



# STRATEGIC ANALYSIS OF SWEDEN'S MARINE ENVIRONMENTAL MONITORING AND ASSESSMENT

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## PREFACE

Sweden has a long history of marine monitoring, which since 1990 sits within the context of several ambitious general objectives for environmental monitoring set by the government. Over the past decades, monitoring of the marine and coastal environment has also been required to support a range of specific policy requirements including assessment of progress towards national environmental quality objectives and reporting according to EU Directives and regional conventions. This review has been commissioned by the Swedish Institute of the Marine Environment to consider how the current organisation and practice of marine environmental monitoring and assessment meets these objectives and requirements. It has been prepared by a project team drawn from the network of the institute and is based on literature review, interviews, the experience of the project team and views of Swedish Institute for the Marine Environment (SIME). The review had a particular focus on data management and the organisation of assessments and analyses. This report seeks to identify difficult issues, initiate discussion regarding monitoring objectives and levels of ambition, and contribute to a more efficient use of monitoring resources and data.

The review makes a series of general recommendations to support work to improve and optimise the organisation of Sweden's marine monitoring and assessment work. More detailed recommendations are presented on steps to improve the management of data. Recommendations are also presented on approaches for developing the systems for producing assessments of marine monitoring data so that they can provide improved marine environmental information to support environmental management.

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Richard Emmerson  
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## EXECUTIVE SUMMARY

Sweden has a long history in marine environmental monitoring which has generated a number of long and uniquely valuable series of data describing how conditions in the sea have varied through time. Data from these time series and from numerous temporary monitoring programmes and campaigns provide the basis for generating information on the sea that is used by policymakers, scientists and the general public. In broad terms monitoring of the marine and coastal environment is organised at three geographical scales. National and regional monitoring is largely state-financed. Local monitoring of waters that receive land-based discharges from industrial facilities and municipalities is financed by municipalities and private actors. Monitoring is performed by a range of agencies, institutes, universities and private companies. A series of national data hosts are also financed to maintain and store monitoring data from the different monitoring programmes and to ensure the availability of collected data.

In 1990 Sweden's government established six objectives for environmental monitoring, which had the purpose of guiding the development of national and regional environmental monitoring programmes financed by the national environmental monitoring budget.

- To describe the status of the environment
- To assess threats to the environment
- To provide a scientific basis for actions or action programmes
- To follow up effects of actions or action programmes
- To follow up progress towards national environmental quality objectives
- To assess the sustainability of pertinent societal trends

These six objectives remain relevant today and are still recognized as guiding monitoring and assessment on the websites of the key national authorities that organise environmental monitoring, the Swedish Agency for Water and Marine Management and the Swedish Environmental Protection Agency. All these objectives need to be addressed to provide effective information for environmental management and governance. Recent developments in national and European policy for the coastal and marine environment have introduced additional demands for information on progress towards national environmental quality objectives and reporting according to EU Directives and regional sea conventions. Together these various demands for information on the marine environment make it important to optimise the organisation of marine monitoring and assessment work to ensure it is both cost-effective and resource-effective.

## PURPOSE OF THE REPORT

The Swedish Institute for the Marine Environment (SIME) has prepared this review to promote a constructive dialogue on what adjustments could be made to optimise the way in which marine monitoring addresses the six Government objectives for environmental monitoring including new requirements from recent marine policy developments. The review had a particular focus on data management and the organisation of assessments and analyses. With this purpose we present general recommendations, which SIME considers as important contributions to the development of Sweden's marine monitoring and assessment work.

## GENERAL RECOMMENDATIONS

Our review shows that more value could be extracted from the current forms of marine monitoring and that greater emphasis on inquiry-based assessments and joint analysis of data from different monitoring programmes are the key to this.

### ASSESSMENT AND ANALYSIS SHOULD DRIVE MONITORING

The generation of data by monitoring is one part of a continuum of activities that have the purpose of providing policy-relevant information. The information currently drawn from monitoring data mainly describes change through time and assesses status of the marine environment (good or bad). Less information is drawn from monitoring data about the effectiveness of policies and actions, potential threats and importance of different ecological processes.

Our review concludes that building knowledge to support environmental management through assessment and analysis of monitoring data needs to be recognized as the main objective and purpose of monitoring. This prioritization is crucial to meet the full range of government objectives for environmental monitoring.

### INQUIRY-BASED USE OF MONITORING DATA CAN CREATE MORE VALUE

To draw more value from investments in marine environmental monitoring our review recommends that the authorities commissioning monitoring should actively promote knowledge building by a more analytical, inquiry-based use of monitoring data. This could be done through establishing goals for addressing a wide range of analytical questions relevant to government objectives for environmental monitoring and international requirements. For example, inquiry-based approaches can address causality from source to sea, identify emerging environmental threats and investigate the sustainability of pertinent trends in society.

### PROMOTE COORDINATED USE OF DATA FROM NATIONAL, REGIONAL AND LOCAL MONITORING

The resolution of the current national monitoring programmes provides limited power for understanding the environmental status of the sea and for relating issues from source to sea. In addition, the results of assessments solely based on national programmes can be biased



because coastal waters and sea areas exposed to strong pressures from human activities are often under-represented in such studies. This strongly indicates that coordination of national, regional and local monitoring can substantially increase the relevance of assessments at all scales.

National authorities have a key role to stimulate the flow of consistent and comparable data and it is to be welcomed that authorities have been looking at ways to improve access to locally-financed recipient control data. Our review recommends that coordination efforts should continue and extend to standardize methods and performance of organisations carrying out monitoring and information available on the quality of data.

## **ROLES AND RESPONSIBILITIES NEED TO BE CLARIFIED**

Our review identifies a series of steps to clarify roles and responsibilities for data stewardship between those generating or working with data:

- developing data flow protocols describing the required flow of data between originators and national data hosts and into assessments and clarifying the respective responsibilities of each organization;
- implementing improved services for stricter control of data submissions to national data hosts and immediate feedback to data providers;
- implementing mechanisms to ensure that errors are updated in all copies of data;
- finalising on-going work to standardise station names, geo- and time references across all marine environmental monitoring programmes through completing a comprehensive common station register and defining standard data format;
- defining a standard for data quality remarks and access to information about sampling and measurement techniques and data origin;
- developing guidelines for standardized graphical presentations of major data types;
- introducing a contractual responsibility for monitoring providers to support the work of the data host by reporting on errors identified in the data, and;
- defining clear roles and responsibilities for developing national assessments. We also present suggestions for strengthening the organisation and content of national assessment processes to benefit from improved data flow and a more inquiry-driven approach to assessment

## **ENGAGING THE RESEARCH COMMUNITY**

Engaging the interest and involvement of the scientific research community plays an important role in extending the use of monitoring data and extracting more value from such data. Whereas status assessments and follow-up of progress towards national environmental objectives are thoroughly scheduled, examining new threats to the environment requires initiatives from the scientific community. The same holds true for improving the scientific basis for actions and action programmes and assessing the sustainability of societal trends. Our review concludes that collaborative opportunities should be increased between authorities, current data reporting processes and the research community, such as developing the role of existing marine monitoring seminars or creating opportunities for researchers to submit proposals to agencies for collaborative investigation of monitoring data.

# 1 INTRODUCTION

## 1.1 BACKGROUND

Sweden has a long tradition in marine environmental monitoring. Gustaf Ekman and Otto Pettersson, the co-founder of ICES, started the first synoptic measurements in the water column in late 19th century in order to examine the link between the spatial distribution of fish and the variation of oceanographic conditions in the North Sea (Smed and Ramster, 2002<sup>1</sup>) and later also the Landsort deep in the Baltic Sea. The scientists taking these measurements never regarded them as anything other than basic oceanographic research and though the findings were published in the transactions of Sweden's Royal Academy of Sciences (Pettersson and Ekman, 1897)<sup>2</sup>, they received no further attention at the time.

Today, these early data have become an invaluable baseline for Sweden's current marine monitoring system. Sweden's marine monitoring has since generated a number of long and uniquely valuable time series and is the basis for generating information on the sea for policymakers, scientists and the general public.

## 1.2 SWEDEN'S GOVERNMENT OBJECTIVES FOR ENVIRONMENTAL MONITORING

In response to the increased environmental awareness of the late 1980s, the Swedish government expressed five objectives for environmental monitoring in government proposition 1990/91:90 *En god livsmiljö*<sup>3</sup>. In 1998 government proposition 1997/98:145 *Svenska miljömål. Miljöpolitik för ett hållbart Sverige*<sup>4</sup> reiterated these five objectives and added objectives relevant to Swedish Environmental Quality Objectives. These propositions still guide the development of national and regional environmental monitoring programs financed by the national environmental monitoring budget. The objectives remain relevant and are still recognized as guiding monitoring and assessment on the websites of SwAM<sup>5</sup> and SEPA<sup>6</sup>. They need to be addressed if the monitoring activity is to provide effective information for environmental management and governance. In this review, we refer to these objectives as the Government Objectives and focus on the six objectives set out in Box 1.

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1 Smed, J. and Ramster, J. (2002). Overfishing, science and politics: the background in the 1890s to the foundation of the International Council for the Exploration of the Sea. ICES Marine Science Symposia 215:13-21. 2002.

2 Pettersson, O. And Ekman, G. (1897). De hydrographiska förändringarne inom Nordsjöns och Östersjöns område under tiden 1892-1897. Royal Swedish Academy of Sciences, Handl. 29:5 (1897)

3 Regeringens proposition 1990/91:1990 En god livsmiljö

4 Regeringens Proposition 1997/98:145. Svenska miljömål. Miljöpolitik för ett hållbart Sverige.

5 <https://www.havochvatten.se/hav/samordning--fakta/miljoovervakning/syftet-med-miljoovervakning.html> (last accessed 17-04-05)

6 <http://www.naturvardsverket.se/Miljoarbete-i-samhallet/Miljoarbete-i-Sverige/Miljoovervakning/> (last accessed 17-04-05)

**Box 1. Sweden's Government Objectives for Environmental Monitoring**

Objective 1: To describe the status of the environment

Objective 2: To assess threats to the environment

Objective 3: To provide a scientific basis for actions or action programmes

Objective 4: To follow up effects of actions or action programmes

Objective 5: To follow up progress towards national environmental quality objectives

Objective 6: To assess the sustainability of pertinent societal trends

**1.3 AIMS AND OBJECTIVES OF THE PROJECT**

The board of the Swedish Institute for the Marine Environment (SIME) has commissioned this review to consider the current practices and organisation around marine environmental monitoring in order to develop a constructive dialogue on what adjustments could be proposed to optimise the way on which marine monitoring addresses the Government's objectives as it is adjusted and developed to respond to policy developments. The project has a particular focus on the outputs from monitoring in the form of data, information, assessments and analysis. Detailed recommendations regarding sampling strategies and techniques for chemical and biological analyses are outside the scope of the project. The project has the following specific objectives:

- a. To summarize how the monitoring data are analysed and presented in assessments, and used for environmental management;
- b. To assess how Sweden's different marine monitoring programmes have fulfilled the government's objectives for environmental monitoring;
- c. To propose improvements in the current procedures for refining monitoring data into information and knowledge for marine environmental management, including on:
  - increasing the use and usability of data produced by Sweden's marine monitoring;
  - how to develop assessments and analysis of marine environmental monitoring data in a manner that deepens the information base for developing environmental management.

The project involved a series of interviews with key organisations involved in Sweden's marine monitoring, including Hafok AB, Swedish Natural History Museum, Swedish University of Agricultural Sciences (SLU), Swedish Meteorological and Hydrological Institute (SMHI), Stockholm University and Umeå Marine Science Centre (UMSC). In parallel, literature relevant to the operation and the outputs from this monitoring was reviewed. An analysis has been carried out of the usability of the data available from national data hosts for marine environmental monitoring data. The outputs and recommendations have been synthesised by a project group involving Daniel Conley (Lund University), Richard Emmerson and Anders

Grimvall (SIME) and Mats Lindegarth (University of Gothenburg). The report focuses on recommendations for the management and use of marine monitoring data, i.e. the processing of data and information after raw data have been stored in a database. SIME intends this report as a contribution to the long-term development of Sweden's marine monitoring and assessment.

The report was largely in preparation primarily during 2014 and 2015 at the same time as the first specification of monitoring programmes under the EU Marine Strategy Framework Directive<sup>7</sup> and the revision of Sweden's national aquatic monitoring programmes<sup>8,9</sup>. At the same time an assignment from the Government on water-related recipient control monitoring has been addressed by relevant agencies<sup>10</sup>. The report seeks to complement these processes and makes a contribution to the long-term development of the use of monitoring data in Sweden.

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7 SwAM(2014). God havsmiljö 2020. Marine strategi för Nordsjön och Östersjön. Del III Övervakningsprogram. Havs och Vatten Myndigheten rapport 2014:20.

8 SwAM (2014). Nationell akvatisk miljöövervakning 2015-2020. Havs- och vattenmyndigheten rapport 2014:18.

9 SEPA (2014). Översyn av nationella akvatiska miljögiftsövervakning 2014. Programområden Sötvatten och Kust och Hav. SEPA Rapport 6627.

10 SwAM (2015). Vattenanknuten recipientkontroll. Redovisning av regeringsuppdrag M2014/1605/Nm. Havs- och vattenmyndigheten 2015-03-31

## 2 POLICY AND MANAGEMENT CONTEXT FOR MARINE MONITORING

A range of more specific requirements for marine environmental monitoring and assessments sit within the context of the overall Government objectives's for environmental monitoring. Many of these are complementary but each have a contrasting emphasis on the need for information.

### 2.1 SWEDEN'S ENVIRONMENTAL QUALITY OBJECTIVES

The Swedish Government has established that the overall goal of environmental policy is to hand on to the next generation a society in which the major environmental problems facing Sweden have been solved. To attain this generational goal, national Environmental Quality Objectives (EQOs) have been formulated for 16 issues. A first fifteen environmental quality objectives were adopted by the Riksdag in 1999. They are contained in the Government Proposition 1997/98:145, Swedish Environmental Quality Goals. An Environmental Policy for a Sustainable Sweden<sup>11</sup>. The Government Bill 2004/05:150 Environmental Quality Objectives - A Shared Responsibility<sup>12</sup> was adopted by the Riksdag in November 2005 and a 16th objective, on biodiversity, was adopted later.

The Environmental Quality Objectives most relevant to the marine environment are as follows:

- a. A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos
- b. Reduced Climate Impact
- c. Natural Acidification Only
- d. A Non-Toxic Environment
- e. A Safe Radiation Environment
- f. Zero Eutrophication

One way that environmental Quality Objectives are given effect is by means of more specific and binding environmental quality standards (miljökvalitetsnormer), which were introduced by the Swedish Environmental Code in 1999. An environmental quality standard may, for example, lay down the maximum allowable concentration of a substance in air, soil or water. Environmental quality standards can be introduced nationwide or for particular geographical areas, such as counties or municipalities. Most of the environmental quality standards are based on requirements on various European Community directives. Environmental quality standards for the marine environment have been set out by the Swedish Agency for Water and Marine Management (SwAM) in Regulation HVMFS 2012:18<sup>13</sup> and 2013:19<sup>14</sup> to implement

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11 1997/98:145 Svenska miljömål. Miljöpolitik för ett hållbart Sverige.

12 Regeringens Proposition 2004/05:150. Svenska miljömål – ett gemensamt uppdrag.

13 Havs- och vattenmyndighetens föreskrifter om vad som kännetecknar god miljöstatus samt miljökvalitetsnormer med indikationer för Nordsjön och Östersjön. HVMFS 2012:18.

14 Havs- och vattenmyndighetens föreskrifter om klassificering och miljökvalitetsnormer avseende ytvatten. HVMFS 2013:19 (this regulation replaces the original version from 2008, NFS 2008:1)

the requirements of the EU Marine Strategy Framework Directive and the Water Framework directive respectively.

## 2.2 EU DIRECTIVES

EU Directives and policies relevant to the marine environment that generate requirements for monitoring and assessment are listed in Table 2.1. Implementation of the EU Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) introduced a range of new conceptual requirements for monitoring and the assessment of monitoring data. These involve among other things: (1) definition of desired states and thresholds (2) international coordination of ways of expressing status (e.g. quality elements (WFD) and descriptors (MSFD)), (3) systems for integrated assessment, and; (4) definition of spatial and temporal units for assessments. These requirements affect what needs to be measured, when it needs to be measured and where. One positive consequence of these developments is that they define in a more specific way the requirements in terms of knowledge, data and assessment procedures, than was previously the case.

The demands defined in the directives may sometimes be partly conflicting with old legislation and may not always be sufficient for maintaining previous environmental aims. One such issue is the strong focus on status assessment in defined spatial units (e.g. water bodies, water body types, regions) and temporal units (6-year assessment period) in the WFD and MSFD. Previous monitoring has been more concerned with monitoring the effects of point sources and temporal trends at a number of more or less independent, strategically selected “stations”. These two perspectives have strong consequences for the design of monitoring programmes and will work differently depending on the indicator or parameter to be monitored (e.g. whether nutrients, plankton, benthos and fish).

The development of monitoring for MSFD has clarified needs for environmental status monitoring across a wide range of marine issues. It has provided opportunities to take a broader look at the current set-up of monitoring and consider which gaps exist and what optimisations are needed (SwAM, 2015). The 6-year cyclical management approach of the MSFD provides the opportunity for implementation approaches and processes to be developed over the course of each cycle. The first reporting on monitoring in 2014 has reflected what can be done in terms of the immediate orientation of existing marine monitoring towards the MSFD.

Table 2.1 Main EU Directives and policies relevant to the marine environment and their main requirements for monitoring and assessment.

