SJÖFARTSVERKET

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A harmonized depth model of the Baltic Sea

Analysis of demands and required specifications

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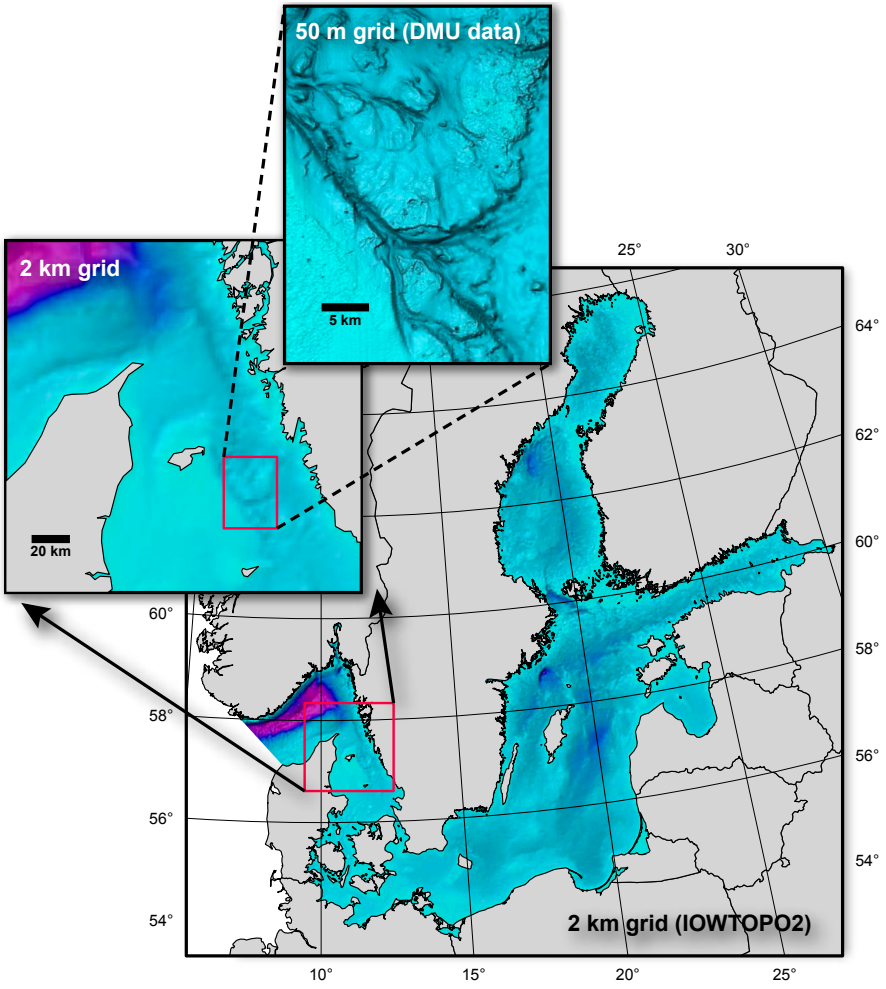

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1. Sammanfattning

Djupdata (batymetriska data) av tillräckligt hög kvalitet är en förutsättning för flera viktiga administrativa och forskningsrelaterade uppgifter. För Östersjön finns det för närvarande ingen homogen, kvalitetskontrollerad och kontinuerligt förvaltad digital batymetrisk modell (DBM) tillgänglig. De djupdata som vanligen används för forskning och administrativa uppgifter har påtagliga kvalitetsbrister avseende geometrisk upplösning, geografisk täckning, noggrannhet och aktualitet. Det existerar dock, och samlas in, avsevärda mängder batymetrisk data av hög kvalitet huvudsakligen för navigationsändamål. Tyvärr är tillgången till djupdata med hög upplösning ofta begränsad av politiska faktorer. Att sammanställa en förbättrad DBM för Östersjön med sådana data skulle gynna en mängd tillämpningar utöver framställning av sjökort.

Ett första steg i utvecklingen av en harmoniserad och konsistent batymetrisk modell för Östersjön är att analysera tekniska krav och specifikationer för en DBM som tillgodoser typiska tillämpningar inom administration och forskning. En enkätundersökning med svenska myndigheter och andra användare av djupdata har genomförts för att belysa de tekniska kraven på en DBM för Östersjön. Dessutom har publicerad vetenskaplig litteratur studerats avseende användning av batymetriska data för Östersjön.

Djupdata är en nödvändig bas för en stor del av den marina forskning som bedrivs vid universitet, forskningscentra och myndigheter och även för miljöplaneringsarbete. Studien visar att de tillgängliga batymetriska modellerna för Östersjön generellt sett saknar den detaljeringsgrad och noggrannhet som behövs för maritim miljöplanering och även för de flesta forskningsinriktade tillämpningarna.

Undersökningen påvisar ett brett omfång av tillämpningar för batymetrisk data och flera av dessa kan kategoriseras som geografisk planering. Även inom området planering är tillämpningarna vitt skilda från uppgifter relaterade till energi- och vattenresurser till miljöskydd, anläggningsarbeten och ett antal andra uppgifter. En annan stor grupp av tillämpningar som är beroende av djupdata är numerisk modellering. Typiska användningsområden för modeller rör cirkulation och hydrologisk transport, kartläggning av habitat och ekosystem samt transporter av näringsämnen och sediment.

Den tredje större gruppen tillämpningar inbegriper marinvetenskaplig forskning, klimatförändringar och geomorfologi.

Vår undersökning visar att generellt sett ska upplösningen vara så hög som möjligt men kraven på upplösning varierar mellan tillämpningsområden. Den högsta upplösningen, decimeter till meter, efterfrågas av marinarkeologer och geotekniker. I nästa grupp av tillämpningar med efterfrågan på rutnät mellan 2 och 50 meter finns habitatkartläggning, fiske, infrastruktur och vattenresurser. Institutioner som studerar cirkulations¬modeller har normalt de lägsta kraven där en upplösning på hundratals meter fortfarande är användbart.

Många svar i vår undersökning ser gärna variabel gridstorlek i data med högre upplösning i grunda och komplexa områden än i Östersjöns djupare områden. I allmänhet uttrycker de som svarat på enkäten ett behov av bättre underlag i form av batymetrisk data än som finns idag. En stor andel av svaren kan summeras i 5 viktiga punkter.

Stark efterfrågan på tillgänglighet till detaljerade djupdata I det moderna samhället används batymetrisk data för många tillämpningar inom fysisk planering, administration, miljöskydd och forskning. I många fall är djupdata nyckeln till tillfredsställande resultat inom dessa områden och ofta hämmas arbetet inom myndigheter och andra aktörer av att tillgängligheten till bra djupdata är för låg. Att hantera den marina miljön och dess resurser blir allt viktigare och metoder för detta är beroende av geografiska data och GIS-applikationer. Värdet och nyttan av djupdata av hög kvalitet kommer att öka påtagligt i framtiden.

Höga krav avseende upplösning (täthet) på djupdata Många tillämpningar kräver en detaljnivå på batymetrisk data som inte kan tillgodoses ur vanliga sjökort, till exempel kartläggning av habitat och arkeologiska undersökningar. Modern sjömätningsteknik som använder flerstråleekolod (multibeam echo sounders) kan leverera mycket hög upplösning. Det finns emellertid stora områden som inte sjömätts med modern teknik och därmed har väsentligt lägre detaljeringsnivå. Vi ser två tydliga åtgärder för att tillfredställa användarnas krav, tillgängliggöra existerande data och fortsätta sjömäta med modern teknik.

Störst intresse för djupdata i kustnära områden Det blev uppenbart från enkätundersökningen att de grunda kustnära områdena är de mest intressanta för de flesta tillämpningar. Det är också i dessa områden som militär sekretess kan medföra allvarliga hinder för tillgänglighet. Dessutom är mätningskostnaden högre eftersom mättiden ökar med avtagande djup.

Det verkar finnas möjligheter till förbättrat samarbete När det gäller svenska myndigheter och aktörer så hanterar flera parter djupdata på flera nivåer från insamling till tillämpningar. Det är Sjöfartsverket som har huvudansvar för sjömätning men avsevärda mätningsresurser finns också hos andra aktörer. Förbättrat samarbete för insamling, hantering och distribution av batymetrisk data leder till mer effektivt resursutnyttjande och att bättre dataset blir tillgängliga för användaren.

Allvarliga hinder när djupdata klassificerats som hemlig information Lagliga och militära restriktioner avseende hantering och användning av djupdata är ett påtagligt hinder för arbetsuppgifter inom myndigheter och forskning och minskar användbarheten av djupdata utanför sjökortsproduktion. Olika länder har olika restriktioner avseende geodata generellt och batymetrisk data i synnerhet. Marin forskning stimuleras av tillgänglighet till djupdata av hög kvalitet och onödiga hinder har en negativ effekt på effektiviteten i samhällets uppgifter inklusive forskning.

2. Summary

Bathymetric data of sufficiently high quality form a requirement for many administrative and research related tasks. For the Baltic Sea presently there is no homogenous, quality controlled and continuously maintained digital bathymetric model (DBM) available. The bathymetric data sets commonly used for research and administrational tasks all have significant drawbacks regarding qualities such as spatial resolution, geographical coverage, accuracy and up-to-dateness. However, large amounts of high-quality bathymetric data exist and are being produced, mainly for safety of navigation purposes. Unfortunately, access to high resolution data is often limited by political factors. By compiling an improved DBM of the Baltic Sea based on such data, the resources spent on hydrographic surveying could benefit a wide range of applications beyond the production of nautical charts.

An initial step towards the development of a harmonized and consistent bathymetry model of the Baltic Sea is to analyze the technical needs and possible specifications for a DBM satisfying typical applications in administration and research. In order to determine the necessity for a DBM of the Baltic Sea and the technical requirements, an investigation amongst Swedish authorities and other users of bathymetric data was carried out. Furthermore, the published scientific literature was analyzed with regards to the use of bathymetric data in the Baltic Sea.

Bathymetric data is the basis for a large part of marine research performed at universities, research centers and administrations as well as for environmental planning. Even if there are bathymetric models covering the Baltic Sea our study shows that they generally feature too little detail and accuracy to satisfy the needs of maritime and environmental planning, as well as that of many research related applications.

The survey reveals a wide range of applications for bathymetric data, many of which can be classified as geographical planning tasks. The range of planning applications is diverse in itself, from energy and water resource related work to environmental protection, exploration and a number of other tasks. Numerical modeling is another large group of tasks relying on bathymetric information. Typical modeling applications are circulation and hydrological transport, habitat and ecosystem mapping or nutrient and sediment transport.

The third larger category of applications encompasses marine scientific research dealing with among other things ecology, climate change mitigation and geomorphology.

Our investigation shows that generally speaking the spatial resolution should be as high as possible, but there are different resolution needs for different applications. The users asking for the highest resolutions, on decimeter to meter level, work with marine archaeology or with geotechnical applications. Next comes a group with mixed applications need grid resolutions between approximately 2m and 50m, which includes habitat mapping, fishery, infrastructure and water resource administrations fall into this resolution range. Institutions performing circulation modeling have the lowest needs concerning resolution, where resolutions in order of hundred meters are useful.

Many answers to our study consider the possibility of variable grid resolutions, with shallow waters and complex areas shown at higher resolutions than deeper part of the Baltic Sea.

In general, the adressees express a sincere need for better bathymetric data of the Baltic Sea than what is available at present. A large part of the answers given by the various users can be summarized in five key points.

Insistent request for availability of detailed depth data In a modern society depth data are used for a wide range of planning, administration, environmental pro- tection and research issues. In many cases bathymetric information is key to achieving satisfactory results in these matters, and often the work carried out by government agencies is impeded by the availability of appropriate depth data. Managing the marine environment and its resources is becoming increasingly important and common managing approaches rely upon geographic data and GIS applications. Therefore the value of high quality bathymetric data can be expected to rise significantly in the future.

