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OBSERVATION OF FISH BEHAVIOUR, DENSITY AND DISTRIBUTION AROUND A SURVEYING VESSEL BY MEANS OF A DEPLOYABLE ECHO SOUNDER SYSTEM

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ABSTRACT

Detailed acoustic observations of fish behaviour, distribution and density in the trawl area are necessary in order to establish quantitative relationships between trawl samples and fish density. Acoustic observation close to the bottom may reduce the near bottom acoustic dead zone. A transducer deployed close to the bottom may resolve deep targets and avoid effects of the bottom acoustic dead zone associated with deep recordings. Ship avoidance is also a well known problem related to acoustic fish abundance surveying.

This paper describes a system consisting of a Simrad EY500 echo sounder built into an aluminium underwater bottle and a portable PC. Two different split-beam transducers can be connected to the bottle. The system is remotely controlled and can be used down to 400 m depth, either powered from a battery bottle or from an external 220/110 V AC supply. All logged data are stored on an internal disk or sent via Ethernet through fibre optical cables to a shipboard device, depending on the application.

The system is used for different purposes. Mounted on the trawl headline, with the transducer pointing upwards, it is used to monitor the escape of fish over the trawl headline. The system can also be mounted on a towed, remotely controlled vehicle (FOCUS 400), to constitute a deep-towed acoustic system to improve precision of acoustic surveys on bathypelagic and deep dwelling demersal fish, or to record fish in the near bottom acoustic dead zone. The vehicle-mounted system is also used to observe fish behaviour relative to trawl and vessel, e. g. abundance variation in areas around the trawl and between the trawl and vessel to facilitate establishing of the catchability of survey trawls. Deployed as a free floating buoy it is also used to quantitatively determine fish avoidance to a surveying vessel.

INTRODUCTION

Acoustic survey is an established method for estimating fish abundance. In order to produce absolute numbers of abundance, it is necessary to know the natural fish density in the surroundings of the survey vessel and the catching efficiency of the trawl (Aglen,1994; Aglen, 1996). Vertical and horizontal fish herding and avoidance to the ship and trawl are key factors in this context (Aglen et al., 1999; Michalsen et al., 1999). To get a better estimation of the catching efficiency of a trawl, it is important to have detailed observations of the area around the trawl and between the trawl and the vessel (Engås, 1994)

It is known that the near-bottom acoustic dead zone is increasing with increasing distance from the bottom to the transducer (e. g. Ona and Mitson, 1996). An important problem is how to determine the underestimation of the S_A-values in the acoustic dead zone by the echo sounders on a survey vessel.

Ship avoidance, particularly for pelagic fish during acoustic fish abundance estimation, is a well established problem (e. g. Olsen et al., 1983; Vabø et al., 1999).

To help resolve these and similar problem areas *en route* to absolute fish abundance estimation, an acoustic underwater observation system was assembled. A Simrad EY 500 echo sounder with on-board computer and connected transducer was mounted in a submersible container. This container can then, depending on the application, be deployed as a free floating buoy on the trawl headline or on a towed remotely controlled underwater vehicle (Focus 400, McArtney AS). The Focus 400 can be directed both horizontally and vertically, and can therefore be positioned at different locations behind the vessel up to around 100 m from the course line. The echo sounder and Focus 400 can be operated from the bridge. All echo sounder data can be transferred in real-time to the vessel.

With this system it is possible to observe the fish distribution around the surveying ship and trawl, and also to compare S_A-values from the echosounder mounted on the towed vehicle with the S_A-values from the hull mounted transducer in order to estimate the magnitude of the acoustic dead zone loss.

MATERIALS AND METHODS

The underwater bottle is made of anodised aluminium and has a lid with a dual O-ring. The system consists of a Simrad EY500 echo sounder and a Toshiba portable PC (Figure 1). The Echo sounder can be controlled from the PC keyboard, or by commands sent from an external PC via a serial line. The serial line on the EY500 PC is connected to a Subcon underwater connector mounted on the bottle. Sample data can be stored on an internal disk or sent to an external server via Ethernet. The Ethernet is connected to an optical transceiver and further to an optical connector on the bottle. The EY500 can also be connected via serial line to a GPS navigator for logging navigation information. Two different transducers ES38_12 (12 full angle split-beam) or ES38_7D (7 full angle split-beam with pressure compensation) can be connected to the system via an underwater plug. The system can be powered by 220/110 V AC or 12 V DC from external power devices. Inside the bottle there is also a backup battery which maintains power for shorter breaks on the external sources.

