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Analysis of the reliability of data on the density of traffic of fishing vessels engaged in fishing with regard to the risk of damage to underwater cables

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Abstract

Accidental damage to underwater cables caused by ship traffic seems to be a current problem. According to the statistics more than 44 percent of such damage is caused by fishing vessels. The reason for the next 14 percent is damage from ships' anchors. The construction of the underwater installation risk model was based on the determination of the density of the traffic in the area where the installation is located. There are several models used to assess the risk of underwater cable damage requiring the implementation of data on the density of traffic of fishing vessels. For this purpose, they usually use AIS (Automatic Identification System) data or statistical data on traffic density in the areas called fishing squares. The aim of this article was to compare traffic data that was based on two independent systems AIS and VMS (Vessel Monitoring System) and verify the reliability of them. The research was carried out in the area of the Slupsk Bank where an underwater cable has been damaged several times. The authors have demonstrated the need to verify the data from both systems in order to obtain reliable information about fishing vessels.

Introduction

Damage to underwater cables has been closely monitored by the International Cable Protection Committee (ICPC) since its inception in 1958. The underwater cable industry has so far thought that the main cause of cable damage was sea fishing activities. However, the increased usability and popularity of the Automatic Identification System (AIS) has changed this view and has revealed the growing threat of damage to submarine cables caused by ships' anchors. The prevention of damage to cables and the reduction of risk is an integral part of the ICPC's activities. It is also an important interest of the members of this organization. It has been estimated that there are around 100–150 failures of international cable systems annually, and the average cost of repairing just one of them varies between $1 and $3 Million dollars. Figure 1 has presented the statistics of the causes of damage to underwater cables. According to the data, fishing vessels activities are the cause of 44% of the damage. Ships' anchors, that were dredged or lost over subsea installations, occupy the next place.

Since 2006, British Telecom has been using AIS to monitor ships in UK waters in the locations of underwater cables. The data obtained from AIS combined with the ships' data enabled them to identify vessels that were particularly likely to damage cables. The AIS system has significantly improved the determination of the cause of damage to cables. In 2007, 53 cables were damaged in the waters around Great Britain, of which 19 were the result of damage by naval anchors. The statistics gathered showed that 67% of cable damage was caused by fishing boats and 8% by ships' anchors

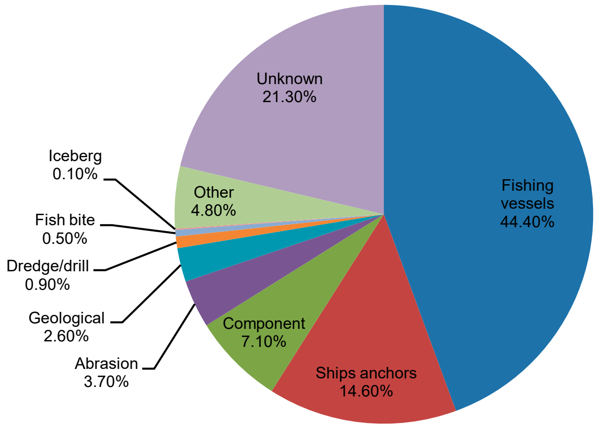

Figure 1. Underwater cables damage statistics. Data collected by the Department of the Interior, Bureau of Ocean Energy Management, 2014

in 2006/2007, and 33% and 48% respectively in 2007/2008.