High demands concerning spatial resolution of depth data Many applications require a level of detail in bathymetric data which cannot be supplied by conventional navigational charts, for example mapping habitats or archaeological studies. Modern surveying techniques using multibeam echo sounders are capable of delivering such high spatial resolution. However, it is common that large areas have only been mapped before the advent of multibeam sonars, and with less detail. This implies a two-fold approach to satisfy the users' needs regarding bathymetric data: Releasing existing data is one priority but (re-)surveying already mapped areas with modern equipment is equally important.

The closer to the coast, the higher the interest in depth data From the questionnaire survey it became clear that the shallowest waters in the immediate vicinity of the coast are the areas most needed for many relevant applications. However, these are the regions where military considerations may imply the severest restrictions to data availibility. Furthermore, the ship time costs for multibeam surveying increase with decreasing water depth.

There appear to be possibilities for improved collaboration In the case of Swedish authorities, there are several instances dealing with depth data on different levels from acquisition to application. Although hydrographic surveying is the sole responsibility of the national maritime administration, significant surveying resources exist at other authorities. Improved collaboration with regard to acquiring, managing and distribution of bathymetric data will lead to a more efficient use of the available resources and better data sets available to the end users.

Severe restrictions when depth data is classified information Legal and military re- strictions around handling and using detailed bathymetric information are severe hinders for administrative duties, research and the overall usefulness of depth data beyond its use for navigational chart production. Different countries have implemented different restrictions with regard to geographic information in general and bathymetric data specifically. Marine research is stimulated by the availability of high quality data sets. Unnecessary complications have a negative impact on administration efficiency as well as research.

3. Background and introduction

According to the Swedish government proposal 2008/09:170 "Integrated Swedish maritime politics"(Government of Sweden, 2009), a consistent overview model of the bathymetry (i. e. underwater topography) of the Baltic Sea shall be developed, satisfying the needs of maritime and environmental planning as well as scientific research. At present, there is no homogeneous, quality controlled and continuously maintained bathymetric model available for the Baltic Sea area that can meet the demands indicated in the government investigations prior to the proposal. For this reason the Swedish Maritime Administration (SMA) in collaboration with the Swedish Environmental Protection Agency was requested to develop an action plan how such a bathymetric model of the Baltic Sea could be obtained and maintained together with the other Baltic States.

Depth data is the basis for a large part of the marine research performed at Swedish universities and research centers. For administration and environmental planning bathymetric data is used in a number of Swedish state authorities. In the deep sea, most bathymetric data is collected primarily for these purposes. Shallow waters and coastal areas such as the Baltic Sea region, however, are typically the territorial waters of one specific state and the picture looks different: Safety of vessel navigation is the most prominent reason coastal states map the seafloor in areas close to the land, around shoals or along shipping routes for hydrographic purposes, i. e. primarily for the production of nautical charts. In most countries the collection of hydrographic data (bathymetric data collected for safety of navigation purposes) lies within the responsibility of national hydrographic offices or the navies.

Detailed bathymetric data is classified information in some countries, and access to the data is therefore restricted. The result in these cases is that nautical charts are the best portrayal of the coastal seafloor available to the public, including the scientific community and often even state authorities.

An initial step towards the development of a depth model of the Baltic Sea is to analyse the technical needs, i. e. to find out technical specifications for how a "harmonized" and "consistent" depth model (as claimed in proposal 2008/09:170) of the Baltic satisfies the needs of most applications. Furthermore it is important to find out how such a model could be made accessible in the best way. This report summarizes the results from studies carried out to investigate the demands for a bathymetric model of the Baltic Sea and the technical specifications required.

Technically, a bathymetric model can come in various flavours depending on the usage of the model. Most common is a digital terrain model of the seafloor with the depth values represented in a regular grid, i. e. with equidistant spacing in north-south and east-west direction. The worldwide usage of this type of depth models has increased enormously during the last years. Today a couple of such models have users going into the hundred thousands every year. ETOPO1 (Amante and Eakins, 2008), maintained by the U.S. National Oceanographic and Atmospheric Administration (NOAA), and the General Bathymetric Chart of the Oceans (GEBCO, IOC et al., 2003) are the global bathymetric models used most often. ETOPO1 features a resolution of one arc-minute, i. e. about 1.8 km spacing between its depth values (at the equator). In the case of GEBCO the resolution is half an arc-minute. In the Baltic Sea area both these models rely upon a depth model compiled at the Leibniz Institute for Baltic Sea Research i Warnemünde (section 5.2.1).

Even if there are depth models covering the Baltic Sea, our study shows that they feature too little detail and accuracy to satisfy the needs of maritime and environmental planning and research, which is being carried out on this small inland sea. What is needed probably looks more like the Coastal Relief Model of the United States, which seamlessly provides the entire U.S. coastal bathymetry and land elevations, for various applications in spatial planning, weather services research etc. The U.S. Coastal Relief Model features a lateral resolution of mostly about 30 m and some areas as high as 10 m (section 5.3.1).

4. The use of bathymetry data in the Baltic Sea

We investigated the public aspect of depth data usage with a questionnaire survey addressed in the first place to representative Swedish state authorities. The investigation of research related needs was twofold: Research institutes and universities were included in the questionnaire survey and a review of the published scientific literature was carried out.

4.1. Questionnaire survey

In order to assess the needs for depth data in today's society and in scientific research, a questionnaire was sent out to Swedish public authorities, administrational bodies, research institutes and universities, asking (in Swedish) about their specific needs concerning the usage of depth information. The questions are listed in Appendix B. The list of recipients (Appendix C, including the abbreviations used in this section) contained 32 of the named entities, specifically

- 12 public authorities and state organizations (including the private company AquaBiota, which mostly works under public contract)
- 11 universities and research institutes
- 6 county administrative boards: those doubling as "water resource authority" (vattenmyndighet) and Länsstyrelsen Stockholms län
- 3 non-governmental organizations (NGOs)

The recipients were chosen according to the following criteria:

- Known users of depth data
- Known to be performing marine research
- Duties within administration of water resource aspects of the Baltic Sea
- Known to be dealing with (Baltic Sea) marine protection issues
- Clear interest in one of the above as expressed in the official response (*remissvar*) to the Swedish government proposition SOU:2008-48 (Miljödepartementet, 2008).
- Own initiative of the recipient showing interest to participate in the survey

The chosen 32 adressees represent a broad variety of users of digital bathymetric data in Sweden at present. This selection is probably representative for both the administrative structures and the research community in Sweden. However, usages in private enterprises are largely not considered, or only indirectly incorporated in the answers received by others.

The questionnaire was sent out by email and addressed to a generic email address at each instance, mostly the registrar (*registrator*), with the request to forward it to the appropriate place as well as a to name a possible contact person.

Of the 32 addressees, 21 answered the questionnaire (all answers in Swedish), whereas one refrained from answering and 10 did not respond in a timely manner (Fig. 4.1). In cases of unclear answers or missing details, the contact person was emailed or called with follow-up questions. For three instances, these questions remained unanswered, so that some (mostly minor) details about the respective depth usage remain unclear. From Lund university six individual answers from different departments were received.

It should be noted that detailed bathymetric data is classified information in Sweden at present (see section 6.5). Producing, keeping and publishing such information needs approval by Swedish authorities and the military. This imposes severe restrictions on how bathymetric data can be used. Since the purpose of the questionnaire was to assess the specific needs when and possibilities of using bathymetric data, the addressees were asked to not consider classification issues in their answers.

4.2. Survey results

In the following sections, key points are summarized and conforming answers are grouped. As the answers were exclusively given in Swedish, all citations are direct translations of the original wording. The addressees' abbreviations are listed in Appendix C.

4.2.1. Questions 1a, 1b: Purpose

The survey answers reveal a wide range of applications for bathymetric data (Tab. 4.1). Many applications can be classified as geographical planning tasks, mostly performed at state authorities (mentioned in 12 answers). The range of planning applications is diverse in itself, ranging from energy and water resource related work to environmental protection, exploration and a number of other tasks.

Numerical and habitat modeling applications are another large group of tasks relying on depth information (mentioned in 11 answers). Typical modeling problems are circulation and hydrological transport, habitat and ecosystem mapping, or nutrient and sediment transport, to name the ones mentioned most often. Modeling is both carried

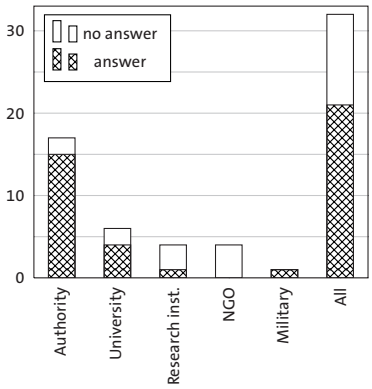

Figure 4.1.: Questionnaire survey response. Overall about two thirds of the addressees answered the questionnaire. Almost all contacted public authorities responded, whereas the response frequency was lower for the research community and zero for non-governmental organizations.

Table 4.1.: Applications for Baltic Sea bathymetric data from questionnaire answers

Category		Institution/Authority
Societal planning ("samhällsplanering")	*all*	BoV, EnM, FiskV, LST-AB, SMM, RAÄ, SGI, SMHI, VM-BV, VM-NÖ, VM-SÖ, VM-VH (total number: 12)
	Wind and wave energy, conventional power plants	BoV, EnM, RAÄ, VM-VH (total number: 4)
	Climate change mitigation	SGI
	Exploration	LST-AB, RAÄ (total number: 2)
	Environmental protection	VM-BV, VM-SÖ, VM-VH (total number: 3)
	Coastal erosion	SGI
	Pipelines and cables	EnM, RAÄ (total number: 2)
	Fishery	FiskV
	Water resources	LST-AB, SMHI, VM-BV, VM-NÖ (total number: 4)
	Ship traffic	BoV
Environmental monitoring		SMF, UmU (total number: 2)
Weather forecast		SMHI
Fishery		FiskV, VM-VH (total number: 2)
Geological mapping		SGU
Defense and military		FM
ROV and diving operations		KustBev, SMF (total number: 2)
Geotechnics		LU-TekGeol, SGI (total number: 2)
Accidents and spills		KustBev
Modeling	*all*	FiskV, FM, LST-AB, FiskV, LU-Vatten, SMHI, MISU, UU, VM-NÖ, VM-SÖ, VM-VH (total number: 11)
	Circulation, water flows	FM, KustBev, LST-AB, LU-Vatten, SMHI, MISU, VM-BV, VM-NÖ, VM-VH, AquaBiota (total number: 10)
	Waves	LU-Vatten, AquaBiota (total number: 2)
	Sediment transport	LU-Vatten, MISU (total number: 2)
	Habitat, ecosystems	FiskV, SMHI, VM-BV, VM-NÖ, VM-SÖ, VM-VH, AquaBiota (total number: 6)
	Nutrient transport	LST-AB, UU-Geo, VM-SÖ (total number: 3)
	Mass balance	UU-Geo
Marine archaeology (this could also be classified as research)		LU-Ark, SMM, RAÄ (total number: 3)
Paleogeomorphology		SMM, RAÄ (total number: 2)
Higher education, outreach		LU-TekGeol, RAÄ (total number: 2)
Research	*all*	LU-Ark, LU-TekGeol, LU-RS, LU-Vatten, SMM, SGI, SGU, SU, SMF, UmU, UU (total number: 11)
	Geomorphology	LU-Ark, LU-TekGeol, SMM (total number: 3)
	Climate change mitigation, coast line changes	LU-RS, LU-Vatten, SGI (total number: 3)
	Sediment transport	LU-Vatten, SGU (total number: 2)
	Waves	LU-Vatten
	Ecology, biology, zoology	LU-Bio, SMF, UmU (total number: 3)

out at administrational instances (especially at the Water Resource Authorities and on county level), as well as in research departments at universities.

The third larger category of applications encompasses marine scientific research (mentioned in 11 answers), where the most common questions deal with ecology, climate change mitigation, or geomorphology. Basic research is predominantly (but not exclusively) carried out at universities.