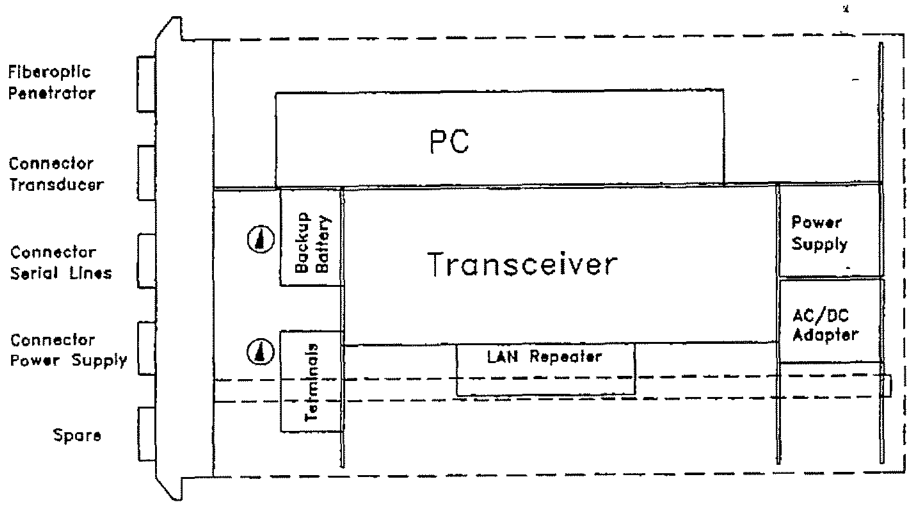

Figure 1 Physical layout of the EY500 underwater bottle.

System description

The EY500 underwater bottle can be used as a stand-alone unit or be mounted on the Focus 400 which is designed to operate at speeds between 3-5 knots down to 400 m depth. The vertical and horizontal movement is controlled by flaps which is operated from the bridge control unit, but it also depends on the speed and applied cable length. The towing cable on the Focus has three optic fibres which are used for the multiplexed communication system to remotely control the vehicle and to transfer signals between the surface and the underwater unit. The Focus 400 is also equipped with a Simrad Osprey SIT low-light camera and an FS300 Simrad Mesotech scanning sonar.

The EY500 bottle is attached to the main electronic bottle (Figure 2) in the centre of the vehicle. The acoustic transducer is fitted at the rear end of the vehicle on an aluminum bracket and is covered by a cap which is designed for minimum drag.

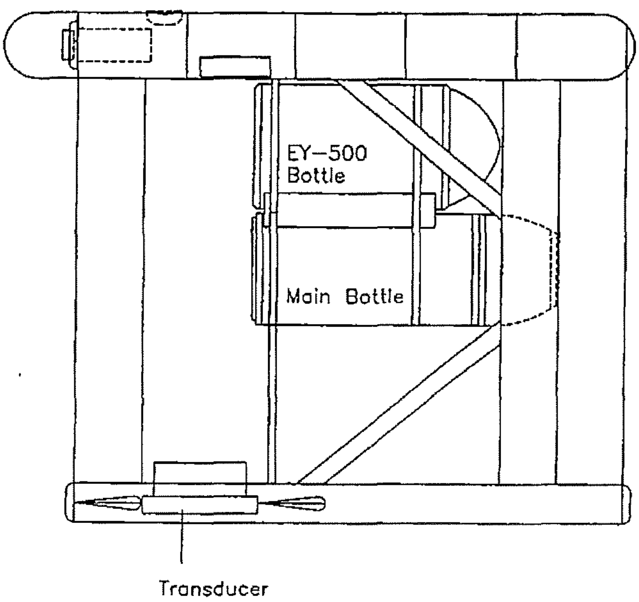

Figure 2. Focus 400 with the EY500 bottle attached to the main bottle.

The fibres also have the capacity to establish an Ethernet connection to transfer the sample data between the EY500 and the surface units. The sample data are then logged on a work station placed in the instrumentation room on the vessel. On the Focus communication system there is serial lines which are used to remotely operate the EY500 and to transfer echo telegrams from EY 500 to the echo processing system EP500. The EP500 is a program used to display echo data from the EY 500 in real-time and to send commands to EY500. The stored acoustic data from the system can later be displayed and manipulated on the Bergen Echo Integrator (BEI) (Knutsen, 1995).

Applications

Deep towed acoustic transducer

Several factors limit the usefulness of a vessel-mounted acoustic system for assessment of deepwater fish. To reduce the factors, one method is to apply deepwater transducers and greatly reduce the range between transducer and target or bottom (Kloser, 1996). When the EY500 is mounted on the Focus 400 and is used for deep water acoustic recordings, the ES38_7 transducer is normally used. Focus 400 is lowered down to about 400 m depth, which reduces the transducer to bottom distance from 700 to 300m (Figure 3). The acoustic ping and summary data are logged on a work station via Ethernet on board the research vessel. Echo data from the serial port are displayed continuously on the EP500 system and are logged together with pitch, roll, heading, and depth of the Focus 400. Navigation information such as speed and position is recorded from the vessel's navigational systems. The navigation signals are transferred via a serial line to the EY500 to have the same sailed distance on these recordings as for the vessel.

