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Technical Completion Report

Biological and Recreational Aspects of Water Level Management for Clear Lake, Iowa

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January 1983

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ABSTRACT

A literature review and field study were conducted to determine the influence of water level stabilization on biological and recreational aspects of a shallow lake. The aquatic plant community was dominated by emergent species that would be adversely influenced by water level stabilization. The fish community has been influenced by introduction of exotic species and by winterkill. Several species found in Clear Lake have strong habitat associations with aquatic plants. While there is evidence that the elimination of aquatic plants would effect the fish community, it is not possible to predict the manner in which the fish community might change as a result of water level stabilization or reduction in abundance of littoral plants. Recreationists preferred water level stabilization, but it was unlikely that their current perceptions included an understanding of potential impacts on the plant community.

KEYWORDS: lake, plants, fish, water level, fluctuation, management, recreation.

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PREFACE

Reason for the Study

A water reclamation demonstration project, involving re-use of municipal effluent and reduction of water removal from Clear Lake by surrounding municipalities, was proposed to meet future water needs in the area and to moderate drastic water level fluctuations occurring with 20-year drought cycles. No information was available to define the impact that water level stabilization, as well as the impact of continued water withdrawal and lake level fluctuations, could have on the biological and recreational aspects of Clear Lake. Considerable information was available on the biology of the fish populations from 1940 to the present, but earlier studies had not been designed to answer questions considered in this report.

Clear Lake Water Level Problem

The magnitude and frequency of droughts is illustrated in Fig. 1. Droughts occurred in the 1930s, 1950s, and 1970s at approximately 20-year intervals. During drought periods the lake level is reduced as much as 1 m (3.3 ft) below the spillway. Because of the shallow basin, this level of water results in severe reduction in lake area and water volume, and exposes large expanses of shoreline. Water level stabilization, particularly at the suggested high operating levels, could have an effect on littoral vegetation with subsequent influence on the fish community.

A mid-1970s drought and the subsequent lowering of Clear Lake brought to the public's attention the severity of both the ecological and human problems associated with continued consumptive use of water. As a response to the problem, planning was initiated to reduce domestic municipal consumption of Clear Lake water, to utilize ground water during drought periods, and to increase water flow to the lake by returning treated municipal effluent. Passing advance-treated wastewater through a nutrient-sink phase (marshes or constructed filter system) was part of the plan.

The proposed plan would have the effect of raising the average lake level and preventing drawdowns experienced in the past. Such an action would probably enhance recreational use of the lake; however, it could affect the balance that maintains emergent vegetation in shallow shoreline areas. The emergent vegetation, primarily giant bulrush (Scirpus validus), constitutes an ecological community adapted to water level fluctuation. It is possible that increasing average lake levels or stabilizing the lake level could damage the bulrush beds.

Emergent vegetation can serve as habitat for young-of-year fish, as well as habitat and feeding areas for adult fish. Loss of bulrushes could influence the Clear Lake fishery. Bulrush stands have been lost to property development around the lake and further loss of this habitat could seriously effect the fish community.

It is possible that water level fluctuation is an integral part of the ecological balances in Clear Lake. Information on current littoral plant communities, associated fish communities, and historical changes in these communities was needed to assess lake level stabilization or to determine the extent of water level fluctuation needed by these communities.

Fishing is one of the most popular water-oriented recreational uses of

Clear Lake. Other recreational activities at Clear Lake include boating, water skiing, hunting, swimming, picnicking and camping. Competition for the use of Clear Lake is severe and each category of use probably is influenced by lake level.

The communities of Clear Lake and Ventura, and the unincorporated village of Ventura Heights, are economically and socially entwined with recreational use of the lake. Water level fluctuations can influence the economic and social patterns of these communities by altering recreational use patterns. On-site measurements of users' attitudes were carried out to determine potential public use patterns to water level fluctuations. Historical changes in lake use as a response to water level fluctuations had not been measured. Therefore, little information was available with which to predict responses to lake level changes. Conducting an attitude survey was a means of inferring behavioral responses that could result from environmental change.

Information on biological community and user response to water level was needed to assess the viability of the Clear Lake water reclamation demonstration project, as well as similar projects in other areas.

Objectives

Describe the components and the extent of the littoral plant and fish communities of Clear Lake.

Determine the influence of continued water-level fluctuations and water-level stabilization on the littoral plant and fish communities of Clear Lake.

Determine the attitudinal differences between and among several categories of users toward fluctuating water levels and water-level stabilization of Clear Lake.

The project stemmed from environmental concern over water level fluctuation and stabilization. The goal was to describe the littoral plant and fish communities of Clear Lake and to determine the influence of continued water level fluctuation or water level stabilization on these communities. In addition, recreational uses of Clear Lake are likely to be influenced by water level. An indication of the public's response to fluctuating water level was obtained from measures of attitude. The attitudes of water-oriented users toward water level fluctuations by type of recreational activity was surveyed in order to assess how they are likely to respond to future water level management or the lack of it.

Research Approach

The present littoral plant community was described around the periphery of the lake. Description included identification of plant species, determination of their relative abundance, mapping of emergent vegetation beds, and assessment of water depths within and adjacent to the vegetation beds.

Fish communities associated with vegetated and nonvegetated shoreline areas were described. Comparisons of fish abundance between vegetated and nonvegetated areas were carried out to assess the importance of vegetation to the fish. Fish community assessment consisted of larval, young-of-year, and adult life stages.

Historical records of fish and plant abundance, as well as water level fluctuations, were summarized and analyzed to determine if such documentation could give insight into water level/plant/fish interactions.

A survey of technical literature dealing with water-level fluctuation influences on littoral plant and fish communities was conducted. Inference of possible responses at Clear Lake was made.

Possible behavioral responses of the public to lake level changes was assessed by attitude measurement instruments. On-site recreational users at Clear Lake and off-site individuals who use Clear Lake in ways other than recreation were surveyed. These measurement instruments were designed using basic survey techniques for socio-economic and general information. Attitudes were measured using a series of Likert semanic differential scales.

DESCRIPTION OF CLEAR LAKE

Clear Lake is a shallow, eutrophic lake located in western Cerro Gordo County in north-central Iowa. The lake lies in the lateral moraine of the Mankato lobe of the Wisconsin glaciation (Bailey and Harrison 1945). The city of Clear Lake is located on the northeastern shore of the lake.

Clear Lake covers an area of 1,474 hectares (3,643 ac) and ranks as the third largest natural lake in Iowa (Bailey and Harrison 1945). Of the 1,474 hectares, 13% are less than 1.5 m (5 ft) in depth, 22% from 1.5 to 3 m (5 to 10 ft), and only 50% from 3 to 4.5 m (10-15 ft), 15% exceed 4.5 m (15 ft) (Bailey and Harrison 1945). The maximum depth is approximately 6 m (20 ft). The mean depth is 3.7 m (12 ft).

Clear Lake is 7.7 km long (4.8 mi) with a maximum width of slightly over 3.2 km (2 mi) in the eastern portion (Bailey and Harrison 1945). The watershed of Clear Lake consists of 3,360 hectares (8,400 ac) of farmland and woodland (Pearcy 1952). Subsurface inlets are presumably significant since, except in dry years, the water level remains at or near the outlet level (Bailey and Harrison 1945).

In the early 1940's, approximately 42% of the shoreline was occupied by private residences and cottages; 29% by woodland; 20% by resorts, cabins, and commercial establishments; 8% by roadsides, grassland, and miscellaneous; and 1% by marsh (Bailey and Harrison 1945). Today, the proportion occupied by residences is even greater. Most of the lake's margin is a narrow, sandy beach. Occasional boulder reefs and rubble or gravel bottoms are present. The substrate in shallow water areas consists mainly of fine sand, which grades into a soft organic bottom at about the

1.8 m (7 ft) contour (Bailey and Harrison 1945).

According to Bailey and Harrison (1945) a chemical analysis of Clear Lake water showed a phenophthalein alkalinity of 16-18 mg/liter, methyl-orange alkalinity of 158 mg/liter, and a pH of 8.6. Pearcy (1952) found dissolved oxygen ranged from 5 to 12.1 mg/liter. The lake does not thermally stratify during the summer due to the shallow depth and wind action (Pearcy 1952). The maximum summer water temperature is around 30 C (86 F) in August (Pearcy 1952). Pearcy (1952) found secchi disk readings during the summer averaged about 1.5 m (5 ft). Sources of turbidity were mainly plankton and suspended soil particles. In more recent times the turbidity has been much higher with secchi disk readings of less than 0.3 m being quite common during the summer. The greater turbidity is due primarily to high phytoplankton levels.

AQUATIC PLANTS

Present Littoral Community

Plant surveys revealed a paucity of submerged species of plants growing at shallow depths (< 1.3 m) in Clear Lake. Two surveys of aquatic vegetation were made during July and August, 1981. Transects perpendicular from the shore to the outermost boundary of the vegetation zone were established at 20 m (66 ft.) intervals in July, and 40 m (132 ft) intervals in August, in each of the nine major vegetation beds shown in Figure 2. The 40 m transects were chosen for the August survey due to the fact that vegetation homogeneity did not warrant the use of closer transects. Vegetation was evaluated in 1 m^2 quadrats at 20 m intervals along each transect.

To obtain estimates of relative abundance of plants, the Braun-Blanquet Cover-Abundance Scale was employed (Braun-Blanquet, 1965). This scale is time efficient, is applicable to aquatic communities, and has been accepted by the scientific community (Mueller-Dombois and Ellenberg, 1974). Water depth, substrate type, and distance to shore were recorded along with the taxa encountered and cover-abundance designations for each species. When applicable, information was recorded on the condition of the vegetation and habitat, particularly in areas of muskrat or man-made damage to the vegetation beds. A total of 1,418 quadrats were sampled over the summer period.

Distribution maps were constructed from aerial photographs taken in 1980 and from data collected in 1981. Nine major vegetation beds were identified (Fig. 2). Photographs were used to ascertain the shape and orientation of each bed. All plant and water depth data were taken from the 1981 surveys as were bed dimensions. Different species were indicated by various symbols and types of shading (Fig. 3). Total areas were determined for those species indicated by shading. Species designated by symbols were usually solitary individuals or represented very small numbers of species and measurement from the maps was therefore not practical. Some taxa such as Scirpus spp. were lumped together in the mapping procedure due to difficulties in their taxonomy. Depth contours were drawn for each vegetation bed. Only the map for the McIntosh East vegetation bed was incomplete. An outer bed of Scirpus (0.8 ha) was not measured because water depth prohibited wading.

The total area of each of the nine major vegetation beds surveyed in 1981 (as measured by planimetry) is shown in Table 1. Areas for the four dominant plant taxa within each of the nine beds is shown in Table 2. Plant distribution maps for all nine beds and their depth contours are illustrated in Fig. 4-14. For the purposes of this report, Typha and Scirpus species have not been differentiated on the maps or in Table 2. Typha in Clear Lake, with the exception of Typha latifolia, tend to overlap considerably and, therefore, only the general areas where each species was encountered is indicated on the maps. The most dominant form of Typha is the hybrid, T. glauca. Scirpus validus and Scirpus acutus have not been differentiated due to the difficulty of identifying them in the field.

The present species composition of the Clear Lake aquatic flora is listed in Table 3. A total of 24 species of aquatic vascular plants were found in 1981. The relative abundance of emergent, submerged, and floating-leaved macrophytes was determined (Table 4). The Clear Lake flora was dominated by two species, softstem bulrush (Scirpus validus) and cattail (Typha glauca). All other species were of minor importance.

The softstem bulrush and cattail were clumped in dense beds near the shoreline, primarily at the western end of Clear Lake. An estimated 22.6 hectares (56 acres) of bulrush and cattail beds were found in Clear Lake (Table 1).

The water depths at which the aquatic flora were found was measured and summarized (Table 5). Distinct depth contours were associated with the occurrence of most species. The dominant softstem bulrush (Scirpus validus) and cattail (Typha glauca) occurred at depths of 10 to 170 cm and 20 to 110 cm, respectively. Pearcy (1952) found that Scirpus validus extended out to the 2 m depth contour. According to Dabbs (1971), Scirpus validus tended to grow in shallower water than Scirpus acutus. He found the mean depth of water in which Scirpus validus grew was 43 cm and rarely over 60 cm. The mean depth of water in which Scirpus acutus was found was 109 cm and it frequently occurred at depths up to 150 cm.

Submerged vegetation

Potamogeton nodosus was the most common of the three Potamogeton species in 1981. As reported by Pearcy (1952), it is found commonly on the shore side of the bulrushes along the north shore. Scattered plants were found in the west end of the Farmer's Beach area near shore and in sparse beds by Ventura Heights in the southwest end of the lake. It was found growing in a range of soil types from sandy to very silty.

Potamogeton pectinatus was found primarily near shore along the north shore of Clear Lake, generally in shallow water. Pearcy (1952) found P. pectinatus to be very abundant in the west end of of the lake, but only the Ventura Heights area had scattered plants in 1981.

Potamogeton illinoensis was found only on the east and west sides of the point extending south from McIntosh Woods State Park. It, too, was reported to be widely distributed about the lake by Pearcy (1952).

Ceratophyllum demersum was found at only one site on the south shore of the lake. A single strand was found entangled in a Scirpus stem on the east edge of the Farmer's Beach bed. As the small marsh adjacent to the Farmer's Beach site contained Ceratophyllum, it is presumed that the specimen washed out of the marsh area into the lake.

One plant species not found prior to 1981 was Utricularia vulgaris, a member of the bladderwort family. It was found growing west of McIntosh Woods point and in a deep cut in the Black Rushes in water up to one meter deep.

Floating-leaved Vegetation

Nymphaea tuberosa and Nuphar advena were commonly found in water one meter deep in vegetation beds on the west side of McIntosh Woods, on both sides of the point extending south from McIntosh Woods, and in the Black Rushes. Overall, Nymphaea tuberosa was more abundant than Nuphar advena at the west end of the Farmer's Beach site.

Lermna minor and Wolffia columbiana were small, free floating plants found in sheltered areas of the north shore and west end of the lake.

Polygonum coccineum was not found in 1981. A survey in late July of 1982, however, found it to be common in water under half a meter in the Ventura Heights area in the southwest end of the lake. The leaves of Polygonum coccineum were floating on the surface. In contrast, Polygonum amphibium may extend its leaves out of the water and it was found only at one quadrat located in the western portion of the Black Rushes.

Emergent vegetation

Three species of cattail were found in Clear Lake. Typha latifolia, the common cattail, was found in muck substrates at water depths of less than 0.5 m in the Kaster's Kove vegetation bed on the west side of McIntosh Woods and on the west side of the point extending south from McIntosh Woods. A few scattered plants were noted in the shallows of the Ventura condominium bed in the northwestern part of the lake. Typha angustifolia, the narrow-leaved cattail, was found scattered in deeper water in the Kaster's Kove beds, McIntosh West, McIntosh East, the Baptist Camp bed, Black Rushes, North Shore, and South Bay sites. By far, the most dominant of the cattail forms present was Typha glauca Godr., a hybrid between Typha latifolia and Typha angustifolia. It was found in every vegetation bed surveyed except for the Farmer's Beach site. Typha glauca had not been reported in Clear Lake prior to the 1981 surveys. The spread of Typha in Clear Lake appears to have occurred rapidly. A plant distribution map drawn by Pearcy (1952) showed only a few stands of Typha latifolia along the north shore of the lake, primarily in the Black Rushes and McIntosh East. Mrachek's 1966 distribution map shows Typha restricted to the Ventura condominium bed and a small area of the North Shore bed. None were found in the Black Rushes. In 1981, over 5.87 hectares (14.5 acres) of Typha were noted.

Carex comosa was found growing in shallow waters on the shore side of the rushes along the north shore of the lake and along the west side of McIntosh Woods south of the boat access. Carex was usually found as solitary plants growing in deep muck substrates.

Salix interior, the sand-bar willow, was found in various locations along the shore of the lake. Salix suckers were not found in waters exceeding 0.3 m in depth.

Phragmites communis was reported from two locations, McIntosh West (north of the swimming beach), and the North Shore vegetation bed. The substrate at both sites was primarily sand.

Bidens cernua was noted in September of 1981, flowering on floating vegetation mats in the shallow waters off of the east side of McIntosh Woods and the Black Rushes. Other marginal emergent vegetation found growing in Kastor's Kove, McIntosh West, and McIntosh East vegetation beds were Sagittaria latifolia, Cyperus sp., and Eleocharis palustris. Muskrat feeding activity apparently eliminated most of the Sagittaria early in the growing season and only a few mature plants were noted in the fall.

Equisetum fluviatile was found in one location in 1981. A small stand was located off the west side of McIntosh Point in shallow water.

Scirpus was by far, the most dominant plant genus found in Clear Lake during the survey. Two species, Scirpus validus, the softstem bulrush, and Scirpus acutus, the hardstem bulrush, are distributed lakewide. The distribution of the two species was combined on the distribution maps (Figure 4-14). Scirpus validus and Scirpus acutus are difficult to identify in the field and there is some question as to whether the two species are separable (Koyama, 1958; Boivin, 1967; Miller and Beal, 1972). Dabbs (1971) found that many of the criteria used to identify the two species in the field, such as hardness of the culm, stem color, and even inflorescence form, are not good diagnostic characteristics. Problems of identification were compounded when it was discovered that the two species hybridize (Dabbs, 1971). The hybrid plants display a number of intermediate characteristics between the parent species. Dabbs (1971) and Fernald (1950) have advocated using floral scale lengths and relative lengths of floral scales to differentiate the two species.

The history of Scirpus in Clear Lake is confusing. Bailey and Harrison (1945) reported Scirpus acutus as very abundant and made no mention of Scirpus validus. Just five years later, Parsons (1950a) found only Scirpus validus and no S. acutus present. Since Parson's paper in 1950, only S. validus has been reported from Clear Lake although clear examples of both species were noted in 1981.

Scirpus validus tends to grow in shallower water than does S. acutus (Dabbs, 1971). Dabbs found that the mean depth for S. validus was 43 cm, whereas S. acutus was found growing at a mean depth of 109 cm in the Saskatchewan River delta. He stated that S. acutus was frequently found in depths up to 150 cm. Dabbs reported that the two species overlap in water depths of 60 to 65 cm. Fassett (1975) reported that S. validus preferred water depths of several feet. Scirpus found in Clear Lake grow to a depth of 1.6 meters. From this information, one would tend to believe that the plants growing at this depth would be S. acutus, rather than S. validus, the label they have carried for the past 37 years. It is possible that they have historically been misidentified. A number of the characteristics of these deep-water plants appear to be intermediate between S. validus and S. acutus, raising the possibility that they are hybrid plants. Further research is needed to solve the identity of Clear Lake's Scirpus populations.

The shift from Scirpus acutus in 1945 to Scirpus validus in 1949 is a possibility. Dabbs (1971) reported such a shift of Scirpus in reverse order in Big Lake, Saskatchewan. In 1966, it was observed that S. validus formed a continuous band of vegetation from the shoreline to a depth of about 45 cm along the northwest side of the lake. S. acutus was found in a fragmented band in deeper water beyond S. validus. High water levels from 1966 to 1968 resulted in a reversal of the relative abundance of the two species. In a matter of two years, S. acutus spread to form a solid community around the northwest shore of the lake, whereas S. validus became restricted to a narrow fringe in the shallow water.

Historical Trends in Littoral Community Structure

Most of what is known of the history of the vegetation in Clear Lake was collected by fisheries and limnology students as adjuncts to their other research problems. For this reason, data often has been subjective and incomplete. The first published account of aquatic plants in Clear Lake was the work of Shimek (1896), a botanist. His species list was the result of a three-day collecting trip in July 1896. Bailey and Harrison (1945) briefly described the vegetation of the littoral zone in their report on fish species of Clear Lake. Parsons (1950b) reported that submerged vegetation was so abundant in 1945 and 1946 that boating was nearly impossible in the west end of the lake. As a byproduct of his research, Parsons (1950a) compiled a plant species list for the lake. Pearcy (1952) was the first to describe and map the depth and area distributions of aquatic macrophytes. He compared the species lists of Parsons (1950a) and Bailey and Harrison (1945) to his own. Pearcy (1952) noted a decline in abundance of submerged plants and emergent bulrush in 1948, 1949, and 1950, but an increase in 1951. Little is known of the vegetational changes that occurred between 1951 and 1956, although Neal (1962) noted that vegetation was moderately abundant from 1951 to 1954. Ridenhour (1958) briefly described the dominant vegetation in his study of young game fish ecology in Clear Lake. Prior to the present study, the last account of aquatic vegetation in Clear Lake was by Mrachek (1966). His study of macroscopic invertebrates on higher aquatic plants included description and mapping of the general distribution of dominant plant species and determination of their relative abundances.

Table 3 presents the list of plant species and their relative abundance in Clear Lake studies between 1896 and the present study. In general, the plant community has shifted from one dominated by submergent plants to one dominated by emergent plants. Major plant groups dominant in the later studies (bulrushes and cattails) were not listed in Shimek's 1896 survey.

Since Shimek (1896) first collected plants at Clear Lake 86 years ago, a number of prominent changes have occurred in the species composition. Of the 52 aquatic plant taxa previously identified from Clear Lake (Table 2), 23 were found in 1981. Five species were found in 1981 for the first time in Clear Lake. Some plants such as Ceratophyllum demersum, Myriophyllum sp., Elodea canadensis, Potamogeton Richardsonii, and Potamogeton natans have drastically declined or disappeared completely since the mid-1940's (Bailey and Harrison, 1945). According to Mrachek (1966), Ceratophyllum demersum, Elodea canadensis, Myriophyllum exalbescens, Najas flexilis, Potamogeton natans, and Vallisneria americana were all found in Clear Lake. However, with the exception of a single strand of Ceratophyllum demersum at the east edge of the Farmer's Beach vegetation bed, these species were not found in 1981. Neither Mrachek (1966) nor his predecessors mentioned the cattail hybrid Typha glauca in Clear Lake, yet in 1981 it was the dominant Typha species. Other species collected by Mrachek in 1966 but not found in 1981 were Heteranthera dubia, Potamogeton pusillus, Sagittaria teres, and Zannichellia palustris.

No vegetation was found growing at depths greater than 1.6 m (5.3 ft) in 1981, but Pearcy (1952) reported vegetation growing at depths up to 4.5 m (14.9 ft). The average Secchi disc reading in 1981 was 0.4 m (1.3 ft) compared to 1.5 m (5.0 ft) reported by Pearcy in 1952. Table 6 shows that apparently turbidity-tolerant species are numerically dominant in Clear Lake while turbidity intolerant species have been reduced or have disappeared.

Two species of bulrush (Scirpus validus and Scirpus acutus) are important constituents of the emergent vegetation of Clear Lake. They are important producers in lakes when they occur in large numbers (Wetzel 1966). Differentiating the two species is difficult (Dabbs 1971) and is suspected to have been a problem for earlier Clear Lake workers. Softstem bulrush is the dominant species in Clear Lake, although Bailey and Harrison

(1945) found only hardstem bulrush (Scirpus acutus). Both Pearcy (1952) and Mrachek (1966) reported only softstem bulrush.