4.2.2. Question 1c: Data sets used

A variety of data sets is currently being used by the adressees (Tab. 4.2). Nautical charts are listed as a source for depth information by about half the users. The IOWTOPO data set or own depth measurements are used by about one third each. Most of the other data sets listed are based on either depths extracted from nautical charts or IOWTOPO.

4.2.3. Question 1d: Problems and drawbacks with existing data sets

Regarding problems with the data the users are working today, a lack of spatial resolution was the complaint expressed most often. Almost three quarters of the answers (15 of 21) mentioned a general lack of resolution or resolution problems in shallow waters. In all these cases, the users are working with the highest resolution data available to them. Eight answers complained about a general lack of measurements, i.e. the need for additional mapping efforts, mostly off the regular shipping routes. Confidentiality of detailed depth data and/or problems to get access to existing data was pointed out in more than one quarter of the answers—mostly by state authorities and even by the military itself.

Apart from these common problems (resolution, coverage and access), a small number of users named problems of more technical nature such as precision deficits, lack of metadata information or poor harmonization between different data sets. For modeling purposes there is a notable issue originating from the way areas with military restrictions ("ringade områden") are displayed in Swedish nautical charts: Generally soundings in such areas are shown very sparsely, however shoals are usually displayed in detail. This leads to a strong shallow bias of the water depths extracted from nautical charts, which can pose severe problems for modeling and is likely to lead to false modeling results in and even around these areas.

4.2.4. Questions 1e, 2cv: Limitations for operations

For many users the lack of sufficient depth information imposes limits on the quality and scope of their work. For example several public authorities (VM-NÖ, VM-SÖ, SGI) point out that bathymetric data is used for decision-making within the administration, and that insufficient data gives a suboptimal foundation for often costly decisions with possible negative consequences for the environment (e. g. KustBev), society (e. g. SGI) or the effectivity of costly offshore operations (e. g. SGU). According to Fiskeriverket, "the lack of detailed depth data is the single most limiting factor for the modeling and mapping of marine natural resources".

Furthermore, the classification of detailed depth information as well as the complexities in obtaining and working with classified information is limiting productivity. The company AquaBiota, to a large extent working on projects of the Nature Conservation Agency (Naturvårdsverket), states that "species and habitat mapping based on the available nautical charts is no good for producing map material, which is sufficient for managing the marine environment's natural resources. When we used classified depth data of higher quality, the modeling was generally more successful." "[Because of the lack of appropriate depth information] operations have been carried out less effectively, cost more and the result has been worse. The fact that depth data is classified caused extra work and increased costs." (SGU).

4.2.5. Question 1f: Urgency and potential of improvements

Many answers underline the general need for depth data of today's society, and the likely increase in importance because of increasingly important marine resources in the future.

Operations in administration are predominantly target-oriented, and a lack of data can present severe hurdles for reaching a goal. Especially for the coastal waters (for more on what is regarded as coastal, see below), the demand of better depth information is high, as is the potential for improvements. The implementation of marine political actions already agreed upon depends on better depth information, as expressed by FiskV and AquaBiota: "The biodiversity related actions proposed in the Swedish undertakings [implementing the HELCOM Baltic Sea Action Plan] aim at the development of a knowledge base in terms of marine landscape and environment maps. A high-resolution depth model of the Baltic Sea is a prerequisite if this shall become reality." (AquaBiota). Also "a condition for meeting the Marine Directive is to map the marine natural resources in a dependable way." (FiskV).

Even though most authorities' focus today lies on coastal areas and shallow waters, several underline the need for depth information of deeper areas to account for the present as well as future needs of exploration (VM-VH, LST-AB). But already today, the work of governmental agencies such as SGU and SMHI is limited by the poor quality of the depth data for deeper parts of the Baltic Sea.

In contrast to administrative, planning and economy related applications, where predefined goals prevail and highlight the need for better databases, research is often steered by what data availibility. Consequently, in the academic world the prevailing opinion is that the access to detailed depth data would stimulate scientific research projects, which are not possible today (or only with limitations) and therefore often not even started in the present

Table 4.2.: Data sets used by questionnaire recipients.

Data set	Institution/Authority
Nautical charts	FiskV, LU-TekGeol, LU-Vatten, LST-AB, SGI, SMF, UmU, VM-BV, VM-VH, KustBev, AquaBiota (total number: 11)
IOWTOPO	FiskV, LU-Bio, LU-TekGeol, SMHI, SU, UU, VM-SÖ, AquaBiota (total number: 8)
Own (or contractor's) measurements	LU-TekGeol, LU-Vatten, SGI, SGU, SMF, VM-BV, VM-VH (total number: 7)
Naturvårdsverket SAKU	FiskV, VM-VH, AquaBiota (total number: 3)
Data by the Swedish Maritime Administration	FiskV, SGU, UmU, AquaBiota (total number: 4)
SMHI HOME	LST-AB, VM-BV, VM-NÖ (total number: 3)
Fiskeriverket Skagerrak	FiskV, VM-VH, AquaBiota (total number: 3)
BALANCE maps	FiskV, AquaBiota (total number: 2)
SMHI kustzonsmodell	LST-AB, VM-SÖ (total number: 2)
Misc. LiDAR	AquaBiota
SMHI V-Ost	SMHI
None yet	EnM, KustBev, SMM (total number: 3)
Unknown	RAÄ, FM (total number: 2)

Table 4.3.: Problems encountered with the bathymetric data used by the questionnaire recipients.

Problem	Encountered by Institution/Authority
Spatial resolution too low, lack of details (applies to IOWTOPO and nautical charts) or lack of resolution in shallow waters	AquaBiota, FiskV, FM, LU-Bio, LU-TekGeol, LST-AB, SGI, SMHI, SU, UmU, VM-BV, VM-NÖ, VM-VH, LU-TekGeol, LU-Vatten (total number: 15)
General lack of data or lack of coverage with modern data	AquaBiota, KustBev, FiskV, SMM, RAÄ, SMF, VM-VH, LU-TekGeol (total number: 8)
Confidentiality and lack of access	BoV, FiskV, FM, LST-AB, SMF (total number: 6)
General quality too low	AquaBiota, SGI, UmU, VM-NÖ (total number: 4)
Precision too low	FiskV, SMHI (total number: 2)
Technical details or metadata lacking (such as errors, coverage…)	LU-TekGeol
Different data sets do not harmonize	SMHI
Differing zero levels	SMHI
Shallow bias in ringade områden	AquaBiota
No problems	UU

Not considered: VM-SÖ (unspecific answer)

Table 4.4.: Geographical areas of interest for the questionnai rerecipients.

Area	Requested by Institution/Authority
Kattegat	VM-VH, UU, UmU, SU, SMHI, LU-TekGeol, LU-Ark, BoV, AquaBiota (total number: 9)
Västerhavet (or "Entire Swedish coast")	SGU, SGI, RAÄ, SMM, LU-TekGeol, FM, FiskV, VM-NÖ (total number: 8)
Skagerrak	VM-VH, UU, UmU, SU, SMHI, BoV, AquaBiota (total number: 7)
North Sea	SMHI
Vänern	VM-VH, SMHI, SGU, RAÄ, SMM, KustBev, EnM, FiskV (total number: 8)
Vättern	SMHI, SGU, RAÄ, SMM, KustBev, EnM, FiskV (total number: 7)
Mälaren	VM-NÖ, SMHI, RAÄ, SMM, LST-AB, KustBev, EnM, FiskV (total number: 8)
Hjälmaren	FiskV, SMHI (lower priority)
Storsjön	FiskV
Major lakes; lakes and water courses; lakes; major regulated rivers	VM-SÖ, UU, VM-NÖ, RAÄ, EnM (lower priority), AquaBiota, VM-BV (lower priority), LU-Vatten (total number: 9 including 2 with lower priority)
Archipelagos; Öresund	LU-Bio, LU-Ark, SMHI (total number: 3)

Table 4.5.: Zones of interest for the questionnaire recipients.

	Category 1 Areas within the base line and archipelagos	**Category 2** Very shallow coastal areas within the ca. 10 m isobath or within a line max. 2 nautical miles beyond the base line and protected areas	**Category 3** Coastal waters and shoals at higher seas shallower than 40 m or within a line about 6 nmi beyond the base line, and shipping routes	**Category 4** Remaining deeper parts of the Baltic Sea or the Swedish Exclusive Economic Zone
RAÄ	high priority	high priority	high priority	
SMM	high priority	high priority		
SGU	high priority	high priority		
VM-VH	high priority	lower priority	lower priority	
SMF	high priority			lower priority
VM-BV	high priority			lower priority
LST-AB	high priority			
VM-SÖ		high priority	high priority	
FM		high priority	lower priority	
BoV		high priority	lower priority	
VM-NÖ		high priority		lower priority
AquaBiota		high priority		lower priority
SGI		high priority		
LU-Vatten		high priority		
FiskV			high priority	lower priority
KustBev			high priority	lower priority
LU-TekGeol			high priority	lower priority
LU-Ark			high priority	
LU-Bio			high priority	
SMHI			high priority	
EnM			high priority	
SU				high priority
UmU				high priority
UU				high priority

No statements made by LU-Mat and LU-RS.

situation. "Good basic [geographical] data would favor and stimulate research." (SMF), or as KustBev put it "To uncover what is below the surface has many pros."

4.2.6. Questions 2ai, 2aii: Geographic coverage

The exact question in the questionnaire was "Which areas of the Baltic Sea need to be covered with a depth model in the first place?" Most answers defined priority areas with regard to the coastline, base line (the line along the outermost points of the land) or certain isobaths (curves of constant depth, comparable to elevation contours on land). Only one third of the answers state a clear geographical preference, namely Southern Baltic Sea, Belt Sea and Sund, Gotland Sea, Swedish east coast south of Gävle, Bay of Bothnia, Swedish west coast and Stockholm archipelago (Tab. 4.4). Since there seems to be no general bias towards any of these areas, the answers are grouped by criteria referring to coastline, base line and isobaths into the four classes shown in Tab. 4.5.

It is obvious that the demand for data in coastal waters and other shallow areas is higher than for the deeper regions of the Baltic Sea: Fourteen (including all of the Water Resource Authorities) gave answers fitting into the two first categories as defined above and another seven expressed great interest in the next deeper category. Only three (all of them universities) were greatly interested regions lying deeper than that, e. g. the exclusive economic zone or the entire Baltic Sea.

Categorizing the user into groups of common interests as above may be used as an indicator for collaboration potential. For example authorities concerned with archaeology, the Swedish Geological Survey and some of the Water Resource Authorities share common interest in the shallowest coastal waters. On the other side (academic) research departments, SMHI and EnM are mostly interested in the bathymetry of the deeper parts of the Baltic Sea.

By definition of the International Hydrographic Organization (IHO, 1953), Kattegat and Belt Sea are part of the Baltic Sea, whereas Skagerrak belongs to the North Sea. This was obviously unclear for some of the addressees of the questionnaire, as many listed the Kattegat when asked about interest in areas beyond the Baltic Sea. Concerning the required coverage beyond the Baltic Sea, 17 are interested in the Swedish West coast as well (Skagerrak, Kattegat and in the case of SMHI even the North Sea). At least three of the four remaining addressees (BoV, KustBev and VM-SÖ) probably consider the Swedish West Coast part of the Baltic Sea as defined above and may be interested in this area as well.

Fourteen answers express significant interest in inland waters, nine at least in the major lakes (Vänern, Vättern, Mälaren) and another six in Hjälmaren or other lakes and watercourses.

4.2.7. Question 2aiii: Combined coastal elevation/bathymetry model

The overwhelming majority of the answers is very positive regarding a seamless coastal elevation model featuring both bathymetry and land elevation. Indications about the necessity of such a model range from "just interesting, but not necessary" to "of great value" for different applications. Especially authorities and institutions working with geotechnical problems or coastal hydrological processes list several applications depending on a seamless coastal elevation model: Studies of habitats characterized by recurring flooding events, coast line changes due to land rise and sea level changes, coastal erosion, paleo-landscape changes or water quality issues, just to name a few.