Literature review

The risk of underwater infrastructure damage is a very important topic for companies operating underwater electrical supply cables and offshore wind farms as well for the classification societies and safety institutions which create the rules and recommendations for them. They can be found in DNV (Det Norske Veritas) (DNV, 2010a, b), or HSE (Health and Safety) recommendations (Spouge, 1999; HSE, 2006). Moreover, there have been scientific studies concerning the safety and risk assessment of underwater damage to cables (Palanques, Guillen & Puig, 2001; Dzikowski & Marcjan, 2016; Dzikowski, Marcjan & Bilewski, 2017). There have been many works devoted to the analysis of the causes of damage to underwater infrastructure. Those causes have been divided into two groups: a) natural hazards like the movement of the water, corrosion, and the movement of sediment; and b) man-made hazards like fishing activity and anchors (De Groot, 1982). It should be noted that fishing has a direct impact on the damage inflicted on underwater cables, but that it causes much less damage to underwater pipelines (Gucma & Zalewski, 2003). In order to assess the probability of damage to cables by fishing vessels, it is first of all necessary to distinguish between and describe the fishing techniques that cause dangerous penetration of the seabed which may be the cause of damage to underwater infrastructure (Drew & Hopper, 1996). Normally, the data used for assessing risks at sea are AIS data, an example of which is the IALA-IRRAP2 application (IALA, 2009). Such data are insufficient to build a risk assessment model for underwater cables in the case of impacts from fishing vessels. This problem occurs also in the case of the investigation of illegal fishing activity (Chang & Yuan, 2014). Though VMS system data has a lower sampling rate than AIS data (Guansekara & Rajapaksha, 2016), it can be used to support the AIS data in the case of building risk assessment models for underwater infrastructure.

Fishing techniques likely to damage underwater cables

There are many different bottom fishing techniques that may interact with underwater cables.

In the Baltic Sea bottom trawling is typically conducted with two main types of trawl gear: the otter and the beam trawl (Świniarski, 1993). Otter trawling (also called stern trawling) occurs at depths of 400 m and deeper, whereas beam trawling occurs in depths down to 100 m. The otter trawl usually consists of a board with a more or less rectangular shaped plate that holds the trawl bag open, while the beam trawl consists of a long steel V shaped beam that holds the trawl open. The greatest threat to underwater cables is the bottom trawl, as shown in Figure 2. It is one of the most common types of commercial fishing gear and has a long history of cable interaction. A bottom otter trawl is a cone-shaped assembly of lines and netting that is dragged along the seabed behind a vessel. Trawl doors, also called otter boards, are steel (or steel and wood) panels that are rigged ahead of the net on each side. To keep the trawl in contact with the seabed and generate a horizontal spreading force to keep the net mouth open they add weight. The weight of an otter board may range from less than 100 kg with a surface area of 1 square meter per panel on the smallest trawlers to over 8 tonnes with a surface area of 3 square meters on the largest trawlers. In the area of the Baltic Sea V shape boards are mostly used with a weight of 200–300 kilograms which are manufactured by the Thyboron Company. The line along the bottom of the net is often rigged with chains, rollers, steel bobbins or rubber discs. This gear is designed to maintain contact with the seabed and stir the top few centimetres of sediment in order to capture fish and shellfish living on or just above the bottom of the sea. The estimated and observed values for seabed penetration of bottom trawls in sand and mud are typically in the range of 5–20 cm but under unusual conditions such as very soft mud, an uneven seabed or a rigging failure, a trawl door may dive 50 cm or more into the sediment for a short period. Fishermen try to avoid deep seabed penetration because it increases fuel costs and gear damage without increasing catches, rising fuel prices and pressure from the environmental community (Palanques, Guillen & Puig, 2001).

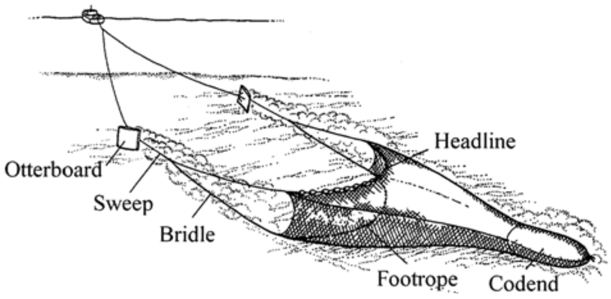

Figure 2. Schematic diagram of an otter trawl (Palanques, Guillen & Puig, 2001)