Of the taxa showing an increase in abundance, the three bulrush species are the most pronounced. Pearcy (1952) showed the lake proper to be free of cattail in 1951. Typha latifolia was reported as common by Bailey and Harrison (1945) whereas only three small stands were found in 1981. Both Typha angustifolia and Typha glauca are recent additions to the Clear Lake flora. Typha glauca is the most common cattail species in the lake, while Typha angustifolia is limited to the outer perimeter of vegetation beds in close association with Typha glauca.

Effect of Water Level on Littoral Plants

A primary objective of this study was to determine the effects water level stabilization may have on plant communities in Clear Lake. Since water depth is one of a myriad of factors determining plant zonation in freshwater lakes, a summary of knowledge of these factors and their relation to water depth is offered. An attempt is made to relate these factors to the unique situation present in Clear Lake. Information has been drawn from recent treatises on aquatic plant zonation and ecology (Davis and Brinson, 1980; Hutchinson, 1975; Kadlec and Wentz, 1974; Spence, 1982; Whitlow and Harris, 1979), as well as a review of pertinent literature.

Major factors affecting the establishment and maintenance of aquatic vegetation are light, temperature, pressure, turbidity, substrate, wave action, current fluctuation, water depth, and water chemistry (Boyd, 1971). Spence (1982) breaks down these factors into two categories: those varying solely in the vertical plane (light, temperature, pressure) and those that have both vertical and horizontal components (water turbulence and substrate). It is important to note that although these factors are treated individually, their combined effects are probably the most important determinants of plant zonation and are the least understood.

Light

It is accepted that light plays the most important role in determining the maximum depth at which plants can grow and that the lower limit of illumination allowing growth varies among plant species (Davis and Brinson, 1980; Hutchinson, 1975; Pearsall, 1920; Wilson, 1941). Davis and Brinson (1980) defined the euphotic zone as the region from the surface to the depth at which 99% of the incident surface light has disappeared. They stated that the intensity of light at this level (1%) represents the compensation light intensity at which photosynthesis and plant respiration are in balance. Plants survive at this depth, but no growth is possible (Meyer et al., 1943).

The amount of light reaching chloroplasts in plant leaves can be reduced by a number of factors (Spence, 1982). Epiphytes and phytoplankton may shade submerged aquatic plants, thus reducing photosynthesis (Kirk, 1975; Sand-Jensen, 1977; Spence, 1982). Westlake (1966) reported that self-shading by submerged macrophytes may be a problem depending upon plant biomass. Back-scattering due to turbidity generated by wind disturbance of sediment, may cause surface radiation loss (Spence, 1982). Finally, turbidity, generally defined as light scattered from suspended silts and clays in water (although the term may be applied to phytoplankton and organic particulate matter), is extremely important in light attenuation through scattering and absorption (Davis and Brinson, 1980). Spence (1982) stated that turbidity of inorganic origin is likely to be most significant as a factor in shallow lakes, in particular where bottom sediments lie wholly within the wave-mixed zone. A dramatic illustration of the effect of turbidity on photosynthesis was given by Meyer and Heritage (1941). They found that high turbidity in Lake Erie reduced the compensation point for Ceratophyllum demersum from 8-10 m to 1-2 m.

Secchi disc transparency can agree well with turbidity of inorganic particles. A number of studies have related Secchi depth to the percent light penetration at which the Secchi disc disappears (Cole and Barry, 1973; Poole and Atkins, 1929; Verduin, 1956). Results of these studies have found that factors of 2.7 to 5 times the Secchi depth approximate the 1% light level, depending upon the body of water. Cole (1975) listed a factor of 3.0 as the general rule-of-thumb used by limnologists. Holmes (1970) suggested that a factor of 3.5 be used for water with a Secchi depth of less than 5 m and a factor of 2.0 for water with Secchi depth of 5 to 12 m.

Davis and Brinson (1980) plotted maximum depths for ten submerged plant species against their Secchi depths and discovered a linear relationship at shallow depths for most species. This suggested that at Secchi depths of 2.5 m or less, turbidity was an important factor affecting the maximum depths of growth. Species found in deeper areas of these waters would then be expected to have a degree of turbidity tolerance. Kadlec and Wentz (1974) compiled a list of aquatic plants and their relative tolerances to turbidity and disturbances, part of which has been reproduced in Table 6 for plants found in Clear Lake.

Temperature

Generally, temperature does not limit the downward penetration of aquatic vegetation in lakes (Pearsall, 1920; Spence, 1964). There is some evidence, however, that the sharp decrease in temperatures below the epilimnion in thermally stratified lakes may affect the lower depth limits of plants, particularly where the epilimnion is shallower than the macrophyte photic zone (Sheldon and Boylan, 1977; Dale and Gillespie, 1977; Spence, 1982).

Although Bachmann et al. (1980) reported Clear Lake to be partially thermally stratified in 1979, no evidence was found in 1980 and 1981 that the lake had stratified. Water temperatures fluctuated between 11° and 25°C during the months of June, July, and August.

Pressure

The role of hydrostatic pressure in the vertical distribution of submerged aquatic plants is unclear. The general view has held that excessive pressure can inhibit shoot and root growth of aquatic plants (Gessner, 1952; Golubic, 1961, 1963, as quoted in Hutchinson, 1975). However, according to Spence (1982), recent evidence (Sheldon and Boylan, 1977; Bodkin, 1979) suggested that pressure is probably not involved in limiting the water depths to which aquatic plants may grow. Since the maximum depth of Clear Lake is 5.8 meters water pressure is not considered a plant-limiting factor.

Substrate

According to Hutchinson (1975), substrate is of importance to plants and plays a determining role in their antecology. Davis and Brinson (1980) discussed the importance of roots in nutrient uptake from sediments. Although it has been accepted that roots take up nutrients from sediment (Davis and Brinson, 1980; Spence, 1982), plants may exhibit significant ion absorption through leaves and shoots. Davis and Brinson (1980) reported that the actual amount of absorption in field situations may be related to the relative supply of nutrients in the water and sediments. Therefore, depending upon vegetation type and water and substrate quality, substrate may be of varying importance for nutrient acquisition by aquatic plants.

In a physical sense, the type of substrate may play a role in the plant's ability to remain rooted in currents or when subjected to erosion from wave action.

Wave Action and Currents

In lakes, the establishment of plants may be prevented by wave action (Davis and Brinson, 1980; Hutchinson, 1975). Most species require relatively calm and sheltered water. According to Davis and Brinson (1980), the absence of plants in the shallowest zones around lakes is the result of abrasive action of waves rather than sediment instability. Hutchinson (1975) stated that the amount of erodable inorganic material in this shallow zone is small (such as Clear Lake) when the basin is mature. Plants which survive in this zone must be resistant to fragmentation.

Wave action may have a definite effect on species diversity. Thunmark (1931) discovered this effect in comparing two shores of Lake Fiolen in

Finland. An exposed shore with sediment deposition at 3.75 m (12.4 ft) water depth had 18 species whereas the sheltered shore with deposition at 1.25 m (4.1 ft) supported 32 species of plants. Reduced water movement may increase silting and accumulation of organic materials, thus creating sites more favorable for plant colonization.

Spence (1982) concluded that emergent vegetation distribution around a lake was largely controlled by the degree of wind-induced wave motion. He stated that the proportion of colonized shoreline was inversely related to the mean fetch of the wind. He also stated that above an undetermined degree of exposure, there were no emergent plants because of direct effects on the establishment and growth of the plants themselves or because of the lack of suitable substrate particle size within colonizable depths.

Spence (1982) hypothesized on the controlling factors of zonation. He postulated that the extent to which wave action (with sediment or light) determines zonation depends on the relative amount of vegetation lying within or below the wave-mixed zone of the lake. Three situations arise in Spence's hypothesis:

1) If the macrophyte zone lies mainly in the wave-mixed zone of the lake, wave action, type of sediment, and rate of sedimentation control zonation and distribution of all macrophytes. Since both horizontal and vertical variations will occur in these factors along a shoreline, species diversity should be different between sheltered and exposed areas.

2) If the macrophyte zone lies mainly below the wave-mixed zone in depositional substrates, most of the vegetation grows in a zone where

at any depth around the lake the sediments are uniform and vary only with depth. In this situation, wave action does not effect vegetation but light is the crucial factor. Species diversity should decrease as the water gets deeper.

3) If the macrophyte zone is not more than twice the depth of the wave-mixed zone, then both sediment type and light control plant zonation.

Drawdowns and flooding

Water depth has been one of the most frequently discussed factors affecting plant distribution in wildlife and fisheries literature. These discussions often pertain to the use of drawdowns or flooding to control aquatic vegetation and to manage preferred wildlife species. A considerable amount of information on artificial drawdowns in marshes, lakes, and reservoirs exists (Beard, 1969, 1973; Burgess, 1969; Hall et al., 1946; Harris and Marshall, 1963; Hestand and Carter, 1974; Kadlec, 1962; Kadlec and Wentz, 1974; Lantz et al., 1964; Mathis, 1966; Meeks, 1969; Nichols, 1975; Richardson, 1975; Tarver, 1980). Little is known, however, about the effects of natural water level fluctuations on lake biota.

Seeds of aquatic plants show a diversity of germination habits in relation to water levels. Some require dewatering, others germinate on the surface and require strandage for establishment, while others can germinate on the lake bottom. Cattails have been extensively studied because of their importance to wildlife. In his studies on the common cattail, Typha latifolia, Yeo (1964) found these plants can germinate in mud or water in depths up to 0.7 m (2.5 ft). Hall et al. (1946) reported that Typha latifolia needs moist soil and a low oxygen environment in order to germinate. On the other hand, Bedish (1967) reported that the optimum moisture condition for seed germination, growth, and vegetative reproduction of Typha glauca was a flooded condition with a water depth of 2.5 cm (one inch). Species of many other taxa require dewatering for seed germination (Kadlec, 1962; Harris and Marshall, 1963; Van der Valk, 1981), while others may germinate on the lake bottom (Hall et al., 1946).

Van der Valk and Davis (1978) assessed the effects of water depth at drawdown and normal levels on aquatic plant germination in prairie marshes in northcentral Iowa. They found that under drawdown conditions, emergent and mudflat plants were the dominant species that germinated. Under submerged or normal water levels, the dominant plants to germinate were submerged and floating-leaved species. They concluded that standing water has a significant impact on which seeds germinate in a marsh seedbank. Weller (1975) suggested that since many emergent seedlings float, it is doubtful that germination of seeds of some emergents under flooded habitats results in the establishment of many plants.

Once established, growth of individual species can be affected by water level. Robel (1962) reported a strong relation between water level of a marsh and growth of submerged vegetation. He found that after a 7.5 cm (3 in) rise in water level, a decrease in the total amount of submerged vegetation occurred in the original area of the marsh. Vegetation production increased in the shallow areas, but decreased in the deeper areas. Robel also noticed an increase in the vigor of some aquatic emergents, most noticebly alkali bulrush (Scirpus poludosus).

Tolerances to water depths differ among emergent species (Uhler, 1944 McDonald, 1955). Harris and Marshall (1963) found Scirpus validus died-out within two years in water over 28 cm (15 in) deep following reflooding after a drawdown. Weller and Frederickson (1974) reported that although Scirpus validus can reproduce vegetatively in flooded periods, it has a life span of only 2 to 3 years.

Tolerances of submerged species also vary (McCombie and Wile, 1971). According to Kadlec and Wentz (1974), most submerged species require reasonably stable water levels. A list of water depth ranges, along with a number of other preferred physical-chemical conditions for numerous aquatic and marsh plants was found in Kadlec and Wentz (1974).

Water levels can be responsible for changes in plant distribution, zonation, and succession. Van der Valk and Davis (1976) found that water level fluctuation may cause aquatic vegetation to shift position in relation to the shoreline. A shoreward shift of many species occurred in response to returning high water levels after a natural drawdown in a prairie kettlehole. Merna (1964) reported the decline in submergent forms of vegetation in a Michigan marl lake when the area of the lake was increased from 134 hectares (335 acres) to 176 hectares (435 ac). High water levels reported by McDonald (1955) triggered succession in submerged species. Drawdowns appear to negatively impact submergent species (Mathis, 1966; Beard, 1966).

Marsh habitat cycles

In its natural state, the vegetation of Clear Lake may be thought of in terms of "marsh habitat cycles" (Weller and Spatcher, 1965). A number of papers have discussed the marsh cycle phenomenon (Weller and Spatcher, 1965; Weller and Fredrickson, 1974; Weller, 1978; Van der Valk and Davis, 1978). While Clear Lake is not a marsh, the importance of this cycling phenomenon in explaining vegetational changes in Clear Lake warrants discussion.

The cyclic pattern of vegetational change in prairie marshes may require 30 years (Van der Valk and Davis, 1978). There are four to five stages in marsh cycles. The first stage is the "germination" phase (Weller, 1978) in which low water levels are present and sedges and shallow-marsh plants dominate. Seeds of both emergent and mudflat species germinate during this period. When water levels return to normal, the mudflat species are eliminated and germination of emergent plants ceases, heralding the "regenerating" phase (Van der Valk and Davis, 1978). At this time, the marsh consists of mixed plant types as seeds of submerged and free floating plants germinate. Growth of emergent species is generally due to vegetative reproduction. Most are not sufficiently adapted to water to enable seed germination in deep water (Weller, 1981). Van der Valk and Davis (1978) reported that emergent species such as <u>Typha glauca</u> and <u>Scirpus validus</u> generally increased in abundance during the "regenerating" marsh phase.

The third phase, the "degenerating" marsh phase (Van der Valk and Davis, 1978) or "open marsh" phase (Weller and Spatcher, 1965), is characterized by a rapid decline in emergent vegetation and increase in submerged and floating-leaved plants. Van der Valk and Davis, (1978) reported that <u>Scirpus validus</u> and <u>Sagittaria latifolia</u> populations were the first to disappear from a northwestern Iowa marsh during this phase and emergent cover dropped from 34% to 6%. Weller and Spatcher (1965) suggested that Scirpus validus and Sagittaria latifolia are intolerant to high water levels. Both Weller (1978) and Van der Valk and Davis (1978) have stated that muskrat feeding contributes to the disappearance of emergent vegetation at this time, particularly cattails.

The final phase is the "open water marsh" phase (Weller and Spatcher, 1965) or "lake marsh" (Van der Valk and Davis, 1978). This phase resembles a lake as most of the emergent vegetation is eliminated and floating-leaved and submerged vegetation become dominant. The marsh remains in the "open water marsh" or "lake marsh" stage until the water level falls and the cycle repeats.

The facts that much of the vegetated portion of Clear Lake is shallow (under 2 m in the weather portion of the lake) and the lake exhibits a 20-year cycle in water level fluctuation provide an explanation for the distribution of Clear Lake's vegetation in terms of marsh cycles. Many changes observed in the lake may be analogous to phases in the marsh cycle. Clear Lake has undergone periods of extreme drought in which the germination phase could have been triggered. Such a phase in the lake's history may have occurred in 1945 and 1946 (Parsons, 1950a) when vegetation was so dense in the western part of the lake that boat traffic was impaired.

When research was begun on Clear Lake in 1980, water levels were high following a drought the previous year. Although clear examples of "germination" and "regenerating" phases were not witnessed, in the three years hence a process similar to Van der Valk and Davis (1978) "degenerating" phase was observed. Most notable was the decrease in the abundance of Typha, primarily due to muskrat "eatout" described by Weller (1978) and Van der Valk and Davis (1978) as common in this phase of the cycle. Because water levels remained high for this study, an increase in the relative abundance of floating-leaved species, such as Nuphar advena and Nymphaea tuberosa, and the appearance in 1982 of Polygonum coccineum was noted. Submerged species, such as Potamogeton pectinatus, also increased over the three-year period, though quite insignificant in relation to other plant species. Van der Valk and Davis (1978) reported that during the "degenerating" phase of the cycle, the stems of Scirpus validus became infested with larvae of a dipteran stem borer which aided in the decline of the Scirpus population in Eagle Lake, Iowa. The same phenomenon has been observed since 1980 in the deep-water rushes in Clear Lake. Scirpus growing in water 1.1 to 1.6 m deep showed evidence of stem borer activity, ultimately resulting in the drying and curling of the stems at the damaged sites.

Impact of Water Level Stabilization

As long as water levels remain high, one would expect the elimination of the majority of emergent species and dominance of the community by submerged and floating-leaved species. The increase in submerged species, however, is possibly being prevented by turbidity. Van der Valk and Davis (1978) stated that the abundance of submerged plants may be adversely affected by the disappearance of the emergents because of the increased turbidity caused by algae blooms or the stirring of sediments by wind and waves. Such seems to be the case in Clear Lake. Algal blooms of considerable magnitude were observed over the three-year period, 1980 through 1982, and turbidity was chronically high.

Considering the similarity of vegetational changes in Clear Lake to those of prairie marshes, the maintenance of present water levels, could result in complete elimination of all emergent vegetation with the exception of those plants in shallow, sheltered areas protected from wind and wave wash. With high turbidity, the dominant plant species would most likely consist of Nuphar and Nymphaea, floating-leaved potamogetons such as Potamogeton nodosus and P. natans, floating-leaved or emergent polygonums such as Polygonum coccineum and P. amphibium, and turbidity-tolerant submerged species such as Potamogeton pectinatus. All of these species are presently in the lake in small numbers. Scirpus spp. and Typha spp. require occasional periods of low water levels for seed germination and hence would disappear as the life spans of the plants were attained.

A model of succession such as that prepared by Van der Valk (1981) could be computed for Clear Lake. If environmental conditions change in a wetland, the future state can be predicted by knowing the life history type of each vegetative component. Water level conditions are an important driving force in this model.

Crum and Bachmann (1973), in an effort to explain the disappearance of emergent and submergent vegetation in East Lake Okoboji, suggested that a possible cause of the decline might be stabilization of water by installation of water control structures in the Iowa Great Lakes chain.

Previous studies indicated that Clear Lake was reaching the marsh stage of succession at the beginning of this century, but artificial stabilization at higher water levels in the summer months reversed the successional process toward more lake-like conditions. The success of vegetation in Clear Lake ultimately depends upon the management strategy applied. This may necessitate allowing water level fluctuations to occur during specified intervals to allow for germination of those desired aquatic plants which require low water levels. Information is available to make a reasonable prediction of plant successional events in relation to water level in Clear Lake.

FISH

Present Fish Community

A total of 20 fish species were captured in Clear Lake in 1981 and 1982 (Table 7). The most abundant species were yellow perch, black bullhead, black crappie, bigmouth buffalo, and common carp. The fish community reflected the impact of a 1978-79 winterkill, with species tolerant of low dissolved oxygen and with high reproductive potential dominating.

Gill net samples

The composition of samples taken in 1981 with experimental gill nets from four habitat types is presented in Tables 8 and 9. Catch rates were 2.5 to 3.3 times higher in littoral habitats than in lemnitic areas of the lake. Statistical analysis for trends were conducted on the ten most abundant species in experimental gill net samples (Stang, 1982).

Three distinct littoral habitat types are present in Clear Lake: non-vegetated areas, vegetated areas (consisting primarily of bulrush, Scirpus), and gravel-rock shoal areas. Non-vegetated areas are more abundant than vegetated and gravel-rock areas, and are present around the entire lake. Vegetated areas cover 22.6 hectares (56 acres). Gravel-rock areas are the most limited shoreline habitat type representing less than ten hectares (25 acres).

Fish from four sites representing each of the three littoral habitat types were sampled with experimental gill nets in 1981 and 1982. Monofilament gill nets with five 7.6 m (25 ft.) panels of 1.9, 2.5, 3.8, 4.4, and 5.1 cm (0.75, 1.00, 1.50, 1.75, and 2.00 in.) bar mesh were set at three time intervals: dawn (set one hour before sunrise), midday (set at

11:00 a.m.), and dusk (set one hour before sunset) in 1981. Gillnets were retrieved after two hours. Only dusk sets were made in 1982.

Sampling occurred at one month intervals in June, July, and August, 1981 and 1982. Four sites were sampled simultaneously during a netting period with at least one site from each habitat type included. Nets were set perpendicular to shore in openings within bulrush beds at vegetated sites and directly over gravel-rock shoals.

Catch-per-unit-effort (CPE) was used to describe relative abundance (catch/hour). Analysis of variance was used to test for differences in CPE between habitat types, times of day, and sampling period. If the hypothesis of no significant difference among the tested treatments was rejected at the 95% level, t-test procedures were used to determine differences between paired treatments. Duncan's multiple range t-test was used to determine differences in CPE between habitat types relative to time of day and sample period.

Variation in experimental gill net samples was observed relative to sampling month, sampling time, and habitat type (Tables 10, 11, and 12). Six species exhibited statistically significant variation in catch per unit effort (ANOVA, $\underline{p}<0.05$) over the three sampling periods, 1981. Black bullhead and yellow perch exhibited declining catch rates from June to August, while white bass and yellow bass increased. Both common carp and channel catfish were most abundant in July samples.

Five species exhibited statistically significant variation in catch rates between morning, mid-day, and evening sampling times (Table 11). Black bullhead were most abundant at dusk, channel catfish and yellow bass were most numerous at dawn and dusk, while white bass were caught in highest numbers at mid-day. Yellow perch catch rates were greatest in the morning and at mid-day.

Significant variation in catch rate among the three littoral habitats (vegetated, non-vegetated, and gravel-rock areas) was observed for five species (Table 12). Vegetated areas had the highest catch rates of bigmouth buffalo and black bullhead. Nonvegetated and gravel-rock areas had the highest catches of channel catfish, yellow bass, and walleye.

The relative importance of littoral habitats compared to limnetic areas of the lake was evaluated for the 10 most abundant species (Table 13). Significantly greater catch rates in littoral habitats were observed for 8 species. Vegetated littoral areas had greater catches of bigmouth buffalo, black bullhead, white bass, black crappie, and yellow perch. Non-vegetated areas had greater catch rates of white sucker, bigmouth buffalo, channel catfish, white bass, yellow perch and walleye, while gravel-rock areas had higher catches for the same six species plus yellow bass.

Fyke net samples

Fyke nets were set at the same locations and according to the same schedule as were gill nets, but fyke nets were set over two time intervals in 1981: day (one hour before sunrise) and night (one hour before sunset). Fyke nets were retrieved after 12 hours. Only night sets were made in 1982. The fyke nets were constructed of 1.3 cm (0.50 in.) bar mesh with a single 15.2 m (50 ft.) lead.

The composition of fyke net samples taken during 1981 from three littoral habitats is presented in Tables 14 and 15. Variation in fyke net catch rates relative to sampling period, sampling time, and habitat type was evaluated statistically for the eight most abundant species in fyke net samples.

