Automatic Identification System (AIS) and Risk-Based Planning of Hydrographic Surveys in Swedish Waters

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Key words: Automatic Identification System (AIS), Hydrographic survey, risk, groundings

SUMMARY

The presentation aims to show and discuss applications of Automatic Identification System (AIS) as a tool for risk-based planning of Hydrographic surveys in the Swedish part of the Baltic Sea. Since AIS-transponders became mandatory on vessels, traffic regimes, particularly in coastal waters, have become much clearer, distinguishing voyages in space and time, speed, vessel size etc. This has enabled improved decision-making for Hydrographic survey, fairway planning and location of aids to navigation. The Baltic Sea is one of the most heavily trafficked areas in the World and the vessels become both faster and larger. The transportation of oil is increasing, implying higher risks. Besides, the area is a very fragile and vulnerable ecosystem and has been classified as a Particularly Sensitive Sea Area (PSSA) by the International Maritime Organization (IMO). Therefore there is an obvious need for risk-based procedure in designing the long-term plan for Hydrographic surveys, taking into account both probability and consequences of groundings. The key questions are thus: Where to conduct Hydrographic surveys in order to reduce the grounding risk as much as possible? How to use Automatic Information System (AIS) in such a risk-based approach? What possible pitfalls are there by using AIS-information? AIS-data can and has already been used in order to consider the grounding risk as a basis for planning of Hydrographic surveying in Swedish waters. AIS has so far contributed much to the planning of surveying but further development is looked for.

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1. BACKGROUND

Waterborne transport is of great importance for trade and prosperity around the world. An indispensable requirement for maritime transport is reliable Hydrographic surveys that ensure safe waters in order to eliminate grounding risks. Water depth, seabed topography, navigational equipment and general character determine the size of the vessels that may navigate a fairway. Significant resources are put annually by responsible national administration to charter their waters in order to decrease the risk of groundings that depend upon defective surveys. In the International Convention for the Safety of Life at Sea (SOLAS) chapter V and Regulation 9 (IMO, 1974) standards for Hydrographic Services and provision of official nautical charts and publications are set. These rules have later been interpreted by the International Hydrographic Organisation (M-1 Basic Documents of the IHO, and M-2 National Maritime Policies and Hydrographic Services). Hydrographic data, which is obtained through Hydrographic surveying, is location-specific information regarding objects and conditions in coastal zones, such as the existence of wrecks, depth, navigational aids and coastline. The techniques used in Hydrographic surveys are primarily multibeam echo sounder and bar sweeping. The key components in the production of hydrographic information are the depth database and nautical chart data base.

The Swedish Maritime Administration (SMA), as the responsible Swedish Hydrographic Service, perform hydrographic surveys and produces both printed and digital nautical charts. This information is also used for other nautical publications. It also distributes maritime safety information, such as navigational warnings, weather and ice conditions. Chartered waters are based on surveys carried out during different decades with improved vertical and horizontal accuracy in more recent surveys. Since 2000 SMA follows the international standard S-44 according to the International Hydrographic Organisation (IHO, 2008). It means that areas are ranked into different orders. Each order has its individual vertical and horizontal accuracy with a 95 % confidence level. Higher accuracy is required for shallow water with heavy traffic and with limited under-keel clearance. The Swedish standard also prescribes that surveys should be comprehensive in their bottom coverage and that bar sweeping is to be carried out in critical fairway segments with minimum under-keel clearance. The Hydrographic surveying carried out by SMA costs around 40 million SEK annually and the cost per unit area varies primarily according the depth. The overall survey plan for the Baltic sea is established together with all Hydrographic Offices concerned and by the Helsinki Commission (HELCOM), the governing body of the Convention on the Protection of the Marine Environment of the Baltic Sea Area.

The importance of Hydrographic surveying in reducing grounding risks is high. From 1985 and onwards accidents and near-misses in Swedish waters have been reported and documented in a database run by the Maritime Safety Inspectorate of SMA. The number of incidents caused by defective survey and chartering procedures between 1985 and 2007 amounts to about 20 which must be regarded as low considering the relatively dense traffic and long waterways along a 1500 nautical miles long coastline with many archipelagos. However, there is an incitement to continue and develop the surveys.

Automatic Identification System

A relatively recent development in shipping is the worldwide use of Automatic Identification System (AIS) which is a system that originally was developed and implemented to provide mariners with more information about vessels in the area than can be obtained via radar. By using two VHF radio channels, information about vessels and voyages is transmitted in short data packets at clearly defined and synchronised intervals as messages. The message consists of static, dynamic and voyage-related information as is displayed in table 1-1. Static information, such as the vessels own vessel as length, etc. is entered into the AIS on installation. Dynamic information is automatically updated from the ship sensors connected to AIS and voyage-related information is manually entered and updated during the voyage (IALA, 2001). Regarding hazardous cargo, the division has been very approximate, excluding some types of cargo, and the routines are now under revision. The usefulness of that information for risk-based purposes is therefore limited.