When a trawl passes over a submarine cable, a number of different outcomes are possible. There may be no apparent contact at all. Trawls are designed to pass over seabed obstacles; therefore more than 90 per cent of such crossings do not result in cable damage (Palanques, Guillen & Puig, 2001). Modern cables are often buried more than 60 cm into the sediment from the shore down to water depths of up to 1,500 m, therefore contact with normal fishing gear is highly unlikely. Even with cables lying on the bottom, trawl contact with the seabed may be light enough for the gear to pass over the cable. If the cable is lying on a hard bottom then a heavy trawl door, ground gear or even mid-water equipment may cause firmer contact. During such contact, the armour may provide enough protection to avoid damage, or alternatively, a sharp corner of the fishing gear may penetrate the armour and insulation (Figure 3), causing a shunt fault, or bend or crush the glass fibres causing an optical fault. The likelihood of damage is far greater if a piece of fishing gear or anchor actually hooks or snags a cable. The cable companies discourage mariners from using anchors, grapnels or other equipment to drag for lost or unmarked gear near cables (Carter et al., 2009).

Figure 3. An example of cable damage caused by fishing gear (Carter et al., 2009)

Risk evaluation methods

To evaluate the risk level for underwater cable damage from fishing gear, impact and pullover forces of otter trawl gear and bottom gear, the DNV (Det Norske Veritas) methodology can be used (DNV – RP-F111). To calculate these parameters the trawling speed and course, fishing equipment data and different span heights are used. The impact frequency of the trawl gear may change during the lifetime of an underwater cable due to the evolution of the fishing equipment. To obtain good quality data about trawl gear impact frequency the following details should be ascertained:

- density of fishing vessels in the relevant area;
- prevailing trawling direction relative to the pipeline;
- distribution of different trawl equipment and size.

To estimate trawl gear impact frequency DNV uses the following formula:

$$f_{\text{imp}} = n_G\, I\, V\, \alpha \cos\varphi \tag{1}$$

where:

n_G – number of trawl boards, beam shoes or clump weights of each ship;
I – expected trawler density (annual mean number of trawlers per unit seabed area);
V – trawling;
α – proportion of cable or pipeline length exposed to trawl loads;
φ – angle of the prevailing trawling direction that is perpendicular relative to the pipeline.

If the data are not available then the most critical frequency class is considered as follows: high – f_{imp} is more than 100 [year/km], medium – f_{imp} is 1–100 [year/km], low – f_{imp} is less than 1 [year/km].

Another method which allows for the evaluation of the risk of damage to a pipeline or cable by fishing gear takes into account the density of fishing boat traffic in the areas of fishing; so called – c-squares (Guansekara & Rajapaksha, 2016). To obtain the risk value the following formula is used (Gucma, 2003):

$$R_{hd}^{P} = \sum_{r=1}^{g} \frac{0.005\, N_R l_R S_{hd} \sqrt{M^2 + (V\varsigma)^2}}{F_r} \tag{2}$$

where:

g – number of c-squares covering the cable or pipeline;
N_R – yearly number of “ship-days” fishing with bottom trawl in the r c-square;
l_R – length of the pipe or cable in the r c-square;
F_r – surface of the r c-square;