Significant variation in catch rate among the three sampling periods was observed for only one species, black bullhead (Table 16). Black bullhead were more abundant in June and July samples that in August samples.

When day and night sampling times were compared, significant differences in fyke net catch rates were observed for white sucker (Table 17). White sucker were more numerous in nighttime samples.

Fyke net samples yielded significant variation in catch rates among the three littoral habitats for only one species, bigmouth buffalo (Table 18). Bigmouth buffalo were much more abundant in vegetated than in non-vegetated areas and were never captured in gravel-rock habitat.

Shoreline Seining Samples

Young-of-the-year fish were collected with a 4.6 m x 1.2 m x 3.2 mm (0.13 in.) mesh bag seine. Seine hauls were made parallel to shore in 0.3-0.9 m of water. Each seine haul covered a distance of about 25 m. Sampling was conducted at weekly intervals beginning at 12:30 a.m. and ending about 2:30 a.m. from May 19 through August 11, 1982. Sampling was conducted at three habitat types:

1) Heavily vegetated littoral areas.
2) Sparsely vegetated areas.
3) Non-vegetated areas with gravel-rock bottoms.

Each of the three habitat types was represented by three stations and there were two seine hauls made at each station on each sampling date.

Preliminary sampling of the Clear Lake shoreline using bag seines was conducted in 1981 (Table 19). Thirteen species were collected, eight as young-of-year or juveniles. The dominant species were spottail shiner, yellow perch, black bullhead, white bass, and yellow bass.

Sampling in 1982 focused on description of temporal variation in shoreline seining catches over the summer (Table 20), as well as differences between vegetated, non-vegetated, and gravel-rock habitats over that time period (Table 21). Eleven species were collected in 1982. Six species captured in 1981 were not collected in 1982: golden shiner, common shiner, channel catfish, green sunfish, pumpkinseed, and largemouth bass. Species captured in 1982, but not in 1981, included muskellunge, common carp, and white sucker.

Seasonal variation in the catch rate was observed for all species captured by shoreline seining in 1982 (Table 20). The earliest species to appear were white sucker and yellow perch. By mid-summer, spottail shiner and darters appeared. At the end of the summer the most diverse catches were obtained with muskellunge, common carp, black bullhead, white bass, yellow bass, black crappie, sunfish, and walleyes appearing in the samples.

Variation in shoreline seining catch rates was observed among three littoral habitats (Table 21). Highest catch rates were observed in vegetated areas for spottail shiners early in the summer, but they became numerous in non-vegetated and vegetated areas as the summer progressed. Vegetated areas yielded the greatest catch rates for young-of-year sunfish, but species were not identified. Non-vegetated areas produced the greatest catches of young-of-year white bass, yellow bass, walleye, and yellow perch, while gravel-rock areas yielded the highest catches of young-of-year white sucker and black bullhead.

The only esocids collected were muskellunge. They were captured during August, most consistently at vegetated sites.

Several cyprinids were collected. Carp were collected only at vegetated sites. Spottail shiners were first captured in non-vegetated areas, but later were found in all habitat types.

One species of catostomid, white sucker, was collected regularly in the seine. White suckers were most numerous in gravel-rock areas, but were found at both vegetated and non-vegetated sites.

While channel catfish were commonly collected in other gears, they were not collected in seines. Black bullheads were consistently captured in non-vegetated and gravel-rock areas.

Morone species were found consistently in all habitat types. White bass were most numerous in non-vegetated areas, while yellow bass were numerous in both non-vegetated and vegetated areas.

Centrarchids were occasional captures in the seine. *Lepomis* sp. were found in all habitats, as were black crappie.

Several percids were collected by seining. Walleye and yellow perch were consistently found in all habitats, but were most numerous at non-vegetated sites. Darters were consistently captured at sandy and vegetated sites.

Most fish species were first captured near their spawning areas. As they grew in size, they moved into open water or other inshore areas.

Larval fish samples

Larvae were collected with a push-net mounted on a boat powered by a 25 horsepower motor. The 0.5 m diameter ring net had 0.75 mm square mesh nylon netting that tapered over a length of 2.9 m to terminate in a plankton bucket. A General Oceanics Model 2030 Flow Meter was mounted in the mouth of the net. Sampling was conducted at a depth of 0.66 m. Sampling runs were one minute in duration at speeds of approximately 100 - 150 meters per minute, so that a distance of 100-150 meters was covered on each run. All sampling was conducted at night, beginning one hour after sunset, and was carried out at weekly intervals beginning April 26 and continuing through August 10, 1982. Twelve stations, located around the lake, were sampled each interval. Stations were chosen to represent the available habitat of four main types:

1) Heavily vegetated littoral area.
2) Sparsely vegetated littoral area.
3) Non-vegetated littoral area.
4) Open-water limnetic area.

The littoral sampling areas had 1.5 m water depths corresponding with the outside edge of the vegetation. Limnetic sampling areas were over 3 m depths. Each habitat type was represented by three stations. Two consecutive sampling runs were made at each station on each sampling date.

Patterns of larval fish occurrence and distribution were described in 1982. Twelve taxa of larval fish were collected (Tables 21 and 22).

Temporal variation in catch rates between May 3 (water temperature 13° C) and August 10 (25° C) is presented in Table 21. Variation in catch rates among the three littoral habitats (vegetated, non-vegetated, and gravel-rock), as well as open water areas of the lake, is presented in Table 22. The mean catch rate tended to vary among the four habitat types with little indication of habitat specialization among the taxa.

Carp were first captured on June 7 at a vegetated site. By June 22 they were found in non-vegetated, gravel-rock, and open water areas. Spottail shiner were captured on June 2 and June 7 at vegetated sites, but by June 15 they were found in all habitat types. The Morone sp. were first collected on June 7 at a vegetated site and then on June 15 at a non-vegetated area. Later collections, June 29 and July 7, were from gravel-rock sites. Lepomis sp. were first captured on July 27 at a non-vegetated site. A week later on August 7, they were taken in all habitat types. Black crappie were first found on May 19 in gravel-rock and vegetated areas.

Walleye were captured on May 13 in non-vegetated, gravel-rock, and open water areas one week after walleye fry were stocked in the lake. Perch were captured first on May 3 at vegetated sites. On May 13 perch were found in all habitats sites. During June perch used all habitat types. During July they were most abundant in littoral vegetated sites. Darters were first collected on May 26 in rocky areas. They were collected occasionally in all habitat types through June and July.

Habitat preferences for each species were determined from the mean catch of larvae for the summer. The mean catch for common carp was highest at non-vegetated sites, spottail shiners at vegetated sites, Morone sp. larvae at gravel-rock sites, green sunfish at gravel-rock sites, crappie at gravel-rock sites, walleye at non-vegetated sites, yellow perch at gravel-rock sites, and darters at open water sites. The highest catch for all species combined for the summer was at gravel-rock sites, largely due to the dominance of yellow perch in our samples.

Every species of larval fish taken in our samples, except walleye, white sucker, and white bass utilized vegetated sites at some time. The vegetation was the preferred habitat of spottail shiners and golden shiners. Vegetated sites served as primary spawning habitats for yellow perch, crappie, common carp, and golden shiners, as indicated by catches of newly hatched larvae. The presence of emergent vegetation may be, therefore, of critical importance to these species, even though their larvae typically utilize other habitats.

If lake level stabilization caused a reduction in the abundance of bulrushes, the preferred spawning habitat of yellow perch, crappie, common carp, and golden shiners would be substantially altered. This might result in reduced survival of the young of these species. Since the yellow perch is the principal forage fish present in the lake, (as well as an important sport fish), a reduction in young perch would be expected to have negative impacts on predatory game fishes. Loss of protective cover provided by the vegetation could also be expected to increase the effects of predation on the early life stages of several species. Although the exact impacts of changes in the amount of emergent vegetation in Clear Lake cannot be quantitatively predicted, it seems certain that substantial effects on larval fishes would result.

Comparison of 1981 and 1982

A comparison of 1981 and 1982 experimental gill net and fyke net samples indicated change in the community composition (Tables 24 and 25). White sucker, bigmouth buffalo, black bullhead, black crappie, and yellow perch were not as numerous in 1982, while white bass, yellow bass, and walleye were more numerous in 1982 experimental gill net samples. Similar trends were observed for black bullhead, yellow perch, and walleyes in fyke net samples.

Historical Trends in Fish Community Structure

No less than 34 fish species have been referenced as being collected from Clear Lake over the years. The common and scientific names of fish species found or made reference to in Clear Lake are presented in Table 26.

Numerous reports on the biology and management of Clear Lake fishes are available; however, information on population trends is limited to experimental gill netting (1952 - 1973) and shoreline seining (1950 - 1973) carried out by Iowa State University personnel and shoreline seining (1972 - 1981) conducted by the Iowa Conservation Commission.

The composition of the catch and total catch/hour/net in gill nets for each year from 1952 to 1973 is presented in Table 27. Substantial fluctuations in the composition of the catch occurred over the three decades. The most dramatic variation occurred among yellow bass, yellow perch, bullhead, and walleye. Following the introduction of yellow bass, this species increased in abundance until 1963 when they comprised 86% of the catch. Between 1964 and 1968 the crowded yellow bass population declined sharply, primarily due to epizootics of bacteria, to a low of only

1% of the catch in 1968.

As the yellow bass population increased in abundance through the 1950's and early 1960's, the abundance of yellow perch, bullhead, and walleye declined in Clear Lake. Following the die-off of yellow bass, the bullhead population rapidly expanded, followed by yellow perch and walleye. In 1969 bullhead, yellow perch, and walleye comprised 71.2, 10.3, and 11.4% of the catch, respectively, while in 1973 they made up 25.2, 53.6, and 13.6% of the catch, respectively.

Over the three decades, other changes in the fish community occurred. Pumpkinseed, bluegill, and largemouth bass were relatively abundant in the 1950's, but became rare or altogether absent in the 1960's and 1970's. White and black crappie both occur in the lake. From 1952 to 1956, the black crappie was the dominant crappie species. In the late 1950's, a shift in dominance occurred and the white crappie became the dominant crappie species. Their dominance lasted through the 1960's and into the 1970's. In 1972 and 1973, the two species were caught in essentally equal numbers. The 1981 and 1982 samples contained almost exclusively black crappie.

Past fluctuations in gill net catch appear to be associated with interspecific competition, especially the introduction of the exotic yellow bass, and not water level fluctuations associated with droughts. Changes in Clear Lake fish fauna have occurred, which may be related to competition, water level fluctuation, or changes in water quality. Since the 1950's, the abundance of phytoplankton, especially blue-green algae, has increased substantially. Subsequent reductions in visibility and in abundance of submerged aquatic macrophytes are likely to have had an effect on the fish community.

Shoreline seining data by both Iowa State University and the Iowa Conservation Commission have shown fluctuations in relative abundance of young-of-year fish and forage fish over the years (Table 28 and 29). Information enabling an assessment of low water level impacts was available for the 1970's drought cycle. The data indicate that reproduction of bullhead, bluegill and pumpkinseed, crappie, and yellow perch may have been negatively influenced by low water levels in 1977 and 1978.

A winterkill during the winter of 1978-79 lead to a dramatic change in shoreline seining results. In 1979, very few fish were captured. The only species in abundance were walleye and these fish were believed to be primarily the product of summer fry stocking by the Iowa Conservation Commission.

The 1978-79 winterkill appeared to have a much greater impact on the abundance of young-of-year and forage fish than either drought cycles or normal fluctuations in year class strength. The 1978-79 winterkill was related to the 1970's drought cycle in that low water levels, coupled with severe winter weather, lead to anoxic conditions under the ice.

<u>Effect of Water Level on Fish</u>

Variations in climate result in fluctuating water levels in natural lakes, but little information exists relative to the affect of such fluctuations on lake fishes. Information on the influence of water level is limited almost exclusively to annual fluctuations in reservoirs. Fluctuations of water level can be beneficial to sport fisheries in reservoirs. For example, Eschmeyer et al. (1947) found that stable, permanent-level pools in Tennessee Valley Authority (TVA) impoundments produced poorer fishing than those reservoirs subject to fluctuating water levels. Observations on fishing in stable-level water supply reservoirs in Illinois showed these waters often became poor for fishing within a few years after impoundment (Bennett, 1954), and data collected on TVA impoundments indicated that impoundments with the largest percentage of predator species also had the widest fluctuation in water level (Bennett, 1970).

Production

Water level plays a major role in the control of littoral vegetation and in vegetation flooding, which result in the formation of suitable spawning substrates and egg incubation conditions for many species (Il'ina and Gordev, 1980). These factors affect the spawning of adult fishes, the hatchability of the eggs, the survival of young-of-the-year fishes, and, consequently, the year class strength of fishes.

Il'ina and Gordev (1972) stated that water level regime best suited for most fish was an increase in spring water levels followed by and the maintenance of a constant high level during the spawning of the fish. Keith (1975) concurred and added that for largemouth bass high water level should continue during the nursery period. Increases in largemouth bass production have been correlated with spring rises in water level associated with flooding of terrestrial vegetation, (Shirley and Andrews, 1977; Aggus and Elliot, 1975). High spring water levels (Johnson, 1957) and stable to rising water levels (Hassler, 1970) provide favorable conditions for northern pike production and have been found to be associated with strong year classes of northern pike. Groen and Schroeder (1975) stated that successful stocking of fingerling northern pike in Kansas reservoirs only occurred when water levels were high and flooded vegetation was present. Strong year classes of yellow perch have been found to occur when water levels are high enough to flood terrestrial vegetation (Benson, 1980). In Lake Francis Case, South Dakota, a direct relationship between water levels in the spring and early summer and the numbers of age-0 fish in summer seine catches has been observed (Gasaway, 1970; Walburg, 1977). In the same lake, Martin et al. (1981) found young-of-the-year yellow perch, white bass, buffalo, and centrarchids to be significantly more abundant in net catches during a high-water year than during a low-water year, yet minnows were found to vary in catch abundance independently of water level. In this same study, age-0 common carp, walleye, and shortnose gar were found to be more abundant in the high-water year, when compared to the low-water year. Shields (1958) found reductions in water level and scarcity of flooded vegetation at time of spawning to have a detrimental effect on the production of common carp.

Ecological factors believed to be responsible for the positive correlation between high water levels and fish production are availability of suitable spawning sites, such as flooded vegetation (Shields, 1958; Hassler, 1970; and Benson, 1980) and algae-free rock substrate (Groen and Schroeder, 1978), protective cover reducing predation on young fishes (Keith, 1975; Shirley and Andrews, 1977), an increase in fish food organisms (Keith, 1975; Groen and Schroeder, 1978; Shirley and Andrews, 1977), and lake area initially devoid of fishes which stimulates reproduction and growth of fish (Bennett, 1970; Keith, 1975; Groen and Schroeder, 1978). However, Keith (1975) cautioned that "the beneficial effects of high water levels are not as spectacular with successive years of major water level increases."

Population structure

Increased water levels prior to, during, and for a short period following spawning have been shown to benefit fish production, yet reductions in water levels during the year have a variety of effects upon fish populations in natural lakes and impoundments.

Following a lowering of water level, a reduction in the density of fry (Hemon et al., 1969) and intermediate size fish (Lantz et al., 1967) in seine catches is often found. Bennett (1954) observed a decrease in standing stock of largemouth bass and bluegill in Ridge Lake, Illinois with lowered water level. Dewatering of a lake has been found to adversely affect pickerel and crappie, yet benefit sunfish (Wegener and Williams, 1974). Neal (1962) found a positive correlation between mean annual water levels and the percent of black crappies in Clear Lake, Iowa. Lantz et al. (1967) found little change in standing stock of predatory game fish resulting from a reduction in lake levels. Threadfin shad and golden shiners were severely cropped during a low-water period, yet their numbers increased following a rise in the lake level (Wegener and Williams, 1974).

The reduction in fish populations as a result of low lake levels is largely due to a reduction of protective shallow water habitat and an increase in predation on small fish by piscivorous fish (Bennett, 1954,1970; Wegener and Williams, 1974) or to a failure of the lake to fill the following spring, thus reducing the availability of spawning sites (Lantz et al., 1967).

Growth

Fluctuating water levels have an impact on fish growth, as well as population numbers. Feeding activity of largemouth bass has been found to increase in association with decreased water levels (Hemon et al., 1969). Accelerated growth of age-1+ largemouth bass (Hemon et al., 1969; Zweiacker et al., 1972), white crappie (Johnson and Andrews, 1973), and channel catfish (Johnson and Andrews, 1973) has been correlated with these low lake levels. Growth of largemouth bass (Shirley and Andrews, 1977; Zweiacker et al., 1972; and Aggus and Elliot, 1975) and white crappie (Johnson and Andrews, 1973) in their first year of life has been shown to be positively correlated with lake level. The decrease of first year growth of largemouth bass and white crappie associated with low lake level is due to the negative effect of low water levels on production of littoral zone invertebrates--upon which young-of-the-year bass and crappie feed, but at the same time a greater vulnerability of forage fish occurs--stemming from reduction in protective cover (Zweiacker, et al. 1972; Johnson and Andrews, 1973). Johnson and Andrews (1973) stated that declining water levels increased growth in channel catfish through reduced intraspecific (decreased spawning sites) and interspecific (predation on young catfish) competition. However, Jackson (1958) found that a drop in water level retarded crappie growth in Lake Spavinaw, Oklahoma. Neal (1962) observed no correlation between crappie growth and mean annual water level in Clear Lake, Iowa.

Impact of Water Level Stabilization

Water level stabilization may impact the Clear Lake fishery by reducing the amount of aquatic vegetation, which is needed in the life cycle of many species occurring in the lake, or by altering the dynamics of the system by changing production, population structure, or growth rates of different species.

Plant requirements

The association with aquatic plants by the important sport, commercial, and forage species found in Clear Lake is discussed. Through a survey of the literature the plant requirements at different life stages has been identified.

Northern pike--according to Ridenhour (1958), young northern pike are restricted to heavily vegetated areas of Clear Lake until they reach 20 cm (8 in.) long. Eddy and Underhill (1974) indicated that northern pike spawn in flooded marshes and grassy margins of lakes. McNamara (1936) reported northern pike spawning in a marsh area where vegetation consisted of profuse stands of bulrush and marsh grasses. The lake bottom was covered with leaves and decaying plant debris. The eggs adhere to vegetation and the young remain in marsh areas for up to one month. Carbine (1941) reported newly hatched northern pike fry hanging to plants by a thread from an adhesive organ. Ten to twenty-two days after hatching, young northern pike moved from spawning areas into the main lake. Fabricius and Gustafson (1958) state that optimal spawning substrate for northern pike was a dense mat of short vegetation, but they felt that the type of vegetation which forms the spawning mat was of small importance. They showed that northern pike deposited eggs only over suitable vegetation. Franklin and Smith (1963) report that northern pike never spawned on cattails, but all other vegetation types were used. Grasses, sedges, or rushes with fine leaves were the best substrates for northern pike spawning. If submerged vegetation was present, northern pike seldom used emergent vegetation such as Scirpus, Typha, or Sagittaria (McCarraher and Thomas, 1972). Pflieger (1975) stated that northern pike are partial to waters with dense growths of aquatic vegetation.

Muskellunge--Pflieger (1975) reported that muskellunge spawn over dead vegetation in shallow water, while Eddy and Underhill (1974) reported that the muskellunge spawn in tributary streams and shallow lake channels, rather than flooded marshes preferred by northern pike. Scott and Crossman (1973) state that muskellunge spawning takes place in water 38-50 cm (15 - 20 in.) deep in heavily vegetated flooded areas. On hatching, the young remain dormant in the vegetation for about 10 days or until the yolk is consumed, at which time they become active and begin feeding. The muskellunge is rarely found far from the protection of emergent and sub-emergent plants or areas of submerged timber and stumps.

Common carp--Bardach (1972) stated that the adhesive eggs of common carp are spawned near the surface on rooted aquatic plants or on submerged terrestrial vegetation. When first hatched, the larvae attach themselves to plants by means of a cement gland. Eddy and Underhill (1974) noted that carp feed on vegetation which they uproot. Carp suck up tender shoots and roots as they settle to the bottom.

Golden shiner--The golden shiner scatters adhesive eggs over filamentous algae or submerged vascular plants (Pflieger, 1975). The golden shiner thrives in heavily vegetated habitats.

Spottail shiner--McCann (1959) noted that the spottail shiner prefers areas with moderate amounts of emergent or submergent vegetation.

Bigmouth buffalo--Eddy and Underhill (1974) stated that the bigmouth buffalo moved into shallow bays and sometimes up small tributary streams to spawn where they deposit their eggs in dead vegetation and debris on the bottom. The eggs adhere to the vegetation until they hatch.

Black bullhead--Eddy and Underhill (1974) reported that black bullheads spawn in shallow water on open mud or sand bottom. Black bullheads eat whatever food (including carrion) is available. They prefer animal food, but are able to digest plant material and will eat vegetation or decayed material when it is the only food available. Ridenhour (1958) reported that young black bullheads were found mainly in heavily vegetated areas in Clear Lake.

Yellow bullhead--Wydoski and Whitney (1979) stated that yellow bullheads prefer lakes with abundant vegetation, while Bailey and Harrison (1945) reported that young yellow bullheads were found under rocks in 2-6 feet of water.

Channel catfish--Wydoski and Whitney (1979) stated that channel catfish are seldom found in dense aquatic vegetation. Adults may come into shallow water at night to feed, but return to deep holes or shelters during daylight.

White bass--Ridenhour (1958) stated that young white bass prefer areas of moderate vegetation in Clear Lake.

Yellow bass--Atchison (1967) stated that yellow bass in Clear Lake were seldom collected in dense weed bed areas, preferring open water, sandy shores, and sparse vegetation. Ridenhour (1958) suggested that other young-of-the-year fish did not share this habitat with young yellow bass. Helm (1958) showed that a loss of vegetation in Buffalo Lake, Wisconsin, allowed an increase in the yellow bass population and a decrease in other species. He reported that in Lake Wingra, Wisconsin, when the carp population was reduced the abundance of plants increased and yellow bass decreased.

Green sunfish--Werner and Hall (1977) noted that when stocked together with bluegill in a pond, green sunfish fed predominantly on prey associated with vegetation and inhabited the border of cattails (Typha) surrounding the pond. Wydoski and Whitney (1979) stated that the habitat of the green sunfish includes weed beds of warm-water lakes and reservoirs. It occupies small forage areas along the edge of the shore, usually under cover of vegetation, rocks, logs, or exposed tree roots.

Pumpkinseed--Ridenhour (1958) noted that young-of-the-year pumpkinseed were concentrated in areas of heavy vegetation in Clear Lake. Wydoski and Whitney (1979) stated that pumpkinseed prefer dense aquatic vegetation and are generally found in more dense vegetation than is the bluegill. Pumpkinseed are not abundant in open or deep water areas. Eddy and Underhill (1974) reported that pumpkinseed feed mostly in deep weed beds or in deep water just beyond the margin of weed beds. Bailey and Harrison (1945) reported that pumpkinseed were common in dense beds of vegetation in Clear Lake, Iowa.

