6 | 7 | 8 | 0 | 0 | 0 |
| 47 | .42 | 1 | 2 | 5 | 7 | 0 | 0 | 0 | 0 |
| 48 | .06 | 1 | 2 | 6 | 0 | 0 | 0 | 0 | 0 |
| 49 | .11 | 1 | 1 | 5 | 7 | 0 | 0 | 0 | 0 |
| 50 | .06 | 1 | 1 | 5 | 7 | 0 | 0 | 0 | 0 |
| 51 | .88 | 1 | 2 | 6 | 7 | 11 | 0 | 0 | 0 |
| 52 | .19 | 1 | 2 | 12 | 0 | 0 | 0 | 0 | 0 |
| 53 | 1.11 | 1 | 3 | 6 | 8 | 10 | 11 | 12 | 0 |
| 54 | .35 | 1 | 2 | 7 | 0 | 0 | 0 | 0 | 0 |
| 55 | .24 | 1 | 3 | 10 | 0 | 0 | 0 | 0 | 0 |
| 56 | .21 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 57 | .18 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 58 | .21 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 59 | .13 | 1 | 2 | 6 | 0 | 0 | 0 | 0 | 0 |
| 60 | .21 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 61 | .34 | 1 | 2 | 6 | 0 | 0 | 0 | 0 | 0 |
| 62 | .06 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| 63 | .55 | 1 | 2 | 6 | 7 | 8 | 11 | 0 | 0 |
| 64 | .03 | 1 | 1 | 5 | 7 | 0 | 0 | 0 | 0 |
| 65 | .31 | 1 | 1 | 5 | 6 | 7 | 0 | 0 | 0 |
| 66 | .04 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 67 | .36 | 1 | 2 | 6 | 7 | 0 | 0 | 0 | 0 |
| 68 | 1.39 | 1 | 3 | 10 | 0 | 0 | 0 | 0 | 0 |
| 69 | .62 | 1 | 3 | 10 | 0 | 0 | 0 | 0 | 0 |
| 70 | 1.03 | 1 | 2 | 6 | 0 | 0 | 0 | 0 | 0 |
| 71 | 2.66 | 1 | 3 | 10 | 0 | 0 | 0 | 0 | 0 |
| 72 | 2.41 | 1 | 2 | 6 | 7 | 8 | 11 | 0 | 0 |
| 73 | 1.46 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 74 | .25 | 1 | 2 | 6 | 0 | 0 | 0 | 0 | 0 |
| 75 | .17 | 1 | 2 | 6 | 8 | 11 | 0 | 0 | 0 |
| 76 | .30 | 1 | 1 | 6 | 7 | 0 | 0 | 0 | 0 |
| 77 | .80 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 78 | .35 | 1 | 2 | 6 | 8 | 0 | 0 | 0 | 0 |
| 79 | .85 | 1 | 2 | 6 | 8 | 11 | 0 | 0 | 0 |
| 80 | .85 | 3 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 81 | .16 | 3 | 1 | 3 | 4 | 5 | 0 | 0 | 0 |
| 82 | .74 | 3 | 1 | 4 | 5 | 8 | 12 | 0 | 0 |
| 83 | 3.02 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 84 | .80 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 85 | 1.36 | 1 | 3 | 1 | 2 | 0 | 0 | 0 | 0 |
| 86 | .17 | 2 | 1 | 2 | 3 | 0 | 0 | 0 | 0 |
| 87 | .18 | 3 | 1 | 4 | 5 | 0 | 0 | 0 | 0 |
| 88 | .25 | 2 | 1 | 1 | 2 | 5 | 0 | 0 | 0 |
| 89 | .20 | 3 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 90 | .26 | 1 | 1 | 3 | 5 | 0 | 0 | 0 | 0 |
| 91 | .32 | 1 | 1 | 5 | 6 | 12 | 0 | 0 | 0 |
| 92 | .47 | 1 | 3 | 10 | 0 | 0 | 0 | 0 | 0 |
| 93 | .21 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 94 | .55 | 1 | 3 | 6 | 8 | 11 | 0 | 0 | 0 |
| 95 | .45 | 2 | 1 | 1 | 3 | 0 | 0 | 0 | 0 |
| 96 | .28 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 97 | .22 | 3 | 1 | 4 | 5 | 0 | 0 | 0 | 0 |
| 98 | 6.73 | 1 | 3 | 5 | 6 | 7 | 8 | 10 | 11 |
| 99 | .61 | 1 | 1 | 5 | 8 | 0 | 0 | 0 | 0 |
| 100 | 1.11 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 101 | .21 | 2 | 1 | 3 | 4 | 5 | 0 | 0 | 0 |
| 102 | .11 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 103 | .44 | 1 | 4 | 4 | 5 | 0 | 0 | 0 | 0 |
| 104 | .77 | 1 | 1 | 3 | 4 | 5 | 0 | 0 | 0 |
| 105 | .29 | 1 | 2 | 7 | 8 | 0 | 0 | 0 | 0 |
| 106 | .41 | 3 | 1 | 3 | 4 | 5 | 0 | 0 | 0 |
| 107 | 1.17 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 108 | .22 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 109 | 1.58 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 110 | .15 | 2 | 1 | 1 | 2 | 5 | 0 | 0 | 0 |
| 111 | .47 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 112 | 2.30 | 1 | 3 | 6 | 8 | 10 | 11 | 12 | 0 |
| 113 | .20 | 3 | 1 | 3 | 4 | 0 | 0 | 0 | 0 |
| 114 | .23 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 115 | .23 | 3 | 1 | 3 | 4 | 0 | 0 | 0 | 0 |
| 116 | .58 | 2 | 1 | 1 | 2 | 3 | 4 | 0 | 0 |
| 117 | 1.86 | 2 | 1 | 1 | 2 | 3 | 4 | 0 | 0 |
| 118 | .23 | 2 | 1 | 2 | 3 | 4 | 0 | 0 | 0 |
| 119 | .16 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 120 | .97 | 2 | 1 | 1 | 2 | 8 | 0 | 0 | 0 |
| 121 | .33 | 2 | 1 | 2 | 3 | 4 | 5 | 0 | 0 |
| 122 | .07 | 2 | 1 | 1 | 2 | 8 | 0 | 0 | 0 |
| 123 | .41 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 124 | .41 | 2 | 1 | 1 | 2 | 3 | 4 | 5 | 0 |
| 125 | 1.24 | 1 | 1 | 4 | 5 | 0 | 0 | 0 | 0 |
| 126 | .19 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 127 | .38 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 128 | .12 | 1 | 1 | 1 | 2 | 5 | 0 | 0 | 0 |
| 129 | .57 | 3 | 1 | 1 | 5 | 0 | 0 | 0 | 0 |
| 130 | .22 | 3 | 1 | 1 | 2 | 5 | 0 | 0 | 0 |
| 131 | .99 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 132 | .08 | 3 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 133 | .16 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 134 | .32 | 2 | 1 | 1 | 2 | 3 | 4 | 5 | 0 |
| 135 | .24 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 136 | .61 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 137 | .31 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 138 | .96 | 1 | 1 | 3 | 2 | 5 | 0 | 0 | 0 |
| 139 | .74 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| 140 | .37 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 141 | 2.83 | 1 | 3 | 8 | 12 | 0 | 0 | 0 | 0 |
| 142 | 1.91 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 143 | .77 | 1 | 1 | 5 | 8 | 0 | 0 | 0 | 0 |
| 144 | 1.21 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 145 | .84 | 1 | 3 | 6 | 10 | 11 | 0 | 0 | 0 |
| 146 | .43 | 1 | 1 | 7 | 0 | 0 | 0 | 0 | 0 |
| 147 | .29 | 1 | 3 | 6 | 10 | 0 | 0 | 0 | 0 |
| 148 | .09 | 1 | 1 | 7 | 0 | 0 | 0 | 0 | 0 |
| 149 | 4.82 | 1 | 3 | 6 | 10 | 0 | 0 | 0 | 0 |
| 150 | 1.40 | 1 | 1 | 5 | 6 | 8 | 0 | 0 | 0 |
| 151 | 1.75 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 152 | 1.59 | 1 | 1 | 5 | 6 | 8 | 10 | 12 | 0 |
| 153 | [illegible] | 1 | 1 | 5 | 8 | 0 | 0 | 0 | 0 |
| 154 | 5.48 | 1 | 1 | 5 | 8 | 0 | 0 | 0 | 0 |
| 155 | 6.37 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 156 | .21 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 157 | .15 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 158 | .36 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 159 | .63 | 3 | 1 | 1 | 3 | 5 | 0 | 0 | 0 |
| 160 | .48 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 161 | 1.06 | 3 | 1 | 1 | 2 | 5 | 0 | 0 | 0 |
| 162 | 1.28 | 2 | 1 | 1 | 2 | 5 | 0 | 0 | 0 |
| 163 | .40 | 1 | 1 | 5 | 8 | 0 | 0 | 0 | 0 |
| 164 | .18 | 1 | 2 | 5 | 8 | 10 | 0 | 0 | 0 |
| 165 | .47 | 2 | 1 | 2 | 3 | 5 | 0 | 0 | 0 |
| 166 | .52 | 1 | 1 | 1 | 2 | 5 | 0 | 0 | 0 |
| 167 | .43 | 1 | 3 | 8 | 10 | 0 | 0 | 0 | 0 |
| 168 | .38 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 169 | .19 | 1 | 2 | 1 | 2 | 5 | 6 | 0 | 0 |
| 170 | .65 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 171 | .30 | 1 | 2 | 1 | 5 | 6 | 7 | 8 | 0 |
| 172 | 2.28 | 1 | 3 | 10 | 0 | 0 | 0 | 0 | 0 |
| 173 | .81 | 1 | 2 | 7 | 0 | 0 | 0 | 0 | 0 |
| 174 | 8.89 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 175 | 1.11 | 1 | 1 | 5 | 6 | 8 | 0 | 0 | 0 |
| 176 | .10 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 177 | .15 | 1 | 1 | 1 | 2 | 5 | 0 | 0 | 0 |
| 178 | .62 | 1 | 2 | 5 | 6 | 8 | 10 | 0 | 0 |
| 179 | .05 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 180 | .11 | 2 | 1 | 2 | 3 | 0 | 0 | 0 | 0 |
| 181 | .16 | 3 | 1 | 2 | 3 | 4 | 5 | 0 | 0 |
| 182 | .24 | 2 | 1 | 1 | 2 | 3 | 4 | 5 | 0 |
| 183 | .09 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 184 | .50 | 2 | 1 | 1 | 2 | 3 | 4 | 5 | 0 |
| 185 | .32 | 1 | 3 | 7 | 0 | 0 | 0 | 0 | 0 |
| 186 | .10 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 187 | .16 | 1 | 2 | 6 | 8 | 0 | 0 | 0 | 0 |
| 188 | .08 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 189 | .69 | 2 | 1 | 1 | 2 | 3 | 4 | 0 | 0 |
| 190 | .11 | 1 | 3 | 6 | 10 | 0 | 0 | 0 | 0 |
| 191 | .11 | 3 | 1 | 1 | 2 | 4 | 0 | 0 | 0 |
| 192 | .06 | 1 | 3 | 6 | 10 | 0 | 0 | 0 | 0 |
| 193 | .06 | 2 | 1 | 1 | 2 | 3 | 4 | 0 | 0 |
| 194 | .08 | 1 | 3 | 6 | 10 | 0 | 0 | 0 | 0 |
| 195 | .10 | 3 | 1 | 1 | 2 | 3 | 5 | 0 | 0 |
| 196 | .11 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 197 | .11 | 1 | 1 | 1 | 2 | 5 | 0 | 0 | 0 |
| 198 | .48 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 199 | 2.83 | 1 | 3 | 6 | 10 | 0 | 0 | 0 | 0 |
| 200 | .20 | 1 | 1 | 1 | 3 | 4 | 5 | 0 | 0 |
| 201 | .66 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 202 | .17 | 1 | 2 | 6 | 8 | 10 | 0 | 0 | 0 |
| 203 | 1.87 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 204 | .47 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 205 | .19 | 1 | 1 | 6 | 0 | 0 | 0 | 0 | 0 |
| 206 | 6.00 | 1 | 3 | 6 | 8 | 10 | 11 | 0 | 0 |
| 207 | .16 | 1 | 2 | 8 | 0 | 0 | 0 | 0 | 0 |
| 208 | .15 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 209 | .52 | 1 | 1 | 5 | 8 | 0 | 0 | 0 | 0 |
| 210 | .17 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 211 | .47 | 1 | 3 | 5 | 8 | 10 | 0 | 0 | 0 |
| 212 | .92 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 213 | .72 | 1 | 3 | 6 | 8 | 0 | 0 | 0 | 0 |
| 214 | .44 | 3 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 215 | 1.85 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 216 | .39 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 217 | .30 | 2 | 1 | 1 | 3 | 5 | 0 | 0 | 0 |
| 218 | .09 | 2 | 1 | 3 | 0 | 0 | 0 | 0 | 0 |
| 219 | .21 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 220 | .11 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 221 | .40 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 222 | .23 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 223 | .15 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 224 | .11 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 225 | .09 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 226 | .09 | 2 | 1 | 3 | 4 | 5 | 0 | 0 | 0 |
| 227 | 1.97 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 228 | .52 | 1 | 1 | [illegible] | 0 | 0 | 0 | 0 | 0 |
| 229 | .11 | 3 | 1 | 1 | 2 | 3 | 4 | 0 | 0 |
| 230 | .21 | 2 | 1 | [illegible] | 0 | 0 | 0 | 0 | 0 |
| 231 | .10 | 1 | 1 | [illegible] | 0 | 0 | 0 | 0 | 0 |
| 232 | .09 | 3 | 1 | 1 | 3 | 0 | 0 | 0 | 0 |
| 233 | .16 | 3 | 1 | 1 | 3 | 0 | 0 | 0 | 0 |
| 234 | .05 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 235 | .13 | 3 | 1 | 1 | 3 | 0 | 0 | 0 | 0 |
| 236 | .50 | 2 | 1 | 2 | 3 | 4 | 0 | 0 | 0 |
| 237 | .16 | 3 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 238 | .35 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 239 | .31 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 240 | 2.50 | 1 | 3 | [illegible] | 10 | 11 | 0 | 0 | 0 |
| 241 | .45 | 2 | 1 | 1 | 2 | 4 | 0 | 0 | 0 |
| 242 | .22 | 2 | 1 | 1 | 2 | 4 | 0 | 0 | 0 |
| 243 | .32 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 244 | .44 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| 245 | .61 | 2 | 1 | 2 | 3 | 0 | 0 | 0 | 0 |
| 246 | .07 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 247 | .14 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 248 | .50 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 249 | .28 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 250 | .49 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| 251 | 1.17 | 1 | 3 | 8 | 10 | 0 | 0 | 0 | 0 |
| 252 | .20 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 253 | .97 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 254 | .08 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| 255 | .42 | 1 | 3 | 8 | 10 | 0 | 0 | 0 | 0 |
| 256 | .37 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| 257 | .04 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 258 | .12 | 1 | 1 | 5 | 8 | 0 | 0 | 0 | 0 |
| 259 | .05 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 260 | .16 | 2 | 1 | 2 | 3 | 0 | 0 | 0 | 0 |
| 261 | .13 | 1 | 2 | 8 | 0 | 0 | 0 | 0 | 0 |
| 262 | .11 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 263 | .49 | 2 | 1 | 2 | 3 | 0 | 0 | 0 | 0 |
| 264 | .14 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 265 | .09 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 266 | .17 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| 267 | .36 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 268 | .11 | 2 | 1 | [illegible] | 0 | 0 | 0 | 0 | 0 |