The required extent of land elevation data ranges from just the coastal zone (e.g. below the 10m contour line) to the entire Baltic Sea drainage basin, with most applications focusing on the coastal areas only.

4.2.8. Question 2bi: Required spatial resolution

Generally, the spatial resolution should be as high as possible, but there are different resolution needs for different applications (Tab. 4.6). The users asking for the highest resolutions (decimetre to metre level) work in marine archaeology (SMM, LU-Ark) or with geotechnical applications (SGI, LU-TekGeol). Next comes a group with mixed applications needing grid resolutions between ca. 2 m to 50 m, with preference towards the higher resolutions. For example habitat mapping, fishery, infrastructure and water resource administration fall into this resolution range. According to AquaBiota"The county administrations [kommunerna] consider a resolution of 25m to be on the edge of too coarse [for species and habitat modelling]."

The lowest needs concerning resolution are expressed by institutions performing circulation modeling (SMHI, SU). Here, resolutions in the order of hundred meters are useful.

Many answers consider the possibility of variable grid resolutions, with shallow waters and complex areas shown at higher resolutions than deeper parts of the Baltic.

4.2.9. Question 2bii: Quantities to be mapped

The majority of the answers state that a mean or median value of all measured depths within each grid cell satisfies the needs of most applications. If the grid resolution is significantly lower than the measurement spacing, other quantities can be interesting. Especially a measure of the seafloor roughness is mentioned in about one quarter of the answers. Other possible measures include minimum and maximum depth as well as various statistical parameters. Parameters regarding data quality are discussed below.

4.2.10. Question 2ci, 2civ: Seafloor morphology and objects

Concerning small-scale morphological structures on the seafloor (such as sand ripples, pockmarks, boulders or cliffs), eleven answers express interest in having them appear in a depth model. Nine answers state that these features are not interesting for them. It should be noted that the interpretation of what is considered a "small scale structure" varies between different institutions and the question is closely related to overall resolution needs.

A great majority also shows interest in additional data showing known objects, such as wrecks, boulders, mines, dumped material, installations or archaeological findings. Some go further and state that even geological or biological data (sediment type and thickness, environmental zoning etc.) should be linked to a depth database.

Taking both resolution and morphology related answers into account it is obvious that there is a great interest in the shape and structure of the seafloor far beyond what can be shown on nautical charts.

4.2.11. Questions 2cii, 2ciii, 2cv, 2cvi: Error margins, quality control and metadata

Generally, the accuracy needs of the users who gave answers to the data quality questions are high. Sufficient data quality is referred to with terms such as "vertically 0.1 m in shallow waters, 0.25 m otherwise", "0.5 m positioning, 0.1 m sounding in shallow waters". One answer states compliance with the hydrographic standard IHO S-44 as a criterion (IHO, 2008). Other criteria for sufficient data quality, such as resolution, are considered as well: "Sufficient data is data with sufficient resolution [10 m in this case]", "small scale structures such as sand waves should be resolved" or "[sufficient data has] at least one sounding per grid cell".

Almost all users would welcome additional metadata with data quality related information. Especially the uncertainty of the grid should be specified in detail, for example with a map showing relative or absolute uncertainty for each grid cell (requested in 13 answers). Information about the source data at a certain place was requested by twelve. The data support (or lack thereof), i. e. where and how original soundings contribute to the final grid, should be conveyed to the end user. This can for example be implemented through map layers showing the number of aggregated soundings for each grid cell, flagging (marking) of interpolated values, or specification of the distance from the grid node to the closest sounding. Apart from this key information, there is interest in the measurement method and the time of the measurements. "It is important to show the data quality in a certain place. Bad data is better than no data, but one has to be clear about the deficits. In most cases the public is entirely unaware about the quality of nautical charts off the shipping tracks." (VM-VH)

If the requirements regarding data quality cannot be satisfied, consequences for the work of authorities and in research can arise. Lower precision and poor results in e.g. modeling habitats or circulation can lead to uncertain assessments, false conclusions and an inferior basis for planning. Eventually this may cause wrong decisions (SGI, FM) or in extreme cases bear risks for environment, material or safety at sea (KustBev, FiskV). Productivity

Table 4.6.: Spatial resolutions needed by the questionnaire recipients.

Resolution	Requested by Institution/Authority
Source data, no aggregation	LU-Ark, LU-TekGeol
0.1...1m	SMM
1...2m	SGI
2...10m	FM, SGU
5m in topographically complex settings, but at least better than 25m	AquaBiota, VM-VH
Better than 25m (as much as 1m) down to 40m depth, lower resolution in deeper waters	LST-AB
10m	FiskV
20...50m	EnM, LU-Bio
30...100m	UmU
50m	KustBev
50...1852m	SMHI
100m	SU
1m (archaeology), 5...10m (< 10m depth), 10...20m (shallow waters), 50m (deep water)	LU-TekGeol
10m (< 10m depth), 50...100m (> 10m depth)	LU-Vatten

can be limited, e. g. through the inefficient use of costly ship time (SGU) or technical problems with modeling runs (SMHI).

4.2.12. Question 2cvii: Measurement series

When asked about the usefulness of measurement series, about half of all users (13) answered that in dynamic environments (estuaries and other environments with strong erosion or deposition) time series of water depth would be useful. Two showed minor interest, seven are not interested in measurement series and five did not answer the question.

4.2.13. Question 3: Other data products

Some users showed interest in other data sets complementing water depth. Especially the marine geological settings (seafloor type, surface sediment type or sediment properties, erosion) are considered a natural supplement to bathymetry, especially for bottom habitat mapping. A few users have use for echo sounder backscatter and Side Scan Sonar data, i.e. data about the amplitude of an acoustic signal scattered acoustic on the seafloor, which is closely related to the seafloor material. Derivatives of bathymetric data, such as gradient and seafloor roughness maps, hypsometric curves or cross-section profiles are also listed by particular users, as is oceanographic data (temperature, salinity, currents).

4.2.14. Question 4: Costs, licensing and accessibility

The overall tenor in the answers is that detailed bathymetric data should be available for free, if not for all purposes then at least for administration, research and the non-commercial public (Tab. 4.7). Since most or all of the data is produced with taxpayer's money, there is no good argument for charging the taxpayer again for the usage of the data in administrative and research matters. Some answers consider bathymetric data a national base resource ("nationell basresurs" or "allmän grundinformation", as done in the USA), which should be freely available for any usage, including commercial use. AquaBiota pointed out that "even companies are taxpayers" and that discriminating commercial usage will lead to problems for companies not exclusively working on public contract. Two answers name the possibility complementing such non-restrictive terms of usage with a data delivery obligation. Putting a price tag on detailed bathymetric data will cut the amount of users and therefore the usefulness of the data, while at the same time the administrative overhead is increased. Fiskeriverket pointed out that according to the INSPIRE directive bathymetry may be considered environmental data and as such has to be freely accessible for administrative purposes.

A fee covering the costs for the delivery of the data to the end user was considered appropriate in several answers.

A small number of users state the ability to pay for detailed bathymetric data (SMHI, FM) although some of them state that the cost threshold should not be too high (LST-AB, SGI, VM-VH) or rather low (LU-Ark, LU-Bio).

Several users mentioned the licensing model implemented for SMHI as an interesting possibility, with overview data free and detail data being charged for.

4.2.15. Question 4b: Internet access

The general trend of the answers is in favor of a flexible and user-friendly web GIS solution for downloading depth data. Since most users are interested in specific regions for their projects, it should be possible to choose the geographical extent of the data downloaded. Furthermore, resolution, projection and data format needs vary between different users, making flexibility even regarding these points desirable.

Some authorities (e. g. KustBev) express the need to connect their existing data management systems to the depth database, integrating depth data into their workflows.

Table 4.7.: Costs and licensing suggestions.

Licensing and costs concept	Suggested by Institution/Authority
Free (maybe apart from administrative and delivery expenses). Reasons: Data produced with taxpayer's money should be free for the public; depth data should be considered a national basic resource ("nationell basresurs", "allmän grundinformation"); low cost and licensing threshold for getting data used; for free is easiest; otherwise IOWTOPO will be used.	KustBev, RAÄ, SGU, VM-NÖ, VM-SÖ, SGI, SMF, LST-AB, UU, VM-BV (total number: 10)
Free or cheap.	LU-Ark, LU-Bio, EnM, SU (total number: 4)
Free for public authorities.	FiskV, LST-AB
According to INSPIRE, environmental data have to be freely available for administration purposes.	FiskV
Not to high costs for administration and public, more expensive for commercial uses. Data delivery duty for users or commercial users.	VM-VH
Free for research and public interests, commercial for businesses; maybe data delivery duty for users or commercial users.	LU-TekGeol, LU-Vatten
Depending on resolution, low resolution free; comparable to the SMHI licensing model.	LU-TekGeol, LU-Vatten, SMF (total number: 4)
Data may cost.	FM, SMHI, UmU (only if contracting authority or science foundation stands for the costs)

4.2.16. Question 5: Participation

5i, 5ii – Data collection and incorporation

It should be emphasized that there are major players amongst the Swedish maritime authorities with notable capacities for seafloor mapping apart from the Swedish Maritime Administration: the Swedish Coast Guard (*Kustbevakningen*), the Swedish Marine (*Försvarsmakten*) and the Swedish Geological Survey (SGU). In particular, the Swedish Coast Guard operates three ships equipped with multibeam echo sounders and plans to commission another four vessels with similar equipment in the near future. The Swedish Geological Survey's Ocean Surveyor is equipped with a single beam echo sounder. In both cases, however, the depth measurements collected are not systematically saved and preserved for uses beyond the respective offshore operations. Bathymetric data collected by the Swedish Marine during military operations on the other hand is forwarded to the Swedish Maritime Administration for future use as far as classification permits.

Apart from these potential major contributors there are some authorities/institutes collecting depth data to a lesser extent (or having the capacity but not using it at present), either themselves or by contracting companies: FiskV, LU, LST-AB, SMM, RAÄ, SGI, SMF, VM-VH. Most bathymetric data collected by these is not quality controlled in the way it is done in hydrographic production environments and in most cases the amount of data collected is small. Nevertheless, if quality aspects are considered properly, all of the above are willing to share the data for incorporation in digital bathymetric models.

5iii, 5iv – Database development and needs regarding rules and leadership

Apart from data sharing as under (5ii) for most state authorities using digital bathymetric data the development, implementation and operation of a national sounding database lies beyond their present public mandate. Notable exceptions are University departments with knowledge in the fields of e.g. cartography, GIS and mathematics (several departments at Lund, Stockholm and Umeå Universities) and the Swedish Geological Survey, which already performs geological mapping in the Baltic Sea. As stated in several answers, any active participation would require adequate funding.

Several authorities (SMM, SGI, SMHI, VM-VH) offered to act as advisors mediating the needs from the data users to those implementing the database. The wish to be informed and consulted regarding the development of the project was expressed by Boverket, Försvarsmakten, Kustbevakningen, SGU and VM-NÖ, mostly to make sure that the database implementation details do not pose problems for the way the data is going to be used.

4.3. Questionnaire survey discussion and conclusions

The questionnaire regarding the needs for depth data in the Baltic Sea area was answered by 15 state authorities, 5 universities and research institutes as well as the Swedish military. It is very likely that the answers represent a broad and representative range of depth data applications in the Swedish administration. Because of the lower number of answers from research institutes and universities, the picture of research related applications is probably less representative.

A large portion of the answers given by the various users can be summarized in five key points:

High demands concerning spatial resolution of depth data: Even the highest resolutions technically possible with modern shallow water multibeam surveying equipment (decimeter resolution) could be utilized for tasks e.g. in archaeol-

ogy and geotechnics. Generally the shallower the water and the closer to the coast the higher the resolution should be. Deeper areas further off the coast are of lesser interest for high-resolution applications and resolutions in the order of 10…100m may suffice.