Table 1-1. Static, dynamic and voyage-related information in the AIS message (IALA, 2001). Information in Italics has not been identified as crucial for the present study.

Static information	Dynamic information	Voyage related information
Maritime Mobile Service Identity	Ship's position with accuracy indication and integrity status	Ship's draught
Call sign and name	Position Time stamp in UTC	Hazardous cargo (type)
IMO Number	Course over ground (COG)	Destination and Estimated Time of Arrival (ETA)
Length and beam	Speed over ground (SOG)	Route plan (waypoints)
Type of ship	Heading	Number of persons onboard
Location of position fixing antenna	Rate of turn (ROT)	
Height over keel		

A geographical visualisation of nearby vessels and related AIS-information is very helpful for mariners including obtaining information about vessels in the vicinity as is exemplified in figure 1-1. Position, speed, headings etc. can be shown on a bridge in ECDIS (Electronic Chart Display and Information System). By pointing at a certain vessel, more information can be obtained about that specific vessel.

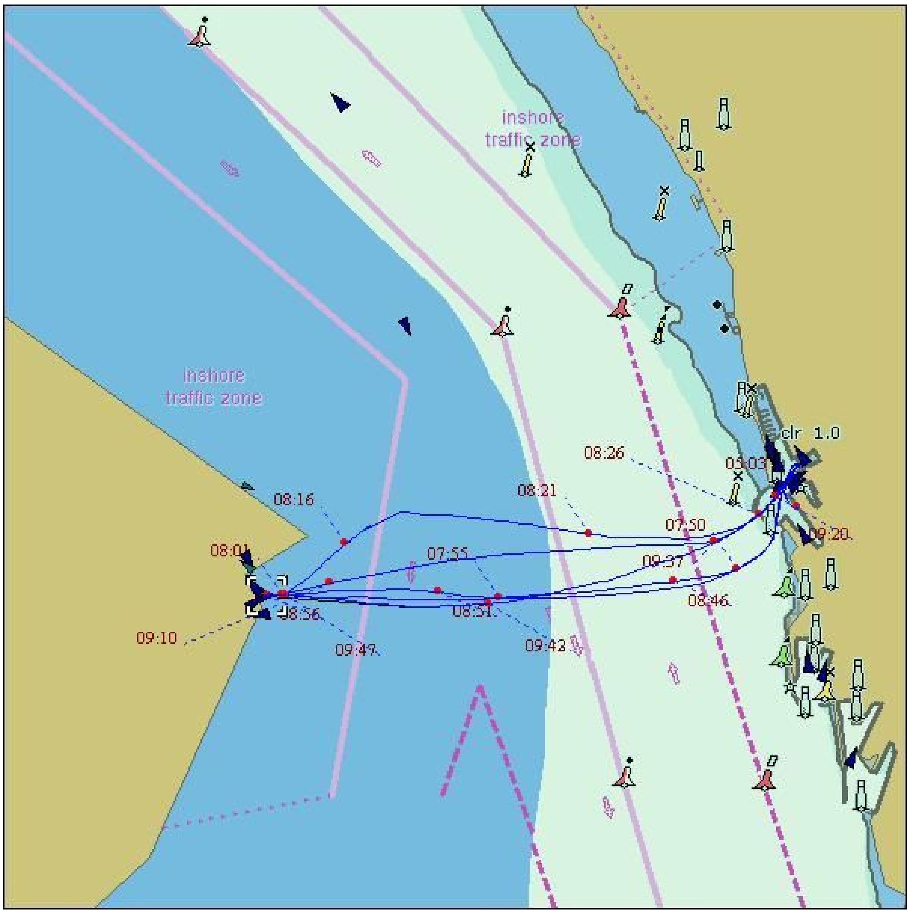

Figure 1-1: Ship tracks and present position of a selected passenger vessel, *Siluna Ace*, in the northern part of the Sound between Denmark and Sweden. The vessel, shown within a white square, has here a draught of 2,9 m and a speed of 13,2 knots when leaving Helsingør in Denmark and heading east towards Helsingborg in Sweden.

The United Nations International Maritime Organization (IMO) resolved in 2001 that all vessels that comply with the SOLAS Convention and are larger than 300 tonnes shall have AIS onboard. The requirement came into force on 1 July 2002 for new vessels and an implementation schedule applies to pre-existing vessels. All vessels in international traffic have been equipped with AIS since 31 December 2004 and vessels in national operation must be equipped with AIS by 1 July 2007. The requirement applies to all passenger ships, regardless of size. This means that abundant amounts of data on vessel movements are stored. It must however be kept in mind that smaller vessels are not obliged to have a transponder on board and that these vessels can neither be detected in real-time visualisations nor in the statistics.

