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A new pass-through PIT tag detection system for marine use

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Abstract

In order to study the frequency of passages of juvenile fish through a trawl in areas of high fishing intensity, an underwater detector system for marine use of PIT tags was built. The system consisted of a cylindrical antenna coil with an inner diameter of 40 cm, connected to an underwater bottle (housing) that contained a battery, a detector board and a pocket PC for data logging. The system was built to operate at depths down to 500 metres. The system was been extensively tested in the laboratory and in a small-scale field experiment. One hundred per cent detection success was achieved with two groups, each of 10 juvenile cod (*Gadus morhua* L., 1758), where the tags had been injected into the dorsal musculature and abdominal cavity respectively. The detector was later used in a pilot study in which 329 cod were caught, tagged with PIT tags and Floy tags and subsequently released at the same location where they had been captured. The detector was mounted onto the open codend of a trawl and the area intensively fished. The 16 hauls taken swept 30% of the study area. Three tagged fish were detected as they passed through the trawl codend. Underwater video observations of fish behaviour directly in front of the antenna were made during four hauls. No fish with external Floy tags were observed on the video recordings, supporting the lack of PIT tag detections during the four tows when the video camera was used. The observed fish swam along the trawl, positioning themselves at a favourable angle for tag detection by the antenna. The recordings did not indicate that fish attempted to avoid passing through the antenna.

Introduction

The management of most commercially exploited fish stocks is based on a harvesting strategy that is designed to minimise the exploitation of juvenile, immature specimens (Gulland, 1977; Halliday and Pinhorn, 2002). This is generally achieved by the use of size-selective gears. The selectivity of trawls has traditionally been regulated by the specification of a minimum legal codend mesh size and during the last decades also by the use of grids, escape windows etc. A prerequisite for the efficacy of such technical devices is that the fish that escape through the meshes or other selective devices should survive. Published studies on the survival of cod indicate generally high survival rates for escaping fish of this species (DeAlteris and Reifsteck, 1993; Soldal *et al*., 1993). However, on intensively fished grounds, fishermen claim that multiple passages of fish through the meshes of the codend or through other size selective devices result in higher mortality rates than have been observed in the survival experiments. Visual observations of the capture process have shown that fish accumulate just ahead of the trawl opening. Some make escape attempts above or below the trawl, while the remainder swim with the trawl just ahead of the ground rope, where they maintain station until they tire and drop back into the body of the trawl (Main and Sangster, 1981). It is thus likely that fish that reach the extension/codend of a trawl are completely exhausted. If such fish manage to escape, it is likely that they will need a long period of time to recover physiologically. Should they be exposed to another trawl shortly after escaping, the added stress of a new escape response may severely affect their survival after being excluded, for example by a sorting grid. Moreover, fish that have been caught by the trawl but manage to escape through the meshes of the codend or through the bars of a sorting grid always run the risk of being injured, e.g. by scale loss (Chopin and Arimoto, 1995). This risk increases with each capture/escape episode.

A project to study the effect of multiple capture/escape episodes on the subsequent survival of fish escapees from towed gears began in 2000. The study required a methodology that enabled the number of passages of individual fish through the trawl to be monitored. The solution put forward was to apply the passive integrated transponder (PIT) technology that has been successfully used for individual tagging of juvenile salmonids (Prentice *et al*., 1990). PIT tag monitoring systems have been installed in hydroelectric dams and fish hatcheries (Prentice *et al*., 1990) and for deployment in streams (Roussell *et al*., 2000). A wide range of commercially produced antennae was also available. Of special relevance to our study is a detection system built for operation on a specially designed pair trawl in the Columbia River estuary (Ledgerwood *et al*., 2000). The system consisted of a 3-pipe bundle of 27 cm-diameter detection tunnels attached at the codend position of the trawl, and with electronics and power supply housed on a buoyant platform bridled to the surface-floating headline of the trawl.

The mentioned systems were all built for operation in fresh water and at shallow depths. The use of PIT tags for in situ detection of animals in the marine environment has been hampered because the equipment built to work in fresh water does not function in seawater, since the conductivity of seawater is higher than that of fresh water. The magnetic flux through seawater induces eddy currents that oppose the field responsible for their creation (Lenz's law) (Finkenzeller, 2000).