| 269 | .06 | 3 | 1 | [illegible] | 5 | 0 | 0 | 0 | 0 |
| 270 | .16 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 271 | 1.08 | 2 | 1 | 2 | 3 | 0 | 0 | 0 | 0 |
| 272 | .36 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 273 | .55 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 274 | .25 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 275 | .40 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 276 | .24 | 2 | 1 | 1 | 2 | 3 | 5 | 0 | 0 |
| 277 | .09 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 278 | .61 | 2 | 1 | 1 | 2 | 8 | 0 | 0 | 0 |
| 279 | .53 | 3 | 1 | 1 | 2 | 3 | 4 | 5 | 0 |
| 280 | .54 | 1 | 2 | 6 | 8 | 0 | 0 | 0 | 0 |
| 281 | .40 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 282 | .49 | 3 | 1 | 1 | 2 | 5 | 8 | 0 | 0 |
| 283 | 1.40 | 1 | 3 | 5 | 6 | 8 | 10 | 11 | 0 |
| 284 | 1.33 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 285 | .54 | 1 | 3 | 8 | 10 | 0 | 0 | 0 | 0 |
| 286 | .78 | 1 | 2 | 5 | 6 | 8 | 0 | 0 | 0 |
| 287 | 1.72 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 288 | .18 | 1 | 2 | 5 | 0 | 0 | 0 | 0 | 0 |
| 289 | .30 | 1 | 2 | 1 | 2 | 3 | 0 | 0 | 0 |
| 290 | .20 | 2 | 1 | 2 | 3 | 4 | 5 | 0 | 0 |
| 291 | .83 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 292 | .13 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 293 | .78 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 294 | 1.26 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 295 | 2.82 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 296 | .25 | 1 | 1 | 3 | 4 | 5 | 0 | 0 | 0 |
| 297 | .33 | 2 | 1 | 6 | 8 | 10 | 0 | 0 | 0 |
| 298 | .20 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 299 | .25 | 3 | 1 | 3 | 5 | 0 | 0 | 0 | 0 |
| 300 | .34 | 1 | 1 | 4 | 5 | 0 | 0 | 0 | 0 |
| 301 | .31 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 302 | .20 | 3 | 1 | 3 | 4 | 5 | 0 | 0 | 0 |
| 303 | .07 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 304 | .09 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 305 | .23 | 3 | 1 | 1 | 2 | 3 | 5 | 0 | 0 |
| 306 | .08 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 307 | .11 | 3 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 308 | .19 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 309 | .13 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 310 | .85 | 3 | 1 | 1 | 2 | 4 | 5 | 0 | 0 |
| 311 | .64 | 3 | 1 | 1 | 2 | 4 | 5 | 0 | 0 |
| 312 | .38 | 1 | 1 | 2 | 4 | 5 | 0 | 0 | 0 |
| 313 | .61 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 314 | .67 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 315 | .10 | 1 | 1 | 4 | 5 | 0 | 0 | 0 | 0 |
| 316 | .48 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 317 | .06 | 3 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 318 | .13 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 319 | .28 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 320 | .49 | 1 | 2 | 8 | 0 | 0 | 0 | 0 | 0 |
| 321 | .54 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 322 | .14 | 1 | 3 | 10 | 0 | 0 | 0 | 0 | 0 |
| 323 | .18 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 324 | .17 | 3 | 1 | 3 | 4 | 5 | 0 | 0 | 0 |
| 325 | .22 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 326 | .39 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 327 | .36 | 1 | 2 | 5 | 6 | 7 | 0 | 0 | 0 |
| 328 | .08 | 1 | 1 | 1 | 5 | 0 | 0 | 0 | 0 |
| 329 | .26 | 1 | 1 | 4 | 5 | 0 | 0 | 0 | 0 |
| 330 | .20 | 3 | 1 | 4 | 5 | 0 | 0 | 0 | 0 |
| 331 | .23 | 1 | 3 | 8 | 10 | 0 | 0 | 0 | 0 |
| 332 | .13 | 1 | 3 | 8 | 10 | 0 | 0 | 0 | 0 |
| 333 | .12 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 334 | .12 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 335 | .13 | 3 | 1 | 2 | 3 | 4 | 5 | 0 | 0 |
| 336 | .25 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 337 | .09 | 1 | 1 | 1 | 2 | 5 | 0 | 0 | 0 |
| 338 | .05 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 339 | .30 | 3 | 1 | 2 | 3 | 0 | 0 | 0 | 0 |
| 340 | .25 | 1 | 2 | 2 | 3 | 5 | 6 | 0 | 0 |
| 341 | .19 | 3 | 1 | 2 | 3 | 4 | 5 | 0 | 0 |
| 342 | .12 | 1 | 2 | 6 | 0 | 0 | 0 | 0 | 0 |
| 343 | .19 | 3 | 1 | 2 | 3 | 4 | 5 | 0 | 0 |
| 344 | .27 | 3 | 1 | 3 | 4 | 5 | 0 | 0 | 0 |
| 345 | .26 | 1 | 1 | 2 | 5 | 0 | 0 | 0 | 0 |
| 346 | .08 | 1 | 3 | 6 | 10 | 0 | 0 | 0 | 0 |
| 347 | 1.87 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 348 | .46 | 1 | 3 | 6 | 10 | 0 | 0 | 0 | 0 |
| 349 | .66 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 350 | .63 | 1 | 1 | 10 | 0 | 0 | 0 | 0 | 0 |
| 351 | .30 | 3 | 1 | 2 | 5 | 0 | 0 | 0 | 0 |
| 352 | .34 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 353 | .17 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 354 | .70 | 1 | 3 | 10 | 0 | 0 | 0 | 0 | 0 |
| 355 | .60 | 1 | 3 | 8 | 10 | 0 | 0 | 0 | 0 |
| 356 | .15 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 357 | .07 | 1 | 3 | 7 | 8 | 0 | 0 | 0 | 0 |
| 358 | .91 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 359 | .13 | 1 | 2 | 8 | 10 | 0 | 0 | 0 | 0 |
| 360 | .19 | 1 | 3 | 6 | 7 | 10 | 12 | 0 | 0 |
| 361 | .29 | 3 | 1 | 2 | 3 | 0 | 0 | 0 | 0 |
| 362 | .20 | 1 | 2 | 8 | 0 | 0 | 0 | 0 | 0 |
| 363 | .13 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 364 | .58 | 3 | 1 | 1 | 2 | 3 | 4 | 0 | 0 |
| 365 | .28 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 366 | 1.43 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 367 | .40 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 368 | .31 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 369 | .24 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 370 | .28 | 1 | 3 | 10 | 0 | 0 | 0 | 0 | 0 |
| 371 | .09 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 372 | .23 | 1 | 2 | 6 | 10 | 0 | 0 | 0 | 0 |
| 373 | .16 | 1 | 3 | 6 | 10 | 0 | 0 | 0 | 0 |
| 374 | .11 | 1 | 3 | 6 | 10 | 0 | 0 | 0 | 0 |
| 375 | .20 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 376 | .16 | 1 | 3 | 6 | 10 | 0 | 0 | 0 | 0 |
| 377 | .24 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 378 | 1.00 | 1 | 3 | 6 | 10 | 0 | 0 | 0 | 0 |
| 379 | .19 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 380 | .16 | 1 | 3 | 6 | 7 | 10 | 0 | 0 | 0 |
| 381 | 1.11 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 382 | 2.46 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 383 | .76 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 384 | .23 | 1 | 2 | 6 | 7 | 10 | 0 | 0 | 0 |
| 385 | .15 | 1 | 3 | 10 | 0 | 0 | 0 | 0 | 0 |
| 386 | .39 | 1 | 2 | 5 | 0 | 0 | 0 | 0 | 0 |
| 387 | .11 | 1 | 3 | 10 | 0 | 0 | 0 | 0 | 0 |
| 388 | .06 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 389 | .12 | 1 | 3 | 6 | 7 | 0 | 0 | 0 | 0 |
| 390 | .16 | 1 | 1 | 5 | 6 | 7 | 0 | 0 | 0 |
| 391 | .11 | 1 | 3 | 6 | 7 | 0 | 0 | 0 | 0 |
| 392 | .15 | 1 | 2 | 6 | 7 | 0 | 0 | 0 | 0 |
| 393 | .13 | 1 | 2 | 6 | 7 | 0 | 0 | 0 | 0 |
| 394 | .25 | 1 | 3 | 6 | 7 | 0 | 0 | 0 | 0 |
| 395 | .46 | 1 | 2 | 6 | 10 | 0 | 0 | 0 | 0 |
| 396 | .46 | 1 | 3 | 6 | 7 | 10 | 0 | 0 | 0 |
| 397 | .33 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 398 | .45 | 1 | 2 | 6 | 7 | 0 | 0 | 0 | 0 |
| 399 | .44 | 1 | 2 | 6 | 7 | 0 | 0 | 0 | 0 |
| 400 | .36 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 401 | .36 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 402 | .21 | 3 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 403 | .08 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 404 | .31 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 405 | .10 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 406 | .13 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 407 | .17 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 408 | .34 | 1 | 3 | 6 | 10 | 0 | 0 | 0 | 0 |
| 409 | .15 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 410 | .11 | 3 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 411 | .31 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 412 | .13 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 413 | .24 | 2 | 1 | 2 | 3 | 4 | 0 | 0 | 0 |
| 414 | .24 | 2 | 1 | 1 | 2 | 5 | 0 | 0 | 0 |
| 415 | .23 | 2 | 1 | 1 | 2 | 5 | 0 | 0 | 0 |
| 416 | .04 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 417 | .12 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 418 | .17 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 419 | .58 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 420 | .07 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 421 | .34 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 422 | .28 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 423 | .09 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 424 | .06 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 425 | .09 | 3 | 2 | 1 | 2 | 5 | 8 | 0 | 0 |
| 426 | .27 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 427 | .60 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 428 | .11 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 429 | .22 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 430 | .14 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 431 | .32 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 432 | .09 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 433 | .34 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 434 | .08 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 435 | .29 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 436 | .23 | 3 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 437 | .10 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 438 | .08 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 439 | .12 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 440 | .24 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 441 | .12 | 1 | 1 | 1 | 5 | 0 | 0 | 0 | 0 |
| 442 | .20 | 1 | 2 | 6 | 7 | 0 | 0 | 0 | 0 |
| 443 | .82 | 1 | 2 | 6 | 8 | 0 | 0 | 0 | 0 |
| 444 | .16 | 1 | 3 | 10 | 0 | 0 | 0 | 0 | 0 |
| 445 | .38 | 1 | 2 | 7 | 13 | 0 | 0 | 0 | 0 |
| 446 | 2.58 | 1 | 3 | 6 | 7 | 8 | 10 | 0 | 0 |
| 447 | 1.35 | 1 | 3 | 10 | 11 | 12 | 0 | 0 | 0 |
| 448 | .40 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 449 | .30 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 450 | .10 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 451 | .05 | 2 | 1 | 2 | 3 | 0 | 0 | 0 | 0 |
| 452 | .13 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 453 | .17 | 2 | 1 | 1 | 2 | 3 | 4 | 0 | 0 |
| 454 | .18 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 455 | .12 | 3 | 1 | 3 | 4 | 0 | 0 | 0 | 0 |
| 456 | 1.39 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 457 | .47 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 458 | .20 | 2 | 1 | 2 | 3 | 4 | 0 | 0 | 0 |
| 459 | .68 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 460 | 3.44 | 2 | 1 | 1 | 2 | 3 | 4 | 0 | 0 |
| 461 | .33 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 462 | 1.90 | 1 | 1 | 1 | 2 | 5 | 0 | 0 | 0 |
| 463 | .26 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 464 | .08 | 1 | 1 | 3 | 5 | 0 | 0 | 0 | 0 |
| 465 | .06 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 466 | .21 | 1 | 1 | 4 | 5 | 0 | 0 | 0 | 0 |
| 467 | 1.64 | 1 | 3 | 6 | 8 | 10 | 0 | 0 | 0 |
| 468 | .75 | 1 | 2 | 4 | 5 | 0 | 0 | 0 | 0 |
| 469 | .46 | 1 | 2 | 6 | 10 | 0 | 0 | 0 | 0 |
| 470 | .52 | 1 | 1 | 8 | 0 | 0 | 0 | 0 | 0 |
| 471 | .48 | 1 | 1 | 6 | 8 | 0 | 0 | 0 | 0 |
| 472 | .72 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 473 | .50 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 474 | .78 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 475 | .28 | 2 | 1 | 2 | 3 | 0 | 0 | 0 | 0 |
| 476 | .56 | 1 | 2 | 6 | 10 | 0 | 0 | 0 | 0 |
| 477 | .60 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 478 | .31 | 3 | 1 | 1 | 2 | 4 | 0 | 0 | 0 |
| 479 | .31 | 3 | 2 | 1 | 2 | 6 | 0 | 0 | 0 |
| 480 | .13 | 1 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 481 | .14 | 2 | 1 | 1 | 5 | 0 | 0 | 0 | 0 |
| 482 | .83 | 2 | 1 | 1 | 2 | 3 | 0 | 0 | 0 |
| 483 | .08 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |

