FIELD METHODS FOR FISH BEHAVIOUR STUDIES USED IN NORWAY

by

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INTRODUCTION

Understanding of fish behaviour is fundamental both for the development of effective and selective fishing methods and for precise abundance estimation of fish stocks. Although the development of different fishing gears have been based on observed or assumed behaviour of fish – until recent years, the possibilities for observations of fish behaviour has been restricted to direct visual observations of fish. However, during the last two decades – our possibilities for observing fish behaviour have increased significantly, through technological developments within hydroacoustics, underwater photography and video, underwater telemetry systems and data storage tags and various other methods. The intention of this paper is to give a brief overview of the development and state of the art for different field methods used for fish behaviour studies in Norway. The main developments writhing methodology for field studies of fish behaviour are summarised in Table 1.

Table 1. Introduction of major new technological innovations in fish behaviour studies during the last 20 years.

Year	**1975**	**1980**	**1985**	**1990**	**1995**
Under-water-Video	Studies of bait, pots longline		ROV Ocean Rover	Self contained systems	Barrel with radio transm Focus
Hydro Acoustics		Mobile echo sounders avoidance behaviour	Trawl sonar Sonar school behaviour	Acoustics on UV-vehicle	
Electronic Tags	UV-telemetry positioning depth,heart beat			VEMCO Accurate positioning	Data storage tags

1. UNDERWATER PHOTOGRAPHY AND VIDEO

Underwater housings for photo- and 16 mm film cameras were developed in the 60-ies. However, these were never extensively used for fish behaviour observations, and thus these photography methods did never add a significant contribution to our knowledge of fish behaviour.

1.1. Underwater video observation in relation to fixed fishing gears.

The development of underwater video cameras was of significant importance for extensive studies of fish behaviour. The first equipment of this kind used for fish behaviour studies in Norway was a low-light, wide angle camera (Hydro Products, SIT) that was used from the mid-seventies, mainly for fish behaviour studies in relation to fixed gears as longlines and pots (Fernø et al, 1976, 1986; Valdemarsen, 1977; Bjordal, 1979, 1986; Huse, 1979, Huse and Fernø, 1990). Fig. 1 shows a typical experimental set-up for studies of fish behaviour related to longlines.

Although more sophisticated cameras (low light, colour, zoom) and other equipment (like pan and tilt units) have been applied in later years, the basic experimental set-up for observation of fixed gears has been maintained as shown in Fig. 1. In addition to the use of a camera systems deployed from an anchored vessel, vessel-independent systems have been developed. One is based on a self-contained unit with an underwater-housing with camera and video-recorder that is set and retrieved with the gear. This has been used successfully for fish behaviour studies with fixed gears as well as with trawls and seine nets. To obtain video observations throughout the fishing period, a time lapse video recorder is often used - with the possibility to compress 24 h of observation in one 3 h video tape. Another development is a camera/gear rig with a cable connection to a surface buoy either with a video recorder or with a unit that transmits the video-signals to the vessel (Fig. 2).

2.2. Underwater video observations of fish behaviour in relation to towed gears.

Observations of fish behaviour in relation to trawl gear dates back to the mid 80s, with the introduction of the towed vehicle Ocean Rover (Seametrix, Scotland). Equipped with a low light underwater video camera, and good manuevering abilities relative to the trawl during towing, this technology opened new and excellent opportunities for observation of fish behaviour at different stages of the trawling process (Fig. 3). The Ocean Rover and in recent years the Focus (Denmark) towed vehicles have been used for extensive studies of fish behaviour, particularly with trawl gear. These observations have provided invaluable information and a significantly increased understanding of the fish capture process in trawling, including major factors as sweeping effects, escapement of fish in front of- and from the trawl as well as the interaction between different species and various selective devices. In later years, self contained camera /recorder units mounted directly on the trawl to observe fish reaction at specific parts of the gear have been used with good results. These units have also proven to be very useful for behaviour studies of fish during the capture process with seine nets.