This paper gives the design properties of a detector system built for marine applications and the results of tests of detection success. It also presents the results of a small-scale experiment that was intended to determine how often multiple encounters occurred.

Materials and methods

Technical description of detector system

The detector antenna is a multi-turn coil wound onto a 60 cm diameter cylinder made of epoxy and fiberglass. In order to insulate the coil from the seawater an epoxy layer 10 cm thick on the outside and 5 cm on the inside encapsulated the windings, producing a "pass through" cylinder of 50 cm inner diameter (Fig. 1). The length of the cylinder was 30 cm. The weight of the antenna was 95 kg in air, while in seawater it had a positive buoyancy of 13 kg. At each end of the cylinder a flange with a series of 10 mm holes was made for attaching the antenna to the trawl net. The inductance of the coil was 280 μH and a tuning capacitor of 7000 pF was connected in series with the windings. In order to situate the tuning capacitance as close as possible to the windings, a watertight housing was located on the outer surface of the antenna cylinder. A connector for the cable connection between the antenna and the detector board was attached to the lid of the housing. The maximum current in the antenna coil was obtained when the system is tuned to its resonance frequency. When the antenna was totally submerged in seawater the current was reduced by approximately 70% compared to the readings in air. Initial testing showed that the magnetic field still had enough energy to detect most kinds of PIT tags used in fish tagging experiments.

The detector was based on the PE105 transceiver board (Patten Engineering) and a data logging system on a pocket PC (Compaq iPAQ). The pocket PC was connected to the detector via an RS-232 serial cable. The PC and detector board were placed in an anodised aluminium bottle together with two rechargeable batteries. A 15 m long cable with low capacity (59 pFm^{-1}) connects the antenna to the detector board via two Subconn underwater connectors (Fig. 4). Whenever a PIT tag was within detection range of the antenna, the detector board transfered its *id*-code to the logger where the code was displayed and stored together with other information.