Bluegill--Ridenhour (1958) noted that young bluegill concentrated in areas of heavy vegetation in Clear Lake. Pflieger (1975) reported that during midday bluegill remain in deep water, but in early morning and again in the evening they move into shallows to feed. Eddy and Underhill (1974) stated that adults forage in deep weed beds. Bailey and Harrison (1945) list bluegill as a weed bed inhabitant in Clear Lake. Wydoski and Whitney (1979) indicated that bluegill usually inhabit warm, shallow lakes with rooted vegetation, but they have done well in reservoirs in which the water fluctuates and rooted vegetation is absent.

Largemouth bass--Ridenhour (1958) noted that young largemouth bass preferred areas of heavy vegetation in Clear Lake. Eddy and Underhill (1974) stated that largemouth bass thrive in lakes with clear water, sandy shores, and a substantial growth of marginal weed beds which produce food for largemouth bass and the fishes they feed upon. In early morning and late afternoon, largemouth bass often feed in shallow weedy lake margins. Wydoski and Whitney (1979) stated that the largemouth bass prefer clear water with substrates of mud, sand, and organic material. These bottom types provide the best substrate for aquatic vegetation. The largemouth bass has done well in fluctuating reservoirs that lack rooted aquatic plants. They are usually found in association with objects that provide cover, such as brush, logs, pilings, or submerged trees. Pflieger (1975) indicated that largemouth bass commonly spend the day in deep water or lurking about logs, drift piles, and other cover, moving into the shallows in the evening to feed.

White crappie--Ridenhour (1958) indicated that young white crappie inhabit the deep open waters of Clear Lake. Wydowski and Whitney (1979) reported that white crappie do not depend on rooted vegetation, whereas black crappie appear to need dense vegetation. White crappie spawn near objects such as brush piles, stumps, and rocky outcroppings, and deposit their eggs on or near dead or living vegetation. Pflieger (1975) reported that young white crappie are often found over open water of considerable depth. White crappie nest sites are near a log or other large object, on a substrate consisting of fine gravel or finely divided plant roots for attachment of the eggs. Eggs hatch in about three days and the fry remain attached to the substrate by an adhesive substance from the egg for several more days.

Black crappie--Ridenhour (1958) reported that young black crappie were found principally in heavy to moderately vegetated areas in Clear Lake. Pflieger (1975) stated that the principal requirements of the black crappie are clear water, absence of noticable current, and abundant cover in the form of submerged timber or aquatic vegetation. Eddy and Underhill (1974) indicated that the deep part of weed beds and the outer edges of the beds are black crappies' favorite feeding areas. Wydowski and Whitney (1975) stated that black crappie prefer dense aquatic vegetation over bottoms of sand, muck, or organic debris.

Yellow perch--Wydoski and Whitney (1979) stated that yellow perch spawn over various types of substrate (sand, gravel, or rubble) on vegetation, submerged brush, or other objects. Yellow perch prefer lakes with a modest amount of vegetation and clear water. Eddy and Underhill (1974) reported that yellow perch eggs settle in heavy adhesive bands on sticks or weeds on sandy bottoms in shallow water. During the day yellow perch are found mostly in the littoral zone where rooted aquatic plants are present. At night they are inactive and rest on the bottom among the weeds. Pflieger (1975) stated that yellow perch spend the day in deep water, moving inshore to feed in late afternoon or evening. Scott and Crossman (1973) reported that perch are most abundant in open water of lakes with moderate vegetation and clear water. Yellow perch numbers will decrease in a body of water in which turbidity increases or vegetation decreases. Ridenhour (1958) reported that young yellow perch prefer heavy to moderately vegetated areas in Clear Lake.

Walleye--Ridenhour (1958) reported that young walleye prefer areas of moderate vegetation in Clear Lake. Eddy and Underhill (1974) stated that walleye move into shallow water at night to feed and then about sunrise they return to the deep waters beyond the weeds. Scott and Crossman (1973) reported that walleye reach their greatest abundance in large, shallow, turbid lakes. Walleye often use sunken trees, boulder shoals, or weed beds as a shield from the sun.

Table 30 summarizes the association of Clear Lake fishes with submerged aquatic vegetation. Out of 21 species for which information was summarized, seven utilize vegetation for spawning, 11 use it as juvenile habitat, and 16 are found in association with plants as adults. The desired species most closely associated with aquatic vegetation include: northern pike, muskellunge, black bullhead, black crappie, yellow perch, and walleye. There is strong evidence to suggest that elimination of aquatic plants would negatively impact the sport fishery of Clear Lake.

<u>Production</u>, <u>population</u> <u>structure</u>, <u>and</u> <u>growth</u>

There is insufficient information in existing literature to enable a quantitative prediction of the influence of water level stabilization on fish production, population structure, or growth. Past information on Clear Lake fishes failed to yield insight due to the confounding factors of exotic species introductions and winterkill. The 1977-1978 winterkill was related to low water levels and severely altered the production of sport fishes. Prevention of future winterkill conditions would benefit the fishery.

RECREATION AND WATER LEVEL

The purpose of the recreation portion of the study was to determine attitudinal differences among several categories of recreationists toward fluctuating water levels and water level stabilization of Clear Lake.

An instrument was constructed using accepted sociological measurement techniques (Dillman, 1978; Miller, 1977). The questionnaire was composed of three parts. The first part consisted of a map of Clear Lake. Respondents were asked to mark on the map lake usage areas, lake entry points, and lake shore usage areas. The second part of the questionnaire consisted of use and perception data. It included questions about how often the lake was used by respondents, type of use, perception of lake quality, and so forth. Included within this section were questions dealing with perception of water level fluctuation or stabilization as it related to individual activities. The final portion of the questionnaire consisted of collecting socioeconomic data about the respondents.

Two instruments were constructed. One instrument was developed for residents and was field tested in the Clear Lake area. This instrument was designed as a mail survey. The second instrument was prepared for use with nonresidents and was distributed to nonresidents while they were on site. The information sought by both instruments was similar. In addition, information specific to a single population was sought.

The population for this study consisted of two major groups, as well as two subgroups of one major group. The two major groups were residents and nonresidents. Residents were defined as individuals currently residing or owning property in Clear Lake, Ventura, or unincorporated areas adjacent to the lake. Nonresidents were defined as individuals who were day users or multiple day users staying in resorts, campgrounds, or motels.

Residents were subdivided into two groups, permanent residents and seasonal residents. Respondents for the resident group were secured from the Cerro Gordo County Data Systems office.

Four mailings were utilized to insure the greatest number of returns for the resident survey. The survey was conducted during the spring and summer, 1981. A total of 484 instruments were sent. Of these, 383 were returned (response rate 79.0%) and 329 were usable.

User access points for Clear Lake were used for administering nonresident questionnaires. Interview locations, times for distribution, and number of questionnaires to be distributed were determined in advance. Questionnaires were distributed to individuals and groups as they entered the area. Self-addressed return envelopes were provided for return of the questionnaire. Addresses of all participants were recorded and three follow-up mailings were conducted to nonrespondents. The questionnaire was administered during summer, 1981. A total of 419 instruments were distributed and 329 were returned (78.5% response rate) with 310 usable.

Description of Respondents

Data were collected for residents (two groups) and nonresidents. Four types of data were common to all groups: sex, age, income, and occupation. In addition, data specific to each respondent group were collected. This included for residents: how long they had lived at Clear Lake and how much of each season was spent at Clear Lake. For nonresidents the profile included: how far they had traveled and number of visits in the last year.

Socioeconomic data

Tables 31 through 34 depict socioeconomic data for the respondents. Table 31, Sex of Respondents, indicated that 69.1% of the respondents were male. This was probably a result of questionnaires being mailed to listed owners of property for residents and for nonresidents distributed to driver of the vehicle.

The age range for all participants in the survey differed from the state as a whole. The disparity in ages was caused by the large number of young users in the twenty to twenty-nine age group for nonresidents (sample size=172, 55.5%). Nonresidents closely reflect age patterns for outdoor recreation participation at a national level (Heritage Conservation and Recreation Service, 1977). Age distribution for residents more closely approached the norm for rural Iowa communities.

Table 33 reflects the income of residents and nonresidents. The largest percentage of seasonal residents (69.8%) made over $25,000 a year while the median income for permanent residents was $15,000 to $24,999 a year. Nonresident respondents had the same median income as permanent residents and their distribution closely paralleled the distribution of income among permanent residents. There were few nonresidents with an income of $50,000 or more a year.

Occupational data indicated that there was a broad range of occupations represented among users. As would be expected (Cunningham, et al., 1970; Deefe, et al., 1974) "professional, technical, and kindred workers" made up a larger percentage of resident (permanent and seasonal) and nonresident respondents (23.6%) than any other single category. The second largest group of residents were "retired and widows" (14.2%), with "managers, officials and proprietors" ranking third (13.1%). Among nonresidents, "managers, officials, and proprietors" tied with "laborers, except farm and mine" for the second largest user group.

Tables 35 and 36 provides additional information about residents, both seasonal and permanent. Table 35 illustrates the length of residence time by permanent residents. It appeared that there was an even distribution of length of residence, except for the thirty-one years or more range which accounts for seventy-five respondents (29.5%).

There was a substantial range among seasonal residents in reporting the number of months spent in residence at the lake (see Table 36), ranging from 0 to 9 months. Some respondents indicated that when they used the residence only on weekends they reported it as residence for an entire month.

Table 37 and 38 portray responses from nonresidents. Table 37 depicts the number of miles that nonresidents traveled to get to Clear Lake. The largest number of nonresidents (31.8%) traveled from 61-120 miles. This region included Des Moines, Waterloo, and Cedar Falls, all metropolitan regions. The category identified as "less than 30 miles" was the second largest group of nonresidents. This region included Mason City, the closest metropolitan area to Clear Lake.

From Table 38 it appeared that the vast majority of respondents are repeat users, having visited Clear Lake at least one or two times during 1981. Only 6.8% of the respondents were first time visitors.

Lake usage by residents

Tables 39 and 40 reflect lake usage by residents and nonresidents for the past year (1980) and for the visit on which the survey was conducted (nonresidents only). Table 39 illustrates uses by residents and indicated that picnicking, sightseeing, beach activity, and lake swimming were the most popular activities. The activities with the least degree of popularity among respondents were classified into two groups. The first was wildlife related recreational activities that are extractive in nature (i.e. trapping, hunting and fishing). The latter category, fishing, was subdivided into winter and summer periods, with winter being least popular. The summer fishing periods were much more popular. The second classification of least popular activities among residents were non-wildlife related recreation activities (i.e. canoeing, camping, and sailing).

It appears that residents use Clear Lake for a variety of water-based activities, but for the most part participate in water-based activities associated with recreation. Canoeing may be seen by most participants as more of a wilderness or river-based activity. The same wilderness perception may be appropriate for hunting and other wildlife related activities. There is no ready explanation of why sailing was not more popular among respondents, but it may be that lake depth, water level fluctuation, or competition with power boats may make Clear Lake less desirable for sailing.

The most popular activity, for repeat participation, was power boating. Over 10% of the respondents participated in this activity more than 25 times during 1981. Power boating has maintained a dominant role in the

Clear Lake region for a number of years and it appeared that residents perceive this to be the case.

<u>Lake usage by nonresidents</u>

Nonresident participation patterns differed from those of residents in some cases. Where differences are present it may be because of availability of the activity. Residents maintain easy access to the lake by virtue of their residence. Nonresidents, by contrast, must make some sacrifice in order to participate in recreational activities at Clear Lake. This concept of availability may be represented by comparing participation in camping. Residents rarely participated in camping, while 40% of all nonresidents participated in camping. Camping provided a part of the total recreation experience for many nonresidents, but may be participated in primarily because of the presence of other recreation opportunities and not as an end in itself.

Sightseeing was the most often participated in activity for both groups of respondents. Nonresidents found fishing from a dock or the shoreline as the second most popular activity, followed closely by beach activity and lake swimming. Picnicking was the fifth most popular activity followed by camping.

Activity participation was similar for both residents and nonresidents. The differences that were present in activity participation were a result of the availability of the experience to the participant. Residents were more likely to take advantage of picnicking opportunities than were nonresidents, while nonresidents were more likely to take advantage of sightseeing, camping, and fishing opportunities than were residents.

Nonresident participation was more diverse for single visits than was that of residents for single visits.

Perceptions of Water Level

Tables 41 and 42 reflect respondent perception toward fluctuation or stabilization of water level at Clear Lake. Table 41 reflects overall attitude by both groups to a statement asking whether water level should be allowed to fluctuate, whether it should be stabilized, or whether they had no opinion. Residents held a much stronger opinion about the need for stabilization of the water level than did nonresidents. Over 64% of the residents responded that water level should be stabilized while only 51.5% of the nonresidents responded similarly. A larger percentage of nonresidents (32.6%) had no opinion than did residents (17.6%).

Table 42 compares both groups of respondents by activity. Only two activities among residents, "hunting for upland game" and "trapping", had a higher percentage of no opinion responses than stabilization responses for residents. No activity received a major percentage of response for continuing fluctuation of water level.

Nonresidents were not as universal in their perception of need for stabilization as were residents. This group of respondents had a higher percentage of no opinion in nine of the activities than any other possible response. In no case, however, were there more responses for water level fluctuation than any other potential response.

Apparently residents and nonresidents view the preference for water stabilization similarly. The strength of these perceptions was influenced by the type of respondent (resident versus nonresident). Residents perceive, to a greater degree, the preference for water level stabilization as it impacts upon recreational usage. The lesser extent of preference toward stabilization expressed by nonresidents may be a reflection of their lack of knowledge of the impact of past water level fluctuations upon lake usage. Residents were well aware of the differences that extreme fluctuation caused upon availability of certain recreation activities.

Impact of Water Level Stabilization

It would appear that some activities should not be adversely affected by water level, but this may not be the case. Activity associations among nonresidents may impact among activities that are seemingly independent of water-based activities (e.g., sightseeing, camping and picknicking). Participation in some of these non-water activities may be dependent upon the presence of other water-based activities. The high number of participants in camping and picknicking, however, would tend to indicate that the activities, when participated in, are part of a "total recreation experience". The total experience may include packages of activities that are grouped together because of their availability at Clear Lake. The degradation of water-based resources may then directly influence the level of participation in those activities not normally associated with requiring a water-based resource. Water stabilization appeared to be preferred by both residents and nonresidents as opposed to continued water level fluctuation.

CONCLUSIONS

The current littoral plant community is dominated by emergent macrophytes, specifically the softstem bulrush. Since the late 19th century, the plant community has shifted from one dominated by submergent plants to one dominated by emergent plants. The shift is probably due to increased turbidity with turbidity-tolerant species becoming most abundant. It is believed that the present community undergoes a cyclic pattern of change similar to prairie marshes in response to 20-year drought cycles. If water levels were completely stabilized, elimination of emergent vegetation could be expected. The extent to which the current plant community would be impacted under a 15 cm (6 in) to 30 cm (12 in) rise in minimum water level cannot be predicted, but based upon depth distribution patterns, a loss exceeding 50% of the present area could be incurred.

The early 1980's fish community was perturbed by winterkill during the 1978-79 winter. In addition to winterkill, the fish community has been impacted by the introduction of exotics and high turbidity levels. Of the species collected in Clear Lake, more than half utilize littoral vegetation as spawning or juvenile habitat, and more than three quarters of the species utilize these habitats as adults. Due to the other biological and physical factors influencing the fish community, it is not possible to predict the manner in which the fish community might change as a result of reduction or elimination of littoral vegetation.

Recreationists preferred water level stabilization and were aware of effects of low water periods on recreation activity. It appeared that water level stabilization would be accepted readily by lake users, but it was unlikely that their current perceptions included an understanding of potential impacts on the plant community.

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FIGURES

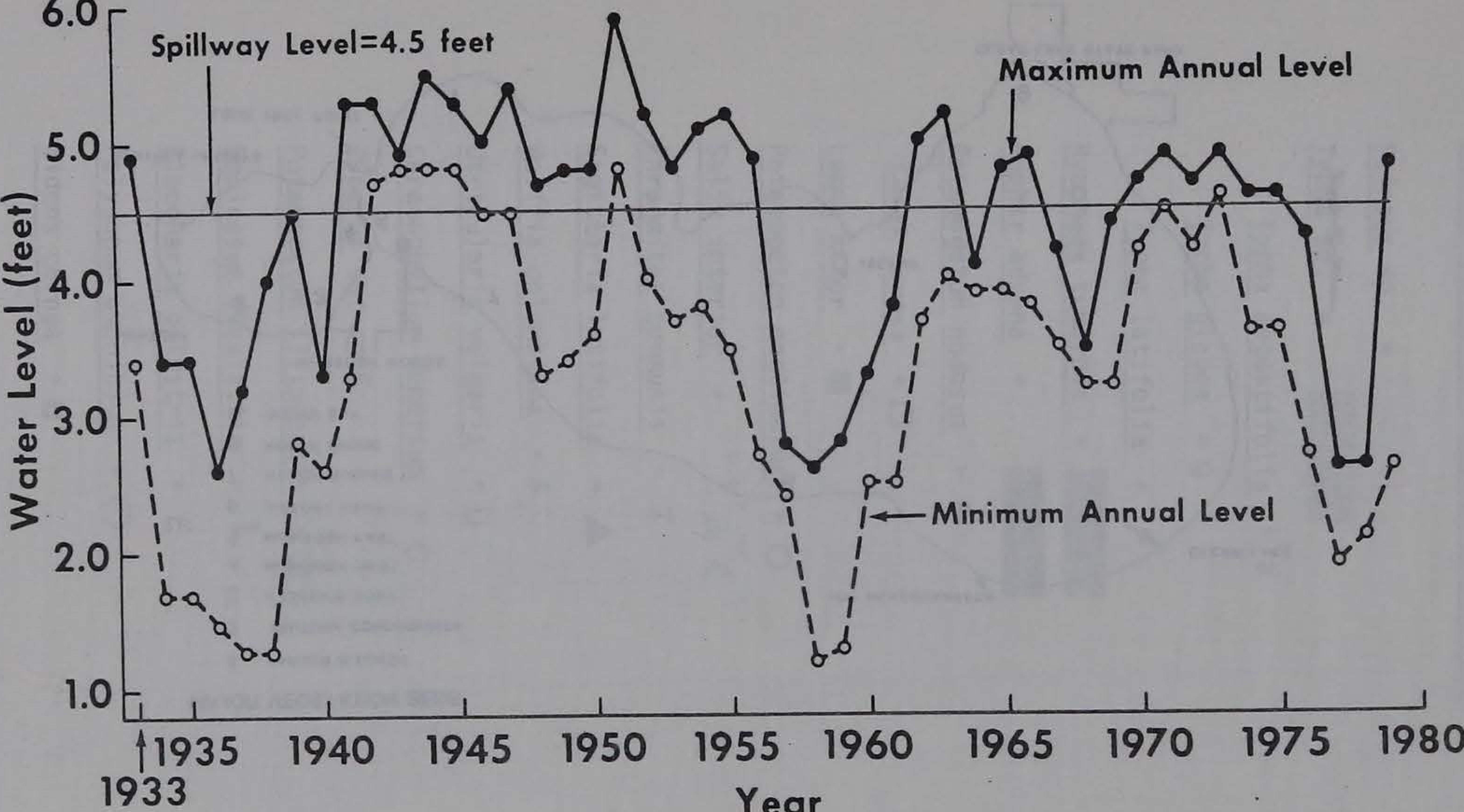


Figure 1. Water level fluctuations in Clear Lake, Iowa, 1933-1980, illustrating 20-year drought cycles.

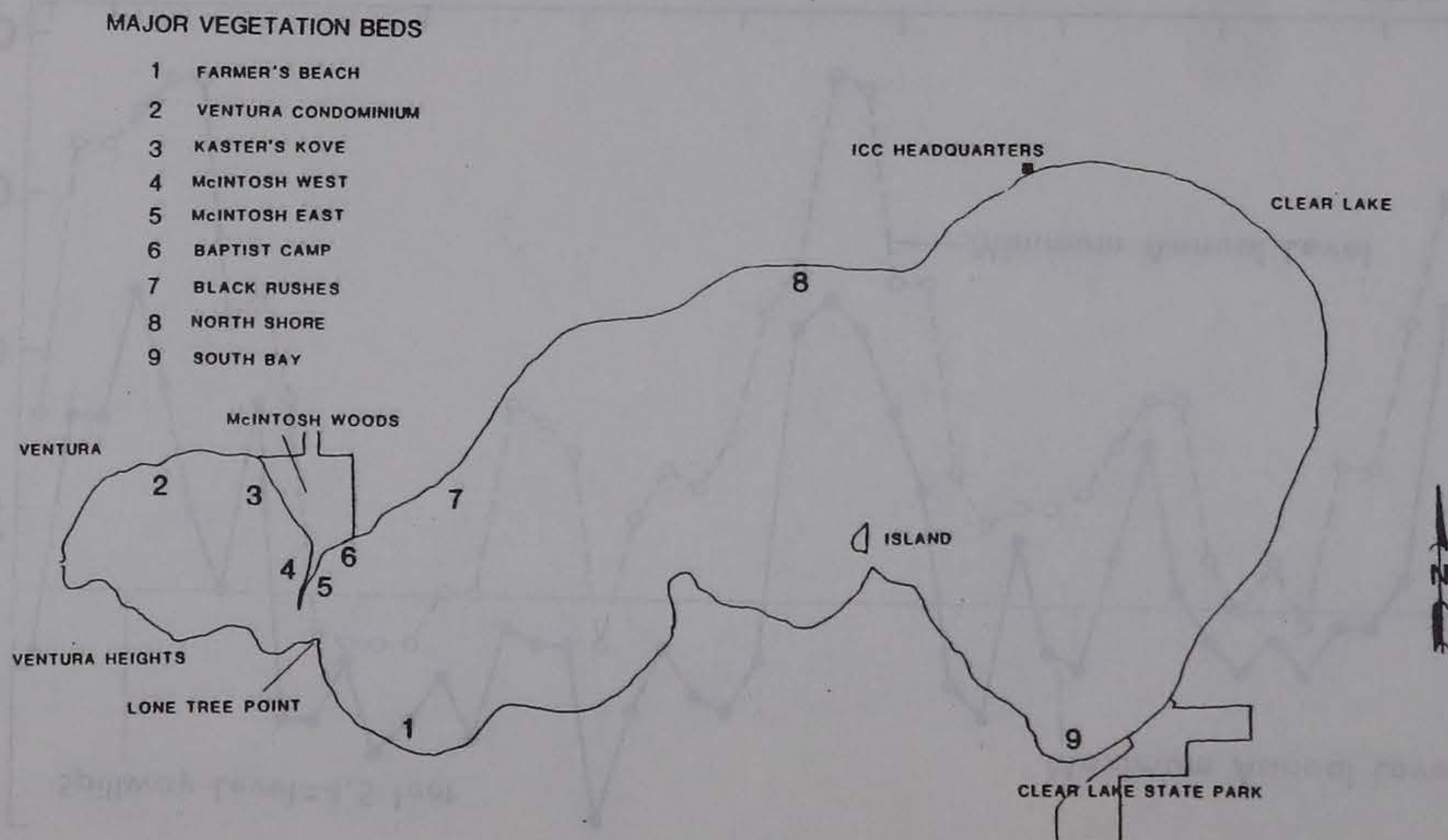
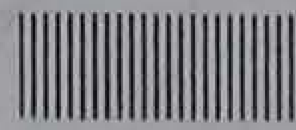


Figure 2. Map of Clear Lake, Iowa showing the locations of the nine major vegetation beds.