3. ACOUSTIC METHODS

Fisheries acoustics techniques for stock assessment and fish behaviour studies have developed tremendously during the last 30-years. We will focus on a brief introduction to those of major interest in relation to fish behaviour studies.

A rough overview of different acoustic systems and the platforms to which they are or may be coupled, are given in Fig. 4 and in Table 2 along with existing and potential applications. Acoustics have been used to study a)*natural fish behaviour*, b)*affected behaviour and* c)*migration direction and speed.* In addition to a survey vessel as the traditional platform type, we apply floating buoys, which either log the data for later retrieval or transmit the results via a radio link. Towed vehicles or bodies (Fig. 3, 4) are used to approach the fish targets and towed gears. Trawl systems include instrumentation with cable connection to the survey vessel, which are attached to trawls to monitor fish distribution in the trawl opening or above the trawl. We are presently about to try stationary systems which in principle are similar to the buoy system but placed on bottom or anchored. Further, a feasibility study of using a remote controlled/automatic underwater vehicles (AUV) is presently being done.

The systems referred to in Table 2 have different applications. *Traditional echo sounders* are split beam sounders connected to echo integrators. They give information on density and distribution of fish (MacLennan and Simmonds, 1991), and, when resolved in single specimen, also facts on movements within the sound beam and fish size can be acquired Ona (1994). *Sonars* are used to monitor distribution and movements of fish schools in relation to the catching process or with respect to availability to the standard acoustic method (Misund *et al.*,1996). Scanning sonars are used on mobile platforms (Table 2) to observe fish distribution in the near field of sampling gears (Ona 1994). *ADCP (Acoustic Doppler Current Profiler)* is developed for *in situ.* water current measurements. It has, however, been shown that fish in "layers" can be distinguished from the movements of the water masses by this system and migration speed and direction measured. *Broad band acoustics* has yet not been used, but an already developed system (Gordon, 1997) will be tested this year.

Table 2. Acoustic methodology by platform type and application.

PLATFORM TYPE • *System*	*NATURAL BEHAVIOUR*	*AFFECTED BEHAVIOUR*	*MIGRATION*
Vessel mounted systems			
• Traditional sounders	X		
• Sonar		X	X
• ADCP	X		X
Floating buoys			
• Traditional sounders	X		
• Broad band acoustics	X	X	X
Stationary systems			
• Traditional sounders		X	X
• Broad band acoustics		X	X
• ADCP			X
Towed vehicles (bodies)			
• Traditional sounders		X	
• Sonar		X	
Automatic vehicles			
• Traditional sounders	X	X	
• Sonar	X	X	
Trawl systems			
• Traditional sounders		X	
• Sonar		X	

3.1. Natural fish behaviour

Knowledge about the natural fish behaviour is essential to evaluate efficiency and reliability of scientific surveys (Godø, 1994). It is also important to know variability of fish natural behaviour in relation to species, fish size, season etc. to avoid confounding impacts on studies of affected behaviour. All assessment methods have a limited observation window (Fig. 4). Mainly sonar and traditional sounders connected to echo integrators (BEI) have been applied during standard surveys to monitor changes in distribution of fish related to the observation windows (Godø and Wespestad, 1993; Misund *et al.*, 1996; Michalsen *et al., 1996).* Experience during recent years has shown that behaviour of fish may vary substantially. Therefore, basic knowledge about fish natural behaviour appears to be a prerequisite for meaningful interpretation of affected behaviour.