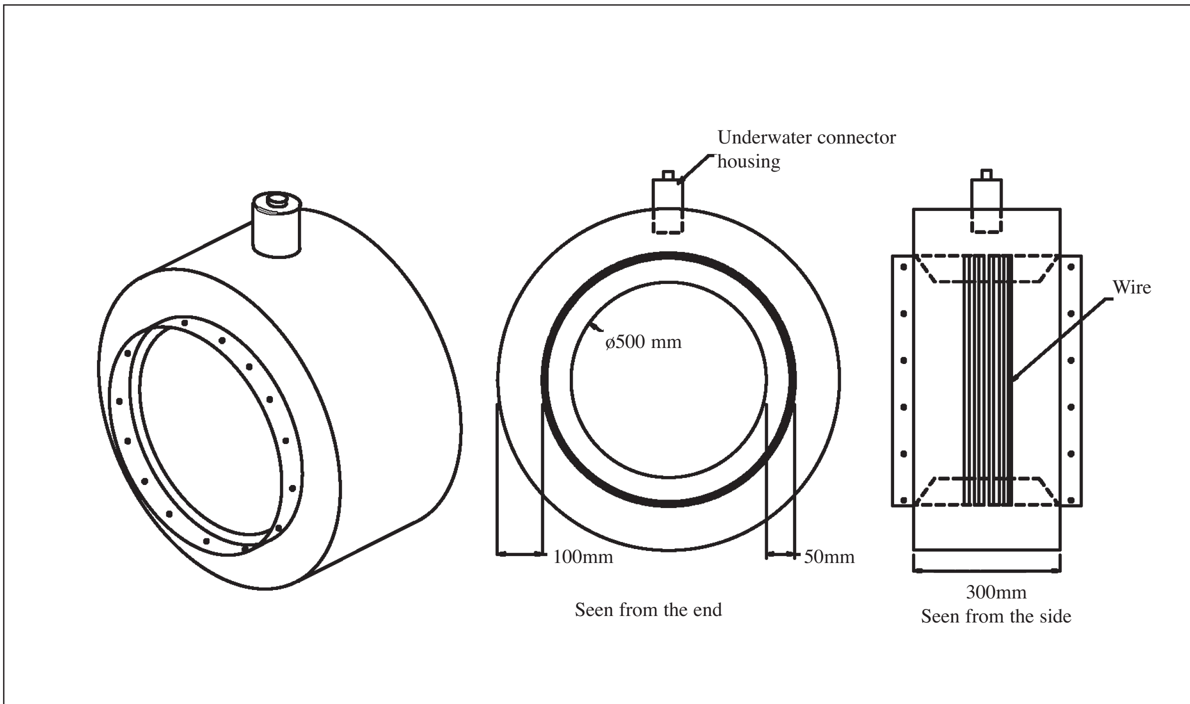

Fig. 1 – Construction drawing of the detector antenna. Note the insulating layers of epoxy on the inside and outside of the windings.

Laboratory tests of tagging procedure and detection success

To estimate tag loss and tagging injury and mortality, a total of 20 cod in the size range 35-40 cm were tagged with Destron TX1415BE tags (23.5x 4mm). The fish were anaesthetised prior to tagging. Ten fish had the tag injected into the dorsal muscle at the base of the first dorsal fin and ten had the tag injected into the abdominal cavity. The tags were injected using the Biomark MK10 injector with a gauge 6 needle. The fish were then transferred to a net cage and kept for 14 days after which they were inspected for tag presence, tag orientation and possible tagging-related injuries.

Tests of detection success were carried out with 35-40 cm cod tagged with TX1400BE (12.5x2 mm), TX1405BE (13.5x2 mm), TX1410BE (20x3 mm) and TX1415BE (23x3.4 mm) tags, all ISO tags operating at 134.2 kHz. The antenna was attached to a cylindrical net section connecting two net cages and the fish were forced to swim from one cage to the other. Trials to monitor detection range and sensitivity to tag orientation were also performed with hand-held tags and tags mounted to sticks or lines.

Field experiment

The field experiment was carried out in the Lyngen Fjord in northern Norway (Fig. 2). In order to facilitate trawling, a flat soft-bottom (clay) area of the fjord was chosen as the experimental site. The site topography and the presence of underwater cables crossing the fjord restricted the experimental site to a 2x1 nautical miles (6.86 km^2) area. The depth was 120 m.

Cod were caught by bottom trawl at the experimental site. On capture, the healthy fish (excluding fish with everted stomachs or otherwise injured by the capture process) were transferred to a net cage where they were kept for approximately one week in order to ensure that only fish that had fully recovered from the capture process were used in