European Union Directives	
Marine Strategy Framework Directive (2008/56/EC)	<p><i>Aim:</i> Measures to achieve or maintain Good Environmental Status in the marine environment by the year 2020 at the latest.</p> <p><i>Monitoring:</i> Coordinated programmes for the ongoing assessment of the environmental status of their marine waters.</p> <p><i>Assessment:</i> Every 6 years from 2012.</p>
Water Framework Directive (2000/60/EC)	<p><i>Aim:</i> to achieve Good Surface water Status (including Good Ecological Status) for water bodies by 2015 at the latest.</p> <p><i>Monitoring and assessment:</i> A river basin management plan for each river basin district within MS territory every six years, including monitoring<sup>15</sup>, classification and reporting on ecological status in coastal and transitional waters.</p>
Common Fisheries Policy (Regulation (EU) No 1380/2013)	<p><i>Aim:</i> To ensure that fishing and aquaculture are environmentally, economically and socially sustainable and that they provide a source of healthy food for EU citizens.</p> <p><i>Monitoring and assessment:</i> under the Data Collection Framework Member States (MS) collect, manage and make available a wide range of fisheries data needed for scientific advice.</p>
Marine Spatial Planning Directive (2014/89/EU)	<p><i>Aim:</i> A framework for maritime spatial planning aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources.</p> <p><i>Monitoring and Assessment:</i> implementation of the Directive can be expected to make use of environmental monitoring data to guide marine spatial planning and evaluate effectiveness.</p>
Habitats Directive (92/43/EEC)	<p><i>Aim:</i> To achieve favourable conservation status for species and habitats and to contribute towards ensuring biodiversity through the conservation of natural habitats and of wild fauna and flora.</p> <p><i>Monitoring and assessment:</i> A report on conservation measures under the Directive and evaluation of the impact of those measures on the conservation status of the natural habitat types.</p>
Birds Directive (2009/147/EC) – amended version 79/409/EEC	<p><i>Aim:</i> Conservation of all species of naturally occurring birds in the wild state.</p> <p><i>Monitoring and assessment:</i> A report on the implementation of national provisions taken under this Directive (every 3 years).</p>

<sup>15</sup> Note also: Commission Directive 2009/90/EC of 31 July 2009 laying down, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, technical specifications for chemical analysis and monitoring of water status

Other EU legislation introduces common standards in the way that monitoring, analysis and data infrastructures are organised across Europe. For example, the INSPIRE Directive (2007/2/EC) has the aim to establish Infrastructure for Spatial Information in the European Community for the purposes of Community environmental policies. The EU Integrated Maritime Policy (IMP) has the aim of providing a more coherent approach to maritime issues with increased coordination between policy areas. The IMP's Marine Knowledge initiative includes the development of a European Marine Observing and Data Network (EMODnet). Initial stages of EMODnet have involved collation of existing data, but it is conceivable that the further development of the network, including its interface with the MSFD may imply requirements for different types of data collection.

## 2.3 REGIONAL AGREEMENTS

Sweden is also party to regional conventions and agreements with data and information collaboration. The two most significant for Sweden's seas are HELCOM and OSPAR. Both organisations are now working to help to coordinate implementation of the MSFD amongst their Contracting Parties. Sweden is also strongly active in the International Council for the Exploration of the Sea, which coordinates fisheries data collection in offshore areas of the Kattegat and Skagerrak. Collected data are used for fish stock assessment in support of the Common EU Fisheries Policy.

Table 2.2. Regional Marine Conventions to which Sweden is a Contracting Party

Regional Conventions	
<p>HELCOM Protection of the marine environment of the Baltic Sea</p>	<p>Coordinated monitoring of physical, chemical and biological variables of the open sea of the Baltic Sea has been carried out since 1979.</p> <p>Periodical assessment reports have been published since the 1980s. Since the 2000s the occasional production of reports evolved to regular publications of Baltic Sea thematic and holistic assessments. HELCOM Monitoring and Assessment Strategy was adopted in 2005 and revised in 2013. The HELCOM Monitoring Manual (2014) provides a detailed and transparent documentation of the monitoring programmes and activities in Baltic Sea.</p> <p>Core Indicators as a regionally agreed set of indicators for use in assessments relevant to the implementation of the MSFD</p>
<p>OSPAR Protection of the marine environment of the North East Atlantic (OSPAR Convention)</p>	<p>Coordinated Environmental Monitoring Programme and Joint Assessment and Monitoring Programme. These include the drawing up of codes of practice for the guidance of Contracting Parties in carrying out these monitoring programmes and to approve the presentation and interpretation of their results.</p> <p>Common Indicators as a regionally agreed set of indicators for use in assessments relevant to the implementation of the MSFD</p>



## **2.4 SCIENTIFIC REQUIREMENTS**

Alongside formalised requirements for environmental information from monitoring, scientific interest and curiosity generate requirements to produce information on both the natural dynamics of the marine environment and its responses to human interventions.

## 3 SUMMARY OF SWEDEN'S MARINE MONITORING PROGRAMMES

### 3.1 DEVELOPMENT OF SWEDEN'S MARINE MONITORING

Sweden's first modern marine monitoring programmes were implemented by the Swedish Meteorological and Hydrological Institute (SMHI) during the 1950's to measure physico-chemical variables. Sampling in the Baltic Sea became increasingly regular and extensive during the 1950's, 1960's and 1970's. A coastal station (B1) in the Askö/Landsort area was established with weekly to biweekly sampling frequency of pelagic variables. The network of stations became finer-meshed and was extended to both the Gulf of Bothnia and the Skagerrak, but sampling frequency was still low. During the period from the 1950's to 1970's the monitoring programme was broadened to include not only physical measurements and concentrations of substances in the sea, but also the abundance of phytoplankton and benthic organisms. Monthly measurements of nutrients, phytoplankton and zooplankton began in the Baltic in 1992 responding to increased attention on environmental status following cyanobacteria blooms and phocine distemper outbreaks of the late 1980's. At one station in the Landsort Deep (BY31) measurements were taken on a weekly to bi-weekly basis to improve the resolution of intra-annual variability.

From the 1950's onwards, increasing concern over the effects of pollutant discharges into coastal waters from factories and municipal sewage works led to the establishment of the first water conservation associations (Vattenvårdsförbund). These associations organised local monitoring to keep a watch on environmental conditions in waters receiving inputs from industrial or municipal facilities. From 1969, the Environmental Protection Act meant that any enterprise could be ordered to undertake monitoring of the consequences of its emissions. The County Administrative Boards (Länsstyrelser) were also given powers to require coordinated monitoring, such as for an entire river system.

In 1978 at the request of the Government, the Swedish Environmental Protection Agency (SEPA) began to develop a National Environmental Monitoring Programme (PMK) to monitor long-term and large-scale changes in the environment and thus identify problems that called for research or counter-measures. The programme had the aim of enabling well-founded assessments of the situation in more polluted areas, as well as identify transport processes, by collecting environmental data in areas relatively unaffected by pollution

### 3.2 ORGANISATION OF MONITORING

There is now a total of approximately 13, 000 monitoring stations along the Swedish coast and sea. In a general sense, the monitoring of these stations takes place at three organisational scales:

- a. national monitoring of offshore waters (utsjövatten) which aims to provides data on the general environmental conditions in the seas around Sweden;
- b. regional monitoring of coastal waters organised by County Adminstrative Boards;
- c. local monitoring of receiving waters (recipient-control monitoring) affected by land-based discharges from industrial facilities and municipalities.

### 3.3 NATIONAL MONITORING

National marine environmental monitoring is performed within a series of subprogrammes (see Table 3.1). Many are part of the national aquatic monitoring programme, with the aim to provide a comprehensive picture of the environmental situation, and detect large-scale changes in the ecosystem. The results form the basis for follow-up of the national environmental quality goals (Miljökvalitetsmålen). The overall coordination of national marine monitoring is the responsibility of SwAM and SEPA. SwAM is the commissioning agency for all programmes, with the exception of the programmes for toxic pollutants, birds and environmental loads, which are commissioned by SEPA. The national subprogrammes are divided into survey areas, for example, Bay of Bothnia, Baltic Sea Proper, South Coast and Kattegat and Skagerrak. In some survey areas, national and regional monitoring are coordinated in a common programme. One role of the national monitoring being to serve as “reference” for regional and recipient-controls monitoring, although how this is done in practice is not clear and this is a potential area for improvement.

Revisions of the national aquatic monitoring programs are generally carried out approximately every six years by the responsible authorities. The last revision was carried out in 2014<sup>16, 17</sup>.

Financial support for environmental monitoring is allocated annually through the Government's budget. Environmental Monitoring is addressed under Chapter 20 General Environment and Nature Conservation (Allmän miljö- och naturvård) and specific priorities or considerations for the year in question are highlighted in explanatory text. In general, the annual budgetary propositions since 1990 have either reiterated the Government objectives for environmental monitoring from the 1990 propositions or have not provided any comment on the objectives to be met through each year's allocations, in which case it can be assumed that the Government saw no reason to change these objectives. The most recent budget proposal (2016) gives particular emphasis to follow-up of Swedish environmental quality objectives and international reporting.

### 3.4 REGIONAL MONITORING.

Regional monitoring has a particular focus on regional environmental conditions, i.e. to capture larger-scale regional impacts and effects and like the national programme is mainly focused on areas that are relatively unaffected by local pollution sources. The results aim to provide a basis for monitoring of environmental objectives and relevant legislation and through this play a large role in the implementation of monitoring requirements from the Water Framework Directive (to support water body classification) and from the Nature Directives (conservation status of species and habitats). The results also contribute to regional and local needs, by assessing whether environmental status meets regional goals. They are used as a basis for overall planning and natural resource management as well as for follow-up of effects of actions. Regional Monitoring is commissioned by the County Administrative Boards, who are specifically charged with "closely monitoring the state of the county" and "following up and responding to regional goals". It includes state-funded regional monitoring,

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16 SwAM(2014).Nationell akvatisk miljöövervakning 2015-2020. Havs- och vattenmyndigheten rapport 2014:18.

17 SEPA (2014). Översyn av nationella akvatiska miljögiftsövervakning 2014. Programområden Sötvatten och Kust och Hav. Naturvårdsverket Rapport 6627.

other monitoring funded by national authorities and local monitoring of receiving waters (see below). County Administrative Boards are charged with coordinating the regional monitoring so that it becomes effective, including commissioning, quality assurance, monitoring, evaluation and data management. The County Administrative Boards also need to coordinate the programme with relevant stakeholders at the regional level and some regional monitoring is conducted in collaboration with Water Conservation Associations (Vattenvårdsförbund). The regional marine monitoring programmes are revised also approximately every six years. Coordination between national and regional monitoring is an important strand of several of the subprogrammes. Results from regional monitoring are reported to national authorities and the data from certain specified programmes should be reported to the relevant national data hosts.

Five Water Authorities (Vattenmyndigheterna) were formed to support the implementation of the Water Framework Directive, based around five water districts (Bothnian Bay, Bothnian Bay, North Baltic Sea, South Baltic Sea and Skagerakk and Kattegat) corresponding to the main natural water basins and watersheds. The Water Authorities' role is to coordinate the implementation work by the County Administrative Boards, including monitoring and assessment of coastal waters, within their own water district. The Water Authorities do not directly commission monitoring.

### 3.5 LOCAL MONITORING

Monitoring at the local scale can be considered to include:

- a. monitoring of waters receiving discharges from municipal wastewater treatment works in order to follow up municipal environmental objectives.
- b. monitoring by organisations carrying out environmentally hazardous activities, who are required as a condition of their permit, in accordance with the Swedish Environmental Code (Miljöbalken), to check the impact of their emissions on the environment in so-called recipient control monitoring.
- c. collection of information about water quality in Swedish bathing waters. This is organised by municipalities who report results to the Swedish Institute for Infectious Disease Control, which stores the results on behalf of the Environmental Protection Agency.

In water areas where there are several environmentally hazardous activities, a common monitoring control programme has been set up, so-called coordinated recipient control monitoring programme.

#### **Coordinated recipient control monitoring (Samordnad recipientkontroll)**

Coordinated Recipient-Control programmes are a collaboration between e.g. counties, municipalities and companies that are licensed to carry out environmentally hazardous activities. The advantage of the coordinated recipient-control monitoring programmes is that they provide information about the emission effects and coordination can lead to lower costs for individual business practitioners. The coordinated recipient-monitoring aims to provide a basis for planning, implementation and monitoring of environmental protection measures. This monitoring is often extensive and, in many counties, includes a substantial share of the regional monitoring coordinated by the County Administrative Boards.

In a number of coastal areas monitoring is organised in the framework of Water Conservation Associations (Vattenvårdsförbund), which for practical and financial reasons provide for collaborative monitoring between different organisations (Länsstyrelsen and operators which are required to monitor as a condition of their permit). By monitoring in a coordinated manner within a Water Conservation Association a better picture of the environmental situation is developed than if each operator would conduct its own monitoring separately. The role of the individual Water Quality Association in the overall monitoring structure can vary because they are voluntary organisations that decide what role they want to assume (SEPA, 2006<sup>18</sup>). However, the monitoring conducted by these associations often consists of two parts. The first part consists of the data that the polluter is required to produce under the regulatory requirements for monitoring the environmental impact of its operations. In addition there is often a voluntary part that goes beyond *de minimis* requirements of the business.

The different Water Conservation Associations vary in terms of the scope of data collection, how they manage data after its generation and how they approach data accessibility. Data collected as required by the environmental permit is passed on to the County Administrative Boards for analysis. Many Water Conservation Associations are open about the reuse of voluntarily collected data. For example, Water Conservation Associations in the Baltic Proper (Svealandskustens Vattenvårdsförbund) collect data and prepare and publish coordinated assessments based on the monitoring it carries out.

### 3.6 INTERNATIONAL MONITORING

Most monitoring of fish and shellfish takes place outside the national and regional environmental programmes. Sweden participates in international monitoring of fish stocks outside the 12 nautical miles territorial sea limit such as the International Bottom Trawl Survey (IBTS) coordinated by ICES to support international assessments of fish stock status and the resulting management advice for the Common Fisheries Policy. The IBTS also includes collection of hydrochemical data, which has the aim of being relevant to the evaluation of ecosystem changes. The IBTS is also seen as a possible means to address needs for the monitoring of ecosystem components or functions in connection to the MSFD.

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18 SEPA (2006). Kust och hav – revision av nationell miljöövervakning 2006. SEPA Rapport 5718, Stockholm. 111pp.

Table 3.1. Summary table listing Sweden's current marine sub monitoring programmes and respective parameters and monitoring and contracting organisations (H – SwAM; N – SEPA; L – County Administration Boards; V – Water Conservation Associations, K – Municipalities). For English and Swedish organisation names see Annex 3.

Programme name	Local Recipient			Parameters/aim	Organisation carrying out monitoring	Contracting Organisation
	National	Regional	Local Recipient			
Input loads to the sea (Belastning på havet)	●			Input loads of nitrogen, phosphorus, selected POPS and metals	SLU (Riverine Input) Official statistics on point source emissions collated by Statistics Sweden Atmospheric inputs (IVL)	N
Water Column Monitoring (Fria Vattenmassan)					Coordinated national-regional programme in Gulf of Bothnia	
hydrography	●	●	●	Hydrographic (salinity, temperature, turbidity), chemical (oxygen content, pH, nutrients, sulphide occurrence) and biological (chlorophyll, primary production) monitoring to detect the effects of eutrophication.	SLU Aqua, SMHI, Linné, Umeå, Stockholm and Gothenburg Universities; Marine Monitoring AB; SMED; Water Quality Association etc.	H, L, V
phytoplankton communities	●			Species composition, abundance, biovolume, primary production, bacterial production	Universities, agencies and consultants, SMHI	H, L, V
zooplankton communities	●			Abundance and biomass	Stockholm University, SMHI, UMSC	H
Vegetated benthos (Vegetationsklädda bottnar)	●	●	●	To detect changes in the structure of the vegetated benthic communities as an effect of eutrophication, pollution and climate change.	Universities, agencies and consultants	H, L, V

				(species biomass, species composition and variation)		
Soft-bottom macrofauna (Makrofauna mjukbotten)	●	●		To detect long-term structural changes in the soft benthic macrofauna caused by eutrophication and oxygen stagnation	Universities, agencies and consultants  Coordinated national-regional programme in Gulf of Bothnia and Baltic Proper.	H, L, V
Integrated coastal fish (Integrerad kustfiskövervakning)	●		●	To identify the state of fish populations and identify changes that indicate large-scale impacts from threats such as eutrophication, fishing, pollution and climate change. Integrated coastal fish monitoring (population status, health and environmental contaminants) is carried out at four locations	SLU Aqua, County Administrative Boards and consultants  Coordinated national-regional programme.	H, L
Metals and organic contaminants (Metaller och organiska miljögifter)	●	●	●	To evaluate state and trends of environmental contaminants in biota in the larger sea basins: Gulf of Bothnia, Baltic Proper, Kattegat and Skagerrak.	SGU, NRM, SSM, KBV, Marine Monitoring AB, SU, GU, County Administrative Boards, SLU	N, L, V
Seals and Sea Eagles (Säl och havsörn)	●			To detect changes in status of seals and sea eagles as a measure of the long-term effects of environmental toxins	NRM	N
Seabirds and Waterbirds (Fåglar)	●	●		Distribution and abundance of overwintering seabirds.  Abundance of breeding birds	Lund University (overwintering birds) , County Administration Boards in Bay of Bothnia (breeding birds)	N, L
Commercial fish stocks				To support international stock assessments of commercially exploited fish species and provide data under the DCF	SLU Aqua	H

Toxic pollutants in fish and shellfish				Dioxins, PCBs, pesticides and mercury in both shellfish and food fish, caught wild and farmed. Algal toxins in mussels.	Swedish National Food Administration	
Radioactive substances				Radioactive substances in seawater close to the surface, in the bottom sediments of the open sea and in fish.	Swedish Radiation Safety Authority	
Illegal discharges of oil and chemicals at sea				Aerial reconnaissance, supplemented by monitoring from ships and using data from satellite images.	Swedish Coastguard	
Bathing Water Quality			●	Microbiological parameters (total coliforms, faecal coliforms, intestinal enterococci and <i>Escherichia coli</i> ) and physicochemical parameters (mineral oils, surface-active substances and phenols)	Local municipalities	K



### 3.7 COORDINATION TOOLS

Monitoring guidelines (undersökningstyper)<sup>19</sup> have been prepared to support the standardisation of all monitoring programmes for coasts and seas. These should be followed in national and regional activities, in order to ensure a standardization and comparability of data across multiple data providers. Use in local monitoring is not compulsory and more infrequent.

Further tools for coordination of quality assurance include Dyntaxa<sup>20</sup> which should be used to quality assure species names in national and regional monitoring.

### 3.8 NATIONAL DATA HOSTS

National data hosts (see Table 1) have been established with the purpose of maintaining and storing monitoring data and to increase the availability of information on data quality. Data hosts are responsible for receiving, storing, presenting and reporting with the aim of enabling efficient collation of data from different sources. The data hosts work under the commission of SwAM and SEPA. Data are intended to be available to anyone wishing to use them and may, as a rule, be ordered or downloaded online free of charge.

