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# ECHO LOCATION OF FISH*

## Introduction

Fishing in the sea in olden days was more like hunting on land. However, over the years, developments in the art and practice of fishing brought forth improved crafts, gears and fishing aids enabling more fish to be caught with less of effort. One of the most significant developments in recent times in the sphere of fishing has been the introduction and use of acoustics in fishing operations. From merely finding the depth of fishing grounds with echo sounders, sophisticated acoustic instruments now aid in the location of fish schools, their identification as well as quantification. As the world's fishing fleets are constantly increasing in number and size, the fish finding instruments on board fishing vessels have become more advanced in presentation of information and also more complicated in operation. Most of these developments in the application of acoustics in fisheries happened during the past few decades. The use of these instruments by fishery scientists has only recently become common.

## Properties of sound and principles of echo sounding

Sound may be defined as the transfer of energy through a compressible medium by means of small oscillations or vibrations of individual particles of the medium and is recognised as the periodic variation of pressure in the medium. Sound needs a medium to travel and cannot do so in vacuum. In sound propagation it is energy that is transported, not mass.

In acoustic parlance the number of oscillations or sound waves produced in one second is termed 'frequency' (C/S). It is also indicated by the abbreviated expression Hz. The human ear can sense oscillations between 20 and 20,000 C/S. Oscillations that have frequency of more than 20,000 C/S which human ear do not hear are termed ultrasonic. In echo sounding techniques ultrasonic sound frequencies are chiefly used.

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In water, sound is propagated more quickly (1,500 m/second) than in air (344 m/second). Speed of sound in sea water is influenced by the salinity, pressure and temperature, the latter having the most dominant influence. Speed increases with increase in these parameters. The distance covered by one cycle of oscillation given in m or cm is termed wave length.

The property of sound waves reflecting back when they hit another medium, different from the one in which they travel is 'echoing'. The echoes are heard after a time lapse equal to the time taken by the sound to travel to and back from this medium or object. The distance of the object which echoed the sound can be calculated, knowing the speed of sound per unit time in the medium. It is also possible to quantify the returned echoes and assess the biomass of the object with an echo integrator. In the sea, living objects like fish, plankton and other organisms as well as the bottom of the sea reflect the sounds and by tracing these echoes through shipboard instruments they can be accurately located.

## The echo sounder

Even though the term 'sonar' (Sound Navigation and Ranging) can in general be applied for the apparatus used for detection of underwater targets by means of transmitted sounds and returned echoes, a sonar system that transmits sound vertically is called an 'Echo sounder' and one that transmits horizontally is more typically known as 'sonar'. An 'active' sonar system involves transmission of sound and receiving of echoes while a 'passive' sonar system only receives sounds generated by underwater objects or other sources of transmission.

A typical echo sounder consists of display unit, transmitter, transducer and receiver (Fig. 1). A cabinet, usually located in the wheel house of the ship, contains the display unit, transmitter and the receiver. The transducer is fitted under the hull of the ship. The display unit is the brain of the echo sounder because it triggers the transmitter, and records the transmitted pulse as well as the received echo.

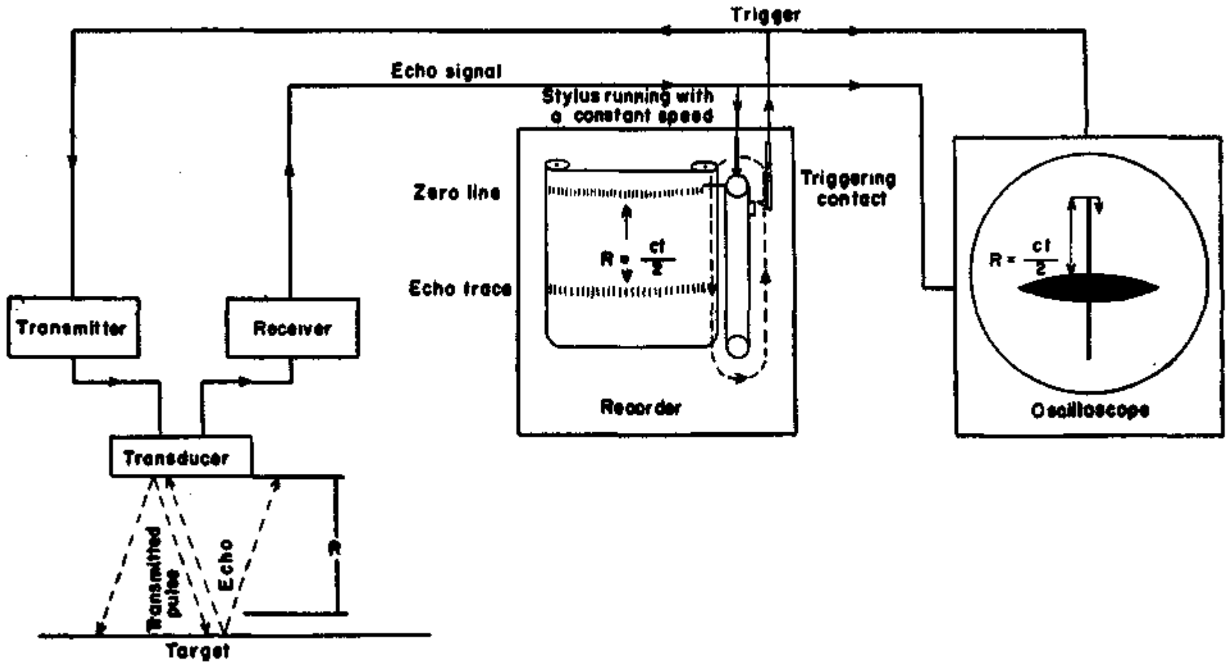


Fig. 1. Block diagram of the functional units of an echo sounder.
R=Range in m; c=speed of sound in water in m/sec; t=time taken in seconds by the sound wave to travel to and fro.