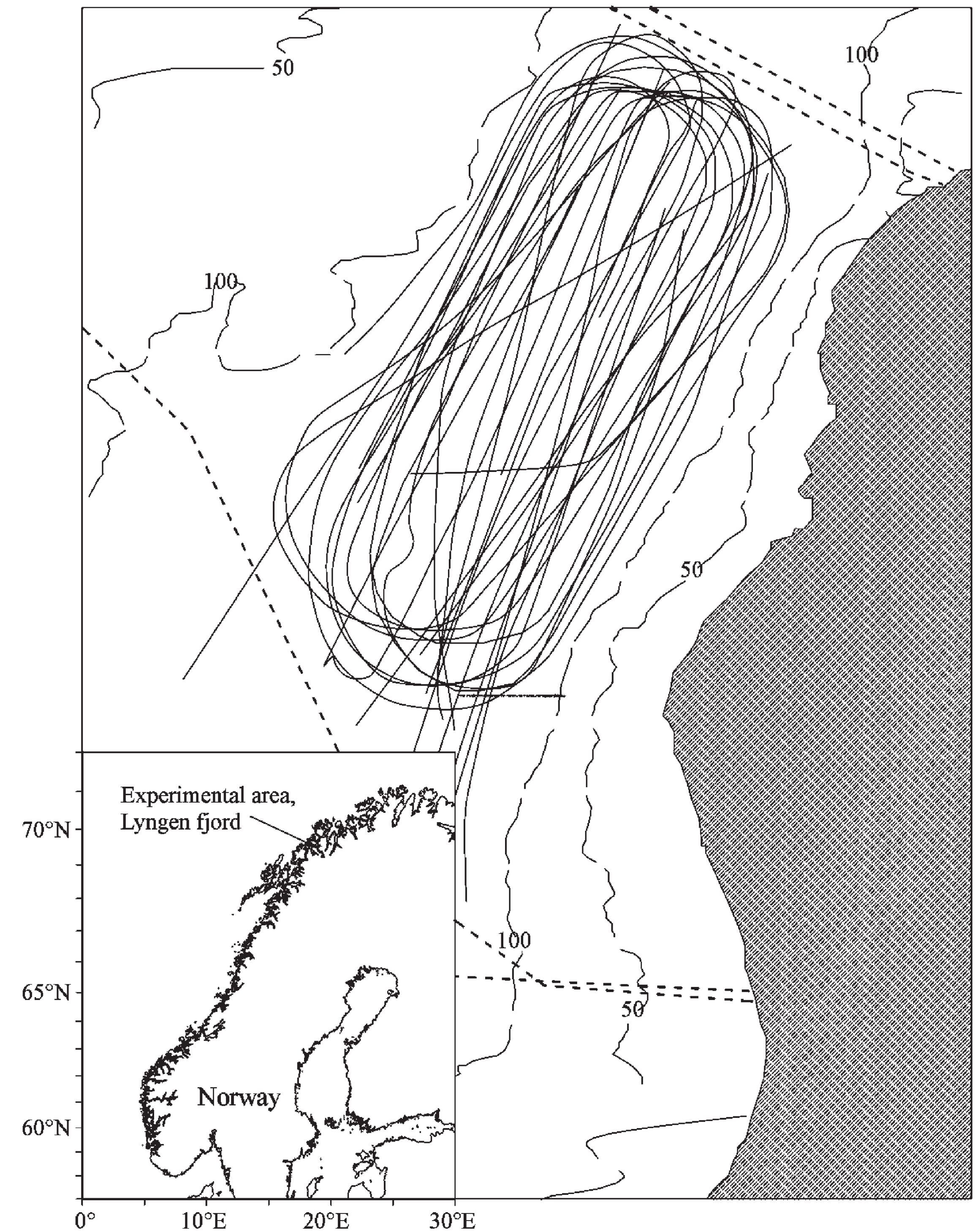

Fig. 2 – The experimental site of the tagging-recapture experiment. The tracks of the 16 recapture hauls are shown. The hatched lines indicate the position of underwater power cables crossing the fjord.

the tag-recapture experiment. A total of 329 cod were tagged, 127 with the Destron TX1410BE tag and the remaining 202 with the Destron TX1415BE. The tags were injected into the dorsal muscle as described above for the laboratory tests. Fish were also tagged with external Floy tags. All tagged fish exhibited normal swimming behaviour and had no external injuries. The tagged fish ranged in size from 29 to 98 cm (Fig. 3). After tagging the tag codes were read using the Destron FS2001-ISO reader kit and the fish were released in the centre of the experimental area.

The bottom trawl used in the experiment had a vertical opening of 7 to 8 m and a door-spread of 55 m, both measured in real time with Scanmar sensors. Towing speed was approximately 2.5 knots (1.29 ms^{-1}). During the recapture experiments, the antenna was mounted at the end of the open codend (Fig. 4). The aluminium cylinder with the detector board, logging unit and battery was attached to the extension, 12 m in front of the antenna. A total of 16 hauls were made with the detector. On four of these hauls (hauls no. 3, 4, 5 and 16), a SIT underwater video camera was used to study the behaviour of fish in front of the antenna and to verify the passage of fish past the antenna. The camera was attached to the inside of the roof of the extension piece, 1.5 m in front of the antenna and was looking towards the antenna. A light tube (11 W) was mounted on starboard side of the camera. The camera and light tube were connected to an aluminium bottle containing a video recorder and power supply (Fig. 4).