Fish behaviour

With the EY500 mounted on the Focus together with the ES38_12, the Simrad ITI trawl geometry system is used to get the position of the vehicle and trawl. One ITI transponder is mounted on the Focus and one on the headline of the trawl, and the relative position between the vehicle, trawl and vessel can be calculated (Engås et al., submitted). The vehicle can be moved to different positions around the trawl and between the trawl and vessel (Figure 4).

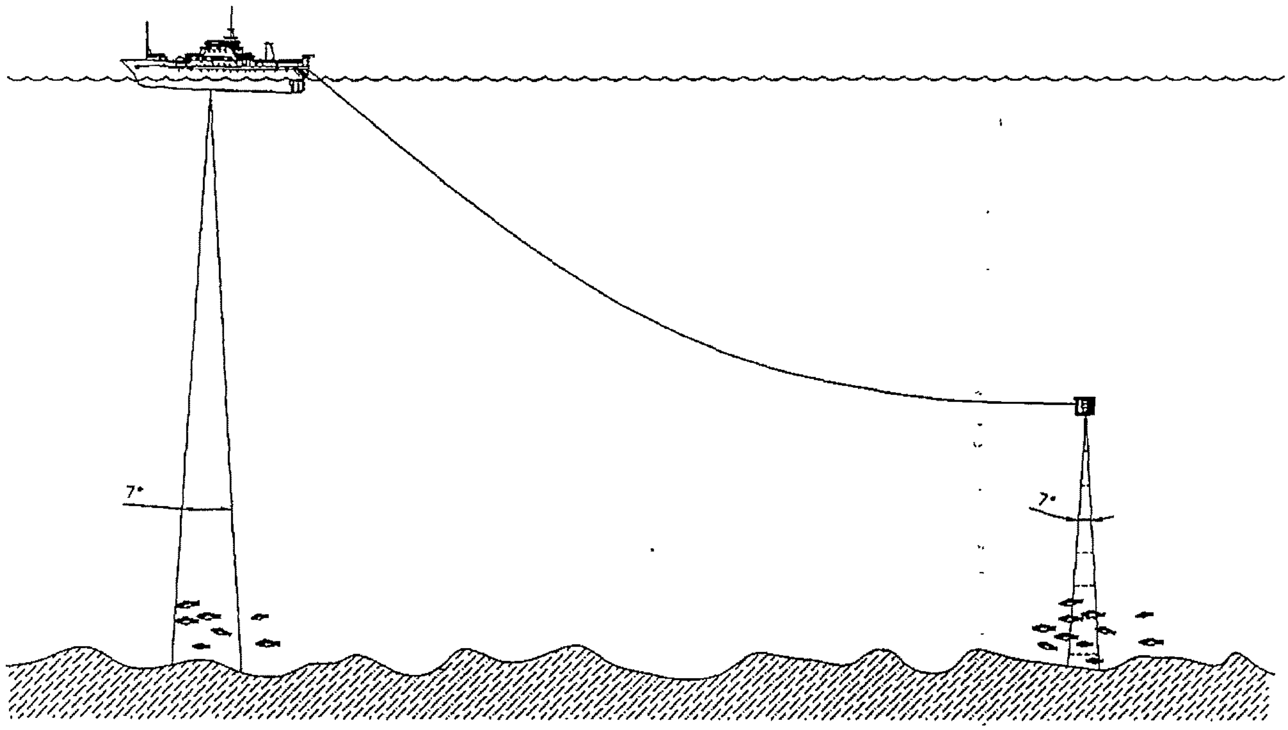

Figure 3. Focus 400 with the EY 500 used for deep water acoustic recordings.