3.2. Affected behaviour

Information on affected behaviour is important for improving efficiency and selectivity of commercial fishing gears. On the other hand, affected behaviour may seriously alter species and size composition in sampling trawls, and if not taken into account, survey estimates of abundance may be seriously biased (Aglen 1994; Engås, 1994; Godø, 1994). The use of self contained systems like acoustic buoys is a major step forward in these studies (Fig. 5, Godø and Totland, 1996; Gordon, 1997). Also, split-beam acoustic systems on towed underwater vehicles represent an innovation with great potential (Fig. 3). Particularly, when these two systems are operated together in a systematic experimental set-up, quantification of the avoidance dynamics will be improved. An underwater vehicle equipped with standard acoustic instrumentation and developed for fish behaviour studies would make such studies much easier (Fig. 7). For studies of schooling fish behaviour the development of sonar technology during the 1990ies represent a new tool both for stock assessment and fish capture. Acoustic instrumentation on trawls has been used to study fish behaviour and distribution both within the trawl opening (Fig. 6) and above the trawl.

3.3. Migration

Migration is considered a major problem for survey reliability (MacLennan and Simmonds, 1991). Detailed information on migration from acoustics has not been widely used in Norway yet. The sonar method has been used to follow the herring migration (Pitcher *et al.*, 1996). It is however, planned to apply ADCP and broad band acoustics for such studies in nearest future.

4. ELECTRONIC TAGS

Tagging is widely applied in fisheries studies today. Traditional external tags are used for migration studies, various internal tags and micro wire tags are used for assessment purposes, and acoustic tags have wide applications in fish behaviour studies. We will here concentrate on applications and developments in electronic tags, which have been used in recent studies in Norway.

4.1. Monitoring fish behaviour, using ultrasonic tags.

Ultrasonic tags were developed in Norway in the early 70s, by the Sintef-group (Trondheim). The tags are attached to the fish and transmit signals to a hydrophone connected to a data storage and analysis unit. Typical parameters that can be measured are depth (pressure), temperature and heart beat frequency. Changes in heart beat frequency did for instance give clear indications of the first response of the fish to an approaching trawl. However, ultrasonic tags have most extensively been used to track fish movements, e.g. the migration behaviour of salmon. (Holm *et al.,* 1996). This has traditionally been done by tagging the fish and and track its movements using a directive hydrophone from a vessel. By obtaining the direction to the fish from different locations, the position of the fish could be calculated and plotted to obtain tracks of the fish movement. However, tracking fish with this system is laborious and only a few fish can be tracked simultaneously.

In the early 90s the VEMCO (Canada) system for automatic positioning of fish was introduced. It is based on fish tagged with ultrasonic tags and array of 3-4 hydrophone buoys that receives the signals and transmit them further to a vessel or base station (Fig. 8). Based on the time difference between signal reception by the different hydrophones, the position of the fish is calculated automatically by a computer and plotted on a monitor. The system also calculates swimming speed and direction for the individual fish. The system is normally used to track 4-6 fish or crustaceans simultaneously.

The Vemco system has been used both to study natural behaviour and behaviour affected by different fishing gears for various fish and crustacean species, as Norway lobster and edible crab in relation to pots (Bjordal, 1993; Skajaa 1997), cod and ling in relation to longlines (Løkkeborg and Skajaa, 1997), cod in relation to trawls (Engås et al., 1997) and to study the difference in migration behaviour between coastal and oceanic cod (Godø, 1995).

4.2. Data storage tags (DST)

The miniaturisation of electronics has opened the way for new tagging applications. Tags, which store information on environmental, physiological and chemical processes, are attached to the fish and the recorded data is downloaded after recovery. Thus, detailed information on natural fish behaviour or physiological rhythm in relation to its environment can be studied over long periods. For species that occur close to surface, a light sensor can be used to determine geographical position from information on sunrise and sunset (Gunn *et al.,*1994). Also, when the fish have certain behaviour in relation to currents, fish movements can be modelled quite adequately (Arnold and Metcalf, 1995). For acoustic surveys, the tilt angle of the fish, which can be monitored by such tags, determines acoustic property of individual fish. In Norway DSTs are now being used to study vertical migration behaviour and the related variation in tilt angle of cod. The results give insight the fish's availability to the bottom trawl survey and its acoustic target strength. Fig. 9 shows a cod being tagged with a data storage tag (DST) that records temperature, depth and tilt angle along with a plot of depth and temperature from a tagged fish at freedom for about one year.

