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AN INTRODUCTION TO HYDROACOUSTIC ECHO TRACES

by

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PREFACE

This textbook, "An Introduction To Hydroacoustic Echo Traces", explains hydroacoustic information on the recording charts in the form of echo traces, digits and lines.

Interpretation of echo traces is one of the most important points of fishing technology : scouting, detecting and catching fish; observation of submerged fishing gear; annual distribution of fish shoals; topographic features of sea-bed; thermal discontinuities; water temperature from surface to sea-bed, etc..

This textbook shows typical diagrams and actual recordings at fishing grounds in the Andaman Sea, the South China Sea, off the East, West and South coast of Africa, the South Pacific Ocean, the Bering Sea, etc..

Hydroacoustic information can help us reconstruct and modify fishing gear; top-entry or side-entry trap cage net; bottom or mid-water longline or drift gill net; mid-water or bottom trawl; purse seine, etc., where to set up stationary trap nets (OTOSHI-AMI), artificial reefs and conservation or prohibited fishing areas.

In addition since many fishing boats in Southeast Asia have been equipped with various electronic devices including fishfinders it would seem advisable that the fishing technology extension officers who participate in the courses at the SEAFDEC Training Department study "Hydroacoustics".

Thank you.

March 1989

M. OISHI
Training Department
SEAFDEC

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An Introduction to Hydroacoustic Echo Traces

Part 1 Basic

Fishfinders show the following echo traces:

1. Fish (both fish shoals and individual or singlé and large fish like tuna, shark and whale);

2. Sea-bed;

3. Layer of organisms and water-mass of different temperature or salinity (zoo- and phytoplankton, scattering layers, thermal discontinuities, front of water mass);

4. Noise from ship's engines and different fishfinder's supersonic sound wave;

5. Wake of ship;

6. Air bubbles near transducer's face;

7. Time interval on the recording (minute marker).

Items 1, 2 and 3 are most important to fishing activities. Item 7 is not an echo trace, it shows the time elapsing; each minute during sounding.

When ship's speed is known, we can calculate the distance run by counting the number of minute markers and estimate the ship's dead reckoning position (D.R.P.).

Figs. 1 and 2 on pages 2 and 3 show the typical arrangement of sonar, fishfinder, net monitor and its supersonic receiver, and trawl.

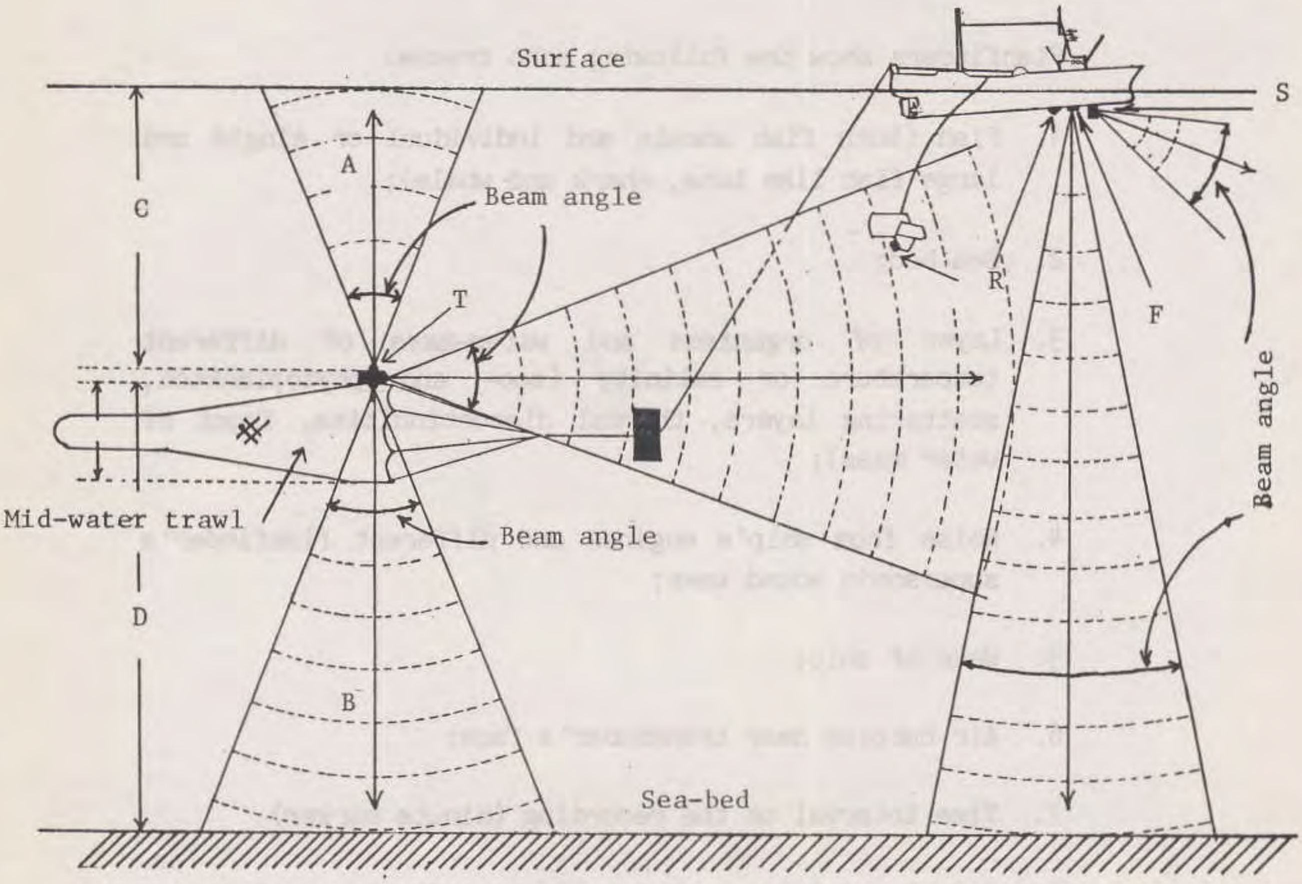

Fig. 1 Diagram of hydroacoustic transducers, mid-water trawl gear, and supersonic sound waves.

A : Upward supersonic sound wave
B : Downward supersonic sound wave
C : Interval between transducer and surface
D : Interval between transducer and sea-bed
T : Transmitting and receiving transducer of net monitor
R : Receiving transducer
F : Transmitting and receiving transducer of fishfinder
S : Transmitting and receiving transducer of *Sonar

* SONAR : Sound Navigation And Ranging

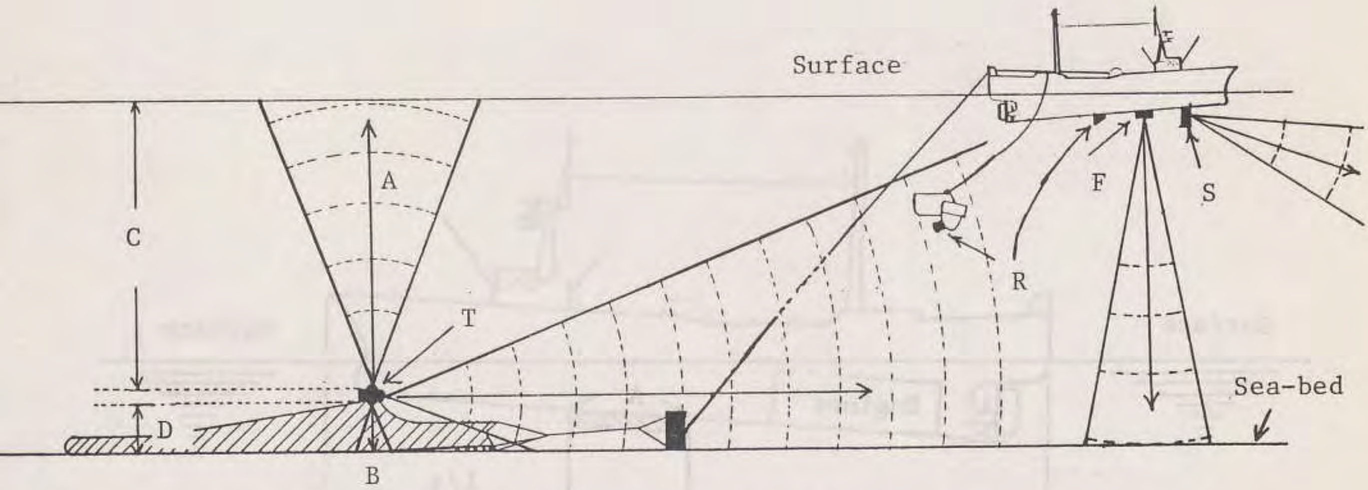

Fig. 2 Diagram of hydroacoustic transducers, bottom trawl gear and supersonic sound waves.

A : Upward supersonic sound wave
B : Downward supersonic sound wave
C : Interval between transmitter of net monitor and surface
D : Interval between transmitter of net monitor and sea-bed (≈ at height of transducer from sea-bed).
T : Transmitting and receiving transducer of net monitor
R : Receiving transducer
F : Transmitting and receiving transducer of fishfinder
S : Transmitting and receiving transducer of sonar.

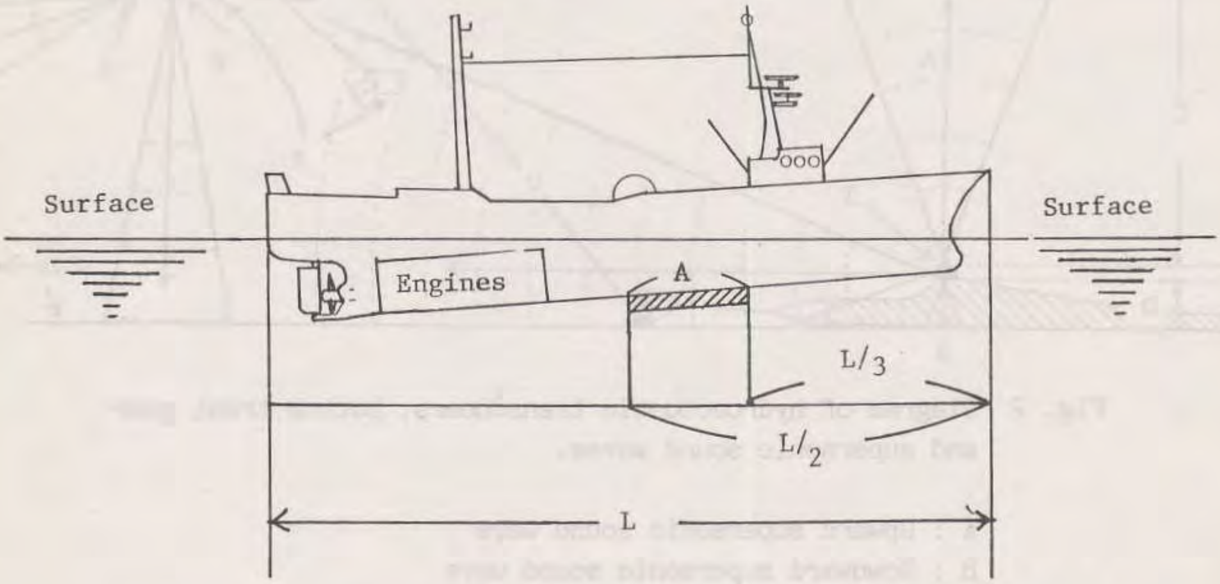

Fig. 3 Positioning of transducer (transmitting and receiving)

Fig. 3 shows the most preferable position "section A" for the installation of the fishfinder's transmitting and receiving transducer on the bottom of the ship's hull in order to minimize interference from:

1. Air bubbles and foam coming from the ship's stem when steaming;

2. Noise of main and/or auxiliary ship engines;

3. Noise from turning propeller.

The position where the transducer is installed on the ship's hull is of importance, it should be free from water turbulence, aeration, and noise from the engines and fishing machinery during both shooting and hauling of the fishing gear.

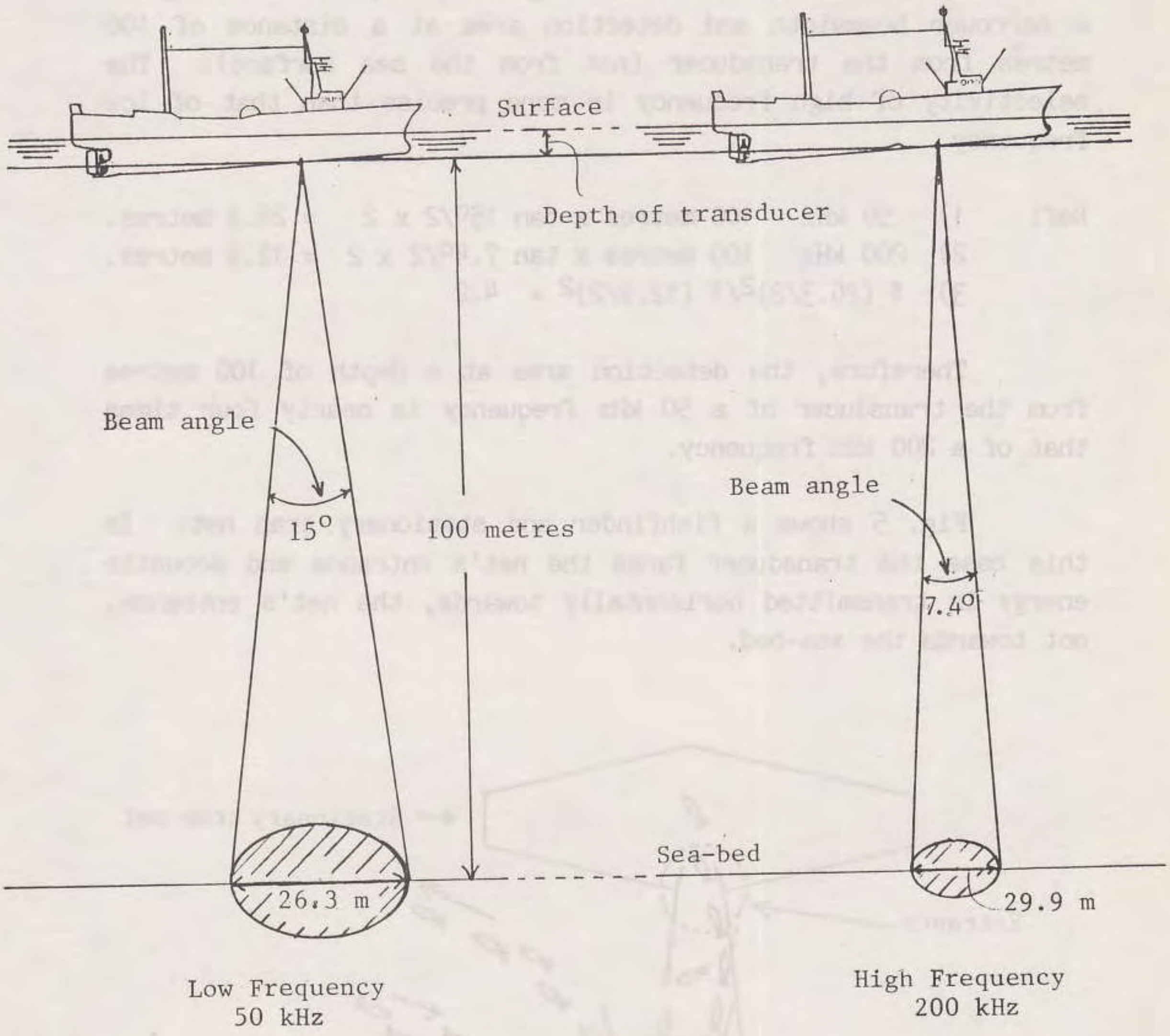

Fig. 4 Fishfinder's detection area

Fig. 4 shows the detection area on the sea-bed of a fish-finder in the case of low frequency (50 kHz) and high frequency (200 kHz) transmission.

The detection area depends on the beamwidth or main lobe of the supersonic sound waves. A high frequency sound wave gives a narrower beamwidth and detection area at a distance of 100 metres from the transducer (not from the sea surface). The selectivity of high frequency in more precise than that of low frequency.

Ref: 1) 50 kHz 100 metres x tan $15^{o}/2$ x 2 = 26.3 metres.
2) 200 kHz 100 metres x tan $7.4^{o}/2$ x 2 = 12.9 metres.
3) $\pi\,(26.3/2)^2/\pi\,(12.9/2)^2 = 4.2$

Therefore, the detection area at a depth of 100 metres from the transducer of a 50 kHz frequency is nearly four times that of a 200 kHz frequency.

Fig. 5 shows a fishfinder and stationary trap net. In this case the transducer faces the net's entrance and acoustic energy is transmitted horizontally towards, the net's entrance, not towards the sea-bed.

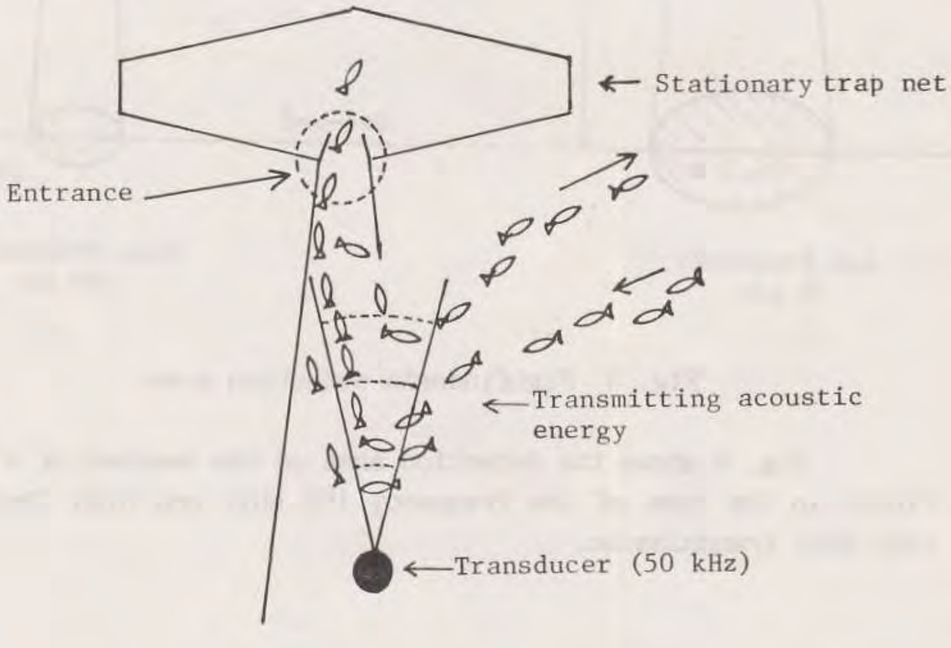

Fig. 5 Fishfinder and stationary trap net

The diagram in Fig. 5 shows that fish coming into the stationary trap net would be traced further and further as time elapses from the transmission line (zero line) of the fish-finder's recording. With regard to a fish shoal going out of the stationary trap net, its echo trace on the recording would near the transmission line as time goes by. (see Fig. 6)

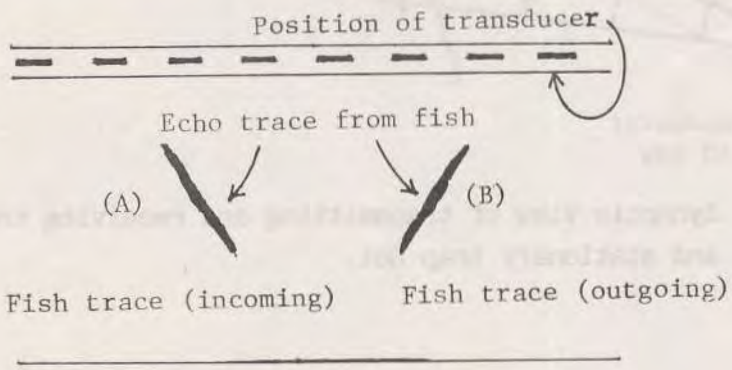

Fig. 6 Typical diagram of fish trace : incoming and outgoing

The diagram shows the patterns of an echo trace; a fish shoal is coming into or going out of the stationary trap net.

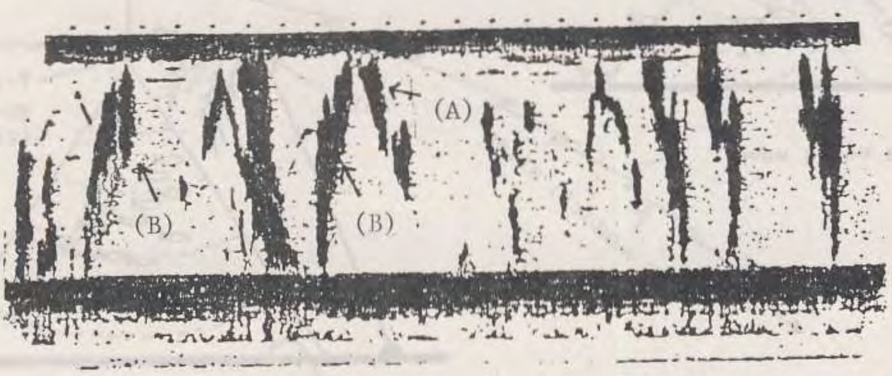

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Fig. 7 The recording of fish behaviour near a stationary trap net, recorded at Kishihata district in Japan on 21 Mar. 1976. In Figs. 6 and 7 the trace marked by (A) means fish shoals are coming into the net and the trace marked by (B) shows fish shoals are leaving the net.

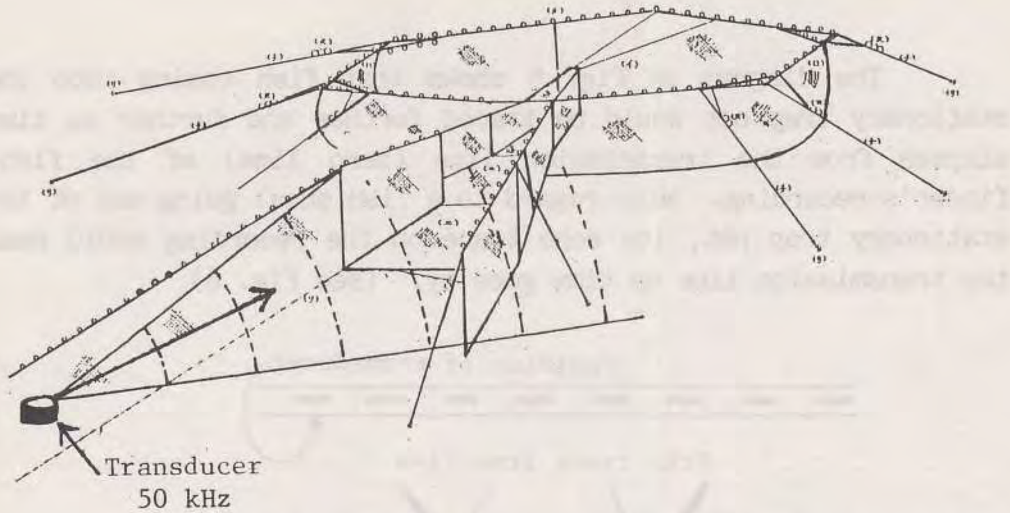


Fig. 8 Synoptic view of transmitting and receiving transducer and stationary trap net.

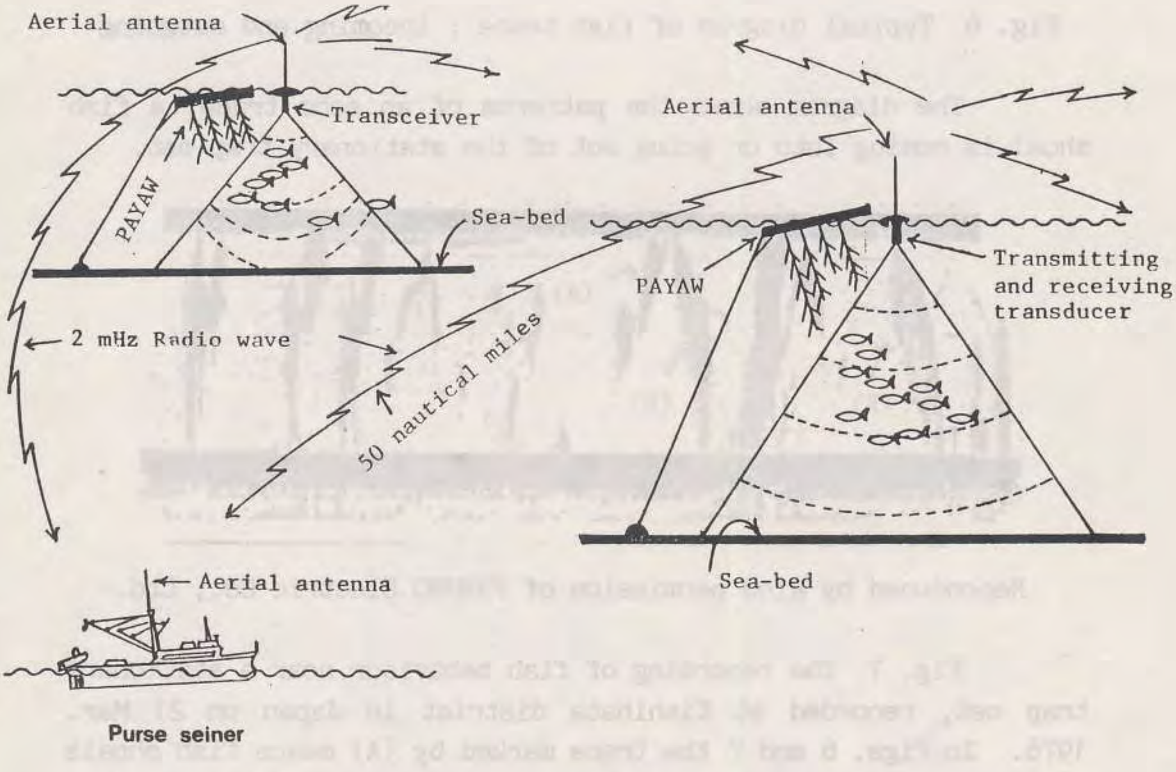
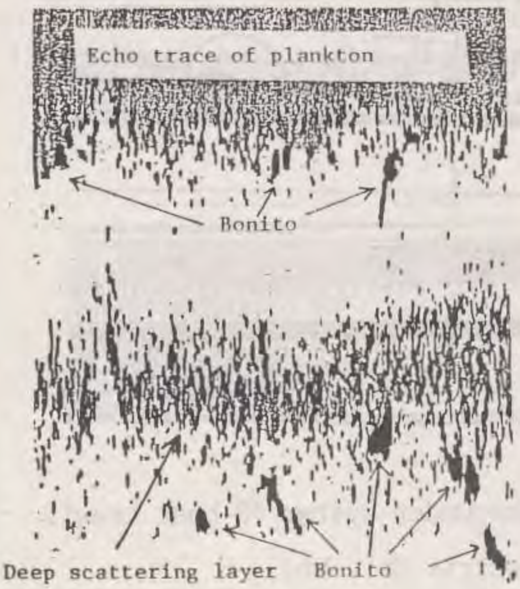


Fig. 9 Telesounding system for a purse seiner

By interfacing a transmitting and receiving transducer with a radio antenna and purse seiner signal recorder, a purse seiner can obtain an echogram of fish shoals gathering under PAYAWS far from the purse seiner. The transducer detects fish shoals and transfers echo signals from the shoals to the purse seiner by radio wave through its aerial antenna. The recorder unit mounted on the purse seiner can display echo traces of fish shoals on the recording chart of its fishfinder.

The telesounder system is very effective and convinient for knowing the presence of fish shoals beneath PAYAWS. This network system can be used by fleets of fishing boats. Three fishing boats, for instance, send their echo traces to the fleet commander, then the commander can interprete the echo traces of fish shoals and their distribution in the fishing ground.



[A] at 1745 hours

[B] at 0445 hours

Fig. 10 Echo traces sent by telesounder system to a purse seiner

Courtesy of FURUNO Electric Co., Ltd.

The echogram in Fig. 10 [A] was recorded at 1745 hours and [B] at 0445 hours the following morning. In Fig. 10 [A] traces from the katsuwonus can be seen below the surface noise from plankton and above the deep scattering layer. In Fig. 10 [B] traces from bonito can be seen between the surface noise and deep scattering layer.

The echograms shown in Fig. 10 show that the leader of a fishing fleet can have information about fish shoals transferred from other fishing boats out scouting for shoals.

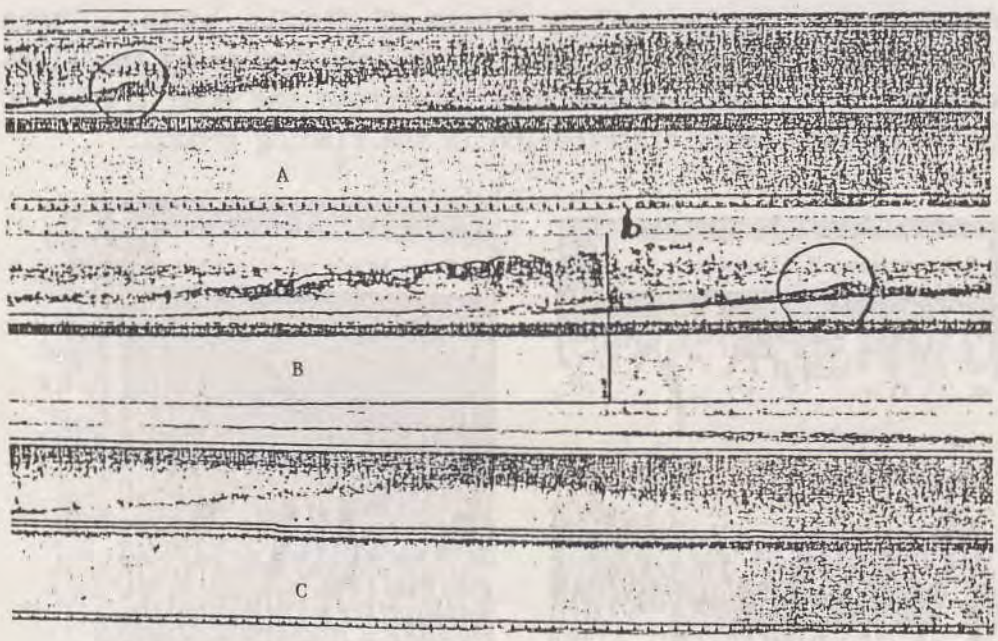
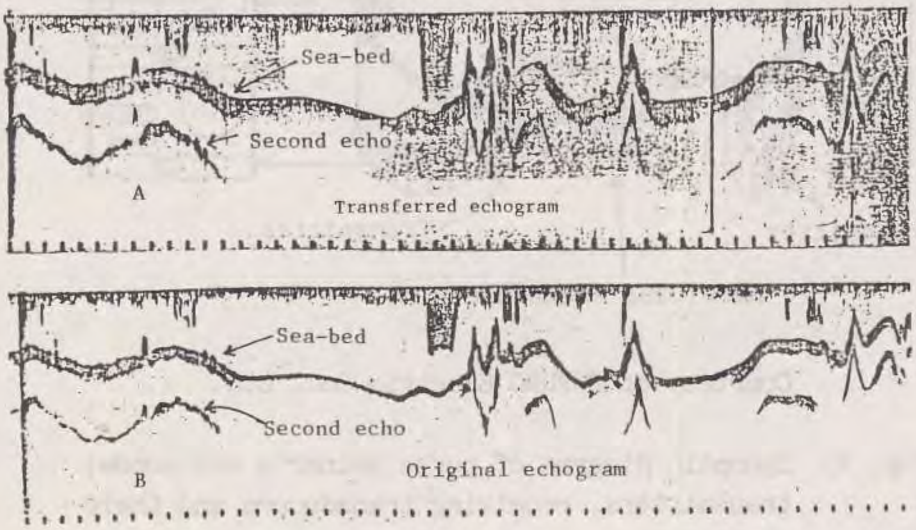


Fig. 11 Recording by intership telesounder system (2-boat trawl)

Courtesy of FURUNO Electric Co., Ltd.

The masterboat of a pair trawl received signals from its counterboat's fishfinder by telesounder system. The echogram A in Fig. 11 was detected by the counterboat's fishfinder and the echogram B was transferred to the masterboat from the counterboat. Echogram C is the echo trace detected by the masterboat's own fishfinder. This way the leader of a 2-Boat trawl can obtain double the information on the distribution of fish shoals simultaneously on his boat and decide dragging direction. This intership telesounder system can be utilized by fleets of purse seiners.

Scouting boats can transfer their echograms to the fleet commander's boat by radio waves.

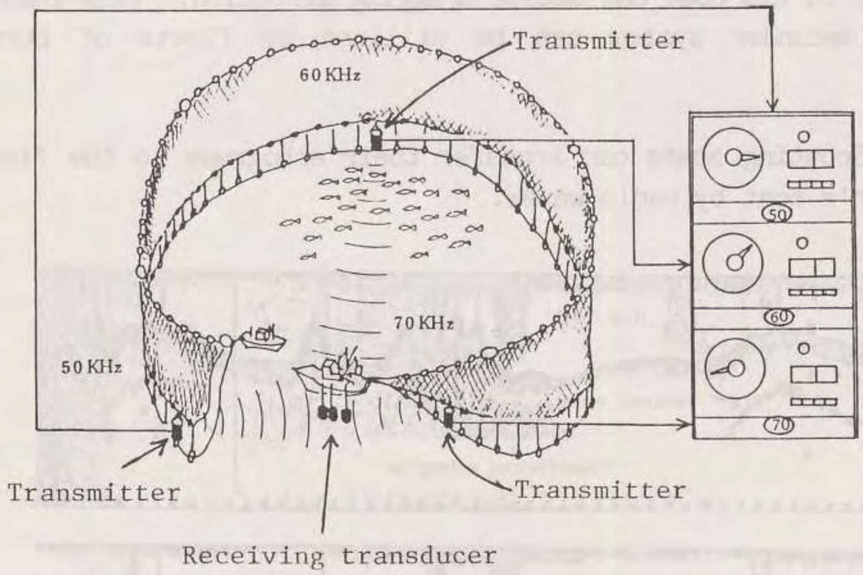


Courtesy of FURUNO Electric Co., Ltd.

Fig. 12 Telesounder echograms of purse seiners

Echogram B in Fig. 12 was recorded by a scouting boat's fishfinder and it was transferred to a purse seiner by radio waves with a telesounder unit.

Echogram A shows the received recording on board the purse seiner which was transferred from the scouting boat. The radio wave frequency was 42 mHz. The distance between both boats was approximately nine kilometres and as shown in Fig. 12 the both recordings A and B are very similar.



Courtesy of FURUNO Electric Co., Ltd.

Fig. 13 Synoptic diagram of purse seiner's net sonde; transmitters, receiving transducers and their positioning.

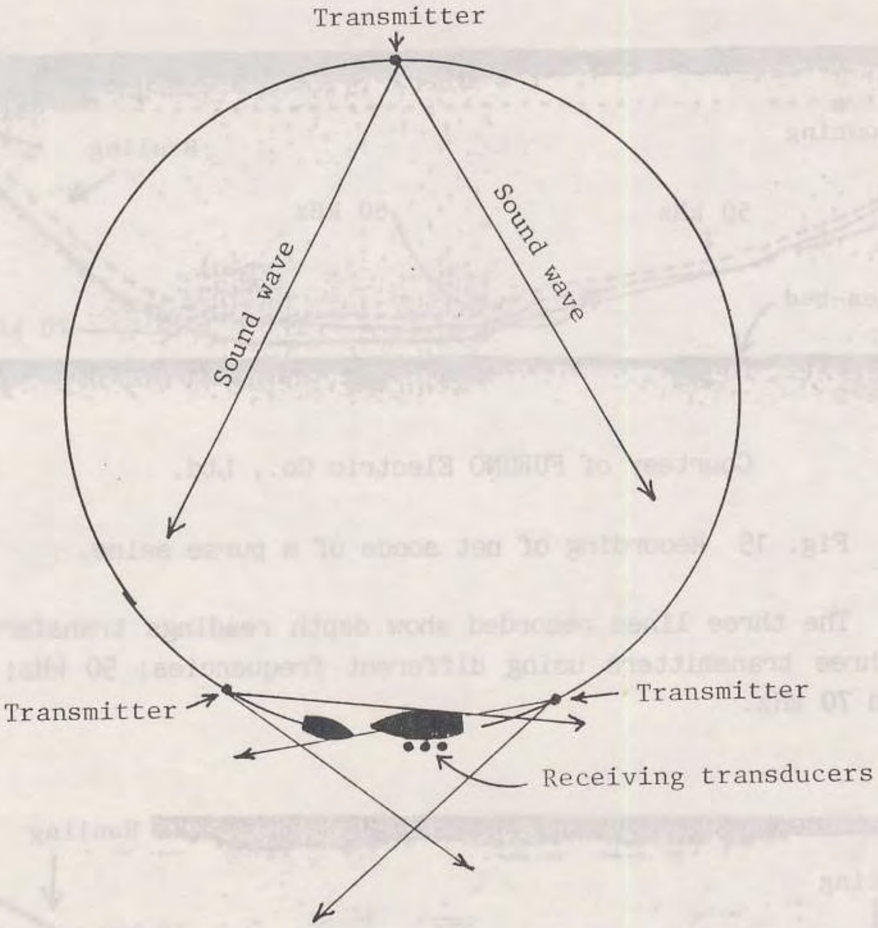
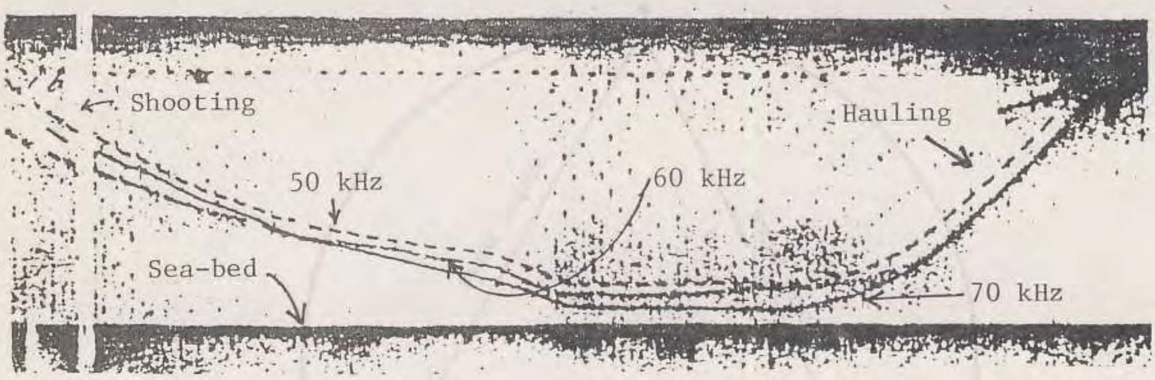


Fig. 14 Purse seiner's net sonde; Top view.

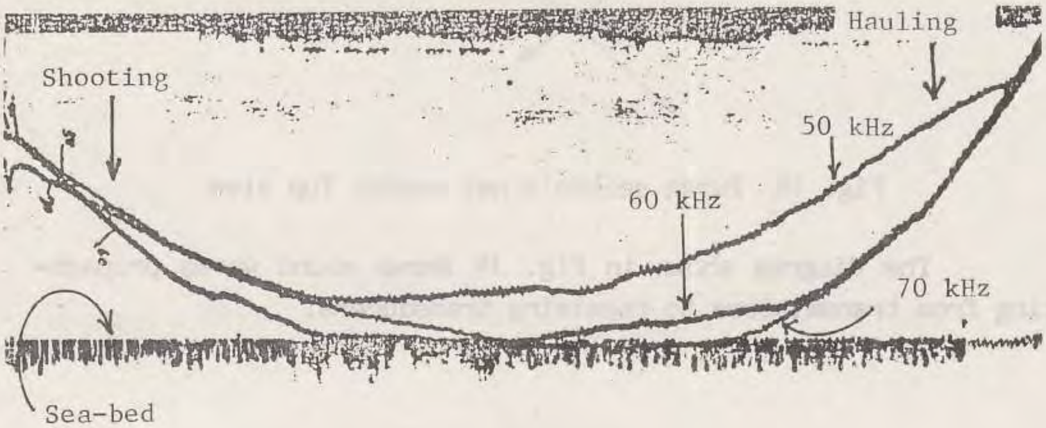
The diagram shown in Fig. 14 shows sound waves propagating from transmitters to receiving transducers.



Courtesy of FURUNO Electric Co., Ltd.

Fig. 15 Recording of net sonde of a purse seine.

The three lines recorded show depth readings transferred from three transmitters using different frequencies: 50 kHz; 60 kHz and 70 kHz.



Courtesy of FURUNO Co., Ltd.

Fig. 16 Recording of net sonde of a purse seine

The echogram in Fig. 16 shows three recorded lines; each depth markers from three transmitters with different frequencies: 50 kHz; 60 kHz and 70 kHz respectively. The lowest depth marker in Fig. 16 is a little bit different from that in Fig. 15 so please see Figs. 137 to 142.

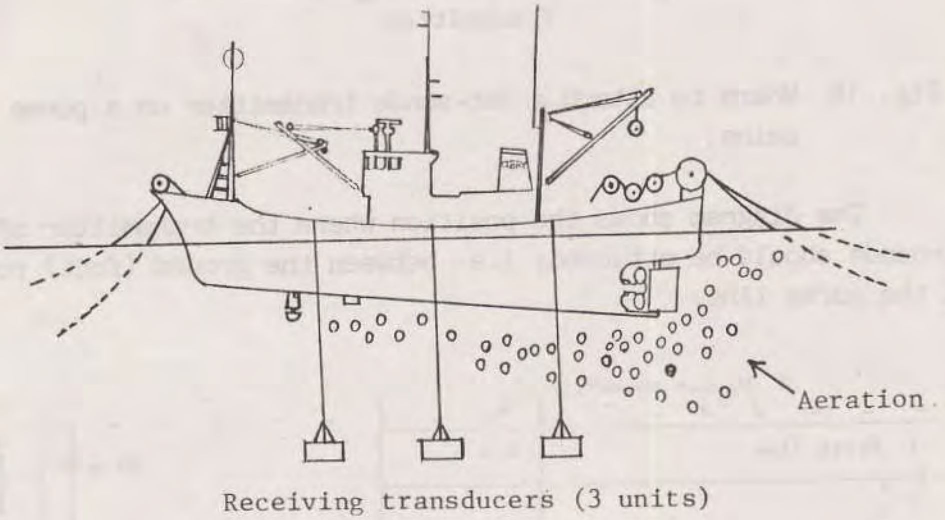


Fig. 17 Position of receiving transducers for a purse seiner's net sonde

The diagram in Fig. 17 shows three receiving transducer units hanging from the top of the bulwark or gun-wale of the purse seiner. Receiving transducers should be set deep enough in the water to avoid noise made by aeration.

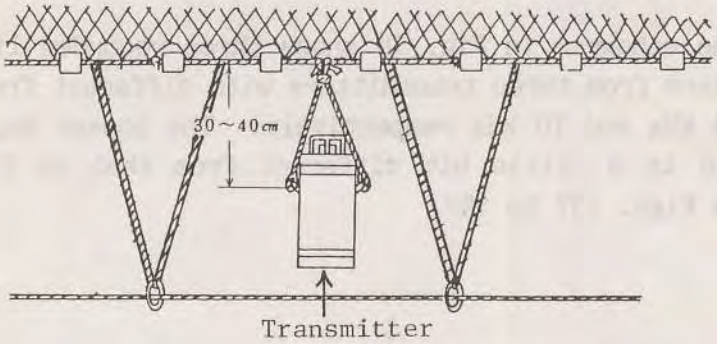


Fig. 18 Where to attach a net-sonde transmitter on a purse seine.

The diagram shows the position where the transmitter of a net-sonde should be attached; i.e. between the ground (foot) rope and the purse line.

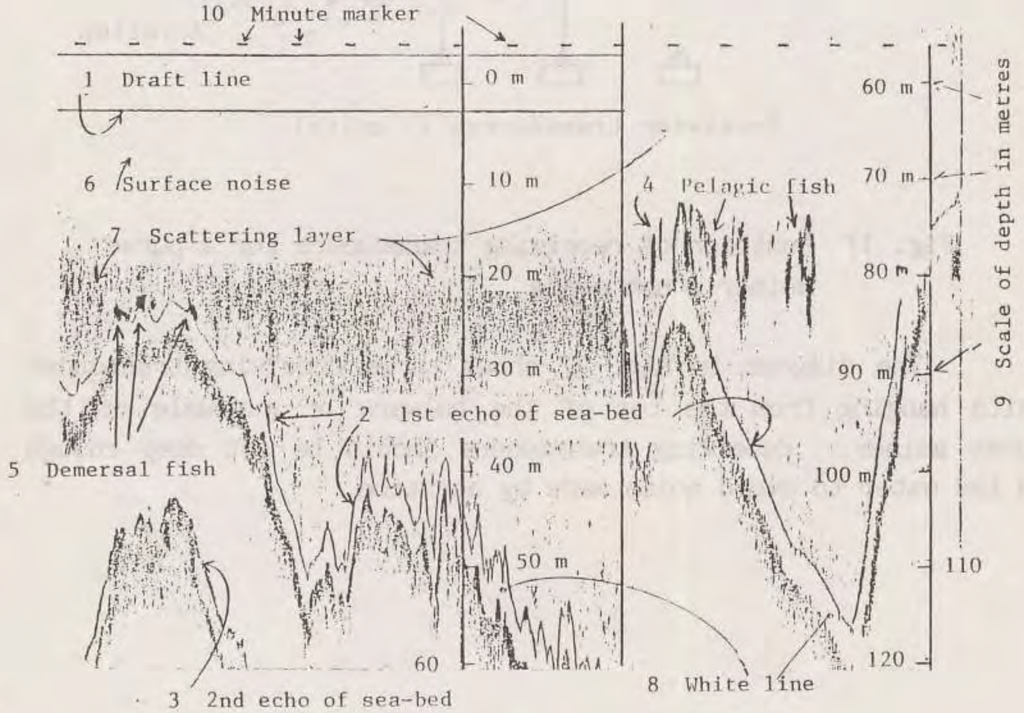


Fig. 19 Recording by fishfinder in the South China Sea

Fig. 19 shows a recording obtained in the South China Sea off Negara Brunei Darussalam on 20 Mar. 1987 by the fishery training ship *M.V. PAKNAM of the SEAFDEC Training Department. The recording shows:

1. Draft line (or Zero line), the draft of transducer;
2. First echo trace of sea-bed and fish shoals;
3. Second echo trace of sea-bed and fish shoals;
4. Echo traces of pelagic fish;
5. Echo traces of demersal species;
6. Acoustic noise;
7. Scattering layer;
8. "White line" control ... mechanical technique;
9. Depth-scale or range in metres;
10. Time-scale (or interval marker) on the recording chart.

---

* "M.V." stands for "Motor Vessel".

Part 2 The Characteristics of echo traces and draft of transducer

1. Draft line (or zero line):

The line as shown in Fig. 19 (at upper part of the recording) is called "Zero line" or "Draft line". The line shows the position of the transducer on the ship's hull bottom or side-board to keel-vertical distance from sea surface to the surface of the transducer-and the transducer transmits supersonic sound waves or acoustic energy and receives reflected sound waves or energy from submerged objects.

The draft line or zero line appears at the upper part of the recording chart when sounding, and the line disappears when the depth range is shifted to a deeper range (see right hand of Fig. 19, the zero line disappeared).

To know true depth-distance from surface to sea-bed by an echo sounder or fishfinder, we have to know the depth of the transmitting and receiving transducer from the sea surface by measuring fore and aft draft of the fishing boat or by the method of "Bar check" (see Fig. 23) before leaving the port or at the fishing ground, survey area of oceanograph and/or topographic survey area.

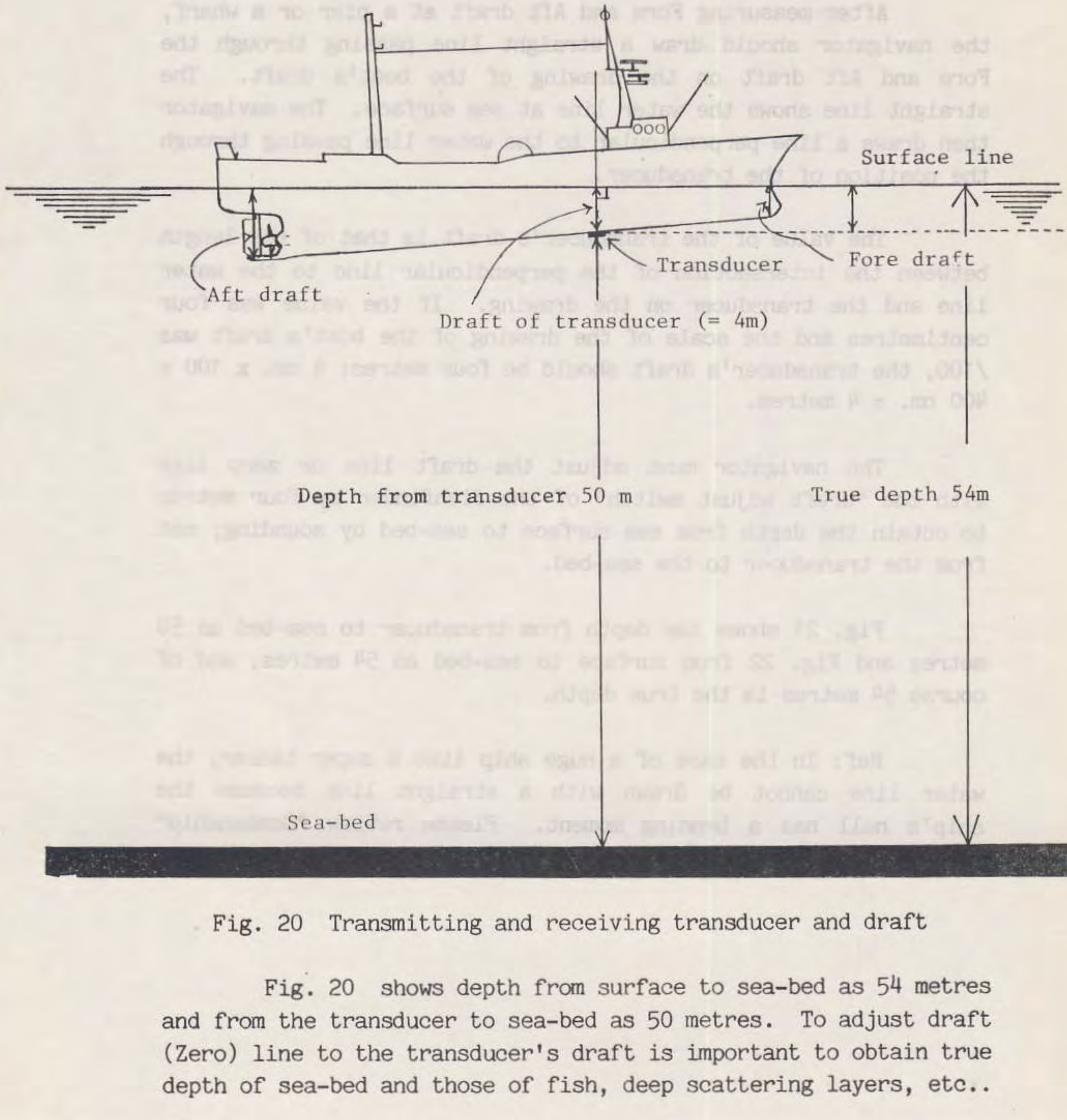


Fig. 20 Transmitting and receiving transducer and draft

Fig. 20 shows depth from surface to sea-bed as 54 metres and from the transducer to sea-bed as 50 metres. To adjust draft (Zero) line to the transducer's draft is important to obtain true depth of sea-bed and those of fish, deep scattering layers, etc..

After measuring Fore and Aft draft at a pier or a wharf, the navigator should draw a straight line passing through the Fore and Aft draft on the drawing of the boat's draft. The straight line shows the water line at sea surface. The navigator then draws a line perpendicular to the water line passing through the position of the transducer.

The value of the transducer's draft is that of the length between the intersection of the perpendicular line to the water line and the transducer on the drawing. If the value was four centimetres and the scale of the drawing of the boat's draft was /100, the transducer's draft should be four metres; 4 cm. x 100 = 400 cm. = 4 metres.

The navigator must adjust the draft line or zero line with the "draft adjust switch" of the fishfinder by four metres to obtain the depth from sea surface to sea-bed by sounding; not from the transducer to the sea-bed.

Fig. 21 shows the depth from transducer to sea-bed as 50 metres and Fig. 22 from surface to sea-bed as 54 metres, and of course 54 metres is the true depth.

Ref: In the case of a huge ship like a super tanker, the water line cannot be drawn with a straight line because the ship's hull has a bending moment. Please review "Seamanship" lecture.

