ECHO SOUNDING OF FROZEN LAKE FROM SURFACE OF ICE

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Note on authors. — Dr. HASHIMOTO is a specialist on echo sounders and fish finder research. He is now the chief of the Instrument Section of the Fishing Boat Laboratory, Fisheries Agency of the Japanese Government. After graduating from Tohoku University in 1929, he was engaged in underwater acoustic apparatus research and manufacture at Nippon Electric Company, Tokyo. He took up his present post at the Fishing Boat Laboratory in 1950 where he is engaged in basic echo sounding research and in its applications in the fishing industry. He obtained the degree of Doctor of Technology in 1956 by presenting a thesis on ultrasonic propagation in the sea. He has also published many papers on his studies.

Dr. MANIWA is engaged in underwater acoustics, such as basic echo sounding research and its applications in the fishing industry, under the direction of Dr. HASHIMOTO at the Fishing Boat Laboratory. After graduating from Tokyo University in 1945, he was engaged in the above mentioned research. He obtained the degree of Doctor of Technology in 1962 by presenting a thesis on studies for the development of echo sounders, and of vertical and horizontal fish finders using ultrasonic millimetric waves.

Mr. OMOTO is engaged in research on the characteristics of barium titanate and its applications, at the Shibaura Technical Institute. He has been engaged on this research work since he graduated from that Institute in 1954.

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ABSTRACT

In this paper the authors give the result of their research carried out on the echo sounding of a frozen lake. The echo trace of the lake bottom was obtained from the ice surface. It is obviously easy to determine accurately the positions of soundings from that surface. Therefore, soundings were carried out more rapidly and accurately on the surface of the ice than they would have been from a boat. Furthermore, the detection of schools of fish from the ice surface was successful for the first time, and the transmission loss of ultrasonic waves in artificial ice and in natural ice was also measured.

INTRODUCTION

For the echo sounding of a lake, of an artificial lake of a hydroelectric power station, etc., the accurate determination of positions is important. When sounding with an echo sounder installed on a boat, it is difficult to determine positions accurately because of shift due to wind or current; therefore, the error due to inaccuracy of position is large and, moreover, great efforts are needed.

When the lake is frozen, it is easy to determine the positions with accuracy on the ice surface and if it were possible to sound from its surface the sounding work would be made easier. But transmission loss of ultrasonic waves in ice and the existence of air between the ice and the water surface were not known. Hence, experiments on sounding from the ice surface were made on frozen Lake Haruna in Gumma Prefecture in January and February 1962.

During these experiments, sounding was carried out rapidly and accurately. Pond smelt swimming beneath the ice were also detected from the surface, and transmission loss in ice was measured.

To the authors' knowledge, echo traces of the bottom and of schools of fish as obtained from the surface of ice have never been published.

SOUNDING OF THE FROZEN LAKE

The sounding experiment was carried out on frozen Lake Haruna.

(1) Apparatus used for experiment

Very small and compact transistorized fish finders were used for echo sounding. One of them was the 400-kc/s type manufactured by Furuno Electric Co., Ltd. on the advice of the Fishing Boat Laboratory. The other was of the 200-kc/s type manufactured by Nippon Electric Co., Ltd.

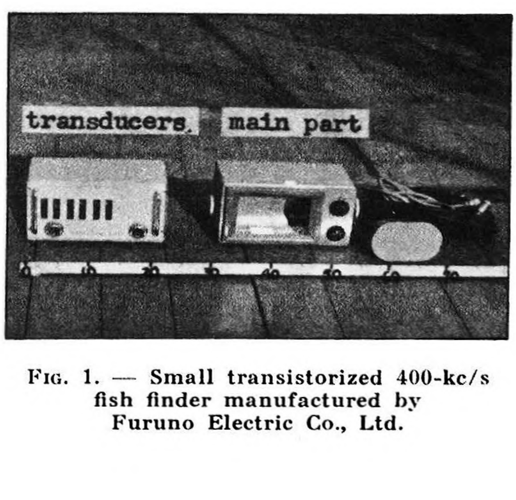

FIG. 1. — Small transistorized 400-kc/s fish finder manufactured by Furuno Electric Co., Ltd.