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The reference list is not comprehensive regarding the work within the field but rather a selection of representative papers for the different methods described.

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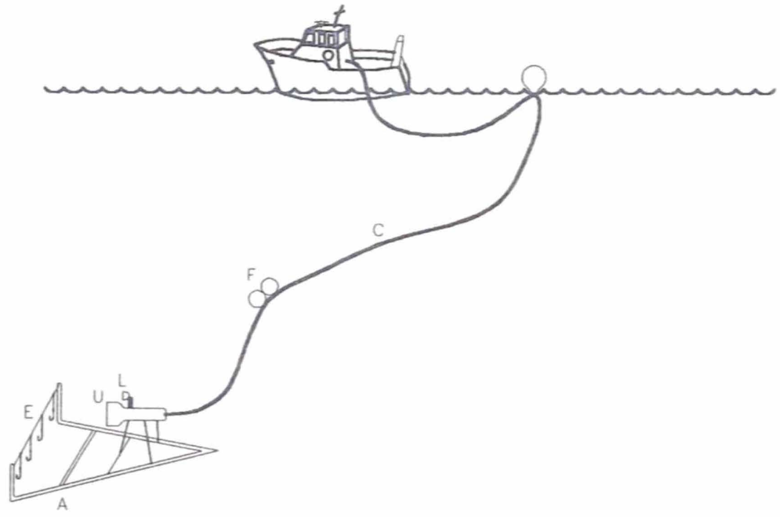

Fig. 1. Observations of fish behaviour with longlines, by a camera and gear rig suspended from a vessel (from Bjordal and Løkkeborg, 1996).

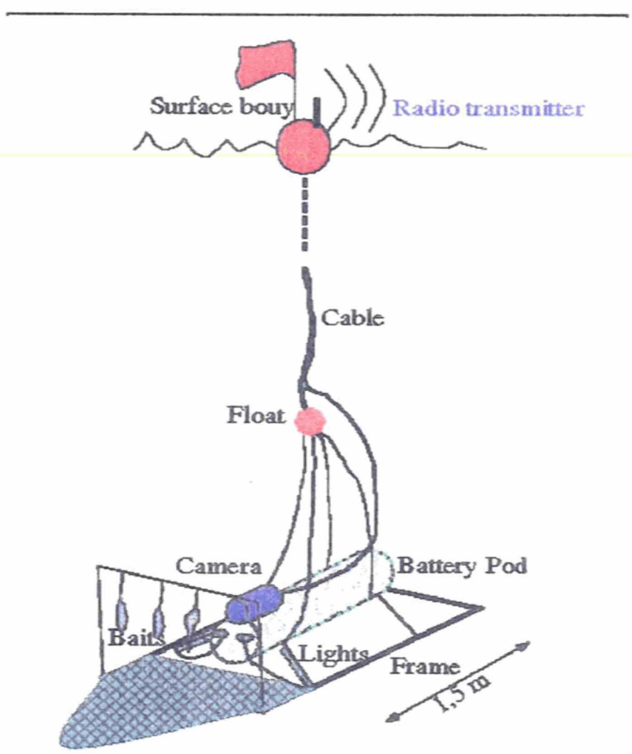

Fig. 2. Fish behaviour observations by self contained unit with wireless transmission of video signals to vessel/ base station (from Godø *et al.* 1997).

