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Hydroacoustic Assessment of the Fish stocks in the Thingvalla lake.

by

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Abstract

Assessment of the fish population in Þingvallavatn (Lake Thingvalla) a deep oligotrophic lake 84 km^2, was made with hydroacoustic methods.

Fish densities of up to 113 fish/100 m^2 were found and the total population was estimated to be 13.4x10^6 fish. No information about species distribution, age or size composition is given, but evidence supports that the dominant species of the fish population is pelagic char, which reaches a maximum size of 21 cm and 80 grams. The average size at spawning is about 20 cm and 65 grams.

Introduction

During August and September of 1974, a portion of a FAO-supported project ICE/73/001 (UNDP) was undertaken in Iceland to introduce the use of hydroacoustic fish stock assessment techniques for use in lakes. The major accomplishments in 1974 were the construction of a data collection system and training in its operation. During the 1975 field season the equipment was functioning properly and surveys of two major lakes were completed with good results. This paper deals with one of these lakes, the Thingvalla Lake in South-

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West Iceland which is an oligotrophic lake of 83,7 km^2 with a maximum depth of 114 m. Three species of fish occur in the lake: char, (Salvelinus alpinus), brown trout (Salmo trutta) and stickleback (Gasterostous aculeatus). The commercial catch is almost entirely char, which is caught in bottom gill nets. The annual catch is 30-50 metric tons, mainly a pelagic plankton feeding char which is caught on its spawning grounds in late September. Average length of the spawners is 19.5 cm and 62 grams.

The Hydoracoustic Data Collection System.

The system consists of a Simrad E4 echosounder modified to 100KHZ, with a Ross narrow beam transducer for registration of data, a Sony cassetterecorder model TC-152SD for conservation of data and a Tektronic 465 oscilloscope for controlling setup in the field and analysis of data in the laboratory. The echosounder is uncalibrated so that target strength analysis of the recorded echo surveys cannot be made and the relative size of fish in different lake areas cannot be compared acoustically. It is still possible to make reliable estimates of fish densities and populations, however.

Hydroacoustic Assessment of the Thingvalla Lake Fish Populations

A complete hydroacoustic survey of Thingvalla Lake was completed during the night of 27 August 1975. Experimental transects were made during the daytime and night time prior to the survey to determine the diel movements of the fish. It was found that during the day the fish formed small, tight schools at depths of from 20 to 40 meters, making it impossible to determine the numbers in any school. During the night time, however, the schools dispersed and nearly all of the detectable fish were scattered throughout the water column, mostly from depths of from 10 to 25 meters. A few fish were detected in deeper and shallower water, but the majority were in this depth stratum.

Prior to this first survey of Thingvalla Lake, nothing was known of the areal or depth distributions of the fish or of what densities would be found. Therefore, an exploratory survey was designed by allocating equal sampling effort to all areas of the lake This was done by transecting across the long axis of the lake with approximately equal spacing between each transect. In all, 5 crossings were made as shown in fig. 1. The highest fish densities were found near the northern and southern ends of the lake with lower densities in the central part. Some samples of the echograms made during the survey are shown in fig. 2. Magnetic tape recordings were made of the survey.

Analysis of Recorded Hydroacoustic Data

The analysis of recorded hydroacoustic data can be divided into 4 major parts; counting of detections, estimation of effective sampling volumes, fish density calculations and estimation of fish populations. The first two parts are done by viewing the recorded echosoundings on an oscilloscope and physically counting fish detection, while the last two are calculated from the counts. The techniniques used to estimate fish populations have been reported thoroughly elsewhere (Nunnalle and Mathisen, 1972a; Nunnallee and Mathisen, 1972b; Nunnallee et. al. 1973; Nunnallee, 1974a; Nunnallee, 1974b). A brief outline of the procedure is given in the next several sections.

Counting of Fish Detections

The basic method of counting echo returns from fish is to play the recorded echo soundings and to display them on an oscilloscope where individual fish detections can be counted within any desired depth interval. Depth is proportional to the elapsed time after the transmitted pulse when an echo of interest is detected (1.37 = 1 sonar meter). However, before echoes can be counted, a threshold must be calculated for all depths and only those echo amplitudes exceeding the threshold are counted. The intensity of sound per unit area is reduced by geometrical spreading in proportion to the reciprical of depth (1/D), therefore an echo return is proportional to $1/D^2$. The time varied circuit (TVG) of the echo sounder acts to increase the sensitivity of the receiver in proportion to depth, but this is only half of the total correction and the return from any specific target size will still appear to decrease proportional to 1/D. The counting threshold then, is computed to represent the theoretical echo amplitude from the smallest detectable target at the maximum depth of interest, if it were moved from that depth to the surface. In this way, the counting threshold represents a depth normalized minimum target amplitude sensitivity. Since the threshold is based on the smallest detectable target at the maximum depth of interest, it is necessary only to measure the peak voltage of the ambient noise at that depth and substitute it into the following equation.

$$E_t = K/D \quad \text{...... Equation 1}$$

where E_t = threshold voltage
D = depth (meters or as ms)
K = constant

As an example, if the peak voltage of the ambient noise = 0.03 V at 50 meters depth, then by substitution into equation 1, k = 1.5 and E_t can then be found for all shallower depths. In practice, the counting threshold is scribed on clear plastic and placed over the oscilloscope screen.