Insistent request for availability of detailed depth data: Bathymetric data can be used and is being used for a wide range of applications. In many cases the lack of sufficiently accurate, reliable and detailed depth data imposes restrictions on research, planning and the administration of the marine resources. The results of investigations concerning e.g. habitat mapping, archaeological conservation issues or geotechnical problems will only be as good as the data basis allows.

The closer to the coast, the higher the interest in depth data: The questionnaire survey clearly shows that the dependency of particularly state agencies on detailed depth data increases with decreasing distance to the coast. For many tasks it is beneficial or necessary that the most fundamental property of the complex coastal environment, topography and bathymetry, is available in a seamless manner, without vertical datum problems along the shore line or resolution differences between land and sea.

There appear to be possibilities for improved collaboration between the authorities dealing with depth data: Today there is a number of actors dealing with depth data in Sweden, with some of them even producing depth data within their own scopes. The possibilities of a centralized database as a "one stop shop" are intriguing, and there may even be the possibility of more effective data acquisition.

However, effective measures to adress all four named points are presently constricted by legal regulations around the fact that detailed depth data is classified information in Sweden.

4.4. Literature analysis

In order to assess the needs regarding bathymetric data for research uses, the scientific literature was scanned for articles documenting scientific work and referring to bathymetry in the Baltic Sea. The articles were analyzed with regards to the same questions as asked in the questionnaire survey. It should be noted that this literature analysis does not represent the situation in Sweden only, but includes numerous articles from other countries, mostly the Baltic Sea states.

4.4.1. General remarks

It should be noted that in the case of an analysis of needs the results from a search of the scientific literature are expected to be essentially different from the results of a similar questionnaire survey. Scientific articles are subject to a peer-review process to guarantee the scientific value of the work. It is therefore very likely that a study is never published (or even started) if deficient underlying data (in this case bathymetry) would jeopardize its results. Unfortunately for an analysis of the needs regarding a specific data set, such studies would be the most interesting ones to look at, however they are grossly underrepresented in the literature. The scientific literature stands for what was possible to be carried out in the past – not for what should be possible to be accomplished in the future.

For data sets of a more generic nature, such as bathymetry in this case, it can be expected that the usage in many cases is not properly documented, e.g. with a citation of the provider of the data set and that there is a lot of cases where the work finally ends up in the shelf drawer.

For these reasons, one can probably not consider the about 130 references presented here a comprehensive image of all scientific work carried out with bathymetric data of the Baltic Sea. Nevertheless, the authors think that the literature gives interesting hints about the kind of scientific work carried out with bathymetric data and at least some clues about the needs of the scientific community.

4.4.2. References for the use of digital bathymetric data in the Baltic Sea

For locating the most comprehensive set of articles and other published work possible, several internet search engines were utilized, both research related (Science Direct, Google Scholar) and general purpose ones (Google web search). Most scientific work relating to bathymetry in the Baltic Sea refers to the IOWTOPO model (Seifert et al., 2001) and the search terms used (Tab. 4.8) reflect this fact. It should be pointed out, however, that with these search terms a number of documents were found, which do not refer to the IOWTOPO model. It is therefore very likely that the strong bias of the literature towards IOWTOPO is not an artifact of the method of finding it. All search hits not relating to Baltic Sea bathymetry in any way were filtered from the results. The reviewed literature includes both peer-reviewed scientific articles and so-called grey literature, e. g. research reports, which have not gone through the peer reviewing process. Because it is not very common to publish peer reviewed articles where the data basis is insufficient for the performed work, we expect that the grey literature may contain valuable indications about deficits in the available bathymetric data.

Although a number of publications can be found which are related to administration, industry or spatial planning, we constrict our analysis to research related publications as the "public" usage of bathymetric data is covered of the questionnaire survey in this work. Of course the border between pure research and other applications is diffuse, and marginal cases are included in this part of the study.

Of a total of 144 references found, 18 were not available in full text to the authors and thus excluded from the study. Another 20 references were not research related and also excluded. A complete list of the remaining 106 references is given in Appendix A.

Each reference was investigated with regards to a set of

Table 4.8.: Search terms used for literature review.

Search string	Notes
"Baltic Sea" +bathymetry –IOWTOPO –IOWTOPO2 –Seifert	Google Scholar: first 100 hits considered. Google: first 200 hits considered
"Baltic Sea" topography	
Seifert +Tauber +Kayser	Only used for Science Direct and Google Scholar searches
Seifert +Tauber +Kayser +topography	Only used for Google web search
IOWTOPO	
IOWTOPO2	
"IOWTOPO 2"	

questions primarily based on the questions in the questionnaire survey.

4.5. Results literature review

4.5.1. Countries and institutes using depth data

For the following analysis only the affiliations of leading authors were considered in cases where a leading role of one researcher or research group was obvious. With 49 of the investigated studies, German researchers contributed the largest part of all studies in comparison to other countries. The second largest part were 22 publications with Swedish affiliation, followed by 12 Estonian. Danish researchers contributed to 7 publications, Finnish and U.S. affiliations appeared in 6 and Polish in 4. The remaining countries present in the affiliations of the publications (Russia, Netherlands, Belarus and the United Kingdom) appeared one ore two times. Two publications were strictly European Union products (see also Fig. 4.3).

Since the most used depth model of the Baltic Sea, IOWTOPO, was published at a German research institute, the large proportion of German publications is not surprising. Sweden, with the longest shoreline of all Baltic countries, obviously has a strong record of Baltic Sea research, too. The somewhat unexpected third position of Estonian publications is partly due to a single researcher contributing with six articles alone.

Within the countries, the activities are rather evenly distributed between the respective university departments active in marine research.Some public authorities, namely the geological surveys, have also published research results. Only one research institute, the Leibniz Institute for Baltic Sea Research in Warnemünde (IOW) appears to be overrepresented. Very likely this can be attributed to the fact that IOW is the home of IOWTOPO.

4.5.2. Purpose depth data is used for

A wide range of research questions are worked on with the help of bathymetric data (Fig. 4.2). In about one quarter of the references bathymetric data is exclusively used for illustration in a map of the study area. Apart from that, two research fields dominate in the references: Physical oceanography and marine geology. Physical oceanography here includes studying the water masses, their circulation, currents and climate (26 references, 18 of them modeling related). The study of waves and tides appears in another 11 references (all modeling related). Marine geology publications deal with sedimentation, erosion and seafloor dynamics (mentioned in 26 references, 11 of which modeling related) as well as coastal evolution, sea level change and paleotopography questions (7 references).

Biology and environmental studies follow long after oceanography and geology, with 10 references concerning biological processes and 3 publications dealing with habitat mapping. Planning of field work, sampling site surveys and underwater vehicle operations are mentioned in 9 references. The remaining publications deal with less common questions (Fig. 4.2).

4.5.3. Data sets being used

Table 4.9 gives an overview of all bathymetric data sets referenced in the reviewed publications. IOWTOPO is by far the most used data set (mentioned in 65 references), both for the entire Baltic Sea (IOWTOPO2) and the Southern Baltic (IOWTOPO1). A significant number of references (10) use bathymetry extracted from nautical charts (paper and electronic) or data sets obtained from the national hydrographic offices. In another 10 references data was measured specifically for the study, e.g. in a high resolution site survey of a limited area.

A number of other data sets were used occasionally. Since often the data is not properly referenced in publications, the situation is confusing. Especially for the Danish parts of the Baltic Sea there has been released a number of very similar depth data sets by different state authorities over the past two decades.

4.5.4. Geographic coverage of the studies

To determine in which areas of the Baltic Sea depth data is used most, the geographic extent of each published study was examined using a GIS. Figure 4.3 shows the number of studies encountered at any specific place in the Baltic Sea and Skagerrak, i.e. the number of publications dealing with a certain location. It can be clearly seen that the "research intensity" is highest in the Arkona Sea and generally decreases as one goes further to the north, both towards Skagerrak and the Gulf of Bothnia. In comparison to the Arkona Sea only about half the number of publications deal with the Gulf of Bothnia or the Skagerrak. The Gulf of Finland is slightly more "research intense" than the Gulf of Bothnia. Most of the publications contributing to the areas with low "research intensity" deal with questions

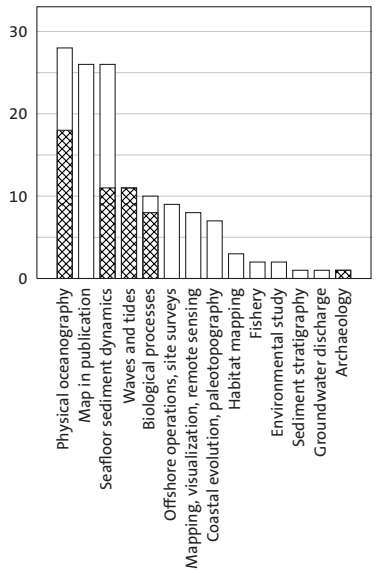

Figure 4.2.: Depth data of the Baltic Sea is used in a variety of research fields.Shown are the numbers of published articles and research reports within a certain area of research mentioning the use of bathymetric data. The filled bars indicate uses in a modeling context.

Table 4.9.: Bathymetric data sets referenced in the reviewed literature.

Data set	Reference	Comment	Used by
IOWTOPO	Seifert et al. (2001)	See section 5.2	65
Chart depths		Digitized nautical charts, ENCs or hydrographic office data	10
Own measurements			10
ETOPO5	NGDC (1988)	Depth model based on ETOPO5	4
Gelumbauskaitė (1998)		See section 5.2	3
Satellite altimetry	Smith and Sandwell (1997), U. S. Department of Commerce et al. (2006), Becker et al. (2009)	Bathymetry derived from satellite altimetry measurements	2
Babenerd and Gerlach (1987)		Bathymetry of the Bay of Kiel	2
DHI DYNOCS	Weiergang (1995)	Danish waters, grid resolution $1'$	2
Olex		See section ??	1
SMHI		Bathymetry from Swedish Meteorological and Hydrological Institute model	1
IOWTOPO 1995		1995 predecessor of IOWTOPO	1
BSH North Sea		German hydrographic office North and Baltic Sea model at $6' \times 10'$	1
BSH Coast		German hydrographic office Baltic coast model at $1' \times 1'40''$	1
DMU		See section 5.2	1
SYKE		Finnish ca. 50 m TIN model from chart data	1
SWAN		Military data(?)	1
TRIMGEO		Circulation model with 10 km resolution	1
RDANH Bornholm		Bathymetry around Bornholm from the Royal Danish Administration of Navigation and Hydrography, 200 m grid resolution	1
Wieser (1987)			1
Unknown		Not stated which DBM was used in study	9

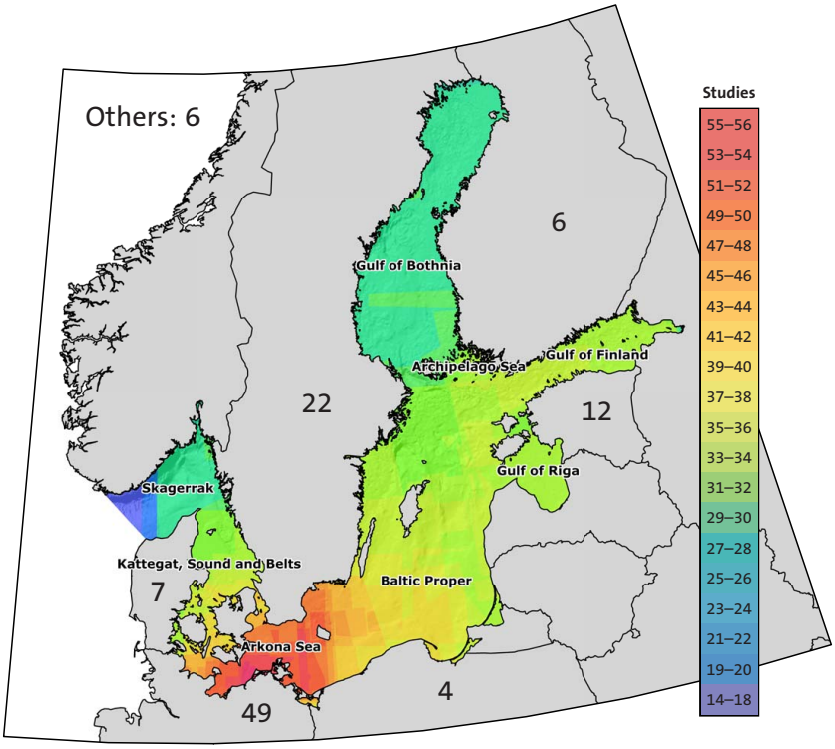

Figure 4.3.: Intensity of research utilizing bathymetric data in the Baltic Sea, as shown by the number of bathymetry related scientific publications at a certain place. The highest research intensity takes place in the Southern Baltic, with about twice as many studies carried out than in the Gulf of Bothnia, where research intensity is lowest.The area around the Leibniz Institute for Baltic Sea Research in Warnemünde (IOW) features the highest concentration of research studies in the entire Baltic. Since the IOWTOPO data set was published at IOW, this bias is not surprising. A discontinuity can be observed at the edge of IOWTOPO2 in the Skagerrak and the edge of IOWTOPO1 on a line through Bornholm. The numbers indicate the amount of first author affiliations to the respective country.

regarding the entire Baltic Sea and there are very few published studies focusing explicitly on these areas. Only 10 studies (i.e. less than 10 %) include areas beyond the Baltic Sea and Skagerrak.