Table 3.2. National data hosts with relevance to Sweden's marine monitoring

SLU - Department of Aquatic Resources	Fisheries data from environmental monitoring of coastal waters
SMHI – Swedish Meteorological and Hydrological Institute	Hydrographic, chemical and marine biological data
SLU - Artdatabanken	Seabirds and other marine diversity data not already included in the SMHI data hosting
SGU – Geological Survey of Sweden	Chemistry of sediments, including metals and organic pollutants Metals and organic pollutants in biota (from 2018)
IVL - Swedish Environmental Research Institute	Metals and organic pollutants in biota (upto 2016) Screening of hazardous substances
SLU - Department of Soil and the Environment	Inputs of nutrients and chemical pollutants
Public Health Agency of Sweden	Bathing water quality

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19 Monitoring guidelines for coastal and marine monitoring are published as follows:

- programmes under the responsibility of SEPA: <http://www.naturvardsverket.se/Stod-i-miljobetet/Vagledning/Miljoovervakning/Handledning/Metoder/Undersokningstyper/Programomrade-Kust-och-Hav/> (last accessed: 2017-04-05)
- programmes under the responsibility of SwAM: <https://www.havochvatten.se/4.2cf45b7613f6ca957cc6adb.html> (last accessed: 2017-04-05)

20 [www.dyntaxa.se](http://www.dyntaxa.se) (last accessed 2017-04-05)

### 3.9 MAIN MARINE ASSESSMENT AND REPORTING ROUTES

#### Official WFD status assessment and other EU reporting

Ecological and chemical status classification for Sweden's surface waterbodies under the Water Framework Directive, including those in coastal and transitional waters, is performed by the County Administrative Boards, consultants and the Water Authorities (Vattenmyndigheterna) in agreement with the 6-year WFD cycle. The resulting information on ecological status, as well as monitoring and proposed measures in each waterbody are compiled in the operational database Vatteninformationsystem Sverige ([www.viss.se](http://www.viss.se)). VISS is a tool for compiling, documenting and interacting with stakeholder in the consultation process of the assessments. EU Reporting also takes place under the Habitats Directive and the Marine Strategy Framework Directive, which is still evolving.

#### HAVET report

The HAVET<sup>21</sup> report was published annually from 2007 to 2012 and biennially in 2013/14 and 2015/16 as a report on the state of Sweden's seas by SIME, SwAM and SEPA. The report aims to provide a regular update on the state of Swedish sea areas primarily based upon data from the national marine environmental monitoring. Havet includes an overall summary of the marine environment conditions shown by national monitoring data and selected scientific publications, and is written by the SIME's environmental analysts from the Universities of Umeå, Stockholm, Linnaeus and Gothenburg. HAVET also contains a number of more advanced articles on regional environmental monitoring, research and other investigations of importance deemed important to management of the marine environment. Since the national environmental monitoring is not comprehensive (i.e. all regional and local monitoring are not included in the report), many areas and types of data are not included. This is particularly so for coastal areas affected by point sources and other human pressures.

The development of a web-based reporting tool, which in the future will fulfil the role of HAVET is currently ongoing. This reporting tool is being developed to encompass reporting on status and trends of marine data and freshwater data.

An annual seminar (Havsmiljöseminariet), organised as part of the production of the HAVET report, has provided a forum for presenting and discussing the state of Sweden's sea areas using the results of the national marine environmental monitoring as a starting point. The meeting brings together organisations and personnel carrying out marine environmental monitoring with researchers and representatives from regional and national authorities for information exchange and creative dialogue. One of the purposes is to highlight trends and observations of interest.

#### Resurs- och miljööversikt

The Resurs- och Miljööversikt is an annual report drawn up by the Swedish University of Agricultural Sciences (SLU) - Department of Aquatic Resources (SLU Aqua), on behalf of SwAM. The report summarises development and population status of the most commercially

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<sup>21</sup> HAVET has been published in 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013/2014 and 2015/16. Havet Reports from 2009 onwards are available at <http://www.havsmiljoinstitutet.se/publikationer/havet/> (last accessed: 2017-04-05)

important fish and crustacean species in Sweden's waters. Assessments and management advice are based on ICES (ICES) advice, SLU Aqua's national and regional exploratory fisheries data and commercial fisheries reporting.

### Other reporting on monitoring

SMHI publish cruise reports, data summaries and analysis of oceanographic data via their Havsmiljö website<sup>22</sup>.

SwAM have published a series of fact sheets on the observations at the four integrated coastal fish monitoring stations during the period 1998-2015<sup>23</sup>.

Three Information Centres for Skagerrak and Kattegat<sup>24</sup>, Baltic Proper<sup>25</sup> and Gulf of Bothnia<sup>26</sup> are run by the County Administrative Boards in those areas and publish information and news on the status of the marine environment and key events (e.g. effects of seal virus or incidence of algal blooms).

Sweden's monitoring also contributes to assessments produced within the regional cooperation frameworks of HELCOM and OSPAR, such as the HOLAS assessment (HELCOM, 2010<sup>27</sup>) and the OSPAR Quality Status Report 2010 and its various feeder reports (OSPAR, 2010<sup>28</sup>) as well as regular fish stock assessments within ICES.

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22 <http://www.smhi.se/tema/havsmiljo> (last accessed 2017-04-05)

23 <https://www.havochvatten.se/hav/samordning--fakta/miljoovervakning/miljoovervakningens-programomrade-kust-och-hav/delprogram-integrerad-kustfiskovervakning.html> (last accessed 2017-04-05)

24 <http://www.lansstyrelsen.se/VastraGotaland/Sv/miljo-och-klimat/tillstandet-i-miljon/infocentralen-vasterhavet/Pages/index.aspx> (last accessed 2017-04-05)

25 <http://www.lansstyrelsen.se/Stockholm/Sv/miljo-och-klimat/tillstandet-i-miljon/informationscentralen-for-egentliga-ostersjon/Pages/default.aspx> (last accessed 2017-04-05)

26 <http://www.lansstyrelsen.se/Vasterbotten/Sv/miljo-och-klimat/tillstandet-i-miljon/informationscentralen-for-bottniska-viken/Pages/default.aspx> (last accessed 2017-04-05)

27 HELCOM, 2010. Ecosystem Health of the Baltic Sea 2003–2007: HELCOM Initial Holistic Assessment. Balt. Sea Environ. Proc. No. 122.

28 OSPAR, 2010. Quality Status Report 2010. OSPAR Commission. London. 176 pp. ([www.qsr2010.ospar.org](http://www.qsr2010.ospar.org)) (last accessed 2014-12-26)

## 4 ORIENTATION OF SWEDEN'S MARINE MONITORING TOWARDS THE SWEDISH GOVERNMENT OBJECTIVES FOR ENVIRONMENTAL MONITORING

### 4.1 INTRODUCTION

In this chapter we review how the organisation of Sweden's marine monitoring is oriented to address the Swedish Government Objectives for environmental monitoring (see Box 1). First we review how the Government Objectives are reflected in the descriptions used by national and regional authorities to guide and report on the organisation of marine environmental monitoring. We then review whether analysis of the Government Objectives is a feature of regular assessments.

#### **Are the Government Objectives reflected in the aims of monitoring programmes?**

*Assessment of SwAM's webpages:* Government Objectives 1-5 are currently reflected in the SwAM webpages as the goals of environmental monitoring<sup>29</sup>. However, the sixth objective on providing information on the sustainability of societal trends does not appear to be reflected here.

The SwAM and the SEPA websites give access to descriptions of the national marine monitoring sub-programmes. These set out objectives for each part of the national programme. Table 4.1 reviews the extent to which these objectives reflect the government objectives. The formulation of these objectives is not totally consistent across the elements of the national programme and demonstrate a focusing of the purpose of marine monitoring on state, trends and environmental quality objectives information. Information on these issues is certainly the basis for fulfilling the other Government objectives, but the need for data to be fit for the purpose of addressing the other Government objectives through assessments is not explicitly recognised and it is not clearly stated how the development of more advanced analytical assessments of monitoring data are taken forward.

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29 <https://www.havochvatten.se/hav/samordning--fakta/miljoovervakning/syftet-med-miljoovervakning.html> (last accessed 2017-04-05)

Table 4.1 Are government objectives for environmental monitoring reflected in the objectives of national monitoring programmes, based on monitoring programme objectives provided in the programme descriptions on SwAM website (accessed 14-05-15)

	State descriptions	Progress Environmental Objectives	Threat assessment	Basis for action	Follow up action	Sustainability societal trends
Input loads to the sea (Belastning på havet)	●					
Water column monitoring (Fria vattenmassan)	●					
Vegetated benthos (Vegetationsklädda bottenar)	●					
Soft-bottom macrofauna (Makrofauna mjukbotten)	●	●				
Contaminants (Miljögifter)	●	●				
Integrated Coastal Fish	●	●				
Seals and sea eagles (Säl och havsörn)	●	●	●	●	●	

*Examination of commissioning contracts and agreements:* Commissioning agreements for national marine monitoring between SwAM and organisations carrying out national marine monitoring take differing approaches to reflecting the overall Swedish objectives. One contract (for nutrient and hydrographic monitoring in the Baltic Sea) sets out goals broadly equivalent to Government Objectives 1-5 in a “background and purpose” section.

Another contract reviewed in this project (i.e. hydrographic and soft-bottom benthic fauna monitoring in the Gulf of Bothnia) includes a purpose section, which describes the need to follow the long-term changes in the environment in response to eutrophication and oxygen stagnation and to follow up biodiversity, and reflect the need to follow up environmental quality objectives. Neither of these contracts have explicit requirements for information related to the Government objectives to be developed from the monitoring carried out. The operative paragraphs focus mainly on the collection and handling of data. Assessment is only covered by a requirement for participation in the production of the HAVET report.

## Are the Government Objectives addressed in assessments of monitoring data?

### Government Objective 1: To describe the status of the marine environment

The commissioning contracts for national monitoring do not always include explicit requirements for the way that monitoring data should be assessed, but where they do the main requirements are focused on transforming data into information on environmental status. For several national programmes (inputs, zooplankton, phytoplankton, benthic habitats) the contract has required that monitoring results are reported in the annual HAVET report or corresponding publications and presented at Havsmiljöseminariet, which has the purpose to presents results and to discuss status. HAVET presented for each monitoring programme graphs and maps for each monitoring programme on status and/or trends in the monitored parameter. Contractual reporting can consist of the addition of new data points with no specific requirement for further analysis unless the monitoring concerned is the focus of a more in-depth consideration in one of the more detailed “perspective on the marine environment” sections.

The contracts for contaminant monitoring and integrated coastal fish monitoring cover the development of annual summary reports on the monitoring programmes which include information on status and trends of the monitored parameters (Naturhistoriska Riksmuseet, 2010<sup>30</sup>; SwAM, 2012<sup>31</sup>). The integrated coastal fish monitoring report, Resurs och Miljööversikt (SwAM, 2012), also presents management advice. Regional monitoring programmes also focus on the production of information on status and trends through a focus on Water Framework Directive requirements. Classification results for coastal and transitional water bodies are compiled in the VISS database (Vatteninformationssystem Sverige<sup>32</sup>) where underlying assessment information can be accessed. Information on the assessment of status and trends in relevant waterbodies is also published by some of the Vattenvårdsförbund, for example Svealandskustens vattenvårdsförbund (2014)<sup>33</sup> or Hultcrantz, C. and Skjevik, A-T (2013)<sup>34</sup>.

### Government Objective 2. To assess threats to the environment

For the purpose of this review we considered threats to be phenomena that pose a risk of deterioration in environmental status. Assessment of threats can therefore be considered to embrace different types of question depending on the state of knowledge of the phenomena concerned, ranging from problem identification (“Is a phenomenon a problem?”) to characterisation (“What is the potential effect and what is the probability of that effect?”) and response. Monitoring alone is not sufficient to deliver a full assessment of threats but can provide relevant information on potential threats or known risks. A combination of monitoring, research and analyses is needed to understand the significance and to determine the response.

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30 Bignert, A., Danielsson, S., Faxneld, S., Miller, A., Nyberg, E., Berger, U., Nylund, K., Egebäck, A. -L., Haglund, P. 2013. Övervakning av metaller och organiska miljögifter i marin biota, 2013. Sakrapport till Naturvårdsverket nr 1:2013, 258 pp. (MG 1159).

31 Havs- och vattenmyndigheten 2012. Fiskbestånd och miljö i hav och vatten. Resurs- och miljööversikt 2012.

32 [www.viss.se](http://www.viss.se)

33 Svealandskustvattenvårdsförbund. 2014. Svealandskusten 2014. Report by Svealands kustvattenvårdsförbund in collaboration with Stockholm University. 36pp.

34 Hultcrantz, C. and Skjevik, A-T. 2012. Årsrapport 2012 Hydrografi & Växtplankton Hallands Kustkontrollprogram. SMHI Rapport NR 2013 – 24. 55pp.

The initial step in threat assessment is problem identification. Monitoring may reveal unusual or unexplained phenomena, such as algal blooms, or rapid or unexpected changes in a particular parameter, which need analysis. Reporting of information on threats does occur through the regional information centres and has been a feature of the in-depth articles in HAVET, for example, if identified during the editorial process or through the Havsmiljöseminariet. Interviews conducted during this project suggest that there are few explicit procedures for how organisations conducting national monitoring should act when they produce information to threats. Monitoring organisations will report new observations to authorities through personal contacts. However, analysis to identify and explore new phenomena often seems to require the initiative and dedication of research scientists, because there is no overall coordinated process for considering how to investigate new developments. It has been suggested that there should be a mechanism either at the national agency level or within the scientific community (marine centres or institutes) for investigating the results from monitoring and formulating or advising on appropriate responses.

In contrast, an analysis of pressures and driving forces at a local level is a formal requirement of the WFD and in connection with the regional monitoring a risk analysis is carried out to identify threats to the status of waterbodies. Although the approach is not particularly rigorous being based upon the current status of a water body and the risk of deterioration.

A second stage in threat assessment is investigation of whether known risks actually lead to a response in the marine environment. The marine monitoring of contaminants sits as part of a national framework of chemicals regulation in which a Swedish national screening programme<sup>35</sup> can include investigation of the presence and effects of hazardous substances recently registered on Chemical Inspectorate Register. Similarly identification that certain non-indigenous species are at risk of introduction to Swedish waters requires that arrangements are in place so that monitoring organisations are alert to the need to report on the observation of these species. Agreements between SwAM and monitoring providers have included a specific clause on “special reporting of non-indigenous species” to the Swedish Species Information Centre (Artdatabanken) at [www.artportalen.se](http://www.artportalen.se). Operation of this requirement requires that alert lists of species to be reported are in place and up-to-date. Contracts examined during this project did not specify which alert list should be followed. Since the commencement of this project the list regarding introduced species in Swedish waters (Främmande arter i Svenska Hav) hosted by the Swedish Species Information Centre has been replaced by lists hosted on the SwAM website including introduced species in Swedish waters and sea<sup>36</sup> and an alert list<sup>37</sup>. It has not been possible to check how this has been reflected in agreements between SwAM and monitoring providers.

**Government Objective 3: To provide a basis for actions or action programmes and  
Government Objective 4: To follow up effects of actions or action programmes**

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35 <http://www.naturvardsverket.se/Miljoarbete-i-samhallet/Miljoarbete-i-Sverige/Miljoovervakning/Miljoovervakning/Miljogifts-samordning/Screening/> (last accessed 2017-04-05)

36 <https://www.havochvatten.se/hav/fiske--fritid/arter/frammande-arter/lista-over-frammande-arter-i-svenska-hav-och-vatten.html> (last accessed 2017-04-05)

37 <https://www.havochvatten.se/hav/fiske--fritid/arter/frammande-arter/lista-over-frammande-arter-i-vart-naromrade---alertlistan.html> (last accessed 2017-04-05)

In practice, relatively few monitoring programmes, especially those at the national scale, have been organised with the explicit purpose of informing the basis for measures through being well coupled to pressures. Efforts to use monitoring data as part of the design process for measures are usually a separate exercise from regular assessments of monitoring data. Exceptions are the integrated coastal fish monitoring programme and monitoring of offshore fish stocks, which are both geared towards the production of management advice. Coastal fish monitoring data is presented in an annual report, which supports the formulation of management actions for fisheries in Swedish territorial waters and considers the effects of management actions that have been taken. Monitoring data on offshore fish stocks is reported to ICES and used in the production of advice for EU fisheries management.

At a more local scale, for example Svealands kustvattenvårdsförbund, recipient-control monitoring<sup>38</sup> has been used to calculate the required nitrogen input reductions from point sources including sewage treatment plants into an estuary located in the greater Stockholm area. By contrast the national marine monitoring of contaminants in biota has not been designed to enable source identification and apportionment, and current implementation of regional monitoring does not allow for joint assessment of national and regional data.

#### **Government Objective 5: To follow progress towards national environmental quality objectives**

Monitoring at the regional level is used to report on progress towards environmental quality objectives within each county<sup>39</sup>. Regional monitoring also links to environmental quality objectives by measuring progress towards environmental quality objectives through the work to classify WFD coastal and transitional water bodies (e.g. Vattenmyndigheten Västerhavet, 2014<sup>40</sup>). Data from contaminant monitoring has also been used in predictive analyses of how long it will take to reach environmental quality standards (MKN) under current measures.

For marine waters the HAVET 2014 report includes assessment in relation to environmental quality standards for data from a number of monitoring programmes (phytoplankton, macrovegetation, soft-bottom benthic fauna). The need to assess progress towards the MKN for marine waters should become an important tool for demonstrating progress towards environmental quality objectives in offshore waters as MSFD implementation is developed. A consideration of whether data from national monitoring alone or from WFD monitoring alone is sufficiently representative for assessing progress towards MKN would inform the need to achieve a better usability of data from national and regional programmes (see Chapter 6).

#### **Government Objective 6. To assess the sustainability of pertinent societal trends**

The sustainability of pertinent societal trends has been rarely addressed as an objective in formal assessments of Swedish marine environment monitoring data. This type of analysis cannot be developed based only on monitoring data on the marine environment. It requires a combination of data from societal, economic monitoring and data on environmental pressures.

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38 to explore the responses of particular water bodies to different levels of pollutants in discharge (e.g. Himmerfjärden)

39 <http://www.miljomal.se/sv/Miljomalen/Regionala/?eqo=10&t=Lan>

40 Vattenmyndigheten Västerhavet (2015). Vattenmyndigheten Västerhavet och Länsstyrelsen Västra Götalands Läns Förslag på förvaltningsplan för Västerhavets vattendistrikt (Dnr 537-34925-2014-1)



However, as data must be combined from different sources fulfilling this Government objective requires collaboration between authorities with responsibility for environmental status and authorities concerned with regulating human activities and guiding societal trends.

## 5 DATA AVAILABILITY AND USABILITY

Almost all measured data about the state of Swedish marine environments and the pressure on such environments are freely available. In addition, a substantial amount of supplementary information is available according to the Swedish principle of public access to official records. However, this does not necessarily imply that all data that might be used to support management of marine environments are readily available in a form useable for assessments.