The display unit may be an electric motor driving a mechanical system for marking on paper, called recorder or an electronic circuit controlling the speed at which a spot of light travels across the face of a cathode ray tube (CRT), with deflection or intensity modulation facility. At one point on its travel the stylus arm on the mechanised system or the spot on the cathode ray tube will pass the zero mark on the depth range scale and at this instant the transmitter is switched on by the trigger and its energy is released to the transducer at the hull of the ship. The transducer converts the electrical energy into acoustic energy which is propagated through the water. In modern equipments the same transducer receives the echo from the objects or sea bed and converts the acoustic signals to electrical signals. This echo signal is amplified by the receiver and fed to the display unit which records the echo on paper recorder or gives an echo picture on the oscilloscope.

Structurally a commonly used transducer is a pile of laminates of feromagnetic substances such as nickel or nickel-like alloys. These are termed 'magnetostrictive' transducers. Such transducers are used for low frequencies upto 100 kHz. In high frequency 'Electrostrictive' transducers, other materials like Barium titanate and Lead zirconate titanate are used. 'Piezoelectric' transducers like those made of quartz crystals are based on the piezoelectric effect. The conventional magnetostrictive transducer of echo sounder is about the size of 10x20 cm and the size selected depends upon the required power output and wave length of sound transmission and usually not greater than 30x30 cm. Transducer mounting position on the hull is selected so as to avoid extraneous disturbances like propeller noise, air bubble interference etc. and is usually fitted in the anterior third of the hull.

**Operating controls of the echo sounder**

It is essential for the user to know the effect of the various operating controls and their settings for the proper operation of the equipment. Important conventional controls of the echo sounder are described below:

*Power and illumination switch:* This switch connects the appropriate power supply to the control cabinet. The intensity of illumination can be varied as per requirement.

*Range switch:* The effective range of operation is determined by the range switch, which has two modes of selection in the advanced models. One is basic range and the other is phased range. Basic range is used to search the full column of water to its effective range, eg. 0 to 50 m, 0 to 100 m etc.; whereas phased range is used when the top layer is not required to be searched and when only the deeper water is to be searched eg. 40 to 90 m, 80 to 180 m etc.

*Transducer selector or beam width selector switch:* This facilitates the selection of one transducer or the other when more than one of different sizes or one transducer with double beam is fitted. This enables the user to select the appropriate width of the beam to be radiated. (Beam width of transducer is the angle between two points in a power polar diagram (intensity) where the intensity falls to half of its maximum value (3 dB) as shown in Fig. 2. It is the measure of the directivity of the transducer).

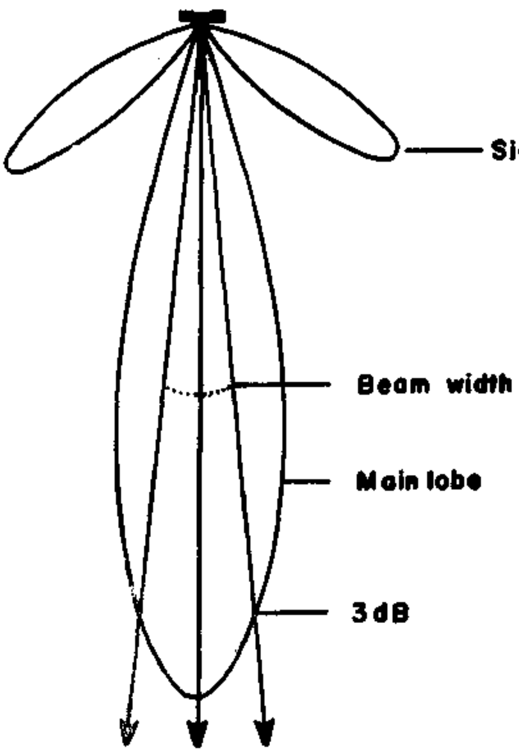


Fig. 2. Diagram showing directivity of the sound beam.

*Mode selector:* The number of modes of operation may vary depending upon the type of equipment. However, there can be minimum two modes of operations, namely White line or Dynaline and Contour line. When White line mode is selected a narrow belt of white area below the bottom line is formed. When contour line is selected, the area below the bottom line will be white all the way for the rest of the paper.

*Pulse length and band width selector:* This would enable the user to select the pulse length of the transmission. Normally narrow (short) pulse length and wide band width are selected for shallow waters and wide (long) pulse length and narrow band width are used for searching deeper waters. (The pulse length or pulse width (T) is the time duration during which the transmission takes place or in general it is the time between the leading edge and the trailing edge of the pulse termed in micro/milli second).

*Output power control:* This enables the user to transmit with full power or reduced power. While using the equipment in deep water, full power is selected and in shallow water reduced power is used. Peak power (PP) is the maximum instantaneous power transmitted during one pulse, expressed in kilo watts and average power is the power transmitted during one second in watts, which is always less than peak power.