LEGEND: NO.: Site number

LEN.: Shoreline length in miles

W: Quality rating as walleye spawning habitat

N: Quality rating as northern spawning habitat

SHORELINE TYPE: Description of materials present on shoreline:

1: Boulder (over 12 inches)
2: Rock (6 to 12 inches)
3: Rubble (1 to 6 inches)
4: Gravel (less than 1 inch)
5: Sand
6: Cattail
7: Burreed
8: Phragmites
10: Sedge
11: Wild rice
12: Terrestrial vegetation

Table 3. Description of Leech Lake shoreline, 1978, giving site location number, shoreline length, quality rating for walleye and northern spawning potential, and a listing of dominate materials or vegetation present.

Table 4. Comparison of calculated shoreline miles on Leech Lake from various sources.

| Shoreline type | 1936[a] | 1943[a] | 1963[a] | 1978 (Mapwheel)[b] | 1978 (Digitizer)[b] |
|---|---|---|---|---|---|
| Bogs and wild rice | - | 59.75 | 57 | - | 115 |
| Rocks and Boulders | - | 30.9 | 57 | - | 56 |
| Gravel | - | 4.9 | 19 | - | 14 |
| Canebreaks, sand, and ice ridges | - | 69.2 | 57 | - | 66 |
| Total | 159.50 | 165 | 190 | 176 | 251 |

[a]data from unpublished reports of the Minnesota DNR, 1936, 1943 and 1963

[b]this investigation

Depending on water level, there are an estimated 2 to 58 acres of good or fair potential northern pike spawning habitat (Figure 7). This includes both floating and non-floating spawning habitat types. The minimum water level at which the maximum area of floating spawning sites became accessible was at 1294.3 m.s.1. At or above 1294.3 m.s.1., there were 47 acres of spawning habitat. In these areas, once the minimum water level is achieved (about 1294.0 m.s.1.) the vegetative mats, comprised mostly of sedge, begin to float allowing northern pike access to the partially submerged fringe portion. With subsequent increases in water level, the areas accessible to northern pike do not change, rather, the vegetative mats maintain a constant position relative to the water level (Figure 8). Water levels below this minimum stage greatly decrease the available spawning sites as the vegetative mats begin to rest on the bottom and become inaccessible as water recedes from the edge.

In non-floating areas, the vegetation is securely attached to a gradually sloped bottom. As water level rises, the area of potential spawning habitat increases to a maximum of 11 acres at a water level of 1295.0 m.s.1. Above this level, the desired vegetation is flooded deeper than 36 inches and is lost as a potential spawning site. During the study, northern pike eggs were not found at depths greater than three feet. Above 1296.0 m.s.1., non-floating areas no longer provide spawning sites (Figure 9).

On the tributaries to Leech Lake, there are approximately 115 linear miles of shoreline or marsh with about 94 acres of potential northern pike spawning area within 7.25 miles of the lake. These areas are not directly affected by the lake level, except at their mouths. Rather, they are dependent on local precipitation through winter and spring. Although

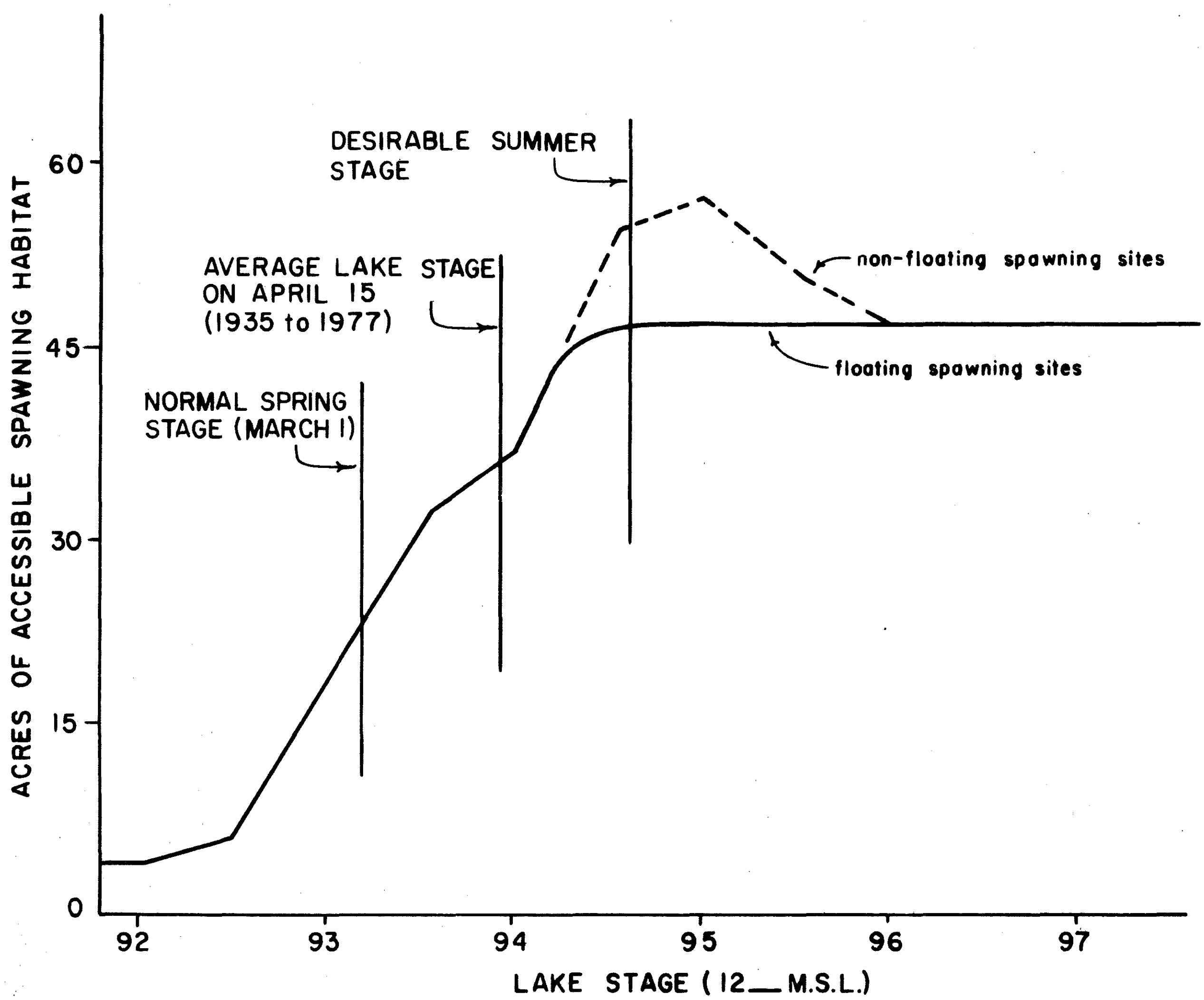



Figure 7. Estimated total acres of spawning habitat for northern pike with changing water levels on Leech Lake. Desirable summer stage and normal spring stage as defined by Corps of Engineers, 1977.

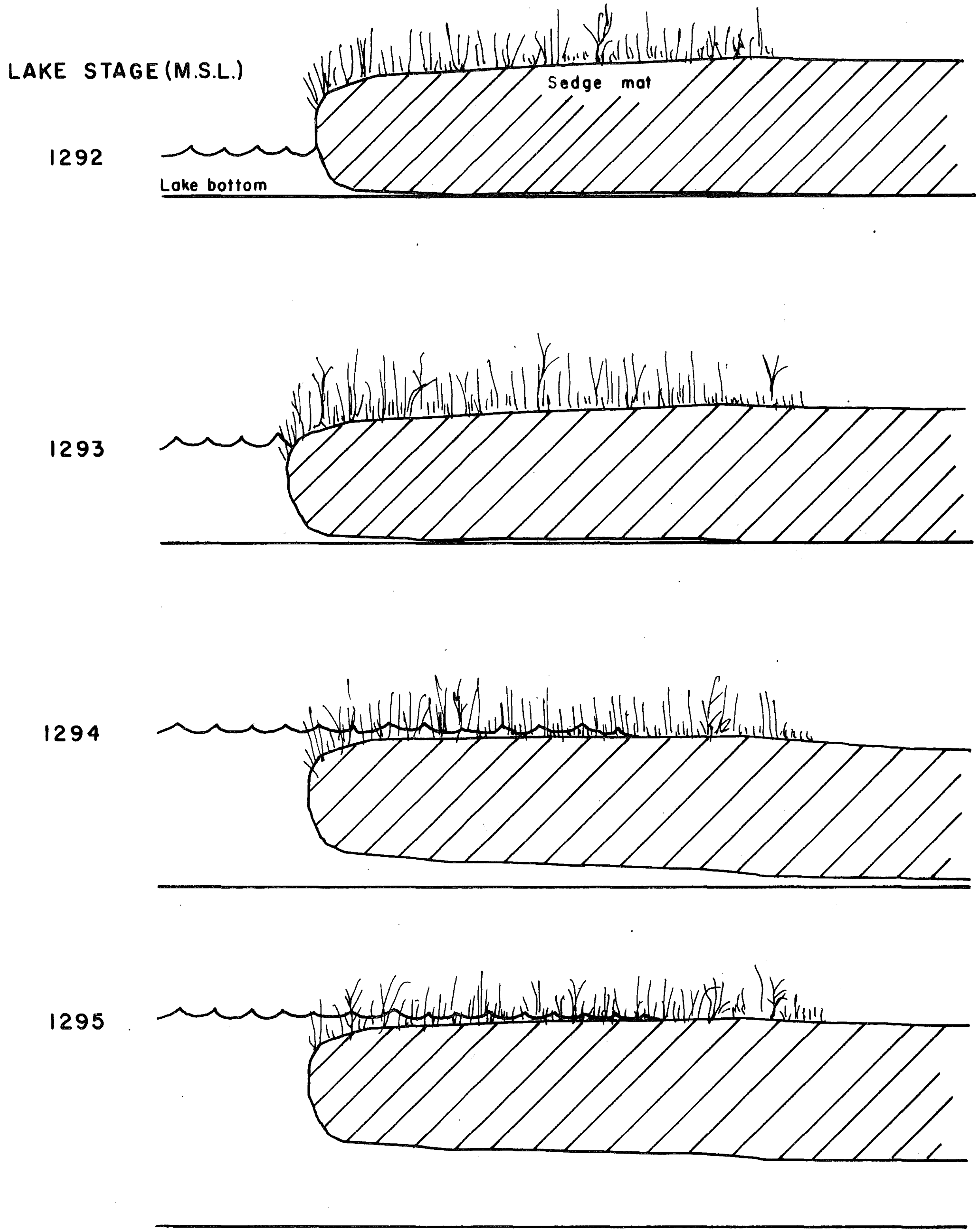



Figure 8. Schematic diagram of the effects of different water levels on floating spawning substrate in Leech Lake.