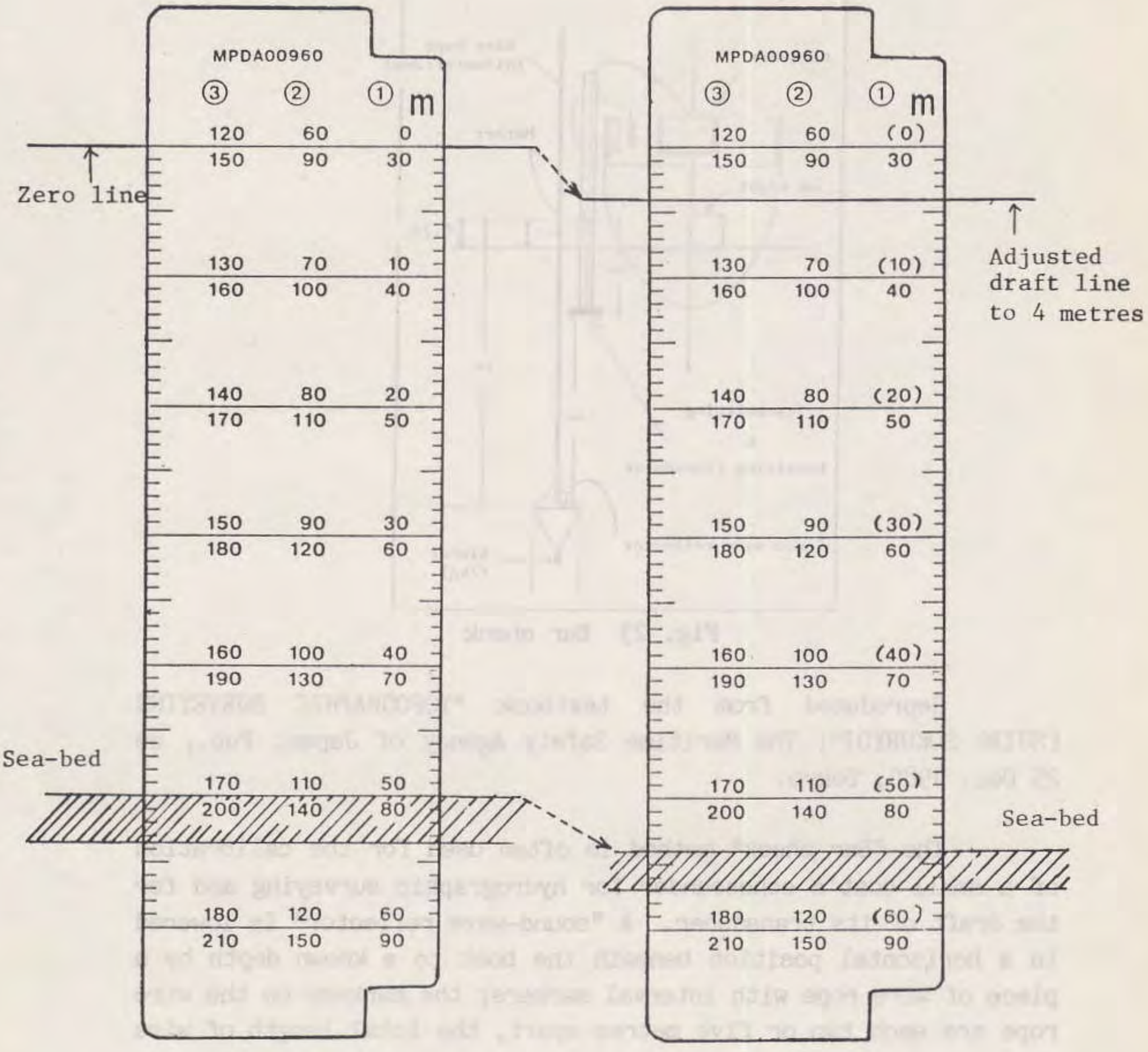


Fig. 21

Fig. 22

Fig. 21 & 22 Depth scale, depth of water and transducer's draft

Fig. 21 shows 50 metres, depth from a transducer to sea-bed.

Fig. 22 shows 54 metres, the true depth from surface to sea-bed.

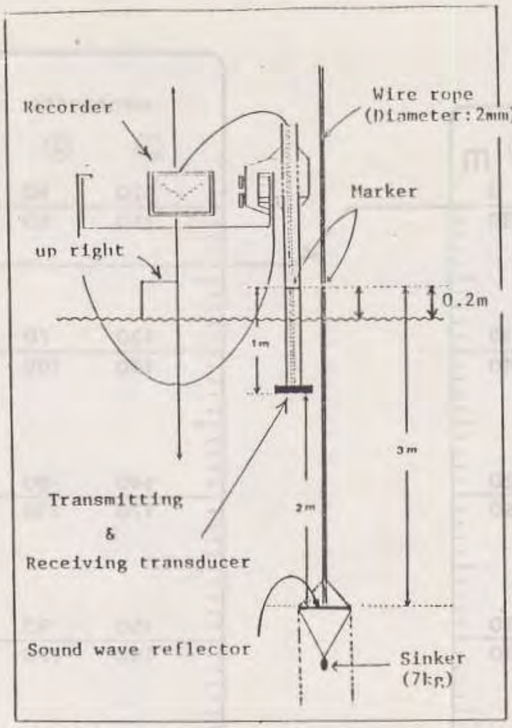


Fig. 23 Bar check

Reproduced from the textbook "TOPOGRAPHIC SURVEYING [SUIRO SOKURYO]"; The Maritime Safety Agency of Japan, Pub., on 25 Dec. 1980, Tokyo.

The "Bar check" method is often used for the calibration of a small boat's echosounder for hydrographic surveying and for the draft of its transducer. A "sound-wave reflector" is lowered in a horizontal position beneath the boat to a known depth by a piece of wire rope with interval markers; the markers on the wire rope are each two or five metres apart, the total length of wire rope, from the first marker to the last marker, is 60 to 70 metres.

After the echosounder starts emitting supersonic sound waves, the echosounder's recording chart can be traced by reflected sound waves from the "Sound-wave reflector" and show the depth of the reflector from the transducer with the echosounder's depth scale.

On the other hand by reading the interval markers on the rope, it is possible to know the true depth of the reflector from the transducer (see Fig. 23), then any error is revealed by comparison of the recorded depth on the echosounder's chart and the depth given by the interval markers on the wire rope attached to the reflector.

In Fig. 23 if the depth of the reflector's trace on the recording chart is shown as 2.50 metres and the marker on the wire rope shows the depth of the reflector as 2.0 metres (3-1 = 2 metres), the revealed error would be $\ominus$ 0.05 metre, and the draft of the transducer would be 0.8 metre (1.0 - 0.2 = 0.8 metre).

After the first measurement the reflector should be lowered four metres deeper than the transducer and a record of the depth of the reflector should be shown by echosounder, then the error would be revealed. The same measurement can be taken up to any desired depth as long as there is sufficient water beneath the boat's keel. From experience the "Bar check" method can be used at a maximum depth of 60 metres because of "Pythagoras error".

2. First echo trace of sea-bed and fish shoals

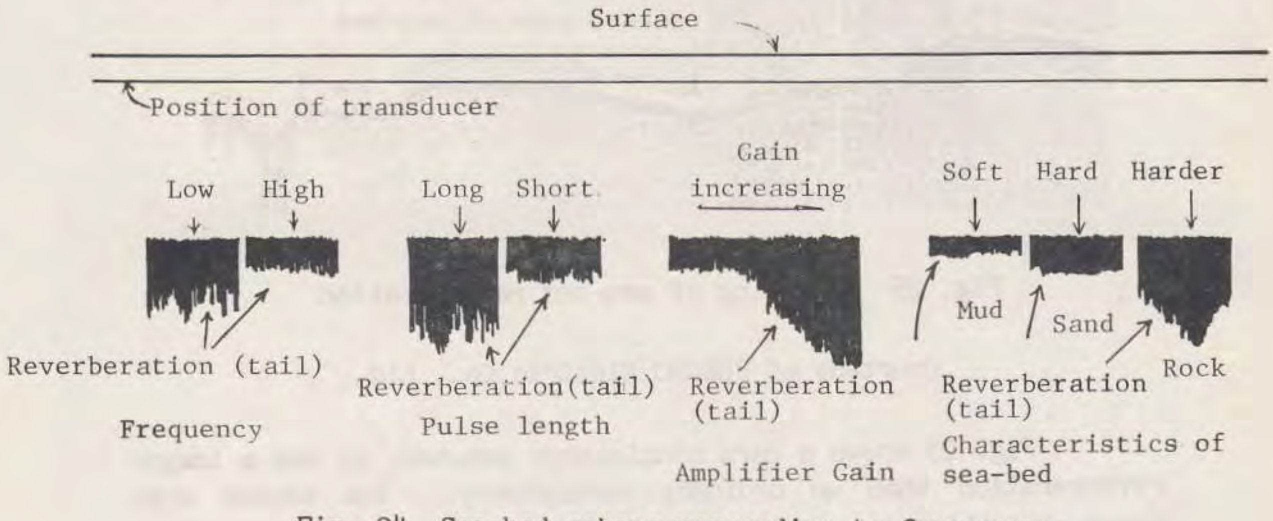


Fig. 24 Sea-bed echoes responding to frequency, pulse length, and the characteristics of the sea-bed's reverberation.

Low frequency sounding shows deeper reverberation and high frequency shallower. Long pulse length shows deeper reverberation and short pulse length shallower. When the "GAIN" control switch of a fishfinder is turned clockwise, the reverberation of the sea-bed will be longer.

If frequency, pulse length and amplifier "GAIN" are stable and constant in value, a soft sea-bed like mud gives a shorter reverberation (tail), a harder one like rock shows a longer reverberation and a hard one like sand indicates a short reverberation recording.

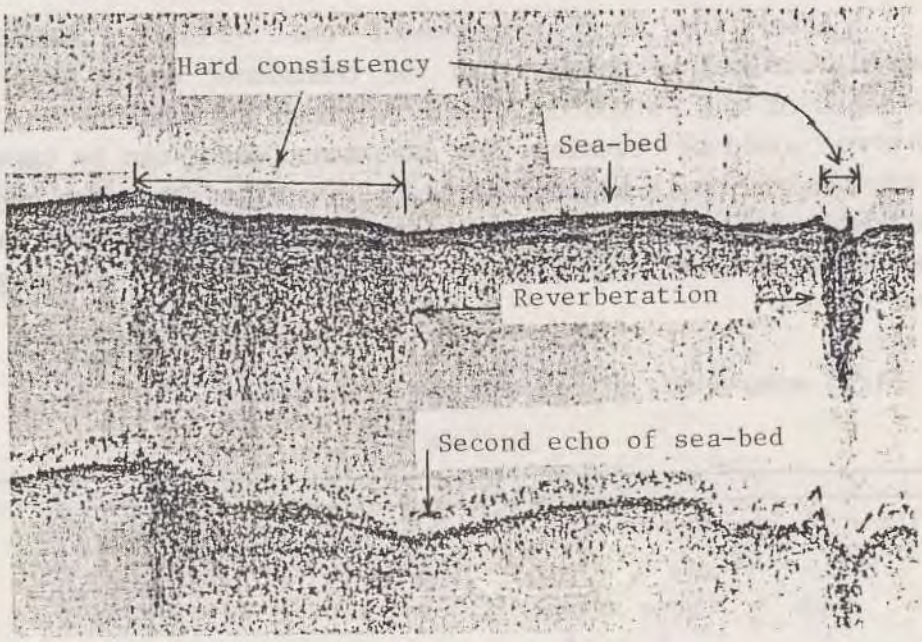


Fig. 25 Recording of sea-bed reverberation

Courtesy of FURUNO Electric Co., Ltd.,

Fig. 25 shows a hard consistency sea-bed, it has a longer reverberation than an ordinary consistency. The second echo trace also shows the same reverberation.

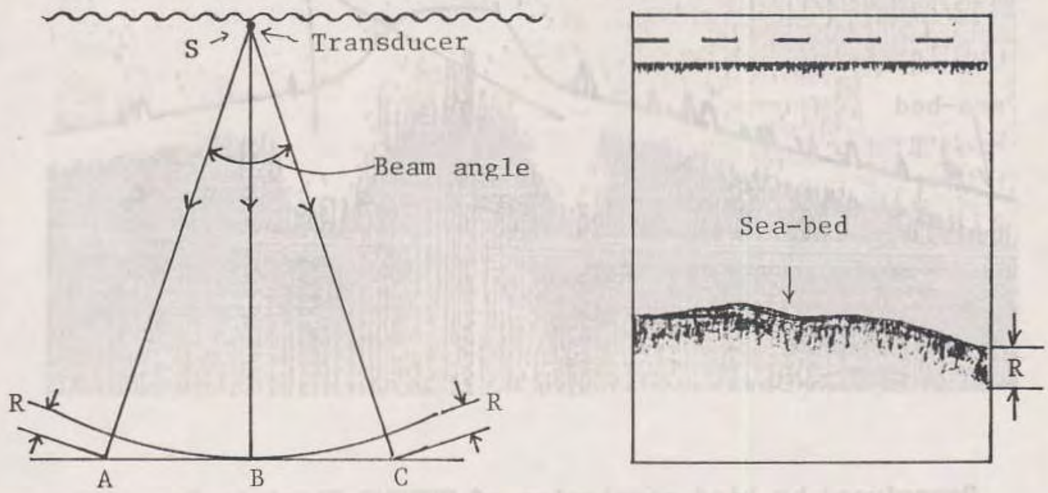


Fig. 26 Cause of sea-bed's reverberation

Fig. 26 shows the cause of the sea-bed's reverberation (R) on recording. Length $\overrightarrow{SA}$ and $\overrightarrow{SC}$ are longer or deeper than the length $\overrightarrow{SB}$. $\overrightarrow{SB}$ is shortest and it is the true depth of the water. So $\overrightarrow{SB}$ is recorded uppermost on the trace and, $\overrightarrow{SA}$ and $\overrightarrow{SC}$ are recorded underneath the trace of SB.

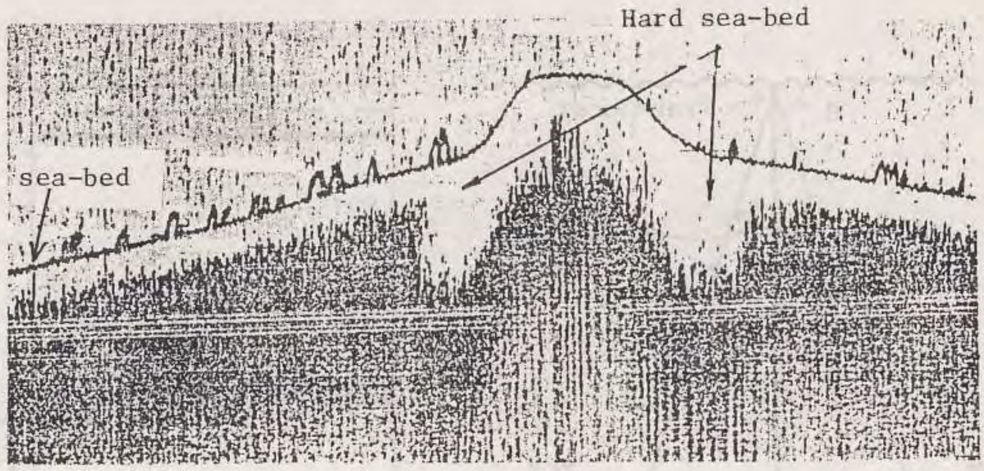


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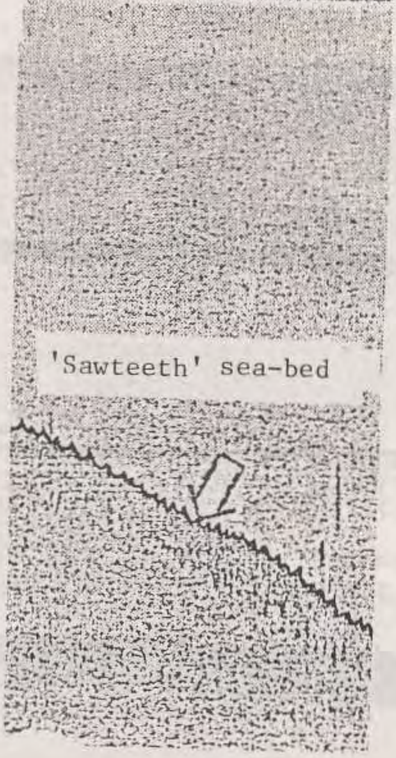
Fig. 27 Recording of hard sea-bed

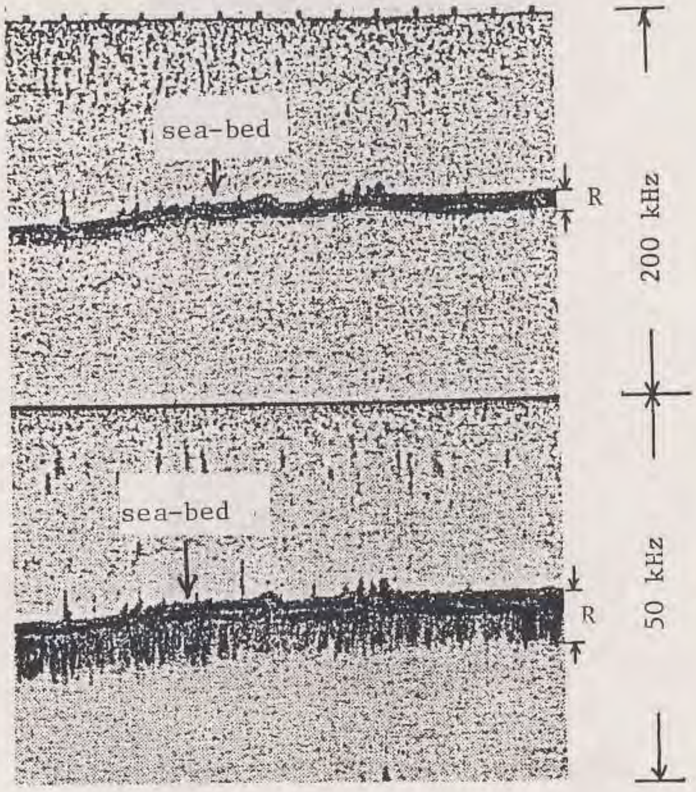
The echogram shown in Fig. 27 shows a hard sea-bed, namely, the wider white part in the recording. The mechanical technique of "White line" control on a fishfinder can record not only the hardness of the sea-bed but, also the degree of denseness of fish shoals (see Figs. 34 & 35).



Courtesy of FURUNO Electric Co., Ltd.

Fig. 28 Recording of "sawteeth" - pattern trace of sea-bed.

The "Sawteeth" pattern on a sea-bed's trace occurs when the ship is heavily pitching and rolling in stormy weather because the transmitting direction of the sound waves is not constant and "Doppler shift" occurs.



Courtesy of FURUNO Electric Co., Ltd.

Fig. 29 Dual recording by different frequencies

Fig. 29 shows dual recording of echo traces on a piece of recording chart. The upper trace was recorded using 200 kHz and the lower using 50 kHz. Reverberation using 50 kHz is greater than when using 200 kHz because the beam angle for 200 kHz is less than that of 50 kHz. "R" in Fig. 29 means "Reverberation" (see Fig. 26).

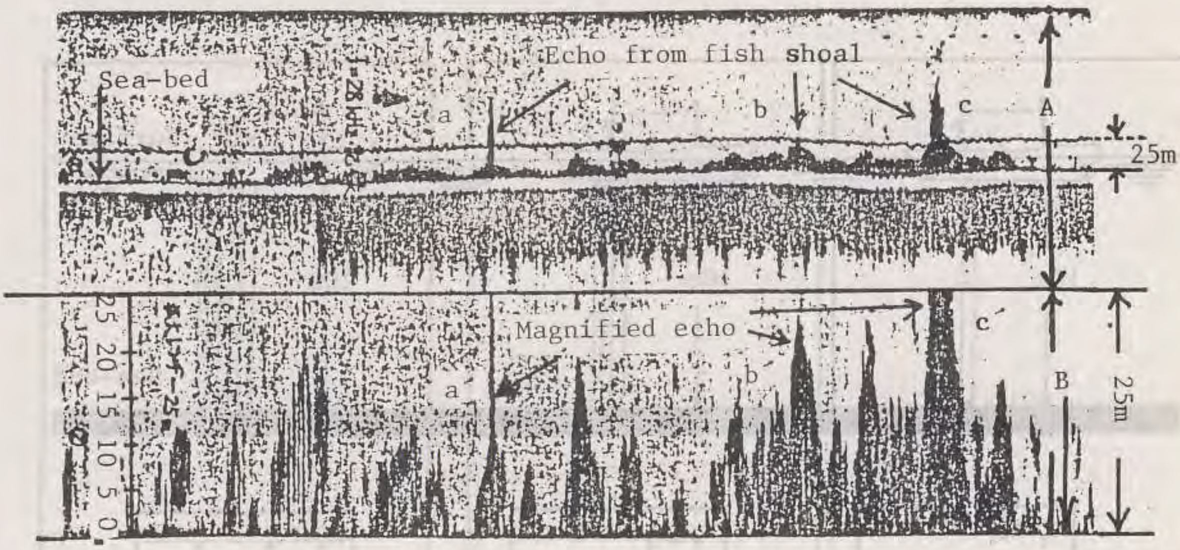


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Fig. 30 Dual recording with mechanically magnified echo traces

The recording shows a mechanically magnified display. The upper recording (section A) is an ordinary display and the lower one (section B) is a magnified display on a piece of recording chart.

In the upper recording in Fig. 30, the distance between the sea-bed and a slightly wavy line is 25 metres. This 25-metre area is magnified and displayed at the lower part of the chart (section B).

Echo traces from Alaska pollack (*Theragra Chalcogramma*). Marker a, b and c in the upper recording correspond to a', b' and c', respectively, in the lower recording. a', b' and c' are magnified traces.

3. Second echo traces of sea-bed and fish shoals

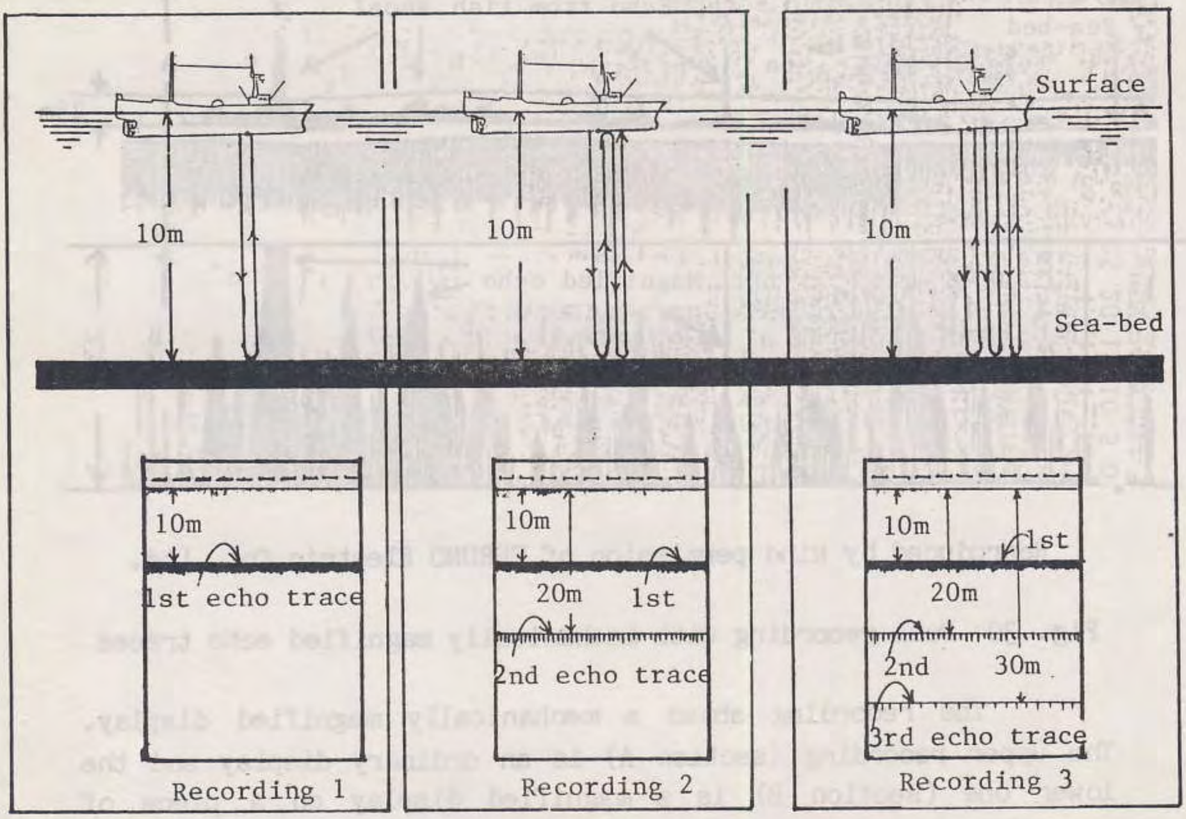

Fig. 31 Typical diagrams of first, second and third echoes

The diagrams in Fig. 31 show how the second and third echo traces almost resemble the first echo trace (true sea-bed). Sounding with high amplification in shallow waters often shows several continuous lines on the recording all nearly parallel to each other.

As shown in Fig. 31 the pulses are reflected a number of times between the sea-bed and ship's hull bottom. Recording 1 shows the first echo trace (true sea-bed, depth 10 metres). Recording 2, first and second echo traces (false sea-bed, apparent depth 20 metres) and Recording 3, first, second and third traces (false sea-bed, apparent depth 30 metres).

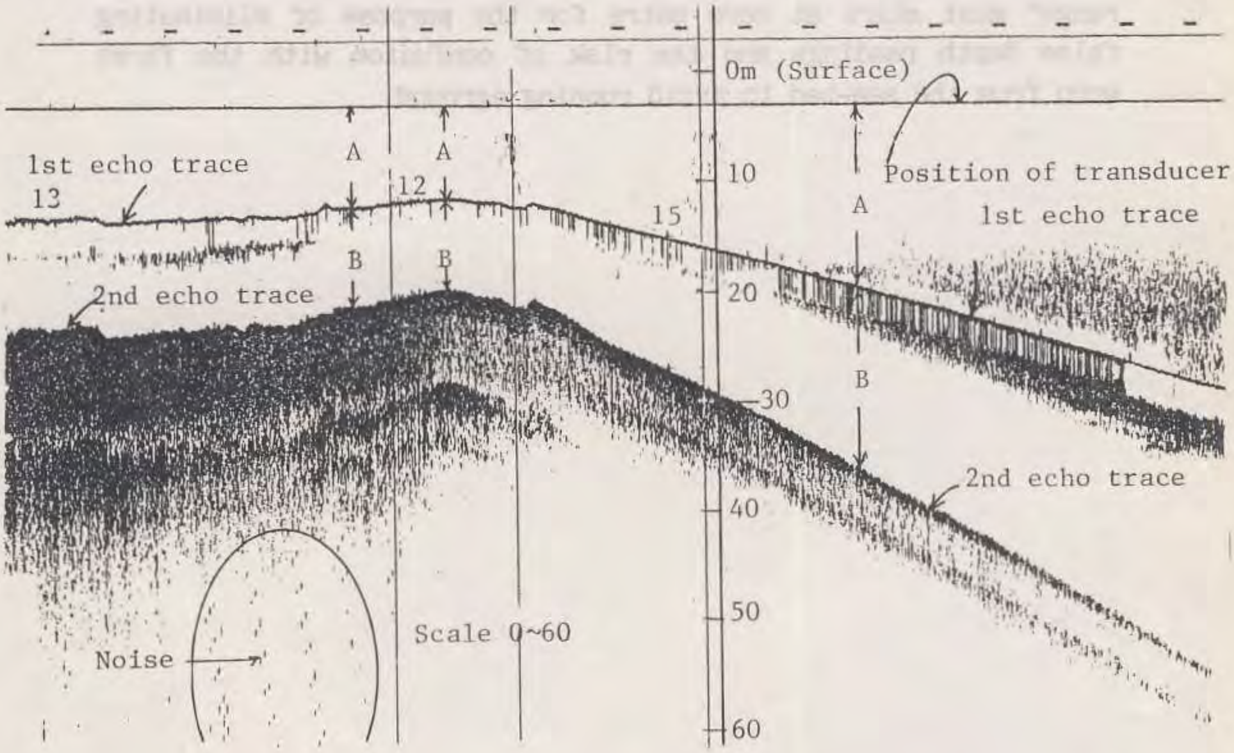

Fig. 32 First and second echo traces with noise trace.

Recorded by different fishfinders (recorded by M.V. PAKNAM off Negara Brunei Darussalam). Fig. 32 shows that the value of interval (A) between transducer and first echo trace (true sea-bed) and the value of interval (B) between first echo trace and second echo trace are almost the same (A B).

If the fishfinder's "Depth recording range" has been adjusted from 15 metres - not from zero metre - no first echo trace at a depth of 12 metres (9 metres from the transducer because of 3 - metre draft) appears, only the second echo trace at 21 (= 12 + 6 + 3) metres on the recording a false depth reading as the second echo trace is taken for the true depth of the sea-bed i.e. the first echo trace. Therefore, the "sounding range" must start at zero metre for the purpose of eliminating false depth readings and the risk of confusion with the first echo from the sea-bed to avoid running aground.

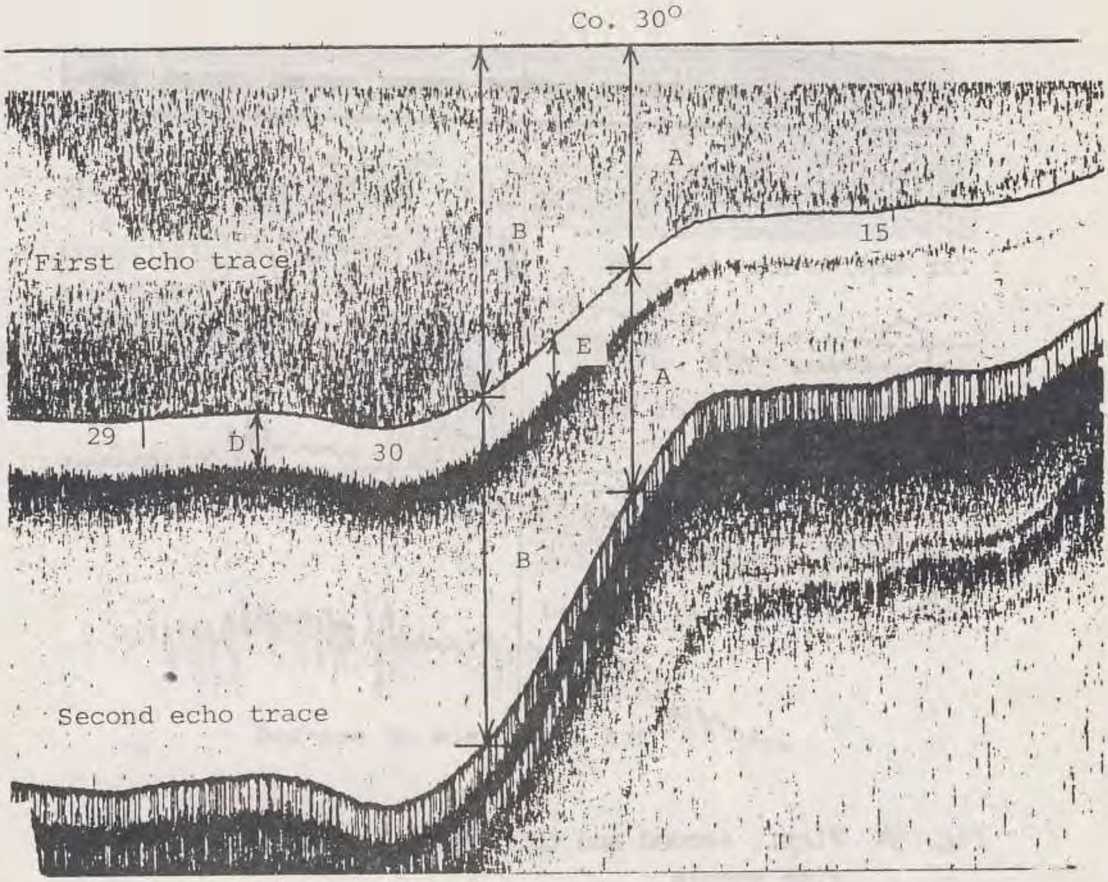

Fig. 33 First and second echo traces of sea-bed

The second echo trace from a flat sea-bed bears a resemblance to the first echo trace, however, the second echo trace from a sloping sea-bed does not resemble the first echo. Measurement of length A and A' and, B and B' shows they resemble each other: A = A' = 3.4 cm., and B = B' = 5.4 cm..

The breadth of the white part in section D underneath the line that represents the surface of the sea-bed looks wider than that, of section E. But measurement of the length of D and E shows the same value: D = E = 0.8 cm.. So please be careful because recordings can sometimes influence our interpretation of echograms.

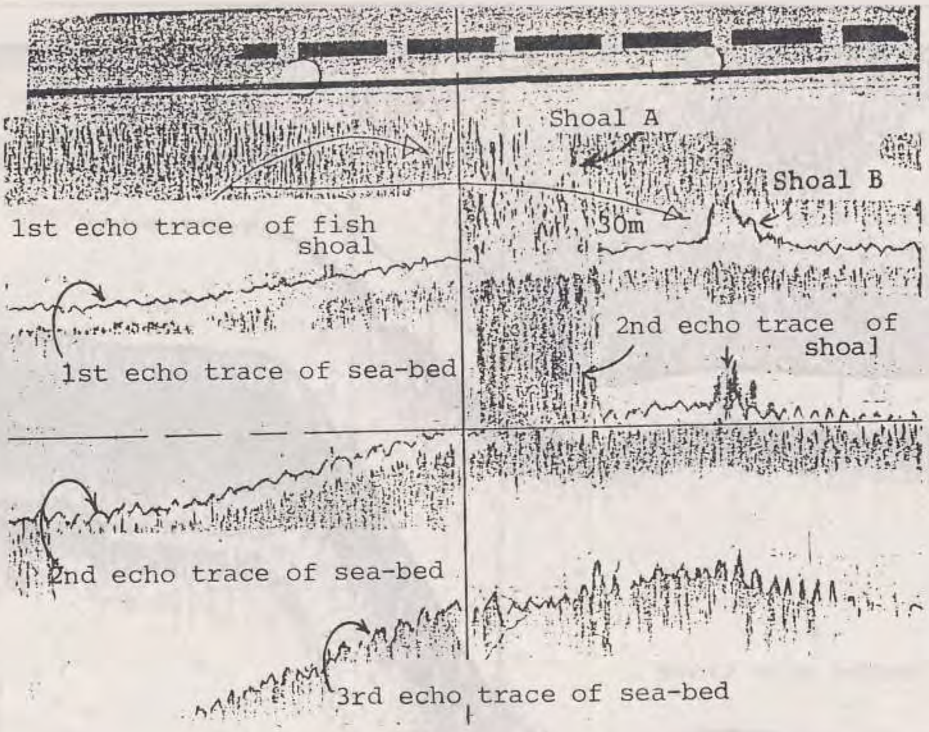

Fig. 34 First, second and third echo traces of sea-bed and fish shoals.

Fig. 34 shows first, second and third echo traces of the sea-bed and from fish shoals recorded by a FURUNO 200 kHz fishfinder in 1973.

The pulses emitted from the transducer are reflected a number of times not only between the ship's hull bottom and the sea-bed but also from fish shoals. In Fig. 34 the echo traces from fish shoals A and B are so dense and concentrated that the emitted pulse is reflected two times between the ship's hull bottom and the shoals. A third one is invisible on the recording because of the attenuation of supersonic energy as time elapses. In this recording the function of the "White line" works well, so the echo trace of fish shoal B looks like a rocky hill and part of the sea-bed. But the second echo trace shows a line dividing the second echo trace of the sea-bed and the second echo of the fish shoal. During fishing operations using the fishfinder, to check the second or third echo traces is very important.

Ref: Shoal A; barracuda, Shoal B; red snapper at a depth of 30 metres.

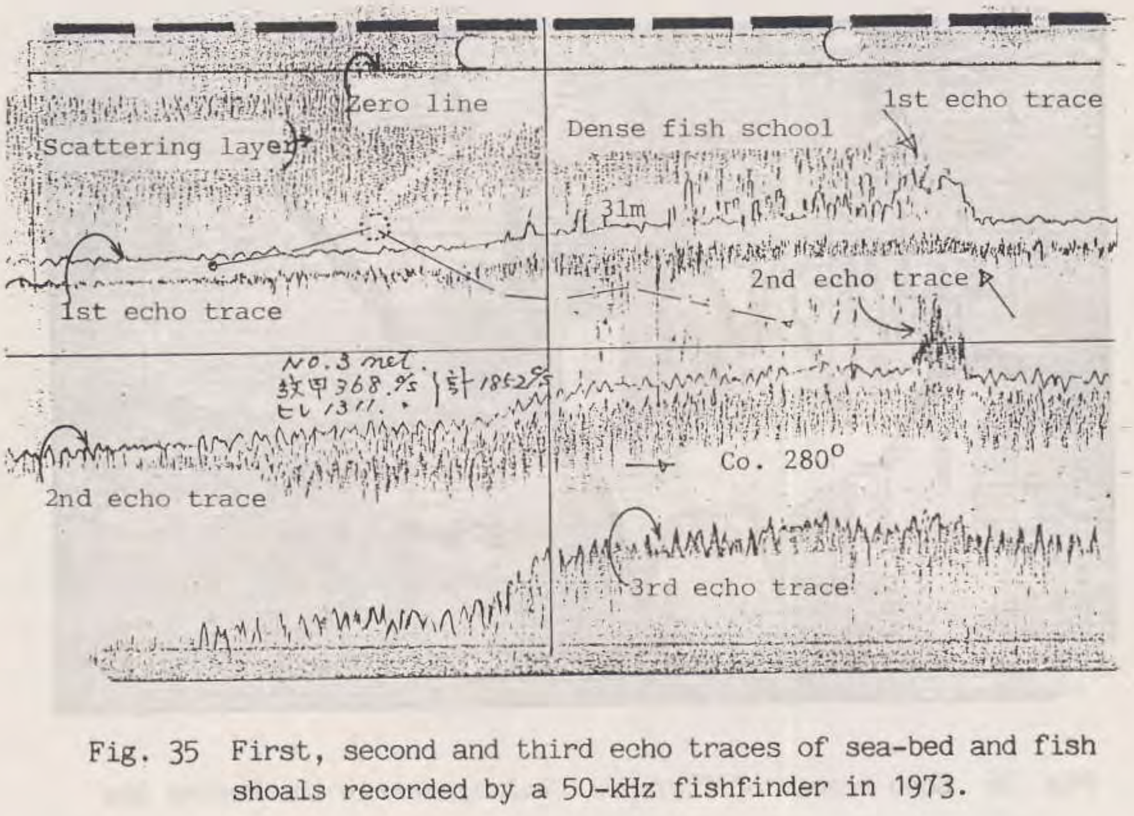

Fig. 35 First, second and third echo traces of sea-bed and fish shoals recorded by a 50-kHz fishfinder in 1973.

Fish schools recorded in Fig. 35 consist of red snappers and cuttlefish. The hyperbolic or "fingernail" echo traces could be taken for a cuttlefish school and the mountainous trace - extreme right - for red snappers (one haul = cuttlefish 4.5 tons and red snapper 13.5 tons, probably 4 to 5% of the total quantity of the schools).

The vertical intervals between "Zero line" and the first echo trace, first echo trace and second echo trace, and second echo trace and third echo trace of the sea-bed and their shapes are similar. Fig. 35 also shows a second echo trace from the fish school, but it is smaller than the first one because of the attenuation of supersonic sounding waves, the third one is invisible.

4. Echo traces of pelagic species.

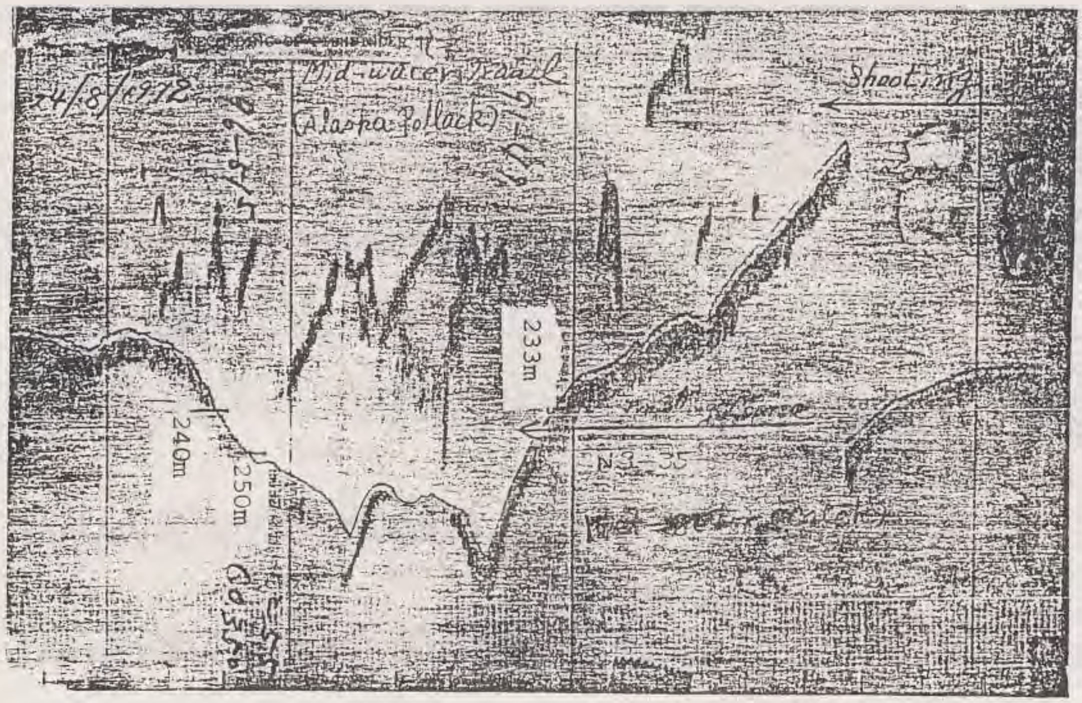

Fig. 36 Echo traces of *Theragra Chalcogramma* in the Bering Sea

The echogram in Fig. 36 shows the traces of *Theragra Chalcogramma* in mid-water recorded by a 50-kHz fishfinder in the Bering Sea in 1972. The sea-bed is very steep and the depth of water ranges from 160 to 270 metres.

60-minute dragging of mid-water trawl produced an 80-ton catch of *Theragra Chalcogramma* (see Fig. 151 the net-monitor recording).

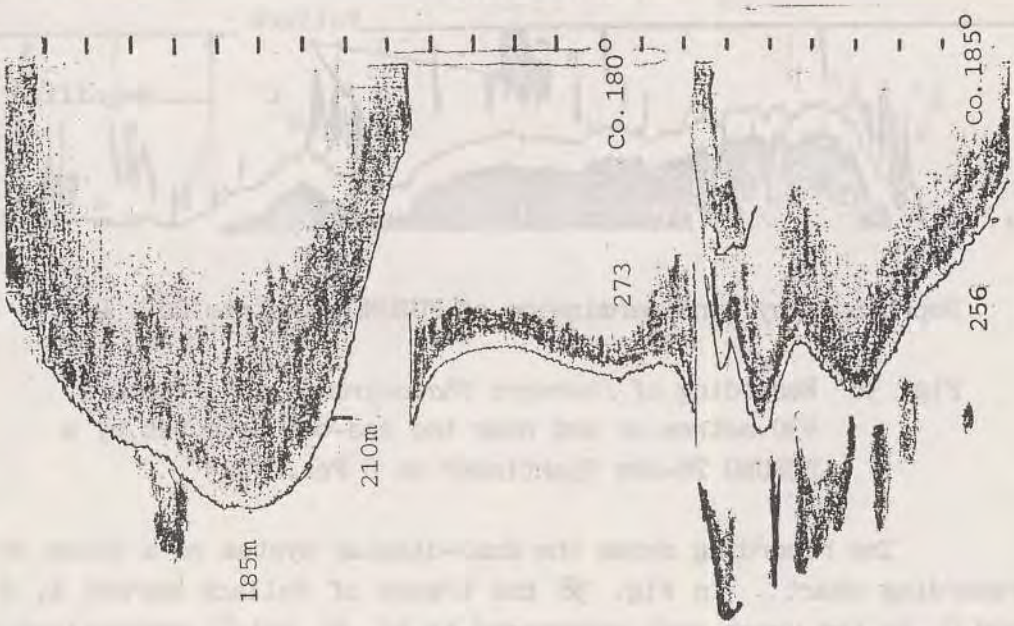

Fig. 37 Echo traces of *Theragra Chalcogramma* in the Bering Sea

The echogram in Fig. 37 shows traces of *Theragra chalcogramma* over the top of a seamount in the Bering Sea, recorded by a 50-kHz fishfinder.

This species of fish spawn in mid-water at a depth of 200 to 300 metres. The sea-bed depth here is more than 1000 metres.

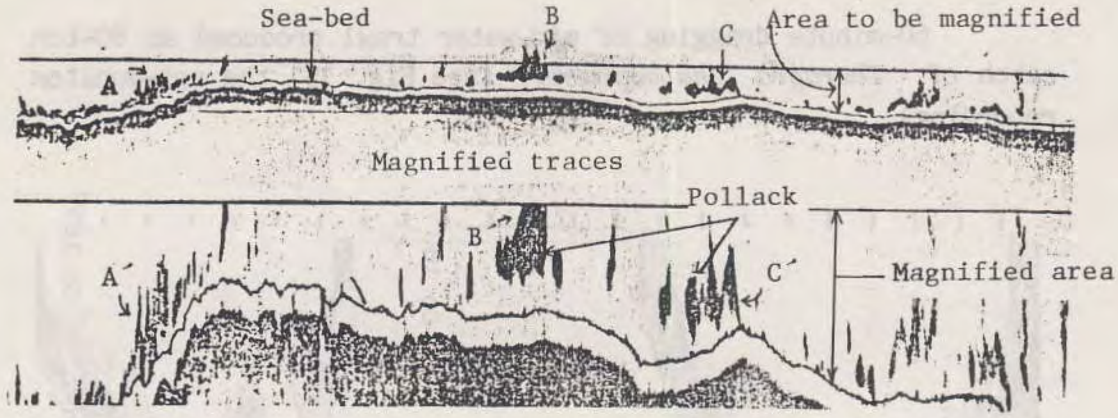

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Fig. 38 Recording of *Theragra Chalcogramma* at a depth of 430 metres on and near the sea-bed detected by a FURUNO 28-kHz fishfinder on 8 Feb. 1973

The recording shows the dual-display system on a piece of recording chart. In Fig. 38 the traces of Pollack marked A, B and C, in the upper part correspond to A', B' and C', respectively, in the lower part of the recording. The echo traces from the Pollack marked by A', B' and C' are magnified to identify the traces from fish more precisely.

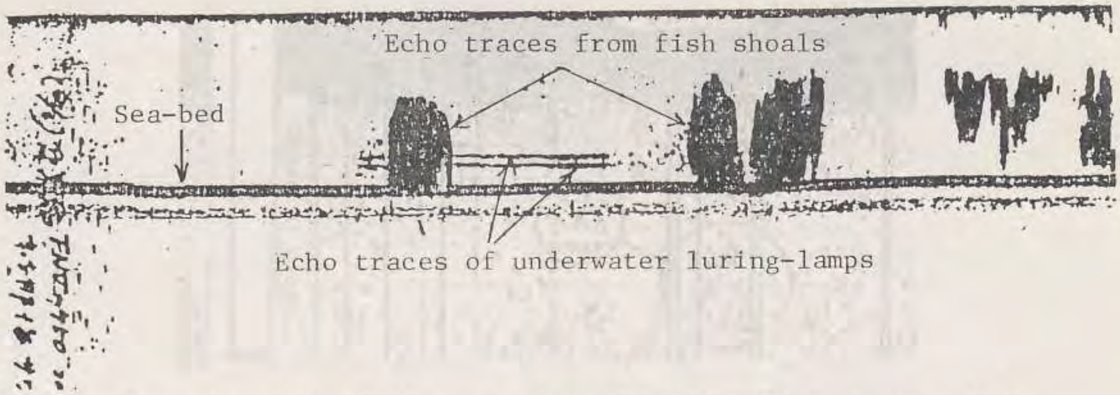

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Fig. 39 Echo traces from *Scomberomorus Commersoni* & underwater luring-lamps.

The recording in Fig. 39 shows echo traces from *Scomberomorus Commersoni* gathering at underwater luring-lamps recorded by a 200-kHz FURUNO fishfinder in the East China Sea in April 1974.

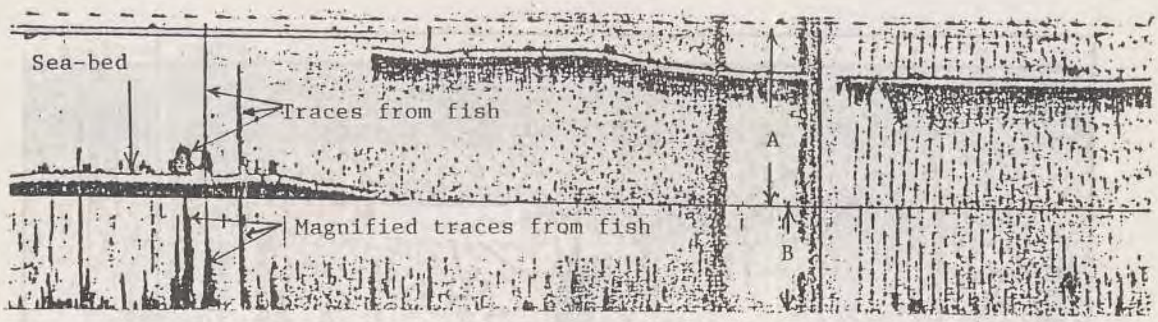

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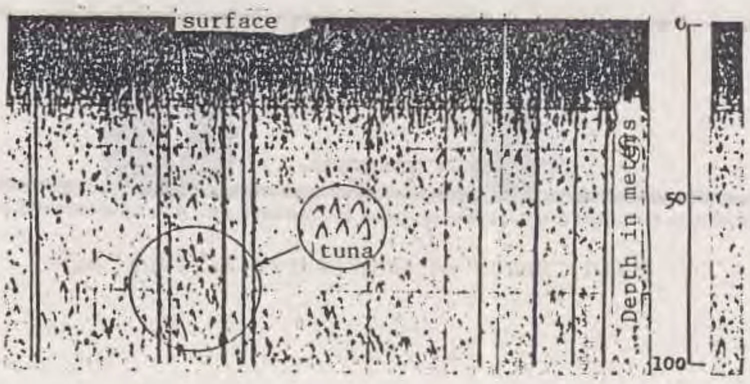
Fig. 40 Echo traces from "Ōnago" with dual recording

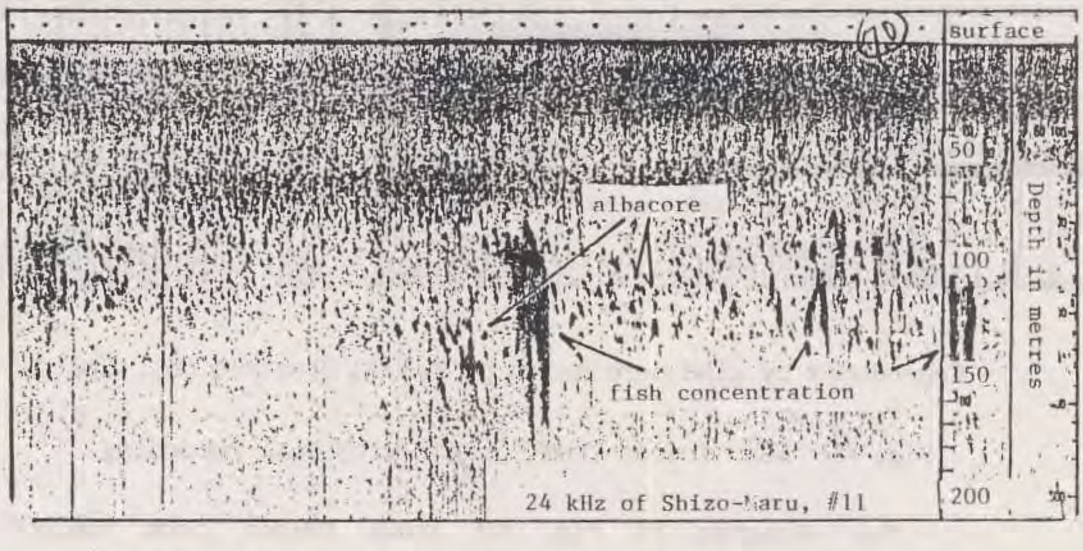
The echogram in Fig. 40 shows traces from "Ōnago" recorded by a 50-kHz FURUNO fishfinder off Hokkaido Island, Japan. The recording shows the dual-display system on a piece of recording chart. In the recording, section A is an ordinary recording and section B is a magnified one.