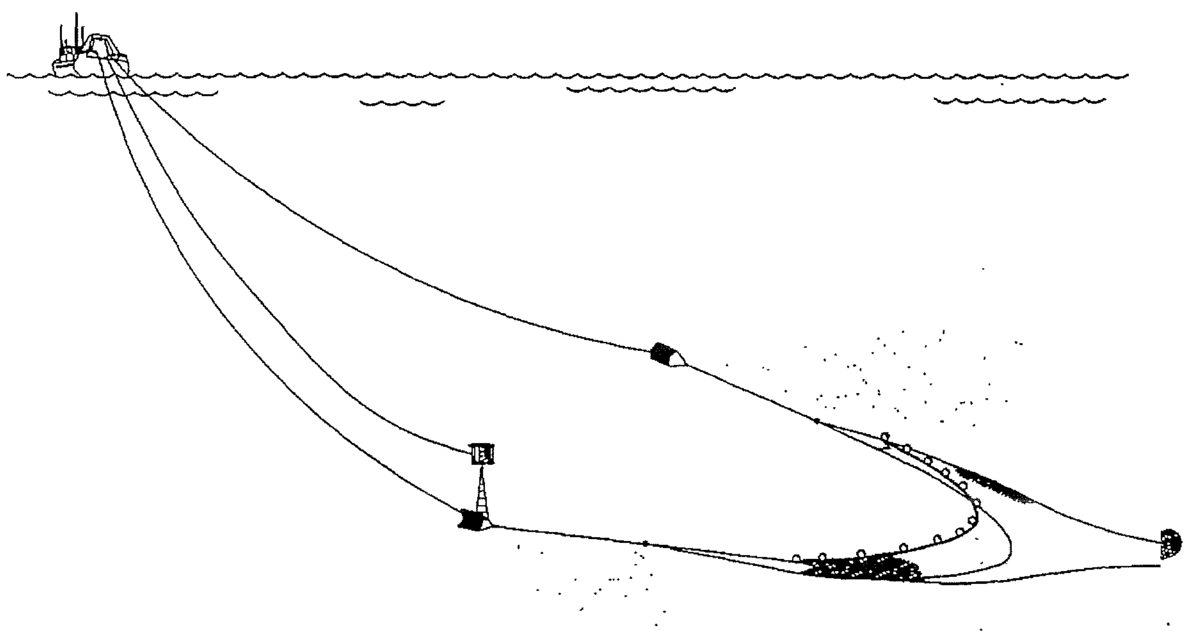

Figure 4 Focus 400 with the ITI positioning system used to observe the area around the trawl and between the trawl and vessel.

The acoustic ping and summary data are logged on a work station via Ethernet aboard the research vessel. Echo data from the serial port are displayed continuously on the EP500 system, and pitch, roll, heading, and depth of the Focus are logged. Echo integration data are recorded simultaneously for each ping from the vessel-mounted transducer and the towed transducer. Comparative observations of abundance variation around the trawl and vessel can therefore be made in addition to acoustic observations of abundance variation in areas around the trawl.

Trawl headline observations

When the EY500 bottle is mounted on the headline of the trawl, it is placed inside a plastic bag attached to the headline. The EY500 is than powered by a separate battery bottle, which has power capacity for 30 hours of use (Figure 5). The system is started and stopped on deck from an external PC, connected to the bottle via a serial line on the underwater plug. In this application data are stored on the internal disk for later transfer to the work station, where the data are scrutinised by BEI. With this application the ES38-12 transducer is used, mounted in a steel frame and attached to the headline. To decrease the backwards radiation from the transducer, the frame is fitted with a 5 cm Divinycell plate (Michalsen at al., 1999).

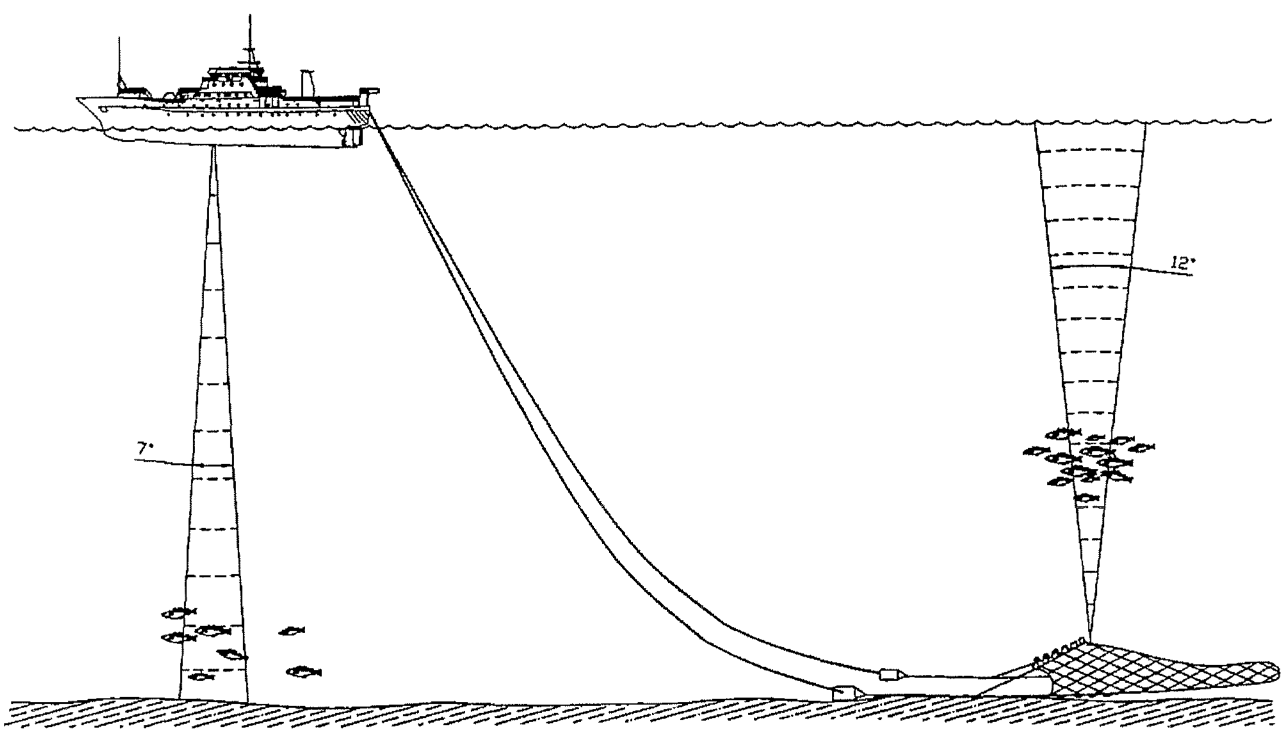

Figure 5. EY500 bottle placed on the headline of the trawl.