*Receiver gain control:* This controls the amplification of the echoes received. When turned clockwise fully, echoes from temperature layer, plankton. and random noise signals are also recorded on the echogram paper. Hence it must be critically adjusted so as to have the clear recording of only the useful echoes, ie. of the fish.

*Recorder gain control:* Also called recording intensity control will control the degree of blackness of the echogram. This does not have any effect on the sensitivity of the receiver and is so adjusted that the weakest echo can be recorded, at the same time avoiding excessive paper residues.

*T. V. G. control:* The 'Time Varied Gain' of the receiver is controlled by this. The TVG function will give equal strength of echo signal for the similar targets, irrespective of the distance of the target.

*Discriminator or sensitivity control:* The signal strength necessary to produce the white line effect, which will differentiate the bottom fish echoes from those of sea bottom is regulated by this control. Normally it is set higher to obtain a stable white line. Relatively low discriminator setting will produce a "broken white line" when the bottom conditions change from hard to soft and again soft to hard, causing a change in the signal strength. If too high a discrimination is set, even a dense school also will produce white line. Hence a critical adjustment is warranted.

*Line density control:* This controls the speed of the recording paper. When the speed is increased the echo picture is elongated and when decreased the picture is compressed. To economise the consumption of the paper, a reduced paper speed is selected.

*Marker switch:* When this is pressed, a line appears on the recording paper as a reference, for later identification of events.

*Recording threshold control:* This control enables the user to fix a threshold for isolating the required echoes efficiently from noise and unwanted weak signals. While setting the control care must be taken to avoid the loss of useful echo signals.

**The Sonar**

Most features of vertical echo sounders apply to the horizontal echo-ranging sonar. The block diagram of the functional units of a sonar is given in Fig. 3. It is possible to receive the sonar echo as an audible tone and distinguish different types of echoes. With the horizontal echo ranging sonar the area covered by the search can be much greater than by the vertical echo sounder. The sonar usually cannot give much useful information on the seabed as it is recorded by a normally operated sonar only in relatively shallow waters. The appearance of fish records on the sonar will differ with the search programme. A normal programme is to search between about 60° to the port and starboard side of the ship, with sound emissions at every 5°. Modern instruments can be set for automatic search programmes. Traces are produced as the beam passes the schools in 5° steps. The same target may appear more times in the echo record depending on its distance from the ship and the range at which it was detected first. This type of search programme is thus not suitable for obtaining a count of the schools.