Courtesy of Dr. T. Shibata, Nagasaki University, Japan

Fig. 41 Echo traces from individual tuna at a depth of 50 to 100 metres

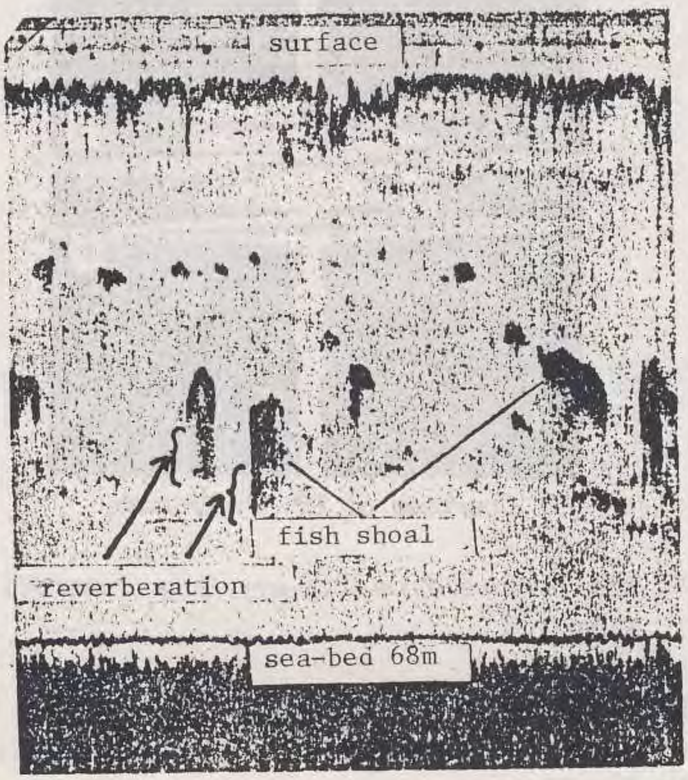
The recording in Fig. 41 shows echo traces of individual tuna swimming beneath the transducer at a depth of 50 to 100 metres, recorded by a 14-kHz fishfinder on M.V. Nagasaki-Maru, the training and research vessel of Nagasaki University, in 1962.



Courtesy of Dr. T. Shibata, Nagasaki University, Japan

Fig. 42 Echo traces from albacore at a depth of 100 to 150 metres

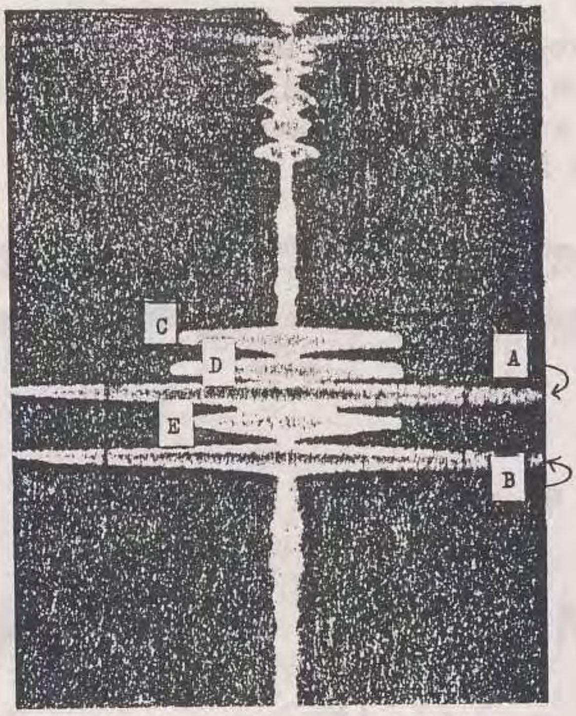
The formation of the trace of albacore on the chart is different from that of demersal fish species. The recording was obtained by a 24-kHz fishfinder on M.V. No. 11 Shizo-Maru, a pole-and-line fishing boat.



Courtesy of Dr. T. Shibata

Fig. 43 Echo traces from anchovy

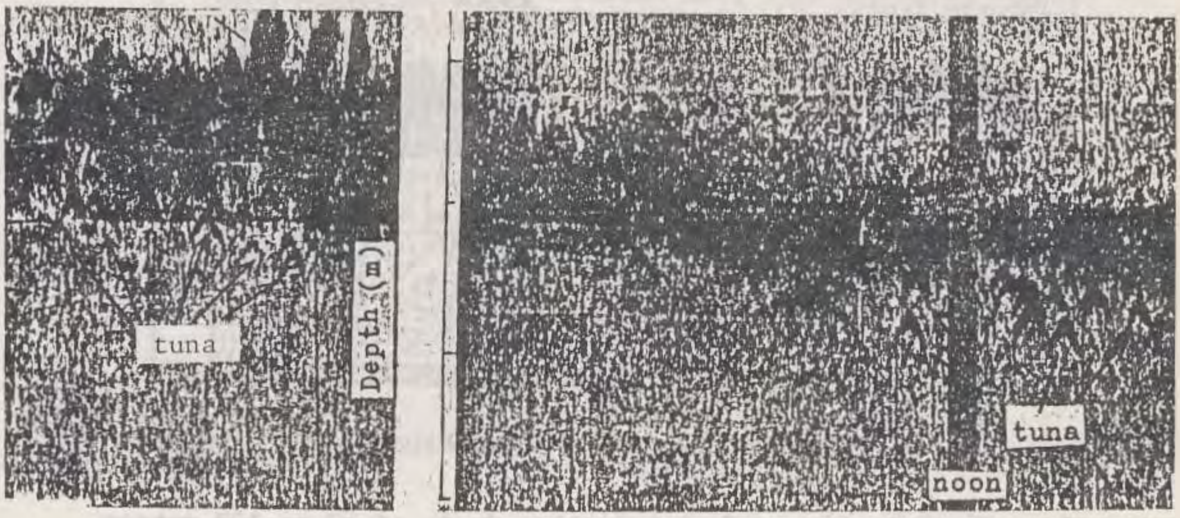
The echo traces shown in Fig. 43 were recorded by a 50-kHz fishfinder, they are from anchovy shoals, in the Yellow Sea during 1963. The Scattering layer near the surface can be seen.



Courtesy of Dr. T. Shibata

Fig. 44 Echo traces from big-eye Tuna recorded by a Brown Tube

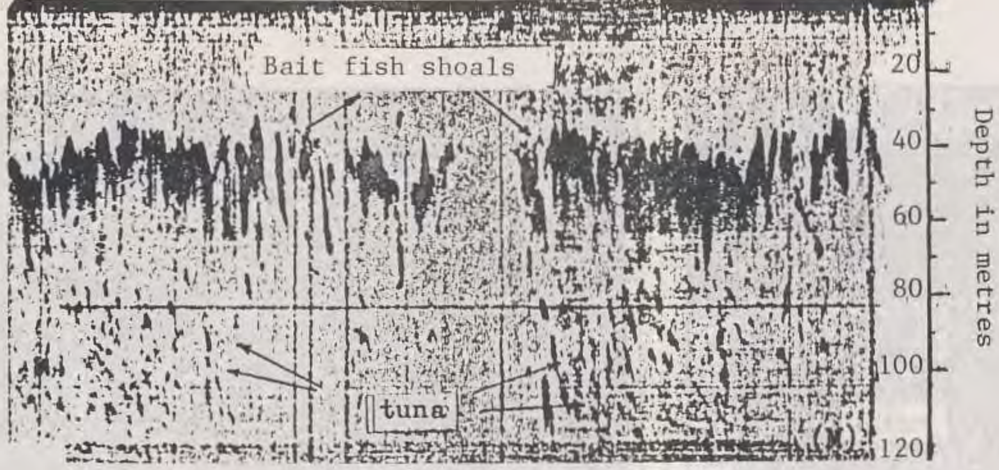
The echo traces in Fig. 44 show single big-eye tuna (marked by "A" and "B" on the Brown tube screen (CRT), detected by a 28-kHz fishfinder.



By courtesy of Dr. T. Shibata

Fig. 45 Echo traces from individual tuna at a depth of 250 to 300 metres

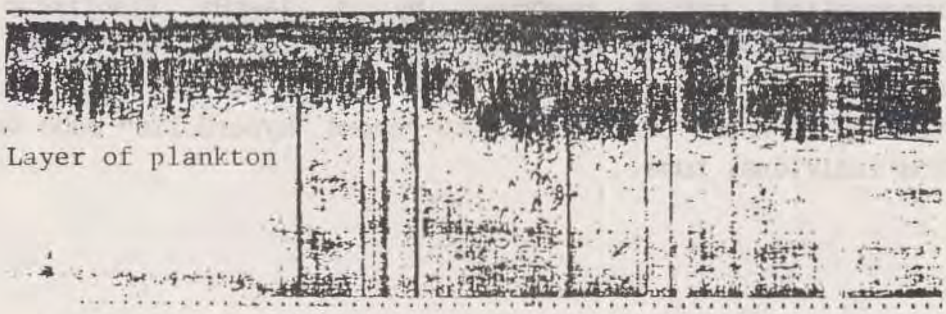
The echo traces in Fig. 45 show individual tuna "hyperbolic" traces recorded by a 14-kHz fishfinder on M.V. Nagasaki-Maru of Nagasaki University on 12 July 1964. The echogram was recorded while the vessel was adrift. During steaming it would be difficult to record "hyperbolic" echo traces from individual tuna.



By courtesy of Dr. T. Shibata

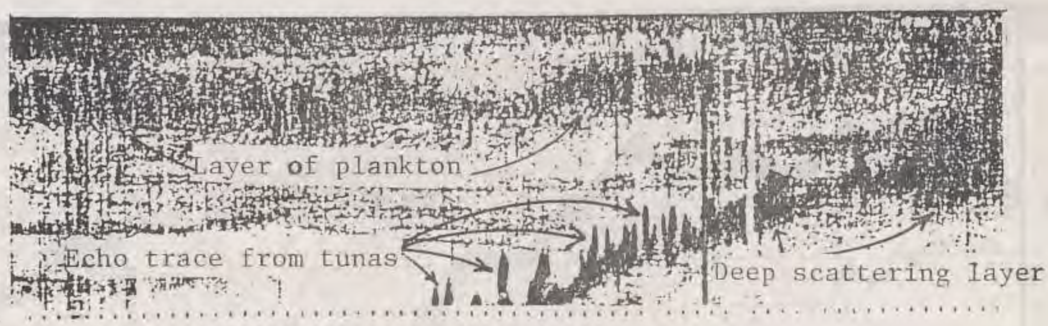
Fig. 46 Echo traces from tuna at a depth of 80 to 120 metres

The echogram was recorded by a 28-kHz fishfinder on M.V. Asahi-Maru, a tuna longliner in the South Pacific Ocean on 14 Feb. 1961. Yellowfin tuna are gathering beneath the bait-fish layer.



Courtesy of FURUNO Electric Co., Ltd.

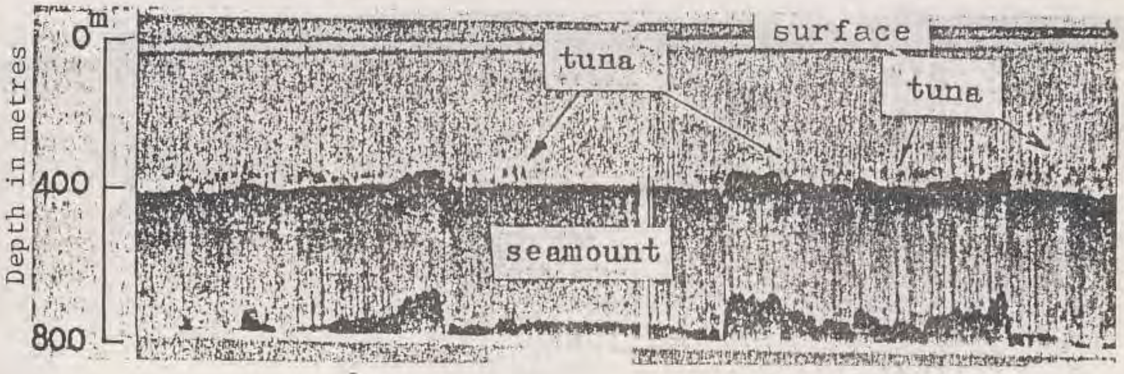
Fig. 47 Echo trace from plankton layer in the Tasman Sea, recorded during the daytime. After sunset the deep scattering layer comes up towards the surface and between the plankton layer and the deep scattering layer echo traces from tuna can be seen (see Fig. 48).



Courtesy of FURUNO Electric Co., Ltd.

Fig. 48 Echo traces from plankton layer, tuna and deep scattering layer in the Tasman Sea.

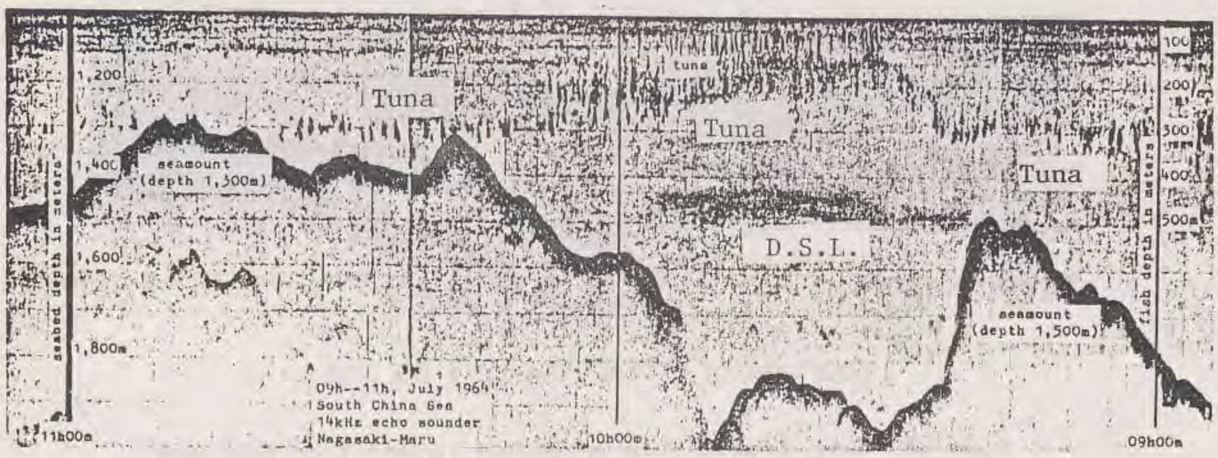
In Fig. 48 the deep scattering layer is moving upward. In the scattering layer the traces of tuna can be seen, these tunas are moving with the deep scattering layer towards the surface. The layers in the echogram of Fig. 48 consist of organisms. The right side of the traces was recorded in the evening and indicates that it is important to know the depth of the deep scattering layer for tuna fishing.



By courtesy of Dr. T. Shibata

Fig. 49 Echo traces of tuna on the Emperor Bank

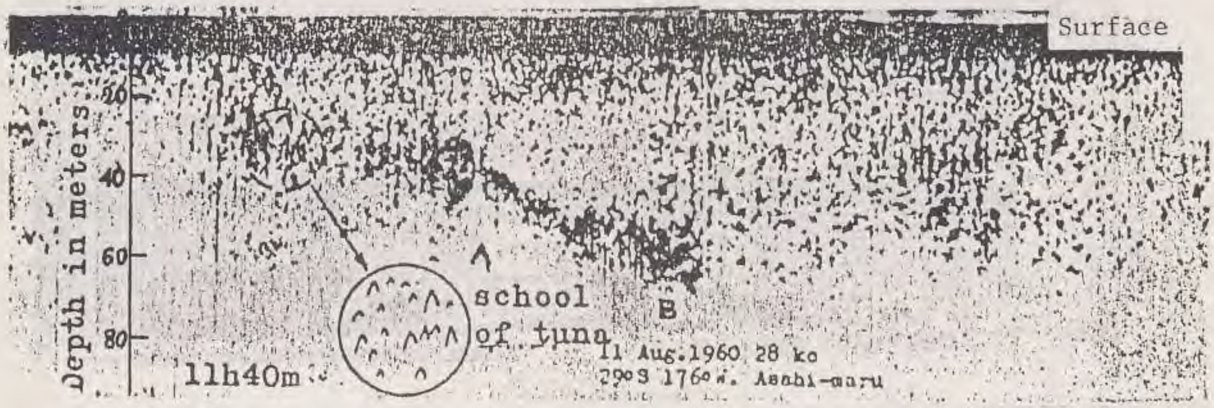
The echogram shows tuna shoals on the Emperor Bank in the North Pacific Ocean, recorded by a 14 kHz fishfinder on M.V. Kosei-Maru on 30 Sept. 1963. As shown in Fig. 49 Tunas are swimming very close to the sea-bed of the tablemount at a depth of 400 metres.



By Courtesy of Dr. Shibata

Fig. 50 Tunas over the ridge of the Ocean floor

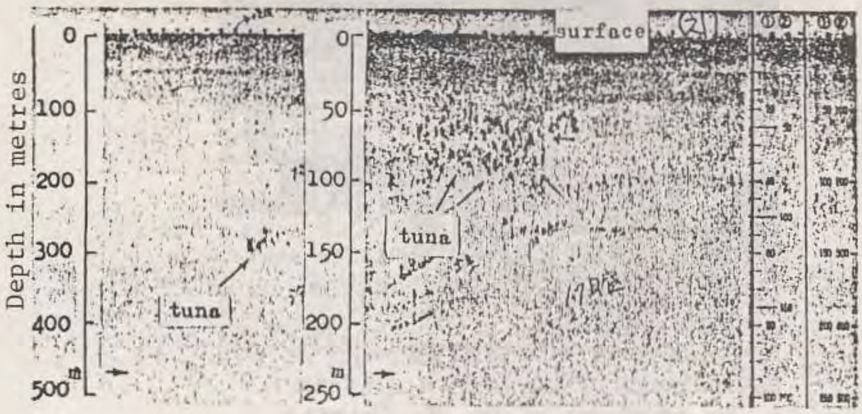
The recording in Fig. 50 shows traces from tuna at a depth of 100 to 300 metres over a ridge on the Ocean floor in the South China Sea, recorded by a 14-kHz fishfinder on M.V. Nagasaki-Maru: the training and research vessel of Nagasaki University, on 21 July 1964.



By courtesy of Dr. T. Shibata

Fig. 51 Echo traces from albacore at a depth of 20 to 40 metres

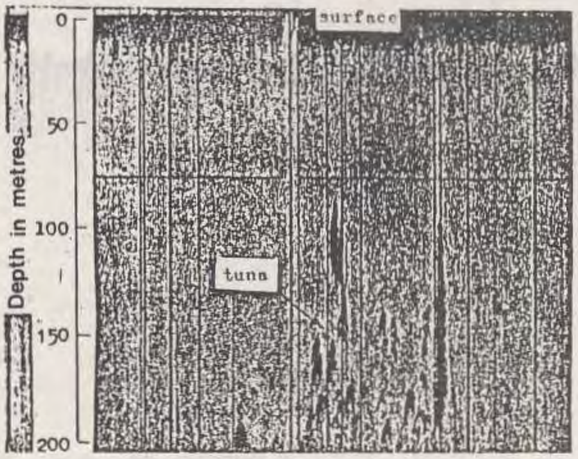
The echogram of Fig. 51 shows echo traces from albacore recorded by a 28-kHz fishfinder and the trace shape looks like a "hyperbolic" or ""inverted V". The fishing ground is at 1000 nautical miles from the Fiji Islands in the South Pacific Ocean.



By courtesy of Dr. T. Shibata

Fig. 52 Echo traces from individual tuna (near the Philippines)

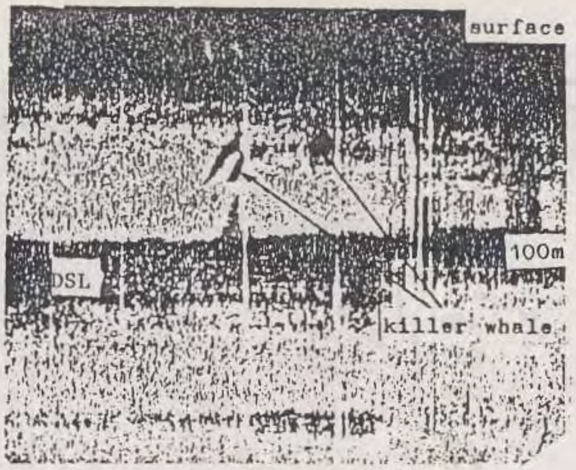
The echogram in Fig. 52 shows echo traces from individual tuna recorded by a 14-kHz fishfinder on M.V. Nagasaki-Maru at a fishing ground near the Philippines on 7 July 1967.



By courtesy of Dr. T. Shibata

Fig. 53 Echo traces from individual big-eye tuna in the Middle Pacific Ocean

The echogram in Fig. 53 shows echo traces from individual big-eye tuna swimming at a depth of 150 to 200 metres, forming an "inverted V", recorded in the Middle Pacific Ocean on 26 Jan. 1965.



By courtesy of Dr. T. Shibata

Fig. 54 Echo traces from a killer whale

The echogram in Fig. 54 shows interesting echo traces from a single killer whale over the deep scattering layer (D.S.L.) and beneath the plankton layer, recorded by a 24-kHz fishfinder on M.V. No. 18 Chiyo-Maru a tuna longliner at latitude 14°S, longitude 91.9°E on 26 Oct. 1965. If killer whales are found in a tuna fishing ground, the catch will be poor.

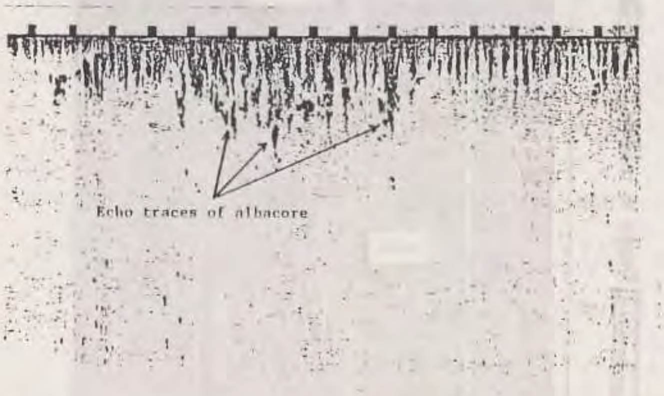


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Fig. 55 Echo traces from albacore recorded off Northeastern Japan

The echogram in Fig. 55 shows traces from albacore recorded by a FURUNO 50-kHz on a 70-ton tuna fishing boat in the fishing ground off Northeastern Japan.

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Fig. 56 Echo traces from individual tuna recorded in the Tasman Sea.

The echogram in Fig. 56 shows traces of individual tuna, recorded by a FURUNO 60-kHz sonar in the Tasman Sea. Many tails of Tuna traces can be seen over the deep scattering layer in the echogram.

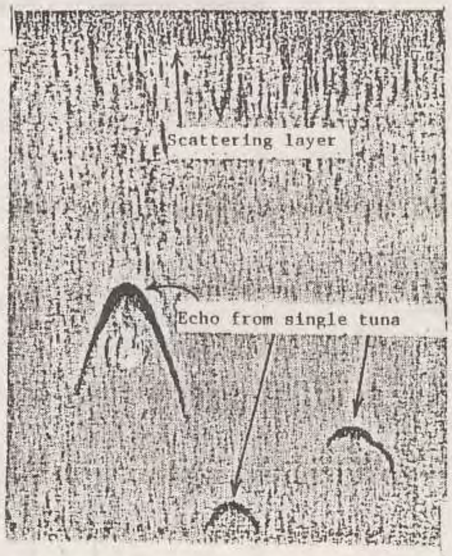

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Fig. 57 Typical "hyperbolic" or "fingernail" echo traces from individual tuna

Fig. 57 shows magnified echo traces from individual tuna. These are typical "hyperbolic" or "fingernail" traces. See Fig. 58 A, B and C. When recording, the boat was adrift.

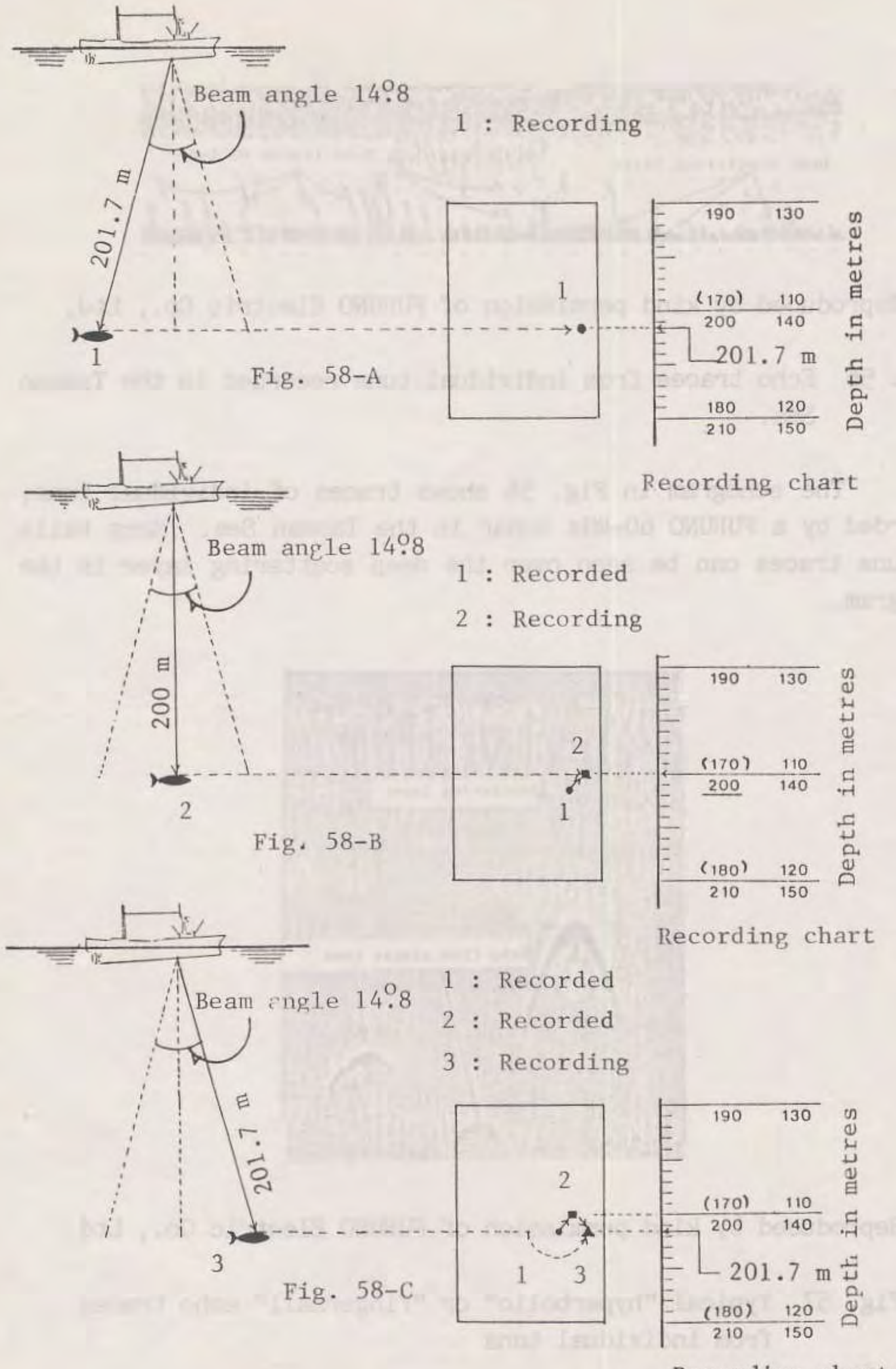

Fig. 58 The cause of "hyperbolic" echo traces from individual tuna

Fig. 58 shows how a trace from an individual tuna appears "hyperbolic" or like a "fingernail" beneath the fishfinder. In Fig. 58-A the fish reaches the extreme-left side of the sounding beam, then the fishfinder's first record trace of the tuna is at a depth of 201.7 metres. Next the fish is beneath the fishfinder (see Fig. 58-B) and, the recorded depth of the tuna is 200 metres, shallower than 201.7 metres as shown in Fig. 58-A. Finally the fish will reach the extreme-right side of the sounding beam (see Fig. 58-C) and the fishfinder records it as an echo trace at a depth of 201.7 metres, deeper than 200 metres in Fig. 58-C.

Therefore, the echo trace will form a "hyperbolic" or "fingernail" trace on the recording chart; (⌒). In this case the fishing boat is adrift during sounding and the beam angle is 14.8°.

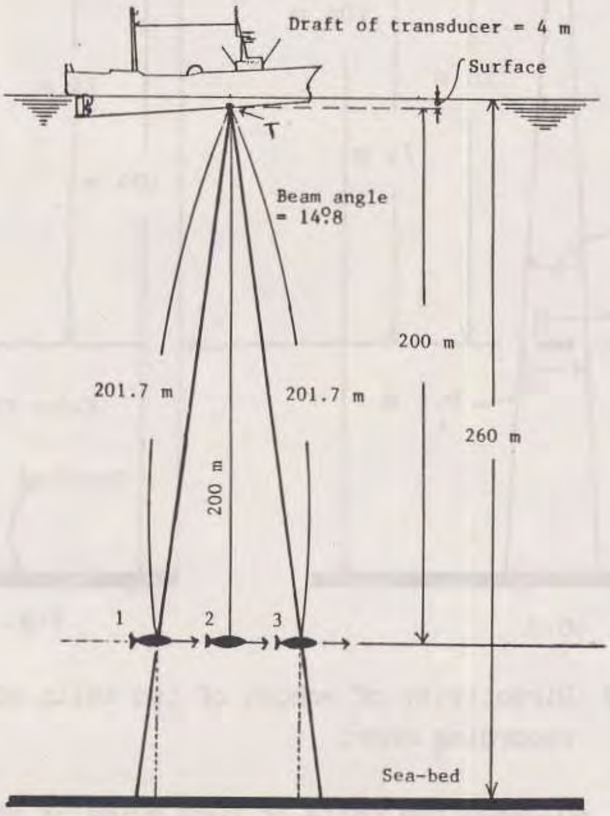

Fig. 59 Distance from transducer to individual moving tuna beneath the boat

The diagram is Fig. 59 shows a single tuna swimming from point 1 to 3 through point 2 beneath the transducer. The distances between "T" and point 1, between "T" and point 2 and, between "T" and point 3 are 201.7, 200 and 201.7 metres, respectively. Then an echo trace of a single tuna would be recorded in a "hyperbolic" formation (⌒).

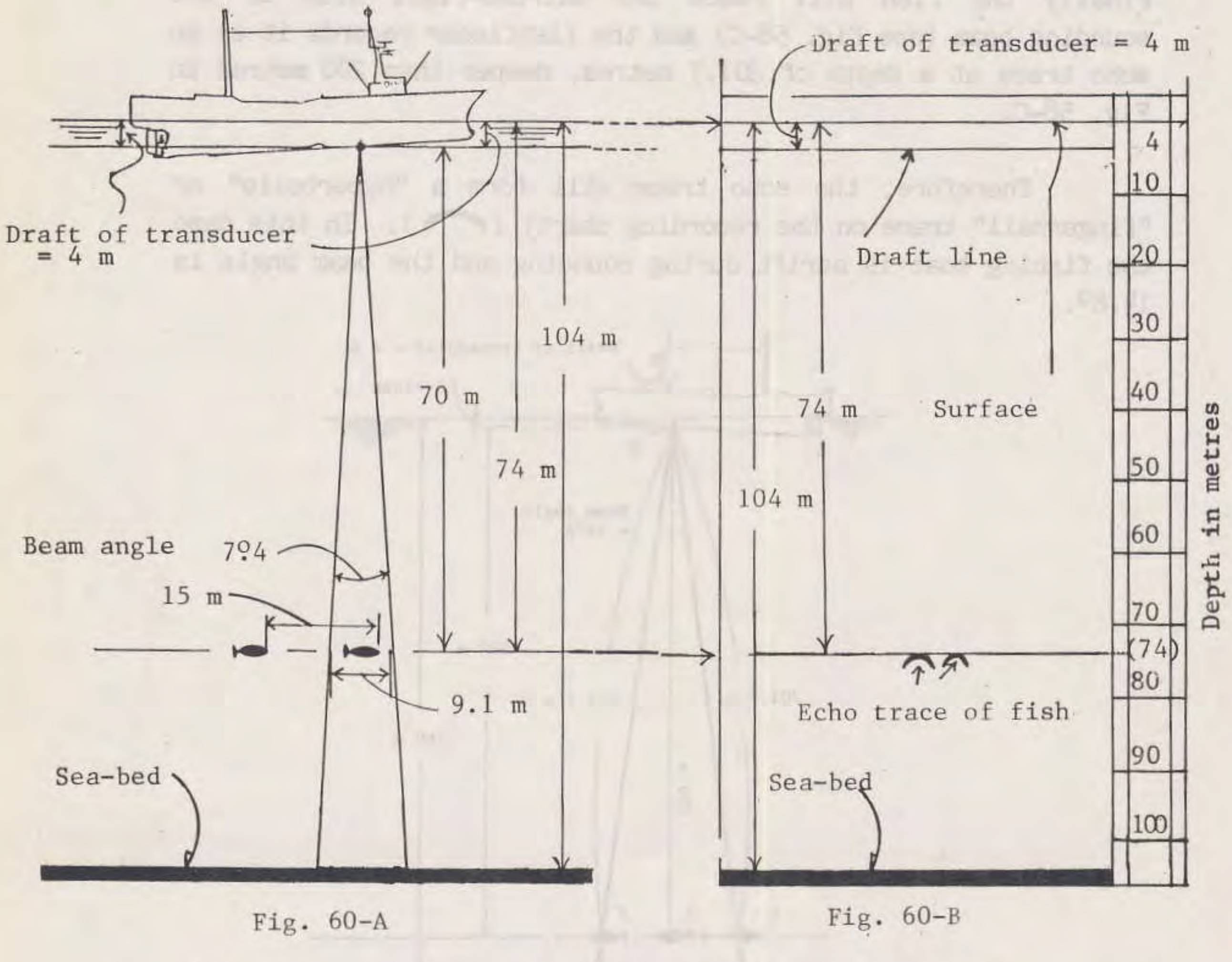

Fig. 60 Directivity of echoes of two tails of tuna on recording chart

Fig. 60 shows two tails of tuna swimming at a depth of 74 metres from left to right beneath a fishing boat's fishfinder, the boat is adrift (speed through the water is nil).

As mentioned in Fig. 59 the echo trace from the tuna on the recording chart should be "hyperbolic" in shape but in Fig. 60 the recorder of the fishfinder shows two traces (see Fig. 60-B). The interval between two tails of tuna should be greater than 9.1 metres. If it is less than 9.1 metres, two echo traces from two tails of tuna become only one trace because the two tails of tuna would be in the same sounding beam at a depth of 74 metres and, the beam angle is 7.4 degrees. Therefore, selectivity of fishfinder depends on beam angles.

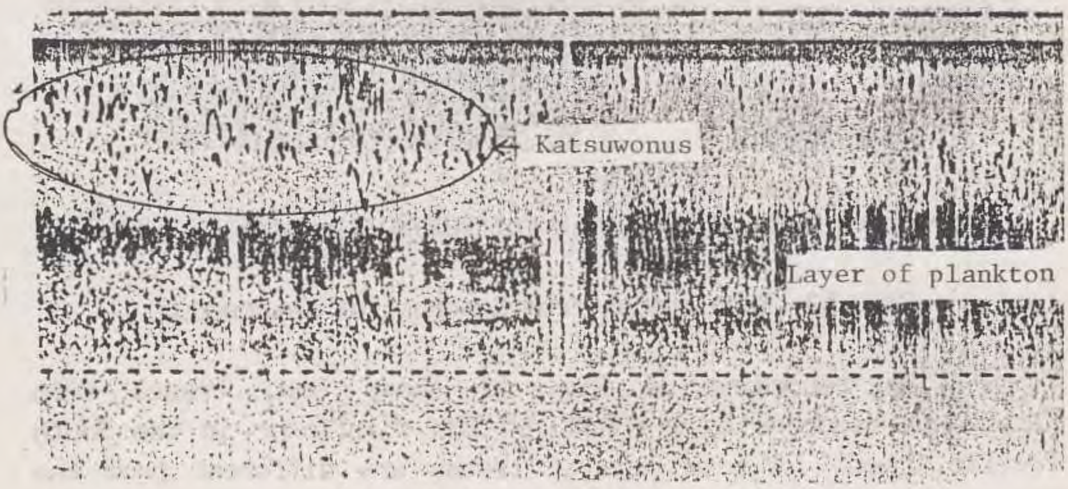

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Fig. 61 Echo traces from a school of Katsuwonus above a layer of plankton

The recording shown in Fig. 61 shows echo traces from Katsuwonus over a layer of plankton, recorded by a 50 kHz fishfinder.

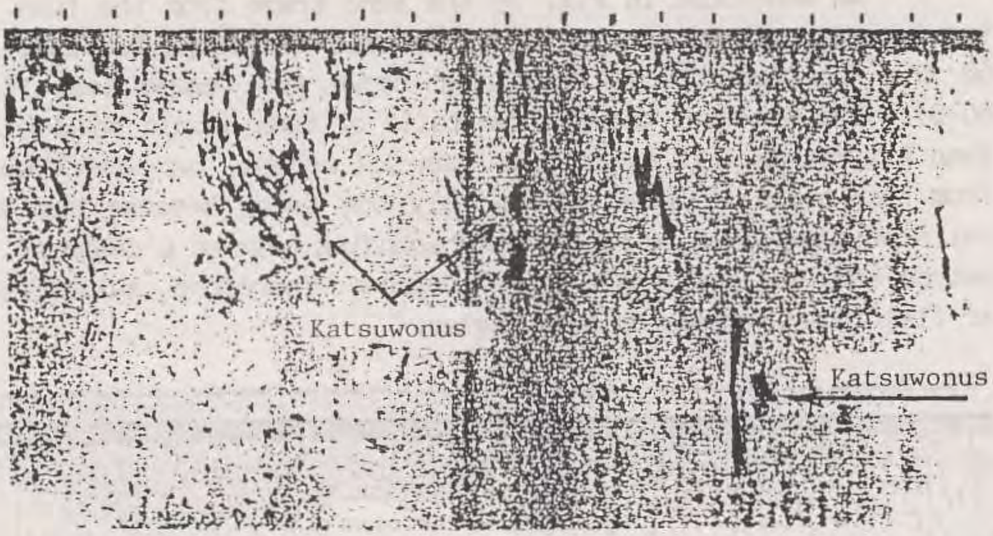

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Fig. 62 Echo traces from a school of Katsuwonus

The recording in Fig. 62 shows echo traces from Katsuwonus recorded by a FURUNO 50 kHz fishfinder in the South Pacific Ocean. The pattern of traces are different from the traces as shown in Fig. 61 and no scattering layer can be seen. It appears that the pattern of the Katsuwonus school links with the pattern of the scattering layer.

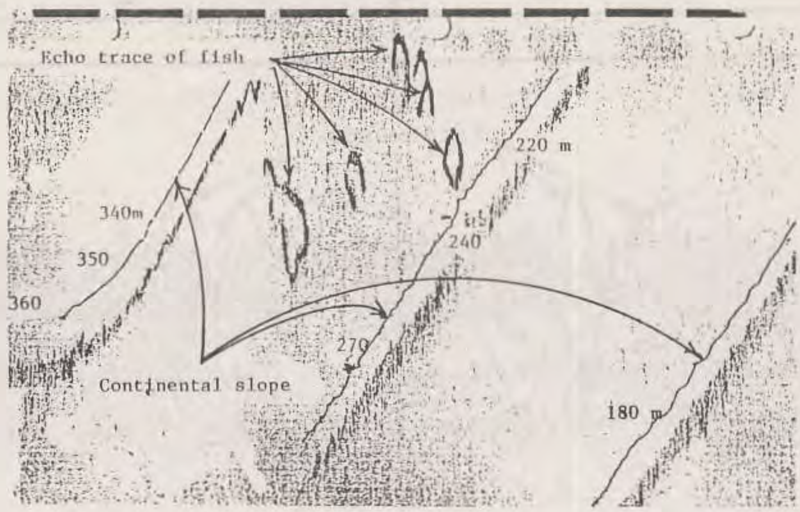

Fig. 63 Echo traces of *Megalaspis Cordyla* above the continental slope

The echogram in Fig. 63 shows echo traces probably from *Megalaspis Cordyla* at a depth of 200 to 260 metres over the continental slope of the Arabian Peninsula, recorded by a FURUNO 50 kHz fishfinder in 1973.

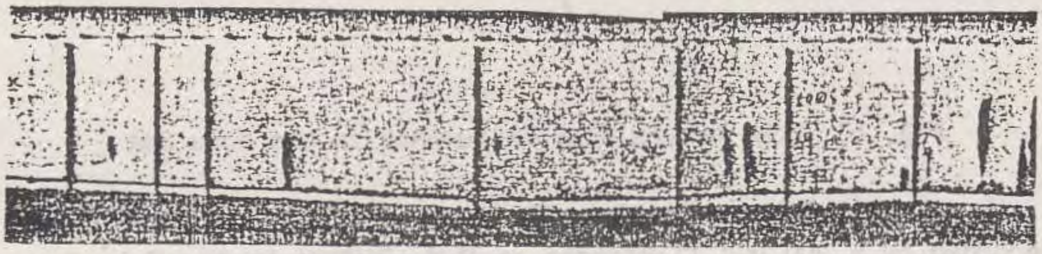

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Fig. 64 Echo traces from herring

The recording in Fig. 64 shows traces of a herring shoal which is forming "flag post" - like shapes, this is one of the features of herring schools.

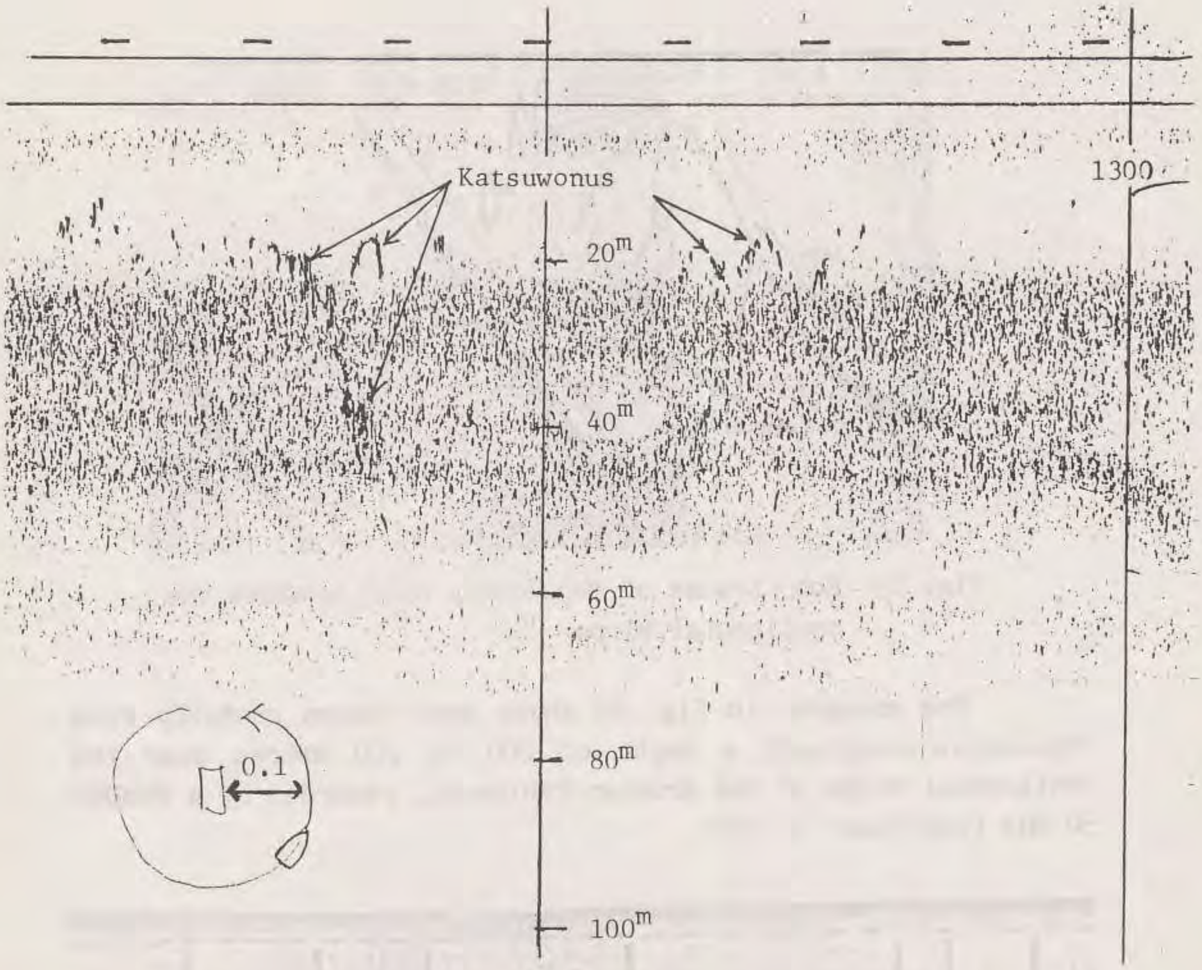


Fig. 65 Echo traces from Katsuwonus in the Sulu Sea

The recording in Fig. 65 shows traces from Katsuwonus recorded by a 200 kHz fishfinder on M.V. PAKNAM in the Sulu Sea on 16 Mar. 1987.

The shoals of Katsuwonus were gathering under a Payaw and some were jumping on the surface but most of them were swimming at a depth of 20 to 50 metres.

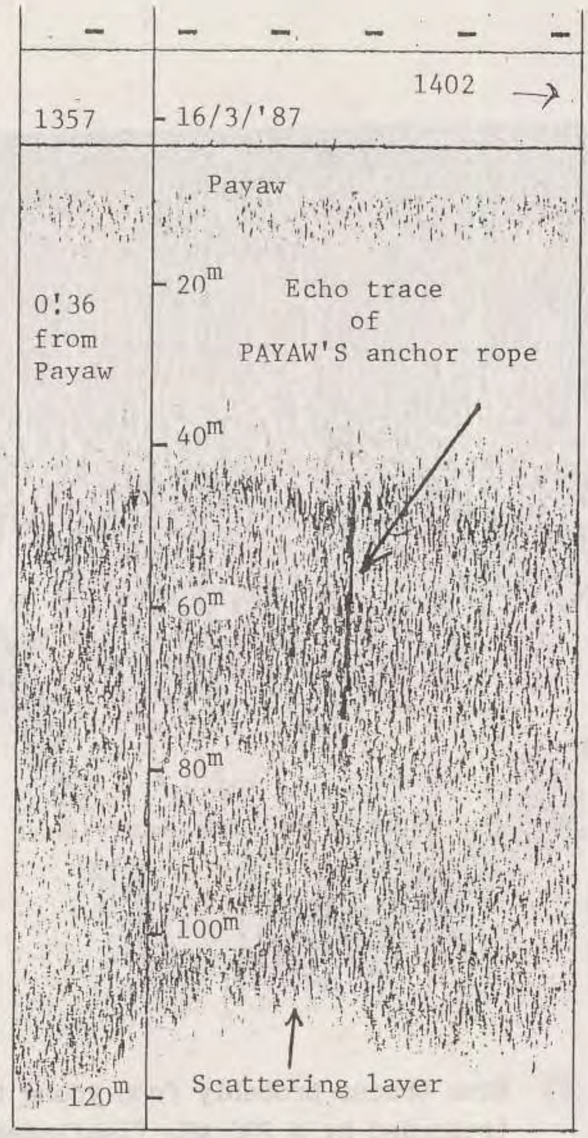


Fig. 66 Echo trace from synthetic fiber rope of Payaw

The echogram in Fig. 66 shows part of the synthetic fiber anchor rope connected to a Payaw in the Sulu Sea on 16 Mar. 1987, recorded by a 200-kHz fishfinder on M.V. PAKNAM. The Diameter of the rope was about 50 millimetres.

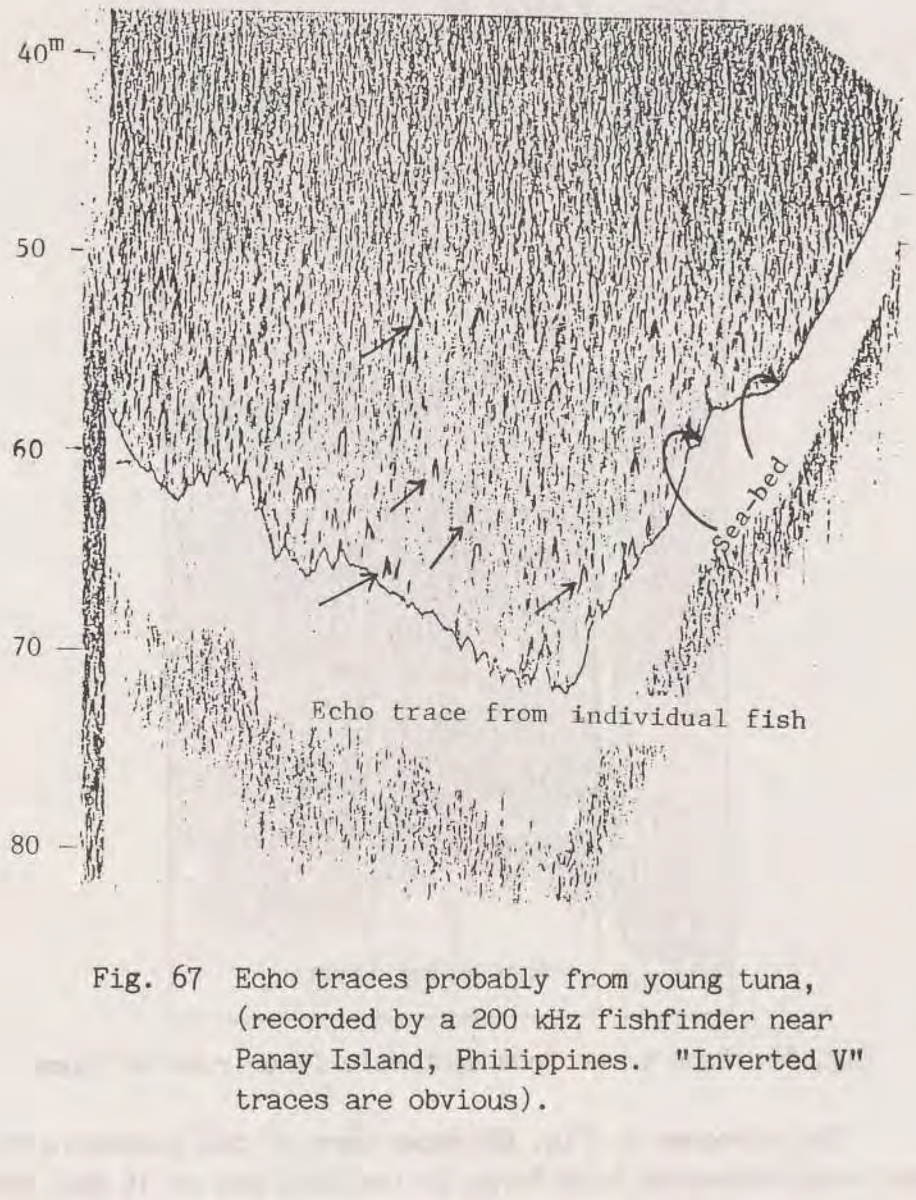


Fig. 67 Echo traces probably from young tuna, (recorded by a 200 kHz fishfinder near Panay Island, Philippines. "Inverted V" traces are obvious).