The 400-kc/s fish finder is shown in figure 1. By comparing it with the scale marked on the figure, it will be seen that this set is very small. The main specifications are as follows :

The sounding range is 0-25 m, 25-30 m and 50-75 m. The number of ultrasonic wave pulses transmitted is 375 per minute. The pulse length is 0.4 milliseconds (for a sounding range of 0-25 m) and 1.2 milliseconds (for the range of 25-50 m, 50-75 m). The transducers are made out of barium titanate. Their diameter is 5 cm. The output power of the oscillator is about 700 mW. The gain of the receiver is about 124 db. The circuit is shown in figure 2.

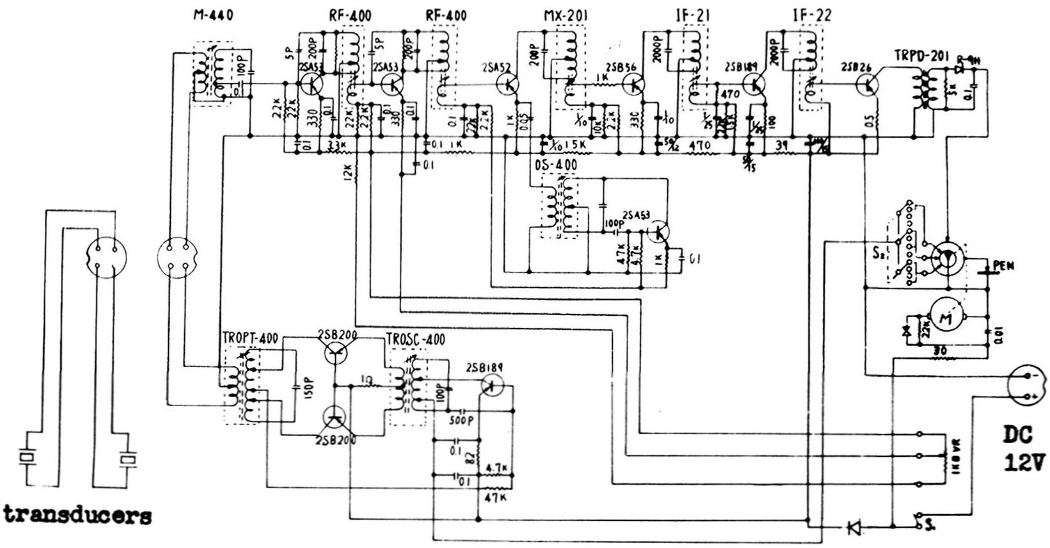

Fig. 2. — Circuit of 400-kc/s fish finder.

The 200-kc/s fish finder is also very small, as can be seen in figure 3 where it is compared with a tobacco box. The sounding range is 0-25 m, 20-45 m and 40-65 m. The number of ultrasonic wave pulses transmitted is 450 per minute. The pulse length is about 1 millisecond. The transducers

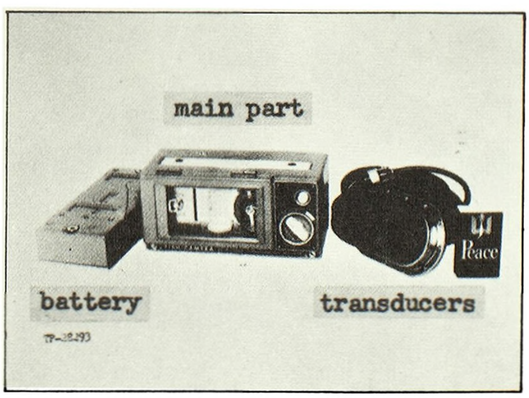

Fig. 3. — Small transistorized 200-kc/s fish finder manufactured by Nippon Electric Co. Ltd.

are of barium titanate. Their diameter is 5 cm. The gain of the receiver is about 130 db.

(2) Sounding of frozen lake from the surface of the ice

Sounding was carried out along the line AC represented on the survey map of Lake Haruna shown in figure 4. Figure 5 shows a view of this place. Starting from A, the distance was measured every 50 metres by means of a 50-metre measuring rope, and 12 sounding points were fixed. However, between A and the 150-metre point, points were fixed every 10 metres. Figure 6 is a photograph of the fixing of sounding points.