In this chapter we examine the availability of environmental monitoring and assessment data based on two criteria: completeness and accessibility. Completeness refers to the existence of data of relevant type, their coverage and resolution in space and time, and the comprehensiveness of information about sampling and measurement techniques. Accessibility refers to the feasibility to download raw data and how easy it is to produce graphs, statistical summaries and indices needed for various types of assessments. In particular, we examine how easy it is to assess long-term temporal trends and perform assessments that require data from two or more monitoring programmes.

Environmental monitoring was for a long time synonymous with in situ sampling followed by physical, chemical or biological analysis of the collected samples. Here, we first focus on the availability of such conventional monitoring data at three data hosts: the Swedish Meteorological and Hydrological Institute (SMHI), the Swedish Environmental Institute (IVL), and the Swedish University of Agricultural Sciences (SLU). More specifically, we examine physical-chemical water column data and marine biological data provided by the SMHI, data on contaminants in biota previously provided by the IVL (which is now being transferred to the Swedish Geological Survey (SGU)), and data on coastal fish and the chemical characteristics of river water provided by the SLU. Thereafter, we present and discuss two examples of the rapidly increasing amount of environmental data that nowadays is gathered by means other than in situ sampling. For example, model simulations, automatically recorded signals, images and video films can all be of great interest in environmental assessment and management.

It should also be noted that some of the problems identified in our study are presently being addressed in on-going projects run by data hosts or agencies responsible for environmental monitoring. However, several projects have been running for a long time and the final outcome is uncertain.

### 5.1 SMHI: PHYSICAL AND CHEMICAL PROPERTIES OF MARINE WATERS

Sea-water samples are regularly collected at more than a hundred sites in the marine waters surrounding Sweden, and the measured physical and chemical parameters include temperature, salinity, pH, alkalinity, oxygen, chlorophyll a, and different forms of nitrogen and phosphorus. In addition, Secchi depth is often measured at the sampling sites. The national monitoring pays special attention to the state of the environment at off-shore stations, whereas the so-called regional monitoring produces data from coastal stations and a few reference stations representing off-shore conditions. Together, the two types of monitoring programmes cover all major water types in Swedish marine waters. Monitoring in the vicinity of point emissions (Samordnad Recipientkontroll) provide supplementary information about the state of water bodies that might be particularly polluted.

The SMHI maintains a database (Svenskt HavsARKiv, SHARK) and a user interface (Sharkweb) from which a substantial part of the data produced within the Swedish national and regional marine monitoring can be downloaded. Physical and chemical records for water samples collected at a wide range of locations and depths can be found in the same database as the marine biological data<sup>41</sup>.

Pull-down menus and maps showing the location of individual sampling sites and the areas covered by different sub-programmes facilitate the downloading of small to medium-sized subsets of data. The entire database can be downloaded in subsets covering different time periods. In general, national data are made available without substantial delay. However, several regional datasets are incomplete because it may take long until such data are made available through Sharkweb (Elam & Grimvall, 2013).

Whether or not the downloaded data have a usable form depends strongly on the type of assessments that shall be performed. Analyses of long time series of data can be very cumbersome. The same is true for assessments of the state of water types or other large sea areas according to EU directives. Although the design of the monitoring program is dominated by repeated visits to fixed stations, there is still no comprehensive station register. A given latitude and longitude may be assigned different station names during different time periods, and stations belonging to different regional sampling programmes are sometimes assigned identical names.

Our remarks on the availability of physical and chemical data for Swedish marine waters are summarized in Table 1. Some of the deficiencies regarding accessibility of data can relatively easily be eliminated. For example, it would require a relatively moderate effort to complete the on-going work to establish unique station names, a unique nominal latitude and longitude, and acceptable ranges of latitudes and longitudes for each station. When such a station register has been established it would also be a fairly easy task to generate complete information about water body, water type and sea basin for each station. At present more than a million observations made within Sweden's economic zone lack easily available information about sea basin.

Increasing the completeness of measured physical and chemical data and relevant supplementary information is a more complex task. More frequent updating of the database would require more efficient tools and more strict rules for submitting data to SHARK and checking the correctness of submitted data. Moreover, it is a fairly extensive task to compile data quality indicators and information about sampling and measurement techniques.

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41 <http://www.smhi.se/klimatdata/oceanografi/havsmiljodata/marina-miljoovervakningsdata>

Table 1. Problems identified in the availability of physical and chemical data in the SHARK database.

Accessibility of data		Completeness of data		
Data selection tools	Availability in usable form	Data currency	Quality indicators	Sampling and measurement techniques
Maps and conventional pull-down menus	Incomplete station register	Slow updating of data from some regional monitoring programmes	Incomplete information about detection limits or other quality remarks	Incomplete information about sampling and measurement techniques

## 5.2 SMHI: MARINE BIOLOGICAL DATA

The marine biological part of the SHARK database is the most diverse and largest database for the state of Swedish marine waters. The data made available on the SMHI website (<http://www.smhi.se/klimatdata/oceanografi/Havsmiljodata/marina-miljoovervakningsdata>) represent monitoring of abundance of plankton (phytoplankton, zooplankton and bacterioplankton), chlorophyll, primary production, sedimentation, phytobenthos, zoobenthos, and seals (grey seal, harbor seal, ringed seal, and seal pathology). When the entire database (including physical and chemical data) is downloaded as a single large table it consists of more than nine million records (rows) and about 250 fields (columns). A versatile tool for data selection provides numerous options to select datasets of interest. For example, the user can specify datatype (sub-programme), species, sampling stations and time periods. However, the downloading procedure is not free from bugs due to inconsistent data formats. Import of large datasets into major statistical software packages, such as SAS, Matlab and R, can result in very long lists of error messages.

Together, the large number of errors and inconsistencies imply that even an experienced data analyst may have to spend days on reformatting and cleaning the data that has been downloaded before an overall assessment of trends and environmental quality can be started. This is particularly true for cross-programme analyses, but inconsistencies within sub-programmes are also prevalent.

Because biological monitoring can be very costly the spatial coverage of data collected is low or very low in some of the sub-programmes. For example, there are few stations where zoobenthos and phytobenthos are monitored. Also, the data currency varies significantly between sub-programmes. In general, it is very good for monitoring programmes run by the data host and more variable for the other programmes.

The availability of supplementary information that can help the user interpret the values is in general good in the biological part of SHARK, although it may be difficult to synthesize such information. Data quality remarks, references to sampling and measurement techniques, and several other forms of information are given in special fields of the database. Table 2 summarizes our assessments of accessibility and completeness.

Table 2. Availability of marine biological data in the SHARK database.

Accessibility of data		Completeness of data			
Data selection tools	Availability in usable form	Spatial coverage	Data currency	Quality indicators	Sampling and measurement techniques
Data selection facilitated by a versatile tool for data selection	Incomplete standardization of station names, field names, data types and formats	Low spatial coverage in several sub-programmes	Varies between monitoring programmes	Quality remarks given in special data fields	Many references to sampling and measurement techniques

Although our study revealed a very large number of errors and inconsistencies many deficiencies could be corrected by rather moderate efforts. In particular, it is both urgent and achievable to establish a common structure of data fields, data types and formats that can be applied to all monitoring programmes included in SHARK. Likewise, it is both urgent and achievable to establish unique identities of stations. Because several of the errors detected seem to be reporting errors there is also an obvious need for more efficient procedures to submit data to SHARK and check the correctness of data submitted.

### 5.3 IVL AND SGU: CONTAMINANTS IN BIOTA

The IVL has long maintained a database on contaminants in biota that still can be accessed via the website <http://www.ivl.se/sidor/omraden/miljodata/miljogifter-i-biologiskt-material/databas-miljogifter.html> which is now being transferred to the SGU. The marine part of this database provides information about concentrations of metals (including mercury), polychlorinated biphenyls (PCBs), DDT, dioxines, brominated flame retardents, organotin compounds, perfluorinated compounds (PFCs), and polyaromatic hydrocarbons (PAHs). The set of organs and species sampled includes muscles of several fish species, whole blue mussels and nassarius snails, and guillemot eggs.

The database constitutes an example of a standard relational database. Each measured value is linked to a unique station and sample identity, and station characteristics are summarized in separate tables.

Data can be downloaded for one contaminant group at a time, and the website provides tools for selecting data with respect to species, organ, station and time. A table comprising station characteristics can be ordered by e-mailing the data host. In general, downloading to Excel sheets works well, but character-to-number conversion errors occur when mercury data are downloaded. Moreover, date formats are not fully standardized, and less-than symbols in predominantly numeric fields should be removed before the data are imported into major statistical software packages.

The database includes data from both national and regional programmes. The set of national data is not complete. By the end of 2017 no marine data had been added from 2016 and for some substances there were very few data from 2015. Regardless of sampling programme, the

spatial coverage of the collected data is low or very low because of high costs to analyse micropollutants in biota. Supplementary information about data quality is given for each record in special data fields, but general information about sampling procedures and analytical techniques is not included in the database. Table 3 summarizes our judgements of accessibility and completeness.

Table 3. Availability of data on toxic substances in marine biota.

Accessibility of data		Completeness of data			
Data selection tools	Availability in usable form	Spatial coverage	Data currency	Quality indicators	Sampling and measurement techniques
Conventional pull-down menus	Minor downloading and data format errors	In general, low spatial coverage	Time lags built into the system for reporting to the data host	Quality remarks given in special data fields	Sparse or missing information about sampling and measurement techniques

After correcting minor downloading and format errors (see above) the database will satisfy high demands on consistency and standardization. Likewise, it would be easy to include information about water bodies, water types and sea areas in the station register. Compiling information about sampling, sample preparation and analytical procedures is a more demanding task because analysis of trace organics involves numerous steps and both sample preparation and instruments have changed over time.

#### 5.4 SLU: RIVER MOUTH CONCENTRATIONS AND LOADS

Concentrations of inorganic ions and organic matter have long been measured by the SLU at nearly 50 river mouths in Sweden. Moreover, substance loads have been compiled by combining concentration records and water discharge data. Measured and computed data can be accessed at <http://miljodata.slu.se/mvm/> and the parameter list includes major cations and anions, different forms of nitrogen and phosphorus, total amount of organic matter and a fairly large number of metals. Sampling is performed once a month at each river mouth.

An advanced data selection tool allows the user to download concentration data for any combination of stations, parameters and time periods, and our study did not reveal any formal downloading errors. All variable formats are standardized, stations are uniquely defined, and each record (row) in the database corresponds to a unique sample. Annual substance loads are computed by county or region and chemical parameter.

The spatial coverage of the river mouth programme is adequate and the database is updated annually. Well-organized information about sampling and measurement techniques can also be downloaded. Table 4 summarizes our judgments of data availability.

Table 4. Availability of data on the chemical composition of water sampled at river mouths.

Accessibility of data		Completeness of data			
Data selection tools	Availability in usable form	Spatial coverage	Data currency	Quality indicators	Sampling and measurement techniques
Conventional pull-down menus	Good	Good	Frequent updating	Adequate information can be downloaded.	Adequate information can be downloaded.

The river mouth data form a small database that has just two data providers (the SLU and SMHI) and a simple but adequate structure. Our study did not reveal any formal errors or inconsistencies. However, cross-programme analyses involving data from both SLU and SMHI would be easier if variable names and data formats in different databases were harmonized.

## 5.5 SLU: COASTAL FISH

A database on coastal fish is maintained by the Department of Aquatic Resources at the SLU. Our study was constrained to data on catches per fishing effort in fish stock surveys. Such data can be accessed from the SLU website: <http://www.slu.se/sv/institutioner/akvatiska-resurser/databaser/kul/>.

The abovementioned fish catch data are stored in a standard relational database. Fish catches and fishing efforts are registered in tables along with information about survey or inventory, fishing area, station, depth and time. Other tables link station identities to latitudes and longitudes and surveys to precise descriptions of fishing methods. Data selection is facilitated by pull-down menus, but the on-line downloading is limited to very small datasets.

Because of high sampling costs the spatial coverage of the fish stock surveys is generally low. Furthermore, it is uncertain to what extent local data can be assumed to be representative for larger areas, and how fishing areas and stations are related to water bodies and stations defined in other parts of the marine environmental monitoring.

The data currency is generally good because most of the monitoring is carried out by or in near collaboration with the data host.

Table 5. Availability of data on coastal fish populations.

Accessibility of data		Completeness of data			
Data selection tool	Availability in usable form	Spatial coverage	Data currency	Quality indicators	Sampling and measurement techniques
Conventional pull-down menus	Downloading constrained to very small datasets	Low spatial coverage	Good	Weather conditions recorded	Adequate information about fishing methods

## 5.6 MODEL OUTPUTS AND NEW FORMS OF DATA COLLECTION

In this section we give two examples of marine environmental data produced outside traditional environmental monitoring programmes, but nevertheless can give added value to such programmes. The first example deals with modelled input of nutrients to the Swedish marine environment, and the second one with automatically recorded ship traffic on the Baltic Sea. A more comprehensive study of modelled or automatically recorded marine environmental data was outside the scope of the present study.

The SMHI maintains a website (<http://vattenweb.smhi.se/>) from which huge amounts of measured and modelled, water-related data can be downloaded (<http://vattenweb.smhi.se/modelarea/>). In particular, it is possible to download inputs and outputs to the catchment model S-HYPE (<http://www.smhi.se/forskning/forskningsomraden/hydrologi/s-hype-hype-modell-for-hela-sverige-1.560>) and the “Coastal zone model” for Swedish coastal waters (<http://www.smhi.se/forskning/forskningsomraden/oceanografi/kustzonsmodellen-1.19391>).

S-HYPE provides time series data of water discharge and loads of nitrogen and phosphorus at the outlets of all main catchments and sub-catchments listed in the database Svenskt Vattenarkiv (SVAR). Model outputs are available as daily, monthly and annual means. The Coastal zone model provides time series data of temperature, salinity, and concentrations of different forms of nitrogen and phosphorus, chlorophyll a, and oxygen. Model outputs for coastal water bodies listed in SVAR are presented as daily, monthly and annual means at a set of standard depths (0, 5, 10, 15, 20, 30, etc.).

So far, the S-HYPE and Coastal zone models have primarily been used for scenario analyses, nowcasting, source apportionment of riverine loads of nutrients and status assessments of coastal waters. Recent research has demonstrated that process-based models can also be used for other assessments. For example, such models can be employed to separate effects of human interventions from weather-driven fluctuations in measured data (Grimvall et al., 2014).

Some activities that can greatly influence the state of marine environments are thoroughly monitored for reasons other than status assessments. For example, the position, speed and direction of all major ships on the Baltic Sea are almost continuously monitored using Automatic Identification Systems (AIS) primarily constructed to prevent ship collisions. In marine environmental management, AIS-data can be used to monitor shipping in protected areas and



the presence in the Baltic Sea of ships from countries that do not fully comply with the requirements in international conventions. Along with additional information, AIS data can also be used to estimate emissions to air and water and underwater noise from shipping.

As indicated above, outputs from the S-HYPE and Coastal zone models can be downloaded on-line, whereas AIS must be ordered from the Swedish Maritime Administration. Moreover, the model outputs are freely available, whereas a service fee is applied to cover the costs of retrieving several Gigabytes of AIS-data from an external server. Table 6 summarizes our assessments of accessibility and completeness of the investigated data.

*Table 6. Availability of some model outputs and automatically recorded maritime data.*

	Accessibility of data		Completeness of data		
	Data selection tool	Availability in usable form	Spatio-temporal coverage	Data currency	Quality indicators
Outputs from the S-HYPE and Coastal zone models	Maps facilitating downloading by area	Nationwide assessments require considerable work	Complete	Varying time intervals between model runs	Summarizing measures of the goodness-of-fit
AIS-data from the Baltic Sea	Data must be ordered from the data host	Cumbersome editing due to the size of the datasets and the presence of numerous errors	Gaps exist	Good	No flagging of dubious data

## 5.7 GRAPHICAL PRESENTATIONS AND APPLICATION PROGRAMMING INTERFACES

So far, we have only briefly mentioned the file formats and presentation modes in which marine environmental monitoring data are made available. However, there are a couple of general trends in human-machine interaction and machine-to-machine communication that need to be taken into account when the accessibility of data is discussed.

Among national data hosts for official statistics there is now a strong trend towards more frequent use of diagrams and maps to visualize the data that have been collected. Bar charts illustrate summary statistics, line charts provide information about changes over time, and colour-coded maps are used to illustrate spatial patterns. Another notable trend is the increasing use of interactive charts and animated graphs. Due to the pioneering work of Hans Rosling ([www.gapminder.com](http://www.gapminder.com)) and many other scientists, it is now generally recognized that such forms of presentations can give added value to data and constitute a very efficient tool to detect flaws in tables of data. Yet another trend is the increasing use of application programming

interfaces (APIs) for reliable exchange of data between data host servers and application developers. In particular, information is coded in the self-describing formats XML (Extensible Markup Language) or JSON (JavaScript Object Notation), which can provide metadata along with observed values in a platform-independent format.

The general trend towards more frequent use of graphical outputs is also gaining ground among the Swedish data hosts for marine environmental monitoring. An example is the interactive maps that have been introduced by SMHI to facilitate selection and downloading of measured data and model inputs and outputs. Moreover, the SLU is implementing a versatile web service for data search, retrieval and visualization of environmental data (<http://www.slu.se/miljodata-mvm/>), especially freshwater and soil data. However, there are still substantial gaps between the current graphical elements and the interactive graphs that would be needed to efficiently support assessments of state and trends in marine waters.

Marine environmental monitoring in its present form is primarily based on repeated measurements at fixed stations, and this has apparently influenced the graphical presentations. For example, the diagrams supplied by the SLU typically show a single time series of data from a single station. However, EU directives related to the marine environment emphasize spatially integrated assessments, such as status assessments of water bodies, water types and even larger sea areas. Moreover, application of the ecosystem approach often requires cross-programme analyses, and this calls for other graphs. For example, it is often interesting to view data from a single station against a background of data from a larger area. Likewise, it may be of great interest to produce maps of status assessments in different spatial scales without being forced to use advanced software packages. Two prototypes developed at the Swedish Institute for the Marine Environment illustrate that such applications would be feasible to implement (references to HavPort and TiDig).

APIs, like those presently being developed by the SLU can no doubt stimulate development of applications in which marine environmental monitoring data are processed and presented (see <http://miljodata.slu.se/mvm/OpenAPI>). In particular, such APIs can promote web services in which it is desirable to frequently update the output of the application when new raw data are entered into the underlying database. If annual or less frequent updating is needed and new raw data need to be carefully inspected, access to open APIs is less groundbreaking.