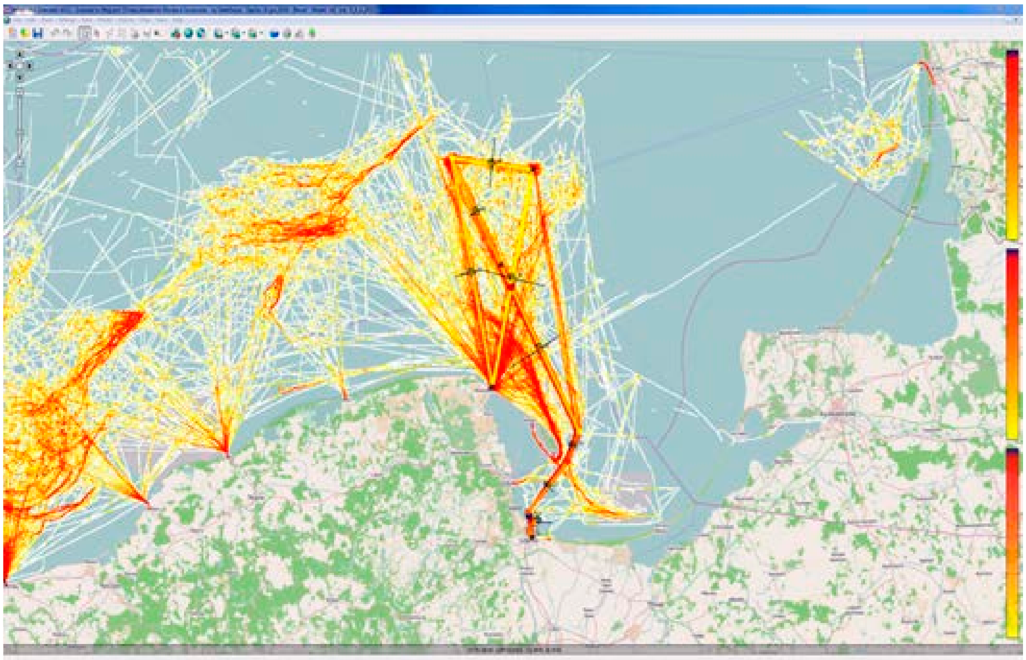

Figure 4. Fishing boat traffic density in the area of the Polish Economy Zone – AIS data

S_{hd} – effects of the contact of the trawl board with the pipe or cable;
M – root mean square error 95%;
V – speed of the fishing vessel during trawling;
ς – frequency of position fixing during trawling.

Both methods in equations (1) and (2) need information about the density of fishing vessels in the cable's area, the speed of the trawling vessel, the time of the trawling activities, and data about the trawling equipment. The AIS data are very helpful in obtaining the density of sea traffic, as shown in Figure 4. They are reliable in reference to the ships' data, but for fishing activities there are very often not complete. There is a lack of data about fishing gear used by the boats. In this paper another method has been proposed using VMS and Electronic Log Book data, the algorithm of which has been shown in Figure 5.

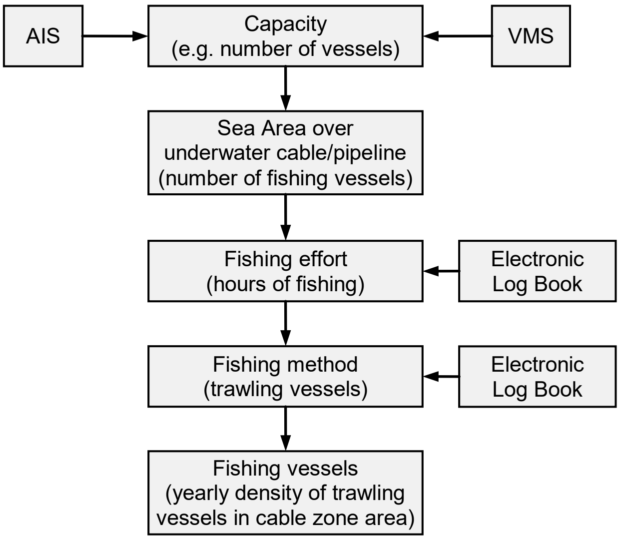

Figure 5. Scheme for estimating which trawling fishing vessels are a danger to underwater cables

Many fishing vessels are smaller than 299 gross tons. In most areas they do not broadcast AIS signals, but some do so for safety or other reasons. Several countries are considering making AIS a requirement for fishing vessels. However, many governments already require their fishing vessels to broadcast confidential messages that are relayed by satellites to agencies that monitor fishing activities. These are often referred to as Vessel Monitoring Systems (VMS) or Vessel Tracking Systems (VTS). In some cases, government policy dictates that VMS data is strictly confidential. In others, it is publicly available, or it may be provided in aggregate or on request. Such data can help identify areas that have been fished by different types of gear (which have different potential impacts on cables), determine which ports are bases for the boats fishing in a cable area, or in some cases identify which vessel may have damaged a cable. A major difference between AIS and VMS is confidentiality. Whereas AIS data can be gathered continuously by anyone with a nearby antenna and the appropriate equipment, VMS signals are confidential, are broadcast less frequently, are relayed by satellite to achieve a virtually global range, and are safeguarded by agencies with different policies regarding confidentiality. In one country it has been used as evidence to show which vessel