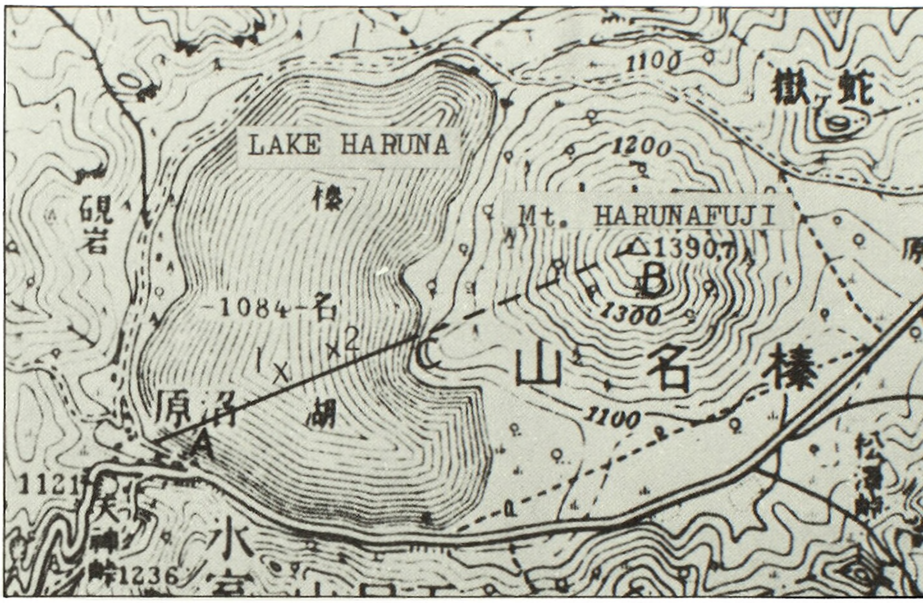

Fig. 4. — Lake Haruna.
(Sounding was carried out along the solid line; the points marked with a cross are where the transmission loss in ice was measured).

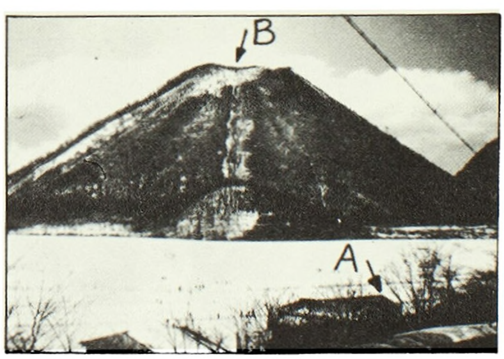

Fig. 5. — View of area where sounding was carried out on Lake Haruna.

The transducers were placed on the surface of the ice after the snow covering it had been scraped away with our shoes, and the transducers

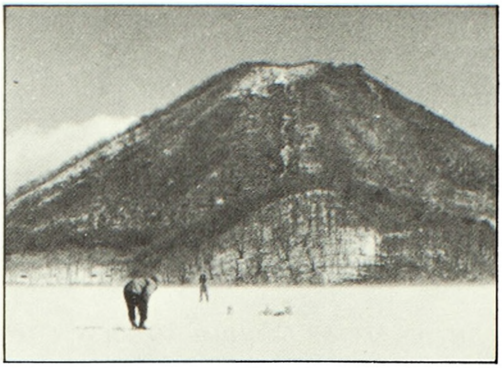

Fig. 6. — Fixing sounding points.

Fig. 7. — Pouring a little water to bring the transducer into contact with the ice.

were brought into contact with the ice by pouring over them a cup of water, as shown in figure 7. Enough echo traces were obtained by this method. Water was found better for contact than oil, such as castor oil.

Fig. 8. — Sounding with two transistorized fish finders.

Figure 8 shows sounding in progress with two transistorized fish finders.

Figure 9 shows the echo traces of the lake bottom. The echo trace at each point is a horizontal line because the transducers were not moved

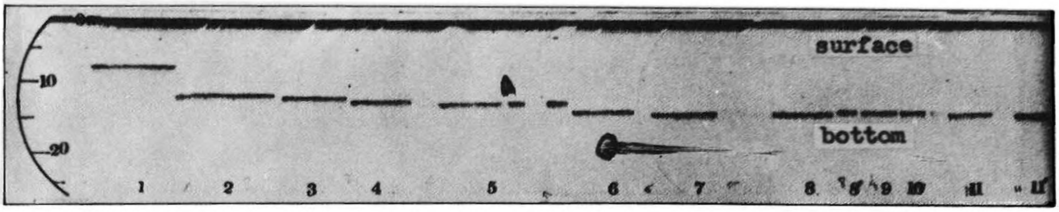

Fig. 9. — Echo trace of lake bottom when sounded from the surface of the ice (400 kc/s; thickness of ice : 25 cm).

while sounding was in progress. Figure 10 shows the transverse section of Lake Haruna established from the echo traces.