KEY TO THE PLANTS OF CLEAR LAKE, IOWA

Scirpus sp. = 

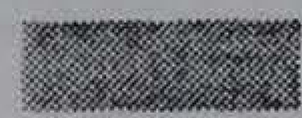
Typha sp. = 

Typha angustifolia = a

Typha glauca = g

Typha latifolia = 

Nymphaea tuberosa = 

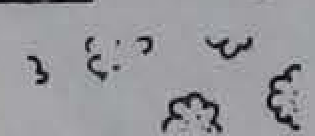
Nuphar advena = 

Potamogeton nodosus = ●

Carex comosa = □

Lemna minor = ■

Potamogeton pectinatus = ○

Salix interior = 

Phragmites communis = T

Sagittaria latifolia = ▲

Wolffia columbiana = ¢

Utricularia vulgaris = U

Ceratophyllum demersum = C

Cyperus sp. = £

Potamogeton illinoensis = ⦶

Equisetum fluviatile = †

Eleocharis palustris = E

Polygonum amphibium = ⬡

Bidens cernua = B

Figure 3. Symbols used in the mapping of the nine major vegetation beds in Clear Lake, Iowa, 1981.

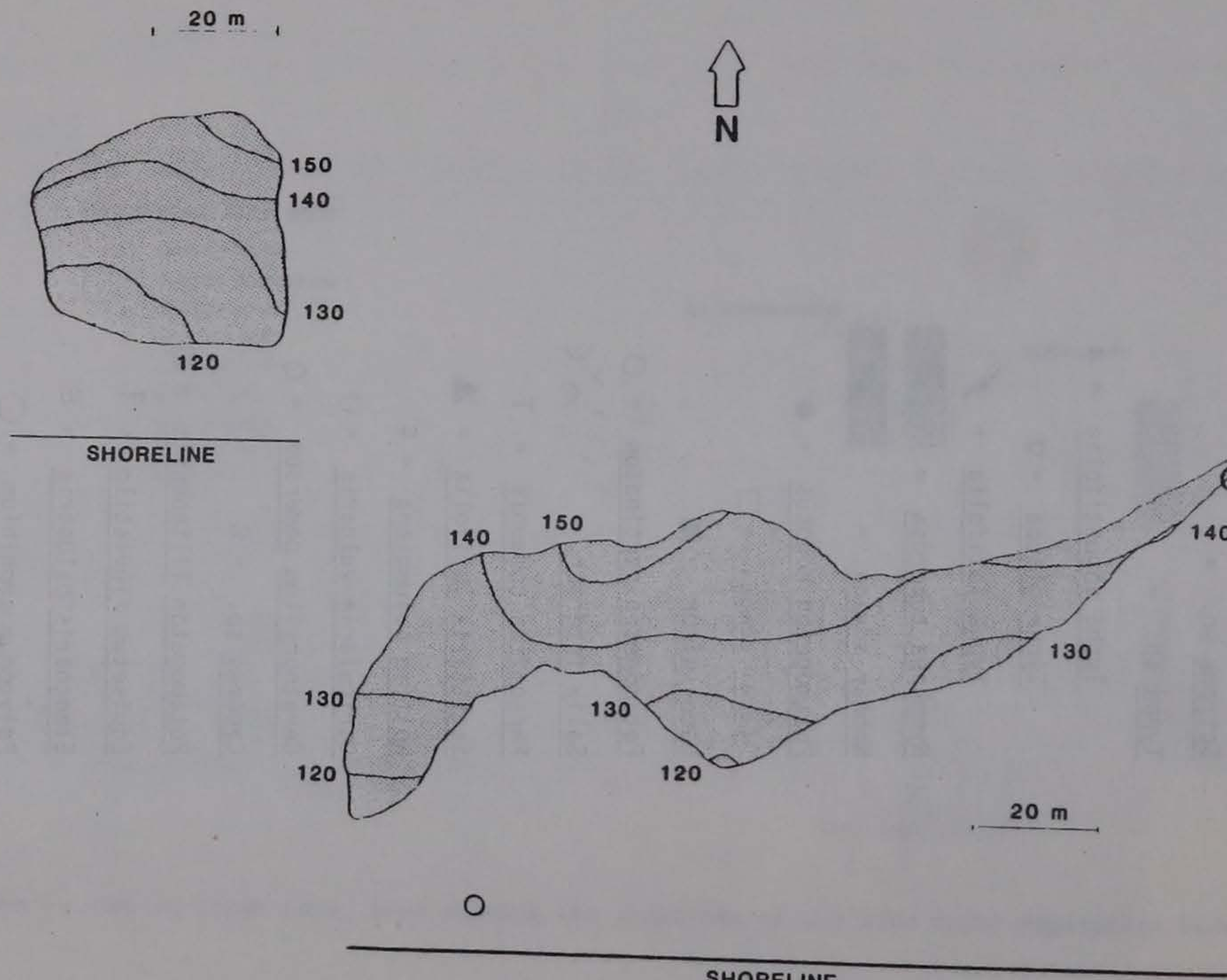


Figure 4. Vegetation and depth distribution (cm) map of the east segment of the Farmer's Beach vegetation bed in Clear Lake, Iowa, 1981.

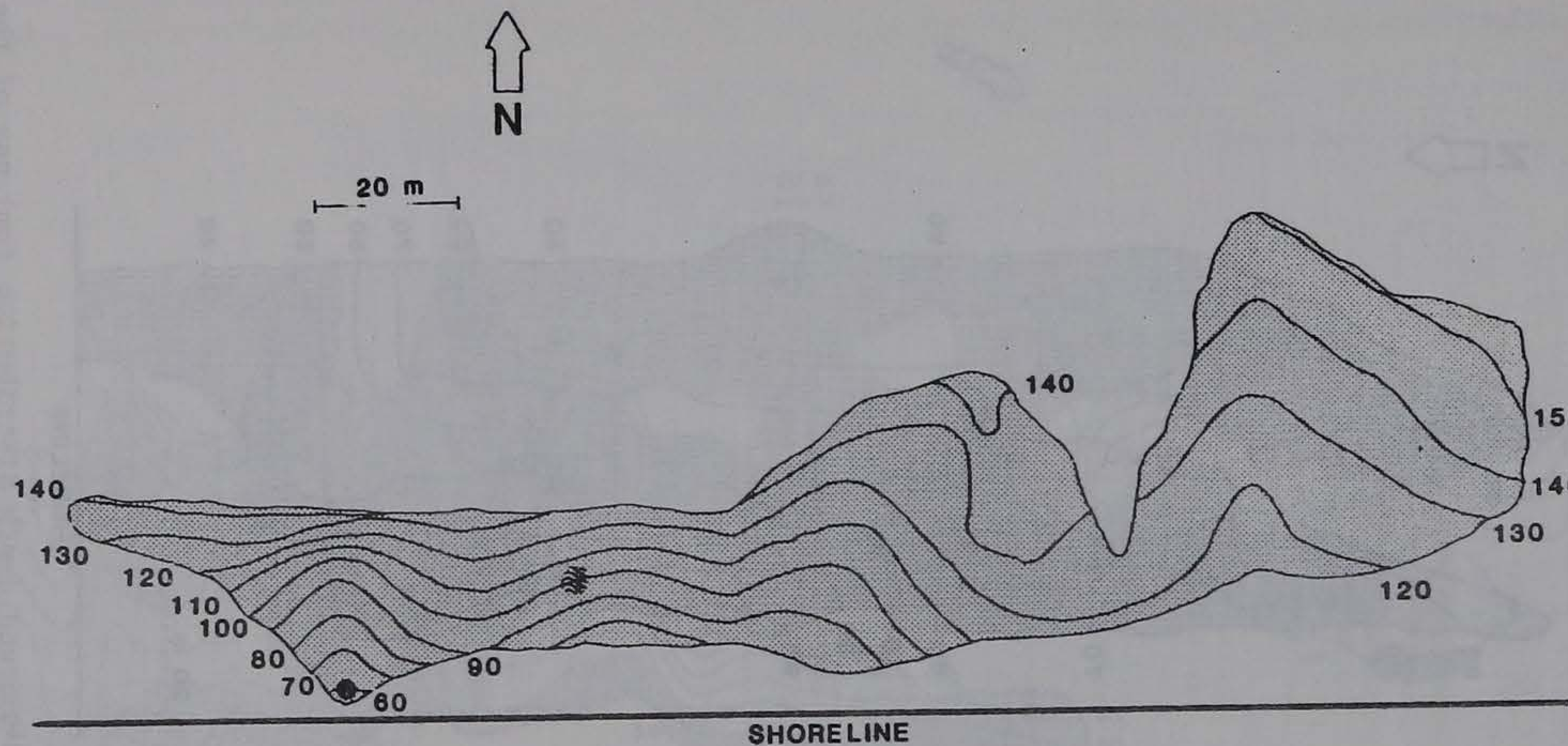


Figure 5. Vegetation and depth distribution (cm) map of the west segment of the Farmer's Beach vegetation bed in Clear Lake, Iowa, 1981.

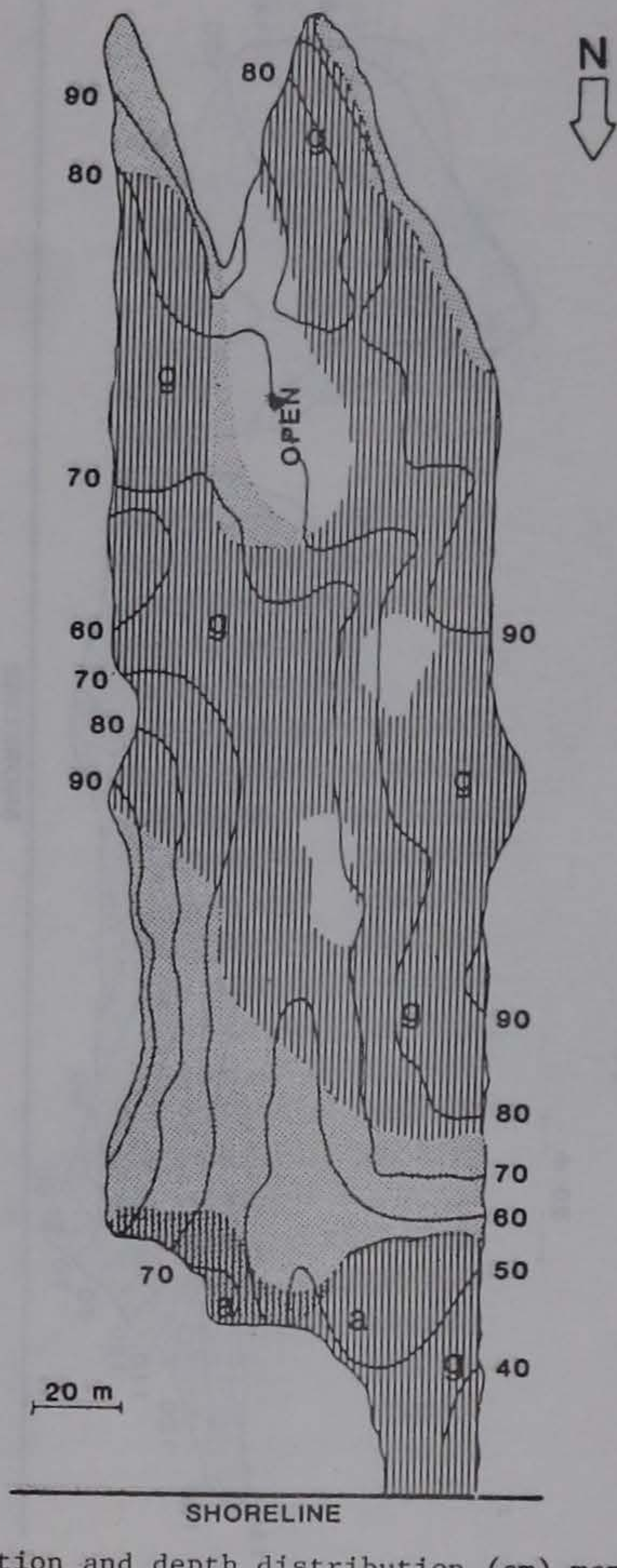


Figure 6. Vegetation and depth distribution (cm) map of the Ventura Condominium vegetation bed in Clear Lake, Iowa, 1981.

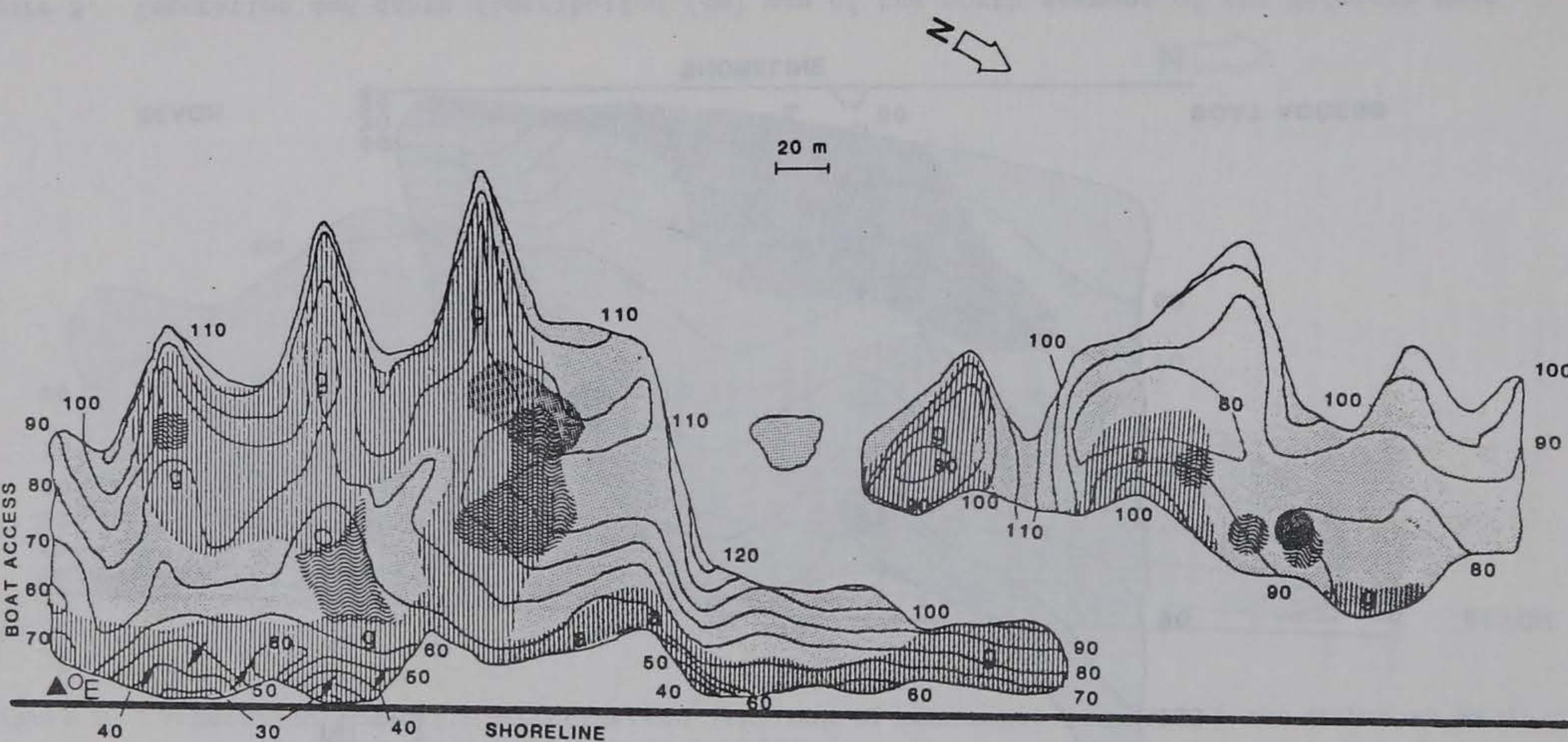


Figure 7. Vegetation and depth distribution (cm) map of the Kaster's Kove vegetation bed in Clear Lake, Iowa, 1981.

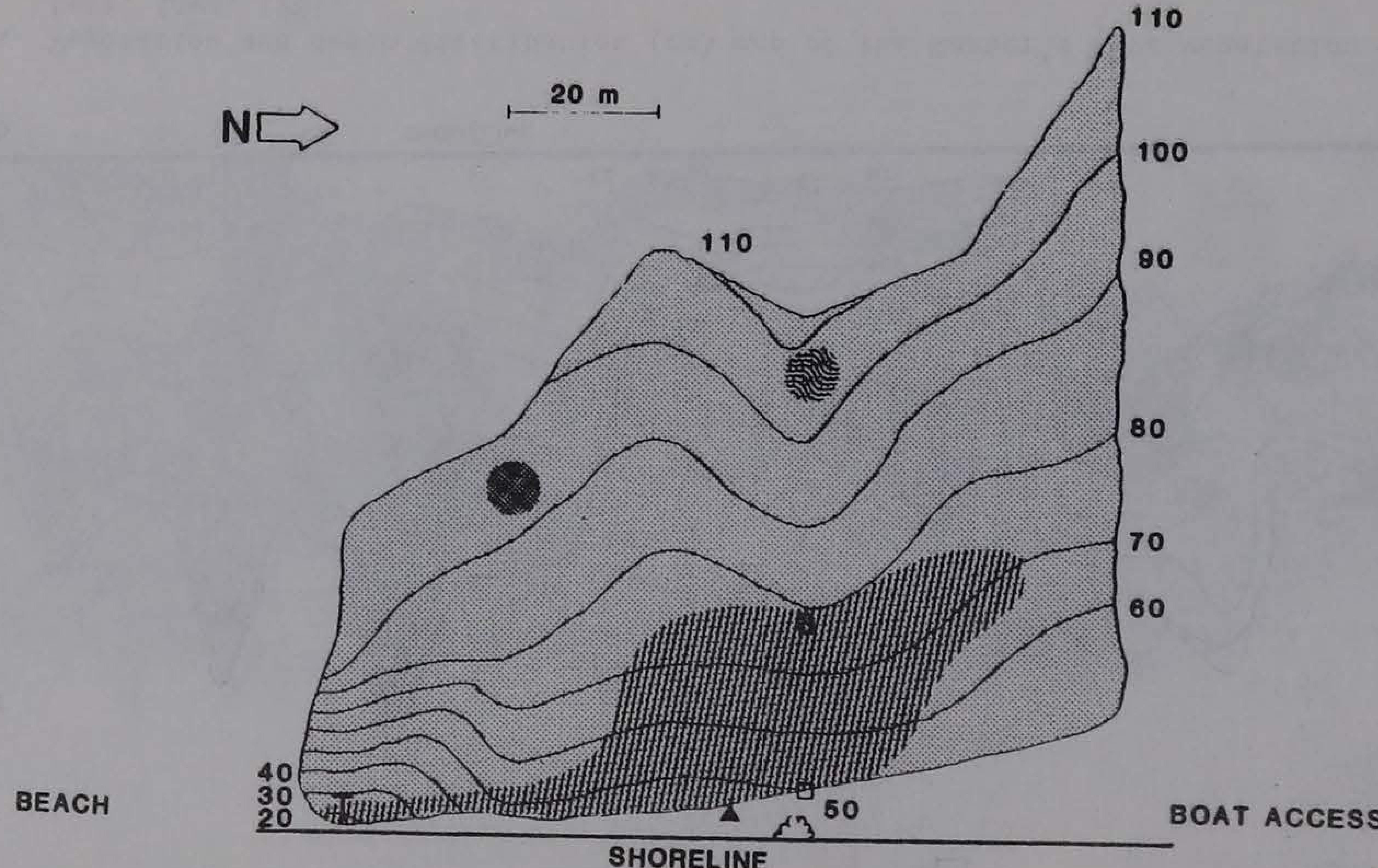


Figure 8. Vegetation and depth distribution (cm) map of the north segment of the McIntosh West vegetation bed in Clear Lake, Iowa, 1981.

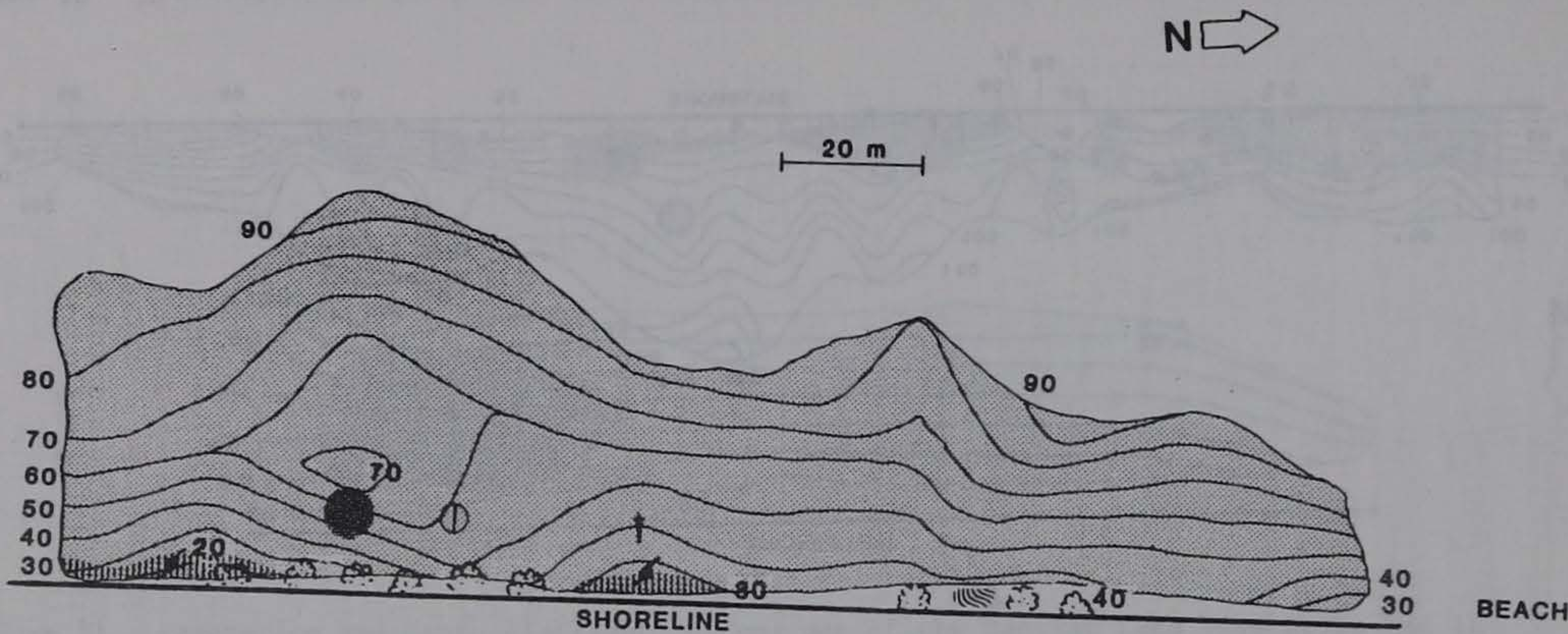


Figure 9. Vegetation and depth distribution (cm) map of the south segment of the McIntosh West vegetation bed in Clear Lake, Iowa, 1981.