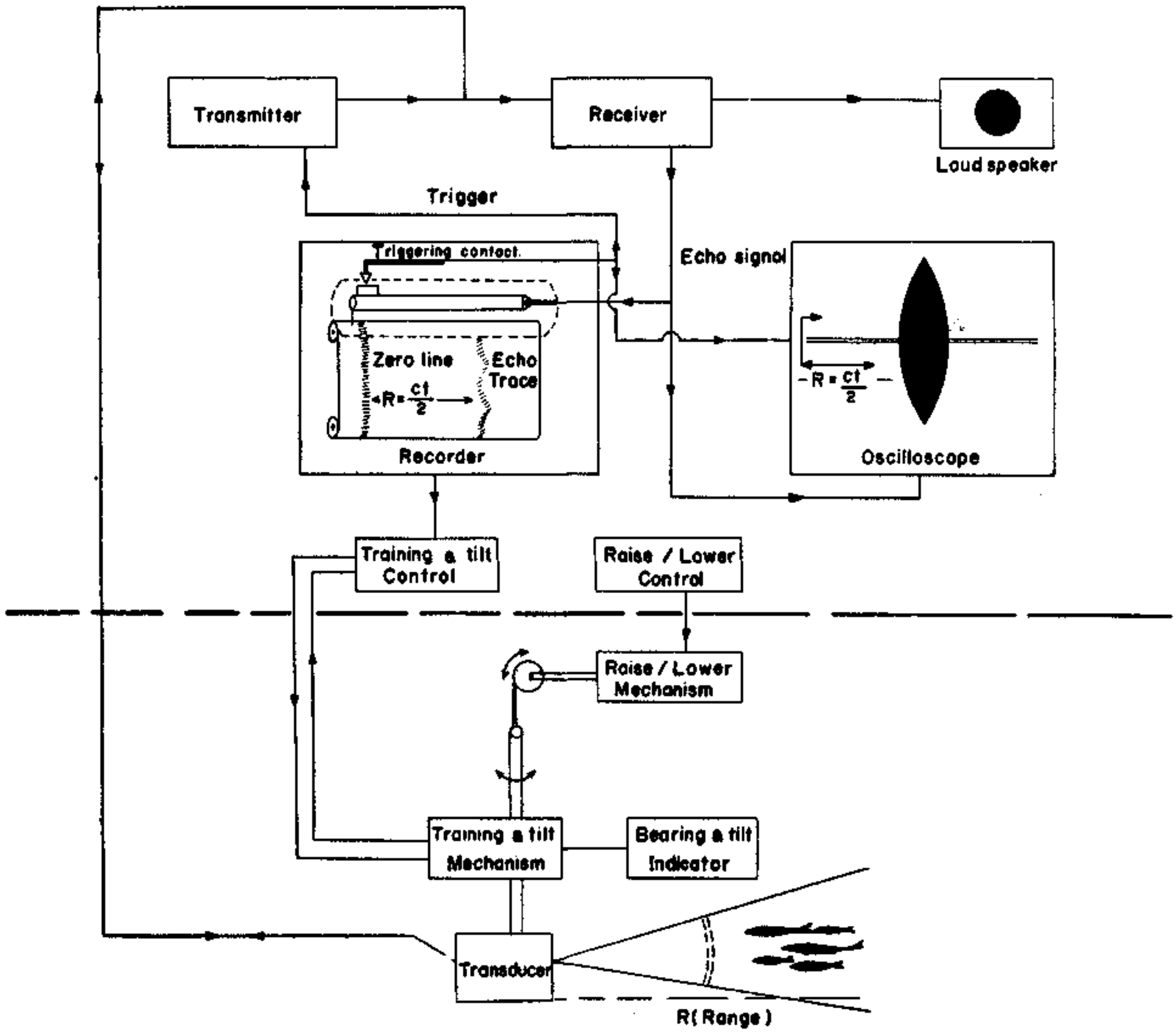


Fig. 3. Block diagram of the functional units of a sonar.

A survey programme commonly used for pelagic schooling fish is to have the transducer at a fixed angle of 45 to 90° to port or starboard. This will allow fairly good coverage.

**Operating controls of Sonar**

Many controls and their functions in the case of the sonar are similar to those of echo sounder. A few additional controls of modern sonars are explained below:

*Hoist lower switch:* The switch lowers the transducer of the sonar for search and hoist it up when not used. Normally the transducer is hoisted so that the speed of the vessel may not be reduced.

*Tilt control:* This is used either to search the school on the surface by tilting the transducer upward or to search the fish school in deeper water, by tilting it downwards. Also when the sound wave is bent due to thermocline effect, an effective range of sonar can be had by tilting the beam accordingly. Tilt angle is indicated by the tilt indicator.

*Training control:* By using this control the transducer can be rotated along 360°. When continuous training is required the control can be put in 'automatic', otherwise in manual position. This is operated by watching the bearing indicator.

*Training speed control:* The speed of the movement of the transducer, while training could be varied by this. When it is required to change the position of the transducer quickly, the speed control may be varied in clockwise direction.

*Sector control:* The sector to be scanned can be selected either from 0 to 90° port by the outer knob or 0 to 90° starboard by the inner knob of this control. The minimum search selector width is approximately 8° in SIMARD S.U. Sonar. This may differ for other types of equipments.

*Programme selector:* This selects either manual or automatic programmes. In manual position the transducer is trained manually. Search and catch are the two programmes in automatic. When put to search the transducer trains step-wise at 3°, 5° or 8° depending on the step angle control. When put to catch programme the transducer trains continuously. Search programme is used while searching for schools. Catch programme is used when the vessel is close to the school.

*Audio Volume Control:* This control varies the receiver output signal given to the loud speaker which gives an audible note of the echo received. Experienced Sonar operator can identify the type of object from the sound heard.

Some other common technical terms related to acoustic equipments are:

*Receiver gain:* It is the ratio of the output to the input signal of a receiver amplifier.

*Receiver Band Width:* It is the range of frequency at which the receiver amplifier gain falls by 3 dB or to half of its maximum power at centre frequency or 0.707 times of its maximum voltage at the centre frequency. It is normally called as half power band width or 3 dB band width.

*Source level (SL):* It is the maximum sound pressure level of a source expressed in dB relative to 1 $\mu$ Bar (dB/1$\mu$ Bar) at a distance of 1 metre along the acoustic axis. It is the measure of the output of the transmitter.

*Spreading loss:* It is the reduction in the sound energy on propagation through medium due to the spherical spreading in the surrounding medium. This loss is directly proportional to the square of the distance.

*Absorption loss:* It is the reduction in the sound energy on propagation due to the dissipation in the medium. This loss is directly proportional to transmission frequency.

*Two way transmission loss (TL):* It is the total reduction in the sound energy on propagation due to spreading loss and absorption loss associated with echo ranging. In logarithmic form it is given as $40 \log R + 20 \alpha R$ where R is the range in metre $\alpha$ is the absorption co-efficient.

*Target strength(Ts):* It is defined as the ratio of the reflected sound intensity to the incident sound intensity at one metre away from the target expressed in dB. It is a measure of the reflecting properties of the target.

**Echo records**

*Build up of a fish mark in an echo sounder:* When a ship operating an echosounder passes over a fish the leading edge of the sound beam first hits the fish and a recording occurs which is not the correct depth position of the fish. Only when the vessel is directly over the fish the correct depth is measured. After the ship has passed over the fish the trailing edge again hits the fish and the characteristic inverted 'V' shape recording is produced (Fig. 4). 'M' shaped marks indicate that the fish has moved inside the main beam,

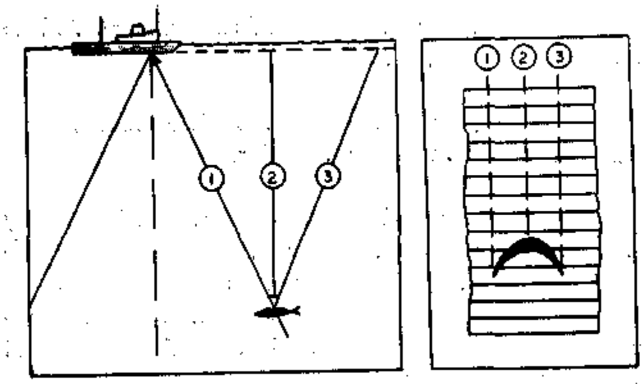

Fig. 4. Diagramatic representation of the build up of a fish echo mark.

most probably swimming in the same direction as the vessel; when the inverted 'V' is incomplete, it may indicate that the fish has left its position rapidly.