The thickness of the ice was 25 cm, and we had some trouble in making a hole through it, but sounding from the surface of the ice avoided

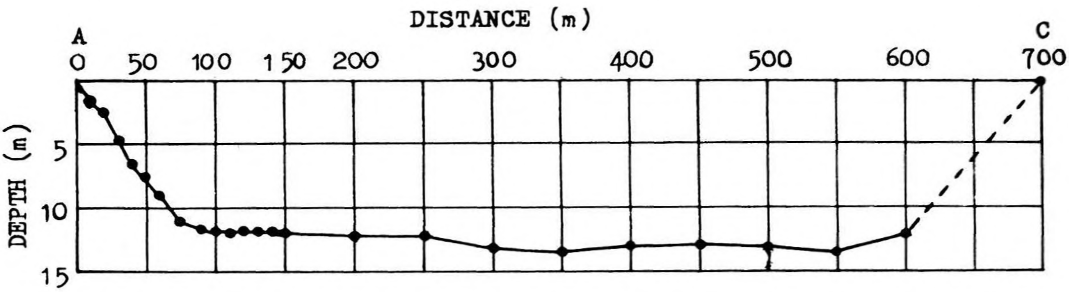

Fig. 10. — Transverse section of Lake Haruna established from the echo traces obtained the surface of the ice.

such trouble. Positions of sounding points were determined more speedily and accurately on the ice than they would have been from a boat. The time needed to determine the positions and then to sound was 1 hour 25 minutes.

By the same method, echo traces of pond smelt were obtained from the surface of ice 31 cm thick. The results are described in the appendix.

TRANSMISSION LOSS AND SOUND VELOCITY IN ICE

The measurement of transmission loss in ice is required for sounding from the ice surface.

Firstly, the transmission loss in artificial ice was measured for 28 kc/s, 100 kc/s, 200 kc/s and 400 kc/s. In a water tank (25 metres long, 50 cm wide and 50 cm deep) the transmitting and receiving transducers were put at opposite ends and the plate of ice was put between them, as shown in figure 11. The sound pressure of ultrasonic wave pulses received by the receiving transducer was measured. Measurements were made for various thicknesses of ice. The relationship between the thickness of the ice and the transmission loss is shown in figure 12. The values measured almost form a straight line, and transmission losses expressed in db/cm are shown in the second column of Table 1. Figure 13 shows measuring in progress.

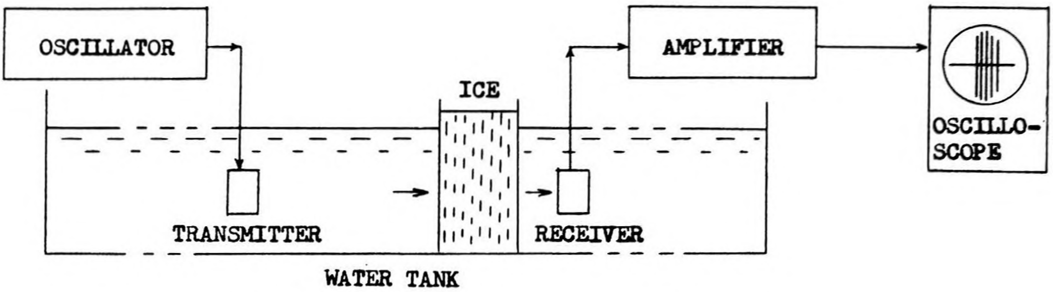

FIG. 11. — Method of measurement of transmission loss of ultrasonic waves in ice.