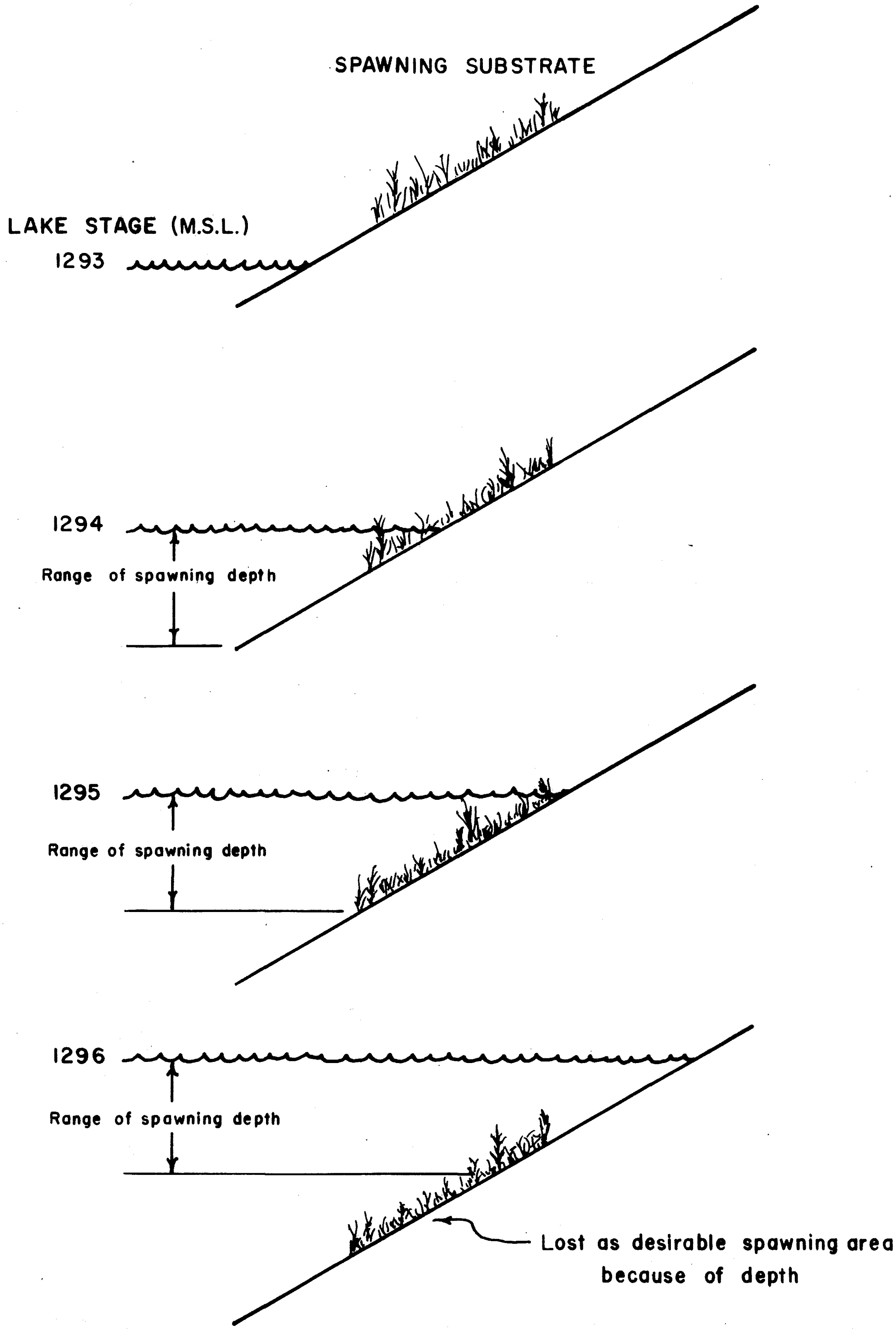



Figure 9. Schematic diagram of the effects of different water levels on non-floating spawning substrate in Leech Lake.

not verified during this study the area of these spawning sites probably remains relatively constant with normal precipitation.

It was found that vegetative types in sample northern pike spawning sites could be reliably determined from the small format (35mm) aerial photography that was undertaken specially for this project. Accurate discrimination between pure strands (defined as being at least 80% of one kind of vegetation) of sedge, phragmites, cattails, wild rice and terrestrial plants could be made based on color and texture. Greater mixtures of these plants were more difficult to interpret but were identifiable. Detailed vegetation maps of potential spawning sites were made from these photographs. An example is shown in Figure 10.

Vegetation density, accessibility of the site to fish or substrate could not be determined.

Changes in water level, do not appear to have greatly affected northern pike population abundance and structure. The average total length, number of fish per lift, and pounds per lift showed no difference between 1950 and 1976 (Strand 1976). The apparent decline (7.44 to 4.03) between 1948 and 1950, if real, had no relation to spring water levels (Table 5). The age frequencies and length frequencies also show no apparent change that could be related to water level. As indicated by the survey data, all year classes were near average, except for 1938 and 1948, which were strong year classes, and the 1941 year class which was relatively weak (Figures 11 and 12). However, water levels during the hatch of these year classes were no different than those in years of good or normal hatches. Though not conclusive, this indicates the northern pike population has remained relatively constant through the past 50 years even though water levels have ranged from 1293.4 m.s.l. to 1294.8 m.s.l. at the commencement of spawning.

Table 5. Numbers and pounds of northern pike per gill net lift from 1936, 1943, 1950 and 1976, Minnesota DNR surveys.

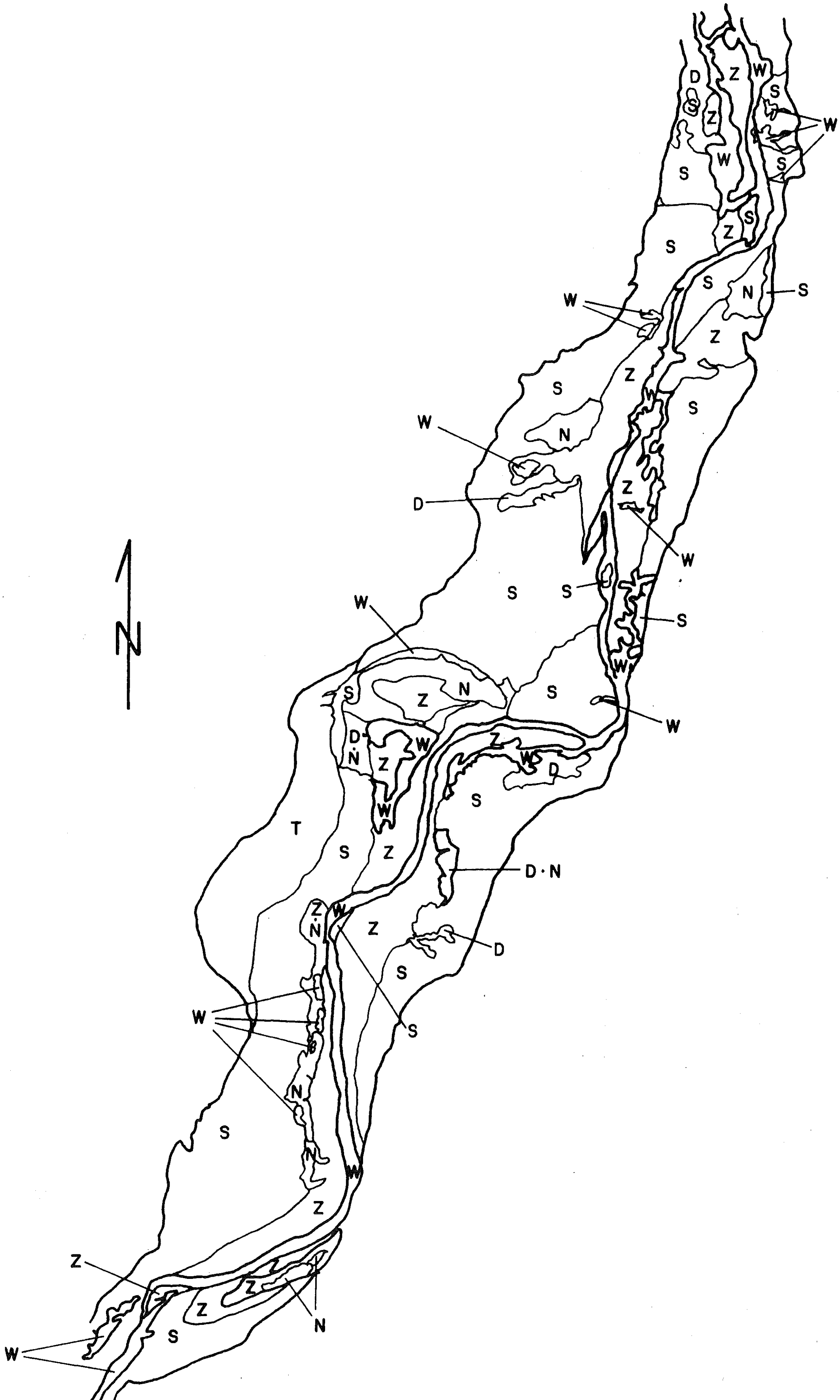
| Year | 1936 | 1943[a] | 1950 | 1976 |
|---|---|---|---|---|
| Water level (April 15) | 1292.5 | 1294.6 | 1294.7 | 1293.7 |
| Average total length | 20.15 | 19.75 | 20.23 | 20.24 |
| Number fish per lift | - | 7.44 | 4.03 | 4.39 |
| [redacted] | | | | - |
| Pounds per lift | - | - | 8.84 | 10.44 |

[a]For comparison with other catches the 1943 data were converted as follows: 1943 catch per set X 2 for hours of set X 2.5 for length of net X 1.2 for depth of net. (Strand 1976)

Figure 10. Vegetation map of head of Shingobee Bay as interpreted from small format (35 mm) aerial photographs July 12, 1978. T. 141 N R. 31W. S. 14 and 15, Scale - 1:3168.