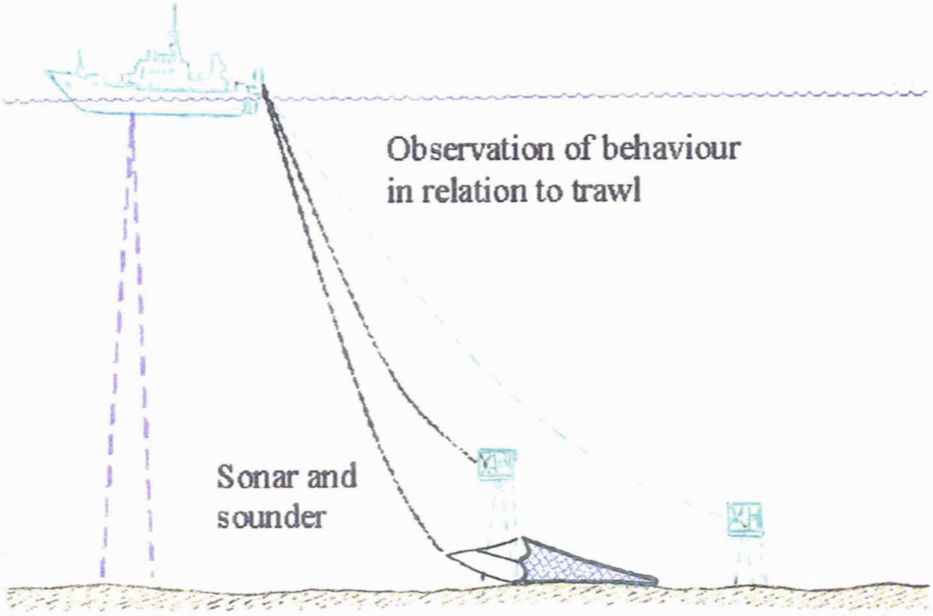

Fig. 3. Observation of fish behaviour during trawling, using a towed vehicle.