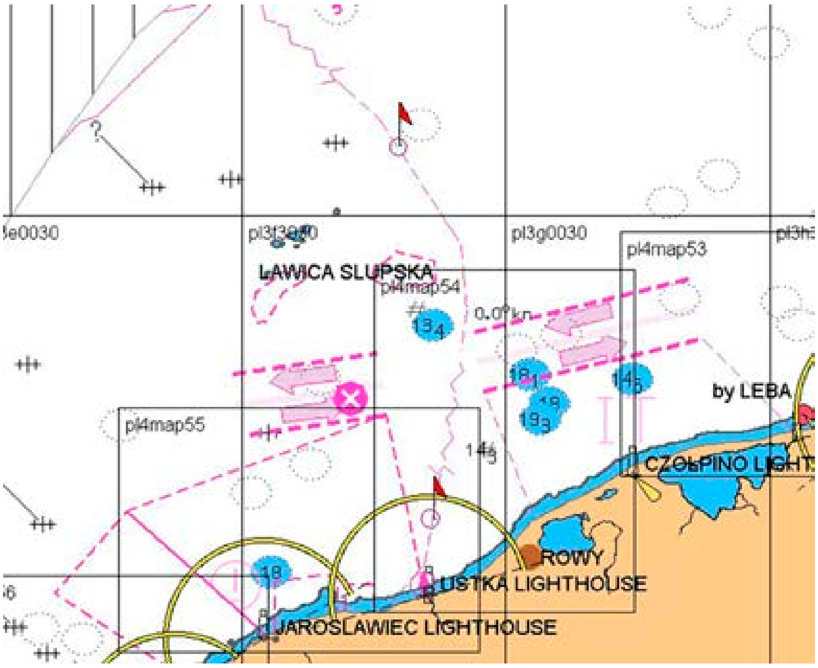

Figure 6. Position of the cable damage

was present when a fault occurred. The VMS system is combined with an electronic logbook which contains such data as: c square, gear category, length of the vessel, fishing activity category, average fishing speed, fishing hours, and average kW. Those data are useful for underwater risk assessment.

The analyzed cable area

The area that was chosen by the authors to analyse the underwater cable risk assessment is situated in the vicinity of the Slupsk Shoal where the cable Swe-Pol was damaged 11 times over the period of 2001–2012. One of the damaged cables has been illustrated in Figure 6, and marked with a red flag.

The area of the sea upon which the research was conducted was the Słupsk Shoal. The Słupsk Shoal is located about 25 nautical miles off the Polish coast, north of the port of Ustka. It is covered with a dense, sandy-gravel bottom, with scattered fields of stones and boulders. The depth in this area starts from 8 meters and increases to 20 meters. In the vicinity of this fishing area there are ports where the largest number of Polish fishing vessels are moored. 66% of Polish fleet vessels, representing 35% of total capacity and 61% of the power, are registered in the ports in this region. Polish fishing vessels in this region use bottom seines (62%), traps (15%), and bottom trawls (14%), although bottom trawls are more often used by medium-sized vessels fishing in the Baltic, representing 63% of the total capacity of all fishing vessels (European Parliament, 2011).

VMS data

VMS data are data that include, among other information, the position of fishing vessels. The authors decoded and analysed 3 million records to designate traffic density over certain cables.