**Double echo**

The seabed can cause a confusing echo called second seabed or 'double echo'. The ground reflects a very large area of sound beam towards the transducer. A great deal of the sound will strike the water surface around the vessel which acts as a reflector. This causes the waves to return to seabed which again reflects the sound back to the vessel marking the paper at exactly twice the actual depth.

**Angular definition**

If the vessel is sailing over a trench in the seabed and the area covered by the main lobe of sound beam is wider than the trench, the transmitted pulse will be reflected first from the edges of the trench and received before the reflections of the bottom of the trench. This will result in a straight line recording because the bottom reflections which arrive later will be masked by the reflections of the edges. Similarly the echo mark of any fish in the trench also is lost (Fig. 5a). Therefore, a trawl may be damaged easily on what falsely appears to be a flat bottom. However, this can be overcome by using a narrow beam width. This ability of the sounder is called angular definition.

When trawling on a slope, the beam edge hits the bottom before the centre of the beam hits the fish, resulting in no fish mark (Fig. 5b).

**General characteristics of fish echo records**

Fish echo records may show individual specimens separately or echoes from 2 or more fish may overlap to form a multiple echo. With the vessel lying stationary single fish will be recorded as continuous line traces. At slow speed the lines shorten and become curved and at high speeds they appear as dots or points. The reason for this is that the number of echoes obtained from each individual decreases as it is swept by the sound beam within a shorter time. The beam angle in the ship's direction of travel will also influence the appearance of single fish traces, the wider the beam the longer the individual traces.

When the fish density exceeds the limit of the power of resolution of the echo sounder used, the records take the form of multiple echo trace which may appear as a layer or as a distinct solid trace. The usual feature of the layer type traces often produced

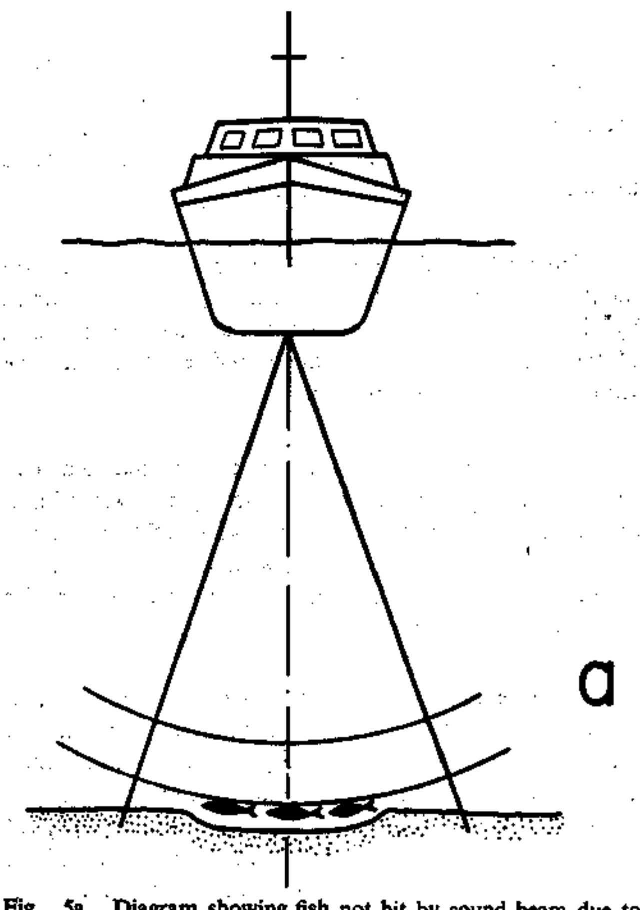


Fig. 5a. Diagram showing fish not hit by sound beam due to trench.

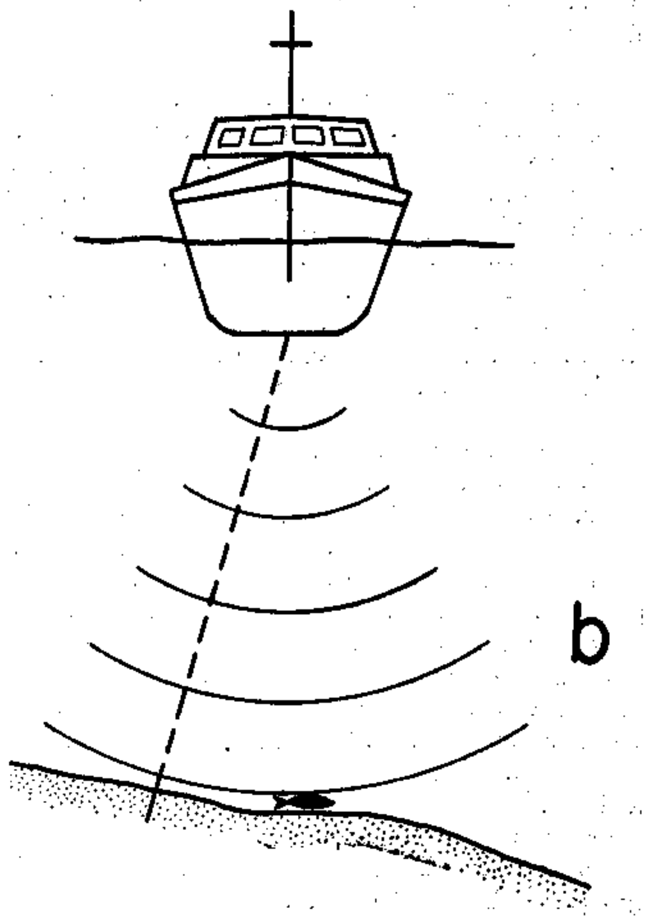


Fig. 5b. Diagram showing fish not hit by sound beam due to sloping ground.

by fish, is the presence of single fish traces at the upper and lower boarders of the layer. This feature can be used for distinguishing layer traces produced by fish and from those of smaller organisms like plankton.