Apart from the original aim of AIS, national maritime administrations have assembled the information into large volumes of statistics as a decision support for various applications within their field of responsibility. SMA has a network of land-based AIS base stations to receive AIS information from vessels and transmit safety-related information. Exchange of

AIS information with equivalent organisations in neighbouring countries has begun through an initiative within HELCOM.

The Baltic Sea

The maritime traffic in the Baltic Sea is very busy and contains about 2000 vessels with AIS-transponders any time. One image of the real-time distribution for the southern Baltic Sea is displayed in figure 1-2. The traffic tends to consist of larger and then primarily wider vessels. Oil transport from especially the Russian port of Primorsk is increasing rapidly. Furthermore, navigation, communication and manoeuvring are more markedly dependent upon technical systems offshore and onshore. Archipelagos and dense traffic make navigation in some areas difficult. On top of this the Baltic Sea is a very fragile area with a unique mix of marine, freshwater and other species specially adapted to its brackish conditions. Its ecosystem is characterized by few species and simple food chains. The disappearance of key species could have serious environmental implications. Bearing this in mind, the Baltic Sea has been classified as Particularly Sensitive Sea Area (PSSA) by IMO (Lindén et al., 2006). Most of the Swedish territorial waters and exclusive economic zone (EEZ) lies within the Baltic Sea.

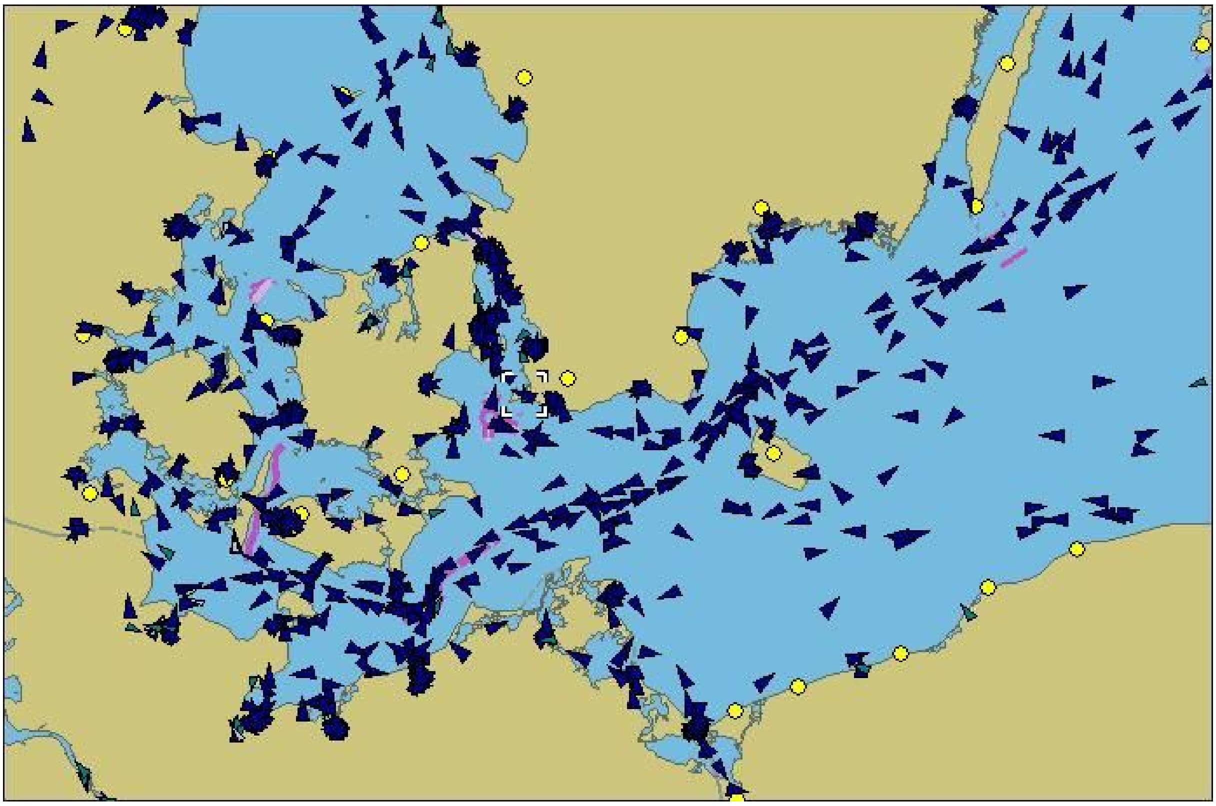

Figure 1-2: The maritime traffic in the southern Baltic Sea around noon on the 14th of April 2008. Each blue triangle represents a vessel with an AIS-transponder. Sharp angles indicate vessel heading.