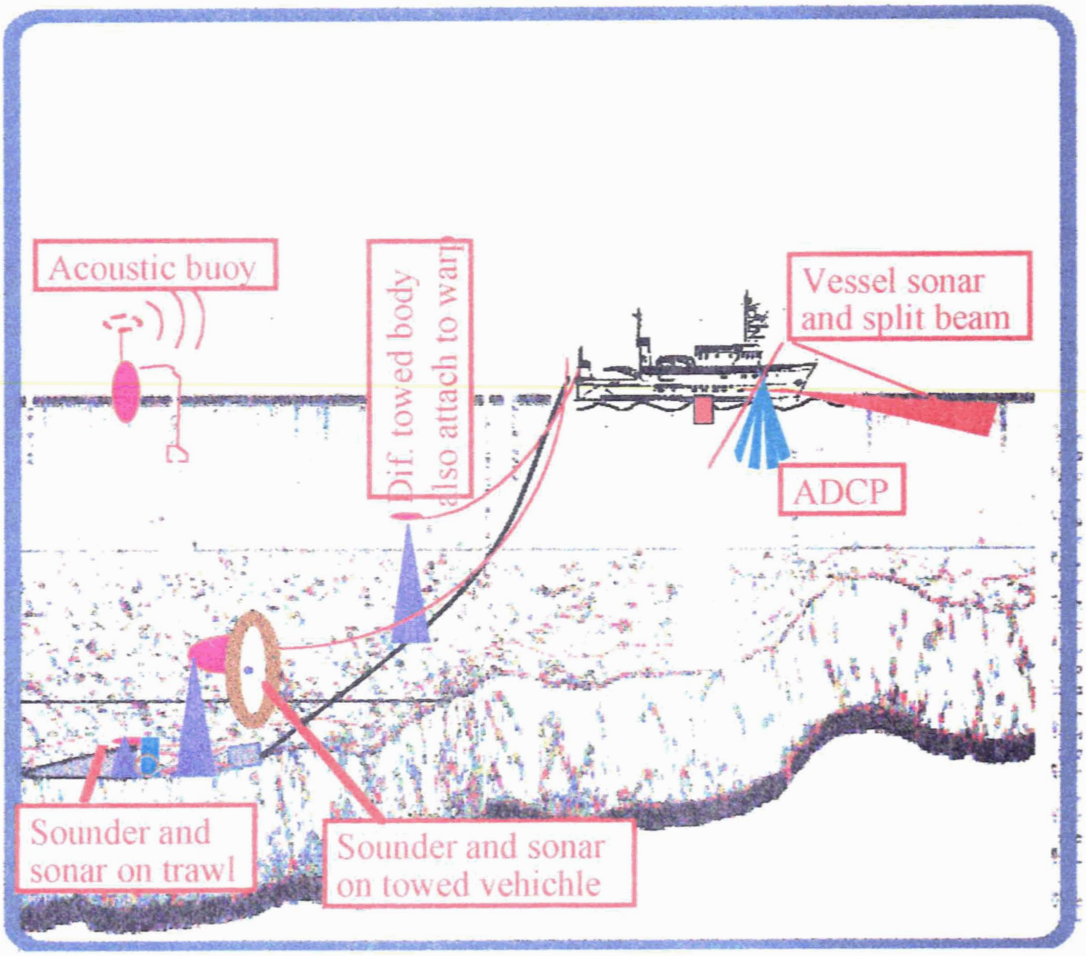

Fig. 4. Acoustic observation techniques attached to various platforms. The echogram shows recordings of gadoids partially available to the bottom trawl and the acoustic observation windows.

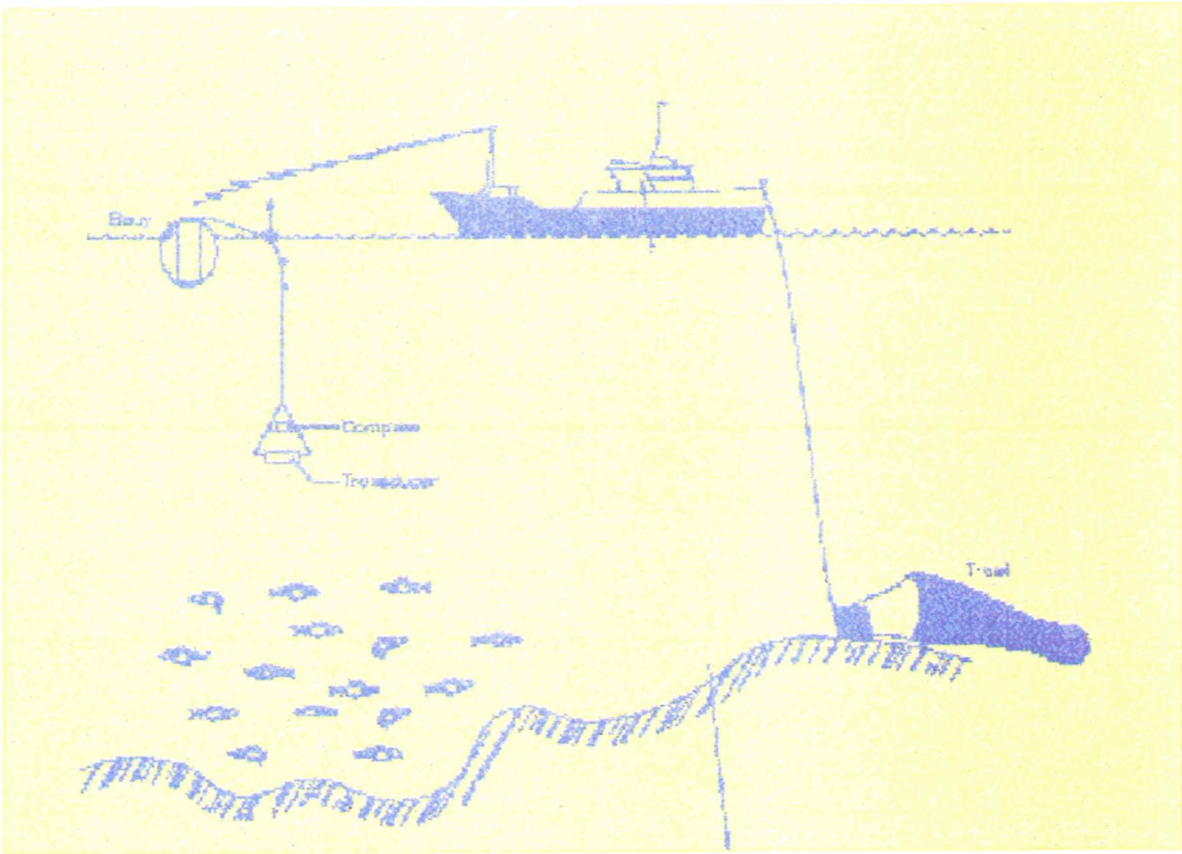

Fig. 5. The acoustic buoy with radio connection to the mother vessel.