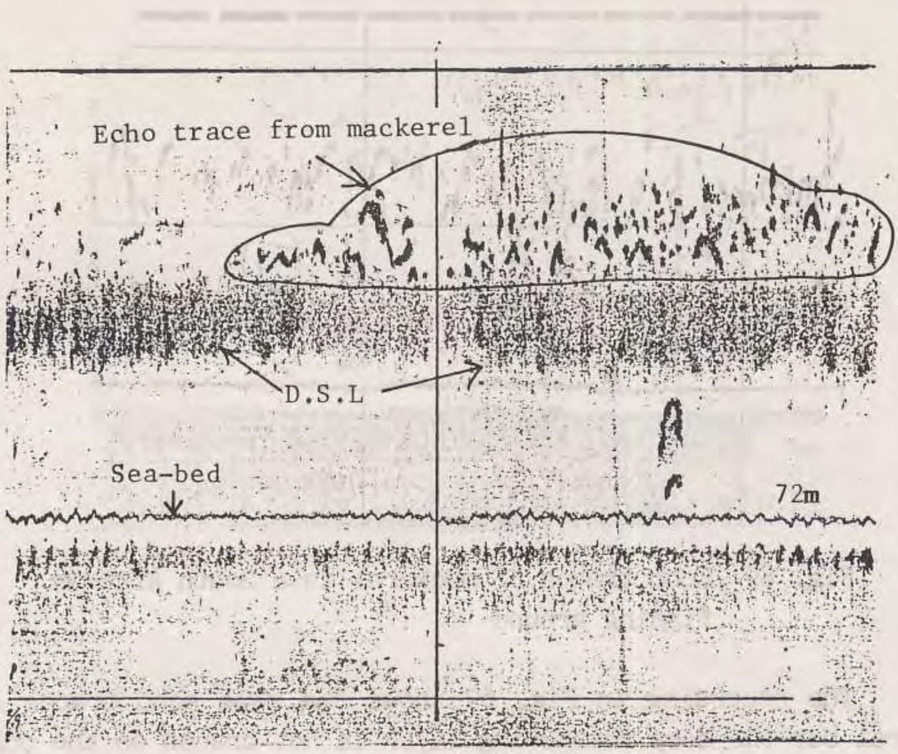


Fig. 68 Echo traces from mackerel above the deep scattering layer, (recorded by a FURUNO 50 kHz fishfinder off South Africa)

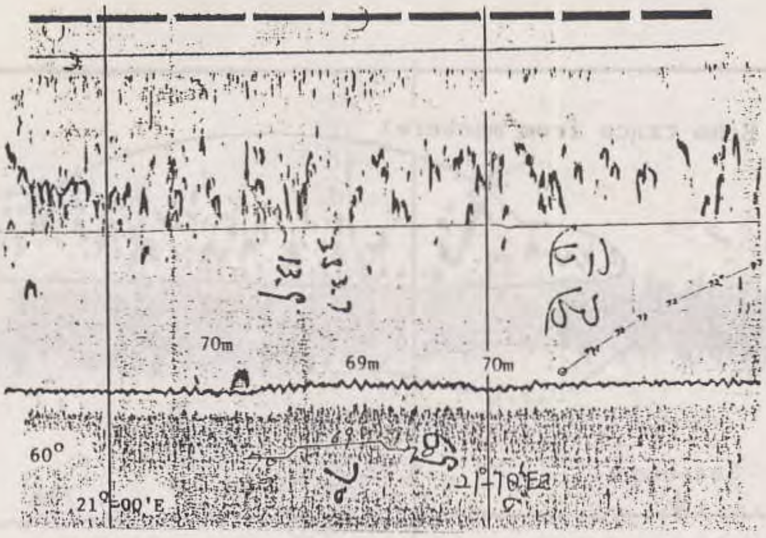
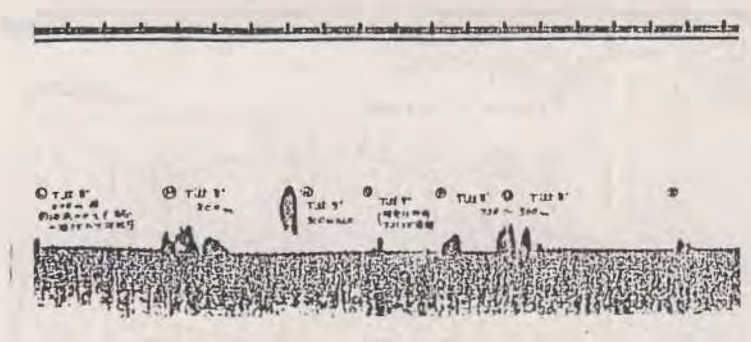


Fig. 69 Echo traces of mackerel in a South African fishing ground

The recording in Fig. 69 shows the same echo traces for mackerel but the deep scattering layer is not traced on the chart and the mackerel swimming depth remains similar to that shown in Fig. 68, recorded by a FURUNO 50 kHz fishfinder in a South African fishing ground in 1973.

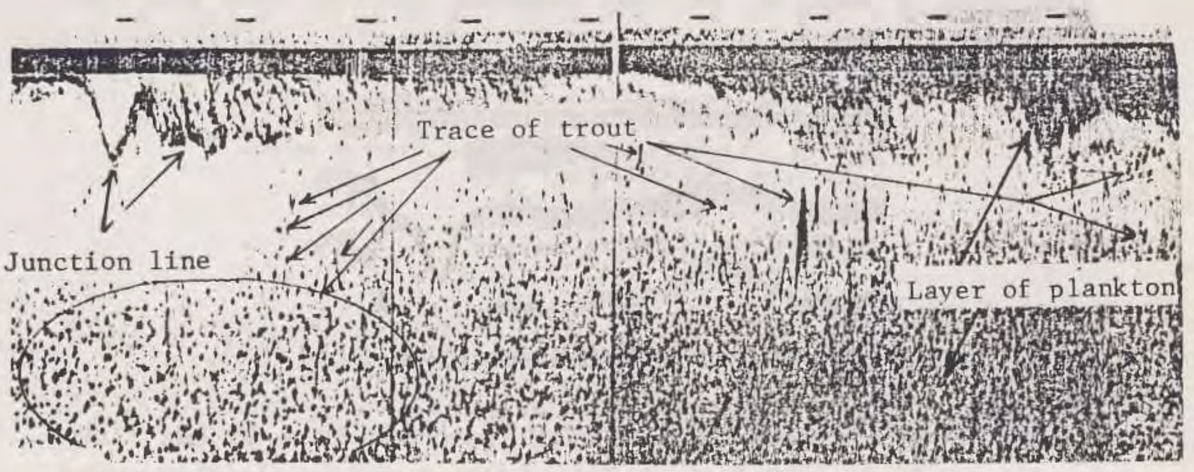
If mid-water trawl fishing were to be carried out, the gear should be dragged at the depth of the fish swimming layer shown by the fishfinder, therefore, interpretation of echo traces given by a fishfinder and net-monitor system are important.



Courtesy of FURUNO Electric Co., Ltd.

Fig. 70 Echo traces from *Pneumatophorus japonicus*

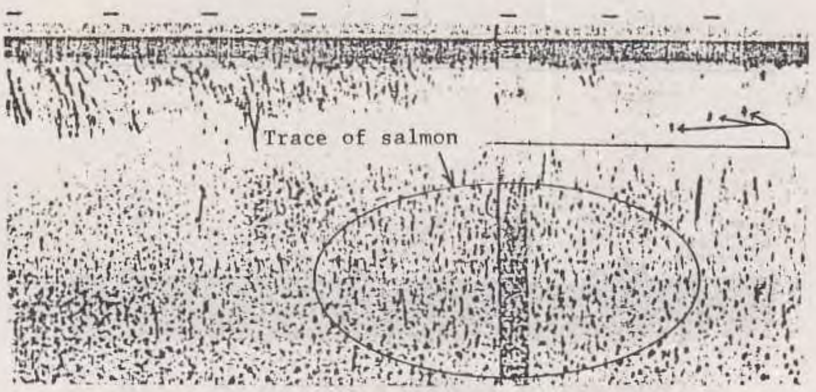
The echogram in Fig. 70 was recorded by a FURUNO 15 kHz sonar (tilt angle = 8^{o}) off Northeastern Japan.



By courtesy of FURUNO Electric Co., Ltd.

Fig. 71 Echo traces from trout, layer of plankton, the junction line between two currents

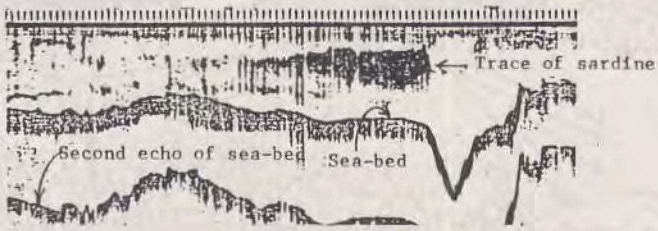
The echogram in Fig. 71 was recorded by a 50 kHz fish-finder. The recording shows how thermal discontinuities can construct a good fishing ground for trout.



By courtesy of FURUNO Electric Co., Ltd.

Fig. 72 Echo traces from salmon - recorded by 50 kHz fishfinder

From Figs. 71 and 72 it would seem evident that the "Social distance"* of trout and salmon in a school is greater than that of sardine, herring, demersal species, etc. and less than that of tuna.



Courtesy of FURUNO Electric Co., Ltd.

Fig. 73 Echo traces from sardine, recorded by a 40 kHz fishfinder off Central Japan, the shoal is closely packed together like a "cloud" in the sky.

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* The term "Social distance" originated in Sociology:

The extent to which individuals or groups are removed from or excluded from participating in each others life ... subtracted from "The New Hamlyn Encyclopedic World Dictionary". The Hamlyn Publishing Group Limited, 1988 London.

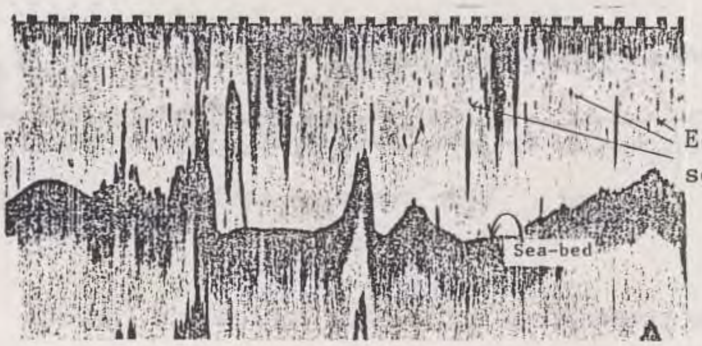

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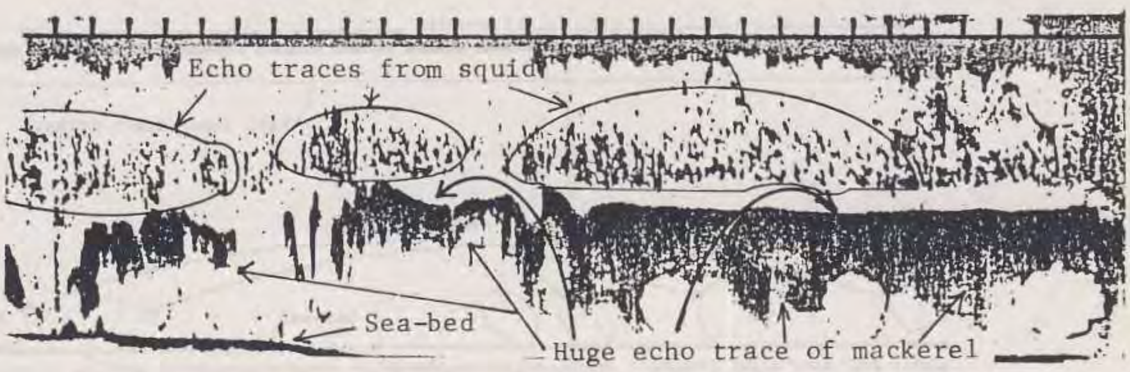
Fig. 74 Echo traces from squid near Northern Japan, recorded by a FURUNO 200 kHz fishfinder. In this echogram it would seem obvious that the squid shoals are not concentrated, but in Fig. 75 very huge shoals of squid and its predators; mackerel are concentrated.



Reproduced by kind permission of FURUNO Electric Co., Ltd.

Fig. 75 Echo traces from shoals of squid with those from predators; shoals of mackerel. (recorded by a 50 kHz fishfinder in 1969 off Northeastern Japan).

The echogram in Fig. 75 shows the predators : mackerel, blocking the shoals of squid; the baitfish.

5. Echo traces of demersal species

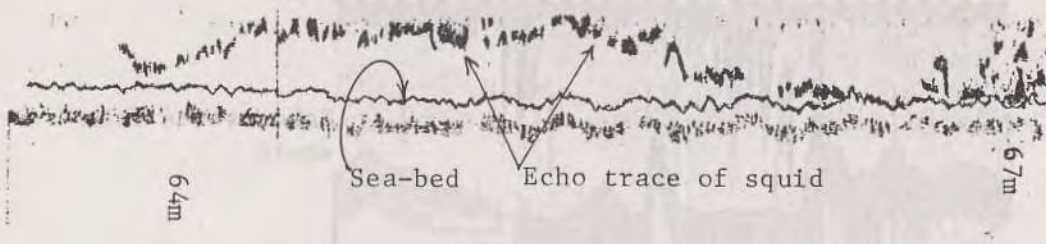


Fig. 76 Echo traces from squid at a tablemount (guyot) in the Indian Ocean.

The recording in Fig. 76 shows very dense and extensive echo traces from a shoal of squid ranging the sea-bed towards mid-water at a tablemount fishing ground, recorded by a 200-kHz fishfinder in 1981.

Ref: Water temperature at surface by fishfinder; 27.4°C and at sea-bed by net-monitor; 15.5°C, current northerly.

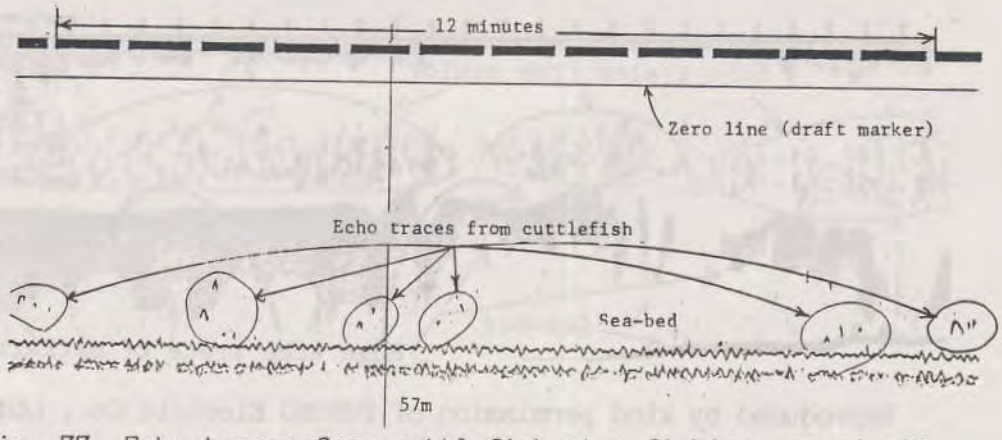


Fig. 77 Echo traces from cuttlefish at a fishing ground off the Arabian Peninsula.

The recording in Fig. 77 shows echo traces from cuttlefish forming a "hyperbolic" and/or "inverted V" formation near the sea-bed. These shoals were very concentrated as proved by the 12-ton catch of cuttlefish after dragging 120 minutes recorded by a 200 kHz fishfinder in 1977.

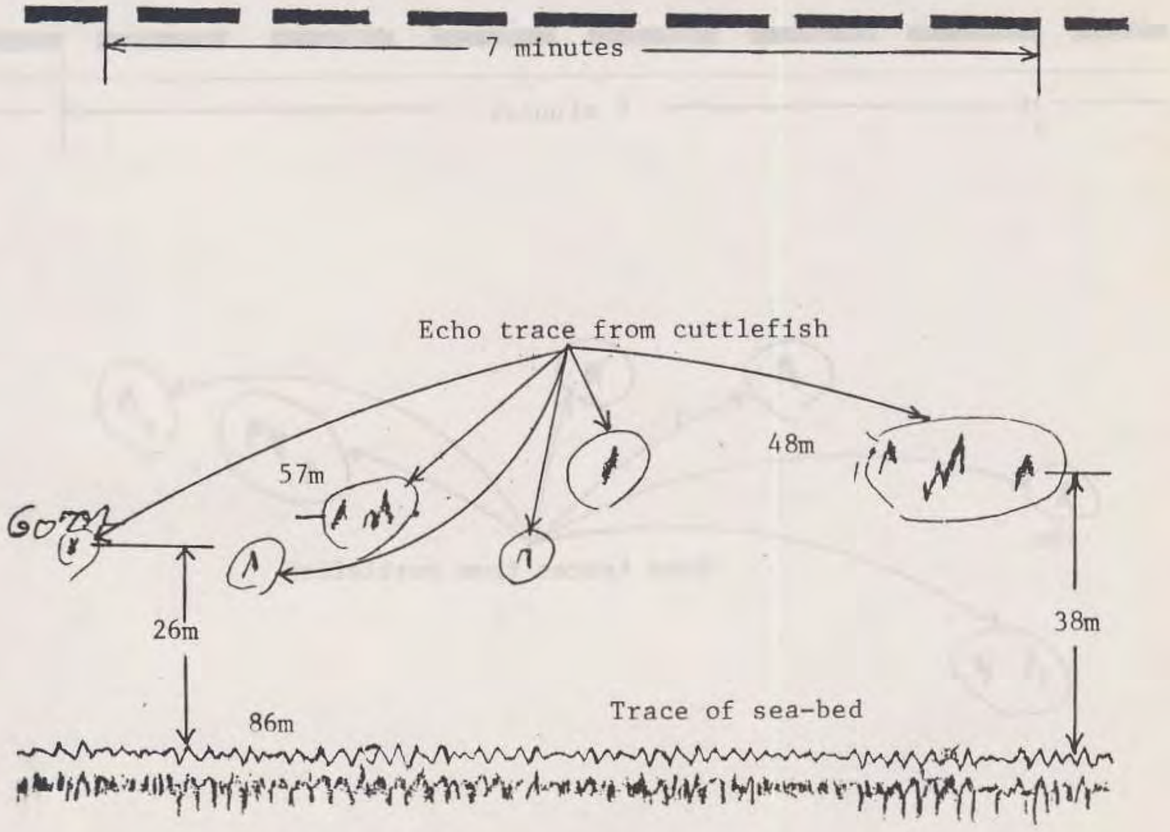


Fig. 78 Echo traces from cuttlefish in mid-water at an Arabian Peninsula fishing ground.

The echogram in Fig. 78 shows traces of cuttlefish shoals migrating vertically from sea-bed to mid-water after sunset. The formation of each trace indicates an "inverted V". The location of the cuttlefish is 26 to 38 metres from the sea-bed and then will migrate to the sea-bed from mid-water after sunrise - recorded by a 200 kKz fishfinder in 1980.

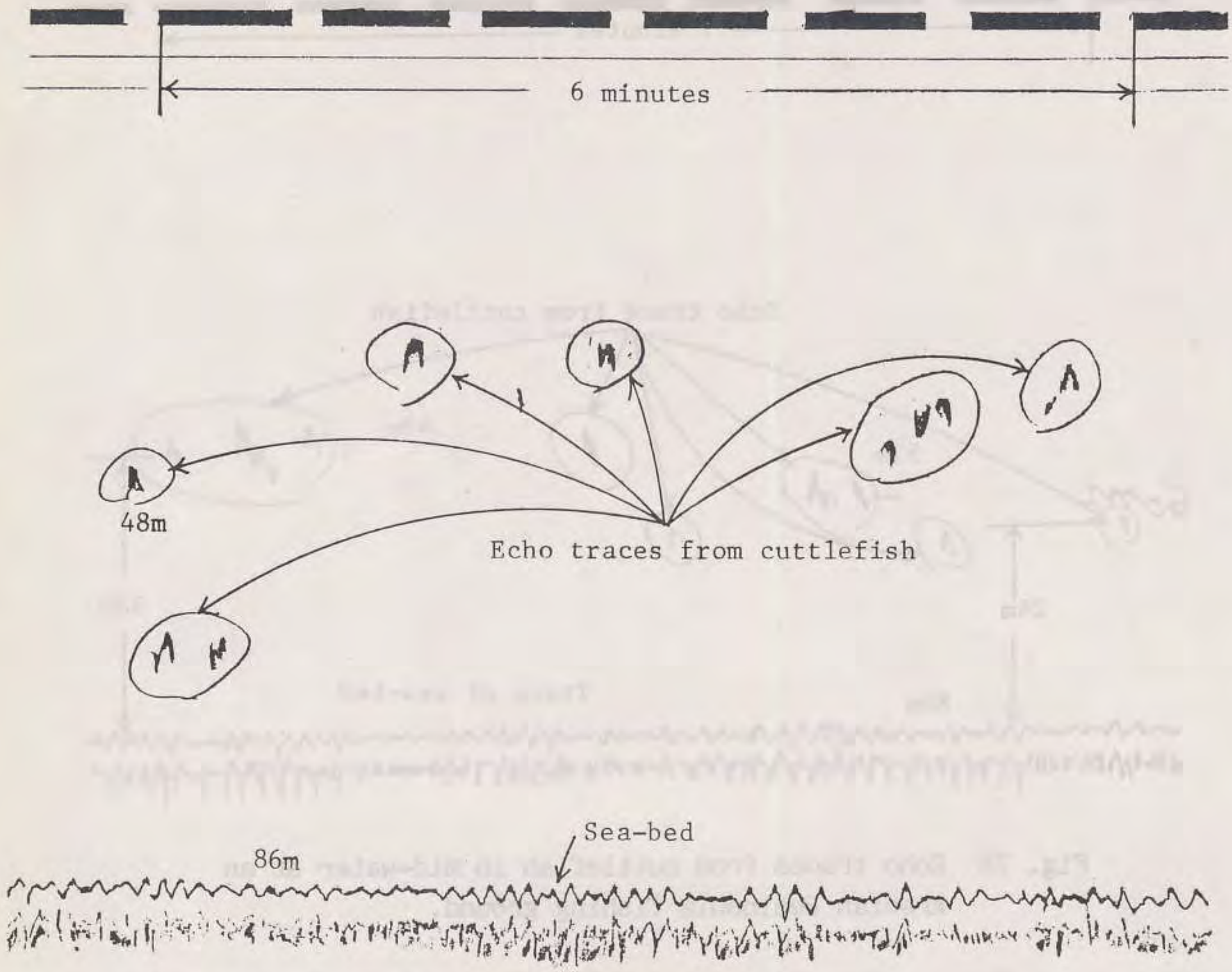


Fig. 79 Echo traces from cuttlefish in mid-water

In Fig. 79 the fishfinder recording shows traces from cuttlefish shoals in mid-water migrating vertically from the sea-bed after sunset. The traces are forming "hyperbolic", "fingernail" and/or "inverted V" shapes. The shoals are located between 38 and 56 metres from the sea-bed, recorded by a 200 kHz fishfinder in 1980.

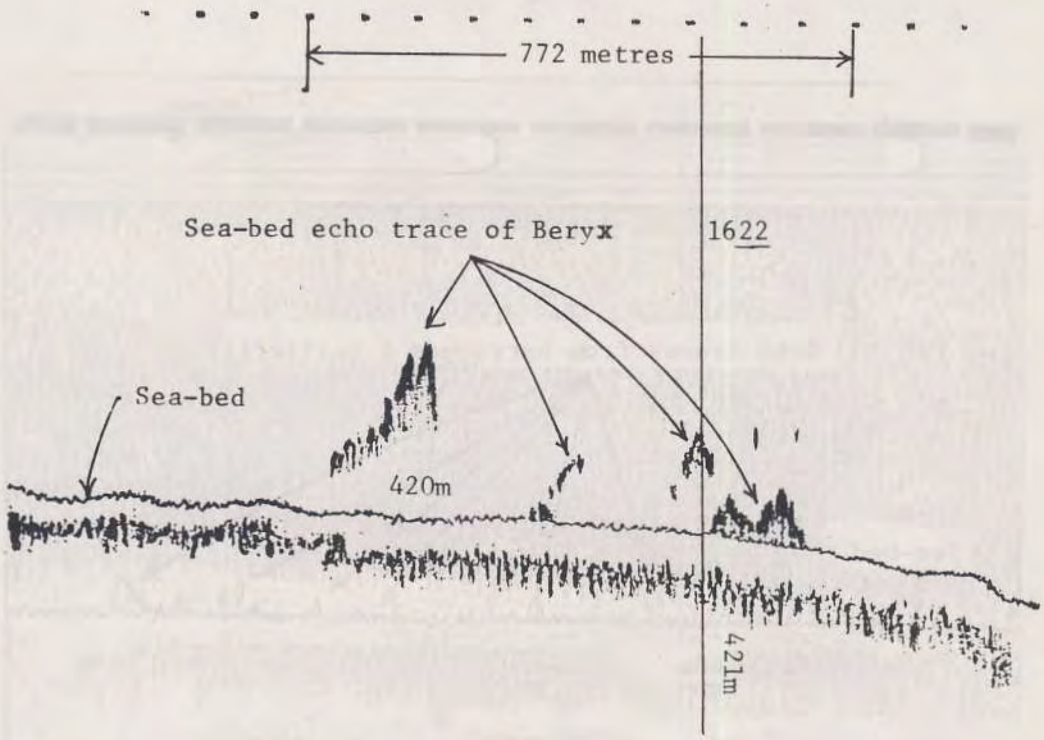


Fig. 80 Echo traces of *Beryx splendense* over a tablemount

The echogram in Fig. 80 shows echo traces from *Beryx splendense* at a depth of 420 to 421 metres on a tablemount in the Indian Ocean recorded by a 50 kHz fishfinder in 1981.

These shoals were very dense because a 44-minute dragging produced a 40-ton catch of *Beryx splendense*.

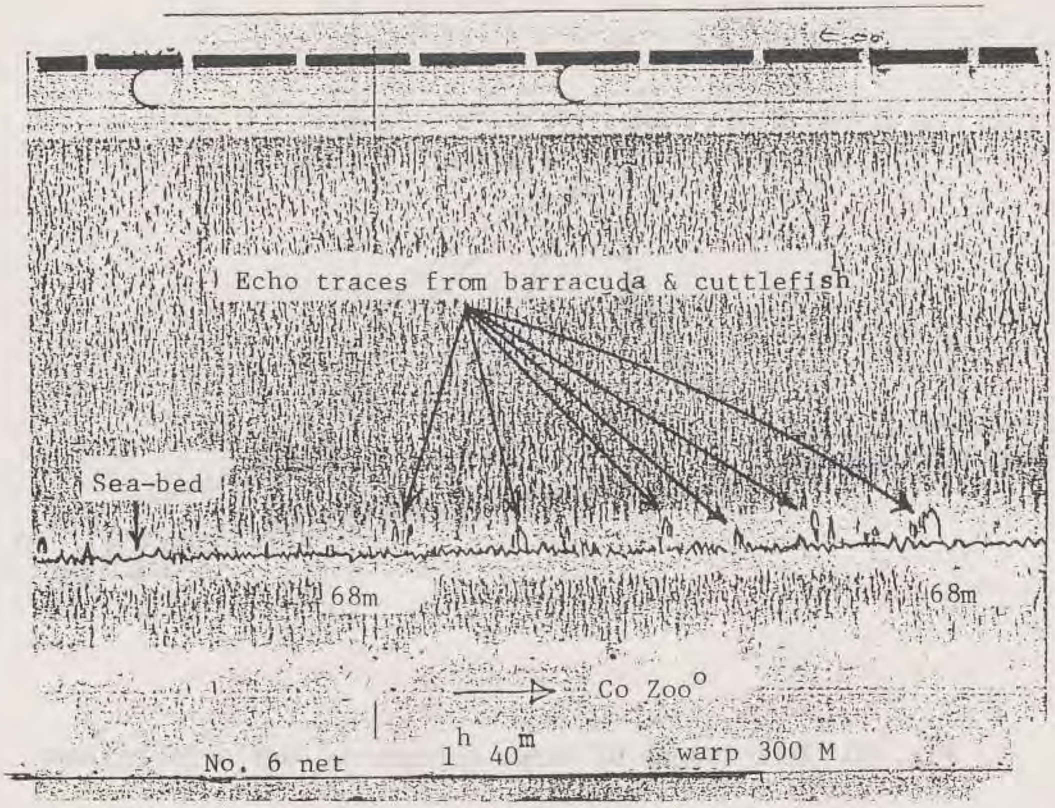


Fig. 81 Echo traces from barracuda and cuttlefish, recorded by a FURUNO 200 kHz fishfinder at a depth of 68 metres in 1973.

Dragging 100 minutes produced a 10.7 tons catch; cuttlefish 3.4 tons, barracuda 6.1 tons and others 1.2 tons.

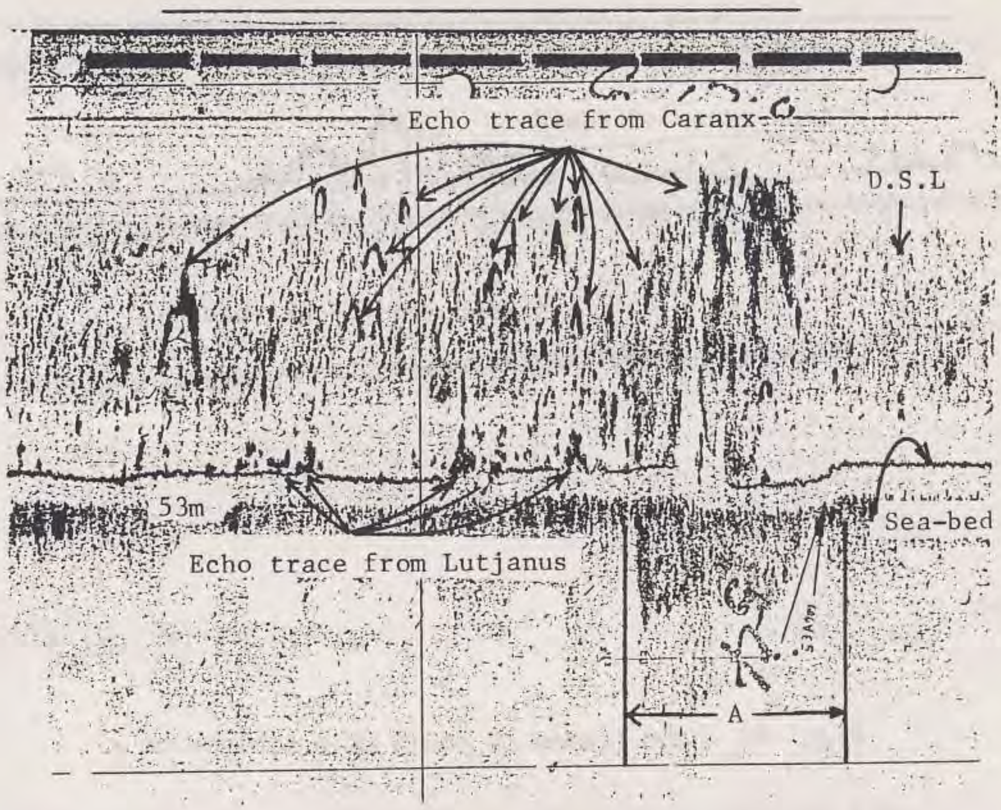


Fig. 82 Echo traces from *Caranx sexfasciatus*, *Lutjanus*, etc. recorded by a FURUNO 200 kHz fishfinder in 1974

Mostly shoals of *Caranx* exist in the deep scattering layer and those of *Lutjanus* on the sea-bed.

Section A shows the composition of the sea-bed as very hard because the long reverberation can be seen just underneath the echo trace of the sea-bed (see Figs. 24 and 25).

Temperature at surface : 26.2°C by fishfinder.

Temperature at sea-bed : 23.0°C by net-monitor.

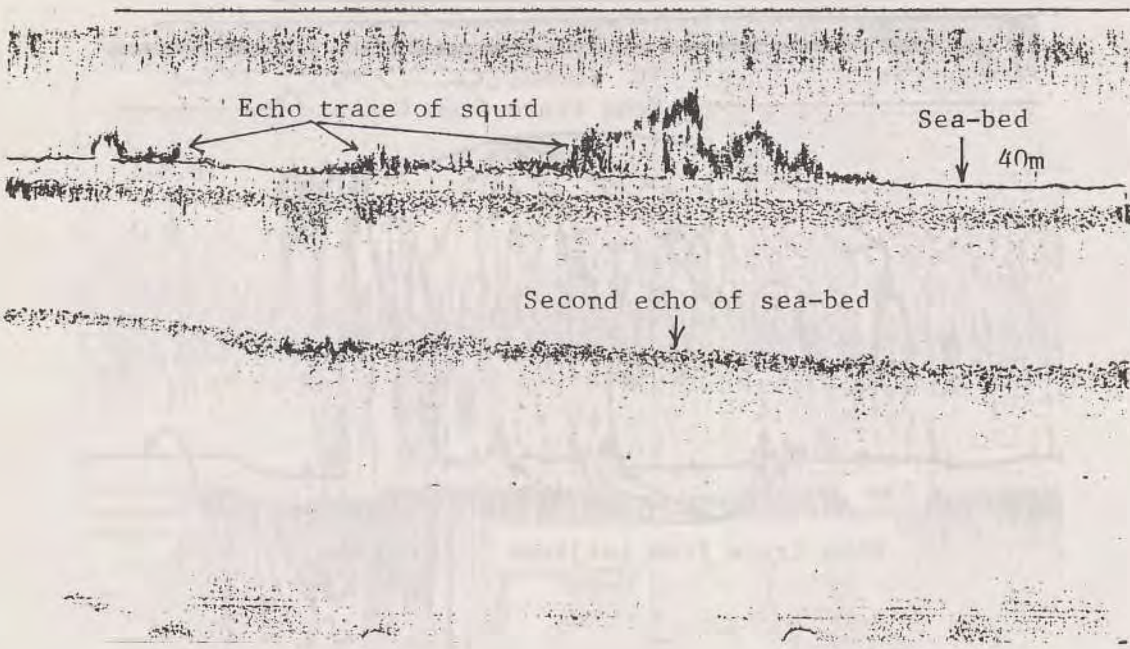


Fig. 83 Echo traces of squid on a tablemount

The fishfinder recording in Fig. 83 shows echo traces of a squid shoal, detected by a 200 kHz fishfinder in 1974.

The echogram was recorded at night-time. Usually squid shoals migrate upward to mid-water after sunset but the squid traces in Fig. 83 are "hard down" on the sea-bed because these is a steeply sloping valley on the sea-bed in the vicinity and it produces an up-welling with rich nutrients. Dragging 120 minutes produced a 5-ton catch of squid.

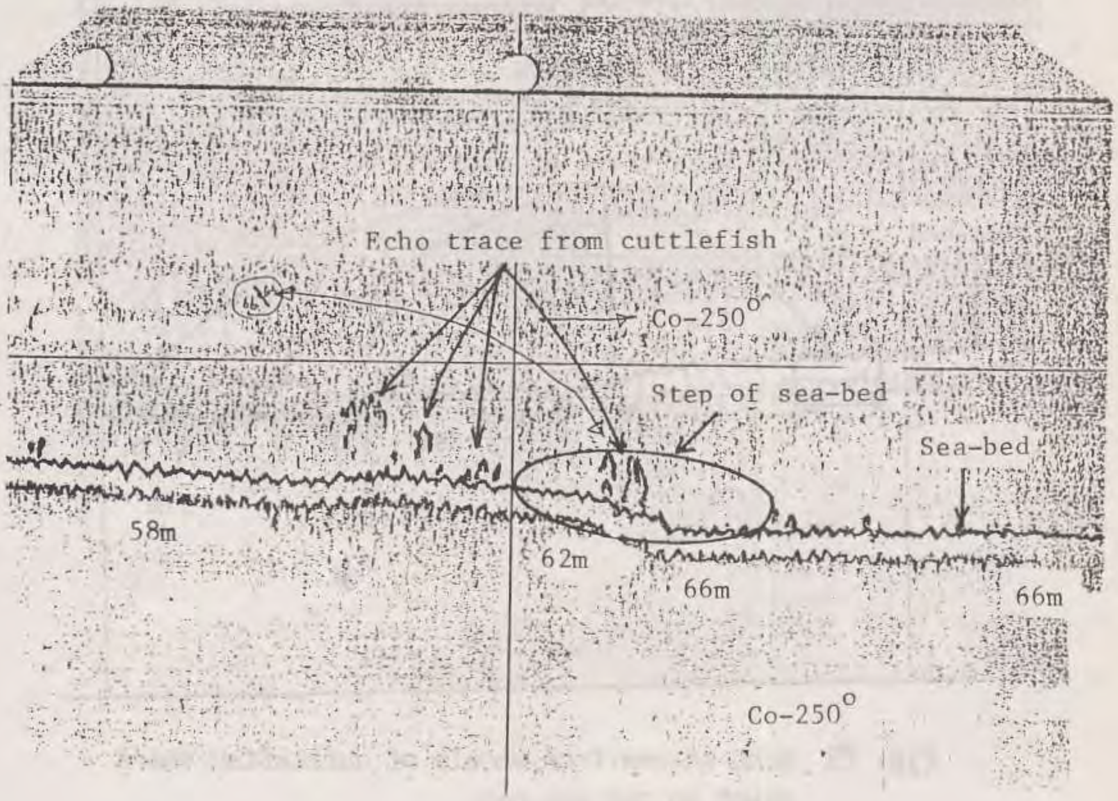


Fig. 84 Echo traces from cuttlefish

The recording in Fig. 84 shows echo traces reflected from cuttlefish shoals recorded by a FURUNO 200 kHz fishfinder in 1973.

The shoals form "hyperbolic" or "fingernail" traces near the sea-bed where there is a step: at a depth of 62 to 66 metres.

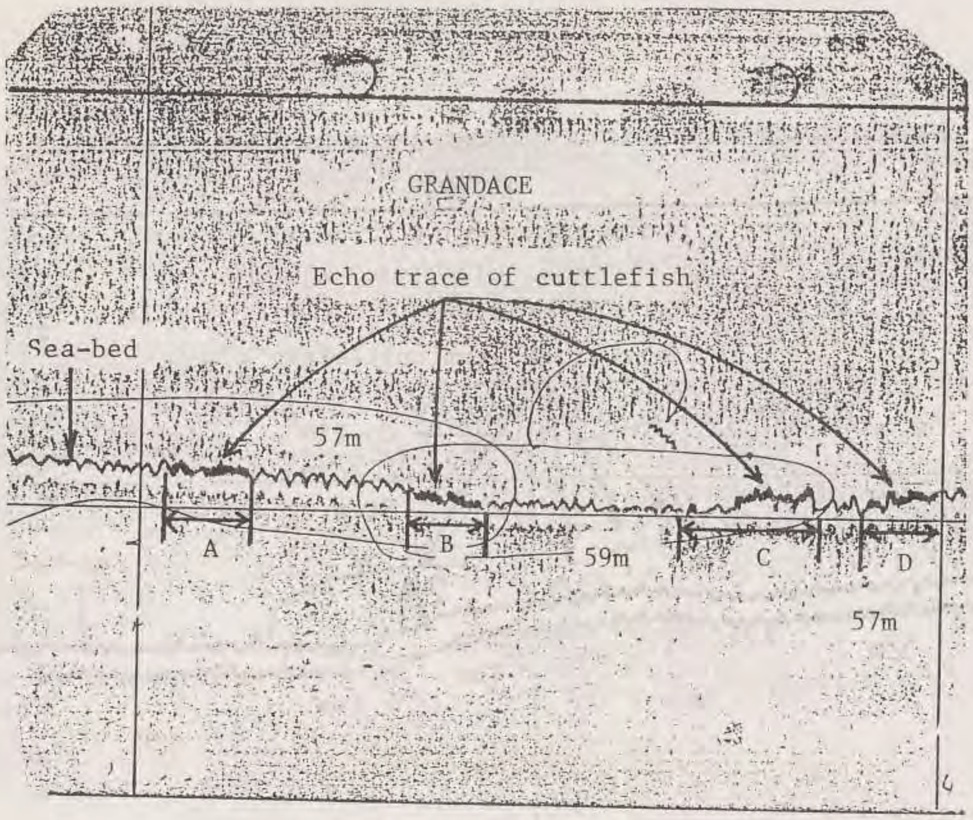


Fig. 85 Echo traces from shoals of cuttlefish "hard down" on the sea-bed.

From the darker traces on the sea-bed in the echogram, we can tell that the traces from section A, B, C and D are from cuttlefish, recorded by a 200 kHz fishfinder.

It requires much effort to detect demersal species of fish "hard down" on the sea-bed by fishfinder because to discriminate between the echo trace of the sea-bed and that of demersal species is very difficult.

An echo trace from a "hard down" fish shoal shows a slightly longer reverberation than that from the sea-bed and this is a very important point and the key to interpreting echograms on the recording chart.

In Fig. 84 shoals of cuttlefish are shown gathering near the sea-bed's steps or, downward or upward slope, as in Fig. 85.

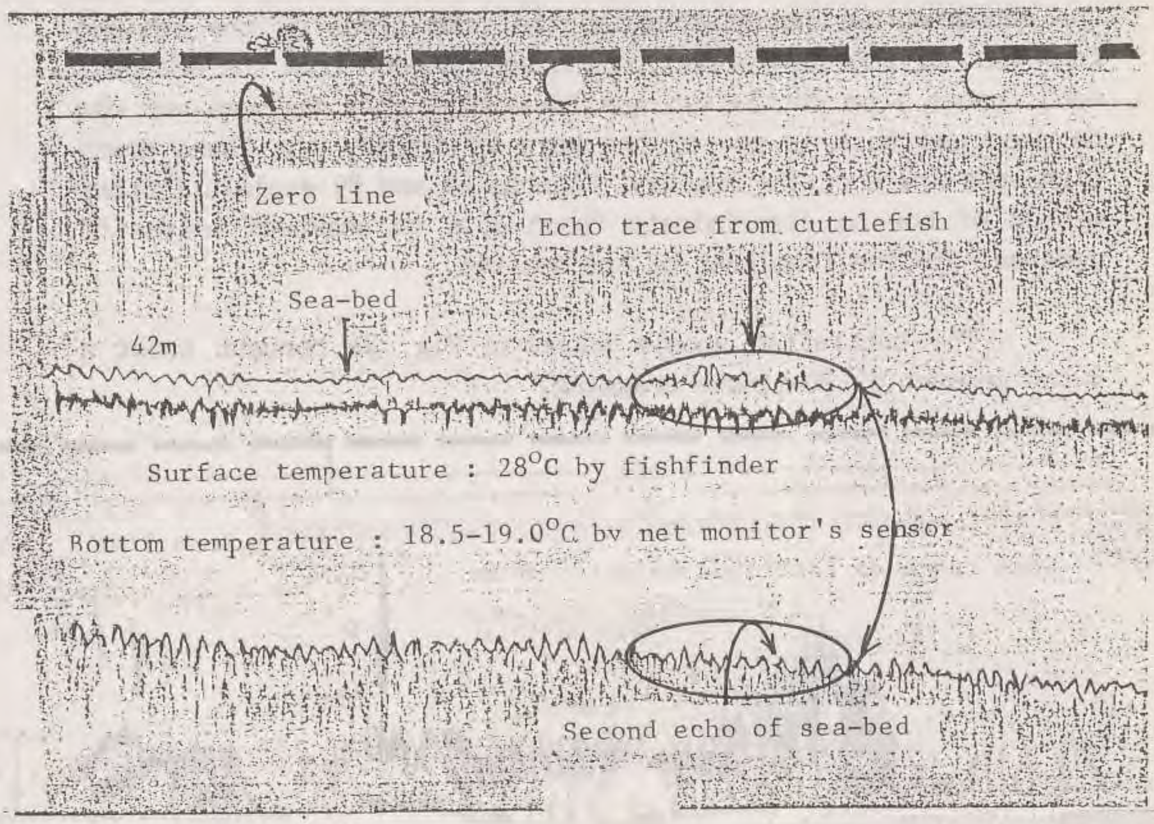


Fig. 86 Echo traces from cuttlefish "hard down" on the sea-bed

The echogram in Fig. 86 shows traces from cuttlefish shoals, also "hard down" on the sea-bed. In this case the longer reverberation of cuttlefish is invisible. The recording in Fig 86 was detected by a 200 kHz fishfinder.

The echograms show that the traces of cuttlefish shoals which are very "hard down" on the sea-bed seem to be part of the bed, at a glance it is hard to distinguish the sea-bed traces from the cuttlefish. However, if we very carefully interprete the echogram, we can distinguish the echo trace of the sea-bed from that of the cuttlefish; on the second echo from the sea-bed, echo traces from cuttlefish are invisible, only the sea-bed can be seen and this is one of the keys to clarify the "hard down" fish echo trace on the sea-bed. Figures 88 and 89 explain another method of how to discriminate "hard down on sea-bed" traces of demersal species from that of the sea-bed.

The cuttlefish shoals shown in Fig. 86 brought about a 4-ton product by 20-minute dragging.

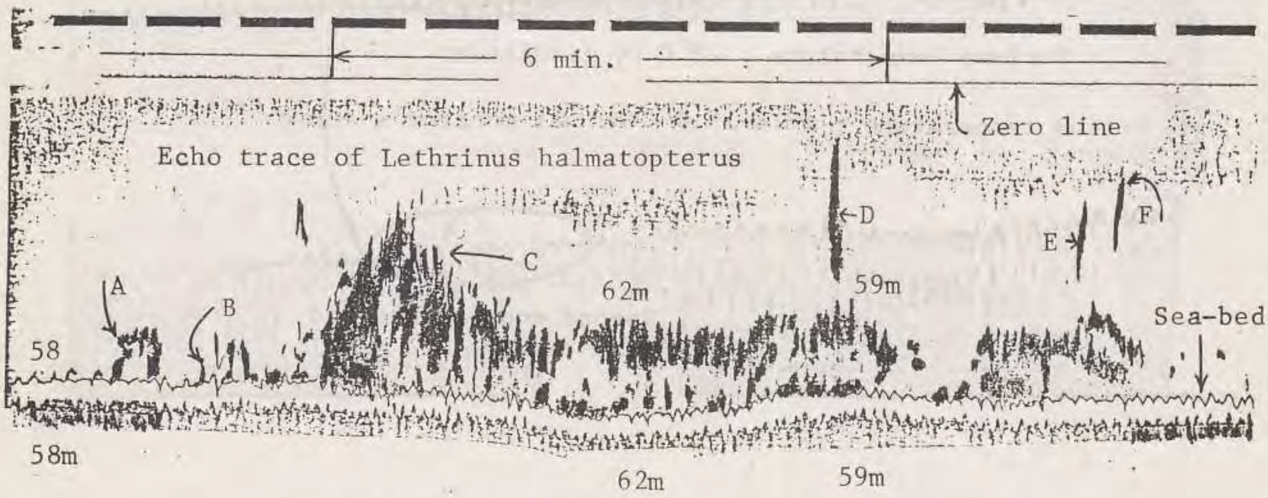


Fig. 87 Echo traces from *Lethrimus haematopterus*

The echogram shown in Fig. 87 shows traces from huge dense shoals of *Lethrinus haematopterus*, recorded by a 50 kHz fishfinder over a tablemount in 1981. Dragging 45 minutes produced a 20-ton catch of *Lethrinus:*

Mark C shows a "veil" echo trace, marks D, E and F show "plume" echo traces in mid-water. Marks A and B also show echo traces of the same species of fish. Mark C shows a "mountainous" echo trace.

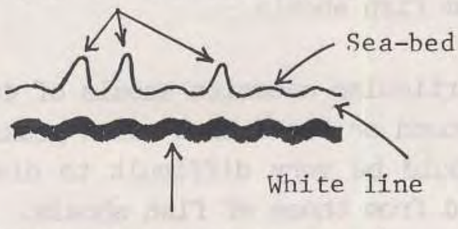


Fig. 88 Diagram : Reverberation of sea-bed (1)

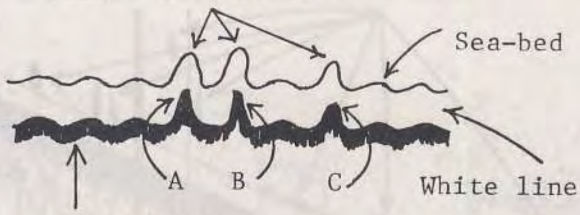


Fig. 89 Diagram : Reverberation of sea-bed (2)

The diagram in Fig. 88 shows an echo trace from the sea-bed, its reverberation, and demersal species which are "hard-down" on sea-bed. The diagram shown in Fig. 89 shows echo traces from the sea-bed and its reverberation.

In Fig. 88 echo traces from demersal species which are very "hard down" on the sea-bed are shown. Three arrows indicate the echoes from demersal species, they are rising upward from the sea-bed like three peaks but the reverberation of the sea-bed underneath the three peaks is not rising.

In Fig. 89 the reverberation of the sea-bed becomes higher and elevated below the three peaks of the sea-bed. This means these three peaks are part of the sea-bed's traces, not echo traces from fish shoals.

On a particular occasion shoals of demersal species could be gathering around or "hard down" such peaks on the sea-bed. In this case it would be very difficult to distinguish echo traces from the sea-bed from those of fish shoals.

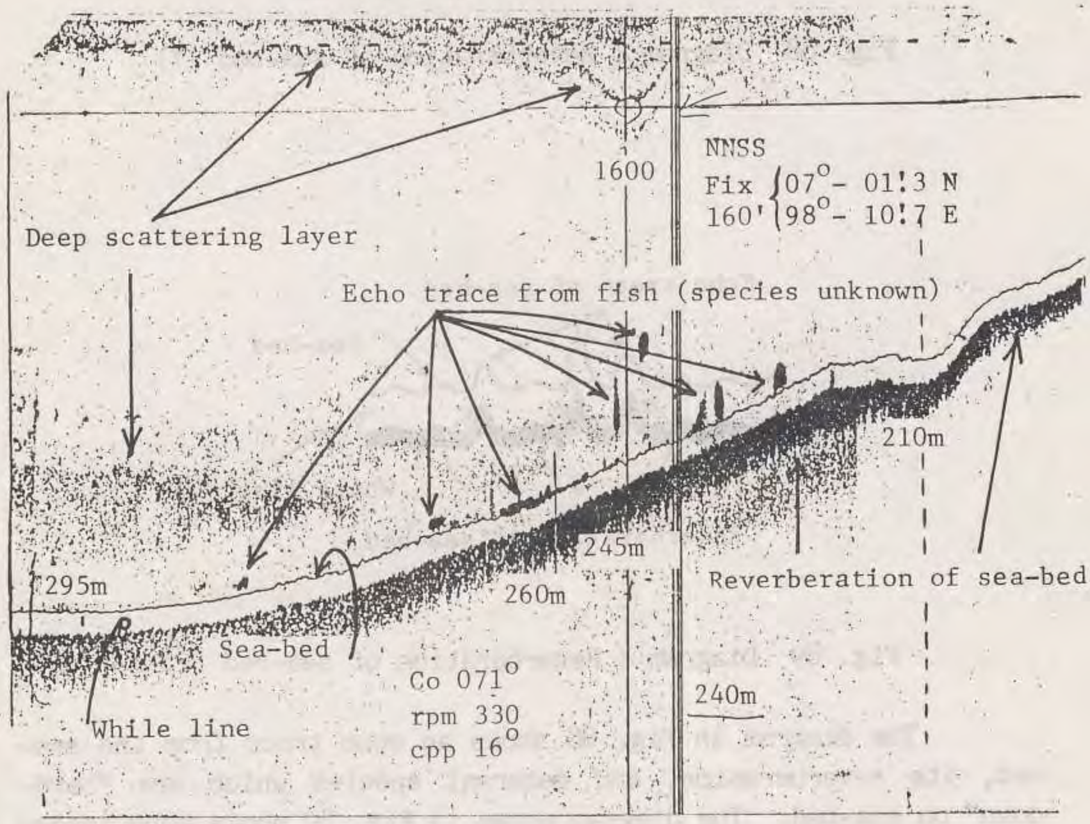


Fig. 90 Echo traces of demersal species over the continental slope

The echogram shown in Fig. 90 indicates traces from demersal fish species on or above the continental slope recorded by a 200 kHz fishfinder on M.V. PAKNAM in the Andaman Sea on 29 Aug. 1987.

The echogram shows that a continental slope may prove a good fishing ground for both demersal and pelagic species. The deep scattering layers can be seen and thermal discontinuities and an upwelling current probably existing there. The fishing ground shown in Fig. 90 might be appropriate for various types of fishing gear : gill net, bottom longline, trap cage net, trawl, etc..

Ref.: In the recording in Fig. 90; 1600 means 1600 hours (4 p.m.); "NNSS Fix 07°01.3 N, 98°10.7 E, 240 m and 1601" means that fixed position by Navy Navigation Satellite System latitude 07°01.3 north, longitude 98°10.7 east, depth of water 240 metres at local mean time 1601 hours.