Ship avoidance

In this application the EY500 bottle is deployed near the surface suspended under a float. The transducer is suspended separately using a string of 8-inch diameter trawl-headline floats as buoyancy aids in order to reduce the effects of wave action. The transducer is normally hanging at 8-10 m depth (Figure 6) . Data are logged on the local PC. Ship avoidance is measured as the reduction in acoustic backscattering when a survey vessel is passing the transducer. The transducer could also be placed on the bottom pinging upwards to measure demersal fish herding by vessels and trawls. However, this application has not been tested.

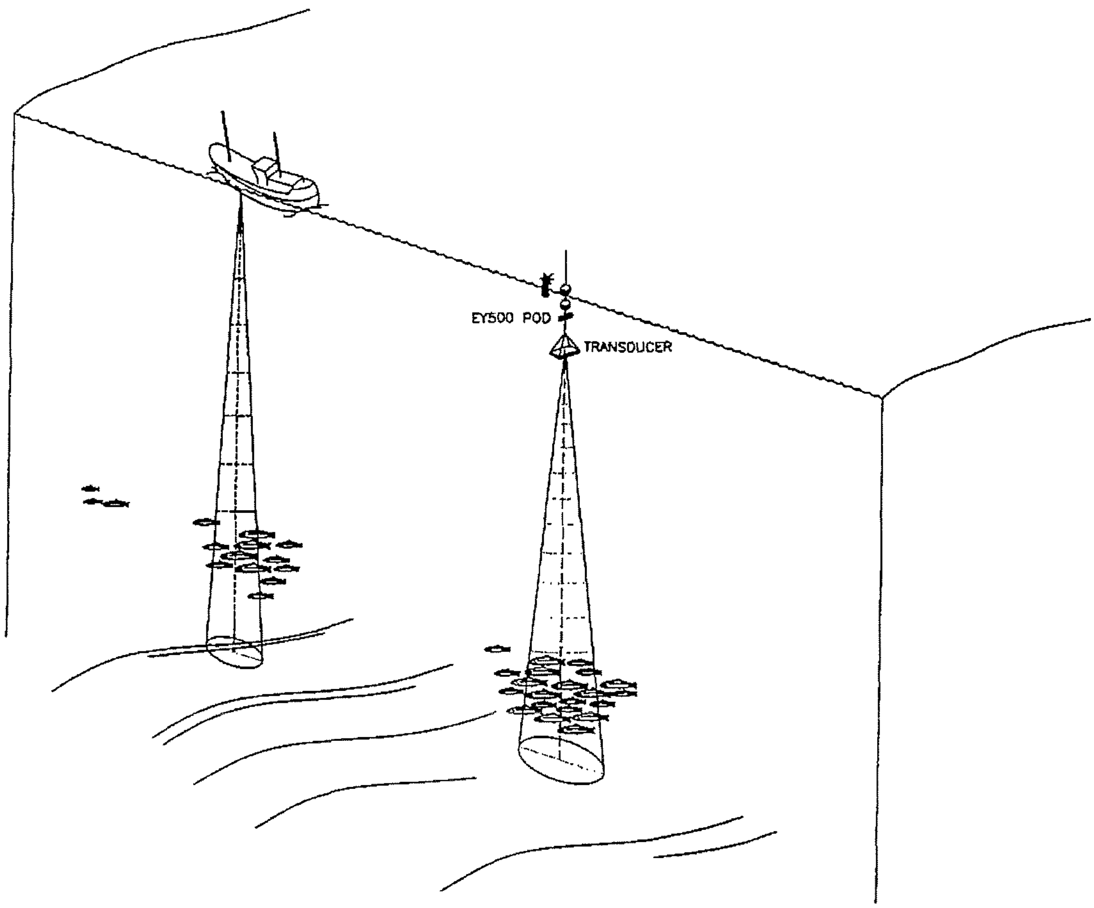

Figure 6. EY500 bottle with transducer deployed near the surface suspended under a float.