Aim

The aim of this paper is to show and discuss how planning of hydrographical surveying can be and has been risk-based by using AIS-data and statistics from Swedish waters and compare it to present and planned hydrographic surveys of S-44 standard. Furthermore, the paper seeks to address obstacles to such a risk-based approach.

2. RISK-BASED PLANNING OF HYDROGRAPHIC SURVEYING

2.1 Risk

The concept of risk has been defined in many ways. Following a common definition, this paper sees risk as a measure of expectancy by combining probabilities of negative impacts with their consequences. Risk thus reflects a measure of expected accumulation of negative impacts over a longer period. These negative impacts can be materialised in accidents and costs. Risk management thus aims to find a balance to limit the sum of impacts from accidents and costs to limit these accidents. Furthermore, with this view, few and severe accidents may be valued as more adverse than numerous accidents with limited impacts. The risk-based approach by balancing maritime safety and costs for risk control measures is also found in the Formal Safety Assessment (FSA) procedure, which has been introduced by IMO (IMO, 2002) to be used when new regulations are to be proposed, implemented and enforced. Changes in accident risk following a new regulation are screened by a risk assessment and a cost-benefit assessment of the risk control measure in order to assess its feasibility. Risk assessment and risk-based methods have been used in numerous maritime applications.

2.2 Priority of hydrographic surveying

The parameters steering the internal priority of future hydrographic surveys are:

- quality of existing surveys, ambition to meet the S-44 standard
- planned traffic intensity and needs, expected vessel types including length and beam
- fairway characteristics and manoeuvring conditions
- expected minimum under-keel clearance, nature of the seabed geology including existence of features
- the risk of changes over time of the seabed
- temporary fairways making ice-breaking assistance possible
- water utilization
- port development plans
- near-misses and accidents
- survey budget

2.3 Risk and AIS-information

In addition to the present governing conditions for hydrographic surveys AIS-information can provide input for how to determine priority for areas to be surveyed in the S-44 standard in line with a risk-based approach. When it comes to grounding risk several parameters are involved to affect either probability or consequence as is shown in a simplified grounding risk model in figure 2-1. Regarding the consequences, much of the impact is dependent upon the damage to the vessel hull in the grounding moment. Involved parties bearing the consequences are not addressed. Some of the parameters are directly or indirectly given by AIS-information which is further expressed in table 2-1.

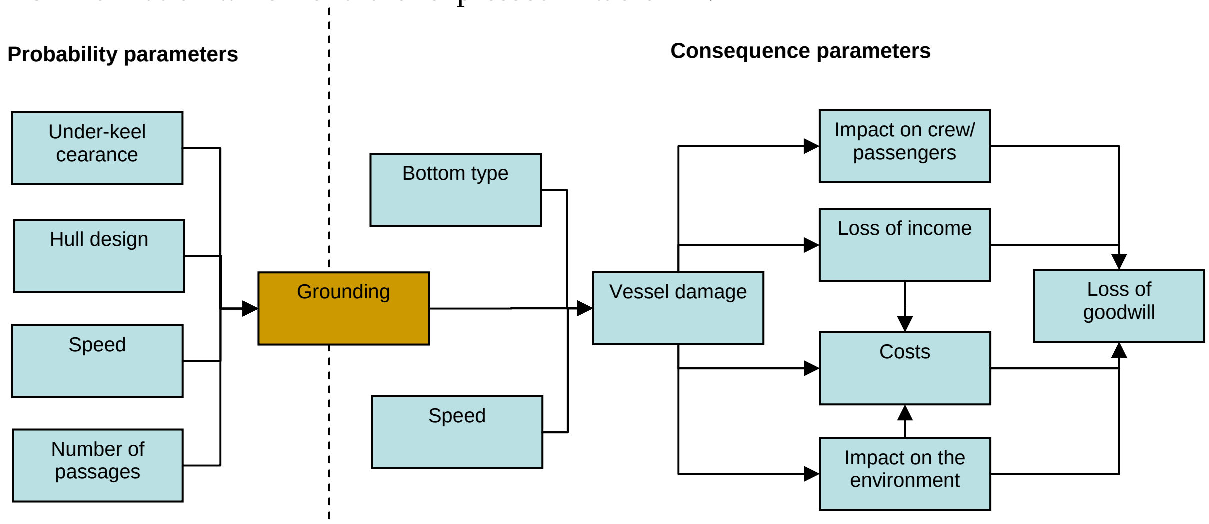

Figure 2-1. A simplified model of grounding risk parameters.

Table 2-1. Parameters in the AIS-information related to probability and consequences in the grounding risk model.