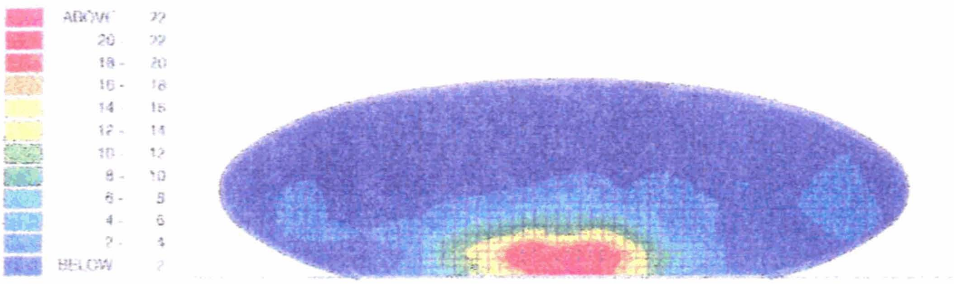

Fig. 6. Density distribution of fish within the trawl opening of a Norwegian bottom sampling trawl observed and positioned by a scanning sonar mounted on the headline of the trawl (from Ona 1994).

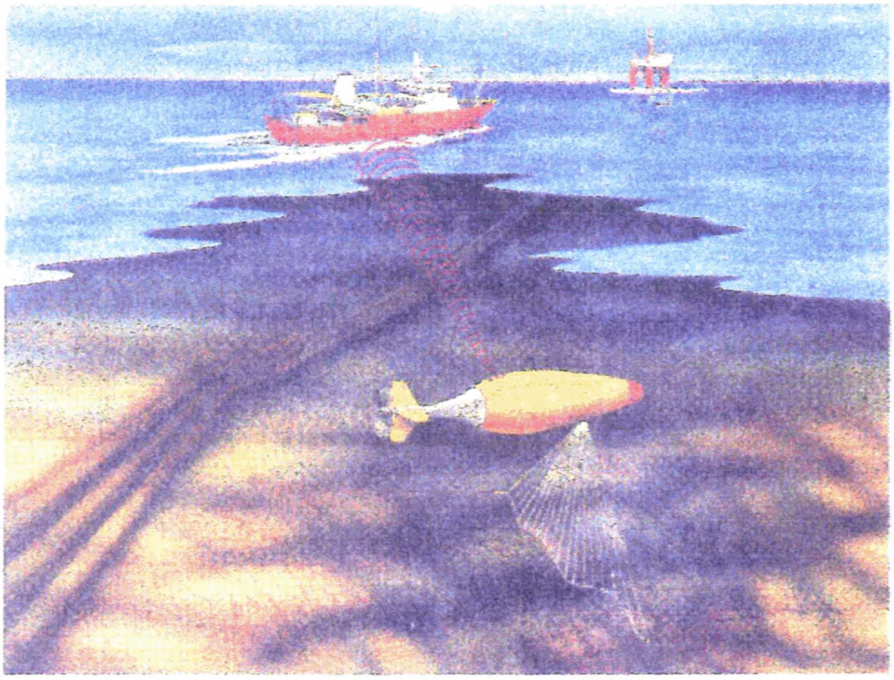

Fig. 7. 'Hugin' is a semi-automatic underwater vehicle able to perform a sonar survey of 36 hours. If along with the mother vessel the data can be transferred via an acoustic link and displayed as survey proceeds. A feasibility study is underway for evaluating adaptation to fish behaviour studies.