A strong discontinuity is present at the edge of IOWTOPO2 in the Skagerrak and to a lesser extent also at the Eastern edge of IOWTOPO1. However, the official border between Baltic Sea and North Sea (between Kattegat and Skagerrak from the northernmost point of Denmark to the Swedish west coast) is not at all prominent in the map. Obviously the geographical extent of a number of studies is determined by data availability rather than natural or administrational boundaries or the official limits of sea subdivisions.

The highest "research intensity" appears to be at the German Baltic Coast, or precisely around Warnemünde, where the The Leibniz Institute for Baltic Sea Research (IOW) is located. Since IOWTOPO was published at this institute and IOW researchers are extensively using the data set, this local bias is not surprising.

4.5.5. Problems and drawbacks encountered with the data sets

It is hard to find hints in the publications indicating problems and drawbacks of the bathymetric data used. The authors think that this is due to the fact that usually scientific research only gets published in case the data basis is sufficient for the task. Nevertheless, as numerous problems have become evident in the questionnaire survey (lack of spatial resolution, lack of access to detailed data), it seems unlikely that no similar problems have an impact on scientific research work.

One can assume that for tasks such as habitat mapping, detailed sedimentology studies, studies of paleo-coastlines or certain modeling questions the spatial resolution of the commonly used data sets is often too low. Clear indications for this are e. g. given by Harff and Meyer (2001), who upsampled the low resolution of the ETOPO5 bathymetry for a coastal geology evolution study, Jakobsson et al. (2007), where a 500 m grid was interpolated from IOWTOPO, or Milbradt and Lehfeldt (2002), who performed modeling of littorial processes on nodes spaced with as little 10 m along the German Baltic coast.

5. Available depth data

5.1. Available depth data in Sweden

The situation as described below is from a Swedish Maritime Administration (SMA) point of view. The administration and its Hydrographic Office have collected bathymetry data for the purpose of producing nautical charts for hundreds of years. There are other organizations in Sweden, which over the years have had permission to carry out for hydrographic surveying. In most, but not all, cases the resulting data have been delivered to and is managed by SMA. Examples of such organizations include the military navy, regional and municipal authorities, port authorities, other nautical chart producers and research institutes.

The technology for measuring or sampling depths has come a long way from soundings by hand lead line to the modern high-resolution multibeam sonars used today. The methods of horizontal positioning have undergone a similar development leading to the RTK GPS positioning now in use.

At the Hydrographic Office, a bathymetry or soundings database was established in the late 1990s. The overall goal for the database is to manage all bathymetry data for Swedish waters, including the exclusive economic zone, and larger inland lakes. All hydrographic surveys with in digital form from about 1980 and onwards have been stored and managed. In an ongoing government funded project, the most relevant material from after ca. 1930 in survey charts and hydrographic fair sheets is being digitized. In the SMA production of nautical charts, all soundings (depth figures) and depth contours shall have their origin in the bathymetry database.

As a result of the history of evolving survey methods, the status within the database varies enormously. The accuracy of depth and position, density, resolution and reliability are a few of the quality parameters that need to be stored in relevant metadata. The total geographical area of interest is 165 000 km^2. Early in 2011, approximately 77 % of this area was covered in the database, with varying quality and survey methods. Approximately 25 % of the area (Fig. 5.1) is surveyed to the modern standards by which SMA has operated since 1995.

5.2. Available bathymetric data for the Baltic Sea

At present, there is no homogeneous, quality controlled and continuously updated bathymetric model available for the Baltic Sea area which can meet the demands indicated by prior government investigations (Miljödepartementet, 2008). Apart from soundings which can be extracted from paper charts or electronic nautical charts (ENCs), a number of publically available bathymetric data sets cover the Baltic Sea area (Fig. 5.2). However, all of them have significant drawbacks concerning spatial resolution, coverage and currentness.

Land elevation and underwater depth are usually measured with respect to different vertical datums, commonly mean sea level and the lowest astronomical tide. Various applications rely upon merging topography and bathymetry data sets, e. g., studying coast line changes or flooding phenomena. To date, there is no digital coastal terrain model available for the Baltic Sea accounting for the potential problems of such vertical datum issues.

5.2.1. IOWTOPO

The IOWTOPO digital bathymetric model (Seifert et al., 2001) is the most used overview DBM of the Baltic Sea today (Fig. 5.3). It displays both bathymetry and land elevations of the Baltic Sea region at a relatively low spatial resolution of about 2 km and about 1 km in the southern Baltic Sea and Belts. The model is based upon data collected for research purposes as well as depths extracted from nautical charts, which were freely available for the compilation. Only a fraction of all depth measurements collected by the Baltic states is included in the IOWTOPO data set.

Coverage: Entire Baltic Sea from 9° to 31°E and 53°30′ to 66°N; both sea and land areas.

Grid resolution: 1′ (arc-minute) in latitude by 2′ in longitude (roughly 2 km in either direction) over the entire region (IOWTOPO2). 30″×1′ (ca. 1 km) in the Belts, Arkona Sea and Southern Kattegat. Large portions of the base data, upon which the DBM is built, are very sparse and required grid nodes to be interpolated from surrounding measurements.

Based upon: Overview nautical charts and depth measurements collected for research purposes. Land elevations from GTOPO30. A total of 1.7 million water depth samples were incorporated in the final grids by calculating a (weighted) average for each grid cell. In the central Baltic Sea, IOWTOPO2 is to a large extent based on the contour map by Gelumbauskaitė (1998).

Accessibility: Freely avalilable for research and other non-commercial purposes.

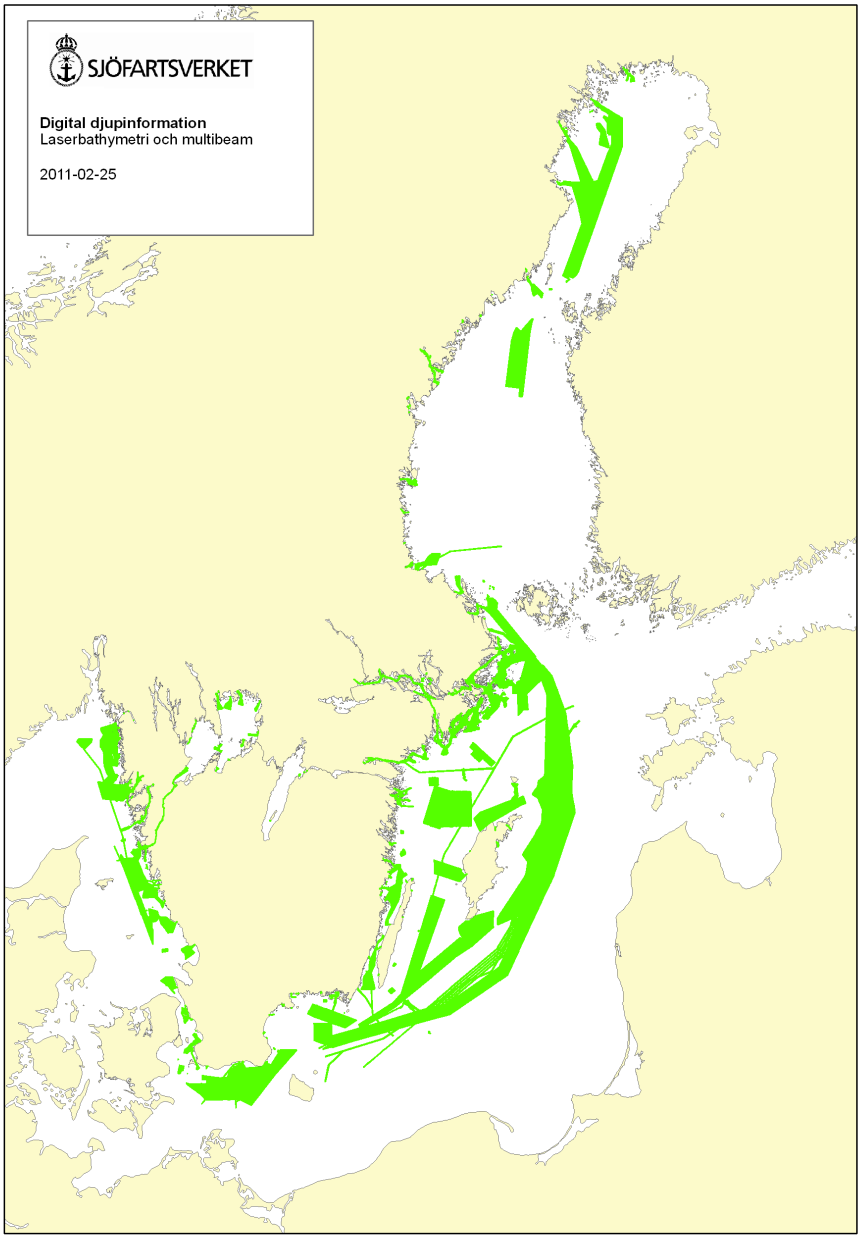

Figure 5.1.: Coverage with modern sounding measurements of the Swedish waters.

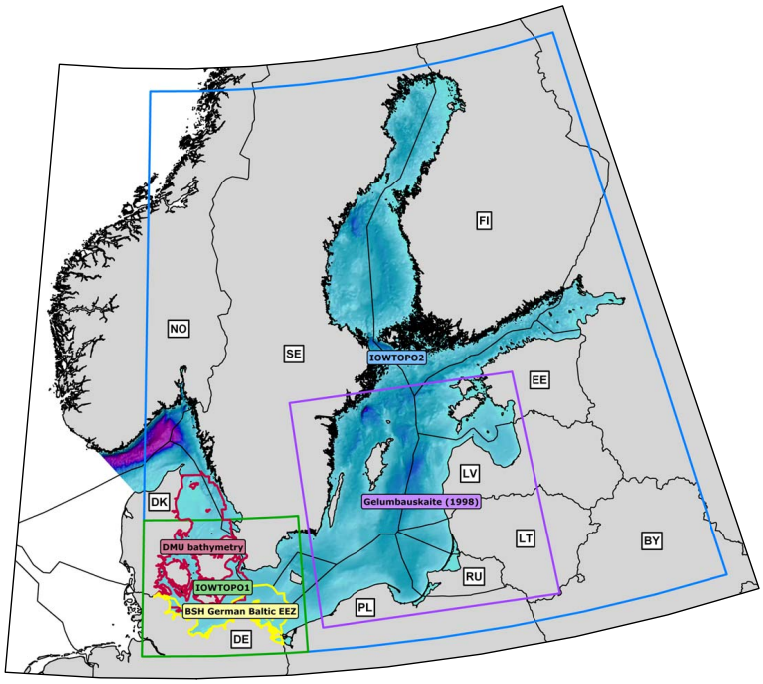

Figure 5.2.: Publically available bathymetric data sets for the Baltic Sea and Skagerrak. The Swedish-Lithuanian GEOBALT project resulted in a map of the central Baltic Sea depicting isobaths every 5 m and 10 m (Gelumbauskaitė, 1998). For the German Baltic exclusive economic zone (EEZ), the responsible hydrographic office has released a bathymetric grid with a cell size of ca. 200 m. A Triangular Irregular Network (TIN) model of the Danish Kattegat, Sound and Belts bathymetry (facet sizes in the order of 50 m is available from the Danish National Environmental Research Institute (DMU). IOWTOPO1 and IOWTOPO2 (Seifert et al., 2001) are DBMs compiled of all publically available depth data from the Baltic Sea at the time of compilation, amongst others including the above mentioned maps and data sets (partly in now outdated versions). The southern Baltic Sea and Belts grid has a cell size of ca. 1 km (see text), and the entire Baltic Sea is covered at ca. 2 km cell size. Maritime boundaries delineate the EEZs of the riparian states.