Acoustic dead zone

I n order to compare the near-bottom acoustic dead zone from the hull-mounted transducer on the survey vessel (ES38B, 7°) and the transducer placed on the vehicle, the EY500 echo sounder is mounted on the Focus 400. In the example described below, the ES38_12 transducer was used. Deployed at 100 m from the bottom, this transducer has about the same dead zone for echo integration as the 7° transducer when the ship surveys at 300 m depth (Dalen and Bodholt, 1991; Ona and Mitson, 1996; Asgeir Aglen, IMR, Bergen, pers. comm.). This set-up provides the opportunity to test whether this is a viable method to investigate dead-zone occurrence of fish (Figure 7), or whether system induced behavioral effects will make such comparisons meaningless. The acoustic ping and summary data are logged on a work station via Ethernet aboard the research vessel. Echo data from the serial port are displayed continuously on the EP500 system, and pitch, roll, heading, and depth of the Focus 400 are logged. Echo-integration data are recorded simultaneously from the vessel-mounted and towed transducer. Both echo sounders are using data from the same GPS navigator. The sailed distance is therefore identical and data can be compared mile by mile. The configuration of both echo sounders is also identical, in terms of e.g. layering. Data from both systems are scrutinised by the BEI system. Logged data from the EY500 are converted from sample data to BEI-format with a conversion program.. After the sample data are logged they are replayed in order to get a printout of the echogram. The scrutinised data normally have a vertical resolution of 1m for the bottom channel and 10 m for pelagic layers.

Presented data from this application were generated by comparing scrutinised area backscattering (S_A) values from the hull-mounted and towed transducers. The research vessel operated at approximately 300 m depth, and the Focus 400 was towed 100 m from the bottom at a speed of 3-4 knots. The S_A value from each depth layer was logged over about 160 nautical miles, with a horizontal sampling resolution of 0.1 nautical mile. Both data sets had bottom reference to facilitate comparison.

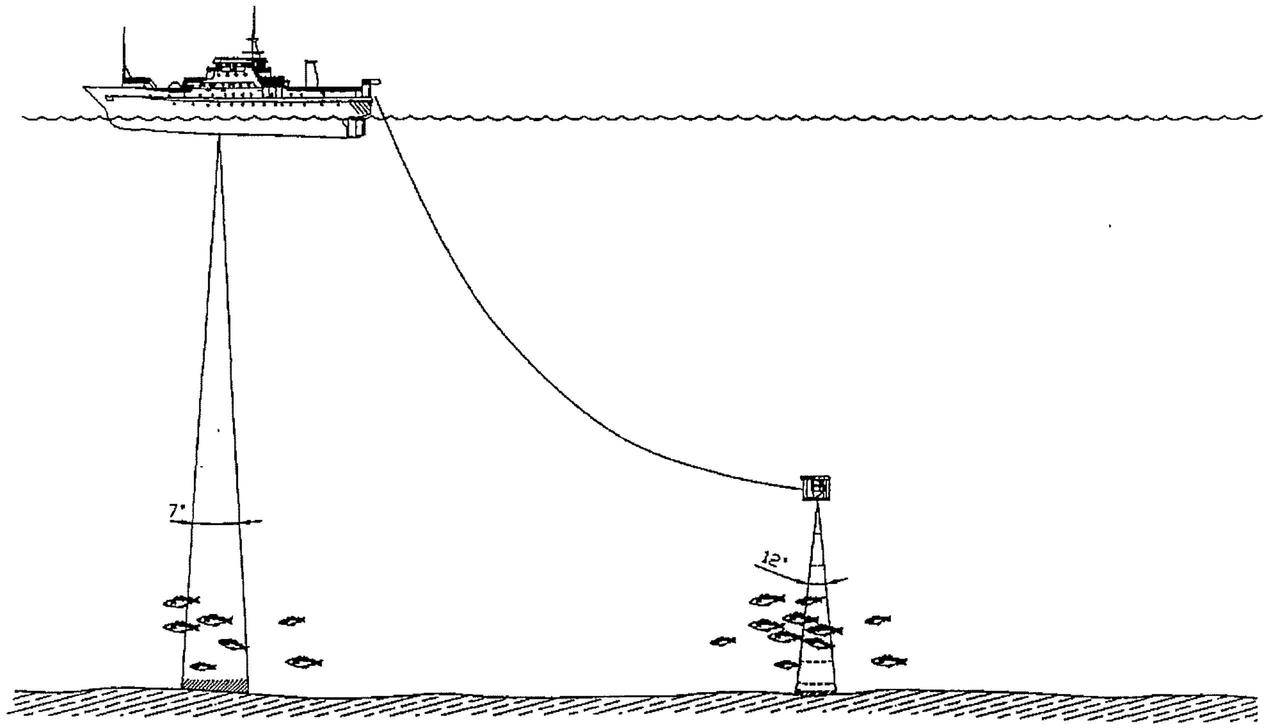

Figure 7. Focus 400 used to investigate the near bottom dead zone

Calibration

In all applications the calibration of EY500 was performed with a standard -33.6 dB, 60mm copper sphere (Foote, 1982; Simrad, 1992) to obtain the target strength and on-axis calibration echo integration constant. Both transducers was calibrated in steps down to 400 m to establish their depth sensitivity in order to facilitate potential depth correction of measured values.