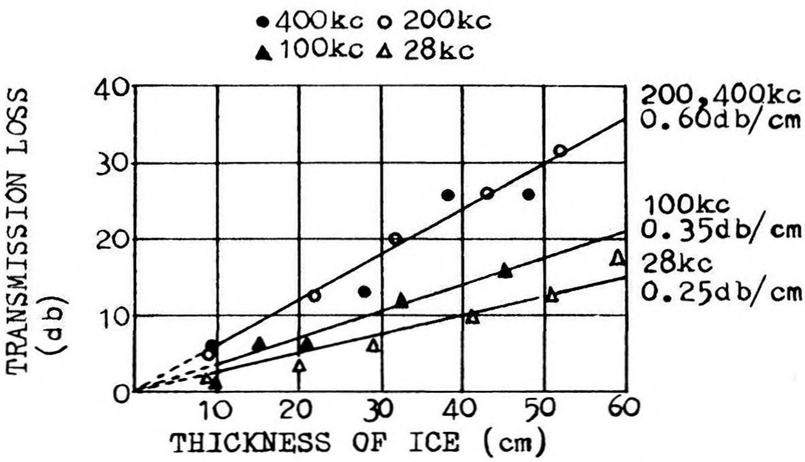

FIG. 12. — Transmission loss in artificial ice such as can be found on the market.

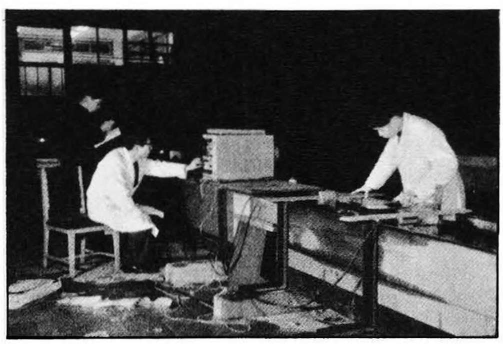

FIG. 13. — Measurement of transmission loss in ice.

Next, the sound pressure of echoes returned from the lake bottom was measured on the ice surface of frozen Lake Haruna at the points marked with a cross in figure 4, and measurements were made for various thicknesses of ice by thinning it. The transmission loss is shown in figure 14 and in the third column of table 1. However, it is not concluded that these values are universal because freezing conditions differ according to snowfall, etc. Figure 15 shows the measurements being made.

TABLE 1

Measured transmission loss in ice

1	2	3
Frequency (kc/s)	Transmission loss (db/cm)	
	Artificial ice	Ice on Lake Haruna
28	0.25	
100	0.35	
200	0.60	0.40
400	0.60	0.40

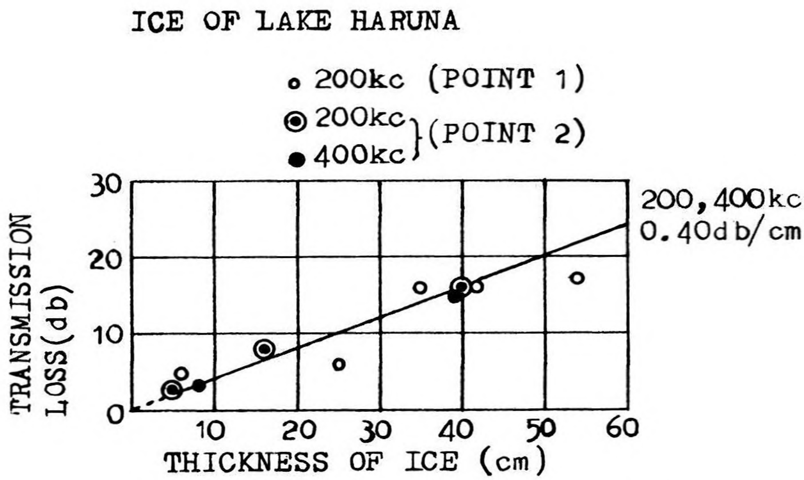

FIG. 14. — Transmission loss in ice from Lake Haruna.

FIG. 15. — Measurement of transmission loss in ice on Lake Haruna.

Sound velocity in ice was measured. The 400-kc/s transducers were placed on the upper surface of a cube of ice 53 cm high, and we measured the time taken by the echoes to be reflected by the opposite surface (see figure 16). By this method, sound velocity was found to be 3120 metres per second.

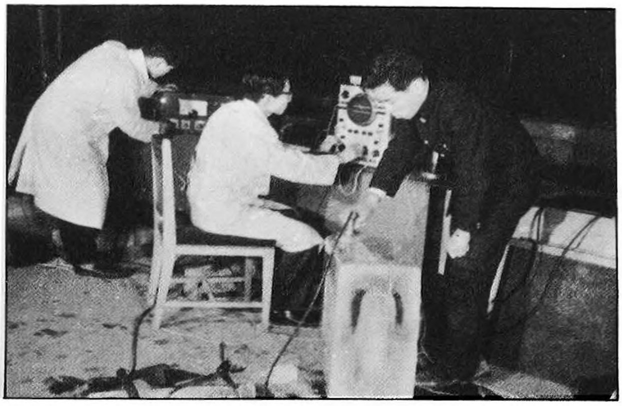

FIG. 16. — Measurement of sound velocity in ice.