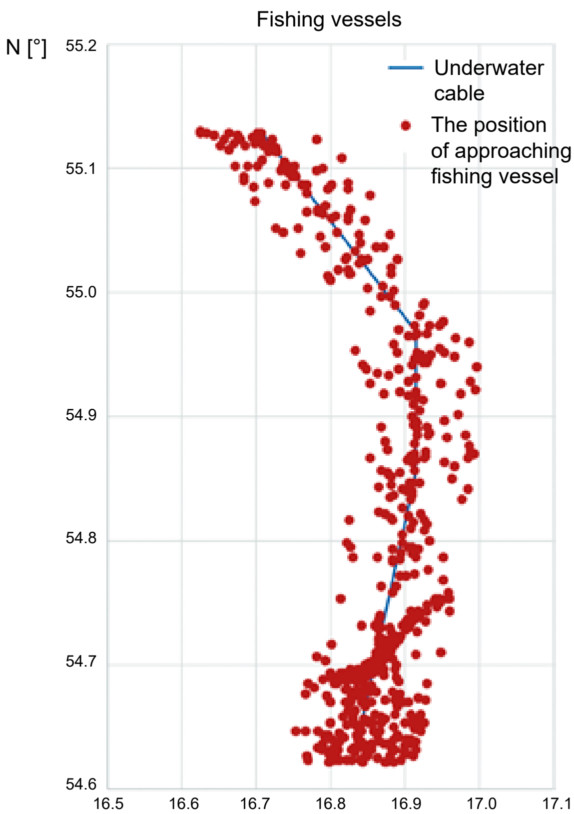

Figure 7. Closing fishing boats situations to underwater cable independently boat speed. VMS data

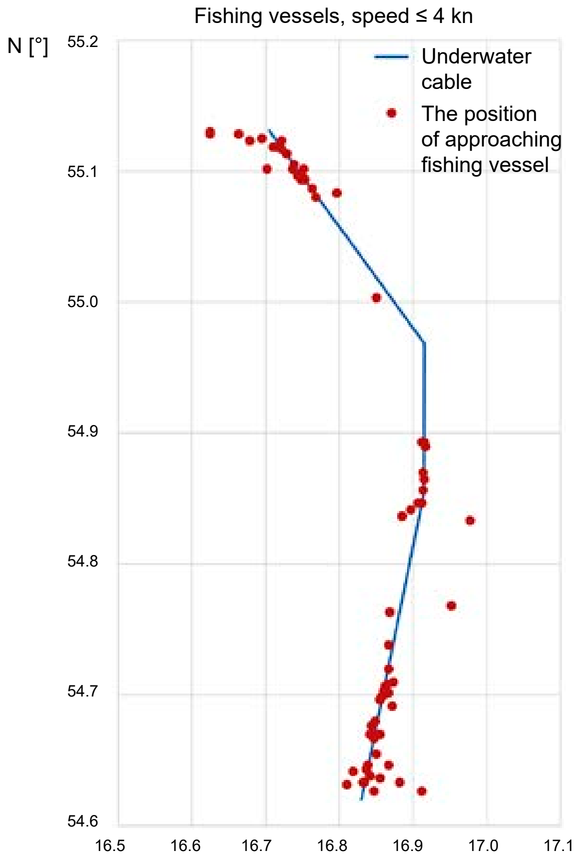

Figure 8. Closest position of fishing vessels to the underwater cable (distance less than 3 Nm, speed less than 4 knots)

Unfortunately their density varied within the range between 4 minutes to 2 hours. According to information about fishing vessels gathered in 2013, 592 boats were in the area of a cable at distances of less than 3 Nm to the cable. Based on the VMS system data, they were supposedly passing over the cable, as shown in Figure 7. The 3 nautical mile distance was adopted due to the relatively low density of fishing vessel position data, which makes it impossible to determine the exact position of a fishing vessel passing over the cable. The authors have created their own application to indicate the positions of trawling fishing boats that endangered an underwater cable.

Figure 8 has shown the 68 closest positions of fishing vessels to the cable at a distance of less than 3 nautical miles when the speed of the fishing vessel was no more than 4 knots, and which could be directly attributed to the fishing vessel having been trawling in the area of the cable.