Estimation of Effective Sampling Volumes

The method used to estimate effective hydroacoustic sampling volumes has been described previously (Nunnallee, 1972b). Basicly, the method relates the average number of times that individual fish are detected by consecutive transmissions of the echo sounder, and boat speed, in order to obtain a measure of the diameter of the continuum of target detectability at various depths. After the dimensions are determined, a pulse volume can be calculated for any depth stratum. The product of one pulse volume and the total number of pulses in a transect or section is equivalent to the total sampling volume.

During the Thingvalla Lake survey there was no reliable way to measure the boat speed, so the sampling volume for the survey was based on a 10° cone. From past experience in a large number of surveys of other lakes, measured conic angles have varied from 8° to 10° using similar methods. Therefore, the assumption of a 10° come is conservative in the worst situation. Also, the signal to noise ratio at the deepest depths of interest suggest, from the directivity pattern of the transducer, a beam angle of from 9° to 9.5°, again marking 10° a conservative estimate.

The survey of Thingvalla Lake was analyzed in 3.7 m (5 ms) depth intervals, from 3.7 m to the lake bottom, or until significant fish densities were no longer encountered.

Calculation of Fish Densities and Population Estimates

The calculation of fish densities, most conveniently expressed as fish/1000 m^3, is straight forward when the total number of target detections and the total sampling volume are known, by use of the following equations (Nunnallee and Mathisen, 1972b).

$$\text{Fish}/1000\ m^3 = \frac{(1000)\ (\text{total fish detections})}{(\text{effective pulse volume})(\text{total pulses})} \quad \text{....Equation 2}$$

Also, the number of fish/100 m^2 surface area of the lake can be calculated from the results of equation 2 by use of the following;

$$\text{Fish}/100\ m^2 = \sum_{i=1}^{n} \frac{D_{Li} - D_{Ui}}{10} (N_i) \quad \text{................Equation 3}$$

where, D_{Li} and D_{Ui} = the upper and lower depth limit of stratum i, respectively

n = the number of depth strata

Ni = Fish/1000 m^3 in stratum i

The next logical step, after a sufficient number of measures of fish density/unit surface area have been made, is to estimate the population of fish in the lake. Various methods can be used to make a population estimate, the simplest being to merely expand the mean density/unit surface area over the area of the lake. A better method is to stratify the densities into several classifications and to expand these over their respective lake areas. Finally, densities of fish/unit volume can be stratified over 3-dimensional units, such that fish densities within each stratum are expanded over their individual volumes and summed to produce a population estimate. Variances and confidence limits are greatest for the first method;

less for the second and lowest for the third. The second method was used in the population estimates for Thingvalla Lake, but the lake was only divided into two depth sections (5-18.5 and 18.5-114 m) because insufficient sampling effort was expended to clearly define the areal and depth distributions of the fish. Further surveys can be designed to gather the necessary data for more detailed analysis.

Test Fishing in Thingvalla Lake

Hydroacoustic fish stock assessment techniques are not complete in themselves as a stock management tool since species, size and age composition of the fish cannot be determined directly. Because of this it is necessary to catch fish by various means, in the most random method possible, in order to monitor these population parameters.

In an attempt to sample the fish in Thingvalla Lake, a mid-water one boat trawl was used (Nunnallee,1974b) and three hauls were made near the central part of transect 2 (fig.1), where considerable densities of fish were observed. The net was submerged to the depth of highest fish abundance and was towed for 30, 20 and 30 minutes for the three respective hauls. The total catch, however, amounted to only four fish, all of which were approximately 18 cm long. All of the fish were adults and were approaching spawning ripeness. No small fish of any kind were caught. The conclusion is that the mid-water trawl is not adequate as a sampling tool in Thingavlla Lake. Reliable test fishing in the lake will be necessary before heavy exploitation of the fish populations can be properly monitored and controlled. A series of gill nets of various mesh sizes is now being used in place of the mid-water trawl, and a two-boat trawl is under construction. The present commercial catch from Thingvalla Lake is not a good sample of the population as the majority is taken on the spawning ground where only a relatively small segment is present. Little is known of the age composition or life history of the pelagic char in Thingvalla Lake.

Results and conclusions

Large populations of char were found in Thingvalla Lake. The concentration of fish through-out the lake ranged from light to very heavy, with the average being higher than was expected prior to the surveys. Fish were detected at all depths, but the majority were stratified between 10 and 25 m.

Usually fewer fish were detected in areas where the water depth was less than 20 m, so for the estimation of the total populations, the lake was divided into two depth areas, a 5-18.5 m area which is 20 km^2 and an area with depths over 18.5 m, which is 54 km^2. The distribution is contagious so all densities were transformed to logarithms. Fish densities in the 5-18.5 m depth area (20 km^2) ranged from 1.23/100 m^2 to 39.76/100 m^2 with an geometric average of 5.42/100m^2. The population estimate for the area was 1.08×10^6 fish.