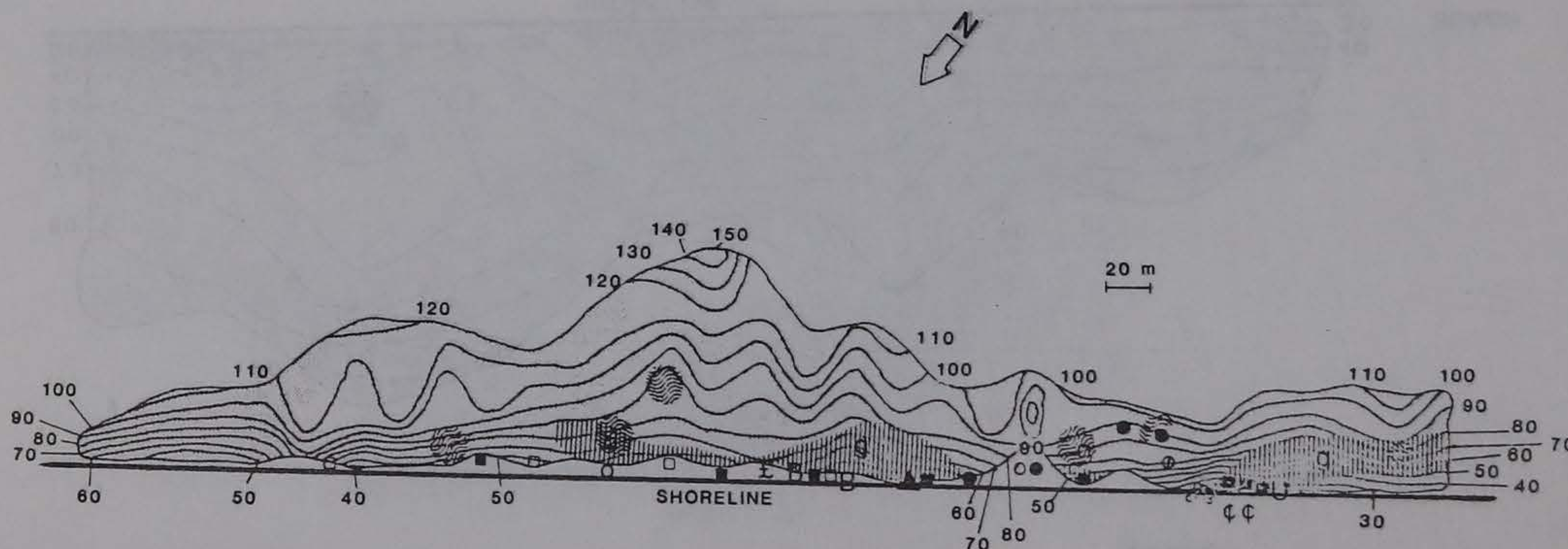


Figure 10. Vegetation and depth distribution (cm) map of the McIntosh East vegetation bed in Clear Lake, Iowa, 1981.

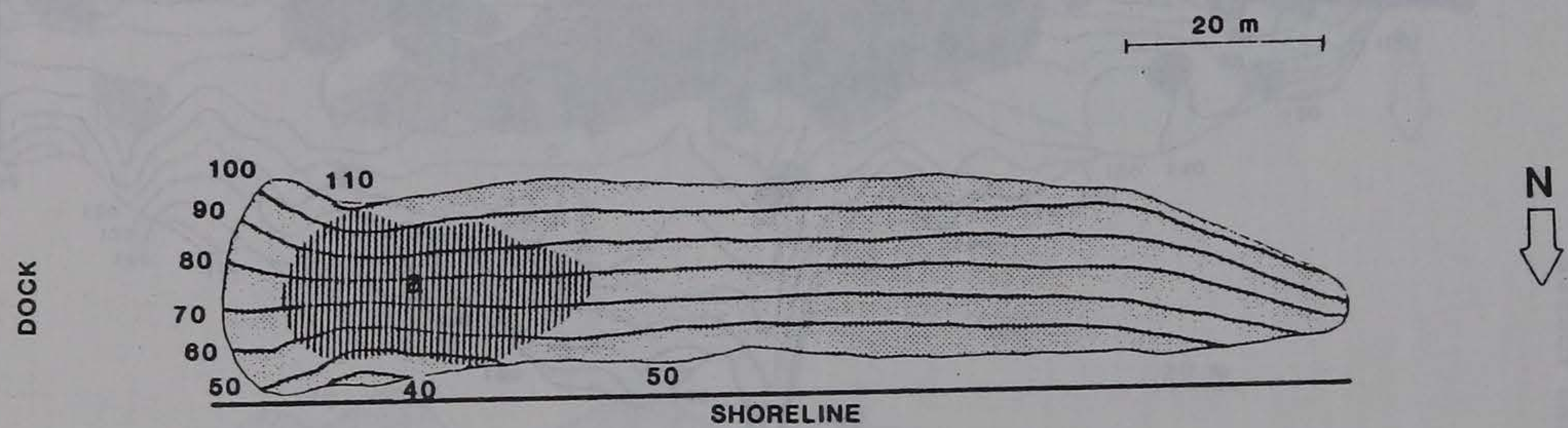


Figure 11. Vegetation and depth distribution (cm) map of the Baptist Camp vegetation bed in Clear Lake, Iowa, 1981.

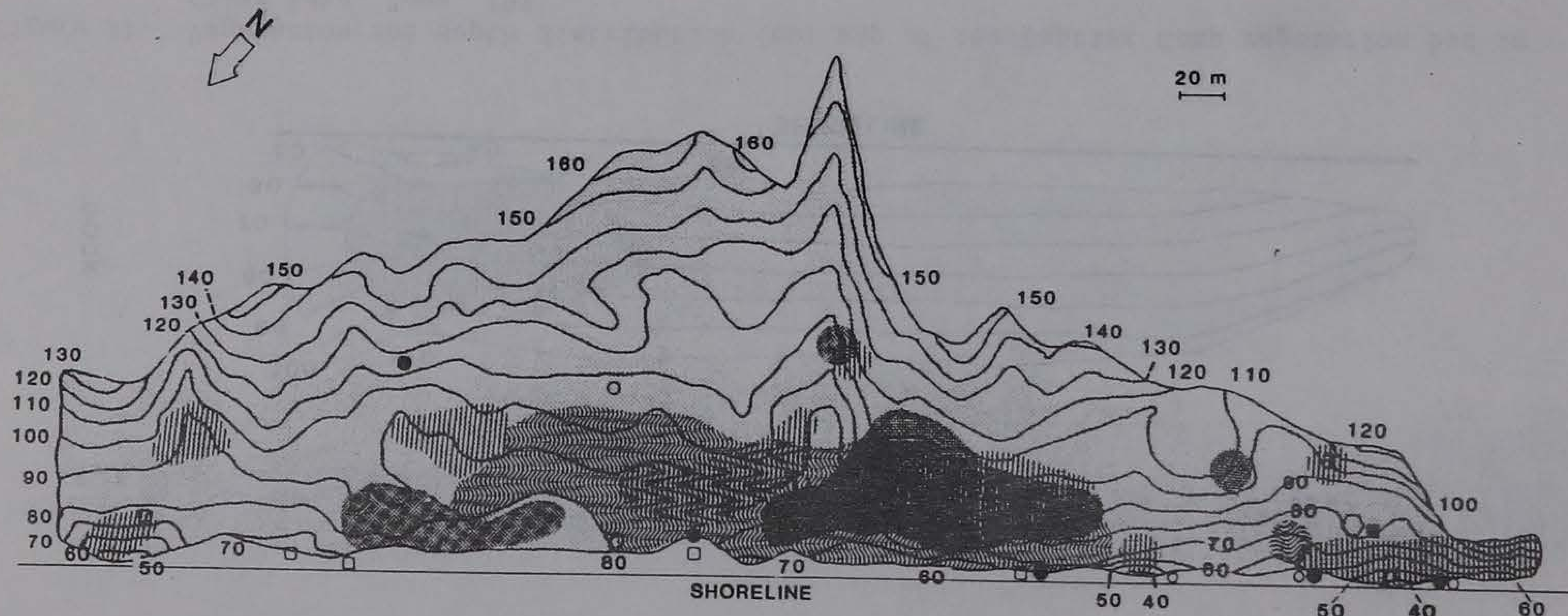


Figure 12. Vegetation and depth distribution (cm) map of the Black Rushes vegetation bed in Clear Lake, Iowa, 1981.

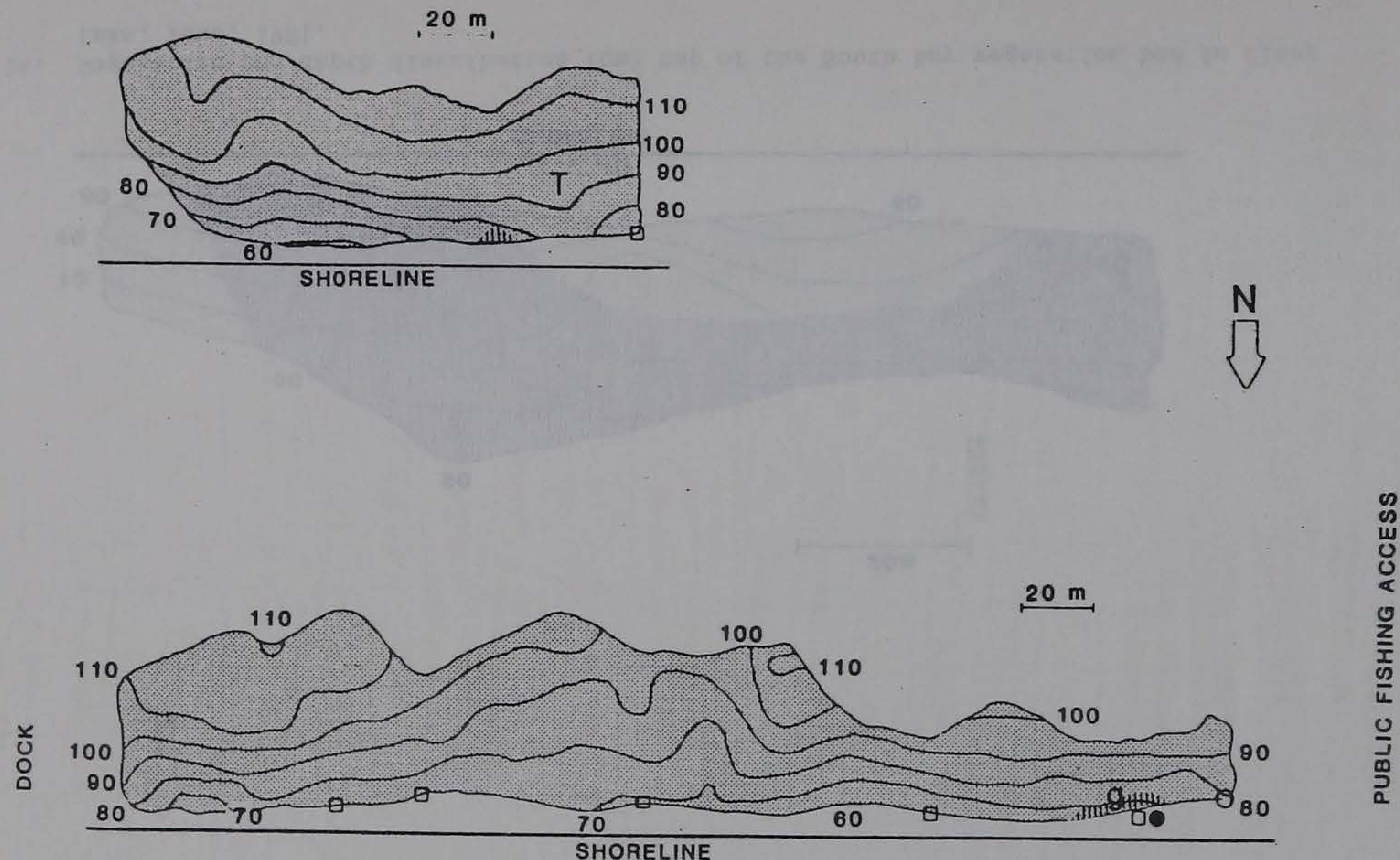


Figure 13. Vegetation and depth distribution (cm) map of the North Shore vegetation bed in Clear Lake, Iowa, 1981.

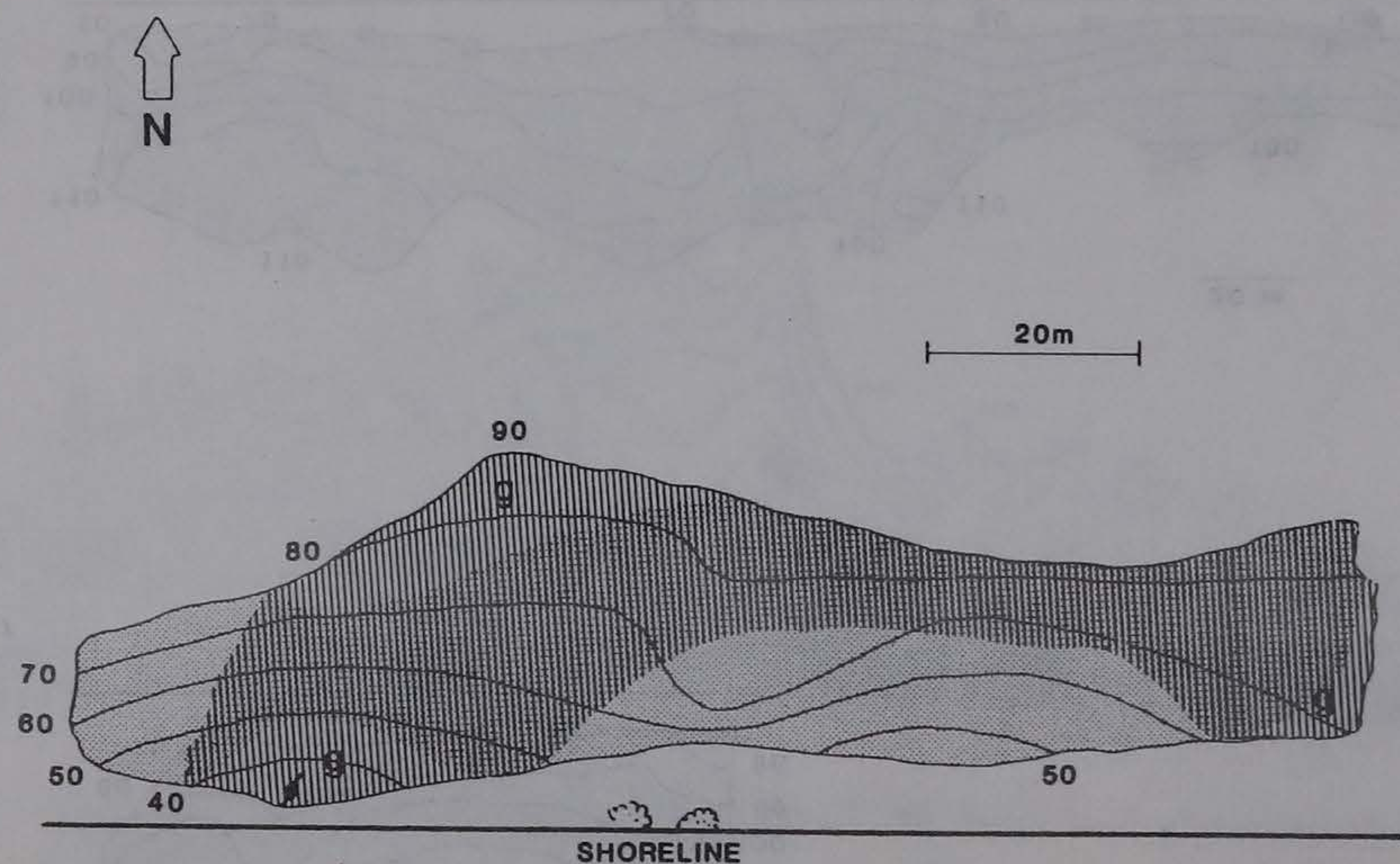


Figure 14. Vegetation and depth distribution (cm) map of the South Bay vegetation bed in Clear Lake, Iowa, 1981.

TABLES

Table 1. Areas of each of the nine major vegetation beds surveyed in 1981

Vegetation bed	Hectares	Acres
Farmer's Beach	1.67	4.13
Ventura Condominium	2.33	5.76
Kaster's Kove	5.48	13.54
McIntosh West	2.32	5.74
McIntosh East	2.88	7.13
Baptist Camp	0.47	1.15
Black Rushes	5.09	12.75
North Shore	1.75	4.31
South Bay	0.63	1.57
Total	22.60	56.08

Table 2. Areas covered by the dominant plant forms in each of the nine major vegetation beds surveyed in Clear Lake, Iowa, 1981. Hectares (acres)

Vegetation beds	Plant species							
	Scirpus sp.		*Typha* sp.		*Nymphaea suberosa*		*Nuphar advena*	
Farmer's Beach	1.67	(4.13)	--	--	--	--	--	--
Ventura Condominum	0.62	(1.52)	1.75	(4.32)	--	--	--	--
Kaster's Kove	3.29	(8.13)	2.37	(5.86)	0.25	(0.63)	0.13	(0.31)
McIntosh West	2.32	(5.74)	0.24	(0.59)	0.01	(0.02)	0.01	(0.02)
McIntosh East	2.89	(7.13)	0.31	(0.76)	0.13	(0.32)	--	--
Baptist Camp	0.47	(1.15)	0.09	(0.23)	--	--	--	--
Black Rushes	5.09	(12.57)	0.69	(1.70)	0.93	(2.29)	0.56	(1.38)
North Shore	1.74	(4.31)	0.02	(0.06)	--	--	--	--
South Bay	0.55	(1.37)	0.45	(1.11)	--	--	--	--
Total	18.64	(46.05)	6.92	(14.63)	1.32	(3.26)	0.69	(1.71)

Table 3. Identification and evaluation of relative abundance of emergent, submersed, and floating-leaved macrophytes in Clear Lake, Iowa (+ = Present [no abundance scheme used], R = Rare, O = Occasional, C = Common, A = Abundant, VA = Very Abundant)

	Shimek (1896)	Bailey and Harrison (1945)	Parsons (1950)	Pearcy (1952)	Ridenhour (1958)	Mrachek (1958)	Niemeier
AQUATIC MACROPHYTES	1896	1944	1949	1951	1956-1957	1965	1981
CHARACEAE							
Chara sp.		C	+	A	VA	O	
EQUISETACEAE							
Equisetum fluviatile							R
TYPHACEAE							
Typha angustifolia			+			C	O
Typha glauca							A
Typha latifolia		C	+			O	O
NAJADACEAE							
Najas flexilis	VC		+	A	O	A	
Potamogeton alpinus				R			
Potamogeton amplifolius	C			R			
Potamogeton freisii	C						
Potamogeton illinoensis			+	C	A	O	R
Potamogeton natans	O	A	+	C	A	C	
Potamogeton nodosus			VA	VA	A	VA	O
Potamogeton pectinatus	C	C	+	VA	O	C	O
Potamogeton praelongus	C		+				
Potamogeton pusillus	R			O		O	
Potamogeton richardsonii	C	A	+	A	O	C	
Potamogeton zosteriformis	C						

Table 3. *Continued*

AQUATIC MACROPHYTES	1896	1944	1949	1951	1956-1957	1965	1981
NAJADACEAE *(cont'd.)*							
Zannichellia palustris				O		R	
ALISMACEAE							
Alisma plantago-aquatica			+				
Sagittaria latifolia			+	A			R
Sagittaria rigida			+	A	O		
Sagittaria teres						R	
HYDROCHARITACEAE							
Elodea canadensis	VC	C		C		O	
Vallisneria americana	VC		+	C	O	O	
GRAMINAE							
Echinochloa pungens				O			
Phragmites communis				R			R
CYPERACEAE							
Carex comosa							R
Carex histricina			+				
Cyperus ferruginescens				O			
Cyperus sp.							R
Eleocharis acicularis				C	R		
Eleocharis palustris							R
Scirpus acutus		VA					R
Scirpus fluviatilis			+	O			
Scirpus validus			VA	VA	C	VA	VA
LEMNACEAE							
Lemna minor		C	+	+		C	O
Spirodela polyrhiza			+				
Wolffia columbiana		C				O	O

Table 3. *Continued*

AQUATIC MACROPHYTES	1896	1944	1949	1951	1956-1957	1965	1981
PONTEDERIACEAE							
Heteranthera dubia				C		R	
SPARGANIACEAE							
Sparganium eurycarpum			+	A			
SALICACEAE							
Salix interior				O			O
Salix niger				O			
POLYGONACEAE							
Polygonum amphibium			+	O			R
Polygonum coccineum			+	O		R	O
Polygonum lapathifolium				O			
Polygonum punctatum			+				
CERATOPHYLLACEAE							
Ceratophyllum demersum		A		R		C	R
NYMPHAEACEAE							
Nuphar advena			+	C		C	O
Nymphaea tuberosa	+		+	C		C	O
CRASSULACEAE							
Penthorum sedoides				O			
HALORAGIDACEAE							
Myriophyllum heterophyllum	VC						
Myriophyllum spicatum	VC					C	
Myriophyllum sp.		A	+	O			
ASCLEPIADACEAE							
Asclepias incarnata				O			

Table 3. *Continued*

AQUATIC MACROPHYTES	1896	1944	1949	1951	1956-1957	1965	1981
LENTIBULARIACEAE							
Utricularia vulgaris							R
COMPOSITAE							
Bidens cernua							R
Bidens connata				O			

Table 4. Absolute[a] and percent frequency of emergent, submersed, and floating-leaved macrophytes in 1981, Clear Lake, Iowa

Species	Absolute Frequency	% Frequency
Scirpus validus	1099	77.50
Typha glauca	270	19.00
Nymphaea tuberosa	31	2.19
Nuphar advena	28	1.97
Typha angustifolia	21	1.48
Typha latifolia	18	1.27
Potamogeton nodosus	12	0.85
Carex commosa	11	0.78
Lemna minor	8	0.56
Scirpus acutus	6	0.42
Potamogeton pectinatus	5	0.35
Salix interior	5	0.35
Phragmites communis	3	0.21
Sagittaria latifolia	2	0.14
Wolffia columbiana	2	0.14
Utricularia vulgaris	1	0.07
Ceratophyllum demersum	1	0.07
Cyperus sp.	1	0.07
Potamogeton illinoensis	1	0.07
Equisetum fluviatile	1	0.07

[a]Frequency values represent absolute frequency out of 1418 quadrats in 1981.