AIS data

For the sake of differentiation, the vessel traffic monitoring data from AIS are much denser than the VMS data. Subsequent ship positions recorded in the AIS system are displayed at intervals of several hundredths and their exact value depends on ship speed, course changes, and navigational status. It is through navigational status that it is possible to ascertain whether a fishing vessel is currently fishing. It should be taken into account that the change of status from not fishing to fishing is handled manually and may therefore be associated with inaccuracies related to human factors (AIS data validity). From the 2013 AIS data (50 million records for the Baltic Sea area) it was found that 228 vessels passed over the cable (Figure 9). The accuracy of the data allowed for the accurate determination of the location where the fishing vessels crossed directly over the cable. Some of the vessels only approached the cable; all of them have been presented in the figure when the distance to the cable from the ships was less than 2 NM. 17 vessels passed with a speed of less than 4 knots and they might have been engaged in fishing while passing – represented as the black circles in Figure 9.

Due to the errors caused by the wrong AIS status, another factor that can be used to determine whether a vessel was engaged in fishing is the speed of the boat. As with the VMS data, it was assumed that a vessel could be busy fishing if its speed did not exceed 4 knots. The authors have presented the data for such a situation in Figure 9. The most reliable data of real fishing activity can only be delivered by the electronic log book.

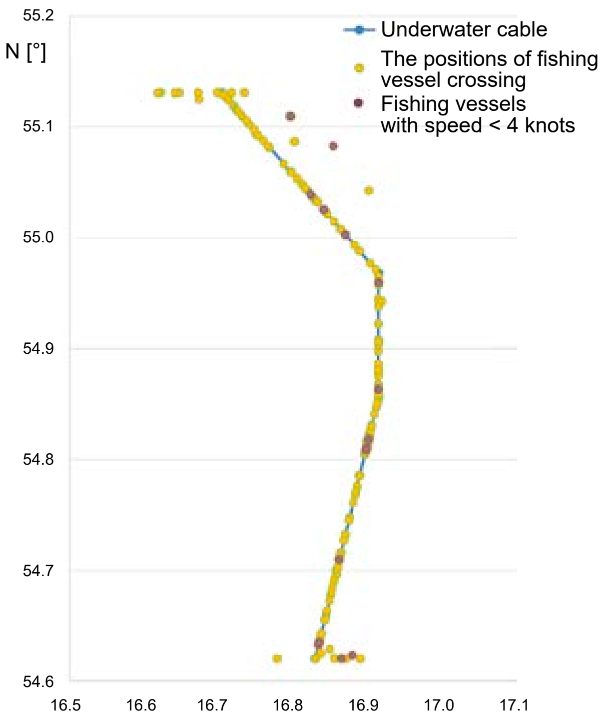

Figure 9. Positions of fishing vessels passing over the underwater cable from the AIS data

Conclusions

1. The AIS information about the traffic density of commercial vessels seems to be very reliable, but in the case of fishing vessels, especially information about their navigational status, it is very often doubtful. Fishing vessels whose length is less than 15 meters can be missed.
2. The AIS information does not contain information about the fishing method and gear that was used. The only way to suppose that a fishing vessel was trawling was a speed of less than 4 knots.
3. The VMS system applies to all EU fishing vessels and all third country vessels in the EU area for vessels over 12 m in length.
4. The VMS data are very reliable for determining fishing vessel traffic density, although the intervals between position reports are between 20 minutes and 1 hour.
5. To determine fishing vessel trawling activity using the AIS system, a speed of the fishing vessels of up to 4 knots was assumed during trawling.
6. Supplementary data to the VMS is the electronic logbook which gives confidence in the fishing vessel's position, speed, the fishing gear used and the fishing activity time.
7. The full set of the information obtained by combining the VMS and fishing vessels' electronic log books has provided enough data to conduct a risk assessment for damage to underwater cables and pipelines.

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