Echo records produced by smaller organisms such as fish larvae and plankton appear as fine grained clouds and are often recorded over large areas. Character of these traces does not change with the change in speed of vessel.

**Fish recording near the bottom–dead field**

Fish very close to seabed are difficult to detect because of the 'dead field' in the sound beam close to the seabed (Fig. 5c). If the bottom is uneven the extent of the 'dead field' increases. This happens also with wider beam width. However, if the fish is off the bottom, recording of fish will be indicated (Fig. 5d).

**Spurious echo records**

Background noise of electric or acoustic origin, propellor noise, noise from the wake of passing ships etc. disturb normal echo records. An important type of interference is the side lobe echo produced from a steeply sloping seabed. Sounds of biological origin traced to mostly marine mammals get recorded on acoustic instruments. Air bubbles in the water immediately under the transducer caused by heavy pitching of the vessel also give disturbed echo records.

There are a number of disturbing 'non fish' records peculiar to the Sonar. Since signals in most sonar sets are also presented as audible sounds, certain kinds of under water sounds may be heard. Propellor noise is one of these. In rough sea with big breakers, air bubbles in the water may cause the Sonar beam to be reflected. So also records of wakes of passing ships may be mistaken for fish schools.

Echoes from small sound scatters in the sea appear as small dots and dashes. Large vertical or horizontal temperature gradients in the sea may give stratified echo records. There may also be interference from other acoustic instruments of the same vessel or of other vessels operating nearby.

The echo records can also give some details of the seabed, like hardness, softness, terrain etc. Soft ground gives weak echoes, whereas hard bottom will

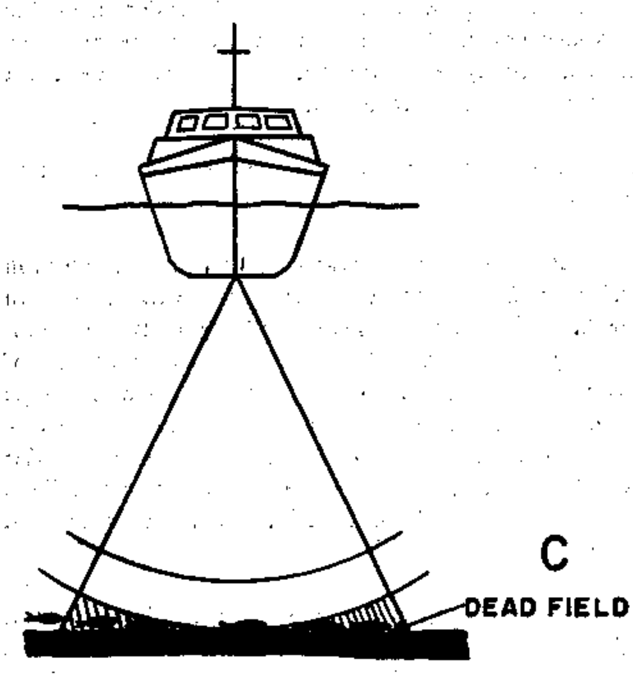


Fig. 5c. Diagram showing the fish hidden from sound beam (dead field) due to their being very close to the bottom.

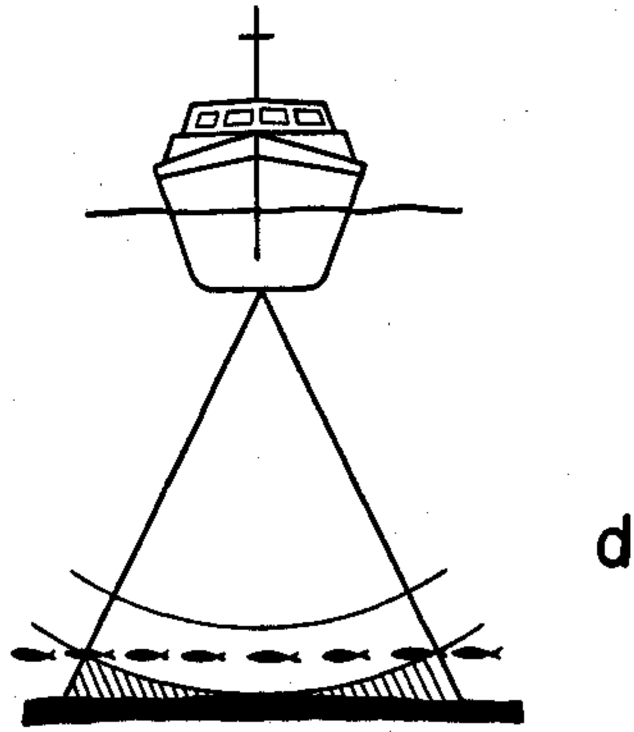

Fig. 5d. Diagram showing the fish off the bottom not hidden from the sound beam.

give strong echoes which usually rebound to give double echoes. In shallow waters also several echoes may be obtained from the seabed.