Table 5. Sample depth-species gradient table observed in 1981, Clear Lake, Iowa

	Interval along a gradient of depth (10 cm intervals)																	
Species	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
Eleocharis palustris	X																	
Bidens cernua	X	X																
Salix interior	X	X	X	X														
Wolffia columbiana		X		X														
Lemna minor		X	X	X	X	X		X	X									
Typha latifolia		X	X	X	X	X	X	X		X								
Scirpus validus		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Equisetum fluviatile			X			X												
Typha glauca			X	X	X	X	X	X	X	X	X	X						
Potamogeton pectinatus			X	X	X	X	X		X									
Sagittaria latifolia			X		X	X			X									
Phragmites communis			X	X		X				X								
Utricularia vulgaris				X														
Potamogeton nodosus				X	X	X	X	X		X	X		X					
Typha angustifolia					X	X	X	X	X	X	X							
Carex commosa					X		X	X	X	X								
Cyperus sp.					X													
Scirpus acutus					X	X				X	X							
Nymphaea tuberosa					X	X	X	X	X	X	X	X	X					
Potamogeton illinoensis						X	X		X									
Polygonum amphibium							X											
Nuphar advena									X	X	X	X	X					
Ceratophyllum demersum																X		

Table 6. Apparent tolerances of some Clear Lake aquatic plant species to turbidity, moderate pollution, and related factors (as compiled by Kadlec and Wentz, 1974, from information in: Lind and Cottam, 1969; Stuckey, 1971; Stuckey and Wentz, 1969; Suominen, 1968; Uotila, 1971; Wentz and Stuckey, 1971)

Species	S[1]	F[2]	E[3]	P[4]	Tolerant	Intolerant
Alisma plantago-aquatica	X		X		X	
Ceratophyllum demersum	X			X	X	
Elodea sp.	X				X	
Equisetum fluviatile			X	X		X
Heteranthera dubia	X				X	
Lemna minor		X		X	X	
Najas flexilis	X					X
Polygonum lapathifolium			X		X	
Polygonum punctatum			X		X	
Potamogeton amplifolius	X					X
Potamogeton friesii	X					X
Potamogeton pectinatus	X			X	X	
Potamogeton praelongus	X					X
Potamogeton richardsonii	X					X
Potamogeton zosteriformis	X					X
Sagittaria latifolia			X	X	X	
Sagittaria rigida			X			X
Sparganium eurycarpum			X		X	
Spirodela polyrhiza		X			X	
Typha angustifolia			X	X	X	
Typha latifolia			X	X	X	
Utricularia vulgaris	X			X	X	
Vallisneria americana	X				X	
Zannichellia palustris	X				X	

[1]S = submerged.

[2]F = floating-leaved.

[3]E = emergent.

[4]P = present in Clear Lake, 1981.

Table 7. Fish species captured in Clear Lake during summer 1981 and 1982 in relative order of abundance

1. Yellow perch, Perca flavescens
2. Black bullhead, Ictalurus melas
3. Black crappie, Pomoxis nigromaculatus
4. Bigmouth buffalo, Ictiobus cyprinellus
5. Common carp, Cyprinus carpio
6. Channel catfish, Ictalarus punctatus
7. Walleye, Stizostedion vitreum vitreum
8. White sucker, Catostomus commersoni
9. White bass, Morone chrysops
10. Yellow bass, Morone mississippiensis
11. Spottail shiner, Notropis hudsonius
12. Pumpkinseed, Lepomis gibbosus
13. Yellow bullhead, Ictaluris natalis
14. Green sunfish, Lepomis cyanellus
15. Muskellunge, Esox mosquinongy
16. Common shiner, Notropis cornutus
17. Golden shiner, Notemigonus crysaleucas
18. Northern pike, Esox lucius
19. Bluegill, Lepomis macrochirus
20. White crappie, Pomoxis annularis

Table 8. Composition of the catch with experimental gill nets[a] fished in four habitat types in Clear Lake during summer, 1981

Species	Littoral			Limnetic	All habitats Combined
	Vegetated	Non-Vegetated	Gravel-Rock	3m depth	
Northern pike	1	0	0	0	1
Muskellunge	1	2	0	0	3
Common carp	31	31	21	22	105
Golden shiner	2	0	0	0	2
Common shiner	1	1	0	0	2
White sucker	12	38	34	6	90
Bigmouth buffalo	71	28	35	3	137
Black bullhead	1241	611	547	342	2741
Yellow bullhead	0	0	0	3	3
Channel catfish	11	55	41	5	112
White bass	6	33	19	0	58
Yellow bass	1	5	20	2	28
Pumpkinseed	2	0	0	0	2
Black crappie	59	49	52	25	185
Yellow perch	1330	2433	1755	592	6110
Walleye	18	29	47	7	101
Total	2787	3315	2571	1007	9680

[a]36 sets of 2-hour duration in each habitat type.

Table 9. Percent composition of the catch with experimental gill nets[a] fished in four habitat types in Clear Lake during summer, 1981

Species	Littoral			Limnetic	All habitats combined
	Vegetated	Non-Vegetated	Gravel-Rock	3m depth	
Northern pike	0.04	0.00	0.00	0.00	0.01
Muskellunge	0.04	0.05	0.00	0.00	0.03
Common carp	1.13	0.95	0.91	2.13	1.08
Golden shiner	0.07	0.00	0.00	0.00	0.02
Common shiner	0.03	0.03	0.00	0.00	0.02
White sucker	0.42	1.15	1.50	0.66	0.93
Bigmouth buffalo	2.56	0.78	1.42	0.30	1.42
Black bullhead	44.31	18.62	20.05	32.91	28.32
Yellow bullhead	0.00	0.00	0.00	0.35	0.03
Channel catfish	0.40	1.66	0.00	0.46	1.16
White bass	0.21	1.00	0.77	0.00	0.60
Yellow bass	0.04	0.15	0.76	0.22	0.29
Pumpkinseed	0.07	0.00	0.00	0.00	0.02
Black crappie	2.18	1.45	2.67	2.35	1.91
Yellow perch	47.85	73.08	69.05	59.88	63.12
Walleye	0.62	0.90	1.86	0.72	1.04
Total	2787	3315	2571	1007	9680

[a]36 sets of 2-hour duration in each habitat type.

Table 10. Mean catch per unit effort (fish/hour/net) with experimental gill nets in littoral habitats of Clear Lake in June, July, and August, 1981. Superscripts show level of significance when differences between months were indicated by analysis of variance

	Month		
Species	June	July	August
Common carp[2]	0.06	0.54	0.23
White sucker	0.32	0.16	0.28
Bigmouth buffalo	0.37	0.56	0.32
Black bullhead[2]	10.93	8.55	4.58
Channel catfish[1]	0.28	0.48	0.21
White bass[1]	0.04	0.09	0.46
Yellow bass[1]	0.02	0.10	0.12
Black crappie	0.58	0.73	0.22
Yellow perch[2]	29.62	15.77	8.38
Walleye	0.27	0.30	0.28

[1]Significant at $P < 0.05$.

[2]Significant at $P < 0.0001$.

Table 11. Mean catch per unit effort (fish/hour/net) with experimental gill nets in littoral habitats of Clear Lake during morning, mid-day, and evening sampling periods of summer, 1981. Superscripts show level of significance when differences between sampling times were indicated by analysis of variance

Species	Sampling time		
	Morning	Mid-day	Evening
Common carp	0.32	0.28	0.22
White sucker	0.33	0.18	0.24
Bigmouth buffalo	0.76	0.20	0.28
Black bullhead[2]	6.99	5.03	12.04
Channel catfish[1]	0.35	0.14	0.47
White bass[1]	0.18	0.37	0.04
Yellow bass[1]	0.06	0.06	0.12
Black crappie	0.57	0.50	0.46
Yellow perch[2]	22.15	23.90	7.72
Walleye	0.32	0.24	0.28

[1]Significant at $P < 0.05$.

[2]Significant at $P < 0.001$.

Table 12. Mean catch per unit effort (fish/hour/net) with experimental gill nets in three littoral habitats of Clear Lake during summer, 1981. Superscripts show level of significance when differences between the three habitats were indicated by analysis of variance

	Habitat type		
Species	Vegetated	Non-vegetated	Gravel-Rock
Common carp	0.36	0.27	0.20
White sucker	0.15	0.33	0.28
Bigmouth buffalo[3]	0.76	0.20	0.28
Black bullhead[3]	14.05	5.27	4.74
Channel catfish[2]	0.14	0.44	0.38
White bass	0.06	0.34	0.19
Yellow bass[2]	0.01	0.05	0.19
Black crappie	0.68	0.39	0.46
Yellow perch	15.36	21.57	16.84
Walleye[1]	0.16	0.26	0.43

[1]Significant at $P < 0.10$.

[2]Significant at $P < 0.05$.

[3]Significant at $P < 0.01$.

Table 13. Mean catch per unit effort (fish/hour/net) with experimental gill nets in limnetic sampling locations of Clear Lake during summer, 1981. Results of paired comparisons of catch rates in the limnetic compared to three types of littoral habitats are presented (Student's t-test; N.S. = not significant)

		Significant differences*		
Species	Catch rate in limnetic samples	Vegetated v.Limnetic	Non-Vegetated v.Limnetic	Gravel-Rock v.Limnetic
Northern pike	0.00	N.S.	N.S.	N.S.
Muskellunge	0.00	N.S.	N.S.	N.S.
Common carp	0.19	N.S.	N.S.	N.S.
Golden shiner	0.00	N.S.	N.S.	N.S.
Common shiner	0.00	N.S.	N.S.	N.S.
White sucker	0.07	N.S.	$P < 0.0001$	$P < 0.0001$
Bigmouth buffalo	0.20	$P < 0.0001$	$P < 0.05$	$P < 0.01$
Black bullhead	3.70	$P < 0.0001$	N.S.	N.S.
Yellow bullhead	0.04	N.S.	N.S.	N.S.
Channel catfish	0.06	N.S.	$P < 0.0005$	$P < 0.0001$
White bass	0.00	$P < 0.05$	$P < 0.05$	$P < 0.05$
Yellow bass	0.02	N.S.	N.S.	$P < 0.005$
Pumpkinseed	0.00	N.S.	N.S.	N.S.
Black crappie	0.26	$P < 0.05$	N.S.	N.S.
Yellow perch	6.28	$P < 0.005$	$P < 0.0001$	$P < 0.0005$
Walleye	0.07	N.S.	$P < 0.005$	$P < 0.0001$

*In all cases where significance was observed, the littoral values were greater than the limnetic.

Table 14. Composition of the catch with fyke nets[a] fished in three littoral habitat types in Clear Lake during summer, 1981

Species	Vegetated	Non-Vegetated	Gravel-Rock	All habitats combined
Northern pike	1	0	0	1
Common carp	9	10	4	23
Golden shiner	1	0	0	1
Spottail shiner	2	12	4	18
White sucker	1	8	1	10
Bigmouth buffalo	17	1	0	18
Black bullhead	953	463	254	1670
Yellow bullhead	0	0	1	1
Channel catfish	0	1	0	1
Green sunfish	0	1	2	3
Pumpkinseed	5	0	0	5
Bluegill	1	0	0	1
White crappie	0	1	0	1
Black crappie	67	101	35	203
Yellow perch	1059	3343	785	5187
Walleye	2	1	1	4
Total	2118	3942	1087	7147

[a]24 sets of 12-hour duration in each habitat type.

Table 15. Percent composition of the catch with fyke nets[a] fished in three littoral habitat types in Clear Lake during summer, 1981

Species	Vegetated	Non-Vegetated	Gravel-Rock	All habitats combined
Northern pike	0.05	0.00	0.00	0.01
Common carp	0.42	0.25	0.37	0.32
Golden shiner	0.05	0.00	0.00	0.01
Spottail shiner	0.09	0.30	0.37	0.25
White sucker	0.05	0.20	0.09	0.14
Bigmouth buffalo	0.80	0.02	0.00	0.25
Black bullhead	45.00	11.74	23.37	23.37
Yellow bullhead	0.00	0.00	0.09	0.01
Channel catfish	0.00	0.02	0.00	0.01
Green sunfish	0.00	0.02	0.18	0.04
Pumpkinseed	0.24	0.00	0.00	0.07
Bluegill	0.05	0.00	0.00	0.01
White crappie	0.00	0.02	0.00	0.01
Black crappie	3.16	2.56	3.22	2.84
Yellow perch	50.00	84.80	72.22	72.58
Walleye	0.09	0.02	0.09	0.06
Total number captured	2118	3942	1087	7147

[a]24 sets of 12-hour duration in each habitat type.

Table 16. Mean catch per unit effort (fish/12-hour set/net) with fyke nets in littoral habitats of Clear Lake in June, July, and August, 1981. Superscript shows level of significance when differences between months were indicated by analysis of variance

Species	Month		
	June	July	August
Common carp	0.50	0.24	0.03
White sucker	0.24	0.07	0.03
Bigmouth buffalo	0.29	0.24	0.15
Black bullhead[1]	26.53	25.04	8.50
Channel catfish	0.00	0.04	0.00
Black crappie	2.95	2.73	2.01
Yellow perch	108.46	49.95	42.65
Walleye	0.08	0.07	0.08

[1]Significant at $P < 0.10$.

Table 17. Mean catch per unit effort (fish/12-hour set/net) with fyke nets in littoral habitats of Clear Lake during day and night sampling periods of summer, 1981. Superscripts show level of significance when differences between sampling times were indicated by analysis of variance

Species	Sampling time — Day	Sampling time — Night
Common carp[1]	0.16	0.36
White sucker[2]	0.00	0.23
Bigmouth buffalo	0.14	0.31
Black bullhead[1]	15.98	24.08
Channel catfish	0.03	0.00
Black crappie	2.56	2.57
Yellow perch[1]	108.03	26.01
Walleye	0.03	0.13

[1]Significant at $P < 0.10$.

[2]Significant at $P < 0.05$.

Table 18. Mean catch per unit effort (fish/12 hour set/net) with fyke nets in three littoral habitats of Clear Lake during summer, 1981. Superscript shows level of significance when differences between the three habitats were indicated by analysis of variance

Species	Habitat type		
	Vegetated	Non-vegetated	Gravel-Rock
Common carp	0.28	0.35	0.15
White sucker	0.04	0.26	0.04
Bigmouth buffalo[1]	0.64	0.03	0.00
Black bullhead	33.70	17.00	9.38
Channel catfish	0.14	0.44	0.38
Black crappie	2.64	3.74	1.32
Yellow perch	42.54	128.05	30.47
Walleye	0.16	0.04	0.04

[1]Significant at $P < 0.10$.

Table 19. Results of shoreline bag-seining[a] at Clear Lake between June 26 and August 19, 1981

Species	Number collected: Young-of-year or juveniles	Adults
Golden shiner	0	2
Common shiner	0	5
Spottail shiner	203[b]	0
Black bullhead	12	65
Channel catfish	1	0
White bass	17	0
Yellow bass	14	0
Green sunfish	0	2
Pumpkinseed	0	1
Largemouth bass	1	0
Black crappie	0	1
Yellow perch	45	1
Walleye	1	0
Total	294	77

[a]100 hauls, each 20 m long, with 15' x 4' bag seine, 1/4" mesh.

[b]Includes young-of-year, juveniles, and adults.

Table 20. Temporal variation in mean catch per haul of age-0 fish sampled by shoreline seining from Clear Lake, 1982

	Sampling dates										
	June					July				August	
Species	2	7	15	22	29	7	11	19	27	5	10
Muskellunge	-	-	-	-	-	-	-	-	-	0.1	0.1
Common carp	-	-	-	-	-	-	-	0.1	-	-	-
Spottail shiner	-	0.1	1.0	0.8	4.3	7.8	6.1	2.1	8.1	8.2	5.6
White sucker	1.3	0.7	0.3	0.2	-	-	-	-	-	-	-
Black bullhead	-	-	-	-	-	-	-	-	-	0.1	1.0
Morone	-	-	-	-	-	-	0.4	0.1	0.2	1.2	1.3
White bass	-	-	-	-	-	-	-	-	-	-	0.4
Yellow bass	-	-	-	-	-	-	-	-	0.2	1.2	0.8
Lepomis	-	-	-	-	-	-	-	-	0.8	0.9	1.3
Black crappie	-	-	-	-	-	-	-	0.1	-	0.1	-
Walleye	-	-	-	-	-	-	-	-	-	0.1	0.6
Yellow perch	25.3	15.9	30.9	8.7	10.7	8.2	15.6	2.3	0.9	1.9	6.3
Darter	-	0.1	0.1	-	-	0.1	0.2	-	-	-	-

Table 21. Habitat differences in mean catch per haul of age-0 fish sampled by shoreline seining from Clear Lake, 1981

Species	Sampling Date	Vegetated		Non-vegatated		Gravel-Rock	
		$\bar{x}$	s^2	$\bar{s}$	s^2	$\bar{x}$	s^2
Muskellunge	Aug. 5	0.2	0.08	0.2	0.0008	--	--
	Aug. 10	0.2	0.08	--	--	0.2	0.08
Common carp	July 19	0.2	0.08	--	--	--	--
Spottail shiner	June 7	--	--	0.2	0.08	--	--
	June 15	1.5	1.0	0.5	0.0	1.0	3.0
	June 22	1.7	6.1	0.3	0.1	0.3	0.3
	June 29	1.5	3.3	6.5	47.3	4.8	50.1
	July 7	2.0	6.8	7.2	36.1	14.2	382.9
	July 11	11.8	252.6	4.0	19.0	2.3	5.5
	July 19	0.8	2.1	2.5	8.8	2.8	6.6
	July 27	13.8	346.4	10.0	204.3	0.5	0.8
	Aug. 5	10.2	295.1	12.9	168.6	1.5	6.8
	Aug. 10	7.5	99.8	8.8	45.6	0.5	0.0
White sucker	June 2	0.3	0.3	0.7	1.3	2.8	20.1
	June 7	0.5	0.8	0.7	0.6	1.0	0.8
	June 15	0.3	0.3	--	--	0.7	0.3
	June 22	0.5	0.8	--	--	--	--
Black bullhead	Aug. 5	--	--	0.2	0.1	--	--
	Aug. 10	--	--	0.3	0.3	2.7	21.3
Morone	July 11	0.2	0.1	0.8	2.1	0.2	0.1
	July 19	--	--	0.2	0.1	0.2	0.1
White bass	Aug. 10	--	--	1.3	5.3	--	--
Yellow bass	July 27	--	--	0.5	0.8	--	--
	Aug. 5	0.5	0.8	0.7	0.6	--	--
	Aug. 10	1.0	0.3	1.5	2.3	--	--
Lepomis	July 27	0.7	1.3	1.5	0.8	0.2	0.1
	Aug. 5	1.8	10.1	1.0	3.0	--	--
	Aug. 10	1.7	4.1	1.2	1.6	1.2	0.3

Table 21. *Continued*

Species	Sampling Date	Vegetated $\bar{x}$	Vegetated s^2	Non-vegetated $\bar{x}$	Non-vegetated s^2	Gravel-Rock $\bar{x}$	Gravel-Rock s^2
Black crappie	July 19	--	--	--	--	0.2	0.1
	July 27	--	--	--	--	--	--
	Aug. 5	0.2	0.1	0.2	0.1	--	--
Walleye	Aug. 5	--	--	0.2	0.1	--	--
	Aug. 10	0.5	0.8	0.8	2.1	0.3	0.3
Yellow perch	June 2	5.5	68.3	56.3	9186.3	14.2	306.1
	June 7	13.8	106.6	29.5	777.8	4.5	13.0
	June 15	27.0	299.3	82.5	9020.3	15.3	321.3
	June 22	9.2	9.1	7.7	4.1	9.2	20.3
	June 29	7.5	59.3	6.3	14.6	18.2	91.1
	July 7	11.2	206.3	9.0	114.3	4.5	16.8
	July 11	23.3	394.3	14.7	160.3	8.7	36.1
	July 19	3.0	19.0	3.0	15.3	0.8	0.3
	July 27	1.0	0.3	1.2	0.3	0.5	0.0
	Aug. 5	0.8	0.3	4.2	23.6	0.7	0.1
	Aug. 10	8.2	27.1	8.8	27.1	1.8	1.6
Darters	June 7	0.2	0.1	0.2	0.1	--	--
	June 15	0.2	0.1	--	--	--	--
	July 7	--	--	0.3	0.3	--	--
	July 11	0.2	0.1	0.3	0.1	--	--

Table 22. Temporal variation in mean catch (number per 100 m^3 of water filtered) and mean length of larval fish sampled by 0.5-m net tows in 1982 from Clear Lake

Calendar Day	Water Temperature	Species: Common carp No. per 100 m^3	Common carp TL (mm)	Spottail shiner No. per 100 m^3	Spottail shiner TL (mm)	Morone No. per 100 m^3	Morone TL (mm)	Lepomis No. per 100 m^3	Lepomis TL (mm)
May 3	13°C	-	-	-	-	-	-	-	-
13	18°C	-	-	-	-	-	-	-	-
19	20°C	-	-	-	-	-	-	-	-
26	16°C	-	-	-	-	-	-	-	-
June 2	16°C	-	-	0.2	10.0	-	-	-	-
7	16°C	0.2	6.0	0.2	9.0	0.2	9.5	-	-
15	18°C	0.2	8.5	1.2	13.0	0.2	10.0	-	-
22	18°C	-	-	2.3	14.5	-	-	-	-
29	23°C	-	-	1.5	21.5	0.2	7.0	-	-
July 7	25°C	-	-	1.0	28.8	0.2	10.0	-	-
11	25°C	-	-	1.3	28.3	-	-	-	-
19	27°C	-	-	2.3	32.3	-	-	-	-
27	25°C	-	-	1.5	41.7	-	-	0.3	7.6
Aug. 5	22°C	-	-	0.9	49.3	-	-	1.2	12.6
10	25°C	-	-	0.4	50.0	-	-	0.4	14.6