RESULTS

The results presented in this paper are from the dead zone application to evaluate this method to measure fish in the acoustic dead zone. All other applications have been tested in separate investigations and will be referred to in the discussion. The average area backscattering data (S_A) from the bottom channel (10 m) for both the vessel-mounted transducer and the transducer mounted on the Focus 400 is presented in Figures 8 and 9.The data from layers 0 to 3 m from the bottom show that the S_A values from the towed transducer were higher than those from the hull-mounted transducer. Figure 8 shows the comparable area backscattering from the pelagic layers for both transducers. The figure is only showing the depth interval up to 90 m from the bottom.

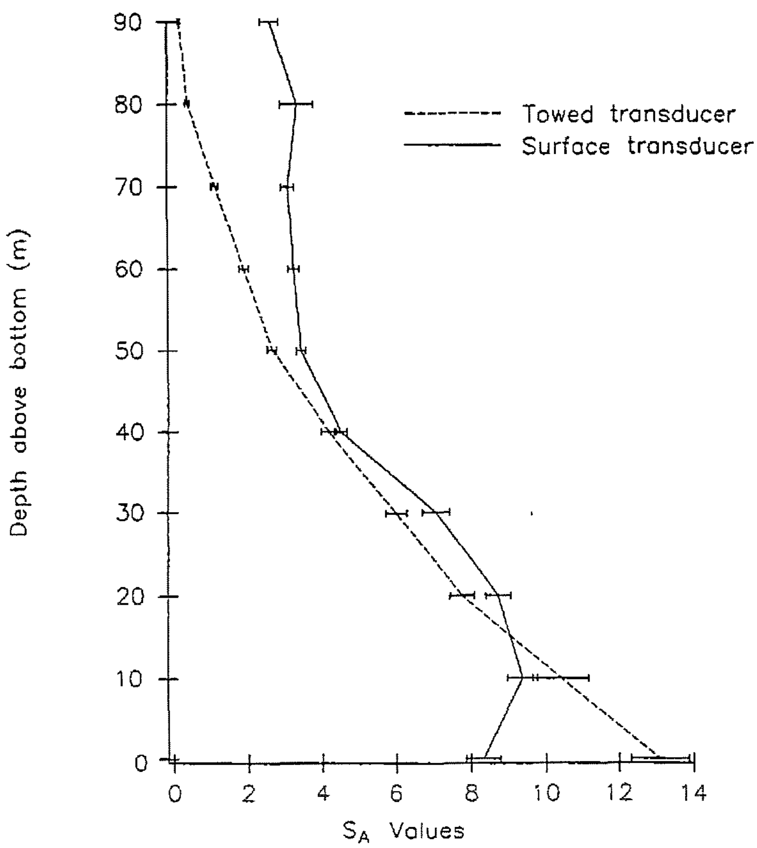

Figure 8. Comparison of integrator values from a hull mounted (7°, 300 m from bottom) and a towed (12°, 100 m from bottom) transducer. Both transducers should have about the same dead zone. The depth range covers the 10 m closest to the bottom. Total number of observations is about 1600 corresponding to 160 nautical miles with a horizontal resolution of 0.1 nautical mile. The vertical resolution is 1 m.