## 5.8 CONCLUSIONS AND RECOMMENDATIONS

The investigated databases have different strengths and weaknesses. Also, they vary strongly in size, the number of data providers, and the complexity of observed data. Nevertheless, our study permits several general conclusions;

- Combining the best features of existing databases and harmonizing variable names and data formats can be a fruitful way forward. For example, the SLU database on soil and water quality shows that it is feasible to combine a flexible user interface with strictly defined data formats and unique station and sample identities, and Sharkweb at the SMHI shows that it is technically feasible to download large datasets.
- Strict procedures for controlled submission of data from providers to data hosts and strict criteria for the data hosts to accept or reject submitted data would substantially increase the quality of large amounts of marine environmental monitoring data.

- It is feasible to incorporate all conventional marine monitoring data into a standard type of relational database, from which a great variety of usable data presentations can readily be derived. In particular, it is feasible to greatly facilitate cross-programme analyses, integrated status assessments, and compilations of informative statistical summaries.
- It has long been generally accepted that measured environmental monitoring data shall be freely available. This idea is now gradually spread to other forms of environmental data. It is urgent to promote this trend and take the measures needed to facilitate joint analysis of different forms of data and introduce technologies that can handle the sometimes very large datasets produced by new forms of monitoring.

Based on these general conclusions and the errors and inconsistencies revealed by our review of marine environmental monitoring data we propose the following:

- Develop tools and protocols for controlled data transfer and entry.
- Establish a comprehensive station register for all marine environmental monitoring and standardize time and georeferences.
- Establish data tables with strictly defined records (rows) and fields (columns) and incorporate these tables into a common relational database.
- Establish guidelines for presentation and accessibility of quality remarks and sampling and measurement techniques.
- Develop standardized graphical outputs for major data types.
- Evaluate how conventional monitoring can best be integrated with empirical or process-based modelling, and new forms of data collection.

The last two tasks may require substantial time and effort, whereas the other tasks can be fulfilled to a cost of a few percent of the annual cost of the marine environmental monitoring.

## 6 INFORMATION FROM MONITORING FOR MANAGEMENT

### 6.1 INTRODUCTION

In this chapter we look more closely at information that has been developed on the basis of marine monitoring data and consider this in relation to the Government objectives. We consider how the use of monitoring data could be developed and try to identify steps that could be taken to support this. Where relevant, reference is made to some specific case studies.

Sweden's marine monitoring programmes have generated long and uniquely valuable time series. These time series have been used to illustrate improved environmental quality following introduction of measures. For example, the decrease in levels of certain contaminants in biota and sediments, the recovery of seal and sea eagle populations and improvements of water quality in coastal areas polluted by sewage discharges. Analyses of monitoring data have also demonstrated the lack of improvements in open Baltic Sea Proper areas in response to nutrient input reduction programmes. Table 6.1 summarises the regular information outputs from Sweden's marine monitoring that have been identified by this review. Data from national monitoring programmes is also used as a basis for classification and assessment reporting to fulfill the requirements of the EU Water Framework Directive and the EU Marine Strategy Framework Directive every six years.

Considerations on addressing societal trends through assessment and monitoring (Government Objective 6) have been presented in a report on societal phenomena and measures against eutrophication in the marine environment (Sundblad et al, 2015)<sup>42</sup> and are not considered further here.

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42 Sundblad, E-L., Vallin, A., Grimvall, A. and Emmerson, R. (2015). Samhällsfenomen och åtgärder mot övergödning av havsmiljön. Havsmiljöinstitutet Rapport nr 2015:6. 76pp

Table 6.1 Summary of (i) how data from national monitoring programmes are analysed, presented and used in assessments and reporting according to contracts, and (ii) use of data from national monitoring programmes in other national and international reporting (as at 2015/2016). Data from national monitoring programmes is also used as a basis for six-yearly assessment reporting to fulfill the requirements of the EU Water Framework Directive and the EU Marine Strategy Framework Directive.

	National reporting by monitoring organisations according to contract		Other national and international reporting using national monitoring data
	Reporting	Type of information	
Inputs to the sea	HAVET report – two pages	Trend graphs for inputs of N, P and TOC to main sea basins (a)	National reporting on Environmental quality objectives HELCOM Pollution Load Compilation/HELCOM Core Indicator OSPAR Comprehensive Study on Riverine and Direct Discharges Reporting/OSPAR Common Indicator EEA Indicator
	Sötvatten publication <sup>43</sup>	Trend graphs for N, P, TOC	
Hydrographic and chemical conditions	SMHI Cruise reports	Text, data, status maps, profiles and trend graphs for temperature, salinity, O, N (Tot, DIN), P (Tot, DIP), Secchi depth	HELCOM Eutrophication status of the Baltic Sea OSPAR Common Procedure assessment HELCOM Core Indicators OSPAR Common Indicators
	HAVET report	Trend graphs for temperature, salinity, O, N (Tot, DIN), P (Tot, DIP), Secchi depth	

43 SwAM (2016). Sötvatten 2016. Om miljötillståndet i Sveriges sjöar, vattendrag och grundvatten.

Phytoplankton	HAVET report	Trend graphs for main sea basins (a)	HELCOM pre-core indicator on cyanobacteria HELCOM Core Indicators on chlorophyll-a, diatom/dinoflagellate index OSPAR Common Indicators for pelagic habitats HELCOM Eutrophication status of the Baltic Sea OSPAR Common Procedure assessment
Zooplankton	HAVET report – two pages	Trend graphs for main sea basins (a)	HELCOM Core indicator for zooplankton OSPAR Common indicator for pelagic habitats
Vegetated benthos	HAVET report	Status classification and trends for national monitoring stations	
Soft-bottom macrofauna	HAVET report	Status classification and trends for national monitoring stations	HELCOM Coreset Indicator – benthic quality index
Metals and organic pollutants	Annual report <sup>44</sup>	Maps of concentrations at stations; stations-based trends graphs. Trend analysis and spatial analysis	OSPAR Common Indicators HELCOM Core Indicators AMAP Reporting
	HAVET report	Substance-based trends in sea-basins (a, b)	HELCOM Fact sheet
Coastal fish - status	HAVET report	Trend at stations for key species	HELCOM Core Indicators key coastal fish species and functional groups

44 Bignert, A., Danielsson, S., Faxneld, S., Nyberg, E., Vasileiou, M., Fång, J., Dahlgren, H., Kylberg, E., Staveley Öhlund, J., Jones, D., Stenström, M., Berger, U., Alsberg, T., Kärsrud, A.-S., Sundbom, M., Holm, K., Eriksson, U., Egebäck, A.-L., Haglund, P. & Kaj, L. 2015. Comments Concerning the National Swedish Contaminant Monitoring Programme in Marine Biota, 2015, 2:2015, Swedish Museum of Natural History, Stockholm, Sweden

	Resurs- och miljööversikt	Species-by-species analysis, including landings (quantities and trends), biomass, fish recruitment	
Coastal fish - health	HAVET report	Station-based trend graphs and classification for key health indicators	
Sea eagles	HAVET report	Station-based trend graphs for key status indicators	HELCOM Core Indicator
Seals	HAVET report	Trends in population and health indicators for key areas;	OSPAR Common Indicator HELCOM Core Indicator
<i>Monoporeia affinis</i> (vitmärkla) in the Baltic Sea	HAVET	Status maps for 10 regions (c)	
Seabirds and waterbirds	Annual report <sup>45</sup>	Indexes, trend graphs and text summaries	HELCOM Core Indicator OSPAR Common indicator
Non-indigenous species			HELCOM Core Indicator OSPAR Common Indicator
Marine litter			OSPAR Common Indicators HELCOM Core indicators under development

(a) MSFD seabasins in Baltic proper aggregated; (b) based on one station in each sea basin; (c) based on groupings of monitoring stations.

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<sup>45</sup> Green, M. And Lindström, Å. (2014). Övervakning av fåglarnas populationutveckling. Årsrapport för 2014. Lunds Universitet. 87pp.

## 6.2 ENVIRONMENTAL STATUS ASSESSMENT AND PROGRESS TOWARDS ENVIRONMENTAL QUALITY OBJECTIVES (GOVERNMENT OBJECTIVES 1 AND 5)

As we describe in Chapter 4 the regular, contractually-required assessments of monitoring data has largely been focused towards extracting information on environmental status and related trends, thus primarily addressing Government Objective 1 and in doing that also addressing Government Objective 5 on environmental quality standards (see Table 6.1). This focus can be expected to continue to drive assessment requirements given the requirements for status classification of water bodies under the WFD and environmental status assessment of marine waters under the MSFD.

Both these Directives create a need for improved spatial coverage when assessing status indicators. SwAM (2012)<sup>46</sup> sets out national assessment areas to be used for the purpose of implementation of the MSFD: management areas and sea basins divided into offshore and coastal waters (inner and outer).

Current environmental status assessments of Sweden's national monitoring data, such as those presented in HAVET provide information on environmental status at particular sampling stations rather than being area-based classifications. Sweden's national monitoring programmes alone provide a rather sparse spatial resolution. This resolution has been judged to be adequate for open-sea oceanographic parameters in the Baltic Sea proper<sup>47</sup>, but it is not likely to be representative in all parts of Sweden's seas and across all monitored variables. Up to now it has not been possible to develop joint assessments of national and regional data through the HAVET report. Regional data is primarily used in the preparation of regional data products that are published through VISS (Vatteninformationssystem Sverige<sup>48</sup>).

Possibilities and prospects for making such a joint assessment involving data from the different levels of Swedish marine monitoring have been considered by Moksnes et al. (2014) in the 2013/14 HAVET report<sup>49</sup> (see also Elam and Grimvall, 2013<sup>50</sup>). This analysis showed that a joint assessment of national and regional data would be possible, but entail considerable challenges: programs and methods need to be thoroughly coordinated and made promptly available in the same place. Efforts to overcome these challenges would both provide increased power of assessment for the MSFD assessment areas and make better use of the resources used for environmental monitoring.

Joint assessment of national and regional data will require development of approaches for grouping stations in time and space to give assessment classifications at the scale of an assessment area. Interpolation or extrapolation methods will also be needed as data may not cover all assessment areas. This is especially an issue in Water Framework Directive implementation

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46 Havs- och vattenmyndigheten (2012). Havs- och vattenmyndighetens föreskrifter om vad som kännetecknar god miljöstatus samt miljö kvalitetsnormer med indikatorer för Nordsjön och Östersjön. HVMFS 2012:18, 39pp.

47 Wulff, F, and L. Rahm. 1989. Optimizing the Baltic sampling programme: The effects of using different stations in calculations of total amounts of nutrients. *Beitr. Meereskd.* Berlin 60:61-66.

48 <http://www.viss.lansstyrelsen.se/>

49 Moksnes, P., Grimvall, A. and Elam., J. (2014) Samlad analys av regionala och nationella miljödata. *Havet* 2014. P13-16.

50 Elam, J. and Grimvall, A. (2013) Kvalitetsgranskning av regionala miljöövervakningsdata. *Havsmiljöinstitutets rapport nr 2013*



where only approximately 60% of the water bodies are monitored in some form. Approaches for grouping and interpolation have been set out by SEPA (2007)<sup>51</sup> to support Water Framework Directive implementation, but Vattenmyndigheterna (2012) have highlighted that these have been little used due to uncertainty remaining over their use in practice and the legal implications. Further developments in approaches to grouping and aggregation have taken place under the WATERS project<sup>52,53</sup>. For some status indicators the development of simple models for the interpolation or extrapolation of data has shown promising results.

There is also a need to determine the most effective design of monitoring for area-based status classification. An example is the analysis of benthic monitoring data by Lindegarth et al. (2014)<sup>54</sup>, which compared monitoring designs of benthic fauna based on repeated sampling of a set of stations (crossed design) to one based on sampling of “new” stations each year (nested design). Lindegarth et al. show that the latter is likely to be substantially more precise at the scale of water body types and assessment periods for benthic monitoring data. However, precision and cost-benefit optimisation for status classification are not the only criteria worth considering (other important monitoring objectives are trend analysis and follow-up of measures), and clearly the optimal allocation of samples in time and space will differ among variables. Nevertheless, the analyses illustrate potential benefits of alternative approaches. Some of the general conclusions by Lindegarth et al (2014), which was a study concerned with data from the Swedish west-coast, were confirmed in a parallel study in the Baltic sea (Leonardsson and Blomqvist 2014<sup>55</sup>). As a result the revised Swedish monitoring program has been designed to increase the number of stations sampled at the expense of yearly sampling at each station (Leonardsson and Blomqvist 2015<sup>56</sup>).

### 6.3 INFORMATION FROM MONITORING ON THREATS (GOVERNMENT OBJECTIVE 2)

Monitoring data can play a part in both identification and characterisation of threats. In most assessments of threats a combination of monitoring data with research and analytical investigation will be needed. The main roles that monitoring will play in threat assessment can be categorised as follows:

- a. indicating deteriorating status where a monitored parameter supports identification of potential threat;

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51 SEPA (2007). Status, potential och kvalitetskrav för sjöar, vattendrag, kustvatten och vatten i övergångszon. Naturvårdsverket 2007:4. 67pp.

52 Lindegarth, M., Bergström, P., Carstensen, J., and Johnson, R.K. Assessing status of biological quality elements in water bodies without adequate monitoring: current approaches and recommended strategies for “expert assessment”. Deliverable 2.3-3, WATERS Report no. 2016:7. Havsmiljöinstitutet, Sweden.

53 Lindegarth M., Carstensen J., Drakare S., Johnson R.K., Nyström Sandman A., Söderpalm A., Wikström S.A. (Editors). Ecological Assessment of Swedish Water Bodies; development, harmonisation and integration of biological indicators. Final report of the research programme WATERS. Deliverable 1.1-4, WATERS report no 2016:10. Havsmiljöinstitutet, Sweden.

54 Lindegarth et al. (2014). Monitoring of benthic fauna for the MSFD on the Swedish west- coast: Modelling precision and uncertainty of current and future programs using WATERS uncertainty framework. WATERS Report no. 2014:3. Havsmiljöinstitutet, Sweden.

55 Leonardsson K. and Blomqvist M. (2014) Utvärdering av bottenfaunakluster längs svenska östkusten. Havs- och vattenmyndigheten rapport 2014:27.

56 Leonardsson K. and Blomqvist M. (2015) Förslag till samordnat bottenfaunaprogram i marin miljö. Havs- och vattenmyndigheten rapport 2015:32

- b. providing an observational capability that can report on events and phenomena outside the direct scope of monitoring, which may need investigation, and;
- c. following up threat identification by collection of data on a relevant parameter that support the characterisation of that threat i.e understanding its significance.

There are several examples where level shifts in monitoring data have provided one of the first indications of deterioration in status. For example, the crash of *Monopereia affinis* in the Bothnian Sea in 2000 – 2004 Leonardsson (2001)<sup>57</sup>, observed a marked decline of this key species in Baltic Sea soft-bottom benthic communities at sites south of Umeå in spring 2000. A year later, in 2001, the decrease had spread to 12 out of 13 investigated areas in the Bothnian Sea/Bay, with the greatest effect in the Quark area. There was no clear mechanism within authorities to promote investigations into the causes of this crash and it is the subject of relatively few scientific articles (Eriksson Wiklund et al. (2014))<sup>58</sup>. Monitoring can best serve the purpose of threat identification when there is a framework for how monitoring organisations and authorities should respond when the monitoring data values change quite rapidly. Such a framework should set out how such results from monitoring should be communicated to authorities and how authorities should set about ensuring that reports of this type are satisfactorily investigated so that risk are characterised and responses formulated. The lack of a response framework between authorities and monitoring organisations means that whether an effective follow-up occurs depends upon the resources and the dedication of those carrying out monitoring, who are in many cases also those making the first assessments.

There have also been instances where the requirements for regular analysis of monitoring data have been so narrow or have been implemented so narrowly, that regular assessments have not commented on trends of concern in the data. One such example was the incidence of brownification in coastal waters in the Baltic Sea, which has not been examined through the assessments of the riverine input monitoring of total organic carbon. The phenomenon was first identified by water companies and not through the reporting of the organisations that carry out monitoring. Another example is ocean acidification, where pH was often disregarded as a measurement that needed to be analysed as it was assumed to be constant. This highlights the need for periodic reanalysis and re-evaluation of data.

One of the functions of the annual Havsmiljöseminariet has been to provide a forum for discussion of observed trends and their implications. This needs to be supported by an ongoing scientific evaluation of monitoring data combined with other relevant data, by the contractors and/or external scientists supporting the formulation of management actions in response to observations of concern.

Evidence of some threats may be outside the direct scope of monitored parameters and monitoring activities need to have a more flexible observation approach if they are to be of value. Introductions of non-indigenous species will only be observed if there is awareness among biological monitoring providers, via watch/alert lists, that the presence of certain species should be recorded and reported. Watch lists need to be up-to-date and regionally relevant (e.g. at the Baltic Sea or eastern North Sea scale and effectively communicated in a coordinated

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<sup>57</sup> Leonardsson, K. 2001. Mjukbottenfauna. Bottniska Viken 2000. [www.havet.nu](http://www.havet.nu)

<sup>58</sup> Eriksson Wiklund, A.-K. and Andersson, A. 2014. Estuarine, Coastal and Shelf Science 144, 46-53.

way by national and regional agencies commissioning monitoring). Reporting of unusual observations should be considered a part of good practice in monitoring (e.g. cruise notes) and one that can be facilitated without requiring huge resource use by monitoring organisations.

Implementation of WFD and MSFD should create a clearer scenario for detecting and responding where there is a change of status of a monitoring station or water body out of good status or towards a poorer status. In theory this type of observation should trigger reporting to national authorities and a follow-up response, initially in the form of investigation to determine the cause and identify response measures.

The arrangements to ensure that information on threats can be derived from monitoring programmes, may need to be quite specific. However, based upon this review we can establish the following as elements of good practice:

- that agencies that commission regular assessments make sure that these assessments examine whether there are any specific trends of concern;
- that these agencies establish clear processes for responding where trends of concern are identified e.g. there needs to be some response mechanism involving reporting and considering whether it is necessary to trigger investigative research into the causal factors;
- an awareness on the part of organisations conducting monitoring of the need to report unusual observations, even if they are outside the direct focus of the monitoring. This needs to be complemented where relevant by watch/alert lists;
- consideration should be given to ensuring that occasional wider observation takes place beyond the strict inventories of parameters to be monitored, e.g. biological inventories or scanning of GC-MS output for unusual peaks.