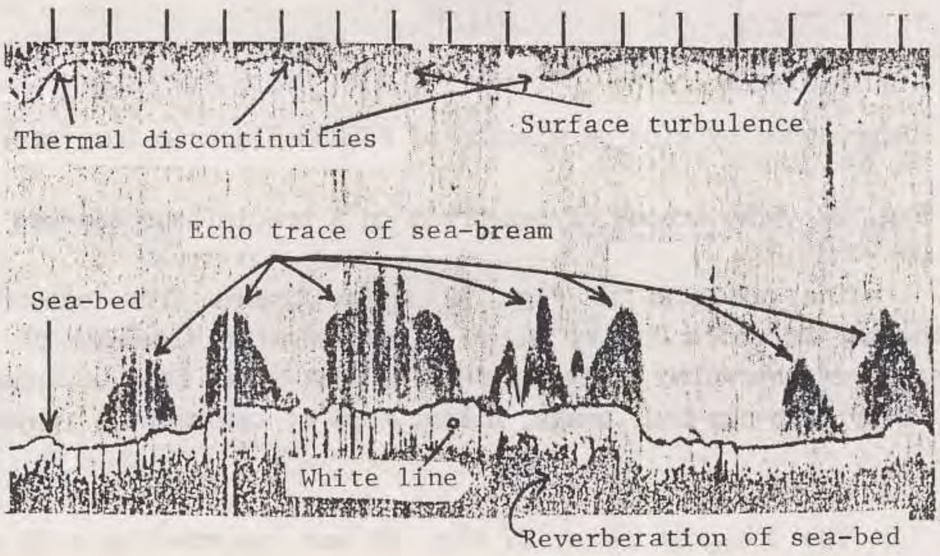


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Fig. 91 Echo traces of sea-bream and thermal discontinuities

The echogram in Fig. 91 shows traces of sea-bream, forming "mountainous" shapes. "White line" control is functioning well to divide echo traces and the sea-bed trace, recorded by a FURUNO a 50 kHz fishfinder.

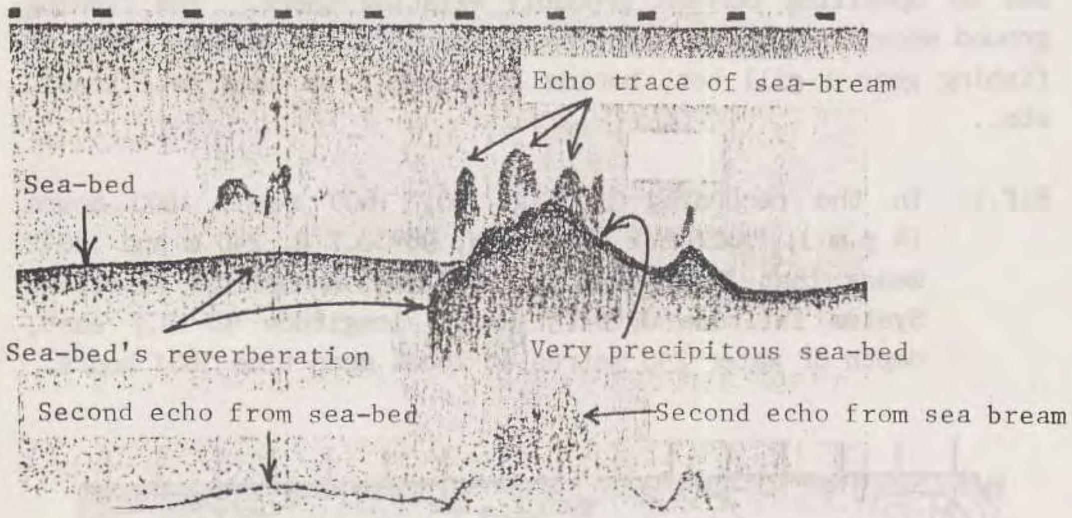

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Fig. 92 Echo traces of sea-bream on a precipitous sea-bed

The echogram in Fig. 92 shows traces from sea-bream gathering around a "rocky hill" on the sea-bed (because of the longer reverberation of the sea-bed). Sea-bream tend to inhabit a precipitous sea-bed; peaks, hills, tops of tablemounts (guyot), etc..

The echogram shown in Fig. 92 was recorded by a 50 kHz fishfinder.

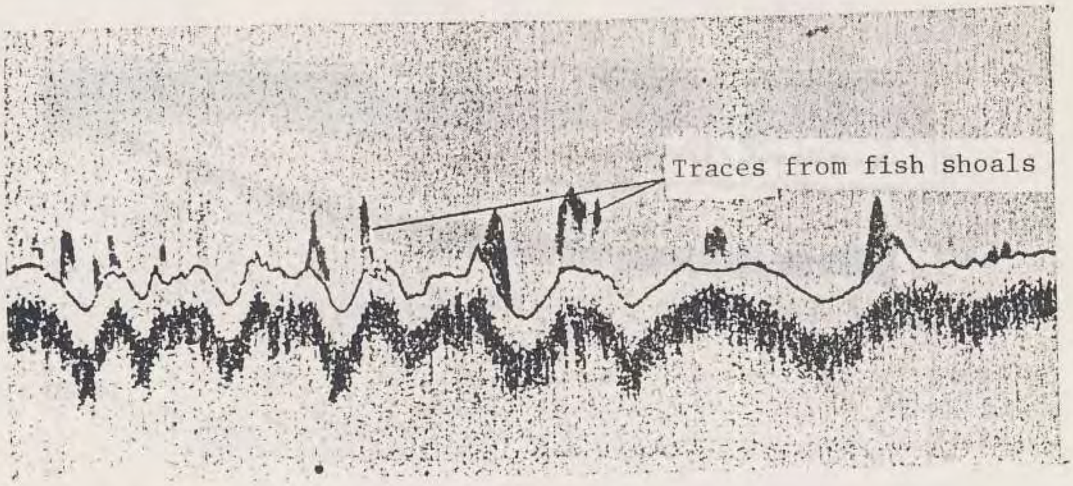

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Fig. 93 Echo traces from *Parapristipoma trilineatum*

The echogram shown in Fig. 93 indicates traces from *Parapristipoma trilineatum* (probably) on the sea-bed, recorded by a 50 kHz fishfinder.

The formation of traces is not "mountainous", they look like "inverted V". These species also tend to inhabit a precipitous sea-bed, the "White line" function of the fishfinder works well: echo traces from shoals of fish are clearly divided from the line that represents the sea-bed.

6. Acoustic noise

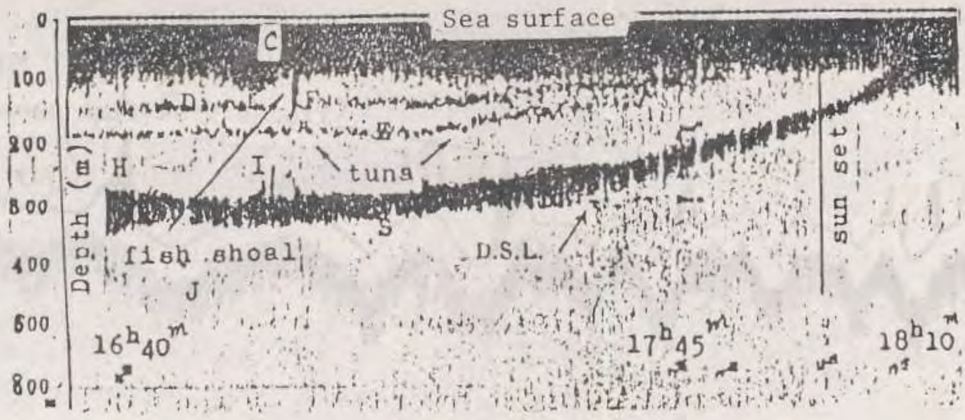

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Fig. 94 Echo traces of surface noise, tuna and deep scattering layer

Surface noise appears beneath the "Zero line" on the recording chart, therefore, if the sounding depth range is from 10 metres, or 20 metres, or 100 metres and so on, the surface noise cannot be recorded on the chart.

The surface noise is caused by air bubbles, heavy surf, rain hitting the sea's surface, plankton, aeration near the transducer, in a word it is caused by surface turbulence, and it often appears on fishfinder recordings. The surface noise leads to a loss in energy of the returning echo from the sea-bed or submerged objects.

The echogram in Fig. 94 shows surface noise (marked by C) and deep scattering layer (marked D.S.L.) at a depth of 300 metres during daytime and 100 metres during night-time. Between the surface noise and the deep scattering layer echo traces of tuna can be seen.

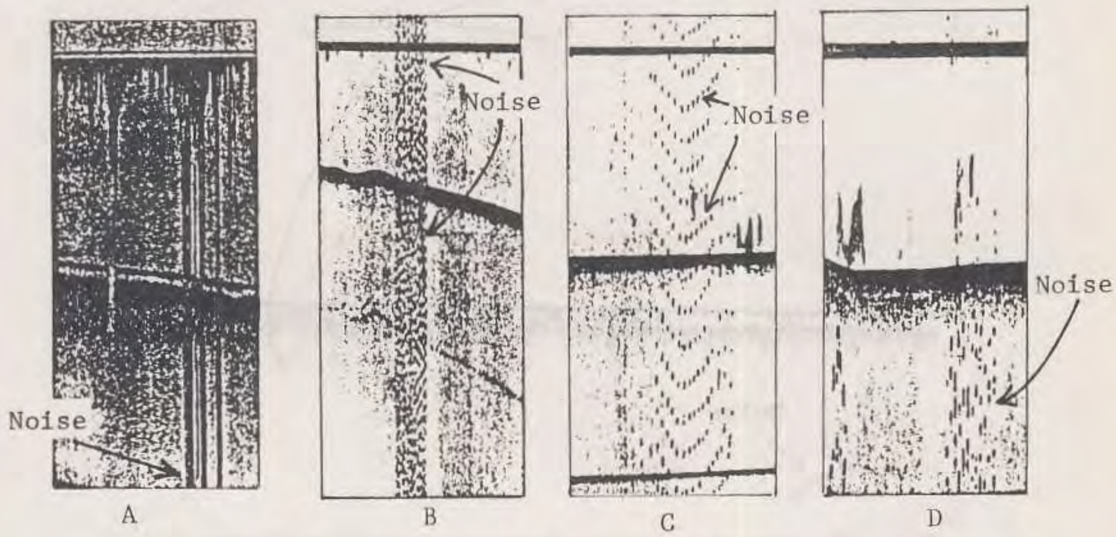

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Fig. 95 Echo traces of acoustic noise

The recording in Fig. 95 shows traces of acoustic noise.

Fig. 95 A shows a noise trace of aeration caused by a turning propeller, Fig. 95 B shows effect of electric induction, Fig. 95 C shows the echo of a different fishfinder (fishing boat is operating two fishfinders at the same time) and Fig. 95 D shows another fishing boat's sounding wave.

When the fishfinder records unfamiliar traces, careful attention should be given to the fishfinder itself;- working normally? or not, and look out of your boat sharply because other fishing boats may be nearing very closely to your boat.

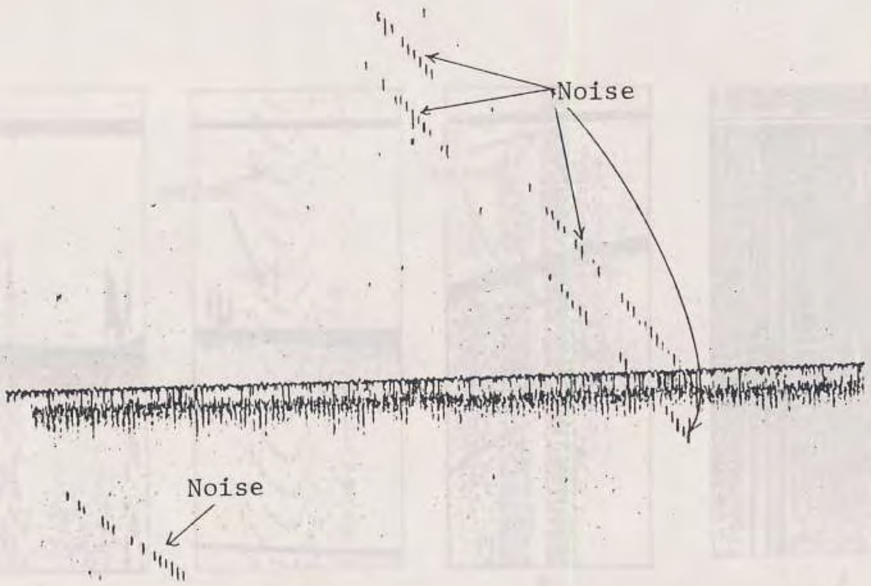


Fig. 96 Acoustic noise from another fishfinder (1)

The oblique and dotted lines in Fig. 96 show acoustic noise caused by transmitted supersonic sound wave from another fishfinder. Two fishfinders on M.V. PAKNAM were simultaneously under operation : one of them received another's supersonic sounding wave with a different frequency, recorded by a 200 kHz fishfinder.

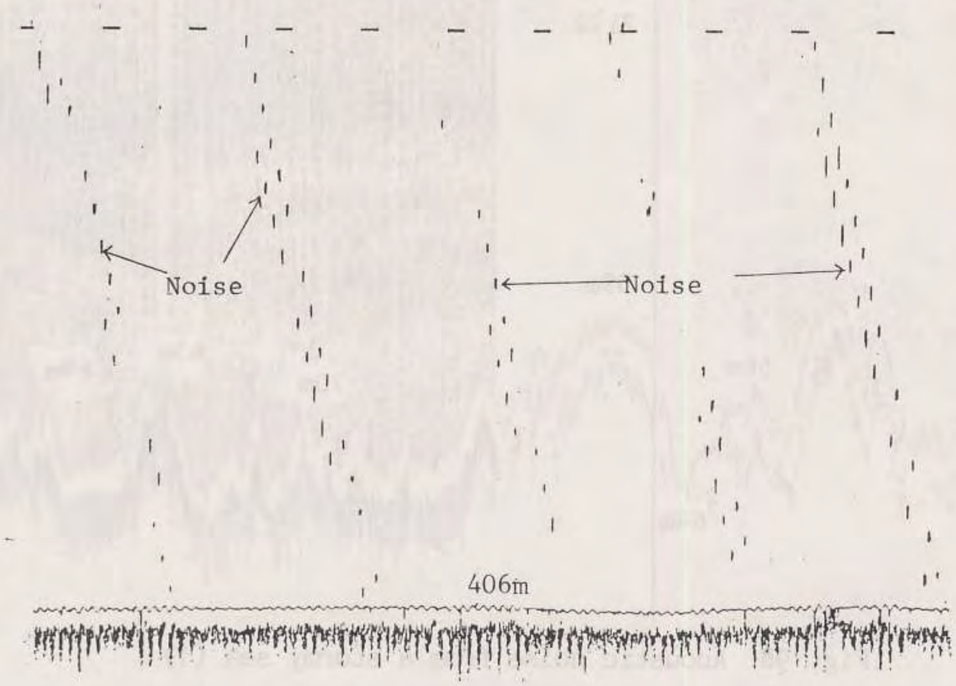


Fig. 97 Acoustic noise from another fishfinder (2)

The slightly oblique and dotted lines in Fig. 97 are caused by receiving signals from another fishfinder, received onboard M.V. PAKNAM on 6 Sept. 1987.

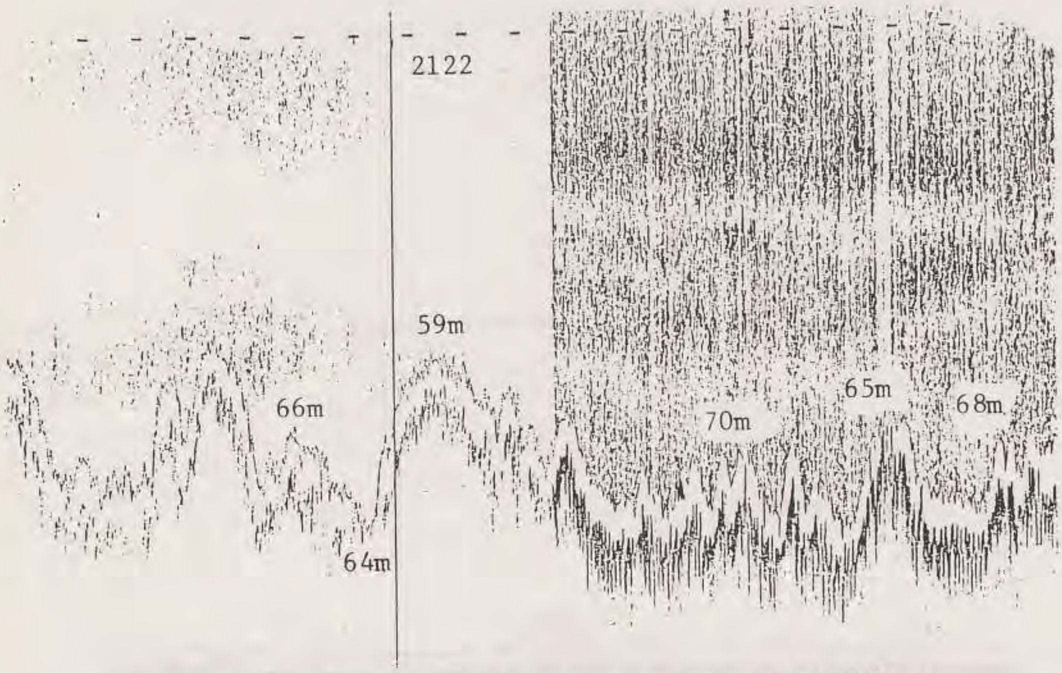


Fig. 98 Acoustic noise from a stormy sea (1)

The echogram in Fig. 98 shows an acoustic noise when the sea becomes very stormy. All the echo traces including the sea-bed's are vague because M.V. PAKNAM was pitching, rolling and yawing on the Rifleman Bank in the South China Sea, recorded by a 200 kHz fishfinder during shipboard training.

The motion of the vessel in heavy weather produces aeration or air bubbles underneath the vessel's hull bottom in the water and these bubbles pass close to the transducer's face and make a considerable noise. They reduce the energy of returning super-sonic sound waves from the sea-bed and/or submerged objects.

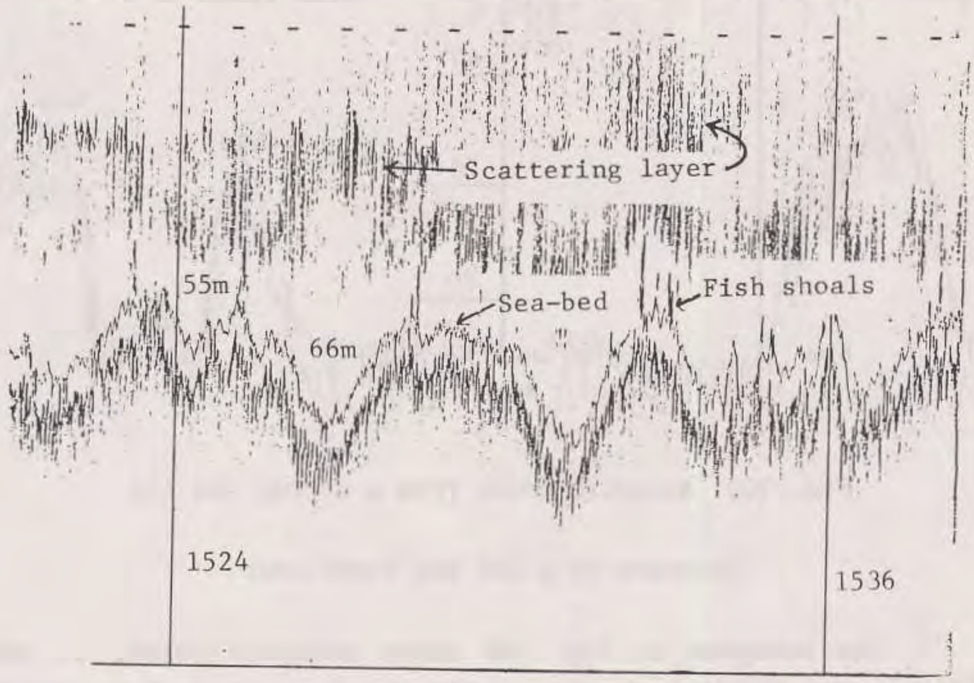


Fig. 99 Acoustic noise from a stormy sea (2)

The echogram shown in Fig. 99 shows very vague echo traces from the scattering layer, fish shoals and sea-bed, which are due to aeration close to the transducer's face, caused by heavy surf on the Rifleman Bank during shipboard training, recorded by a 200 kHz fishfinder.

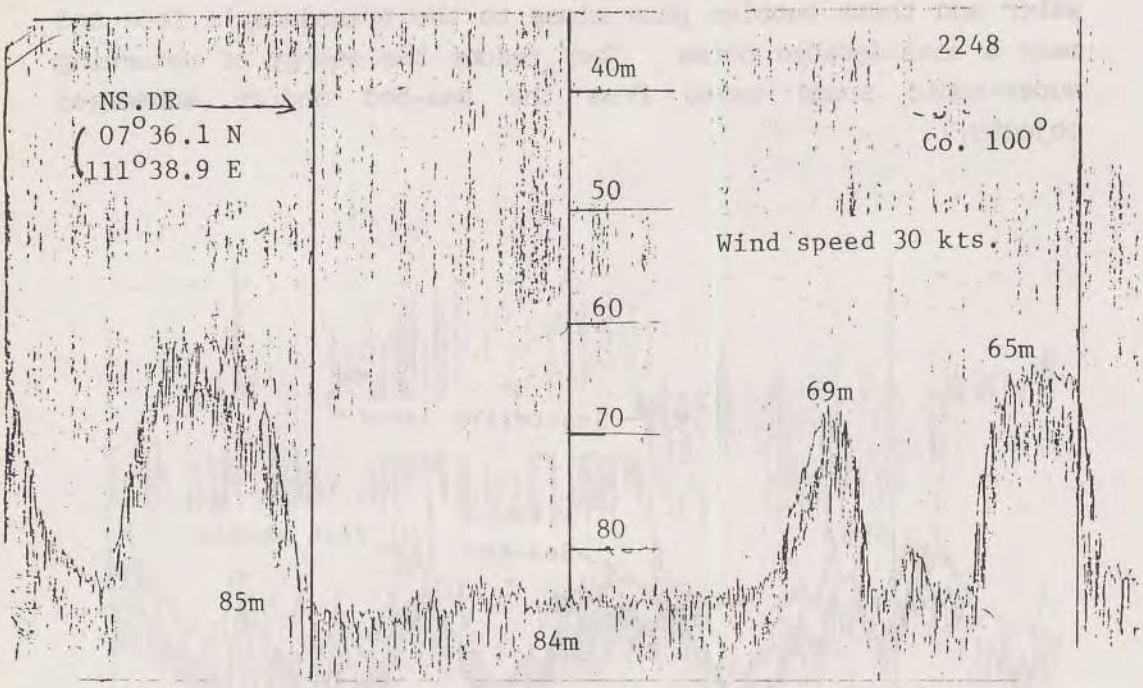


Fig. 100 Acoustic noise from a stormy sea (3)

Recorded by a 200 khz fishfinder

The echogram in Fig. 100 shows acoustic noise, it was difficult to distinguish the scattering layer and fish echoes from the noise because M.V. PAKNAM was cutting through a heavy sea : wind speed was 30 knots on the Rifleman Bank.

7. Scattering layer

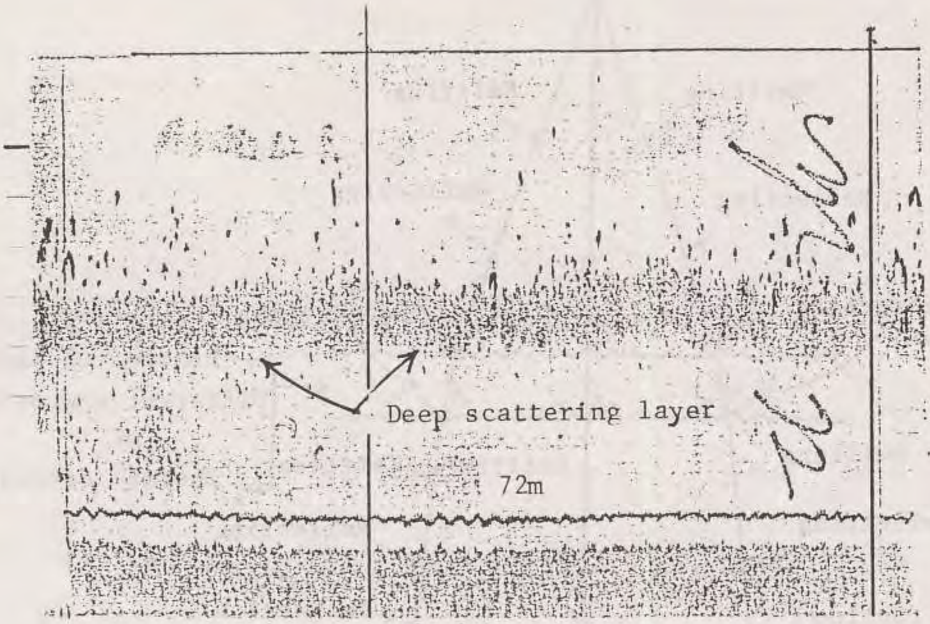


Fig. 101 Echo traces from the scattering layer, recorded by a 50 kHz fishfinder on M.V. No. 71 Akebono-Maru, 8 Dec. 1973

The echogram in Fig. 101 shows the scattering layer in a fishing ground off South Africa. Above or on the layer, the echo traces from fish shoals are visible. Some are "hyperbolic" is shape and some are dotted. They are almost above the layer, not beneath the layer.

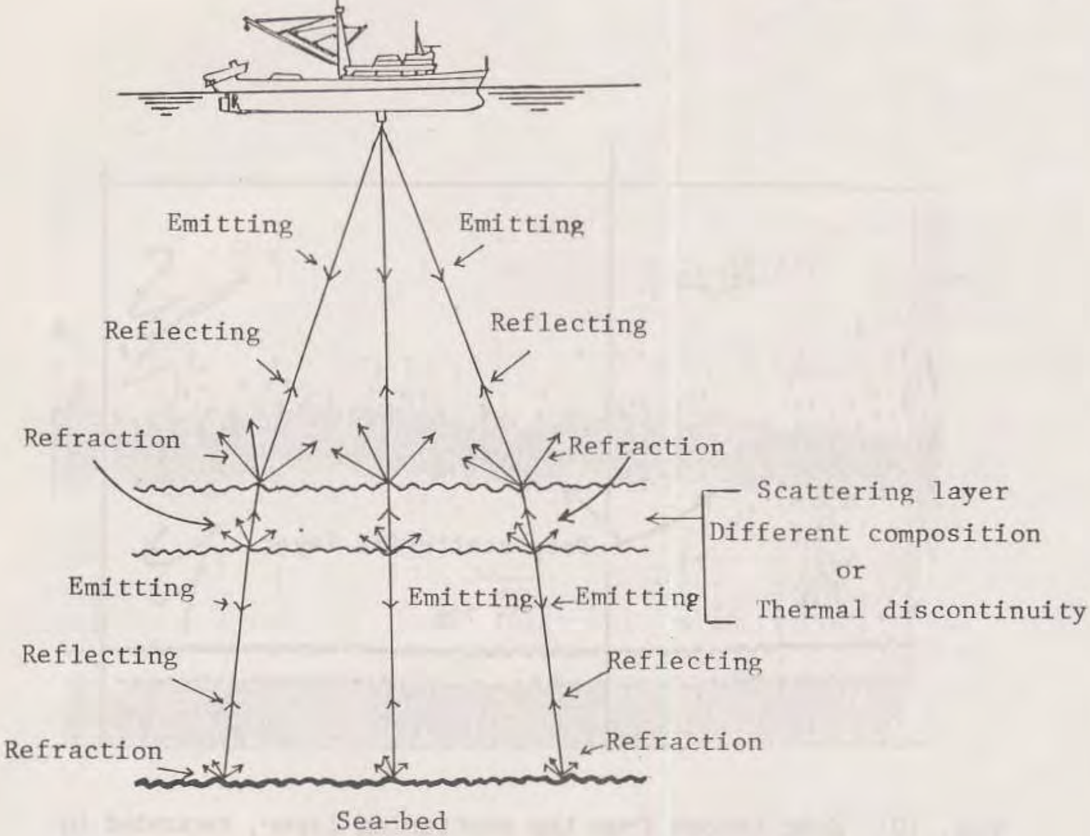


Fig. 102 Relation between sound waves, scattering layer and sea-bed

Fig. 102 shows a typical diagram of reflection and refraction of sound waves. When supersonic sound waves propagate and cross from one layer to another different layer, reflection and refraction are generated on the layer's surface and the sound wave energy is attenuated. This is the reason why fishfinder recordings trace the scattering layer on the chart.

The layers have a different composition (oceanic organisms, etc.) and/or thermal discontinuities. The scattering layer is an important piece of information for pelagic fishing : tuna longline; drift gill net; mid-water trawl, etc.. Because pelagic species are largely linked to the deep scattering layer.

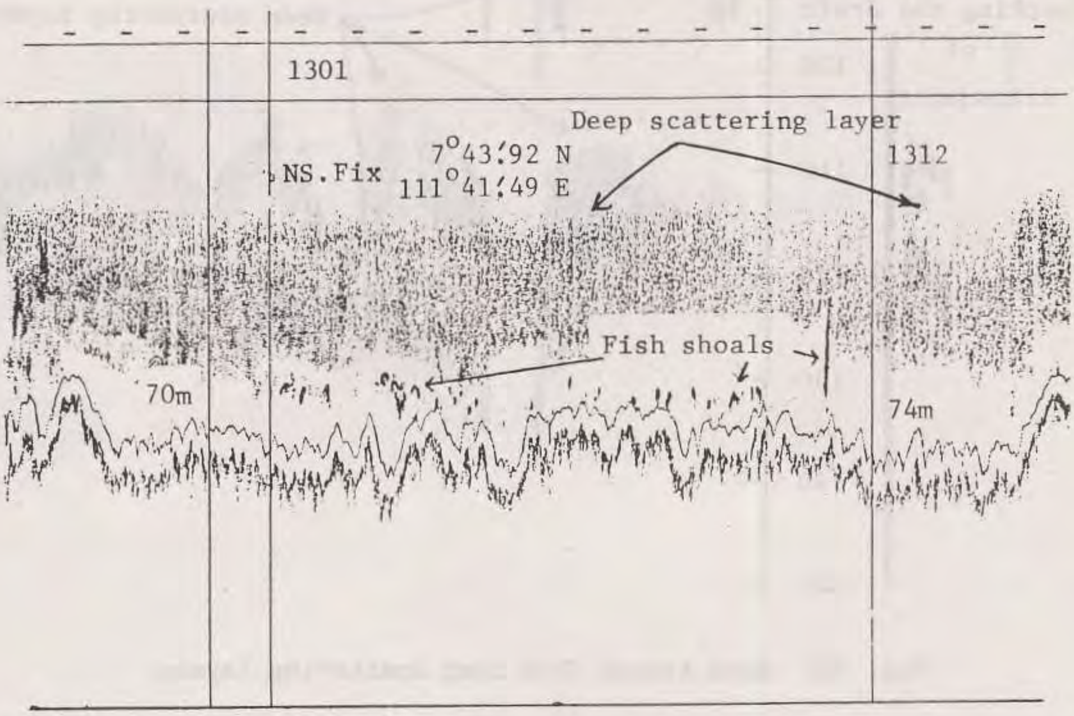


Fig. 103 Echo trace of deep scattering layer (recorded by a 200 kHz)

Fig. 103 shows the deep scattering layer like a "curtain" close to the sea-bed. Beneath the layer echo traces from fish shoals are visible but invisible above it and different from the echogram in Fig. 101. Fish shoals inhabit the area near the layer.

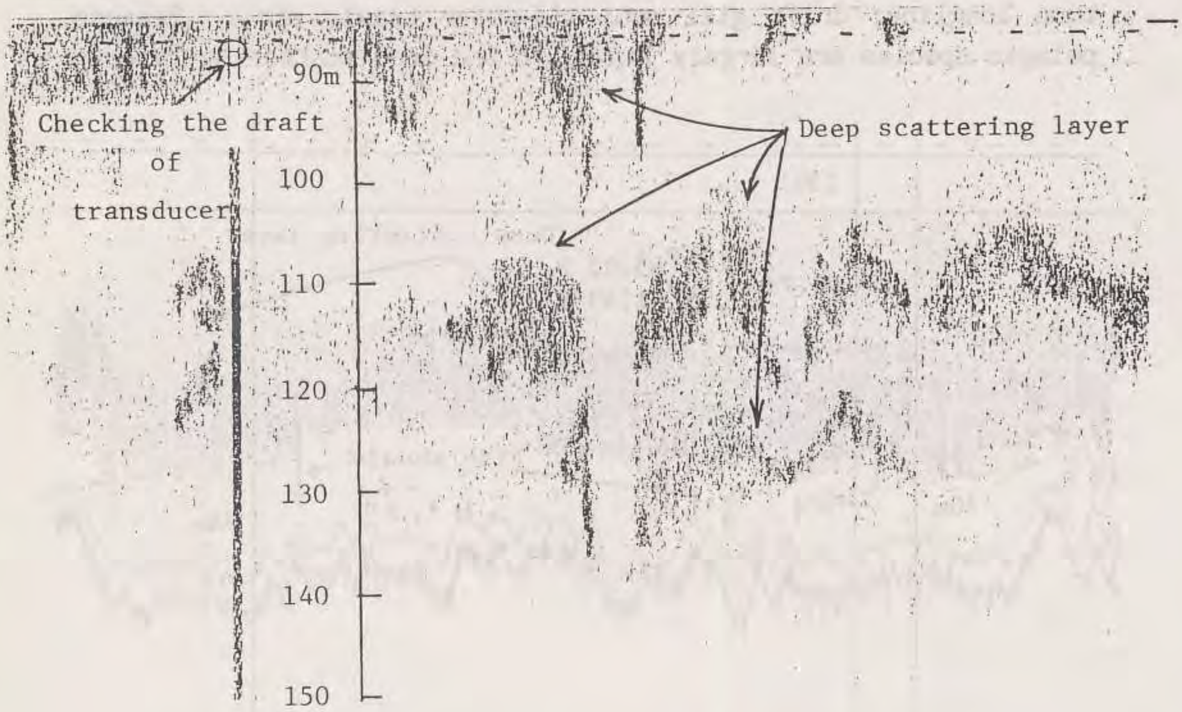


Fig. 104 Echo traces from deep scattering layers

The echogram in Fig. 104 shows deep sea scattering layers, one is shallow in depth (less than 100 metres) and another in deeper water. Since the fishfinder records such a multi-scattering layer, water turbulence occurs there. From fishermen's experience of tuna longline the multi-scattering layer brings a poor catch.

Recorded by a 200 kHz fishfinder on M.V. PAKNAM

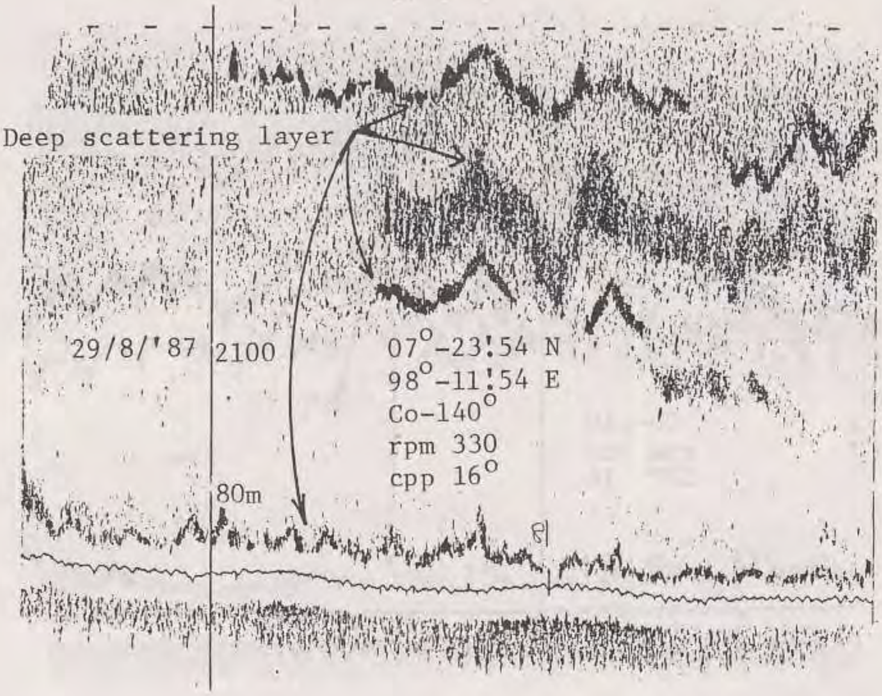


Fig. 105 Echo traces from multi-scattering layer (1)

The echogram in Fig. 105 shows a multi-scattering layer (there are three or four layers) recorded by M.V. PAKNAM in the Andaman Sea on 29 Aug. 1987.

One layer is very close to the sea-bed. The water turbulence is radical. Bottom line fishing will probably bring poor catch, bottom trawl fishing as well.

The echogram was recorded by a 200 kHz fishfinder.

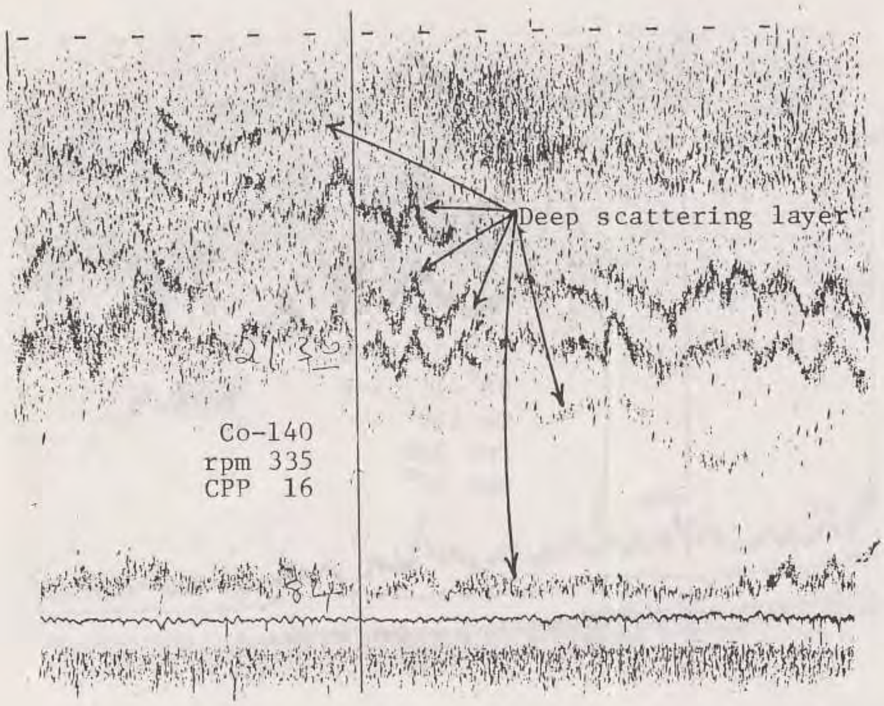


Fig. 106 Echo traces of multi-scattering layer (2)

The echogram shows a very complicated multi-scattering layer recorded by a 200 kHz fishfinder on M.V. PAKNAM at 2130 hours on 29 Aug. 1987 at 07°20!9 N, 98°14!6 E. Sea turbulence is very active and the configuration of fishing gear in mid-water would lose its balance because of a strong undercurrent.

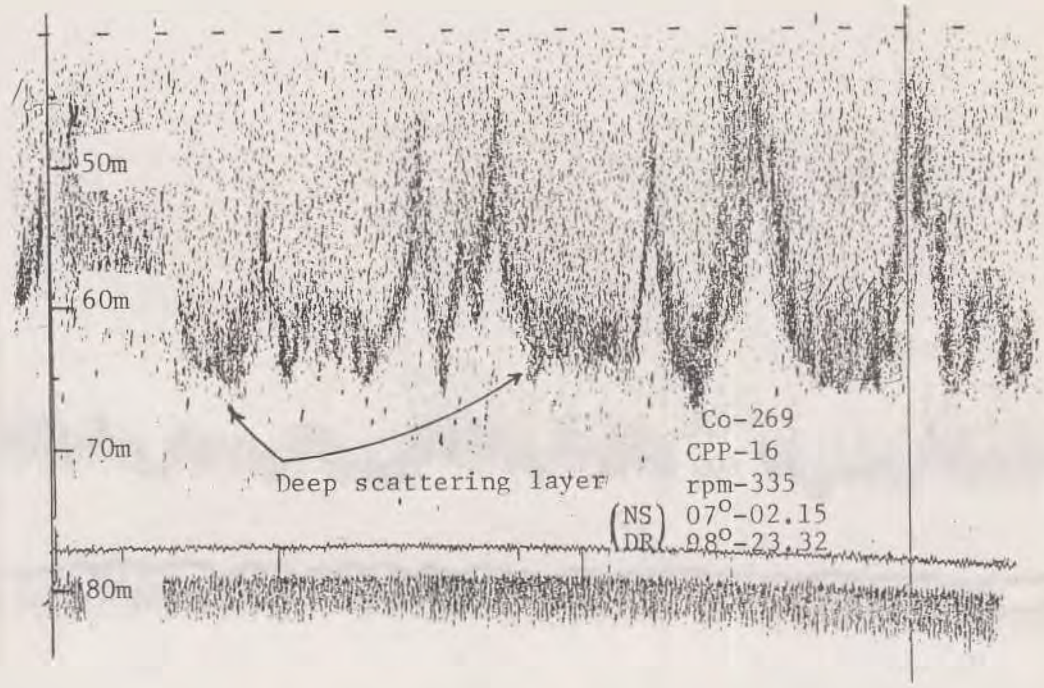


Fig. 107 Echo traces from "veil" scattering layer

The echogram in Fig. 107 shows "veil" scattering layers with water turbulence, small fish echoes can be seen in and beneath the layer traces.

In the recording in Fig. 107 the water turbulence occurs at a depth of 40 to 65 metres. Deeper than 65 metres the thermal condition would be stable.

The echogram was recorded by a 200 kHz fishfinder on M.V. PAKNAM on 29 Aug. 1987 in the Andaman Sea.

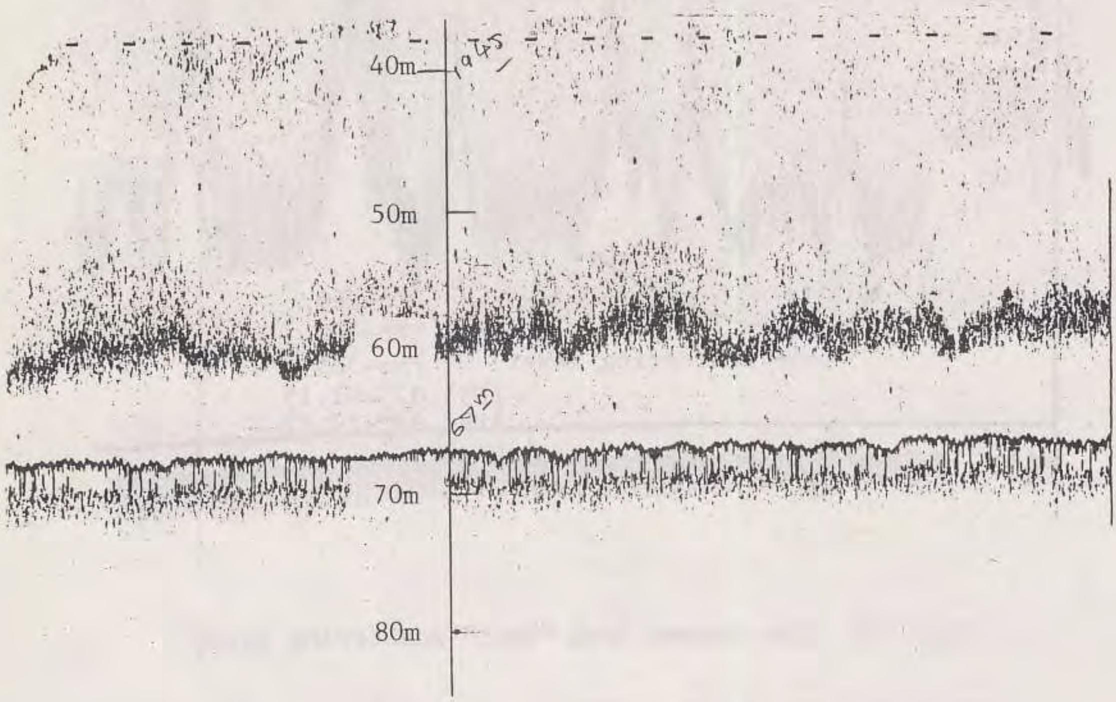


Fig. 108 Echo trace from scattering layer

The echogram in Fig. 108 shows the deep scattering layer at a depth of 60 metres. Water temperature shallower than 60 metres is probably different from that deeper than 60 metres. There would be thermal discontinuities at a depth of 60 metres.

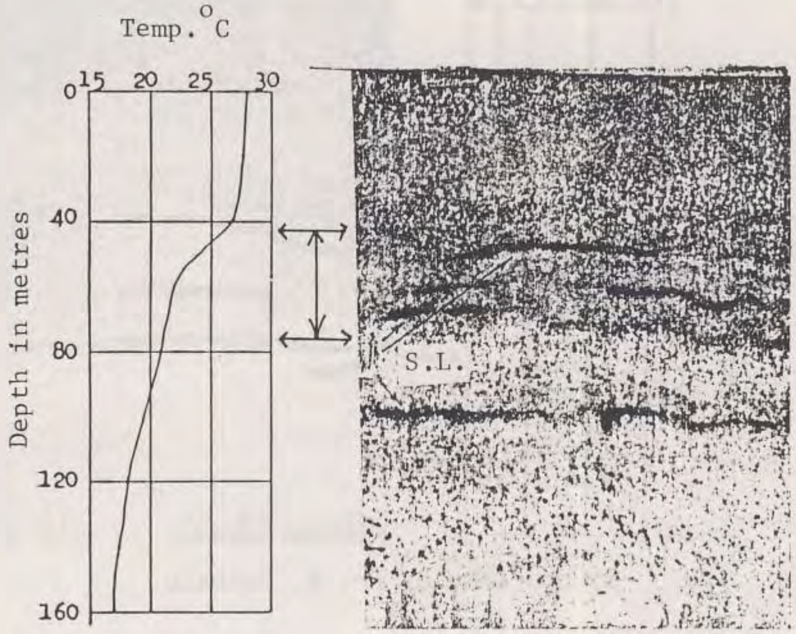
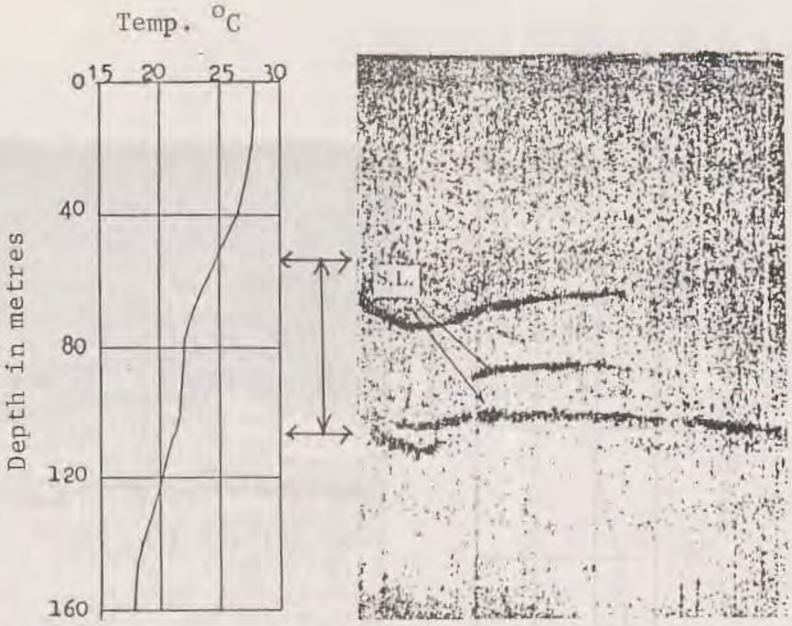


Fig. 109 Bathythermogram and echo traces of deep scattering layer

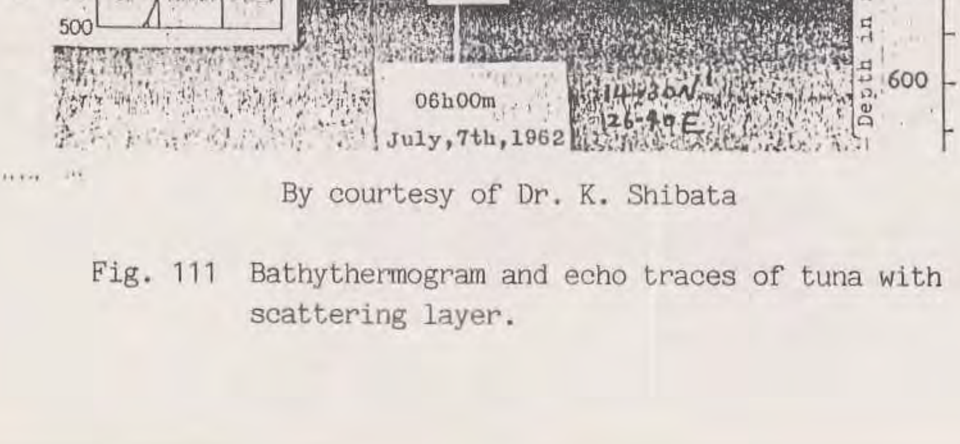
The echogram in Fig. 109 shows recordings of both a bathythermogram and the multi-scattering layer. A thermocline on the bathythermogram appears at the same depth of the multi-scattering layer on the fishfinders recording.



By courtesy of Dr. K. Shibata

Fig. 110 Bathythermogram and echo traces of deep scattering layer

Fig. 110 shows a thermocline on the bathythermogram appearing at the same depth of the multi-scattering layers on the fishfinder recording. Thus fishfinders show thermoclines and/or thermal discontinuities clearly on recording charts.



By courtesy of Dr. K. Shibata

Fig. 111 Bathythermogram and echo traces of tuna with scattering layer.

Fig. 111 shows a recording of tuna migrating vertically towards the sea-bed after sunrise. The deep scattering layer can be seen at a depth of 300 to 500 metres. The recording shows that tuna swim at a depth of less than 150 metres during the night-time but they may swim down to deeper water than 200 metres.

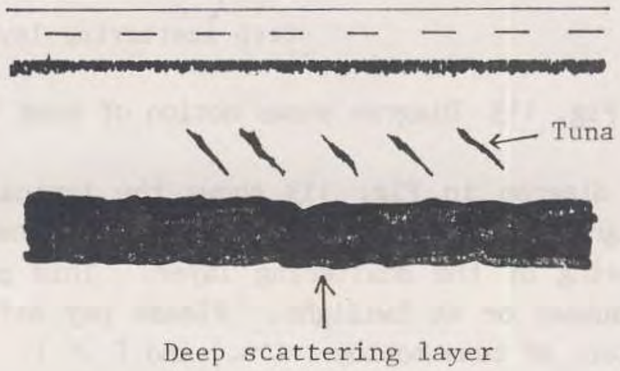


Fig. 112 Diagram shows motion of tuna (1)

The diagram in Fig. 112 shows the typical motion when tuna are migrating vertically towards the sea-bed following the deep scattering layer. This can be seen after sunrise or before down.

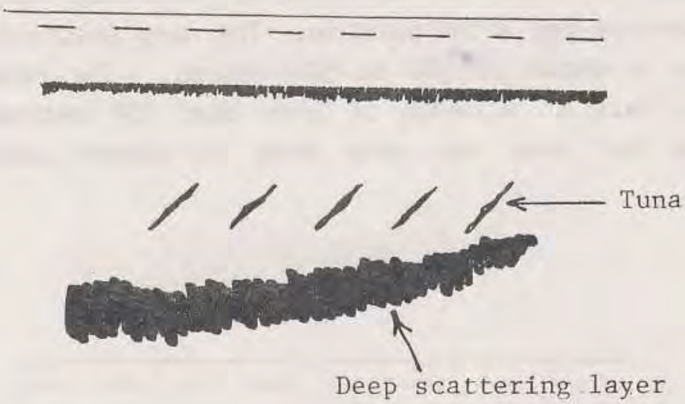


Fig. 113 Diagram shows motion of tuna (2)

The diagram in Fig. 113 shows the typical motion when tuna are migrating vertically towards the surface synchronized with the moving of the scattering layer. This pattern can be seen after sunset or at twilight. Please pay attention to the typical pattern of tuna motion : (⟍) and (/).