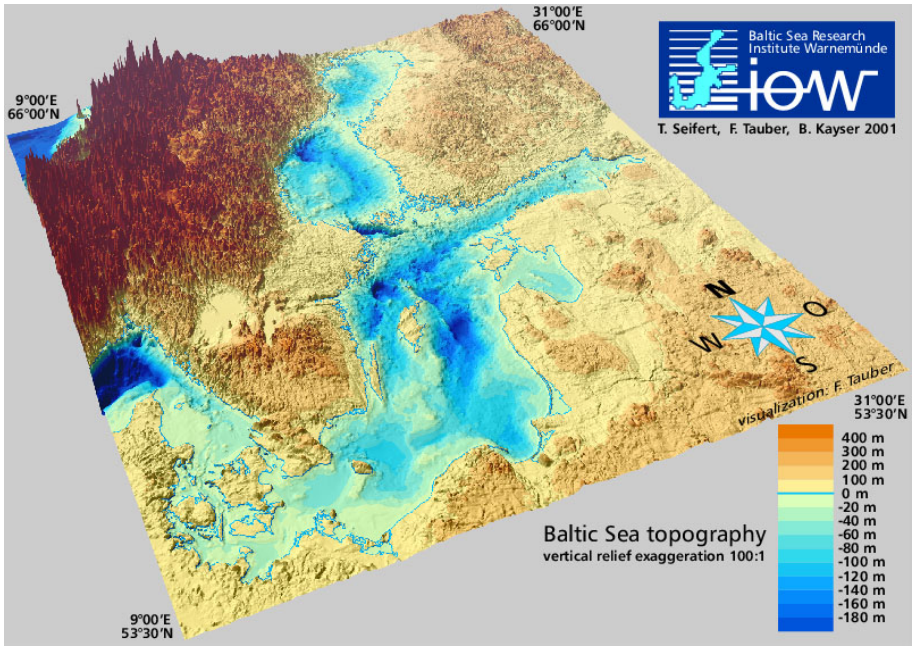

Figure 5.3.: IOW Digital Topography of the Baltic Sea (IOWTOPO2). Image from `http://www.io-warnemuende.de/topography-of-the-baltic-sea.html`

5.2.2. Gelumbauskaitė (1998)

The GEOBALT project was a co-operation between the Swedish and Lithuanian geological surveys and resulted, amongst other outcomes, in a paper chart of the central Baltic Sea (Gelumbauskaitė, 1998). Bathymetric contours (isobaths) are charted every 5 m apart from an area on the northern sheet with 10 m equidistance.

5.2.3. Danish DMU bathymetry

The Danish National Environmental Research Institute (DMU) has published a series of environmental data sets, including bathymetry of the Danish part of the Baltic Sea and Belt Sea (Nielsen et al., 2000). Bathymetric data are released as a Triangular Irregular Network (TIN) model with facet sizes on the order of 25 m, accompanied with a coast line data set. Most of the bathymetric data were acquired before 1988 with single beam echo sounders and a line spacing of typically 25 m. Only smaller parts of the TIN model are based on more recent multibeam measurements. There are relatively few interpolated gaps, but the data quality and spatial resolution varies within the data set.

5.2.4. German BSH data

The German hydrographic authority BSH provides a Web Map Service, which includes a bathymetric data set of the German Exclusive Economic Zone (EEZ) at a cell size of $6'' \times 10''$ (ca. 200 m). The displayed values are average depths in the grid cells and most likely based on measurements for chart production.

5.3. Examples of other international depth models

5.3.1. NGDC Coastal Relief Model

The U.S. coastal relief model (Divins and Metzger, 2011) provides a seamless and complete picture of the bathymetry and land topography for the U.S. coastal states and seas. In many cases the bathymetry extends to the edge of the continental shelf (Fig. ??).

Coverage: Coastal land and sea areas of the USA.

Resolution: 3″, (ca. 30 m). Partly interpolated data.

Based upon: U.S. National Ocean Service Hydrographic Database; USGS data; SRTM DEM; International Bathymetric Charts of the Caribbean and Gulf of Mexico.

Accessibility: "Public domain", i.e. can be freely downloaded from the internet an used without restrictions.

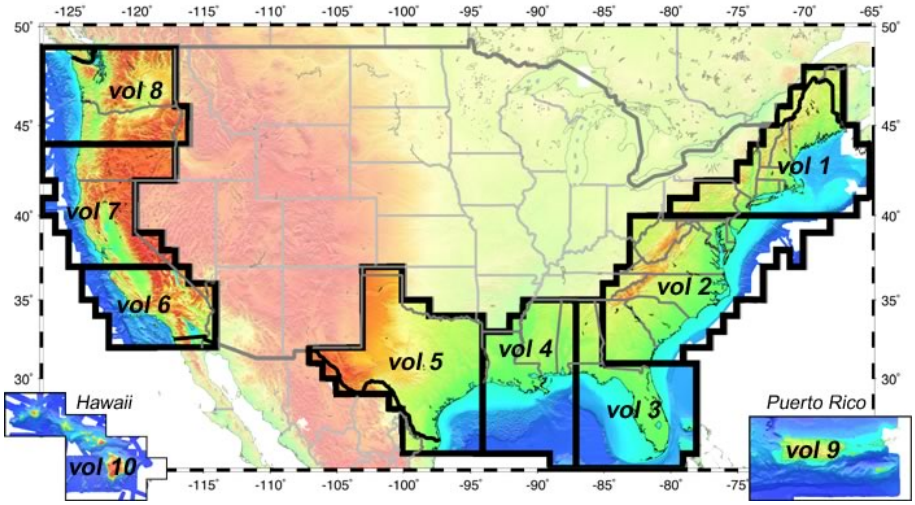

Figure 5.4.: U.S. NGDC Coastal Relief Model. Image from `http://www.ngdc.noaa.gov/mgg/coastal/crm.html`

6. Legislations and conventions in force

6.1. United Nations Convention on the Law of the Sea

The United Nations Convention on the Law of the Sea (UNCLOS, United Nations, 1982) defines the modern standard of international law at sea, including laws and regulations for internal waters, archipelagic waters, territorial sea, contiguous zone, exclusive economic zone, continental shelf and the high seas; named below "maritime zones". As of 1 January 2010 160 states have joined the convention.

UNCLOS also defines rights and duties for the coastal State and foreign ship as regards marine scientific research and hydrographic surveys activities in the mentioned maritime zones. The coastal State may adopt laws and regulations in respect of among other things; marine scientific research and hydrographic surveys in the territorial sea. In the exclusive economic zone, the coastal State has certain jurisdiction with regard to marine scientific research but not hydrographic surveys. The high seas are open to all States including the freedom of hydrographic surveys and scientific research.

For the purposes of the Convention, "enclosed or semi-enclosed sea" means a gulf, basin or sea surrounded by two or more States and connected to another sea or the ocean by a narrow outlet or consisting entirely or primarily of the territorial seas and exclusive economic zones of two or more coastal States. States bordering an enclosed or semi-enclosed sea should cooperate with each other in the exercise of their rights and in the performance of their duties under this Convention. To this end they shall endeavor, directly or through an appropriate regional organization:

- to coordinate the management, conservation, exploration and exploitation of the living resources of the sea;
- to coordinate the implementation of their rights and duties with respect to the protection and preservation of the marine environment;
- to coordinate their scientific research policies and undertake where appropriate joint programmes of scientific research in the area;
- and to invite, as appropriate, other interested States or international organizations to cooperate with them.

UNCLOS supports and encourages the elaboration of boundary delimitation agreements and give each state the necessary authorities to develop compatible and applicable national legislations including deciding the demarcation of the stated maritime zones.

According to UNCLOS, the limits and boundaries of the maritime zones refer to the baselines. The water on the landward side of the baselines forms part of the internal water. Normally, the limits for the maritime zones outside the baselines are measured from the baselines and the boundaries agreed on with neighbor countries refer to the baselines at both (all) coastlines concerned.

According to UNCLOS the normal baselines are represented of the low-water line along the coast as marked on large-scale charts officially recognized by the coastal State. UNCLOS also provides as an alternative, straight baselines joining appropriate points which may be employed where the coastline is deeply indented and cut into, or if there is a fringe of islands along the coast in its immediate vicinity. The conditions needed to be fulfilled for using straight baselines and how to define the baselines is specified in the convention.

The baselines and other limits and boundaries of the stated maritime zones shall be shown on charts of a scale or scales adequate for ascertaining their position. Alternatively, a list of geographical coordinates of points, specifying the geodetic datum, may be substituted.

6.2. Co-ordinated ENC by "WEND Principles" developed by IHO members

The earlier tradition of presenting only limits and boundaries of maritime zones of the coastal state in official paper charts published by the responsible Hydrographic Office (HO) is changing. The majority of HO deliver or will, most likely, in the near future deliver maritime borders together with all other electronic nautical chart (ENC) data. This international co-operation is constituted by the International Hydrographic Organization (IHO) member states and data will be accessible according to the "WEND Principles" developed by the members. The policy is worked out with respect to matters related to administration, legality, technical processes, etc. including routines for weekly update, validation of data, etc. Especially the ENC data (such as depth contours) in the area close to the bilateral line defining each Hydrographic offices area of responsibility (waters) is of interest for joint investigation by the adjacent countries.

6.3. Quality assurance by IHO recommendations and IMO regulations

ENC used in approved Electronic Chart Display and Information System (ECDIS) is accepted by the International

Maritime Administration (IMO) as an alternative to nautical paper charts. By this infrastructure, ENC, including official maritime borders from different countries, will be linked together, quality controlled and published. The relation between IHO and IMO and the overall responsibility of these organizations is used to design solutions and valid regulations within the international maritime field. As an example the above ENC concept is designed within the frame of IHO. In extension, ECDIS presupposes access to ENC and will be, as decided by IMO, mandatory in the near future (starting 2012 for specific types of vessels).

6.4. Swedish legislation related to maritime zones and the Law of the Sea

The Government of Sweden has recently called attention to the important potential IHO has as an international organization within the hydrographic field, with a well performing infrastructure for developing and standardization of hydrographic information and additionally; having the necessary qualities to improve the distribution and exchange of hydrographic information on a broad scale.

UNCLOS is implemented in the Swedish legislation, in spite of the fact that the original legislation defining baselines, internal water, and territorial sea was published 1965. The Swedish law[1] regarding the internal water and the territorial sea defines the Swedish "marine territory" ("sjöterritorium")—and also the baselines (Fig. 6.1). Nearly 90 % of the Swedish coastline is represented of straight baselines, considering the state of the extensive archipelago and that some parts of the coastline deeply indented. The breadth of the territorial sea is normally 12 nautical miles; but less in some areas. Sweden has not (yet) established any contiguous zone to its territorial sea.