Risk parameter	Relation to AIS-information
Under-keel clearance	Indicated by *ship's draught*. In shallow waters where the vessel has a low under-keel clearance, a deep draught can together with high speed contribute to squat[1] effect and thus to grounding.
Hull design	Roughly indicated by *type of ship*. The type of design can increase the squat-effect.
Speed	Directly given by *speed over ground*. A high grounding speed implies severe consequences. Furthermore, with a low under-keel clearance, a high speed may lead to squat-effect and thus to grounding.
Number of passages	Given by AIS-statistics. If the number of passages of vessels with a low under-keel clearance is high, it can indicate an increased probability of grounding. However, the number of passages has to be combined with some other parameters in order to estimate risk more appropriate.
Bottom type	*Not given by AIS. Important for grounding consequences.*
Vessel damage	Roughly indicated by *type of ship.*
Impact on crew/passengers	Given by *number of persons onboard*. In case of a severe grounding the number of crew/passengers increase the consequences.
Loss of income	Indicated by *type of ship* and *length and beam* as more valuable cargo and larger vessel size indicate higher losses if vessel is unusable.
Costs	*Not directly indicated by AIS-information.*
Impact on the environment	Indicated by *ship type* in case grounding leads to spill of bunker oil or cargo. Information about *hazardous cargo* is of limited use.
Loss of goodwill	*Not directly indicated by AIS-information.*

[1] Squat is the reduction in under-keel clearance between a vessel at-rest and underway due to the increased flow of water past the moving body.

2.4 Examples

Below are some examples of how AIS-information can be and has been used in risk-based planning of Hydrographic surveying by extracting and analysing risk-related parameters in AIS-data.
As AIS-data is used to display ship tracks it is a natural starting point to compare how present and planned surveys according to S-44 match with an overall view of the cargo vessel traffic as is displayed in figure 2-2.

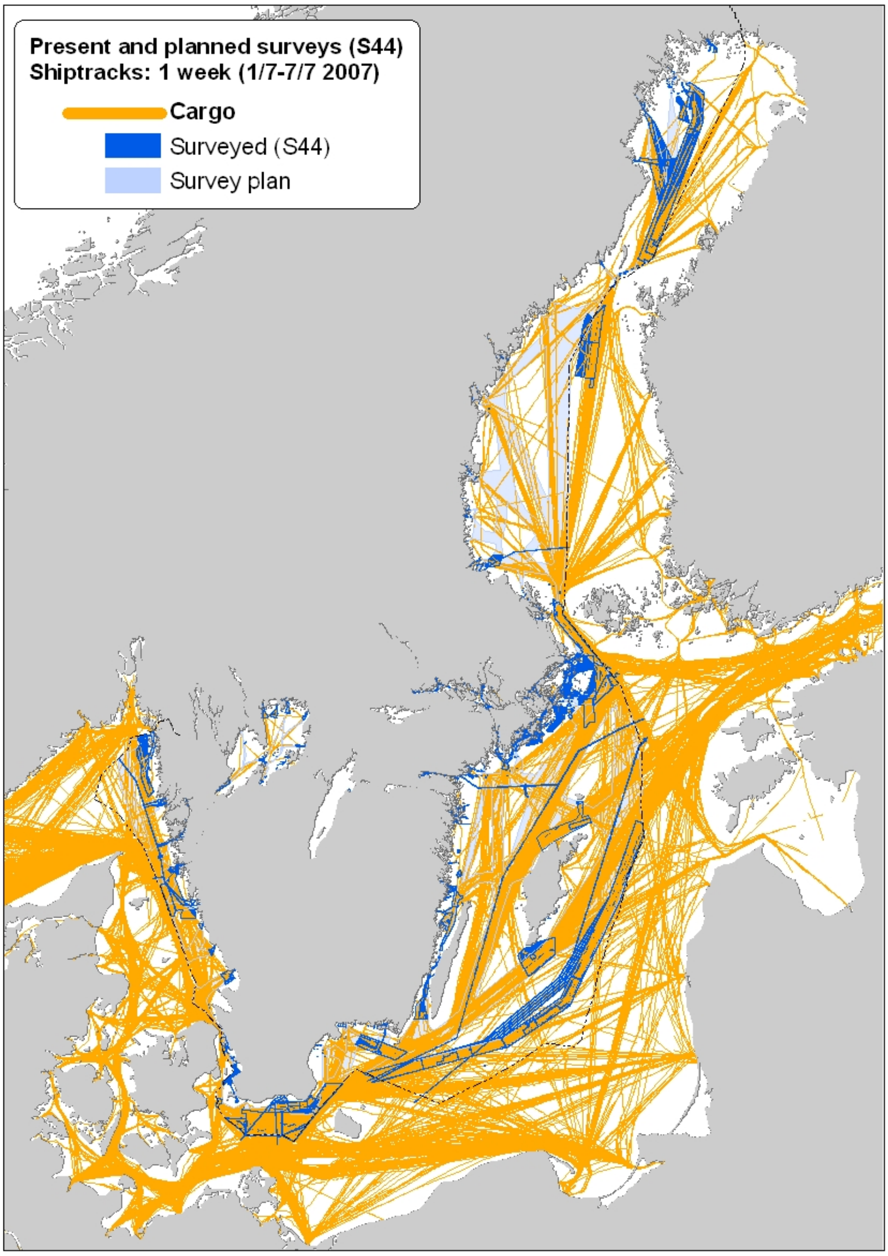

Figure 2-2. Present and planned surveys (S44) and ship tracks of cargo vessels during one week in July 2007.