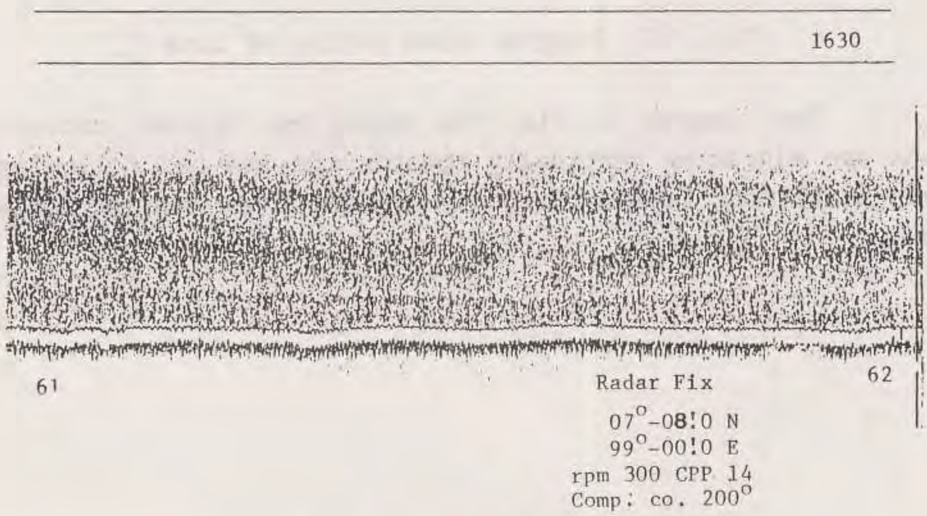


Fig. 114 Echo trace of turbulence

The echogram in Fig. 114 shows water turbulence "hard down" on the sea-bed. This turbulence yields poor catch of demersal species, recorded by a 200 kHz fishfinder on M.V. PAKNAM on 31 Aug. 1987 in the Andaman Sea.

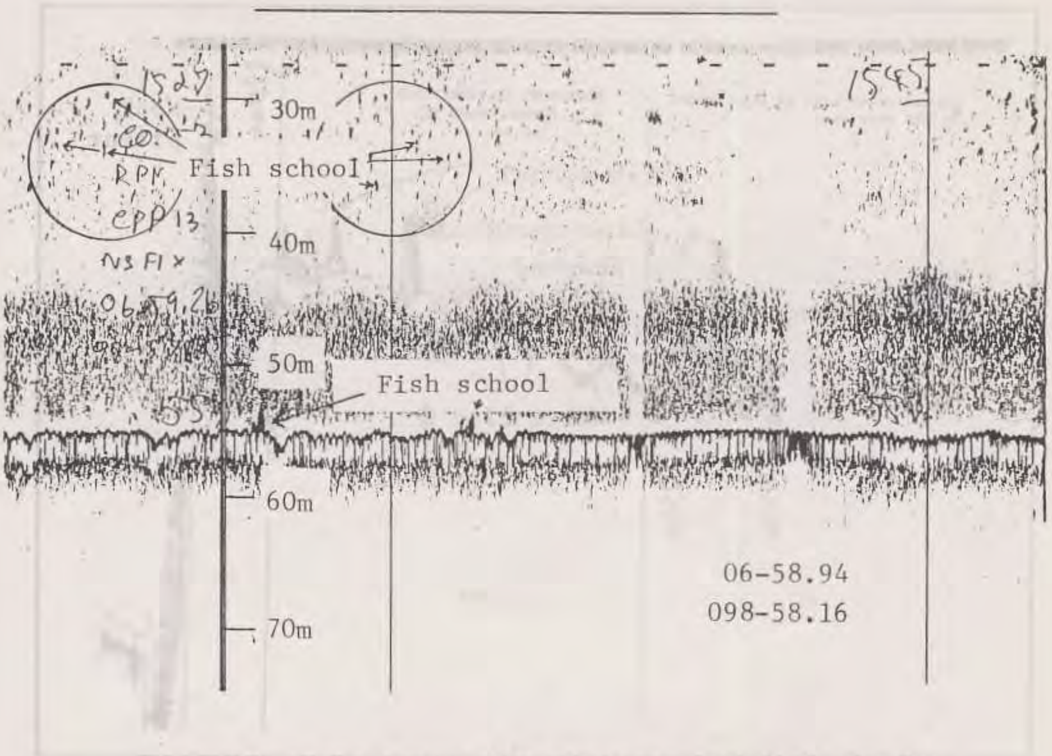


Fig. 115 Echo trace of turbulence and fish shoals

The recording in Fig. 115 shows water turbulence near the sea-bed and echo traces probably from bonito, recorded individually, in mid-water. Echo traces from demersal species can also be seen at a depth of 55 metres. Between the 54 and 55 metres depths there is no water turbulence.

The echogram shown in Fig. 115 was recorded by a 200 kHz fishfinder on M.V. PAKNAM.

8. "White line" control ... mechanical technique

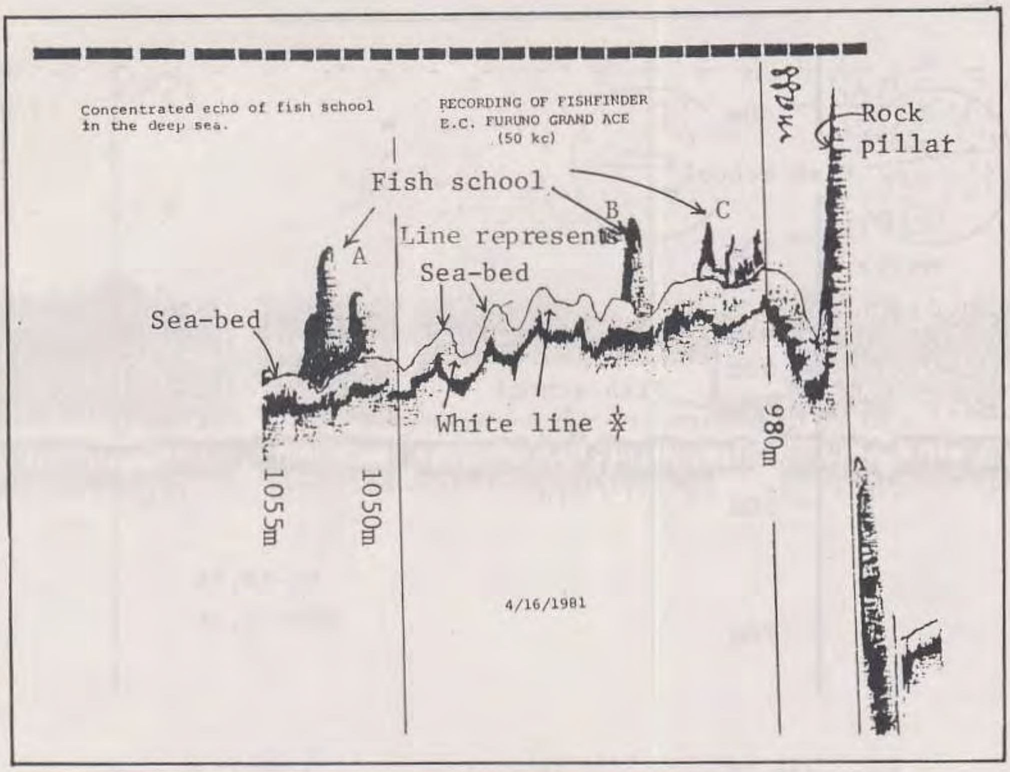


Fig. 116 "White line", fish school and sea-bed

The echogram in Fig. 116 shows very dense "tower-like" echo traces (marked by A, B and C) from demersal fish species at a depth of 980 to 1055 metres. The sea-bed is so hard and precipitous that bottom longline and/or trap cage net gear are preferable for fishing. The recording was obtained by a 50 kHz fishfinder in 1981 off East Africa.

"White line" control is one of the mechanical techniques of a fishfinder to distinguish signals of fish "hard down" on the sea-bed from those of the sea-bed. If the "white line" control is not functioning, the recording shown in Fig. 116 would appear like the modified echogram shown in Fig. 117.

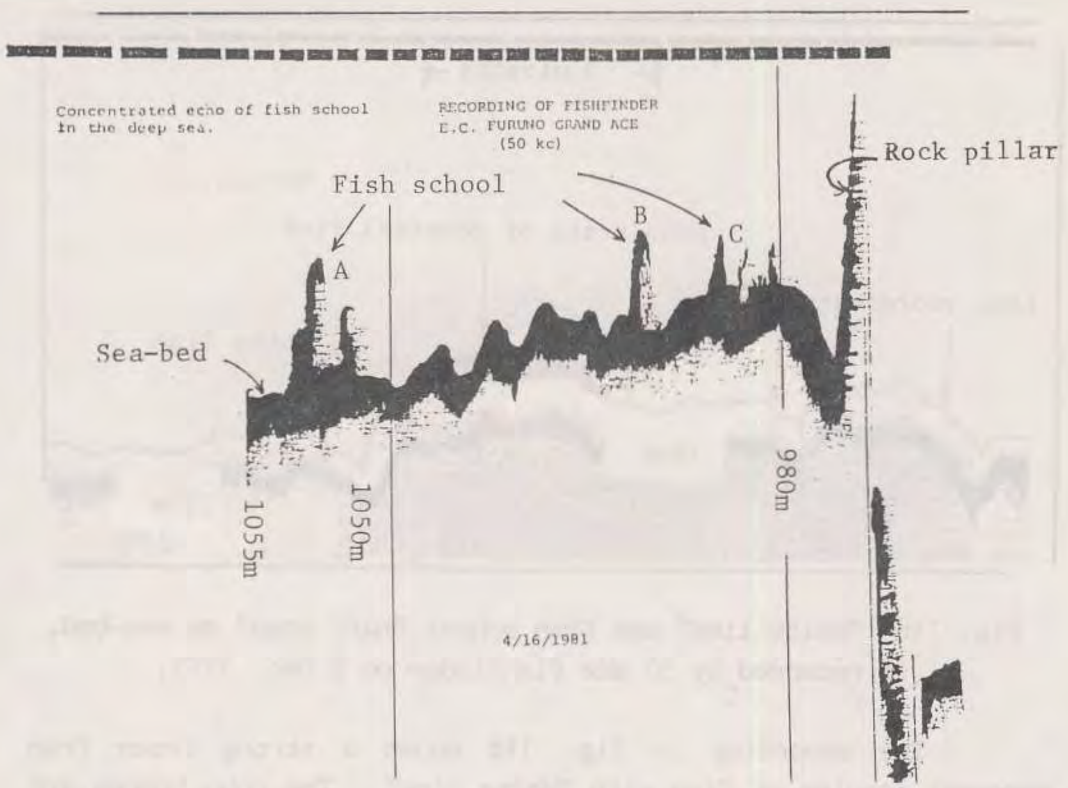


Fig. 117 Modified recording of Fig. 116

The modified recording in Fig. 117 shows that the fishfinder is unable to discriminate the sea-bed and the fish shoals marked by A, B and C and the traces of fish shoals look like rocky towers or pillars on the sea-bed.

In Fig. 117, extreme right, the echo trace is a huge rocky pillar, part of the sea-bed. If we refer once again to Fig. 116,we can realize that the fish shoals marked by A, B and C, the sea-bed and the rocky pillar are all distinguished from each other by "White line" control. "White line" control on a fishfinder can be utilized to know the degree of concentration of afish shoal both on the sea-bed and in mid-water.

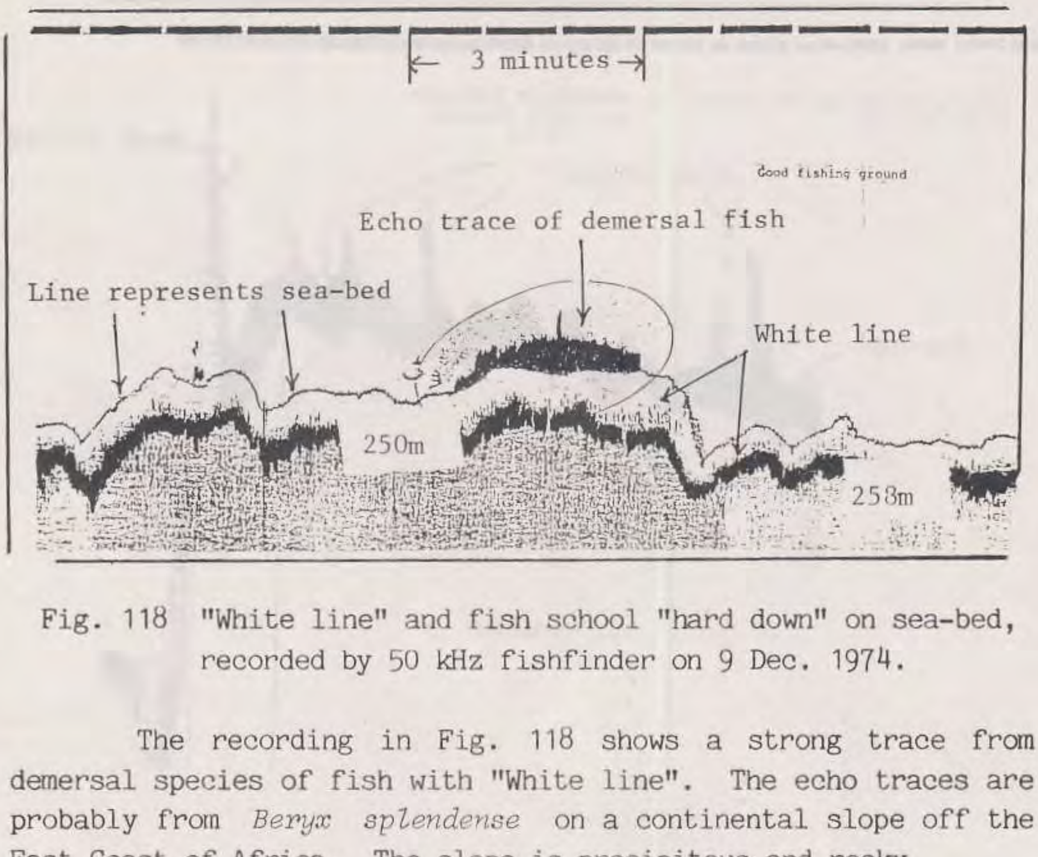


Fig. 118 "White line" and fish school "hard down" on sea-bed, recorded by 50 kHz fishfinder on 9 Dec. 1974.

The recording in Fig. 118 shows a strong trace from demersal species of fish with "White line". The echo traces are probably from *Beryx splendense* on a continental slope off the East Coast of Africa. The slope is precipitous and rocky.

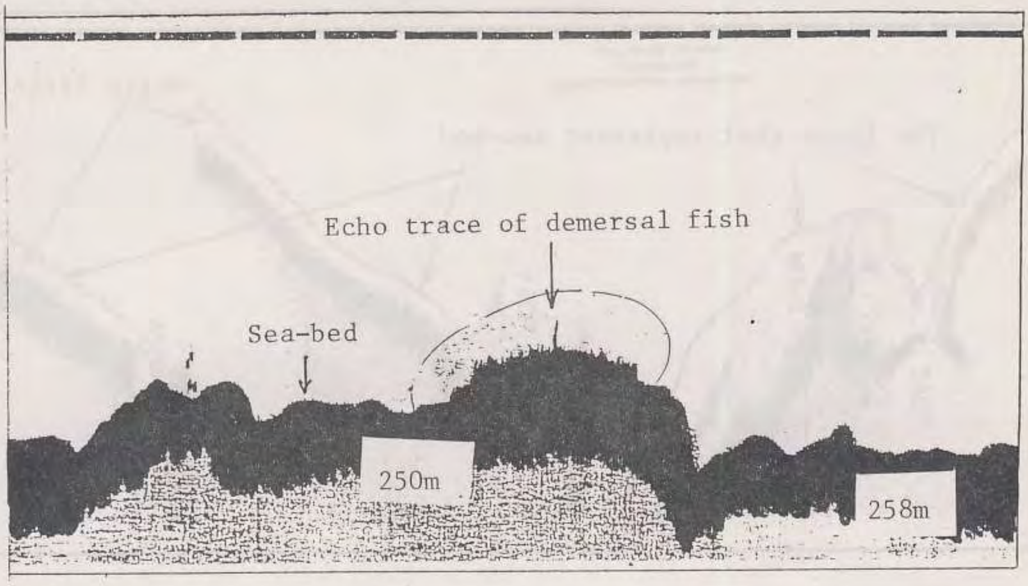


Fig. 119 Modified echogram of Fig. 118

The modified echogram in Fig. 119 shows that it is difficult to distinguish the echo trace of the sea-bed from that of fish shoals when "White line" control is not functioning.

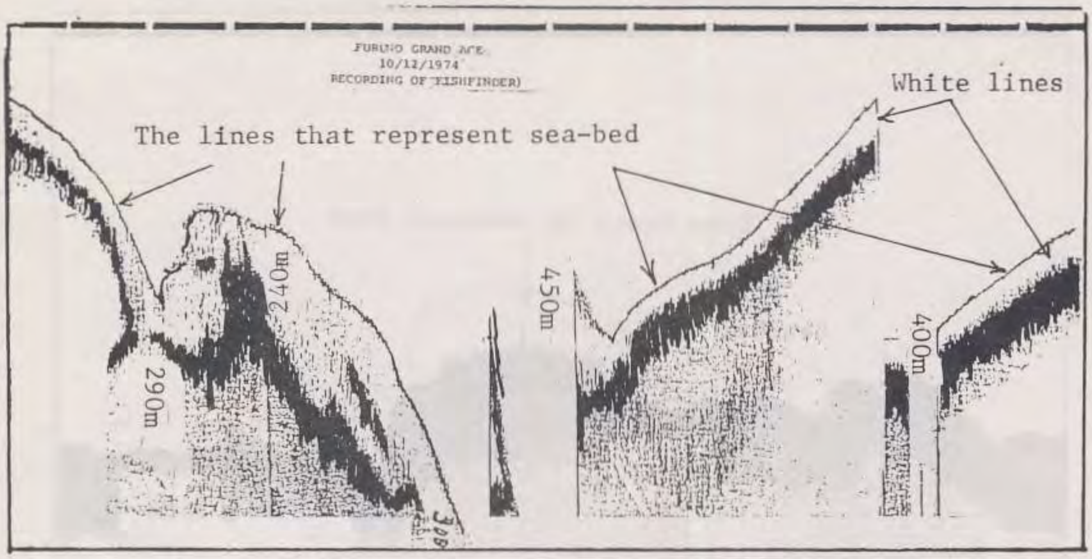


Fig. 120 "White line" and the line that represents sea-bed

The echogram shown in Fig. 120 shows a very steep continental slope and a depth of water ranging from 240 to 450 metres. Using the "White line" the lines that represent the sea-bed appear very clearly, recorded by a 50 kHz fishfinder in 1974 off East Africa.

To detect fish shoals by fishfinder is very necessary in deep-sea fishing grounds, especially in areas deeper than 300 metres. If the fishfinder detects no fish echoes, the fishing gear set on the sea-bed cannot have a good catch of any demersal fish species except perhaps deep-sea shrimps.

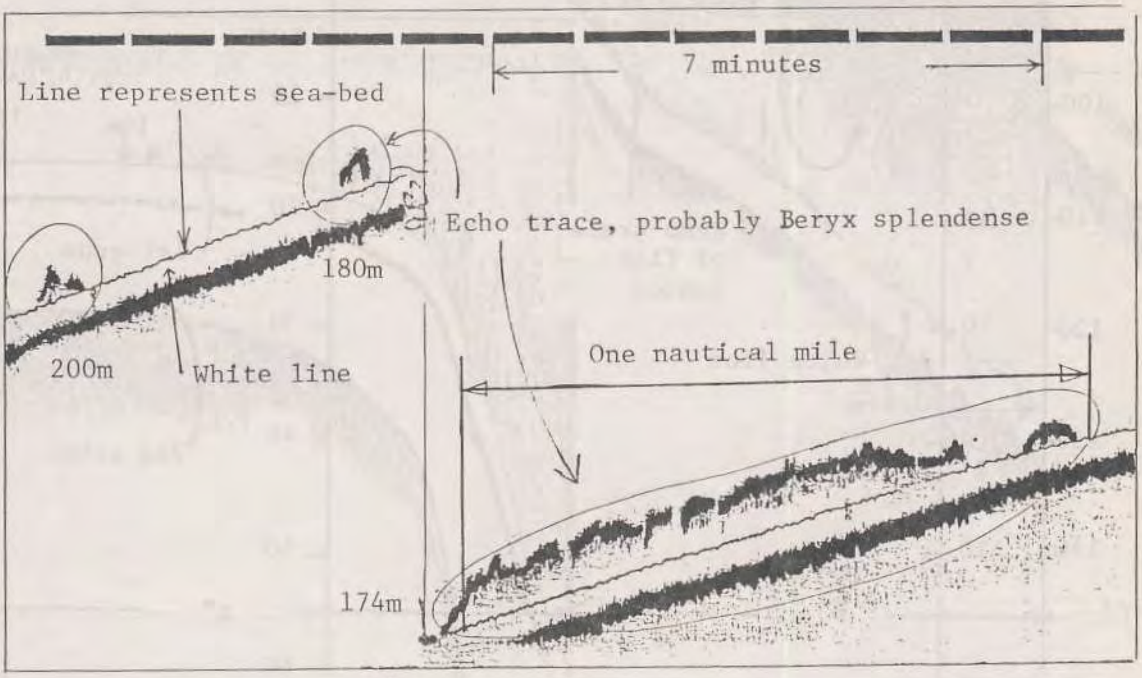


Fig. 121 "White line", sea-bed and fish shoals,
recorded by 50 kHz fishfinder.

The recording shown in Fig. 121 shows extensive shoals of *Beryx splendense* a demersal species on the continental slope off East African Coast. The white line control is working effectively to divide fish shoals from the line that represents the sea-bed's surface.

9. Depth scale or range in metres.

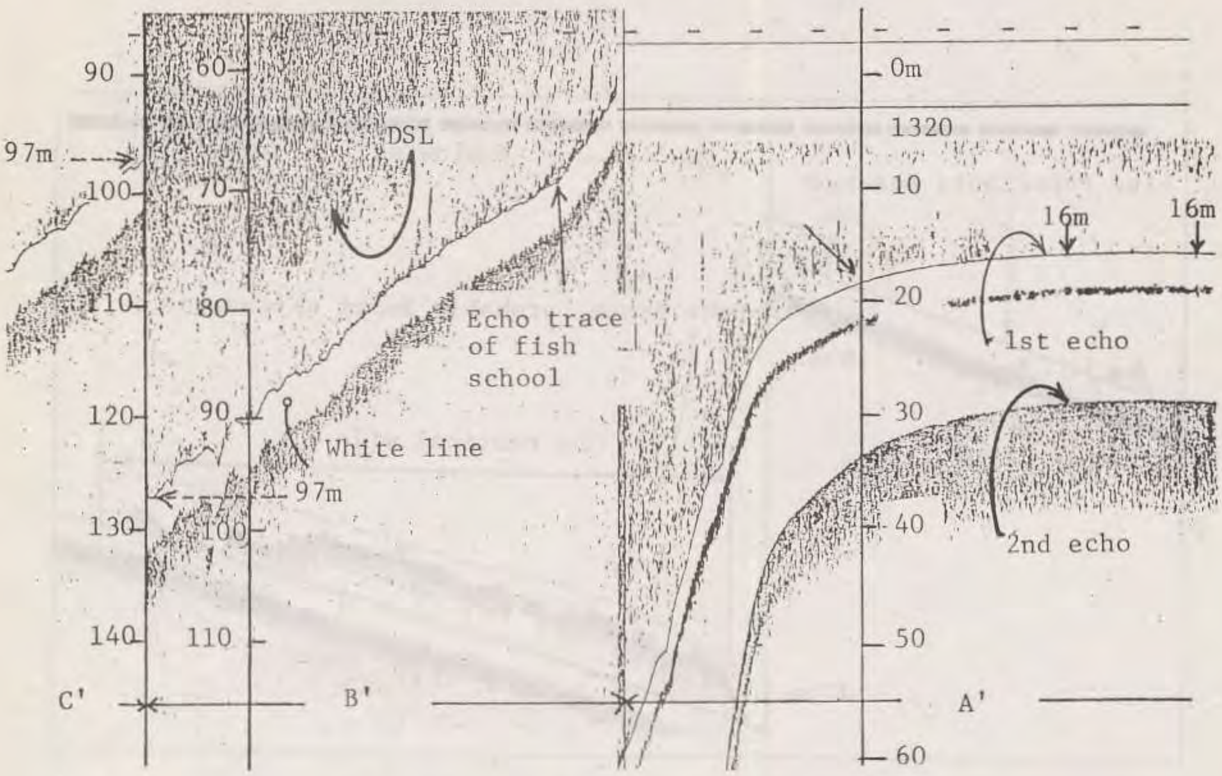


Fig. 122 Depth scale and its shift

Fig. 122 shows a fishfinder's recording with different "Depth scales"; 0 to 60 metres in section A', 60 to 110 metres in section B' and 90 to 140 metres in section C'.

To sound the depth on the sloping sea-bed the fishfinder or echosounder should be adjusted to the appropriate "Depth scale" otherwise no echo trace of the sea-bed is available on the recording chart even if the machine is under normal operation.

The echogram shown in Fig. 122 was recorded by a 200 kHz fishfinder on M.V. PAKNAM.

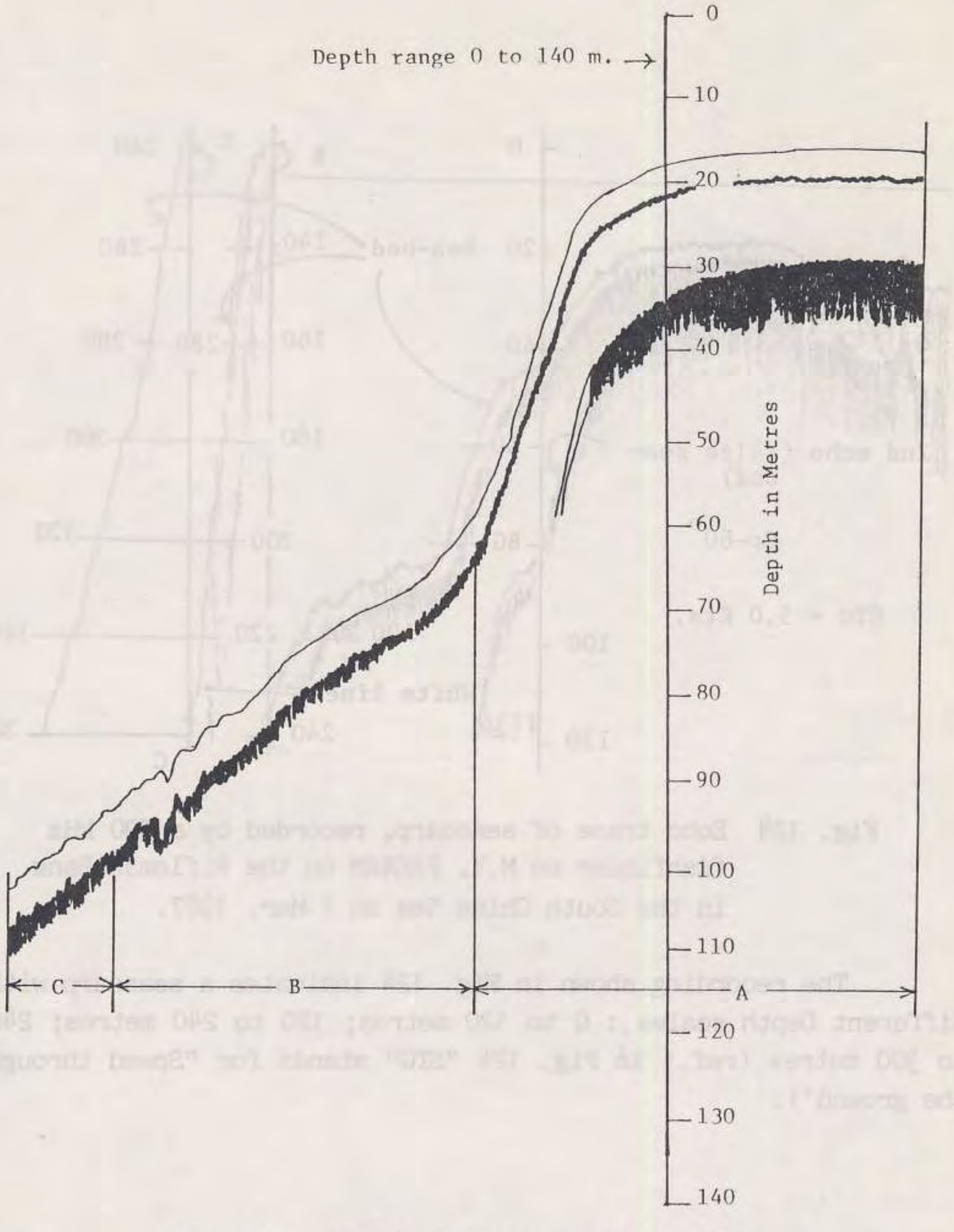


Fig. 123 Modified diagram of Fig. 122

The diagram shown in Fig. 123 shows a modified picture of Fig. 122 with Depth scale : ranging from 0 to 140 metres. Sections A, B and C in Fig. 123 correspond to sections A', B' and C' in Fig. 122.

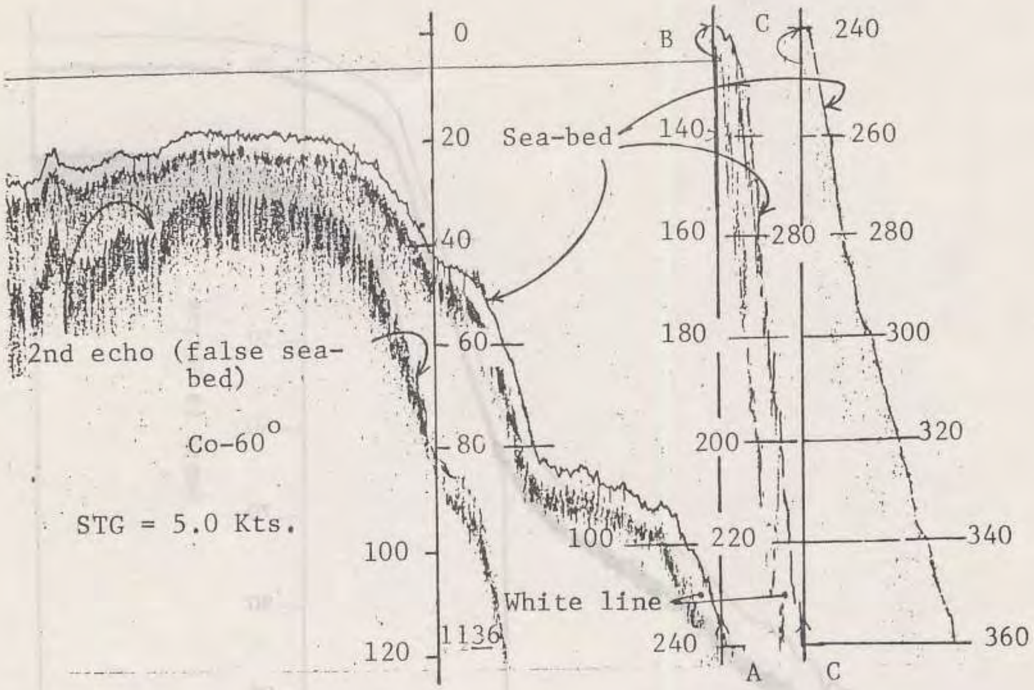


Fig. 124 Echo trace of seascarp, recorded by a 200 kHz fishfinder on M.V. PAKNAM on the Rifleman Bank in the South China Sea on 1 Mar. 1987.

The recording shown in Fig. 124 indicates a seascarp with different Depth scales : 0 to 120 metres; 120 to 240 metres; 240 to 300 metres (ref.: in Fig. 124 "STG" stands for "Speed through the ground').

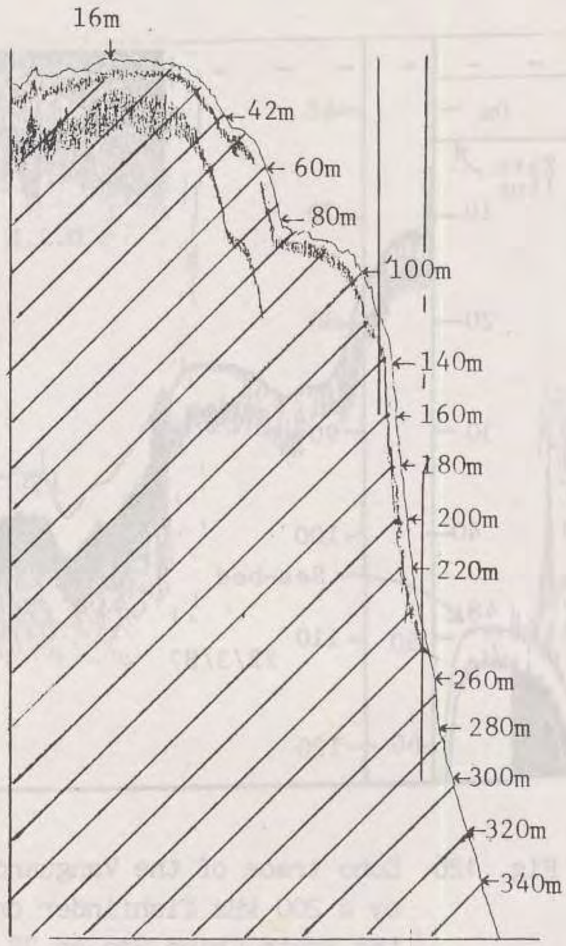


Fig. 125 Modified echogram of Fig. 124

The modified echogram of Fig. 124 shown in Fig. 125 shows the same trace of the seascarps. The modified echogram shows the feature of the seascarp very clearly.

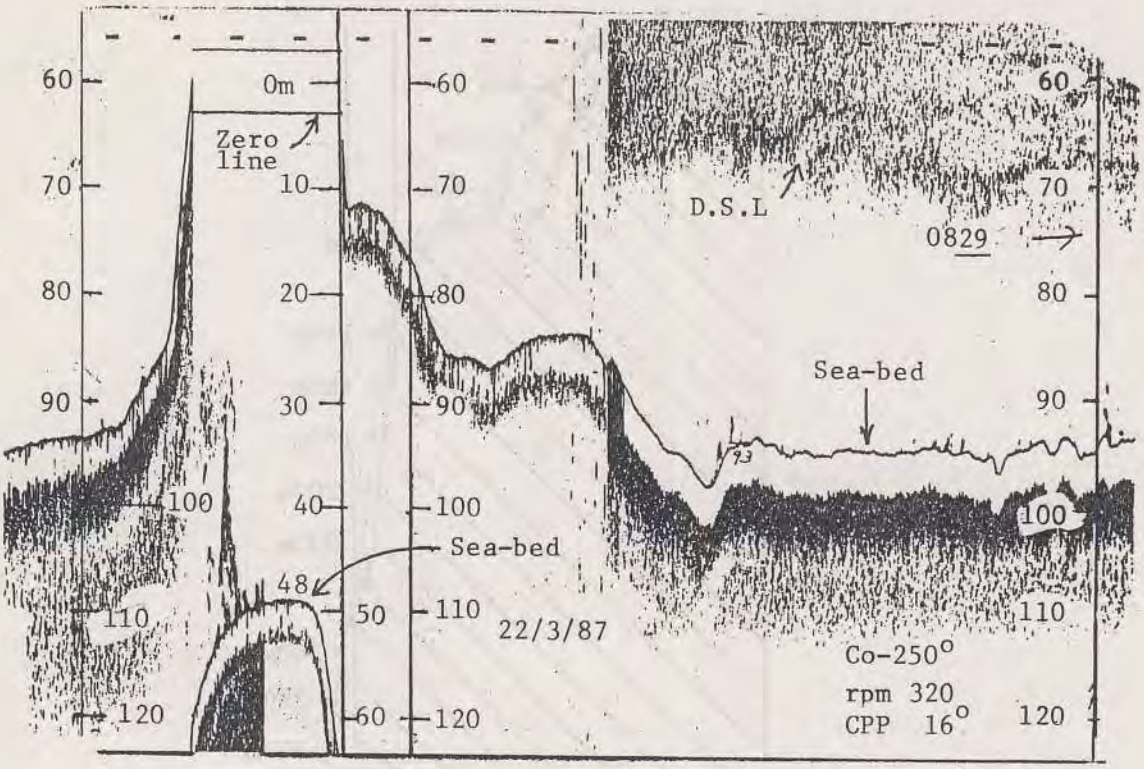


Fig. 126 Echo trace of the Vanguard Bank, recorded by a 200 kHz fishfinder on M.V. PAKNAM in the South China Sea on 22 Mar. 1987.

The echogram shown in Fig. 127 shows a "pillar-like" formation on a rocky sea-bed on the Vanguard Bank with different Depth scales : 0 to 60 metres; 60 to 120 metres. Zero line (draft of transducer's surface), D.S.L., sea-bed and echo traces from fish shoals can be seen in the recording.

But it is a little bit difficult to imagine "pillar-like" formations on the sea-bed. If Depth scale, 0 to 120 metres, is used, it would clearly show the shape of "pillar-like" formations on the sea-bed, therefore, it would be better for the interpreter of fishfinder's echo traces to draw another diagram, modified from the recording, as shown in Fig. 127, to know the feature of the sea-bed precisely.

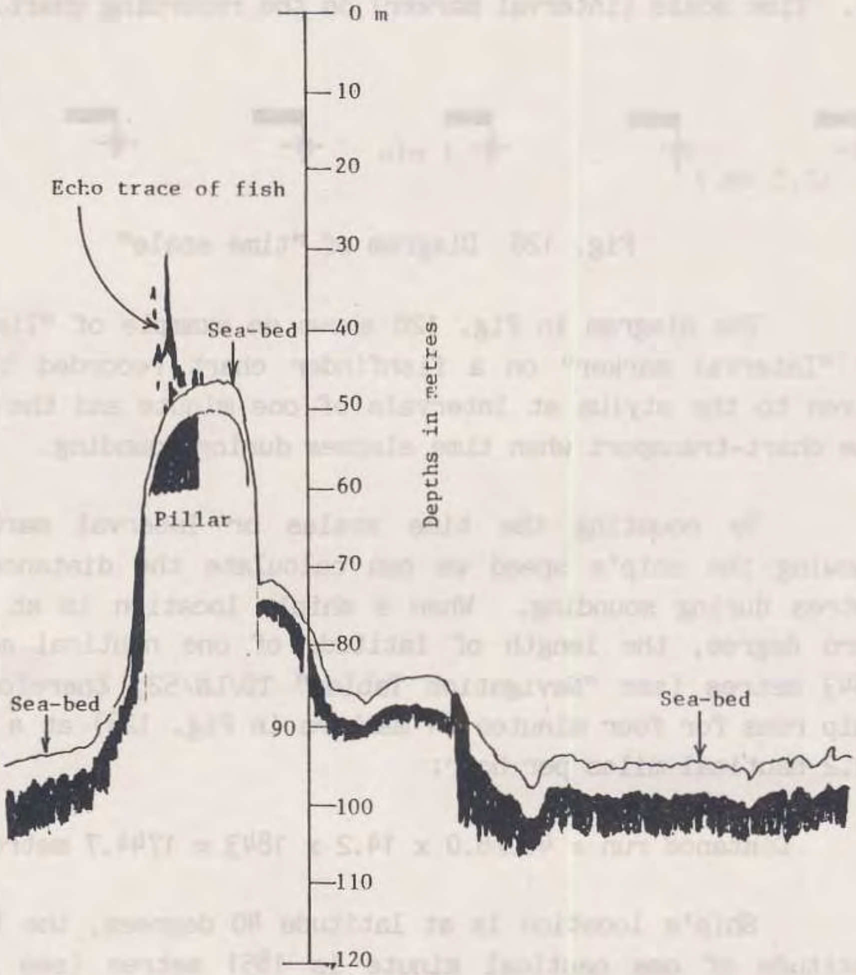


Fig. 127 Modified diagram of Fig. 126

The diagram shown in Fig. 127 indicates the feature of a "pillar-like" sea-bed more clearly than Fig. 126. It would be very significant to produce diagrams of banks, seamounts, guyots, valleys, etc. on the sea-bed from the data of echo traces given by fishfinders to have a better knowledge of a fishing ground's topographical characteristics and to make ones own fishing ground charts.

10. Time scale (interval marker) on the recording chart.

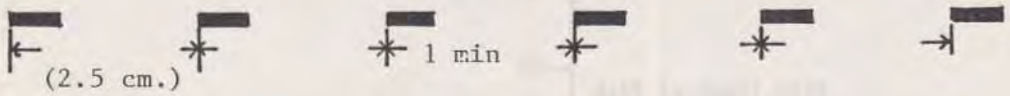


Fig. 128 Diagram of "time scale"

The diagram in Fig. 128 shows an example of "Time scale" or "Interval marker" on a fishfinder chart recorded by pulses given to the stylus at intervals of one minute and the speed of the chart-transport when time elapses during sounding.

By counting the time scales or Interval markers and knowing the ship's speed we can calculate the distance run in metres during sounding. When a ship's location is at latitude zero degree, the length of latitude of one nautical minute is 1843 metres (see "Navigation Tables" TD/LN/52, therefore, if a ship runs for four minutes (4 markers in Fig. 128) at a speed of 14.2 nautical miles per hour:

Distance run = 4.0/6.0 x 14.2 x 1843 = 1744.7 metres.

Ship's location is at latitude 40 degrees, the length of latitude of one nautical minute is 1851 metres (see the same "Navigation Table"), if a survey boat runs for three minutes (3 markers in Fig. 128) at a speed of 3.2 knots:

Distance run = 3.0/60 x 3.2 x 1851 = 296.2 metres.

Fishfinder's recording chart shows longitudinally the depth of sea-bed and distance from submerged objects in metres, fathoms and feet but it shows distance run with time scales or Interval markers latitudinally.

In other words the recording chart indicates two units : Scale in metres for depth and scale in minutes for distance run. Both scales are not based on the same unit, one is radius value another is chronogrammatic. When interpreting echo traces on the chart, it is be necessary to convert the chronogrammatic value shown by time scale into radius value in metres.

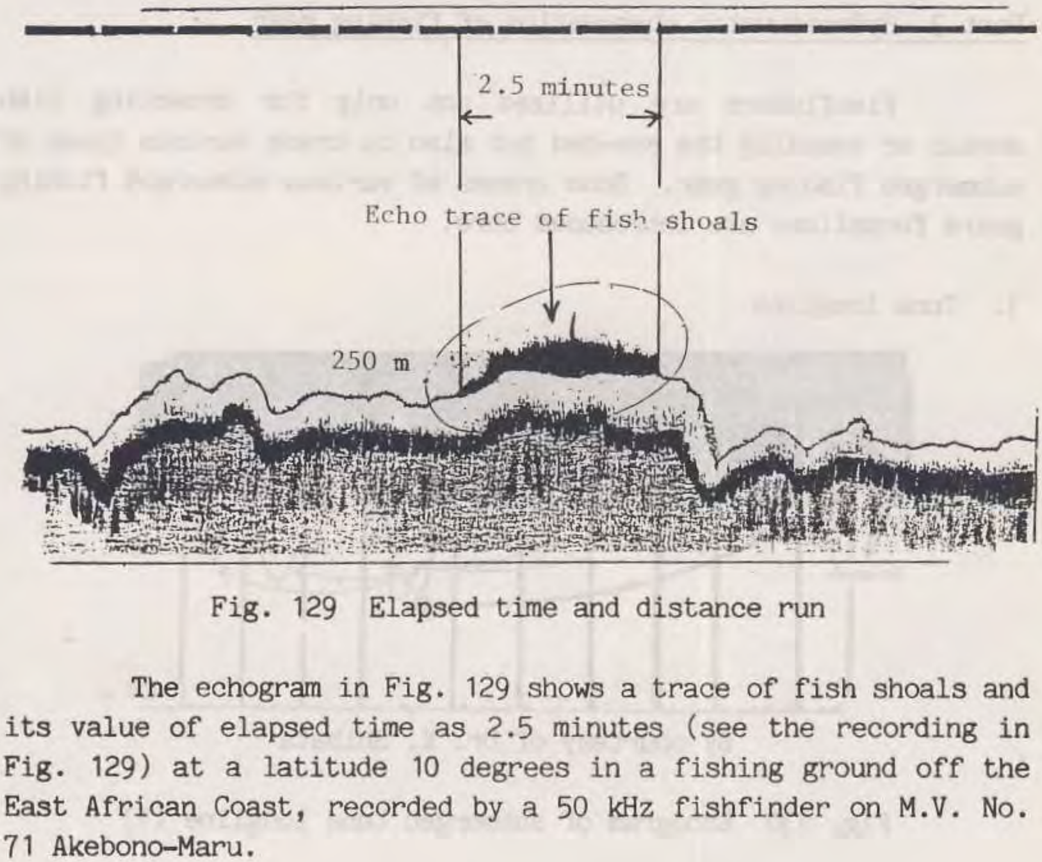


Fig. 129 Elapsed time and distance run

The echogram in Fig. 129 shows a trace of fish shoals and its value of elapsed time as 2.5 minutes (see the recording in Fig. 129) at a latitude 10 degrees in a fishing ground off the East African Coast, recorded by a 50 kHz fishfinder on M.V. No. 71 Akebono-Maru.

If a survey boat's speed is 3.0 knots, the horizontal length of fish shoals recorded on the chart would approximately be:

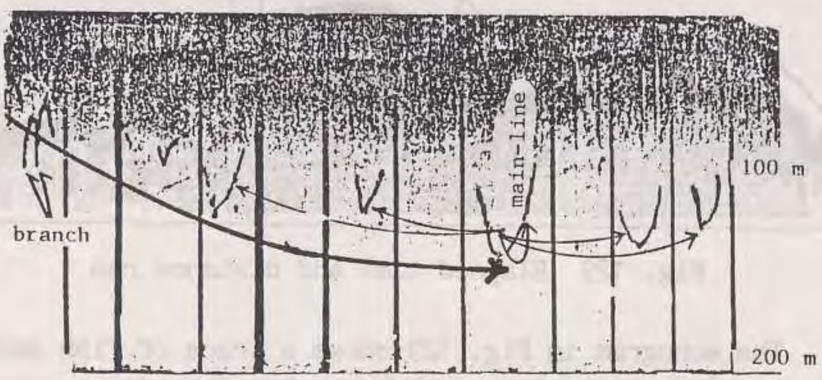
Distance run = 2.5/60 x 3.0 x 1843 = 230.4 metres.

But if the boat's speed is 12 knots, it would be 921.5 metres. For the aforementioned calculation it is important to take into consideration three basic elements : ship's speed; elapsed time; and latitude in order to interprete echograms on charts.

Part 3 Hydroacoustic observation of fishing gear

Fishfinders are utilized not only for detecting fish shoals or sounding the sea-bed but also to trace various types of submerged fishing gear. Echo traces of various submerged fishing gears formations are introduced here.

1. Tuna longline

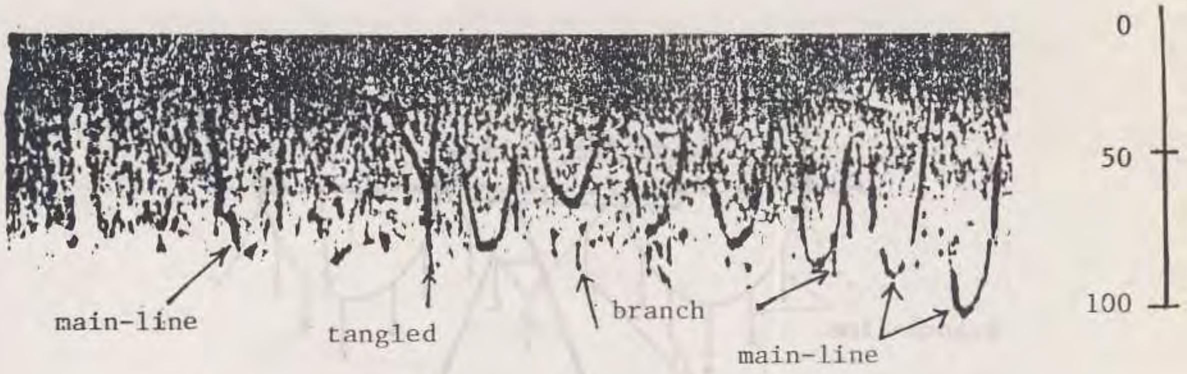


By courtesy of Dr. K. Shibata

Fig. 130 Echogram of submerged tuna longline (1)

The echogram in Fig. 130 shows the formation of tuna longline in the water, recorded by a 200 kHz echosounder on M.V. Nagasaki-Maru; the fishery training and research vessel of Nagasaki University, Japan, on 1 May 1961 off Kyushu Island.

In Fig. 130 the main-line (trunk line) and branch-lines were recorded at a depth of 100 to 150 metres. The diameter of the main-line is 5.6 millimetres.



By courtesy of Dr. K. Shibata

Fig. 131 Echogram of submerged tuna longline (2)

The echogram shown in Fig. 131 shows the formation of a tuna longline underwater ; maximum depth of the vertex of the main-line's catenary is 100 metres and branch lines tangled with the main-line and other branch-lines can be seen in the echogram.

The echogram was recorded by a 200 kHz echosounder on M.V. Nagasaki-Maru. A low frequency such as a 50 kHz echosounder could not clearly record the lines as shown in Fig. 131.

After finish shooting a tuna longline it is useful and interesting to observe the formation of the submerged longline with a fishfinder to have information of the actual depth of the hooks and the gear's balance and configuration in the stream. In particular the relative positioning between the deep scattering layer and the hooks should be considered in order to carry out fishing most effectively.

Tuna longliner

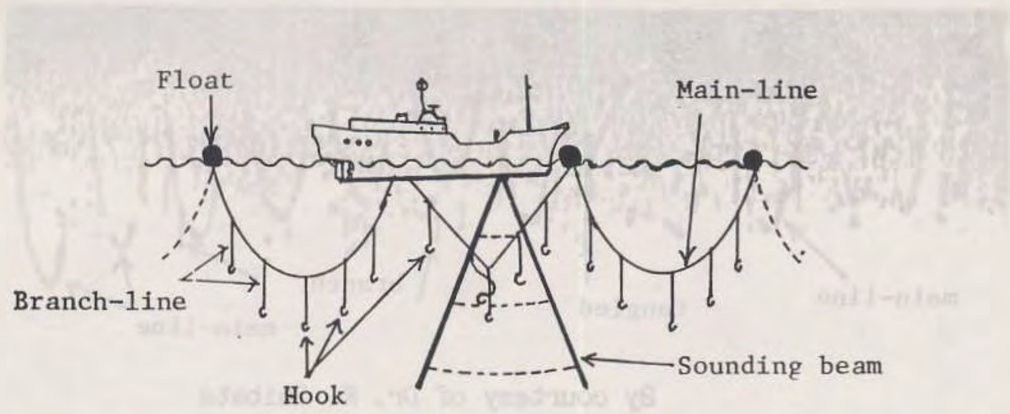
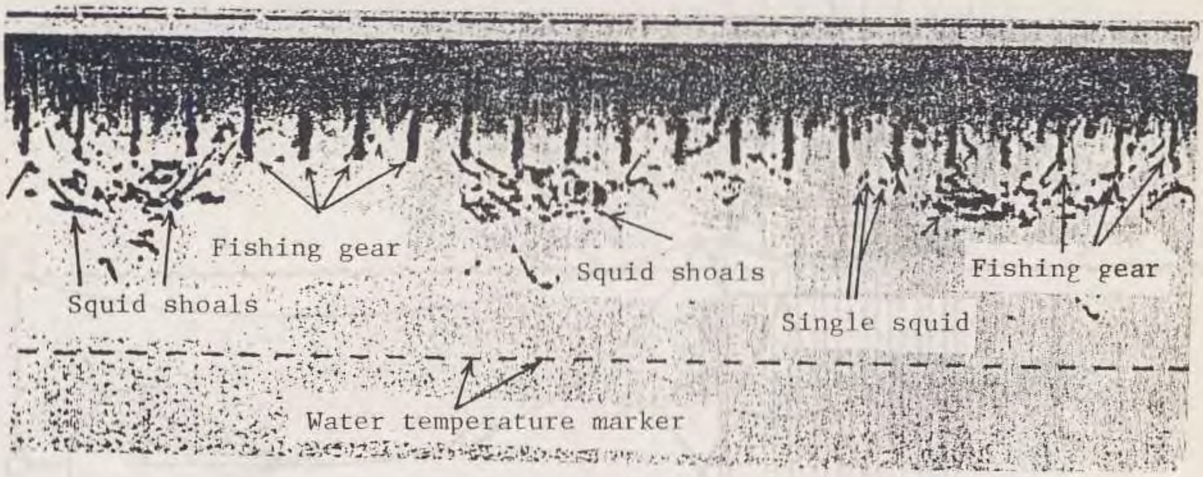


Fig. 132 Tuna longliner checking longline with fishfinder

The diagram in Fig. 132 shows a tuna longliner checking its fishing gear after shooting. The boat is proceeding at slowspeed over the submurged fishing gear while sounding and the recording chart traces the gear's formation.