Fish densities for areas with depth over 18.5 m (54 km^2) ranged from 3.06/100 m^2 to 100.11/100 m^2 with an average geometric density of 24.65 fish/100 m^2. The population estimate for the area was 13.3×10^6 fish.

The population estimate for the whole lake was thus 14.4×10^6 fish. No information was available as to the size or species composition of these fish, however. Further sampling is now going on to determine these parameters. It is fairly certain that the dominant fish species in the lake is pelagic char, other fish being benthic char, brown trout and stickleback.

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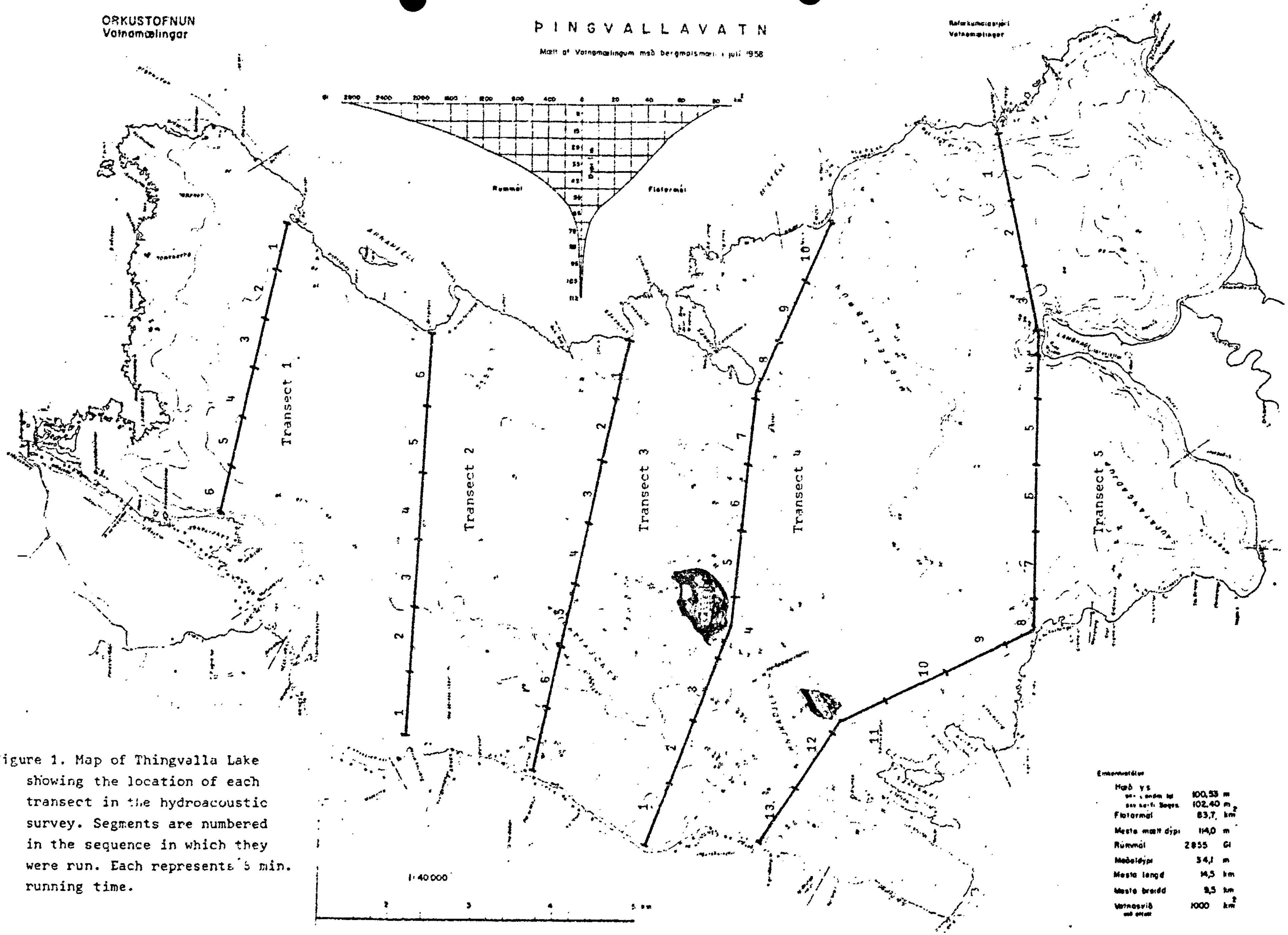

Figure 1. Map of Thingvalla Lake showing the location of each transect in the hydroacoustic survey. Segments are numbered in the sequence in which they were run. Each represents 5 min. running time.

Figure 2. Echograms collected during the survey of Thingvalla Lake.
Upper- daytime distribution of fish.
Lower- night-time distribution of fish.