Key:

- D = dead vegetative debris, primarily wild rice (Zizania aquatica)
- N = floating and submerged vegetation, primarily water lily (Nymphaea sp.), muskgrass (Chara sp.), and coontail (Cerato phyllum demersum)
- S = primarily sedge (Carex sp.)
- W = open water
- Z = primarily wild rice (Zizania aquatica)


N
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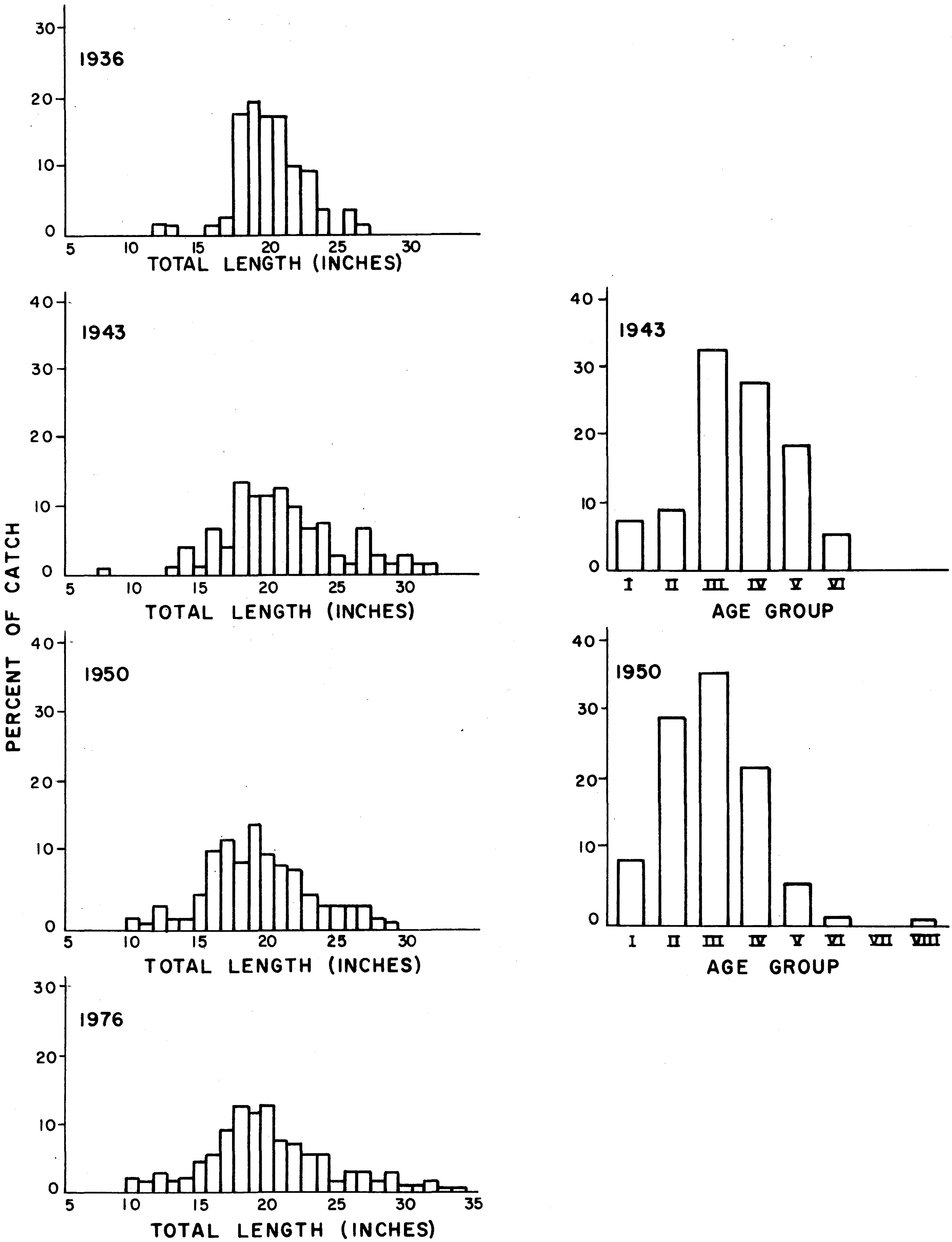


Figure 11. Length and age frequency of northern pike in Leech Lake caught in experimental gill net, 1936 - 1976 (1936 catch data available for 1½ and 2 inch mesh sizes only).

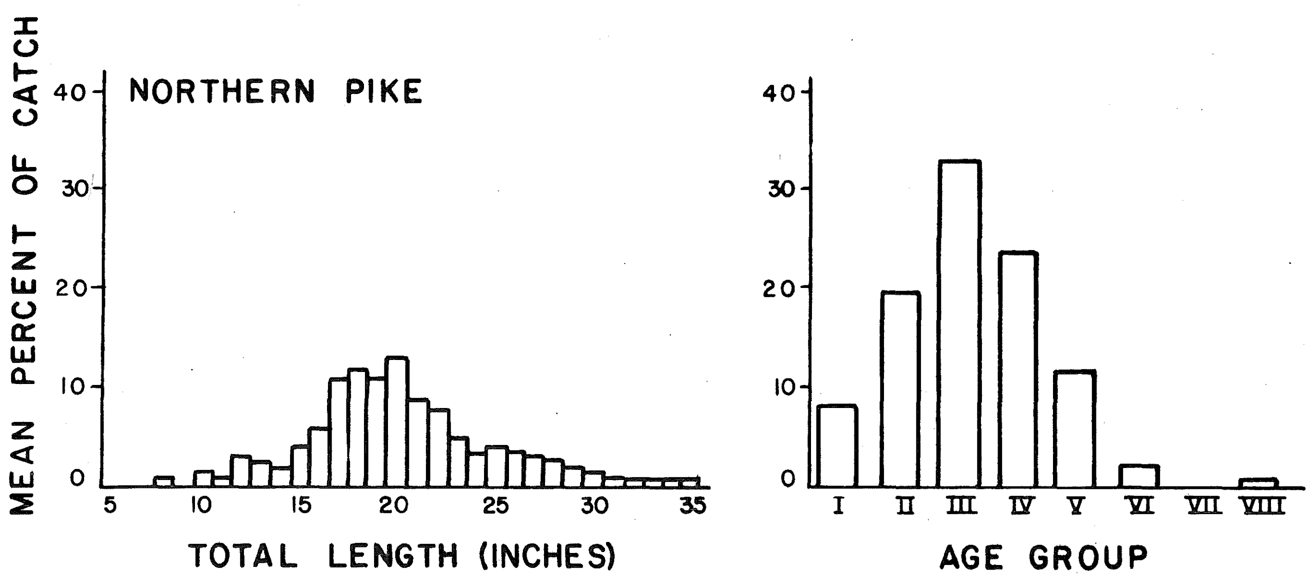


Figure 12. Composite length and age frequency of northern pike in Leech Lake caught in experimental gill nets, 1936 - 1976.

This is in contrast to Ball Club Lake, Minnesota (Johnson 1956), a lake within 30 miles of Leech Lake, where the success of the year class was dependent upon the average water level and maximum water drop during the spawning season. In Ball Club Lake the average water level during the spawning season varied within a range of 3 feet from year to year. The water level during the spawning season also dropped 0.3 to 1.6 feet, in the years examined. These conditions apparently affected the population by limiting the spawning sites available or causing mortalities to the eggs and young by exposure. At Leech Lake the situation is different. The water level at the time spawning is usually near or above 1294.0 m.s.l., except for a period during the 1930's. At this water level, spawning sites are abundant in both the lake and the tributaries. Because Leech Lake is used for water storage it is normal that the water level during the spring is either stable or rising. Consequently, exposure of eggs or young from falling water levels is not a problem.

Walleye

The spawning season for walleye is about one week later than for northern pike. Preferred sites are areas in less than 3 to 5 feet of water with bottom materials primarily rock and rubble approximately 1 to 6 inches in size. Other materials may be used (sand, sand-muck, muck-detritus) but Johnson (1961) found lesser egg deposition and survival on other substrate in Cut Foot Sioux and Winnibigoshish Lakes.

On Leech Lake the spawning season for walleye is usually from late April to mid May. The spawning beds are generally composed of 60% rocks ( 6 to 12 inches in diameter), 30% rubble ( 1 to 6 inches), and 10% boulders (greater than 12 inches). Sand may also be present in some sites, however, in most spawning areas, the finer materials have been washed away.

Walleye spawning areas are present along 78 miles of the 251 miles of shoreline on Leech Lake. Forty-seven miles were judged of good quality spawning habitat and 31 miles were of fair quality.

Walleye eggs were found in all potential spawning sites examined throughout the lake in 1962.[1/]

Whether spawning runs of walleye into tributaries contribute significantly to reproduction in the lake is questionable because the available streams have little substrate suitable for successful egg incubation. The streams flow mostly through, bogs, marshes, and beaver ponds which have soft mucky bottom. In a previous survey no walleye eggs were found in tributaries except in the artificial rock pilings below the county road 51 bridge over the Boy River.[2/]

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1/ Minnesota DNR unpublished report, Schupp 1962.

2/ Schupp. Ibid.

Estimates of the amount of walleye spawning area in the lake were hampered because of poor visibility caused by algal blooms which prevented observation of spawning sites at depths greater than about four feet (1291.0 m.s.1.). As a result, all estimates of spawning areas below 1291.0 m.s.1. were minimal. Therefore, data from previous surveys were averaged and substituted.[3/] These surveys indicated that 475 to 600 acres of usable walleye spawning area are available depending on water level (Figure 13). The appararent increase in spawning area with water levels above 1294.0 m.s.1., (Figure 13) is not a real trend; rather it is an artifact of variations in survey methods.

Gradually rising water levels through the spawning period do not greatly change the total area available within five feet of water depth. Rather, as the level rises a constant supply of new, unused spawning material becomes available, resulting in more efficient use of the total spawning site.

The effect of increasing water depth on survival of eggs which have been deposited is unknown. However, viable, developing walleye eggs have been sampled in Minnesota waters to depths of at least six feet. These eggs had higher survival rates than those deposited in shallow water (Newburg 1975).

Information available from past surveys indicates these has been no apparent change in the average length, number per lift, or pounds per lift of walleyes between 1943 and 1976 (Table 6) although water levels at the commencement of spawning (April 20) have ranged from 1292.4 m.s.1. to 1295.2 m.s.1. (1921 to 1977). Therefore, there was no apparent relationship between population size or age group structure and water levels. Length and age frequency data for walleye from the available surveys were too limited to permit analysis. Since there are abundant spawning grounds at all water levels within the historic range, the availability of spawning sites does not appear to be a limiting factor on walleye reproduction. In contrast, it was found in Rainy Lake (Johnson 1966, Chevalier 1977) that low spring water levels prevented walleye access to spawning areas and this was correlated with the decline of the walleye population.

Wind has little affect on the accessibility of northern pike or walleye spawning sites. Although seiches were observed to cause a 12 inch change in water level during the summer, ice conditions during the northern pike spawning season inhibited seiche and most wave activity so that wind had little effect on accessibility to spawning areas. The lake is ice free when walleye spawning takes place and wind action has no effect on the accessibility to spawning shoals.

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3/ Minnesota DNR unpublished survey data or reports from 1936, 1943, and 1961.

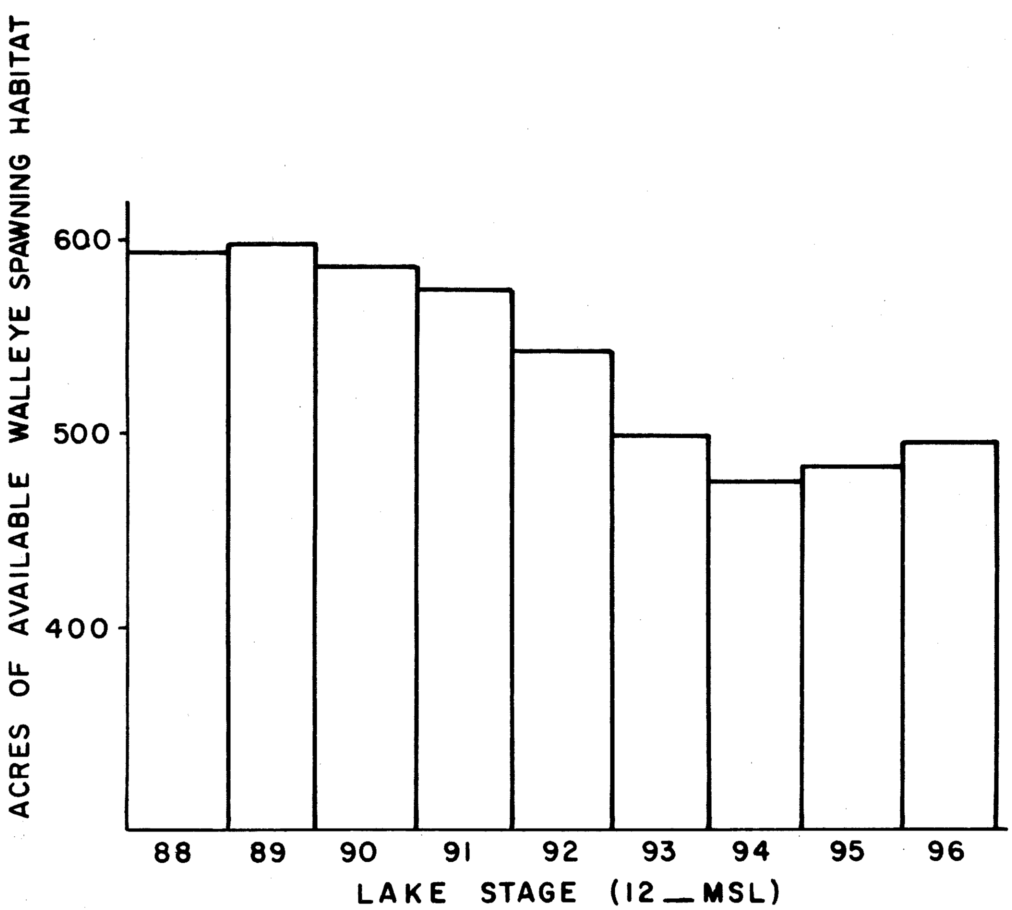


Figure 13. Acres of potential walleye spawning habitat within 5 foot water depth at water levels from 1288.0 m.s.l. to 1296.0 m.s.l.