The black dashed line displays the Swedish Exclusive Economic Zone (EEZ).
It is noted that the vast majority of vessel movements take place outside both present and planned survey areas. In addition, some planned surveys in northern waters are to take place in areas not frequently visited by cargo vessels. This is primarily due to the needs of temporary fairways during ice-breaking conditions where detailed consideration is taken to local ice conditions.

Tankers, with their potential to cause large oil spills in severe groundings, are of interest in a risk perspective. Figure 2-3 indicates that many of the planned surveys are located to areas outside the tanker traffic lanes.

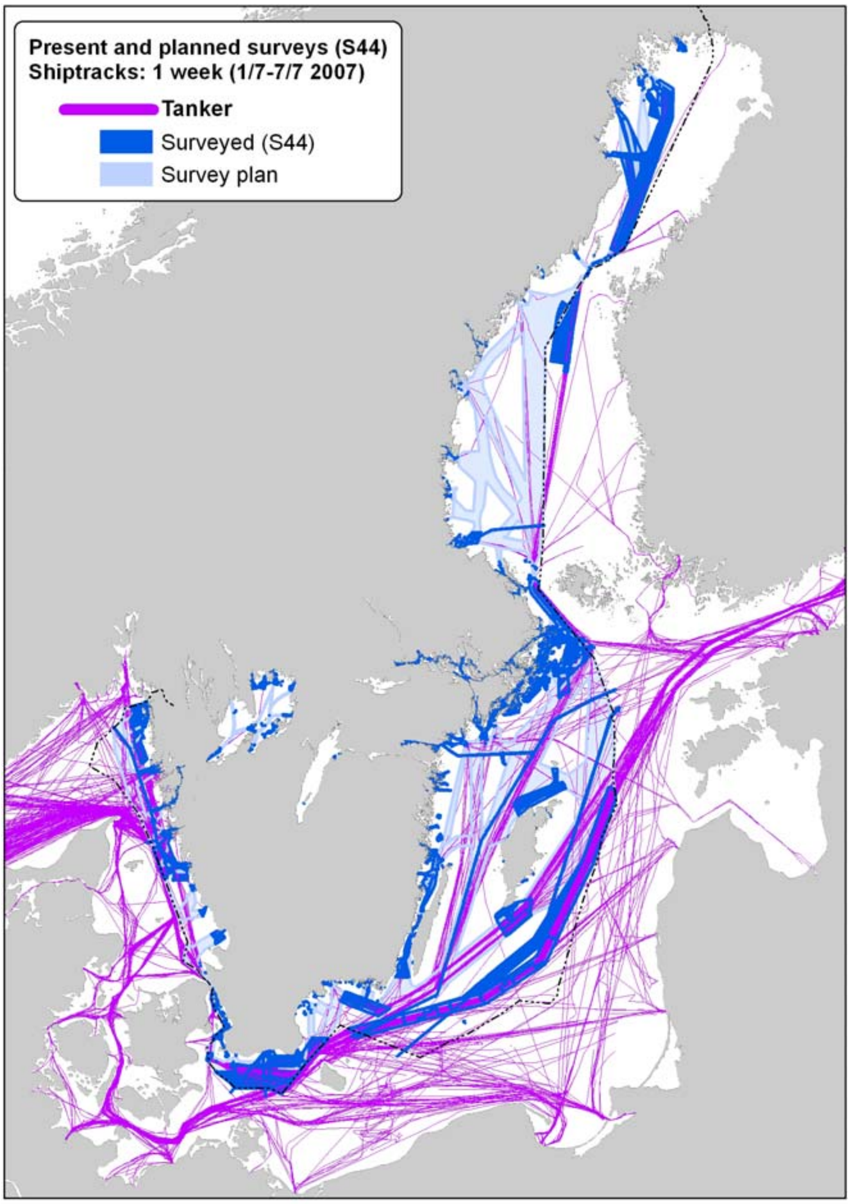

Figure 2-3. Present and planned surveys (S44) and ship tracks of tankers during one week in July 2007.

The black dashed line displays the Swedish Exclusive Economic Zone (EEZ).