2. Squid jigs



Reproduced by kind permission of FURUNO Electric Co., Ltd.

Fig. 133 Echo traces of squid jig

The echogram in Fig. 133 shows a 200 kHz fishfinder detecting the automatic squid jig fishing gear and shoals of squid. The uppermost "curtain" trace in the recording is from the plankton layer. The squid fishing boat's speed through the water is nil during sounding and fishing.

It is very clear that the squid shoals are gathering under the light of the luring lamps and nearing the gear. Some squids' traces are resolved into a single recording. During fishing it is recommendable to search for fish even if the shoal's nearing the gear, not only by eye but by fishfinder too.

Continuously watching the fishfinder's recording will provide information and knowledge of whether the shoals are migrating deeper or towards the boat.

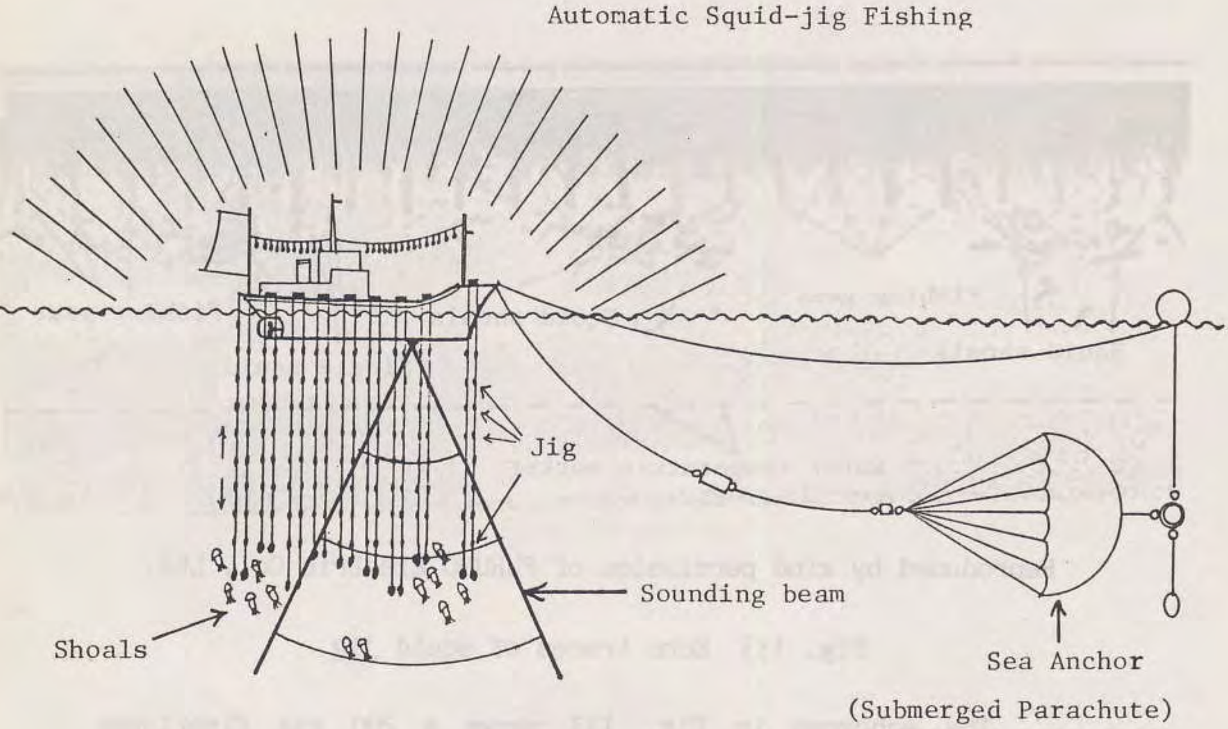


Fig. 134 Squid jig fishing boat while sounding

The diagram in Fig. 134 shows a typical view of a squid jig fishing boat sounding squid shoals and its gear with a 200 kHz fishfinder.

3. Purse seine

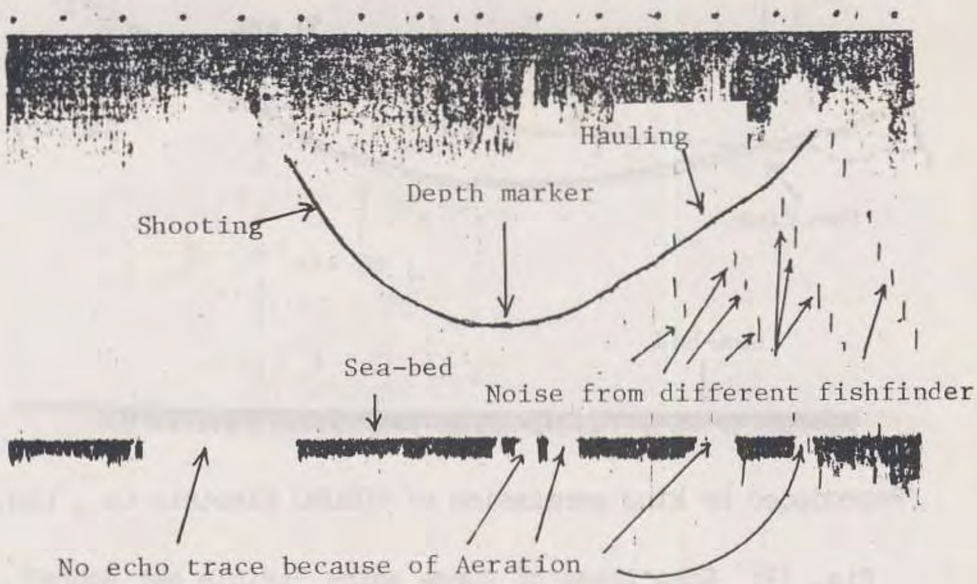


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Fig. 135 Echo trace of purse seine single net sonde

The echogram shows the recording of a purse seine's net sonde with a single "depth-marker" detected by a single transmitter. The echo trace of noise from a different fishfinder and the effect of areation can be seen (echo trace from sea-bed is only partially recorded).

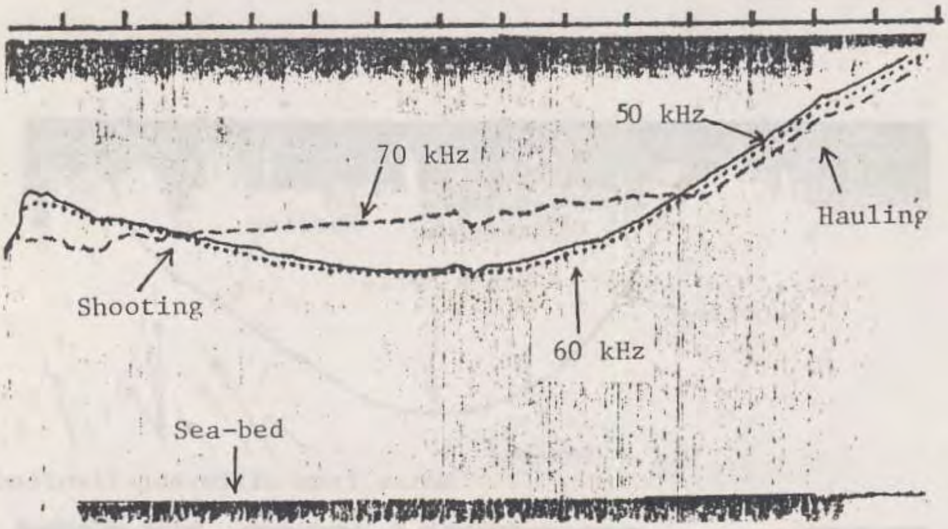

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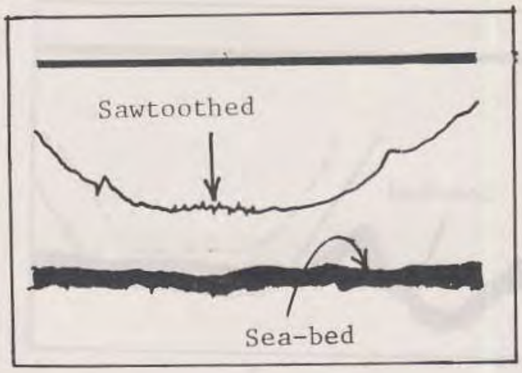
Fig. 136 Echo trace of purse seine "triple net sonde"

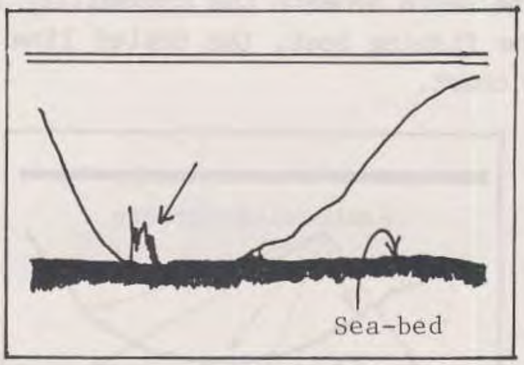
Fig. 136 shows the recording received from the three transmitters of a purse seine's net sonde with "triple depth marker" : 50 kHz; 60 kHz; 70 kHz. Depth marker indicated by a broken line (---) is from 70 kHz transmitter, dotted line (---) from 60 kHz and solid line (——) from 50 kHz (see Figs. 13 & 14). The echogram shows that the foot rope of the purse seine does not touch the sea-bed.



Reproduced by kind permission of FURUNO Electric Co., Ltd.

Fig. 137 Diagram of depth marker (1)

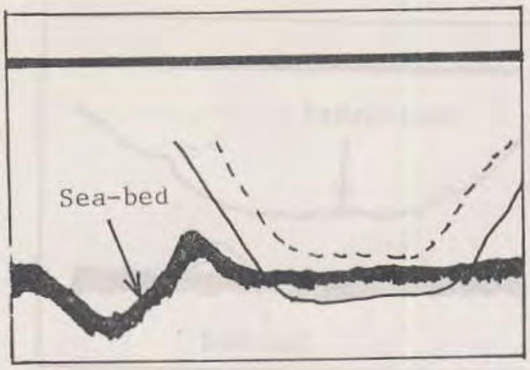
The depth marker in Fig. 137 shows a sawtoothed pattern, which occurs when a receiving transducer is pushed towards the surface by a strong undercurrent or if there is a big quantity of fish in a shoal between the transmitter and receiving transducer.



By courtesy of FURUNO Electric Co., Ltd.

Fig. 138 Diagram of depth marker (2)

The depth marker in Fig. 138 shows the transmitter moving up and down (indicated by an arrow in the diagram). This occurs when the transmitter lands on the sea-bed during the shooting of the gear. The transmitter faces the opposite side to the receiving transducer because of the shock at the moment when the transmitter landed on the sea-bed.

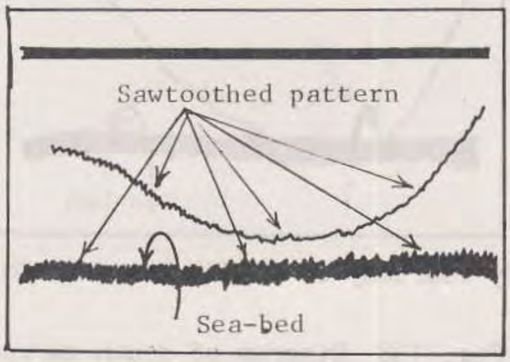


By courtesy of FURUNO Electric Co., Ltd.

Fig. 139 Diagram of depth marker (3)

A depth marker is underneath the sea-bed and another is above the surface of the sea-bed in Fig. 139.

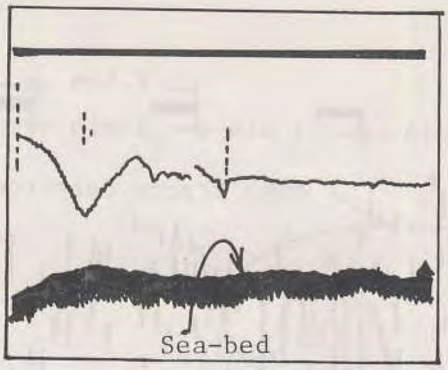
The depth of water beneath the transmitter is greater than that beneath the fishing boat, and the solid line pattern appears. When the depth beneath the transmitter is less than the depth beneath the fishing boat, the dotted line pattern appears on the recording chart.



By courtesy of FURUNO Electric Co., Ltd.

Fig. 140 Diagram of depth marker (4)

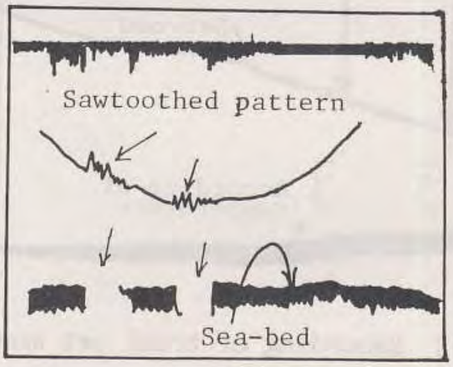
When a fishing boat is pitching and rolling, the pulse repetition received is not stable and "Doppler-shift" is generated, therefore, a sawtoothed pattern appears both for the depth marker and the trace of the sea-bed, as shown in Fig. 140.



By courtesy of FURUNO Electric Co., Ltd.

Fig. 141 Diagram of depth marker (5)

The diagram in Fig. 141 shows that when no transmitter or receiving transducer are submerged, the pattern shown in Fig. 141 appears.



By courtesy of FURUNO Electric Co., Ltd.

Fig. 142 Diagram of depth marker (6)

The diagram in Fig. 142 shows the depth marker producing a partial sawtoothed pattern and the echo trace of the sea-bed is only partially recorded. Also the transmission line's reverberation is slightly thin and unstable.

This happens when aeration is generated near the receiving transducer. When a similar echogram appears as that shown in Fig. 142 it is best to lower the receiving transducer deeper.

4. Trawl

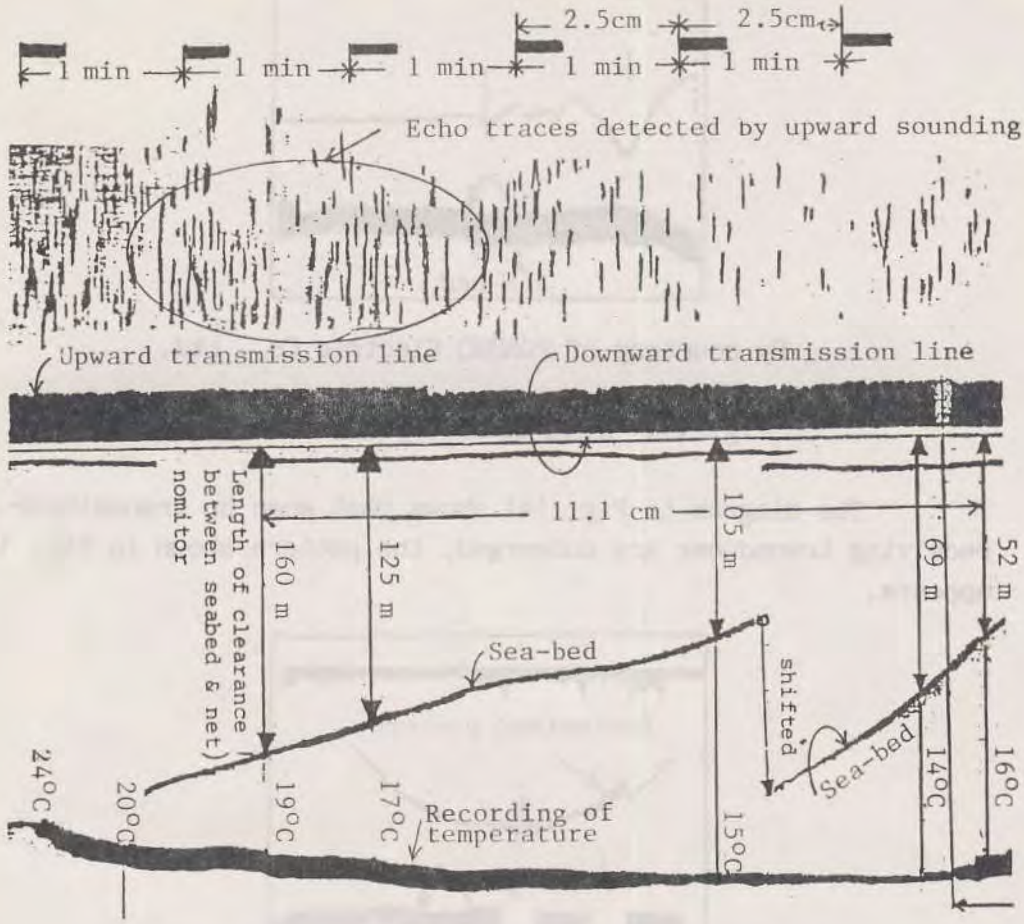


Fig. 143 Recording of trawl net monitor (1)

Fig. 143 Recording of trawl's net monitor, obtained by a 75 kHz transmitting and receiving transducer in 1971 off East Africa.

The recording shows that the trawl is being shot, the numbers in metres written on the recording, i.e., 160, 125, 105, 69 and 52 are distances between the sea-bed and the transducer of the net monitor mounted on the trawl's head rope as time elapses and it sinks down onto the sea-bed. From the recording the sinking speed of the trawl is; $\frac{60 \text{ min} \times (160\text{m} - 52 \text{ m})}{11\text{-}1 \text{ cm}/2.5 \text{ cm}} = 1459.5$ metres per hour = 24.3 metres per minute.

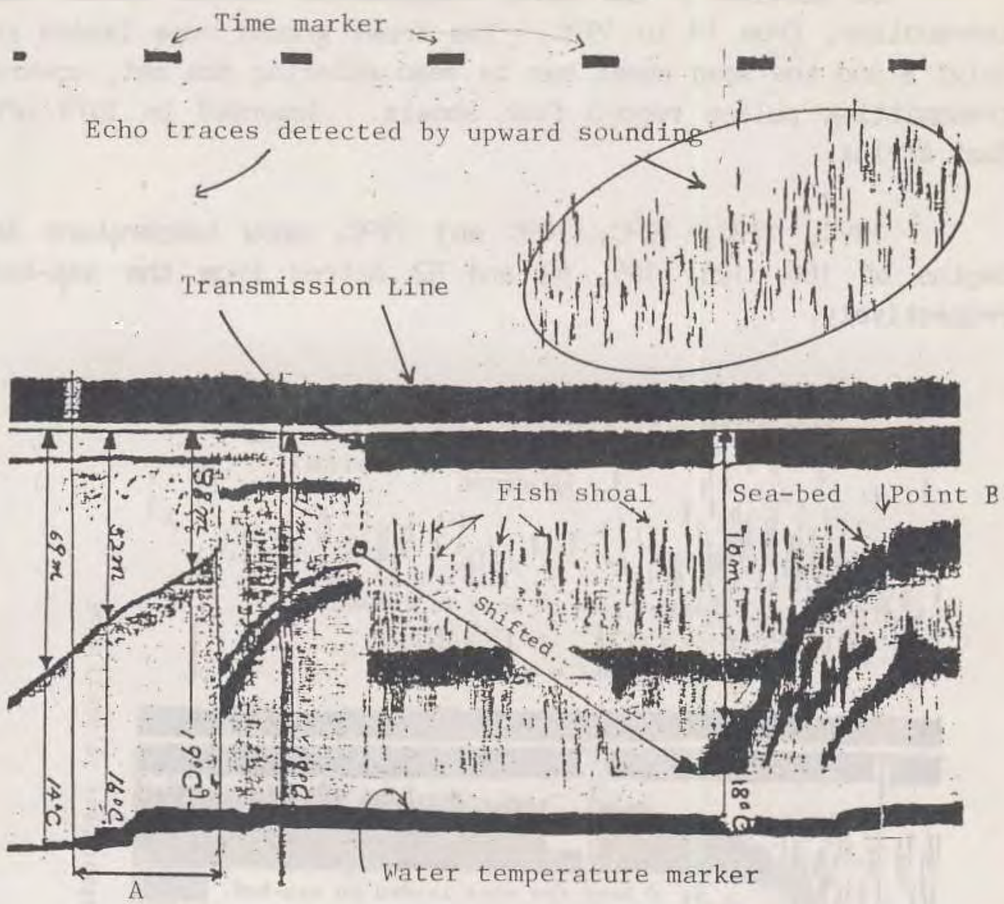


Fig. 144 Recording of trawl net monitor (2)

Fig. 144 Echo traces of a trawl net monitor recorded by a FURUNO 75 kHz transmitting and receiving transducer; the trace from the sea-bed, water temperature marker and fish shoals are recorded.

At section A the water temperature marker shows the thermocline, from 14 to 19°C. The trawl ground rope landed at point B and the scad shoal can be seen entering the net, upward transmitting pulses record fish shoals. Recorded in 1974 off East Africa.

19°C, 17°C, 15°C, 14°C and 16°C, show temperature at depths of 160, 125, 105, 69 and 52 metres from the sea-bed respectively.

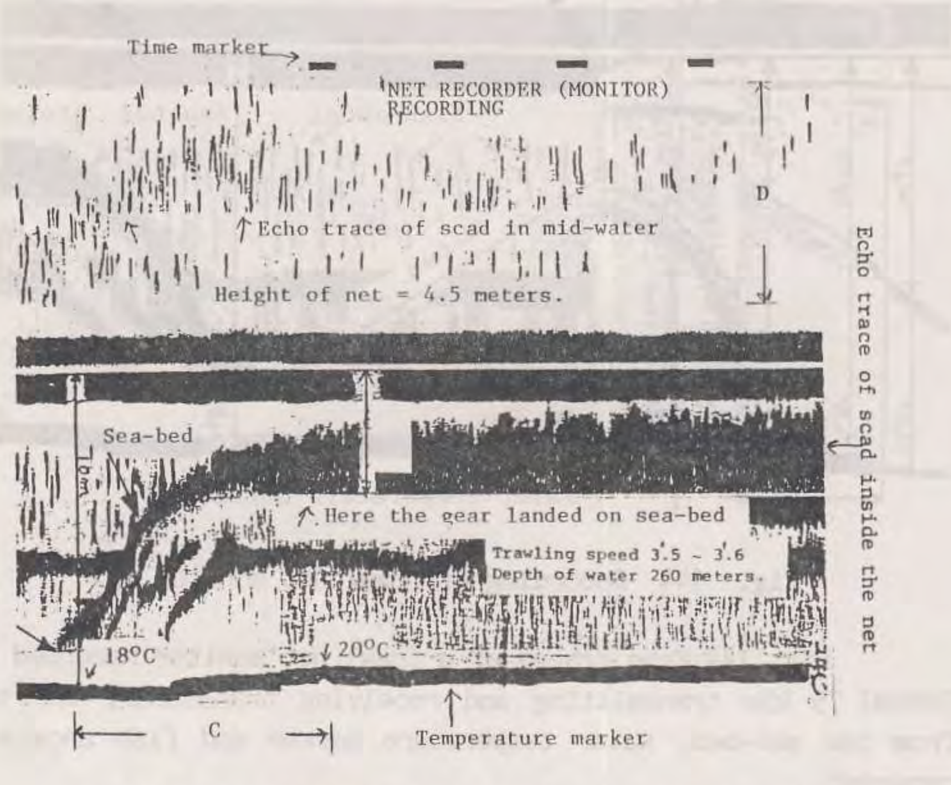


Fig. 145 Recording of trawl net monitor (3)

The echogram of the net monitor in Fig. 145 shows the trawl gear on the sea-bed at a depth of 260 metres. It has already started to catch the shoals of scad. The extent of the net's mouth opening is shown as 4.5 metres and a "Veil" echo trace from the scad shoal inside the net is indicated.

Section C shows the thermal discontinuities ranging from 18 to 20°C on the temperature marker.

Section D shows the trace of scad detected by upward sounding supersonic wave, recorded in 1974 off East Africa.

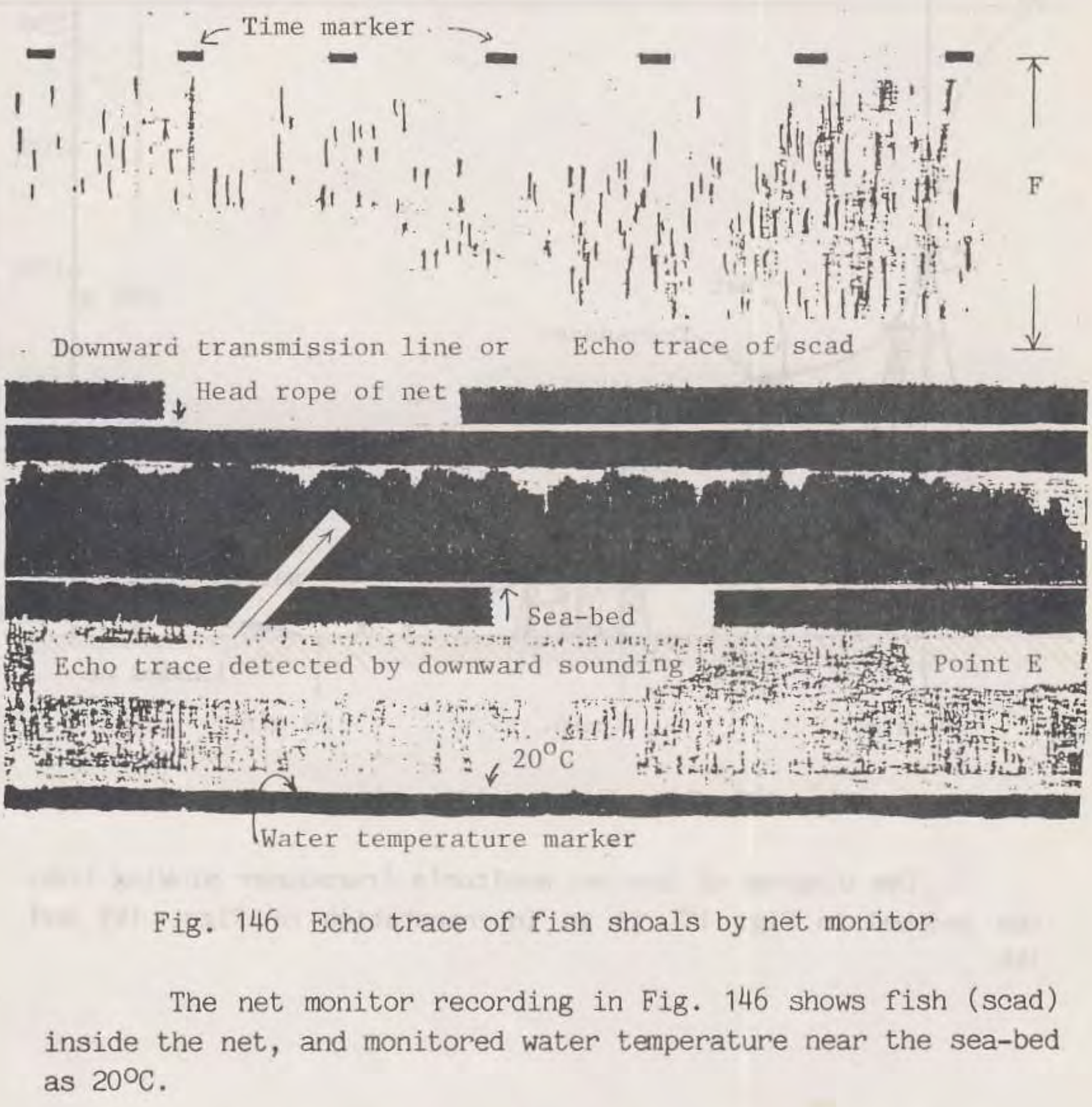


Fig. 146 Echo trace of fish shoals by net monitor

The net monitor recording in Fig. 146 shows fish (scad) inside the net, and monitored water temperature near the sea-bed as 20°C.

Point E (extreme right hand) in the echogram indicates the gear has been hauled up, recorded in 1974 off East Africa.

Section F shows the traces from scad detected by upward supersonic sounding wave.

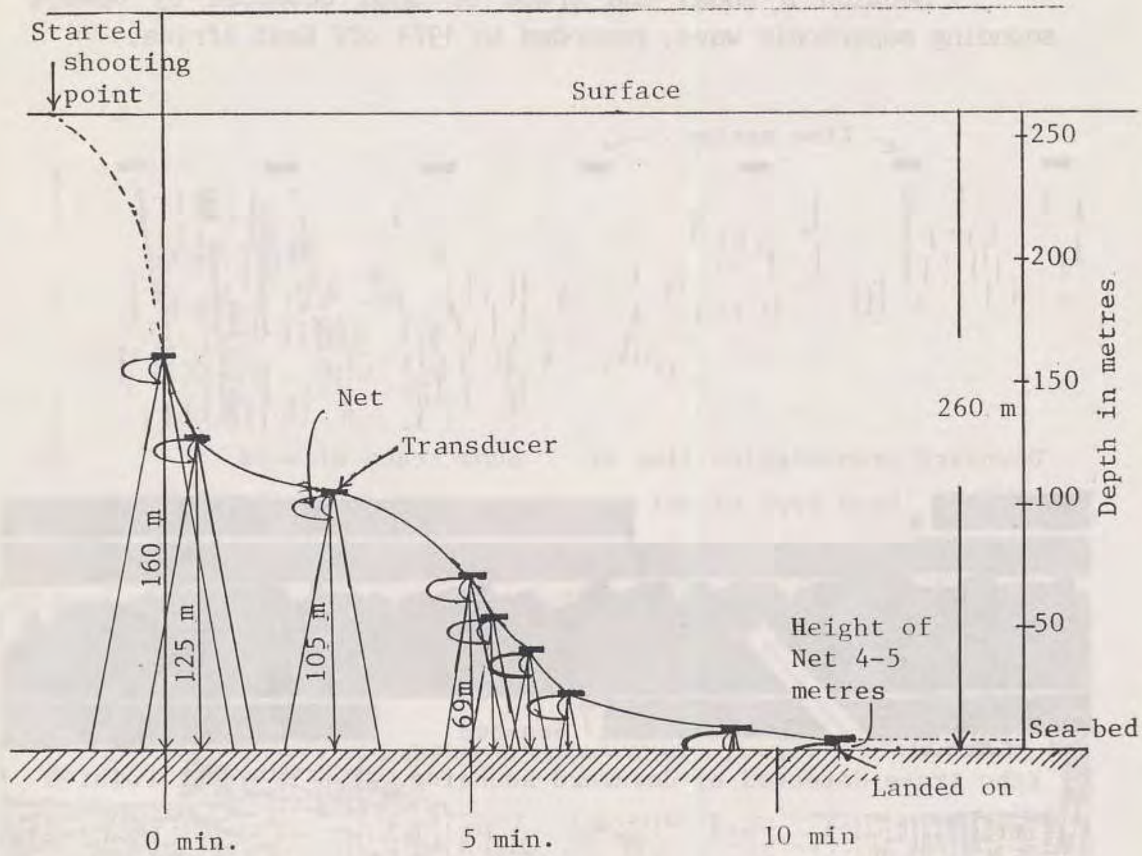


Fig. 147 Transducer sinking onto sea-bed

The diagram of the net monitor's transducer sinking onto the sea-bed in Fig. 147 is an interpretation of Figs. 143 and 144.

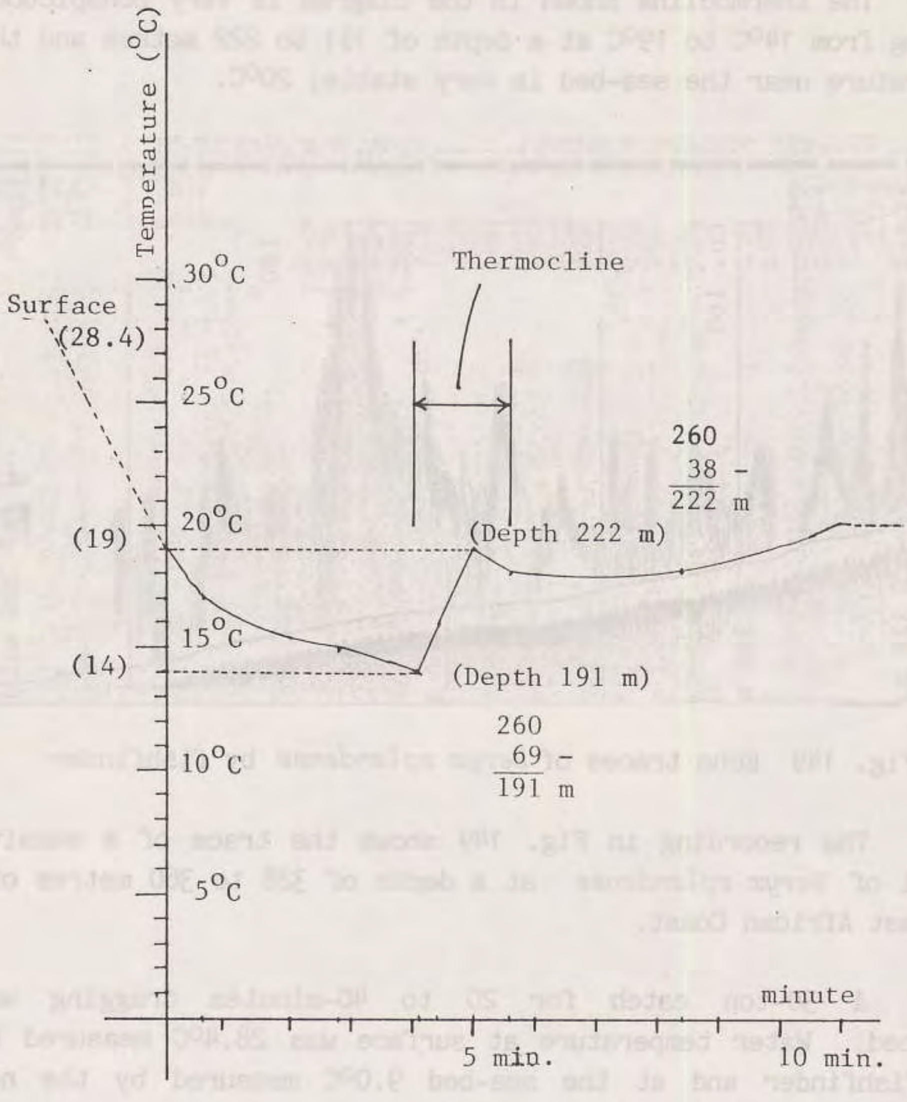


Fig. 148 Water temperature and elapsed time

The diagram in Fig. 148 shows water temperature in relation to time elapsing while shooting trawl gear, interpreted from the net monitor recordings of Figs. 143 and 144.

The thermocline shown in the diagram is very conspicuous ranging from 14°C to 19°C at a depth of 191 to 222 metres and the temperature near the sea-bed is very stable; 20°C.

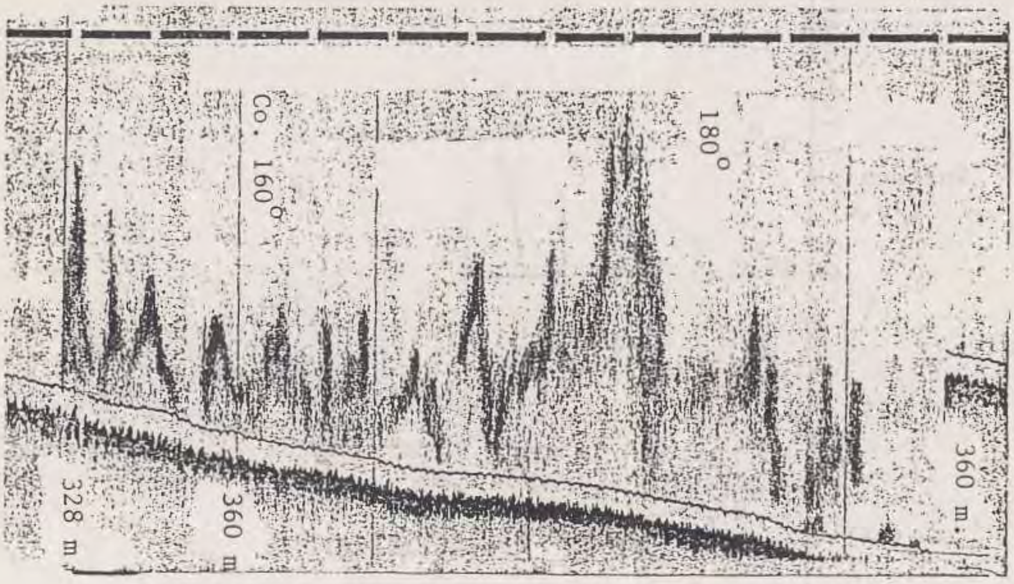


Fig. 149 Echo traces of *Beryx splendense* by fishfinder

The recording in Fig. 149 shows the trace of a massive school of *Beryx splendense* at a depth of 328 to 360 metres off the East African Coast.

A 30-ton catch for 20 to 40-minutes dragging was produced. Water temperature at surface was 28.4°C measured by the fishfinder and at the sea-bed 9.0°C measured by the net monitor, recorded by a 50 kHz fishfinder.

The vessel dragged its gear on the sea-bed as shown in Fig. 149 and the echogram recorded by the net monitor is shown in Fig. 150.

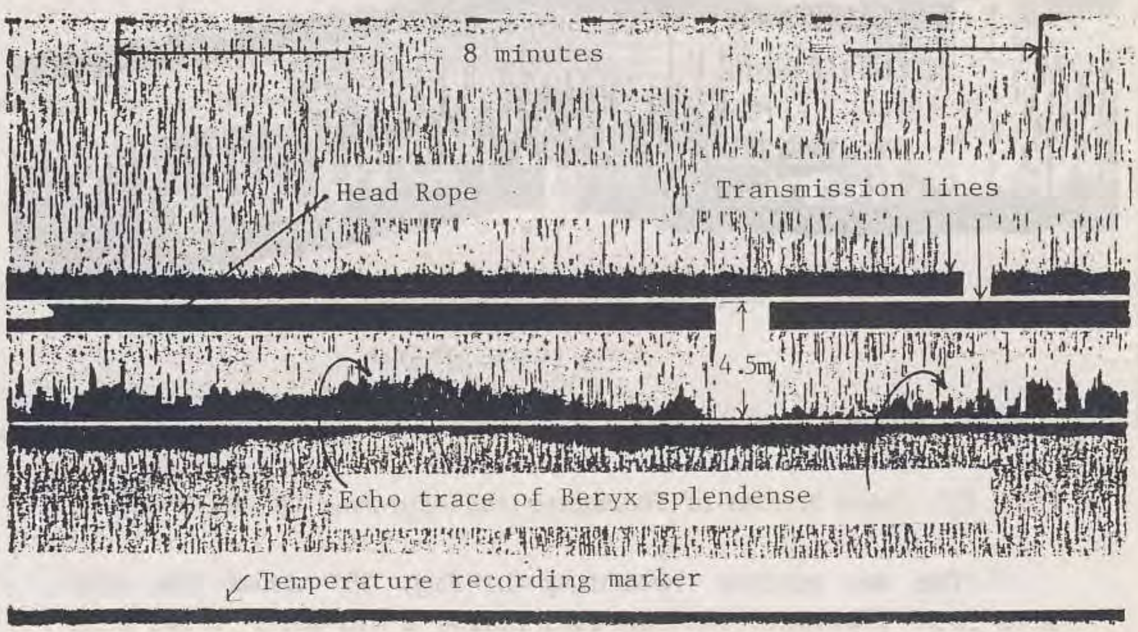


Fig. 150 Echo traces of *Beryx splendense* by net monitor

The net monitor recording in Fig. 150 shows echo traces of *Beryx splendense* inside the net. The extent of the net's mouth (from sea-bed to transducer) as 4.5 metres and water temperature at height of transducer - 4.5 metres from sea-bed - as 9°C. A 40-minute dragging period brought a 30-ton catch of *Beryx splendense*.

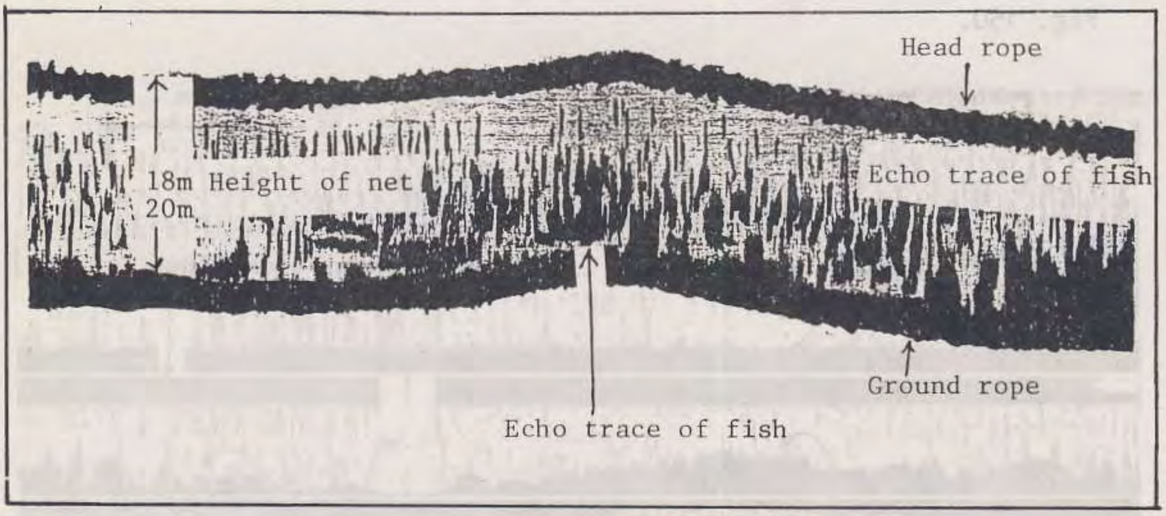


Fig. 151 Echo traces of *Theragara chalcogramma* by net monitor

The net monitor recording in Fig. 151 shows the echo traces from *Theragara chalcogramma* inside a mid-water trawl net. The opening of the net's mouth during dragging at a speed of four knots ranged from 18 to 20 metres, recorded by a 70 kHz net monitor (see Fig. 36).

The net's mouth opening is very stable and the echogram shows the gear is functioning well.

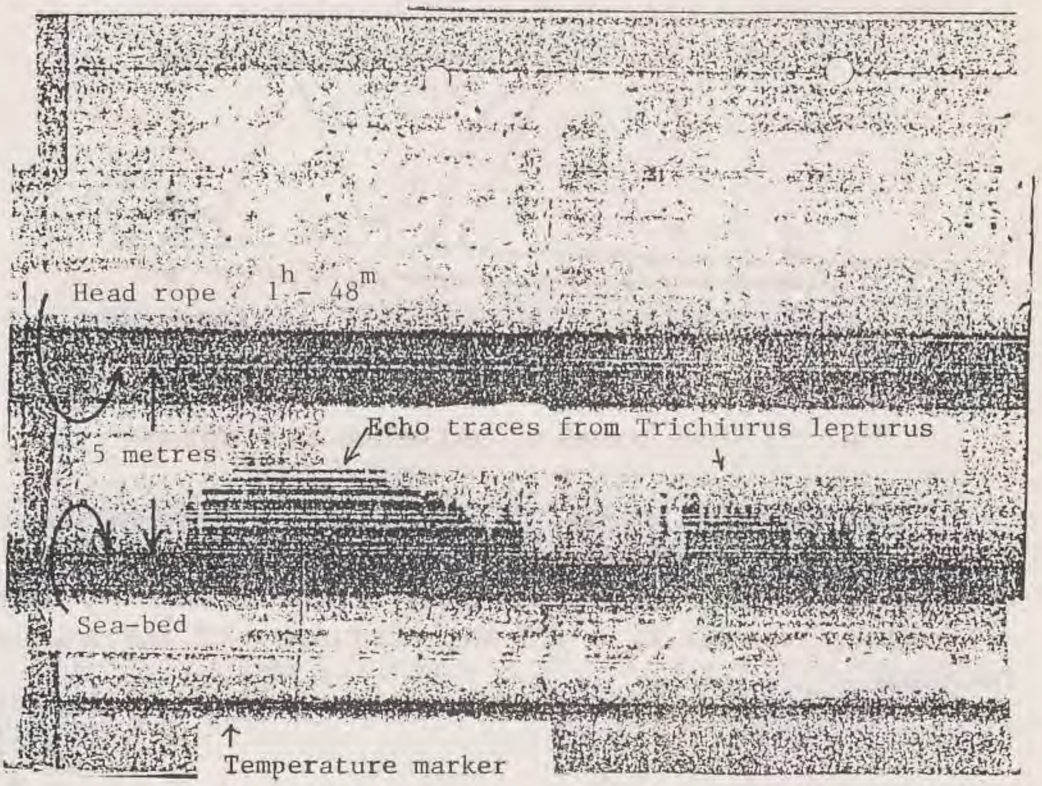


Fig. 152 Echo traces of *Trichiurus lepturus* by net monitor

The recording shown in Fig. 152 shows the echo traces from *Trichiurus lepturus* inside the net. 108 minutes of dragging brought a 6.1-ton catch, recorded by a FURUNO 70 kHz net monitor off the West African Coast on 3 Aug. 1970.

The echogram shows the opening of the net's mouth is 5 metres and very stable during dragging on the sea-bed.

If the echogram showed the extent of opening suddenly as zero metre or 2 metres or 10 metres and so on, there would have been some serious damage to the trawl.

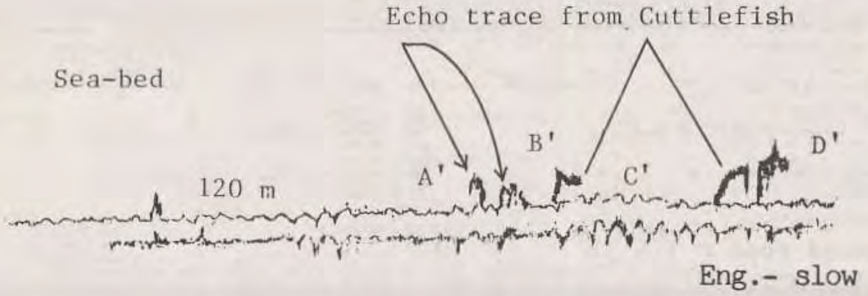


Fig. 153 Echo traces of cuttlefish by fishfinder

The echogram in Fig. 153 shows traces from shoals of cuttlefish, grouper and barracuda at a depth of 102 metres. 60 minutes dragging brought 6.6 tons of cuttlefish, 1.6 tons of grouper, recorded by a 200 kHz fishfinder off the Arabian Peninsula.

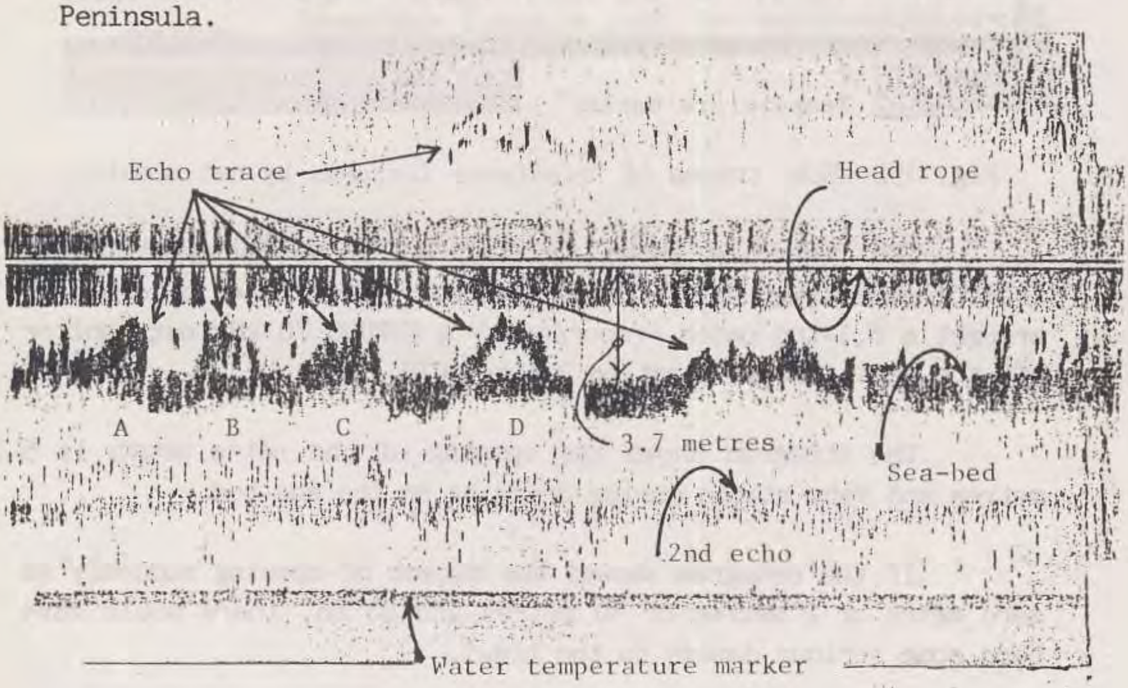


Fig. 154 Echo traces of cuttlefish by net monitor

Fig. 154 shows a net monitor recording, the echo trace marked by A in Fig. 154 corresponds to the echo trace marked by A' in Fig. 153, B to B', C to C' and D to D' during dragging of the trawl. Height of opening of net's mouth was 3.7 metres.

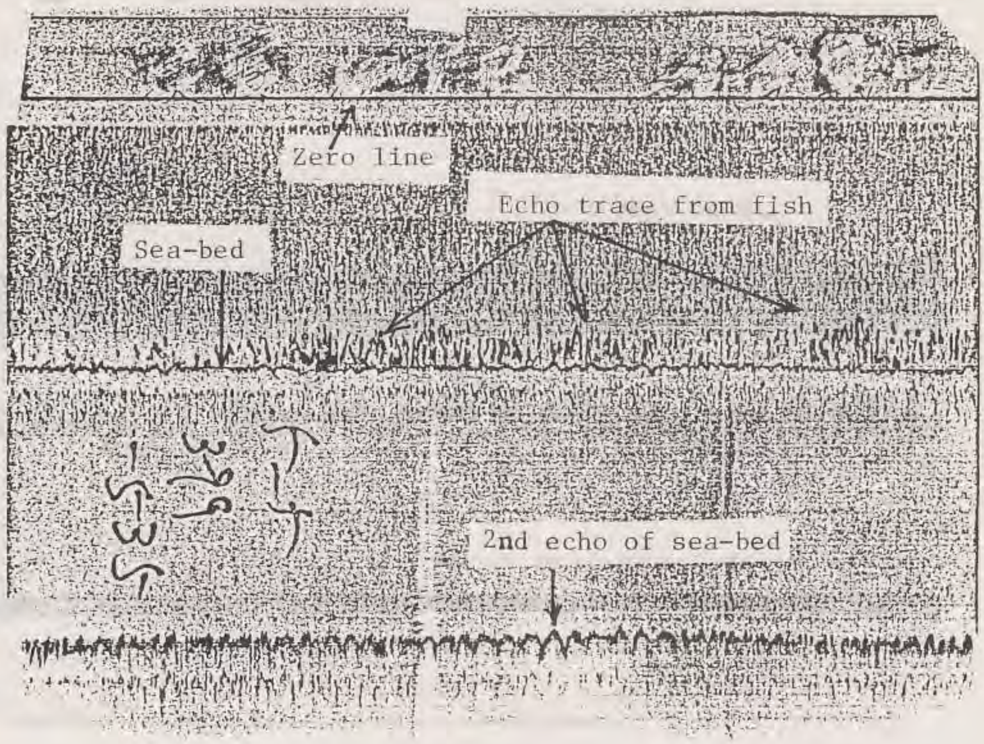


Fig. 155 Echo traces of *Nemipterus virgatus* by fishfinder

The recording in Fig. 155 shows the echo traces of *Nemipterus virgatus*, recorded by a FURUNO 200 kHz fishfinder during scouting for fish shoals. To detect *Nemipterus virgatus* with a 50 kHz fishfinder is quite difficult, therefore, it is important to select the appropriate value of fishfinder frequency; low or high frequency depending on species of fish.

The recording shows thin and "pin-like" traces from a very dense and concentrated shoal, because 20 minutes of dragging produced a 15-ton catch. As shown in Fig. 155 the echo traces from threadfin bream are quite different from those of cuttle-fish, squid, scad, etc..

After detecting the presence of dense shoals of *Nemipterus* with the fishfinder. The boat shot the gear and the net monitoring system recorded echo traces as shown in Fig. 156.