When using a sensitive Echo Sounder in depths of water beyond the depth scale set on the recorder, the seabed may be recorded at an incorrect scale and a 'Ghost bottom' may appear.

**Echo location and surveys for fish resources in Indian waters**

Use of echo sounders and sonars for fish detection and scientific studies in Indian waters was initiated in the late fifties by the vessels of the erstwhile Indo-Norwegian Project. Typical echogram patterns of some of the important commercial species and groups have been available from these studies. These echograms relate to the Simrad Scientific Echo Sounder EK–S system. Location of the *Kalava* grounds off the south west coast of India was largely aided by acoustic instruments.

Extensive surveys for the important fish resources of the south-west coast of India were carried out by the Pelagic Fishery Project from 1971 to 1978. These surveys using echosounder, sonar and echo integrator estimated the biomass of the standing stocks of different fish resources.

Major fish resources amenable to acoustic surveys using echosounder and echo integrator in Indian waters are the column fishes such as white baits, cat fish, ribbon fish and horse mackerel. In the case of mainly surface schooling fishes such as oil-sardine and the Indian mackerel sonar surveys have been found to be the more suitable acoustic technique for location and quantification. Biomass of benthic species such as prawns and lobsters cannot easily be estimated using the present acoustic instruments and techniques.

During the repeated acoustic surveys along the south west coast it has been possible to have some typical echograms of schooling fishes. The identity of the fish referred to particular echogram type has been confirmed by several fishing operations. The profiles and configurations of the echograms are basically governed by the size of the fish, their sound reflection, properties and schooling behaviour. However, instrument characteristics, their settings and the vessel speed are also vital factors influencing the shape of the echograms. The quick surveys of extensive areas and charting the density distribution of several of these resources have been possible mainly due to the clear identification of the echograms of different groups of fishes. The characteristic types of echograms referable to fishes such as oil sardine, white bait, cat fish, ribbon fish, horse mackerel as well as plankton are given in figures 6 to 11. These echograms have been recorded on dry paper with SIMRAD EK 120 echosounder through an EX recorder.

Looking at these echograms it will be seen that the echogram of the plankton is characteristically different in being evenly distributed fine dots and dashes, some times forming continous band-like profiles for long distances (Fig. 6). The echogram of cat fishes which are relatively large sized and positioned at some distance from each other while schooling, looks like inverted 'V' figures spread more or less evenly (Fig. 7). Large ribbon fishes also give inverted 'V' patterns, but on the whole more compact and straight vertical configurations (Fig. 8). The echograms of horse mackerel schools are typically straight and narrow stick like vertically disposed patterns (Fig. 9). The white baits disperse in the entire water column during the night (Fig. 10a), but form compact schools during the day (Fig. 10b). The dominantly surface schooling fishes like oil-sardine and mackerel do now and then come under the range of the echosounder. The echogram of the oil sardine appear as dense

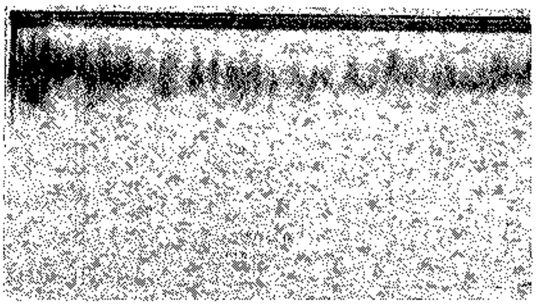

Fig. 6. Echogram of plankton.

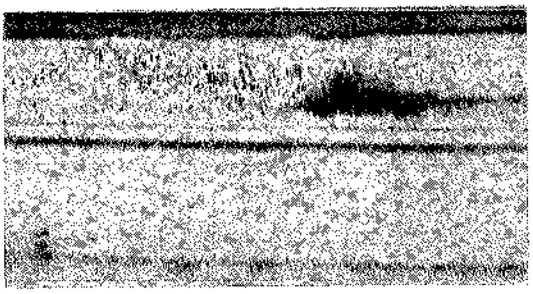

Fig. 7. Echogram of cat fish.

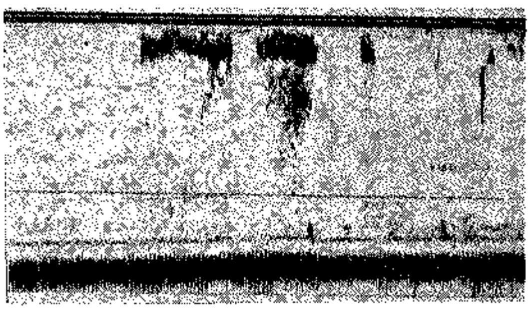

Fig. 8. Echogram of ribbon fish.

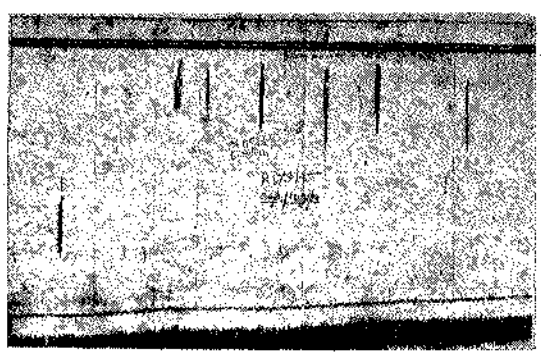

Fig. 9. Echogram of horse mackerel schools.