Table 22. *Continued*

Calendar Day	Water Temperature	Black crappie No. per 100 m^3	Black crappie TL (mm)	Walleye No. per 100 m^3	Walleye TL (mm)	Yellow perch No. per 100 m^3	Yellow perch TL (mm)	Darter No. per 100 m^3	Darter TL (mm)
May 3	13°C	-	-	-	-	22.7	5.8	-	-
13	18°C	-	-	2.3	10.7	130.9	9.3	-	-
19	20°C	0.6	5.8	-	-	28.0	13.1	-	-
26	16°C	-	-	-	-	25.9	16.2	0.2	9.0
June 2	16°C	-	-	-	-	27.0	20.2	0.2	6.0
7	16°C	0.7	6.5	-	-	10.7	22.8	0.5	10.3
15	18°C	-	-	-	-	4.7	26.5	0.3	18.5
22	18°C	0.4	5.8	-	-	21.8	30.5	-	-
29	23°C	-	-	-	-	19.3	34.8	0.3	10.5
July 7	25°C	0.3	4.8	-	-	3.3	41.2	0.3	18.0
11	25°C	-	-	-	-	3.9	40.1	0.5	12.0
19	27°C	-	-	-	-	5.1	46.9	0.3	18.3
27	25°C	-	-	-	-	0.6	52.4	-	-
Aug. 4	22°C	-	-	-	-	0.3	52.5	-	-
10	25°C	-	-	-	-	1.0	54.8	-	-

Table 23. Habitat differences in mean catch of larval fish (number per 100 m^3 of water filtered) sampled by 0.5-m net tows from Clear Lake, Iowa, 1982

		Habitat Type			
Species	Calendar Day	Non-vegetated	Vegetated	Gravel/ Rock	Open water
Common carp	June 7	-	0.7	-	-
	June 22	3.4	-	1.9	0.7
Spottail shiner	June 2	-	0.8	-	-
	June 7	-	0.7	-	-
	June 15	1.8	1.9	0.6	0.6
	June 22	1.5	9.0	0.8	0.7
	June 29	-	2.7	2.7	0.6
	July 7	2.3	1.7	-	-
	July 11	2.7	-	1.2	1.2
	July 19	2.2	3.2	1.7	2.3
	July 27	0.6	2.1	1.6	1.6
	Aug. 4	2.5	0.5	-	0.6
	Aug. 10	1.1	-	0.5	-
Morone	June 7	-	0.7	-	-
	June 15	0.6	-	-	-
	June 29	-	-	0.6	-
	July 7	-	-	0.7	-
Lepomis	July 27	1.2	-	-	-
	Aug. 4	1.2	0.5	1.8	1.2
	Aug. 10	-	-	1.6	-
Black crappie	May 19	-	0.8	1.5	-
	June 7	-	0.7	-	-
	June 22	0.8	-	0.9	-
	July 7	1.1	-	-	-
Walleye	May 13	4.9	-	2.5	1.7

Table 23. *Continued*

Species	Calendar Day	Habitat Type: Non-vegetated	Vegetated	Gravel/ Rock	Open water
Yellow perch	May 3	-	82.6	6.2	1.9
	May 13	70.8	18.1	452.7	60.1
	May 19	50.6	11.9	21.6	27.8
	May 26	22.4	2.3	25.3	53.7
	June 2	32.7	53.1	5.6	16.7
	June 7	6.6	3.0	12.8	20.4
	June 15	6.5	2.0	5.8	3.8
	June 22	22.0	23.7	20.8	20.6
	June 29	32.2	31.3	6.4	7.4
	July 7	8.3	3.1	1.9	1.2
	July 11	6.2	-	3.2	6.2
	July 19	10.8	6.0	2.3	1.2
	July 27	1.1	-	0.6	0.5
	Aug. 4	-	-	0.7	0.6
	Aug. 10	0.6	1.1	2.4	-
Darter	May 26	-	-	0.8	-
	June 2	-	-	0.6	-
	June 7	0.7	-	-	1.3
	June 15	-	-	0.6	0.7
	June 29	-	-	-	1.2
	July 7	0.6	0.5	-	-
	July 11	0.6	-	-	-
	July 19	-	-	-	1.2

Table 24. Composition of the catch with experimental gill nets[a] fished in three littoral habitat types in Clear Lake during summers of 1981 and 1982

Species	Vegetated		Non-vegetated		Gravel-Rock	
	1981	1982	1981	1982	1981	1982
Northern pike	0	0	0	0	0	0
Muskellunge	0	0	0	2	0	0
Common carp	10	9	8	2	3	11
Golden shiner	0	0	0	0	0	0
Common shiner	0	0	0	0	0	0
White sucker	2	0	13	4	12	3
Bigmouth buffalo	25	9	6	4	12	0
Black bullhead	602	80	238	62	250	51
Yellow bullhead	0	0	0	0	0	3
Channel catfish	2	5	30	34	22	16
White bass	1	6	2	28	1	10
Yellow bass	0	8	3	24	8	13
Pumpkinseed	0	0	0	0	0	0
Black crappie	24	12	10	5	8	6
Yellow perch	172	113	410	155	198	275
Walleye	3	12	5	29	22	39
Total	841	254	725	349	536	427

[a]12 sets of 2-hour duration (at dusk) in each habitat type.

Table 25. Composition of the catch with fyke nets[a] fished in three littoral habitat types in Clear Lake during summers of 1981 and 1982

Species	Vegetated 1981	Vegetated 1982	Non-vegetated 1981	Non-vegetated 1982	Gravel-Rock 1981	Gravel-Rock 1982
Northern pike	1	0	0	0	0	0
Muskellunge	0	0	0	0	0	1
Common carp	6	12	8	12	3	5
Golden shiner	1	0	0	0	0	0
Spottail shiner	0	1	3	4	0	5
White sucker	1	1	8	5	1	3
Bigmouth buffalo	12	12	1	10	0	5
Black bullhead	701	205	186	378	172	175
Yellow bullhead	0	0	0	1	1	0
Channel catfish	0	0	0	0	0	0
White bass	0	0	0	2	0	0
Yellow bass	0	0	0	1	0	0
Green sunfish	0	0	1	0	1	1
Pumpkinseed	2	0	0	0	0	0
Bluegill	1	0	0	0	0	0
White crappie	0	3	0	0	0	0
Black crappie	30	62	50	19	27	31
Yellow perch	210	90	600	161	272	64
Walleye	2	6	1	1	0	3
Total	967	392	858	594	477	293

[a] 12 sets of 12-hour duration in each habitat type.

Table 26. The common and scientific names of fish species collected from Clear Lake, Iowa

Common names	Scientific names
Esocidae	
Northern pike	*Esox lucius*
Muskellunge	*Esox masquinongy*
Cyprinidae	
Common carp	*Cyprinus carpio*
Brassy minnow	*Hybognathus hankinsoni*
Golden shiner	*Notemigonus crysoleucas*
Emerald shiner	*Notropis atherinoides*
Common shiner	*Notropis cornutus*
Bigmouth shiner	*Notropis dorsalis*
Pugnose minnow	*Notropis emuliae*
Spottail shiner	*Notropis hudsonius*
Fathead minnow	*Pimephales promelas*
Catostomidae	
Quillback	*Carpiodes cyprinus*
White sucker	*Catostomus commersoni*
Bigmouth buffalo	*Ictiobus cyprinellus*
Redhorse	*Moxostoma*
Ictaluridae	
Black bullhead	*Ictalurus melas*
Yellow bullhead	*Ictalurus natalis*
Channel catfish	*Ictalurus punctatus*
Ictaluridae (cont'd.)	
Stonecat	*Noturus flavus*
Tadpole madtom	*Noturus gyrinus*
Gasterosteidae	
Brook stickleback	*Culaea inconstans*
Percichthyidae	
White bass	*Morone chrysops*
Yellow bass	*Morone mississippiensis*
Centrarchidae	
Green sunfish	*Lepomis cyanellus*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Redear sunfish	*Lepomis microlophus*
Smallmouth bass	*Micropterus dolomieui*
Largemouth bass	*Micropterus salmoides*
White crappie	*Pomoxis annularis*
Black crappie	*Pomoxis nigromaculatus*
Percidae	
Johnny darter	*Etheostoma nigrum*
Yellow perch	*Perca flavescens*
Walleye	*Stizostedion vitreum vitreum*

Table 27. Percent composition of experimental gill net samples from Clear Lake, Iowa, 1952-1973

Species	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Northern pike	0.6	3.1	1.7	0.5	0.1	0.1	0.1	0.2	0.1	0.6	0.9	0.4	0.4	0.1	0.7	1.1	0.8	0.4	2.9	1.9	0.9	0.2
Muskellunge*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	t	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	t	0.0
Common carp	1.1	0.4	0.5	0.1	0.3	1.0	0.9	0.6	0.1	0.8	0.2	0.1	0.0	0.1	4.5	17.2	6.3	1.0	0.1	0.0	t	t
Bullhead**	12.5	51.3	51.2	44.0	50.0	43.1	22.0	27.2	8.5	8.7	1.7	2.7	18.3	40.2	45.0	14.7	63.2	71.2	26.2	45.1	59.6	25.2
Channel catfish	0.3	0.7	0.2	0.0	t	0.2	0.1	0.9	0.2	0.9	0.2	0.2	0.1	t	0.3	0.0	0.4	0.2	0.3	0.0	0.0	0.0
White bass	0.6	0.1	0.0	0.1	0.6	1.1	1.3	0.6	0.2	0.6	0.1	0.1	t	t	0.0	1.4	1.8	1.7	14.9	10.8	2.6	0.7
Yellow bass	19.7	11.7	24.8	34.4	35.3	36.8	59.3	60.0	82.1	78.2	82.4	85.9	73.9	46.4	33.0	51.2	0.9	2.2	13.7	11.5	8.6	5.6
Pumpkinseed	4.4	0.6	0.3	t	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.0	0.1	0.1	t	0.0	0.0	0.1	0.0	0.0	0.0
Bluegill	6.7	5.2	3.8	6.2	6.9	7.2	2.5	0.7	0.0	0.0	0.0	0.0	t	0.0	0.0	t	0.2	0.1	0.3	0.0	0.2	0.0
Largemouth bass	0.6	0.2	0.1	0.1	t	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
White crappie	0.0	t	t	0.6	0.5	1.7	6.9	2.6	5.7	5.9	8.4	3.5	2.2	2.0	1.6	1.7	3.5	0.5	10.4	8.6	1.0	0.4
Black crappie	2.7	2.0	1.9	0.8	0.8	0.6	0.6	0.2	0.4	0.2	t	0.1	0.5	0.5	0.4	t	0.5	0.2	1.3	0.5	0.9	0.3
Yellow perch	35.1	17.2	5.0	4.3	0.7	0.7	0.6	0.4	0.5	0.8	2.9	5.8	1.8	4.1	4.3	3.2	6.9	10.3	9.2	3.2	20.9	53.6
Walleye	14.5	6.6	8.3	8.5	4.2	6.5	4.8	6.2	2.2	3.4	2.5	0.8	2.4	5.6	9.2	9.0	14.7	11.4	19.1	18.1	4.9	13.6
Other***	1.1	0.9	2.2	0.2	0.6	1.0	0.8	0.4	0.1	0.0	0.1	0.2	0.5	0.8	1.0	0.4	0.7	0.4	1.3	0.3	0.3	0.0
Fish/hour/net	2.55	5.54	6.40	5.09	5.00	4.90	4.20	4.11		4.66	6.22	3.97	4.09	5.68	3.13	3.93	3.21	2.21	1.34	1.02	2.63	5.49

*First stocked in 1960.

**Includes predominantly black bullhead, but also yellow bullhead.

***Includes golden shiner, white sucker, quillback, bigmouth buffalo, redear sunfish, and smallmouth bass.

Table 28. Collections with bag seines in the littoral zone of Clear Lake during various projects conducted 1950-73

Species	1950	1951	1965	1966	1967	1968	1969	1970	1971	1972	1973
Northern pike				18							
Muskellunge					1						
Common carp			5	389	3	7	29	6		24	4
Brassy minnow				1							
Golden shiner				5							
Emerald shiner						48					
Common shiner					3		21				
Bigmouth shiner				1			7				
Pugnose minnow							4				
Spottail shiner			578	563	232	146	120				
Fathead minnow				4	34	1	15				
Redhorse					1						
Black bullhead		1658	15	2408	2421	462	779	127	5412	679	4960
Yellow bullhead				67							
Channel catfish			7	25	1		1	2			
Stonecat					1						
Tadpole madtom			22	59	1		18				
Brook stickleback							8				
White bass				70		40	144	163	1	13	27
Yellow bass	407	741	16235	4212	8417	80	56	211	13	96	389
Sunfish			236	9477	1						
Green sunfish							1		1		
Pumpkinseed									1		
Bluegill	211	461				345	995		1	128	207
Smallmouth bass					1						
Largemouth bass	94	100	2	93	11	43			4	27	7
White crappie			154	194	922	152	301	48	13	27	190
Black crappie	102	318	71	191	1564		57	651	1018	118	556
Johnny darter			22	48	8	27	34				
Yellow perch		430	286	745	224	316	114	40	117	686	270
Walleye	77		27	186	22	82	30	16	42	291	7
Total	1741	3708	17660	18756	13871	1749	2734	1264	6623	2089	6617

Table 29. Comparisons of reproductive success of Clear Lake fish, 1972-1981, as determined by night bag-seining[a] at seven sampling stations

Species	1972	1973	1974	1975	1976	1977[b]	1978[c]	1979[d]	1980	1981
Muskellunge	0	0	0	0	0	0	1	0	0	0
Common carp and bigmouth buffalo	0	5	0	0	1	37	3	20	4	5
Spottail shiner	0	0	0	0	0	0	0	0	47	131
White sucker	0	0	0	0	0	0	0	0	2	9
Black and yellow bullhead	563	-[e]	291	1545	-[e]	175	87	108	40	68
Channel catfish	0	0	0	5	1	0	0	0	1	2
White and yellow bass	23	97	1342	686	10	839	25	0	9	16
Pumpkinseed and bluegill	102	76	1493	1187	253	68	99	0	4	8
Largemouth bass	3	1	2	0	6	0	0	0	0	0
White and black crappie	82	229	252	134	3	14	2	8	9	11
Yellow perch	294	120	523	519	481	325	3	92	193	101
Walleye	121	16	8	36	25	14	25	242	142	0
Total	1188	544[f]	3911	4112	780[f]	1472	245	470	451	351

[a]Seine, 1/4" mesh, 1/8" bag, 50' long, pulled in 90^{o} arc to shore, 2 hauls per station; conducted

[b]Lake at least 30 inches low. Could not seine at 1 location. Data based on 12 hauls from 6 locations.

[c] 20.

[d]Data based on 13 hauls. Could not seine at 1 location in October.

[e]Bullheads not counted. Extremely numerous.

[f]Excluding bullheads.

Table 30. Utilization of submersed aquatic vegetation by fish species found in Clear Lake

Species	Stage in life		
	Spawning	Young	Adult
Esocidae			
Northern pike	H[a]	H	H
Muskellunge	H	H	H
Cyprinidae			
Common carp	H	-	F[b]
Golden shiner	H	-	H
Common shiner	-	-	-
Spottail shiner	-	-	M[c]
Catostomidae			
White sucker	-	-	-
Bigmouth buffalo	H	-	-
Ictaluridae			
Black bullhead	-	H	H
Yellow bullhead	-	-	H
Channel catfish	-	-	-
Percichthyidae			
White bass	-	M	M
Yellow bass	-	S	S
Centrarchidae			
Green sunfish	-	-	H
Pumpkinseed	-	H	H
Bluegill	-	H	F
Largemouth bass	-	H	F
White crappie	S[d]	-	-
Black crappie	-	H	F
Percidae			
Yellow perch	M	M	F
Walleye	-	M	F

[a]H indicates use of heavy vegetation as habitat.

[b]F indicates only feeding in areas of vegetation.

[c]M indicates use of moderately dense vegetation as habitat.

[d]S indicates use of sparce vegetation as habitat.

Table 31. Sex of respondents to attitude survey, Clear Lake, Iowa, 1981

	Sex		
Population	Male	Female	Total[a]
Resident			
Seasonal	26	17	43
Permanent	176	79	255
Non-resident	210	87	297
Total[a]	412	183	596

[a]Difference in results due to non-respondents.

Table 32. Age of respondents to attitude survey, Clear Lake, Iowa, 1981

	Age					
Population	0-19	20-29	30-39	40-49	50-59	60+
Resident						
Seasonal	0	1	3	10	13	15
Permanent	2	24	58	46	47	76
Non-Resident	20	172	67	58	39	41
Total[a]	22	197	129	114	99	132

[a]Difference in results due to non-respondents.

Table 33. Income of respondents to attitude survey, Clear Lake, Iowa, 1981

Population	Income (dollars/year)					
	Under 5,999	6,000-9,999	10,000-14,999	15,000-24,999	25,000-49,999	50,000 or more
Resident						
Permanent	16	17	43	87	58	17
Seasonal	2	1	2	8	15	15
Non-Resident	18	33	44	100	55	16
Total	46	51	89	195	128	48

Table 34. Occupation of respondents to attitude survey, Clear Lake, Iowa, 1981

	Residents			
Occupation	Permanent	Seasonal	Non-Residents	Total
Professional, Technical Kindred	50	17	60	127
Farmers	10	2	26	38
Manager, Officials and Proprietors	35	4	31	70
Clerical and Kindred	12	0	11	23
Sales Workers	21	1	12	34
Craftsmen, Foremen, Kindred Workers	16	0	27	43
Operators and Kindred Workers	14	0	13	27
Service Workers	10	0	11	21
Laborers, except Farm and Mine	14	0	31	45
Retired, Widow	40	11	25	76
Student	1	0	19	20
Unemployed, laid off, relief	1	0	4	5
Housewife	18	5	19	42
Other	2	0	2	4
Total[a]	230	36	272	

[a]Difference in results due to non-respondents.

Table 35. Length of residence by permanent residents responding to attitude survey, Clear Lake, Iowa, 1981

Years	0-5	6-10	11-20	21-30	31+
Number	47	39	52	41	75

Table 36. Number of months resided at Clear Lake by seasonal residents responding to attitude survey, Clear Lake, Iowa, 1981

Months	0	1	2	3	4	5	6	7	8	9	10	11	12
Number	1	6	1	11	8	5	2	0	3	1	0	0	0

Table 37. Distance traveled by non-residents responding to attitude survey, Clear Lake, Iowa, 1981

Miles	Less than 30	31-60	61-120	121-300	301+
Number	70	62	94	48	22

Table 38. Number of visits by non-residents responding to 1981 Clear Lake attitude survey during 1980

Visits	0	1	2	3	4	5
Number	21	111	102	34	26	16

Table 39. Type and frequency of lake usage by residents responding to attitude survey, Clear Lake, 1981

	Number of times participated					
Activity	None	1-5	6-10	11-15	16-20	25+
Sightseeing	37	96	44	35	18	47
Picnicking	73	159	27	9	3	2
Beach Activity	81	80	38	19	17	30
Lake Swimming	101	70	33	17	18	34
Camping	222	21	3	2	0	0
Fishing from Shore/Dock	117	70	31	17	9	21
Fishing from Boat	167	53	16	11	4	5
Fishing through Ice	225	15	6	2	1	4
Canoeing	216	26	4	0	4	1
Sailing	193	31	6	3	2	18
Power Boating	113	61	25	10	18	43
Water Skiing	161	40	20	11	11	20
Hunting for Waterfowl	208	24	9	4	2	4
Hunting for Upland Game	213	20	6	7	1	2
Trapping	238	6	0	2	1	3

Table 40. Type of usage this visit and frequency of usage for past visits of non-residents responding to attitude survey, Clear Lake, Iowa, 1981

	This visit		Number of times last year (1980)						
Activity	Yes	No	None	1-5	6-10	11-15	16-20	25+	Total
Sightseeing	151	159	25	75	15	9	4	4	132
Picnicking	124	186	30	88	14	4	0	0	166
Beach Activity	144	166	29	64	18	8	6	4	129
Lake Swimming	143	167	28	67	22	7	3	4	131
Camping	117	193	52	51	11	1	0	1	116
Fishing from Dock/Shore	145	165	35	79	16	5	2	4	141
Fishing from Boat	55	255	54	41	11	1	1	0	108
Fishing through Ice	0	306	74	8	3	0	0	0	85
Canoeing	6	304	72	10	1	0	0	0	84
Sailing	10	300	71	11	2	1	0	0	85
Power Boating	51	259	42	40	10	7	5	1	105
Water Skiing	39	271	52	32	8	6	3	0	101
Hunting for Waterfowl	0	310	78	2	1	0	0	0	81
Hunting for Upland Game	0	310	73	7	1	0	0	0	81
Trapping	0	310	79	1	0	0	0	0	80

Table 41. Overall perception of residents and non-residents towards water level alternatives, Clear Lake, Iowa, 1981

	Water Level					
	Fluctuating		Stabilized		None	
Population	No.	%	No.	%	No.	%
Resident	54	17.6	199	64.8	54	17.6
Non-resident	47	16.3	149	51.5	93	32.2

Table 42. Residents and non-residents perceptions towards water level by activity, Clear Lake, Iowa, 1981

Activity	Population	Water level: Fluctuating		Stabilized		None	
		No.	%	No.	%	No.	%
Sightseeing	Resident	44	15.4	161	56.3	81	28.3
	Non-resident	42	16.3	86	33.3	130	50.4
Picnicking	Resident	20	7.1	165	58.7	96	34.2
	Non-resident	28	11.2	98	39.0	125	49.8
Beach Activity	Resident	14	4.7	224	75.2	40	13.4
	Non-resident	24	9.3	184	71.3	50	19.4
Lake Swimming	Resident	13	4.6	231	82.2	37	13.2
	Non-resident	23	5.9	184	71.3	51	19.8
Camping	Resident	18	6.6	156	56.9	100	36.5
	Non-resident	31	12.2	97	38.0	127	49.8
Fishing from Dock/Shore	Resident	25	8.9	213	75.8	43	15.3
	Non-resident	35	13.1	167	62.3	66	24.6
Fishing from Boat	Resident	33	11.6	186	65.8	64	22.6
	Non-resident	35	13.9	132	52.6	84	33.5
Fishing through Ice	Resident	23	8.3	159	57.6	94	34.1
	Non-resident	21	8.8	93	38.7	126	52.5
Canoeing	Resident	19	6.9	154	56.0	102	37.1
	Non-resident	28	11.6	88	36.4	126	52.0
Sailing	Resident	18	6.5	179	64.6	80	28.9
	Non-resident	23	9.5	101	41.7	118	48.8
Power Boating	Resident	16	5.7	204	72.9	60	21.4
	Non-resident	16	6.5	134	54.9	94	38.5
Water Skiing	Resident	18	6.5	199	71.6	61	21.9
	Non-resident	14	5.8	132	54.3	97	39.9
Hunting for Waterfowl	Resident	38	13.3	124	43.5	123	43.2
	Non-resident	36	15.0	56	23.3	148	61.7
Hunting for	Resident	35	12.8	93	33.9	146	53.3
	Non-resident	27	11.3	51	21.3	161	67.4
Trapping	Resident	33	12.0	95	34.7	146	53.3
	Non-resident	27	11.3	53	22.2	159	66.5