There is some traffic east of the narrow island of Öland along the Swedish east coast as well as along the west coast that is located outside the planned surveying areas. The AIS-data has now led to that planned areas are to be revised. Existing surveying according to S-44 has been carried out south of the island of Gotland in the southern Baltic Sea where tanker traffic is uncommon. In that survey shallow areas were detected and dredging of these areas was regarded to be too costly and the traffic has been routed further south.

In the examples above, only ship type and ship tracks have been shown. However, with reference to the grounding risk model, it is possible to combine more parameters included in the AIS-information. In figure 2-4 is an example from the Bornholm gat, between the southernmost Sweden and the Danish island of Bornholm, of how to combine certain conditions and thresholds of parameters such as ship type, draught and speed. Closer to the Swedish mainland in the west there are tracks of vessels with a draught deeper than 10 m outside both present and planned surveys with fulfilling S-44 standard. Of concern is of course whether the tankers are loaded with hazardous cargo and if so of what type. As pointed out above the access of useful information about hazardous cargo is unfortunately limited.

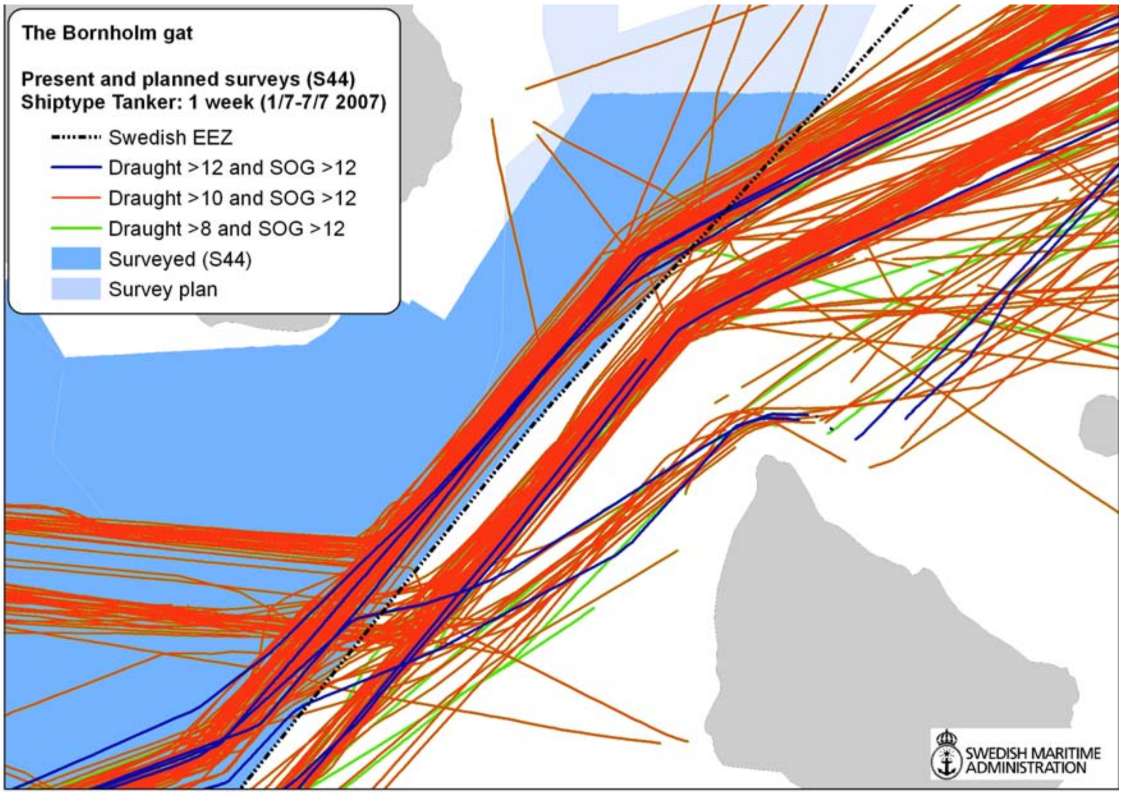

Figure 2-4. Present and planned surveys (S44) and ship tracks of tanker during one week in July 2007 in the Bornholm Gat between Denmark and Sweden. The black dashed line displays the Swedish Exclusive
Economic Zone (EEZ).

Another example of risk related use of AIS-data is in the Flintrännan fairway southwest of Malmö. A number of minor groundings led to a new hydrographic survey revealing marked and recently formed ridges of cobbles. The ridges were then compared to AIS-data for fast ferries with a limited under-keel clearance and there was a clear overlap of the ridges and the ship tracks, supporting a hypothesis that these ridges were formed during passages of fast ferries with a limited under-keel clearance. The squat-effect and related forces have likely pulled cobbles into ridges.