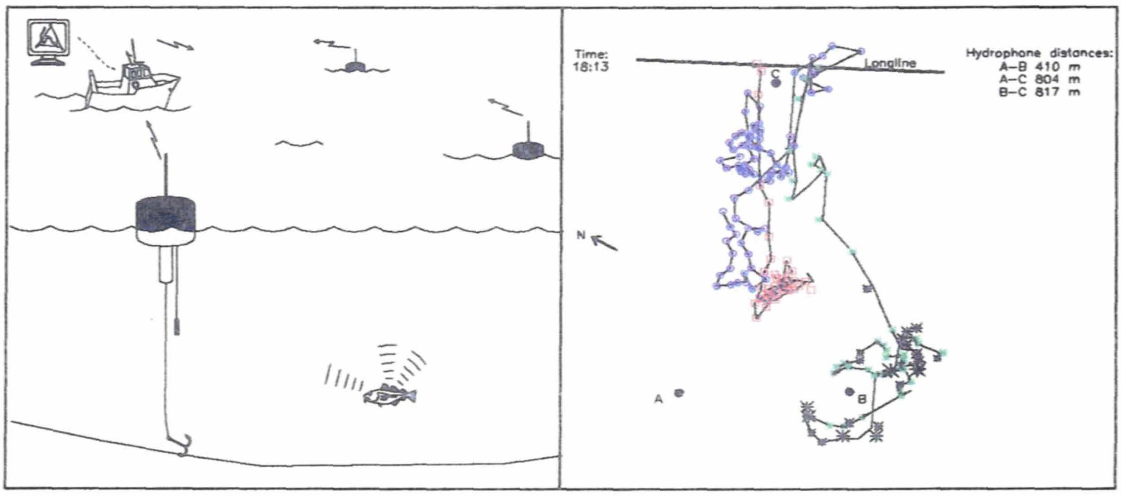

Fig. 8. The Vemco system for automatic positioning of fish (left), and a plot showing the track of three cod being attracted to a longline (right).

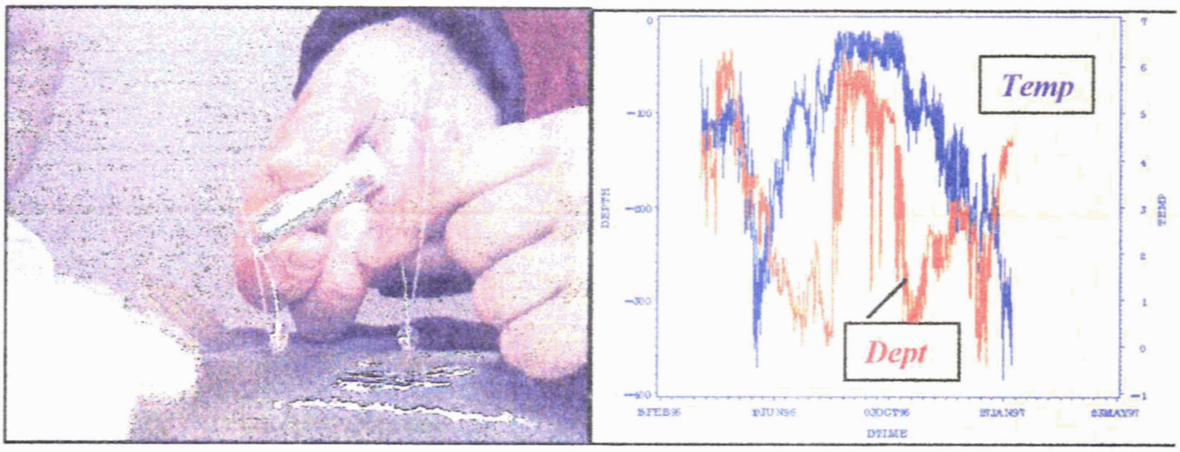

Fig. 9. Data storage tag being attached to a cod (left) and a temperature and depth time series after about one year in sea.