#### **6.4 INFORMATION FROM MONITORING AS A BASIS FOR ACTIONS AND ACTION PROGRAMMES (GOVERNMENT OBJECTIVE 3)**

Government Objective 3 calls for environmental monitoring to provide information as a basis for actions and action programmes. While information from monitoring of pressure and state parameters can certainly be important in the development of actions, there are very few monitoring programmes that have been the sole basis for the development of programmes of measures. In practice, the development of actions and action programmes needs information on linkages between relevant activities that influence the monitored parameter, resulting environmental pressures and environmental state (activity-pressure-state relationships). There is also a need for combination with information on the hydrology, ecology, geography of the marine system. Information from monitoring is one part of this mosaic of information.

The combination of this information requires scientific analysis, investigation and modelling combining data from monitoring with data on human activities and their pressures and a conceptualisation of the structure and functioning of the marine ecosystem. In practice, data availability and confidence act as limitations on the scientific basis for measures and a degree of pragmatism or societal choice is needed in the selection and adoption of any measure. Economic costs, social acceptability and political will are important considerations in setting up measures. The exact role of information from monitoring alone may be difficult to trace.

A high profile example of where the use of monitoring data has provided a basis for measures is the Baltic Sea Action plan, where data from monitoring of input loads of nitrogen and phosphorus has been used in combination with modelled data to provide estimates of the required nutrient load reduction targets on a country by country and basin-by-basin basis. One of the major highlights of the action plan is that it established politically the concept of a maximum allowable nutrient input that still makes it possible for the Baltic Sea to reach a good ecological status. The Baltic Sea coastal countries acknowledged in the plan that 'there is a need to reduce the nutrient inputs and that the needed reductions shall be fairly shared by all Baltic Sea countries. At the time of the adoption of the BSAP, it was recognized that the calculated maximum allowable nutrient loads and the country-wise allocations were based on the best knowledge available at the time and that review and revision of the figures would be necessary as soon as more updated data, information and more advanced models becomes available. Further monitoring and assessment is the task of the HELCOM Monitoring and Assessment Strategy.

The Baltic Sea Action Plan is rather unique in that uncertainties in the modelled relationship between pressure from inputs and state in the Baltic Sea were not considered to be a barrier to achieving political agreement between coastal states of the Baltic. Indeed political will was such that ways were found to cope with concerns over these uncertainties. Likewise, in the well-established fisheries management framework, monitoring data from the national Coastal Fish monitoring programme and the International Bottom Trawl Survey are analysed against assessment criteria and in combination catch and fishing pressure data, to generate management advice.

The above examples demonstrate that the really essential base for the development of actions and action programmes is the scientific understanding of activity – pressure state relationship and alongside that information on the natural functioning marine system that any actions are seeking to protect. In the definition of a programme of measures for the first implementation phase of the MSFD, it is the uncertainty over this activity–pressure state relationship that has led to many of the proposed measures involving a high proportion of further research and investigation (SwAM, 2015<sup>59</sup>)

Well-defined analyses that link data on status in the marine environment and pressures data and factors that influence pressures are an important element of the knowledge generation to support the effective formulation and targeting of measures, especially the quantification of measures. Monitoring can play an important role in generating data on environmental status and pressures.

Information from monitoring also has an important role as a basis for the development of programmes of measures in the context of adaptive management, where there is an iterative development of measures informed by ongoing monitoring of their effects. This brings us on to Government Objective 4.

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59 Havs- och vattenmyndigheten, 2015. God Havsmiljö 2020. Marin Strategi för Nordsjön och Östersjön. Del 4: Åtgärdsprogram för havsmiljön. Havs- och vattenmyndighetens remissversion 2015-02-01. Dnr 3562-14)

## 6.5 INFORMATION FROM MONITORING ON THE EFFECTS OF ACTIONS OR ACTION PROGRAMMES (GOVERNMENT OBJECTIVE 4)

Determining the effectiveness of programmes of management measures is frequently cited as a key purpose of environmental monitoring. This type of monitoring is sometimes termed “operational monitoring” and is an important part of adaptive management. In this context monitoring can be used to check whether measures achieve the desired effects on the environment, to guide any adjustments to the measures programme (adaptive management) and to justify costs for economic and social sectors. The lack of proper assessment of the actual effects of different management actions was one of the main conclusions in the study done by Havsiljöinstitutet on the effect of the “Havsmiljöanslaget”<sup>60</sup>. Effective operational monitoring requires careful planning to show the effects of measures, ideally including sampling before and after actions and control sites in parallel with the operation of the measures. Of equivalent importance for effective information generation is planning and attention to the processes of developing assessments of the collected data. This requires effective dialogue mechanisms between analysts and environmental managers. Considerable additional value and knowledge generation can be extracted from monitoring data through the careful design of analytical questions and combined analysis of data from multiple sources. The Danish NOVANA programme provides an example of a monitoring programme closely integrated with implementation of action plans (see Box 6.1).

### **Box 6.1. Assessment of effects of nutrient reductions on Danish coastal waters based on monitoring data.**

A key step in any nutrient management strategy is monitoring for improvements in eutrophication status. In 1987 Demark initiated a series of Action Plans on the Aquatic Environment that specified mitigation measures to reduce nutrient losses from three sectors: agriculture, urban waste water treatment plants and industries with separate discharge. These nutrient reduction measures were based upon the tenet that degraded eutrophication status can be reversed through removal of nutrient pressure. The Action Plans included the NOVANA integrated monitoring programme for Danish waters (Conley et al. 2002<sup>61</sup>). To evaluate the effectiveness of the measures regular data-driven assessments and long-term analysis was necessary to provide evidence of whether coastal marine ecosystems are recovering. This, in turn, can be used to guide whether further measures are needed to reduce nutrient loads.

NOVANA (The Danish National Programme for Monitoring and Assessment of the Aquatic Environment and Nature) is an integrated programme with estimates regularly made of the inputs of nutrients from different sources (atmospheric deposition, point discharges, diffuse loading from agriculture and household waste waters) and the concentrations in the water column. Measurements are also made of nutrients and

60 Havsmiljöinstitutet (2013). Utvärdering av projektverksamheten av havs- och vattenmiljöanslaget 2007-2012. Rapporten skriven av Havsmiljöinstitutet (HMI) på uppdrag (HaV-4637-12) av Havs- och vattenmyndigheten. Havs- och vattenmyndigheten Rapport 2013:17

61 Conley, D.J., S. Markager, J. Andersen, T. Ellermann, and L.M. Svendsen. 2002. Coastal eutrophication and the Danish National Aquatic Monitoring and Assessment Program. *Estuaries* 25: 706-719.

biological responses in lakes, rivers and the coastal marine ecosystems. In addition, coordination with international programmes and regional sea commissions is an important component of the monitoring programme in order to contribute to the evaluation of progress towards internationally agreed upon reductions in nutrient inputs.

A number of scientific data centers were established in NOVANA, including a Marine Topic Centre (M-FDC). The center develops methods for sampling and data collection by local, regional and national authorities following common guidelines, which have been continuously updated (<http://bios.au.dk/videnudveksling/til-myndigheder-og-saerligt-interesserede/fagdatacentre/fdcmarintny/ta2011-2015/>). The M-FDC also provides nationwide data storage, data quality assurance and data processing. All data are publicly available on a web site associated with the programme. In addition, the M-FDC was responsible for preparation of nationwide scientific reporting.

The data and information originating from NOVANA monitoring activities resulted in the annual NOVA reports produced by a team of scientists, which have been used for regular evaluations of the effectiveness of the Danish Action Plan(s). All scientific and technical reports can be found on the web site of the Danish Centre for Environment and Energy (<http://dce.au.dk/udgivelser/>). The reports are science-based and targeted towards to provide regular scientific advice on solutions regarding the environment to their customers, who range from The Danish Ministry of the Environment and Danish municipalities, to the European Commission and private businesses. The M-FDC also produced peer-reviewed papers of eutrophication trends (Conley et al., 2000<sup>62</sup>; Carstensen et al., 2006<sup>63</sup>). As a result both the reductions in loads and the effects of these load reductions in Danish coastal waters are well documented: (1) inputs have decreased significantly, both for nitrogen and phosphorus, (2) nutrient concentrations in lakes, rivers and coastal waters have decreased significantly, (3) primary productivity and phytoplankton biomass have decreased as well, and (4) the ecological status of benthic communities has improved in some areas.

In Denmark agricultural practices have changed and sewage treatment from urban settlements and industries has improved over the last three decades. Analysis of monitoring data documents the trends in nutrient inputs and the delays in responses of various ecosystem components to these nutrient reductions. Nearly three decades after the first mitigation measures were implemented, all key ecosystem components show evidence of a gradually healthier coastal ecosystem (Riemann et al. 2015<sup>64</sup>), although Danish coastal marine ecosystems have not fully recovered. Without the monitoring programme the effectiveness of reduction measures would not be known. The activities of the Danish Monitoring and Assessment Programme demonstrate the importance of regular assessments to provide the necessary evaluations of the effectiveness of nutrient reductions.

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62 Conley, D.J., H. Kaas, F. Møhlenberg, B. Rasmussen, and J. Windolf. 2000. Characteristics of Danish estuaries. *Estuaries* 23: 820-837.

63 Carstensen, J., D.J. Conley, J.H. Andersen, and G. Ærtebjerg. 2006. Coastal eutrophication and trend reversal: A Danish case study. *Limnol. Oceanogr.* 51: 398-408.

64 Riemann, B., J. Carstensen, K. Dahl, H. Fossing, J.W. Hansen, H.H. Jakobsen, A.B. Josefson, D. Krause-Jensen, S. Markager, P.A. Stæhr, K. Timmermann, J. Windolf, J.H. Andersen. 2015. Recovery of Danish coastal ecosystems after reductions in nutrient loading: A holistic ecosystem approach. *Estuaries and Coasts* DOI 10.1007/s12237-015-9980-0

Future priorities for the management of nutrient loads and the impact of contaminants on chemical and biological conditions must be based on the knowledge gained from monitoring programmes.

Links between monitoring observations and measures are most directly observed at the local scale. Striking improvements of water quality in coastal areas affected by sewage discharges have been seen through the coastal recipient-control monitoring programmes (Boesch et al. 2006<sup>65</sup>). However, such changes to local environments need to be understood within the context of the variation of parameters in time and space at the sea-basin or regional-sea scale. The examination of the reported poor status of fish in Hanöbukten demonstrates the importance of this (SwAM, 2013)<sup>66</sup>. The organisation of Swedish marine monitoring, with national and county-level marine monitoring providing the context for local-scale monitoring, should allow for changes in the quality of local environments to be distinguished from variability at a larger scale, either regionally or on a whole sea-basin scale. However, use of data from the different programme levels is dependent on their consistency, comparability and availability, which is not assured. As mentioned earlier the analysis by Elam and Grimvall (2013)<sup>67</sup> has shown that a combined assessment of physical and chemical data between programmes is certainly possible, when steps are taken to understand bias within different parts of the programme. Leonardsson and Karlsson (2004)<sup>68</sup> have also presented an approach for analysing the data from the recipient-control monitoring by using the regional and national data as reference data (See also Underwood, 1998<sup>69</sup>). Steps to improve the comparability between the different elements of the monitoring programmes are essential to realise these approaches. Monitoring and analysis of fish community health beyond the regular scope of the national coastal fish programme has been needed to address the effectiveness of area-specific measures such as closed areas, with the national monitoring providing a context. Here consistency and comparability of data has been ensured through compliance with the national monitoring guidelines.

Developing an informed understanding of the processes in the Baltic has required the combined analysis of monitoring data with data drawn from multiple sources beyond the national monitoring programme. Assessments of monitoring data have highlighted a lack of improvement in the nutrient status of open Baltic Sea Proper areas in response to reductions in land-based inputs of phosphorus, which has not been predicted by modelling. Inputs of phosphorus have decreased by 60-70% since 1990s and models show decreasing phosphorus concentrations and decreased cyanobacteria blooms. However, empirical data from monitoring at station BY31 has showed no change in phosphorus concentrations. Integrated analyses of data

65 Boesch, D., Hecky, R., O'Melia, C., Schindler, D., Seitzinger, S. (2006). Eutrophication of Sweden's Sea. SEPA. 72pp.

66 SwAM (2013). Hanöbuktenutredning. Regeringsuppdrag. Havs och Vatten Myndigheten rapport 2013-10-31.

67 Elam, J. and Grimvall, A. (2013). Kvalitetsgranskning av fysikalisk- kemiska data från den regionala havsmiljöövervakningen. Havsmiljöinstitutet rapport nr 2013:2. 42pp.

68 Leonardsson, K., and Karlsson, A., (2004). Utvärdering av recipientkontrollprogrammet på mjukbottenfauna i Skellefteåbukten (Rönnskärsverken). Inst. för Ekologi och Geovetenskap och Umeå Marina Forskningscentrum Umeå universitet also in Samordnat nationellt-regionalt bottenfaunaprogram för egentliga Östersjön, Leonardsson report to SEPA

69 Underwood, A.J. and Chapman, M.G. (1998). Spatial analyses of intertidal assemblages on sheltered rocky shores. *Aust. J. Ecol.* 23, 138-157.

from multiple sources have shown that at the same time hypoxia has increased, partly due to physical factors related to salt balance, and P release from sediments has increased tremendously (Conley et al. 2002<sup>70</sup>)(see Box 6.2).

**Box 6.2. Hypoxia burden in the Baltic: Benefits of analyzing data from multiple sources and the large amount of data available beyond the national monitoring programmes**

Excessive nutrient inputs over the last century have altered the subtle balance between oxygen supply and consumption and changed the Baltic Sea from a state with hypoxia confined to the deepest bottom waters to widespread hypoxia in most bottom waters. However, determination of the areal extent of hypoxia is highly dependent upon the large spatial distribution of stations sampled by different countries around the Baltic Sea (Fonselius and Valderrama, 2003<sup>71</sup>).

In a recent study by Carstensen et al. (2014<sup>72</sup>) the extensive network of water column oxygen and salinity profiles were used to reconstruct oxygen and stratification conditions over the last 115 years and compare the influence of both climate and anthropogenic forcing on hypoxia. This work brought together the extensive data available from different countries; their monitoring programs and research cruises allowed for the computation of basin-wide trends of stratification and oxygen conditions over more than a century.

The first measurements of salinity, temperature, and oxygen in the Baltic Sea were carried out in the late 19th century, but the number of profiles before 1960 was low with most profiles from research cruises. Reasonable data coverage after 1960 has allowed assessment of the extent of hypoxia through spatially interpolating the values, but such purely empirical approaches are not applicable to the period before 1960 due to the sparseness of data. Therefore, Carstensen et al. (2014) chose an approach that statistically modelled salinity and oxygen profiles with a small number of parameters, and use the spatial and seasonal structure of these parameters to assess the properties of the halocline and the oxygen conditions below the halocline from 1898 to 2012. The low oxygen zone has increased by a factor of 10 times over the last 115 years. It has grown from about 5000 km<sup>2</sup> around 1900 to more than 60 000 km<sup>2</sup> in recent years.

Baltic Sea wide assessments are dependent upon the high-quality measurements made by the countries surrounding the Baltic Sea. In the Carstensen et al. (2014) study the data from the Swedish monitoring program comprised about 20 percent of the total measurements. Therefore, this work demonstrates the importance of integrated assessments of data from multiple sources and the benefits of having access to and using the large amount of data available beyond the national monitoring programmes.

70 Conley, D.J., C. Humborg, L. Rahm, O.P. Savchuk, and F. Wulff. 2002. Hypoxia in the Baltic. Sea and basin-scale changes in phosphorus biogeochemistry. *Environmental Science and Technology* 36: 5315–5320. doi: 10.1021/es025763w.

71 Fonselius, S., J. Valderrama. 2003. One hundred years of hydrographic measurements in the Baltic Sea. *Journal of Sea Research* 49: 229–241

72 Carstensen, J., J. Andersen, B.G. Gustafsson, D.J. Conley. 2014. Deoxygenation of the Baltic Sea during the last century. *Proceedings of the National Academy of Sciences USA* 111: 5628–5633.



Regular assessments of data on contaminants in biota (e.g. Naturhistoriska Riksmuseet, 2013<sup>73</sup>) are primarily descriptive and include relatively few analyses of factors influencing trends. For persistent synthetic man-made pollutants that are subject to long-range transport the identification of downward trends in monitoring data has been used to infer that bans or controls at a national and international scale have been effective, e.g. recovery of seal and sea eagle populations, and the decrease in concentrations in these species of regulated contaminant levels (lindane, CBs, DDTs). Similar inferences have also been drawn for naturally-occurring substances (e.g. lead, mercury). Assessments of national monitoring data also show signals that more recently introduced synthetic chemicals have increased (Faxneld et al. (2014)<sup>74</sup>, and that contaminated sediments continue act as a continued source to the environment after releases to the environment have been controlled.

Effective follow-up of measures within an adaptive context requires more in-depth analysis that explores and identifies if trends and their spatial pattern can be explained by information on how effectively controls have been implemented. Follow-up of measures should coordinate environmental monitoring with monitoring of how the implementation of the measures is progressing among the authorities and other actors in society. For example, for input load monitoring it could be considered that the lack of combined analysis with corresponding data on how far measures were implemented physically within catchments limits the amount of useful information that is extracted from the monitoring to direct further management. From the assessment of riverine input data the overall aggregated effect of measures within a catchment can be understood, but is this sufficient to identify and address problems in the application of required measures?

Conclusions drawn from the analysis of monitoring data need to be revisited through the extension of monitoring time-series and reanalysis as marine ecosystems can display non-linear and chaotic behaviour, showing sensitivity to initial conditions and, thus, are potentially unpredictable in the medium to long-term perspective. One of the most important activities of a long-term monitoring program should be a regular in-depth evaluation of collected data. Regular evaluation ensures that information on the state of the environment is updated and also that societal understanding of the factors influencing environmental status is refreshed.

For example, the use of empirical relationships between chlorophyll and nutrient concentrations constitute fundamental quantitative tools for predicting effects of nutrients on aquatic ecosystems. Nutrient management plans based on such linear relationships, mostly established during periods of increasing rather than decreasing nutrient concentrations, assume full reversibility of eutrophication. An analysis of the response to nutrient abatement in coastal marine ecosystems that received increased nutrient inputs from the 1960s to the 1980s showed that the trajectories of many coastal ecosystems are not directly reversible (Duarte et

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73 Naturhistoriska Riksmuseet (2013). Övervakning av metaller och organiska miljögifter i marin biota, 2013. Naturhistoriska Riksmuseet Report nr 1:2013. National Environmental Monitoring Commissioned by the Swedish EPA. <http://www.nrm.se/download/18.3688e97313f58cd832059a0/1376578049930/Marinrapporten+2013.pdf>

74 Suzanne Faxneld, Björn Helander, Britt-Marie Bäcklin, Charlotta Moraeus, Anna Roos, Urs Berger, Anna-Lena Egebäck, Anna Strid, Amelie Kierkegaard, Anders Bignert. (2014). Biological effects and environmental contaminants in herring and Baltic Sea top predators. Naturhistoriska Riksmuseet report 6:2014.

al. 2009<sup>75</sup>). In addition, the chlorophyll-*a* versus nitrogen relationships are non-linear and display convoluted trajectories over time. Our current understanding suggests they may result from large-scale changes, possibly associated with global climate change and increasing human stress on coastal ecosystems (Carstensen et al. 2011<sup>76</sup>). Understanding ecosystem response to changes in nutrient loading through time is essential to set reliable targets for restoration efforts.