2.3 Pitfalls

There are some possible pitfalls in risk-based approach to Hydrographic surveying by using AIS-data. The first pitfall is to identify future needs of surveying based on historical ship track data. Shipping is a dynamic business and is quite likely to change in spatial traffic distribution in the future with changes in goods flows. Besides, AIS has not been existing long enough to detect trends over decades, which is a preferable time perspective compared to years when it comes to Hydrographic surveying. However, AIS data offers a better view of the traffic than any other present mean. Secondly, voyage-related information needs an active input by the mariner. An example of the obedience to adjust this type of information is the draught distribution of tankers in the Bornholm Gat which is expected to show lower values for northbound-traffic compared to the southbound traffic as vessels are loaded with oil in ports in the Gulf of Finland before transported to other ports in and outside the Baltic Sea. A comparison of draught distribution for tankers is presented in figure 2-5 which shows on a general pattern that southbound traffic shows higher draught values which is expected.

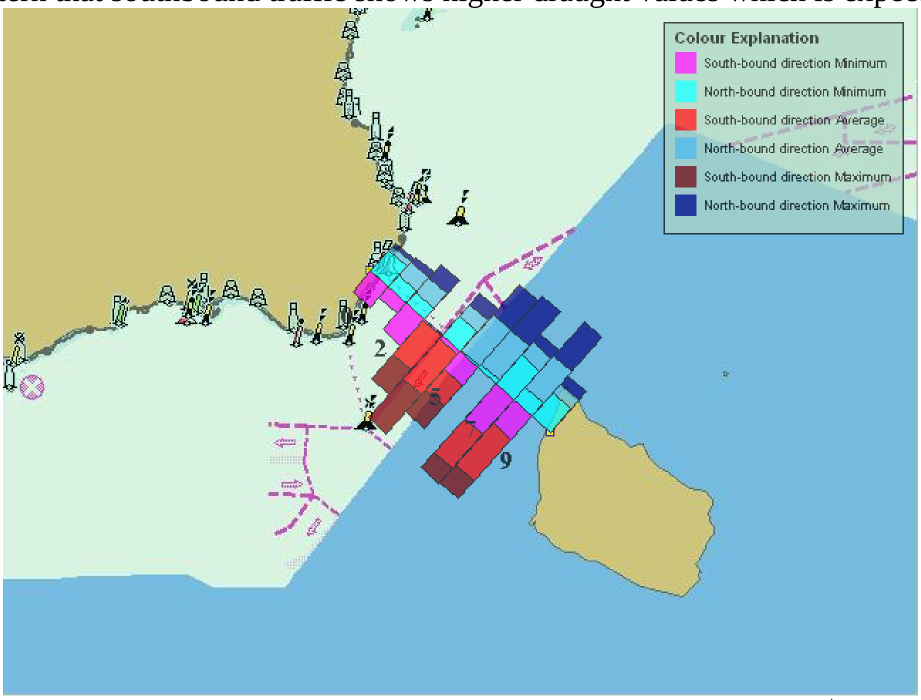

Figure 2-5. Draught distribution for tankers in the Bornholm Gat between the 1st of July and 31st of December in 2007. Proportions of draught are given at it is seen that southbound tankers have a deeper draught than north-bound ones. This is expected and shows that mariners to at least some extent have updated the AIS-information to the actual draught.

Thirdly, to estimate risk levels by combining different parameters of importance for both grounding probability and consequences is not an easy task. To quantify the importance of each parameter in the grounding risk model is difficult. By only counting the number of vessel tracks as the only risk-related basis is thus a too simplified way. Differentiation by taking other parameters into account is strongly recommended.

Uncertainty in addressing the future grounding risk can cause either costs for grounding accidents or costs for a non-optimal priority of Hydrographic surveying. Therefore there is a need for those Hydrographic services responsible to further develop their approaches on risk-based plann
ing of Hydrographic surveying.

3. CONCLUSIONS

he paper has shown some examples of how AIS-data can be and has been used in order to consider the grounding risk as a basis for planning of Hydrographic surveying in Swedish waters. AIS has so far contributed much to the planning of surveying but further development is looked for. There are some pitfalls related to the utilisation of historic tracks for future traffic, input of draught data and estimation of risk level by balancing different parameters which have to be considered.

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BIOGRAPHICAL NOTES

Dr. Markus Lundkvist, born in 1973. Graduated in 1998 as MSc, Physical Geography at Uppsala University where he also in 2005 earned his PhD in Earth Sciences with specialization in environmental risk assessment. Since 2004 he is employed at the Swedish Maritime Administration as a risk analyst.

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Ms. Renée Modigh, born in 1951. Graduated in 1970 as a Cartographer. In 1970 she was employed in the National Land Survey of Sweden as a Cartographer. Since 1988 she is employed at the Swedish Maritime Administration, first as a Cartographer and since 2002 as a GIS Administrator.

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