CONCLUSION

The results of the above mentioned experiments may be summarized as follows :

(1) The echo trace of the bottom could be obtained from the surface of the ice on a frozen lake by clearing the surface with our shoes, putting the transducers on it and then pouring over a little water.

(2) Precise sounding was carried out rapidly by determining positions on the surface of the ice and by sounding from the surface.

(3) The measured transmission loss in ice is shown in Table 1.

(4) The echo trace of pond smelt was obtained for the first time from the surface of ice.

APPENDIX

By the same method as mentioned above, 400-kc/s echo traces of pond smelt were obtained for the first time from the surface of ice. They are shown in figures 1A and 2A.

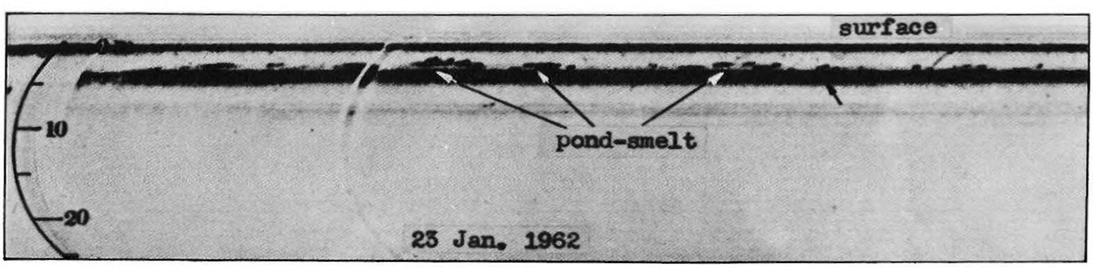

FIG. 1A. — Echo traces of pond smelt as obtained from the ice surface.

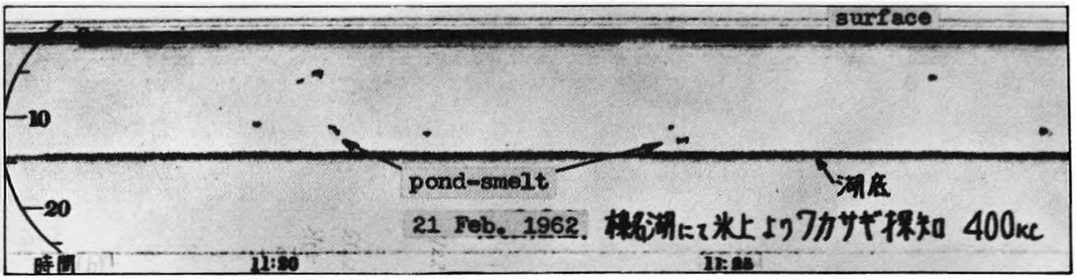

FIG. 2A. — Echo traces of pond smelt as obtained from the ice surface.

In the case of figure 1A, the depth is about 3.5 metres, and it was found that schools of pond smelt swim close to the bottom. The surface ice was 25 cm thick. Figure 2A shows the traces of several small schools scattered between a depth of 5 metres and the bottom. The depth is about 14 metres, and the surface ice was about 31 cm thick.

Figure 3A shows some pond smelt that were caught. They were about 11 cm long.

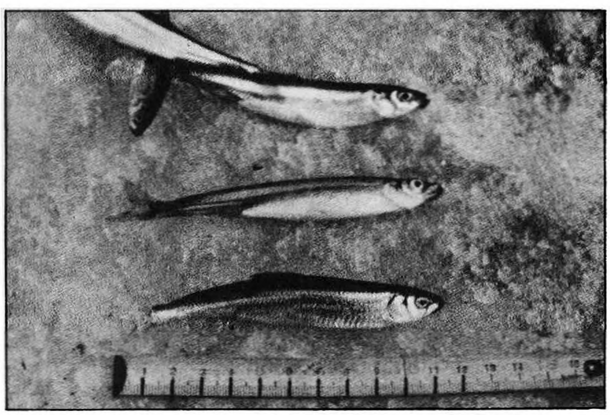

FIG. 3A. — Pond smelt.