Ambitions to manage whole sea basins and areas, such as the Baltic Sea, must recognize that there is no alternative reference system to compare with. Changes in monitored measurements need to be interpreted when they occur and, if possible, separated them from natural variations. This is a formidable task since intermittent events connected to the exchange with the North Sea can have very extensive effects. Joint evaluation of model outputs and observational data can contribute to more precise attribution of trends detected in observational data (see Box 6.3).

Many large-scale ecological systems, such as the Baltic Sea, may require one or several decades in order to respond remedial measures and therefore appropriate action to improve the environmental state must be informed by long-time series. We are now at a stage where for some variables we have fragmentary information from 100 years back in time and high-quality data from about 20 to 40 years back. Our understanding of fundamental processes has improved considerably and continues to grow. Continuation of robust monitoring is of paramount importance for understanding and model development, and it is critically important that data from monitoring is made available for scientific analysis and investigation to support this understanding.

**Box 6.3. Using process-based catchment models to estimate the total effect of measures to reduce nutrient loads**

Time series of riverine loads of nutrients are often difficult to interpret because effects of human interventions in the drainage area can be strongly modified by natural fluctuations in river discharge. To reduce such interpretation problems, several statistical approaches have been developed to filter out weather-driven variation in measured data. In particular, there are several parametric or semi-parametric methods for flow adjustment of empirically determined loads or concentrations of nitrogen and phosphorus (e.g., Stålnacke & Grimvall 2001<sup>77</sup>; HELCOM 2011<sup>78</sup>).

A study of nitrogen and phosphorus concentrations at all major river mouths in Sweden revealed that process-based catchment models can offer alternative methods to filter out natural fluctuations. More specifically, outputs from the catchment model S-HYPE

75 Duarte, C.M., D.J. Conley, J. Carstensen, and M. Sánchez-Camacho. 2009. Return to Neverland: Shifting baselines affect ecosystem restoration targets. *Estuaries & Coasts* 32: 29-36.

76 Carstensen, J., M. Sanchez-Camacho, C.M. Duarte, D. Krause-Jensen, and N. Marba. 2011. Connecting the Dots: Responses of coastal ecosystems to changing nutrient concentrations. *Environ. Sci. Technol.* 45: 9122-9132.

77 Stålnacke, P., & Grimvall, A. (2001). Semiparametric approaches to flow-normalisation and source apportionment of substance transport in rivers. *Environmetrics*, 12, 233-250.

78 HELCOM (2011). Fifth Baltic Sea Load Compilation (PLC-5). Baltic Sea Environment Proceedings No. 128.

(Strömqvist et al., 2012<sup>79</sup>) were used to filter out weather-driven variation in measured data from the national river mouth programme (SLU, 2013<sup>80</sup>). The principal premise in this investigation was that model runs with constant anthropogenic forcing can be used to extract the weather-driven temporal variation in the concentrations of total nitrogen and phosphorus. Provided that the model applied is reasonably correct, and there are no significant interaction effects of the physical and anthropogenic forcing, the difference between observed concentrations and the model outputs can then be regarded as an estimate of the combined impact of human interventions in the catchment.

The results obtained for total nitrogen showed that, after using S-HYPE outputs to filter out weather-driven fluctuations, the presence of downward trends had a very distinct spatial pattern. The most significant downward trends were obtained for the four catchments with the largest proportions of agricultural land (Råån, 90%; Skivarpsån, 85%; Kävlingeån, 63%; Smedjeån, 40%). Considering that substantial efforts have been made to establish agricultural practices that reduce the loss of nutrients it was concluded that these downward trends could be attributed to changes in the agricultural sector. This is in line with the findings of a recent study of nutrient losses from small agricultural watersheds in Sweden (Fölster et al. 2012<sup>81</sup>). Conventional flow-adjustment would have indicated that downward trends were present also in other catchments (e.g., Göta River), where human interventions have been less pronounced but unusual weather events occurred during the studied time period.

Evaluation of modelled and observed total phosphorus concentrations raised questions about both the performance of the S-HYPE model and the ability of the present systems to ensure that environmental monitoring data are not seriously contaminated by measurement errors. The relationship between observed and modelled concentrations was generally weak. Moreover, a statistically significant shift in the observed concentration levels occurred between 2001 and 2002, and this coincided in time with a change in instrumentation at the laboratory responsible for the river water monitoring.

## 6.6 CONCLUSIONS

There are good examples of important and valuable information being derived on the basis of marine monitoring data. While the primary goals of Sweden's marine monitoring, (i.e. to assess the state and threats to the marine environment and evaluate if the national environmental quality standards are fulfilled) are the focus of regular assessment processes, the use of data generated by these programs in a broader scientific context is critical to further develop knowledge of the marine ecosystems surrounding Sweden and provide a coherent basis to

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79 Strömqvist, J., Arheimer, B., Dahné, J., Donnelly, C., & Lindström, G. (2012). Water and nutrient predictions in ungauged basins: set-up and evaluation of a model at the national scale. *Hydrological Sciences Journal*, 57, 229-247.

80 SLU, Water chemistry data. <http://info1.ma.slu.se/db.html?epslanguage=sv> Accessed 26 Aug 2013.

81 Fölster, J., Kyllmar, K., Wallin, M., & Hellgren, S. (2012). Kväve- och fosfortrender i jordbruksvattendrag. Har åtgärderna gett effekt? Rapport 2012:1 (in Swedish). Department of Aquatic Sciences and Assessment, Swedish University of Agricultural Sciences (SLU), Ultuna, Sweden.

assess and understand the effects of management actions and provide a basis for guiding management.

There has long been a substantial use of monitoring data in research, but a close integration of monitoring and research is less common. This is clearly demonstrated by the references given in a survey of trends and knowledge gaps in Baltic Sea science by Rolff and Nekoro (2013)<sup>82</sup> of which the vast majority are found in peer reviewed international journals, a few are HELCOM, ICES or OSPAR reports, and still fewer are from HAVET or reports from national, or regional authorities.

We conclude that more value could be extracted from existing monitoring efforts through a clearer information strategy giving more emphasis to assessments and knowledge building for environmental management as a main objective and purpose of monitoring. This should include both a strategic specification of which national and international information needs are to be fulfilled through regular assessments as well as the facilitation of closer integration between monitoring and research as a means of addressing a wider range of analytical questions relevant to government objectives for environmental monitoring and international requirements other than government objectives for environmental monitoring.

Understanding of Sweden's seas has increased greatly in the last decade. Many processes have become quantitatively better known and models have been developed to describe them. The greatest and most important knowledge gaps are in understanding of the food web and the general biogeochemical cycles of the nutrients and carbon. There is still a great need for fundamental scientific interdisciplinary work, both in the field, and in laboratory and theoretical work to address these gaps. Since most of the large-scale processes can only be studied at the spatial and temporal scale that they occur, the value of quality assured, high frequency, long-term monitoring must be emphasised. Connecting long-term monitoring with long-term ecological research, including experimental work and modelling, is a strong mechanism for providing efficient data flow, quality assurance, preserving methodological and taxonomic skills and providing modelling with new ideas for conceptual understanding.

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82 Rolff C and Nekoro M, 2013. A survey of some current trends, scientific standpoints and knowledge gaps in Baltic Sea science. Stockholms universitets Östersjöcentrum. In: Miljösituationen I Östersjön-en översiktlig bedömning av kunskapsläge, trender och forskningsbehov. Redovisning till Miljödepartementet Januari 2014.

## 7 COMMENTS ON THE ORGANISATION OF SWEDEN'S MONITORING AND ASSESSMENT

### 7.1 INTRODUCTION

This chapter considers the overall organisation of Sweden's marine monitoring and develops comments on themes raised during interviews with monitoring practitioners and by the project group. We also draw on the experience of SIME as an organisation charged with carrying out national analysis and synthesis of data and information on Sweden's marine environment. Some of the issues mentioned here have started to be addressed for parts of Sweden's marine monitoring programmes. We recommend that they should be implemented across the entirety of Sweden's marine monitoring effort.

### 7.2 COORDINATION

The overall structural design of Sweden's monitoring programmes into different geographic programme levels (national, regional and local) has its basis in the Swedish Environmental Code and the historical organisation of Sweden's environmental monitoring work. It should have the benefit of enabling interpretation of changes at a local level within a regional context and within a whole sea-basin context. Bringing together data from all three programme levels would also strengthen environmental analysis as has been shown by Carstensen et al. (2014) and Moksnes et al. (2015)<sup>83</sup>. The resolution of national marine monitoring programmes alone provides limited power for understanding environmental status and addressing government objectives for environmental monitoring and the addition of regional and local data can substantially improve the situation. The assessment requirements of the Water Framework Directive, Marine Strategy Framework Directive and the corresponding environmental quality standards provide strong drivers to improve spatial resolution of data.

Realising the full potential of the monitoring system for environmental analysis depends upon effective coordination between the different elements, so that all parts are working with the same approaches and with the same goals. The need for greater coordination between these elements has long been recognised. SEPA (1990)<sup>84</sup> highlighted that coordination is necessary "if we are to be in a position to assess the overall environmental state of the country at regular intervals, and that as a basic prior condition of coordination all the different elements of environmental monitoring should have the same aims".

Data from national, regional and recipient-control programmes are not yet in consistent form and comparability has been demonstrated in relatively few cases. It is hard to see this as making the best use of investments in monitoring. More value could be extracted from these investments by increased attention on the coordination of national, regional and recipient-control monitoring programmes. This has been addressed to an extent in the response to the Government assignment on water-related recipient-control monitoring (SwAM, 2015). More focus is needed on achieving the objective of joint assessments of data from all programmes.

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83 Moksnes, P-E., Grimvall, A. and Elam, J. (2015). Samlad analys av regional och nationell havsmiljödata. Havsmiljöinstitutets Rapport NR 2015:2.

84 SEPA (1990). Monitor 1990. Environmental monitoring in Sweden. SEPA (ed. Bernes, C.). 180pp.

Improved coordination will realise additional benefits for scientific synthesis of data, interpretation and interaction with academic research.

Various structural elements exist to support coordination. We have not examined the working procedures that are in place to apply these in order to ensure coordination. However, during the course of project interviews and discussions a number of issues have arisen which we address in the following paragraphs.

*Can the overall strategy for marine monitoring be more clearly set out?* It is unsatisfactory that when national assessments are prepared (such as those in HAVET), a substantial effort needs to be given to assemble data from the different monitoring programmes. Steps to optimise the return on financial investments in monitoring would seem justified. Giving more emphasis to the eventual use and purpose of monitoring data can provide a clearer overall direction to the way that monitoring and assessment is organised. A clear strategic objective that national assessments should evaluate national, regional and local data would underpin and direct this optimisation. For example, a specific target that data from both national and regional programmes is available and usable in assessments within, for example, two years could also be useful. This could be supported by the development of data flow protocols running from data collection to their transformation into information setting out for how data for each indicator/parameter should be brought together, assembled and evaluated in order to fulfil information needs. We consider the organisation of assessment work itself later in this chapter.

*Can this strategy be more effectively communicated?* Effective communication of national objectives at all levels is needed. This starts outwards from national authorities. We have also noted experience from monitoring of benthic macrofauna in the Gulf of Bothnia where coordination between national monitoring and regional monitoring has worked well and the data from national monitoring can be used in a combined way in assessments as there has been a coherent use of methods and control procedures across those performing monitoring. Although, there is probably not one single reason for this, a clear benefit accrues from having personnel with dedicated responsibilities who can effectively maintain all parties focus on coordination underpinned the efforts in this direction.

*Are there ways of insisting on consistency and comparability?* Developing consistent and comparable data requires that all organisations generating data are using standardised methods and have comparable levels of performance and that this becomes a requirement from those commissioning monitoring activities and using data. While recommendations on improving monitoring guidelines and guidance for recipient-control design have been made (SwAM, 2015), this may not be enough without a concerted cultural change towards consistent and comparable data throughout the Sweden's marine monitoring system. There is successful practical experience of communicating on goals for combined assessment of national, regional and recipient control monitoring programmes in the north of Sweden which could be built on (Leonardsson, pers. comm.). Seminars, workshops, and communication can also be used to emphasise the aims for assessments and the need for improved coordination. Finally, inclusion of data in assessments can also be guided by a systematic evaluation of data quality with the performance of different monitoring organisations is reported alongside the assessment.

### 7.3 DATA STEWARDSHIP

The term data stewardship is used in a data management context to refer to the management and oversight of an organisation's data assets. It aims that high-quality data are available in a consistent manner by providing a means of considering the tactical coordination and implementation of data policies and strategies throughout the life-cycle of data. It is, therefore, intimately linked to the chain of activities involved in monitoring and assessment.

The approach to management of Sweden's marine data resources would benefit from a much more explicit articulation by national authorities. While many organisations are involved in the data flow chain from data creation to use in assessment and archival, the respective responsibilities of national data hosts and data producers, their purposes and the way that they should work with each other could be communicated at a general level as part of a joint effort with overall mutual benefit.

At the data acquisition stage, consistent and comparable data require that standardised approaches are used towards ensuring content and quality of data. The current set of monitoring guidelines (undersökningstyp) provides an excellent basis for standardisation of monitoring, however, although they are used and adhered to in several monitoring programmes, there are some monitoring programmes where they are not followed. These guidelines should provide the basis for standardisation across national, regional and local monitoring. National authorities should reinforce the need for organisations commissioning and carrying out monitoring to apply the guidelines at all relevant opportunities.

Uptake and acceptability of the monitoring guidelines is critical for any reinforcement to be successful. The guidelines need to be reviewed and where necessary updated to ensure that the different variables are appropriate and calibrated. Larsson et al (2013)<sup>85</sup> have identified a number of issues where the guidelines need to be updated. The current monitoring guideline for phytobenthic monitoring appears to be a very extreme example of a guideline that does not support the generation of consistent data by prescribing the use of a number of different approaches generating incomparable data with different units. This needs revision to ensure that consistent approaches are taken at least within the same sea-basin.

A further issue is the lack of clarity on how new methodologies and technologies, being developed through a number of technology projects, are evaluated and, if appropriate, incorporated within the monitoring guidelines. There is a need to develop and implement strategies for calibrating the use of new methods to ensure that they produce comparable output to existing methods.

Data specifications within the monitoring guidelines provide the foundation for subsequent steps in the data stewardship chain. They must also be up-to-date and make sense to organisations that are applying them. SwAM (2015) proposes a clarification of the monitoring guidelines. It is really important that there should be a consultative element to any review or updating in order to take into account the experience of those practitioners who are expected to apply them. At the same time it should be absolutely clear that once agreed and issued by

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<sup>85</sup> Larsson, U., Blomquist, M., Höglander, H., and Walve, J. (2013). Kvalitetssäkring inom den akvatiska miljöövervakningen idag och i framtiden. Draft report in response to a commission from SwAM (2013-06-05). 53pp.

national authorities, regional and local authorities must require their use and monitoring practitioners are required to apply them.

## 7.4 DATA QUALITY

All data collected should have a high quality in order to provide a comparable and consistent picture of the environment they intend to describe. Each data should be accompanied by all the necessary quality information so that other users, now and in the future, are able to assess, and account for, its quality. Quality assurance in Sweden's aquatic environment monitoring has recently been reviewed by Larsson et al. (2013) under commission from SwAM.

### Data quality during generation

Authorities commissioning and requiring monitoring have a critical role in ensuring the quality of monitoring data through appropriate documentation for procurement and commissioning. Performance of organisations involved in monitoring is an important value-for-money consideration during procurement. It can be seen as a reasonable and basic requirement that organisations performing monitoring for national purposes are accredited, e.g. by complying with ISO/IEC 17025:2005 and its accreditation by SWEDAC. However, following review of contracts for national monitoring, Larsson et al. (2013) observed that accreditation of monitoring is not consistently required.

There are also needs for national coordination of quality assurance for biological data through regular inter-laboratory comparison tests (at regional, national and international scales) to maintain and monitor the quality of the analysis. Information on the results should be available and stored with the data. Inter-laboratory testing would require establishment of national reference laboratories. There are also quality control schemes internationally. It may be possible to participate in these where this is not already used as an option.

There is a coupled issue on the need to maintain sufficient support for development of taxonomic expertise. As highlighted by Boero (2010)<sup>86</sup> the pool of trained taxonomists in many countries has shunk in recent decades alongside an overwhelming focus on investment in new technologies in Universities and no clear responsibility amongst other authorities. A combination of novel and traditional methods is essential to characterise and assess biodivers

It is really critical that information on data quality is reported to the data hosts to ensure that it is archived and available for examination by those making use of the data for analytical investigations. National data hosts do not always archive all the fields that can be required for assessment of data and important metadata are not included.

### Data quality during reporting

One important component in a well-functioning data management system is to have tools for ensuring that data are entered and reported to the data-host in a way that fulfils consistent

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<sup>86</sup> Boero, F., 'Study of species in the era of biodiversity: a tale of stupidity', *Diversity*, Vol. 2, No 1, pp. 115-126. 2010 (doi:10.3390/d2010115).



quality standards. This is perhaps particularly important for biological data containing information about abundances of species, where, the risk of misspelling, for example of taxon names, is very large unless there are protective systems prohibiting this.

Judging from various presentations from the data-host, it appears that there exist a number of such tools for different types of data, but two of the most well-known examples for biological data are “Marina Transekt” (MarTrans) and “Benthic Data” (BEDA). These are specific applications based on Microsoft Access database software, developed on commission from SEPA by a private consultant (HAFOK AB). These tools clearly provide useful quality procedures and another important aspect is that the databases are coupled to routines, which allows the consultant to extract various indices used in status assessment. Nevertheless, despite their obvious benefits, several aspects related to these tools and their roles in the overall data management system are not entirely clear. For example, it is uncertain whether they are used in all monitoring programmes; the tools seem to function as parallel databases in relation to the national data-hosts; the formal partitioning of responsibilities access rights among data-producers, consultants, data-host and potential users are not evident.