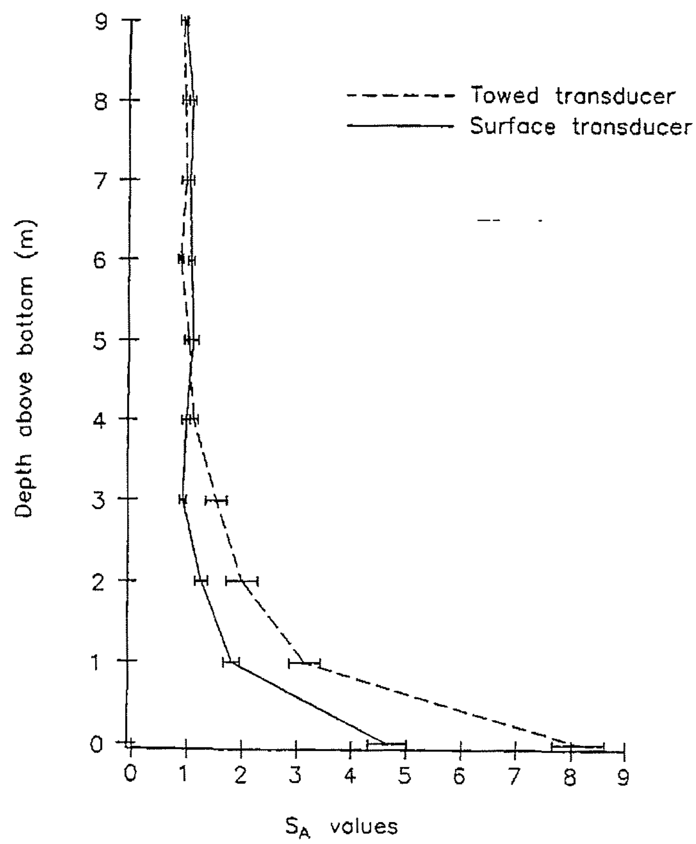

Figure 9. Comparison of integrator values from a hull mounted (7°, 300 m from bottom) and a towed (12°, 100 m from bottom) transducer. Both transducers should have about the same dead zone. The depth range covers the 100 m closest to the bottom. Total number of observations is about 1600 corresponding to 160 nautical miles with a horizontal resolution of 0.1 nautical mile. The vertical resolution is 10 m.

DISCUSSION

Applications

Deep towed acoustic transducer

This application has been tested in Namibian waters on board the "Dr. Fridtjof Nansen" during orange roughy surveys with the authors participating. The experience was that the quantitative survey results were less valuable than the qualitative. The slow survey speed (3-4 knots) made it difficult to widely apply the system. However, detailed studies of spawning plumes close to the bottom in areas with highly variable topography the recordings facilitated the distinction between side lobe echoes of the bottom and fish, which is a general problem in such investigations. The depth limitation (400 m) of the system is unfavourable in this application, and for deep sea (>1000 m) work an upgraded system could readily be constructed and should be considered.

Fish behaviour

This application has been tested, but no results has been published yet. At IMR, Bergen, there is a substantial effort towards absolute abundance estimation in general and for demersal fish like cod and haddock in particular. The system facilitates observation of fish distribution behind the vessel and around the trawl, and will be applied as an instrument in a large effort to establish the catching efficiency of the trawl as well as the availability of fish to the trawl (Engås et al., submitted). These are necessary parameters to establish in order to provide meaningful absolute abundance figures from trawl surveys. It is known that the herding effect from the ship and the trawl varies (e.g. Michalsen et al., 1999), demonstrating that an elucidation of this complex to provide the necessary background for detailed modelling of catchability and availability will take time and effort and require a variety of tools. This application of the system will no doubt be of value in this context.

Acoustic dead zone

The acoustic bottom dead zone has been the object of much debate and many experiments as well as theoretical considerations (e.g. Ona and Mitson, 1996). The present data will not contribute to that debate, and may more be looked upon as a feasibility study of the application. The dead zones of the two transducers as applied were more or less identical. Still the recordings both in the pelagic water column and in the 10 m bottom channel showed variation, with more fish pelagicly for the hull-mounted transducer and more in the bottom zone for the towed one. The most obvious explanation is that noise from the ship and the towing cable is herding the fish down. A number of more complicated explanations could also be suggested, but would be mere speculations. Additional experiments where the system e.g. is towed at the surface with the 7° transducer would reveal to what degree the ship- or the cable noise are responsible for the herding. Such experiments will either way have to be carried out for this and other applications to evaluate to what extent if at all the system itself introduces behavioural responses when deployed.

Before such experiments are run, the value of applying the system in bottom dead zone experiments is doubtful. Fearing the vehicle tow cable may help in reducing noise and should be done if further experiments show that the system noise induces behavioural reactions during application.

Trawl headline observations

This application has been tested on hake in Namibian waters (present authors, in prep.) and cod in the Barents Sea. The Namibian hake did not react to the vessel or trawl by diving. This is in accordance with earlier results (Huse et al., 1998). For cod the tool proved useful in measuring the diving reaction, which at times was substantial, but also variable (Michalsen et al., 1999).

Ship avoidance

This is a well described problem, particularly in pelagic fish (Olsen et al., 1983; Vabø et al., 1999). So far this application of the system has been tested on horse mackerel in Namibian waters. The biggest advantage compared to previous systems based on the use of small boats observing the fish while a survey vessel is passing, is that the system can be deployed in rough weather and off-shore from the survey vessel. More sophisticated systems based on radio transmission of data also exist (Godø and Totland, 1996), but are more expensive, larger, and less flexible in other possible applications. The horse mackerel experiments with this system showed substantial ship avoidance (Bjørn Axelsen, IMR, Bergen, pers. comm.).

CONCLUSION

Venturing towards absolute fish abundance measurements will require modelling of fish and gear behaviour to compensate adequately for variation in availability, catchability and acoustic target strength. This modelling will require detailed knowledge of fish reaction in both the temporal and spatial domain. The tools required for this work are now under development and will probably, together with a rising awareness of the problems, growing competence and increased effort, pave the road to a paradigm shift in fish stock assessment.

The presented tool is one of many needed, and will no doubt be a work horse in this context. It has already proven its value, and will grow in capacity and applicability with the next generation of echo sounders.

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