Table 6. Numbers and pounds of walleye per gill net lift from 1936, 1943, 1950 and 1976 Minnesota DNR surveys.

| Year | 1936 | 1943[a] | 1950 | 1976 |
|---|---|---|---|---|
| Water level (April 20) | 1292.5 | 1294.6 | 1294.7 | 1293.7 |
| Average total length | 13.1 | 14.1 | 14.8 | 13.0 |
| Number fish per lift | - | 3.84 | 3.78 | 3.48 |
| [redacted] | | | | - |
| Pounds per lift | - | - | 4.56 | 3.56 |

[a]For comparison with other catch data 1943 data were converted as follows: 1943 catch per set X 2 for hours of set, X 2.5 for length of net, X 1.2 for depth of net. (Strand 1976)

## Wild Rice

Water levels in the early spring at the time of walleye and northern spawning do not affect rice production. At this time rice is just beginning to germinate and is not affected by water levels attained during normal operations. However, lake water levels must remain relatively stable during the rice vegetation and reproduction states from mid-June through late August. Rising water levels tend to float the vegetative and reproductive stages of wild rice out of its substrate. Falling water levels do not affect the vegetative stage, but cause great losses to the reproductive state because the plants will break easily at the exposed node.

Rice harvesting which is restricted to Indian and non-Indian residents of the reservation provides a significant source of income for area residents. There are 4840 acres of wild rice on Leech Lake, Leech Lake River, and Boy River up to Little Boy Lake. The statewide average wild rice yield is 200 pounds of dry rice per acre. From this information, it is estimated that 968,000 pounds of wild rice are produced in the Leech Lake area. The economic yield from harvest of this wild rice is $6,292,000, assuming $6.50 wholesale price of finished, processed rice. However, this estimate is conservative because it does not include the income from intermediate sales of the harvestors, buyers, small processors and consumers.[4/]

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4/ Personal communications, Edward Fairbanks, Director of Natural Resources, Leech Lake Reservation, August 16, 1979.

## Evaluation of Alternative Operating Plans

Alternative operating plans for water levels and flow developed by the Corps of Engineers for Leech Lake were evaluated in relation to their potential effects on northern pike and walleye spawning areas. Computer generated lake level curves for 1975, a "typical" operating year, and 1976 a "low water" year were compared with actual water levels for those years.

Of the four plans, "Present Plan", "Natural Plan", "High Flow Plan" and "Low Flow Plan", none would appear to have an effect on northern pike spawning in 1975 or 1976 with two possible exceptions.

During the "typical" year of 1976 under the "Natural Plan" the estimated lake elevation during the period April 15 to May 15 would be 1293.0 m.s.l. This is one foot below the recommended elevation of 1294.0 m.s.l. and would reduce the estimated number of acres of available northern pike spawning habitat from 34 to 17. The actual level in 1976 was 1294.0 m.s.l. There is not enough data available on northern pike populations produced in years of low spring water levels to determine what effect, if any, the reduction of available spawning habitat in the lake would have on northern pike population abundance. There are, however, about 94 acres of northern pike spawning area available along the tributaries which are not affected by lake level fluctuations.

In 1975, under the "Natural Plan" the estimated lake elevation of 1293.75 m.s.l. is also below the recommended elevation at the beginning of the spawning period (approximately April 15) but reaches the desired level of 1294.0 m.s.l. by May 1. Since the estimated loss of northern pike spawning area would amount to about one acre, or roughly 3 percent of what is available at 1294.0 m.s.l. it does not seem likely it would have a measureable effect on northern pike reproduction. The actual level on April 15 was 1294.3 m.s.l.

The amount of substrate used by walleyes for spawning during 1976 (typical year) under the alternative plans would remain about the same under the "Present" and "High Flow" plans and would improve somewhat under the "Natural" and "Low Flow" plans when compared with "actual" levels. There tends to be more of the suitable substrate available at lower lake elevations (Figure 13).

During 1976 (low water year) there would be a small decrease in area available under the "Present" and "Low Flow" plans, little change under the "High Flow Plan" and some improvement under the natural flow plans as compared with "actual" levels.

In view of the long term stability of the walleye population in Leech Lake it does not appear likely any of the plans would have a measureable effect on the population abundance.

## Application to Other Headwater Reservoirs

Each of the headwater reservoirs was briefly examined on a one-day shoreline tour to determine whether the findings and methodology of the study on Leech Lake were applicable to these lakes. The shorelines were examined by boat and on foot to determine abundance and quality of spawning habitat and to assess other factors, such as water level, erosion, or periphyton growth, which might affect northern pike and walleye production.

It was determined that the findings from the Leech Lake study were not directly applicable to the other reservoir lakes without detailed examination of each lake. Each of the headwater reservoirs differs in its water level management, bottom substrates, shoreline slopes, shoreline stability and in the kinds and abundance of vegetation present. Without analysis of the individual factors in each lake, extrapolation of findings from Leech Lake to the other reservoirs is not possible.

However, the survey methodology developed for Leech Lake could be easily applied to the other lakes with only a few modifications. Since remote sensing analysis, such as the one performed by the University of Minnesota at Leech Lake (Minor and Meyer, 1978) is not available for the other reservoirs, uninterpreted aerial photography would have to be substituted and personnel who are familiar with aerial interpretation would be needed. In addition the relationship between water level and shoreline erosion and the effect of deposition of the eroded materials on the quality of spawning sites would have to be analyzed. Westerberg (1962) has reported on the effects of erosion in Lake Winnibigoshish and in Leech Lake. He indicated that effects of erosion were very minor under prevailing operating limits in Leech Lake.

Brief notes on the general availability of northern pike and walleye spawning areas in the other reservoirs are included in the appendix.

## SUMMARY

Northern pike and walleye are most affected by water levels during their spawning season. Low water levels at this time can prevent access to the spawning sites. High water levels can inundate the sites to depths beyond which the species spawn. Falling water level after spawning has commenced can expose eggs or young of either species to desication or strand adult northern pike in the spawning sites.

Potential northern pike spawning sites in Leech Lake were examined to determine site preference by adult fish and the effects of water levels on site accessibility and egg and fry survival.

The entire shoreline of Leech Lake was examined to locate and evaluate walleye spawning habitat, and to determine how water levels affect the spawning sites.

Egg deposition by northern pike on Leech Lake indicated that the flooded fringes of sedge mats, the most "grassy" type vegetation generally available, are the principal spawning sites. At the water level of 1294.0 m.s.l., or above, there is a minimum of 47 acres or 115 shoreline miles of northern pike spawning habit in Leech Lake plus 97 acres or 115 miles along the first 7.25 miles of streams tributary to the lake. Increases in water level above 1294.0 m.s.l. do not appreciably increase the amount of spawning area available since the sedge mats rise with the water level and the fringes of the mats remain at the same relative position as water levels increase. Water levels below 1294.0 m.s.l. greatly reduces the spawning area accessible to northern pike in the lake, but spawning sites on tributaries to the lake are not greatly affected.

There are between 475 and 600 acres or about 78 shoreline miles of walleye spawning habitat on Leech Lake at water levels between 1285.0 m.s.l. and 1296.0 m.s.l., and the availability of spawning habitat does not appear to be a limiting factor on walleye reproduction. Tributaries to Leech Lake provide little or no suitable habitat for successful walleye spawning.

Within the range of water levels at which the lake has been held since the 1930's, no relationship was found between lake water level at spawning time and reproductive success or population size for either northern pike or walleye.

Wind has little effect on the availability of spawning areas for northern pike in Leech Lake because ice cover at the time of spawning dampens the effect of wind induced water level fluctuations in the ice free fringe areas where spawning takes place.

Wind induced water level fluctuation appear to have little or no effect on the availability of walleye spawning areas.

Aerial photography can be accurately interpreted for preparation of detailed wetland vegetation maps. However, it does not provide all the information necessary for complete analysis of potential northern pike spawning areas.

Wild rice was observed to be greatly affected by rising water levels from June through August because the young plants are uprooted from their substrate.

Findings from Leech Lake can not be extrapolated to fit other headwater reservoirs because of wide differences in water level management, shoreline stability and in the kinds of vegetation present.

Methodology developed during the Leech Lake study for analysis and evaluation of potential northern pike spawning areas is applicable to other headwater reservoirs with some modification.

Evaluation of four alternative operating plans indicated that only the "Natural Plan" would affect availability of northern pike spawning areas.

In the "low water" year of 1976 the amount of area in the lake would have been reduced by approximately 50%. In the "typical" year of 1975 the reduction in area would have been about 3%. The area available along tributaries is unaffected by lake level fluctuations.

It appears that alternative plans would have only a minor effect on the amount of walleye spawning habitat available.

## RECOMMENDATIONS

Though no relationship could be demonstrated between the population size or year class strength of northern pike and water levels over the past 50 years, a water level of 1294.0 m.s.l. by April 15 would appear to be optimal for providing maximum spawning area for northern pike in Leech Lake. This level also appears to be satisfactory for walleye spawning.

The water level of Leech Lake, during the normal spawning and incubation periods for northern pike and walleyes, April 15 to May 15, should be stable or rising to prevent exposure of eggs or young of both species, or stranding of northern pike in the spawning areas.

In unusual years with late spring warmup the period of stable or rising water levels should continue until spawning has been completed or until May 25th.

## LITERATURE CITED


Bryan, James E. 1967. Northern Pike Production in Phalen Pond, Minnesota. J. Minn. Acad. of Sci. 34:2, 101-109

Carbine, W.F. 1941. Observations on the Spawning Habits of the Northern Pike Esox lucius, in Houghton Lake, Michigan. Trans. Am. Fish. Soc. 71:149-164

Clark, C.F. 1950. Observation on the Spawning Habits of the Northern Pike, Esox lucius, in Northwestern Ohio. Copeia 4:285-288

Chevalier, J.R. 1977. Changes in Walleye (Stizostedim viterum vitreum) Population in Rainy Lake and Factors in Abundance, 1924-75. J. Fish. Res. Board Can. 34:10, 969-1702.

Fabricius, E. and K.J. Gustafson. 1958. Some New Observations on Spawning Behavior of Pike, Esox lucius. Inst. Freshwater Res. Drottningham 39:23-54

Forney, John L. 1968. Production of Young Northern Pike in a Regulated Marsh. N.Y. Fish and Game Journal 15:2, 143-154

Johnson, F.H. 1956. Northern Pike Year Class Strength and Spring Water Levels., Trans. Am. Fish. Soc. 86:285-293.

1961. Walleye Egg Survivial During Incubation on Several Types of Bottom in Lake Winnibigoshish, Minnesota, and Connecting Waters., Trans. Am. Fish. Soc., 90:312-322.

McNamara, Fred. 1935. Breeding and Food Habits of the Pike, (Esox lucius) and Esox vermiculatus). Trans. Amer. Fish. Soc. 66:372-373.

Minor, J. and M. Meyer. 1978. Remote Sensing Analysis of the Vegetation of the Mississippi River Headwaters - Leech Lake, Minnesota, IAFHE RSL Research Report 78-3, University of Minnesota.

Minnesota Conservation Department. 1968. An Inventory of Minnesota Lakes. Minnesota Conservation Department, Division of Water Soils and Minerals, Bulletin #25.

Newburg, H.J. 1975. Evaluation of an Improved Walleye (Stizostedim viterum) Spawning Shoal with Criteria for Design and Placement. Investigational Report No. 340 Minn. Dept. Nat. Res., Div. Fish and Wildlife, Section of Fisheries.

Oakes, E.L. and L.E. Bidwell. 1968. Water Resources of the Mississippi Headwaters Watershed, North Central Minn., Dept. of Interior, U.S.G.S., Atlas HA-278.

Ryder, R.A., S.R. Keir, K.H. Loftus, and H.A. Regier. 1974. The Morphoedaphic Index, a Fish Yield Estimator - Review and Evaluation. J. Fish. Res. Board Can. 31:663-688.

Schupp, Dennis H. 1972. The Walleye Fisheries of Leech Lake, Investigational Report No. 137 Minn. Dept. Nat. Res., Div. Fish and Wildlife, Section of Fisheries.

1978. Walleye Abundance, Growth, Movement, and Yield in Disparate Environments Within a Minnesota Lake. In: Selected Coolwater Fishes of North American. Robert L. Kendal. Ed.,Spec. Pub. No. 11, American Fisheries Society 58-65.

Shaw, S.P. and C.G. Fredine. 1971. Wetlands of the United States, U.S. D.I., Fish and Wildlife Service Circular 39, 47 pp.

Smith, L.L., Jr. and D.R. Franklin. 1958. Determination of Factors Influencing Year Class Strength in Northern Pike and Largemouth Bass, DJ Project F12R, Minnesota Project Numbers 11 and 111.

Strand, Robert. 1976. Status of Leech Lake Walleye Population, 1976. Staff Report, Minn. Dept. Nat. Res., Div. Fish and Wildlife, Section of Fisheries.

1979. Assessment of Leech Lake Band Member Gillnet Fishery, 1978. Staff Report, Minn. Dept. Nat. Res., Div. Fish and Wildlife, Section of Fisheries.