Like many coastal states Sweden also has implemented an exclusive economic zone. The limit of the Swedish exclusive economic zone is also the limit for the continental shelf. The Swedish law[2] regarding the Swedish exclusive economic zone regulates the protection of the marine environment within the zone and other rights and obligations over and above those stated in the laws regarding the continental shelf and fishery. Marine scientific research performed by foreign parties is not allowed in the zone without permission. The Swedish regulation[3] regarding the Swedish exclusive economic zone defines the zone outside the territorial sea out to the boundary as agreed with neighbor countries.

The Swedish law[4] and regulation[5] regarding the continental shelf regulates the rights to explore and extract natural resources located on the continental shelf located within internal waters,[6] the territorial sea and the exclusive economical zone. The right to explore and extract natural resources located on the continental shelf belongs to the Swedish State.

The fishery law[7] regulates the rights within the internal water, the territerial sea and the exclusive economic zone together with other rights regarding fishing.

Sweden has signed several successful agreements with her neighboring countries aimed towards delimiting the surrounding maritime area. All the limits and boundaries of the maritime zones are shown on nautical paper charts published by the Swedish Maritime Administration (SMA). SMA delivers ENC covering all Swedish waters, but the maritime borders in accordance with UNCLOS are for the present excluded due to the fact that the laws in force do not support publishing any official co-ordinate list of maritime borders.

6.5. Swedish legislation referring to spatial landscape data according to the Law of the Sea

The Swedish law[8] and regulation[9] regarding the protection of spatial landscape data regulates, among other things, the provision of permission to carry out hydrographic surveys, establishing data bases of landscape spatial data and also the distribution and publishing of landscape spatial data. Hydrographic surveying is not allowed without permission in internal waters[10] or the territorial sea, except surveying performed by a port authority in the port area. It is not allowed without permission to establish data bases[11] storing spatial landscape data[12] of the Swedish land territory, internal waters or the territorial sea. Permission is required to distribute aerial photos and maps at a larger scale than 1:100 000 and other compilations of landscape data[13].

The Swedish law[14] and regulation[15] regarding the official secrets act, contains the rules for secrecy for such information which can be assumed to cause damage to the country´s defense. If not otherwise stated then secrecy is in force for forty years. For some spatial landscape data one hundred and fifty year is stipulated.

1: The law about the Swedish "marine territory"; "Lag (1966:374) om Sveriges sjöterritorium"
2: The Swedish law "Lagen (1992:1140) om ekonomiska zonen"
3: The Swedish regulation "Förordningen 1992:1226 om ekonomiska zonen"
4: The Swedish law "Lag (1966:314) om kontinentalsockeln"
5: The Swedish regulation "Kontinentalsockelförordning (1966:315)"
6: Except areas defined as cadastral/premises
7: The Swedish fishery law "Fiskelagen (1993:787)"
8: The Swedish law "Lag (1993:1742) om skydd för landskapsinformation"
9: The Swedish regulation "Förordning (1993:1745) om skydd för landskapsinformation"
10: Except lakes, watercourse and channels
11: Data bases, custom for automatic data processing
12: If—according to the same law—required permission to distribute the data openly
13: Except aerial photos and maps made before 1900 and compilations of landscape data based on satellite data only
14: The Swedish law "Offentlighets- och sekretesslag (2009:400)" Chapter 15
15: The Swedish regulation "Offentlighets- och sekretessförordning (2009:641)" 4§

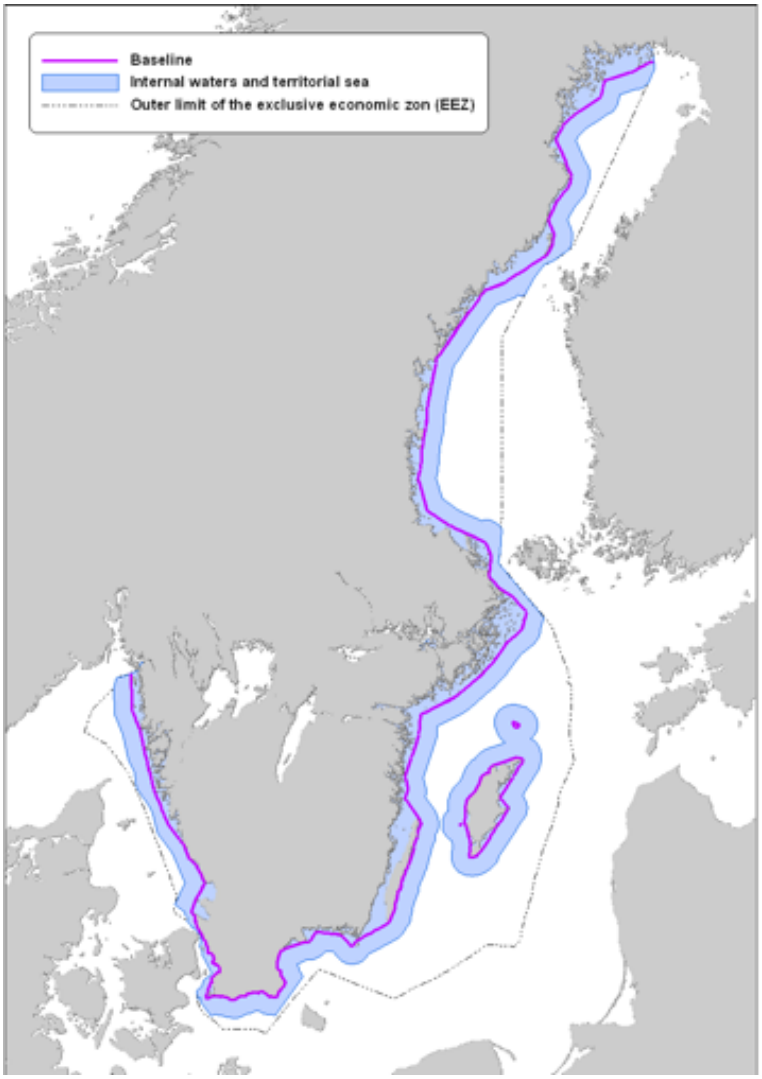

Figure 6.1.: The jurisdictional areas of Swedish waters

6.6. INSPIRE Directive

The INSPIRE directive[16] came into force on 15 May 2007 and will be implemented in various stages, with full implementation required by 2019.

The INSPIRE directive aims to create a European Union (EU) spatial data infrastructure. This will enable the sharing of environmental spatial information among public sector organizations and better facilitate public access to spatial information across Europe.

A European Spatial Data Infrastructure will assist in policy-making across boundaries. Therefore the spatial information considered under the directive is extensive and includes a great variety of topical and technical themes.

INSPIRE is based on a number of common principles:

- Data should be collected only once and kept where it can be maintained most effectively.
- It should be possible to combine seamless spatial information from different sources across Europe and share it with many users and applications.
- It should be possible for information collected at one level/scale to be shared with all levels/scales; detailed for thorough investigations, general for strategic purposes.
- Geographic information needed for good governance at all levels should be readily and transparently available.
- Easy to find what geographic information is available, how it can be used to meet a particular need, and under which conditions it can be acquired and used.

16: Source: `http://inspire.jrc.ec.europa.eu`

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Appendix

A. List of reviewed literature

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B. Questionnaire

1. Depth data usage
   a) What needs do you have concerning a depth model of the Baltic Sea?
   b) For which purposes are the needs greatest (base data for circulation modeling, sediment transport etc.)?
   c) Which depth models have you used so far for the Baltic Sea?
   d) Have you encountered obvious drawbacks in the available depth models?
   e) Has the lack of good depth models of the Baltic Sea limited your activities?
   f) How big is the need for a harmonized depth model of the Baltic Sea? Please specify possibilities for improvements.
2. How should a depth model of the Baltic Sea look like?
   a) Geographic coverage
      i. Which areas of the Baltic Sea would need to be covered by a depth model in the first place?
      ii. Do you need a depth model covering areas beyond the Baltic Sea (if yes, please specify)? How about inland lakes?
      iii. Is there a need for a continuous terrain model covering both land and sea?
   b) Resolution
      i. Which horizontal grid resolution is necessary (i. e. distance between depth values in the depth model)?
      ii. Which quantities are interesting? E. g. maximum, minimum or average depth, or some measure of seafloor roughness.
   c) Accuracy and error sources
      i. Is the representation of small-scale seafloor structures important?
      ii. What would be "sufficiently accurate"? How would you describe acceptable uncertainty?
      iii. Is there a need for an uncertainty estimate of the specified values in the depth model? E. g. horizontal or vertical uncertainty, standard deviation or deviation from the mean.
      iv. Should certain objects be shown specifically? E. g. larger boulders, wrecks, mines, ammunition, timber or other dumped material.
      v. What problems could arise if the data does not conform to the quality standards?
      vi. Do you need to know from what source data a value in the depth model is derived or when the measurements were carried out?
      vii. Is there a need for measurement series, e. g. to study changes? If yes, are certain areas of specific interest?
   d) Is there a need for other digital depth data products apart from a depth model?
   e) Accessibility
      i. May it cost?
      ii. Do you have an idea about how depth data should be accessible via the internet?
   f) Participation
      i. Do you acquire depth data in the Baltic Sea?
      ii. If yes: Could the data be incorporated in a bathymetric grid of the Baltic Sea?
      iii. Could you consider to participate in the building of the database?
      iv. Wishes concerning the steering around data formats, procedures where to send data or accepting quality requirements.

C. List of questionnaire recipients

Name	English name	Abbreviation
AquaBiota Water Research	AquaBiota Water Research	AquaBiota
Boverket	Swedish National Board of Housing, Building and Planning	BoV
Energimyndigheten	Swedish Energy Agency	EnM
Fiskeriverket	Swedish Board of Fisheries	FiskV
Försvarsmakten	Swedish Armed Forces	FM
Totalförsvarets forskningsinstitut	Swedish Defence Research Agency	FOI
Göteborgs universitet	Gothenburg University	GU
Havsmiljöinstitutet	Swedish Institute for the Marine Environment	HavsmI
Kungliga tekniska högskolan	KTH Royal Institute of Technology	KTH
Kustbevakningen	Swedish Coast Guard	KustBev
Länsstyrelsen i Stockholms län	County Administrative Board Stockholm County	LST-AB
Lunds universitet (only one request, but six individual answers)	Lund University	LU
LU Arkeologiska institutionen	LU Archaeology Department	LU-Ark
LU Biologiska institutionen	LU Biology Department	LU-Bio
LU Matematisk statistik	LU Mathematical Statistics Department	LU-Mat
LU Mätteknik och industriell elektroteknik / Teknisk geologi	LU Engineering Geology Department	LU-TekGeol
	LU Risk- och säkerhetshantering	LU-RS
	LU Teknisk vattenresurslära	LU-Vatten
Naturvårdsverket	Swedish Environmental Protection Agency	NV
Riksantikvarieämbetet	Swedish National Heritage Board	RAÄ
Sveriges fiskares riksförbund		SFR
Statens geotekniska institut	Swedish Geotechnical Institute	SGI
Sveriges geologiska undersökning	Swedish Geological Survey	SGU
Skärgårdsstiftelsen	Archipelago Foundation	SkStift
Sveriges lantbruksuniversitet (ArtDatabanken)	Swedish University of Agricultural Sciences	SLU
Stockholms marina forskningscentrum	Stockholm Marine Research Centre	SMF
Sveriges meteorologiska och hydrologiska institut	Swedish Meteorological and Hydrological Institute	SMHI
Statens maritima museer	Swedish National Maritime Museums	SMM
Svenska Naturskyddsföreningen	Swedish Society for Nature Conservation	SNF
Stockholms universitet	Stockholm University	SU
Umeå marina forskningscentrum	Umeå Marine Sciences Centre	UMF
Umeå universitet	Umeå University	UmU
Uppsala universitet	Uppsala University	UU
Världsnaturfonden	World Wide Fund for nature	WWF