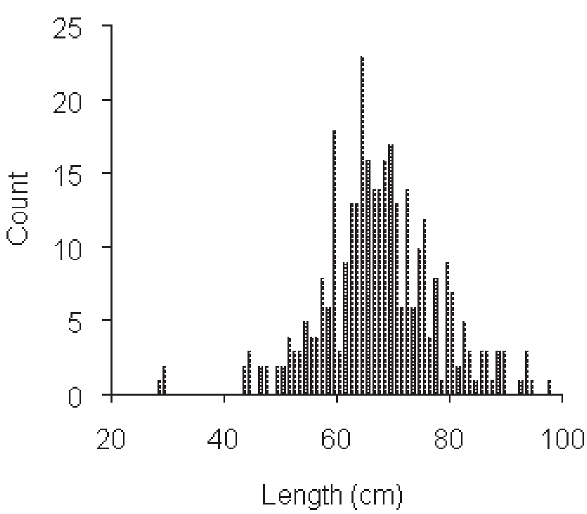

Fig. 3 – Size frequency distribution of the tagged cod.

Results

Laboratory tests of tagging procedure and detection success

No tag loss or mortality was observed for the 20 cod tagged in the laboratory study. The wounds left by the needle used to implant the tags had completely healed by the end of the two-week period in all but one fish. Dissection of the fish after the experiment had finished showed various orientations of the tags injected into the abdominal cavity, although the tags were all injected with the tags parallel to the long axis of the fish. There was no evidence of tag ejection for any of the tagged fish, nor that tags injected into the dorsal musculature had migrated further into the tissue. Three of the tags injected into the body cavity were showing indications of tissue encapsulation.

All tagged fish were successfully detected as they passed through the antenna during the laboratory tests. However, the manual test of the various tag sizes showed that the smaller tags (TX1400BE, TX1405BE) with shorter detection ranges were more likely to escape detection when they passed near the centre line of the antenna and at a large angle (>45 degrees) to the long axis of the detector cylinder.

Field experiment

The tracks of the trawl hauls in the study area are shown in Figure 2. The area swept by the 16 tows corresponds to roughly 30% of the designated study area. A total of three tagged fish were detected during the recapture tows, one fish during each of hauls 1, 8 and 10, respectively. Two of the fish (measuring 52 and 64 cm) were tagged with TX1415BE tags and one (64 cm) with the TX1410BE. The video