U.S. Corps of Engineers, U.S. Army Engineer District, St. Paul. 1977. Plan of Study, Mississippi River Headwaters Lakes in Minnesota 144 pp. with appendice.

U.S. Fish and Wildlife Service. 1977. 1975 National Survey of Hunting, Fishing, and Wildlife-Associated Recreation., U.S. Dept. of the Interior, Fish and Wildlife Service, Minnesota Addendum.

Westerberg, D.D. 1962. Multiple Use Survey, Winnibigoshish and Leech Reservoirs. Chippewa National Forest, Minnesota, U.S. Forest Service, U.S. Dept. of Ag.

APPENDIX

## CONTENTS OF APPENDIX

Figure 1A. Survey Form for Northern Pike Egg Collections

# NORTHERN PIKE
# EGG COLLECTIONS

Date: ____/____/____ Time: ______

Location: ______ ________________________________________

Access description: ________________________________________

Weather: ________________________________________

General description: ________________________________________

________________________________________

________________________________________

Water temp. ______ Frost dist. ______ Minutes ______
Air temp. ______ Current dist. ______
Lake level ______ Ice dist. ______

| Vegetation type | No. passes | No. eggs | Eggs per pass | Area covered | Water depth | No. Adults | Den-sity | Acc-ess | Sub-stra | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sedge | | | | | | | | | | |
| Phragmites | | | | | | | | | | |
| Cattails | | | | | | | | | | |
| Bulrush | | | | | | | | | | |
| Rice | | | | | | | | | | |
| Burreed | | | | | | | | | | |
| Terrestial | | | | | | | | | | |
| Sed./Phrag. | | | | | | | | | | |
| Sed./Cat. | | | | | | | | | | |
| Phrag./Cat. | | | | | | | | | | |
| Sed./Phrag./Cat. | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

## DEFINITION OF TERMS FOR EGG COLLECTION SURVEY FORM

Date: Date of egg collections

Time: Time of egg collections

Location: Site number or verbal description of location of egg collection site.

Access description: Directions to site by land vehicles

Weather: Weather conditions at time of egg collections

General description: Verbal description of physical characteristics of egg collection site.

Water temp: Water temperature at site

Air temp: Air temperature

Lake level: Lake water level on day of egg collection

Frost dist.: Average distance from water edge of spawning site to where ground is frozen.

Current dist.: Average distance from water edge of spawning site to where water current is present

Ice distance: Average distance from water edge of spawning site to ice sheet.

Minutes: Number of minutes spent collecting eggs

Vegetation type: Kinds of vegetation present at site

No. passes: Number of passes of the net in each kind of vegetation

No. eggs: Number of eggs found in each kind of vegetation

Eggs per pass: Average number of eggs per pass in each kind of vegetation (No. eggs divided by no. passes)

Area Covered: Total area covered by net samples in each kind of vegetation (usually 2 sq. ft. multiplied by no. passes)

Water depth: Average water depth in areas where eggs were found in each kind of vegetation

No adults: Number of adults seen in each kind of vegetation

Density: Density of each kind of vegetation as rated by northern pike spawning area evaluation (see Northern Pike Spawning Area Survey Form, Figure A-2)

Access: Access to spawning area as rated by northern pike spawning area evaluation (see Northern Pike Spawning Area Survey Form, Figure A-2)

Substrate: Substrate of spawning area as rated by northern pike spawning area evaluation (see Northern Pike Spawning Area Survey Form, Figure A-2)

Figure 2A. Survey Form for Northern Pike Spawning Area Evaluation

Leech Lake Contract

Site No. ____________

Location No. ____________

VEGETATION

5 Grasses and Sedge

3 Phragmites

1 Cattails

____ 1 Bulrush

0 No vegetation

_ ____________

DENSITY

10 Very dense

7 Moderate

____ 4 Thin

1 Scattered

_ ____________

ACCESS

10 access point at least once every 3 feet

5 access point at least once every 5 feet

____ 0 access point less frequent than once every 7 feet

SUBSTRATE

5 Continuous vegetative root mass with no muck

4 Mostly vegetative root mass or debris with some muck

1 Muck or sand with loose vegetation on top

____ 0 Muck or sand only

PROTECTION

3 Protected

____ 0 Unprotected

CURRENT

3 Current present

____ 0 No current present

Total ____

36-30 GOOD

20-29 FAIR

10-19 POOR

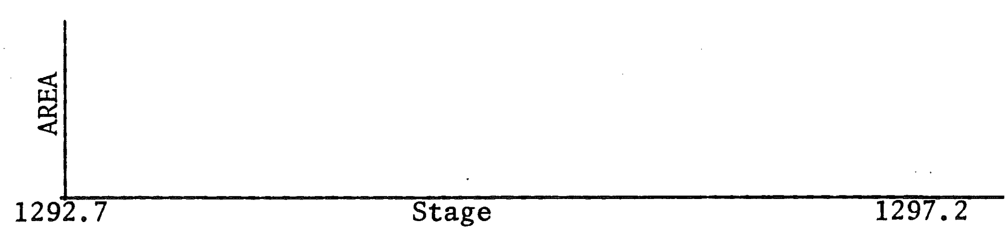
Minimum Depth ____

Maximum Depth ____

Optimum Depth ____

Average Width ____

Optimum Width ____



DEFINITIONS OF QUALITATIVE AND QUANITATIVE TERMS USED IN EVALUATING NORTHERN PIKE SPAWNING AREAS

<u>Definition of quality ratings</u>

Vegetation type

5 points - Grasses and Sedge: Grasses and sedge or mixtures with less than 75% of other plants.

3 points - Phragmites: At least 75% phragmites when mixed with sedge. In all other cases at least 25% phragmites

1 points - Cattails: At least 75% cattails or burreed

1 points - Bulrush: At least 75% bulrush

Rice: 5 points-Grassy appearance, stable, not decomposing
0 points-Mostly debris, easily moved by wind, decomposing

If the vegetation in a sample site is a mixture, the habitat needs to be at least 75% of the lower rate vegetation to be rated as such, otherwise, it receives the full points allotted for the higher rated vegetation.

Density

| | |
|---|---|
| 10 points-Very dense | 36 plants/sq. ft. or greater |
| 7 points-Moderate | 20 to 35 plants/sq. ft. |
| 4 points-Thin | 10 to 19 plants/sq. ft. |
| 1 points-Scattered | 0 to 10 plants/sq. ft. |

Points were assigned only in steps as described.

Access

10 points-access point at least once every 3 feet
5 points-access point at least once every 5 feet
0 points-access else frequent than once every 10 feet

Intermediate points were assigned for gradation between classes

Substrate

5 points-continuous detritus or root mat without loose sand or muck
4 points-nearly continuous detritus or root mat with some sand or muck
1 points-loose vegetation on sand bottom
1 points-some vegetation on muck bottom
0 points-sand or muck with no vegetation

Intermediate points were assigned for gradation between classes.

Protection

3 points-well harbored by land form
  1 point for every 15 feet of bulrush protecting potential spawning sites up to 2 points
  1 point for every 5 feet of phragmites or cattails protecting potential spawning sites up to 2 points
0 points-no protection

Intermediate points were assigned for gradation between classes.

Current

3 points-current within 10 feet
2 points-current within 25 feet
1 points-current within 50 feet
0 points-current farther than 50 feet

Definition of quantity estimates

Minimum Depth - The lowest water level at which a spawning area is flooded by 3 inches of water.

Maximum Depth - The lowest water level at which a spawning area is flooded by more than 36 inches of water (There is no maximum depth for floating areas)

Optimum Depth - The minimum water level with the maximum amount of spawning area that is accessible to pike and flooded by water 3 to 36 inches deep. (Applicable only for non-floating spawning areas)

Average Width - The average width of the spawning area that is accessible to pike and flooded by water 3 to 36 inches deep. (Applicable only for floating area)

Optimum Width - The average width of the spawning area at the optimum water depth that is accessible to pike and flooded 3 to 36 inches of water. (Applicable only for non-floating spawning areas)

Figure 3A-6A. Photographs showing characteristics of some typical northern pike spawning sites.

Figure A3.
Phragmites
Thin density
Good access

Figure A4.
Cattails and Sedge
Moderate density
Poor access
(Wave and ice damage)

Figure A5.
Sedge with some cattails
Very dense
Good access

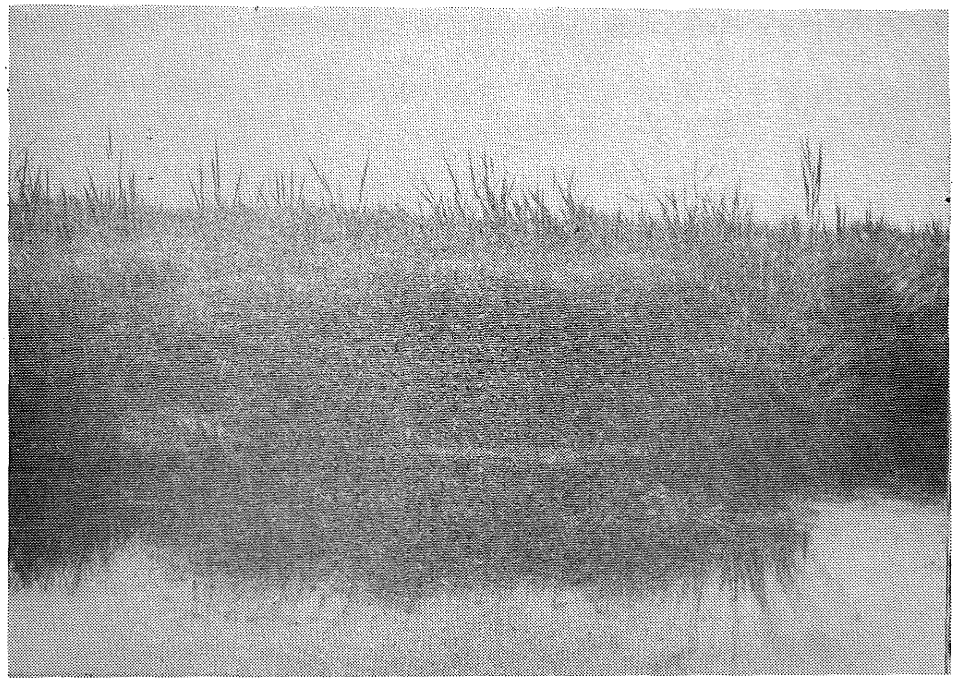
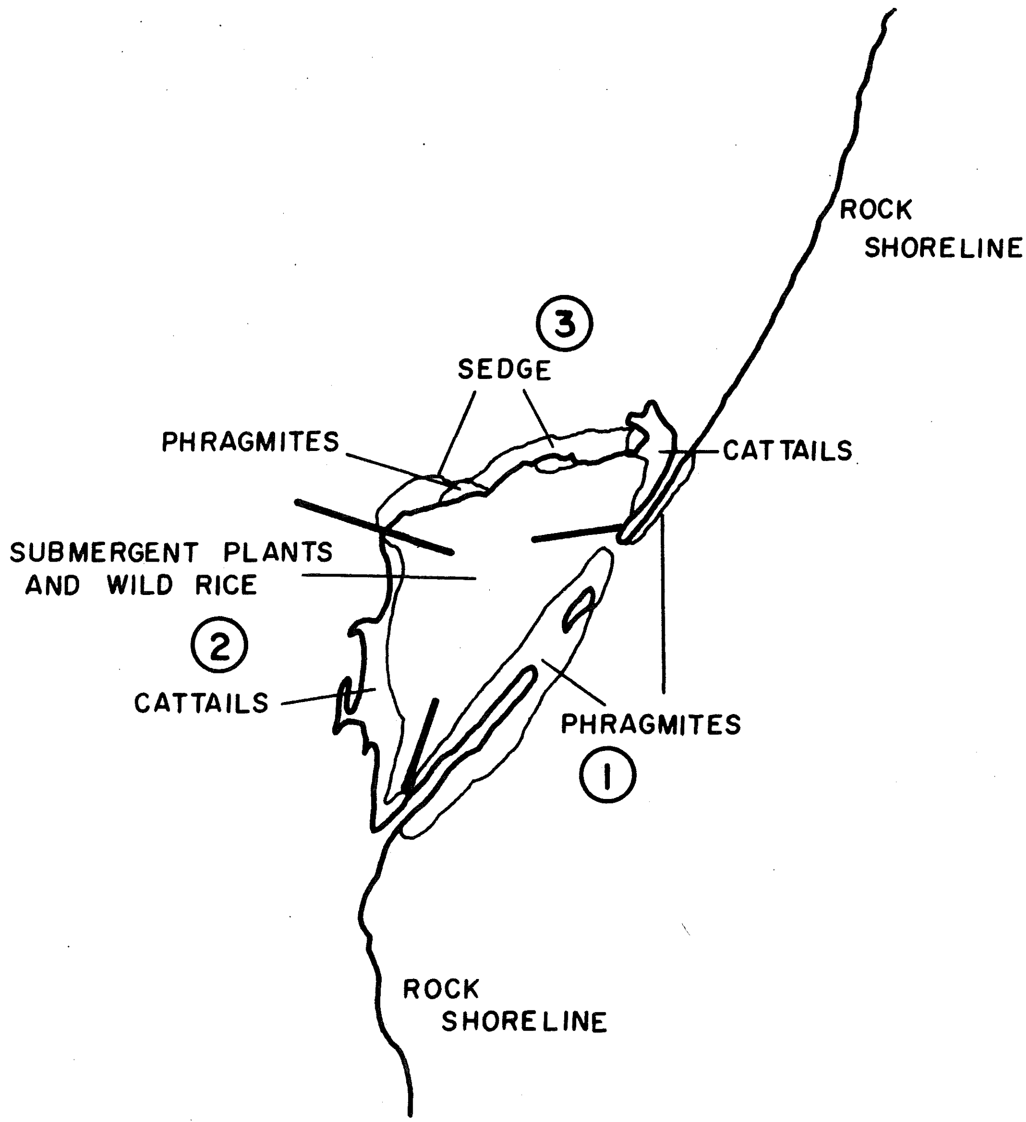


Figure A6.
Cattails
Moderately dense
Good access

Figure 7A. Example: Base map of site 50, used for evaluation of area as northern pike spawning site. T. 142N. R. 30W. Sec. 27.