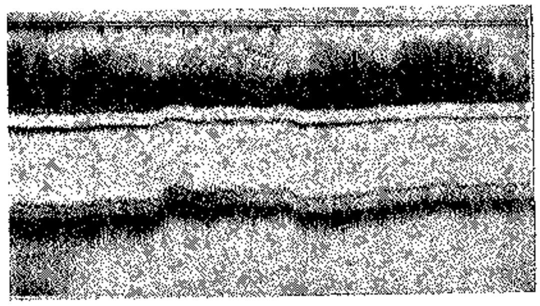

Fig. 10a. Echogram of white baits, night.

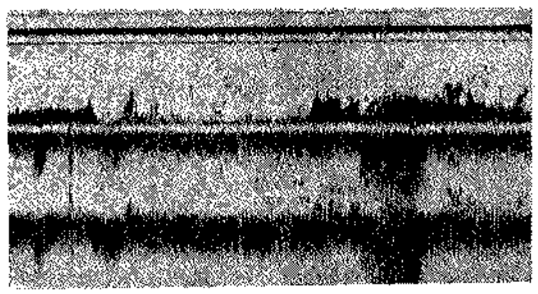

Fig. 10b. Echogram of white baits, day.

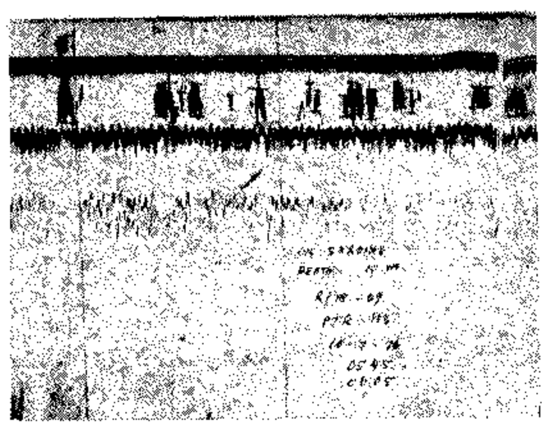

Fig. 11. Echogram of oil sardine schools.

patches which indicate closely packed fish in medium and large schools (Fig. 11).

The biomass estimates have indicated under-exploitation of several resources. Particularly it has been highlighted that the resources of whitebaits, horse mackerel and cat fishes are only marginally exploited and that there is immense scope for increasing the catches of these resources.

Apart from the estimates of the standing stocks of these resources, their distribution patterns in time and space could also be brought out by these surveys. It was pointed out that a large segment of the resources of horse mackerel, cat fish and white bait are over the midshelf beyond the present limits of their traditional fisheries. The best school concentrations of horse mackerel have been noticed beyond the 30 m depth contour. High levels of abundance of this fish have been observed for longer periods off the coasts of Kerala and south Tamilnadu and for shorter duration off Karnataka and southern Maharashtra.

The cat fishes and ribbon fishes have been located in good quantities in waters 20 to 80 m depths, particularly during the monsoon months between Cape Comorin and Honavar. The characteristic migration of a large population of white bait to the south-east coast during the June-September period and their concentration in the gulf of Mannar have been revealed by the acoustic surveys.

The use of acoustic technology in modern fishing and fisheries research is becoming more relevant in developing countries due to its proven advantages. The technology is being continuously developed to obtain more precise results. However, large scale production of the common units like echosounders and sonars at economic prices only will make their use popular.

**Points to be remembered while operating echosounders and sonars**

1. Select the high operating frequency of the sounder in shallow waters and low operating frequency in deeper waters.
2. Short pulse length would give better vertical resolution of the echoes.
3. When greater depth is to be covered, select long pulse length and narrow band width.
4. Select short pulse length and wide band-width while searching shallow waters.
5. Choose narrow beam width for better horizontal resolution of the echoes and wide beam width to cover more volume of water.
6. When only general information is needed reduced paper speed would economise on recording paper. Higher paper speed would have enlarged picture (horizontally) of the echo mark.
7. A lower depth range will be enough while searching shallow water, so as to get enlarged vertical view of the echo picture (now pen speed is automatically increased) and higher depth range for searching deep water (now pen speed is reduced).
8. Increase the recorder gain to get a clear mark of the weakest echo signal from deep water but reduce the gain to avoid the unwanted noise echo from shallow water.
9. Use phased ranges to search deeper water, so as to get enlarged picture of the echo from the searched column.
10. White line facility may be used during bottom trawling to distinguish fish echoes from the bottom.
11. TVG will be useful when the echo sounder is set for fish finding.
12. Use Contour line recording if available, for navigation.
13. While judging the size of the school from the recording, consider the speed of the vessel, speed of the paper or line densities and the range selected.
14. In calculating the actual depth of the school from the surface, measure from the top of the echo picture and add the depth of the transducer from the surface of the water as the depth recorded denotes only the distance of the school from the transducer.
15. Do not use too much receiver and recorder gain as this blackens the whole recording paper even with weak extraneous noise signals, creating difficulty in distinguishing the noise and echo.
16. The downward tilt of transducer should not be used while using the sonar at shallow water to avoid the bottom echo marks in the recording paper.