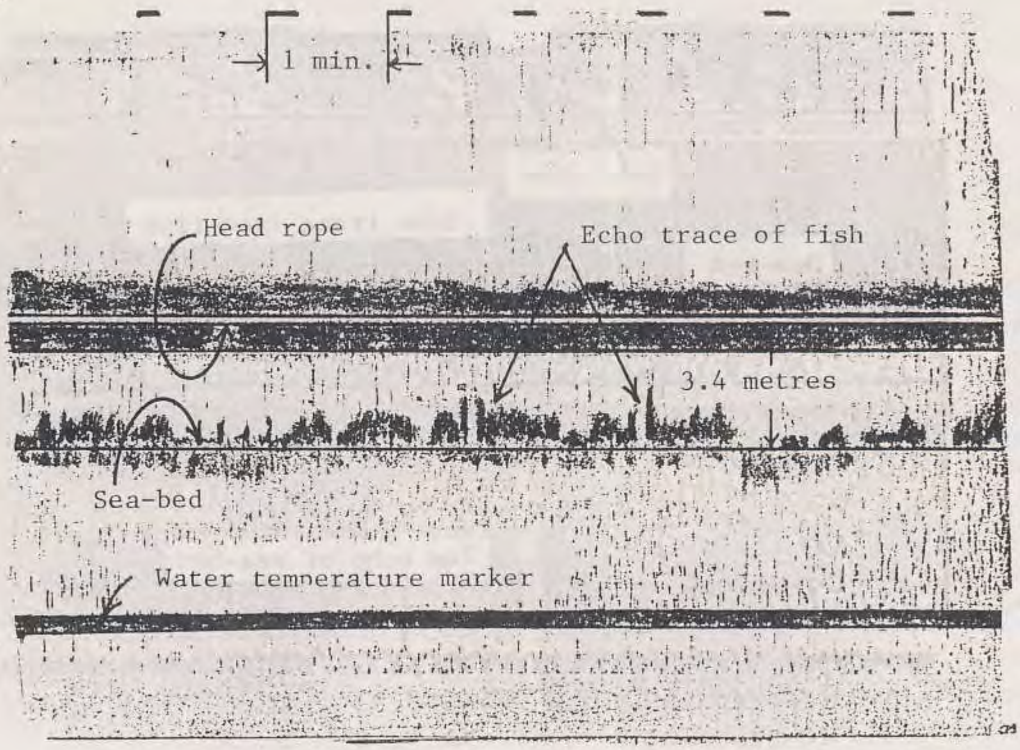


Fig. 156 Echo traces of *Nemipterus virgatus* by net monitor, recorded by a 75 kHz net monitor transmitter. Extent of net mouth opening was 3.4 metres and stable while dragging.

The sea-bed of the fishing ground is over the continental shelf of the Arabian Peninsula, therefore, it is very flat as shown in Fig. 155. But the sea-bed on guyots or seamounts is hilly or precipitous and the echogram of the net monitor would be different, as shown in Fig. 157.

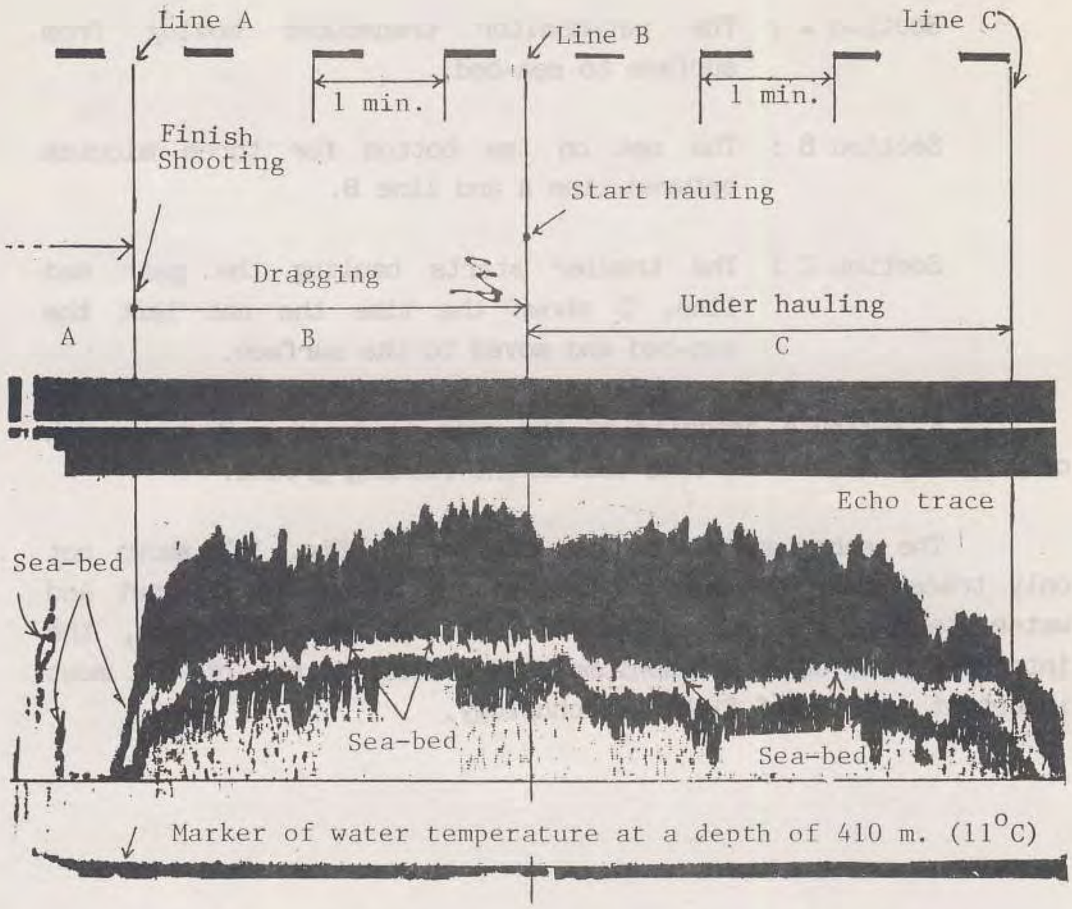


Fig. 157 Echo traces of *Beryx splendense* by net monitor

The net monitor recording in Fig. 157 shows the net pattern motion, temperature at height of net's head rope (or at the transducer's position), the sea-bed and echo traces from demersal fish species : *Beryx splendense*, recorded by a 75 kHz transducer.

Section A : The net-monitor transducer moving from surface to sea-bed.

Section B : The net on the bottom for three minutes between line A and line B.

Scetion C : The trawler starts hauling the gear and line, C shows the time the net left the sea-bed and moved to the surface.

A 3-minute dragging of the gear produced a 30-ton catch of *Beryx splendense* at this tablemount fishing ground.

The echogram of the net monitor in Fig. 157 shows not only traces of fish shoals but also the motion of the net and water temperature where fish shoals inhabit, therefore, the interpretation of a net-monitor's recording is one of the most important aspects of fishing technology.

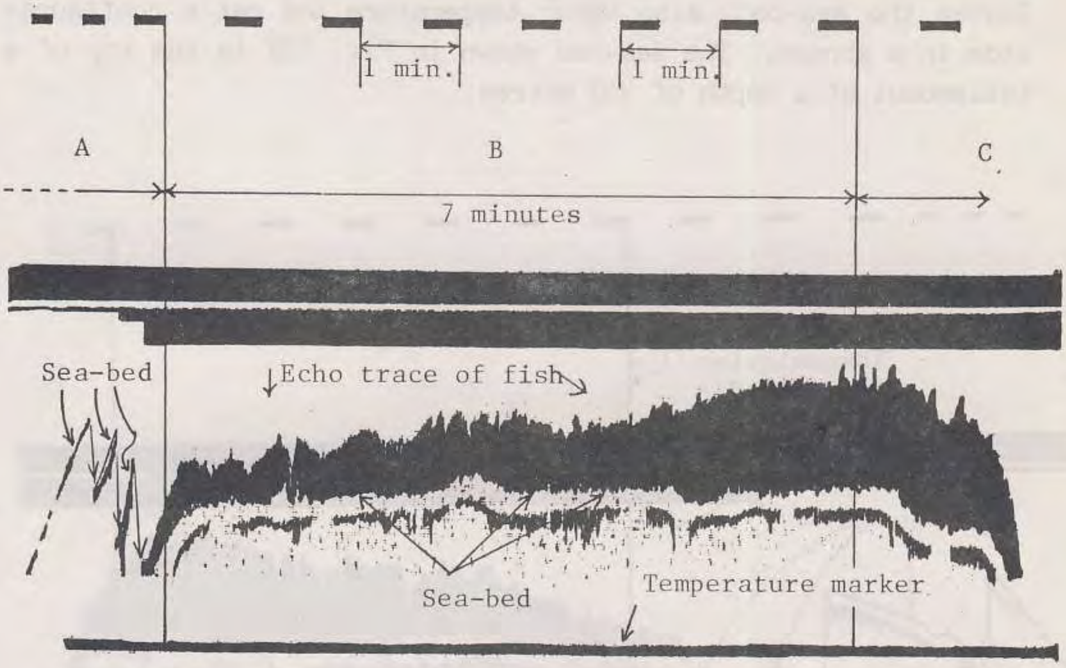


Fig. 158 Echo traces of *Beryx splendense*, water temperature and sea-bed by net monitor (1)

The net monitor recording in Fig. 158 shows an operation trace which resulted in a 12-ton catch of *Beryx splendense* after dragging for 7 minutes at a tablemount in 1981, recorded by a 75 kHz transducer.

Section A : During the shooting of the gear and as it is approaching the sea-bed.

Section B : Net landing on the sea-bed and dragging

Section C : Starting hauling the gear up.

A net monitoring system shows when the gear lands and/or leaves the sea-bed, also water temperature and net's configuration in a stream. The sea-bed shown in Fig. 158 is the top of a tablemount at a depth of 410 metres.

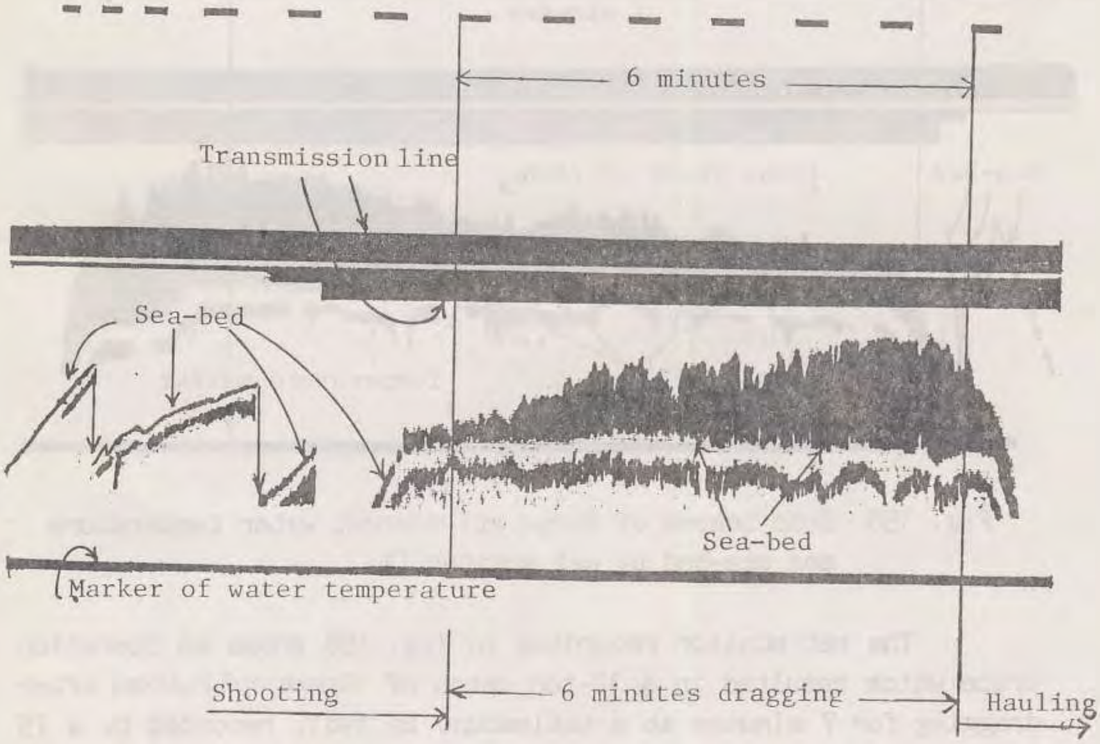


Fig. 159 Echo traces of *Beryx splendense*, water temperature and sea-bed by net monitor (2)

Net monitor recording in Fig. 159 shows an echo trace of a 12-ton catch of *Beryx splendense* taken at tablemount fishing ground, recorded by 75 kHz transducer.

The echogram in Fig. 159 clearly shows the motion pattern of the fishing gear under shooting, dragging and hauling conditions. The net monitoring system sends signals not only of echo traces of fish inside the net and formation of net but also the distance from the sea-bed to the net.

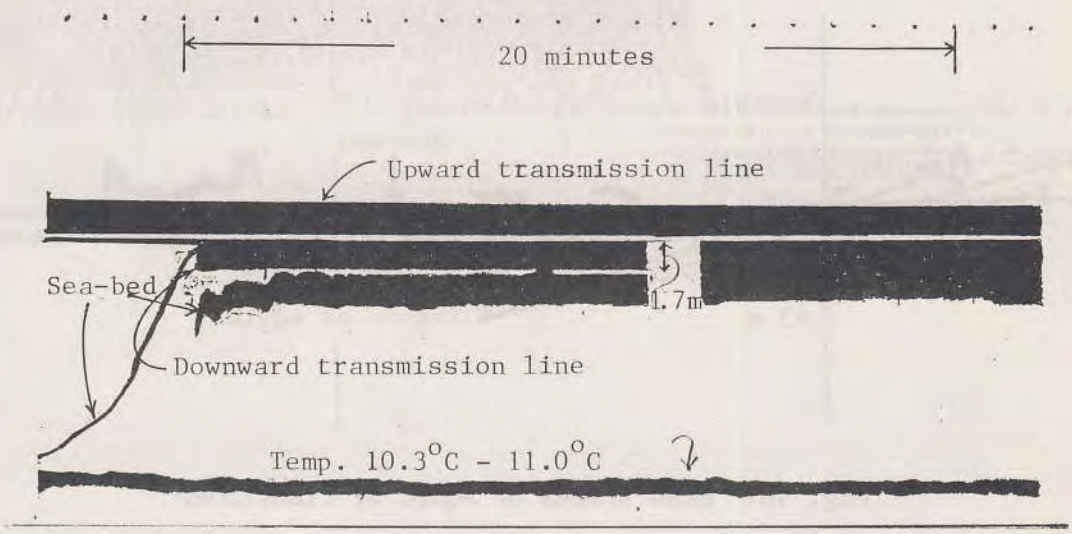


Fig. 160 Echo traces of sea-bed and water temperature by net monitor of deep-sea lobster trawl by net monitor.

The net monitor recording in Fig. 160 shows that the net mouth opening is 1.7 metres. If the height of net is less than 1.7 metres, this net monitor could not show it on the recording chart but only by cathode ray tube. The temperature marker shows 10.3°C to 11.0°C near the sea-bed (1.7 metres from the sea-bed) at a depth of 360 metres off East Africa.

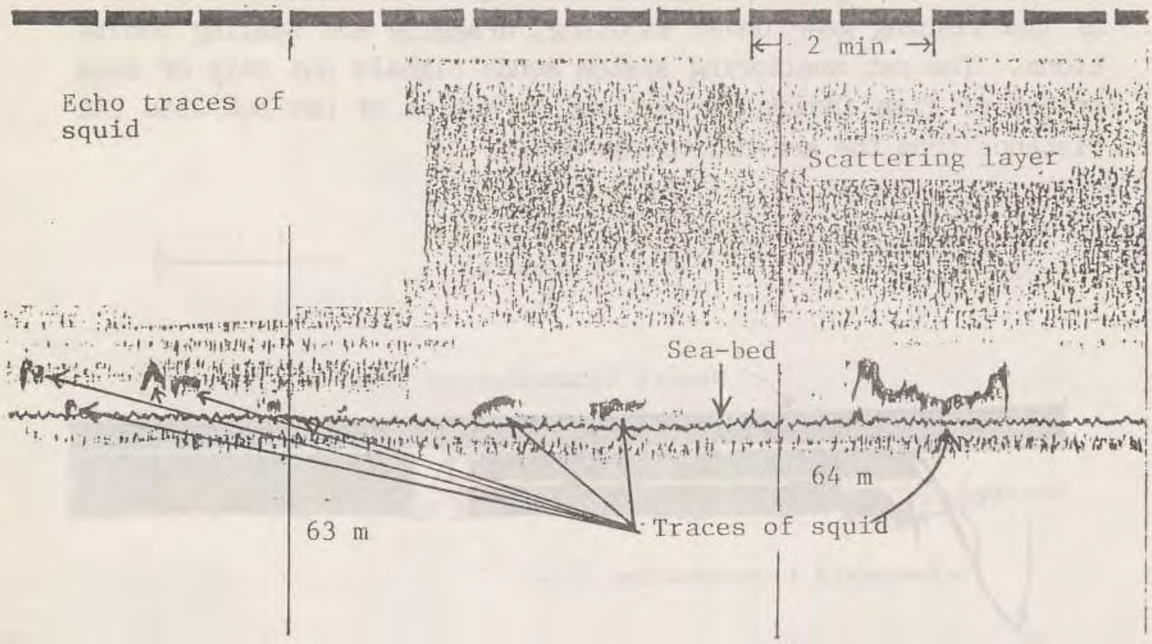


Fig. 161 Echo traces of squid by fishfinder

The fishfinder recording in Fig. 161 shows traces of concentrated shoals of squid at a tablemount fishing ground, recorded by a 200 kHz fishfinder.

Temperature at surface was 27.4°C detected by the fish-finder, at sea-bed 15.5 to 18.0°C detected by net monitor's sensor with current direction northerly. The echo traces from the shoals of squid are shown as a "veil" formation.

After detecting the squid shoals, the trawler shot her gear onto the sea-bed and monitored the extent of the net's mouth opening, water temperature and whether the gear was catching squid shoals or not as shown in Fig. 162.

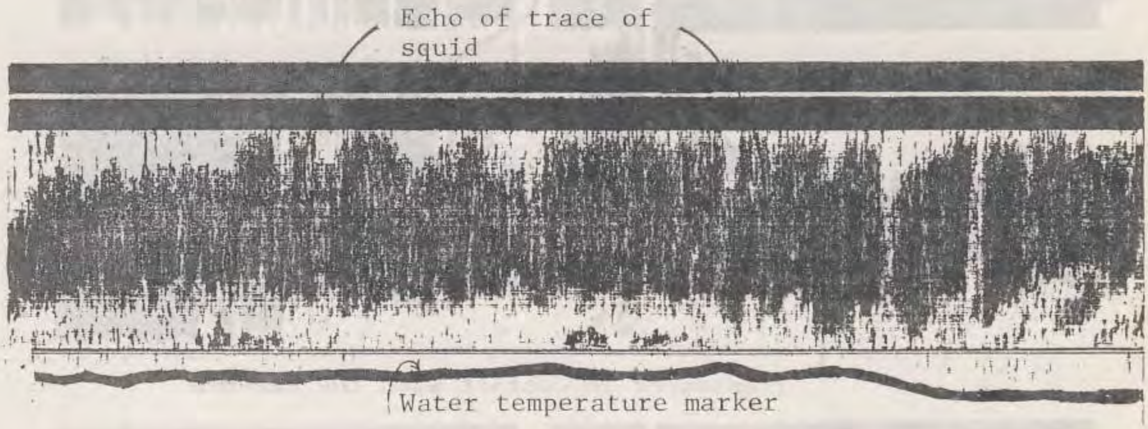


Fig. 162 Echo traces of squid and water temperature by net monitor

The echogram in Fig. 162 shows traces of squid entering the trawl net at a depth of 63 metres and water temperature 15.5°C to 18.0°C by temperature marker, recorded by a 75 kHz transducer.

The water temperature marker is wavy, not stable, this shows that the water-mass near the sea-bed consits of thermally different masses because of an up welling current. The fishing ground is a seamount. A 35-minute dragging period produced a 12-ton catch of squid.

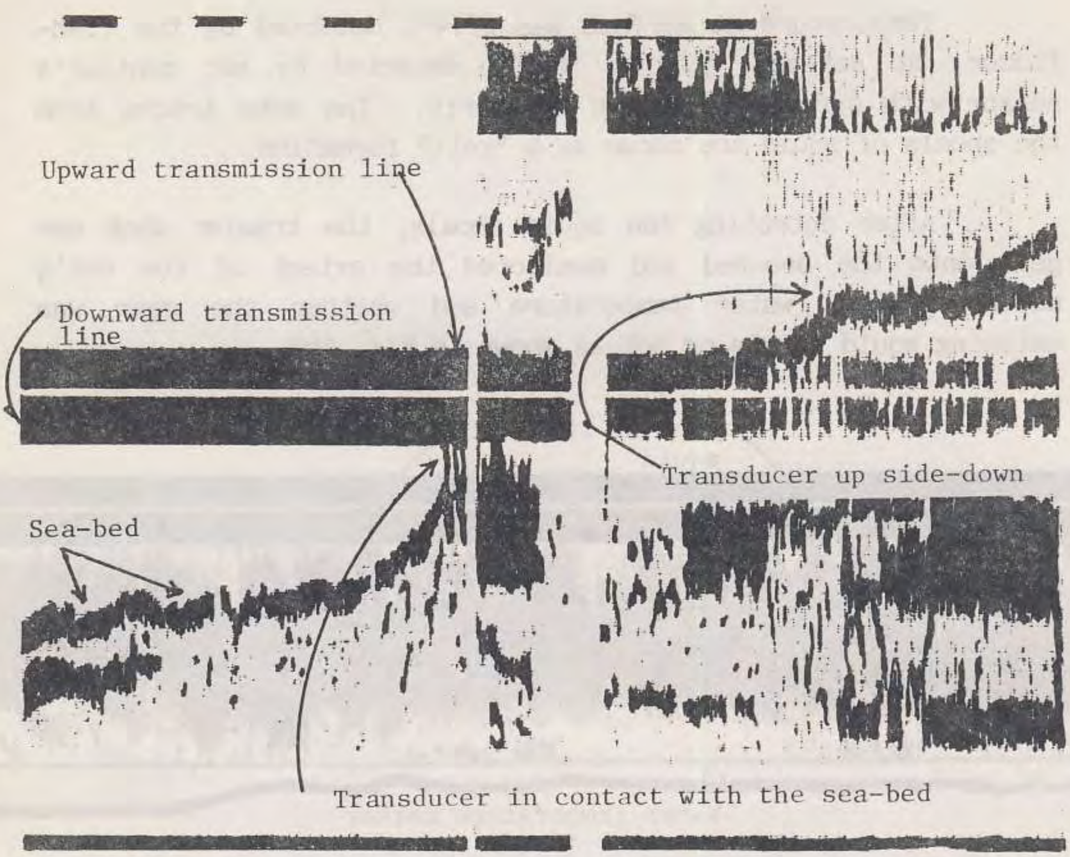


Fig. 163 Echo traces of damaged net recorded by net monitor (1)

The echogram of the net monitor in Fig. 163 shows that the net has come stick fast on an obstacle on the sea-bed (i.e. rock, reef, sunken ship, etc.).

The trawl net was designed to maintain the net's mouth opening during dragging on the sea-bed at 4.0 metres. But as shown in Fig. 163 the extent of the net's mouth was sometimes over 4.0 metres and sometimes zero metre. The right of the recording shows much noise above and under the transmission lines. In this case the net has been seriously damaged and has lost its catching function, recorded by a 75 kHz fishfinder.

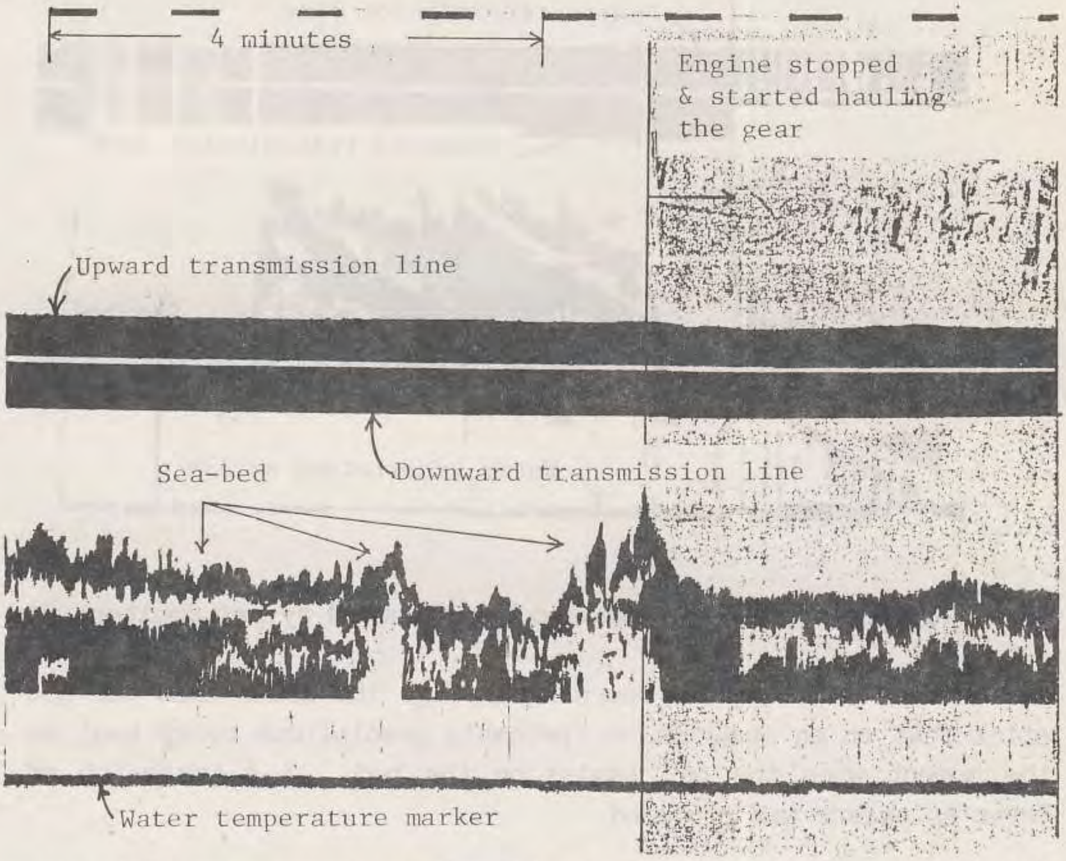


Fig. 164 Echo traces of damaged net recorded by net monitor (2)

The echogram of the net monitor shown in Fig. 164 shows that the net has come stick fast on an obstacle on the sea-bed during dragging and is slightly damaged, recorded by a 70 kHz transducer.

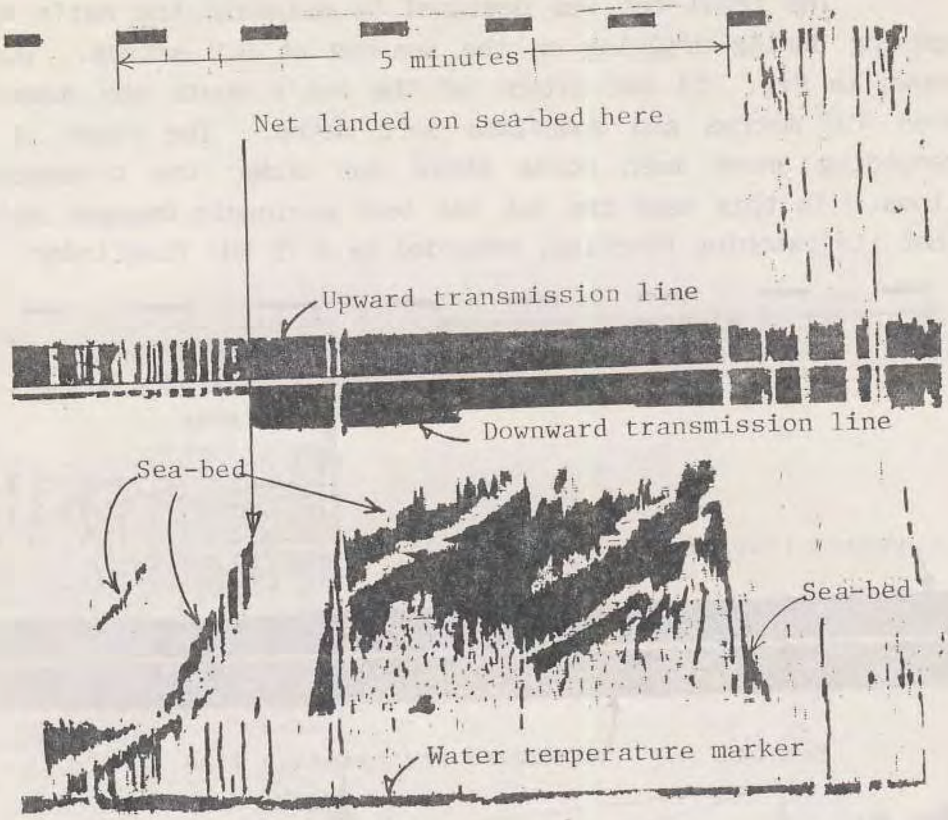


Fig. 165 Echo traces of damaged net recorded by net monitor (3)

The net monitor recording in Fig. 165 shows that the net stick fast on an obstruction (probably precipitous rocky bed) at the moment when the net landed on the bed. A 6-ton catch of *Beryx splendens* was produced.

If the net monitor recording displays such traces, we have to haul the net up immediately because the gear has lost its catching function.

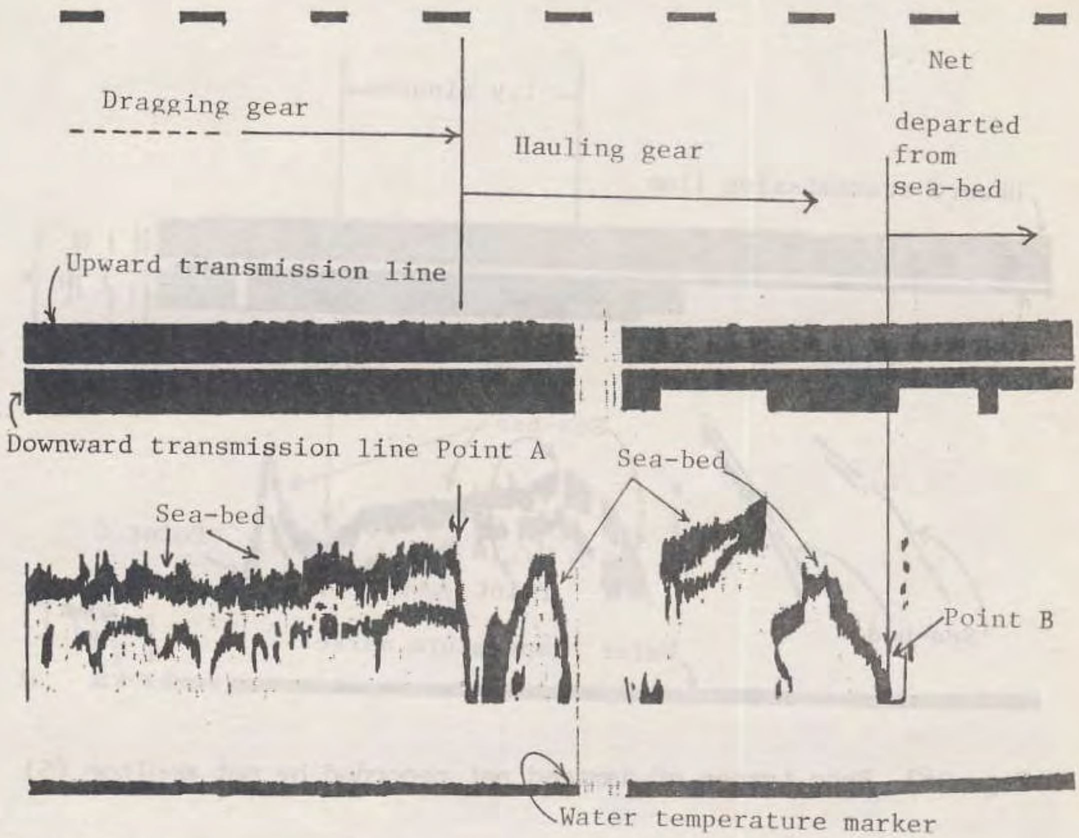


Fig. 166 Echo traces of damaged net recorded by net monitor (4)

The net monitor recording in Fig. 166 shows that the net has stick fast during dragging on an obstacle on the sea-bed at point A.

The trawler started hauling the gear up at point A and at point B the net was released from the obstacle on the sea-bed.

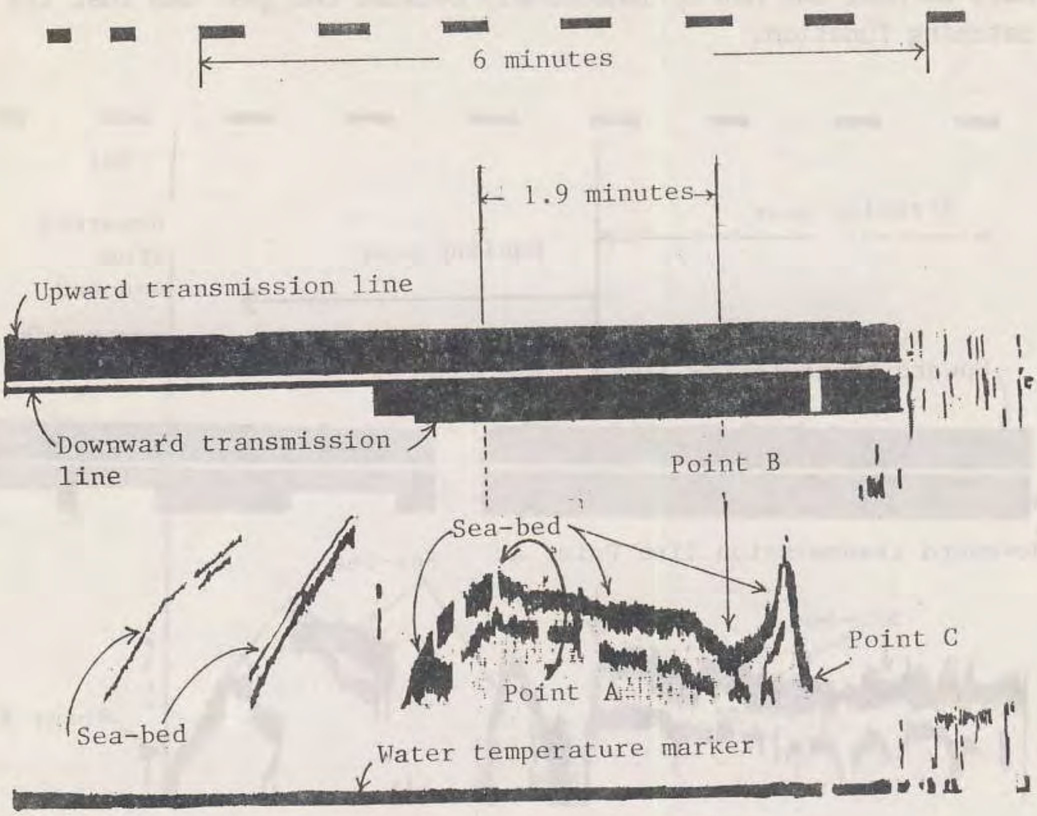


Fig. 167 Echo traces of damaged net recorded by net monitor (5)

The net monitor recording in Fig. 167 shows that the net has come fast upon the precipitous sea-bed on top of a tablemount after 1.9 minutes of dragging. The gear is seriously damaged, recorded by a 75 kHz transducer in 1981.

In Fig. 167 at point A, the net landed on the sea-bed and the boat started dragged the gear for 1.9 minutes, at point B the net had a strong shock and was seriously damaged. At point C the gear was released from the precipitous sea-bed because the distance between the transducer (transmission line) and the sea-bed is more than 10 metres and the transducer is moving towards the surface.

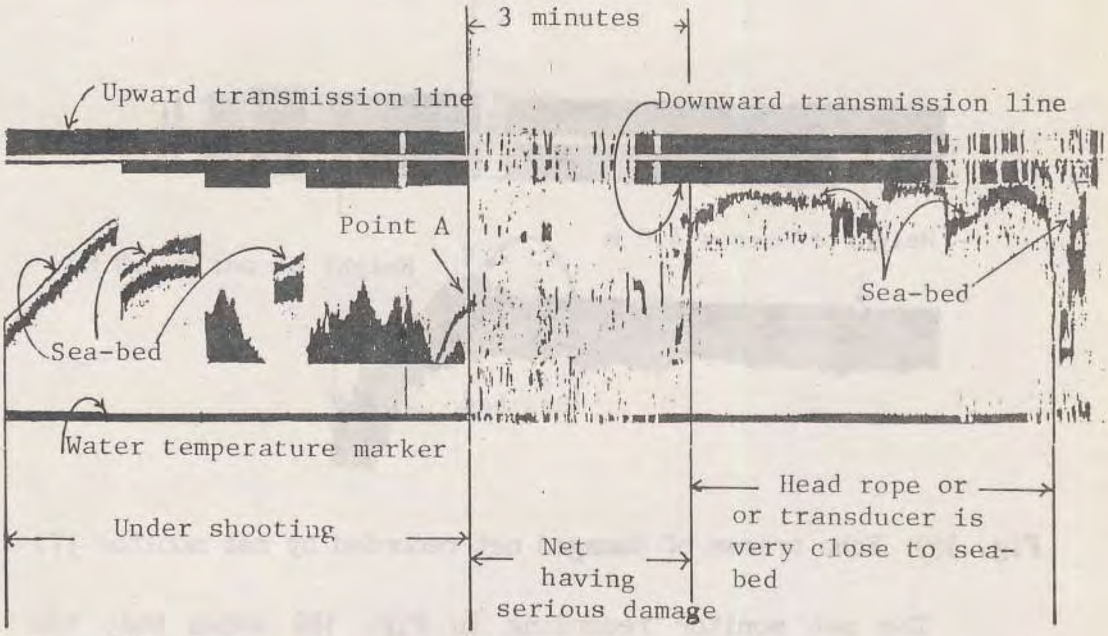


Fig. 168 Echo traces of damaged net recorded by net monitor (6)

The net monitor recording in Fig. 168 shows that the net is seriously damaged after it landed on the sea-bed at point A in Fig. 168. The right hand of the recording shows the height of net mouth as less than 2 metres, recorded by a 70 kHz transducer.

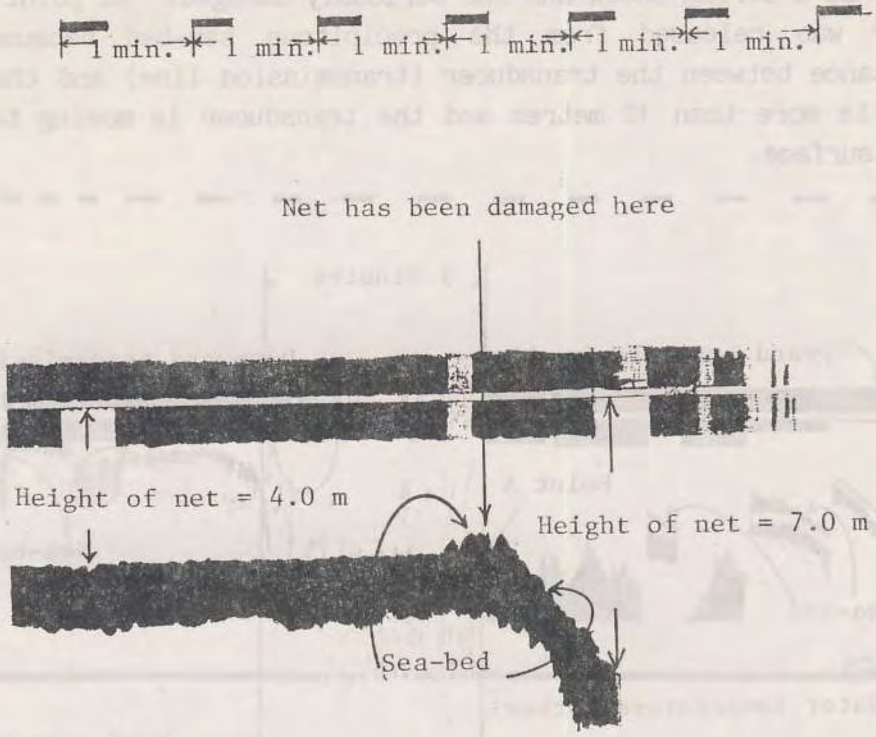


Fig. 169 Echo traces of damaged net recorded by net monitor (7)

The net monitor recording in Fig. 169 shows that the extent of the net's mouth opening suddenly increased from 4 to 7 metres and the ship's speed reduced because the gear was seriously damaged, recorded by a 75 kHz transducer.

The echogram shows a trace pattern when the gear is damaged during dragging different from the patterns shown in Figures 163, 164, 165, 166, 167 and 168.

Part 4 Final part

The trainees and/or participants of the Courses should understand that hydroacoustic devices are utilized not only for detecting and scouting shoals of fish and sounding the depth of water but also for observing fish behaviour, and the formation and motion of submerged fishing gear : longline, squid jig, purse seine, mid-water and bottom trawl.

These devices record layers of oceanic organisms, thermal discontinuities : thermoclines; junction line between two ocean currents, eddy currents; water temperature at surface, mid-water, water near sea-bed, etc..

If the readers become familiar with echo traces and devices and have both the theoretical knowledge and experience, they can discriminate a hard sea-bed from a soft one, seaweeds and a mud-sand sea-bed also echo traces of cuttlefish from those of squid, threadfin bream from starry emperor snapper, tuna from katsuwonus, "hyperbolic" traces, etc..

In addition they could acoustically analyze the fishing grounds under their management. In the field of marine fishing it could be top priority to have sufficient knowledge of fishing grounds scientific methods and have experience. It is desirable to distribute the knowledge obtained to local fishermen.

After obtaining topographic data we could design fishing gear, select a certain ground where to set up stationary trap nets (Otosi-ami), artificial reefs, Payaw and so on.

Next, applications of hydroacoustic devices are introduced, the net monitor's transmitter, for instance, could be applied to measure the space between otterboards during dragging (see Fig. 170).

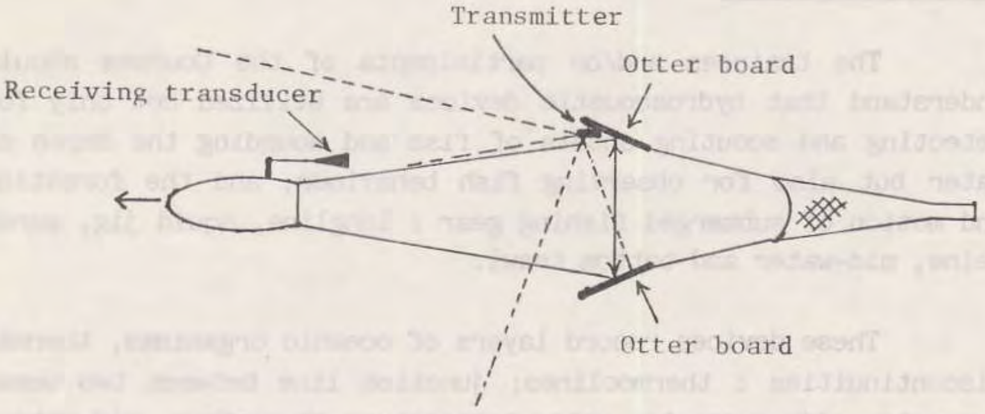


Fig. 170 Acoustic measurement of distance between otter-boards by net monitor.

Also the net monitor's transmitter could detect fish shoals under Payaw and transfer signals of the shoals to the net monitor recorder (see Fig. 171).

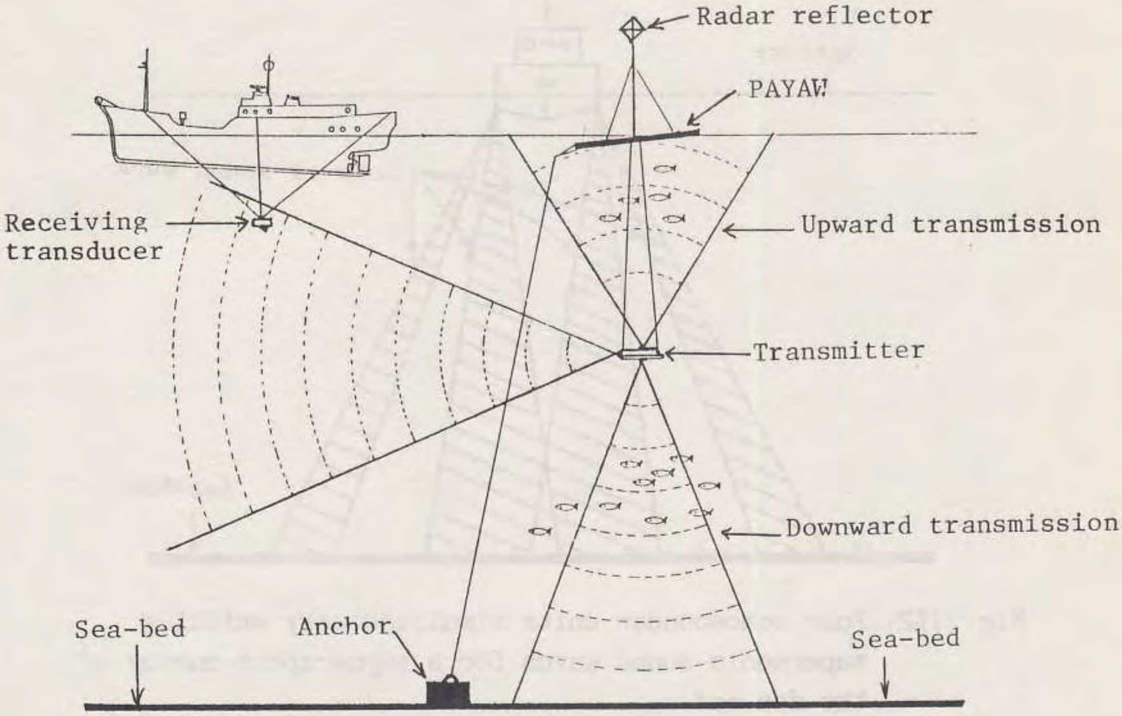


Fig. 171 Net monitor's transmitter beneath the Payaw sending signals of fish shoals.

In the past for topographic surveys of the sea-bed, we used only one echosounder for a long time, but nowadays three or four units are being utilized simultaneously for sounding. This sounding method is more effective and convinient when analyzing fishing grounds topographically, in particular, in the vicinity of the coast (see Fig. 172).

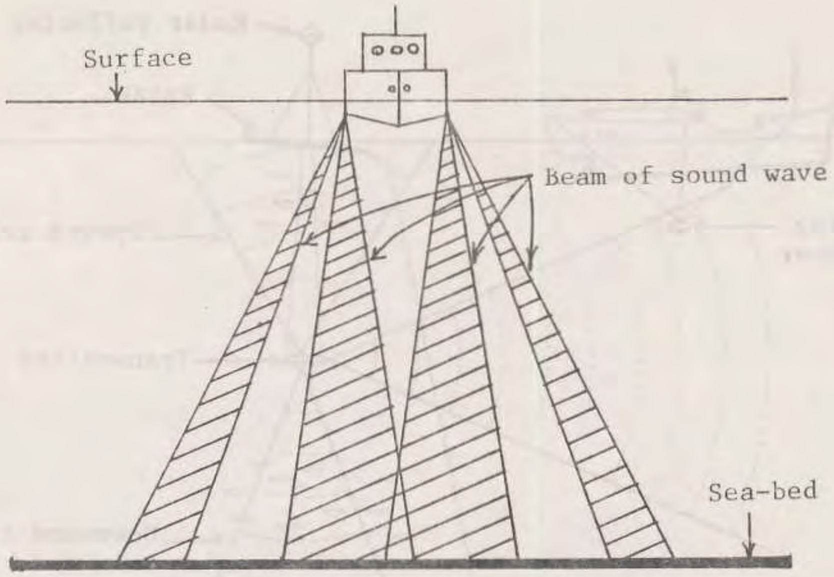


Fig. 172 Four echosounder units simultaneously emitting supersonic sound waves for a topographic survey of the sea-bed.

On the other hand, since as a rule the velocity of sound waves (Vs) in salt water is calibrated at 1500 metres per second (1500 ms^{-1}) and if precise depth measurement is required the depth of water obtained by the echosounder should be calibrated by means of a "Bar check" or according to salinity; temperature; and depth of water because the velocity of a sound wave in salt water is largely linked with salinity, temperature and depth.

If the velocity of a sound wave in salt water is not 1500 ms^{-1} in the surveyed area, we should calculate true velocity to know the true depth of water. The velocity could be calculated by the following formula:

$$V_S = \frac{1}{D}\left\{(\int_0^D V_{35},\ 0,\ d\ dD + \int_0^D C_G.\ dD + \int_0^D (C_s + C_t + C_{std})\ dD\right\}$$

where : V35, 0, d, → Velocity when temperature $0^{o}C$, salinity 35% at a depth;

C_g → Correction for gravity;

C_s → Correction for salinity;

C_t → Correction for temperature;

C_{std} → Correction for salinity & temperature at a depth;

D → Depth; $D = \frac{1}{2} V_m T$

V_m = Mean velocity,

T = the measured time interval between transmission and reception.

Here is another empirical formula to compute the velocity as follows:

$$Vs = (1410 + 4.21t - 0.037t^2 + 1.14S + 0.0182d)\ m\ sec^{-1}$$

where : Vs = propagating velocity of sound wave in salt water
t = temperature (°C);
S = salinity (%)
d = depth of water (m).

Please recall following equations:

1) $f = 1/T$ where; T = period of a wave,
f = frequency of the wave,

2) $v = \lambda/T$ where; λ = the wavelength
ν = the velocity of the wave

Ref: λ the Greek letter lambda.

By applying Equations 1) and 2)

$$\nu = \frac{\lambda}{\frac{1}{f}} = f\lambda \quad \text{or } \lambda = \frac{\nu}{f}$$

When the propagating velocity of sound in salt water is 1500 ms^{-1}, the wave length ( ) could be:

$$\lambda = \frac{1500 \times 100}{f} \text{ cm. (centimetres)}$$

Therefore if a fishfinder's frequency is 10 khz (Kilo-Herz), the wavelength $\lambda = \frac{1500 \times 100}{10,000} = 15$ cm.

30 kHz : $\lambda = \frac{1500 \times 100}{30,000} = 5$ cm.

40 kHz : $\lambda = \frac{1500 \times 100}{40,000} = 3.75$ cm.

200 kHz : $\lambda = \frac{1500 \times 100}{200,000} = 0.75$ cm.

The aforementioned calculations explain that a high frequency such as 200 kHz gives better "selectivity" of echo traces from submerged objects than a low frequency.

"Penetration" of sound wave in water is shown by the equation:

$$P = 4.2 \frac{10^{13}}{f^2} \text{ metres,}$$

therefore, if the frequencies are respectively; $f_1 = 10^2$, $f_2 = 10^3$, $f_3 - 10^4$ and $f_4 = 10^5$, the "penetration" would be respectively; P_1 = 4,200,000 Kilometres, P_2 = 42,000 Kilometres P_3 - 420 Kilometres and P_4 = 4.2 Kilometres.

Ref: In case of $f_2 = 10^3$, $P = 4.2 \times \frac{10^{13}}{(10^3)^2}$ = 42,000,000 metres

= 42,000 Kilometres.

This explanation shows that it is appropriate to sound a deep sea-bed with a low frequency.

Needles to say the basic knowledge of acoustics : attenuation, decibels, propagation of acoustic energy and resistance; salinity, temperature and depth of water; reflection of sea-bed's surface or submerged objects and reverberation; reflection and refraction; beam angle and directivity; wave length, pulselength and selectivity; frequency, period and wave-length; transmission and reception; aeration and cavitation; transmitting and receiving transducer and its position; digital display, analogue display, chart display or visual display, etc., is essentical. Would you please study further the aforementioned items with other reference books or textbooks.

Ref: The position of the fishfinder's transducer on the ship's hull bottom should be marked by a nameplate on the hull side near the bulwark or gunwale in order to avoid being crushed by keel blocks on the dry-dock floor when the ship is set on such blocks.

Also it is recommendable to study technical terms regarding the sea-bed such as : Province; Continental borderland and shelf; Continental slope and rise; Archipelagic apron; Fan; Leave; Bank, shoal and reef; Plateau, seamount, tablemount (guyot) and knoll; Seamount range, seamount chain and seamount group; Cordillera, rise and ridge; Spur and sill; Gap and saddle; Escarpment (seascarp) and fracture zone; Plain and basin; trench and trough; Channel, canyon and valley; Strath, moat and gully.

Thank you.

1989 April,