ROCK
SHORELINE
3
SEDGE
PHRAGMITES
CATTAILS
SUBMERGENT PLANTS
AND WILD RICE
2
CATTAILS
PHRAGMITES
1
ROCK
SHORELINE

Figures 8A-10A. Evaluation forms describing habitat of site 50.

NORTHERN PIKE SPAWNING AREA SURVEY
Leech Lake Contract

Date 7/18/78
Site No. 50
Location No. 1

VEGETATION TYPE
- 5 Grasses and Sedge
- (3) Phragmites
- 1 Cattails
- 1 Bulrush
- 0 No vegetation

Score: 3

DENSITY
- 10 Very dense
- 7 Moderate
- (4) Thin
- 1 Scattered

Score: 4

ACCESS
- (10) access point at least once every 3 feet
- 5 access point at least once every 5 feet
- 0 access point less frequent than once every 7 feet

Score: 10

SUBSTRATE
- 5 Continuous vegetative root mass with no muck
- 4 Mostly vegetative root mass or debris with some muck
- 1 Muck or sand with loose vegetation on top
- (0) Muck or sand only

Score: 0

PROTECTION
- 3 Protected
- (0) Unprotected

Score: 0

CURRENT
- 3 Current present
- (0) No current present

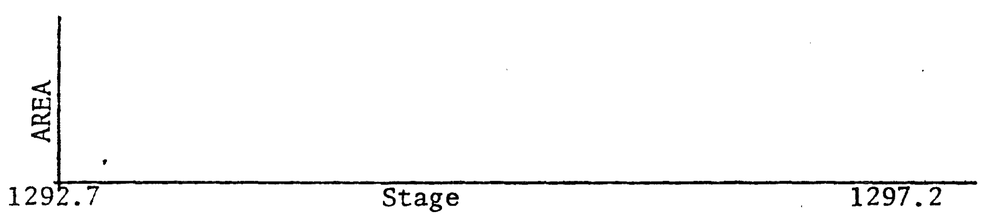
Score: 0

Total 17

36-30 GOOD
20-29 FAIR
10-19 POOR

Minimum Depth ____
Maximum Depth ____
Optimum Depth ____

Average Width ____
Optimum Width ____




Phragmites, no spawning area.

NORTHERN PIKE SPAWNING AREA SURVEY
Leech Lake Contract

Date 7/18/78
Site No. 50
Location No. 2

VEGETATION TYPE

1
- 5 Grasses and Sedge
- 3 Phragmites
- (1) Cattails
- 1 Bulrush
- 0 No vegetation

DENSITY

7
- 10 Very dense
- (7) Moderate
- 4 Thin
- 1 Scattered

ACCESS

10
- (10) access point at least once every 3 feet
- 5 access point at least once every 5 feet
- 0 access point less frequent than once every 7 feet

SUBSTRATE

3
- 5 Continuous vegetative root mass with no muck
- (4) Mostly vegetative root mass or debris with some muck
- 1 Muck or sand with loose vegetation on top
- 0 Muck or sand only

PROTECTION

0
- 3 Protected
- (0) Unprotected

CURRENT

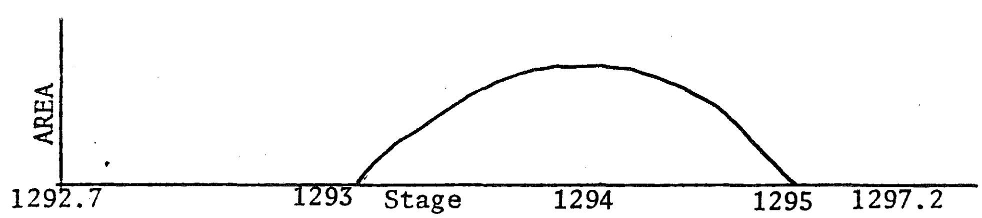
0
- 3 Current present
- (0) No current present

Total 21

36-30 GOOD
20-29 FAIR
10-19 POOR

Minimum Depth 1293
Maximum Depth 1295
Optimum Depth 1294

Average Width ____
Optimum Width 7




some grasses behind cattails

NORTHERN PIKE SPAWNING AREA SURVEY
Leech Lake Contract

Date 7/18/78
Site No. 50
Location No. 3

VEGETATION TYPE

(5) Grasses and Sedge
3 Phragmites
1 Cattails
1 Bulrush
0 No vegetation

5

DENSITY

(10) Very dense
7 Moderate
4 Thin
1 Scattered

10

ACCESS

(10) access point at least once every 3 feet
5 access point at least once every 5 feet
0 access point less frequent than once every 7 feet

10

SUBSTRATE

(5) Continuous vegetative root mass with no muck
4 Mostly vegetative root mass or debris with some muck
1 Muck or sand with loose vegetation on top
0 Muck or sand only

5

PROTECTION

(3) Protected
0 Unprotected

3

CURRENT

3 Current present
(0) No current present

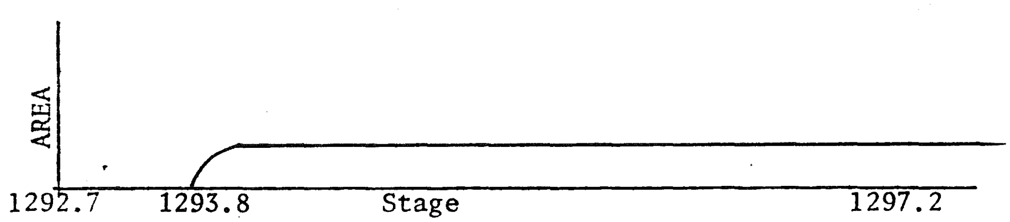
0

Total 33

36-30 GOOD
20-29 FAIR
10-19 POOR

Minimum Depth 1293.8
Maximum Depth floating
Optimum Depth ____

Average Width 7.5
Optimum Width ____



## NOTES ON THE GENERAL AVAILABILITY OF NORTHERN PIKE AND WALLEYE SPAWNING AREAS IN OTHER HEADWATER RESERVOIRS

### Pokegema Lake

The shoreline is predominately sand, rubble and rocks with some shallow marshy areas scattered around the lake.

Pokegema Lake drains into the Mississippi just upstream from Pokegema Dam. Because of this connection and its limited water storage capacity, the lake water level is directly affected by the combined discharge of Leech and Winnibigoshish Lakes.

In Pokegema Lake, northern pike spawning area are limited. The spawning areas that were examined were accessible only at water levels about 1272 m.s.l. However, in tributaries and flowages of Pokegema Lake there are an abundance of northern pike spawning areas that would accessible at most spring water levels.

Rocks and rubble cover much of the shoreline and extend into the lake 5 to 20 feet to depth of about 1269 m.s.l. These areas provide abundant spawning areas for walleye at all water levels.

### Winnibigoshish Lake

Winnibigoshish Lake lies over a glacial sand outwash and therefore most of its shoreline is sand. However, there are scattered patches of gravel, rubble and rocks along its shore and in shoal areas. There are few marshy areas in the lake itself.

Northern pike spawning areas are very abundant in all the flowages of Winnibigoshish Lake and one, the Pigeon River flowage, is managed as a controlled northern pike spawning area by the Minnesota Department of Natural Resources. The Mississippi River upstream from Winnibigoshish Lake also provides extensive potential northern pike spawning areas. Low water levels above 1298.94 m.s.l. were described as being detrimental by Westerberg, (1962). This is probably because of destruction to the vegetated areas by wave action and the uprooting of plants during high water.

Walleye spawning areas are limited and their accessibility is dependent on water levels. Westerberg in 1962 recommended water levels to be kept between 1297.44 m.s.l. to 1298.44 m.s.l. feet from April 20 to May 20 to provide suitable spawning habitat for walleyes. The lake was studied again in 1975 by the Department of Natural Resources and the same recommendation was made.[5/]

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5/ Unpublished memo, William Johnson, Minn. DNR, March 3, 1975.

Big Sandy Lake

The shoreline of Big Sandy Lake is predominately sand, gravel, rubble and rock and there are few marshy areas in the lake itself. However, cattails, burreed, wild rice and other aquatic plants are very abundant in the flowages and tributaries.

The water level is dependent on the flow of the near by Mississippi River which floods frequently in this area. The dam at the outlet, regulates waterflow either in or out of the lake, depending on local water conditions. The storage capacity of this lake is small so that it is rapidly filled to the normal summer level prior to or very shortly after the commencement of the spawning season.[6/] Under this plan of operation there appears to be abundant northern pike and walleye spawning habitat available. However, higher or lower water levels would have to be examined more closely to determine their effect on the spawning sites.

Northern pike spawning areas are abundant in the flowages and tributaries of the lake, especially in Aitkin Lake and Van Duse Creek.[7/]

Walleye spawning habitat is abundant throughout the lake and flowages. The dimensions and depth to which walleye spawning areas extend was not determined because water color and an algal bloom inhibited observation.

The shoreline showed little sign of erosion because of a well established ice ridge and vegetated banks.

Pine River Reservoir

The Pine River Reservoir is composed of 11 lakes. Although the shoreline of these lakes is primarily sand and loam, there are small patches of rocks, rubble and gravel. Erosion of the sandy high banks paralleling the shoreline is common. There are few marshy areas in this chain of lakes, except in Arrowhead Lake where wild rice, cattails, and sedge are abundant. The storage capacity of this reservoir is small so that it is rapidly filled to the normal summer level prior to or very shortly after the commencement of the spawning season.[8/] Under this plan of operation northern pike spawning habitat is limited but walleye spawning habitat is abundant. Higher or lower water levels would have to be examined more closely to determine their effect on the spawning sites.

Although northern pike spawning sites in these lakes are limited, tributaries that were not examined at this time, (Arrowhead Lake and Pine River) may provide enough spawning area to support the population.

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6/ Personal communications, John Seemann, U.S. Corps of Engineers, July 16, 1979.

7/ Minnesota DNR unpublish lake survey report, 1975.

8/ John Seemann *Ibid.* pp 56.

Spawning sites available to walleye are primarily gravel and smaller size rubble and can be found throughout the lakes. However, deposition of sand in these spawning areas may be a limiting factor. Dimensions of the spawning beds could not be estimated because cloudy, choppy water inhibited observations at the time of examination.

## Gull Lake

The Gull Lake Reservoir is composed of a chain of seven lakes. There is abundant sand, gravel, and rubble along the shorelines and all of the lakes have marshy areas. The storage capacity of this reservoir is small so that it is rapidly filled to the normal summer level prior to or very shortly after commencement of the spawning season.[9/]

Northern pike spawning habitat is present in all lakes, especially in Hole-in-the-Day and Roy Lakes. These spawning sites are extensive enough that normal water level fluctuations probably do not limit their availability to northern pike.

The shoreline materials are smaller than what is considered preferable for walleye spawning (Johnson 1961) consisting primarily of gravel one inch or smaller. This may provide adequate spawning material, since the walleye population of Gull Lake has generally been mostly self sustaining. These materials form a band paralleling the shore extending out four to five feet to a depth of about two feet at a water level of 1194 m.s.l. There is a large reef northeast of Rocky Point that has abundant rock (6 to 12 inches in diameter) and rubble (1 to 6 inches) that could provide good spawning substrate, but reproductive success in this area may be questionable because of the periphyton that covers the bottom materials.

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9/ John Seemann Ibid. pp 56.