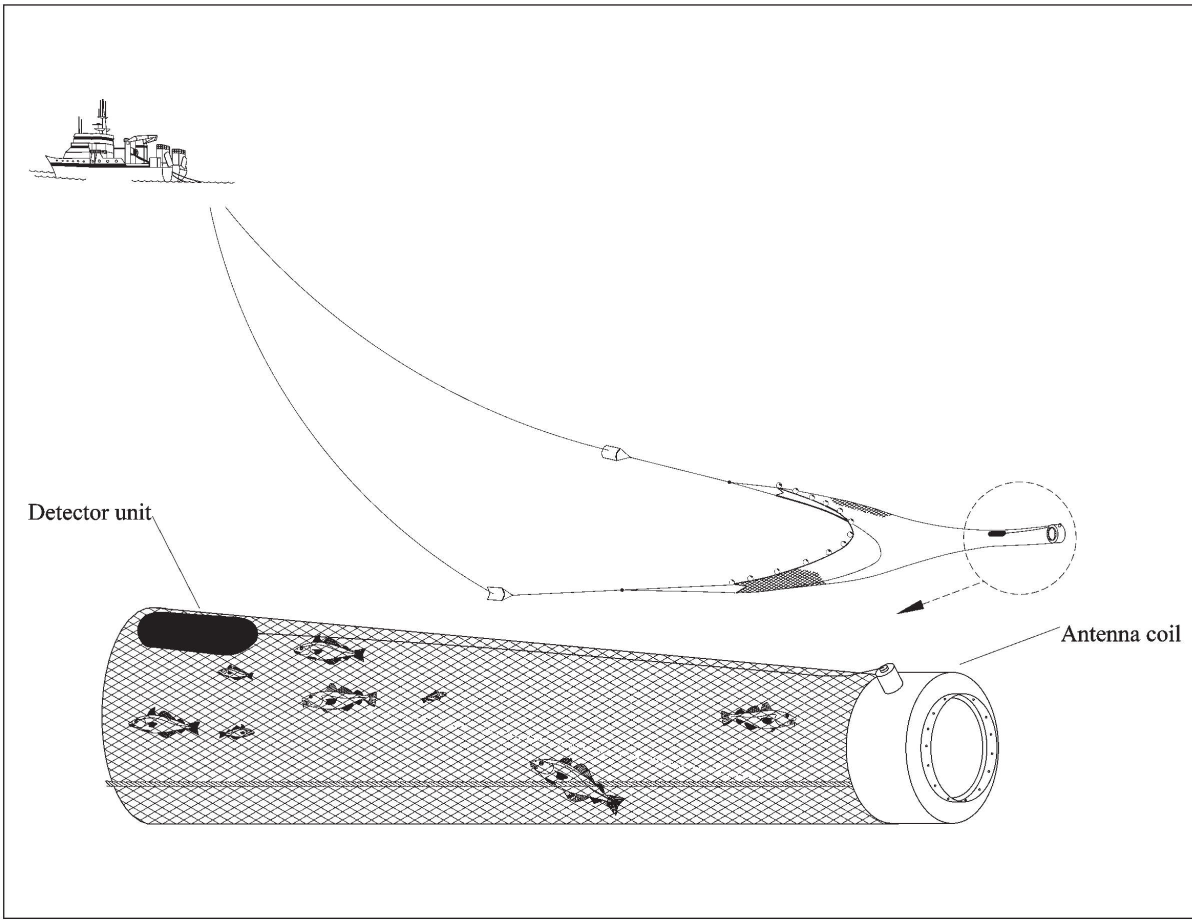

Fig. 4 – Sketch illustrating the mounting of the antenna at the end of an open codend.

recordings during hauls 3, 4, 5 and 16 did not indicate that any fish attempted to avoid passing through the antenna. The fish swam along the trawl, positioning themselves at a favourable angle for detection (i.e. parallel with the long axis of the cylinder). No fish with external Floy tags were observed on the video recordings, supporting the lack of PIT tag detections during the four tows when the video camera was used.

Discussion

The detector system for PIT tag detection in seawater has been successfully tested in both laboratory and field experiments. The antenna was specifically designed for mounting in the extension section of a trawl or at the end of an open codend to study repeated encounters of fish with a trawl on intensively fished grounds. The equipment is also suitable for other tagging-recapture situations, e.g. the monitoring of river/hatchery-tagged salmonids during their marine life stage. The advantage of this method for collecting "recapture" information is that the animal does not need to be brought onboard or even to the surface, thereby reducing recapture mortality to practically nil.

The antenna was built of epoxy, which has four main advantages. It has high electrical resistance, which reduces the occurrence of eddy currents. It also kept the antenna waterproof and extended the operating depth down to 500 m. Near neutral buoyancy in seawater and high mechanical strength improved the handling properties of the antenna and enabled it to be used on board commercial fishing vessels.

The field experiments were performed using the two largest of the four Destron tags tested, the TX1410BE and TX1415BE. The larger tags had a larger ferrite coil, and required less magnetic field strength to operate than the smaller coils. They could therefore be detected at a greater distance from the antenna and were less sensitive to the orientation of the tag than the smaller tags. To improve the detection success of the system, attempts will be made to increase the current throughput of the antenna by modifying the coil specifications. An auto tune option will also be implemented. Further planned improvements include an acoustic link between detector and vessel for real-time registration of detected tags.

No detection will take place if several tags are within detection range of the antenna simultaneously. Interference of the signals from the tags will in such cases result in a signal the detector cannot decode. Theoretically, some tagged fish could therefore avoid detection. However, the proportion of tagged individuals in sampled populations is normally very low, and the probability of simultaneous passages therefore negligible. This technical limitation of the system therefore has no practical consequences in a tag-recapture situation.

The recapture rate (three fish out of 329) in the field experiment was low. Assuming that the fish were uniformly distributed across the study area and accessible for capture by the bottom trawl, the expected number of recaptures would be 104. We speculate that some of the tagged fish may gradually have moved out of the study area due to the disturbance caused by the intensive trawling or moved up into the water column above the influence of the headline. However, this could not be verified as the ship was not equipped with a pelagic trawl and sampling outside the study area was prohibited because of electrical powercables crossing the fjord and by non-trawlable bottom (Fig. 2).

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