SEPA and SwAM are in the process of developing a validation service that can be used to check data exchanged between a data supplier and national data host against a data specification to ensure it meets recognised standards before inclusion in national databases. Some validation criteria have been set up for most data hosts and are being tested and implemented with the data hosts in a stepwise fashion. The validation service has been implemented for air quality and is now being tested for data on toxic substances, fish monitoring in lakes, groundwater, oceanography and marine biology. It may take some time until data specifications are available for all marine data types. Checking of old data using the validation service may be done where data hosts are commissioned to carry out control of time series, although correction of errors will depend upon whether the data supplier can still be required to correct errors. SwAM and the data hosts are aware that communication with data suppliers will be essential to make data flows work efficiently. One advantage with a validation service will be that the data format used by the data supplier will be more clear and unambiguous and it will hopefully make it easier for the data supplier to plan the work since feedback from the validation services will be immediate and not arrive after the data host has checked the data.

A common, agreed station dictionary that is adhered to by all data producers has been a long-term need. This is needed to ensure a standardised entry of monitoring data into national databases with standardised time and georeferences and with inconsistencies and duplication of station names removed. SEPA have been working on an authoritative dictionary of Swedish monitoring stations for a number of years. SEPA and SwAM have developed a national station dictionary and made this available through a cloud service. National data hosts have been busy populating the dictionary and are engaged in the substantial task of quality checking the reported sites against different organisations commissioning data. Data hosts and the validation service will then follow the protocol of checking that reported stations are described consistently with the station dictionary before the inclusion of data in national databases.

### **Data quality during use**

The use of data in assessments also provides an important quality assurance function. Extractions of data from the national data hosts can be very time-consuming with considerable treatment of data required to enable assessment. This hampers the transformation of monitoring

data into information products. A number of data hosts have undertaken work to improve the possibilities for download of data from their web sites including the information that is available on the data sets and the possibilities for combining datasets. This work is extremely valuable as a basis for reducing the degree of manipulation that is needed in downloaded datasets. These improved tools for access of data held by the data host need to be combined with strictly defined station and sample identities and descriptions of measurement techniques

Throughout the data chain there are needs for a strict procedure for handling the identification of errors in the data. One of the benefits of assessing datasets should be the quality assurance function provided through the identification of errors. It is possible that data will be assessed or analysed by data providers, by national researchers and analysts and by international assessors (e.g. in HELCOM and OSPAR). We are not aware of a documented protocol for ensuring that wherever errors are identified they are corrected in all copies of dataset. We note here that most monitoring providers retain their own copy of a dataset as the basis for their assessments and do not use the national data host version. Protocols to ensure the ongoing integrity of the datasets would be of benefit, so that, whether an error is identified by a user of the national data host dataset or by the data originator data errors are corrected in the main copies of the data.

## 7.5 ORGANISATION OF ASSESSMENTS

More emphasis needs to be given to the transformation of monitoring data into environmental information through marine assessments and in turn to knowledge building that can guide and inform environmental management. The absence of an explicit plan for organisation and development of assessments, especially those at national level, was a common observation from those involved in monitoring that we have spoken to during this project. Clarification of goals, requirements, leadership, project management and implementation responsibilities will support and enhance the preparation of national assessments and can be used to drive marine monitoring (see Box 7.1).

Although there are some dedicated assessments for sub-programmes, the main assessment output for monitoring data is the HAVET report. HAVET reports currently mix a routine updating on status with an accessible more journalistic presentation readable by a wide audience and explorations of specific issues through its "perspectives on the marine environment" section. Although HAVET is highly appreciated by the authorities, universities and public (Moksnes et al., 2015) there is a relatively low transparency of how assessments are developed. There is no clear explanation of criteria for data to be used or defined working methods for how a status assessment is to be carried out, such as a "decision tree" where it is possible to follow the results of the indicator level to final assessment.

The Danish NOVANA monitoring programme produces regular NOVA assessment reports, which take a more science-based approach to reporting on monitoring. NOVA reports were targeted towards providing regular scientific advice on solutions regarding the environment to their customers, who range from The Danish Ministry of the Environment and Danish municipalities, to the European Commission and private businesses. A comparison of the current HAVET report with NOVA assessments highlights that there is a gap in the type of information that could be generated based on Sweden's marine monitoring with there being no rigorous and transparent scientific assessment of the data. Steps which could be taken to strengthen the reporting in HAVET, include:

- combined assessment of regional and national monitoring data when this is possible;
- a condition assessment with clear structure and high transparency could be developed, for example, using the assessment tools used within the HELCOM holistic assessment;
- assessment of data representing societal factors that influence the state of the sea;
- structured review of relevant scientific literature to assessed issues;
- deepened analysis of combined datasets;
- transparency of assessed data and criteria for data selection and assessment;
- explanation of assumptions and uncertainties;

Assessments and analyses need to contribute toward knowledge building on how to manage human interactions with the sea. They should also guide further monitoring and connect up key data series on a regular basis. A more analytical, inquiry-based use of monitoring data could be promoted by encouraging collaborative analysis across and beyond marine monitoring programmes including data providers and analytical experts.

Assessment requirements should be clearly articulated and communicated to all involved parties in order to drive Sweden's monitoring and assessment system. As we have already commented, the objective of a joint assessment of national, regional and local data should be set to make clear the expectations for availability, usability and quality of data from all parts of the programme. The purposes of national and regional assessments need to be clearly specified by the commissioning agencies, with an explicit identification of which of the government objectives for marine monitoring and which international requirements need to be addressed. Where possible, the stipulation of scientific standards, such as accuracy, geographical resolution and manner of coverage can help to guide long-term capacity development amongst organisations conducting monitoring.

Within assessment, information drawn from monitoring must be set within a context of information on the ecosystems concerned. Prevailing understanding and uncertainties of ecosystem functioning needs to be reflected, relevant to the issue being assessed so that any tendencies towards over-interpretation are buffered.

#### **Box 7.1. Elements needed for a strategy for a national marine assessment**

A main objective for marine environmental monitoring that recognises that its purpose is to support assessment and analysis that improves knowledge of:

- the status of marine ecosystems (Government objectives 1 and 5),
- potential risks to ecosystem health and human welfare (Government objective 2),
- intervention options and their efficiency to achieve or maintain good environmental status, (Government objectives 3 and 4), and;
- the role of societal phenomena and behaviours in the pressures on marine ecosystems (Government objective 6).

A commissioning specification for regular assessments that specifies:

- a. the Government Objectives for environmental monitoring to be addressed;
- b. the national and international legal requirements to be addressed;
- c. the data from national, regional and recipient control monitoring programmes to be included;
- d. quality criteria to govern inclusion of data;
- e. assessment criteria to be used
- f. requirements for area-based assessment to guide the use of aggregation and interpolation techniques;
- g. peer review requirements and procedures;

Defined responsibilities for the production of the national assessments, including clear contractual responsibilities for monitoring experts to prepare assessments

Promotion of a more analytical, inquiry-based use of monitoring data that drives improvements in monitoring and promotes knowledge building, through encouraging collaborative analysis beyond marine monitoring programmes involving data originators and the science community in:

- a. analysis with contextual (control) data from a wider spatial scale,
- b. analysis with data on contextual physical and chemical parameters
- c. analysis with data on changes in human activities and pressures in response to actions and measures
- d. analysis that clarifies the functioning of marine ecosystems, how they respond to input or removal of substances and organisms, and how societal phenomena and behaviours contribute to such disturbances

Finance available to support work on deeper analysis of issues that require further analysis

A process for dealing with the identification of unusual observations following up from early warning identified from monitoring

A stronger focus on ensuring that data from marine monitoring are discoverable and accessible to promote involvement of scientific analysts and researchers. It could be instructive to work to achieve this if national authorities organised the development of a list of datasets that should be publically available, but are not currently, and used this to guide efforts to address the availability.

Identifying a set of requirements for integrated environmental assessment for which data should be standardised and comparable.

## 7.6 INCREASED INTERACTION WITH THE SCIENTIFIC COMMUNITY

In parallel to the routine processes for assessing these data a more in-depth analysis of monitoring data needs to be promoted to address the full range of government objectives for

environmental monitoring. Initiatives from researchers operating outside the regular monitoring community are needed to cross-fertilise these investigations. The science community can, in particular, help to clarify the functioning of marine ecosystems, how they respond to input or removal of substances and organisms, and how societal phenomena and behaviours contribute to such disturbances. This will have particular scientific value for the definition of programmes of action.

A more collaborative process between national authorities and the scientific community in formulating in-depth analytical investigations of monitoring data would foster interest, investigation and provide a greater return on the investments in monitoring. This needs to be supported with funding, but will have benefits in ensuring a better use of investments in monitoring.

A possible process to encourage a collaborative approach would involve:

- a regular joint seminar between data originators, analytical experts and environmental managers focused on monitoring data and information on environmental and societal dynamics and ecosystem processes in Sweden's seas. The Havsmiljöseminariet has been used as process to bring together those involved in monitoring, reporting and commissioning of monitoring. It could be used to encourage wider engagement in the issues that are being monitored by involving scientists from the wider science community.
- a call for proposals from researchers and analysts for investigations of analytical questions identified by the seminar;
- an advisory board of experienced scientists and regulators to review and advise on questions to be addressed and to select proposals for investigations that should be funded.
- availability of funding support for this more in-depth investigation.

## 8 CONCLUSIONS AND RECOMMENDATIONS

*Conclusion 1: More focus is needed on the information to be extracted from monitoring. A greater focus on assessments and knowledge building to inform environmental management is the key to meet the full range of government objectives for environmental monitoring.*

**Recommendation: A main objective and purpose of monitoring that gives more emphasis to assessments and knowledge building, by**

- i. defining clear objectives and targets for assessments that improve knowledge of: the status of marine ecosystems, and also consider potential risks to ecosystem health and human welfare, intervention options and their efficiency to achieve or maintain good environmental status, and the role of societal phenomena and behaviours in the pressures on marine ecosystems
- ii. using these objectives and targets to drive and direct the organisation of monitoring

*Comment:* National authorities need to ensure that the objectives and targets are defined in collaboration between data originators, analytical experts from the wider science community and environmental managers.

*Conclusion 2: A more analytical, inquiry-driven use of monitoring data is needed to drive improvements in monitoring and to promote knowledge building.*

**Recommendation: Promote a more analytical, inquiry-driven use of monitoring data, by**

- i. establishing goals for addressing a wider range of analytical questions relevant to government objectives for environmental monitoring and international requirements
- ii. establishing clearly defined responsibilities for developing national assessments
- iii. encouraging collaborative analysis across and beyond marine monitoring programmes involving data originators and analytical experts from the wider science community
- iv. introducing scientifically rigorous editing and peer review before publication of assessments

*Comment 1:* National authorities need to establish a clear plan for the preparation of national assessments identifying clearly the overall leadership, project management and implementation responsibilities, including leadership and implementation responsibilities for thematic analyses.

*Comment 2:* The role of and timing of Havsmiljöseminariet should be reviewed to optimise its role for discussing and formulating analytical assessment questions.

*Conclusion 3: Knowledge building can be promoted through increased interaction between monitoring analysis and the research community.*

**Recommendation: Establish collaborative processes between agencies, current reporting processes and the research community, by**

- i. developing a process enabling research scientists to submit proposals to agencies for collaborative investigation of monitoring data
- ii. developing the role of existing marine monitoring seminars
- iii. offering funding to develop a scientific basis for actions or action programmes

*Comment:* In particular, the science community can help to clarify the functioning of marine ecosystems, how they respond to input or removal of substances and organisms, and how societal phenomena and behaviours contribute to such disturbances.

*Conclusion 4: A more effective coordination between all monitoring programmes will improve assessments and facilitate knowledge building.*

**Recommendation: Promote coordination between marine monitoring programmes, by:**

- i. emphasizing the importance of considering national, regional and recipient control monitoring programmes as one entity with common guidance, quality assurance and data stewardship
- ii. engaging specific personnel responsible for encouraging, communicating and promoting coordination amongst organisations at all levels
- iii. supporting demonstration projects that examine the benefits of coordination both at an overall level and for individual programmes
- iv. taking steps to ensure that data from regional and recipient control monitoring are promptly transferred to a national data host and made publicly available
- v. setting the target that national assessments should evaluate national and regional and recipient control monitoring data

*Conclusion 5: Consistency and continuity of methods in all monitoring programmes constitutes the basis for effective coordination.*

**Recommendation: Promote standardization to ensure consistency and comparability of data, by**

- i. requiring that organisations performing monitoring and analysis are commonly accredited by SWEDAC

- ii. promoting adherence to monitoring guidelines (undersökningstyp, after revision) to stimulate a better coherence and comparability of data
- iii. developing and implementing national coordination of quality assurance of biological monitoring, and reference laboratories for physical, chemical and biological monitoring
- iv. establishing national procurement guidelines for government funded national and regional monitoring, when needed, and recommendations for recipient control programmes
- v. developing and implementing strategies for calibrating the use of new methods to ensure comparable output

*Conclusion 6: Clearer rules for the management of data resources will help steer data stewardship.*

**Recommendation: Define more clear responsibilities and rules for organisations generating or working with data,** by

- i. developing data flow protocols describing the required flow of data between originators and national data hosts and into assessments and clarifying the respective responsibilities of each organisations
- ii. implementing improved services for stricter control of data submissions to national data hosts and immediate feedback to data providers
- iii. implementing mechanisms to ensure that errors are updated in all copies of data
- iv. finalise ongoing work to standardise station names, geo- and time references across all marine environmental monitoring programmes through completing a comprehensive common station register and defining standard data formats
- v. defining a standard for data quality remarks and access to information about sampling and measurement techniques and data origin
- vi. developing guidelines for standardized graphical presentations of major data types
- vii. introducing a contractual responsibility for monitoring providers to support the work of the data host by reporting on errors identified in the data.

*Conclusion 7: Efficient management of marine ecosystems call for cross-programme analyses and joint evaluation of ecological and societal data.*

**Recommendation: Facilitate integrated ecosystem assessments and development and implementation of programmes of measures,** by



- i. ensuring that data from national databases can be incorporated into a common relational database and presented as tables with strictly defined fields (columns) and records (rows) with unique identities of samples and subsamples
- ii. making monitoring data and outputs of process-based or statistical models available in forms that enable joint analysis of measured data and model outputs without excessive manipulation
- iii. developing a plan for integrating new types of data (videos, satellite images etc) with existing conventional monitoring data
- iv. developing a plan for collecting data about societal phenomena and synthesize them into indicators that are compatible with existing indicators of physical, chemical and biological disturbances of marine environments.

## ANNEX 1. LIST OF PROJECT GROUP AND INTERVIEWEES DURING THE PROJECT

### Project Group

Richard Emmerson	Swedish Institute for the Marine Environment
Anders Grimvall	Swedish Institute for the Marine Environment
Daniel Conley	Lund University
Mats Lindegarth	University of Gothenburg / Swedish Institute for the Marine Environment

### Interviewees

Anders Bignert	Natural History Museum
Elena Gorokhova	Stockholm University
Helena Högländer	Stockholm University
Johan Erlandsson	Västerhavets Vattenmyndighet, Västerhavets Vattendistrikt / Länsstyrelsen i Västra Götalands län (County Administrative Board of Västra Götaland)
Johan Wikner	Umeå Marine Sciences Centre
Kjell Leonardsson	SLU
Lars Andersson	SMHI
Lars Johan Hansson	Swedish Agency for Marine and Water Management
Lars Sonesten	SLU
Lena Bergstöm	SLU
Malin Kronholm	Vattenmyndigheten i Bottenvikens Vattendistrikt / Länsstyrelsen i Norrbottens län (County Administrative Board of Norrbotten)
Martin Hansson	SMHI
Mats Blomquist	Hafok AB
Pia Andersson	SMHI

All interviews were conducted during 2014.

## ANNEX 2 GLOSSARY OF TERMS USED IN REPORT (ENGLISH – SWEDISH)

English name (and abbreviation used in the report)	Svenskt namn
Baltic Proper	Egentliga Östersjön
Coordinated recipient control monitoring	Samordnad recipientkontroll
County Administration Boards	Länsstyrelser
Bay of Bothnia	Bottenviken
Bothnian Sea	Bottenhavet
Public Health Agency of Sweden	Folkhälsomyndigheten
Geological Survey of Sweden (SGU)	Sveriges geologiska undersökning
Gothenburg University	Göteborgs universitet
Gulf of Bothnia	Bottniska viken (Bottenviken + Bottenhavet)
IVL Swedish Environmental Research institute ltd. (IVL)	IVL Svenska miljöinstitutet
Linnaeus University	Linnéuniversitet
Municipalities	Kommuner
National Data Host	Nationell datavärd
Natural History Museum	Naturhistoriska riksmuseet
Skagerrak and Kattegat (also part of the OSPAR Greater North Sea Region)	Västerhavet
North Baltic Sea	Norra Östersjön
South Baltic Sea	Södra Östersjön
Statistics Sweden	Statistiska centralbyrån
Stockholm University	Stockholmsuniversitet
Swedish Agency for Marine and Water Management (SwAM)	Havs- och vattenmyndigheten
Swedish Coastguard	Kustbevakningen
Swedish Environmental Code	Miljöbalken
Swedish Environmental Protection Agency (SEPA)	Naturvårdsverket
Swedish Environmental Emissions Data	Svenska MiljöEmissionsData (SMED)
Swedish Institute for the Marine Environment (SIME)	Havsmiljöinstitutet
Swedish Meteorological and Hydrological Institute (SMHI)	Sveriges meteorologiska och hydrologiska institut (SMHI)
Swedish National Food Agency	Livsmedelsverket
Swedish Radiation Safety Authority	Strålsäkerhetsmyndigheten

Swedish University of Agricultural Sciences (SLU)	Sverige lantbruksuniversitet (SLU)
Swedish University of Agricultural Sciences – Department of Soil and the Environment	Sverige lantbruksuniversitet – Institutionen för mark och miljö
Swedish University of Agricultural Sciences – Institute of Aquatic Resources (SLU Aqua)	Sverige lantbruksuniversitet – Institutionen för akvatiska resurser
The Swedish Species Information Centre	Artdatabanken
Umeå University	Umeå universitet
Umeå Marine Sciences Centre (UMSC)	Umeå marina forskningscentrum
Water Authorities	Vattenmyndigheterna
Water Information System Sweden (WISS)	Vatteninformationssystem Sverige (VISS)
Water Conservation Association	Vattenvårdsförbund





# Havsmiljöinstitutet

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Göteborgs universitet • Linnéuniversitetet  
Sveriges lantbruksuniversitet